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27th March, 1986.

The Secretary,
F.I.R.T.A.,
Australian Fisheries Service,
Department of Primary Industry,
CANBERRA, A.C.T. 2600.

Attention : Ms. G. Stablum

Dear Ms. Stablum,

PROJECT 85/43

Further to our telephone conversation, I enclose, as a Final Report, ten copies of abstracts of student projects as follows:-

- | | |
|-------------|---|
| K. COLGAN | The analysis of length-frequency data of juvenile and adolescent banana prawns, <u>Penaeus merguensis</u> : a comparison of computer and graphical methods. |
| G. CORNELL | Species composition and abundance of juvenile fish from Trinity Bay and Mornington Island prawn nursery grounds. |
| M. COSGROVE | Species composition, abundance, fecundity and morphometry of the crab by-catch from a Gulf of Carpentaria prawn research project. |
| * G. DEWS | The investigation and evaluation of using larger mesh size in prawn trawl to reduce drag resistance. |

.../2

- * D. LOWE The effects of 3 different on board handling treatments on the landed quality of the Tasmanian commercial scallop (Pecten Fumata).
- * R. WIEK Separation of coral trout species based on otolith morphology.
- B. WILSON Application of small business computers in the commercial sector of the fishing industry.

I also enclose one copy each of the full student project reports where the work has received a pass grade or better. Three projects (marked with an asterisk) have been returned to their respective authors for revision and are not yet available.

Yours sincerely,

A handwritten signature in dark ink, appearing to read 'A. Carver', is written over a faint, circular official stamp.

A. CARVER
Head of School of Fisheries

enc.

BRUCE A. WILSON

Application of small business computers in the commercial sector of the fishing industry.

ABSTRACT

Examination of the Australian fishing industry, using a number of different approaches, established with reasonable certainty that there is currently no significant use of micro-computers as an operational or business management tool, at least in small to medium enterprises in the industry. This is true of the catching, processing and aquaculture sectors, although there are some recent developments in the catching sector, which are described here. A range of potential applications for micro-computers was developed and evaluated, with particular emphasis on the catching sector, and a broad-brush examination of costs, benefits and market prospects was carried out. The type of system considered to have most immediate application in the catching sector was the "Catch/effort data base", in essence the maintenance of fishing log book information in a computer data base, with flexible and powerful interrogation facilities. A simple prototype was developed, based on a Tasmanian danish-seining operation, to illustrate the capabilities of such a system, and to identify practical issues relating to hardware, software and overall system use. Coincidentally, a project involving a prototype trout farm feeding system was initiated, and the results of this are reported. A significant point to emerge from the catch/effort system trial is the possibility of using this concept as a means of improving the quality of catch data provided by fishermen to fisheries authorities.

MICHAEL G. COSGROVE

Species composition, abundance, fecundity and morphometry of the crab by-catch from a Gulf of Carpentaria prawn research project.

SUMMARY

The abundant species found in the crab by-catch from the Gulf of Carpentaria were the swimming crabs belonging to the families Portunidae and Calappidae. Fewer crabs were found in winter and during the daylight hours.

Males and females of the five most abundant swimming crabs were represented in approximately similar numbers. Species of the family Portunidae maintained a similar size range between the sexes and for the family Calappidae females remained in a narrower size range than males.

The family Calappidae also possessed fewer soft carapace animals than did the family Portunidae. Moulting stage was related to reproductive condition and not to temperature. The calappid M.inermis had the most ovigerous females, caught mainly from summer. Ovigerous females of other species were poorly represented.

The relative growth of P.rubromarginatus and P.gracilimanus using morphometric techniques was different between the species. Both linear and weight measurements were used to ascertain differences in the three dimensional conformation of the cephalothorax and abdomen. Growth was isometric between the sexes of P.gracilimanus. The relative growth of P.rubromarginatus differed between the sexes with both positive and negative allometry shown. Carapace width was confirmed as a suitable reference measurement.

CATHERINE COLGAN

The analysis of length-frequency data of juvenile and adolescent banana prawns, *Penaeus merguensis*: a comparison of computer and graphical methods.

ABSTRACT

This paper examines three methods of analysing length-frequency data: the Cassie method, the Macdonald Pitcher program for analysing distribution mixtures and the ELEFAN I method. The aim of the study is to answer the following questions about each method: (i) ease of use, (ii) subjectivity, (iii) time taken to apply each method, (iv) biological application of the results and (v) possible combination of methods. The data used in this study was collected by Staples (1980b) for juvenile banana prawns, *Penaeus merguensis*, in the Norman river from September 1975 to September 1976. It was found that the Cassie method had the advantage of being easy to use by subjective in the selection of the number of groups in a set of data. The Macdonald Pitcher method was also easy to use but the number of groups in a set of data had to be known before the method provided useful results. With ELEFAN I it is suggested that the Von Bertalanffy growth equation on which ELEFAN I is based may not adequately describe the growth of juvenile prawns. The method required accurate values of K and L_{∞} to be entered into the program before running otherwise the results were unsatisfactory.

It is suggested that ELEFAN I and Macdonald Pitcher could be used together to give a better tool for analysis. A further development could be the modification of the ELEFAN I program to describe the growth of juvenile prawns which approximates a linear relationship. There should also be further study into the growth of juvenile prawns to try and accurately determine their rates of growth before applying length-frequency methods.

GRAEME R. CORNELL

Species composition and abundance of juvenile fish from Trinity Bay and Mornington Island Prawn Nursery Grounds.

SUMMARY

Juvenile fish were collected by beam trawl at three sites for a period of twelve months in Trinity Bay, Cairns, North Queensland, Australia. Species composition, abundance and richness are compared between trawl sites which had different seagrass covers. The fish species composition is compared with samples collected from the Dugong River, Mornington Island.

Species richness and abundance was found to be greater in an area of dense seagrass than an adjacent site without seagrass demonstrating the importance of these areas of nursery habitats for many species of juvenile fish. Fish abundance throughout the survey period were greater in the warmer months than in winter while the species richness was variable.

The fish abundances were dominated by just a few species. In Trinity Bay eighty percent of the total fish were the species Leiognathus splendens, Pelates quadrilineatus and species of the Siganidae, Sp.5. In the Dugong River the family Teraponidae accounted for eighty seven percent of the total fish numbers with P. quadrilineatus and Helotes sexlineatus prevalent.

Only a few of the juvenile fish were of commercial value and the importance of the sea grass beds in this study do not seem important as nursery areas for these fish. This study was confined to small fish by the selectivity of the gear and the importance of the seagrasses as feeding grounds for larger fish has not been established and needs investigation.

RYSZARD A. WIEK

Separation of coral trout species based on otolith morphology.

SUMMARY

Investigations in this project have shown morphological differences in the otoliths of the five species of coral trout examined.

Statistical analyses carried out show those differences to be significant.

Otolith length/standard fish length relationships were found to be significantly linear for all four Plectropomus species tested. The regression equation, $Y = 28.0 + 1.3X$, expresses the otolith length/standard length relationship for the species P.leopardus, which exhibited the strongest correlation.

The otoliths from the species Plectropomus maculatus were significantly larger than in other species.

It was found that otolith length/standard length ratios of the different species were not significant and not an aid in species identification.

Otoliths from the species P. areolatus were readily distinguished on the basis of their morphology. The surface features of the otoliths of the other species, were similar with interspecific differences predominantly located in the posterior half of the otoliths.

Characteristic features were not sufficiently developed in P.leopardus until a standard length of 17.0cm. There exists a large degree of morphological variation within the size ranges of the different species. The extent and degree of this intra-specific variation is unknown, so that the reliability of using otoliths in species identification cannot be determined.

Further work needs to be carried out to determine the extent and degree of otolith variation and otolith development in each species at different age groups. Data on the ageing and growth rates of the various species were not available. This material would be necessary to evaluate within species variations and to gauge the reliability of otolith morphology in species identification of coral trout.

DAVID LOWE

The effects of 3 different on board handling treatments on the landed quality of the Tasmanian commercial scallop (Pecten Fumata).

ABSTRACT

The landed quality of scallops taken in Banks Strait, Tasmania held under three on board treatments was tested by sensory evaluation. Bagged scallops were held whole in shell in bags on deck with one treatment having a 'curtain of ice' placed over the top of the bags, the other left uniced. The third treatment had whole scallops stored at 0°C in below deck air chillers.

The scallops, from each treatment were tested by trained tasters using profile and consumer acceptability panels after storage of 0,3 and 5 days at 4°C.

On the basis of various odour responses the chilled scallops were seen to give a significantly better product than either of the two on deck treatments, of which the curtain of ice was superior in terms of quality.

Responses for taste and textural characteristics gave less significant results in comparison with odour. The consumer acceptability panel using deep fried, breadcrumbed scallops gave no significant results, whereas the steamed scallops used in the profile panel showed significant differences in the quality of product held under the 3 treatments for odour and overall acceptability. There were no significant differences in flavour responses for both panels conducted.

Recommendations to the scallop fishery with regards to on board handling are here given and the possibility of the removal of the at sea shucking restriction discussed.

GEOFFREY J. DEWS

The investigation and evaluation of using larger mesh size in prawn trawl to reduce drag resistance.

SUMMARY

The need for more economical fishing gear in the prawn trawl fishery has led to the investigation of ways of reducing fuel oil operating costs.

The use of large mesh sizes in selected parts of prawn nets was investigated.

Large mesh sizes reduce the twine area in the net, hence a reduction in drag resistance was anticipated. A reduction in drag would result in fuel oil savings by trawlers when towing nets.

A full-scale Florida Flyer design prawn net was tested in the Flume Tank at the Australian Maritime College for drag/speed relations. These results were compared to tests carried out on the net when the twine area was reduced by increasing the size of mesh in the forward section of the net.

An attempt was made to test the catching performance of a full-scale prawn net, with larger mesh, in the southern Queensland prawn fishery.

AUSTRALIAN MARITIME COLLEGE

POSTGRADUATE FISHERIES THESIS

**APPLICATION OF SMALL BUSINESS COMPUTERS IN THE
COMMERCIAL SECTOR OF THE FISHING INDUSTRY**

by

WILSON, B. A.*

This project was undertaken in conjunction with the CSIRO Division of Food Research, Tasmanian Food Research Unit, Hobart, Tasmania.

- The project report has been prepared as partial fulfillment of the requirements for the award of the Graduate Diploma in Fisheries Technology at the School of Fisheries, Australian Maritime College, Launceston, Tasmania.

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TABLE OF CONTENTS

| | Page |
|--|------|
| List of Figures | iv. |
| List of Tables | iv. |
| Acknowledgement | v. |
| Abstract | 1 |
| 1.00 Introduction | |
| 1.10 Background | 2 |
| 1.20 A word about microcomputers | 2 |
| 1.30 Project objectives | 3 |
| 1.40 Project scope | 3 |
| 2.00 Project Strategy and Methodology | |
| 2.10 Analysis of current usage | 4 |
| 2.20 Evaluation of potential applications | 7 |
| 2.30 Development of prototype systems | 8 |
| 2.31 Choice of an application in the catching sector | 8 |
| 2.32 Hardware | 8 |
| 2.33 Software | 9 |
| 2.34 Fact finding and system specification | 10 |
| 2.35 Testing the prototype | 11 |

3.00 Results

| | |
|---|----|
| 3.10 Current usage | |
| 3.11 Literature search | 12 |
| 3.12 Direct canvassing and personal interviews | 14 |
| 3.13 Visit to <i>Seadays 85</i> | 15 |
| 3.20 Potential Applications | 15 |
| 3.21 Maxwell and Carter | 15 |
| 3.22 KFV <i>INFISH</i> system | 16 |
| 3.23 Catching sector | 16 |
| 3.24 Processing sector | 20 |
| 3.25 Aquaculture sector | 21 |
| 3.30 Prototype application- catching sector | |
| 3.31 Hardware | 22 |
| 3.32 Software | 26 |
| 3.33 Overall <i>Catchdata</i> system | 28 |
| 3.34 Lap-top calculator & communications | 28 |
| 3.40 Prototype application - aquaculture sector | 29 |

4.00 Discussion

| | |
|--|----|
| 4.10 Current usage | 30 |
| 4.20 Potential applications | |
| 4.21 Catching sector | 31 |
| 4.22 Processing and aquaculture sectors | 33 |
| 4.23 Cost/benefit evaluation | 34 |
| 4.24 Market prospects | 37 |
| 4.30 Prototype application - catching sector | |
| 4.31 Hardware - general | 40 |
| 4.32 Hardware - onboard computers | 41 |

iii.

| | |
|--|----|
| 4.33 Software | 43 |
| 4.34 <i>Catchdata</i> system - overall evaluation | 45 |
| 4.40 Prototype application - aquaculture sector | 45 |
| 5.00 Conclusions | |
| Recommendations | 47 |
| 6.00 Bibliography | |
| Appendices | |
| Appendix 1: <i>Compuspeak</i> - A Glossary of Computer Jargon | 52 |
| Appendix 2: Developments undertaken by the Trawler Owners Association | 55 |
| Appendix 3: Prototype Catch/Effort Database | 60 |
| Appendix 4: Prototype Trout Farm Feeding System | 74 |

LIST OF FIGURES

| Figure No. | Title | Page |
|------------|--|------|
| Fig. 1 | Pictorial representation of data base report | 44 |
| Fig. 2 | <i>Helix</i> icons | 61 |
| Fig. 3 | Flowchart of <i>Catchdata</i> relation | 62 |
| Fig. 4 | Flowchart of <i>Trip Log</i> relation | 63 |
| Fig. 5 | The <i>Catchdata</i> collection | 64 |
| Fig. 6 | Data entry form | 71 |
| Fig. 7 | Gear codes? form | 71 |
| Fig. 8 | File stats report | 72 |
| Fig. 9 | Trip log form | 72 |
| Fig. 10 | List query report | 73 |
| Fig. 11 | Feed requirements report | 79 |
| Fig. 12 | Current fish holdings report | 80 |

LIST OF TABLES

| Table No. | Title | Page |
|-----------|---|------|
| Table 1 | Benchtest of <i>Catchdata</i> processes | 25 |
| Table 2 | Structural aspects of the owner/operator sector of the Australian fishing industry | 38 |

ACKNOWLEDGEMENT

The author is indebted to a large number of people for the advice and support given throughout this project, which depended to a large extent on input from as many people associated with the fishing industry as it was possible to contact. It is not practicable to list all these contacts, but those having a more significant contribution are listed in the bibliography.

A few people, however, must be singled out for particular thanks, namely Mr S. Thrower for his guidance and support, Dr A. Heron and Mr I. Lerner for their technical advice in software applications, Ms. J. Adamaski for an untiring and skilful literature search, and teaching and support staff at the Australian Maritime College (particularly the staff at the Newnham library of the AMC). Finally, the author wished to record his gratitude to Mr D. O'Brien for his most generous donation of time and knowledge in the development of the prototype application.

ABSTRACT

Examination of the Australian fishing industry, using a number of different approaches, established with reasonable certainty that there is currently no significant use of microcomputers as an operational or business management tool, at least in small to medium enterprises in the industry. This is true of the catching, processing and aquaculture sectors, although there are some recent developments in the catching sector, which are described here. A range of potential applications for microcomputers was developed and evaluated, with particular emphasis on the catching sector, and a broad-brush examination of costs, benefits and market prospects was carried out. The type of system considered to have most immediate application in the catching sector was the "Catch/effort data base", in essence the maintenance of fishing log book information in a computer data base, with flexible and powerful interrogation facilities. A simple prototype was developed, based on a Tasmanian danish-seining operation, to illustrate the capabilities of such a system, and to identify practical issues relating to hardware, software and overall system use. Coincidentally, a project involving a prototype trout farm feeding system was initiated, and the results of this are reported. A significant point to emerge from the catch/effort system trial is the possibility of using this concept as a means of improving the quality of catch data provided by fishermen to fisheries authorities.

1.00 INTRODUCTION

1.10 Background

The enormous growth in recent years in the use of microcomputers in business, in education, and now in the home, is a commonly-known phenomenon. Primary industry has not been isolated from these developments, and small-business computers with specialist software packages are used by an increasing number of farmers, particularly in areas of intensive stock-raising and cropping. However, in the fishery sector, there are indications that the microcomputer has thus far not been embraced as a clerical and management tool to the same extent as it has in land-based primary industries. To be sure, a number of the larger fishing companies have developed their own computer-based accounting, control and reporting systems, for example the KFY *INFISH* system (Kesteven & Carter). Maxwell and Carter (1984) have described some of the applications already employed by companies and other larger institutions associated with the fishing industry, and have outlined some of the potential applications, covering various levels in the industry. Eighteen months down the track, it appears as if little if any use is being made of microcomputers and associated commercial software applications by the smaller elements of the industry. This is surprising, given the increasing use of medium to high technology particularly in the catching sector), the considerable capital investment in even a small family fishing enterprise, and the need which most enterprises of this kind have for good management information and efficient clerical activities. Accordingly, it is of value to gain an informed view of the extent to which computers are presently being used in the fishing industry, and to identify the areas of greatest potential benefit to the industry in the use of microcomputers.

1.20 A word about microcomputers.

The terms "microcomputer", "small business computer", and "personal computer" tend to be used interchangeably. Some computing writers make a technical distinction between these terms, based on criteria of price, capability, or type of use (Webster and Champion 1984). However, for the purposes of this report, all can be considered simply as denoting devices comprising:

- . central processing unit;
- . screen (visual display unit);

- . keyboard;
- . printer;
- . storage medium (usually one or two floppy disk units).

Although all microcomputers operate in much the same way, they vary greatly in power and capability. Hence, price can vary from as low as around \$1000 to well in excess of \$10000. Nevertheless, machines at either end of the price scale can still be meaningfully referred to collectively as "small business computers". Given the preponderance of technical jargon in the computing industry, a glossary of such terms used in this report is attached at Appendix 1.

1.30 Project Objectives

- i. To obtain an overview of the present level of use of small business computers in the fishing industry in Australia, with particular reference to the smaller end of the industry (including catching, processing and aquaculture).
- ii. To examine and evaluate a range of potential small-business applications (ie programs), together with an attempt to assess their marketability in the industry.
- iii. To illustrate the likely prospects and problems of such applications by developing and testing at least one "live" prototype system, in either the catching, processing or aquaculture sector, and to examine the market potential for systems of this kind.

1.40 Project Scope.

As suggested earlier, this project seeks to limit itself to the commercial application of microcomputers to small enterprises involved in the catching, processing and aquaculture sectors. That is to say, it is *not* concerned with the use of computers by larger companies, nor by government bodies or research institutions. The applications of primary interest are those whereby the computer is used as a tool to improve the efficiency of clerical activities, and to assist the management of a fishing enterprise in commercial decision-making. Hence we are not concerned with applications involving resource assessment and management, except insofar as these might form part of a small company's range of decision-making tools. Having said this, the point should also be made that computers can be a valuable tool in education, and fisheries training is no exception in this regard. Consequently, although this project is primarily concerned with commercial applications of microcomputers, the systems discussed herein also have potential as educational tools, particularly in the areas of economics and business management. This point will be reiterated throughout the ensuing discussion.

2.00 PROJECT STRATEGY and METHODOLOGY

2.10 Analysis of current usage.

With the overall objective of gaining an overview of the present level of usage of microcomputers in the small commercial sector of the industry, the following approaches were taken:

- i. First, a search was made of technical and industry periodicals for any details on the development and marketing of software tailored to the commercial fishing industry. Although this project concerns the industry in Australia, it was considered appropriate to include overseas developments in this search, given the paucity of indications of this software availability in Australia, together with the common practice of marketing commercial software packages developed overseas in Australia. In addition to this search of formally listed material in regular databases, a perusal of computer and fisheries magazines (published both in this country and overseas) was undertaken, with a view to finding advertisements or promotional articles for such products.
- ii. Secondly, personal interviews were carried out with a wide range of people associated with the fishing industry, in both the commercial and government institutions sectors. In addition, a programme of direct canvassing of the fisheries industry for information on this matter was undertaken.
- iii. Finally, a visit was arranged to the fishing industry exposition *Seadays*, held in Melbourne from 5 - 8 September 1985, to inspect possible displays of fishing-industry oriented business software.

These approaches are detailed in the following sections.

2.11 The literature search carried out accessed the Dialog database, and the following files were accessed:

- i. File 44: *Aquatic Science Abstracts*, using the combination of key word sets FISH? AND (COMPUTER PROGRAMS OR COMPUTER PROGRAMMES OR MICROCOMPUTER? OR SOFTWARE). It was felt, after some initial broader searching of the database, that this combination was necessary and sufficient to pinpoint references in that particular database to any published software developments relevant to the commercial sector of the fishing industry.
- ii. File 51: *Food Science and Technology Abstracts*, using the key word combination FISH? AND (SOFTWARE OR COMPUTER? OR MICROCOMPUTER?), which

again was considered capable of accessing any material of interest in this area.

iii. File 232: *International Software Database*, using the keyword FISH? which it was considered likely to access the description of any commercial software on this particular database concerning fisheries applications.

It was considered that commercially-available software packages would not necessarily be covered by the abstracting services associated with these databases, particularly software designed by private industry, so in addition to the literature search, an examination was carried out of the following hard-copy catalogues of microcomputer software:

- . *Greenbook 3* (1984), which is the most authoritative guide to software available on the Australian market;

- . *Microcomputer Software Buyer's Guide*, Webster and Champion (1984), another Australian publication;

- . *The Software Catalogue*, which is an American publication in similar vein to *Greenbook* and is in fact the hard copy version of the *International Software Database*.

- . The provisional world list of fisheries programs, compiled by McElroy (1983), which is an attempt to bring together into the one volume a list of software applications used in fisheries (in the research, institutional and commercial sectors). This list is based on responses to a questionnaire published in a number of international fisheries and aquaculture journals and newspapers in 1982/83 requesting advice from fisheries institutions and companies on their use of software. Although McElroy's investigation was somewhat institutionally-oriented, it is considered this line of investigation would still have a fair probability of turning up applications marketed by and for the private sector (the results confirm this supposition).

Finally, relatively recent editions of the following fisheries and computer trade journals were examined to elicit evidence of commercially-available software, through either advertisements or promotional articles:

- . *Australian Fisheries*;

- . *Professional Fisherman*;

- . *Fishing News International*;

- . *Today's Computers*;

- . *Australian Personal Computer*.

2.12 Direct canvassing for views from the industry on present usage of microcomputers took the form of a letter to the Editor of those journals most likely to be read by people in the fishing industry. The letter sought advice from readers who were using microcomputers in their business, with regard to the following:

- . type of application;
- . hardware/software used;
- . benefits gained;
- . problems experienced;
- . suggested improvements.

Views were also sought from readers (whether they used a computer or not) on the types of applications they would like to see developed for their sector of the industry. The letter was published verbatim in the September issue of *Professional Fisherman*, and was also published in the October issue of *Fishletter*, a newsletter produced for the New Zealand fishing industry by Fishing Industry Services Limited of Christchurch (Welker, pers. comm.). At the time of writing (early November 85), the letter had not yet been published by the other journal concerned, *Australian Fisheries*, although an acknowledgement had been received.

To supplement the direct canvassing, personal interviews were carried out with a large number of people associated with the fishing industry, including researchers, academics, public sector managers, fishermen (including skippers and vessel owners), processors and aquaculturists. Where time permitted, discussions were held with other people not directly connected with the fishing industry, but having an input to this project, for example agricultural advisors with experience in the development and operation of computer-based farm management systems. Most of these discussions were conducted in person or by telephone. These contacts are listed in the "Personal Communications" section of the bibliography.

2.13 With regard to the *Seadays* visit, it should be said that although it is not as large as the *Fishexpo* expositions which are held every 3 years or so, *Seadays* represented the only opportunity in 1985 for the fisheries supply/support industry to demonstrate its products. It was assumed that any significant development in commercial software for the fishing industry would be likely to be displayed at that venue.

2.20 Evaluation of potential applications.

The objective in this segment of the project was to specify, in some degree of detail, a number of potential microcomputer applications in the fishing industry and, in consultation with the end users and other interested parties, develop a "short list" of the most useful (and marketable) applications. It should be remarked here that the fishing industry, like any other area of productive activity, is "wide open" as it were to potential uses for computers and related technology. All that is required to develop a list of suggested applications is a rudimentary knowledge of the capabilities of the technology, some knowledge of the industry, and a fertile imagination. Hopefully, the temptation to make this part of the project a "blue skies" exercise, has been resisted, and the range of applications suggested here are all systems which could be developed commercially and utilised by the industry now, using proven techniques and without embarking on a path of technological experimentation.

2.21 Although the overall scope of this project includes all sectors of the fishing industry (catching, processing and aquaculture), it was found impractical, given the time constraints, to properly carry out this exercise for each sector. Consequently, it was decided to concentrate effort on the catching sector, given that:

- i. this is the area of the Australian industry with the largest number of individual owner-operators;
- ii. it is also the area preliminary research showed to have the least acquaintance with computer-based systems.

Therefore, this report contains only a superficial discussion of the potential applications in the other sectors, although it is suggested that these areas too present a great range of opportunities for commercial software development.

2.22 The strategy employed was essentially along the same lines followed in the first part of the project, namely the eliciting of opinion from as many people involved or interested in the fishing industry as could be consulted, together with a perusal of Australian and overseas trade literature for reports of experience and opinion in computer applications. This "fact finding exercise" established a short list of potential applications, from which an attempt was made to identify the one or two most important applications. Finally, a simple cost/benefit evaluation was carried out, together with a brief market analysis, to gain some perspective on the commercial

prospects for these applications.

2.30 Development of prototype systems.

As already remarked above, it was decided to concentrate effort in examining the range of potential applications in the catching sector, given the constraints of time and resources. For the same reason, it was not feasible to develop more than one prototype application, and so the catching sector was again chosen for this purpose. Coincidentally, however, an interest was expressed in this project by the School of Business Studies at the Tasmanian State Institute of Technology (TSIT), and a second prototype application in the aquaculture sector was pursued at the suggestion of the author, although it was primarily carried out as a computing project by a student at the TSIT. The methodology employed in this second application is detailed in Appendix 4.

2.31 Choice of an application in the catching sector.

After contemplation of the list of possible applications in this area (see Discussion, Section 4.2), it was decided to develop as a prototype the Catch/Effort database. Some initial work was done on the Vessel History Log and Cash Book systems, but these were not pursued, given the time constraints.

2.32 Hardware

Hardware chosen for the prototype applications was an Apple Macintosh 512K microcomputer with 2 floppy disk drives (handling 3.5 in. diskettes, with 400K capacity) and an Apple Imagewriter 15 inch printer. The whole unit was purchased by the author as an Apple "business package". In addition to this, a Sharp PC-2500 "lap top" microcomputer was borrowed briefly from Cox-Kay Pty. Ltd. in Hobart and used for testing a possible operation involving initial data capture at sea on a smaller machine of this kind, with subsequent transfer of data to an on-shore system, such as the Macintosh. Inspection of the Viatel-based *FISHNET* system being developed by the Trawler Owners Association required use of an Apple communications modem connected to the Macintosh.

The reason for the choice of the Macintosh, rather than a "mainstream" small business computer, such as an IBM Personal Computer (or one of its many imitations), was largely for personal reasons (ie for educational use by the author's family). However, it was also felt the Macintosh would be appropriate for the project, for the following reasons:

i. Ease of operation

The Macintosh has a unique operating system which is aimed at making it as "user friendly" as possible, through the use of a simulated "desk top", "icons" (pictorial symbols which represent logical elements of the system), and the "mouse", which is a device by which the user can quickly select and move icons on the screen. This was felt to be an advantage in this project, given the relative lack of microcomputer expertise of the author, the short period wherein an application was to be developed and tested, and the fact that the ultimate user (the fisherman) was likely to have no computing experience whatsoever.

ii. High quality screen display and powerful graphics

This is an undisputed feature of the Macintosh, and preliminary examination of the project strategy had suggested that an effective way of introducing computing concepts in the catching sector would be by means of systems with comprehensive graphical (indeed, pictorial) outputs.

iii. Size

There was a prospect of developing an application which could be used on board. Accordingly, the small size and compactness of the Macintosh, by comparison to most other PC's (with the exception of portables), was a definite advantage, as was its pioneering use of 3.5 in. floppy diskettes, rather than the conventional 5.25 in. ones.

iv. Finally, it was discovered that Macintoshes are being used extensively by a number of fisheries-related institutions - at least in Tasmania. These include Dept of Sea Fisheries, Dept of Inland Fisheries, CSIRO Marine Labs and the Antarctic Division of the Dept of Science. Although this was not a deciding factor, it gave further support to the author's decision.

2.33 Software

i. A number of software packages were briefly examined, including the spreadsheet *Multiplan* and several database programs, including *Helix*, *DBMaster*, *Microsoft File* and *Omnis 3*. Eventually, it was decided to use *Helix*, produced by the Odesta Corporation, a copy of which had been purchased by the CSIRO in Hobart. Reasons for the choice were basically as follows:

. *Helix* had been used extensively by a number of people in Hobart, and others of the author's acquaintance elsewhere, and was generally considered a good package for this particular type of application, whereas some of the other databases were an

unknown quantity.

. *Multiplan*, like other spreadsheets, while probably capable of doing the job, was not felt to be as easy to operate for the first time user than a database such as *Helix* (with its custom-designed forms and other features).

. *Omnis 3* was recommended by a number of users as being more powerful and sophisticated than *Helix*, but the author felt that the time period involved in mastering *Omnis* was likely to be too long, given the limited duration of this project.

. Finally, in a recent review of 13 database programs available for the Macintosh (Aker 1985), *Helix* was rated very highly, particularly in the areas of ease of use, power and general performance.

Version 1.1 of *Helix* was used initially, but this was subsequently upgraded to Version 1.13.

ii. To carry out the test data interface between the Sharp PC-2500 and the Macintosh, the *MacTerminal* communications software package was used. Unfortunately, for the brief time the Sharp was on loan, a voltage leveller and interface cable was not available anywhere in Hobart, nor was any comparable hand-held computer available for testing. Consequently the communications process had to be simulated in a piecemeal fashion, as follows:

. a small program was written on the Sharp to receive entry of the Catch data (by means of simple screen prompts), store a group of records corresponding to a whole trip, and transmit this data as text to the Sharp's communications port, when required;

. it was known that the Macintosh was capable of receiving such data input in text form through its own RS232 serial port, using *MacTerminal*;

. finally, the capability of a *Helix* file to receive data in text form (ie from a text file already created in the Macintosh) using the *Load* command and place it correctly formatted in a nominated collection, was tested simply by creating a text file in *MacWrite* and loading it into *Catchdata*.

iii. For accessing the *FISHNET* system, both *MacTerminal* and *MacVideotex* software was required by the Macintosh. These were made available through the Tasmanian Dept of Sea Fisheries.

2.34 Fact finding and system specification.

This is the most important phase in the development of a computer-based system, involving the investigation into the user's requirements, and the drawing up of

detailed system specifications, which define the future shape of the system.

This exercise was carried out largely in consultation with Mr D. O'Brian, who operates a danish seining vessel out of Hobart, and consisted in examining the specific information requirements of Mr O'Brian in respect of the Catch/Effort database. Mr O'Brian, like many other professional fishermen, has maintained a detailed manual logbook for many years. It was fairly straightforward, therefore, to construct a database consistent with the information gathered by Mr O'Brian's system over the years, and this formed the basis of the prototype Catch/Effort system.

2.35 Testing the prototype.

The Catch/Effort database was tested by keying in actual data from Mr O'Brian's fishing log, covering the 12 month period 1 May 1983 to 30 April 1984. This comprised 123 fishing days, giving 428 shot records, each containing data for up to 23 fields (ie data items). The fields comprised number, text and date-types. Although most of the data entry was performed by the author, Mr O'Brian also carried out some data entry, with the objective of testing how "user-friendly" this part of the system was.

Mr O'Brian was given a brief training session in the other aspects of the system, namely specifying queries and setting up and running output reports, again with the objective of assessing how easy the system was to use. This session was supplemented with a set of operating instructions, a copy of which is attached at Appendix 3.

Unfortunately, due to unavailability of the hardware, there was not the opportunity to carry out a live test of the on-board capture of data on the Sharp PC-2500, however this process was simulated, to establish how feasible it was.

3.00 RESULTS

3.10 Current usage

As a result of the investigations into the current level of usage of small business computers in the fishing industry, the following results were obtained.

3.11 Literature search

i. The *Aquatic Science Abstracts* search produced 107 items, of which the great majority were concerned with the application of computers in fisheries research and (biological) management. Breakdown of items of even marginal interest to this project is as follows:

- . nine items concerned the commercial aquaculture sector, although here too, the majority were produced by research institutions: nor was there any indication in the abstracts that any of these described commercial software which was available to the aquaculture sector in Australia;

- . only two items concerned the application of computer models to the catching sector, namely *Management Workshop St Hull* and Lierens (1978), the abstracts of which suggested that in neither case would these be directly applicable to the commercial catching sector in Australia;

- . only one item on the practical application of computer technology in the processing sector (Bertheussen 1984), which may be of interest to the processing sector, although it does not concern software commercially available in this country.

- . eight items concerning the application of computers in gear design and fishing operations, but, as with the other examples, all related to the work of overseas research institutions and were not regarded as coming within the scope of this project;

- . Finally, there was a reference to the *Provisional World List of Computer Programmes...* (see McElroy 1983), which is discussed below.

ii. The *Food Science and Technology Abstracts* search, as might be expected, turned up more items concerning the application of computers to the processing sector. None of the abstracts referred to software commercially available to the industry in Australia, but those thought to be of interest are listed in the *Further Reading* section of the Bibliography.

iii. The *International Software Database* search did not identify any items

which related to business software applications for any sector of the fishing industry, notwithstanding the fact that this database has been recently promoted in issues of *Aquaculture* magazine (Elsevier, New York) as a medium for listing software packages of interest to the aquaculture sector.

iv. None of the commercial software catalogues referred to in section 2.11 listed any software specifically tailored to the fishing industry, either in Australia or elsewhere. The most comprehensive catalogue was *Greenbook 3* (1984), which did contain listings of software available in Australia for other vertical markets, such as real estate management, farming, and hotel management. It is reasonable to conclude, given the range of software carried in this catalogue, that any serious attempt to market software packages for the fishing industry in Australia would give rise to a listing here.

The provisional software list compiled by McElroy (1983) would also be likely to contain this type of software, given the manner in which the survey was conducted. Indeed this catalogue does list both the *INFISH* system (see Kesteven and Carter) and the *Fish Farm Computer Programs* (see Landless). Since the author had already been acquainted with these from other sources as representing two of the very few commercially-available packages, this tends to support the proposition that the *Provisional World List* is a reasonably comprehensive list of such software, at least as at 1982/83. Apart from these two packages, there were no other software listings which were directly relevant to this project, although there were a number of systems modelling various aquaculture operations, which appeared to be of a research-oriented nature. It was noted that the McElroy listing was indeed provisional and contained reference to an updated version based on a new questionnaire, however, at the time of writing (November 1985), no such further publication had been located.

Perusal of recent copies of general-interest fisheries and computer magazines also failed to turn up evidence of the existence of commercially available software aimed at the smaller end of the fishing industry. Indeed the only recent reference to commercial software for the Australian industry was contained in advertisements for the fisheries consultants Laurie Walkear and Associates (see section 3.13), whose major activities in this respect appear to be in connection with the Trawler Owners Association project (see sect. 3.13).

3.12 Direct canvassing and personal interviews.

At the time of writing, only one reply has been received as a result of the published letters to the editors. This outlines the private development of a database program for rock lobster fishing in Western Australia - essentially a catch/effort database. Two interesting points emerge from the reply:

- i. The fisherman involved is, to his knowledge, the only one in his area using a microcomputer for this sort of purpose, despite the fact that it is the centre of a very lucrative and progressive fishery.
- ii. The system is being developed by a hobbyist friend, after a period of unsatisfactory software support from the local computer dealer.

Personal interviews confirmed the original impression that there are at present no software packages being generally marketed in this country, aimed at the small operator in the fishing industry. This appears to be equally true of the catching, processing and aquaculture sectors. To be sure, the *INFISH* and *Fish Farm Computer Programmes* systems, as already mentioned, are listed as being commercially available. However, neither falls within our criteria for such packages. The *INFISH* system is aimed at the larger, fleet type of operation, and communication with D. Carter indicated that the purchase price of this large and complex system would place it well outside the scope of the small owner-operator. The Landless *Fish Farm* package is appropriate to even quite small trout farms, but although a copy of the system has been purchased by the TSIT, the system could not be regarded as being generally commercially marketed in this country.

Moreover, Walker (pers. comm.) advises that in his opinion, the situation in the New Zealand industry is similar to that described above, with few if any operators using microcomputers for applications other than accounting and stock control (and these are limited to the companies).

Despite the present dearth of commercial packages in Australia, some developments are now under way in this area.

- i. The Trawler Owners Association are developing some commercial software for the catching sector, which is discussed below.
- ii. The Tasmanian Dept of Sea Fisheries is developing a salmon farm package under the auspices of the *Saltas* salmon farming joint venture. This contains a feed budgeting system, together with a financial analysis system based on a spreadsheet

concept. This is not strictly a commercial software venture, but will be made available to members of the *Salpas* consortium.

iii. A number of individual operators who have an interest in computers are devising systems for their own use, and in some cases are considering making these available commercially to other operators in their particular area of activity (this appears to be more the case in aquaculture than in the other sectors).

3.13 Visit to *Seadays 85*

This visit was of great benefit, because *Seadays* did contain an exhibition of the developments currently being carried out by the Trawler Owners Association (TOA), which were the only activities of their kind on display. These developments, which it is understood are partly funded by FIRTA, comprise two parts:

- i. the *FISHNET* fish marketing and industry information service, using the Telecom *Viatel* system;
- ii. Business software tailored for the catching sector, designed to run on microcomputers, or to be accessed through the *Viatel* system.

Because of the significance of these developments, they are described in more detail in Appendix 2.

3.20 Potential applications

3.21 As indicated in the Introduction, Maxwell and Carter (1984) described a range of applications in the catching and processing sectors where the microcomputer and associated technology were already proving their worth. Although it was not specified, these applications all appeared to have been implemented by the companies, rather than by small operators. Broadly, they fell into two categories.

- i. On-board applications, including catch/effort data recording (and transmission in code to base) and logging of vessel performance (for maintenance purposes).
- ii. On-shore applications, including:
 - . general clerical/book keeping work;
 - . processing plant management;
 - . marketing communications;
 - . training (eg using simulation techniques);
 - . resource management (ie in co-operation with government institutions).

3.22 The KfV *INFISH* brochure (Kesteven and Carter), gives a fairly detailed picture of the type of applications used by that company. Although these relate to the management of an integrated catching and processing operation which is large by Australian standards, using a large central computer installation, they are considered to represent in most cases the type of system immediately applicable to the smaller operators in the industry. Accordingly, it is useful to outline the KfV applications here.

i. Catch Analysis

- . predictions
- . yearly and seasonal trends (quality and quantity)
- . ground performance
- . vessel deployment

ii. Vessel Management (Engineering)

- . refit and maintenance
- . cost control
- . performance analysis
- . licensing

iii. Stock Control

- . on board
- . on shore (processed and unprocessed)
- . stock movements (ship to shore, store to store)
- . product in production
- . sales and orders

iv. Production Analysis

- . yields, recoveries and wastage
- . cost breakdown of production
- . relative and absolute profitability

v. Crew Management

- . personal records and employment history
- . bonus calculations
- . licence listing

3.23 Potential applications in the catching sector

Discussions with people from various areas of the industry, having regard to the company developments outlined above, together with developments being undertaken

by the Trawler Owners Association, suggested the following set of applications, each of which was considered to be of potential benefit to the small operator in the catching sector. Each application (ie system) is described separately, although it is likely that any commercial software development would link the applications in an integrated system. Comments on the general attitude of contacts toward each application are included.

i. Catch/Effort Data Base

This is essentially a file based on the fisherman's log book, storing relevant details of each fishing operation and providing flexible and powerful enquiry facilities. The data base would include such items as positions, depths, time of day, type of gear, catch by species, hook ups etc.

The primary purpose of this data base is to assist the fisherman to identify patterns in his catching results, with a view to guiding fishing strategy in the future (ie *when*, *where* and *how* to fish), in order to improve catch rates and/or reduce effort. A secondary purpose of this system would be as an input into a financial performance reporting system for the catching operation.

This could be either an on-board or on-shore system, although it would have more direct benefit on-board, giving the fisherman the capability of enquiring on the data base in the course of a trip, and thus allowing immediate decisions to be made on such things as moving to another location, changing gear, or returning to port.

Technically, this application can be classified as a typical data base management system.

Comments: This was considered by those fishermen contacted to be the most important application in the catching sector, for the reason that any means of improving the catch: effort ratio in fishing operations is paramount. Other contacts, such as non-fishing vessel owners and fisheries educators also considered this to be one of the most important applications, although not necessarily the most important from their own point of view. Although it was generally agreed that the operation of this system on-board would be the most desirable option (and there were suggestions that position co-ordinates could be input by linking the micro to a satellite navigator), it was generally felt that the system would still be valuable as an on-shore application, should it prove impractical to carry the microcomputer on the vessel.

ii. Vessel History

This system is again a data base type of application, comprising several related files

on the performance and maintenance history of the vessel and fishing gear: for example:

- . Maintenance Log, detailing work carried out to the vessel, by whom, and at what cost;

- . Performance Log, recording on a continuing basis such items as running times (main and auxiliaries), operations carried out (eg steaming, trawling), fuel consumption, and perhaps more detailed parameters, such as fuel flows, manifold pressures, fish room temperatures etc.

- . Parts Inventory, comprising a list of at least all the important components of the vessel and gear, detailing such things as manufacturer, serial number, address of supplier, expected life etc.

The primary purpose of this system would be to support an informed strategy of preventive maintenance, prompted by reminder / checklist reports generated by the system (eg prior to the next survey inspection, or in preparation for the next fishing season). Additionally, the system would have the potential to save time in ordering replacement parts on the occurrence of breakdowns, by means of access to the parts inventory file. Finally, it would assist cost control of the maintenance function, and could be an input to a financial performance system for the whole catching operation.

The Vessel History database could reasonably be maintained as an on-shore clerical application, although the Performance Log subsystem could be sufficiently advanced to involve the collection of data on board using data-logging devices (eg connected to engine room instruments).

Comments: Interestingly, this system concept generated more divergence of views from the people contacted than the other suggested applications, with opinion on its usefulness varying from great enthusiasm at one extreme, to less-than-lukewarm acceptance at the other. The attitudes depended on the background, circumstances, and particular experience of each individual. Even among the owner-operators contacted, opinion varied. Some regarded such a system as essential, relating anecdotes about the catastrophic failure of some key component at the beginning of the fishing season, the possible detection of which would have paid for a computer system several times over. Others suggested that this type of system would be unnecessary, given the relative simplicity of maintaining smaller vessels, and the efficiency of experienced maintenance and support firms (this latter point being disputed by several of the contacts).

iii. Book Keeping and Financial Analysis System

This is an application suitable to either a data base package or a spreadsheet, and consists in a computer-based record of all the fisherman's financial transactions (ie revenue and expenditure). Expenditure items are classified by user-defined "budget heads" for example "fuel and lubricants", "crew payments", "bait and ice" etc. and revenue should also be broken down to some extent, eg by type of fishing operation. The system would perform the function of the Cash Book, maintained by most fishermen, and as well as serving as an ongoing record of financial transactions (which the fisherman is required to maintain, as a taxation record if for no other purpose), allows the fisherman to carry out an ongoing analysis of the profitability of his operations. This data can also be used in the preparation and monitoring of various types of budgets, including cash flow budgets. Finally, the ~~what if?~~ capability of spreadsheet or database software allows the fisherman to calculate quickly the likely financial outcomes under a variety of circumstances (eg a change in interest rates or fuel prices), and accordingly to plan future business strategies and to evaluate the feasibility of new ventures. Stuart (1982) demonstrates the basic layout of a spreadsheet as applied to the evaluation of a new trawling venture.

Comments: This type of application was recognised by most people contacted as being useful and desirable. Not surprisingly, most in favour were those having a management, advisory or educational connection with the industry. A number of interesting points were made in the discussions on this application.

. It was maintained that failures of small fishing enterprises are more frequently the result of bad financial management than poor fishing ability, and some saw the most important function of the microcomputer as being a device for encouraging fishermen to become more familiar with the basic mechanisms of book keeping and budgeting.

. Another point supporting this type of application was its focus on the "bottom line" ie overall profitability of the operation, which is after all, the piece of management information which is of most immediate concern to the fisherman. This aspect was seen as a good selling point for the whole concept of using microcomputers in the catching sector.

. It was also maintained that, when a fisherman is seeking a loan from a financial institution, a properly maintained set of financial records greatly assists him in this process. A computer-based record would be, if anything, more impressive.

iv. General clerical systems

The range of general clerical tasks which can be performed by the small business computer should not be overlooked as suitable applications in the catching sector. It is maintained that the most common use of small business computers is in word processing, and even a small fishing enterprise would be expected to have a range of tasks such as letter writing, address lists etc.

3.24 Potential applications in the processing sector

As mentioned earlier, it has not been possible to devote any significant time to evaluate applications in this or the aquaculture sectors, however the following types of applications suggest themselves as being appropriate, after examination of the processing applications employed in the KfV *INFISH* system (section 3.22), and brief discussions with people involved in the processing sector.

i. Stock Control System which would keep a record of product at various stages of processing and storage in order to ensure minimal wastage, optimal use of freezer facilities, allow order filling to be carried out etc. Such a system is considered of great value in an activity such as seafood processing, where a range of valuable, time-sensitive product is involved.

ii. Plant Monitoring System

This would record the level of inputs and outputs at various parts of the process in order to monitor performance of the plant against predetermined standards ensuring that resources (eg labour, raw material, energy) are being used as efficiently as possible. A more sophisticated extension of this, which should perhaps be separately categorised as a Process Control System involves semi-automatic control of machines, weighing-off of product, labelling, bar coding etc. There have been numerous news notes in *Fishing News International* over the years concerning, in particular, the use of computers connected to weigh-sorting machines, particularly for fillet-packing lines. Computers are particularly useful in this regard as, when confronted with a batch of fillets, each of slightly different (known) weight, they can quickly run through a large number of alternative packing arrangements to select the option which minimises the degree of overweight packing, while ensuring there are no underweight packs.

iii. Book keeping, accounting and general clerical applications

As already described for the catching sector, these types of application would be appropriate for even a small processing operation, assisting the administrative and

financial management process, through such subsystems as payroll, invoicing, debtor/creditor records, budgeting etc.

3.25 Potential applications in the aquaculture sector

Given the similarity of at least some forms of aquaculture to intensive farming, the type of computer system already common in areas such as pig farming should be applicable to intensive aquaculture (ie pond or cage rearing of fish). Examination of software directories, such as *Greenbook 3* or *The Software Catalogue* reveal numerous packages designed for specific areas of farming. Generally these are built around a feeding and growth monitoring system, extending in some cases to a complete, integrated farm management package retailing for thousands of dollars. Given the significance of feed in the cost structure of salmonid farming (the most common form of intensive aquaculture in Australia), a system based on feed/growth monitoring would seem the most obvious application here. The prototype application being developed for Sevrup Trout Pty Ltd (see Watson 1985) follows this form and is outlined in Appendix 4. A larger scale system along similar lines is currently being developed by the Tasmanian Dept of Sea Fisheries on behalf of the Saltas atlantic salmon joint venture in Hobart (Woodward, pers. comm.). These intensive fish rearing systems have some similarities, typically comprising the following basic subsystems:

- i. Fish Accounting System which is essentially a stock recording system, keeping a record of number and weight of fish in each pond/cage, updating this database in the light of information on expected growth, known mortality, and transfers in and out (eg after culling for market).
- ii. Feed Rationing System which calculates at each feeding time the optimal ration for each pond, based on known stock numbers, size, and growth parameters such as feed composition, water temperature etc.
- iii. Feed Monitoring System which monitors the effectiveness of the feeding regime by means of periodic sample checks of weight gain in the ponds, and in turn can influence the parameters used in the rationing calculations.

This basic management system can be extended by means of additional data inputs and enhanced reporting facilities to include such functions as feed mix planning and ordering, controlled growing (eg to ensure a steady flow of product onto the market), and a range of financial monitoring and planning systems similar to those discussed for the catching sector (section 3.23).

The major form of non-intensive aquaculture carried out in Australia is oyster growing, which again suggests itself as an area where microcomputers can assist in the improvement of operational and financial management. Discussions with a number of oyster farmers in Tasmania suggest that there is a basic requirement for a stock-monitoring system which can record the progress of batches of hatchery stock as they are grown out, periodically graded, merged with other batches and culled for market. Further, given the extremely seasonal nature of oyster growing, there is a clear need for accurate and comprehensive cash flow budgeting. Stuart (1983) discusses the requirements for cash flow budgeting in oyster growing operations, together with other financial monitoring systems such as annual operating budgets and financial evaluation of new ventures.

3.30 Prototype application - catching sector

After evaluating the type of applications appropriate to the catching sector, outlined in section 3.23, it was decided to proceed with the Catch/Effort database as the system to be developed as a prototype. Basically, the reasons for this decision were as follows:

- . it was the application with the most consistent appeal over the range of industry people consulted (see discussion, sect. 4.21)
- . live data to test the system and its capabilities was immediately available, namely through the fishing log books kept by Mr O'Brian;
- . it represented a fairly straightforward data base application, and so was appropriate to the available software;
- . it could be applied to both on-board and on-shore data collection procedures;
- . it was relevant to the perennial problem in the industry of accurate log book returns, currently something of an issue in the South East Trawl management scheme.

A detailed description of the system is contained in Appendix 3.

3.31 Hardware

Performance of the Macintosh in setting up and testing the prototype system was generally very good, and by and large the features which initially attracted the author to the Macintosh were found during the course of the exercise to apply, as outlined in the following observations.

Note: It should be emphasised that, given there was no comparative testing of the system with different hardware or software, these observations are only intended to indicate that the chosen approach was satisfactory. They are not adduced as facts supporting any contention that this was necessarily the best approach.

i. Ease of operation

The author was able to familiarise himself with the general operating procedures in 2-3 days, sufficiently to be able to run and test a number of different software packages. More importantly, Mr O'Brien (a first-time user of microcomputers) was able to run the Catch/Effort system after only a 2 hour practical training session carried out by the author, involving both the general operation of the Macintosh and specific instruction in the operation of the Catch/Effort system. This was due in part to the software, but was also largely attributable to the "user-friendly" nature of the Macintosh and its operating system, around which the *Helix* software is, in any event, designed.

ii. High quality display and graphics

This feature of the Macintosh was not really exploited by the prototype application, which does not make use of graphical or pictorial displays. However, the capability of the Macintosh for this type of feature is clearly demonstrable through the use of other software, such as *MacPaint*, *Microsoft Chart* and various games. Moreover, it is understood that the latest version of *Helix* has graphics capability, which could be incorporated with advantage into a full-scale Catch/Effort system (see discussion on this aspect, section 4.33).

iii. Compactness and portability

The Macintosh is sufficiently compact to take on a medium to large fishing vessel (larger than, say 20 m.), where it can be accommodated on a desk, chart table or similar. The unit (without the printer) is also easy to carry between ship and shoreside, if this was a requirement (say each trip). Indeed, the author took his machine on the training vessel *Bluefin* for the visit to the *Seadays* exhibition in Melbourne with no difficulty (except for a slight tendency for the operator to feel seasick during prolonged periods of operation in a moderate sea!).

iv. Capacity

This is the only area where the Macintosh configuration used was found to be wanting, even though this configuration (512 K main memory and 2 x 400 K floppy discs) is by no means the smallest available in the Macintosh line. It is difficult to judge how much of this deficiency can be attributed to the hardware, how much to the particular software used, and how much to the manner in which the author designed the system.

It was found that the 12 months' information in the Catch/Effort database, together with the database specifications (field descriptions, form layouts etc.) was about the maximum sized collection which could be safely accommodated on a 400 K disk, given the following operating needs:

| <u>Disk 1</u> | | <u>Disk 2</u> | |
|-----------------------------|---------|---------------------------------|---------|
| Operating system | : 132 K | <i>Helix</i> program | : 260 K |
| <i>Catchdata</i> collection | : 125 K | Backup copy of <i>Catchdata</i> | : 125 K |
| Balance | : 138 K | Balance | : 11 K |

The major constraint here is the second disk, which contains the backup copy (the following discussion on software explains the need for this), although even the fair degree of space on the first disk is needed under some circumstances (eg for larger print jobs).

This problem of capacity becomes more serious when we consider the following points:

- . this *Catchdata* collection was only partly developed, requiring in the longer term additional data fields, more space for additional reporting facilities, as well as inclusion of the *Trip Log* subsystem;
- . many of the records in the database contained several blank field entries, that is, if more data items had been filled in, capacity would have been reached with considerably less than 12 months' records.

