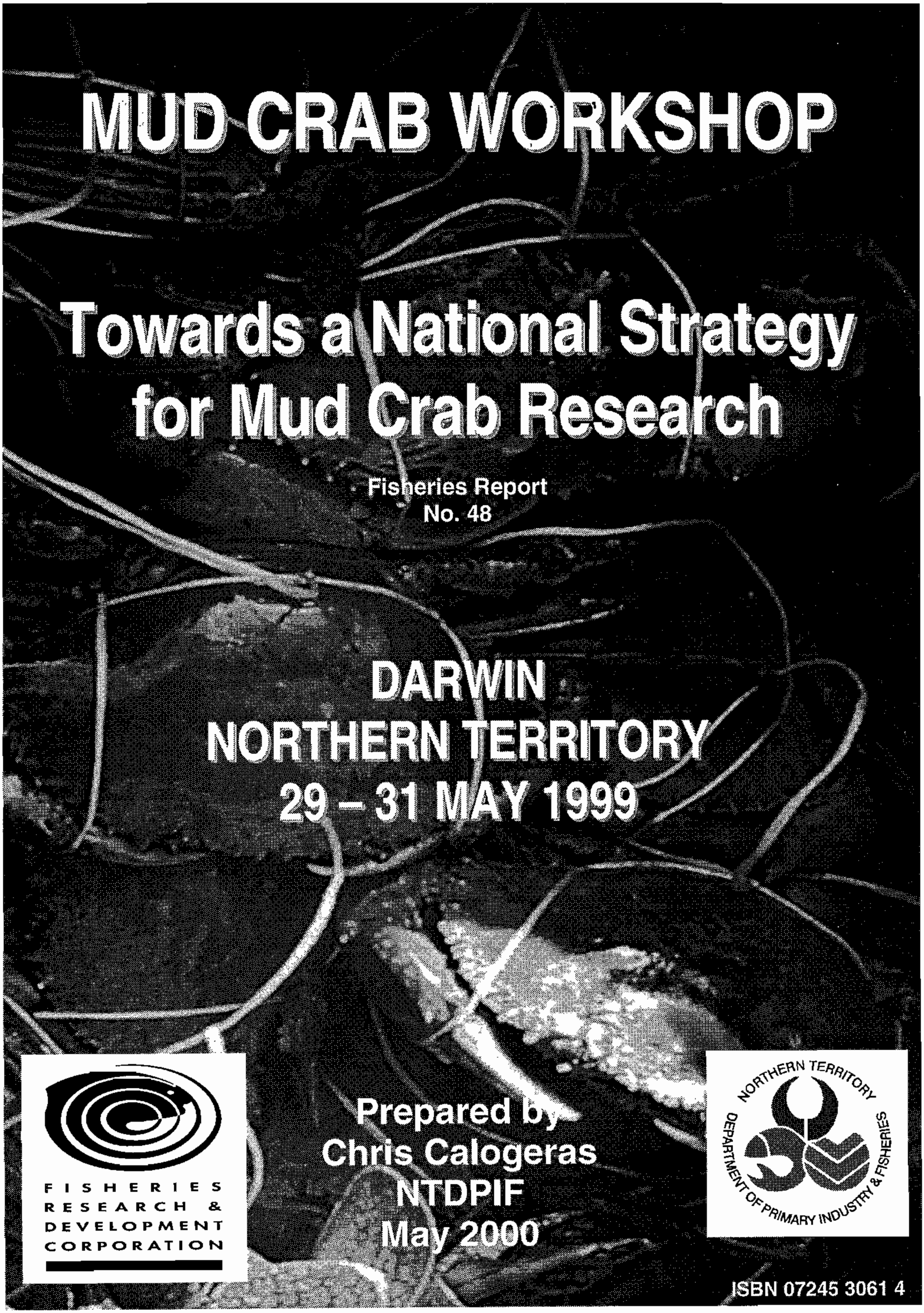

MUD CRAB WORKSHOP

Towards a National Strategy for Mud Crab Research

Fisheries Report
No. 48

DARWIN
NORTHERN TERRITORY
29 – 31 MAY 1999

Prepared by
Chris Calogeras
NTDPIF
May 2000

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

NORTHERN TERRITORY DEPARTMENT OF PRIMARY INDUSTRY & FISHERIES

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1. Executive Summary

A workshop was held in Darwin, the Northern Territory (NT) in May 1999, to develop a National Strategy for Research on Mud Crab (*Scylla sp.)* in Australia. Fisheries managers and researchers from Western Australia, the NT and Queensland attended, along with Industry representatives from the NT.

The workshop participants shared existing information on the fishery and biological details on the species and evaluated that data to develop a strategy for research which would seek to fill existing gaps in knowledge.

A number of specific management and research issues were identified by each jurisdiction, but there was agreement that research should focus on opportunities for collaborative work with stakeholders and government agencies which would assist in addressing the key issues identified.

This led to the development of a five-year research strategy for the fishery as outlined in Table 3. In order to maximise the benefits of available resources it was decided to adopt a phased approach to the research strategy, with complementary FRAB proposals to be prepared for consideration by individual State/Territory prior to the development of an FRDC proposal.

The key areas of new research identified were:

Phase 1. To develop a process to estimate relative productivity of mud crab habitat based on satellite imagery and abundance estimation techniques;
Phase 2. To use validated commercial catch and effort data as an index of stock abundance; and
Phase 3. To develop a fishery independent index of stock abundance based on juvenile pre-recruit index.

Other outcomes arising from the above research would provide information relating to different fishery strategies and subsequent impacts on population characteristics such as sex ratios and fertilisation rates. Additionally, the information may assist in the long term goals of determining offshore migration patterns.

Support was also given to an existing project which seeks to identify, based on genetic identification, if there are discrete stocks within the mud crab population.

2. Workshop Participants

Ben Fraser	Fisheries Western Australia
Chris Calogeras	Northern Territory Department of Primary Industry and Fisheries
Darryl Everett	Northern Territory Seafood Council
Geoff Broadhead	Northern Territory Seafood Council
Ian Brown	Queensland Department of Primary Industry
Ian Knuckey	Marine and Fisheries Research Institute - Victoria
Mark Doohan	Queensland Fisheries Management Authority
Mike Fraser	Northern Territory Seafood Council
Neil Gribble	Queensland Department of Primary Industry
Nick Rayns	Northern Territory Department of Primary Industry and Fisheries
Tracy Hay	Northern Territory Department of Primary Industry and Fisheries

3. Acknowledgments

The assistance of the following organisations in making this workshop possible is gratefully acknowledged;

- Fisheries Western Australia (Fisheries WA)
- The Northern Territory Department.of Primary Industry and Fisheries (NTDPIF)
- The Northern Territory Seafood Council (NTSC)
- The Queensland Department of Primary Industries (QDPI)
- The Queensland Fisheries Management Authority (QFMA)
- The Fisheries Research and Development Corporation (FRDC)

4. Introduction

Mud crabs (*Scylla sp.)* are widely distributed throughout the Indo-west Pacific region. In Australia, the mud crab extends from the mid coast of New South Wales north through Queensland and the Northern Territory to the mid coast of Western Australia. Significant commercial, recreational and indigenous fisheries occur within that distribution.

The level of development of the fishery in the different Australian jurisdictions varies considerably, with WA having a virtually unexploited fishery, whereas the NT and Queensland have large developed fisheries for mud crab. It is estimated that the commercial fishery in Australia is valued in the vicinity of $20 million annually.

Interest in the resource from all user groups has increased in recent years, but no clear national management strategy or research program has been identified.

5. Rationale for the Workshop

Previously a National Workshop on mud crabs was held in Terrigal (NSW) in 1993 in conjunction with the inaugural Fisheries and Aquatic Resource Managers Association of Australia (FARMAA) workshop. At the mud crab workshop, management considerations were discussed with a view to seeing if the inconsistencies in legislative controls could be minimised. Researchers identified projects that could provide scientific advice that could fill existing gaps in knowledge about the resource, and assist in resolving many of the management inconsistencies.

Due to the lack of a national program few of the research tasks identified at the workshop have been completed.

However, the NT Fisheries Division has had an ongoing research program on mud crabs in place since 1991. The scientist responsible for the research from 1991 to 1995 (Ian Knuckey), as part of his PhD thesis, has during 1999 completed the writing up of the research he undertook whilst in the NT.

Further, FRDC sponsored a workshop led by Dr Carl Walters on various NT fisheries, including the mud crab fishery with a view to providing more reliable and ongoing advice on the status of fish stocks with the aim of ensuring the sustainable use of NT fishery resources. Dr Walters identified a number of weaknesses in the use of existing catch per unit of effort (CPUE) data and suggested developing fishery independent techniques to assist in determining the status of the fishery (Attachment 1). Since that time the NT and Queensland have been developing habitat mapping and abundance estimation techniques.

In addition to research matters, the NT is in the process of reviewing the management plan for the Mud Crab Fishery. Queensland has prepared a discussion paper prior to the preparation of a management plan for the mud crab fishery and WA is considering options for the possible development of a mud crab fishery.

The NT Mud Crab Fishery Advisory Committee as well as the Queensland CRABMAC had also identified research priorities for the fishery.

With all these factors in mind it was considered an opportune time to take stock of the most recent research on the fishery and compare management arrangements with a view to developing a strategy for research which would seek to fill existing gaps in knowledge on the resource.

Darwin was chosen as the venue as it allowed the NT industry, which provided extensive support to Dr Ian Knuckey's research findings, to participate via a seminar on his recently completed PhD. Attachment II provides an overview of the workshop itinerary and format.

6. Objectives

The objectives of the workshop were to:

- Provide a forum for researchers and managers to present the most up to date information on the fishery
- Identify key management issues and identify possible research strategies to fill gaps
- Develop FRAB proposals for consideration by individual State/Territory industries prior to the development of an FRDC proposal
- Develop a five year research strategy for the fishery

7. Status of the Australian Fishery - Management and Research Overviews

Each jurisdiction provided an overview of the management arrangements in place, key management issues and background of research undertaken to date.

A brief summary of management arrangements by State and Territory for the mud crab fishery is provided in Table 1, with a more complete overview in Appendix III.

A summary of research activities by State and Territory is provided in Table 2, with a more complete overview in Appendix IV.

The information contained in Tables 1 and 2 provided the basis for the development of the National Strategy.

8. Proposed Five Year Research Strategy

A number of specific management and research issues were identified by each jurisdiction. However there was general agreement that research should address the key management issues identified above and also focus on providing opportunities for collaborative work with stakeholders and government agencies.

The three key areas as fully outlined in Table 3 were:

- Determination of relative productivity of mud crab habitat using satellite imagery and abundance estimation techniques
- Stock abundance indicators using validated commercial catch and effort data as well as developing fishery independent index of stock abundance based on juvenile pre-recruit index
- Assessing the effects of regional harvest policy through analysis of spatial differences in population reproductive characteristics, sex ratios and fertilisation rates, and, in the longer term, attempting to elucidate the offshore migration patterns of spawning female crabs

A further important project was also identified on the genetic identification of mud crab to determine if there were discrete stocks within the mud crab population. This information could be gained from a project being undertaken in Queensland at Griffith University by PhD student David Gopurenko. It was decided to consider the outcomes from that study before deciding on the need for any further research in this area.

With approval from the workshop members, including NT industry representatives, it was agreed that State/Territory FRAB proposals should be prepared in line with the outcomes identified in Table 3, to seek support for the development of an FRDC proposal for a National Strategy for Research on Mud Crab.

The proposed research program was also presented at the North Australian Fisheries Management (NAFM) forum held in July 1999 in Cairns to seek support.

Although officers from NSW could not attend the workshop, a letter of support for the research directions endorsed at the workshop was submitted (see Appendix V).

TABLE 1: Summary of Management Arrangements by State and Territory for the Mud Crab Fishery

Control	WA	NT	Qld
Licences	4 non transferable	49 fully transferable	950 entitlements
Degree of utilisation	Limited	Fully	≈ 50%, with 85% less than 1t
Commercial Gear	No pot limit	60 pots	50 pots
Tangle nets	Prohibited	Prohibited	Permitted
Size Limits (carapace)	150 mm green 120 mm brown	130 mm male 140 mm female	150 mm males (underside 46mm)
Females protection	Release of berried females	Release of berried females	Prohibited take
Meating / clawing	Prohibited	Prohibited	Prohibited
Recreational licences	N/A	N/A	N/A
Recreational possession/bag limits	10/person	10/person maximum 30/vessel	10 per person
Recreational gear limits	10 drop nets/person	5 pots/person maximum 10/vessel	4 pots/person
Traditional sector	No commercial sales, (except under Aboriginal Community Licences)	No commercial sales	No commercial sales
Average Commercial catch 1996-98	3 tonnes	600 tonnes	450 tonnes (95-97)
Recreational catch	Unknown	52t in 1996	Unknown (angler diary results in 99)
Traditional catch	Unknown	Unknown	Unknown
Advisory Committee	No	Yes	Yes
Management Plan	No (controls by regulation)	Since 1991 (limited entry since 1984)	Being developed 2000, discussion paper released 1/4/99
Major Markets	Local	NSW, Vic with overseas developing	Local, NSW and Vic
Key Issues	Sustainable fishery development Transferability Resource allocation Review of recreational limits	Overpotting by commercial sector Black market sales Stock size estimates Post harvest mortality	Existing size limit Female protection Spawning closures Recreational limit Latent effort and permitted gear Management costs Stock assessment and monitoring Regional fisheries

TABLE 2: Summary of Research Activities by State and Territory for the Mud Crab Fishery

Jurisdiction	Research undertaken	Researcher
Northern Territory	• Preliminary habitat mapping and density estimates • Movement and growth studies -Tagging • Analysis of commercial mud crab fisheries data (1996-99) • Mud crab size and sex monitoring	T Hay
	• Description of fishery including analysis of fisheries data (1983-95) • Reproduction • Growth • Pot selectivity and mortality • Modelling of the fishery	I Knuckey
Queensland	• Aspects of the general biology and fishery of the mud crab (1976-80)	M Heasman
	• Study on methods for determining the size and sex of marketed mud crabs	M Williams /C Lee
	• Queensland mud crab fishery (1979-82)	B Hill et al
	• Genetic relationship and identification of mud crabs from Indo-Pacific (1996-8)	C Keenan et al
	• Development of improved mud crab culture systems (ongoing)	C Keenan et al
	• Mud crab necrotic lesion study (ongoing)	M Walker et al
	• Analysis of commercial mud crab fisheries data (1999)	I Brown
	• Gulf tropical resource assessment program – summary of mud crab status (1996)	N Gribble / S Helmke
	• East Coast tropical resource assessment - summary of mud crab status (1997)	N Gribble / S Helmke
	• Estimation of size of mud crab stock for Qld coast using a habitat alias (1998)	N Gribble / S Helmke
	• Genetic analysis of *Scylla sp.*	D Gopurenko
Western Australia	• No specific research	

TABLE 3: Proposed Research Directions for the Mud Crab Fishery Endorsed at the Mud Crab Workshop* - Darwin NT 29 - 31 May 1999

Area of Research	*Term/period*	*States endorsed*	*Justification*
Relative productivity of mud crab habitat Habitat alias • Satellite imagery • Abundance estimation • Trials of sampling and protocols	 Year 1 Year 2, 3, 4 Year 1	WA/NT/QLD	• Request from Industry • Protection of critical habitat • Estimate of stock size for WA - development opportunities • Possible long-term monitoring of fishery health • Identification of major fishing area
Stock abundance indicators Commercial catch and effort data • Effort validation • Effectiveness of "pot lift" as an index of abundance • Comparison of pot design Fishery independent index of stock abundance • Juvenile pre-recruit index - Trials of juvenile sampling/behaviour - Habitat identification - Field trials	 Year 1 Year 2 Year 2 Year 1, 2 Year 1, 2 Year 3, 4, 5	NT/QLD/WA	• Determination of sustainability indicators • Increasing economic efficiency of operation • National consistency in effort measurements • Capacity to predict future catches • Possible link to offshore migration of females
Spatial difference in population reproductive characteristics • Comparison of sex ratio • Comparison of % frequency of sperm plugs • Comparison of % females with >1 sperm plug • Offshore migration	 Year 2 Year 2 Year 2 Long term	NT/QLD/WA	• Impacts of alternative harvest strategies on reproductive (mating) success • Appropriateness of single-sex and size limit regulations

* Person present at meeting 31.5.99 in Darwin at HVP Conference Room where directions were endorsed

Nick Rayns, Chris Calogeras, Tracy Hay (NT Government)
Neil Gribble, Ian Brown, Mark Doohan (Qld Government)
Ben Fraser (WA Government)
Geoff Broadhead, Mike Fraser, Darryl Everett (NT Industry)
Ian Knuckey (Vic Fisheries [formerly NT Government])

APPENDIX I Extract from FRDC Report - Towards the Sustainable Use of Northern Territory Fishery Resources (Mud Crab)

Towards the Sustainable Use of Northern Territory Fishery Resources: Review Workshops

Led by Carl J. Walters

Edited by D. C. Ramm

Project 96/158
Fishery Report No. 39
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Status and Future Development Potential of the Mud Crab Fishery

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2 Fisheries Division, Department of Primary Industry and Fisheries, Darwin
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Summary

The mud crab fishery probably takes a very high proportion (70% or more) of the available stock each year in the areas that are now fished, so that the fishery depends primarily on newly recruited crabs rather than an accumulation of crabs from several past breeding years. This means that any future development potential for the fishery would have to involve finding new fishing areas in remote areas that have not been economically or physically accessible to fishermen to date. There appear to be few such areas, so the fishery should be viewed for management purposes as fully developed at present. It is very unlikely that large new grounds will be found (that the fishermen have not already exploited), or that much more catch can be taken from existing grounds. It is also very unlikely that catches can be improved through simple management controls such as changes in size limits. On the other hand, there appears to be little risk of a conservation problem in the form of recruitment overfishing. Good recruitments have been produced in spite of high exploitation rates since the early 1980s, and there is a partial refuge from exploitation for female crabs because of their offshore spawning migration (into areas that are not fished). The only hint that recruitment overfishing could become a problem has come from limited experience on the Adelaide River, where crab densities have remained low since a period of very high effort in 1989. With the current wide distribution of fishing effort, it is unlikely that such a situation would arise again or commonly over the fishery, unless there is substantial increase in the number of vessels licensed to fish and move widely over the territory.

We cannot be certain that there is not a larger biological population than indicated by exploitation statistics and depletion experiments consisting of individuals that for some reason are not vulnerable to crab pots. But the possible existence of such a "pot-inactive" population will remain purely a matter of academic interest unless some change in fishing techniques reveals its existence, and depletion of it reveals that it is somehow important to maintaining recruitment to the population that is vulnerable to crab pots. Continued monitoring of catches, spatial distribution of fishing efforts, and fishing techniques should reveal any such scenario in time to avoid risk of serious overfishing.

Methods of Assessment

Catch-effort models and assessment methods based on catch-rate data cannot be used in this fishery due to non-randomness in the spatial pattern of fishing effort. Fishermen appear to systematically deplete local areas then move on to other ones through the fishing season, so as to maintain hyperstability in catch per effort (see below). Likewise, traditional length-based methods for estimating mortality and growth rates are invalid due to the way crabs grow (by moulting rather than continuous body growth). Also such methods are insufficient due to the lack of discrete length cohorts in the stock due either to high variance in individual growth rates, or mortality).

We have therefore chosen to base assessments on the simple approach of recognising that the fishing mortality rate (F), defined as F = (catch)/(stock size), can be estimated directly by obtaining a stock size estimate from local fishery depletion and/or depletion experiments. Then dividing this stock estimate into the measured catch. To obtain a stock size estimate for typical or average years, we use the fact that total stock size consists of the product of two factors that can be independently estimated:

stock size = (crabs per unit habitat area) x (total habitat area).

We made rough estimates of total habitat area for several fishing locations along the coast for which local catch statistics are available, and estimated crabs per unit area within these locations by two methods that agreed quite closely: (1) swept area for a single pot based on pot spacing used by fishermen (assume each pot sweeps a circular area with 50 m radius, ie 7800 m2, based on how fishermen have found that pots should be set around 100 m apart), and (2) depletion and mark-recapture estimates made in a small creek by Ian Knuckey. Both these methods indicate mid-season crab densities of roughly 150 crabs/km2 of creek/shallow coast water surface area. Taking these densities times estimated total habitat area for several locations, then dividing this total into measured catches, gives annual exploitation rates of around 70-90%.