Given the impossibility of spreading a collection over more than one disk (see discussion on software below), it is concluded that the only way of storing a reasonable-sized database (ie with several years' data) would be by upgrading the hardware capacity, for example to a hard disk with capacity of several megabytes.

v. Speed of operation

The key processes involved in operating the *Catchdata* system were subjected to a "benchtest", the results of which are given in Table 1. below. As for the capacity question, speed of execution is a composite function of hardware, software and system design, but for convenience the results are listed in this section. All tests relate to the 12 months' danish seining data (ie 428 records).

Table 1. Benchtest of *Catchdata* processes

| Process | Execution time | Remarks |
|--|--|--|
| . start up system (load disk, step through initial screens to working screen): | about 2min 20sec. | |
| . enter data for complete record(ie shot) and file away: | about 1.2 min per record when number of records entered (eg a trip) | this rate achieved after a little experience |
| . set up query (ie set limits on several fields): | about 1 min. for 3 fields | |
| . find first record under preset query conditions: | immediate(1 sec.or less) | time indept. of query complexity |
| . run "list query" under preset query conditions | about 40 sec to display list on screen | time indept. of query complexity |
| . run "file stats" report | about 2 min 15 sec. for 14 reporting items | seemed a linear function of no. of items |
| . re-index whole file (2 new index fields) | about 1 min. | |
| . backup whole collection (after each data entry session) | about 50 sec. | |

3.32 Software

i. Specifying the system

By and large the performance of the *Helix* package was considered good in this regard. The basic processes of setting up fields, indexes and queries for each relation, and designing templates for input and output forms were straightforward, and with practice, a user without programming skills could set up a complete database application in a couple of hours.

If anything, *Helix* attempts to be too simple, overdoing to some extent the use of icons for the various processes, which in some cases might be more quickly performed by the use of more conventional commands, algorithms etc.

One minor irritation was the slow response to "dragging" operations on the screen, particularly in the specification of data and text rectangles when setting up templates, although it is conceded that, as with other aspects of specifying, is only a one time occurrence for any particular system.

The manual is very comprehensive, running to some 235 pages. However, the author, had some difficulty on occasions in coming to grips with the overall logical structure of the software, that is, in applying general principles of the package to the solution of some fairly fundamental problems. For example, the best approach to adopt when dealing with several related, but different files (namely the *Trip Log* and *Catchdata* relations) turned out to be in creating separate relations and running common reports by use of a facility called the "lookup tile", but this fundamental characteristic of the system was covered only cursorily in the manual. Even now, the author is by no means sure that the *Catchdata* collection has been set up in the most efficient way, making the best use of *Helix's* capabilities.

A limitation of the lookup tile which had a bearing on the *Catchdata* specification was its inability to link relations on the basis of more than one common field. This facility would be useful in setting up the Log book return (as yet unspecified), which requires the accessing of records on the basis of both date and shot number. There may be some way of doing this in *Helix*, but it is not as straightforward as the author would like!

ii. Operating the system

This aspect of *Helix* was also good. Data entry was fast and simple and run time for reports was considered satisfactory, with the possible exception of the "File stats"

report, which, as reported in the benchtest results (Table 1), took more than 2 min. to summarise a few items on 1 year's data, and appears to be proportional to both the number of items reported and the number of records. It can be estimated therefore that summarising, say 25 items for 3 year's data could take about 12 min. which is a bit unreasonable. The query facility, which is the most important type of report to be provided within the *Catchdata* system was quick and easy to operate and run. The system was, in some respects, a little *too* flexible for the operator, in the sense that it is not possible to constrain the system operation to a strict sequence of menus. That is, the operator could, deliberately or inadvertently, "get into" the system specification parameters, which are contained in the same windows as the operating selections. Again, as a result of this flexibility, the sequence of operating procedures was not constrained, and the operator on occasions would need to vary procedures, depending on the prior sequence. To illustrate, under some circumstances, accessing a particular selection will throw up the "show selection" window, rather than the required report or blank form, and so the operator must know how to access the required window.

Another slight irritation in operating the system was that selected queries would be automatically "de-selected" under certain operating sequences. Again, this is not a major problem, but does require the operator to exercise a degree of flexibility and care.

During the testing of the system, a number of "crashes" occurred. For the most part these were attributable to errors made by the author, although there was at least one inexplicable system failure. These resulted either in a situation where some form of recovery procedure was required, or in the destruction of the whole *Catchdata* collection, which could have been somewhat embarrassing if the collection had not been backed-up (which is a highly recommended practice). Two examples of this:

- . the author attempted to run *Helix* using a utility program called *Turbocontrol*, which speeds up the execution of programs on the Macintosh by loading the more often-used routines or files into a predetermined amount of RAM (32K being nominated on this occasion), rather than leaving them on a disk: this resulted in a catastrophic crash situation which required the system to be aborted, and resulted in the loss of the *Catchdata* collection (Heron advises that *Turbocontrol* can be used with *Helix* with no ill effects, using up to 32K, but the author would recommend against this practice);

- . on another occasion, a *Catchdata* field containing some data was discarded, because it was considered not to be useful: although *Helix* provides appropriate

prompts in this circumstance, it still allows the user to discard a field, and in this case produced a curious result, namely a blank query template, which itself had to be discarded and recreated before the field transaction could be finalised.

The examples quoted above indicate that the version of Helix used was by no means fool proof (ie author proof), and that system problems could destroy an entire collection, rather than just parts of it.

3.33 The *Catchdata* system overall

The tests carried out with Mr O'Brian supported the proposition that it is a useful and easily-operated system, with considerable appeal to the fisherman. However, further development is required (eg incorporating the *Trip Log* relation, and allowing the production of Log Book returns and other trip reports) before it could be considered a viable system.

There has not been an opportunity at the time of writing to carry out a detailed analysis of Mr O'Brian's historical catch data, but it is clear that the *Catchdata* system is quite capable of identifying patterns and causal factors in fishing performance, where they are present. The most significant result of the prototype development is described below.

Mr O'Brian was impressed with the relative ease of running quite powerful and flexible queries on the data base. He took the view that the availability of this facility, together with access to the historical data, could constitute the best incentive for fishermen to provide accurate Log Book returns in the first place.

This issue has been taken up with the Tasmanian Department of Sea Fisheries, and there are indications that procedures will be established to provide retrospective Log Book data to those fishermen who request it, in a form which will allow them to analyse their own data in a manner similar to that used by the *Catchdata* system. Tasmania, unlike some of the other states, has maintained for a number of years a detailed Log Book programme for several of its fisheries. The trawl data is currently stored on *CSIRONET*, but is being off-loaded onto a hard disk-based network which can be accessed by a number of Macintosh applications.

3.34 Lap top calculator and communications link

The results obtained here are inconclusive, due to the lack of opportunity to set up and comprehensively test the procedure for on-board data recording and transfer on-shore. The simulation that was carried out (described in sect.2.33) established that

there was no *technical* problem in using a portable micro such as the Sharp to capture data, store it, then transfer it as a text file into a larger on-shore installation such as the Macintosh, using an RS-232 port, and in turn to load the data into a structured database, such as *Helix*. The simulation was *not* sufficient to demonstrate to the author's satisfaction that this procedure could be accomplished easily by an inexperienced user.

3.40 Prototype system - aquaculture sector

Results arising from the development and trial of the prototype Trout Feeding system are covered, together with other aspects of that system, in Appendix 4.

4.00 DISCUSSION

4.10 Current usage of business computers in the Australian fishing industry

As a result of the investigations carried out in this phase of the project, the following picture of current nature and extent of use emerges:

- i. The initial observations, made at the commencement of the project, have been largely confirmed. To reiterate, the small business computer and associated information technology have made minimal penetration of the fishing industry in this country, with particular reference to the smaller end of the industry. This proposition appears to hold for all sectors, namely catching, processing and aquaculture.
- ii. The larger fishing companies have developed, or are in the process of developing their own computer-based accounting, fleet management and business information systems. These systems are not, however, designed to be applied generally (ie by smaller operators) in the industry.
- iii. There are a few individuals who are using microcomputers, and are developing applications appropriate to their own areas of activity. Some of these people are contemplating the possible commercial marketing of software. However, there is no evidence of any co-ordination of these individual activities, at either a private or institutional level.
- iv. To date, vertically-integrated software packages suitable for various sectors of the fishing industry are not generally available in this country. The only commercial developments in this regard that are known of at present are those being undertaken by the Trawler Owners Association (see Appendix 2).

4.11 It is impossible in principle to prove conclusively the *non-existence* of some phenomenon. Accordingly, the picture drawn above cannot be considered as conclusive, particularly given that this investigation has been carried out from Tasmania, somewhat remote from the major centres of software applications development and from the major part of the Australian fishing industry. Nevertheless, it is submitted that the literature search, perusal of commercial industry magazines, and consultation with people in the industry *should* have identified any significant software development, if it existed (indeed, it could be argued that any development which takes place unannounced to the industry at large would hardly qualify as a "significant commercial development"). The poor response

to the author's letters in the fishing magazines, while again not being conclusive, is at least consistent with the overall picture of little if anything happening in the area of software development. It is conceded though, that the incidence of microcomputer use by private individuals in the industry *could* be higher than that uncovered by these investigations, given the likely desire of such individuals to gain an advantage over competing operators in their sector, by the use of more effective business management tools. Those with this attitude would be unlikely to publicise their activities in fishing publications or to respond to the author's canvassing of the issue.

4.20 Potential Applications

4.21 Catching Sector

Each of the four broad categories of application outlined in section 3.23 was considered by at least *some* of those consulted to be of potential benefit to at least some areas of the catching sector, although there was no consensus on their relative merits or importance. This is not surprising given the range of different interests and backgrounds of these people.

i. It can be concluded however that the Catch/Effort Data Base was the most favoured individual application overall. Fishermen and owners felt that this system had the potential to *increase* catch while *maintaining* or even *reducing* effort, which is clearly the most fundamental objective of a catching enterprise. It is perhaps no coincidence that:

- . the only response to the published letter described a form of catch/effort database for the W.A. rock lobster fishery (which was claimed to be beneficial to the fisherman);

- . the Trawler Owners Association appear to be currently concentrating software development on a "Log Book" (ie catch/effort) system (see Appendix 2).

The point should be made that the fishing log is in most cases the *only* document pertaining to fishing operations which is systematically maintained by the fisherman. Although in some fisheries the completion of a regular (official) fishing log return is compulsory, it appears that the major reason for such an assiduous collection of data in an otherwise "paperless" activity is the belief that this historical data can give a clue to the more productive grounds, times of day, types of gear etc. It is easy to demonstrate that the comprehensive analysis of such a database, extending back over a number of years, is relatively simple and quick for a microcomputer, whereas it is impossible to perform a similar analysis manually.

For these reasons, together with some other practical aspects listed in section 3.30, it

was decided to use a simple version of the Catch/Effort data base as the prototype application for this project.

ii. Of the other suggested systems, the Vessel History system, or at least some parts of it, had the most appeal to vessel operators, although as reported in the results (sect. 3.23) there was a range of opinion about the necessity for such a system. The uncertainty here is considered due in part to the fact that manual systems to maintain this kind of data are not commonplace, contrasting with the fishing log situation. Given the limited opportunity to evaluate potential systems in this project, it can only be concluded that the Vessel History system would be a worthwhile option in an integrated software package (it certainly figures as a major element of the KFV *INFISH* system), but its use is likely to a case of "horses for courses". That is, some operators would make use of such a system, and could no doubt demonstrate significant savings through prompt identification of declining fuel consumption, quick location of spare parts etc. Others might be so much in command of their vessel maintenance routines that such a system would be redundant. Even in the latter case, however, it can be argued that a new owner may *not* initially find the vessel maintenance procedures so simple, and would benefit from a systematic record of components, suppliers, and work carried out. Indeed it is suggested that an up to date list of this kind, maintained on a computer, would actually constitute a selling point when disposing of a vessel. With regard to the Performance Log subsystem, there was some enthusiasm expressed about the potential benefits of a "fully-wired" vessel, that is, one containing an on-board computer linked to sensing devices all over the ship, allowing a comprehensive and continuous monitoring of all relevant aspects of the vessel's performance. While conceding that this was an attractive idea, the author feels that its exploitation would be somewhat premature in the owner-operator sector in Australia, where there is even some debate about the merits of a simple system involving the manual recording of a few key items, such as engine running times.

iii. The Book Keeping/Financial Analysis type of system proved even more difficult to "sell" as a concept than the Vessel History system. While there is no doubt that a microcomputer is a useful tool in supporting systems of this kind, many of those consulted were not convinced of the merits of such a system in the first place (not all of these were fishermen). In discussions, the point was often made about fishermen's well-known reluctance to commit anything, particularly financial information, to paper. There is no easy response to this proposition, which essentially involves a philosophical debate about the merits of "scientific" as opposed to intuitive business

management. The author confesses to being a little perplexed that an enterprise with a capitalisation in excess of \$200,000 and annual turnover of \$100,000 or more can continue indefinitely as a viable unit without some sort of structured financial management. Perhaps the increasing financial problems being faced by at least some fisheries will generate a demand for systems of the kind proposed! Certainly the Trawler Owners' Assoc. software developments appear to recognise this point.

iv. With regard to general clerical systems (eg word processing), there is little to be said, apart from the fact that the small business computer is an effective labour saving device in clerical activities. This type of work, where it is carried out in a smaller catching enterprise, is usually performed by a member of the family, and is not regarded as an operating cost. Although it is unlikely that these systems on their own would be considered justification for the acquisition of a microcomputer, they would inevitably become one of the most often-used applications.

4.22 Processing and aquaculture sectors

Given the concentration of this phase of the the project on the catching sector, there has been no opportunity to consider the relative merits of the types of microcomputer applications suggested for these sectors in section 3.24 and 3.25. It is clear that both sectors demonstrate considerable potential benefits from the application of such systems, and some examples are outlined in the cost/benefit discussion below.

It is likely, in fact, that these sectors of the industry would be if anything more amenable than the catching sector to the application of microcomputers, given:

- i. Processing plants are larger operations (than fishing vessels) with more staff, equally significant energy-management problems, storage installations, more formal clerical/book keeping systems, and consequently more complex management requirements. To illustrate, the IAC report on the fishing industry quotes 1977/78 figures of 89 processing establishments with 4 or more employees, an average wage bill of \$200000 p.a., and average turnover of product valued at \$2.13 m. (IAC 1983, pA41). Contrast this with comparable data in Table 2 below (p 36).
- ii. Aquaculture operations, although not necessarily bigger than catching operations, tend to be managed using more formal techniques, possibly because of their closer resemblance to farms, and possibly due also to the background of the people involved in these activities. They also tend to have processing functions incorporated.
- iii. There is also a stronger element of *control* over the output, in both the

aquaculture and (to a lesser extent) the processing sectors than in catching. To illustrate: the fisherman is largely at the mercy of the weather, natural resource stocks and government policy, over which he has little or no control. When he has a full hold, he must return to port and dispose of it as quickly as possible. On the other hand, the fish farmer can make decisions about how much to feed, when to cull stocks for market etc, and the processing plant manager can make some decisions about holding stock for some time prior to and after processing, as well as about purchasing feedstock in the first place. These increased options for making management decisions may also increase the perceived need for decision-making systems.

4.23 Cost/Benefit Evaluation

Although it has been suggested throughout this report that the fishing industry, and the catching sector in particular, would benefit from the use of microcomputers and specially-designed software, there has been no attempt to quantify this assumed benefit and relate it to the costs involved. Nor is it possible to carry out such an exercise properly without performing a detailed analysis of the economics of a particular fishing operation, which is beyond the scope of this project.

A number of people consulted during the project made the point (not unreasonably) that fishermen would not contemplate the use of microcomputers as a decision-making tool until they were convinced that the investment in hardware and software would produce a concomitant increase in their profits. The following argument, albeit simplistic and generalised, attempts to attach some notional costs and benefits to the use of computer applications, in order to put this issue into some sort of perspective.

Catching sector

i. Costs

Assume the fisherman purchases a reasonably powerful small business computer, such as IBM PC look-alike, Macintosh or similar, with integrated fisheries software package and communications modem, at a purchase price of, say \$6000 (net of sales tax).

| | |
|---|-----------------|
| <u>ANNUAL OPERATING COSTS:</u> | \$ |
| . interest on borrowed funds for purchase (@ 18% p.a.) | 1080 |
| . depreciation (@ say 30% p.a. "straight line" method) | 1800 |
| . consumables (ribbons, paper, disks etc) | 100 |
| . repairs & maintenance | 100 |
| . insurance (ie household contents) | <u>30</u> |
| Subtotal: | <u>3110</u> |
| <u>LESS:</u> | |
| . reduction in income tax accruing to the annual | \$ |
| operating costs (@ say, 40 c in the dollar) | (1244) |
| <u>TOTAL ANNUAL COSTS:</u> | <u>1866</u> |

ii. Benefits

In order for the purchase of a system of this kind to make economic sense, the computer must be able to demonstrate annual savings in excess of these operating costs, that is, with a breakeven point of say, \$2000 p.a.

The following is a range of *hypothetical* situations, or "scenarios", each of which could satisfy this breakeven criterion.

- Reduction in clerical labour (ie making use of book keeping and word processing software etc.): if labour valued at \$8 per hour, breakeven would require reduction of 250 hours p.a. = 5 hours per week.
- Increase in catch (ie from improved decision making resulting from the Catch/Effort data base): assuming annual catch valued at \$100,000, breakeven would require increase in catch (ie fishing power) of 2%.
- Reduction in steaming time (again, based on analysis of the Catch/Effort data base): assuming fuel costs of \$15 per hour for a 20m. vessel, breakeven would require reduction in steaming time of 133 hours per annum, the equivalent of approx. 6 full days steaming.
- Increase in price received for catch (ie through use of marketing systems such as *FISHNET*, or concentration of effort on higher valued species, guided by Catch/Effort data base): assuming \$100,000 annual catch value, breakeven would require increase in average price of product by 2%.
- Reduction in down time (ie by use of the Vessel History Log): assuming a net

operating surplus (ie surplus of revenue over variable costs) averaging \$250 per (trip) day, breakeven would require a reduction in down time by 8 days p.a.

Comments:

The figures quoted above for costs and revenues are only *hypothetical*, nevertheless they are considered to represent a reasonable and conservative assessment of the financial factors typically involved in a modest sized fishing operation.

It can be seen from these calculations that, for the most part, even a *modest* improvement in the performance of any *one* of these operations would achieve the breakeven point for the acquisition of a small business computer. Any further improvements would constitute a *profitable outcome* from the decision to computerise. To be sure, not all of the above scenarios will apply to all fishing operations, for example, the author would expect the reference to a possible saving in clerical labour to be disputed by many fishermen, who would regard this as an uncoded domestic task! Again, some fishing operations (eg those governed by catch quota systems) will have no opportunity to improve financial performance by increasing total catch.

These scenarios *do*, however, establish the point that there are a number of options for improving the profitability of a fishing operation, and that any combination of these *could* justify the acquisition of a business computer system, provided it can be shown that the computer will contribute to a modest improvement in operating performance.

The most likely scenario is some combination of the above examples, and we conclude this analysis by setting out the following *combined* group of possible benefits of computerisation, which in total would justify the acquisition of an integrated system, by improving the trading position of the fishing operation by at least \$2000 p.a.

- . reduction in clerical labour by $1/2$ hr per week;
- . increase in annual catch by $1/2$ %;
- . reduction in steaming time by 36 hours p.a.;
- . increase in average price by $1/2$ %;
- . reduction in down time by 1 day p.a.

Processing and aquaculture sectors

It is not proposed to go to the same degree of detail in evaluating the cost/benefit scenarios for these sectors, but the same sort of argument as above could be advanced to illustrate the type and order of magnitude of operational improvements arising

from computerisation to justify acquisition of a hardware/software package. Again, a proper cost/benefit analysis would have to be performed for each specific operation.

Costs for smaller scale processing or aquaculture enterprises would be the same as described for the catching sector, although a processing plant might justify some additional special purpose hardware such as weigh-scale interfaces, bar coding/reading devices and the like.

Benefits accruing from the types of applications referred to in sections 3.24 and 3.25 could include the following examples:

- reduction in clerical labour (likely to be a more significant component in the processing operation);
- increase in the turnover of freezer room stock (by use of better stock-control information);
- reduction in inputs to the processing operation, such as power and water(by means of better-informed plant management decisions);
- reduction of overweight level in packaged product;
- reduction of feed requirement in the fish farm(by using optimising feed rationing system);
- increase in growth rates in the oyster farm (eg by identifying more productive areas of the lease, based on historical growth data);
- receiving better price for product (eg by use of marketing systems such as *FISHNET*, controlling production to take advantage of seasonal movements in market prices etc).

It is clear that in these sectors too, only a modest improvement in one or more aspects of the enterprise resulting from computerisation would be required to justify the original acquisition.

4.24 Market Prospects

It is appropriate to discuss briefly the potential market for a vertically-integrated fisheries software package, and associated hardware. This discussion has been limited to the catching sector, as there has been insufficient opportunity to gather relevant

information relating to the processing and aquaculture sectors.

Table 2 summarises structural aspects of the owner-operator sector of the Australian fishing industry, and is derived from the DPI Fisheries Report No. 34 (Sudmalis 1981). Unfortunately this data reflects the situation as it was in 1977/78, but it is understood from discussions with the Bureau of Agricultural Economics that there has been no similar comprehensive study performed since then. The Australian Bureau of Statistics does have more recent statistics on fishing vessels, but these are not in a form as accessible and usable as those in the DPI report.

Table 2

**Structural Aspects of the Owner/Operator Sector of the
Australian Fishing Industry 1977-78**

| Vessel Length (m.) | No. of Vessels | Av. Engine Power (KW) | Market Value (\$) | Av. Annual Catch (\$) |
|-----------------------|-------------------|--------------------------|----------------------|--------------------------|
| less than 6 | 3026 | 40 | 7000 | 8000 |
| 6 - 9 | 1809 | 75 | 29000 | 17000 |
| 9 - 12 | 1228 | 100 | 55000 | 27000 |
| 12 - 15 | 941 | 120 | 80000 | 39000 |
| 15 - 18 | 493 | 140 | 115000 | 56000 |
| over 18 | 306 | 250 | 280000 | 130000 |
| all vessels | 7803 | 83 | 47000 | 25000 |

Source: DPI Fisheries Report No 34, April 1981

Notes:

- . excludes semi-commercial vessels and tenders (ie less than 4m.)
- . excludes fleet vessels (ie where 3 or more vessels have the one owner)
- . Market Value, includes vessel, gear and all licences
- . Annual Catch expressed as gross value, averaged over 1975/76 - 1977/78

In considering marketing implications, the above data needs to be adjusted for the effects of inflation since the data was gathered. Examination of Commonwealth statistics on the value of fish, crustacean and mollusc production in Australia, published in issues of *Australian Fisheries*, indicates that overall, the nominal value of product has more than doubled between 1977/78 and the present. Although

supporting data is not to hand, it is suggested that market value of vessels (inc. gear and licences) will have increased similarly over this period, and average engine power is also likely to have increased, although less significantly.

These statistics are useful in making an *a priori* assessment of the potential market for hardware/software packages, although obviously a proper market survey would be part of any serious commercial analysis of the prospects for software development. Consider the following points:

- i. The majority of vessels over 18 m (at least 80%, say, which equates to 240 vessels) are likely candidates for a microcomputer system, given:
 - . the high capital value of the vessel, in comparison to which the \$6000 investment is relatively insignificant;
 - . the high value of catch (averaging, say \$250000 p.a. at current prices) - the cost/benefit evaluation above indicates that an improvement in this catch level attributable to better catch/effort data of only 0.8% would pay for the microcomputer;
 - . the high level of operating costs for a vessel of this size and horse power - again, minimal improvements in the financial operation through better trip management and better financial management would cover the cost of the information system. Vessels in this size range would be appropriate for an on board microcomputer system (see discussion on hardware, sect 4.32). Note that the figures quoted in Table 2 do not include fleet-owned vessels, so it could be expected that few if any of this group of operators would presently make use of computer systems.
- ii. A significant proportion of the vessels in the 15m - 18m size range (at least say, 50%, equating to 240 vessels) would be a potential market. The cost/benefit evaluation carried out above used parameters appropriate to the scale of operation of vessels in this "middle sized" group, and led to the conclusion that just a few modest improvements in operational/financial efficiency would justify the acquisition of a microcomputer. In vessels of this size, an on board system seems a less feasible prospect, so an on shore system would be the most common prospect for this group.
- iii. Even some vessels in the groups less than 12 m would be expected to represent a potential market. These make up the majority of the population of commercial vessels, and it can be assumed that those at the upper end of the range (ie in terms of market value, horse power and value of catch) would satisfy the broad criteria suggested for justification of a microcomputer. Let us make the arbitrary (and probably

conservative) assumption that the potential market here comprises 20% of the 12m - 15m vessels, 10% of the 9m - 12m vessels, 5% of the 6m - 9m, and none of the vessels under 6m. This equates to about 400 vessels.

The above argument, arbitrary and hypothetical as it is, is considered to be a conservative means of assessing the scale of the potential market. Even so, this yields a total estimate of some 880 potential sales in the catching sector in Australia, with a gross value of \$5.28m. By Australian standards, this represents quite a significant vertical market for hardware/software packages, for example perusal of commercial software catalogues such as *Greenbook 3* reveals that there are few packages marketed in this country with sales of more than, say 100 units. Of course, this may be more a reflection on the number of competing suppliers or on consumer resistance in these markets, rather than on the size of the potential market.

It is not proposed to go into an examination of the likely profitability of developing and marketing software for the fishing industry, but it is relevant to this discussion to point out that a professionally-designed software package with good quality documentation can cost tens, or even hundreds of thousands of dollars to develop. There are also significant costs involved in marketing the package, providing user support (ie initial training and follow-up advice), and maintaining/enhancing the software. These costs could be particularly high for a market such as the fishing industry, where the operators are "first time users" of computers, and are widely spread geographically. Therefore it is quite possible that, notwithstanding the apparent attractiveness of this potential market, the overall economics may not be so attractive. It is possibly for this reason that this market has not been exploited by commercial software companies.

4.30 Prototype application - catching sector

The Catch/Effort data base, although not fully developed by any means during the course of this project, is considered to be a successful prototype application, for reasons that will be discussed in the conclusion to this section.

4.31 Hardware - General

It is not proposed to enter into the contentious area of comparing different types of hardware, which inevitably involves:
more-or-less philosophical issues such as "user friendliness"; "upward compatibility"

(ie the ability of the microcomputer to communicate with mainframes); use of "industry- standard" operating systems; accessibility of the operating system to more expert users;

. practical issues, such as the size of the unit; the availability of commercial software; the reliability of the supplier.

The current protagonists in these arguments are those espousing microcomputers with innovative (ie non-standard) operating systems, of which the most popular example is the Apple Macintosh , and those advocating machines with standardised operating systems (eg the IBM PC and all its imitations).

It has already been indicated (sect. 2.32) that the author's choice of the Macintosh for development of the prototype system was based on considerations outside the scope of this project, and it is not suggested that this machine was necessarily the *best* one for the job. Indeed, it can be asserted with confidence that *any* recent model of small business computer from a reputable manufacturer is quite capable of supporting the types of potential applications for the fishing industry outlined in sect. 3.20.

It is *also* asserted, with equal confidence that the Macintosh, despite its unconventional features, is not thereby *disadvantaged* as a serious business/operational management tool. Burns and Venit(1985) carried out a comparison between the Macintosh and the IBM PC in terms of their performance of a range of business applications, and concluded that, overall, the two machines were not significantly different in performance, and that many of the statements made by supporters/detractors in respect of either machine were exaggerated. In fact, it was suggested that these machines were following a path of *convergent evolution* (the author felt that *this* was a bit exaggerated!).

The original proposition that the Macintosh has an advantage over more conventional microcomputers in the areas of ease of operation and graphics capabilities is supported by Burns & Venit. Walker(1985) outlines current software developments which emulate this "Mac interface" on more conventional machines.

4.32 Hardware - onboard computers

The technical issue concerning the use of microcomputers on board vessels is of particular interest. Discussions with various contacts revealed a range of opinion about how feasible it was to take these machines aboard even medium-sized vessels, the major concerns being:

- i. the effects of the maritime environment on sensitive electromechanical

components such as disk drives;

ii. the effects of fluctuating voltages in the vessel's power supply (ie corrupting data in RAM or on disks).

The literature and other searches described earlier in this report, although directed toward identifying commercial software developments in the fishing industry, were structured in such a way as to identify any material relating to technical aspects concerned in the use of on-board computers. No such material was found.

The author has already reported (sect. 3.31) the experience of taking a Macintosh on board the 34 m *Bluefin*. Marchant (1985) describes his experience in successfully operating a Macintosh aboard the antarctic research and supply vessel *M. V. Nella Dan*, which although being a fairly large vessel (75m), would be expected to present the same problems in this regard as would a large fishing vessel, given the rugged conditions experienced in the Southern Ocean (rolls of over 45° are commonplace). Carter (pers. comm.) advises that Apple II micros have been used on board some of the KFY vessels (around 25 m in length) for periods of up to 3 years in the Northern Prawn Fishery without any hardware problems, despite the fact that they have been located in a variety of sites on board. There is also anecdotal information to the effect that microcomputers are becoming a standard piece of equipment on board 12 m racing yachts.

Although it is beyond the scope of this project to evaluate the technical aspects of on-board computers, it can be concluded with some confidence that microcomputers generally, and Macintoshes in particular, can perform satisfactorily on board larger vessels (eg upwards of 18 m), with their relatively dry wheelhouses and protected power supplies. It is also likely that many smaller vessels (say, larger than 10 m) could accommodate micros without undue technical problems. Finally, the interesting point has been made to the author that micros could have a particular advantage over larger computers on board vessels of any size, in the respect that the bearings of large disk drives can suffer extreme mechanical wear resulting from their gyroscopic stability in a roll. Light floppy disk drives do not have this problem.

Vessels which are unable to accommodate a small business computer could still take advantage of information technology by use of small portable computers. There are many makes of battery operated, programmable hand held micros, and the simulated exercise in data capture and transfer using the Sharp, while not conclusively demonstrating its practicality, is at least technically feasible. Heron and Larner (pers. comm.) are confident that an arrangement of this kind could also be made easy to operate, involving only the writing of communications/formatting programs in

both the on-board and the onshore computers. Yet another solution to this problem could consist in the exclusive use of the more powerful types of portable computer (such as *Epson*, *Kaypro*, *Husky*, *Toshiba* etc) which have large fold-up LCD display screens, large memories (eg 256K of RAM), and use standard operating systems such as MS-DOS or CP/M. Some of these machines are specially designed for "hostile" environments.

4.3.3 Software

The *Helix* database package, although quite satisfactory for the simplistic prototype development that was carried out for this project, is limited by a number of factors, some of the more important of which are:

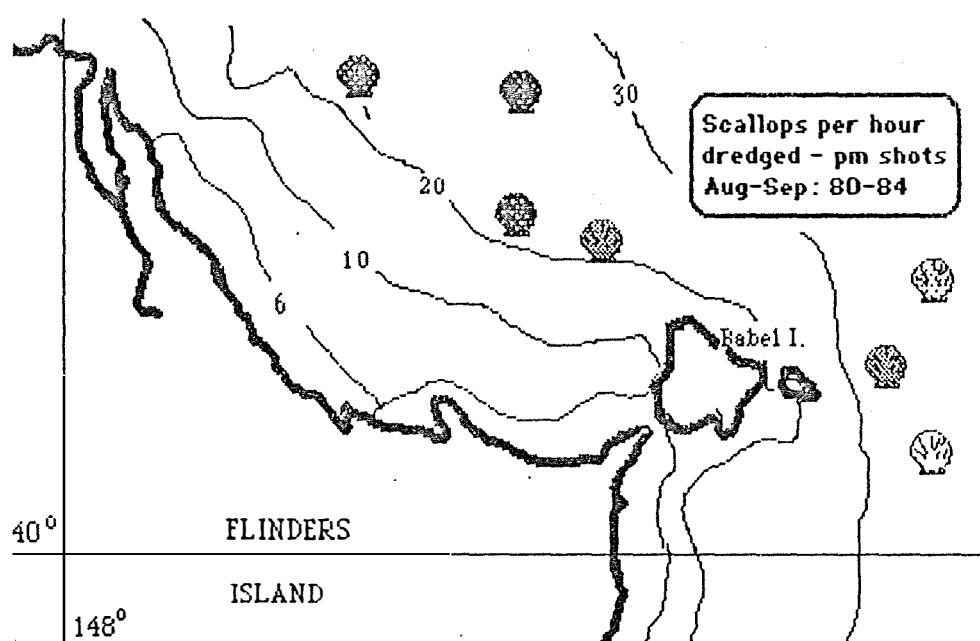
- unconstrained access of the user to the specification parameters of the collection, with the attendant risk of inadvertent loss of these specifications;
- sheer size of the *Helix* application, which limits the amount of data which can be stored on one disk - and it does not seem possible to store a collection on more than one disk (this could be overcome with upgraded hardware);
- vulnerability of the whole collection to system crashes;
- inability of the "statistical tiles" (ie means, totals) to be delimited by query settings;
- difficulties in linking records from different relations.

The key role of a database package such as *Helix* is in the initial draft specification phase of a system, where user requirements are particularly likely to go through a continuing process of adjustment. However, subsequent to this (ie in the phase where the commercial program is being written), it is considered that a more formal language or system would be better. This aspect has not been investigated in detail, so it is only possible to make suggestions, based on advice from other people. *Omnis 3* is advanced as one option; this apparently has the kind of flexibility and user-friendliness as *Helix*, but at the same time has more powerful file-handling capabilities, as well as having more constraints on the operator. Again, more traditional languages such as *Pascal* or even Microsoft *Basic* are considered well able to deal with this kind of application while making optimum use of the interactive features of the Macintosh.

Another point which emerged during the development of this prototype was the desirability of exploiting the graphics capability of the Macintosh (although other micros are now emulating this, see Walker 1985). The Catch/Effort database could be

made more graphical (and hence more user-friendly) by, for example, displaying the results of queries on historical catches as symbols superimposed on digitised charts. Fig. 1 below is a crude (and non-factual) example of this concept, depicting a distribution of average scallop catches in a particular region, with shading denoting different levels of catch rate. This type of presentation would be fairly straightforward to display on a Macintosh, either on the screen or as hard copy.

Fig. 1



Tufte (1983) enunciates a number of principals applying to the efficient, effective and aesthetic representation of information in graphical or pictorial form, and is recommended reading for anyone interested in this particular aspect. There are several software packages on the market which can handle graphics as part of a database, of which the new version of *Helix* is an example.

4.34 The *Catchdata* system - overall evaluation

As already reported in the Results (sect. 3.33), there was a particularly significant point which emerged from the *Catchdata* development, namely the notion that feedback to fishermen of the kind available through the *Catchdata* query facility would constitute the best possible incentive for them to complete their Log Book returns honestly and reliably. This is considered by the author to be the most significant outcome of this project.

It is axiomatic of primary industry statistical systems that, *unless* there is an incentive or *quid pro quo*, such as useful feedback reports, information providers will be less than assiduous in the accuracy of their reporting to the authorities.

Wallace (pers. comm.) advises that this is a recognised problem in the areas of agricultural and forestry statistics, and that efforts are being made in these areas to provide useful analytical reports back to the field. It is understood that there is some thought being given to providing feedback to fishermen in the South East Trawl fishery, for which a new log book programme is currently a contentious issue.

It is a common allegation, often by fishermen themselves, that the data in official fishing returns is, by and large, completely unreliable (note: O'Brian's data is no doubt one of the few exceptions in this regard!).

Given the large commitment of scientific resources in *analysing* this data, and the significance of basing management decisions on this analysis, it can be safely concluded that *any* device which can improve the accuracy of the data base, even by a few percentage points, has a potential worth to the industry that could be enormous.

4.40 Prototype application - aquaculture sector

The trout feeding system is discussed in Appendix 4.

5.00 CONCLUSIONS

This project has demonstrated that there is a significant potential market for microcomputer applications in the Australian fishing industry, with a range of useful applications being seen for the catching processing and aquaculture sectors.

With the exception of the projects now being undertaken by the Trawler Owners Association (TOA), it appears to date that there has been no significant development of commercial software oriented toward the smaller enterprises in the industry. Even overseas, there is little indication of this type of development.

The TOA activities, particularly the use of modern communications technology to improve the marketing and distribution of fish, are timely and commendable.

The prototype applications carried out within this project, simplistic as they might have been, are considered to have been successful prototypes, and have demonstrated in practical terms some of the potential benefits arising from the use of microcomputers in the catching and intensive aquaculture areas.

The trout farm feeding system can produce significant savings in the feed costs of this type of operation, and at the same time provide an immediate and detailed picture of the stock situation in the farm.

The catch/effort database can assist the fisherman in his fishing strategies, with the potential to improve catching performance while reducing effort.

However, the most significant point to have emerged from the project is *not* that the microcomputer can assist small enterprises in the fishing industry to improve their operations and hence their profits, although this is an important point. It is, rather, that one way of addressing the perennial problem of inaccurate fishing log book returns, and thereby improving the basis upon which key resource management decisions are made, is to introduce a form of feedback reporting to fishermen, along the lines of the primitive query facilities developed in the prototype *Catch/Effort* data base. Although this issue does not directly relate to the private use of microcomputers, its significance was brought to attention by the development of the

prototype application. If this project can contribute even in a small way to the improvement in the *quality* of information maintained by fisheries authorities, it can be considered a major success.

Recommendation No 1: The relevant fisheries authorities should, as a matter of priority, develop a mechanism by which log book data held in their computer files can be made available on request to each fisherman who provided the data, in a form suitable for flexible structured queries on the data base using a private microcomputer. The option of producing some standardised analytical reports to be returned regularly to fishermen, using the authorities' own computing resources should also be followed up.

An area which is considered very important, but was not really covered adequately in this project, was the potential to use simple computer-based systems, such as financial spreadsheets, as *educational* devices. It is suggested that part of the difficulty in evaluating some of the potential applications was the fact that many fishermen simply do not run their businesses in a structured fashion, conducive to the introduction of a computer.

Recommendation No 2: The Australian Maritime College should use this project as a starting point in the development of some software, particularly in the area of financial management, to be used as a training medium in the business management modules of its fisheries courses.

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APPENDIX 1.

COMPUSPEAK - A Glossary of Computer Jargon.

The purpose of this glossary is to elucidate the computer jargon which is used unavoidably and, to some extent inadvertently in this report, and which may also be encountered in reading publications on computing. The definitions are derived in part from the glossary produced by Skillman(1982), itself derived from McGlynn(1979) and *Popular Computing* (1981), in part from the glossary in Webster and Champion(1984), and partly from the author's understanding of current usage of these terms.

| | |
|-----------------------------------|---|
| Application | Specific problem or area of activity to which a specific computer program or set of related programs can be applied. |
| BASIC | The most popular high level language used on microcomputers; an acronym for "Beginner's All-purpose Symbolic Instruction Code". |
| Byte | Sequence of binary digits grouped in such a way as to represent to the computer an alphabetical or numeric character. Usually the smallest unit in a system which can be addressed. |
| Compile | The process of converting (automatically) program instructions written in a high level, symbolic language into machine language <u>prior</u> to the execution of the program (contrast with "interpret"). |
| Consumables | Those materials used up in the process of running a computing system, e.g. paper, printer ribbons. |
| Database | A structured collection of information, or collection of data files, which can be treated as an entity. |
| Database Management System (DBMS) | A system which is designed to create and maintain a database, or group of related databases, including the facility to produce various types of reports resulting from interrogation of the databases. |
| Field | Reserved area in a record which denotes an item of data and has the same meaning for all records in a related group. |
| File | An organised, named collection of records, treated as a unit. |
| Floppy disk/diskette | Small data-storage device in form of small, flexible magnetic disk, typically holding 300 - 400 Kb. |
| Hard copy | Output of the system in visually readable form, eg printout on paper. |
| Hard disk | Rigid, high capacity magnetic data storage device, typically holding 5 Mb to over 300 MB. |

| | |
|---------------------|--|
| Hardware | The collection of equipment forming a computing system (contrast with <i>Software</i> and <i>Consumables</i>). |
| High level language | Programming method that uses commands which symbolically represent the operations required of the computer (contrast with "machine language"). |
| Interface | Boundary between different elements of a system, across which there is a transmission of information (eg interface between main unit and printer). |
| Interpret | Process of translating into machine language and executing each step of a program <u>while</u> the program is running (see "compile"). |
| Kb or K. storage | <i>Kilobyte</i> : measure of data storage capacity of computer or medium, such as a disk; equal to 1,000 bytes. |
| LCD | <i>Liquid crystal diode</i> : form of display on screens of small portable or hand-held microcomputers, similar to that on digital watches and games. |
| Machine Language | Method of expressing program commands in binary code directly comprehensible to the computer. |
| Menu-driven | Method of structuring a program so that the user directs the course of the program by selection of choices displayed on the screen (ie a menu) at strategic points of execution. |
| Mb. | <i>Megabyte</i> : as for <i>Kb</i> , equal to 1 million bytes of storage. |
| Modem | Device which allows a computer to send and receive information through the normal telephone network; short for "modulator/demodulator". |
| Operating System | Software that controls the overall operation of the computer (eg controlling the simultaneous execution of a number of processes, invoking standard housekeeping and troubleshooting routines). |
| Package | Used in the context of <i>software package</i> , meaning a set of commercial programs, together with documentation, manuals, warranties etc which is sold as a complete package. |
| Professional | Person whose native language is <i>Compuspeak</i> . |
| Program | Set of coded instructions which, when "executed", direct the computer in its task of receiving, storing and processing data. |
| RAM | <i>Random Access Memory</i> ; memory internal to the computer which stores program instructions and data, and which can be overwritten by the user. Any specified part of this memory can be immediately accessed by the computer (ie without searching through the information file from beginning to end). |

| | |
|-------------------|--|
| Record | Collection of related items of data (ie "fields") treated as a unit. |
| Report | Form of output from the computer system, eg hard copy printout or output listing on the screen. |
| ROM | <i>Read-only Memory</i> ; part of the hardware which contains permanently stored information (usually programs); can be <i>read from</i> at any time, but cannot be <i>overwritten</i> . |
| RS-232-C | Convention specifying the requirements for compatibility between computers or other connected devices (eg modems), allowing the transmission of data; usually describes the "ports" or input/output conduits of a computer or peripheral device. |
| Software | Programs (including operating systems) associated with a computer system. Contrast with <i>Hardware</i> , which is controlled by the software. |
| Spreadsheet | Type of software package which allows the user to specify formatted arrays of related information (ie "spreadsheets"), which structure the way data is input, processed, and output; although particularly useful for accounting-type applications, they are useful for many other types of application as well. |
| Storage Medium | Physical means by which information in the system is permanently stored (eg internal RAM, hard disk, magnetic tape). |
| Terminal | Device equipped with keyboard and output facilities (eg printer) which is connected to a computer system either directly or indirectly (eg by means of the telephone lines). |
| User | Person who seeks to use the computer as a tool to achieve some objective beyond the computer itself. |
| User friendly | Description of a computer application's capacity to be easily understood and operated, particularly by inexperienced people. |
| Vertical (market) | Describes an area of application whose requirement is for an integrated set of systems (or programs) specifically tailored for that area of activity or industry. |
| VDU/VDT | <i>Visual Display Terminal/Unit</i> ; the television-like screen attached to the computer. |
| VIATEL | Public access information retrieval system using the telephone network; the system is run by Telecom, but information is supplied by "service providers" unconnected with Telecom; access to the system is by any screen-based device equipped with a modem and some special software. |

APPENDIX 2

DEVELOPMENTS BEING UNDERTAKEN BY THE TRAWLER OWNER'S ASSOCIATION (TOA)**1.0 The *FISHNET* marketing and information service provided on Viatel****1.1 Overview of Viatel**

Viatel is a public-access information retrieval system. Information is provided by a variety of independent Service Providers and distributed through the telephone network from a central computer (operated by Telecom). The information can be accessed and displayed using an appropriate computer terminal, a special Viatel terminal, or a TV set connected with an adaptor. Some information on the system is freely accessible and free of charge, in other cases the user is charged a fee for access to each page of information, and in some cases the information is accessible only to a Closed User Group (CUG), by means of access codes and passwords. Finally, Viatel provides the means not only of accessing information, but also of sending messages to Service Providers or other users.

1.2 The TOA's *FISHNET* system contains some types of information which are freely accessible, namely:

- . regional weather reports;
- . news bulletin board;
- . vessel brokerage (ie classified advertising for vessels);
- . a variety of indexes of organisations associated with the industry, eg buyers, restaurateurs, exporters;
- . fishing equipment (ie a form of advertisement for gear suppliers) and other general advertising material eg Guide to Eating Out.

It is understood that in the future, most of these will be available only to members of the Trawler Owner's CUG.

1.3 Other parts of the system are currently accessible only to members of the CUG, namely those relating to the marketing aspects of the system. These are as follows :

- i. Offering or updating a standing offer of catch for sale.

This is a page of information generated by the fisherman, and includes details of species, quantity and price offered. There is also potential to include a description of the quality of the catch, based on the system of quality evaluation developed by the CSIRO Division of Food Research.

ii. Acceptance of a purchase order.

This page is generated by the buyer, responding to a sale offer, and gives details of the buyer, species type and quantity accepted, price, and shipment details. The NSW Fish Marketing Authority (FMA) is to be connected to the *FISHNET* system, and will handle the accounting aspects of each transaction conducted through the system, extracting a commission on the sale (it is understood the TOA also takes a commission on each sale).

1.4 It is understood users can access the *FISHNET* system either through their own terminals, or through terminals located in fisheries co-operatives along the coast. The current strategy, as advised by Steele and Walkear (pers. comm.) is that the FMA will initially provide funding to the value of the basic Viatel terminals to co-ops on the South Coast of NSW, who will have the option of purchasing these or putting the funds toward buying more powerful microcomputers with Viatel capability. After trialling the system for some time, a decision will be made about extending the support to other areas of NSW.

1.5 Practical observations

As discussed in Section 3.13, a display of the *FISHNET* system was initially given at the *Seadays 85* exhibition. Subsequently, by arrangement with the TOA, the author accessed the system using a *Tandata* dedicated Viatel terminal loaned by the regional Telecom office in Hobart and also by means of an Apple Macintosh microcomputer fitted with a modem and appropriate communications software, namely *MacTerminal* and *MacVideotex*.

The author and Mr D O'Brian, neither of whom had direct experience using Viatel, had no difficulty stepping through the pages, or entering test messages, using the *Tandata* terminal. Operation of the system using the Macintosh computer was equally easy, using the pull-down menu commands provided on *MacVideotex*, although during this demonstration there was a problem with the transmission of the data, causing some of the characters making up the message to be dropped out or corrupted slightly. At the time of writing, it has not been established whether this problem was caused by a poor quality exchange line, or whether there was a problem with the *MacVideotex* software. Apart from this however, the display on the Macintosh, although using a small monochromatic screen, was considered to be quite satisfactory (note: Viatel displays are in colour). Also, the Viatel screens could be printed off on the Macintosh printer, which is a facility most desirable option which most microcomputers are capable of providing.

2.0 Commercial Software

This development by the TOA is the first attempt of which the author is aware to develop and market small business computer software designed specifically for the fishing industry in this country.

The system which was on display at the *Seafair 85* exhibition had been developed on IBM-compatible hardware, using the database *dBase II*, together with the package *Open Access*, which produced graphical displays of data. The system inspected by the author consisted essentially in an expenditure accounting system for the catching sector, which took data input from cash book entries and invoices, and allocated expenditure to user-defined budget heads (eg fuel, supplies, crew payments, boat repayments etc) producing the range of financial statements usual to this type of application. There was also the facility to allocate expenditures to specified projects, permitting for example the analysis of costs incurred by each type of activity in a multipurpose fishery. The TOA's software consultant advised that this was but one subsystem of a planned integrated package for commercial management of a fishing operation.

It is understood that since this demonstration, a "Log Book" system has been developed, which appears similar to the "Catch/Effort" database referred to throughout this project report. At the time of writing, there has not been the opportunity to inspect this new application, although it is understood to consist essentially of a database made up of the items captured through the new South East Trawl log book, supplemented with a few others required by the fisherman for his personal records. Walkear (pers. comm.) has advised that discussions have commenced between the TOA and the Commonwealth Department of Primary Industry (DPI) concerning the possibility of their accepting data files from this system (probably transmitted through the CSIRONET network) in lieu of manually-completed returns from the fishermen. There has been some suggestion that fishermen providing the data in this way may gain some rebate on their licence levy, due to the possible savings in clerical manpower by the DPI.

On the question of on-board computers, it is understood that although the TOA are considering this issue, the systems currently being developed are regarded essentially as on-shore applications.

3.0 Discussion

3.1 The *FISHNET* system appears to have considerable potential benefit to the catching, and processing/wholesaling sectors, through the use of this new communications technology to provide an information service and to facilitate off-market purchasing transactions, which should be more efficient than the present centralised marketing system in NSW. A strong point in its favour is that the system promotes the concept of buying product from a specific vessel, which should increase the buyer's ability to give preference (and higher prices) to vessels with a record of well-handled product. This in turn should be an incentive to all fishermen to improve the quality of their catch.

The system is only in its early days, but the range of information services which could be carried through this medium is virtually limitless, covering such categories as:

- . advertising and promotional material;
- . classified advertising;
- . "real time" information, such as weather and market prices;
- . reference material, such as fisheries regulations and survey requirements;
- . education;
- . ordering/purchasing system, eg for spare parts.

Finally, the Viatel system could be used to link terminal users to private computer systems, so for example a user with an appropriate terminal could in fact use a remote computing service to maintain his own business information system. Walkear is of the view that this option would not be attractive to most fishermen, who understandably would prefer to maintain physical custody of their own fishing and business records.

3.2 There was insufficient opportunity at *Seadays* (or since) to properly evaluate and comment upon the commercial software being developed by the TOA. As discussed in section 4, book-keeping and cost accounting systems are an essential part of a properly managed small business, and lend themselves to microcomputer applications, and so the applications under development are appropriate for, and likely to benefit, certain sections of the industry. The "Log Book" system now being developed is considered to have more direct appeal to fishermen, for reasons also discussed in section 4.

Choice of hardware and software is a contentious issue (see Discussion, sect 4.31). The

author's opinion was that the TOA cost accounting system was somewhat cumbersome to operate, although it is emphasised this was based on a fairly brief inspection of the system in the rather hectic environment of the *Seadays* exhibition. Also in this regard, the graphics employed were not of the same quality as those available using the Macintosh.

4.0 Conclusions

The developments discussed above are potentially of considerable significance to the catching and wholesaling sectors of the fishing industry. Ultimately, the success of the *FISHNET* Viatel system depends on how many fishermen and buyers can be persuaded to join the system. Although the author considers the marketing aspects of the system to be desirable, the receptiveness of fishermen to the system is an issue which cannot be authoritatively commented upon in this paper. The attitude of fishermen outside the NSW sector of the SE Trawl fishery (which is understood to be the major constituency of the TOA) is particularly unclear, given the different nature of marketing arrangements in the other States.

Availability of the Viatel system would constitute an additional selling point for small business computers to the fishing industry, given the ability of these machines to be used as terminals (technical problems with the *Mac Videotex* notwithstanding). However, one should recognise the significant price difference between a basic Viatel adaptor (about \$1400, including the TV monitor), and a small business computer with communications package (in excess of \$4000). The capability for a computer to print off Viatel screens could be a desirable option, under some circumstances.

As indicated by their other line of development (ie small business software for the industry), the TOA clearly believes that the application of microcomputers should be considered a basic tool to be used by fishermen in day to day management of their business activities to maintain profitability in a sector which is being increasingly subject to cost pressures. The general type of applications they are envisaging is essentially along the same lines as those outlined in this report (section 3.20).

APPENDIX 3

PROTOTYPE CATCH/EFFORT DATA BASE

1.0 System Outline

This system comprises a database, structured along the lines of the (private) fishing log book maintained by the skipper, containing details of fishing effort(type of gear, duration of shot, towing and winch speeds etc), catch details (weight by species),together with supplementary environmental details and remarks considered to be relevant to the catching operation (time of day, sea conditions, depth, location etc).

The system has at least three uses:

- i. To provide a collection of historical data which the fisherman can interrogate in a variety of ways in order to identify patterns and key factors associated with his historical fishing performance (the ultimate aim of which is to make more informed decisions about when and where to fish).
- ii. To link with other systems (eg market price system, cost accounting system) to produce financial performance reports relating to the fishing operation, calculating, for example, trip profitability. The ultimate aim of this exercise is to assist the more effective management of the enterprise.
- iii. In those cases where the data is input directly into an on-board computer system, the system can also produce automatically the log book returns required by the relevant fisheries authority.

2.0 Design Criteria

The Catch/Effort system should be capable of the following:

- i. Ease of data entry, by means of simple and comprehensible screen prompts and formats. Formats to be capable of easy modification, as required.
- ii. Capacity to store and quickly access at least 2 years' data, with the facility to pull in further historical data (at least an additional 3 years' data) for analysis.
- iii. Flexible and simple procedures to interrogate the data in a variety of ways.
- iv. Production of neat and comprehensible outputs, both on the screen and on hard copy printouts (including proforma Log Book returns). Output formats to be capable of easy modification, as required.
- v. Capacity to link with other databases.
- vi. Some degree of flexibility in the design of the database itself (eg fields can added or deleted, mathematical computations can be varied).

vii. Capability of operating the system on a reasonably-sized vessel (eg over 15 m.).

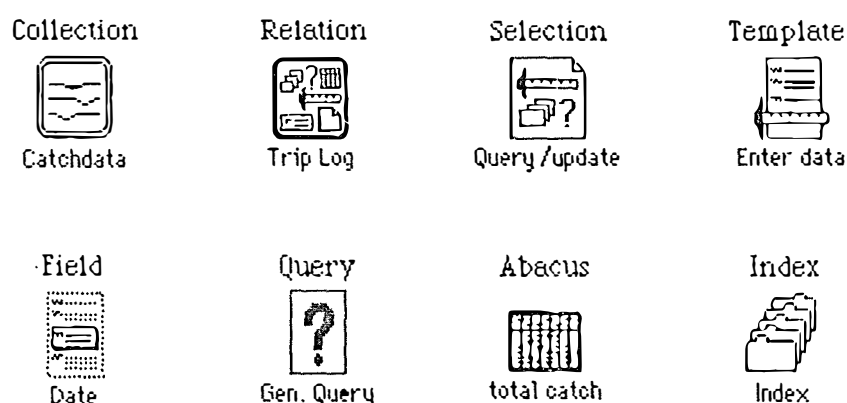
3.0 System Structure

Structure of the system is best described by reference to a flowchart. The *Helix* software package chosen to develop the prototype on is strongly oriented toward the use of "icons" ie pictorial symbols for system elements and processes. Therefore it is appropriate to depict the system structure using, where possible, these symbols.

3.1 Brief introduction to *Helix*

Fig. 2 below depicts the icons are used in setting up and running a *Helix* application.

Fig. 2



These icons are defined as follows:

Collection represents the main database, with all its associated forms, functions and data files. The example shown here is the *Catchdata* collection, which denotes the Catch/Effort data base.

Relation represents each subsidiary database in the collection, and can to some extent be thought of as a data-file.

Selection represents a process which can be initiated by the user, such as entering data, querying or updating the database (the example shown here), or producing an output report.

Template represents the layout of a form for the entry or display of data (in this case the main data input form).

Field represents each item of data in a relation, in this example the date of a fishing

operation. Fields are grouped into records, which are not assigned an icon in *Helix* (see Glossary, Appendix 1).

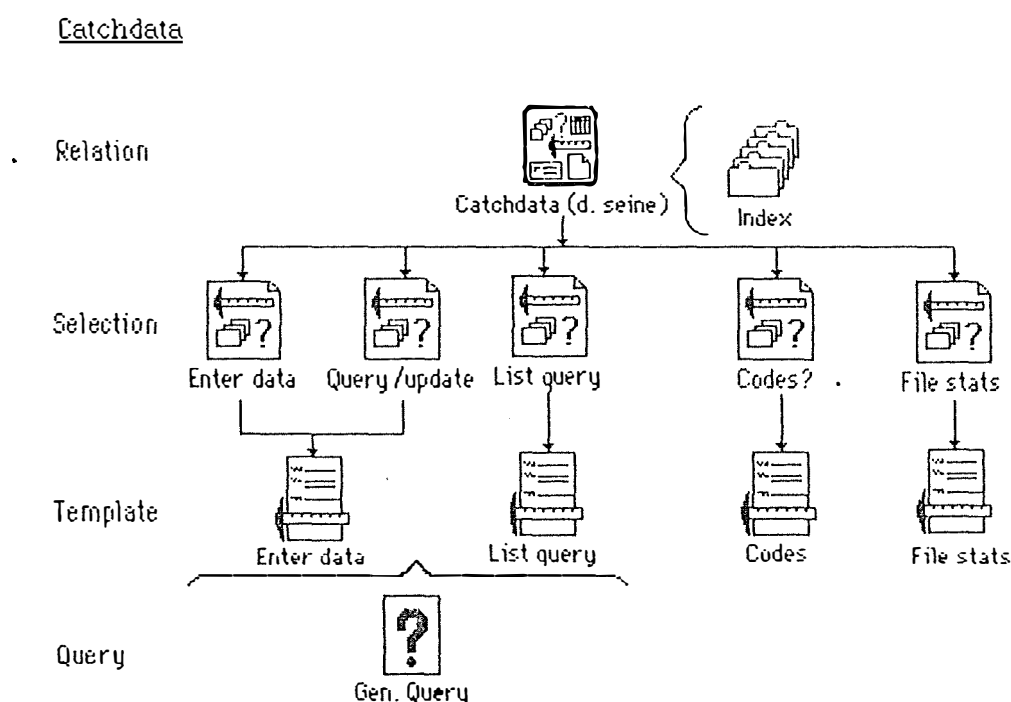
Query represents a structured enquiry on the data in a relation, setting specified limitations on particular fields in the database and accessing the records which satisfy these defined criteria.

Abacus represents a calculated value associated with a record or group of records in a relation, eg the sum of several fields (such as total catch-the example here), the first few letters of a text field etc. Calculations can be arithmetical, textual, or logical.

Index represents the process of setting up an index which establishes an order in which records are accessed and displayed (eg by ascending order of date and shot number).

3.2 The *Catchdata* collection comprises two relations, or files, namely the *Trip Log* and *Catchdata* relations. The following figures (Figs 3 - 5) depict the logical layout of each of these relations, and how they fit together in the collection. Note: the *Catchdata* icon shown here is specific to the danish seining operation, as developed in the prototype application, but the flow chart structure will be identical for all forms of fishing.

Fig. 3



Explanation

. *Catchdata* ('*d. seine*,' is the name of the "relation", or main file (in this case it is specific to the danish seining operation).

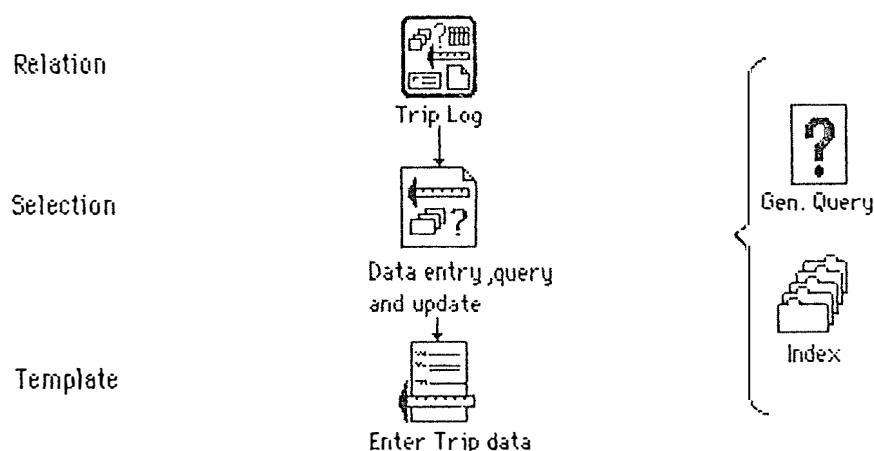
. There are five "selections" falling within this relation, ie processes that can be carried out by the user, which consist in: initial data entry, general query on the database (which can also be used to update a specific record), a listing type of query (ie a report that automatically lists out all records conforming to the query criteria), an enquiry on various codes used in the data entry process (ie species and gear codes), and finally a statistical report on the database (which can produce totals, averages etc for the items in the database).

. There are four "templates" or form designs used in the operation of this part of the system, namely *Enter data*, *List query*, *File stats and Codes?* The lines show which template is used by which selection (as we can see, the initial data entry and general query/update processes use the same form layout). Figures 6, 10, 8 and 7 attached to this Appendix depict the four form layouts, respectively.

. Some of the selections in this relation are governed by a single type of enquiry (*Gen. Query*), which itself uses the *Enter Data* form layout, and the data for the whole relation is stored and accessed by a single indexing arrangement (*Index*), which indexes catch records in ascending order of date and shot number, respectively.

Fig. 4

Trip Log



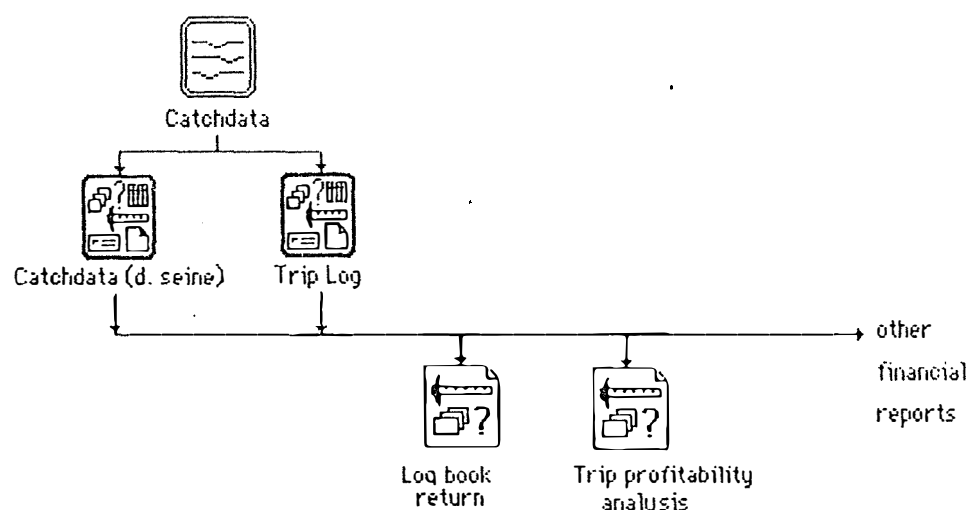
Explanation:

. The *Trip Log* relation contains only one selection, which performs data entry, query and update functions, using the form layout *Enter trip data*. The attached Fig. 9 depicts the layout of this form.

. This relation is governed by a single query type and a single index, in this case the records are indexed by date and time of observation.

Fig. 5

The Catchdata Collection



Explanation:

This diagram shows how the two relations are connected for the purpose of providing the Log Book return (in this case the SE Trawl Log Book), Trip Profitability Analysis, and linking into other financial and operating reports. These output reports have yet to be developed.

It should be pointed out that the splitting of the database into two relations stems from the fact that catch details and more general trip details (including weather etc) are not collected simultaneously. To illustrate, Mr O'Brian generally only records trip details once per day, whereas he might make up to eight shots per day, each with its own set of catch records. It is undesirable within *Helix* to have more than one data entry process in a relation, so it was necessary to create two relations to accommodate the separate data entry.

4.0 OPERATING INSTRUCTIONS FOR THE *CATCHDATA* SYSTEM

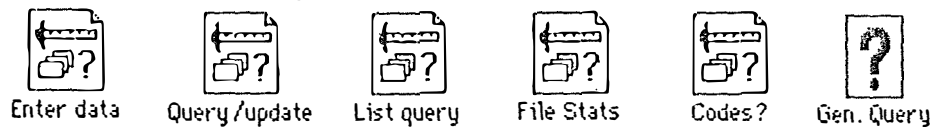
Note: These instructions assume you have a basic familiarity with the operation of the Macintosh, and a knowledge of the terminology. For example, you should be able to:

- perform the basic "mouse" operations of **point**, **click** and **double click**
- start up the system, and **load** and **eject** disks
- **select**, **open** and **drag** icons
- position the cursor to type text or numbers
- **pull down** menus and select options
- **scroll** through a window
- move, redimension and **close** windows
- make appropriate choices in the dialogue boxes controlling the printing process

THE *CATCHDATA* SYSTEM

1. START-UP

- load the start-up disk *Catchdata Disk #1*, followed by the disk *Catchdata Disk #2* (in the external drive)
- open *Catchdata Disk #1*: you must wait a while here, because the *Helix* program takes some time to load
- when the disk has stopped grinding away, the program has been loaded, so then you pull down the **File** menu and select **Show Collection**
- this will open the *Catchdata* collection, from which you select and open up the *Catchdata* icon (there is another choice, the *Trip Log* icon, but this part of the system has not yet been developed)
- you now see the *main relation menu* for the *Catchdata* system (not the same as a *pull down* menu), and can select whichever process you want to perform, by opening up the desired icon, which will be one of the following:



2. ENTERING DATA

- open up the *Enter data* icon; you should see a blank form on the screen, but if there is some other stuff (which depicts the Enter data relation), pull down the Search menu and select **Show Form**, which will give you the clear form (Clear Form will do the same thing and is used if you have a partly completed form you wish to delete)
- the cursor prompts you on which box to put your data, so key in your data using the keyboard, pressing TAB at the end of each entry to move to the next box (note: the Catchdata system has been set up to accept dates in the format "11Oct85" and you will get a beep if you don't use the right format, as you will if for example you try to enter words into a field which is specified for numerical data)
- if you make a mistake within a data box, correct simply using the BACKSPACE key
- if you discover a mistake after you have TABbed to the next box, the data can be corrected by pointing to the box, dragging the cursor across it (which highlights the box), and typing in the correct data
- if you wish to jump over a number of boxes for which you don't have data, you can either keep TABbing through the form or use the mouse to select the next box where data is to be entered
- when all data is entered for that form, press the ENTER key and that data will be stored away; a fresh blank form should then appear and a new record (ie shot) can be entered
- if there are no more records to enter, close the window, using the close box, and you will be returned to the main relation menu

3. SETTING UP A QUERY

This has to be done before you can locate a given record in the database, or run a report on a specified part of the database. The query function allows you to put limits on the data you wish to locate, display, or print. In other word, it allows you to set conditions on specified elements of the database, and accesses only those records that satisfy all the conditions you set in a specific query. To set up a query:

- open the *Gen. Query* icon in the main relation menu

- this will open up a window displaying a blank form which looks like the regular data entry form
- click once on the first data item you wish to limit, for example if you are interested only in shots made between 20 fm and 30 fm, click on the *Depth* box on the query form
- this will open up a *Query field dialogue box* which allows you to set two conditions on the chosen field (eg *Depth*)
- to set the first condition click once on the required button on the left hand side of the dialogue box, selecting in the case of this example the *greater than or equal to* button, labelled with the sign \geq , then type in the required value in the top right of the dialogue box, as prompted by the cursor (in this example, type *20*)
- you can set just one such limit if you wish, but in this example we want a second limit on depth, so you now select the right button in the lower right area of the dialogue box, in this example selecting the sign \leq (*less than or equal to*), and typing in the value of the second limit, (ie type *30*)
- if you are satisfied you have set up the limitation correctly, close the dialogue box by clicking once on **OK**
- this returns you to the general query form, which now contains a little notation in the *Depth* box about the limit you have just set; if you want to set limitations on other fields (eg for shooting times between 1500 and 1800), you click on the required data box and go through the limit setting process again, as was done for depth
- you can set limits on every field on the form, if you wish, and the limits can be numerical, as in the example, or can relate to dates or *text* (ie alphabetical characters); dates are still limited by arithmetical values
- with text-type field, the query dialogue box gives you some additional buttons to select, for example **Starts with** lets you limit the data to those text fields starting with a specified set of letters which you type into the right hand box; if you always record hookups as such in the *Comments* box, typing *hook* (or even *hoo*) in the box will find all those particular records, although the **Contains** button is a safer way of choosing these, because the *Comments* box may contain the word *hookup*, but may start with other comments, and so be missed
- you have now set up the limitation on the whole database that you are only interested in records (ie shots) where depth was between 20 and 30 fm, and where a hookup occurred; all reports run on the data will access only those records

- you then exit from the query mode by closing the window, which returns you to the main relation menu

3(a). "UNSETTING" A QUERY

The last query you set up will remain in force and affect all subsequent access and reports until such time as you return to the query mode and change or unset the limits you placed on the various fields. Unsetting is done in the same way as setting up a query, except that you select the **All** button in the dialogue box which unsets the existing limits on that field. It is a good practice to do this as a matter of course after you have finished with a particular type of query and before you do anything else.

4. FINDING, UPDATING or DELETING A PARTICULAR RECORD

This may be necessary if you want details on a particular shot, or if you wish to change some data after it has been entered.

- if you have just entered the data, and are still in the *Enter data* mode, you can find recently-entered records by stepping through them
- in this case, pull down the **Search** menu and select **Find Previous**; *Catchdata* stores records in ascending order of date and shot number (ie the earliest data is at the beginning of the file), so **Find Previous** will throw up the next (earlier) record to the one displayed; you can keep repeating this process and step back through the records (you can also step forward if required by using **Find Next**)
- if however the record you want is buried somewhere in the middle of the database, you can locate it by setting up a query (as described in point 3, using the date as the limiting factor, ie setting the = (*equals*) button and typing in the required date
- having set up this query and returned to the main relation menu, open the *Query/update* icon, which will display a blank data entry form
- you then select **Find First** from the **Search** menu, and the record of the first shot for this date will appear on the screen; use **Find Next** to step through the record until you find the particular shot record you want
- data in any box can be amended by moving the cursor to the appropriate data box, dragging, and overtyping, as described for the Data entry mode; after the amendment has been made, press the ENTER key and the record will be filed away again
- if for some reason you want to delete the whole record you have located, select **Delete** from the **Search** menu and that record will disappear from the database
- return to the main relation menu by closing the window in the usual way

5. RUNNING A LIST QUERY

A "list query" is an output report (on the screen or the printer) which lists out relevant items of catch/effort data for each record in the database satisfying a given set of query conditions. It is so far the most useful report to be produced by the *Catchdata* system, allowing a quick scan of historical data to look for key factors affecting catch rates, such as time of day, depth, type of gear etc. To run a list query:

- first, set the specific query conditions you want, using the procedures already described in paragraph 3
- open up the *List query* icon from the main relation menu
- the machine should quietly search away for a while, and then start displaying the listing on the screen, which you keep moving by clicking on the scroll arrow on the right of the screen
- if the screen displays some funny stuff (ie showing the selection) and doesn't come up with the report, select **Show Form** on the **Search** menu
- to print the listing form, select **Print Form...** from the **File** menu; this will open up a dialogue box which gives you a few options to select by clicking on the desired button (see sect. 8 for general procedures on Printing); **Print Draft** is the best option for this particular form
- when printing is complete, return to the main relation menu by closing the current window

6. RUNNING THE FILE STATS REPORT

This is a single report which lists out a summary of the overall *Catchdata* data base, eg total no. of shots, average weight of flathead per shot etc. It is run simply by:

- opening the *File stats* icon in the main relation menu
- the report takes a fair while to run (ie 2 or 3 minutes for a full year's data), but when it has managed to finish you will have the data displayed on the screen, and can print this in the usual way (see sect. 8)
- return to the main relation menu by closing the window

7. ACCESSING THE CODES? REPORT

This is a little reminder report you can throw up on the screen if you've forgotten the various abbreviation codes used in the main *Data entry* form, such as gear code and species codes.

- access it by opening the *Codes?* icon, which will display the codes on the screen (you may need to scroll around the screen a bit)
- return to the main relation menu by closing this window

8. PRINTING

Anything displayed on the screen can be printed off. You should have some familiarity with printing on the Macintosh, but the general procedures in *Catchdata* are:

- when what you want printed is displayed on the screen, pull down the **File** menu and select the print option which can be **Print...** or **Print Form...** depending on what particular process you are performing
- this will open up a dialogue box which lets you chose from a number of options by clicking on buttons; **Standard** or **Draft** with **Continuous** feed for **All** pages is the usual arrangement, but you can't do any harm by experimenting with the others
- you will then be given another dialogue box with the option to **Print Now** or **Save until later**; select the **Print now** option and make sure the printer is turned on!

Fig 6. Data Entry Form

CATCH/EFFORT RECORDING SYSTEM
CATCH DATA

DATE SHOT NO. GEAR CODE
 LAT Deg Min S: LONG Deg Min E
 START TIME DEPTH fm TOW DIRECTION
 FLATHEAD Kg Whiting Kg MORWONG Kg

OTHER (specify)

| SPECIES | CODE | Kg |
|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |

COMMENTS

Fig 7. Gear Codes ? form

GEAR CODES

SPECIES CODES

| | | | | | |
|-----------------|-----|--------------------|-----|------------------|-----|
| 4 SEAMER: | 424 | Blue Grenadier | GRE | Shark, Dog | SHD |
| | | King Dory | DOK | Shark, Gummy | SHG |
| GREDED BLUE EC: | 425 | Spiky Dory | DOP | Elephant Shark | ELE |
| | | Gemfish | GEM | Squid | SQD |
| STANDARD NET: | 422 | Red Gurnard Perch | REG | Morwong | MOW |
| | | Ling | LIG | Silver Dory | DOS |
| | | Trevalla, Deep Sea | TRD | Latchet | LAT |
| | | Trevalla, Spotted | TRS | Flathead | FLT |
| | | Shark, School | SHS | Flounder | FDR |
| | | | | Whiting, School | WHS |
| | | | | Other Commercial | OTR |
| | | | | Trash Fish | TRS |

Fig. 8 File stats report

Statistics for Whole Catchdata File

No. of shots: 428

No. invalid shots: 21

| Species | Flathead | Whiting | Morwong | Other |
|--------------|----------|---------|---------|-------|
| No. shots : | 346 | 22 | 37 | 42 |
| Total catch: | 50665 | 2020 | 7470 | 2915 |
| Av. catch : | 146 | 92 | 202 | 69 |

Fig. 9 Trip Log form

CATCH/EFFORT SYSTEM

TRIP LOG DETAILS

DATE 11Oct85

TYPE OF OPERATION: (enter Y where applicable)

TIME 600

LEAVING PORT ☐STEAMING ☐FISHING ☒ARRIVING IN PORT ☐

WIND DIR. AND FORCE: D 15 F 03

SEA CONDITIONS:

CURRENT DIR. & FORCE: D 05 F 02

(use 2 digit code) 04

BAROM. PRESSURE: 1010 R, F or S F

COMMENTS

discolouration in water

Fig 10. List Query Report

| Date | Shot | Lat | | Long | | Depth | Start | F'head | Whit. | Morw. | Total |
|---------|------|-----|----|------|----|-------|-------|--------|-------|-------|-------|
| 20Dec83 | 4 | 43 | 7 | 147 | 35 | 28 | 1425 | 385 | | | 385 |
| 20Dec83 | 5 | 43 | 7 | 147 | 35 | 26 | 1620 | 800 | | | 800 |
| 27Dec83 | 3 | 43 | 3 | 147 | 28 | 23 | 1205 | 300 | | | 300 |
| 27Dec83 | 4 | 43 | 3 | 147 | 28 | 21 | 1335 | 440 | | | 440 |
| 27Dec83 | 5 | 43 | 3 | 147 | 28 | 21 | 1520 | 170 | | | 170 |
| 6Jan84 | 5 | 43 | 26 | 146 | 58 | 29 | 1230 | 200 | | | 440 |
| 6Jan84 | 6 | 43 | 26 | 146 | 58 | 29 | 1410 | 200 | | | 480 |
| 18Jan84 | 1 | 43 | 16 | 146 | 19 | 26 | 1550 | 170 | | | 170 |
| 18Jan84 | 2 | 43 | 16 | 146 | 19 | 27 | 1630 | 210 | | | 210 |
| 24Jan84 | 1 | 43 | 8 | 147 | 37 | 26 | 1550 | 350 | | | 350 |
| 24Jan84 | 2 | 43 | 8 | 147 | 37 | 26 | 1730 | 450 | | | 450 |
| 25Jan84 | 4 | 43 | 9 | 147 | 40 | 26 | 1210 | 450 | | | 450 |
| 18Feb84 | 3 | 43 | 2 | 147 | 32 | 31 | 1405 | 400 | | | 400 |
| 18Feb84 | 4 | 43 | 2 | 147 | 32 | 31 | 1545 | 200 | | | 200 |
| 18Feb84 | 5 | 43 | 2 | 147 | 32 | 31 | 1725 | 250 | | | 250 |
| 22Feb84 | 3 | 43 | 30 | 147 | 0 | 29 | 1305 | 400 | | | 400 |
| 22Feb84 | 4 | 43 | 30 | 147 | 0 | 29 | 1440 | 300 | | | 300 |
| 4Mar84 | 1 | 43 | 16 | 147 | 24 | 25 | 1500 | 280 | | | 280 |
| 9Apr84 | 1 | 43 | 30 | 147 | 0 | 25 | 1430 | 240 | | | 240 |

APPENDIX 4

PROTOTYPE TROUT FARM FEEDING SYSTEM

As mentioned earlier (section 2.30), this work was carried out within the TSIT, at the suggestion of the author. It was carried out by Ms R. Watson as a final year computing project in the School of Business Studies. Given the role of the author in initiating this second project, together with his involvement in some supporting and liaison work, it is appropriate to describe this aquaculture project in some detail here (for a detailed description and discussion of results, see Watson 1985). There is also benefit in discussing this application as it employed quite different hardware and software from the catching sector applications developed within the Maritime College project.

1.0 Project Strategy and Methodology

1.1 Choice of an application.

Initial discussions on possible applications were entered between Mr N Forteath of the Aquaculture Dept in the TSIT, Mr A. Purves, owner of Sevrup Trout Pty. Ltd. and the author. Mr Purves had recently acquired a small business computer, and although making use of it in the area of book keeping and word processing, was anxious to extend its functions to the operational management of his trout farms in northern Tasmania. An initial examination by Mr Purves of the Landless trout farming programs suggested that in some aspects that package was not directly applicable to Mr Purves's style of operation, and given the difficulty of modifying a system developed overseas, it was decided that Mr Purves's immediate needs might best be met by a program developed locally, on an experimental basis. Ms Watson was interested in carrying this out as her computing project, and accordingly it was decided to proceed with the development of the pilot system, known as the *Feed/Growth/Inventory System*. The role of the author was essentially one of providing (gratuitous) advice and assistance in the initial fact finding and system specification phase of the project.

1.2 Hardware

Because Mr Purves owned an IBM-compatible Dick Smith *Challenger* computer, it was appropriate to develop the system on an IBM PC. In any event, this type of machine is that favoured by the School of Business at the TSIT for business-type applications.

1.3 Software

Initially it was decided to develop the system using the database system *dBase II*, however, after some consideration, Ms Watson was advised that a spreadsheet might be more appropriate, at least for the initial trial system and accordingly she developed the prototype system in *Multiplan*. Although the system was developed to a stage where it was demonstrated to Mr Purves, Ms Watson felt that *Multiplan* was not sufficiently "user friendly" in this particular application, so she converted it to *Lotus 1.2.3* which is a general purpose business software package comprising a spreadsheet and some other facilities.

1.4 Fact finding and system specifications

This exercise was carried out primarily by Ms Watson, with some minor involvement by the author, and consisted in on site examination of the Sevrup operations, at both the Bridport on-growing farm and the Cressy hatchery, and interviews with Mr Purves and some of his staff. Mr Forteach was also involved in providing technical advice on the feeding system.

2.0 System outline

2.1 System objectives

The overall objective of the system was to provide a means by which the feeding rations of the trout could be calculated accurately, based on data about the age and mean size of trout in each pond, and other parameters relevant to the growth curve for salmonids, such as water temperature. It was hoped that as a consequence of this, there would be an overall reduction in the trout farm feed bill (the biggest single operating cost), as the current tendency to overfeed was replaced by a more finely tuned ration requirement.

It was initially recognised that such a system would require some form of inventory system for the stock held in each pond, and the maintenance of this subsystem was considered to have other benefits to the operation as well, so it could be considered to be a secondary objective of the system. The system was intended initially to serve the 40 ponds at the Sevrup Bridport trout farm and its Waterhouse outstation, with possible extension to the other sites operated by the company.

2.2 System structure

The system consists of the following key elements:

- i. a main file serving as an inventory of pond holdings, containing current details for each pond such as number of fish, age group, mean size etc.
- ii. an automatic process to update of this inventory, as a result of information on the quantity of feed going to each pond;
- iii. additional updating facilities for the main file, enabling data items to be changed as a result of transfers into a pond, transfers out (eg mortality, cull for market);
- iv. an adjustment process, working on the main file, based on the results of periodical sample checks of actual mean fish sizes in each pond;
- v. two major reports generated by the system each day:
 - . the *Feed Requirements* report, displaying the optimum quantity of feed for each pond in the farm for a range of water temperatures;
 - . the *Current Fish Holdings* report, displaying the estimated present contents of each pond;

examples of each report are attached, as Figures 11 and 12, respectively.

The system calculates feed requirements and estimated current fish holdings by the application of an empirical growth model, based on one recommended by Piper(1970), adapted by Purves and Forreath for local conditions. One feature of the system is that the user can vary the "target" feed rate applying to each pond (for example, some ponds will deliberately be given a ration below the optimum, in order to retard growth and so control the flow of marketable product), and the model takes account of this.

2.3 System operation

The operating procedures (once the commencing stock data has been specified in the file) are broadly as follows:

- i. The daily *Feed Requirements* report is run at the end of each day by the computer operator, in readiness for the next day.
- ii. Next morning, farm staff use this report, in conjunction with the measured water temperature, to read off the optimum ration required for each pond (there is a degree of discretion exercised here, allowing for other factors, such as turbidity).
- iii. After feeding, the farm staff check off the amount actually fed to each pond, and this data is input to the computer.

- iv. The main file is automatically updated as a result, and the next day's *Feed Requirements* report can be run, as can the updated Current Fish Holdings report, if required.
- v. Other adjustments, due to transfers in or out, or to the running of a sample check, are made by separate data entry procedures.

3. Discussion

Site testing of the system is not expected to be carried out before late November 1985, so it is not possible to report results at this stage. It is possible however to make some general observations about this system.

- i. The *Lotus 1.2.3* software is considered by Watson to be appropriate for the job, and has the capacity to store pre-programmed operating steps known as "macros", which the user can initiate by a simple keystroke sequence. This makes the operation of the system fairly easy, although it is suggested that a one day on-site training session for the operator would be desirable, in addition to the provision of a procedural manual.
- ii. Another advantage of the software is that it will be possible to add on new parts to the system if required with relative ease.
- iii. Execution times are considered reasonable, with the main updating processes taking only a minute or two. Because there is no storage of historical data in the system at this stage, there are no machine or disk capacity problems.
- iv. The author would have liked to have seen a file containing the *historical* fish holdings data incorporated in this system, although Watson decided against this in the prototype, due to the additional complexity and the possible occurrence of disk management problems. Such a database would permit the testing of the growth model itself, with possible adjustments to the model to reflect the *actual* growth rates achieved on the farm. It should not be difficult to provide such a facility in a future version of the system.

In summary, the *Feed/Growth Inventory System* appears to work satisfactorily and is considered to have the potential to be a very valuable tool in the management

of a salmonid farm. Indeed it may have application in other areas of intensive fish rearing, with adaption of the growth model being a relatively straightforward process, according to Watson. Given that a medium sized salmonid farming venture can have an annual feed bill in excess of \$200,000, the potential for savings resulting from the use of this relatively simple system could be significant, with just a 1% reduction in the feed bill being sufficient to justify the acquisition of hardware and software (see cost/ benefit evaluation in the Discussion, sect 4.23).

Fig. 11 *Feed Requirements Report* 79

INSTRUCTIONS:

- 1. Amounts are in GRAMS. Temperatures are in degrees CELCIUS..
- 2. Amounts shown are the total amounts of feed required for each pond for 24 HOURS. Feed amount shown for the pond temperature (measured) unless, due to some factor, the fish will not eat that amount.
- 3. Please record the amounts fed for each pond or tick that figure if that amount was fed.
- 4. Feed rate shows the rate at which the fish are being fed.
- 5. Please fill in the date and the temperature at which you fed the fish in the relevant position (top left corner of the form).

Feed Requirements: Sevrup Fisheries Pty Ltd (Bridport)

DATE:--

TEMPERATURE:--

| Pond No. | Temperature: | | | | | Feed Rate = 100% ?? |
|----------|--------------|----------|----------|----------|----------|---------------------|
| | Lowest: 8 | 10 | 12 | 14 | 16 | |
| 01 | 381.86 | 468.69 | 532.74 | 599.80 | 633.44 | 100% |
| 02 | 470.64 | 573.96 | 656.61 | 739.26 | 780.72 | 100% |
| 03 | 2316.22 | 2824.66 | 3231.41 | 3638.17 | 3842.21 | 100% |
| 04 | 4141.29 | 5050.36 | 5777.61 | 6504.86 | 6869.68 | 100% |
| 05 | 6346.99 | 7740.23 | 8854.82 | 9969.41 | 10528.54 | 100% |
| 06 | 9278.67 | 11315.45 | 12944.87 | 14574.30 | 15391.69 | 100% |
| 07 | 10916.28 | 13312.53 | 15229.54 | 17146.54 | 18108.19 | 100% |
| 08 | 9356.50 | 11410.37 | 13053.46 | 14696.55 | 15520.80 | 100% |
| 09 | 9356.50 | 11410.37 | 13053.46 | 14696.55 | 15520.80 | 100% |
| 10 | 11499.19 | 14023.40 | 16042.77 | 18062.14 | 19075.14 | 100% |
| 11 | 12614.17 | 15383.13 | 17598.30 | 19813.47 | 20924.69 | 100% |
| 12 | 13140.93 | 16025.52 | 18333.20 | 20640.87 | 21798.50 | 100% |
| 13 | 14942.43 | 18222.48 | 20846.52 | 23470.55 | 24786.88 | 100% |
| 14 | 14601.03 | 17806.14 | 20370.22 | 22934.30 | 24220.55 | 100% |
| 15 | 29202.06 | 35612.27 | 40740.44 | 45868.61 | 48441.11 | 100% |
| 16 | 22791.00 | 27793.90 | 31796.22 | 35798.54 | 37806.27 | 100% |
| 17 | 29628.30 | 36132.07 | 41335.09 | 46538.11 | 49148.15 | 100% |
| 18 | 35289.42 | 43035.88 | 49233.04 | 55430.21 | 58538.96 | 100% |
| 19 | 42397.47 | 51704.23 | 59149.64 | 66595.05 | 70329.97 | 100% |
| 20 | 17623.79 | 21492.43 | 24587.34 | 27682.25 | 29234.78 | 100% |
| 21 | 25195.78 | 30726.56 | 35151.18 | 39575.80 | 41795.37 | 100% |
| 22 | 22494.72 | 27432.58 | 31382.87 | 35333.16 | 37314.79 | 100% |
| 23 | 27125.62 | 33080.02 | 37843.54 | 42607.07 | 44996.64 | 100% |
| 24 | 24597.64 | 29997.13 | 34316.71 | 38636.30 | 40803.18 | 100% |
| 25 | 19678.11 | 23997.70 | 27453.37 | 30909.04 | 32642.54 | 100% |
| 26 | 16966.38 | 20690.71 | 23670.17 | 26649.63 | 28144.25 | 80% |
| 27 | 19439.28 | 23706.44 | 27120.17 | 30533.89 | 32246.36 | 100% |
| 28 | 18960.32 | 23123.34 | 26451.95 | 29781.57 | 31451.84 | 75% |
| 29 | 13075.93 | 15946.25 | 18242.51 | 20538.77 | 21690.67 | 60% |
| 30 | 6683.09 | 8150.12 | 9323.73 | 10497.35 | 11086.08 | 50% |
| 31 | 31549.97 | 38475.58 | 44016.06 | 49556.54 | 52335.87 | 100% |
| 32 | 15099.79 | 19123.21 | 21876.61 | 24630.31 | 26011.68 | 50% |
| 33 | 7085.48 | 8640.83 | 9885.11 | 11129.39 | 11753.57 | 30% |
| 34 | 29128.13 | 35522.11 | 40637.29 | 45752.47 | 48318.45 | 100% |
| 35 | 20615.70 | 25141.10 | 29761.41 | 32381.73 | 34197.83 | 60% |
| 36 | 20873.17 | 25455.08 | 29120.62 | 32786.15 | 34624.93 | 50% |
| 37 | 44078.45 | 53754.21 | 61494.82 | 69235.43 | 73118.43 | 100% |
| 38 | 43412.56 | 52942.14 | 60565.81 | 68189.48 | 72013.82 | 100% |
| 39 | 30468.02 | 37156.12 | 42506.60 | 47857.09 | 50541.10 | 100% |
| 40 | 5274.14 | 6431.88 | 7358.07 | 8284.26 | 8748.88 | 100% |

Current Fish Holdings: Sevrup Fisheries Pty. Ltd. (Bridport)

Date:

7 1985

| Pond Desc. | Predicted Weight (g) | Predicted Length (cm) | No. Fish in Pond | Total Pond Weight (g) | Fish Year Group |
|------------|----------------------|-----------------------|------------------|-----------------------|-----------------|
| HT1 | 1.19 | 2.05 | 2500 | 2984.05 | 1985 |
| HT2 | 1.42 | 2.17 | 2750 | 3893.09 | 1985 |
| R1 | 17.83 | 5.05 | 2500 | 44578.20 | 1985 |
| R2 | 59.58 | 7.55 | 2000 | 119154.63 | 1985 |
| R3 | 140.51 | 10.05 | 1730 | 243080.45 | 1985 |
| R4 | 307.62 | 13.05 | 1500 | 461428.81 | 1985 |
| R5 | 516.02 | 15.51 | 1250 | 645028.07 | 1985 |
| R6 | 572.26 | 16.05 | 1000 | 572258.29 | 1985 |
| R7 | 572.26 | 16.05 | 1000 | 572258.29 | 1985 |
| R8 | 795.15 | 17.91 | 987 | 784809.31 | 1985 |
| R9 | 956.85 | 19.05 | 957 | 915700.88 | 1985 |
| R10 | 1115.57 | 20.05 | 900 | 1004013.77 | 1985 |
| R11 | 1247.29 | 20.81 | 950 | 1184928.03 | 1985 |
| R12 | 1115.57 | 20.05 | 1000 | 1115570.85 | 1985 |
| R13 | 1115.57 | 20.05 | 2000 | 2231141.70 | 1985 |
| R14 | 2175.54 | 25.05 | 1000 | 2175538.84 | 1985 |
| R15 | 2175.54 | 25.05 | 1300 | 2828200.50 | 1985 |
| CIRC. | 3755.52 | 30.05 | 1076 | 4040940.24 | 1985 |
| P1 | 5249.90 | 33.60 | 1034 | 5428394.91 | 1985 |
| P2 | 1483.80 | 22.05 | 998 | 1480831.47 | 1985 |
| P3 | 1844.76 | 23.71 | 1234 | 2276437.99 | 1985 |
| P4 | 2175.54 | 25.05 | 987 | 2147256.84 | 1985 |
| P5 | 3392.94 | 29.05 | 885 | 3002752.95 | 1985 |
| P6 | 3755.52 | 30.05 | 750 | 2816640.51 | 1985 |
| P7 | 3755.52 | 30.05 | 600 | 2253312.40 | 1985 |
| P8 | 4342.24 | 31.54 | 587 | 2548893.26 | 1985 |
| P9 | 4996.29 | 33.05 | 490 | 2448183.98 | 1985 |
| P10 | 5952.83 | 35.04 | 567 | 3375256.21 | 1985 |
| P11 | 5948.95 | 35.03 | 489 | 2909036.47 | 1985 |
| P12 | 5946.36 | 35.03 | 300 | 1783908.64 | 1985 |
| P13 | 7624.18 | 38.05 | 600 | 4574510.93 | 1985 |
| W1 | 8225.16 | 39.03 | 567 | 4663663.33 | 1986 |
| W2 | 7602.83 | 38.02 | 450 | 3421273.29 | 1986 |
| W3 | 8890.69 | 40.05 | 500 | 4445346.65 | 1986 |
| W4 | 11813.06 | 44.03 | 488 | 5764771.86 | 1986 |
| W5 | 12632.08 | 45.03 | 567 | 7162387.95 | 1986 |
| W6 | 12653.47 | 45.05 | 598 | 7566773.76 | 1986 |
| W7 | 10290.22 | 42.05 | 676 | 6956191.45 | 1986 |
| W8 | 8890.69 | 40.05 | 523 | 4649832.60 | 1986 |
| W9 | 242.19 | 12.05 | 1000 | 242186.36 | 1985 |

The analysis of length-frequency data of juvenile and adolescent
banana prawns, Penaeus merguensis: a comparison of
computer and graphical methods.

by

Katherine Colgan, Cert. Ed., B.Sc.

A project report submitted to the School of Fisheries,
Australian Maritime College, in partial fulfilment of the
requirements for the Graduate Diploma in Fisheries Technology.

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INTRODUCTION

Length frequency data is often used to estimate both growth and mortality parameters in fish stock assessments. The techniques for analysing length frequency data are: (i) graphical methods such as those described by Buchanan and Wollaston (1929), Harding (1949), Cassie (1950, 1954) and more recently by Tanaka (1962) and Taylor (1965) and (ii) computer programs such as those described by Pauly and David (1981), Macdonald and Pitcher (1979), Kumar and Adams (1977), Hassleblad (1966) and Schnute and Fournier (1980).

The Cassie graphical method has been used over a number of years and is still being used today to analyse for example larval cohort succession in herring, Clupea harengus, (Lambert 1984), and growth of the threadfin bream, Nemipterus peronii, (Sainsbury and Whitelaw 1984).

The Macdonald Pitcher program for the analysis of distribution mixtures has been used to determine the growth of the pollan Coregonus autumnalis pollan, (Wilson and Pitcher 1984) and it has also been used with the Cassie Method where the starting values for the Macdonald Pitcher method have been taken from the Cassie values for example in assessing the population dynamics of Amphiura filiformis, (O'Connor et al. 1983) and the biology of the threadfin bream, Nemipterus peronii, (Sainsbury and Whitelaw 1984). There are not many papers published in which ELEFAN I has been used. Two of the more recent studies which have used this method are a study on the growth of giant edible clams, Codakia orbicularis Berg and Alatalo (1984) and a study on the growth of the Sea Hare, Delabela auricularia (Pauly and Calumpong 1984).

Literature on the analysis of penaeid prawn length frequency data is very sparse. Pauly et al. (1981) applied ELEFAN I to a number of different sets of penaeid prawn data taken from the literature and collected in a number of different ways e.g., from shrimps grown in captivity, from tag recapture programs and from length frequency data. The only growth analysis on juvenile penaeid prawns found to date was conducted on data collected in the Gulf of Carpentaria by Staples (1980b) in which he used the Cassie method to determine growth rates.

In the present study length frequency analysis has been carried out on a subset of the data used by Staples (1980b) for the juvenile banana prawn, Penaeus merguensis. It has been shown that this species has a mixed life cycle with the adult, spawning and larval stages offshore and the juvenile stage taking place in an estuarine environment (Rothlisberg

et al. 1985). It was noted that postlarval immigration from the Norman River during the period September 1975 to September 1976 occurred as a series of pulses with one major peak occurring in November and three smaller pulses occurring in later months (Staples and Vance 1985). Emigration out of the river was in three main waves with the time spent in the river varying between one and nine weeks (Staples 1980b). Three smaller cohorts came into the river during March and April and the majority of these prawns overwintered in the river until the following Spring (Staples 1980b). It seems that there were a number of cohorts entering and leaving the river during the wet season of 1975/1976 and that individuals did not necessarily leave with the group that they entered with. Pulses of immigration and emmigration were not consecutive.

Staples (1980b) estimated, using the same data as used in the present study, that the carapace length of juvenile banana prawns, P. merguensis, increased by 1.2mm per week for the November to December and February to March periods and at this time growth approximated a linear relationship. The growth rate was found to decline with decreasing temperature during the autumn and winter months.

The purpose of the present study is to re-examine the data set collected by Staples (1980a,1980b) by using three methods of analysis and make comparisons between them. Firstly a "pencil and paper" method as described by Cassie (1950,1954). Secondly, two computer methods ELEFAN I developed by Pauly and David (1981) and another which analyses a distribution mixture developed by Macdonald and Pitcher (1979).

There are many differences between the three methods. The Cassie method is used for analysing one data set at a time. It was developed as a method of separating polymodal distributions into separate component groups based on a technique described by Harding (1949). The Macdonald Pitcher method also analyses single samples but separates out different component groups from a distribution mixture and the user has to choose the number of component groups in the sample and provide starting values for means, standard deviations, and proportions. ELEFAN analyses multiple samples and traces growth curves through a set of length frequency samples. It estimates growth based on the Von Bertalanffy growth formula and by fitting growth curves to the data selects which curve fits the data best and gives those parameters.

One of the aims of the present study has been to examine these methods with the following questions to be answered:

1. Ease of use.
2. Subjectivity.
3. The time taken to apply each method.

4. The biological relevance of the results.
5. The possibility of combining methods to give a better tool for the analysis of length frequency.

Abstract

This paper examines three methods of analysing length-frequency data: the Cassie method, the Macdonald Pitcher program for analysing distribution mixtures and the ELEFAN I method. The aim of the study is to answer the following questions about each method: (i) ease of use, (ii) subjectivity, (iii) time taken to apply each method, (iv) biological application of the results and (v) possible combination of methods. The data used in this study was collected by Staples (1980b) for juvenile banana prawns, Penaeus merguensis, in the Norman river from September 1975 to September 1976. It was found that the Cassie method had the advantage of being easy to use but subjective in the selection of the number of groups in a set of data. The Macdonald Pitcher method was also easy to use but the number of groups in a set of data had to be known before the method provided useful results. With ELEFAN I it is suggested that the Von Bertalanffy growth equation on which ELEFAN I is based may not adequately describe the growth of juvenile prawns. The method required accurate values of K and L_{∞} to be entered into the program before running otherwise the results were unsatisfactory.

It is suggested that ELEFAN I and Macdonald Pitcher could be used together to give a better tool for analysis. A further development could be the modification of the ELEFAN I program to describe the growth of juvenile prawns which approximates a linear relationship. There should be also be further study into the growth of juvenile prawns to try and accurately determine their rates of growth before applying length-frequency methods.

METHODS

Development of data and computer programs

The data analysed in the present study was collected at a number of sites situated along the Norman River on the eastern side of the Gulf of Carpentaria from September 1975 to September 1976 and has been published by Staples (1980b). Eighteen sets of data, collected at three weekly intervals, were collated from the original fieldwork notes with three lots of data collected from different sites being placed together to give reasonably sized samples to analyse. The eighteen data sets were then plotted into frequency histograms (Fig. 1). The Cassie method was applied to all data sets to determine number of component groups, means and standard deviations. From these, the length distribution of the component groups were drawn onto the frequency histograms (Fig. 2)

The MacDonald Pitcher program was originally obtained as a batch version which was found to be restrictive. The interactive version was obtained, debugged and a few minor modifications were made to assist the user, such as a counter is displayed on the screen while the program runs through its iterations to let the user know it is still running. There are two types of interactive program the single precision and the double precision version. The double precision version gives greater accuracy and was used throughout this analysis.

A set of normal data was generated for use with the Macdonald Pitcher method to test its sensitivity. Two normal curves were generated with means of 10.5 and 15.5 and a standard deviation of 1.5 (Table 3). This data set was used to see what kind of differences in results occurred when changes were made in the original starting values. These results were then used as a comparative model for the P.merguiensis results.

A number of modifications were made to the original ELEFAN I program. A plotting routine was developed to enable the data to be printed out in the form of histograms and a length value was calculated for each three weekly sample entered and this was marked on the histogram by a cross these could then be joined to give the growth curve (Fig. 3). The restructured data was also plotted with length values marked on (Fig. 4). The program was also modified to allow time at which the animal has zero length to be printed for each set of data

used.

Cassie Method

For each data set the frequencies of the different length categories were converted into probabilities which were then summed as a cumulative frequency totals. These were then plotted onto probability paper which transforms normal curves to straight lines. The plot was then studied and points of inflexion were picked out and component groups were identified. Inflexions correspond to low points in the frequency distribution. The means and standard deviations for each group were then estimated by drawing a line through the plotted data points at the fifty percent mark to estimate the means and drawing lines at approximately the sixteen and eighty one percent marks and dividing the different measurements by two to give the standard deviation. The assumptions of the method are that each component group is normally distributed and each curve can be fitted by taking away the curves one at a time and thereby exposing the flank of the next curve.

Macdonald Pitcher Method

This program has two versions, the batch version and the interactive version. Both of these versions were used with these data and it was found that the interactive version was more satisfactory as it enabled us to make decisions to be made based on immediate previous choices rather than waiting until the end of the run before changing the parameters.

The aim of this method is to separate out different component groups of a distribution mixture and to give the best proportions, means and standard deviations to the data. A measure of how well the data has been fitted is given by the chi square value. To do this the number of component groups in the mixture had to be decided upon and then the proportions, means and standard deviations of each group had to be entered. It was decided to use the values obtained from the Cassie method as starting points for this method.

Certain criteria have to be met for the method to be successful; the proportions have to add up to one, any standard deviation must be greater than zero and the mean of the first group must be less than the mean of the second group and any other succeeding group. The mixture has to be identifiable. After the initial parameters of the mixture were entered a number of options of how to analyse the data were made. These choices are called options. To determine which set of parameters best fit the data two methods of fitting are used, the Minimum chi

square or the maximum likelihood methods (MacDonald and Pitcher 1979).

In order to get meaningful results it is suggested by Macdonald and Pitcher (1979) that there be at least fifty observations in each component group. After a series of trials the following option sequence was selected.

1. The starting values for the proportions, means and standard deviations were obtained initially from the Cassie results (Table 2).
2. The proportions were estimated with the means and standard deviations held fixed
3. The means were estimated by constrained search while the proportions and standard deviations were held fixed.
4. The proportions were then re-estimated.
5. The standard deviation was estimated while the proportions and means were held fixed.
6. The proportions were then re-estimated.
7. Neither the means or standard deviations were held fixed while constrained search was carried out.
8. The proportions were then re-estimated.
9. Final estimates of all parameters were made using the maximum likelihood method.

ELEFAN Method

ELEFAN I was used to analyse twelve sets of data starting with the sample dated NOV275 (Table 1, Fig. 1) this was chosen as a starting point as a wave of recruitment started here and could be traced through the succeeding eleven samples.

ELEFAN I is based on the Von Bertalanffy growth formula which can be described by:

$$L_t = L_{\infty} (1 - e^{-K(T-T_0)})$$

where L_t = length at time T

L_{∞} = asymptotic length

K = a growth constant which determines the shape of the curve

T_0 = time at which the animal has zero length

The program as it is structured will only accept twelve sets of data. Therefore, we were unable to analyse the full eighteen data sets at the one time.

The twelve data sets were entered and a number of alterations to the data took place:

1. Each sample entered was restructured and scoring points were assigned to each peak in the data (Estimated sum of peaks=ESP).

2. The maximum number of possible points available for all the peaks was summed (Available sum of peaks=ASP).
3. A series of growth curves was traced through the data after the L_{∞} and K values were entered.
4. All the points a particular curve scores were summed.
5. The best fitting curve was then selected.
6. The process was then repeated according to the step sizes fixed.
7. A table of the ESP/ASP scores was printed out and the best fitting curve was selected by choosing the highest ESP/ASP ratio (Pauly and David 1981).

This process relies on four assumptions.

- a. That the sample used is representative of the population being investigated.
- b. The growth patterns in the population are the same from year to year.
- c. The Von Bertalanffy growth formula describes the growth of the population being investigated.
- d. All animals in the set of samples have the same length at the same age and that differences in length can be attributed to differences in age (Pauly and David 1981).

Two additional parameters are also included in the programme.

Winter point which adds a factor in when growth is slowest and C which expresses the intensity of the growth oscillation (Pauly and David 1981). Neither of these were used with the prawn data.

RESULTS

Length frequency data

Using the number of prawns <4 mm carapace length as an indicator of recently recruited prawns a major recruitment period can be seen in NOV275, which was the largest group sampled with 5376 individuals. Smaller pulses of recruitment can be seen in early November, January, March and April (Fig. 1). The structure of the population also changes throughout the year. During the summer months the population appears to be made up of greater numbers of smaller individuals with few large prawns remaining in the river. In contrast during the winter there are fewer prawns but these are more representative of different size groups. It is possible to trace some cohorts, visually from the raw data, from month to month as they grow in the river and it can be seen that in some cases cohorts appear, disappear and then reappear.

Cassie method

Using the Cassie method it was possible to separate out different component groups for each data set. However in some cases this proved difficult as the points of inflection were not clear. The proportions, means and standard deviations were also found (Table 2).

From these results it is possible to trace groups through the different months by following their increase in mean length. For example using the large recruitment wave which entered the river in the NOV275 sample with a carapace length of 3.6mm it was found three weeks later, assuming some of the group were sampled again, that this group had grown to 5.5mm in the DEC75 sample (Table 2). The same group were found to have a carapace length of 8.2mm in JAN75 and 11.5mm in FEB176. This group probably left the river at the end of February 1976 giving an approximate mean growth rate of 0.9mm p.w.

The Cassie results can seem to give a negative growth rate in some cases e.g., if the group entering the river in FEB276 is traced through it appears that growth may decrease from 12.5mm in APR276 to 12.3mm in MAY76 (Table 2), the next mean carapace length of 17.3 would not be a reasonable estimate of growth at this time of year. If the Cassie means are then fitted on to the length frequency histograms the progress of different cohorts can be traced through time (Fig. 2).