Another way to estimate an upper bound (worst case scenario) for the fishing mortality rate F is to calculate the total "swept area" by pots and to divide this swept area by the total area of habitat. Assuming each pot set sweeps an area of 7800 m2, multiplying this times total pot lifts and dividing by habitat area gives maximum F values ranging from 2.7 in the Adelaide River to 4.0 in the Roper River and 6.4 in the McArthur River. These swept area values imply annual exploitation rates of 93-96%, and agree fairly well with the habitat area/density calculations if we assume that about half the crabs in each area swept by a pot actually enter the pot during any set.

Further evidence of high exploitation rates was obtained by examining the seasonal pattern of recruitment of new crabs to the fishery, and using this to predict changes in average size of crabs through the season under alternative assumptions about the numbers of larger, older crabs still alive at the start of the season. If there were a substantial carryover of older crabs, average body sizes near the start of each season should be considerably larger (170-200 mm carapace width) than later in the season when new recruits enter the fishery at carapace widths of 140-160 mm. Average body sizes from fishery sampling change from 152-153 mm carapace width in the early February-March period prior to major recruitment, to around 157 mm in the July-November period. The observed pattern is thus indicative of extremely high exploitation rate, and very little carryover of larger crabs from previous years' recruitments.

We attempted to still further cross-validate the assessment that F is very high by fitting a seasonal population dynamics model developed by Ian Knuckey (including seasonal recruitment, growth, vulnerability, and natural mortality effects as well as interannual carryover of crabs) to the monthly time series of catch and CPUE data for 1985-95. When fitted to both catch and CPUE data, this model indicates annual F values of around 2.0. However, when the model is fitted only to catch data, the parameter estimates converge to a very low F, high recruitment scenario in which the fishery is estimated to have had almost no impact on the stock. This optimistic scenario occurs because the computer fitting procedure sees increasing catch with increasing effort over the years, and can fit such a pattern most readily by assuming the increasing effort has had no impact whatsoever on stock size. When we force the impact of fishing to be large, either by fixing catchability or by including seasonal CPUE depletion data in the fitting, the model fits imply a recruitment anomaly trend that is positively correlated with fishing effort; such a pattern could happen if either recruitment is stimulated as increasing fishing mortality removes more large, cannibalistic crabs or if effective recruitment increases as fishermen include more fishing areas in their activities (and hence a larger effective population size in the statistics they report).

If exploitation rates are as high as we estimate, then why has fishing success as measured by catch per effort remained high as total fishing effort has grown? Such hyperstability in CPUE is usually associated with schooling fish, where fishermen can target on schools to keep success rates high even if school size or number of schools declines greatly. Here we likely have the opposite behavioural situation, with aggressive behaviour and risk of cannibalism driving the crabs to spread themselves more evenly over the habitat than would be expected from chance variation in recruitment seeding or availability of juvenile nursery areas. If spacing behaviour were continually driving the crabs to stay as far from neighbours as possible, densities would decline uniformly over the whole fishing area during each season and catch rates would closely reflect the seasonal depletion. The data do not show a seasonal pattern involving more rapid depletion with increasing fishing effort. Partly this lack of clear change in seasonal pattern is due to recruitment of new crabs moulting into the sizes that enter pots, especially during the middle of the fishing season (March-August), and this tends to mask strong CPUE decline until late in the season. Another possible effect is that only a proportion of the crabs at any site are behaviourally vulnerable to entering pots during any short fishing bout; in some pot fisheries (such as WA, SA rock lobsters) this proportion is quite low so multiple visits are necessary to generate high annual exploitation rates.

There are two likely reasons for lack of CPUE response to increasing exploitation rates. First, the harvest process involves "sequential depletion" of small fishing sites, where fishermen apparently remove most of the crabs from each site then move on to new sites. In such effort movement situations and where densities at all sites are initially similar, CPUE is expected to remain high until all sites have been fished at least once, then to decline sharply when fishermen revisit sites that now have only new recruits available. Second, there is an economic threshold to keep fishing, such that it is uneconomic to keep fishing (cannot meet operating costs) when CPUE drops below about 0.2 kg/pot lift (season average is order 0.5kg/pot lift). Fishermen that cannot achieve this threshold (due to local crab density conditions, operator skill, luck) are expected to drop out of the fishery earlier in each season than other fishermen who are luckier or more skilled, so that CPUE statistics later in the season come only from the fishermen who are still achieving higher catch rates. This "effort sorting" process can bias the CPUE statistics upward considerably from levels that would be expected if all fishermen stayed out. As a side comment, effort sorting effects are particularly notorious in recreational fisheries where fishing skill varies enormously among individual fishermen; in such fisheries, CPUE is almost completely independent of fish abundance, and the best indication of changes in stock size is changes in fishing effort.

Alternative Hypotheses About Stock Status and Sustainability

Main alternative hypotheses about the future of this fishery concern the possible existence of substantial inshore areas that have not yet been heavily fished. There are only a few such areas. Fishermen report good crab abundances in the Arnhem Land, but this area is difficult to access and raises aboriginal issues. There may be some potential for development in inaccessible locations on the Gulf of Carpentaria, but we strongly suspect that fishermen would already have found such areas if they existed, and would have found ways to gain access to them other than by the usual land routes.

Information required for Future Assessments

There are three key needs for future assessments in this fishery:

1. refined estimates, and estimates from more spatial locations around the fishery, of crab densities per unit habitat area;
2. refined estimates, using maps, GIS computer mapping techniques, and discussions with experienced fishermen, of total habitat area and density variation across different habitat types (e.g. open coast versus mangrove creeks).
3. development of a more precise fishery reporting system for spatial location of catches, changes in fishing techniques, and size distributions of crabs taken and released from traps.

Note that all of these needs can be met most efficiently and cheaply through cooperative work between fishermen and government. If depletion experiments (with buffer zone around each depletion area to measure and reduce effect of immigration into the area) are used to estimate local crab densities, an obvious way to do these is to have a fisherman do the depletion harvesting under supervision, following a time period during which the experimental area is closed to fishing to insure that catch rates in the area are likely to be high enough to be attractive to the fisherman. Likewise, fishermen have an incentive to cooperate in providing their knowledge and experience for habitat area mapping, since demonstration that there are areas currently not being utilised would help to provide confidence that the existing fishery need not be restricted further to reduce the risk of overfishing. Improved reporting is an investment by fishermen to protect the asset value of the fishing license, since better information will provide a warning system to help reduce the severity of any stock collapse that might be triggered by increased exploitation rate due to improved gear efficiency.

Management Options

This fishery is currently under an input control management system with limits on the number of licenses and pots fished per license. Pot fisheries managed this way in Australia (e.g., rock lobsters) have generally performed quite well from a conservation viewpoint, and I know of no instances where rapid changes in potting gear efficiency have led to dangerous increases in fishing mortality rate (but see above about need to monitor for such changes).

Major management options concern whether to allow limited expansion of fishing licences, and whether to restrict the location(s) where each license holder is allowed to fish. Data presently available on crab densities and habitat area suggest that increasing license numbers would not result in substantial increases in catches, and would instead reduce incomes per license holder already in the fishery. Thus increases in the number of licenses should be viewed as an option for distributing income from the fishery more widely (generating more employment), but not for increasing net production for the industry as a whole.

Allowing fishermen to move freely among fishing areas has led in the past to some social and economic problems (competition for fishing sites), but has likely helped at least some fishermen to stabilise their incomes by shifting their effort in response to local variations in crab abundance and number of competing fishermen. However, some crab fishermen are now voluntarily restricting their operations to single areas, and are trying to treat these as exclusive fishing territories. It is likely that much of the crab fishing area of the NT will evolve into informal fishing territories no matter what the government policy is on this matter. Perhaps it is time to explicitly recognise and even deliberately protect this emerging fishery structure.

The primary arguments for restricting all fishermen to single, at least partially exclusive areas are: (1) having one fishing site without unpredictable competition from other license holders can allow operators to reduce costs and learn to fish the site more efficiently; and (2) being restricted to one area creates an incentive for the operator to support prudent conservation and management (if he cannot move, he must live with economic consequences like reduced license asset value if he engages in destructive practices or overharvesting). The second of these arguments is particularly compelling from a public conservation perspective. Further, the argument by fishermen that they have to move a lot to find good fishing opportunities and stabilise incomes is somewhat misleading; some variation in fishing success is due to natural variation in abundance from place to place over time, but much of the variation is created by the fishermen themselves when they move about trying to beat one another to the best fishing sites (when a fisherman encounters low catch per pot in a site, this low success is as likely to be due to someone else having cleaned out the site within the past few days or weeks, as it is to be due to overall low abundance independent of fishing pressure). Also, under an exclusive area license system there would presumably be nothing to prevent operators from acquiring rights to several locations should they deem it wise to do so based on personal preferences regarding risk spreading and ability to fish different sites successfully. I cannot venture to say what option would be best overall for fishermen and for the Australian public, but the matter of localised and exclusive licensing should be a central subject of debate and policy analysis in the near future.

APPENDIX II Workshop Itinerary and Format

MUD CRAB WORKSHOP DARWIN 29-31 May 1999

Welcome to Darwin. Following is a proposed itinerary for the weekend, along with a map to help you find your way around.

It is hoped that the final outcome will be the preparation of workshop proceedings which will give a snapshot of the existing management arrangements in place and research undertaken to date and currently underway. Most importantly there will be the development of a national FRDC research proposal outline for mud crab.

Confirmed attendance:

- Ben Fraser - WA Fisheries (Broome)
- Chris Calogeras – NT Fisheries
- Ian Brown – QDPI Southern Fisheries Centre
- Ian Knuckey – MAFRI (Victoria)
- Mark Doohan – QFMA
- Neil Gribble - QDPI Northern Fisheries Centre
- Tracy Hay - NT Fisheries
- Nick Rayns, Director of Fisheries, will be available to act as Chair

The program will be as follows:

Saturday 29 May 1999 - presentation of Ian Knuckey's PhD thesis
Time: approx from 1.00pm to about 3.00 or 4.00pm
Venue: Nemarluk Conference Room, Mirrambeena Resort, Cavenagh Street.

All Industry members have been invited to attend and comment on Ian's comprehensive findings. As well as industry and those here for the workshop, the recreational sector and other relevant or interested persons and organisations have been invited.

Sunday 30 May 1999 - Mud Crab Workshop
Time: from 9.30am to about 2.00 or 3.00pm
Venue: Harbour View Plaza (HVP*) Fisheries Conference Room 2nd Floor corner of McMinn and Bennett Streets.

* *Please note that HVP has a security system to challenge NASA. If everyone can meet at the carpark lifts (under the building) at 9.30am, access will be arranged to the conference room.*

Research and Management staff from Qld, WA and NT will briefly review management arrangements in place and outline research needs from each state. Both the NT and Qld industry have also identified research priorities for incorporation into any proposal. With those matters in mind a national FRDC research proposal outline will be developed.

Monday 31 May 1999 - Industry/Government consideration of proposal

Time: from 9.30am to about midday
Venue: Harbour View Plaza (HVP*) Fisheries Conference Room 2nd Floor corner of McMinn and Bennett Streets.
* *Security is more relaxed on weekdays and access is available through lifts on ground floor, or from the car park*

Northern Territory Industry representatives will be invited to consider and comment on the research proposal outline developed from the workshop, prior to the development of a full FRDC proposal. Dr Rayns will chair the session.

Hope you enjoy your time in Darwin and if we can be of any assistance give Tracy Hay or myself a call respectively on 0417835972 or 0419818549.

CHRIS CALOGERAS

APPENDIX III Overview of Management Arrangements in Place for the Mud Crab Fishery in Australia

DESCRIPTION OF THE NORTHERN TERRITORY MUD CRAB FISHERY

Prepared by Chris Calogeras and Tracy Hay (NTDPIF)

Introduction

The NT Mud Crab Fishery is best described as a single species fishery in which baited pots or traps are used to take live mud crabs (generally *Scylla serrata*). The major user groups of the NT mud crab resource are the commercial and recreational sectors whilst crabs are also an important food source for indigenous fishers. At present a small quantity of mud crabs are also required for aquaculture broodstock purposes.

The Fishery encompasses tidal waters from the Queensland border to the Western Australian border and is managed by the Northern Territory.

Since 1984 the Fishery has been actively managed, with a Management Plan first introduced in 1991. Amendments were made to the Plan in 1993 and 1995. A review of the Plan commenced in 1999.

Crabbing is confined to coastal and estuarine areas. The Fishery is not regionalised, although some access restrictions may occur due to the presence of Aboriginal sacred sites or land, Aquatic Reserves, closures specified in the Management Plan or by Commonwealth authorities such as Parks North which prohibits commercial fishing within Kakadu National Park.

A major workshop was held in Darwin during 1996 to provide more reliable and ongoing advice on the status of NT fish stocks, including mud crabs. Dr Carl Walters, an internationally recognised expert on fisheries matters, led the review and found that based on available logbook data and documented fishing practices, the mud crab fishery was heavily exploited. However, as extensive areas of the NT coastline were not yet exploited it was unlikely that the fishery would suffer from recruitment overfishing.

Since that time commercial catches have continued to increase and the first estimates of recreational fishing impacts for mud crab have become available with the release of the 1995 recreational fishing survey, FISHCOUNT, in 1998.

PROFILE OF THE FISHERY

Commercial

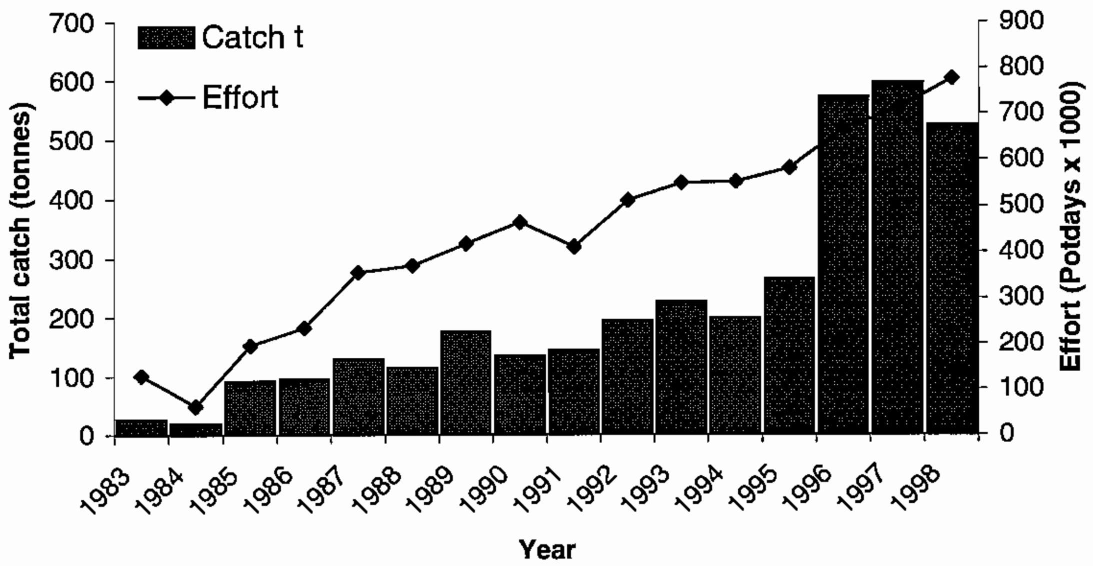
The commercial Fishery is a limited entry fishery. No new licences are available; only existing licences can be renewed. Provisions exist for licensees to permanently or temporarily transfer their licence and as such the majority of licences are not operated by the owner, but are leased to other persons who work the licence, or alternatively employ other persons.

A total of 49 fully transferable licences are renewed annually, all of which are utilised. Each licence holder is entitled to use a maximum of 60 pots, which must comply with specified dimensions and construction materials. As well as other general closures, commercial crabbing is prohibited in some areas in the vicinity of Darwin.

The mud crab fishery can be considered a low technology fishery, operating from 5.0 m aluminium dinghies powered by 70 to 115 horsepower outboard motors. As yet use of electronic equipment is not evident apart from HF radios for emergency communication purposes. Some effort creep is however evident as a few crabbers move towards larger motors; some now operating four-stroke outboard motors, believing them more economical and efficient in transporting significant loads over long distances. Some crabbers may travel in excess of 100 km to set their pots. They generally then stay in the vicinity for a number of days before returning to their camp to unload their catch.

Most often crabbing operations work from very remote, small, rudimentary land based camps. Some though, such as those in the McArthur River region, where restricted bait nets are prohibited and bait must be purchased, may have generators and freezers to store bait. The use of mother boats, pontoons or barges as a base has the potential to become more common as crabbers travel further afield.

A summary of total catches and effort from 1983 to 1998 is shown in the figure below.



The Fishery in 1998 was valued at around $7.5 million at the point of first sale. This represented almost 40% of the total value of all NT fishery landings (excluding the Northern Prawn Fishery and aquaculture). This makes the mud crab fishery the most valuable wild harvest fishery managed by the NT.

Catches by individual fishers have increased substantially as the fishery has developed, but as shown in the proceeding figure, total effort reported in pot days has increased steadily but in proportion to the increase in catch. This is for a number of reasons, including possible greater availability of crab, a much higher incidence of multiple checking of pots and some reports of crabbers using more than the permitted 60 pots.

Major fishing areas are in the Borroloola region (McArthur River to the Qld border), Roper River (Limmen River to Roper River), Darwin Area (Daly River to the Mary River) and Arnhem Land (East Alligator River to the Roper River). Negligible activity was again reported on the western coast of the Territory. Fishing activity over recent years has been concentrated in the south and west of the Gulf of Carpentaria, with around 80% of the catch from that region.

Recreational

Mud crabbing is a popular recreational activity and is often undertaken with other fishing activities in coastal and estuarine regions. A wide variety of vessels are used although the serious crabber prefers small dinghies. Nearly all of the catch is taken using pots or dillies, although a small amount is taken by the use of hooks or spears. Most crabbing occurs in the vicinity of the major population centres of Darwin, Gove and Borroloola.

No licence is required to take mud crab for recreational purposes, but gear restrictions and possession limits apply.

The Recreational Fishing Assessment Program, FISHCOUNT, provided estimates that in 1995 approximately 52 tonnes of mud crab was landed by recreational fishers.

Indigenous

Mud crabs are a significant food source for coastal Aboriginals. Section 53 of the Fisheries Act guarantees indigenous people the right to utilise the resource in a traditional manner. Indigenous people are entitled to use recreational fishing gear to crab, but spearing or hand harvesting is often preferred.

No information has been gathered on this sector to date, but the National Recreational and Indigenous Survey being conducted during 2000 should provide estimates of indigenous harvest rates.

Aquaculture

Production of juvenile crabs from larvae has become increasingly reliable at the Darwin Aquaculture Centre. Survival rates through the hatchery are approaching what may be considered as economically viable. This project has been undertaken as part of a collaborative research program on mud crab aquaculture with QDPI and institutions from the Philippines funded by ACIAR.

Considerable work is still required on the nursery production of mud crabs, the growout of large crabs and adult nutrition. However, it is anticipated that commercialisation of research results will be possible within 3 years.

Marketing

Marketing continues to be based on live product airfreighted to southern markets, primarily Sydney and Melbourne. The high catches since 1996 have provided traders with the economic incentive to increase exports to overseas markets in South-East Asia.

One of the major concerns expressed by importers is the prevalence, at certain times of the year, of "empty" crabs. These are early post moult crabs in which the muscle has not fully developed. Industry and traders are attempting to obtain a uniformly high standard of product from fishers to address this marketing concern.

Management

Since 1991, the fishery has been controlled under the Mud Crab Fishery Management Plan. Amendments were made in 1993 relating to non-retention of berried females and again in 1995 relating to a 10-mm increase in the minimum size limit for females.

The Mud Crab Fishery Advisory Committee (MCFAC) is the peak advisory body to the Director of Fisheries and comprises representatives from various stakeholder groups and Government.

As well as MCFAC, a series of regional coastal consultative committees have been formed. These provide formal advice from the Aboriginal constituents of the regions on all aspects of fishing, including mud crab.

An FRDC funded project saw Dr Carl Walters lead an extensive workshop in Darwin to determine the status of the NT mud crab stocks, state of the fishery and possible management options. The analysis and assessment indicated that a very high proportion of the available stock in the areas fished is taken each year. This means the fishery most likely depends on annual recruits entering the fishery, rather than an accumulation of crabs from previous seasons.

Research

The Mud Crab Research Program initiated in 1990 is now focussing on:

- Mud crab monthly monitoring to evaluate any changes in the size or sex composition of the commercial catch;
- Habitat mapping and density estimates with a view to determining fishery independent stock abundance techniques;
- Tagging studies to determine growth and movement;
- Analysis of commercial mud crab fisheries data to monitor the general status of the fishery and determine any trends evident from logbook data.

Compliance

Most commercial crabbers are interviewed in the field annually by DPIF, Fisheries Division staff. Crabbers are advised of any amendments to the legislation and general comments on the status of the fishery, research, management and compliance are sought.

As English is not the first language of many of the mud crab fishers, Fishnotes and other relevant information are also produced in Vietnamese and Khmer.

The NT Police Marine and Fisheries Enforcement Unit undertakes enforcement. The major area of concern relates to the illegal use of gear and the storage of fishing apparatus at non approved sites, including on Aboriginal Land. The under-reporting on compulsory logbook returns and alleged black marketing activities were also investigated.

DESCRIPTION OF THE QUEENSLAND MUD CRAB FISHERY

Prepared by Mark Doohan QFMA

Target species

Queensland's mud crab fishery is specific to the genus *Scylla*. In 1998, a taxonomic revision of the genus was undertaken and, as a result, two species (*S. serrata* and *S. olivacea)* were identified as inhabiting northern Australian and Queensland waters. However, by far the predominant species in Queensland is the species *S. serrata*, which is known colloquially as the mud crab or mangrove crab. The agreed marketing name is mud crab.

In view of the very small contribution of *S. olivacea* to the mud crab population and its apparent limited distribution in Queensland waters, no specific management proposals to deal with its management are included in the Discussion Paper. All references to mud crabs are applicable to both *S. serrata* and *S. olivacea*.

Fishery area

The fishery area comprises all waters relevant to the State of Queensland, including the waters of the east coast of Queensland, waters of the Torres Strait and waters of the Gulf of Carpentaria.

Most of the mud crab catch is harvested between December and June. The principal harvest locations are estuaries along the Queensland coast, including Hervey Bay, Moreton Bay, Gladstone/Fitzroy, Hinchinbrook, Townsville, Princess Charlotte Bay and the Gulf of Carpentaria.

FISHERY PARTICIPANTS, APPARATUS AND MANAGEMENT ARRANGEMENTS

Commercial fishery

Boat numbers and size

The number of primary commercial fishing boats authorised to take mud crabs in Queensland waters is currently restricted to about 950. However, only about 400 of these boats record mud crab catches. Of these boats, about 85% record a catch of less than one tonne each year.

A limitation on the issue of additional primary commercial fishing boat licences has existed in Queensland since 1984.

A primary commercial fishing boat taking mud crabs in Queensland waters must have marked on its licence the fishery symbol C1. A fishery symbol, previously referred to as an endorsement, authorises the holder to operate in the fishery represented by that fishery symbol.

A QFMA boat replacement policy exists for non-trawl boats in the fishery. This policy is set out below.

Commercial crab fishers may replace a primary commercial fishing boat with another boat no longer than 14 metres or tender a commercial fishing boat with another boat no longer than 7 metres. Any existing primary or tender commercial boat that exceeds 14 or 7 metres, respectively, may be replaced with a boat up to the length of the existing boat. For primary boats, a 20-metre maximum length applies. All commercial fishing boat replacements are subject to QFMA approval.

Apparatus
Mud crabs may be taken only by using crab pots, dillies or inverted dillies; and not more than 50 crab pots, dillies or inverted dillies alone or in a combination may be used at a time.

The most common apparatus used is the crab pot, which is checked and baited daily. Most commercial fishers leave their pots in the water continuously, moving them around periodically.

Marking
All crab apparatus used to take crabs must have a tag with the owner's name written on it or marked with the owner's primary commercial fishing boat marking. If the crab apparatus is not fixed to something while it is in use, the apparatus must also have a light-coloured float attached to it. The float must be at least 15 cm in any dimension and have the owner's primary commercial fishing boat marking on it.

Size
Under current fisheries size legislation, it is illegal for a commercial fisher to keep mud crabs with a carapace width of less than 15 cm. Where the carapace is damaged, the alternative (body) underside minimum size measurement of 4.6 cm is used.

Crab meat
A person must not possess a mud crab with its carapace missing, or crab meat, unless the person is a buyer or fish retailer. This arrangement does not apply if the crab is bought by retail or the person possesses it for immediate consumption.

Crab claws
The possession or sale of crab claws (without the crab's body) is prohibited.

Female
The taking of female mud crabs by commercial fishers is prohibited.

Closed waters
In the Gladstone region, Eurimbula Creek (north of Round Hill Creek) and waterways adjoining it are closed to the taking of mud crabs.

Recreational fishery

Bag limit
A recreational fisher is allowed to have in his/her possession at any one time a maximum of 10 mud crabs.

Apparatus
A recreational fisher is limited to four apparatus (crab pot, collapsible trap, dilly or inverted dilly) in any combination.

Marking
The apparatus must be marked with the owner's name and address. If the crab apparatus is not fixed to something while it is in use, the apparatus must also have a light-coloured float attached to it. The float must be at least 15 cm in any dimension and have the owner's name written on it.

Size
Recreational fishers are prohibited from keeping mud crabs with a carapace width of less than 15 cm. Where the carapace is damaged, the alternative (body) underside minimum size measurement of 4.6 cm is used.

Females
The taking of female mud crabs by recreational fishers is prohibited.

Age
A person under 15 must not use a crab pot, collapsible trap, dilly or inverted dilly.

Crab meat
A person must not possess a mud crab with its carapace missing, or crab meat, unless the person is a buyer or fish retailer. This arrangement does not apply if the crab is bought by retail or the person possesses it for immediate consumption.

Closed waters
In the Gladstone region, Eurimbula Creek (north of Round Hill Creek) and waterways adjoining it are closed to the taking of mud crabs.

Traditional fishery

The taking of fisheries resources is an important part of the tradition and custom of indigenous people. Section 14 of the *Fisheries Act 1994* states that 'an Aborigine may take, use or keep fisheries resources under Aboriginal tradition and a Torres Strait Islander may take, use or keep fisheries resources under Island custom.

Traditional fishing is not regulated by fisheries legislation relating to commercial and recreational fishing.

The development of a fishery Management Plan that impacts on Aboriginal tradition and/or on Torres Strait Island custom must be carried out in cooperation with Aboriginal and Islander stakeholders.

KNOWN STATUS OF FISHERY

Commercial fishery

The total catch of mud crabs each year for the whole of the Queensland fishery is shown in Figure 1. This indicates a slight but steady upward trend in catches, from about 300 t in 1988 to more than 500 t in 1997. Some data for 1998 are available; but, because they are incomplete, they are not shown in Figure 1.

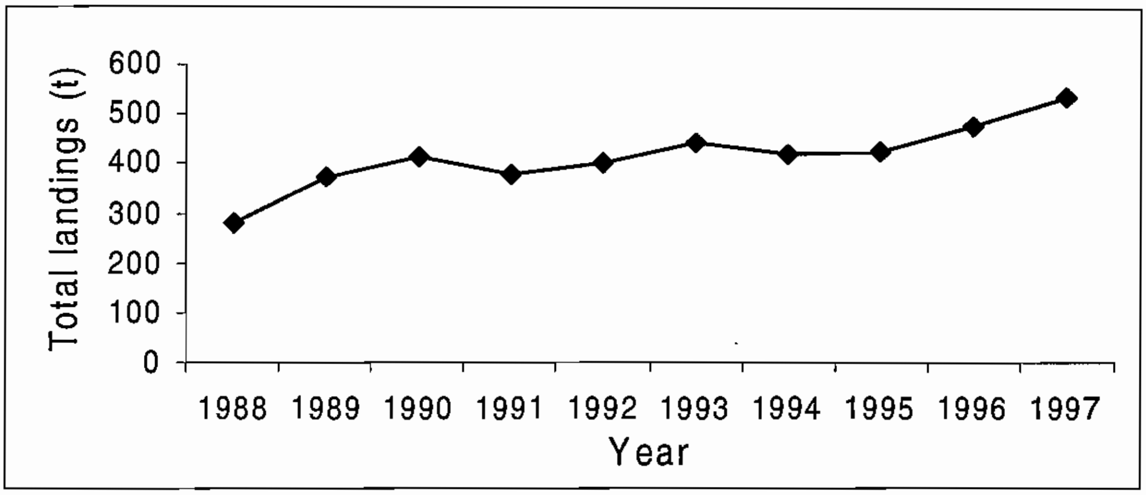


Figure 1. Total annual reported catch of mud crabs (including catches of 'unspecified' crabs) for the entire Queensland coast, including the Gulf of Carpentaria.

Recreational fishery

The QFMA has developed a Recreational Fishing Information System (RFISH) to provide an estimate of participation levels in recreational fishing throughout Queensland. These estimates are obtained from a statewide telephone survey designed to estimate the number of people fishing, and a diary program that records the catch of a cross section of the fishing public.

Information from the first telephone survey conducted in 1996 suggest that mud crabs were the third most frequently targeted species, behind whiting and flathead, with about 42 000 fishers having actively targeted mud crabs in the previous 12 months. Fishers in the Fitzroy, Mackay and Townsville regions were more likely to have fished for mud crabs than fishers from other areas. Mud crab fishers were also more likely to be avid fishers, fishing monthly or more often.

Estimates of the number of mud crabs caught by Queensland residents will be produced from the angler diary program conducted in 1997 and will be available in July1999.

Traditional fishery

Mud crab catch for Aboriginal tradition and Torres Strait Islander custom is unknown. However, it is believed to be small in comparison to the commercial and recreational catch.

QUEENSLAND MUD CRAB FISHERY MANAGEMENT PLAN

Under the provisions of the *Fisheries Act 1994* ('the Act'), the Queensland Fisheries Management Authority (QFMA) has determined to produce a fishery Management Plan for Queensland's mud crab resources.

The Management Plan will cover mud crabs of the genus *Scylla.*

As a first step in the development of a management plan for a fishery, the QFMA has released a discussion paper that presents and seeks comments on, current management issues. The Queensland Mud Crab Fishery Discussion Paper was released on 1 April 1999. The closing date for submissions is 30 June 1999.

The Paper also seeks comment on what objectives might be appropriate for the proper conservation of Queensland's mud crab resources and sets out approaches to appraise the performance of the proposed Management Plan on an objective basis.

Management issues presented in the Discussion Paper include:

- Protection of female crabs;
- Size limit for male mud crabs;
- Spawning closures;
- Method of measurement;
- Changes in the recreational bag limit;
- Habitat protection;
- Gulf of Carpentaria crab fishery;
- Moreton Bay crab fishery;
- Inverted dillies;
- Turtle interaction with crab apparatus;
- Compliance, enforcement and education;
- Cost of management;
- Stock assessment and long-term monitoring; and
- Research and development needs and priorities.

Current Management Interventions

- Limited entry fishery
- Prohibition on taking females
- Apparatus restrictions - commercial limit 50 / recreational limit 4
- Minimum legal size - 150 mm carapace width
- Recreational 'in-possession' bag limit - 10 crabs

Management Planning

- Queensland Mud Crab Fishery Discussion Paper released April 1999
- Queensland Mud Crab Fishery Draft Management Plan to be released early 2000
- Queensland Mud Crab Fishery Management Plan to be released late 2000

CATCHES

Commercial Catch

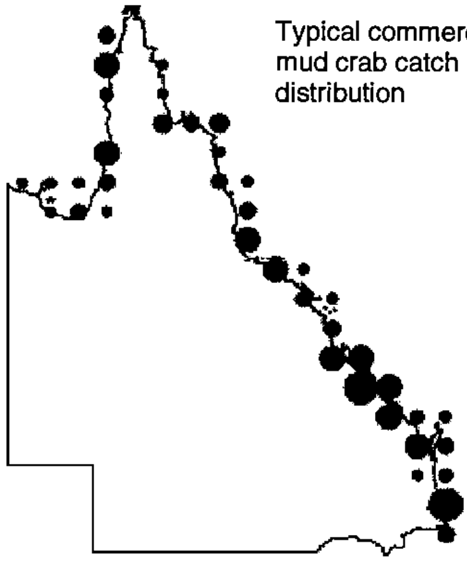
1995 - 420 tonnes
1996 - 460 tonnes
1997 - 520 tonnes

Recreational Catch

Not known - probably significant

Traditional Catch

Not known



Typical commercial mud crab catch distribution

DESCRIPTION OF THE WESTERN AUSTRALIAN MUD CRAB FISHERY

Prepared by Ben Fraser (WA Fisheries)

INTRODUCTION

The commercial mud crab fishery in Western Australia encompasses the fishing for mud crab (*Scylla spp.*) in all Western Australian waters north of 21^0 44'S latitude (Exmouth Gulf) by means of traps for the purpose of sale.

Fishing for mud crab for the purpose of sale is prohibited by a number of Notices written pursuant to the *Fish Resources Management Act 1994* (the Act). Notwithstanding, the Executive Director of Fisheries WA has the power under the Act and subsidiary legislation to authorise a person to collect mud crabs for a commercial purpose.

There are presently 4 commercial operators authorised by way of endorsement on a Fishing Boat Licence to fish for mud crab. Aboriginal communities are also able to apply for an Aboriginal Community Fishing Licence to commercially take mud crab. Both types of mud crab authorisations are non-transferable.

In addition, recreational fishing for mud crab, including traditional and subsistence fishing by Aboriginal people, is a popular activity and is managed under a separate set of management measures to the commercial fishery.

COMMERCIAL MUD CRAB FISHERY

A number of mechanisms are currently used to manage the commercial mud crab fishery, including:

- Endorsement on a Fishing Boat Licence;
- Limited entry - there are 4 endorsement holders;
- Fishing is restricted to traps;
- Size limits (green mud crab 150mm, brown mud crab 120mm);
- Prohibition on keeping berried females;
- Non transferability of mud crab endorsements;
- Owner/operator provision of the mud crab endorsement;
- Closed commercial fishing areas around the major population centres and prime recreational mud crabbing areas; and
- Provision for Aboriginal Community Fishing Licences for mud crab to be issued.

Level of Activity

Generally, the quantity of mud crab catch taken in Western Australia reflects the minimal effort, which has been expended in this fishery. The low level of catch, and generally the lack of effort in the fishery, may be a result of:

- Lack of marketing;
- Not being targeted as a primary fishery;

- Mud crab fishing areas in remote locations;
- Low catches recorded as a result of endorsement collecting

Demand for Mud Crab Endorsements

Since the freeze on the grant of any further mud crab endorsements in 1994, there have been numerous enquires from people wishing to gain access to the mud crab fishery. As such, a "Register of Interested Parties" has been established. To be placed on the "Register of Interested Parties," the interested person is required to submit a detailed business plan of their proposed fishing operation. Placement on this Register does not guarantee access to the mud crab fishery.

There are presently four people listed on the Register and an additional three people who have shown a continuing interest in the fishery over the years.

ABORIGINAL COMMUNITY FISHING LICENCES

In 1989, the Minister for Fisheries made provision for the granting of "Aboriginal Community Fishing Licences" to Aboriginal communities for the commercial take of mud crab, beche-de-mer and trochus.

Under this arrangement, commercial fishing is restricted to areas adjacent to land on which the community lives or waters adjacent to adjoining land with the permission of traditional owners (areas generally correspond to Native Title claim areas). The licence is issued to the corporate body of the community and the council of that community is responsible for determining who may fish under the licence.

An Aboriginal community which has been granted an Aboriginal Community Fishing Licence is subject to the same conditions as a commercial mud crab operator. These include such items as size limits, a restriction on the take of berried female crabs, individual fishers to have Commercial Fishing Licences, and a requirement to complete monthly catch and effort returns.

At present there are two Aboriginal communities authorised to take mud crab (Kimberley region) and another application is currently being processed. Commercial catches of mud crab from Aboriginal communities have been low.

RECREATIONAL FISHING

Recreational fishing for mud crabs in the Kimberley, Pilbara and Gascoyne regions is highly popular. As a result, commercial fishing for mud crabs has been prohibited around the major population centres and prime recreational mud crab fishing locations. This management arrangement has effectively minimised the potential for conflict between the recreational and commercial fishing sectors.

Recreational fishing for mud crabs is restricted by bag and size limits as well as methods by which mud crabs can be taken. Management arrangements which apply to the recreational fishing sector include:

- Bag limit of 10 mud crabs;
- Size limit of 120 mm for Brown Mud Crab and 150 mm for Green Mud Crab;
- Crabs may be taken by crab hook, drop net or scoop net;
- Drop nets must be less than 1.5 metres in diameter;
- No more than 10 drop nets are permitted to be used at any one time; and
- Berried females are not permitted to be retained.

The management arrangements pertaining to the recreational mud crab fishery will be subject to review during the development of Regional Management Plans for recreational fishing in the Kimberley, Pilbara and Gascoyne regions. The Gascoyne review is currently in the "proposals for public discussion" phase and the Pilbara and Kimberley region recreational fishing review will commence within the next 12 months. Proposals for recreational mud crab fishing in the Gascoyne include a reduction in the bag limit of mud crab to 5 per person, per day with a boat limit of 10 crabs.

AQUACULTURE

Interest has been shown by Aboriginal communities in the penning and fattening of commercially caught mud crab for the purpose of value adding the product prior to sale. This activity would require an aquaculture licence and would be considered on a case-by-case basis as part of the assessment process for the granting of an aquaculture licence.

RESEARCH

Opportunities for funding a joint mud crab research proposal between Western Australia, the Northern Territory and Queensland are currently being considered. If successful, the research proposal will provide an opportunity for Western Australia to obtain valuable information on mud crab habitat and stock abundance.

Although there are only limited catch and effort statistics available on the commercial mud crab fishery in WA, it is considered unlikely that the mud crab resource in WA could withstand the equivalent fishing pressure exerted in the Northern Territory.

For the above reason, the Research Division has recommended that a precautionary approach be adopted in the management of the commercial mud crab fishery.

FUTURE MANAGEMENT OF THE MUD CRAB FISHERY

Fisheries Western Australia is currently reviewing the commercial mud crab fishery. The major issues facing future management of the mud crab fishery include;

Sustainable development of the fishery
One of the objects of the *Fish Resources Management Act 1995* is to "foster development of commercial fishing". With limited information on mud crab stocks, a precautionary approach to the development of the mud crab fishery in Western Australia will be undertaken. It is likely that protective management measures such as existing size limits (green mud crab 150mm, brown mud crab 120mm) and the prohibition on retaining berried females will be maintained.

Transferability
In 1995 mud crab endorsements were made non-transferable for a three-year period. Transferability of commercial mud crab endorsements is now due to be reviewed.

Resource allocation
It is likely that existing commercial mud crab closures around major population centres and prime recreational mud crabbing areas will be maintained. These areas have been successful in minimising conflict between recreational and commercial crab fishers to date.

Arrangements for commercial access to mud crab stocks by both commercial mud crab fishers and Aboriginal communities will be addressed as part of the review of the mud crab fishery.

Appendix IV Overview of Research Undertaken on the Mud Crab Fishery in Australia

Northern Territory
Mud Crab Research Program

Report Prepared
For the
Mud Crab Fishery Advisory Committee

7 April 1999

Tracy Hay
NT Department of Primary Industry and Fisheries

Background

The NT mud crab research program commenced in 1989. This project was aimed at collecting important information on the population dynamics of the mud crab (*Scylla serrata).* Data was collected over a 7-year period and the results form a large part of Ian Knuckey's Ph.D thesis.

On completion of Ian Knuckey's study in 1995 this research program was wound down to a monitoring program. The major aim of this work is to monitor the average size of mud crabs from the three important commercial regions.

In October 1996 Dr Carl Walters found that standard fishery assessment techniques, based on the current commercial logbook data, could not be utilised in assessing the mud crab fishery. He estimated using available data that the exploitation rate for areas fished at the time of the analysis was perhaps as high as 70-90% of available stock.

Briefly, in ensuring the sustainability of this fishery, Dr Walters recommended the following research directions be adopted for this fishery:

1. Detailed Habitat Mapping to identify and quantify NT mud crab habitat;
2. Develop a fishery independent method to assess crab abundance; and
3. Improve commercial logbook data detailing precise areas fished changes in fishing techniques and biological information.

Fishery Status

The Fishcount survey conducted in 1995 estimated the NT recreational mud crab harvest at around 52 000 individual crabs or 42 tonnes. In 2000 a new national recreational survey will be conducted providing more information on recreational participation in this fishery.