Three distinct growth rates can be seen during the 1975/19767 period
(i) Prior to the large wave of recruitment in NOV275 three groups can be

identified in SEP75 the growth rate of the first group is approximately 1mm per week. (ii) In NOV275 a large recruitment group enters and remains in the river until February. The growth rate for this group is as stated above. (iii) A third group overwinter in the river from MAR76 to JUN176. The growth rate of this group is 0.83mm per week. There is a difference in growth rates between winter and summer and this agrees with Staples (1980b) comments on growth.

Macdonald Pitcher

Normal data

When the normal data set was used with the Macdonald Pitcher method a number of things occurred:

1. The known values for the means, standard deviations and proportion were entered into the program. After the program had run new values were given for the proportions means and standard and these differed from the starting values by the following: the proportions were changed by 0.0583, the standard deviations by 0.01460 and the means by 0.52 (Table 7).

2. When the number of component groups was known it was possible to vary the proportions means and standard deviations widely and still get the same result. The proportions were varied between 0.1-0.9 while the means and standard deviations were held constant and the same χ^2 value was given whatever the proportions.

The critical χ^2 value for this set of data is χ^2 d.f.=19, $P < .05[19] = 30.144$. Therefore the calculated value of 0.6364 was very significant (Table 4).

When the means were varied by being placed closer together e.g., 11.0 and 15.0, 11.5 and 15.5, or further apart e.g., 10.0 and 16, 9.5 and 16.5. The same final result was also achieved (Table 4). The standard deviations were treated in a similar manner with the same results (Table 4).

3. When the number of component groups was altered e.g., three components or four components the method would follow the fitting procedure up to the final step where the maximum likelihood method of fitting took place. So even though significant χ^2 values were obtained at the previous step, the final fitting process did not take place. The method would not work at all when five component groups were entered (Table 5).

Juvenile *P.merguensis* data

The method was then tried on the juvenile banana prawn data. Certain data sets were selected for analysis. SEP75 was analysed and up until the final fitting procedure using the maximum likelihood method gave a significant χ^2 value but was not accepted for the final step (Table 6). This happened to other data sets as well NOV175, OCT75 and APR276.

At the end of each analysis a revised set of parameters was given as with the normal data. In general it appears that the Macdonald Pitcher method estimated larger standard deviation values for component groups with larger individuals than the Cassie method (Table 6). It also seems that the proportions vary widely in larger size groups.

A way of assessing how well the method has worked is to see how far the starting values for the proportions, means and standard deviations differ from the values given by the program. When analysing the juvenile *P.merguensis* data it was found that, in general, the means were similar to the Cassie values but the proportions and standard deviations differed. Where the starting values differed widely from the values given by the method as in the case of APR276 a large χ^2 is given and the final fitting process does not take place.

Two data sets were rejected at the first step of the analysis where the proportions are estimated these were NOV275 and FEB276 (Table 6).

Only one data set went through the whole procedure and came out with a significant chi square result this was JUN176 (Table 6).

ELEFAN I

NOV275 was selected as a starting point for the ELEFAN analysis because there was an obvious pulse of recruitment at this time and it was hoped that a growth curve would be traced from this point.

The seeded parameters entered of L_{∞} and K were 35 and 3.7 respectively with an increment of 1 for L_{∞} and .1 for K for seven steps (Table 8a). Based on adult growth parameters these values were chosen because Lucas et al (1979) stated that *P.merguensis* had an L_{∞} value of 38 and a K value of .08 per week or 4.16 per year. It is preferable when using this method to have the expected L_{∞} and K values in the middle of the step values.

Four different values of T_0 were tried to correspond with waves of

recruits coming into the river and a knowledge of approximate spawning time. From the results of this analysis it can be seen that no growth curve was drawn that passed through the obvious modes in the data (Fig 3). Only a very minor part of the variation could be explained by the ESP/ASP ratio. In the case of $T_0=0.0$ only 9.5% of the variation is explained, for $T_0=-0.1$ 13%, $T_0=0.1$ 11.5% and $T_0=0.18$ 5.7% (Table 8b). When using four different values of T_0 all the ESP/ASP ratios were low the best result being obtained for $T_0=-0.1$ which would be approximately six weeks. All the different T_0 values gave approximately the same values for L_∞ but differing values for the growth constant K (Table 8b). The restructured data, which are plots of the peaks and troughs in the data, show that the curves did not pass through the peaks (Fig 4).

As an alternative method not available on the ELEFAN I program, linear growth curves were fitted by eye and four different groups were traced through the time period (Fig 5).

Average rates of growth were estimated using the four curves generated by the ELEFAN method and the four lines fitted by eye. It was found that when using the ELEFAN curves the value of K seemed very high when compared with the rates of growth obtained by the eye fitted line (Table 9).

DISCUSSION

General comments

The purpose of this present study was to look at a number of different methods of analysing length-frequency data and assess aspects of their performance with respect to; their ease of use, subjectivity, time taken to use the method, the biological implications of the results given and the possibility of combining methods. Their ability to separate out different recruitment groups was also investigated as was the use of the Von Bertalanffy growth equation used by Pauly and David(1981) in the ELEFAN I program for describing the growth of juvenile banana prawns.

It was possible to use all methods of analysis on this data set and to gain information about the growth of juvenile P.merguensis from the results. Even though the methods were different in their approach to the analysis of the data e.g., ELEFAN I required multiple sample inputs and Macdonald Pitcher and Cassie only analysed single samples certain comparisons between them can be made.

Cassie method

The Cassie method was easy to use and after the initial learning phase became repetitive. Because of this ease of use it is still used today and it has the added advantage of not requiring high technology machinery. Only a calculator is needed.

One of the major problems with the Cassie method was its subjectivity when placing the inflexion points on the curve. At times it was very difficult to decide where the inflexion point should go. Schnute and Fournier (1980) point out that if an ambiguous decision is made regarding these points it then becomes cumulative when selecting the other points.

A further disadvantage of this method was that it is not really suitable for large data sets as the length of time taken to compute the answer increases and the possibility for error also increases.

Using the Cassie method on the P.merguensis data proved difficult

as the modes were often indistinct and selecting points of inflexion became difficult. This method appears to work well if the modes are clear but does not appear sensitive enough to pick up small differences in the data set which could denote different groups particularly when tracing juvenile cohorts of P.merguiensis through time. Even though this method only analyses one sample at a time it is possible to plot the data as a series of histograms and plot the curves on the graphs and trace possible cohort movement forward and backward in time (Fig. 2).

The parameters obtained from this method were used as starting points for the the Macdonald Pitcher method but the lack of results obtained with this data set with the Macdonald Pitcher method could either be due to the wrong number of components being used because of the problem of picking inflection points or a problem with the type of data being used.

It is difficult to say whether the growth rates obtained from using this method are biologically realistic although similar growth rates have been observed in the laboratory under optimal environmental conditions (Staples, pers. com.)

Macdonald Pitcher method

This method proved easy to use once the interactive version of the program was being used. The batch version was very tedious as the data input had to be set out correctly and decisions had to be made without seeing the results of the previous choices.

This method was subjective as the number of component groups had to be selected. This is often the piece of information which is unknown. Macdonald and Pitcher (1979) suggest that where possible a small sub sample of the population be aged separately in order to determine the component groups. However with this data set it was not possible to do this therefore the Cassie results were used as a starting point.

The results show that when using the normal data with a known number of components, in this case two, the method will complete all the steps of the analysis as stated in the methods and give a final χ^2 value which shows a good fit when compared with the critical χ^2 value.

When the number of component groups is changed from two to three or four the method will not complete the analysis at the final step but will give a χ^2 value at the previous step that suggests a good fit. This shows that this method is sensitive to the number of component groups given in the initial parameters and also a χ^2 value can be

obtained for the wrong number of component groups which looks good but is dependant on the options chosen and possibly the sequence of options chosen. Further work would have to be done to test this.

Macdonald and Pitcher (1979) state that that if the number of components is known the proportions used as the starting values are unimportant but the initial guesses for the means and standard deviations are important and should be as accurate as possible. Upper and lower limits have to be placed on the means and standard deviations and these values assist in the fitting process. The results from the generated normal data set support the claim made by Macdonald and Pitcher that the proportions are unimportant and, with this data set, the means and standard deviations were also varied widely without greatly affecting the final outcome.

Another interesting result is that even when the known means of 10.5 and 15.5 were used as starting values for the normal data set the method gave calculated means that differed markedly. I am unsure as to why this occurred.

When the juvenile P.merguensis data was used, the method only completely analysed one set of data. Two interpretations are possible. Either that the lack of results meant that this data was not suitable for this method or that the starting values given by the Cassie method were incorrect. I would tend to favour the latter suggestion. Perhaps with a better method of selecting component groups this method would have been more successful with this data.

The program would not accept two of the data sets. With the FEB276 data set there were only 131 observations the first component group having many more individuals than the second. The second group did not meet the criteria of having more than fifty individuals in it and so the data was unacceptable. In the case of NOV175 the starting parameters were probably too far removed from the real ones.

JUN176 was successfully analysed by the program it appears that the Cassie parameters were close enough to reality to allow the analysis to take place. This data set was taken during the winter period when there are small numbers of prawns overwintering in the river and there are representatives from different cohorts which makes clearly identifiable modes.

The three data sets that were analysed up to the final fitting process gave an invalid parameter message. This can mean one of two things, either one of the component standard deviation is negative or the parameters do not have a positive probability over every grouping

interval (MacDonald and Pitcher 1979).

ELEFAN I method

This method was reasonably easy to use apart from the time taken for the program to run. The method did not require subjective decisions on the number of groups in a data set but did require values for L_{∞} and K which suggests a good knowledge of the life history of the animal. Beddington and Rosen(1985) note that ELEFAN I requires good starting estimates of K to find an acceptable value for it. This was a problem when using this data set as the K value was unknown for juvenile P.merguensis. From the curves that were fitted to the data it can be seen that the value of K was probably too high and consequently the growth curve estimated from the L_t values did not pass through the modes. The L_{∞} value was also probably not correct and could possibly be as high as 44 for female P.merguensis(Somers, pers. com.).

It has been noted by other authors that a major problem with this method is that it consistently under estimates the value of K and over estimates the value of L_{∞} (Majkowski and Hampton in press, Rosenberg and Beddington in press). The values of K and L_{∞} used here did not seem appropriate for this data set. This could be because they do not describe the growth of juvenile prawns very accurately or that they were being affected by the problems of over estimation and under estimation. There is a need for more information about the growth of juvenile banana prawns. Rosenberg and Beddington (in press) conclude that "The ELEFAN method does not appear to reliably estimate growth parameters unless the input parameter range is narrow and the true value lies within this range".

The results obtained from this method showed that the value of K was high and so the prawns were appearing to grow very quickly and therefore were not following the peaks in the data. The K constant used did not seem suitable for juvenile prawns. The parameters which were originally given were worked out using commercial fishing returns and it is believed that the L_{∞} value should be much higher, closer to 39 for males and 42 for females and that the K value should be much lower, around .04 per week (Somers pers. comm.). When these results are compared with the growth rates given by the Cassie method and the eye fitted lines there is a large discrepancy between them, with the ELEFAN I growth rates being nearly twice the other rates in some cases. Biologically the Cassie rates or the eye fitted rates seem more realistic and these agree with the work of Staples(1980b) who estimated the growth rate of juvenile banana prawns to be 1.2mm p.w. during November to December and February to March 1975/1976. Unfortunately growth rates for the Macdonald Pitcher method could not be calculated.

The Von Bertalanffy growth formula describes the growth of an animal throughout its life and assumes a decreasing rate of growth through time. The data used in this study only describes a very short period in the animals life history. It may not be appropriate to use this formula as it stands to describe the growth of juvenile P.merguiensis.

One of the major disadvantages with ELEFAN I was its slowness and its effect on the computer system. It could bring the system to a halt if it had a number of iterations to do. This factor highlighted the need to select accurate seeded values where possible to cut down on the time taken to give a final result.

Comparison of methods

The Cassie method though subjective was easy to use and is still being used today. It appeared to give biologically meaningful results although there is little known about the growth of juvenile P.merguiensis. Its major drawback was the selection of inflexion points to determine the number of component groups and its subjectivity.

The Macdonald Pitcher method was robust once the number of components had been selected. If the parameters were too far away from reality then the method would not work. Sample size was also important here, groups with at least fifty individuals were required.

ELEFAN I was cumbersome to use particularly if you are unsure of the growth parameters for the animal you are studying. If this information is known then it traces growth curves quite well. The plotting routine assists the user considerably.

It was found to be more satisfactory with this data set to enter realistic values of T_0 rather than allow the program to choose one. A knowledge of the spawning time was therefore essential.

Recommendations and further work

No one method proved entirely satisfactory for the analysis of these data but it seems possible that the methods could be modified to give a better tool for the analysis of this kind of data.

The restructured data of the ELEFAN I technique could be used as a starting point for the selection of modes in the data. It would then be possible to calculate the proportions, means and standard deviations and use these as a starting point for the fitting procedure of the Macdonald Pitcher method.

Another approach is to look at the basis of ELEFAN I which is the Von Bertalanffy growth equation and adjust that to describe the type of growth found with juveniles which approximates a linear relationship.

There are other programs which have now become available for analysing length frequency data. One has been developed by Dr. A. Heron (CSIRO Marine Laboratory, Hobart) which objectively selects the number of components in a group even if they are overlapping. This is a repeatable process and does not require prior knowledge of the number of component groups in a sample. Another of these is a program developed by Schnute and Fournier (1980) which also analyses a distribution mixture without a knowledge of the number of component groups being necessary.

A final point to make here is that a knowledge of the growth of juvenile banana prawns is essential and further biological study could be done to address this problem such as a tagging program designed specifically to answer questions about the growth of juvenile prawns.

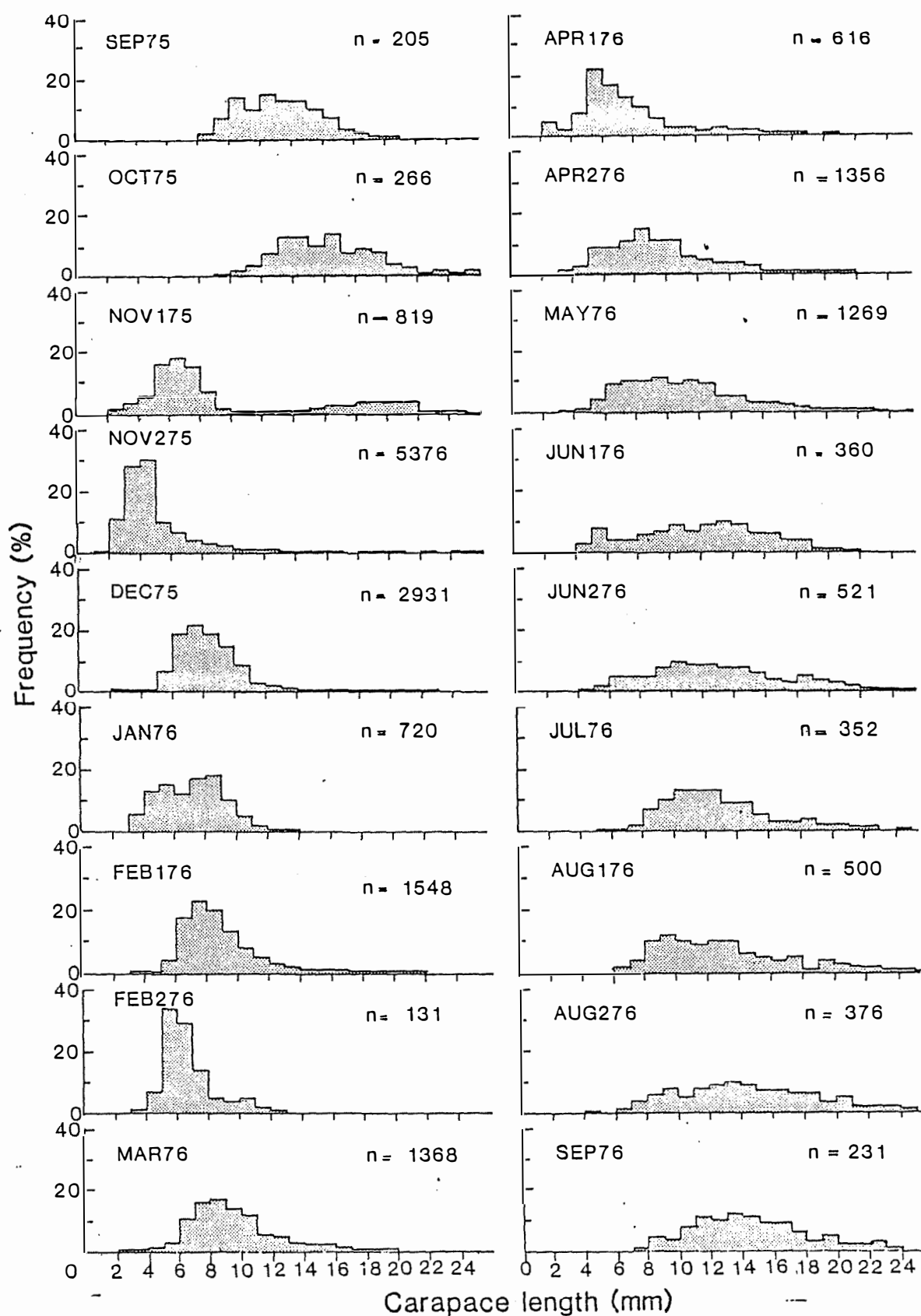


Figure 1. Three weekly size (carapace length) frequency distribution of juvenile *Penaeus merguensis* from September 1975 to September 1976. Data was collected by Staples (1980b).

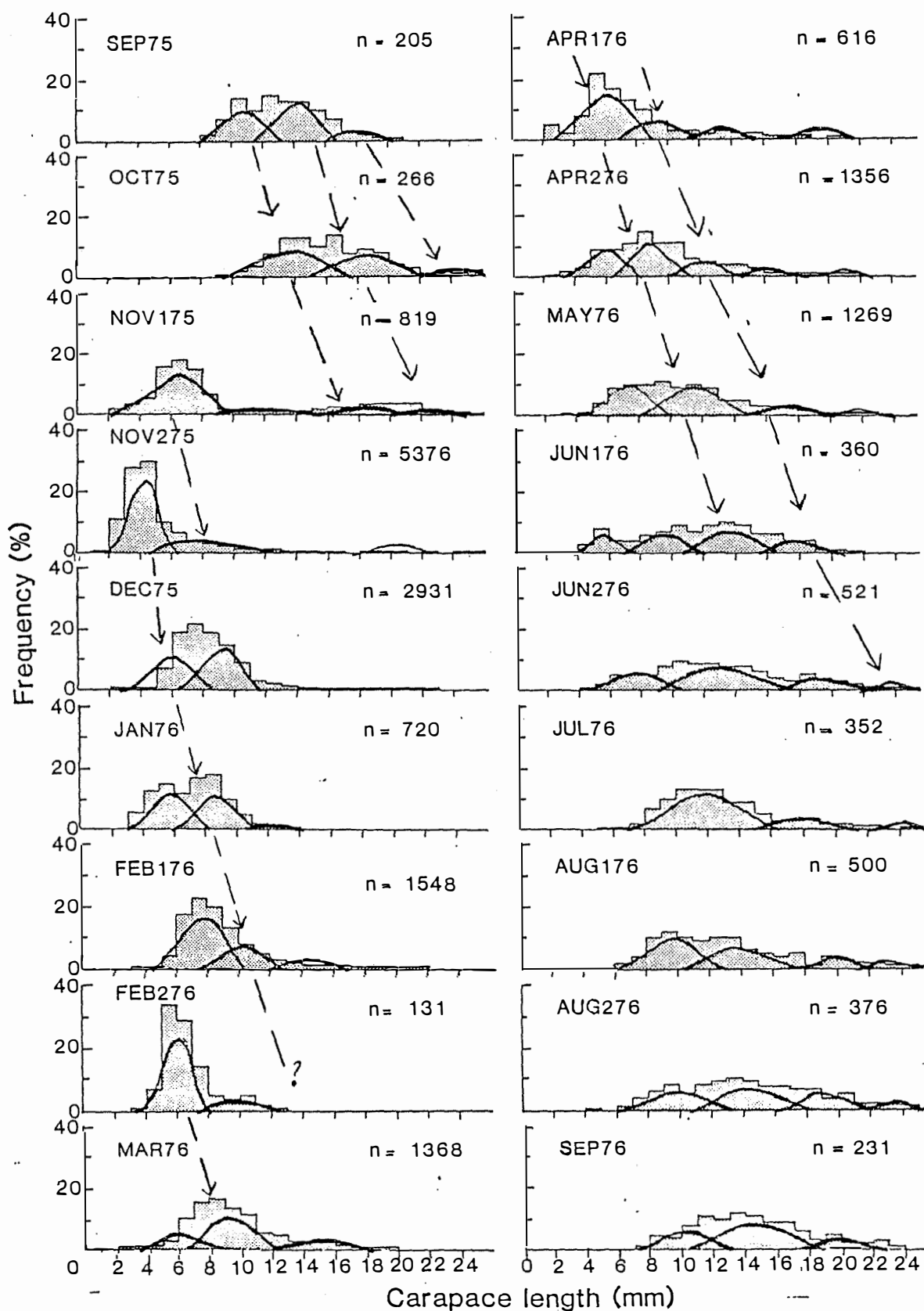


Figure 2. Length frequency histograms of the *Penaeus merguensis* data collected by Staples (1980b) with the length distribution of the component groups, as found by the Cassie method, superimposed. Some cohorts are traced through several months.

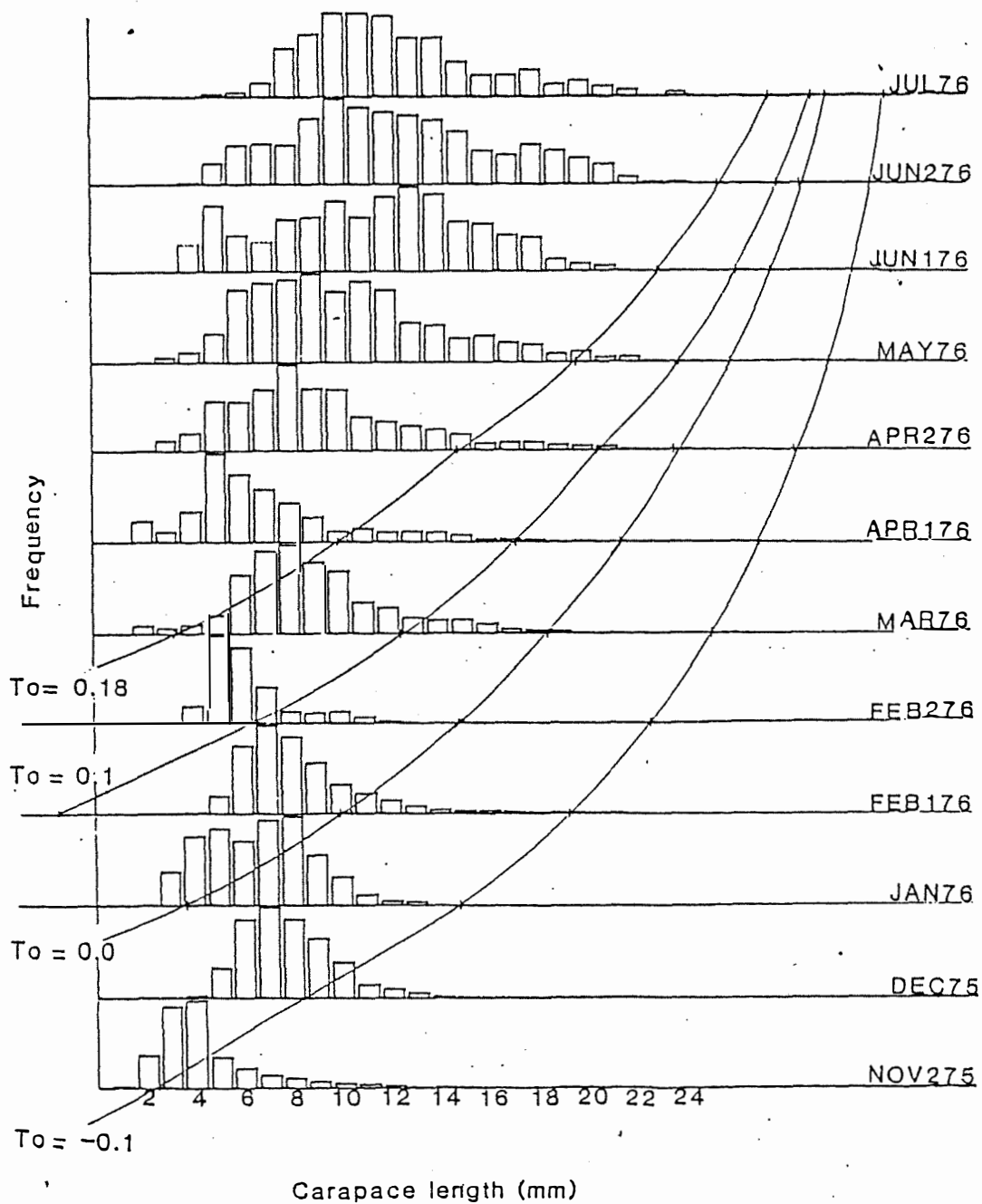


Figure 3. Length frequency histograms from the ELEFAN I method using juvenile *Penaeus merguensis* data. Twelve samples were analysed. Four T_0 values were used growth curves were plotted for each T_0 value.

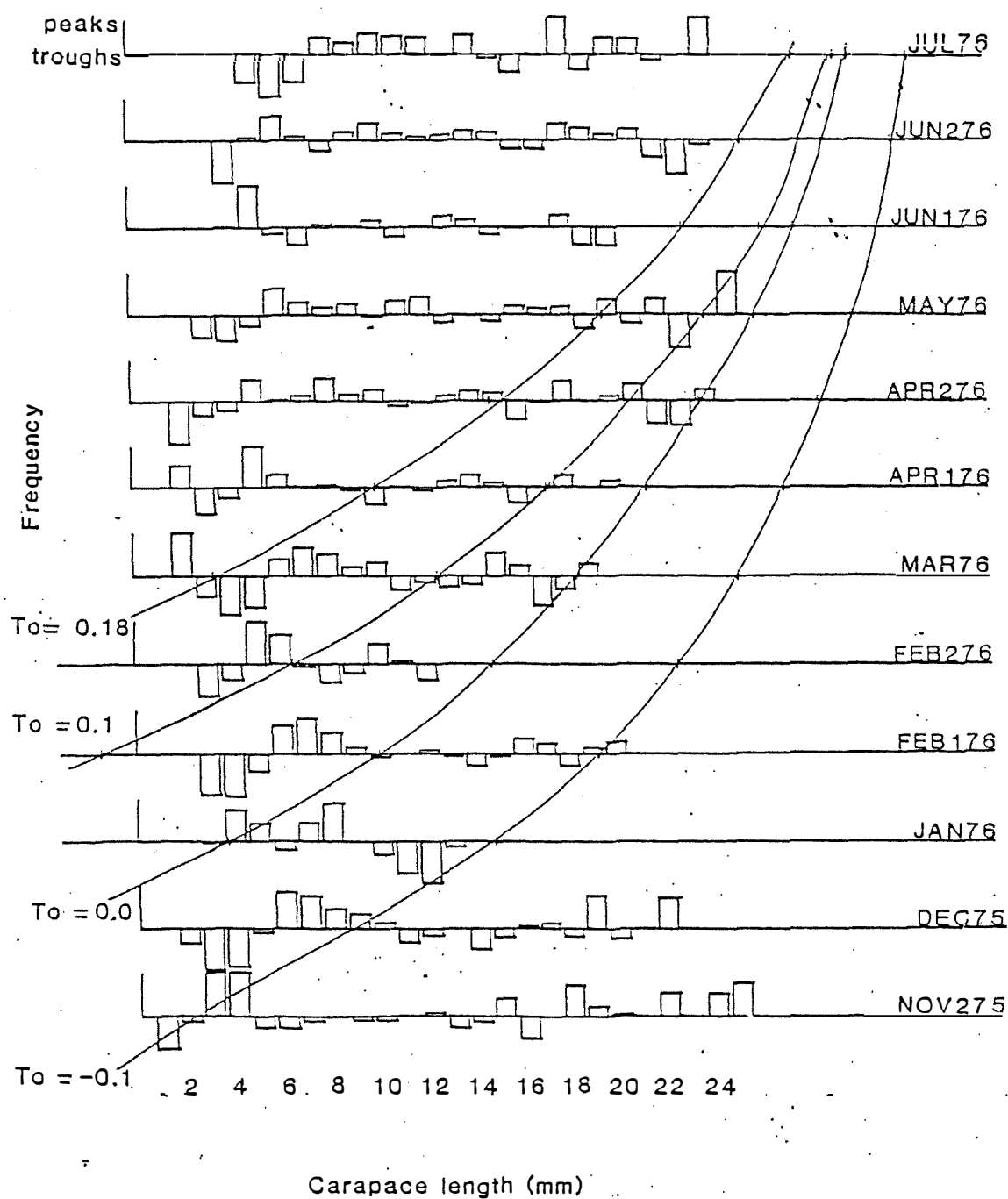


Figure 4. Growth curves drawn on the restructured data output from the ELEFAN I method. The restructured data is a plot of the peaks and troughs in each set of data. The data used here is the juvenile *Penaeus merguensis* data collected by Staples (1980b). Four different values of T_0 were used.

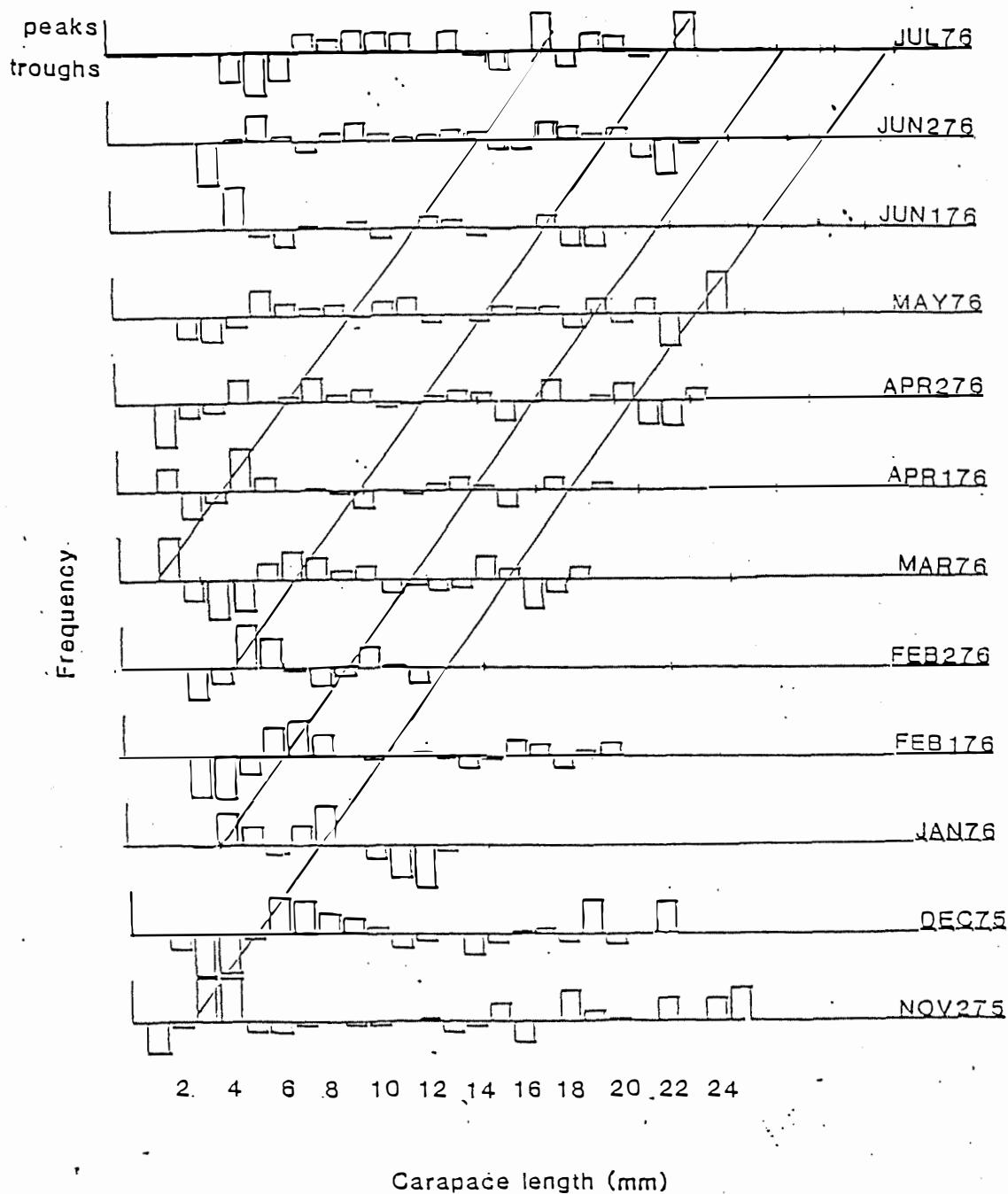


Figure 5. Linear growth curves are superimposed on the restructured data output from the ELEFAN I method. The restructured data is a plot of the peaks and troughs in each set of data. The data used here is the juvenile *Penaeus merguensis* data collected by Staples (1980b). Four cohorts of juvenile prawns are traced through time.

Table 1. Original data set for Penaeus merguensis juveniles used for examining length-frequency methods. Size is given in mm. The data sets are spaced at three weekly intervals and identified by the first three letters of the appropriate month.

| Size | Sample | | | | | | | | | | | | | | | | | |
|-----------|--------|-------|-------|--------|-------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|
| | SEP75 | OCT75 | NOV75 | NOV275 | DEC75 | JAN76 | FEB176 | FEB276 | MAR76 | APR176 | APR276 | MAY76 | JUN176 | JUN276 | JUL76 | AUG176 | AUG276 | SEP76 |
| 0.5- 1.5 | | | | 24 | | | | | | | | | | | | | | |
| 1.5- 2.5 | | | 14 | 593 | 2 | | | | 20 | 32 | 1 | | | | | | | |
| 2.5- 3.5 | | | 31 | 1501 | 2 | 46 | 1 | 1 | 14 | 15 | 24 | 7 | | | | | | |
| 3.5- 4.5 | | | 53 | 1619 | 15 | 97 | 3 | 9 | 22 | 47 | 44 | 16 | 12 | 1 | | | 1 | |
| 4.5- 5.5 | | | 131 | 550 | 213 | 108 | 70 | 44 | 48 | 137 | 121 | 46 | 29 | 13 | 1 | | 0 | |
| 5.5- 6.5 | | | 148 | 359 | 565 | 90 | 272 | 38 | 155 | 104 | 119 | 118 | 16 | 25 | 2 | 9 | 3 | |
| 6.5- 7.5 | | | 123 | 232 | 652 | 121 | 358 | 18 | 215 | 81 | 149 | 128 | 13 | 26 | 7 | 18 | 15 | 3 |
| 7.5- 8.5 | 5 | | 55 | 173 | 567 | 126 | 309 | 6 | 232 | 60 | 208 | 134 | 23 | 25 | 26 | 50 | 21 | 11 |
| 8.5- 9.5 | 14 | 2 | 18 | 105 | 428 | 70 | 203 | 5 | 187 | 38 | 150 | 143 | 24 | 42 | 34 | 62 | 29 | 9 |
| 9.5-10.5 | 29 | 4 | 6 | 73 | 259 | 39 | 118 | 6 | 164 | 16 | 148 | 115 | 31 | 54 | 47 | 52 | 20 | 18 |
| 10.5-11.5 | 20 | 12 | 9 | 54 | 96 | 14 | 81 | 3 | 83 | 20 | 83 | 131 | 24 | 49 | 47 | 45 | 31 | 26 |
| 11.5-12.5 | 31 | 22 | 11 | 39 | 63 | 5 | 53 | 1 | 69 | 14 | 71 | 117 | 33 | 46 | 46 | 49 | 33 | 23 |
| 12.5-13.5 | 27 | 34 | 5 | 17 | 34 | 4 | 29 | | 43 | 16 | 61 | 65 | 37 | 44 | 32 | 48 | 39 | 27 |
| 13.5-14.5 | 27 | 34 | 11 | 13 | 10 | | 14 | | 35 | 14 | 52 | 60 | 34 | 41 | 32 | 32 | 33 | 26 |
| 14.5-15.5 | 20 | 26 | 14 | 12 | 8 | | 11 | | 36 | 10 | 39 | 39 | 22 | 34 | 18 | 26 | 25 | 20 |
| 15.5-16.5 | 15 | 36 | 23 | 2 | 5 | | 10 | | 24 | 4 | 15 | 43 | 21 | 21 | 11 | 18 | 26 | 20 |
| 16.5-17.5 | 7 | 20 | 25 | 0 | 4 | | 7 | | 9 | 4 | 18 | 32 | 16 | 18 | 11 | 27 | 23 | 14 |
| 17.5-18.5 | 5 | 24 | 29 | 2 | 2 | | 3 | | 7 | 3 | 19 | 28 | 15 | 25 | 14 | 6 | 22 | 6 |
| 18.5-19.5 | 3 | 21 | 33 | 1 | 3 | | 3 | | 5 | 0 | 12 | 13 | 5 | 21 | 6 | 18 | 11 | 11 |
| 19.5-20.5 | 2 | 11 | 29 | 1 | 1 | | 2 | | | 1 | 10 | 17 | 3 | 16 | 8 | 13 | 18 | 4 |
| 20.5-21.5 | | 8 | 28 | 0 | 1 | | 1 | | | | 8 | 7 | 2 | 12 | 5 | 10 | 8 | 5 |
| 21.5-22.5 | | 3 | 11 | 1 | 1 | | | | | | 2 | 8 | | 4 | 3 | 9 | 6 | 6 |
| 22.5-23.5 | | 4 | 7 | 0 | | | | | | | 1 | 1 | | 1 | 0 | 4 | 7 | 2 |
| 23.5-24.5 | | 1 | 4 | 1 | | | | | | | 1 | 0 | | 1 | 2 | 3 | 4 | |
| 24.5-25.5 | | 4 | 1 | 1 | | | | | | | | 1 | | 2 | | 1 | | |

Table 2. Results obtained using the Cassie method for analysing P.merguensis length frequency data. Components, proportions, means and standard deviations were calculated.

| | Sample | | | | | | | | | | | | | | | | | |
|-----------------|--------|-------|--------|--------|-------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|
| | SEP75 | OCT75 | NOV175 | NOV275 | DEC75 | JAN76 | FEB176 | FEB276 | MAR76 | APR176 | APR276 | MAY76 | JUN176 | JUN276 | JUL76 | AUG176 | AUG276 | SEP76 |
| Components | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 2 | 3 | 4 | 5 | 4 | 4 | 4 | 3 | 4 | 5 | 3 |
| Proportions | 0.3 | 0.5 | 0.7 | 0.8 | 0.2 | 0.5 | 0.8 | 0.8 | 0.1 | 0.8 | 0.1 | 0.5 | 0.2 | 0.2 | 0.8 | 0.5 | 0.2 | 0.1 |
| | 0.6 | 0.4 | 0.1 | 0.1 | 0.7 | 0.4 | 0.1 | 0.2 | 0.8 | .05 | 0.6 | 0.3 | 0.3 | 0.6 | 0.1 | 0.3 | 0.4 | 0.8 |
| | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | - | 0.1 | 0.1 | 0.2 | 0.1 | 0.4 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 |
| | - | - | 0.1 | - | - | - | - | - | - | .05 | .05 | 0.1 | 0.1 | 0.1 | - | 0.1 | 0.1 | - |
| | - | - | - | - | - | - | - | - | - | - | .05 | - | - | - | - | - | 0.1 | - |
| Means | 10.0 | 13.2 | 5.8 | 3.6 | 5.5 | 4.7 | 7.5 | 5.6 | 4.1 | 5.9 | 4.6 | 7.7 | 5.5 | 6.7 | 1.7 | 9.2 | 8.5 | 8.3 |
| | 13.6 | 17.8 | 11.7 | 6.7 | 8.3 | 8.2 | 11.5 | 9.2 | 8.5 | 10.8 | 8.1 | 12.3 | 9.6 | 12.4 | 18.6 | 13.8 | 12.8 | 13.5 |
| | 18.0 | 24.2 | 18.1 | 19.7 | 16.1 | 12.6 | 16.5 | - | 15.5 | 14.1 | 12.5 | 17.3 | 14.1 | 19.1 | 24.5 | 19.7 | 17.1 | 20.5 |
| | - | - | 22.2 | - | - | - | - | - | - | 20.9 | 18.1 | 22.4 | 18.5 | 23.1 | - | 23.6 | 20.2 | - |
| | - | - | - | - | - | - | - | - | - | - | 22.7 | - | - | - | - | - | 23.4 | - |
| Std. Deviations | 1.0 | 1.6 | 1.7 | 1.0 | 0.7 | 1.1 | 1.1 | 0.9 | 1.8 | 1.7 | 0.8 | 1.7 | 1.1 | 0.9 | 2.3 | 1.3 | 1.2 | 0.7 |
| | 0.5 | 1.7 | 0.7 | 3.4 | 1.5 | 1.4 | 1.0 | 1.3 | 2.1 | 0.9 | 1.4 | 1.7 | 1.4 | 2.3 | 1.6 | 2.1 | 1.5 | 2.2 |
| | 1.7 | 1.6 | 2.2 | 3.0 | 2.1 | 0.4 | 2.1 | - | 2.2 | 1.6 | 1.6 | 1.8 | 2.0 | 1.2 | .25 | 1.5 | 1.3 | 1.1 |
| | - | - | 2.0 | - | - | - | - | - | - | 0.2 | 1.7 | 0.9 | 1.4 | 1.2 | - | .65 | 1.6 | - |
| | - | - | - | - | - | - | - | - | - | - | 0.8 | - | - | - | - | - | .65 | - |

Table 3. Normal data generated to test the sensitivity of the Macdonald Pitcher method. Size is given in mm.

| <u>Size</u> | <u>Frequency</u> |
|-------------|------------------|
| 0.5- 1.5 | |
| 1.5- 2.5 | |
| 2.5- 3.5 | |
| 3.5- 4.5 | |
| 4.5- 5.5 | |
| 5.5- 6.5 | 1 |
| 6.5- 7.5 | 4 |
| 7.5- 8.5 | 11 |
| 8.5- 9.5 | 21 |
| 9.5-10.5 | 26 |
| 10.5-11.5 | 21 |
| 11.5-12.5 | 15 |
| 12.5-13.5 | 15 |
| 13.5-14.5 | 22 |
| 14.5-15.5 | 26 |
| 15.5-16.5 | 21 |
| 16.5-17.5 | 11 |
| 17.5-18.5 | 4 |
| 18.5-19.5 | 1 |
| 19.5-20.5 | |
| 20.5-21.5 | |
| 21.5-22.5 | |
| 22.5-23.5 | |
| 23.5-24.5 | |
| 24.5-25.5 | |

Table 4 Macdonald Pitcher results for normal data. Std.Dev=Standard deviation.

| Proportions | Means | Std.Dev. | Final χ^2 |
|-------------|-----------|----------|----------------|
| 0.1-0.9 | 10.5 | 1.5 | 0.6364 |
| 0.1-0.9 | 15.5 | 1.5 | 0.6364 |
| 0.5 | 7.5-12.5 | 1.5 | 0.6364 |
| 0.5 | 13.5-18.5 | 1.5 | 0.6364 |
| 0.5 | 10.5 | 1.0-2.1 | 0.6364 |
| 0.5 | 15.5 | 1.0-2.1 | 0.6364 |

** No result possible at a Std.Dev of 0.9

Table 5 Normal data using varied numbers of components to test the sensitivity of the Macdonald Pitcher method

| Proportions | Means | Std.Deviations | Best χ^2 | Final χ^2 |
|-------------|-------|----------------|---------------|----------------|
| 0.33 | 10.5 | 1.5 | | |
| 0.33 | 12.5 | 1.5 | | |
| 0.33 | 15.5 | 1.5 | 0.6591 | Invalid |
| 0.25 | 8.5 | 1.5 | | |
| 0.25 | 10.5 | 1.5 | | |
| 0.25 | 12.5 | 1.5 | | |
| 0.25 | 14.5 | 1.5 | 0.6938 | Invalid |
| 0.2 | 8.5 | 1.5 | | |
| 0.2 | 10.5 | 1.5 | | |
| 0.2 | 12.5 | 1.5 | | |
| 0.2 | 15.5 | 1.5 | | |
| 0.2 | 17.5 | 1.5 | No result | |

Table 6 Macdonald Pitcher results for P.merguiensis using selected months.
 Propor=Proportions, Std.Dev=Standard Deviation.

| | Original values | | | Revised values | | | Best χ^2 | Final χ^2 |
|--------|-----------------|-------|---------|----------------|-------|---------|---------------|----------------|
| | Propor | Means | Std.Dev | Propor | Means | Std.Dev | | |
| SEP75 | 0.3 | 10.0 | 1.0 | 0.45 | 10.59 | 1.3 | 8.34 | --- |
| | 0.6 | 13.6 | 0.5 | 0.35 | 13.7 | 1.27 | | |
| | 0.1 | 18.0 | 1.7 | 0.19 | 16.1 | 1.9 | | |
| OCT75 | 0.5 | 13.2 | 1.6 | 0.52 | 13.5 | 1.77 | 7.96 | --- |
| | 0.4 | 17.8 | 1.7 | 0.429 | 17.7 | 2.05 | | |
| | 0.1 | 24.2 | 1.6 | 0.04 | 23.4 | 2.63 | | |
| NOV175 | 0.7 | 5.8 | 1.7 | 0.7 | 5.8 | 1.5 | 24.31 | --- |
| | 0.1 | 11.7 | 0.7 | 0.05 | 12.6 | 2.2 | | |
| | 0.1 | 18.1 | 2.2 | 0.21 | 18.5 | 2.2 | | |
| | 0.1 | 22.2 | 2.0 | 0.02 | 21.2 | 1.6 | | |
| NOV275 | 0.8 | 3.6 | 1.0 | | | | No result | |
| | 0.1 | 6.7 | 3.4 | | | | | |
| | 0.1 | 19.7 | 3.0 | | | | | |
| FEB276 | 0.8 | 5.6 | 0.9 | | | | No result | |
| | 0.2 | 9.2 | 1.3 | | | | | |
| APR276 | 0.1 | 4.6 | 0.8 | 0.13 | 7.07 | 2.0 | 47.56 | --- |
| | 0.6 | 8.1 | 1.4 | 0.58 | 7.64 | 2.11 | | |
| | 0.2 | 12.5 | 1.6 | 0.23 | 12.38 | 2.19 | | |
| | .05 | 18.1 | 1.7 | 0.046 | 18.22 | 2.1 | | |
| | .05 | 22.7 | 0.8 | 0.007 | 19.28 | 1.99 | | |
| JUN176 | 0.2 | 5.5 | 1.1 | 0.13 | 4.98 | 0.61 | 5.32 | 5.32 |
| | 0.3 | 9.6 | 1.4 | 0.37 | 9.39 | 1.87 | | |
| | 0.4 | 14.1 | 2.0 | 0.23 | 13.08 | 1.10 | | |
| | 0.1 | 18.5 | 1.4 | 0.26 | 16.21 | 1.96 | | |

Table 7 Macdonald Pitcher results for the normal data set after the fitting procedure had taken place

| | Original Values | Revised Values |
|----------------|-----------------|----------------|
| Proportions | 0.5 | 0.49417 |
| | 0.5 | 0.50583 |
| Means | 10.5 | 9.97423 |
| | 15.5 | 14.98241 |
| Std.Deviations | 1.5 | 1.49761 |
| | 1.5 | 1.51460 |

Table 8a An example of the output given from the ELEFAN I program
showing the seeded values.

| <u>Input</u> | | <u>Output</u> | | | | | | | |
|----------------|-------------|---|------------|------------|------------|------------|------------|------------|--|
| To=0.0 | | HIGHEST ESP/ASP=95 K=3.7 L _∞ =35 | | | | | | | |
| | | <u>K</u> | | | | | | | |
| | | <u>3.7</u> | <u>3.8</u> | <u>3.9</u> | <u>4.0</u> | <u>4.1</u> | <u>4.2</u> | <u>4.3</u> | |
| | 35.0 | <u>95</u> | 87 | 80 | 80 | 72 | 76 | 76 | |
| | 36.0 | 87 | 80 | 80 | 72 | 76 | 76 | 76 | |
| | 37.0 | 80 | 72 | 72 | 76 | 76 | 76 | 76 | |
| L _∞ | 38.0 | 72 | 76 | 76 | 76 | 76 | 68 | 68 | |
| | 39.0 | 76 | 76 | 76 | 76 | 68 | 68 | 68 | |
| | 40.0 | 76 | 76 | 76 | 68 | 68 | 68 | 68 | |
| | <u>41.0</u> | <u>76</u> | <u>76</u> | <u>68</u> | <u>68</u> | <u>68</u> | <u>68</u> | <u>68</u> | |

Table 8b Results from the ELEFAN method when four different values of
To were entered.

| <u>To</u> | <u>ESP/ASP</u> | <u>K</u> | <u>L_∞</u> |
|-------------|----------------|------------|----------------------|
| 0.0 | 95 | 3.7 | 35 |
| -0.1 | 130 | 4.2 | 35 |
| 0.1 | 115 | 4.3 | 35 |
| <u>0.18</u> | <u>57</u> | <u>4.2</u> | <u>36</u> |

Table 9 Growth rates per week obtained for juvenile P.merguiensis by using ELEFAN I, Cassie and the eye fitted lines. p.w.=per week

| ELEFAN | | Cassie | Eye fitted |
|---------|------------|------------|-------------|
| To=-0.1 | 1.8mm p.w. | 1.5mm p.w. | 0.77mm p.w. |
| To= 0.0 | 1.6mm p.w. | 0.9mm p.w. | 1.0mm p.w. |
| To= 0.1 | 1.6mm p.w. | 0.9mm p.w. | 0.88mm p.w. |
| To=0.18 | 1.3mm p.w. | 0.6mm p.w. | 0.70mm p.w. |

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SPECIES COMPOSITION AND ABUNDANCE OF JUVENILE FISH FROM

TRINITY BAY AND MORNINGTON ISLAND PRAWN NURSERY GROUNDS

BY

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TABLE OF CONTENTS

| | page |
|---------------------------------|------|
| Acknowledgements | 1 |
| Summary | 2 |
| Introduction | 3 |
| Previous Studies | 5 |
| Materials and Methods | |
| -Study areas | 6 |
| -Sampling methods | 8 |
| -Analysis | 9 |
| Results | |
| -Temperatures | 11 |
| -Species composition | 13 |
| -Species richness | 14 |
| -Abundance | 17 |
| -Changes in abundance over time | |
| Discussion | 25 |
| Bibliography | 29 |
| Appendix | 33 |

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SUMMARY.

Juvenile fish were collected by beam trawl at three sites for a period of twelve months in Trinity Bay, Cairns, North Queensland, Australia. Species composition, abundance and richness are compared between trawl sites which had different seagrass covers. The fish species composition is compared with samples collected from the Dugong River, Mornington Island.

Species richness and abundance was found to be greater in an area of dense seagrass than an adjacent site without seagrass demonstrating the importance of these areas as nursery habitats for many species of juvenile fish. Fish abundance throughout the survey period were greater in the warmer months than in winter while the species richness was variable.

The fish abundances were dominated by just a few species. In Trinity Bay eighty percent of the total fish were the species *Leiognathus splendens*, *Pelates quadrilineatus* and a species of the *Siganidae*, *Sp.5*. In the Dugong River the family *Teraponidae* accounted for eighty seven percent of the total fish numbers with *P. quadrilineatus* and *Helotes sexlineatus* prevalent.

Only a few of the the juvenile fish were of commercial value and the importance of the seagrass beds in this study do not seem important as nursery areas for for these fish. This study was confined to small fish by the selectivity of the gear and the importance of the seagrasses as feeding grounds for larger fish has not been established and needs investigation.

INTRODUCTION

Seagrass beds are an important aquatic habitat for rich and diverse communities of fish and invertebrates, and are utilised by a number of species as nursery areas. They provide fish with shelter from predation and are areas of high food abundance, particularly of small organisms feeding on the detritus in seagrass beds.

Species composition and abundance of the seagrass fauna may vary with factors such as species and density of seagrass, seasonal trends, diurnal variation, depth, substrate type, and geographical location. Predation by fish and seabirds may also be of importance.

The objective of this study was to examine the species composition of fish fauna collected as the incidental by-catch from beam trawl surveys conducted by Northern Fisheries Research Centre staff. These surveys sampled inshore nursery grounds for penaeid prawns along the east coast of Queensland from Cairns to Cape York (Coles et.al., 1985) and around the Wellesley Islands (Coles and Lee Long, 1985) in the Gulf of Carpentaria.

The purpose of these surveys was to locate seagrass areas important as prawn nursery grounds, and to gain information on the distribution and life histories of commercially important prawn species. This information is valuable in determining a strategy for the management of the prawn fishery and the protection of nursery grounds.