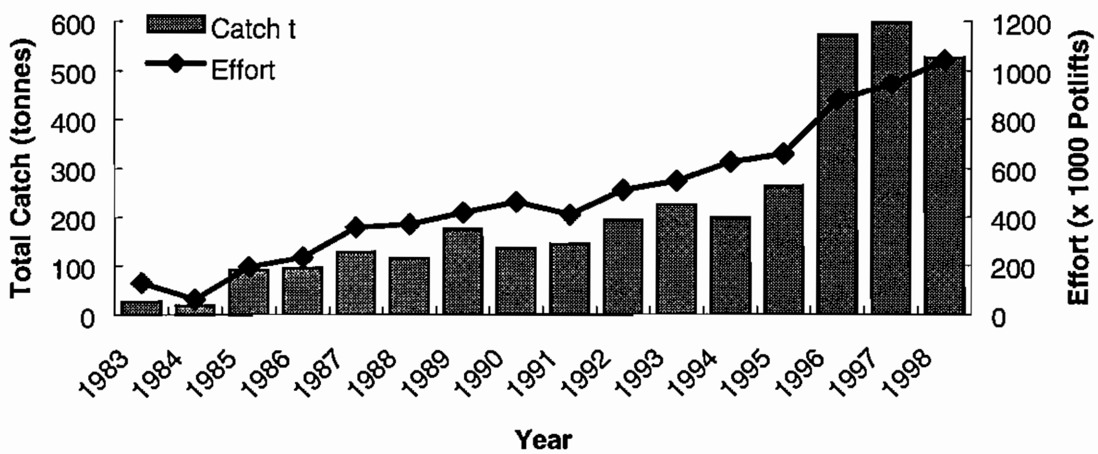


Figure 1. NT Mud Crab Fishery Catch and Effort Data 1983 - 1998.

Commercial catch and effort data for the mud crab fishery has been collected since 1983. The first ten years of data shows a steady increase in both catch and effort as the fishery and subsequent expertise developed. In 1996 reported effort increased by 33% resulting in a dramatic increased in commercial catch from 264 tonnes to 573 tonnes. This trend steadied in 1997 with 7% increase in effort and a 4% increase in catch (reaching 595 tonnes). Effort again increased in 1998 by around 9.5%. However the upward trend in catch was not evident as total catch declined by around 12% or 70 tonnes.

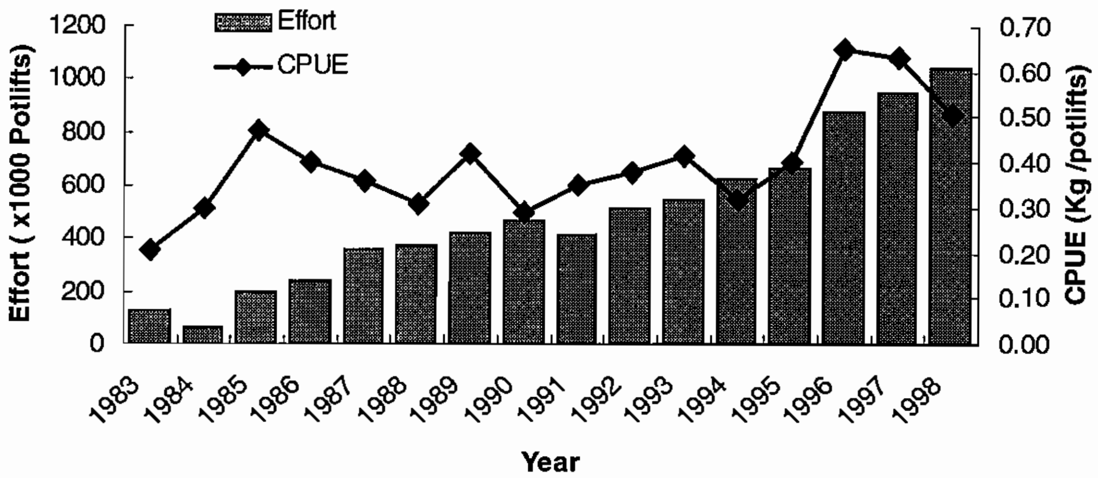


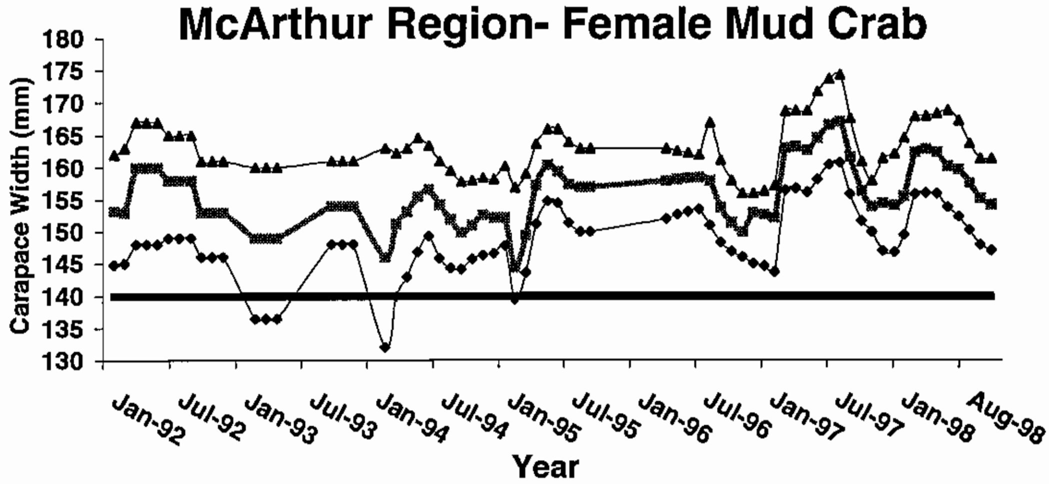
Figure 2. Illustrates CPUE (kg per potlift) Trends of the NT Mud Crab Fishery for the 1983 to 1998.

Annual CPUE remained relatively stable at around 0.4 kg/potlift for the period 1993-1995. In 1996 CPUE increased to 0.65 and this trend continued in 1997 with CPUE reaching 0.63. In 1998 CPUE declined to 0.51, yet still remains well above the 0.4 kg/potlift figure set in the early years of the fishery.

A reduction in CPUE may reflect early changes in the abundance of fish stocks. As mentioned earlier CPUE is not considered a good measure of relative abundance for this fishery. Development of independent fishery assessment techniques therefore remains a high priority for this fishery. This job would also be made much easier if logbooks more closely reflected actual fishing activity i.e. areas/rivers fished and fisher movement patterns.

Mud Crab Size Monitoring

Crab size (carapace width) is monitored on a monthly basis throughout the year from three commercially important regions in the NT (McArthur, Roper and Adelaide River regions). Figures 3 and 4 demonstrate the median size of female and male crabs from the McArthur River region. Mud crab growth is not continuous as an increase in size is only achieved by moulting. Size and sex compositions vary throughout the year with large males making up a large majority of the catch in the early new year and smaller individuals not recruiting to the fishery till mid year reflected as smaller crabs recruit to the fishery later in the year. Taking this into account there is no evidence of significant decline in carapace width for male or female crab from the three regions currently monitored. We will continue to monitor the fishery to determine any changes in the size composition.



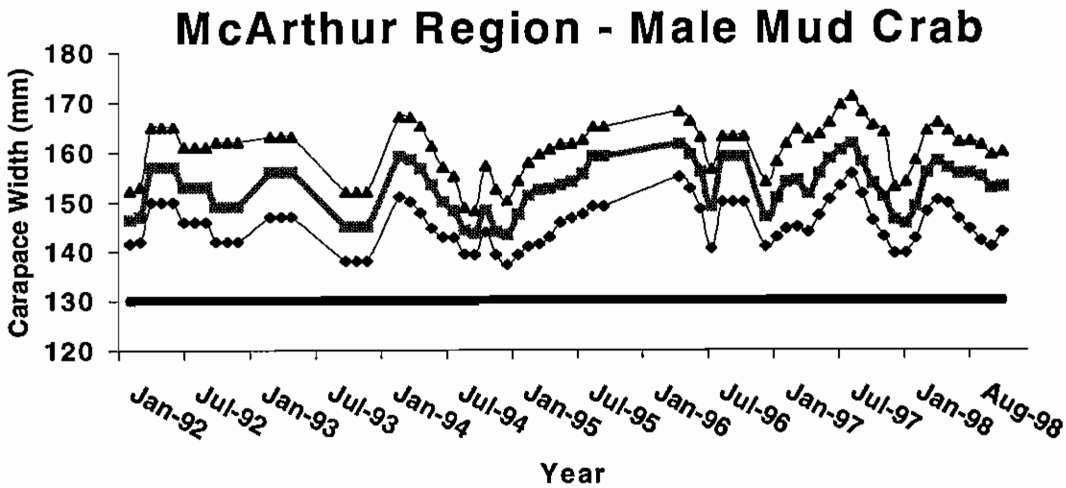


Figure 3 and 4 **Median Carapace Width for Female and Male Mud Crabs From the McArthur Region 1992-1998. The Median, Lower Quartile and Upper Quartile Have Been Calculated and Graphed Illustrating the Carapace Width Range That 50% of McArthur Mud Crabs Fall Within.**

Habitat Mapping and Mud Crab Estimates

The fishing patterns adopted in this fishery are not accurately reflected in logbook returns hence the importance of development of a fishery independent method of assessment of relative abundance.

In May 1997 and May 1998 the mud crab team conducted two preliminary mud crab habitat and density experiments in the Adelaide River area and the southern Gulf of Carpentaria. The aim of these experiments was to develop a technique to estimate area of mud crab habitat and thereby quantitate the relationship between habitat and crab density. This fishery independent survey is designed to overcome difficulties arising from analyses of CPUE using inadequate logbook data. Results from the preliminary trials are promising and small changes to the methodology are currently being discussed following advice from industry.

Strong support for this work has been expressed from both Qld and WA Fisheries. A collaborative 3-year project is now proposed looking at the extension of this work across Northern Australia. This project aims to complete detailed habitat mapping and estimation of associated mud crab abundance.

It is proposed to hold a workshop in June involving crustacean research scientists from around Australia. The aim of this workshop is to gather expertise in assessing crab fisheries and develop a proposal for submission for FRDC funding in late 1999. As an aside to this we intending to invite Ian Knuckey to present the results of his PHD to industry and other interested parties as a one-day open workshop.

Tagging

In May 1998 a mud crab-tagging program was commenced in the Gulf of Carpentaria. The program will provide valuable information on movement and growth of crabs in the southern Gulf. Commercial fishers are assisting this work by permitting Fisheries Staff aboard their vessels on crabbing runs. All undersized and empty crabs can then be tagged and released at the capture site. A total of 1309 crabs have been tagged. (694 males and 632 females). It is hoped to further expand this program to include the Roper River area on completion of the wet season. Continuing this work for a further year will permit us to collect information and gain further understanding of female migration patterns.

	Female	Male	Time frame	No. of recaptures	%
No. of crabs tagged	632	694	1 week	34	27.2
			2 weeks	19	15.2
No. recaptured	57	68	1 month	38	30.4
			2 months	15	12
			3 months	6	4.8
% Tag recovery	9.0	9.8	4 months	7	5.6
			5 months	5	4
			6 months	1	0.8

Movement	No. of recaptures	Av. km moved	Av Days out
South	41	1	35
East	16	6	59
West	21	4.7	19.8
North	12	5	45
No movement	36	0	47
Total	126		

Genetic studies

Recent genetic analyses of *Scylla serrata* (mudcrab) populations have determined that four species currently exist. Of these four species only two have been identified as occurring within NT waters. It is thought that in the NT the true *Scylla serrata* species makes up around 95% of the commercial catch. The other species is called *Scylla olivacea* and can be identified by the following characteristics.

Scylla serrata

- Frontal spines between the eyes are high and bluntly pointed.
- When looking from above the carapace two obvious spines on outer margin of elbow joint of the claw
- Polygonal patterning on claws, legs and for females on abdominal flap.
- Colour variable from purple through green to brown/black depending on habitat.

Scylla olivacea

- Frontal spines between the eyes are low and rounded with shallow interspaces.
- When looking from above the carapace one blunt spines on elbow joint of the claw
- No obvious polygonal patterning on claws or legs.
- Colour variable from rusty red through brown to dark brown depending on habitat.

We are currently collecting specimens for a detailed genetic study and are seeking assistance from industry to access crabs from 5 sites across the NT.

Recommendations

It is recommended that the members of the Mud Crab Advisory Committee:

- Note and endorse the work undertaken by the mud crab research program;
- Endorse the continued monthly sampling and tagging of commercial catches of mud crab from major fishing areas around the NT;
- Endorse the continued liaison of the Department with commercial mud crab fishermen through printed material (Fishnotes, Status Reports and Newsletters) and at least two annual field trips to major crabbing areas (2 Officers for 10 days per year);
- Endorse the proposed workshop looking at a coordinated approach to mud crab research across Northern Australia;
- Support the 1999 submission to FRDC for funding to proceed with the habitat and crab density work with Qld and WA.

Abstract, Table of Contents and Conclusion of PhD Thesis

"Mud Crab (*S. serrata*) Population Dynamics in the Northern Territory, Australia and their Relationship to the Commercial Fishery"

Prepared by

Dr Ian Knuckey

GENERAL INTRODUCTION

Since hunters and fishers first depended on animals as a food source, humankind has been affected by fluctuations in the abundance of animal populations. For many millennia hunting and fishing activities probably had minimal impact on animal populations, but as human populations increased and technology improved, this began to change, especially with the relatively recent advent of mechanisation and industrialisation (Cushing 1988). The impact was probably first apparent on land, where humans could easily see and hunt down their prey and also readily observe the resultant decline in animal numbers. In the oceans, however, it was far more difficult to gauge the impact of fishing, and even at the turn of the century the notion that fish stocks were inexhaustible was still common (reviewed in Cushing 1988). Thus, despite the long history of exploitation of fish resources, their vulnerability to overfishing only became apparent during the last century. Among some of the earliest concerns, Garstang (1900) noted "impoverishment of the sea" as a result of trawling activity. Since then, there have been numerous reports about the problems of overfishing (eg. Russell 1931; Comte 1993) and the collapse of many fisheries has left no doubt as to the potential impact of man on the oceans. As Gulland (1977) stated, "The increasingly serious effect that man's activities are having on natural population of animals – whether deliberately, through direct exploitation, or accidentally through pollution or changes in the environment – is now well recognised". Recognition that fish stocks, far from being inexhaustible, require careful management if they are to sustain productive fisheries, prompted the development of modern fisheries science. This science endeavours to explain the relationships between fishing and the composition and dynamics of fish stocks.

In the early 1980's, a commercial mud crab fishery began in the Northern Territory, Australia. Over the next decade, there was considerable development of the fishery and catches increased almost tenfold. With little known about the fishery, there was concern from managers about the sustainability of the mud crab resource and whether it could be in danger of over–exploitation. As such, a research project was initiated to determine the relationships between fishing and the population biology and stock dynamics of the mud crab resource. This thesis presents much of this research.

1.1 Background information on *Scylla serrata*

1.1.1 Taxonomy

The mud crab, *Scylla serrata* (Forskål 1775), is the largest member of the family Portunidae. The main characteristics of portunids are the flattened fifth pair of legs and the typically broad, depressed or slightly convex carapace with a number of teeth cut into the front. The family is divided into six subfamilies: Carcininae Alcock 1899; Catoptrinae Borradaile 1903; Macropininae Stephenson and Campbell 1960; Caphyrinae Alcock 1899; Portuninae Stephenson and Campbell 1960; and Podophthalminae Borradaile 1907. The Portuninae contains the genus *Scylla* de Haan, 1833, of which at present, *S. serrata* (Forskål) is the only species (Table 1.1).

Keenan *et al.* (1995) and Keenan (1995) provide a good summary of the taxonomy of mud crabs. Since the species was first named as *Cancer serratus* by Forskål (1775), it has been classified into the genus *Scylla* de Haan 1883 and there have been numerous subsequent reviews of its taxonomy. One of the most extensive was by Estampador (1949a; 1949b), based on the morphology, colour, habitat, differences in gamete development and chromosome form. He proposed three species of mud crabs: *Scylla oceanica* (Dana 1852); *Scylla tranquebarica* (Fabricius 1798); *S. serrata* (Forskål 1775); and its variety *paramamosain* (Estampador 1949a). He placed the species in two easily recognisable groups: the *mamosain* (*S. serrata* and its variety), which often lived in holes and had a generally rusty/brown colour with little patterning; and the *banhawin* (*S. oceanica* and *S. tranquebarica*), which tended to have a more "nomadic life", were greenish in colouration and had large pigmented patterns on the carapace, legs and abdomen. Serene (1952) recognised only two species, which corresponded to Estampador's, groups, each with its own variety. Even though both authors agreed that there were four forms, whether species or varieties, they disagreed on features other than colour in separating them. Consequently, for simplicity, Serene (1952) retained Estampador's nomenclature. Serene (1952) also noted that colour differences were useless features for differentiating preserved specimens.

In Australia, Stephenson and Campbell (1960) classified all live specimens from New South Wales and Queensland as *S. serrata*, or its variety *paramamosain*, because they were unmarked. Although acknowledging reports of mottled crabs north of Cairns and one specimen which could possibly be classified as Serene's *S. tranquebarica*, they concluded that, until further work was undertaken, the four forms of Estampador and Serene should be tentatively fused into the synonymy as *Scylla serrata* (Forskål), the sole species of the genus *Scylla*.

Most recently, a comprehensive study by Keenan *et al.* (1995) used morphological characteristics and the genetic techniques of allozyme electrophoresis and mitochondrial DNA sequence analysis to identify three distinct species of *Scylla*. Described as "green", "brown" and "spined" forms, their scientific names have not been finalised, although the green form will almost definitely be *Scylla serrata* (Keenan pers. comm.). This is the most common form in the Northern Territory and therefore *S. serrata* is considered as the species addressed in the present study. The smaller brown form does occur in the Northern Territory, but only rarely (less than one hundred were found in the present study). It was easily differentiated from *S. serrata* and was excluded from all analyses.

1.1.2 Life cycle

Information on the biology and life–history of mud crabs has been gained from studies of natural populations (eg. Arriola 1940; Hill 1975; Perrine 1978) and laboratory reared crabs (eg. Raja Bai Naidu 1955; Ong 1964, 1966; Motoh *et al.* 1977; Heasman 1980; Heasman and Fielder 1983).

Mud crabs have a marine planktonic larval stage, which lasts approximately one month. During this time currents move the larvae inshore as they moult through four zoeal stages into a demersal megalopal stage (Fielder and Heasman 1978). In the inshore environment, larval characteristics are lost and over the next one to two years the juvenile crabs develop through sub–adult to adult over 15 – 17 instars (Ong 1966). Sexual dimorphism becomes increasingly apparent as the crabs reach maturity. Females develop a large, pigmented abdominal flap, while males develop extremely large claws, but retain a narrow, triangular abdominal flap. Mating occurs between mature, intermoult males and soft–shelled, post–pubescent females. The sperm is stored in the female's spermathecae for between two (Ong 1966) and six months (Du Plessis 1971) while the ova mature. The ova are fertilised as they are extruded onto the pleopods under the female's abdominal flap. Females migrate offshore to spawn. The eggs hatch into free–swimming zoeal larvae 20 to 40 days after fertilisation and the life–cycle is completed. Females may mate more than once (Ong 1966; Heasman 1980; present study) and can spawn up to three times from the one mating (Ong 1966). Mud crabs are reported to live to an age of at least three years (Heasman 1980).

1.1.3 Distribution and utilisation

Mud crabs are found in sheltered waters of mangrove–lined coasts throughout the Indo–West–Pacific region (Fig. 1.1). Mud crabs are prized for their tasty flesh and fisheries exist throughout most of their distribution in South Africa (Piatek 1981; Hill 1975; Robertson and Kruger 1994), Madagascar (Le Reste *et al.* 1976), Pakistan (Mustaquim and Rabbani 1976), India (Chopra 1939; Chapgar 1962), Japan and Taiwan (Cowan 1984; Sakai 1965, 1976), Malaysia (Ong 1966), the Philippines (Arriola 1940; Chua 1973; Motoh 1979), Indonesia (Kasry 1986), some Pacific Islands (Perrine 1978; Brock 1960; Delathiere 1988), Papua New Guinea (Matsuoka and Kan 1989), New Zealand (Dell 1964, Manikiam 1967) and Australia (Kailola *et al.* 1993). Although mud crabs have been found up to 50km offshore in water up to 30m deep, probably as a result of the spawning migrations of females (Hill 1982; Hill 1994), the fisheries are generally restricted to coastal areas. The total annual catch of mud crabs was estimated at around 23,000 tonnes in 1992 (FAO 1994).