The by-catch from surveys in Trinity Bay, Cairns forms the basis of the data used in this report this is compared with data collected at a sampling station in the Dugong

River, Mornington Island (the largest island in the Wellesley group).

Heasman (1983) conducted a beam trawl study in the Trinity Bay and Inlet areas and looked at the juvenile prawn populations of seagrass beds. More than twenty species of penaeid prawns were found including two endeavour and two tiger prawn species. They were: The true or blue tailed endeavour prawn, *Metapenaeus endeavouri*; the false or red tailed endeavour prawn, *Metapenaeus ensis*; the brown tiger prawn, *Penaeus esculentus* and the grooved tiger prawn, *Penaeus semisulcatus*.

Within Trinity Bay fishing activities are limited to about four professional fishermen who work the area frequently (Olsen, 1983). The major fish species landed are Barramundi, *Lates calcarifer*; Grunters, *Pomadasys hasta*; Salmon, *Eleutheronepra tetradactylum*; Mangrove Jack; *Lutjanus argentimaculatus*; Bream, *Acanthopagrus berda*; King Salmon, *Polydactylus sheridan*; Mullet, *mugil spp.*; and two Gar species *Arrhamphus sclerolepis* and *Hyporhamphus dussumeri*.

This study reports the results of an investigation into the juvenile fish fauna of seagrass beds from two areas of North Queensland. It examines species abundance, diversity and composition of these fish and makes comparisons of these factors between different sites. Little work has been done on the fish fauna of North Queensland seagrass beds and as their importance as nursery areas for juvenile fish of commercial or recreational value is not clear, this aspect is also examined.

PREVIOUS STUDIES

Pollard (1980) reviews various studys of seagrass-fish communitites, with particular emphasis on Australian studies and compares species composition relationships between different areas.

There have been several surveys of fish communities in Australia using a variety of sampling techniques including: beam trawls (Young, 1981; Young and Wadley, 1979.); and poisoning (Middleton, 1984). Seine, gill and stake nets were used by Blaber to examined the fish of the Trinity Inlet system at various sites in the bay and estuary and the species compositions can be compared with the results from beam trawling.

Young (1981) compared the species composition and abundance from beam trawl sampling of vagile epibenthic fauna of *Posidina australis* and *Zostera capricorni* seagrass beds , at Port Hacking, N.S.W. It was found that the same general compositon of fish species in both species of seagrass but a greater abundance in the *Zostera* seagrass. Species richness and relative abundance was found generally to be higher in summer than winter.

MATERIALS AND METHODS.

Study Area

Trinity Bay

The Trinity Inlet system adjacent to Cairns in Queensland (latitude 16°55'S., longitude 145°46'E.) consists of a tidal estuary approximately 10 Km. long entering a wide bay (Fig.1.1). Trinity Bay is a shallow embayment with extensive mud flats, seagrass beds, sandbars and small areas of rocky outcrops. The area has a maximum tidal range of 3 metres and at low tides large areas of mudflats and seagrass beds are exposed. The area occupied by intertidal flats in the bay is approximately 1000 ha including 640 ha of mangroves (Olsen, 1983).

Seagrass communities form an important component of the extensive shoal areas of silt and sand. The species of seagrass present in Trinity Bay include *Zostera capricorni*, *Halodule uninervis*, *Cymodocea serrulata*, and *Halophila ovalis*. The western side of the bay seaward of Cairns Esplanade has an dense cover of seagrass extending to Ellie Point. The eastern side of Trinity Bay has seagrass meadows in the Hills Creek and Bessie Point areas.

Three sampling sites were chosen within Trinity Bay (Fig.1). Site 1 and site 2 were located off the esplanade, site 1 in shallow area of dense seagrass cover and site 2 positioned at a deeper area with no seagrass present. A third location, site 3, was sampled on the eastern side of the bay near the mouth of Hills Creek. This site was a

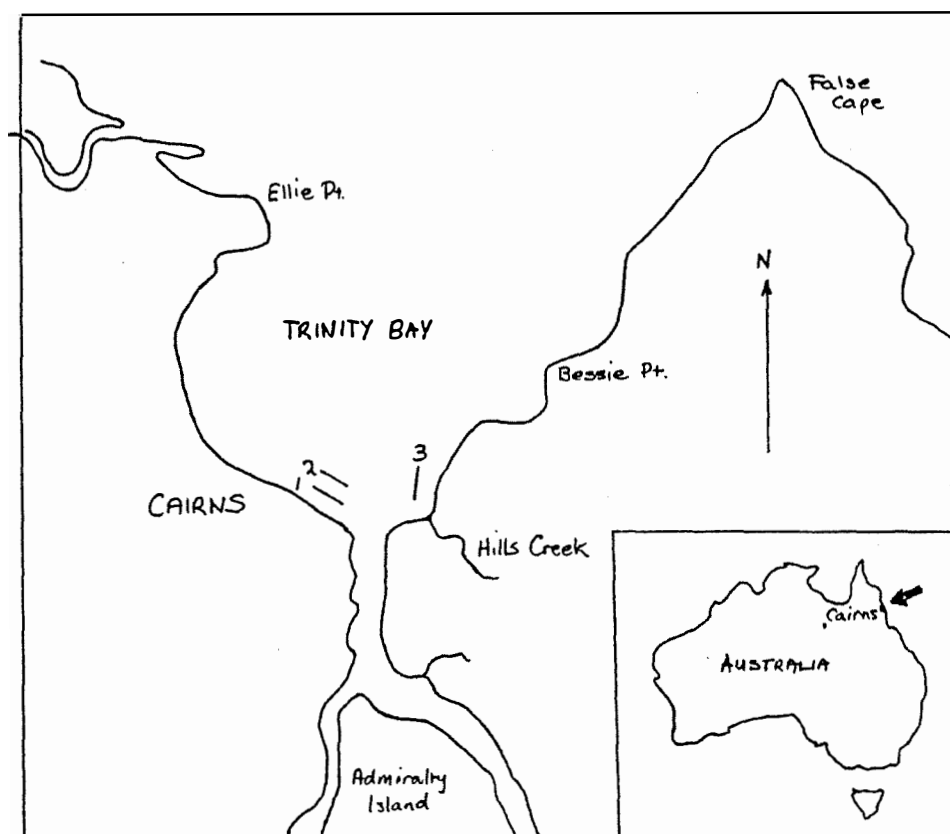


Figure 1.1
Trinity Bay, Cairns
sampling sites.

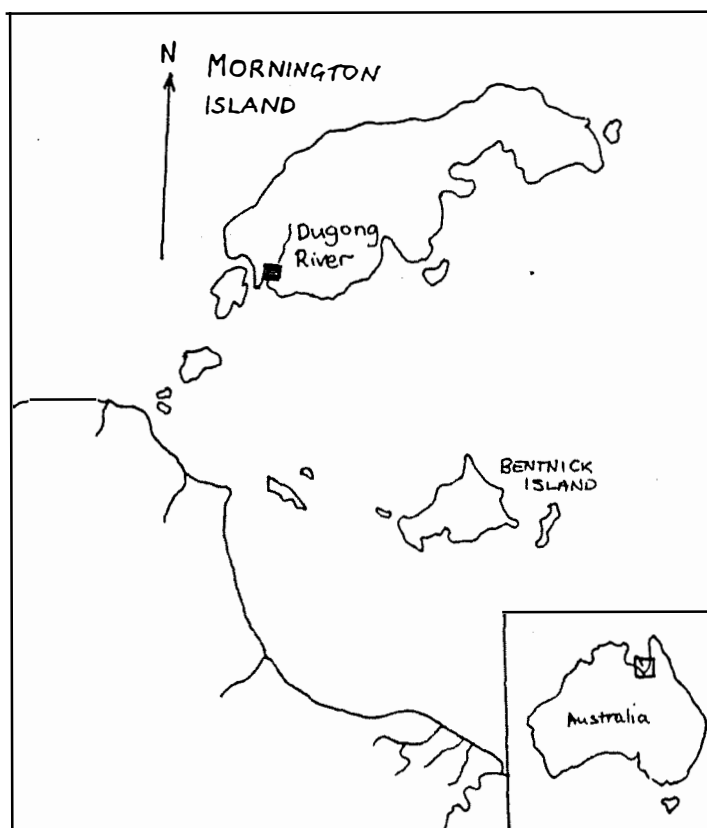


Figure 1.2
Dugong River, Mornington Island
sampling site.-■

shallow area with a patchy cover of seagrass and like site 1 was exposed at low tide.

Mornington Island

A single site was examined from the Dugong river, Mornington Island (Fig 1.2) in an area of dense seagrass cover

SAMPLING METHOD

The Trinity Bay sites were sampled with a beam trawl 1.5 metres wide by 0.5 metres high, fitted with 2.0 mm mesh. The beam trawl was towed at a speed of 0.5 metres per second (approximately 1 knot) for 2.5 minutes duration between the marker bouys, covering a length of approximately 75 metres (a swept area of about 112.5 m²). A four metre aluminium dinghy powered by an outboard motor was used to tow the beam trawl. Water temperatures were recorded and water samples taken for salinity tests at each site.

Trawling was undertaken from October 1983 to October 1984 on each new moon at the three Trinity Bay sites and also every full moon at site 1. The trawls were done at night on the high tide, during slack water at depths of 1.0 m to 2.0 m at site 1 and site 3, and from 2.5 to 3.5 m at Site 2.

The sampling procedure was similar for Mornington Island except that the beam trawls were towed behind a 7.3 m launch over a distance of 50 m. Dugong River data was available for nine sampling occasions from November 1982 to

October 1983.

Samples collected in the field were returned to the laboratory and sorted into seagrass, prawn and fish components and frozen for later analysis. In this study the fish component only was examined. The fish were identified with reference to taxonomic keys (Lewis et al, 1983; Knapp, 1981; anon., FAO) and reference books (Grant, 1982; Gloerfelt-Tarp and Kailola, 1985; Monroe, 1967 and Russell, 1983) and using an established collection of photographs and preserved specimens.

Fish were counted and measured to the nearest millimetre, either as:

- (1) "Caudal fork length" (FL), the distance from the tip of the snout to to the caudal fork, or
- 2) "Total length" (TL), the distance from the tip of the snout to the tip of the tail; depending on tail configuration.

ANALYSIS

Three measures of community parameters were used to describe aspects of species diversity, dominance and similarity.

(i) The diversity of a community can be estimated by calculating Shannon-Weaver diversity indices H' (Pielo, 1977).

$$H' = - \sum N_j / N \times \log N_j / N$$

where N = the total number of individuals in the sample and,

N_j = the number of individuals in the j th species in the sample,

(ii) Sorenson's coefficient of community, CC (Pielou 1977) is a useful measure of similarity between groups. It is defined as:

$$CC = 2a / (2a + b + c)$$

Where a = the number of species common to the two samples concerned, and b and c are the number of species found only in the first and only in the second samples respectively.

(iii) McNaughtons dominance index, DI, (Greening, 1982) gives a measure of the degree of dominance of a sample population by one or two species.

$$DI = (n_1 + n_2) / N$$

where n_1 and n_2 are the numbers of fish in the first and second most numerous species of a sample and N = the total number of individuals in the particular sample.

Total abundances from the three Trinity bay sites were compared for significant differences between means by one way ANOVA. The values were transformed to $\log x$ prior to analysis as the standard deviation of animal populations is often proportional to the mean and log transformations are appropriate for stabilizing the variances.

Student T tests or Student-Newman-Keuls range tests were used to compare means where significant differences were detected from analysis of variance.

RESULTS

Fish species collected during this survey together with relative abundance and frequency of occurrence for each Trinity Bay site are presented in appendix I. The species composition of the Dugong river is presented in appendix II, and the number of each species caught throughout the sampling periods for each Trinity Bay site in appendix III.

TEMPERATURES

Water temperatures measured at site 1 in Trinity bay (Fig.2), were close to 30 °C from October 1983 to February 1984 reaching a maximum of 32.5 °C in January. Temperatures declined steadily to a low of 22.5 °C in July. Temperatures at the other Trinity Bay sites when measured did not vary greatly from those at site 1. Water temperatures from the Dugong River on Mornington Island reached a maximum of 33.2 °C and were above 30 °C during the summer months. There was a sharp drop in temperatures for the months June and July with a minimum of 14.5 °C, considerably lower than the minimum at Trinity Bay.

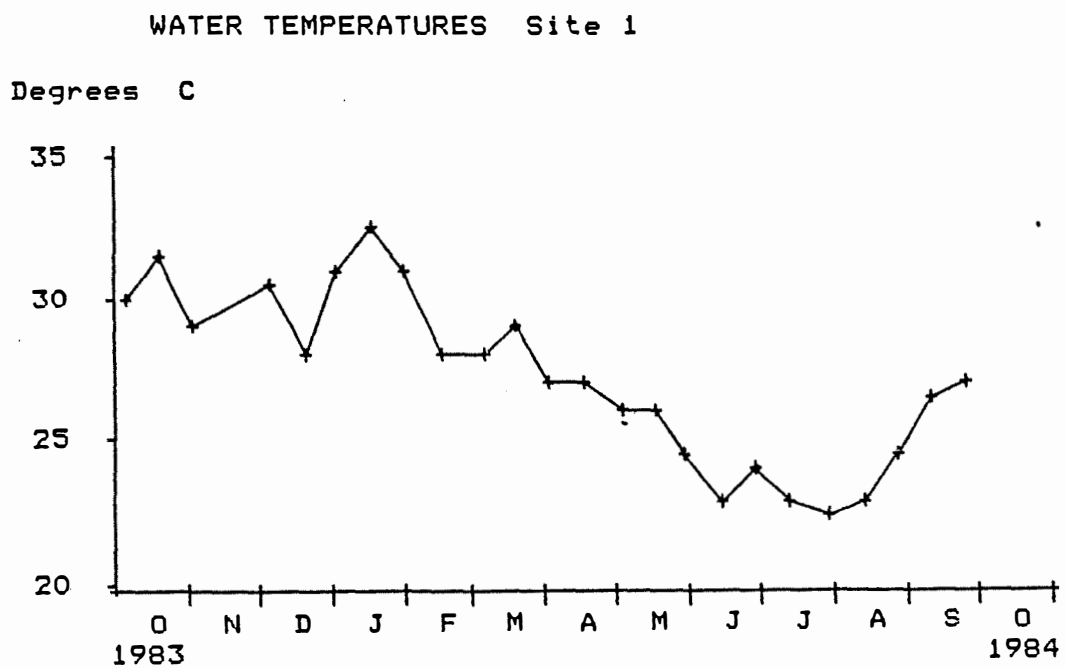


Figure 2: Water temperatures in Trinity Bay, site 1.

SPECIES COMPOSITION

A total of 6751 fish were collected from the three Trinity Bay sites. Thirty five families were identified and 106 species. The Siganidae family had the most member species with ten, followed by the Tetraontidae and Leiognathidae with nine species each. Twenty three species from 17 families were present in the 946 fish collected in the Dugong River.

The number of families and representative species were are shown for each site as follows :

Trinity Bay

| | | | |
|--------|---|--------------|------------|
| site 1 | : | 27 families, | 73 species |
| site 2 | : | 26 families, | 53 species |
| site 3 | : | 24 families, | 52 species |

Mornington Island

Dugong river : 17 families, 23 species

Sorenson's coefficient of community, (CC) was calculated between pairs of sites to give an indication of similarity of species composition between sites. The number of species common to pairs of sites and CC values are given in table 2. Higher values of coefficient of community demonstrate a closer correlation of species present in the two sites being compared.

| sites compared | No. of species common to both sites | Sorenson's community coefficient |
|-------------------|---|--|
| site1 & site2 | 32 | 0.51 |
| site1 & site3 | 32 | 0.51 |
| site1 & Dugong R. | 11 | 0.23 |
| site2 & site3 | 28 | 0.58 |
| site2 & Dugong R. | 7 | 0.18 |
| site3 & Dugong R. | 9 | 0.23 |

Table 2. Sorenson's community coefficient

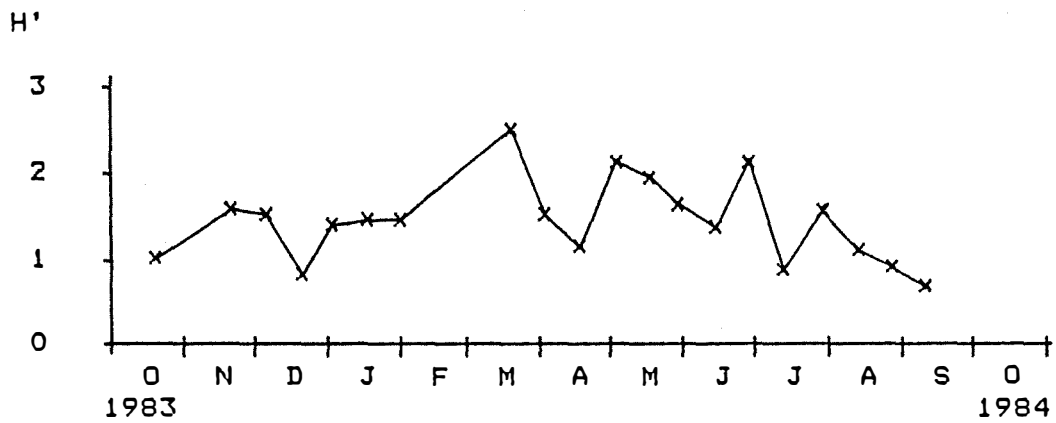
An estimate of the diversity of the fish communities is given by the Shannon - Weaver community parameter H' . H' values for the total populations at each location were, site 1, 2.28; site 2, 2.88; site 3, 1.90; and Dugong River, 0.63. H' values are plotted against sampling period for the Trinity Bay sites (Fig. 3), and range from 0.73 to 2.54 at site 1, 0.86 to 2.38 at site 2 and 0.86 to 2.34 at site 3.

SPECIES RICHNESS

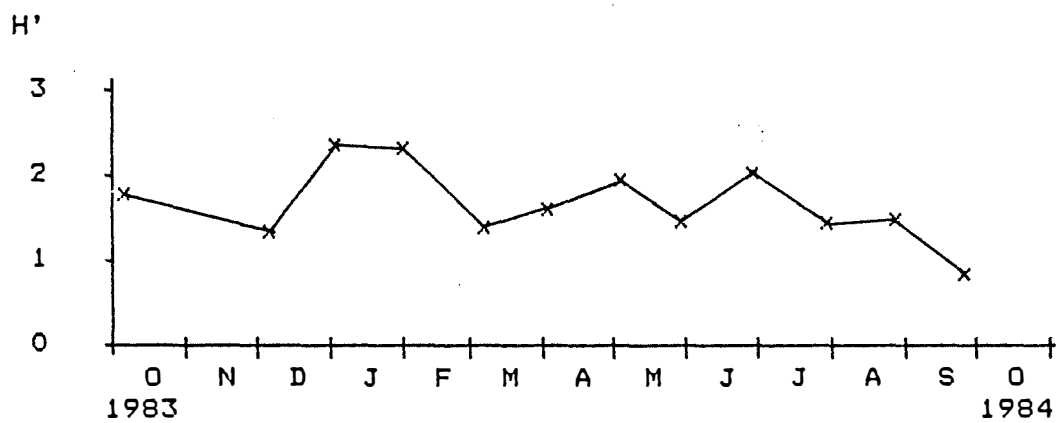
The mean number of species per sample was greatest for site 1 with 14.6, next was site 3, 10.2; followed by site 2 with 9.8 . Significant difference was found between site 1 and site 2 ($P < 0.05$) only. The species richness changes over the sampling period are presented for the three Trinity Bay sites (Fig. 4)

Site 1. Species richness fluctuated considerably throughout the years sampling. The smallest number of species present

SITE 1 H' diversity index



SITE 2 H' diversity index



SITE 3 H' diversity index

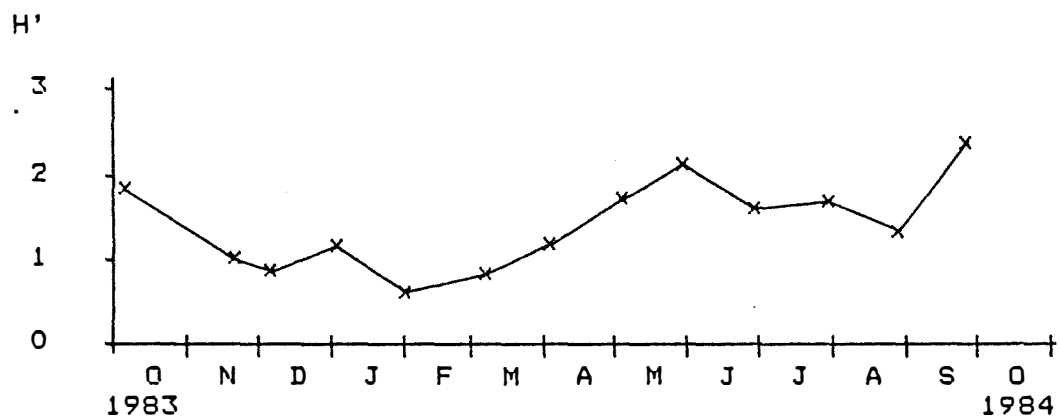


Figure 3: Trinity Bay, Shannon-Weaver community parameter H'. (measure of diversity)

Figure 4: SPECIES RICHNESS ; TRINITY BAY

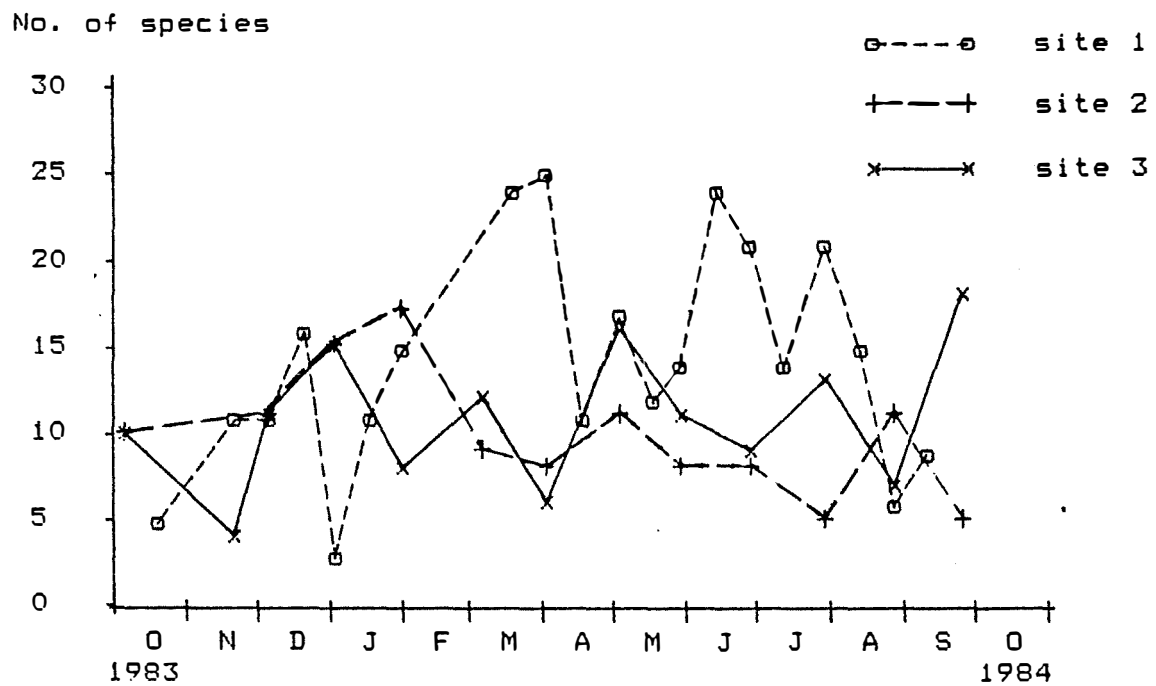
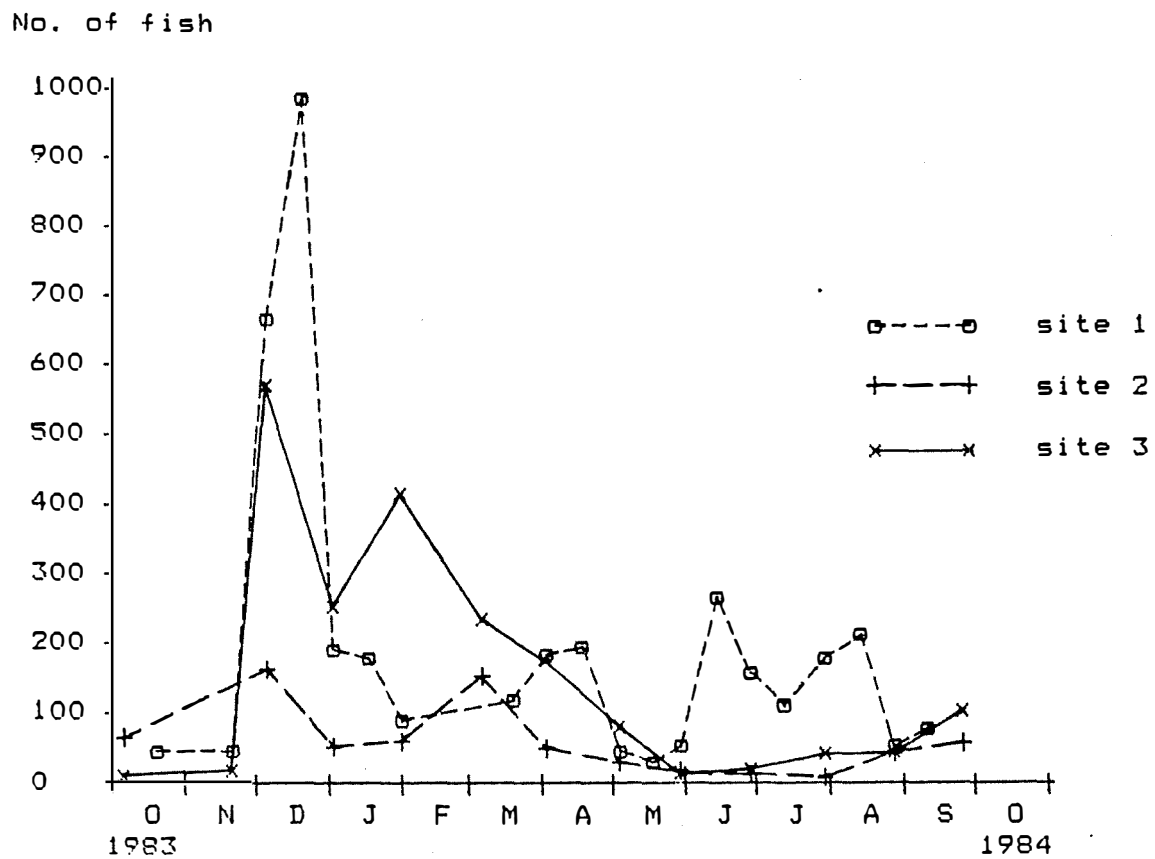


Figure 5: TOTAL ABUNDANCE ; TRINITY BAY



was five in October, and the a maximum number of twenty five in April.

Site 2 Species numbers were fairly steady over the study period with a gradual decrease in number during the cooler months. A minimum of five species were present in July and September and the maximum number was fifteen for January.

Site 3 The species richness at site 3 was highly variable with a maximum number of species of twenty five in April and a minimum of four species during October 1983 and September 1984.

ABUNDANCE

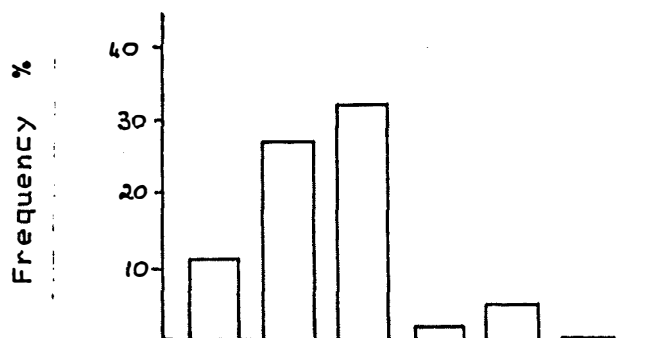
Three species and comprised two thirds of the total numbers of fish from the three sites in Trinity Bay. The most abundant species was *Leiognathus splendens* comprising 26 % of the total fish numbers. The next most abundant species was the Siganid, sp 5, 24 % and the Teraponid, *Pelates quadrilineatus* with 17 % of the total fish numbers. Fish samples from the Dugong River were dominated by the family Teraponidae with 87 % of the total catch, *P. quadrilineatus* with 50 %, *Helotes sexlineatus*, 30 % and *Autisthes puta*, 7 %.

The percentage frequencies of the most abundant species are shown for each site in Figure 6.

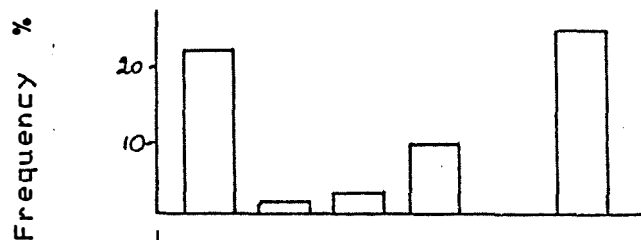
McNaughton's degree of dominance (DI) was calculated for each site. The value of DI was highest for the Dugong River site (0.81); followed by site 3 (0.70); site 1 (0.59)

TRINITY BAY

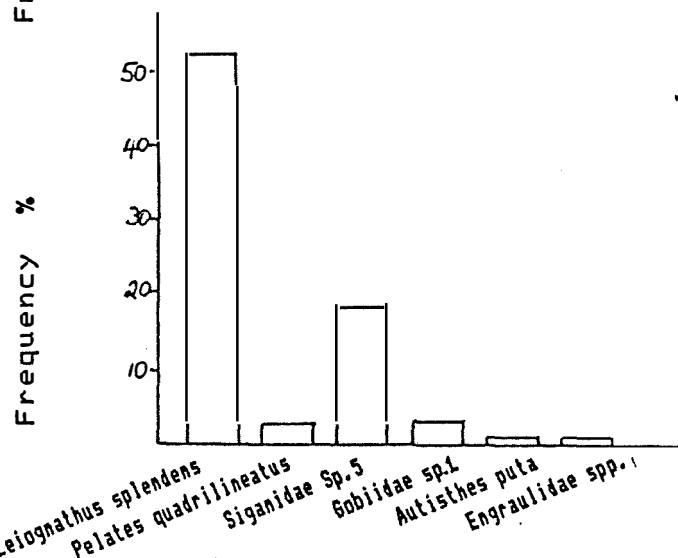
Site 1



Site 2



Site 3



MORNINGTON ISLAND

Dugong River

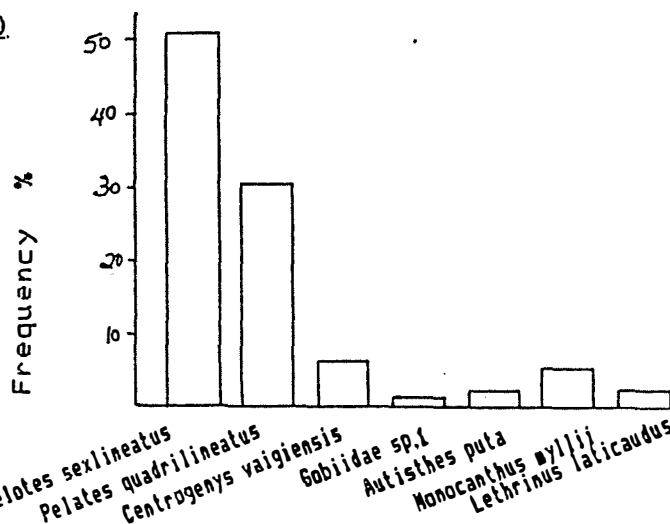


Figure 6: The species composition of the more abundant species at three sites in Trinity Bay and at a site in the Dugong River.

and site 2 (0.42)

Differences in mean abundances for sites 1, 2 and 3 were compared by ANOVA. Significant differences were found ($P < 0.05$), and t tests revealed significant differences between site 1 and site 2 ($P < 0.01$) and site 2 and site 3 ($P < 0.05$). No significant difference was detected between site 1 and site 3.

The numbers of fish at site 2 were considerably less than for the two seagrass sites in Trinity Bay and were less for all sample times at except for one occasion in October when abundances were low at all the sites.

CHANGES IN ABUNDANCE OVER TIME (Fig. 5)

The abundance at the Trinity Bay sites was examined for significant changes between "seasons" by ANOVA. Significant variation was found only for site 2 ($P < .05$).

Student-Newman-Keuls range tests indicated significant differences ($P < .05$) between the winter months and the three other "seasons" separately. No significant differences were found between other combinations.

Abundance changes over the study period for the three Trinity Bay sites are outlined below.

Site 1:

Total abundance at site 1 reached a peak during December and for the remainder of the sampling period the number of fish fluctuated at low levels with three minor peaks.

The abundance of *P. quadrilineatus* (Fig. 7.1) the dominant species at site 1 showed an isolated peak in December 1983. The abundance remained low from January to April and

peaked again in June and August. *L. splendens* (Fig. 7.2) was collected from sixteen of the twenty samples and reached a peak abundance of 126 fish in April. Two smaller peaks were during December and June. The December peak yielded *L. splendens* individuals below 25 mm in length, smaller than the lengths recorded for other sampling times. The third most abundant species was the *Siganid, sp.5* (Fig 7.3) and was present almost exclusively in December and January with a length range of 16 to 34 mm.

Site 2:

Total abundances at site 2 were low in comparison to site 2 and site 3. The cooler months from May to August yielded fewer than 45 fish per sample. The highest abundances were for fish collected in December 1985 and March 1984 with 160 and 150 fish. The remainder of the months yielded fewer than 70 fish per sample. The most abundant species *L. splendens* (Fig 8.1) reached peak numbers in December 1983 and was rare from May to October 1984. The most fish in the months December 1983 and September 1984 were small juveniles of the family Engraulidae, *Stolephorus spp.* (Fig. 8.2) .

Site 3:

The total abundance at site 3 was greatest in December and closely follows the abundance for site 1 from October to December 1983. After December the fish population declined to low level of abundance during the winter months. The December abundance was due almost entirely to two species; *L. splendens* and *Siganidae sp.5* which contributed 95 % of the total abundance. The *Siganid* species contributed 378 individuals to the December abundance and was absent from all other trawls at site 3 (Fig. 9.1). *Leiognathus splendens*

the most abundant of the species at this site had a maximum abundance in February and was rare in the months August to October 1984 (Fig. 9.2).

TRINITY BAY

Fig. 7.1 : SITE 1 Pelates quadrilineatus, abundance

No. of fish

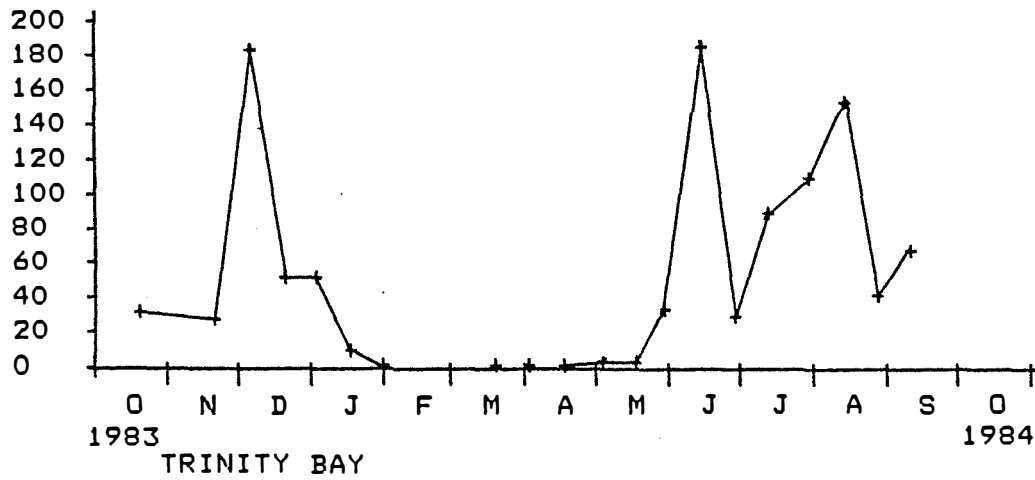


Fig. 7.2 : SITE 1 Leiognathus splendens, abundance

No. of fish

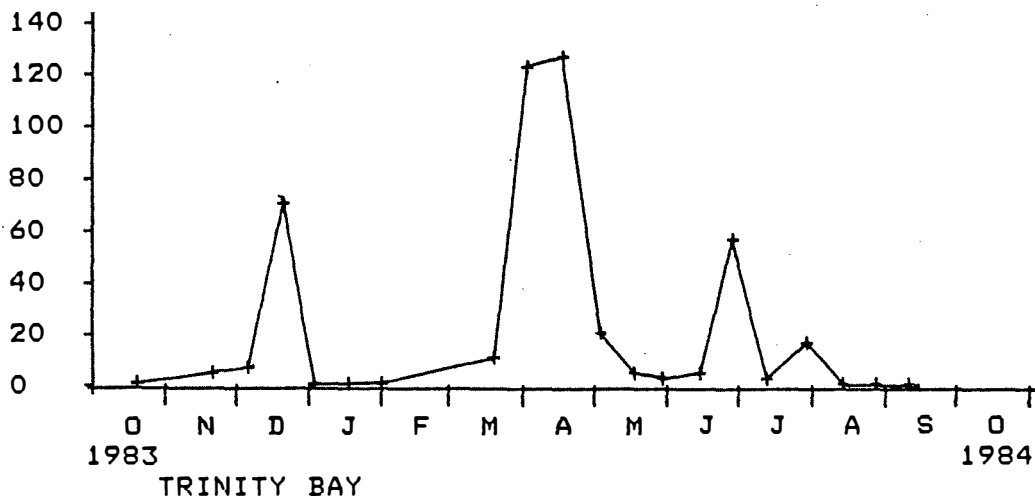


Fig. 7.3 : SITE 1 SIGANIDAE Sp.5, abundance

No. of fish

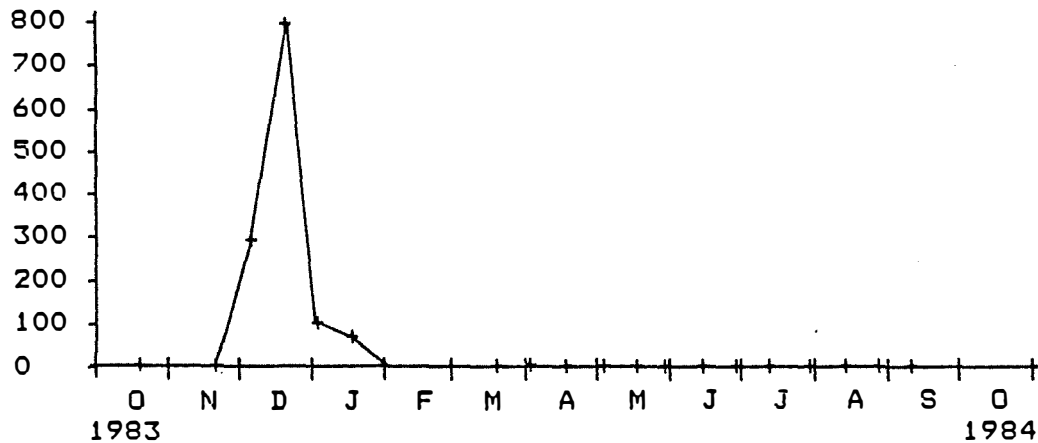


Fig. 8.1 : TRINITY BAY

SITE 2 Leiognathus splendens . Abundance

No. of fish

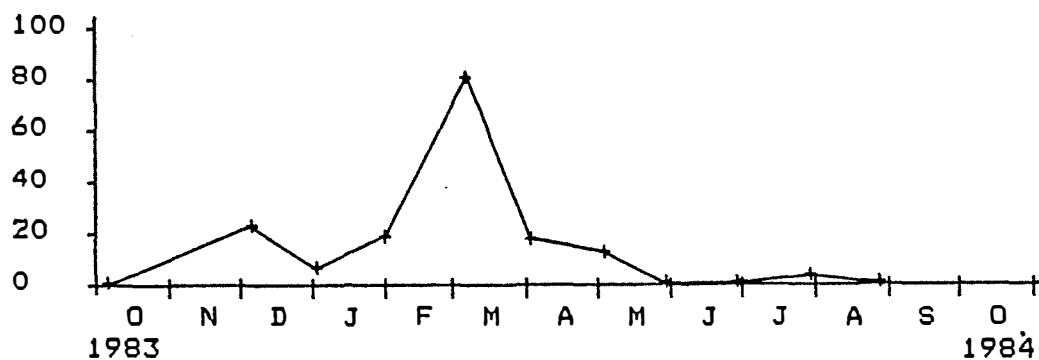


Fig. 8.2 : TRINITY BAY

SITE 2 Stolephorus Spp. Abundance

No. of fish

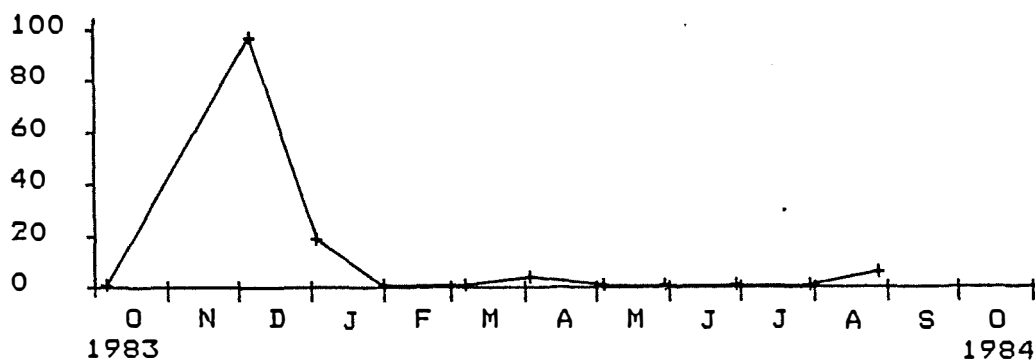


FIG 9.1 TRINITY BAY

SITE 3 Leiognathus splendens

No. of fish

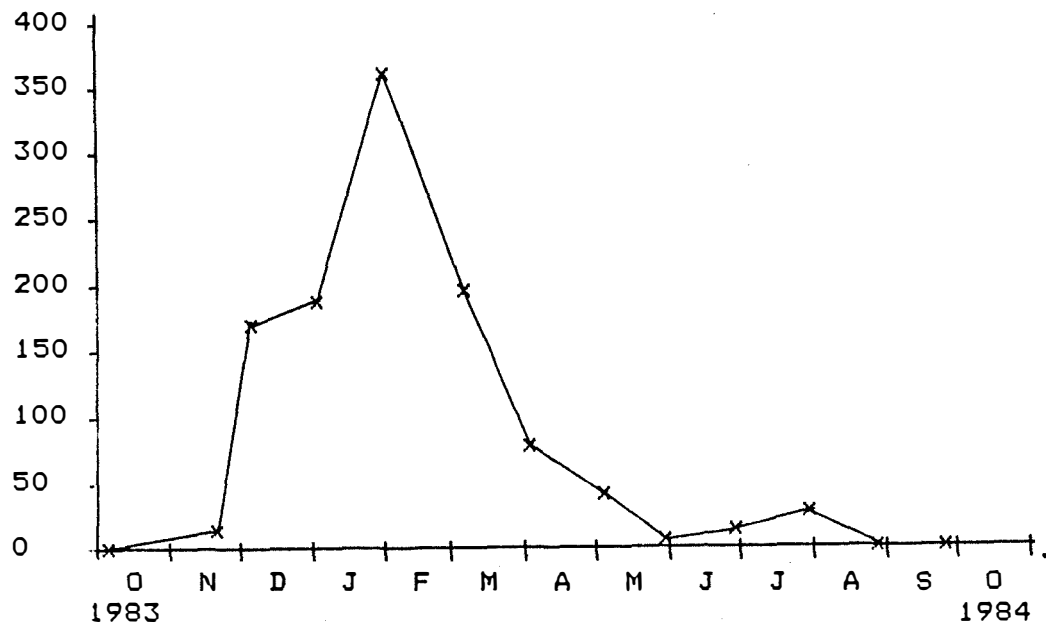
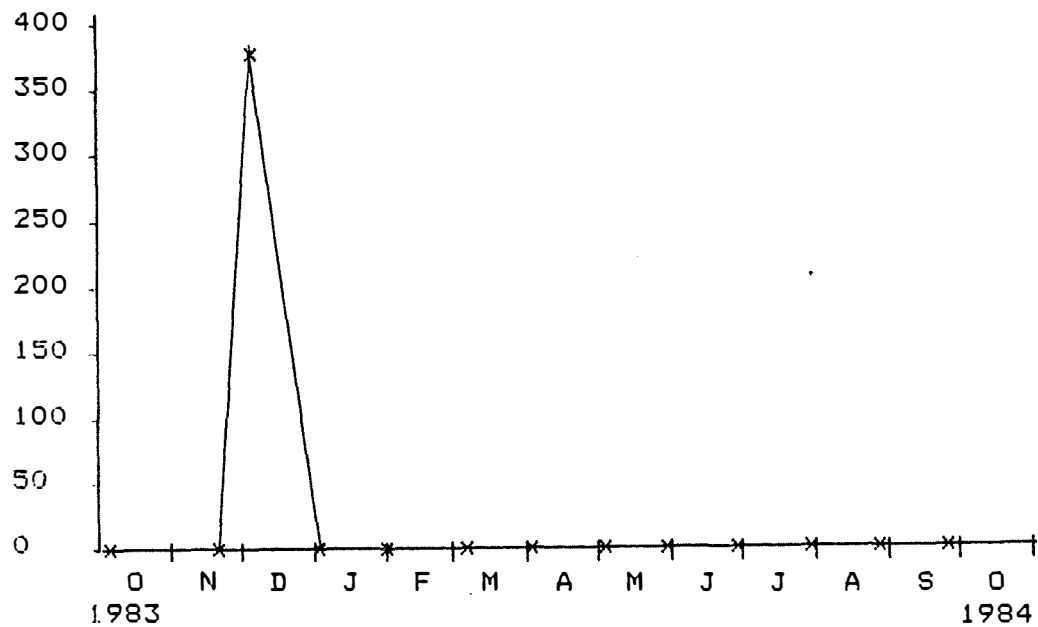


FIG 9.2 TRINITY BAY

SITE 3 Siganidae sp.5

No. of fish



DISCUSSION

This study shows that while many species of juvenile fish were present in Trinity Bay seagrasses, just a few accounted for most of the abundance.

The species collected in this study differ markedly from those present in a study of the Trinity Bay and Inlet fishes by Blaber (1980). Blaber sampled juvenile and adult fish populations with gill nets, seine nets and stake nets from various sites in the bay and estuary. Of the species present in this study less than fifteen percent were identified in Blaber's study. None of the more dominant species (*Leiognathus splendens*, *Pelates quadrilineatus* and the Siganid Sp. 5) from the beam trawling of seagrass beds were collected by Blaber.

These differences can be attributed to factors such as gear selectivity, locations of sampling sites and diurnal and seasonal fluctuations. The beam trawl selectivity is towards small and less motile fish and in this study few fish were collected with lengths greater than sixty millimetres. The gill nets would be expected to catch larger fish (depending on mesh size) than the beam trawl. The seine net, however, would be more effective in sampling a wider size range of fish and if a small mesh size is used should catch fish sampled by the beam trawl.

Of the sampling sites examined in Trinity Bay the average fish numbers per sample was greatest at site 1 (dense cover of seagrass), lower for site 2 (patchy seagrass cover), although not statistically, and the least for site 3 (deeper, no seagrass). This indicates a

preference for seagrass habitats for many species. The total abundance at each site increased during the warmer months as has been found in other studies (Young, 1981; Middleton et al., 1984).

Seasonal trends cannot be determined in this study as only one year's data was examined. However, no species was abundant for the complete survey period, and there were often pulses of increase abundance. The decline in numbers of fish in the cooler months may be correlated to the dieback of seagrass and to reduced availability of food in the form of small invertebrates.

Species richness was also greatest at site 1, with significantly more species present per sample than site 2. Site 3 had a greater mean number of species per sample than site 2 although this was not significantly different.

It has been thought that species richness and abundance of fish are a function of the complexity of the seagrass beds and that the change in the ratio of plant surface area to bottom substrate area may hinder or facilitate predation (Heck and Orth, 1980). Heck and Orth hypothesised that as seagrass density increases, the juvenile fish and invertebrate populations increase to an asymptote and the population of predators until the seagrass density is so great as to make hunting success less than in surrounding areas.

The Shannon-Weaver diversity index and McNaughton's dominance index give a measure of the spread of species within a sample and the degree of dominance of one or two species in a population respectively. The diversity index was highest for site 2 (no seagrass), and was reflected

by a low level of dominance.

The similarity of the species compositions between sites was compared using a Sorenson's community coefficient and showed a large difference between the species compositions of the Trinity Bay sites in comparison to the site in the Dugong River. Between sites in Trinity Bay the highest degree of similarity was between sites 2 and 3. This parameter however only takes into account only the presence or absence of particular species between samples and gives the same importance to rare and dominant species.

Studies of fish in seagrass habitats in Australia have been conducted mostly in the cool to warm temperate climates. The dominant families found in these areas include the Syngnathidae, Monocanthidae, Gobiidae, Scorpaenidae, Sparidae, Tetraodontidae, Apogonidae, Ambassidae and Kyphosidae (Pollard, 1984). Examples of all but the family Kyphosidae were collected from Trinity Bay.

The value of the seagrass beds of Trinity Bay and the Dugong River sampled as nursery grounds for commercially important fish species does not seem high from this study. This contrasts the value of these seagrassess for juveniles of commercially important penaid prawn species (Heasman, 1983). Less than twenty percent of the species of fish collected from Trinity Bay were of commercial value and they contributed little to the total abundance. Many of the commercial fish occured on only one or two occasions (eg. Barramundi, *Lates calcarifer* and the Flathead, *Platycephalus indicus*) and do not seem characteristic of

the seagrass beds as juveniles. The site in the Dugong river also had poor representation and low abundances of commercial species.

The three dominant species in Trinity Bay, L. *splendens*, *P. quadrilineatus* and the Siganinid Sp.5 contributed eighty percent of the total abundance. In the Dugong River three species of the family Teraponidae, *Helotes sexlineatus*, *P. quadrilineatus* and *Autisthes puta* accounted for eighty seven percent of the total fish numbers. None of these species are recognised as having commercial significance in Australia.

Studies in other areas however have shown the importance of seagrass beds as nursery habitats for juvenile fish. *Posidonia australis* and *Zostera capricorni* seagrass beds in Botany Bay N.S.W. have been recognised as valuable nursery areas for commercially important fish and may provide spawning areas for two important species (State Pollution Control Commission, N.S.W. ,1981). Of fourteen dominant species of commercial fish in the Botany Bay area nine were strongly associated with the seagrasses at some stage of their lifestyle. (Bell, 1980)

Further study would be required to ascertain the value of the the seagrass beds in Trinity Bay and other seagrass areas of North Queensland as habitats for commercial species of fish. Additional work could include examination of diurnal characteristics of the fish populations and the use of seagrass beds as a food source by adult and sub-adult fish.

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APPENDIX I. Species collected in Trininty Bay, with relative abundances an frequency of occurrence.

Relative abundance = number of fish caught / number of samples.

(relative abundances < 0.1 fish per sample are shown as +.)