In Australia, mud crabs are distributed from Exmouth Gulf on the coast of Western Australia, through the Northern Territory and Queensland to the southern coast of New South Wales. Fisheries in these states and territories have both recreational and commercial components as well as traditional indigenous users. Although the extent of recreational fishing sector is difficult to quantify, there is relatively good information available from the commercial sector. In 1990, commercial operators caught approximately 700 tonnes of mud crabs, with an estimated landed value of $7 million (Kailola *et al.* 1993). Most of this catch originated from the Northern Territory, Queensland or New South Wales and was exported live to major Australian capital cities, where it is usually sold through restaurants as a high quality seafood.

Many methods of fishing for mud crabs have developed in different countries. The most basic of these is the use of a stick or hook to extract crabs from burrows, depressions or amongst mangrove roots where they shelter at low tide. Mud crabs may also be speared, or captured by hand, while they swim in the shallows.

Commercial "crabbers" who need to keep the crabs alive for sale avoid these methods, which often damage or kill the crabs. They consequently use various styles of drag nets, tangle nets, baited hooks, long–lines, dillies, and traps; all may be constructed from a variety of materials (see Gupta and Chattergee (1976) for a review). Small canoes or dinghies are usually used to set this gear. As a reflection of the developing nature of many of the countries involved in mud crab fisheries, many fishing methods utilise limited modern technology. Even in countries such as Australia, where modern technology is readily available, people working from small outboard powered dinghies still usually catch mud crabs in simple baited traps. Despite the popularity of mud crabs as a seafood item and the extent of their exploitation throughout the Indo–west pacific region, there has been very little research on impact these fisheries have on the crabs' population dynamics.

1.2 Sustainable exploitation of a fisheries resource

A general goal in the management of many fisheries is to maximise yield whilst ensuring the long–term viability of the resource. Although this seems reasonably straight forward, the collapse of many fisheries is testament to the difficulties of such a task. The dynamics of fish stocks, like most other natural systems, are inherently complex and involve many biotic and abiotic interactions (eg. Le Cren and Holdgate 1962; Laevastu and Favorite 1988). Furthermore, exploited stocks are also influenced by the dynamics of fishing fleets and underlying economic, sociological and ethnological factors. Superimposed over this complexity is the obstacle that we are usually unable to directly observe the system and must rely on indirect methods of determining the status of the stocks and the impact of fishing. Herein lies the core role of fisheries science and it is a difficult science often relying on imprecise data. Nevertheless, there are a few principles, which need to be understood about the exploitation of a renewable resource if it is to be undertaken in a sustainable manner.

The basic principles underlying the dynamics of a fishery were summarised by Russell (1931) who hypothesised that in a closed fish population (with no immigration or emigration), the biomass would increase from the growth of fish and recruitment of young fish to the fishery. Decreases in the biomass would occur through death (natural mortality) and capture by man (fishing mortality). Thus, if the system is to be sustainable in the long–term, the removal of biomass through mortality needs to match the increases from recruitment and growth. Theoretically, we strive to achieve this "state of equilibrium" in a fishery, though in reality stock sizes always fluctuate, even without fishing (Hilborn and Walters 1992). An important factor to consider is that for recruitment to occur there must be certain proportion of the population which can reproduce – the "spawning stock". Fisheries, which have been overexploited, may collapse because the spawning stock has been reduced to such an extent (through fishing as well as other factors) that recruitment has failed. Fisheries science is used to provide sufficient knowledge of the status of the stocks to ensure the spawning stock remains adequate to support the fishery or, at the very least, provide prior warning of over–exploitation. Over the last two decades, the use of computers has revolutionised the ability of fisheries scientists to gain this type of knowledge. No longer restricted to the use of calculus and assumptions of populations in equilibrium, computer modelling allowed scientists to simulate the dynamics of fish populations under different situations and provide parameter estimates with stated levels of uncertainty. These are powerful techniques which enabled a quantum improvement in the advice fisheries scientists could give to managers so that fish stocks can be better managed in a sustainable manner with reduced risks of over–exploiation or stock collapse. Such techniques are used extensively throughout this study.

1.3 Outline of the study

The main goal of the project was to describe mud crab population dynamics in the Northern Territory and their relationship to the commercial fishery. This was undertaken so as to understand the level of impact that commercial fishing may have on the stocks and the sustainability of the fishery. To achieve this goal, there were a number of distinct, but inter–related objectives designed to provide information on the processes of growth, recruitment, migration and mortality in the Mud Crab Fishery. These are outlined below and detailed in the following chapters.

1.3.1 Objectives

- Describe the Northern Territory Mud Crab Fishery

An understanding of the fishing fleet and fishing methods is essential in the study of an exploited resource because not only does it have the potential to significantly impact the stocks, but much of the information derived from the population is fishery dependent. This includes estimates of stock abundance based on commercial catch and effort information. Without fully understanding important aspects of the fishery, such as the behaviour of crabbers, dynamics of the fishing fleet, operation and selectivity of the fishing gear, there is a strong likelihood that the catch and effort data could be misinterpreted. As such, the chapter which describes the fishery had the following aims:

- ➢ describe fishing methods, the fishing gear and the broad dynamics of the fishing fleet;
- ➢ validate and analyse the commercial catch and effort data;
- ➢ determine whether catch per unit effort (CPUE) is a valid index of abundance; and,
- ➢ discuss the potential implications of the catch and effort data for the fishery.

- Investigate the reproductive biology of mud crabs in the Northern Territory

The reproductive cycle of crustaceans has important short–term influences on a range of biological processes, such as feeding, growth, and migration (Hartnoll 1969). Moreover, for a fishery to be sustainable, enough animals must reach maturity to maintain the reproductive capacity of the population by which the resource is renewed. Thus, to understand the potential impact of fishing on the mud crab resource, it was important to gain a sound knowledge of their reproductive biology. The following steps were taken to reach this objective:

- ➢ describe the maturation in both male and female mud crabs;

- ascertain the seasonal patterns of mating, spawning and spawning migrations;
- compare the above results with other studies; and,
- discuss the implications of the reproductive cycle for the fishery.

- Describe the growth rate of mud crabs

Growth is important for a fishery because as individuals in a population grow, their increase in weight improves the yield that can be obtained from that resource. Growth rates also determine how quickly animals reach a catchable size. In a stock with limited immigration or emigration, these two aspects of population dynamics are critical to fishery production. The chapter on growth had the following aims:

- determine the growth rate of mud crabs using size frequency analysis and tagging studies;
- determine the age/size at which mud crabs are recruited to the fishery; and,
- establish size–weight relationships for male and female mud crabs.

- Describe mortality rates in the fishery

Mortality processes remove biomass from a fishery through either fishing activities or natural causes such as predation, disease and old age. It is important to distinguish and understand the relationship between these two mortality sources, because whereas levels of natural mortality are beyond our control, fishing mortality can be controlled and ultimately determines the yield that is gained from the fishery. These controls may include restricting the amount of fishing allowed, the gear that can be used or the size of crab that can be removed. They are usually introduced to ensure that total mortality rates are not high enough to threaten the reproductive capacity of a stock. My research into mortality had the following aims:

- investigate a range of methods to estimate natural and fishing mortality rates in the Mud Crab Fishery; and
- determine the selectivity of commercial fishing gear and its influence on mortality rates.

- Develop mathematical models which help describe the Mud Crab Fishery

Mathematical modelling provides a means of simulating and exploring the population dynamics of a fishery. The following aims were incorporated into the modelling chapter:

- develop models of the fishery which incorporate and synthesise the available information to help understand and explain the population dynamics of mud crabs in the Northern Territory and determine the impact of commercial fishing on the stocks;
- provide fisheries managers with the most current information and interpretation of the major factors influencing the fishery;
- develop a modelling framework as a basis for further investigations into the fishery; and,

- highlight areas of uncertainty in our understanding of the processes underlying the fishery and suggest future research avenues.

1.3.2 Outcomes

The scope of the thesis is defined by the goal of describing mud crab population dynamics in the Northern Territory and their relationship to the commercial fishery. In achieving this goal, an extensive amount of information was collected on important biological processes such as growth reproduction and mortality. Thus, whilst describing the fishery, I also hope to contribute to our general understanding of crustacean biology and ecology. As a study of a fishery, however, it is important to highlight the limitations in the scope of the project. Regardless of how much is known about a fishery, its long–term sustainability and economic viability depends on a sound management strategy. Whilst my research may provide the information and modelling tools with which management decisions can be made, there has been no endeavour to suggest or test different management strategies that could be utilised in the fishery. To do this, one would need to undertake further research to understand and assess the economic, sociological and hence political implications of such strategies on the specific resource users and society in general. The evaluation of management strategies was considered well outside the scope of this thesis. However, it is hoped that the information provided in this thesis will be used by fisheries managers to support and guide management decisions, which will ensure the long–term viability of the fishery with regards to both the stocks and the people who utilise the resource.

Conclusions

"The essential biological feature of any fishery is the dynamics of the fish population" Hilborn and Walters 1992.

The Northern Territory Mud Crab Fishery is characterised by a seasonal pattern of high catches during the dry season months of June to October followed by lower catches during the wet season, when the fishery virtually closes down. The present study has elucidated aspects of the population dynamics of the mud crab resource that explain this pattern.

Whilst a low level of spawning may occur throughout the year, the main spawning period appears to be during the peak of the wet season (December – February), when the females move offshore to spawn, and beyond susceptibility to the inshore fishery. The months following spawning and the early life history of mud crabs are the least well known of the mud crab life–cycle. Although it appears that most mature females move offshore to spawn, it is unclear how long they remain offshore, what proportion of females undergo multiple spawnings, or what is the batch size and viability of subsequent spawns. Little is also known of the timing or mechanisms by which the larvae or small juveniles move back into the inshore mangrove regions or of their growth and survival during this period. Nevertheless, it appears that about one year after spawning, the crabs have reached a size of around 130-mm CW at which stage they begin to become vulnerable to the fishery. This recruitment to the fishery begins in February/March but their small size determines that a low proportion will be caught by the pots at this stage. The fishery builds up during the following months as these new recruits become increasingly vulnerable to capture by the commercial gear, which is biased towards the larger crabs. Effort increases rapidly as crabbers return to the fishery after their break during the relatively unproductive months of the wet season. CPUE also increases during this time and by mid–year the effort, catches and CPUE in the fishery have usually reached their maximum. There may be a slight drop in catches in July to August possibly because lower water temperatures reduce the catchability of the crabs, but catches generally remain high until November. Catches in the early months of the year consist mainly of males, but by mid year, the sex ratio of catches is even, and moves to an increasing predominance of females during the latter months of the year. This is probably because crabbers specifically target the females as they begin to migrate offshore, but it is also possible that female's catchability increases during this time. At the end of the year, however, catch rates drop rapidly, females virtually disappear, catches decline and the fishery closes down. The timing and extent of this annual decline is probably determined by the complex interplay of the dynamics of the resource, the behaviour of the fishing fleet and the onset of the wet season. It appears that one of the major reasons is that extensive fishing has significantly reduced the number of crabs remaining in the stock from the recruitment pulse early in the year. The movement of spawning females away from the inshore fishery and possibly reduced catchability of males during the wet season compounds this effect. Combined with these inherent stock dynamics, the onset of the wet season reduces road access to many of the major fishing areas and living in tents or shacks and working from small dinghies becomes most impractical and unpleasant. Consequently, the crabbers, who have been working virtually seven days a week for up to nine months in these isolated conditions, are ready to stop fishing. There is three months of little activity in the fishery. Crabbers begin to return to the fishery as early as February / March, as much to ensure a "claim" on good fishing areas as to begin fishing; because catches at this time are generally low. Catches are mainly comprised of the few remaining crabs from the previous season and males dominate the catches because most mature females are probably still offshore. Catches begin to improve as the next season's recruits begin to enter the fishery and the females return from offshore. The annual cycle in the fishery then repeats.

Within this seasonal regime, the fishery has undergone significant development since 1983. Details of this development were elucidated through analysis of catch and effort data from commercial fishing logbooks. Logbook catch records were validated using airline cargo figures and revealed that under–reporting did occur but was not consistent and usually below 10%. Effort has expanded from 100,000 potdays/year to nearly 600,000 and has resulted in an increase in annual reported catches from around 30 t in 1983 to 260 t in 1995. This expansion occurred despite the introduction of input controls in 1985; basically through the uptake of latent effort. The 49 licences in the fishery when it became limited entry are now being worked more days each month and more months of the year. Furthermore, the maximum of 60 pots per licence is now being fully utilised. During this period of expansion, the use of "potday" has remained as a relatively stable measure of effort. Technology creep does not appear to have been a major issue in the fishery. Double checking of pots has become more common, however, possibly resulting in about a 10 – 15% increase of the effective effort of a potday over the last decade. This figure is of a similar magnitude to the level of under–reporting, so overall, CPUE figures were considered to be reasonably valid. They were not, however, necessarily a good index of abundance over the years.

As the fishery developed, it also expanded into new and more remote regions of the Northern Territory. As such, the stock available to the fishery has effectively increased over time. Consequently, we have seen annual catches increase in almost direct proportion to the significant increase in effort. Accordingly, annual CPUE has remained relatively stable. Whilst this could be interpreted as the fishery having little impact on the stocks, this was not supported in the model of the fishery or by other data. The more likely hypothesis was that annual CPUE was not a good index of abundance. Within individual years, however, it was considered that expansion was negligible and the selective use of monthly CPUE could be used as an index of abundance. Analysis and modelling of monthly catch and effort figures suggested that the regular seasonal decline in CPUE during the wet season reflected a decline in mud crab abundance and/or catchability during this period. Furthermore, it was apparent that the fishery was exerting considerable pressure on the stocks. With exploitation rates around 50%, most of the crabs are caught during their first year in the fishery. Although most of these crabs are mature when they are caught, they may not have necessarily spawned, so the high exploitation rates have the potential to significantly reduce the reproductive capacity of the stock. Model predictions indicate that only about 20% of 1+ females are left in the stock at the time of the main offshore spawning migrations. Whether this could result in recruitment over-fishing is uncertain, because as yet, no stock–recruitment relationship has been established. Nevertheless, the potential exists, and this has important implications for a fishery dependent on input controls. These are discussed below.

The main management controls in the commercial Mud Crab Fishery in the Northern Territory are the minimum legal size limit (130-mm) and the restrictions on the number of licences (49) and the number of pots operated by each licence (60). These input controls were introduced in 1985, but in the following decade, developments in the fishery have had important implications of the effectiveness of these controls.

Minimum size regulations are common in invertebrate fisheries and, as Jamieson and Caddy (1986) state "... are often justified to protect the reproductive capacity of the stock, even if a clear stock-recruitment relationship is not known, and/or to restrict the harvest of size categories to those sizes most amenable to processing or market demand." This was the case in the Mud Crab Fishery, where a size limit was initially introduced based on marketing requirements and only minimal understanding of the animal's biology and population dynamics. Unbeknown to managers at the time, the adoption of a relatively standard pot construction and mesh size (75mm × 50mm) by commercial crabbers, introduced a gear selectivity which effectively increased the size limit and has provided protection for a greater proportion of the mud crab population to reach maturity than the legislated size limit. This highlights the importance of understanding the interaction of size limits and gear selectivity. In many crab and lobster fisheries, introduction of minimum-sized mesh or escape gaps into the traps has been required so that these undersize animals do not get caught (Brown 1982; Methot 1986; Elner and Bailey 1986). It is fortunate in the Northern Territory Mud Crab Fishery, that the standard gear has a selectivity well suited to both the size at maturity and yield-per-recruit of mud crabs. The controls on this selectivity are not legislated, however, so there is potential for a reduction in capture size if gear designs change. Recognising this, in 1995 managers introduced a higher size limit for female mud crabs (140 mm) in the Northern Territory. This corresponds to a size at which about 70% of female crabs are mature. Although there was no evidence of recruitment overfishing, there was negligible opposition to this introduction, as it was seen as a precautionary measure which would protect the reproductive stock and have little impact on catches. The size limit for males remained at 130 mm. This was justified because crabbers expressed that small males were important for their markets, and based on the present study, there appeared to be less of a need for the same protection as females (see Chapter 4).

In the Northern Territory Mud Crab Fishery, both male and female crabs are retained. Many crab fisheries, (Methot 1989; Bailey and Elner 1989) including the mud crab fishery in Queensland (Heasman and Fielder 1977), do not allow females to be retained. This is a conservative measure, which assumes that the size limit protects sufficient mature males to adequately fertilise the unfished female population. The validity of this assumption has been questioned (eg. Heasman 1980; Hill 1982) and research into the fertilisation rates of female mud crabs in Queensland revealed that between 70 and 90% of females were fertilised. This is lower than fertilisation rates in the Northern Territory, which were around 100%, but the relative proportion of females in catches in Queensland (Wayne Sumpton pers. comm. Queensland Department of Primary Industry) is higher than the Northern Territory, presumably because they are fully protected. Also, the present study found that only about one third of male mud crabs had mating scars, although there was the potential for other males to mate. Thus, it may be concluded that, to a certain extent, the sex ratio of a population could be significantly biased towards females without the risk of increasing the levels of unfertilised females. Nevertheless, there is ultimately a trade-off between a management strategy that totally protects females at the risk that a proportion of these females may not be fertilised and another that allows females to be taken at an increased risk of recruitment overfishing. These two management regimes are evident in Queensland and the Northern Territory respectively. Whether one proves to be more successful in maintaining the long-term viability of the fishery remains to be seen. The input controls and restrictions on fishing effort in Queensland are far less restrictive than in the Northern Territory (Bartleet *et al.* 1993), so it is possible that the Queensland fishery requires more stringent controls on the size limit (which is 150 mm CW) and the taking of females. Nevertheless, there are indications that recent developments (see below) in the Northern Territory fishery may be undermining the current input controls.

Limitation of potential fishing effort through pot and licence restrictions is the other major aspect of the management controls in the Northern Territory Mud Crab Fishery. During the term of this study, the fishery appeared to be developing within the bounds of these restrictions. The practice of hauling pots more than once a day, began to be more prevalent in the later years of the study and indicates a means of "getting around" these restrictions. Apparently, this practice is now very common and is not just restricted to spring tides (Chris Calogeras pers. comm. NTDPIF, 1997; also see Chapter 3). Calogeras (pers. comm. 1997) also reports that based on enforcement activity undertaken in 1997, large numbers of illegal pots (above the maximum of 60 per licence) were evident in the fishery and crabbers use their "crew" to assist working these extra pots. All of these practices reduce the effectiveness of input controls. Similar problems are encountered in most fishery managed by input controls (Hilborn and Walters 1992). The ways in which such problems are addressed, however, are extremely varied and depend on the specific circumstances in the fishery; not just the factors effecting stock dynamics, but also the economic, sociological and ethnological aspects of the fishery. As mentioned in the General Introduction, this is the role of fisheries management and outside the scope of this thesis. Nevertheless, in concluding this thesis, it is worthwhile discussing the management implications of the research and the potential areas of future research.

Due to the cryptic nature of mangrove habitats and the vast and isolated coast over which the Northern Territory Mud Crab Fishery operates, enforcement of the number of pots which crabbers use will always be difficult. As such, the potential for effort to increase beyond that envisaged in the initial management restrictions will exist. In contrast, the size limit is an aspect of the management controls which is easily enforceable because nearly all of the mud crabs caught in the Northern Territory are air-freighted out through Darwin. This being the case, if input controls are to remain as the main management tool, the requirement for an adequate size limit is essential to protect the stocks from recruitment overfishing. Despite the work undertaken in the present study, there are still components of the mud crab life cycle and population dynamics, which require further research if this protection is to be ensured. High among these is the establishment of a stock-recruitment relationship (see Chapter 4). Underpinning this is the need to develop a means of determining the size of the female spawning stock and an index of recruitment. Neither of these is simple.

Determination of spawning stock size will require a better understanding of the reproductive outputs by the two or more mature female instars, and this will be influenced by incidence of multiple spawnings within each instar, their relative fecundity and fertilisation rates, and timing relative to the seasonal fishing pressure. The percentage of the mature stock which migrate offshore and spawn will also be important, as will be the length of time they remain offshore and their movement back into the inshore environment.

The difficulties in developing a recruitment index based on larval abundance or 0+ crabs have already been highlighted. Although continued research into these areas may be fruitful, it is expensive and alternative measures may be more appropriate. Other invertebrate fisheries have used methods such as pre-season catch rates or surveys of larvae or juveniles (eg. Phillips and Hall 1978; Okutani and Watanabe 1983) as recruitment indices. In the Northern Territory Mud Crab Fishery, commercial catch rates between March and May combined with information on the percentage of immature females may be useful in this manner, although allowance for the selectivity of the commercial gear would have to be included.

Mud Crab Research in South Queensland

(prepared by Ian Brown 27/05/99)

Heasman, M. 1976-80 Aspects of the general biology and fishery of the mud *crab Scylla serrata* (Forskal) in Moreton Bay, Queensland. Ph.D. thesis, Zoology Dept University of Queensland.

Williams, M. and Lee, C. 1980. Short study on methods for determining the size and sex of marketed mud crabs in Queensland.

- Introduced concept of alternative (underbody) measurement in both species. Also provided criteria for distinguishing female claws on basis of meral setae brush.

Hill, B. *et al.* The Queensland mud crab fishery. 1979-82. FIRTA Project.

- Description of the fishery (fishing gear and operations, economic survey, catch trends)
- Biology (population studies, movement and growth, larval recruitment, storage and transport)
- Management issues (legislation and enforcement, minimum legal size, protection of females, pot restrictions, bah limits, impact of hooking, crab meating operations, fattening and grow-out, habitat protection.

Keenan, C., Davie, P and Mann, D. ~ 1996-8. ACIAR Small Project "Genetic relationships and identification of mud crabs, genus *Scylla*, from the Indo-Pacific."

- Resulted in a revision of the genus, published 1998.

Keenan, C. *et al.* (Current collaborative ACIAR Project with NT and Philippines). Development of improved mud crab culture systems in the Philippines and Australia.

- Aimed at optimising broodstock management, hatchery and larval rearing procedures, and pond grow-out techniques.

Walker, M., Anderson, L. and Norton, J. Mud crab carapace necrotic lesion project.

- Current collaborative project between Central Queensland University and QDPI Vet Pathology; commenced 1996 and this year funded by FRDC. Aimed at determining the cause of necrotic degeneration of the carapaces of mud crabs in (primarily) the Port Curtis (Gladstone) area. Investigating histopathology, intra-and inter-specific transmission, geographic distribution and incidence. An extension of the project, to include a tagging study, is proposed.

Keenan, C. et al. 1998. Commercialisation of mud crab aquaculture in Australia.

- FRDC proposal for 1999-2000; unsuccessful.

Brown, I., Hay, T. and Gribble, N. 1998. Estimation of mud crab stocks and the effects of the single-sex harvesting policy.

- FRDC proposal for 1999-2000; unsuccessful (at QFIRAC level).

MUD CRABS (*Scylla serrata*)

Analysis of commercial fisheries data

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13 January 1999

INTRODUCTION:

The following tabulations and graphs are based upon data extracted from the commercial fisheries logbook database Qfish by Ms K Yeomans (Southern Fisheries Centre) on 27 October 1998. The extract (from the MIXED FISHERY database) used a modified "Dump" SQL script which selected records where the species code was identified as 702001 (mud crab) and 702000 (unspecified crab). A separate retrieval was done for species code 702800 (mud crab claws) but this was not used in the present analysis. The modified Dump script selected records regardless of whether location data (latitude and longitude) were present.

The total number of records (i.e. supposed daily logbook records) for the period between 1.1.88 and 27.10.98 was 232,030. Of these, 230,707 related to species code 702001, and 1,323 to species code 702000. Mud crab catches are usually reported in the logbooks as kilograms, but in some instances they are reported as number of bodies. Records with catch as weight numbered 218,671, and those with catch as bodies numbered 13,836. This has been dealt with simply by adding the number of bodies to the weight figure, on the basis that on average a mud crab weighs 1.0 kg.

TOTAL COMMERCIAL LANDINGS:

The total catch of mud crabs each year for the whole of the Queensland fishery is shown in Figure 1. This indicates a slight but steady upward trend in catches, from about 300 t in 1988 to over 500 t in 1987. Some data for 1998 are available, but because they are incomplete they are not shown here.

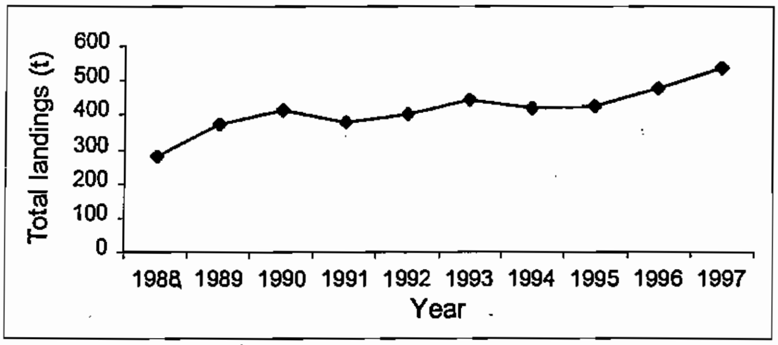


Figure 1 Total annual reported catch of mud crabs (including catches of "unspecified" crabs) for the entire Queensland coast, including the Gulf of Carpentaria.

CATCH, EFFORT AND CPUE:

In this section certain filters have been applied to the catch data in order to remove inconsistent or problematic records which may compromise an analysis of catch-per-unit-effort. The filters are as follows:

- Only mud crabs (spc = 702001) are included, because of the possibility that "unspecified crabs" may have included blue swimmer crabs. This is a likely scenario, as catch rates for "unspecified crabs" tended to be higher than those for mud crabs.

- Catch weight was calculated as the sum of Wt and catch_number.

- Only records where Wt<100 kg were included. While this may have had the effect of excluding a few genuine high daily catches, its main function was to eliminate as many as possible of the "bulked" entries, the inclusion of which would have introduced serious error into the catch rate (CPUE) calculations. Bulked entries are those where only the cumulative catch from (say) a week or a month's fishing is reported.

- Only includes records where lifts>4 and <=100. Again this is to remove records where (i) there is no pot lifts information given, (ii) where the catch has been bulk-entered.

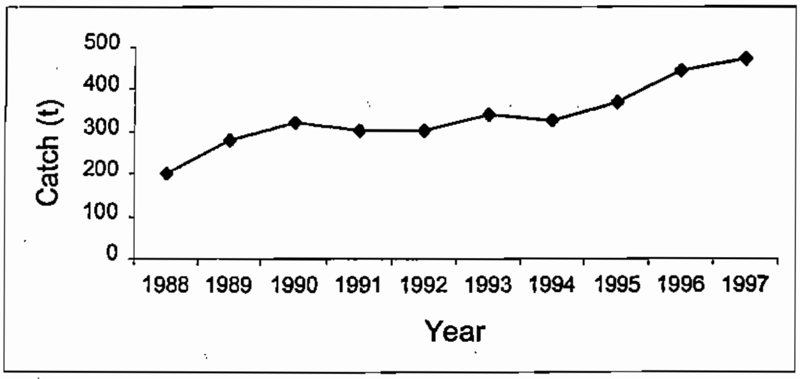


Figure 2. Annual catches (filtered data) used to calculate CPUE.

The annual trend in the filtered data (Figure 2) is similar to that in Figure 1, although the filtering has slightly reduced the annual catches. It would appear from an assessment of changes in fishing effort over the same period of time (Figure 3) that the increase in total commercial landings may be attributable - at least in part - to increased fishing effort. Reported pot lifts have risen from a little over 400,000 in 1988 to about 1,100,000 in 1997, an increase of 175%. The resultant catch rate or CPUE trajectory shows a gradual decline (Figure 4) from around 5.5 kg/pot lift in the early part of the logbook period to 4.5 kg/lift in 1997.

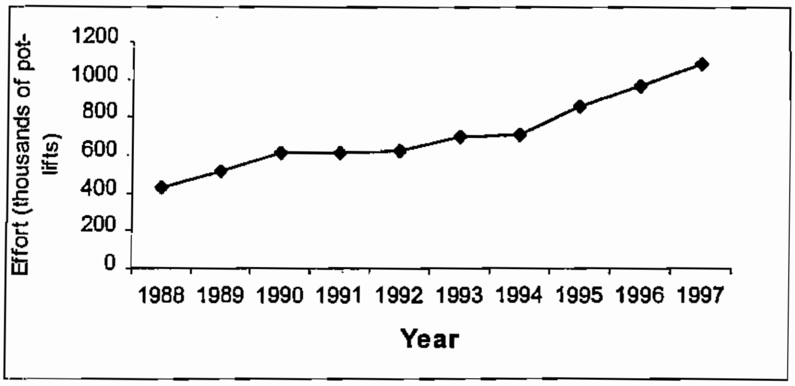


Figure 3. Fishing effort trends over time for the whole Queensland mud crab pot fishery. This slightly underestimates actual total effort because of data filtering.

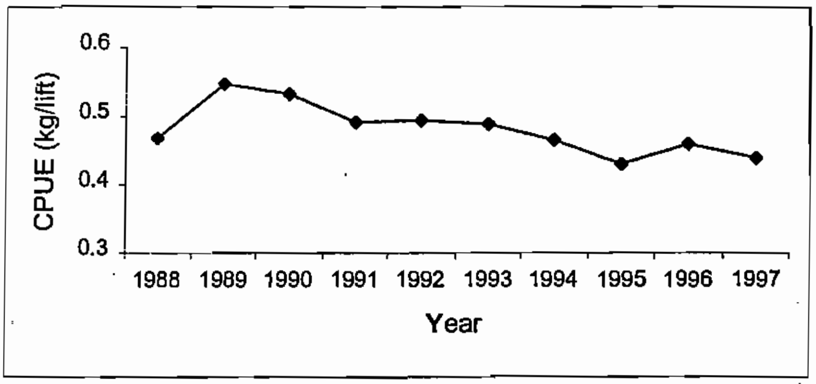


Figure 4. Catch rate (catch-per-unit-effort, as kg/pot lift) of mud crabs (code 702001 only) derived from filtered data set for the entire Queensland coast.

REGIONAL TRENDS IN CATCH, EFFORT AND CPUE:

It is possible that this decrease in overall catch rate may have been due to the depletion of areas in the fishery which have only recently become established. In order to examine this more closely, the (filtered) data set was analysed by region to identify which geographic areas has contributed most to the aggregate catch over the logbook period. Data from the Gulf of Carpentaria (GOC; west of longitude 142° 30') and the East Coast (east of longitude 142° 30') are examined separately, because of the intention to apply different management strategies to the two regions. For consistency, the data have been filtered in the same way as previously, although it is recognised that this may result in a slight bias between regions because of differences in the "typical" fishing operation.

The distribution of catch by one-degree latitude band (as a percentage of the total aggregate landings over the 10-year logbook period) is shown in Figure 5. The bands are identified in the figure by an obvious local feature, river, city or town, and are arranged so that the upper section of the graph refers to the GOC and the lower section to the East Coast. Clearly the areas which have contributed most to Queensland's mud crab landings are those in the vicinity of Curtis Island (Gladstone), Broad Sound, Maryborough, and Moreton Bay. The catch from each of these areas constituted more than 10% of the total landings, Curtis Is/Gladstone itself being responsible for more than one-fifth (Fig 5).

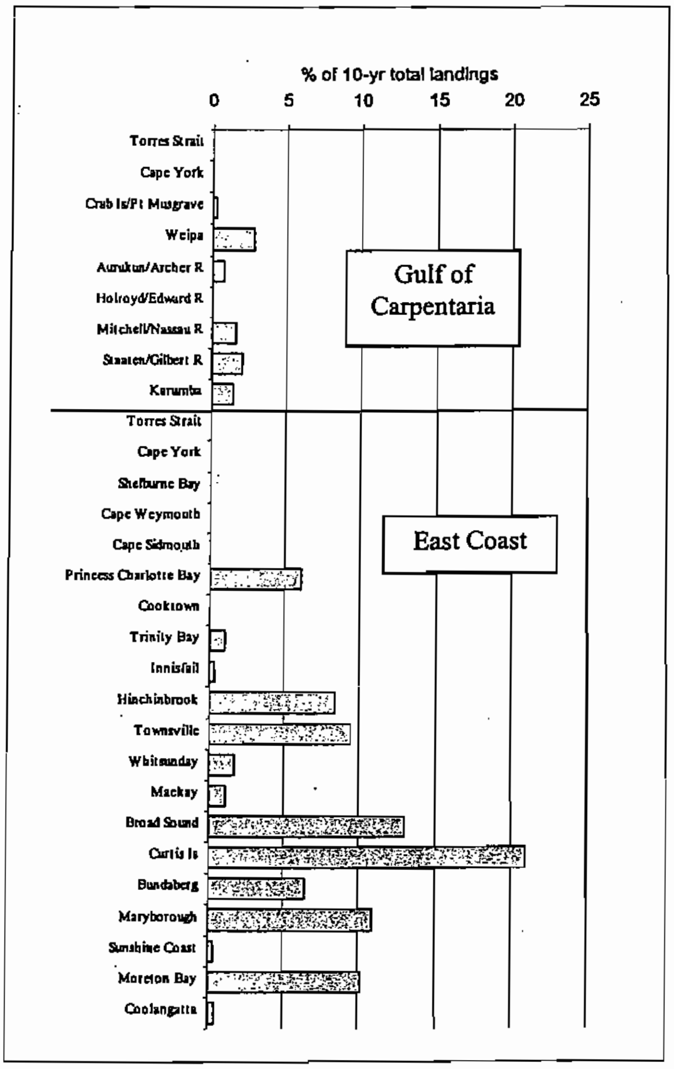


Figure 5. Spatial distribution of the Queensland mud crab fishery, showing the proportional contribution to the 10-yr aggregate landings of each area spanning 1° of latitude and identified by major feature or town.

The four top producing areas along both the GOC and the East Coasts were examined in more detail to see whether there were any trends in catch rate that might provide evidence of changes in stock density. The following figures are again based on records for mud crabs (not unspecified crabs), with the application of the filters specified on page 2.

Gulf of Carpentaria

Catches of mud crabs in the Gulf were modest and variable from 1989 (when fisheries data collection commenced) to 1994, with annual landings up to approx. 10 tonnes registered in the Staaten/Gilbert, Karumba and Mitchell/Nassau areas (Figure 6). Catches from around Karumba declined from about 8 t in 1992 to almost nothing in 1994, but subsequently showed a strong recovery, increasing to 15 t in 1997. There was also a

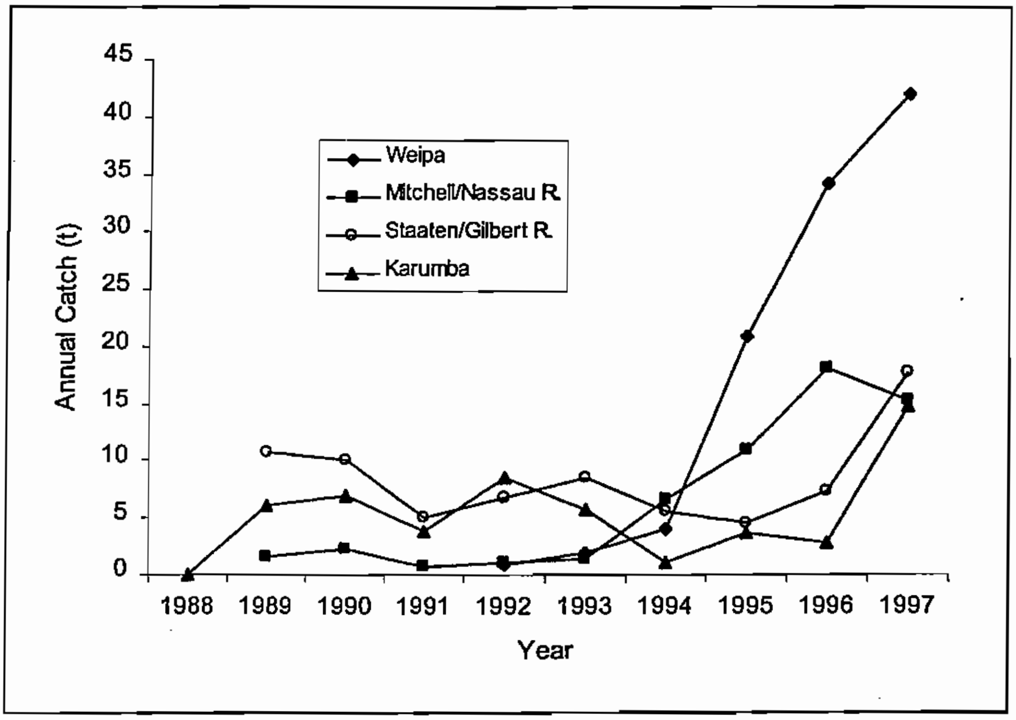


Figure 6 Annual trends in reported catch (t) of mud crabs from each of the four highest-producing 1° latitude bands on the Gulf coast.

significant increase in the Staaten/Gilbert catch between 1996 and 1997, and a general upward trend in production in the Mitchell/Nassau area after 1992-93. However the most spectacular expansion in the Gulf component of the fishery occurred in the Weipa area (i.e. the 1° band of latitude including the town of Weipa). Here production rose progressively from less than 1 t in 1992 to over 40 t in 1997. The figures portrayed in Figure 6 do not, by themselves, provide much information about stock abundance - changes in catch (production) may simply be due to changes in the amount of fishing effort applied in over time in the different areas. To factor out the "effort effect", catches are divided by effort (in this case the number of pot lifts required to take the catch) to produce catch rates or CPUEs.

Recognising the presence of some year-to-year variation in catch rates, there seems to have been a general tendency in the Gulf for CPUEs to decline between 1989 and about 1992, then to increase over the next 4-5 years to levels similar to those at the commencement of catch reporting (Figure 7). The very low CPUE shown for Karumba in 1988 is not of concern, since it represents data based on a mere 28 fishing days. Some of the increase in catch rate shown in Figure 7 can probably be attributed to increasing skill amongst crab fishers, but a general and gradual increase in mud-crab abundance since 1992 may also have been a contributing factor. It is of interest to note that the catch-rate trajectory for Weipa is consistently higher (by nearly 20%) than those in the more southerly parts of the Gulf. This may again reflect greater operator-skill or experience in that area, but the data cannot rule out the possibility that the Weipa sub-fishery (having only become established in the past 5 or so years) has been harvesting accumulated stock. With time, catch rates in that area may decline to those reported from areas which have been fished for considerably longer.

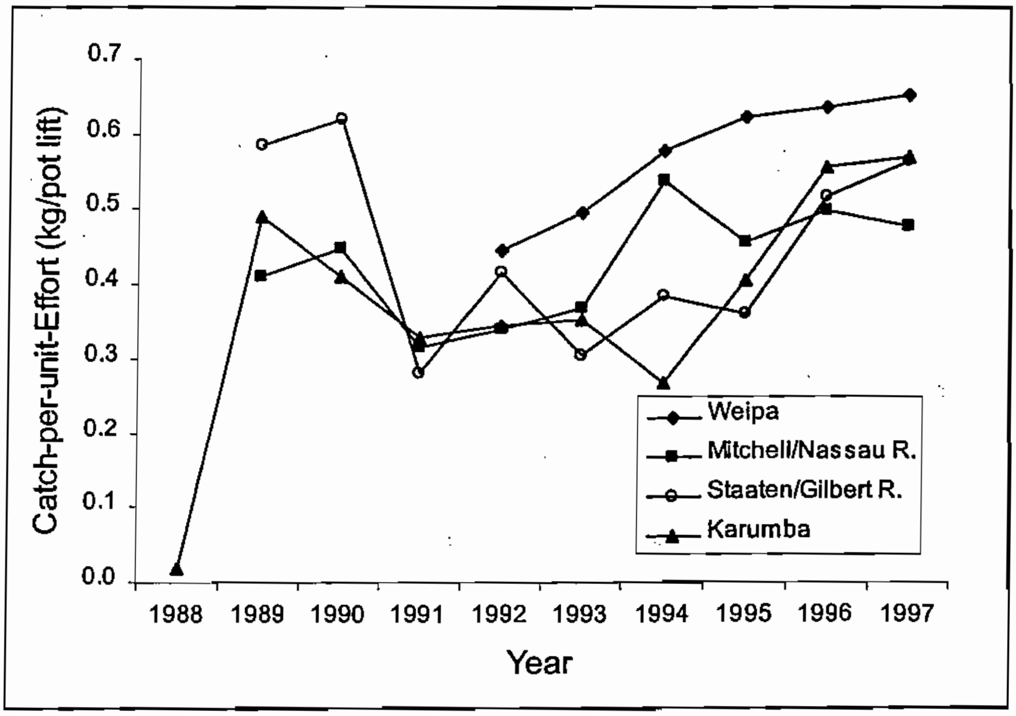


Figure 7 Annual trends in reported catch-per-unit-effort of mud crabs from each of the four highest-producing areas on the Gulf coast. CPUE is defined as kilograms per pot lift.

East Coast

In terms of changes in total annual catch, three of the four areas (Broad Sound/St Lawrence, Maryborough and Moreton) appear to have been relatively stable over the 10-year reporting period, with annual catches ranging from about 20 to 50 tonnes (Figure 8). Of particular interest, however, is the trajectory for Curtis/Gladstone. In this area the mud crab fishery expanded quite dramatically between 1988 (with an annual catch of 34 t) and 1993 (when the reported catch was nearly 90 tonnes) (Figure 8).