Frequency of occurrence = proportion of samples with
a particular species present

| FAMILY Species | SITE | Relative abundance | | | Freq. of occurrence | | |
|--------------------------------------|------|--------------------|------|-----|---------------------|-----|-----|
| | | 1 | 2 | 3 | 1 | 2 | 3 |
| ALUTERIDAE | | | | | | | |
| <i>Monocanthus mylii</i> | | .1 | .8 | .2 | .10 | .17 | .08 |
| <i>Sp.1</i> | | + | | | .05 | | |
| <i>Sp.2</i> | | | + | + | | .08 | .08 |
| <i>Sp.3</i> | | | | + | | | .08 |
| APOGONIDAE | | | | | | | |
| <i>Sp.1</i> | | .2 | | | .10 | | |
| <i>Sp.2</i> | | | | + | | | .08 |
| <i>Sp.3</i> | | | .5 | | | .25 | |
| ATHERINIDAE | | | | | | | |
| <i>Sp.1</i> | | .2 | | 1.5 | .15 | | .23 |
| BOTHIDAE | | | | | | | |
| <i>Pseudorhombus elevatus</i> | | | | + | | | .08 |
| <i>Sp.1</i> | | | .2 | | .17 | | |
| CALIONYMIDAE | | | | | | | |
| <i>Sp.1</i> | | | + | + | | .08 | .08 |
| CARANGIDAE | | | | | | | |
| <i>Alepes kalla</i> | | + | | | .05 | | |
| CENTRISCIDAE | | | | | | | |
| <i>Aeoliscus strigatus</i> | | | + | | | .08 | |
| CHANDIDAE | | | | | | | |
| <i>Ambassus buriensis</i> | | 2.6 | .3 | .9 | .25 | .08 | .25 |
| <i>Ambassus macrocanthus</i> | | 2.9 | | 2.2 | .50 | | .15 |
| CLUPEIDAE | | | | | | | |
| <i>Sardinella melanura</i> | | .3 | | 2.5 | .05 | | .15 |
| CYNOGLOSSIDAE | | | | | | | |
| <i>Arnoglossus tapeinsoma</i> | | | .3 | | | .17 | |
| <i>Cynoglossus puncticeps</i> | | | .8 | | | .42 | |
| <i>Cynoglossus bilineatus</i> | | | .2 | | | .08 | |
| DREPANIDAE | | | | | | | |
| <i>Drepane punctata</i> | | | | .2 | | | .15 |
| ELEUTERIDAE | | | | | | | |
| <i>Sp.1</i> | | .4 | | | .15 | | |
| ENGRAULIDAE | | | | | | | |
| <i>Sp.1</i> | | .1 | 11.9 | | .05 | .25 | |
| <i>Stolephorus tysoni</i> | | 3.8 | 1.2 | .2 | .20 | .25 | .15 |
| <i>Stolephorus devisi</i> | | 1.8 | | + | .15 | | .08 |
| <i>Thryssodes mystax</i> | | .4 | | .2 | .20 | | .08 |
| EPINEPHALIDAE | | | | | | | |
| <i>Centrogenys waigiensis</i> | | .9 | .3 | + | .15 | .17 | .08 |
| <i>Epinephalis tauvina</i> | | .6 | | | .25 | | |
| <i>Richardsonichthys leucogaster</i> | | .4 | | | .15 | | |
| GERRIDAE | | | | | | | |
| <i>Gerres sp.1</i> | | + | | .2 | .05 | | .08 |
| <i>Gerres setifer</i> | | .2 | + | .5 | .10 | .08 | .15 |
| GOBIIDAE | | | | | | | |
| <i>Bathygobius fuscus</i> | | .8 | .3 | .5 | .30 | .08 | .23 |
| <i>Stenogobius genivittatus</i> | | 1.7 | .8 | 2.2 | .40 | .17 | .54 |
| <i>Sp.1</i> | | 3.2 | 5.9 | 4.4 | .65 | .67 | .54 |

APPENDIX I cont. Trinity Bay

| | | Relative abundance | | | Freq. of occurrence | | |
|--------------------------------------|------|--------------------|------|------|---------------------|-----|-----|
| FAMILY | SITE | 1 | 2 | 3 | 1 | 2 | 3 |
| GOBIIDAE cont. | | | | | | | |
| <i>Sp.3</i> | | .2 | | | .05 | | |
| <i>Sp.4</i> | | .9 | | | .25 | | |
| <i>Sp.6</i> | | .7 | + | 1.2 | .25 | .17 | .46 |
| <i>Sp.7</i> | | .1 | | | .10 | | |
| <i>Sp.8</i> | | | .5 | .2 | | .08 | .08 |
| LATIDAE | | | | | | | |
| <i>Lates calcarifer</i> | | + | | | .05 | | |
| <i>Psammammoperca waigiensis</i> | | .1 | | | .10 | | |
| LEIOGNATHIDAE | | | | | | | |
| <i>Leiognathus splendens</i> | | 22.4 | 13.2 | 84.8 | .80 | .58 | .85 |
| <i>Leiognathus equulus</i> | | 1.6 | .3 | 4.4 | .40 | .25 | .77 |
| <i>Leiognathus bindus</i> | | .4 | 1.8 | .4 | .15 | .25 | .23 |
| <i>Leiognathus decorus</i> | | .5 | | 1.2 | .15 | | .23 |
| <i>Leiognathus fasciata</i> | | .2 | | | | .05 | |
| <i>Leiognathus moretoniensis</i> | | .1 | .2 | + | .05 | .17 | .08 |
| <i>Gazza minuta</i> | | | .3 | + | | .08 | .08 |
| <i>Secutor ruconius</i> | | 1.0 | 4.9 | 10.8 | .30 | .42 | .54 |
| <i>Sp.3</i> | | + | + | .8 | .05 | .08 | .15 |
| LEPTOCEPHALIDAE | | | | | | | |
| <i>Brachyconger platyrhynchus</i> | | + | | | .05 | | |
| LETHRINIDAE | | | | | | | |
| <i>Sp.1</i> | | .4 | .6 | .9 | .20 | .23 | .38 |
| <i>Sp.2</i> | | .4 | .9 | | .15 | .23 | |
| LUTJANIDAE | | | | | | | |
| <i>Lutjanus fulviflamma</i> | | 2.9 | .2 | .2 | .65 | .08 | .08 |
| <i>Lutjanus russelli</i> | | .3 | | | .15 | | |
| MULLIDAE | | | | | | | |
| <i>Sp.3</i> | | | + | | | .08 | |
| <i>Sp.2</i> | | + | .2 | + | .05 | .08 | .08 |
| <i>Upaeneus tragula</i> | | | + | | .08 | | |
| <i>Upaeneus sulphureus</i> | | | | .3 | | | .15 |
| OSTRACIIDAE | | | | | | | |
| <i>Lactoria cornuta</i> | | | + | | | .08 | |
| PLATYCEPHALIDAE | | | | | | | |
| <i>Cymbacephalus nematophthalmus</i> | | + | | + | .05 | | .08 |
| <i>Platycephalus indicus</i> | | | | + | | | .08 |
| <i>Sp.4</i> | | .1 | | | .10 | | |
| <i>Suggrundus isocanthus</i> | | + | .4 | | .05 | .42 | |
| <i>Suggrundus staigeri</i> | | | | + | | | .08 |
| POMADASYDAE | | | | | | | |
| <i>Pomadasyds hasta</i> | | .6 | .3 | 1.3 | .30 | .23 | .31 |
| SCIAENIDAE | | | | | | | |
| <i>Sciaena dussuneri</i> | | | + | | | .08 | |
| <i>Pseudosciaena soldado</i> | | | .3 | | | .17 | |
| <i>Sp.1</i> | | | .3 | .2 | | .08 | .08 |
| SCORPAENIDAE | | | | | | | |
| <i>Paracentropogon sp.</i> | | + | | | .05 | | |
| <i>Sp.1</i> | | 1.5 | .3 | | .40 | .17 | |
| <i>Sp.3</i> | | + | .2 | | .05 | .08 | |
| <i>Sp.4</i> | | .4 | + | | .05 | .08 | |
| <i>Sp.5</i> | | .2 | | | .05 | | |

APPENDIX I cont. Trinity Bay

| | | Relative abundance | | | Freq. of occurrence | | | |
|---------------|------------------------------------|--------------------|------|-----|---------------------|-----|-----|-----|
| FAMILY | Species | SITE | 1 | 2 | 3 | 1 | 2 | 3 |
| SIGANIDAE | | | | | | | | |
| | <i>Siganus spinus</i> | | 1.0 | | 1.4 | .30 | | .31 |
| | <i>Siganus guttatus</i> | | + | | | .05 | | |
| | <i>Siganus fuscescens</i> | | | + | | | .08 | |
| | <i>Sp.2</i> | | 5.3 | .2 | | .20 | .08 | |
| | <i>Sp.3</i> | | .1 | | + | .05 | | .08 |
| | <i>Sp.4</i> | | .4 | | | .05 | | |
| | <i>Sp.5</i> | | 62.5 | 1.8 | 29.1 | .25 | .08 | .08 |
| | <i>Sp.6</i> | | .2 | | | .05 | | |
| | <i>Sp.7</i> | | | | .2 | | | .08 |
| | <i>Sp.8</i> | | .2 | | | .05 | | |
| SILLAGINIDAE | | | | | | | | |
| | <i>Sillago sihama</i> | | 1.0 | .5 | .2 | .40 | .17 | .08 |
| | <i>Sillago sp.2</i> | | .1 | | | .05 | | |
| SOLEIDAE | | | | | | | | |
| | <i>Synaptura meulleri</i> | | + | | | .05 | | |
| | <i>Sp.1</i> | | | | + | | | .08 |
| SPARIDAE | | | | | | | | |
| | <i>Acanthopagrus berda</i> | | .1 | | | .10 | | |
| SYNGNATHIDAE | | | | | | | | |
| | <i>Saurida sp.</i> | | | .2 | | | .08 | |
| | <i>Sp.1</i> | | 1.3 | | | .35 | | |
| | <i>Sp.2</i> | | .6 | .2 | | .35 | .08 | |
| TERAPONIDAE | | | | | | | | |
| | <i>Autisthes puta</i> | | 10.0 | 1.4 | .8 | .70 | .33 | .38 |
| | <i>Amphitherapon caudivittatus</i> | | .2 | | | .15 | | |
| | <i>Pelates quadrilineatus</i> | | 52.9 | .9 | 4.0 | .90 | .23 | .46 |
| | <i>Sp.1</i> | | + | | | .05 | | |
| TETRAONTIDAE | | | | | | | | |
| | <i>Arothron immaculatus</i> | | 1.8 | .5 | | .20 | .08 | |
| | <i>Arothron hispidis</i> | | .2 | .3 | | .15 | .17 | |
| | <i>Arothron nigropunctus</i> | | | | + | | | .08 |
| | <i>Arothron reticularis</i> | | + | | | .05 | | |
| | <i>Sphaeroides hamiltoni</i> | | .2 | | | .05 | | |
| | <i>Sphaeroides punctata</i> | | | | + | | | .08 |
| | <i>Gastrophysus spadiceus</i> | | | | .2 | | | .15 |
| | <i>Sp.1</i> | | .8 | | | .30 | | |
| | <i>Sp.2</i> | | .7 | | | .35 | | |
| TRIACANTHIDAE | | | | | | | | |
| | <i>Triacanthus biaculeatus</i> | | | + | | | .08 | |
| | <i>Sp.1</i> | | | .3 | .6 | | .17 | .23 |

TOTAL MEAN ABUNDANCE 196.4 59.5 162.2

APPENDIX II

DUGONG RIVER , MORNINGTON ISLAND

BEAM TRAWL PROGRAM

Fish species list, November 1982 to October 1983. (9 samples)

FAMILY

| <u>Species</u> | <u>number of fish</u> |
|--------------------------------------|-----------------------|
| TERAPONIDAE | |
| <i>Pelates quadrilineatus</i> | 475 |
| <i>Helotes sexlineatus</i> | 288 |
| <i>Autisthes puta</i> | 16 |
| ALUTERIDAE | |
| <i>Monocanthus mylii</i> | 45 |
| EPINEPHALIDAE | |
| <i>Centrogenys vaigiensis</i> | 55 |
| <i>Epinephalis tauvina</i> | 1 |
| LETHRINIDAE | |
| <i>Lethrinus laticaudus</i> | 16 |
| GOBIIDAE | |
| <i>Gobiidae Sp.1</i> | 9 |
| LUTJANIDAE | |
| <i>Lutjanus fuscescens</i> | 8 |
| <i>Lutjanus russelli</i> | 1 |
| ENGRAULIDAE | |
| <i>Stolephorus sp.</i> | 7 |
| LABRIDAE | |
| <i>Choerodon schoenleinii</i> | 6 |
| LATIDAE | |
| <i>Psamoperca vaigiensis</i> | 5 |
| ATHERINIDAE | |
| <i>Atherinidae Sp.</i> | 3 |
| GERRIDAE | |
| <i>Gerres argyreus</i> | 3 |
| PLATYCEPHALIDAE | |
| <i>Suggrundus staigeri</i> | 1 |
| <i>Suggrundus rodericensis</i> | 1 |
| <i>Cymbacephalus nematophthalmus</i> | 1 |
| SCOLOPSIDAE | |
| <i>Scolopsis trilineatus</i> | 1 |
| CHAETODONIA | |
| <i>Parachaetodon ocellatus</i> | 1 |
| SIGANIDAE | |
| <i>Siganus fuscescens</i> | 1 |
| BLENNIDAE | |
| <i>Dasson variabilis</i> | 1 |
| HEMIRHAMPHIDAE | |
| <i>Zenarchopterus sp.</i> | 1 |
| TOTAL | 946 |

APPENDIX III: Trinity Bay, Site 1 , number of fish per sample.

| SITE 1 | | | | | | | | | | | | | | | | | Number of fish per sample. (20/10/83 to 10/09/84) | | | | | | | | | | |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|------|------|------|-------------------|------------------------|----------------------|--|--|--|--|
| 2010 | 2111 | 0612 | 2112 | 0301 | 1801 | 0102 | 1903 | 0204 | 1704 | 0305 | 1705 | 2905 | 1406 | 2806 | 1207 | 2907 | 1308 | 2708 | 1009 | F. | Tot. | Species | | | | | |
| . | . | . | . | . | . | . | . | . | . | 1 | . | . | 1 | . | . | . | . | . | . | 2 | 2 | Monacanthus tomentosus | | | | | |
| . | . | . | . | . | . | . | . | . | . | 1 | . | . | 1 | . | . | . | . | . | . | 1 | 1 | ALU.Sp.1 | | | | | |
| . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | . | . | . | 1 | . | . | . | 2 | 2 | APD.Sp.1 | | | | | |
| . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | 3 | 3 | ATH.Sp.1 | | | | | |
| . | . | . | 2 | . | . | 2 | . | . | . | . | . | . | . | 13 | . | . | 21 | . | . | 1 | 1 | Alepes kalla | | | | | |
| . | . | . | . | . | 12 | 11 | 7 | 9 | 3 | . | 14 | . | 2 | 2 | . | 8 | 1 | . | 3 | 5 | 52 | Ambassus buriensis | | | | | |
| . | . | 6 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 10 | 58 | Ambassus macrocanthus | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | 6 | . | . | 1 | . | . | 6 | 6 | Sardinella melanura | | | | | |
| 2 | . | . | . | . | 72 | 1 | 2 | 1 | . | . | . | . | . | . | . | . | 1 | . | . | 3 | 8 | ELE.Sp.1 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 2 | ENG.Sp.1 | | | | | |
| . | . | . | . | . | . | 1 | 2 | 1 | 31 | . | . | . | 4 | . | . | 1 | . | . | . | 4 | 76 | Stolephorus tysoni | | | | | |
| 4 | . | . | . | . | . | 1 | . | . | . | . | 2 | . | 1 | . | . | . | . | . | . | 3 | 36 | Stolephorus devisi | | | | | |
| . | . | 6 | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | 4 | 8 | Thryssodes mystax | | | | | |
| . | . | . | . | . | 2 | . | . | . | . | . | 1 | . | . | . | 1 | . | . | . | 2 | 3 | 9 | Centrogenys waigiensis | | | | | |
| . | 1 | . | . | . | . | . | . | 1 | . | 2 | . | . | 4 | . | 1 | 3 | 4 | . | . | 5 | 11 | Eplenephalis tauvina | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 3 | 7 | Richardsonichthys le | | | | | |
| 4 | 1 | . | . | . | . | . | . | 1 | . | . | . | . | 2 | . | . | . | . | . | . | 1 | 1 | Gerres sp.1 | | | | | |
| . | 2 | 6 | 6 | 2 | . | . | 3 | . | . | . | 1 | . | . | . | . | 1 | . | . | . | 2 | 3 | Gerres setifer | | | | | |
| . | . | 6 | . | . | 6 | 3 | . | . | . | . | . | . | . | . | . | . | . | 8 | . | 6 | 16 | Bathygobius fuscus | | | | | |
| . | . | . | . | . | . | 4 | . | . | . | . | . | . | . | . | . | . | . | . | . | 8 | 34 | Stenogobius genivitt | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 15 | 1 | 16 | 5 | 4 | 1 | 13 | 63 | 60B.Sp.1 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 4 | 60B.Sp.3 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 10 | . | . | 5 | 18 | 60B.Sp.4 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 13 | 5 | 60B.Sp.6 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 2 | 60B.Sp.7 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | Lates calcarifer | | | | | |
| . | 4 | 6 | 70 | 31 | . | 1 | 10 | 122 | 126 | 21 | 4 | 2 | 4 | 57 | 2 | 16 | 1 | . | . | 2 | 2 | Psammoperca waigi | | | | | |
| . | . | . | . | 1 | 2 | 4 | . | 2 | 20 | 2 | . | . | 1 | 1 | . | . | . | . | . | 16 | 477 | Leiognathus splendens | | | | | |
| . | . | . | . | 3 | . | . | . | . | 3 | . | . | . | . | . | . | . | . | . | . | 8 | 33 | Leiognathus equulus | | | | | |
| . | . | . | . | . | . | . | . | 8 | . | . | . | . | 1 | . | . | 1 | . | . | . | 3 | 7 | Leiognathus bindus | | | | | |
| . | . | . | . | . | . | . | . | . | 3 | . | . | . | . | . | . | . | . | . | . | 3 | 10 | Leiognathus decorus | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | 2 | . | . | . | . | . | . | 1 | 3 | Leiognathus fasciata | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | Leiognathus moretoni | | | | | |
| . | . | . | . | 2 | . | . | 3 | 10 | 2 | . | . | . | 2 | . | 1 | . | . | . | . | 6 | 20 | Secutor ruconius | | | | | |
| . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | 1 | 1 | LET.Sp.3 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | 1 | 1 | Bradycoelax platyrhy | | | | | |
| . | . | . | 2 | . | . | 1 | 2 | 2 | . | . | . | . | . | . | . | . | . | . | . | 4 | 7 | LET.Sp.1 | | | | | |
| . | . | 36 | . | . | 2 | 2 | 2 | 4 | 1 | . | 1 | 3 | 1 | 2 | 1 | 4 | 2 | . | 3 | 8 | LET.Sp.2 | | | | | | |
| . | . | . | . | . | . | 3 | 1 | 1 | . | . | . | . | . | . | . | . | 2 | . | 1 | 13 | 58 | Lutjanus fulviflamma | | | | | |
| . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | 1 | . | . | . | 3 | 5 | Lutjanus russelli | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | 1 | 1 | MUL.Sp.2 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | 1 | 1 | Cymbacephalus nemato | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | 2 | 2 | PLA.Sp.4 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | 1 | 1 | Suggrundus isocanthu | | | | | |
| . | . | . | . | 1 | 2 | . | 5 | 1 | 1 | . | . | . | 1 | . | . | . | . | . | . | 6 | 11 | Pomadourus hasta | | | | | |
| . | . | 12 | . | . | . | . | . | . | . | 1 | . | 5 | 5 | 1 | 1 | . | . | . | . | 1 | 2 | Paracentropogon sp. | | | | | |
| . | . | . | 8 | . | . | . | 1 | 4 | . | 1 | . | . | . | . | . | . | . | . | . | 8 | 30 | SCO.Sp.1 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 8 | SCO.Sp.4 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | SCO.Sp.3 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | 4 | . | . | . | . | . | . | 4 | 4 | SCO.Sp.5 | | | | | |
| . | . | 288 | 792 | 101 | 66 | . | . | 3 | . | . | . | . | . | . | . | . | . | . | . | 5 | 1250 | SIG.Sp.5 | | | | | |
| . | . | . | 5 | . | . | 57 | 41 | 3 | . | . | . | . | 14 | . | 1 | . | . | . | . | 4 | 106 | SIG.Sp.2 | | | | | |
| . | . | . | 2 | . | . | 1 | 1 | . | . | 1 | . | . | . | . | . | . | . | . | . | 6 | 20 | Siganus spinus | | | | | |
| . | . | . | 4 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | Siganus guttatus | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 4 | SIG.Sp.8 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | SIG.Sp.3 | | | | | |
| . | . | . | . | . | . | . | 8 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 8 | SIG.Sp.4 | | | | | |
| . | 2 | . | . | . | . | . | 7 | 2 | . | . | . | . | 3 | . | . | . | . | . | . | 1 | 3 | SIG.Sp.6 | | | | | |
| . | . | . | . | . | . | . | . | . | 2 | . | . | 1 | . | . | . | 2 | 3 | 1 | . | 8 | 19 | Sillago sihama | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | Sillago sp.2 | | | | | |
| . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | 1 | 1 | Synaptura meulleri | | | | | |
| . | 7 | . | 12 | . | 2 | . | . | 1 | . | . | . | . | 1 | 2 | 1 | 1 | . | . | . | 2 | 2 | Acanthopagrus berda | | | | | |
| . | 1 | . | 2 | . | . | . | . | 1 | . | . | . | . | 1 | 2 | . | 2 | . | . | . | 7 | 26 | SYN.Sp.1 | | | | | |
| . | 1 | 96 | 22 | 40 | . | 1 | 5 | 4 | . | 4 | . | 3 | 14 | 3 | 2 | 2 | . | . | 1 | 7 | 11 | SYN.Sp.2 | | | | | |
| 31 | 26 | 182 | 51 | 50 | 8 | 1 | . | 1 | . | 3 | 2 | 32 | 185 | 29 | 88 | 108 | 153 | 40 | 67 | 14 | 199 | Autisthes puta | | | | | |
| 5 | . | 24 | 6 | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | 3 | 3 | 3 | Amphitherapon caudiv | | | | |
| . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | . | . | . | . | 1 | 1 | 1 | Pelates quadrilineat | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 4 | 36 | 4 | TER.Sp.1 | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 3 | 3 | 3 | Arothron immaculatus | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | Arothron hispidis | | | | |
| . | 2 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | Arothron reticularis | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | 6 | 16 | TET.Sp.1 | | | | | |
| . | . | . | . | . | 4 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 4 | 4 | Sphaeroides hamilton | | | | |
| . | . | . | . | . | . | . | . | . | 2 | 3 | . | 1 | . | 2 | 7 | 1 | 1 | . | 1 | 7 | 14 | TET.Sp.2 | | | | | |
| . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 4 | 7 | 7 | Unknown | | | | |
| 5 | 11 | 11 | 16 | 9 | 11 | 15 | 24 | 25 | 11 | 17 | 12 | 14 | 24 | 21 | 14 | 21 | 15 | 6 | 9 | 3928 | number of species | | | | | | |
| 46 | 48 | 668 | 987 | 231 | 178 | 91 | 118 | 183 | 194 | 47 | 32 | 55 | 264 | 154 | 109 | 176 | 212 | 56 | 79 | | total no. of fish | | | | | | |

APPENDIX III cont.:

Trinity Bay, Site 2, number of fish per sample.

TRINITY BAY SITE 2; number of fish per sample

Date: 1983 to 1984

| | 0610 | 0612 | 0301 | 0102 | 0603 | 0204 | 0305 | 2905 | 2806 | 2907 | 2708 | 2509 | F. | Tot. | Species |
|--|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|-------------------------------|
| | 7 | . | . | . | . | . | 1 | . | 2 | . | . | . | 2 | 9 | ALU.Monocanthus mylii |
| | . | . | . | . | . | . | 3 | 2 | . | . | 1 | . | 1 | 1 | ALU.Sp.2 |
| | . | . | . | . | . | . | . | . | . | . | 1 | . | 3 | 6 | APD.Sp.3 |
| | . | . | . | . | . | . | . | . | 1 | . | 1 | . | 2 | 2 | BOT.Sp.1 |
| | . | . | . | . | . | . | . | . | . | . | 1 | . | 1 | 1 | CAL.Sp.1 |
| | . | . | . | . | 2 | . | . | . | . | . | . | . | 1 | 2 | CEN.Acoliscus strigatus |
| | 2 | . | . | . | . | . | . | . | . | . | 3 | . | 1 | 3 | CHA.Ambassus buriensis |
| | 3 | . | . | 2 | . | . | . | 1 | 2 | . | 2 | . | 2 | 4 | CYM.Arnoglossus tapeinoma |
| | . | . | . | . | 2 | . | . | . | . | . | . | . | 1 | 5 | CYM.Cynoglossus puncticeps |
| | . | 96 | . | . | . | 3 | . | . | . | . | . | 44 | 1 | 2 | CYM.Cynoglossus bilineatus |
| | . | . | 13 | . | . | . | . | . | . | . | . | . | 3 | 143 | ENG.Sp.1 |
| | . | . | 5 | . | . | . | . | . | . | . | . | . | 1 | 13 | ENG.Sp.(small) |
| | . | . | . | 3 | 6 | . | . | . | . | . | 5 | . | 1 | 5 | ENG.Stolephorus bataviensis |
| | 1 | . | 3 | . | . | . | . | . | . | . | . | . | 3 | 14 | ENG.Stolephorus tysoni |
| | 3 | . | . | . | . | . | 1 | . | . | . | . | . | 2 | 4 | EPI.Centrogenys waigiensis |
| | 30 | 2 | . | . | . | 2 | 1 | 1 | . | 3 | 26 | 4 | 1 | 1 | GER.Gerres setifer |
| | 8 | . | . | . | . | . | . | . | . | . | 1 | . | 1 | 3 | GOB.Bathygobius fuscus |
| | 7 | . | 2 | . | . | . | . | . | . | . | . | . | 2 | 9 | GOB.Sp.1 |
| | . | 6 | . | . | . | . | . | . | . | . | . | . | 2 | 9 | GOB.Sp.6 |
| | . | . | 3 | . | . | . | . | . | . | . | . | . | 1 | 9 | GOB.Stenogobius genivittatus |
| | . | 22 | 6 | 18 | 80 | 17 | 12 | . | . | . | . | . | 1 | 6 | GOB.Sp.8 |
| | . | . | . | 1 | 18 | 3 | 1 | 1 | . | 3 | . | . | 1 | 3 | LEI.Gazza minuta |
| | . | . | . | 1 | 18 | 3 | 1 | 1 | . | . | . | . | 7 | 158 | LEI.Leiognathus splendens |
| | . | . | . | 1 | 18 | 3 | 1 | 1 | . | . | . | . | 3 | 3 | LEI.Leiognathus equulus |
| | . | . | . | 1 | 18 | 3 | 1 | 1 | . | . | . | . | 3 | 22 | LEI.Leiognathus bindus |
| | . | 2 | . | 6 | 32 | 18 | . | . | 1 | . | . | . | 2 | 2 | LEI.Leiognathus moretoniensis |
| | . | . | . | 1 | . | . | . | . | . | . | . | . | 5 | 59 | LEI.Secutor ruconius |
| | . | . | 1 | 6 | . | . | . | . | . | . | . | . | 1 | 1 | LEI.Sp.3 |
| | . | . | 6 | . | . | 3 | . | . | 2 | . | . | . | 2 | 7 | LEI.Unidentified |
| | . | . | 2 | 4 | 2 | . | . | 1 | . | . | . | . | 3 | 11 | LET.Sp.2 |
| | . | . | . | . | . | . | . | . | . | . | . | . | 3 | 7 | LET.Sp.1 |
| | . | 2 | . | . | . | . | . | . | . | . | . | . | 1 | 2 | LUT.Lutjanus fulviflamma |
| | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | MUL.Sp.2 |
| | . | . | . | . | . | . | . | . | . | 1 | . | . | 1 | 1 | MUL.Sp.3 |
| | . | . | . | 1 | . | . | . | . | . | . | . | . | 1 | 1 | MUL.Upeneus tragula |
| | . | . | . | 2 | . | . | . | . | . | . | . | . | 1 | 2 | OST.Lactoria cornuta |
| | 1 | 2 | . | 1 | . | . | 1 | 1 | . | 1 | 1 | . | 5 | 5 | PLA.Suggrundus isocanthus |
| | . | . | . | . | . | 3 | . | . | . | . | 1 | . | 3 | 4 | POM.Pomadasyd hasta |
| | . | . | . | . | . | . | 4 | . | . | . | . | . | 2 | 4 | SCI.Pseudosciaena soldado |
| | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 4 | SCI.Sp.1 |
| | . | . | 1 | . | . | . | . | . | 2 | . | 1 | . | 1 | 1 | SCI.Sciaena dussumieri |
| | . | . | . | . | . | . | 2 | . | . | . | . | . | 2 | 3 | SCO.Sp.1 |
| | . | . | . | . | . | . | 1 | . | . | . | . | . | 1 | 2 | SCO.Sp.3 |
| | . | 22 | . | . | . | . | . | . | . | . | . | . | 1 | 1 | SCO.Sp.4 |
| | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 22 | SIG.Sp.5 |
| | . | . | . | 1 | . | . | . | . | . | . | . | . | 1 | 1 | SIG.Siganus fuscescens |
| | . | . | 2 | . | . | . | . | . | . | . | . | . | 1 | 2 | SIG.Sp.2 |
| | 5 | . | . | . | . | . | . | . | . | 1 | . | . | 2 | 6 | SIL.Sillago sihama |
| | . | . | 2 | . | . | . | . | . | . | . | . | 2 | 1 | 2 | SYN.Sp.2 |
| | . | 2 | 1 | 8 | 6 | . | . | . | . | . | . | . | 4 | 17 | SYN.Saurida Sp. |
| | . | . | . | 3 | . | . | . | . | 2 | . | . | 6 | 3 | 11 | TER.Autisthes puta |
| | . | . | 1 | . | . | . | . | . | . | . | . | 2 | 2 | 3 | TER.Pelates quadrilineatus |
| | . | 2 | 6 | . | . | . | . | . | . | . | . | . | 1 | 6 | TET.Arothron hispidus |
| | . | . | 1 | . | . | . | . | . | . | . | . | . | 2 | 3 | TET.Arothron immaculatus |
| | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | TRI.Sp.1 |
| | . | 2 | . | . | . | . | 4 | 11 | . | . | . | . | 3 | 17 | TRI.Triacanthus biaculeatus |
| | 10 | 11 | 15 | 17 | 9 | 8 | 11 | 8 | 8 | 5 | 11 | 5 | | | number of species |
| | 67 | 160 | 53 | 60 | 150 | 50 | 31 | 19 | 14 | 9 | 43 | 58 | 714 | | total no. of fish |

APPENDIX III cont.:

TRINITY BAY

Site 3, number of fish per sample.

Date: 1983 to 1984

| 0610 | 2111 | 0612 | 0301 | 0102 | 0603 | 0204 | 0305 | 2905 | 2806 | 2907 | 2708 | 2509 | F. | Tot. | Species |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-----------------------------------|
| . | . | . | . | . | . | . | 2 | . | . | . | . | . | 1 | 2 | ALU.Monocanthus tolyi |
| . | . | . | . | . | . | . | 1 | . | . | . | . | . | 1 | 1 | ALU.Sp.3 |
| . | . | . | . | . | . | . | . | 1 | . | . | . | . | 1 | 1 | ALU.Sp.2 |
| . | . | . | . | . | . | . | 1 | . | . | . | . | . | 1 | 1 | APD.Sp.2 |
| . | . | 2 | . | . | 16 | . | . | . | . | 1 | . | . | 3 | 19 | ATH.Sp.1 |
| . | . | . | 1 | . | . | . | . | . | . | . | . | . | 1 | 1 | BOT.Pseudorhombus elevatus |
| . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | CAL.Sp.1 |
| . | 2 | . | 5 | . | 1 | . | . | . | . | 1 | 3 | . | 5 | 12 | CHA.Ambassus burlensis |
| . | . | . | . | . | . | . | . | . | . | . | 12 | 17 | 2 | 29 | CHA.Ambassus macrocanthus |
| . | . | . | . | . | 13 | 20 | . | . | . | . | . | . | 2 | 33 | CLU.Sardinella melanura |
| . | . | . | . | . | . | 1 | . | . | . | 1 | . | . | 2 | 2 | DRE.Drepane punctata |
| . | . | . | 4 | . | 1 | . | . | . | . | . | . | . | 2 | 5 | ENG.Stolephorus tysoni |
| . | . | . | . | . | . | 2 | . | . | 1 | . | . | . | 1 | 1 | ENG.Stolephorus devisi |
| . | . | . | . | . | . | . | 1 | . | 1 | . | . | . | 1 | 2 | ENG.Thryssodes mystax |
| . | . | . | . | . | . | . | . | . | 1 | . | . | . | 1 | 1 | EPI.Centrogenys waigiensis |
| . | . | . | . | 6 | . | . | 1 | . | . | . | . | . | 2 | 7 | GER.Gerres setifer |
| . | . | . | 2 | . | . | . | . | . | . | . | . | . | 1 | 2 | GER.Sp.1 |
| 1 | . | . | . | . | . | . | . | . | . | . | 4 | 2 | 3 | 7 | GOB.Bathygobius fuscus |
| 3 | . | 4 | 8 | 2 | . | . | . | . | 3 | . | 4 | 4 | 7 | 28 | GOB.Stenogobius genivittatus |
| 2 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | GOB.Sp.8 |
| 1 | . | . | . | . | . | . | 1 | 2 | 1 | 1 | . | 10 | 6 | 16 | GOB.Sp.6 |
| . | . | . | . | . | 1 | . | 2 | 5 | 6 | 6 | 30 | 7 | 7 | 57 | GOB.Sp.1 |
| . | . | . | . | . | . | . | . | . | . | . | . | 17 | 1 | 17 | LEI.small |
| . | . | . | . | . | . | . | . | 1 | . | . | . | . | 1 | 1 | LEI.Gazza minuta |
| . | 14 | 170 | 189 | 362 | 196 | 78 | 42 | 7 | 15 | 29 | . | 1 | 11 | 1103 | LEI.Leiognathus splendens |
| . | . | 2 | 13 | 28 | 5 | 2 | 1 | 3 | 1 | 1 | 1 | . | 10 | 57 | LEI.Leiognathus equulus |
| . | . | . | 3 | . | 1 | . | 1 | . | . | . | . | . | 3 | 5 | LEI.Leiognathus bindus |
| . | . | . | . | . | 4 | . | 9 | 2 | . | . | . | . | 3 | 15 | LEI.Leiognathus decorus |
| . | . | . | . | . | . | . | . | 1 | . | . | . | . | 1 | 1 | LEI.Leiognathus moretoniensis |
| . | . | . | 24 | 14 | 4 | 74 | 21 | . | 2 | 2 | . | . | 7 | 141 | LEI.Secutor ruconius |
| . | . | . | 3 | . | . | 8 | . | . | . | . | . | . | 2 | 11 | LEI.Sp.3 |
| . | . | 2 | 2 | 4 | . | . | 1 | 2 | . | . | . | 3 | 5 | 12 | LET.Sp.1 |
| 1 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | LUT.Lutjanus fulviflamma |
| . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | MUL.Sp.2 |
| . | . | . | 1 | . | . | . | 3 | . | . | . | . | . | 2 | 4 | MUL.Upeneus sulphureus |
| . | . | . | . | . | . | . | 1 | . | . | . | . | . | 1 | 1 | PLA.Cymbacephalus newatophthalmus |
| . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | PLA.Platycephalus indicus |
| . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | PLA.Suggrundus staigeri |
| . | . | 2 | 2 | . | . | . | . | 1 | . | . | . | 12 | 4 | 17 | POM.Pomadasys hasta |
| . | . | . | . | . | . | . | . | . | . | . | . | 3 | 1 | 3 | SCI.Sp.1 |
| . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | SCO.Richardsonichthys leucogaster |
| . | . | 378 | . | . | . | . | . | . | . | . | . | . | 1 | 378 | SIG.sp.5 |
| . | 2 | 8 | . | 6 | . | . | . | . | . | . | . | 2 | 4 | 18 | SIG.Siganus spinus |
| . | . | 2 | . | . | . | . | . | . | . | . | . | . | 1 | 2 | SIG.Sp.7 |
| . | . | . | . | . | 1 | . | . | . | . | . | . | . | 1 | 1 | SIG.Sp.3 |
| . | . | . | . | . | . | . | . | . | . | 2 | . | . | 1 | 2 | SIL.Sillago sihama |
| 1 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | SOL.Sp.1 |
| 1 | . | 4 | . | 2 | 1 | . | . | . | . | 1 | . | . | 5 | 9 | TER.Autisthes puta |
| 7 | 10 | . | 3 | . | . | . | . | . | . | 6 | 1 | 25 | 6 | 52 | TER.Pelates quadrilineatus |
| . | . | . | . | . | . | . | . | . | 1 | . | . | . | 1 | 1 | TET.Arothron nigropunctatus |
| . | . | . | . | . | . | . | 2 | . | 1 | . | . | . | 2 | 3 | TET.Gastrophysus spadiceus |
| . | . | . | . | . | . | . | . | . | . | 1 | . | . | 1 | 1 | TET.Spheroides punctata |
| . | . | . | 2 | . | . | . | . | . | . | . | . | . | 1 | 2 | THE.Autisthes puta |
| 1 | . | 4 | . | . | . | . | . | . | . | . | . | 3 | 3 | 8 | TRI.Sp.1 |
| 3 | . | . | . | . | . | . | . | 1 | . | . | . | 3 | 3 | 7 | UNI.Unknown |
| 10 | 4 | 11 | 15 | 8 | 12 | 6 | 16 | 11 | 9 | 13 | 7 | 18 | | | number of species |
| 21 | 28 | 578 | 262 | 424 | 244 | 184 | 90 | 26 | 31 | 53 | 55 | 113 | 2109 | | total no. of fish |

SPECIES COMPOSITION , ABUNDANCE , FECUNDITY AND MORPHOMETRY
OF THE CRAB BY-CATCH FROM A GULF OF CARPENTARIA PRAWN RESEARCH
PROJECT

BY

MICHAEL GEARY COSGROVE
BACHELOR OF SCIENCE (ZOOLOGY)

8th. November, 1985.

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THIS THESIS IS SUBMITTED TO THE AUSTRALIAN MARITIME COLLEGE
AS PARTIAL FULFILMENT FOR THE GRADUATE DIPLOMA IN FISHERIES
TECHNOLOGY.

CONTENTS

| | |
|---------------------------------------|----|
| Introduction | 1 |
| Literature Review | 4 |
| Materials and Methods | |
| -Sampling | 7 |
| -Taxonomy | 8 |
| -Measurements | 8 |
| -Morphometric Analysis | 10 |
| -Statistical Analysis | 10 |
| Results | |
| -Species Composition and Abundance | 12 |
| -Sex Ratios | 13 |
| -Moult Staging | 14 |
| -Percent Ovigerous Females | 14 |
| -Parasitization | 15 |
| -Morphometry | 16 |
| Discussion | |
| -Species Composition and Abundance | 17 |
| -Sex Ratios | 18 |
| -Moult Staging | 19 |
| -Percent Ovigerous Females | 19 |
| -Morphometry | 20 |
| Summary | 22 |
| Acknowledgements | 23 |
| Bibliography | 23 |
| Appendix | 29 |

LIST OF FIGURES AND TABLES

Figure 1 - Map of study sites showing positions of sample sites.

Figure 2 - (a) Conformation of male and female abdomen
and (b & c) linear dimensions of carapace.

Figure 3 - Monthly temperature profiles for three sites.

Figure 4 - Graphs of male and female monthly abundance.

Figure 5 - Percentage soft carapace animals.

Figure 6 - Hourly percentages of ovigerous females.

Table 1.1 - Least squares linear regressions.

Table 1.2 - Least squares linear regressions.

Figure 7.1-7.10 - Graphs of least squares linear regression slopes.

TITLE.

Species composition, abundance, fecundity and morphometry of the crab by-catch from a Gulf of Carpentaria prawn research project.

INTRODUCTION

The Gulf of Carpentaria (referred to as the Gulf) is a large, shallow bay enclosed on three sides by the Queensland and Northern Territory coastline. In winter the Gulf waters are mixed due to convection while in summer a thermocline exists from September until March causing surface and bottom temperatures to vary by as much as five degrees celsius (Church and Forbes, 1983) Closer to the coast , well mixed conditions prevail except during periods of heavy rainfall and river runoff. The survey area receives runoff from numerous rivers and streams, with particularly large volumes discharged in the monsoon season (January to March). The observed salinities ranged from almost fresh water to hypersaline water in both surface and bottom layers. The greatest diversity of salinity occurred inshore immediately prior and during the monsoon season. Also in these shallow waters , barotropic and wind induced circulation were predominant.

The Gulf waters include the most important commercial fishing grounds in Australia. As part of a study of one of these fishing^{grounds} (reported in Robertson et. al. 1985) samples were made of crabs caught during trawling.

Little work has been conducted on crabs caught during trawling operations in Australian fishing grounds. The first

attempt to review the Australian decapod crustacea was made by Haswell in 1882. His catalogue of that year recorded only 32% of the decapods now known from Australian waters and shores. Since his study, several definitive studies have appeared covering selected groups of Australian decapods. Amongst these are systematic reviews on the portunid swimming crabs (Stephenson and co-authors 1957-1960) and the account of Tyndale-Biscoe and George (1962), on the oxystomata and gymnopleuran crabs of Western Australia.

The study area lies totally within the 20 fathom contour and 75% within the 10 fathom contour. Topographically, the Gulf floor consists of a variety of gutters produced by rivers from previous geological periods. Sediments of the Gulf floor range from silts and muds to muddy sands and clean sands and usually consist of a high calcium component derived from invertebrate exoskeletons.

Twenty-seven species of crabs were identified from the area of which the five most common were selected for study (see appendix 1). The five species include three portunid representatives, Portunus rubromarginatus, Portunus gracilimanus and Charybdis jaubertensis and two calappid species, Matuta inermis and Matuta granulosa.

The majority of research into the swimming crabs has been performed on the larger commercial crabs of Australia such as the mud crab Scylla serrata and the sand crab Portunus pelagicus. Nevertheless, an understanding of non-commercial crabs is a valuable addition to our overall

knowledge of the Brachyuran fauna of Australia and particularly the Gulf.

The aim of the present study is to investigate the composition and biology of the decapod crustacea from the Gulf of Carpentaria. The area in question is located in the south-east corner centred around the Wellesley Islands and bounded to the north by the 16 degrees south line of latitude (figure 1).

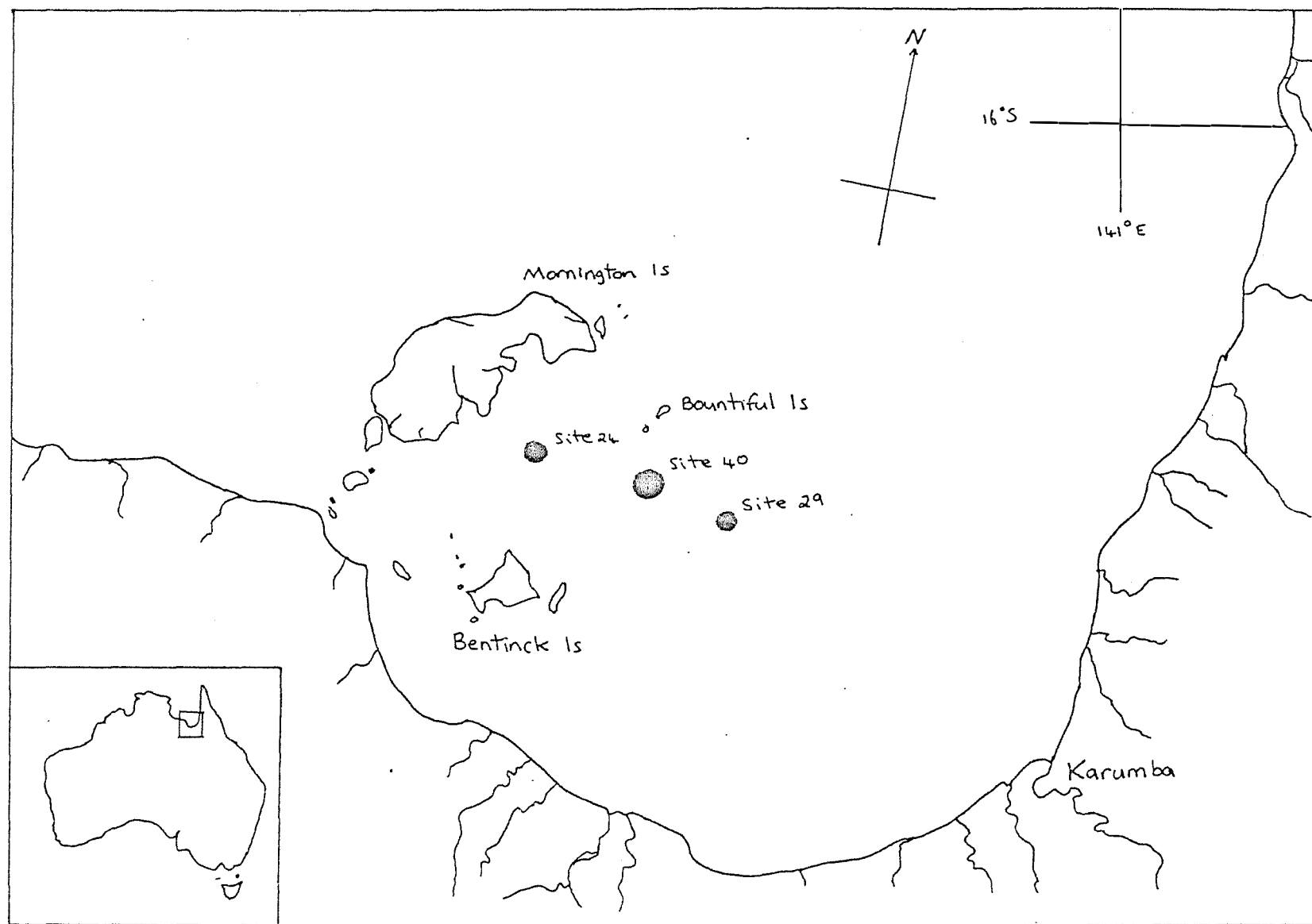


Fig.1. Map of study area showing positions of sample sites (after Robertson et. al. 1985)

Literature Review

Stephenson (1972) in reviewing the portunid fauna of the Indo-West Pacific described six sub-families of the Family Portunidae. In his review he described the sub-family Portuninae as the most successful in terms of the number of genera and species. This sub-family includes the genera Portunus, Charybdis and Thalamita. There are numerous references to genera given in the literature. The following briefly describes a number of studies dealing with the portunids and swimming crabs in general.

An examination of the pattern of change in sex ratios is useful for indicating differences between male and female behaviour in crustacea (Thompson, 1951; Prasad and Tampi, 1953; Potter et.al., 1983). Du Preez and McLachlan (1984), working with the three-spotted swimming crab Ovalipes punctatus related differences in sex ratios to differential mortality. In stating this they had to assume that the catchability of the animals remained constant. Thompson (1951) studying the sand crab Portunus pelagicus observed that the dominance of males was attributable to the swarming or schooling of crabs according to sex. Potter et.al. (1983) also attributed a preponderance of males of P. pelagicus to differential migration between the sexes. They related this difference to a more marked increase in activity of males as temperatures start to rise in summer. Hill (1975) investigating Scylla serrata in a South African estuary found that females migrated out of the estuary and into the sea after mating .

He stated that this migration after copulation was a general phenomenon for the species. This work was supported by Brick (1974) who found females of S. serrata in Hawaii migrated from brackish water to marine conditions prior to spawning. Hill (1974) had previously shown that the presence of berried females in marine conditions is essential as the first stage zoel larva of S. serrata is killed by salinities below 20 p.p.t.

Geise (1959) has summarized the methods for determining the annual reproductive cycles in marine invetebrates. One of the five methods he outlined was the detection of ovigerous females. This method has been applied to a variety of crustacea by numerous authors (Booolootian, 1959; Hartnoll, 1972; Haley, 1973). The percentage of berried females can be related to time to give a curve for the annual reproductive cycle. Reproductive cycles may vary seasonally with changes in temperature, salinity, food supply and light. For example, Du Preez and McLachlan (1984) have found that O. punctatus berried females exist throughout the year yet have two breeding peaks, one in winter and a shorter one in summer.

In the Brachyura the most common form of mating is between hard carapace males and soft carapace females. Pugettia producta is an exception, in this species copulation occurs between hard carapace males and hard carapace females (Booolootian, 1959). Pairing may occur between hard carapace males and females of S. serrata, the male carrying the female until her copulatory moult

(Hill, 1975).

Temperature and photoperiod have an important influence on growth and growth increment during moult. Leffler (1972) has found for the blue crab Callinectes sapidus that moult increments decrease with a decrease in temperature. It has also been found by Sather (1966) that the majority of animals of the portunid Podophthalmus vigil moulted during the late evening or early morning hours.

Due to their rigid exoskeleton and consequent discontinuous growth, crustaceans have been extensively used for relative growth analyses (Tessier, 1960; Haley, 1969, 1973; Hartnoll, 1974). Morphometric data has been used to separate sexually mature from immature animals for various species. This separation is achieved by relating discontinuity in the relative growth curve to the size at which maturity is reached (Tessier, 1960; Haley, 1969, 1973).

Relative growth in crustaceans is usually described by isometric and allometric growth equations. Allometry has been defined by Gould (1969) as "the study of proportion changes correlated with variation in size of either the total organism or the part under consideration". Huxley (1932) was the first to demonstrate that the growth of appendages and other body dimensions is usually a close approximation to the allometric growth equation: $Y = a \text{ times } X \text{ to the power of } b$, where a and b are constants. This equation is usually presented in a logarithmic form: $\log Y = \log a + b \log X$, and is called the equation of simple

allometry. While Huxley's mathematical models were seen to fit simply to empirical data, Gould (1966) has stated that the models are chosen for three reasons, adequacy of statistical fit, simplicity and interpretability. Recently, Williams et al.(1980), have illustrated the appropriate use of statistical technology in multivariate morphometrics. They applied modern techniques to analyse the relative growth of three species of the genera Uca.

Hartnoll(1974) has reviewed the variation in growth pattern between secondary sexual characters of the Brachyura. In this review he noted the existence of subdivisions of juvenile and adult growth phases. Such subdivisions have been demonstrated for the mudcrab S.serrata by Heasman (1980-) who found four distinct growth phases .

Materials and methods

Sampling

Samples were collected between January and December 1983 using the F.R.V. "Gwendoline May" rigged with twin commercial otter trawls (six fathom headrope length Florida Flyers).

Each lunar month, duplicate 30 minute trawls were made within four nights of the new moon. The survey area composed of thirty-eight sites situated around the Wellesley Islands in the south-east corner of the Gulf (Latitude 16 degrees south- 17 degrees 15 minutes south, Longitude 138 degrees 42 minutes east- 140 degrees 18 minutes east). Of these sites, one located south of Bountiful Island was trawled at two

hourly intervals over a twenty-four hour period in order to assess the day/night changes in species composition and abundance. For the purposes of this study only three sites from the thirty-eight were utilized. These sites were (in order of increasing depth along a transect running in a south-easterly direction away from Mornington Island) site 24, site 40 (the twenty-four hour site) and site 29.

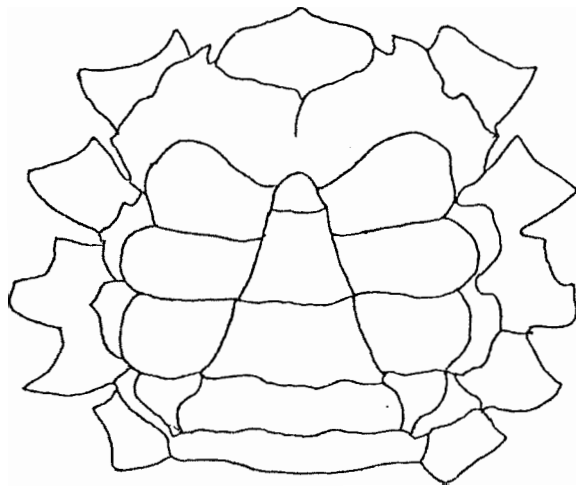
Surface and bottom temperatures were taken at the completion of each trawl. Information on depth was recorded.

Taxonomy

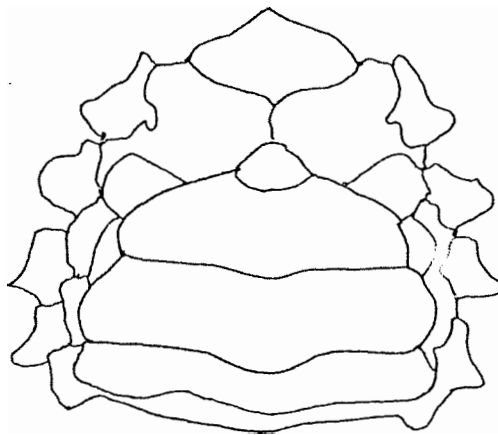
Species identification was based on the keys, diagrams and photographic references of several authors (Stephenson et.al., 1957, 1959, 1960; Stephenson, 1961, 1962, 1972; Sakai, 1976; Shen, 1937; Tyndale-Biscoe and George, 1962). A review of the taxonomic references used in this study is presented in Appendix 1. For the more common species (Families Portunidae and Calappidae) a variety of simple distinguishing features were used. Both families have representatives with flattened dactyls of the fifth leg but can be separated by differences in their carapace. The portunids have a tendency for broadening of the carapace and especially the antero-lateral borders while the calappid genus Matuta has a more circular carapace. The portunid genera can be distinguished by the number of their antero-lateral teeth, Portunus has nine, Charybdis has six and Thalamita has five.

Measurements

Sexing was performed by inspection of the differential shape of the male and female abdomen (Figure 2a). The



MALE - NARROW ABDOMEN



FEMALE - BROAD ABDOMEN

FIGURE 2a- CONFORMATION OF
MALE AND FEMALE ABDOMEN

(After Heasman, 1980)

abdomen of the adult female is characteristically broader than that of the adult male. Sexual dimorphism was overt for all crabs. Sexual maturity was recorded as the presence of egg masses beneath the female abdomen (ovigerous condition).