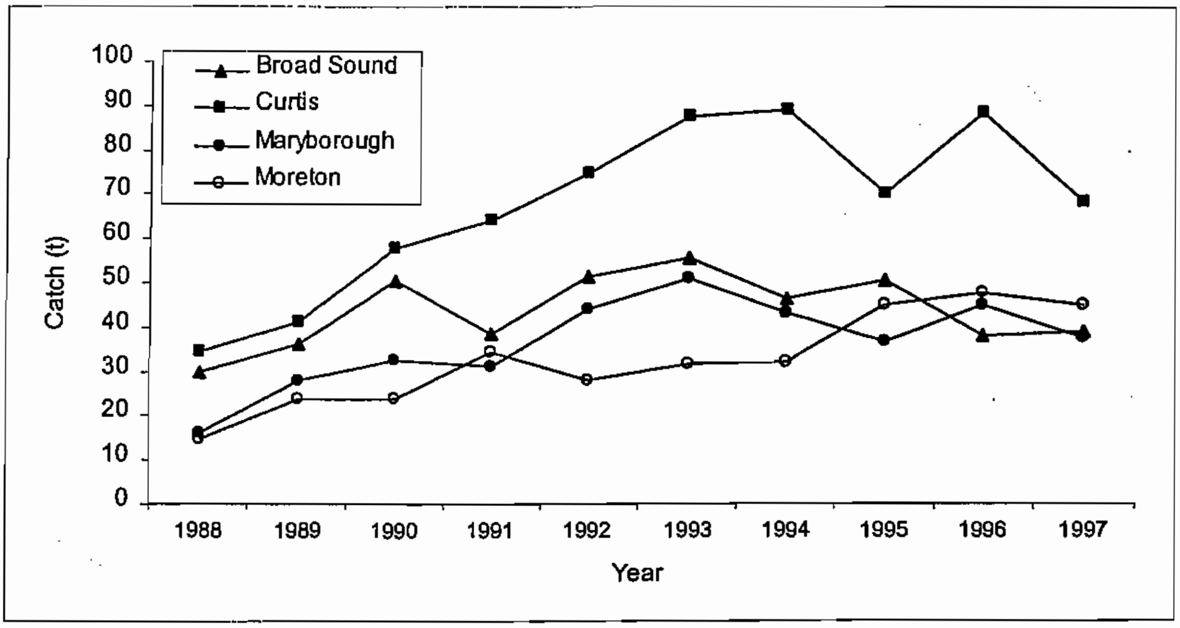


Figure 8. Annual trends in reported catch (t) of mud crabs from each of the four highest-producing areas on the east coast.

When the catch rates (CPUEs) are calculated, it becomes evident that the variation in total catches in all areas except for Broad Sound/St Lawrence were driven primarily by changes in fishing effort rather than by any clear fluctuation in stock density. This is shown by the relatively horizontal CPUE trajectories in Figure 9. Clearly there were year-to-year variations, but these were minor, and showed little consistent trend in one direction or the other. The outstanding exception to this situation occurred in the Broad Sound/St Lawrence area, where CPUEs remained very high (0.7-0.8 kg/pot lift) during the period up to 1992, then declined progressively to about 0.45 kg/pot lift in 1997

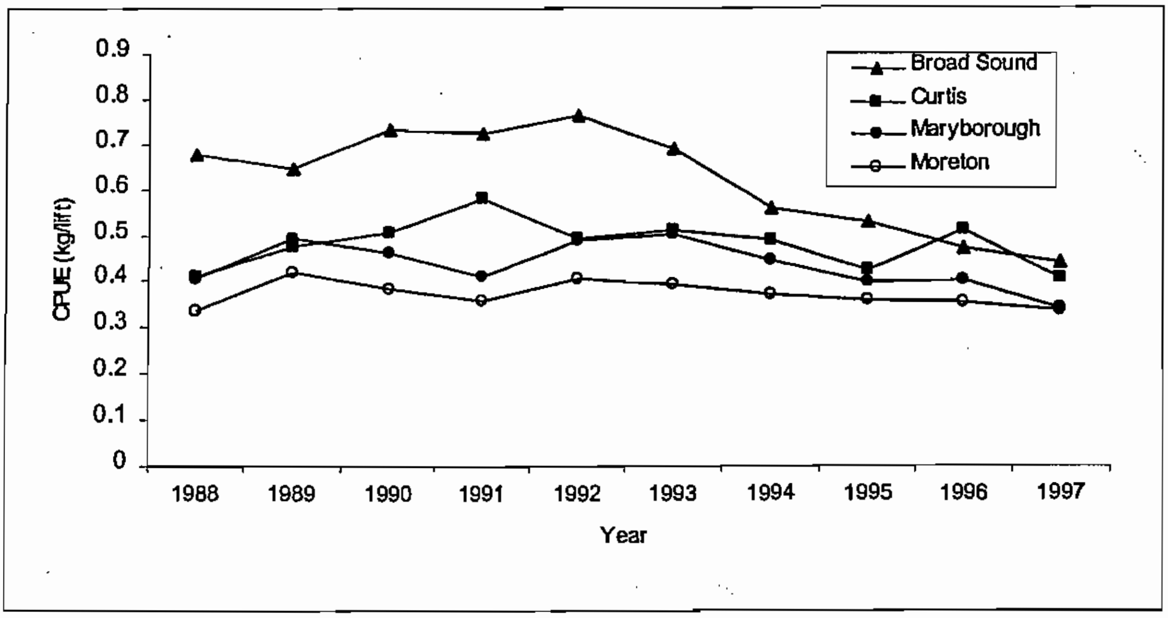
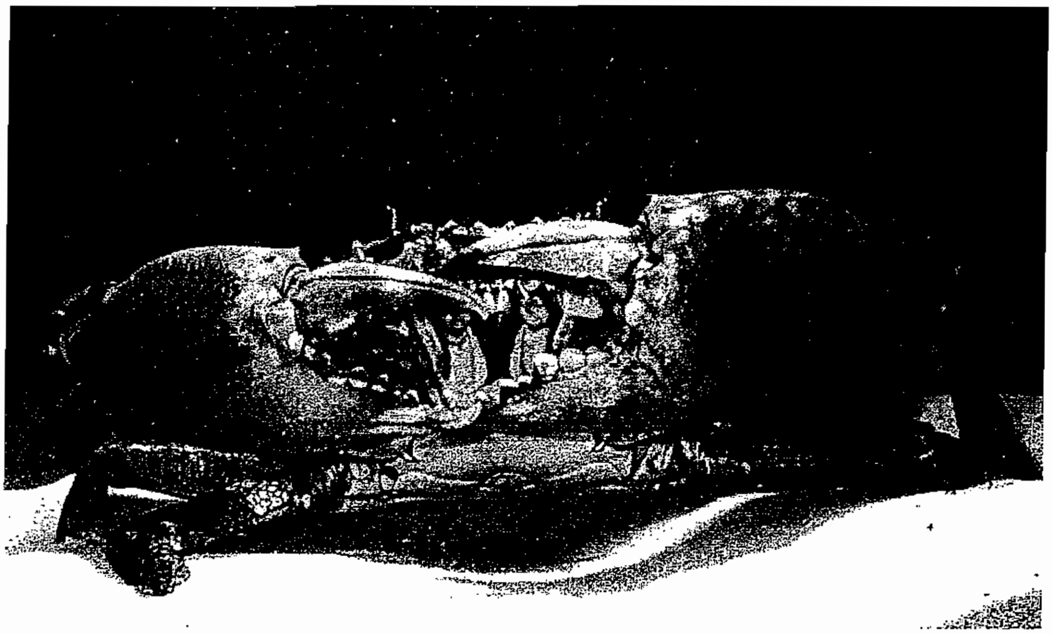


Figure 9 Annual trends in reported catch-per-unit-effort of mud crabs from each of the four highest-producing areas on the East Coast. CPUE is defined as kilograms per pot lift.

(Figure 9). This indicates that the increasing fishing effort being applied in this area may have resulted in an overall stock reduction in the past five or six years, which manifests as a drop in catch rate.

In general terms Queensland's mud crab fishery appears (from basic analysis of the commercial catch and effort data reported through the compulsory Qfish Logbook system) to be in a reasonably healthy state. While annual fishing effort is increasing - in some areas quite dramatically - catches are also increasing, although perhaps not quite at the same rate. The data suggest that on the East Coast there is a slight downward trend in catch rate, perhaps signifying a reduction in overall stock size, but this may be due to the effect of a single area (Broad Sound/St Lawrence). In contrast, CPUEs in the Gulf component of the fishery appear to be increasing. In 1997 (the most recent year for which the fishery data are considered complete), catch rates in the Gulf ranged from about 0.4 to 0.6 kg/lift (i.e. about one legal sized crab per two pot lifts), while those on the more heavily-fished East Coast ranged from 0.3 to 0.45 kg/lift (about two crabs per five pot lifts).

Most of the above analyses and comparisons are based on a subset of the data, representing a small number of geographic areas where (over the past 10 years) catches have been consistently higher than elsewhere. It is possible that slightly different result may be obtained if the total data set were analysed, as there are undoubtedly less productive areas where moderate amounts of fishing effort are being expended. However the foregoing may be considered a baseline against which future changes in catch, effort and catch-rate can be tested in the most important parts of the Queensland mud crab fishery.



Tropical Resource Assessment Program: Summary of Mud crab distribution in Queensland.

Produced for the CRABMAC working group meeting
Northern Fisheries Centre
17 September 1998

Dr Neil Gribble and Sue Helmke
Northern Fisheries Centre, Cairns

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Tropical Resource Assessment Program: Summary of mud crab distribution in Tropical Queensland.

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Tropical Resource Assessment Program
Northern Fisheries Centre, Cairns

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Summary of Mud Crab stock status.

Gulf (1996 TRAP Annual report)

- Total catch of mud crabs in the Queensland Gulf of Carpentaria has continually increased since 1994, as has fishing effort, but CPUE has remained relatively stable over this period.
- The catch and effort for mud crabs in the Karrumba region has remained steady with a slight increase in CPUE over 1994 to 1997.
- The catch and effort for mud crabs in the Weipa region has continually increased over 1994 to 1997, but again CPUE has remained relatively stable over this period.
- The trends in catch and effort for mud crabs from the Queensland Gulf of Carpentaria are those of a developing fishery with some areas of the Gulf at maturity while others are newly exploited.
- The overall CPUE is still relatively stable which would suggest that the fishery is healthy, but the CPUE could be being maintained by the continual exploitation of new areas; ie Weipa.

Comment

- The data reflect a continuation of trends observed and noted in the TRAP 1996 Annual report. The fishery is developing and it will not be possible to model the stock dynamics until the catch and effect has stabilised or until the CPUE starts to drop.
- The current summary has extracted data relating to the major river systems (ie the main areas of mud crab habitat). This breakdown was originally requested by fishers that set pots in particular rivers rather than travel long distances, and subsequently by the TRAP stock assessment workshop.
- Staff of the NT Fisheries informally requested information on the catch close to the NT/Qld border. There had been a marked increase in crabs reported caught on the NT side but no corresponding increase on the Queensland side in 1996.

East Coast (1997 TRAP Annual report)

- The catch and effort logbook records indicate an increase in the annual catch of Mud Crab from 21 tonnes in 1985 to 116 tonnes in 1996. The annual catch was highest in 1991 at 146 tonnes.
- Only the current database contained information on the number of pots and pot lifts. Historic data prior to 1988 reports only the boats that caught mud crab.
- A minimum of 51 days per boat was spent harvesting Mud Crab in 1985 and 84 days per boat was the maximum observed in 1989. On average, 71 days were fished per boat each year between 1985 and 1996. Effort has increased roughly in line with catch although there are apparent discrepancies.
- CPUE was highest in 1990 at 1 148 kg per boat. However, the annual CPUE remained relatively stable from 1991 to 1996 at approximately one tonne per boat, except for 1993 when the annual CPUE decreased to 688 kg per boat.

Comment.

- The historic and current logbooks were unfortunately incompatible in terms of the recorded Mud Crab information (pot lift information), and therefore for reliability detailed assessment has had to be restricted to 1989 to 1995.
- There is a wider spatial disparity in catches and a large number of operators on the East Coast compared to the Gulf fishery. Also the relationship between effort and catch was not as direct, all of which limits the use of CPUE as an indicator of stock abundance.
- Taking these constraints into consideration, the CPUE and catch for Mud Crab appear to have been relatively stable for the East Coast fishery with a slight upward trend over the last 4 years. Again it will not be possible to model the stock dynamics until the catch and effect has stabilised or until the CPUE starts to drop.

Recommendation from the TRAP stock Assessment Workshop, Cairns 1997.

There were two major suggestions made during analysis of the collated catch and effort data:

- **Use habitat area (mangrove area and stream length) as an alias for mud crab abundance to estimate the size of mud crab stocks.**

Prof. Carl Walters, of the University of British Columbia, acting as a stock assessment consultant to the NT Government used the area of mangrove habitat in coastal NT as an alias for mud crab abundance. Given that there was little stock assessment information in the Queensland mud crab logbook CPUE it was recommended that a similar technique might be applied in Queensland.

- **Analyse CPUE for mud crab by grouping data by catchment/river system.**

It was recommended that breaking-up the catch/effort data into the different catchments would be a better reflection of where they are caught (ie, incorporate information on their habitat) and possibly show latitudinal trends in population dynamics.

Estimation of size of Mud crab stock for the Queensland Gulf and East Coast using a habitat alias.

Introduction.

This chapter describes the methodology and preliminary results of an assessment of the potential catches/stock size for Queenslands Gulf and East Coast Mud Crabs (*Scylla serrata* complex). Catch and effort data were extracted for regions in the Gulf of Carpentaria and the tropical Queensland East Cost from the CFISH logbook database based on the major river systems (QFMA 1997, TRAP 1997). Complementary habitat area was derived from analysis of satellite images to give the area of various vegetation types, in particular mangroves. The satellite coverage's had been produced as part of the Commonwealth funded CYPLUS program (see Danaher 1995).

Assumptions and constraints on analysis

Estimates of the area of mangrove for each river system were used in conjunction with the Catch and Effort information to give estimates of "potential legal-size male crab numbers" for the Gulf and East Coasts, subject to the following assumptions:

- all mud crabs in the CFISH data are male and >15cm Carapace Width (ie legal)
- all logbook information is correct
- 1 crab = 1kg
- each pot has a drawing area of 50m radius ≈ 7854 m^2 (or 0.007854 km^2)

Total biomass or abundance estimates

The steps in this form of analysis are simple and relatively straightforward.

1. Estimate the total area of mud crab habitat. For this study, mud crab habitat was taken as the area of mangrove identified from satellite imagery (Danaher, 1995), (method 1), plus the length of all streams multiplied by 0.05 km (this is an arbitrary figure to represent the average stream width) to give an area estimate of in-stream habitat (method 2). The length of stream adjacent to mangrove areas was calculated from AUSLIG maps of creek systems.

$$A_1 = A_m \qquad \text{method 1}$$

where A_m = Area of mangrove (km^2)

or

$$A_2 = A_m + A_r \qquad \text{method 2}$$

where A_m = Area of mangrove (km^2)
A_r = Area of river (km^2)

2. Estimate the weight of crabs taken per pot lift and the number of pot lifts in each region. This information was calculated from QFMA Qfish logbook information.

$$W_{Av} = \frac{C}{(E \times L)}$$

where C = average annual catch between 1989 and 1997 (kg)

E = average annual effort between 1989 and 1997 (number of pots per year)

L = number of pot lifts per day. (This is assumed to be 1 for the Gulf of Carpentaria.)

3. Estimate the 'drawing area' of a crab pot. The optimal setting distance is one pot every 0.1 km (Williams and Hill, 1982). Each pot draws crabs from a 0.05 km radius or 0.0079 km^2.

A_p = pot drawing area (km^2)
$= \Pi * r^2$
$= \Pi * 0.05^2$
$= 0.0079\ km^2$

4. Estimate the number of "pot areas" by dividing the area of habitat by the drawing area of a pot

$$P_A = \frac{A_1}{A_p} \quad \text{(method1)}$$

$$P_A = \frac{A_2}{A_p} \quad \text{(method 2)}$$

5. Estimate the potential biomass (tonnes) of legal-sized, male, mud crabs in the population, by dividing the area of mangrove habitat by the number of drawing areas of a crab pot (pot areas or P_A) and multiply this by the average weight of crabs taken per lift (W_{Av}). To estimate the number of crabs (abundance) assume that a legal sized mud crab weighs about 1kg.

$$Biomass = \frac{(P_A \times W_{Av})}{1000}$$

$$Abundance = \frac{(P_A \times W_{Av})}{1}$$

Detail of Procedure.

Method 1.

Information on the East Coast Mangrove areas was incomplete, hence only those areas in the CYPLUS database have been analysed. These areas were restricted to the nearest reliable fishing grid that encompassed the river and its catchment (see below, Table 1, Fig 1).

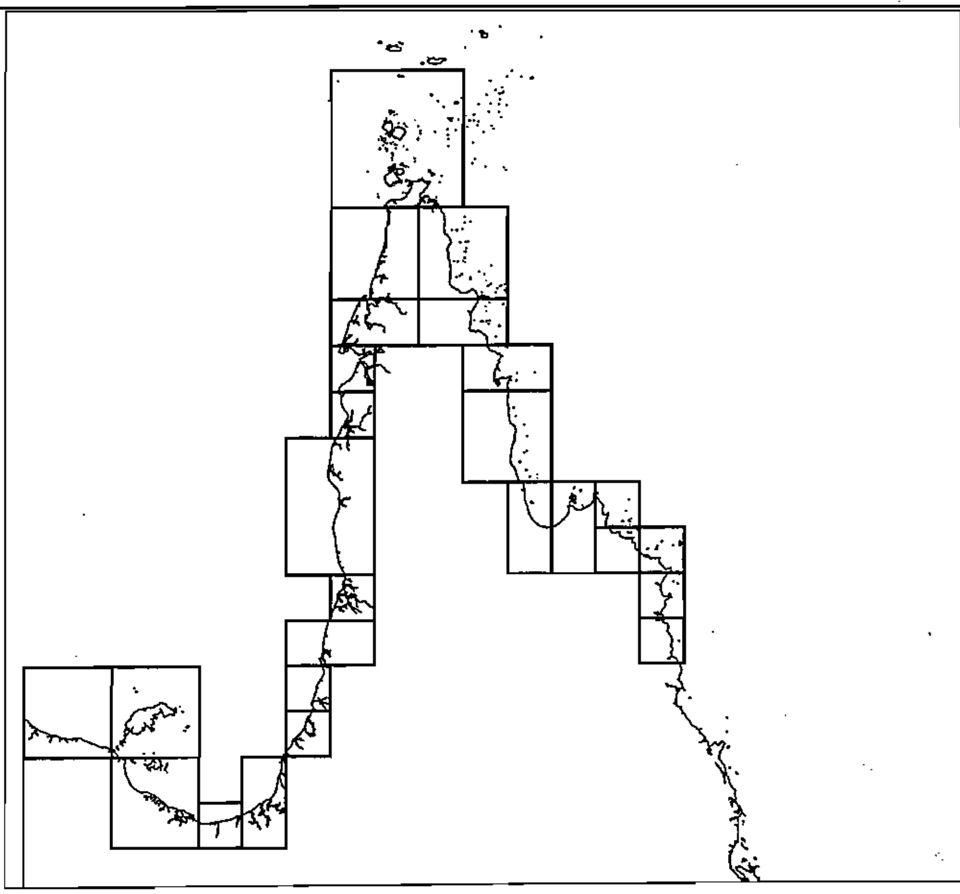


Figure 1: Areas (Grids) used in the habit/catch analysis.

Table 1: Latitudinal and Longitudinal boundaries for the Areas in CrabGrids taken from the CFISH database.