The ovigerous female carries her spawn attached to her pleopods, with her abdomen deflexed.

The following linear dimensions of crabs were measured:-

1. Carapace width (Figure 2b)- the minimum distance between the tips of the furthest protruding antero-lateral teeth or spines.
2. Carapace length (Figure 2b)- the minimum distance along the midline between the posterior margin of the carapace and the nadir between the central pair of frontal teeth or spines.
3. Body depth (Figure 2c)- the maximum dorso-ventral distance measured in the sagittal plane.

Linear measurements of crabs were recorded using dial calipers. All lengths were measured to the nearest 0.1 mm. Carapace width (CW) and length (CL) are common reference measurements. Carapace depth (CD) was recorded to identify any possible differences in the three dimensional conformation of the soma (cephalothorax and abdomen).

Two weight parameters were also employed. Limbless weight (cephalothorax and abdomen) was chosen as the main parameter because many crabs had lost legs during two years frozen storage. Crabs with their full complement of legs

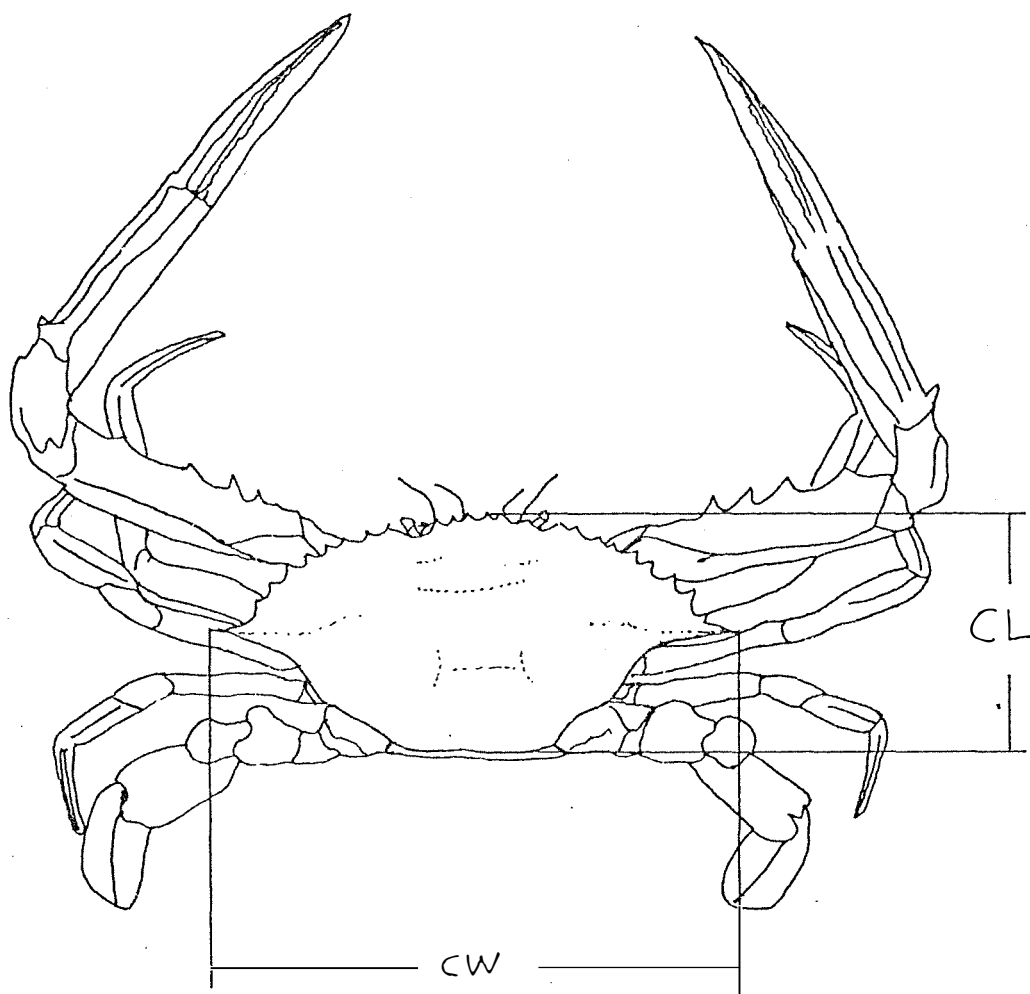


FIGURE 2b- LINEAR DIMENSIONS OF
CARAPACE (CW) CARAPACE WIDTH AND
(CL) CARAPACE LENGTH

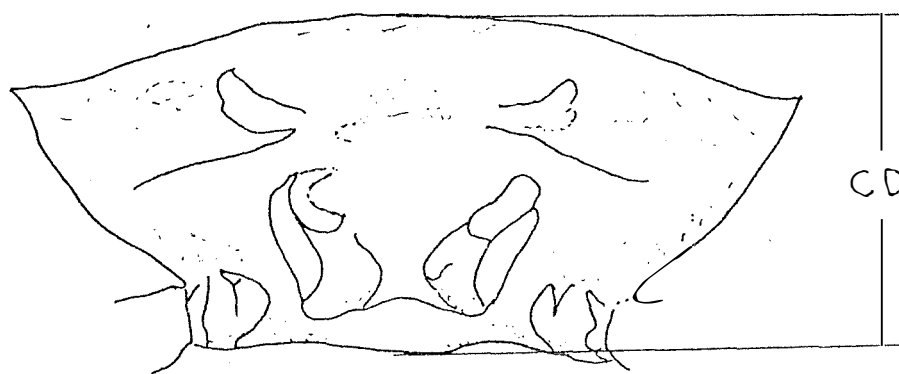


FIGURE 2c- (CD) CARAPACE DEPTH

were measured before their limbless weight was recorded. The amputation of limbs occurred at the basal-ischial joint using a pair of surgical scissors. Weights were recorded to the nearest 0.1 g using a Mettler PC 4400 balance.

Moult stage was separated into two stages, soft carapace (period post moult) and hard carapace (intermoult).

Morphometric analysis

Two species, P.rubromarginatus and P.gracilimanus were selected. For males and females of each species the following relationships were analysed to determine if each two parameters were growing isometrically or allometrically.

1. Carapace width versus carapace length.
2. Carapace width versus carapace depth.
3. Carapace length versus carapace depth.
4. Carapace width versus limbless body weight.
5. Carapace width versus intact body weight.

These were assessed by transforming data to log 10 scale and subjecting these to least squares linear regression (Karmack and Haldane, 1950). For all relationships the computed values of intercepts (a), regression slopes (b) and regression co-efficients (r) were determined.

Statistical analysis

Three statistical tests were used. Chi-square tests were used to determine if there were any significant differences in sex ratios both on a monthly and an hourly basis. Chi-square tests were also employed to analyse monthly moult stage data. Significant differences were determined at the 95% confidence level.

F-tests (Sokal and Rohlf,1969), were used to determine differing levels of allometry between the slopes of regression lines for males and females. Significant differences were determined at the 95% confidence level. Student "t" tests (Sokal and Rohlf,1969), were applied to the same slopes to determine differing levels of allometry within the sexes. This was done by comparing slopes involving weight parameters to the isometric growth constant (3) and slopes of linear dimensions against the isometric growth constant (1) (Haley,1973). Significant differences were ascribed at the 95%,99%,and 99.9% confidence levels.

Results

Abiotic data

The recorded surface and bottom water temperatures for sites 24, 29 and 40, including the diurnal temperatures for July and December at site 40 are graphed in Figure 3. Depth measurements are also shown.

Species composition and abundance

Monthly (site 40)

A total of 467 crabs (15 species) were identified from the nine months of sampling. The most abundant species belonged to the Family Calappidae with Matuta inermis 42% of the catch and M. granulosa 19%. The next most abundant species were Portunus rubromarginatus and P. gracilimanus with 19% and 12% respectively. Charybdis jaubertensis comprised 5% and the occasional C. callianassa and C. truncata were found. The largest catches occurred in late autumn and early winter. The calappids were also abundant in December.

Monthly (site 24)

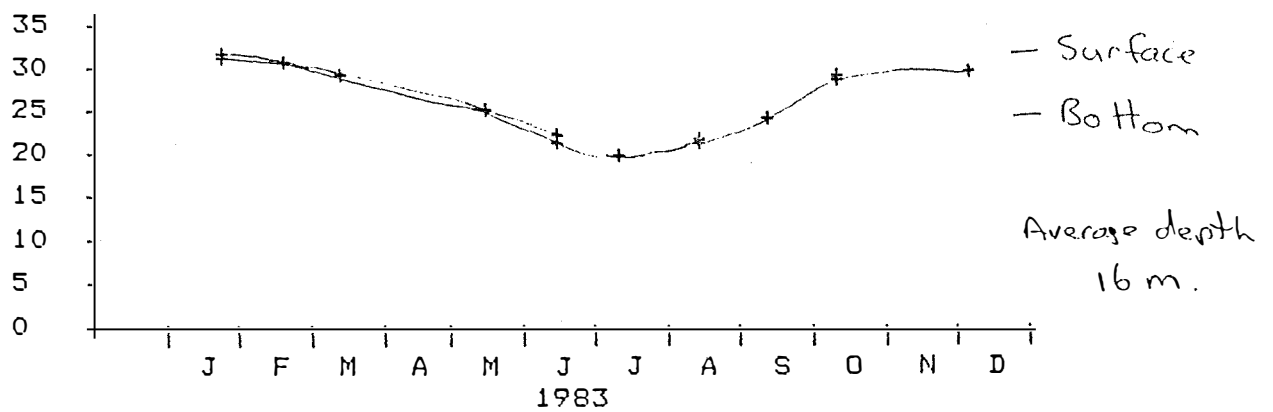
A total of 125 crabs belonging to 10 species were recorded from the eight months sampled. The most abundant species were P. rubromarginatus 30% and P. gracilimanus 22%. These were followed by C. truncata and Parthenope australiensis with 10% each, Podophthalmus vigil 7% and C. jaubertensis 6%.

Monthly (site 29)

One hundred and forty crabs from 15 species were recorded from ten sampling months. P. rubromarginatus was

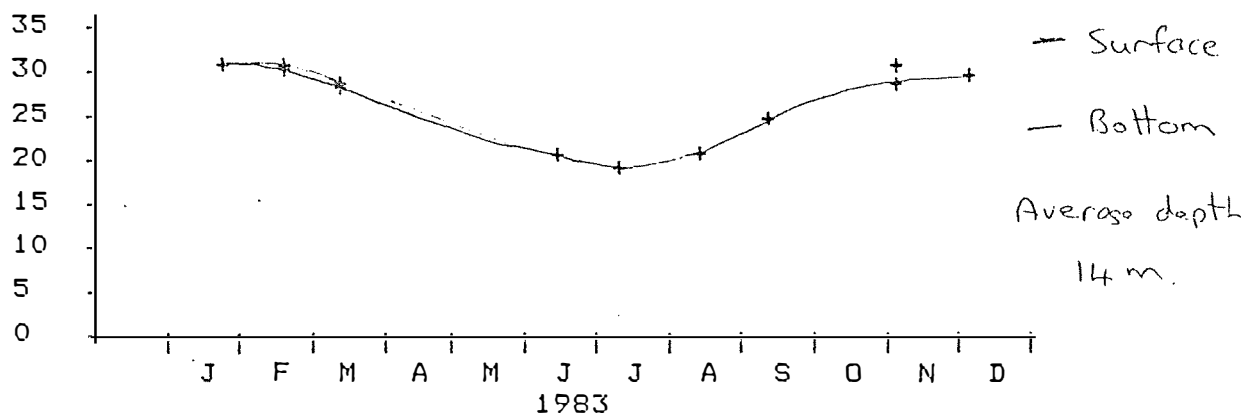
Site 40 water temperature profiles (surface & bottom)

degrees C



Site 24 water temperature profiles (surface & bottom)

degrees C



Site 29 water temperature profiles (surface & bottom)

degrees C

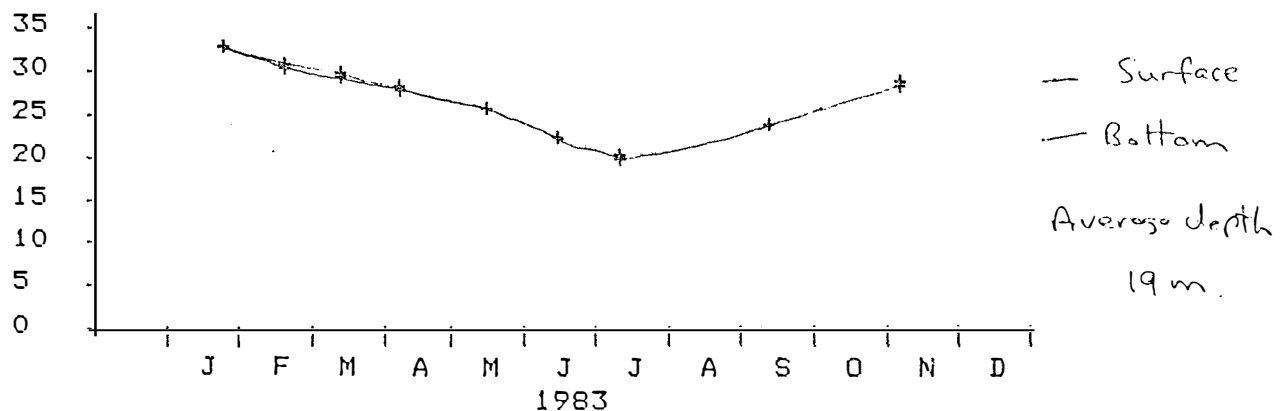


FIGURE 3
MONTHLY TEMPERATURE PROFILES
FOR THREE SITES

the most abundant comprising 31% of the catch, closely followed by P. gracilimanus 29% , C. jaubertensis 17% and C. anisodon 9% .

Hourly (site 40)

In this study a total of 1409 crabs from 18 species were recorded from a winter month (July) and a summer month (December). July samples contained 157 crabs and December 1252 crabs.

In July P. rubromarginatus was the most abundant comprising 27% of the catch, C. jaubertensis 24% , M. inermis 19% , P. gracilimanus 13% and M. granulosa 11% .

In December the most abundant was M. inermis with 51% of the catch. This was more than twice that of M. granulosa 18% . P. rubromarginatus comprised 12% , P. gracilimanus 11% followed by C. jaubertensis and C. truncata with 3% and 2% respectively.

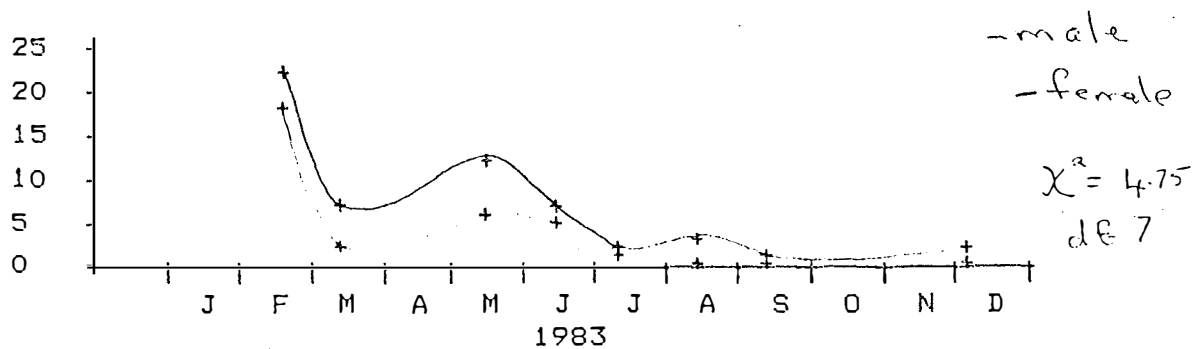
In both July and December the greatest abundance was between sunset and midnight. Fewer crabs were caught after midnight except for the calappids which were most abundant just after midnight. Very few crabs were caught during daylight hours.

Sex ratios

The results of the investigation of sex ratios are shown in Figure 1. This provides hourly and monthly information with the results of chi-square analyses. For all species the particular size range (CW) for each sex is provided. Figure 4 also depicts the monthly sex ratios of

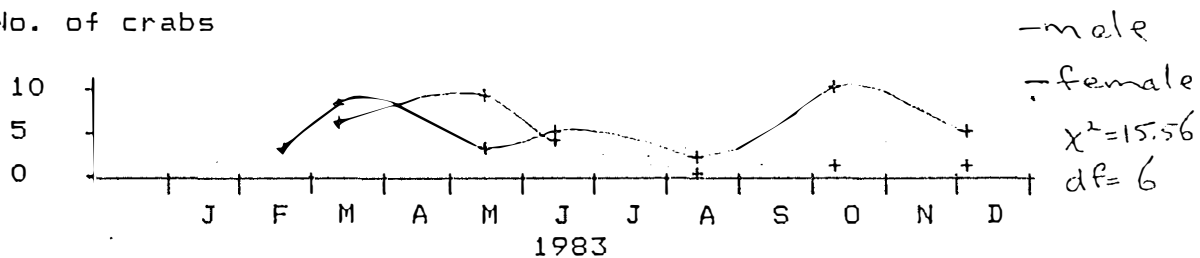
P. rubromarginatus monthly abundance (site 40)

No. of crabs



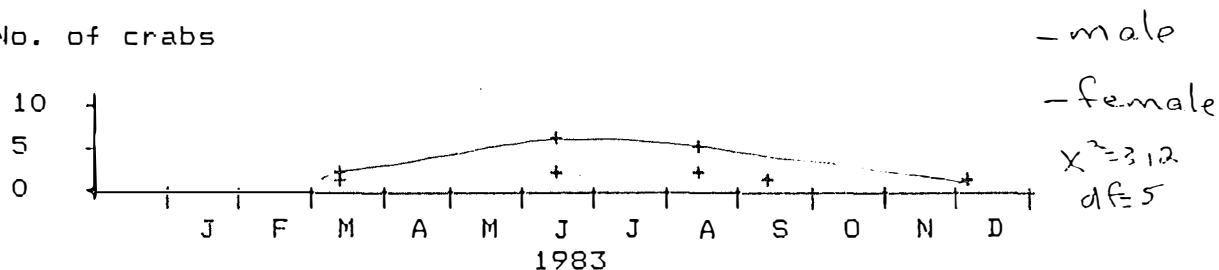
P. gracilimanus monthly abundance (site 40)

No. of crabs



C. jaubertensis monthly abundance (site 40)

No. of crabs



M. granulosa monthly abundance (site 40)

No. of crabs

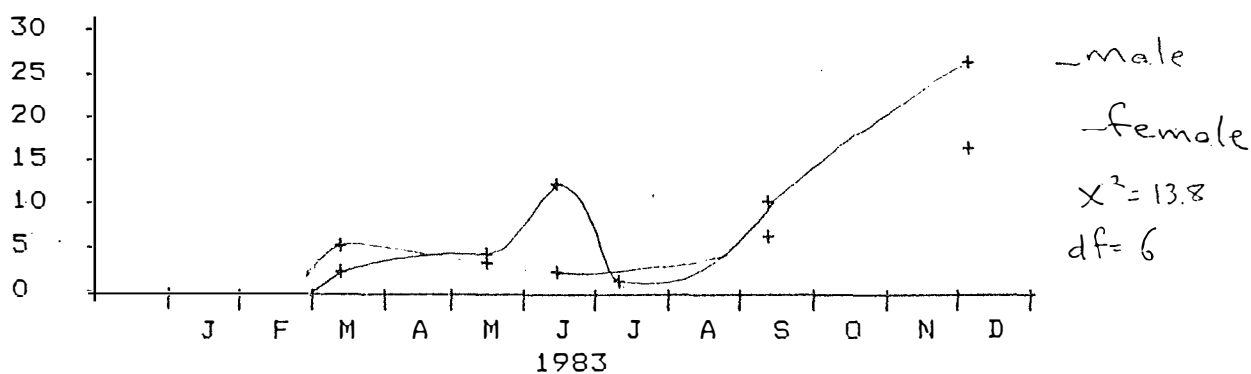


FIGURE 4
GRAPHS OF MALE FEMALE MONTHLY
ABUNDANCE

M.inermis monthly abundance (site 40)

No. of crabs

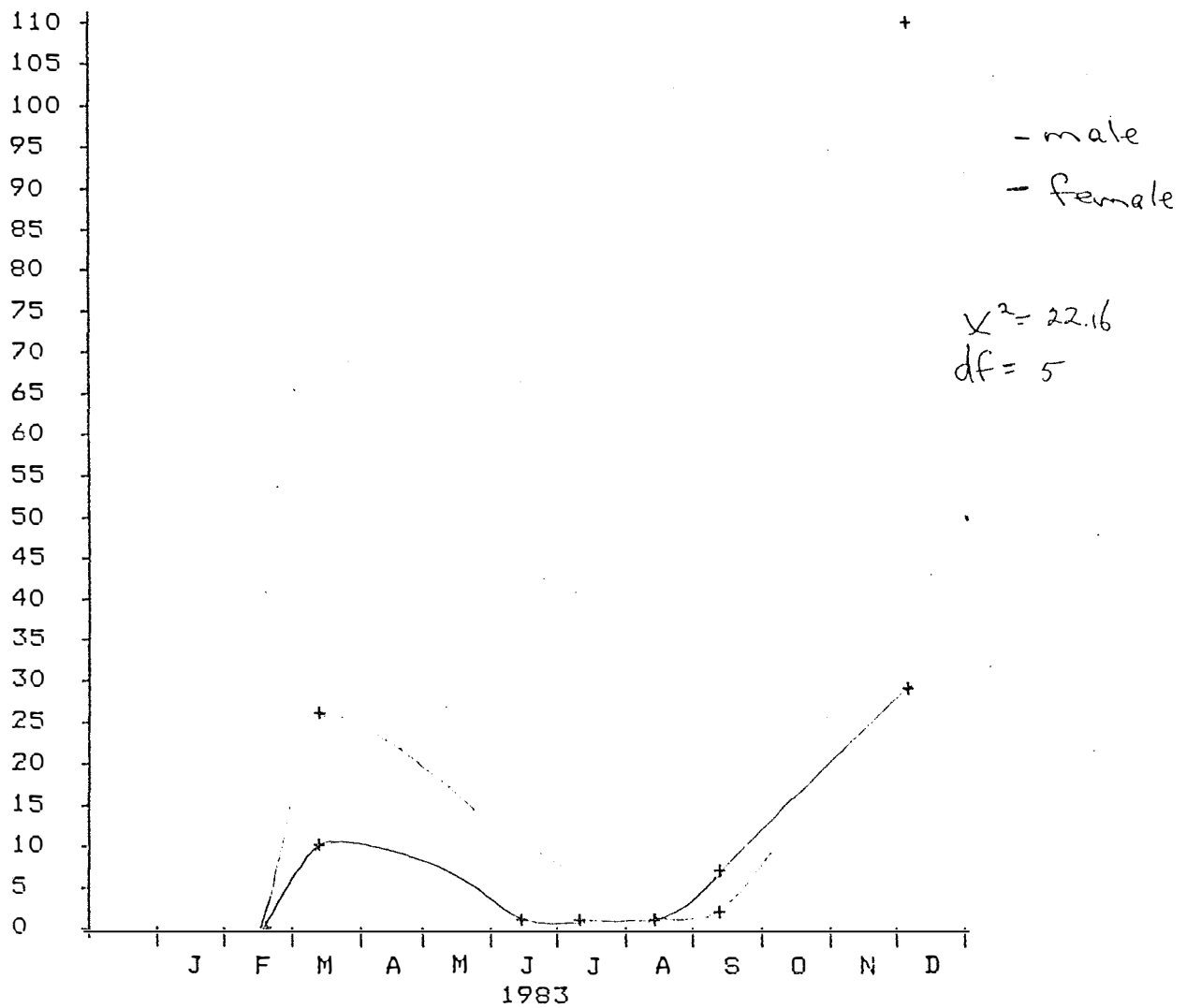


FIGURE 4

GRAPHS OF MALE AND FEMALE
MONTHLY ABUNDANCE

the five species.

Moult staging

The three portunid species, P. rubromarginatus, P. gracilimanus and C. jaubertensis all possess significantly greater percentages of soft carapace throughout the year than the calappids (Figure 5). A greater percentage of soft carapace was observed during winter, particularly for the three portunids.

Chi-square tests for each species indicate that there is a significant monthly difference between the number of males and females with soft carapace .

Percentage females ovigerous

On a monthly basis M.inermis was the only species to be regularly berried. In March samples of this species were 23% berried ,in September 50% and in December 19% berried. The size (CW) of the berried females ranged from 26 mm to 32 mm (n=29). P. gracilimanus had 67% females berried in March and 11% in May. Their size ranged from 37 to 41 mm (n=5).

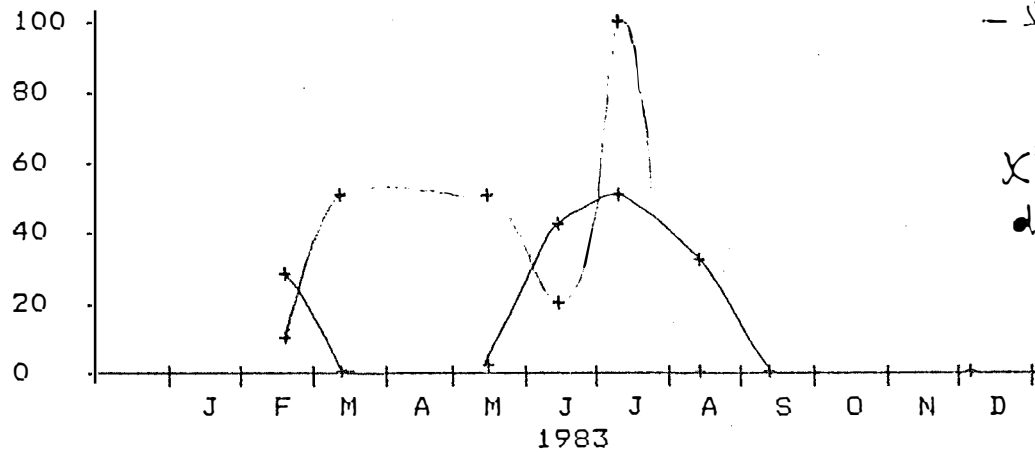
In July P.rubromarginatus had one female berried at 0423 hours (35mm).No other species were ovigerous.

Conversely,in December (Figure 6) all species except P.rubromarginatus were ovigerous. M.inermis was shown to be consistently berried throughout the night. A trend with the other three ovigerous species was a preponderance in the four hours preceding midnight. Few ovigerous females of any species were found during daylight hours.

At sites 24 and 29 the only species found to be ovigerous was P.gracilimanus with four females from each

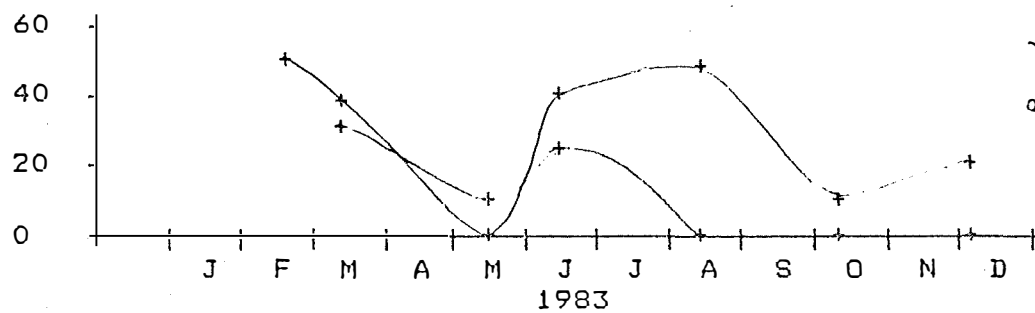
P. rubromarginatus monthly percentage soft carapace

% soft carapace



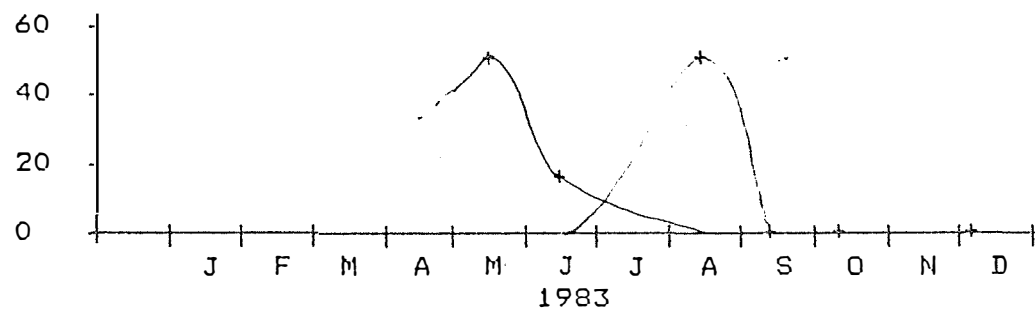
P. gracilimanus monthly percentage soft carapace

% soft carapace



C. jaubertensis monthly percentage soft carapace

% soft carapace



M. granulosa percentage soft carapace

% soft carapace

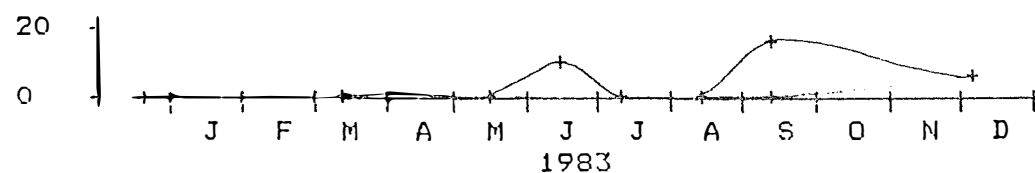


FIGURE 5

PERCENTAGE SOFT CARAPACE ANIMALS

M.inermis percentage soft carapace

% soft carapace

$$\chi^2 = 25.00$$
$$df = 2$$

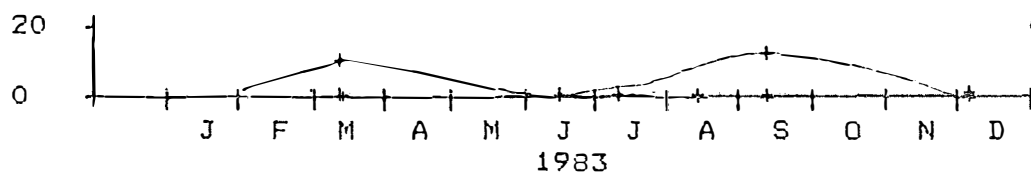
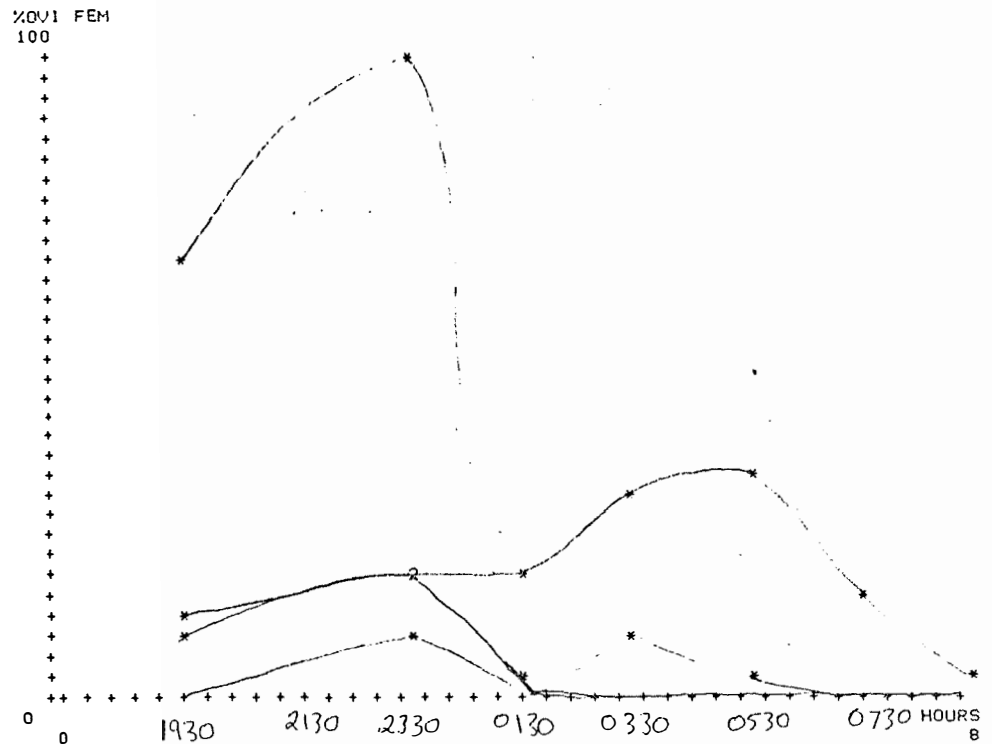


FIGURE 5

PERCENTAGE SOFT CARAPACE ANIMALS

FIGURE 6



HOURLY PERCENTAGES OF OVIGEROUS FEMALES

(DECEMBER)

- P. gracilimanus
- C. jaubertensis
- M. granulosa
- M. inermis

site.

Parasitization

The incidence of ecto-parasites amongst the samples was negligible. The only species found to be parasitized were P.rubromarginatus and M.granulosa with abdominal parasites and M.inermis with a carapace parasite. Hyastenus diacanthus, the sponge crab was totally covered in algal growth whenever it was found.

Morphometric relationships (Tables 1.1 and 1.2, Figures 7.1-7.10)

1. Carapace width compared to total intact weight.

Male P.rubromarginatus showed a highly significant level of positive allometry ($b = 3.837$) for this relationship. Females showed no significant allometry even though there was an appearance of negative allometry. There was a significant difference between the slopes of regressions for male and female crabs.

For P.gracilimanus, neither sex showed any significant allometry. Males favoured positive allometry and females negative allometry. The regression slopes of the sexes were significantly different.

2. Carapace width compared to limbless body weight.

P.rubromarginatus males showed a high degree of significant positive allometry ($b = 3.323$). Females showed an isometric relationship and there was a significant difference between the regression slopes of the sexes.

Conversely, P.gracilimanus males exhibited isometry and

the females small significant negative allometry ($b = 2.162$). The regression slopes of the sexes were significantly different.

3. Carapace width compared to carapace length.

P.rubromarginatus males were found to have highly significant positive allometry ($b = 1.127$) and the females isometric growth.

P.gracilimanus showed the reverse result with males having isometric growth and females small but significant negative allometry ($b = 0.764$). The regression slopes for the sexes were significantly different.

4. Carapace width compared to carapace depth.

Males and females both showed small significant allometry for P.rubromarginatus. Males showed positive allometry and females negative allometry ($b = 1.061$ and $b = 0.904$).

Both sexes of P.gracilimanus revealed isometric growth although there was a significant difference between their slopes.

5. Carapace length compared to carapace depth.

P.rubromarginatus males and females both have highly significant negative allometry ($b = 0.939$ and $b = 0.938$) and their slopes were not significantly different.

P.gracilimanus males and females both exhibited isometry. There was however a significant difference between their slopes.

TABLE 1.1

COMPARISONS BETWEEN SLOPES (b) OF LEAST SQUARES LINEAR REGRESSIONS FITTED TO LOG10 TRANSFORMED DATA OF TWO LINEAR/WEIGHT RELATIONSHIPS FOR P.rubromarginatus and P.gracilimanus.
(SEE ALSO FIGURES 7.1-7.4)

| RELATIONSHIP | SEX | SLOPE | SE | SIG. | NO. |
|--|-----|-----------------|----|------|--------|
| <u>P.rubromarginatus</u> | | | | | |
| Carapace width vs Intact weight | M | 3.837 +/- 0.132 | | **** | (n=17) |
| | F | 2.522 +/- 0.232 | | * | (n=9) |
| Carapace width vs Limbless weight | M | 3.323 +/- 0.099 | | *** | (n=53) |
| | F | 2.818 +/- 0.125 | | * | (n=32) |
| <u>P.gracilimanus</u> | | | | | |
| Carapace width vs. Intact weight | M | 3.281 +/- 0.299 | | * | (n=11) |
| | F | 1.976 +/- 0.384 | | * | (n=8) |
| Carapace width vs. Limbless weight | M | 2.671 +/- 0.237 | | * | (n=31) |
| | F | 2.162 +/- 0.359 | | ** | (n=20) |

Student "t" test

| | | | |
|------|---|------|----------|
| * | Not significantly different from 3.0 at the P | 0.05 | conf.lev |
| ** | Slope | " | " |
| *** | " | " | " |
| **** | " | " | " |

Table 1.2

COMPARISONS BETWEEN SLOPES (b) OF LEAST SQUARES LINEAR REGRESSIONS FITTED TO LOG 10 TRANSFORMED DATA OF THREE LINEAR RELATIONSHIPS FOR P.rubromarginatus and P.gracilimanus
(SEE ALSO FIGURES 7.5-7.10)

| RELATIONSHIP | SEX | SLOPE | SE | SIG. | NO. |
|--------------------------|-----|----------------------------------|----|------|--------|
| <u>P.rubromarginatus</u> | | | | | |
| Carapace width vs. | M | 1.127 +/- 0.024 | | **** | (n=53) |
| Carapace length | F | 0.955 +/- 0.039 | | * | (n=32) |
| Carapace width vs. | M | 1.061 +/- 0.026 | | ** | (n=53) |
| Carapace depth | F | 0.904 +/- 0.036 | | ** | (n=32) |
| Carapace length vs. | M | 0.939 +/- 0.015 N.S. (P=0.05) | | **** | (n=53) |
| Carapace depth | F | 0.938 +/- 0.022 | | *** | (n=32) |
| <u>P.gracilimanus</u> | | | | | |
| Carapace width vs. | M | 0.864 +/- 0.072 | | * | (n=31) |
| Carapace length | F | 0.764 +/- 0.092 | | ** | (n=20) |
| Carapace width vs. | M | 0.942 +/- 0.109 | | * | (n=31) |
| Carapace depth | F | 0.908 +/- 0.193 | | * | (n=20) |
| Carapace length vs. | M | 1.112 +/- 0.070 | | * | (n=31) |
| Carapace depth | F | 1.287 +/- 0.143 | | * | (n=20) |

Student "t" test

| | | | | |
|------|-------|---------------------------------------|-------|------------|
| * | Not | significantly different from 1.0 at P | 0.05 | conf. leve |
| ** | Slope | " | 0.05 | " |
| *** | " | " | 0.01 | " |
| **** | " | " | 0.001 | " |

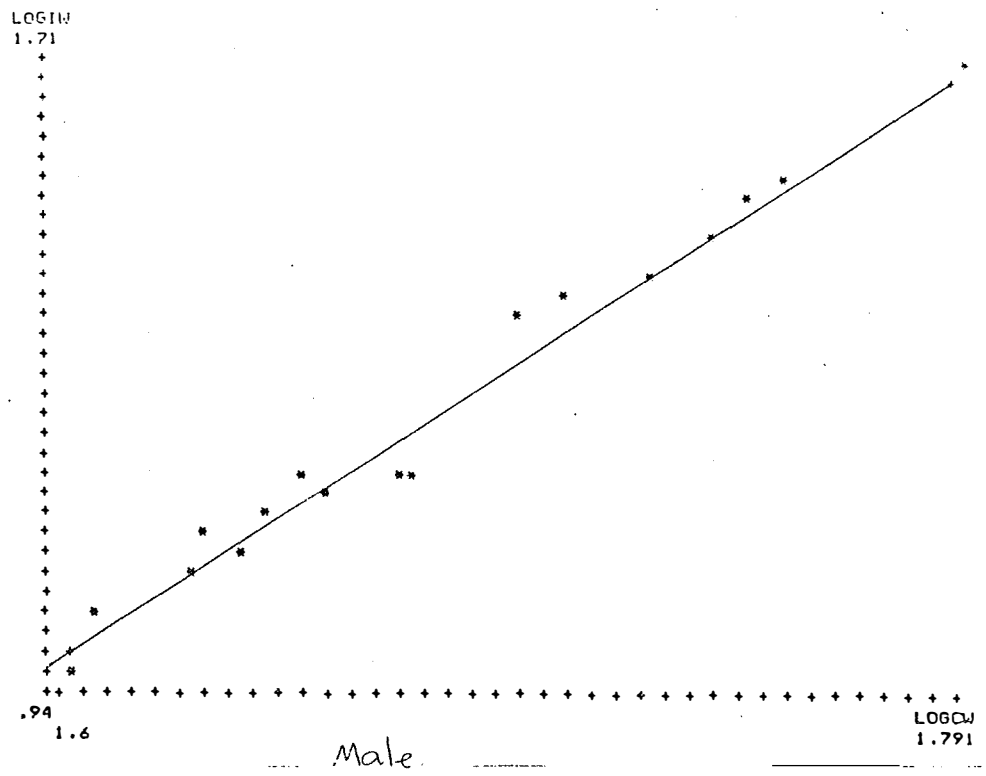
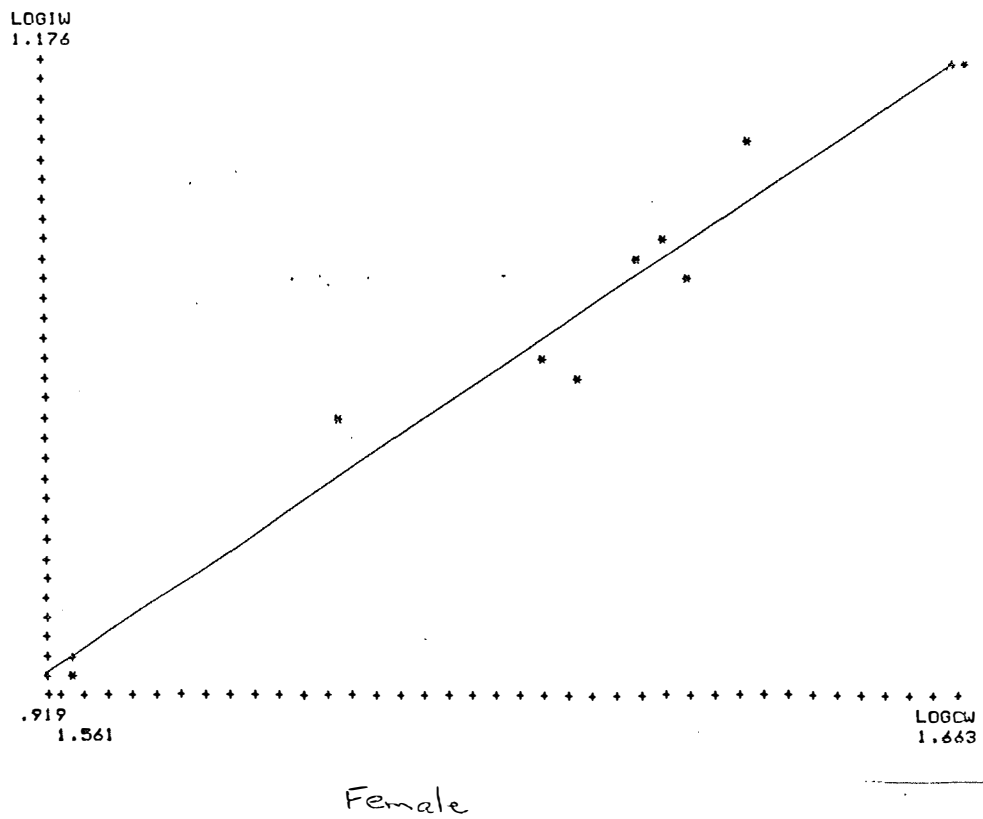


FIGURE 7.1 LEAST SQUARES LINEAR REGRESSIONS
FOR *P. rubromarginatus*



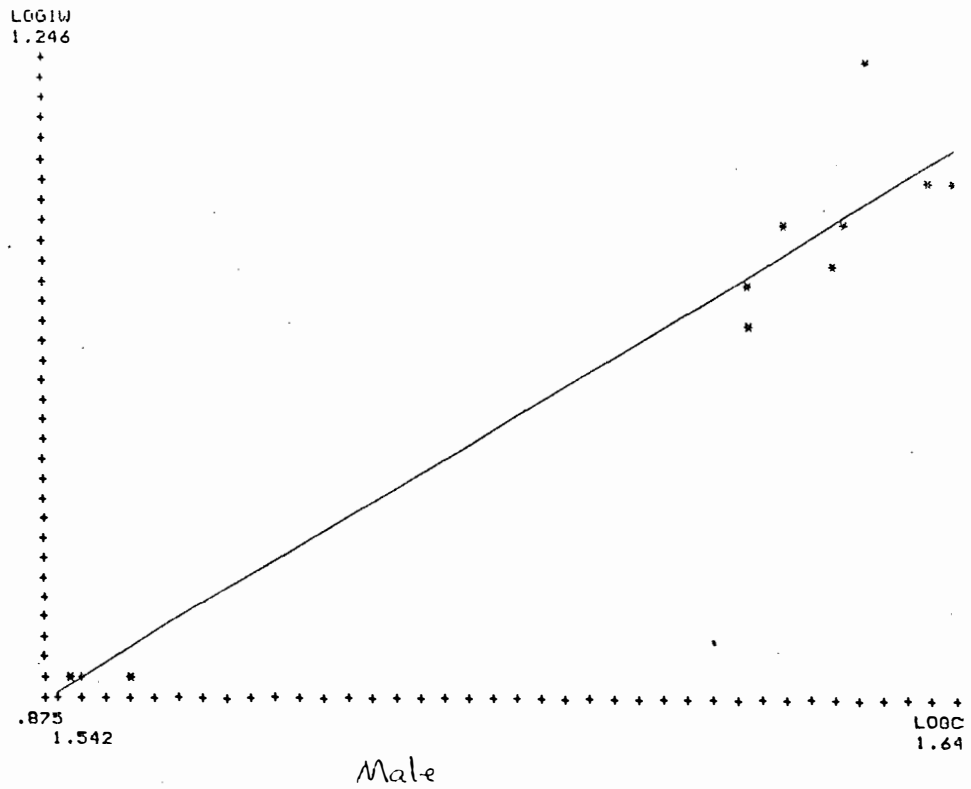
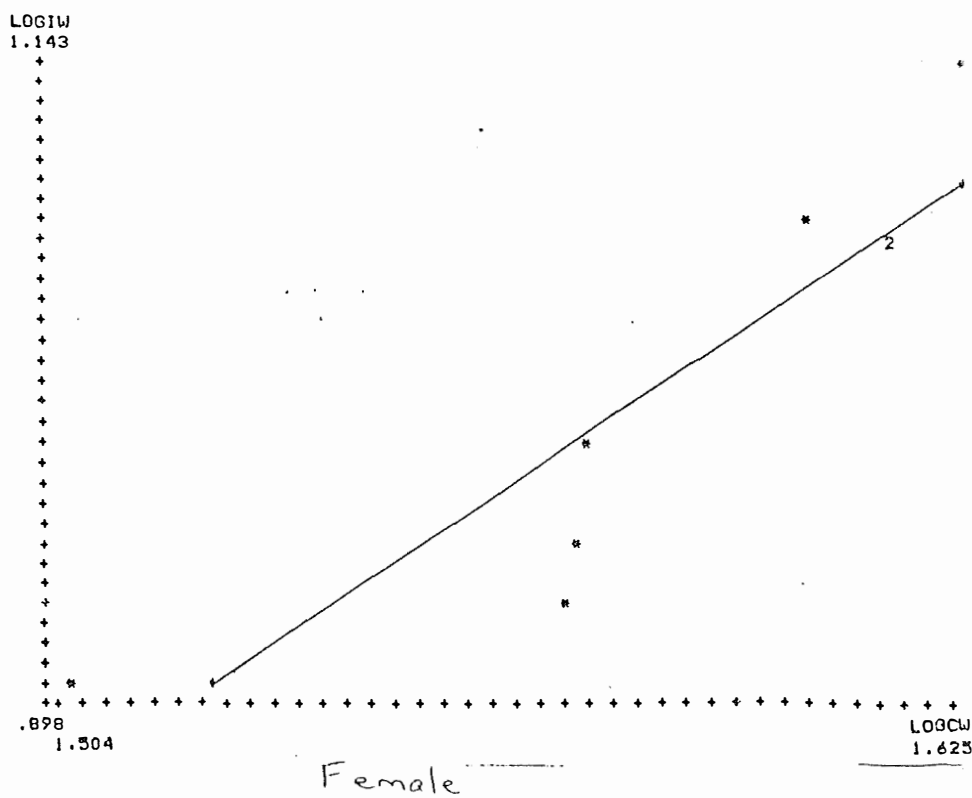


FIGURE 7.2 LEAST SQUARES LINEAR REGRESSIONS FOR *P. gracilimanus*



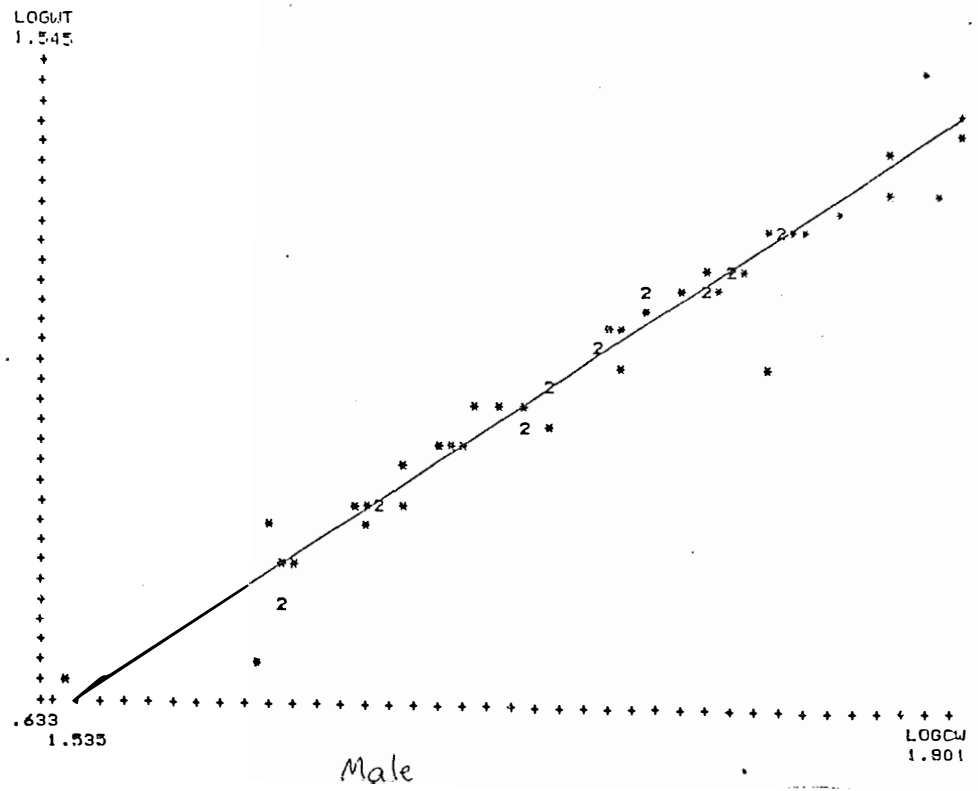
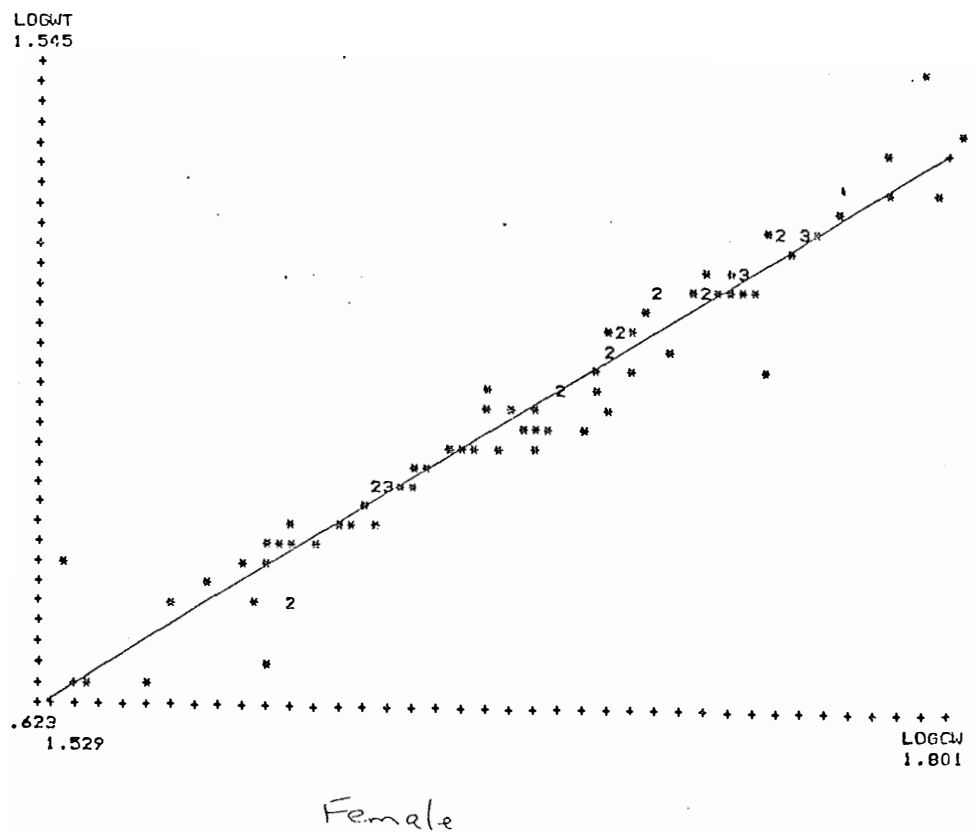


FIGURE 7.3 LEAST SQUARES LINEAR REGRESSIONS
FOR *P. rubromarginatus*



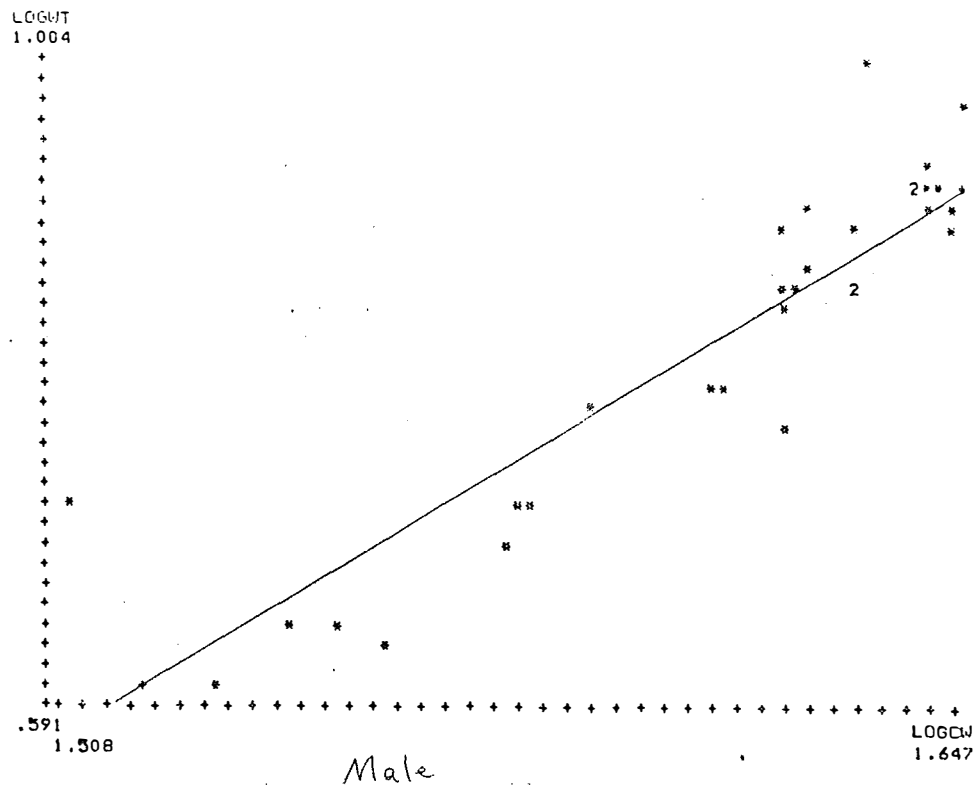
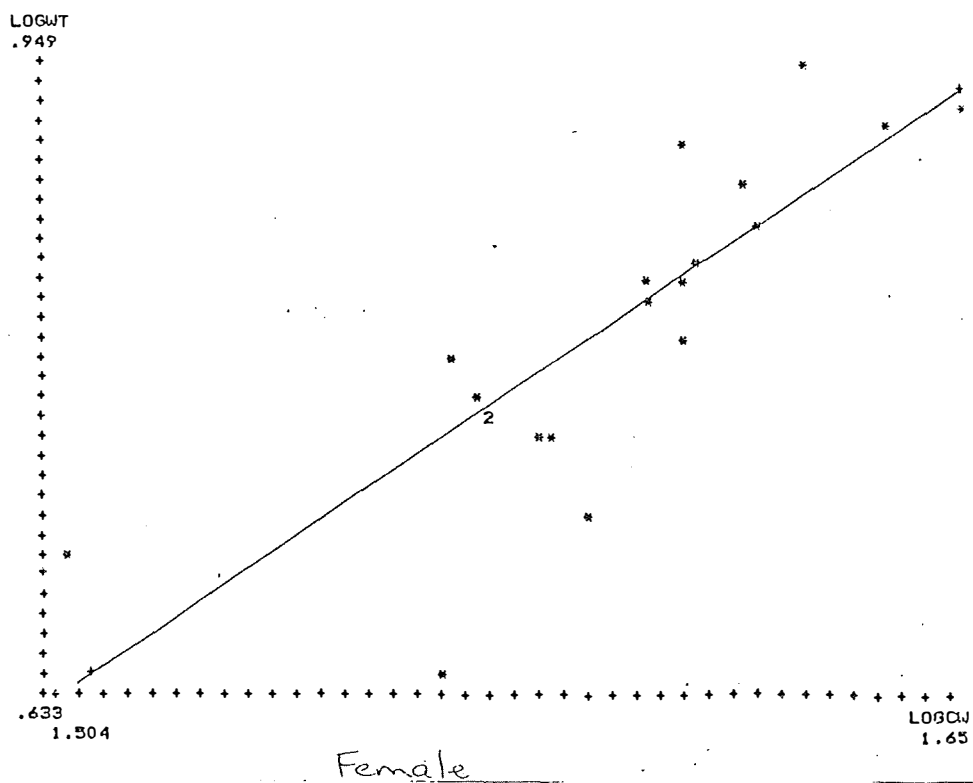


FIGURE 7.4 LEAST SQUARES LINEAR REGRESSIONS
FOR P. gracilimanus



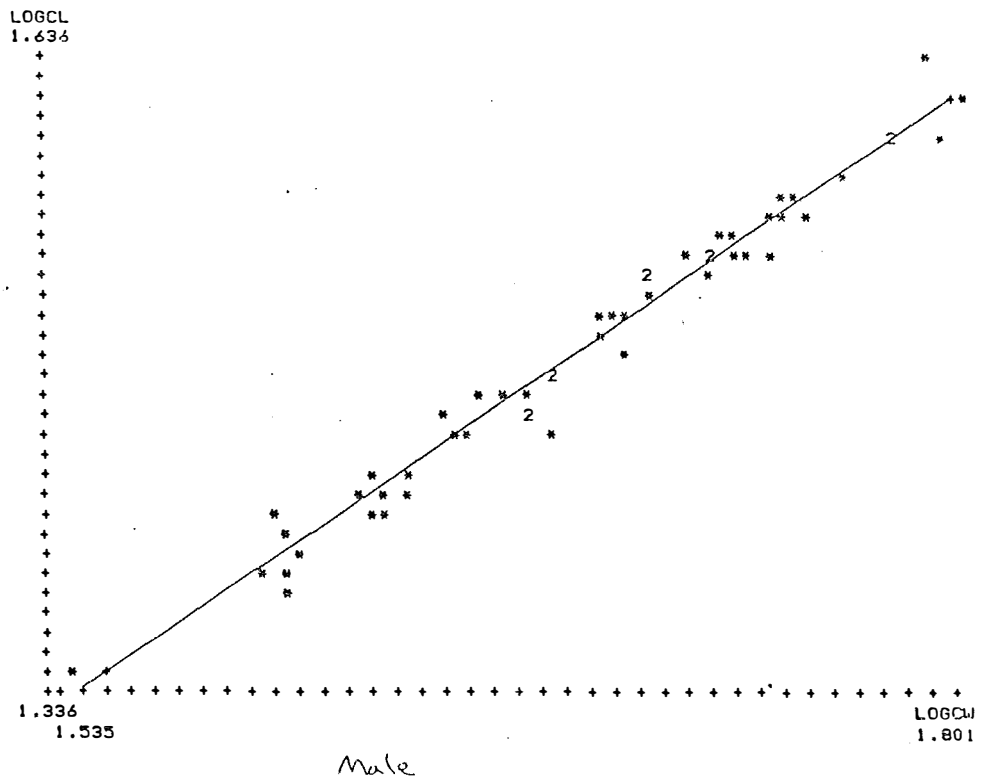
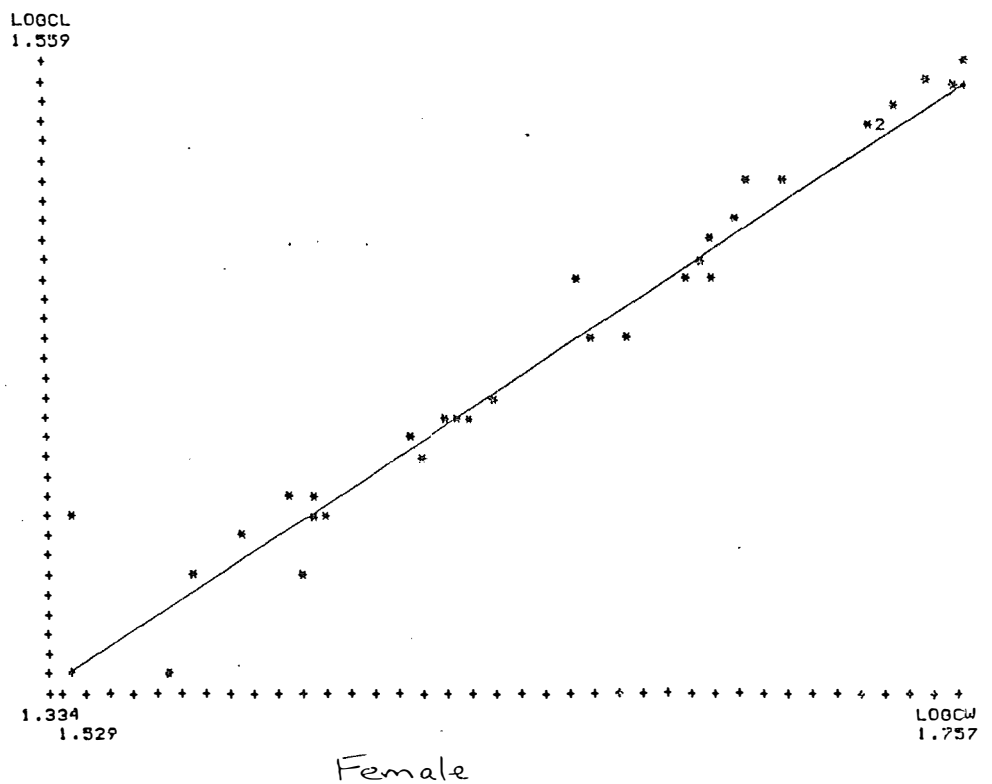


FIGURE 7.5 LEAST SQUARES LINEAR REGRESSIONS
FOR P. rubromarginatus



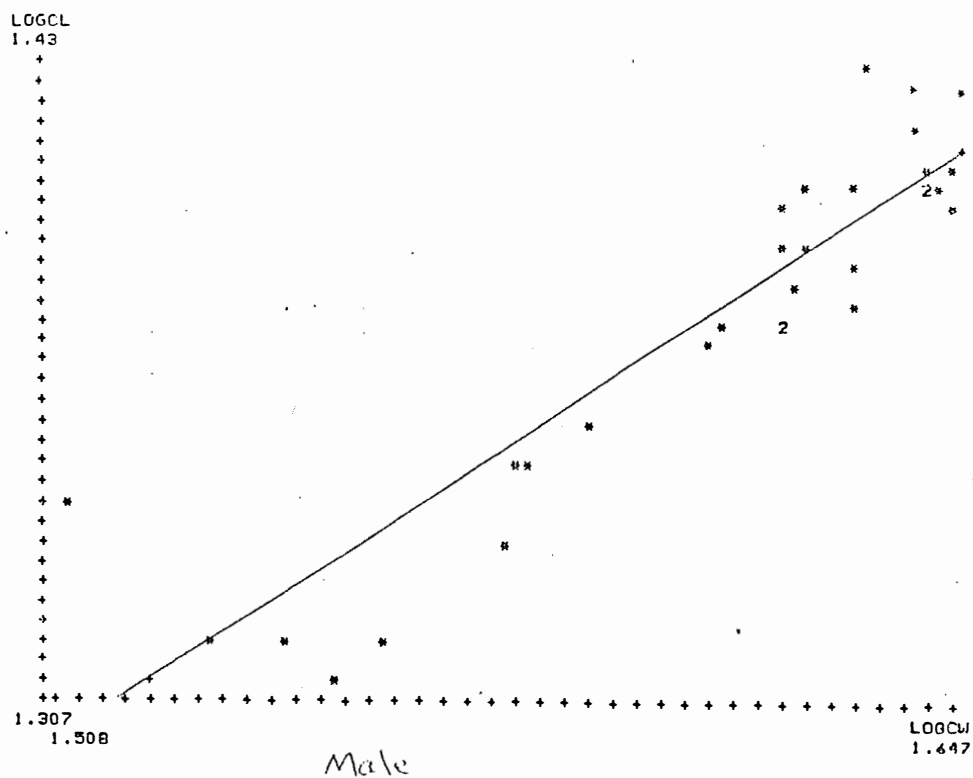
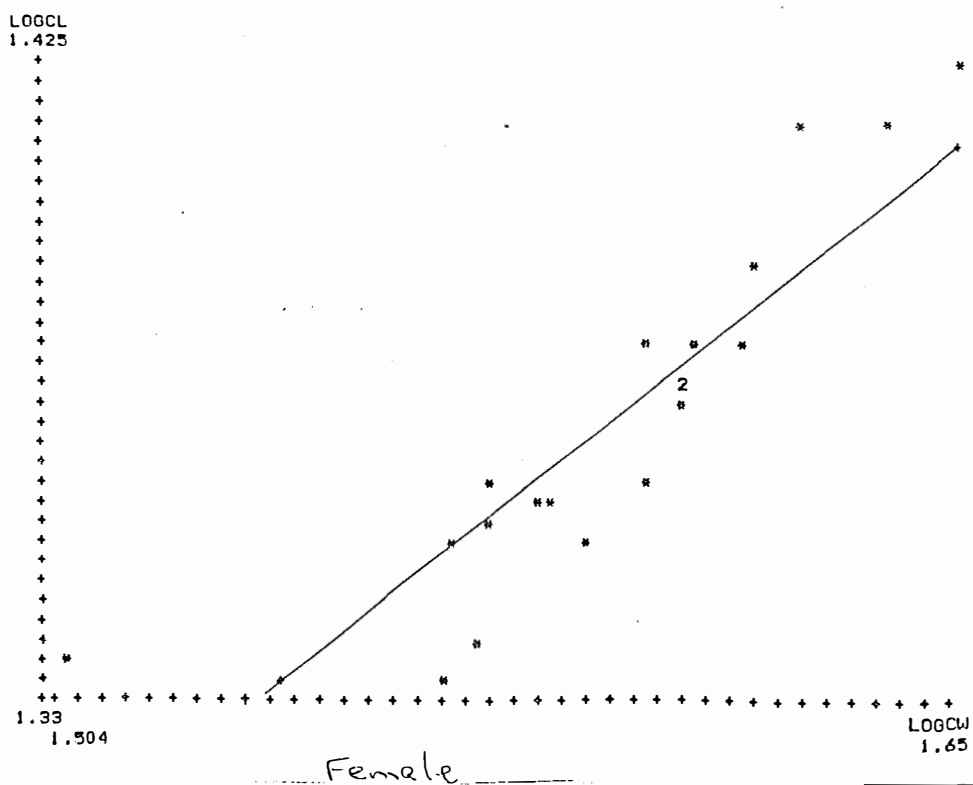


FIGURE 7.6 LEAST SQUARES LINEAR REGRESSIONS
FOR *p.gracilimanus*



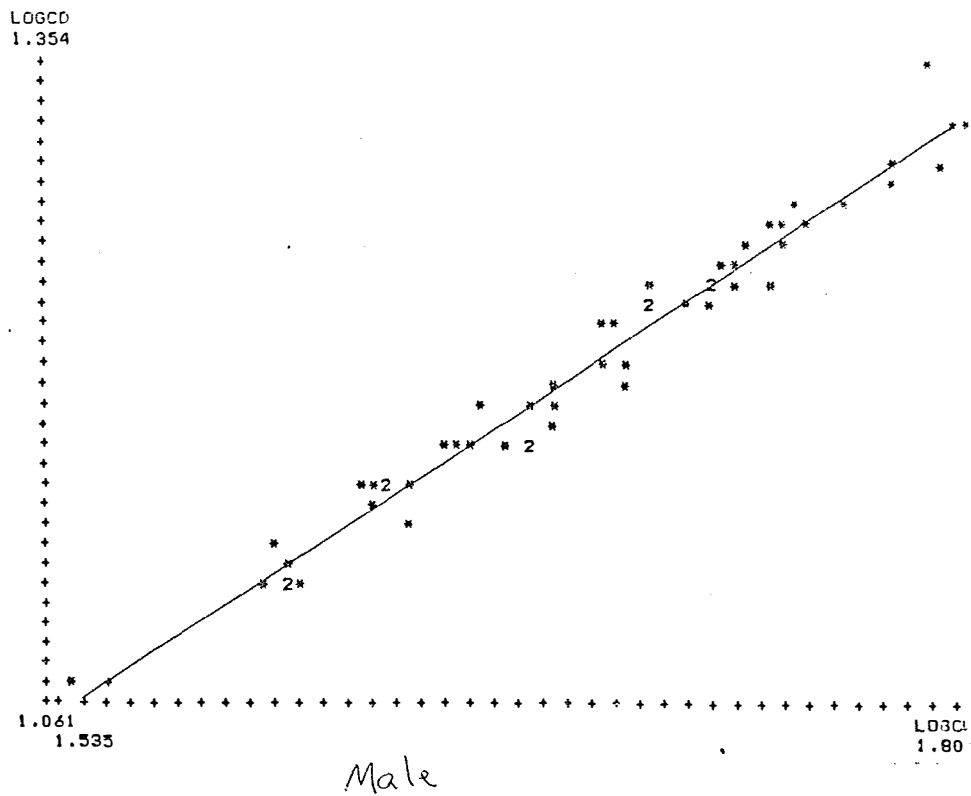
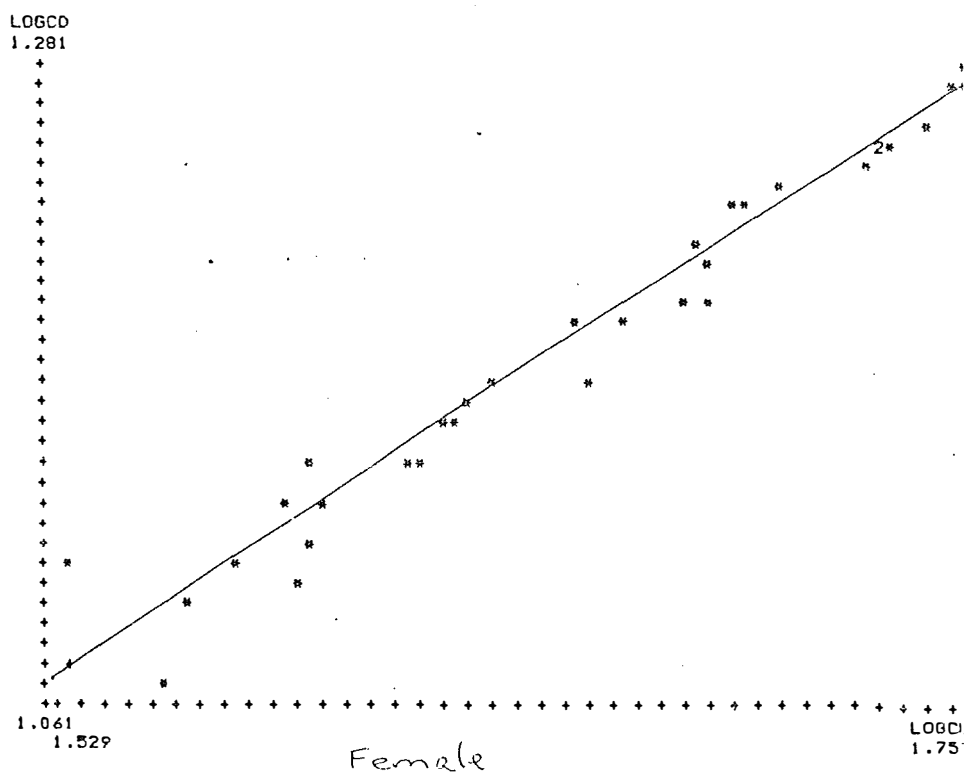


FIGURE 7.7 LEAST SQUARES LINEAR REGRESSIONS
FOR P. rubromarginatus



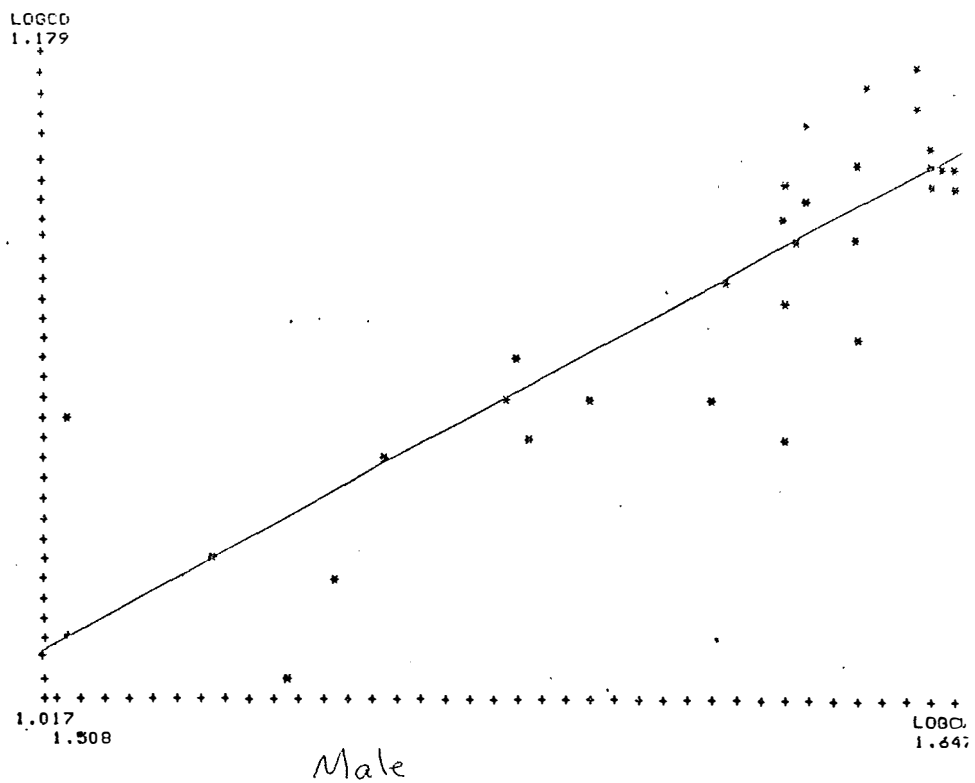
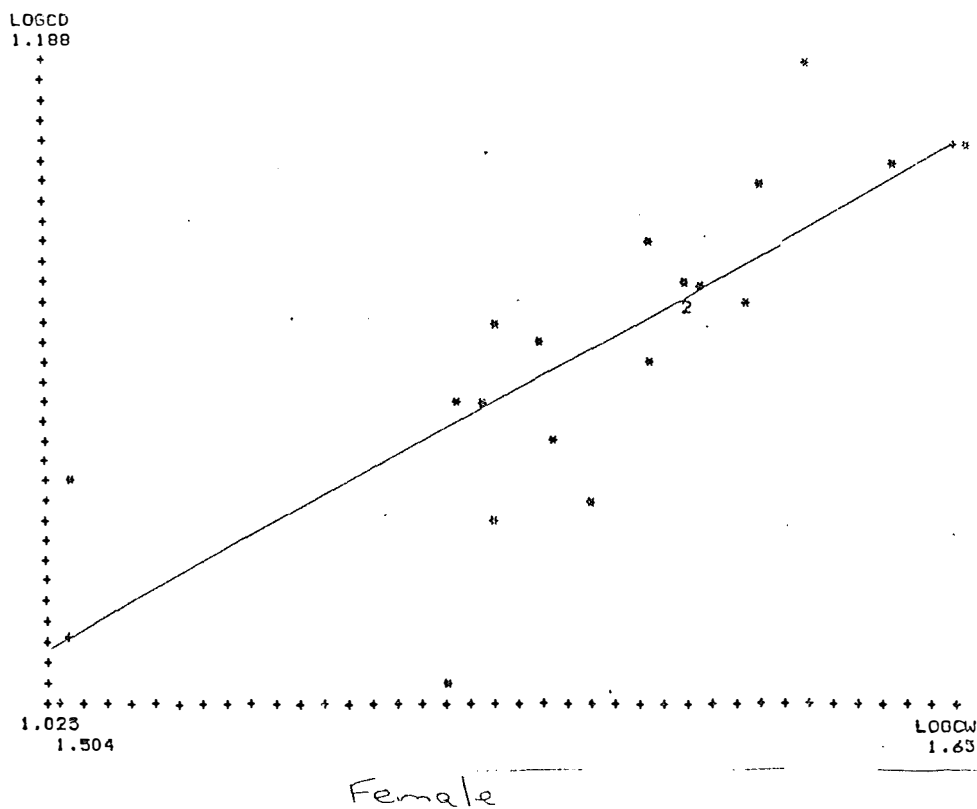


FIGURE 7.8 LEAST SQUARES LINEAR REGRESSIONS
FOR *P. gracilimanus*



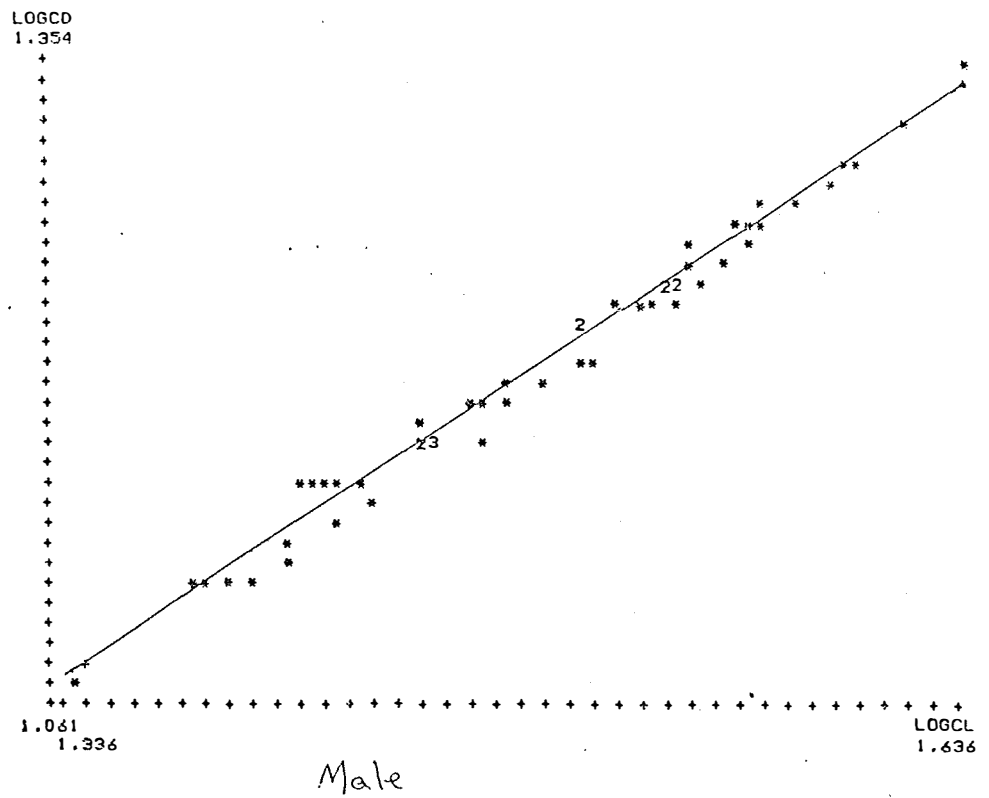
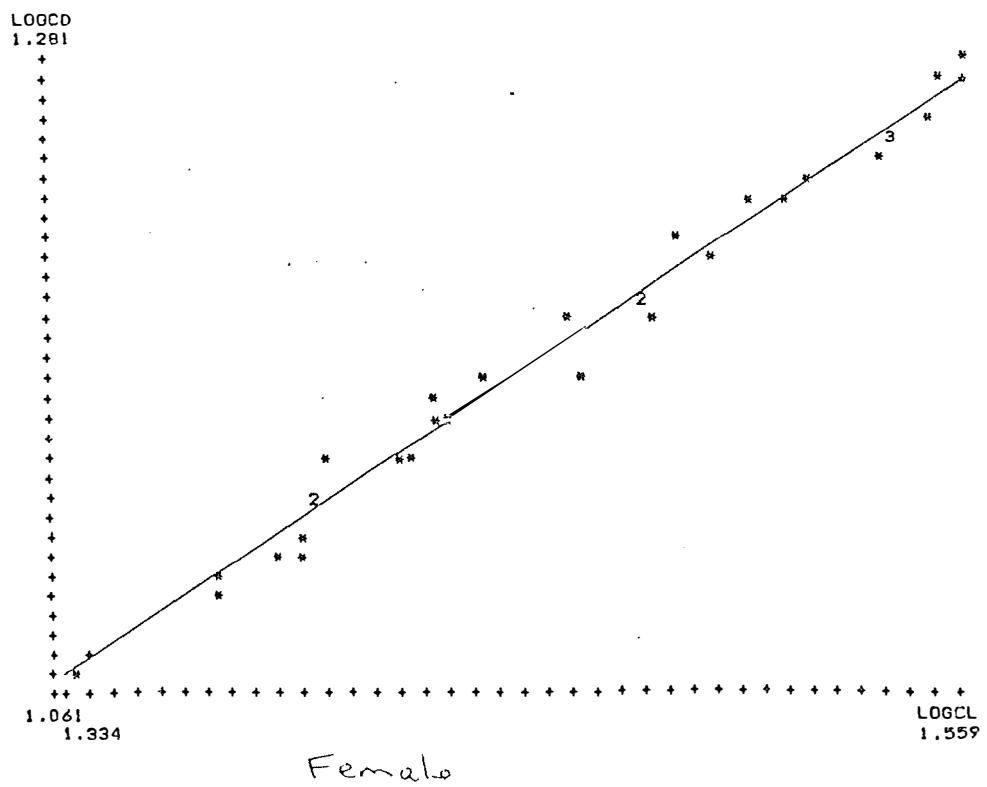


FIGURE 7.9 LEAST SQUARES LINEAR REGRESSIONS
FOR P. rubromarginatus



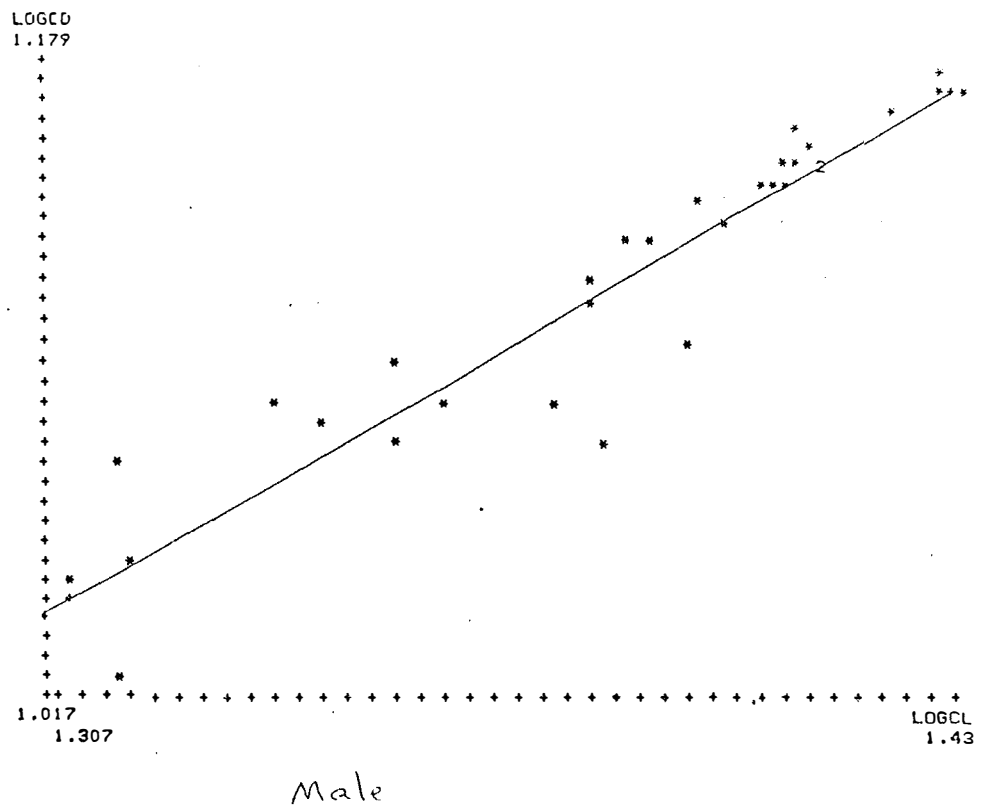
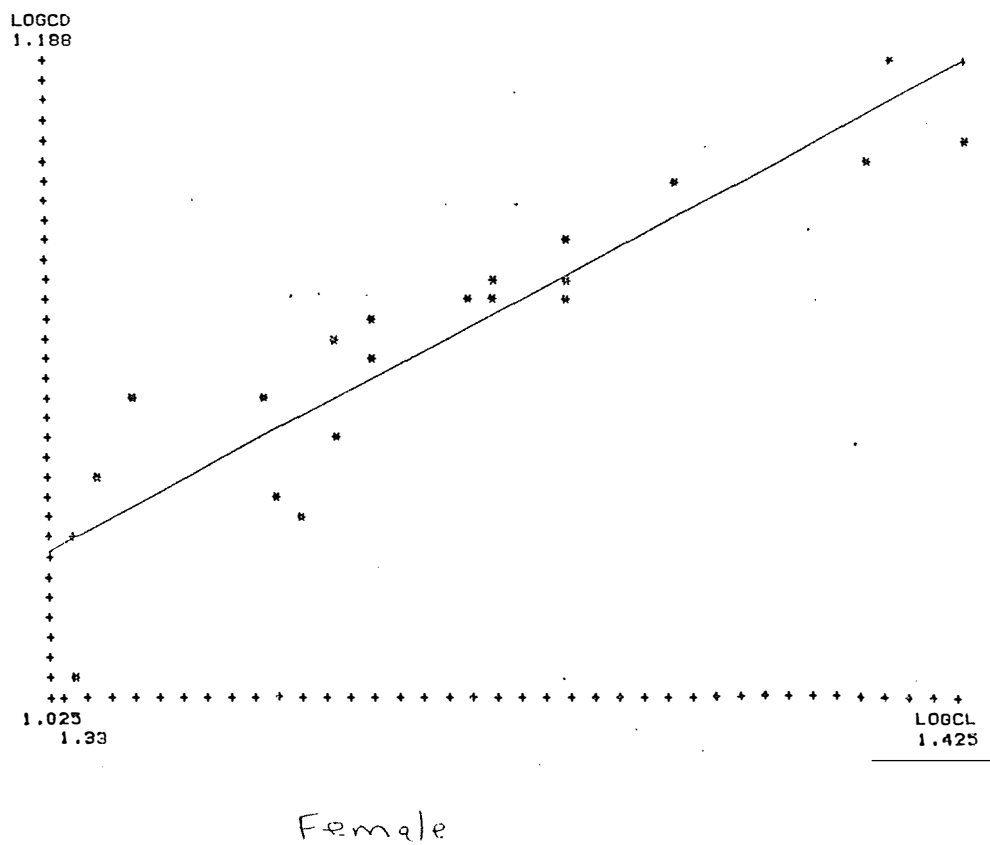


FIGURE 7.10 LEAST SQUARES LINEAR REGRESSIONS
FOR *P. gracilimanus*



DISCUSSION

Species composition and abundance

Most crabs caught (99%) were swimming crabs. Seventeen of the twenty-seven species recorded belonged to families such as Portunidae, Calappidae, Corystidae and Hymenosomatidae. According to Hartnoll (1971) all these families have swimming representatives. The reason for this high percentage may involve a combination of factors of which behaviour might be the most important. Swimming crabs are more likely to be caught in the water column by otter trawls. Once caught in the net, the mesh size will be the factor determining the eventual abundance of crabs brought to the surface. Larger swimmers such as P. pelagicus may be able to escape a net by means of their greater swimming ability. According to Stephenson (1972) "broadening of the carapace relates to streamlining with respect to lateral motion, and the best swimmers ought to be the broadest animals".

Swimming ability alone does not account for capture. Other factors in play include temperature, the type of sediment, the topography of the sea floor, the efficiency of the fishing gear, etc.

Sex ratios

An analysis of the sex ratios provided distinct trends although less than expected due to the small size of the samples. Also contributing to this result was the particular choice of samples. The largest samples were collected prior to midnight. However, as the period after midnight

represented the best continuum of data it was selected. In retrospect a preliminary assessment of this hourly data could have been made to ascertain the best monthly samples for analysis.

There are obvious trends amongst the results. On a monthly basis most sex ratios are close to parity. When differences were found they were most likely to be due to differential migration between the sexes, differential mortality or schooling according to sex.

Both sexes of the three portunid species were similar in size distribution. The calappid species differ, however, as their females have a distinctly narrower size range than the males.

Moult staging

This investigation showed that there was a significantly smaller proportion of soft carapace calappids in relation to portunids (Figure 5) . Crabs were kept in frozen storage for over two years and this may have had a softening effect on some of the crabs.

The effect of temperature on the percentage of soft carapace animals does not concur with the findings of Leffler (1972) who found moult increments decrease with decreased temperature. This result might again be influenced by the sample selection. No analysis was made of moult stage over twenty-four hours and in view of Sather's (1966) findings for the portunid Podophthalmus vigil of increased moulting around late evening and early morning, the choice

of post midnight samples in this study may have been unfavourable.

For each species there were differences between the number of soft carapace males and females. This is related to the particular reproductive cycles of the species. For example , P.rubromarginatus was seldom found ovigerous and maintained a parity between the soft carapace males and females. Conversely ,when the other species were ovigerous the males represented the majority of soft carapace animals. This is because females need to carry their eggs.

Percentage females ovigerous

As Hill (1974) showed with S.serrata, the reason M.inermis had so many females berried was probably because the prevalent conditions were ideal for their offspring. Hourly trends such as the preponderance of ovigerous females in the four hours preceding midnight and the paucity during daylight hours may be indicative of general behaviour rather than reproductive behaviour.

Morphometrics

Linear/weight relationships

P.rubromarginatus males have a distinctly different growth pattern than do the females (Table 1.1). This result could partially be explained by positive allometric growth of the male appendages. However, since with limbless animals the same allometry applies, the significant difference must be an inherent characteristic of the cephalothorax and abdomen. This does not hold true for P.gracilimanus as the growth pattern for this species was isometric. The above

growth patterns may vary with age and moult stage.

Linear relationships

The most obvious result apparent from Table 2.2 is the consistently allometric growth (both positive and negative) of P.rubromarginatus and the consistently isometric growth of P.gracilimanus. For P.rubromarginatus the results for all relationships indicate that carapace width is a good reference parameter for studying relative growth between the sexes. In relationships without carapace width as a component (length vs depth) there was no significant difference between male and female regression slopes. Although the allometry results for P.gracilimanus did not confirm this, it may require a larger sample size for it to be evident in this species.

Carapace width is adopted as a common reference dimension by many workers (Haley, 1969, 1973; Heasman, 1980; Williams et al. 1980; Potter et al. 1983; DuPreez and McLachlan, 1984) involved with morphometric studies and is an accepted measure. Williams, et al (1980). have discussed the limitations of many morphometric studies. In their paper they termed results that are acquired from samples measured only once as cross-sectional. Measurements made at successive intervals in time they called longitudinal studies. No matter which of these methods is used they both suffer from the same problems. These include individuals of the same size having different migrational patterns (Potter et al., 1983) and individuals of the same size having higher death rates

than younger animals(Du Preez and McLachlan,1984). There may also be sampling biases in the collection procedures. Williams et.al.(1980) in their study of three species of Uca stated "... we do not know whether such biases have caused serious departures from what one would obtain if longitudinal data could have been obtained". They did however assume that comparisons between samples can be used provided their size frequency distributions are the same for respective ages.

Overall, this study has provided some useful results. Undoubtedly a lot of work still remains to be done on the biology of the Gulf fauna. However it is hoped that the knowledge gained from studies such as the present one is exploited in the future to the benefit of the fauna and our appreciation of it.

SUMMARY

The abundant species found in the crab by-catch from the Gulf of Carpentaria were the swimming crabs belonging to the Families Portunidae and Calappidae. Fewer crabs were found in winter and during the daylight hours.

Males and females of the five most abundant swimming crabs were represented in approximately similar numbers. Species of the Family Portunidae maintained a similar size range between the sexes and for the Family Calappidae females remained in a narrower size range than males.

The Family Calappidae also possessed fewer soft carapace animals than did the Family Portunidae. Moulting stage was related to reproductive condition and not to temperature. The calappid M.inermis had the most ovigerous females, caught mainly from summer. Ovigerous females of other species were poorly represented.

The relative growth of P.rubromarginatus and P.gracilimanus using morphometric techniques was different between the species. Both linear and weight measurements were used to ascertain differences in the three dimensional conformation of the cephalothorax and abdomen. Growth was isometric between the sexes of P.gracilimanus. The relative growth of P.rubromarginatus differed between the sexes with both positive and negative allometry shown. Carapace width was confirmed as a suitable reference measurement.

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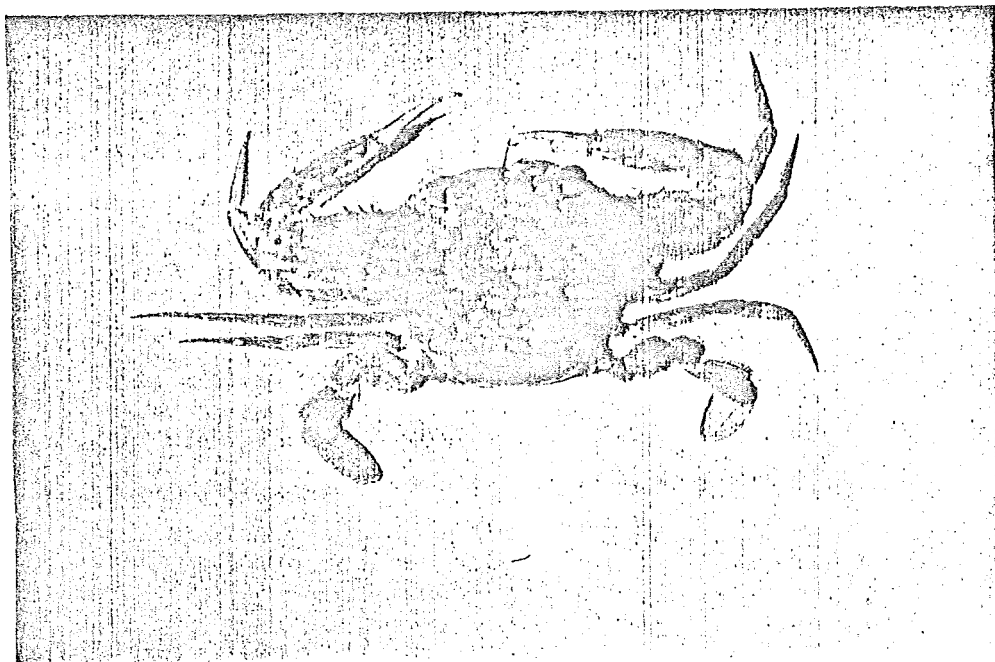
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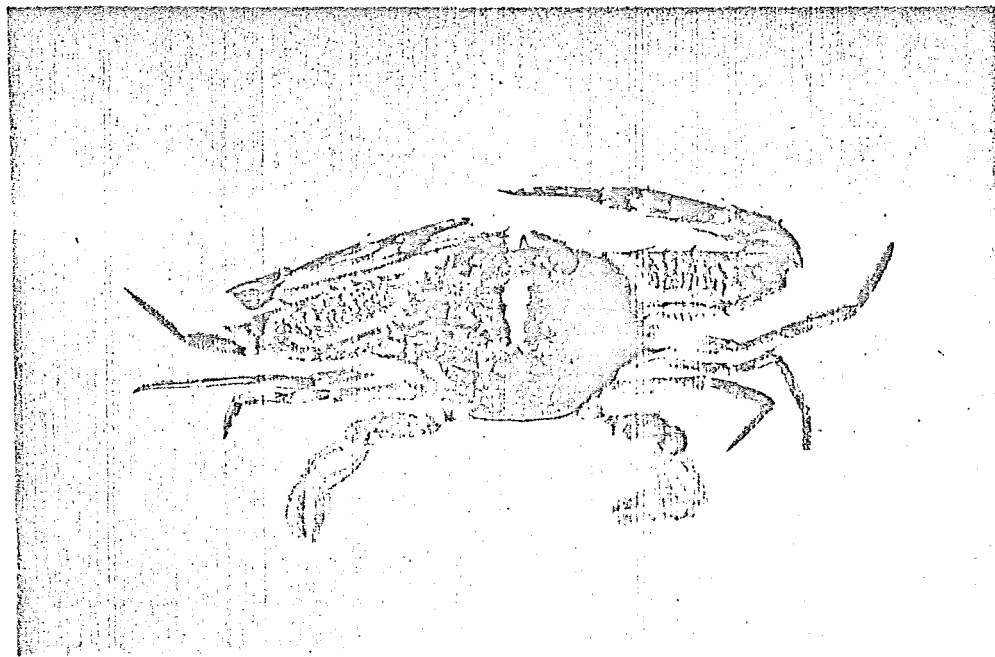
APPENDIX 1

| <u>Species Identification</u> <u>No.</u> | <u>Identifier</u> | <u>Reference</u> |
|---|-------------------|---------------------------|
| 1. Portunus rubromarginatus | Lanchester | Stephenson 1959 |
| 2. P.gracilimanus | Stimpson | Stephenson 1959 |
| 3. P.hastatoides | Fabricius | Stephenson 1959 |
| 4. Charybdis jaubertensis | Rathbun | Stephenson 1957 |
| 5. C.callianassa | Herbst | Stephenson 1957 |
| 6. C.truncata | Fabricius | Stephenson 1957 |
| 7. C.anisodon | De Haan | Stephenson 1957 |
| 8. C.hellerii | A. Milne-Edwards | Stephenson 1957 |
| 9. C.feriata | Linnaeus | Stephenson 1957 |
| 10. Thalamita sima | H. Milne-Edwards | Stephenson 1957 |
| 11. Podophthalmus vigil | Weber | Stephenson 1960 |
| 12. Matuta inermis | Miers | Tyndale-Biscoe et.al.1962 |
| 13. M.granulosa | Miers | Tyndale-Biscoe et.al.1962 |
| 14. Dorippe frascone | Herbst | Tyndale-Biscoe et.al.1962 |
| 15. Phalangipus australiensis | | Sakai 1976 |
| 16. Parthenope longimanus | | Sakai 1976 |
| 17. Hyastenus diacanthus | | Sakai 1976 |
| 18. Family Corystidae | | Sakai 1976 |
| 19. Family Corystidae | | Sakai 1976 |
| 20. Family Corystidae | | Sakai 1976 |
| 21. Family Goneplacidae | | Sakai 1976 |
| 22. Family Goneplacidae | | Sakai 1976 |
| 23. Family Goneplacidae | | Sakai 1976 |
| 24. Family Majidae | | Sakai 1976 |
| 25. Family Majidae | | Sakai 1976 |
| 26. Family Hymenosomatidae | | Sakai 1976 |
| 27. Unidentified | | |

APPENDIX 1

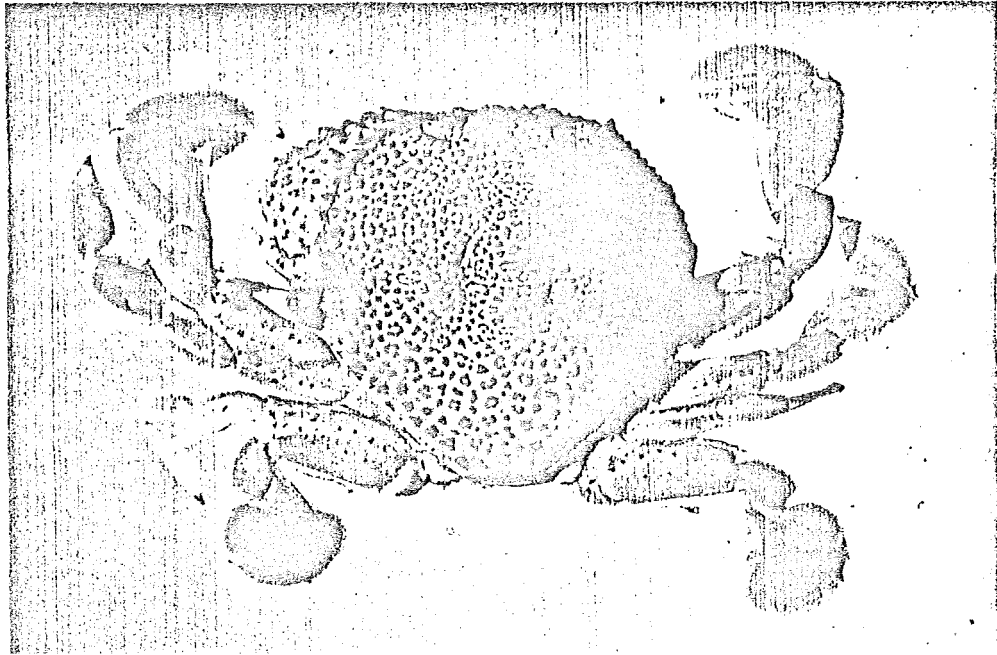


P. rubromarginatus- arm with 1 spine on posterior border
no dark spot on dactyls of propodus of fifth leg ; last
tooth distinctly larger than other teeth; carapace relatively
broad; antero-external angle of 3 rd maxilliped strongly
produced laterally; postero-lateral border of carapace rounded
; hand of cheliped robust or slender at most only a little
less massive than arm.

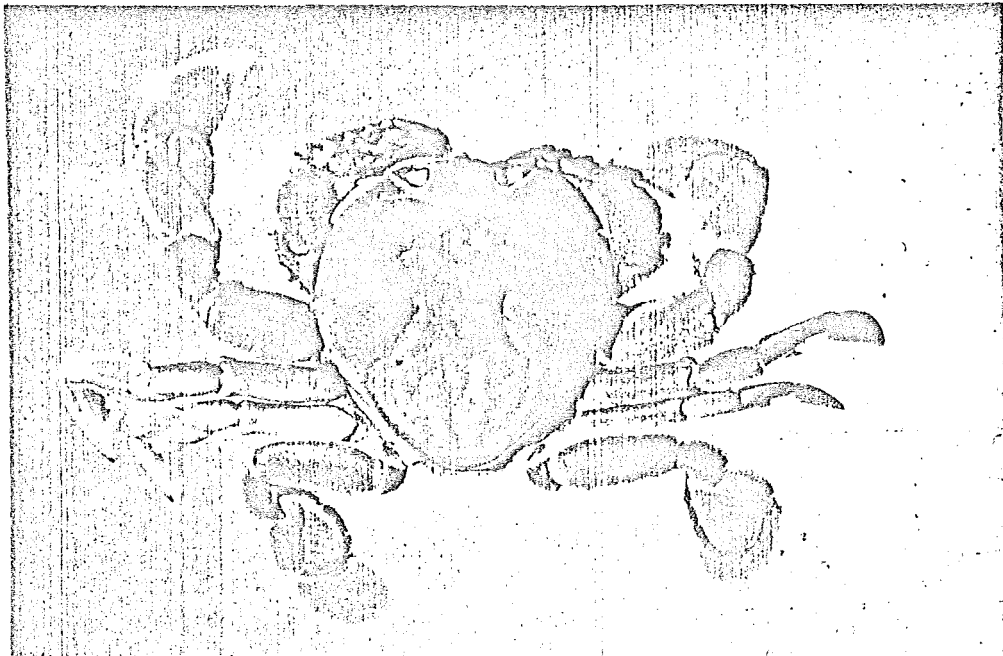


P. gracilimanus- lateral frontal teeth almost the same width
as medians; mesogastric region of carapace with transverse
ridges ; 4-6 spines on anterior border of arm; hand of
cheliped extremely slender; carapace without conspicuous
spots.

APPENDIX 1



M. granulosa- a line of distinct spines and three granules on the outer surface of hands; carapace, legs and chelipeds covered with red spots; base of lateral spines red



M. inermis- carapace longer than broad; anterior 2/3's covered in coarse granules; lateral margin with small tubercles; crest of hands with 3 sharp spines; pinkish beige in colour.