Crab Grid Name	Latitude (°S)	Longitude (°E)
West Qld Gulf	16.0 to 17.0	138.0 to 139.0
Mornington	16.0 to 17.0	139.0 to 140.0
Burketown	17.0 to 18.0	139.0 to 140.0
Southern Gulf	17.5 to 18.0	140.0 to 140.5
Norman	17.0 to 18.0	140.5 to 141.0
Gilbert	16.5 to 17.0	141.0 to 141.5
Staaten	16.0 to 16.5	141.0 to 141.5
Nassau	15.5 to 16.0	141.0 to 142.0
Mitchell	15.0 to 15.5	141.5 to 142.0
Central Gulf	13.5 to 15.0	141.0 to 142.0
Archer	13.0 to 13.5	141.5 to 142.0
Weipa	12.5 to 13.0	141.5 to 142.0
Pt Musgrave	12.0 to 12.5	141.5 to 142.5
Gulf tip	11.0 to 12.0	141.5 to 142.5
Torres Straits	9.5 to 11.0	141.5 to 143.0
Shelburne Bay	11.0 to 12.0	142.5 to 143.5
Temple Bay	12.0 to 12.5	142.5 to 143.5
Lloyd Bay	12.5 to 13.0	143.0 to 144.0
C Sidmouth	13.0 to 14.0	143.0 to 144.0
PCB West	14.0 to 15.0	143.5 to 144.0
PCB East	14.0 to 15.0	144.0 to 144.5
Ninian Bay	14.0 to 14.5	144.5 to 145.0
Jennie R	14.5 to 15.0	144.5 to 145.0
Starke R	14.5 to 15.0	145.0 to 145.5
C Bedford	15.0 to 15.5	145.0 to 145.5
Bloomfield	15.5 to 16.0	145.0 to 145.5

Calculations.

There were three main methods for the estimation of mud crab stock size.

- firstly, using the CYPLUS coverage file Mar_veg data in MapInfo™, areas were calculated and a *.txt file for each Region was imported into Access™ Summaries of the Areas for the different Mangrove types within each of the Regions were calculated (using an Access Query that Groups-by "Zone" and "Mar_veg" and sums "Area"). Then a pivot table was created in Excel™, using the summarized data, giving the number of mangrove vegetation classes and then total mangrove areas for each Region. Total Gulf of Carpentaria areas (= "All Gulf") and East Coast areas were calculated only from known coverages. In the case of the Gulf this will be a gross underestimate of the mangrove areas, as the Albert/Leichardt system is excluded, also the coast/rivers westward to the Queensland border.
- secondly, using the above mangrove areas, but also including a 50m wide band of water adjacent to the rivers and coast to estimate habitat adjacent to the mangroves. The AUSLIG Queensland coast coverage (the line file not the

polygon file) was used to estimate the adjacent areas. The associated coastal coverage data for each of the Regions was exported into Access (or SQL selected in MapInfo and then "Calculate statistics" used) and the lengths (in kilometres) calculated by summing the line objects (records). The river and coast line objects within the Region boundaries were summed, except for Weipa, where the line objects for the entire Albatross Bay system was used, as it extended beyond the Region boundaries. Example : The "All Gulf" calculations were estimated from the summing of the 8 Region stream lengths. The "Adjacent Areas" were then calculated by multiplying the system river/coastal lengths by 50m. This was added to the mangrove areas calculated in the previous method to provide an estimate of modified available areas.

- finally, multiplying an estimate of crabs per km^2 of habitat with the estimated area of available habitat for the Queensland Gulf and East Coasts, the potential commercial stock may be assesed. The Northern Territory Fisheries (Walters 1997) provided a preliminary estimate of 150 crabs per km^2 for NT waters. It has been assumed in this study that this value was for commercial crabs (ie both males and females over NT minimum legal size of 14cm CW). We have assumed a sex ratio of 1:1 (Hyland QDPI Fisheries pers comm) and that no more or less crabs are taken due to the differences of minimum legal size between NT (=14cm) and Qld (=15cm). As Queensland takes only male crabs >15cm CW, the NT figure was halved to give the availability of commercial males (≈75 males/km^2). This figure was multiplied to the estimated habitat area (both methods).

Estimates for the Gulf and East Coast of male crabs per km^2 were calculated, using the two habitat area estimates, and the available commercial catch information. None of the estimates account for recreational, indigenous, or non-reported commercial catches.

Method 2.

A second series of areas were created to allow for "Intuitive" assessments of habitat areas, such that all the mangrove areas in a catchment/river system could be calculated, not just those within the confines of the CFISH grid areas (see Fig 2). This enabled more reasonable estimates as to the potential "bank" or reservoir of crabs available for capture in a crab grid area. Table 2 shows how the "CrabGrid" (method 1) and the "Intuitive Grid" (method 2) areas are related. All Mud crab catches were calculated using the MIXED database from the CFISH system. Catches were summarised into the CrabGrid areas as per Table 1.

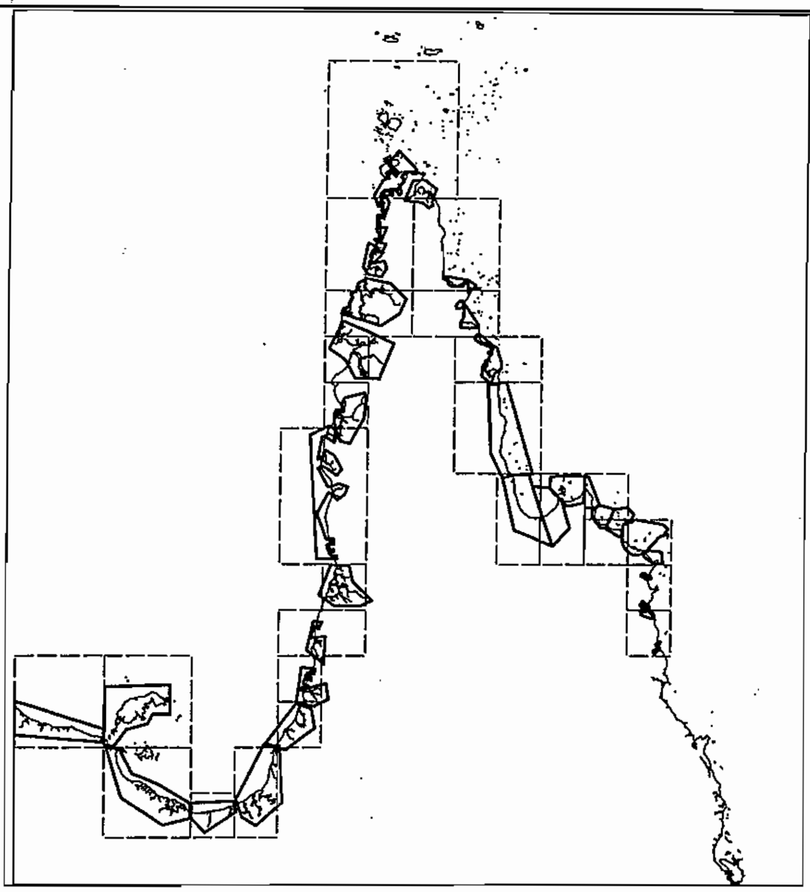


Figure 2: Areas as defined by Intuitive Grids

Both coastline lengths and mangrove areas were estimated using the SQL Select feature in MapInfo. These files were then imported into the respective Access database file (=MarVeg.mdb) using a macro within the Access. File names for the text files are as follows.

Coastal information

- "GridCoast.txt" (for coastl.obj within crabgrids.obj)
- "Int_coast.txt" (for coastl.obj within IntuitiveGrids.obj)

Marine Vegetation information (MarVeg derived from the satellite image analysis)

- MarVeg table name less the p (for poly) plus the file number (or a 1 where no number is present) when referring to the exact "crabgrids" data, eg. "Gulf1.TXT" for marveg table "gulfp.TAB" and "Weip4a.TXT" for "Weip4ap.TAB".
- Full area name) plus the file number (or a 1where no number is present) when referring to East Coast "IntuitiveGrids" data, else just using the above marveg files except for Weipa and Pt Musgrave, where Weip4a and Weip4b were replaced with WeipaAll, Weip3a, Weip3b and Weip2.TXT were replaced with PtMusAll.TXT.

Table 2: Relationship between "CrabGrid" and "IntuitiveGrid" areas for analysis

Intuitive Region	Crab Grid Area
West Qld Gulf	West Qld Gulf
Mornington	Mornington
Burketown	Burketown
Southern Gulf	Southern Gulf
Norman	Norman
Gilbert	Gilbert
Staaten	Staaten
Nassau	Nassau
Mitchell	Mitchell
Central Gulf	Central Gulf
Archer R	Archer
Weipa	Weipa
Pt Musgrave	Pt Musgrave
Gulf tip	Gulf tip
Escape R	Torres Straits
Torres Straits	Torres Straits
Shelburne B	Shelburne Bay
Temple B	Temple Bay
Weymouth B	Lloyd Bay
Lloyd B	Lloyd Bay
C Sidmouth	C Sidmouth
PCB West	PCB West
PCB East	PCB East
Bathurst B	PCB East
Ninian B	Ninian Bay
Howick West	Ninian Bay
Howick East	Jennie R
Turtle Gp	Starke R
C Flattery	Starke R
Endeavour	C Bedford
McIvor R	C Bedford
Annan R	Bloomfield
Bloomfield R	Bloomfield

Areas without marine vegetation information (MarVeg) were not included in any of the further analyses. This restricted the crab grid areas analysed to the Norman River through to Bloomfield River (see Fig 2, Table 2), excluding all the southern and western Gulf of Carpentaria, and any areas south of Cooktown. Analysis of other areas is not possible until reliable MarVeg data becomes available.

The data including the catch and effort data from "Mud crab.mdb", were cut and pasted into their respective sheets in Excel ("Crabs and mangroves.xls"), and then the respective pivot tables updated (for data ranges, as well as data). Calculations were as per the initial analysis, except that an extra field was added such that the effect that "number of lifts" per day had on effort could be taken into account.

Results of "habitat alias" model of crab abundance.

The Tables 3 to 6 summarise the results of the analysis.

For the Gulf, the average annual catch over the 89-96 period was approximately 42.43 tonnes of male mud crabs. The habitat alias analysis based on the historic catch rates in each river system indicates that a stock of legal male crabs of between 43.5 and 64.5 tonnes is available. The habitat alias based on the catch rates in the Norman River (assuming this is a "mature" rather than newly exploited area) gives an estimated stock size of between 34.4 and 51 tonnes.

For the East Coast, the average annual catch over the 89-96 period was approximately 25.8 tonnes of male mud crabs. The habitat alias analysis based on the historic catch rates in each river system/catchment indicates a stock of legal male crabs of between 25.4 and 30.9 tonnes is available. The habitat alias based on the catch rates in the Norman River (assuming this is a "mature" rather than newly exploited area) gives an estimated stock size of between 18.7 and 22.7 tonnes.

In both the Gulf and on the East Coast there are river systems where the habitat alias analysis predicts a stock that is lower than what is actually taken. Two examples are the Mitchell River in the Gulf and Princess Charlotte Bay (PCB) on the East Coast. In both these cases the foreshore and mud flats may be important habitat areas but these are under-represented in the current analysis. Hence both method one and two would give conservative estimates of crab abundance.

It should also be remembered that the estimates are for legal sized male crabs; ie, the potential fishery. The total crab abundance would include both females and all crabs smaller than legal size. Assuming a sex ratio of 1:1 males to females and that there would be at least as many sub-legal sized crabs as legal crabs then the true abundance would be at least four times that estimated above.

Summary of potential
crab catches
- Area Method #1

Drawing area (km^2) of pot (assuming 50m radius)
= 0.0079 km2

	Gulf										
	Norman	Gilbert	Staaten	Nassau	Mitchell	Central Gulf	Archer	Weipa	Pt Musgrave	Gulf tip	Gulf Totals
Area of Mangrove (km^2)	83.54	29.48	9.39	6.08	17.94	14.13	29.16	164.40	128.65	73.89	556.67
Average Annual catch (t)	5.43	5.54	3.33	3.77	6.68	0.51	4.57	13.02	9.54	1.58	42.43
Average Number of pots/yr	11195.44	10688.89	6449.22	6568.29	13185.13	698.00	5289.25	15709.83	13117.80	1858.43	69070.22
Lifts per day (estimated)	1	1	1	1	1	1	1	1	1	1	1
1) Area of pot drawing effect [Pi*(50m radius)^2]	as per Norman 0.0079	as per Norman 0.0079	as per Norman 0.0079	as per Norman 0.0079	as per Norman 0.0079	as per Norman 0.0079	as per Norman 0.0079	as per Norman 0.0079	as per Norman 0.0079	as per Norman 0.0079	as per Norman 0.0079
2) Number of pot areas [(area of mangrove)-(draw area of pot)]	10637 pots 10637	3754 pots 3754	1195 pots 1195	774 pots 774	2285 pots 2285	1800 pots 1800	3713 pots 3713	20932 pots 20932	16381 pots 16381	9408 pots 9408	70877 pots 70877
3) Potential number of crabs (Annual Catch)/(number of pots/yr)) *(Number of pot areas)	5157 5.2	1946 1.9	616 0.6	443 0.4	1157 1.2	1326 1.3	3205 3.2	17351 17.4	11908 11.9	7999 8	43544 43.5
4) Ave Annual Harvest	5.4	5.5	3.3	3.8	6.7	0.5	4.6	13	9.5	1.6	42.4
5) Potential as per Norman (Annual Catch)/(number of pots/yr)) *(Number of pot areas)	5157 5.2	1820 1.8	579 0.6	375 0.4	1107 1.1	872 0.9	1800 1.8	10148 10.1	7942 7.9	4561 4.6	34363 34.4
Number of Mangrove categories	2	2	4	4	4	5	5	7	7	8	8

Summary of potential
crab catches
- Area Method 2

Drawing area (km²) of pot (assuming 50m radius) and combining Mangroves plus River/Foreshore adjustment = 0.0079 km2

	Gulf Norman	Gilbert	Staaten	Nassau	Mitchell	Central Gulf	Archer	Weipa	Pt Musgrave	Gulf Up	Gulf Totals
Area of Mangrove (km^2)	83.54	29.48	9.39	6.08	17.94	14.13	29.16	164.40	128.65	73.89	556.67
Area of River (km^2)	35.30	22.75	13.98	11.22	46.27	24.58	27.59	37.13	28.75	21.93	269.50
Combined areas (km^2)	118.84	52.23	23.37	17.29	64.22	38.71	56.76	201.53	157.40	95.82	826.16
Average Annual catch (t)	5.43	5.54	3.33	3.77	6.68	0.51	4.57	13.02	9.54	1.58	42.43
Average Number of pots/yr	11195	10689	6449	6568	13185	698	5289	15710	13118	1858	69070
Lifts per day (estimated)	1	1	1	1	1	1	1	1	1	1	1
1) Area of pot drawing effect [Pi*(50m radius)^2]	7854 m2	7854 m2	7854 m2	7854 m2	7651 m2	7854 m2	7854 m2	7854 m2	7854 m2	7854 m2	7854 m2
	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079
2) Number of pot areas [(area of mangrove)/(draw area of pot)]	15131 pots	6651 pots	2975 pots	2202 pots	8176 pots	4929 pots	7227 pots	25659 pots	20041 pots	12200 pots	105191 pots
	15131	6651	2975	2202	8176	4929	7227	25659	20041	12200	105191
3) Potential number of crabs	7335	3449	1535	1262	4142	3631	6238	21270	14569	10374	64626
(Annual Catch)/(number of pots/yr)) *(Number of pot areas) in tonnes/yr	7.3	3.4	1.5	1.3	4.1	3.6	6.2	21.3	14.6	10.4	64.6
4) Ave Annual Harvest in tonnes	5.4	5.5	3.3	3.8	6.7	0.5	4.6	13	9.5	1.6	42.4
5) Potential as per Norman	7335	3224	1442	1067	3963	2389	3503	12440	9716	5914	50999
(Annual Catch)/(number of pots/yr)) *(Number of pot areas) in tonnes/yr	7.3	3.2	1.4	1.1	4	2.4	3.5	12.4	9.7	5.9	51
Number of Mangrove categories	2	2	4	4	4	5	5	7	7	8	8

Summary of potential
crab catches
- Area Method #1

Drawing area (km²) of pot (assuming 50m radius) = 0.0079 km2

Enter lift factor | East Coast | Gulf | Torres Straits

East Coast

	Shelburne Bay	Temple Bay	Lloyd Bay	C Sidmouth	PCB West	PCB East	Ninian Bay	Jennie R	Starke R	C Bedford	Bloomfield	EC Totals
Area of Mangrove (km²)	23.77	30.95	81.23	37.67	14.72	22.75	9.01	14.51	51.19	11.34	5.90	303.05
Average Annual catch (t)	0.22	0.10	0.01	0.17	6.14	10.22	0.70	2.04	6.16	0.27	0.24	25.80
Average Number of pots/yr	454.14	163.40	18.00	293.86	11520.70	16307.40	743.57	2165.40	6874.90	751.67	591.63	39149.40
Lifts per day (estimated)	1	1	1	1	1	1	1	1	1	1	1	1
1) Area of pot drawing effect [Pi*(50m radius)^2]	7854 m2	as per Norman	as per Norman	as per Norman	as per Norman	as per Norman	as per Norman	as per Norman	as per Norman	as per Norman	as per Norman	as per Norman
	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079
2) Number of pot areas	3027 pots	3941 pots	10343 pots	4797 pots	1874 pots	2897 pots	1148 pots	1847 pots	6517 pots	1444 pots	751 pots	38585 pots
[(area of mangrove)/(draw area of pot)]	3027	3941	10343	4797	1874	2897	1148	1847	6517	1444	751	38585
3) Potential number of crabs	1476	2517	2873	2714	999	1814	1074	1737	5841	513	300	25428
(Annual Catch)/(number of pots/yr))*(Number of pot areas)	1.5	2.5	2.9	2.7	1	1.8	1.1	1.7	5.8	0.5	0.3	25.4
4) Ave Annual Harvest	0.2	0.1	0	0.2	6.1	10.2	0.7	2	6.2	0.3	0.2	25.8
5) Potential as per Norman	1467	1910	5014	2325	908	1404	556	895	3159	700	364	18707
(Annual Catch)/(number of pots/yr))*(Number of pot areas)	1.5	1.9	5	2.3	0.9	1.4	0.6	0.9	3.2	0.7	0.4	18.7
Number of Mangrove categories	5	4	5	7	6	5	7	7	7	6	6	8

[redacted]

Summary of potential
crab catches
- Area Method 2

Drawing area (km^2) of pot (assuming 50m radius) and combining Mangroves plus River/Foreshore adjustment = 0.0079 km2

Enter lift factor | East Coast | Gulf | Torres Straits

East Coast	Shelburne Bay	Temple Bay	Lloyd Bay	C Sidmouth	PCB West	PCB East	Ninian Bay	Jennie R	Starke R	C Bedford	Bloomfield	EC Totals
Area of Mangrove (km^2)	23.77	30.95	81.23	37.67	14.72	22.75	9.01	14.51	51.19	11.34	5.90	303.05
Area of River (km^2)	2.98	2.11	9.41	10.82	5.29	9.27	4.15	5.70	8.13	3.77	3.10	64.73
Combined areas (km^2)	26.75	33.06	90.65	48.49	20.01	32.02	13.16	20.21	59.32	15.12	9.00	367.77
Average Annual catch (t)	0.22	0.10	0.01	0.17	6.14	10.22	0.70	2.04	6.16	0.27	0.24	25.80
Average Number of pots/yr	454	163	18	294	11521	16307	744	2165	6875	752	592	39149
Lifts per day (estimated)	1	1	1	1	1	1	1	1	1	1	1	1
1) Area of pot drawing effect [Pi*(50m radius)^2]	7854 m2	7854 m2	7854 m2	7854 m2	7854 m2	7854 m2	7854 m2	7854 m2	7854 m2	7854 m2	7854 m2	7854 m2
	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079
2) Number of pot areas [(area of mangrove)/(draw area of pot)]	3406 pots	4210 pots	11542 pots	6174 pots	2547 pots	4077 pots	1676 pots	2573 pots	7552 pots	1925 pots	1145 pots	46826 pots
	3406	4210	11542	6174	2547	4077	1676	2573	7552	1926	1145	46826
3) Potential number of crabs	1661	2689	3206	3493	1358	2554	1568	2420	6769	684	458	30859
(Annual Catch)/(number of pots/yr)) *(Number of pot areas) in tonnes/yr	1.7	2.7	3.2	3.5	1.4	2.6	1.6	2.4	6.8	0.7	0.5	30.9
4) Ave Annual Harvest in tonne	0.20	0.1	0	0.2	6.1	10.2	0.7	2	6.2	0.3	0.2	26.8
5) Potential as per Norman	1651	2041	5595	2993	1234	1976	812	1247	3661	933	555	22702
(Annual Catch)/(number of pots/yr)) *(Number of pot areas) in tonnes/yr	1.7	2	5.6	3	1.2	2	0.8	1.2	3.7	0.9	0.6	22.7
Number of Mangrove categorie	5	4	5	7	6	5	7	7	7	6	6	8

[redacted]

Areas used as close to same between fishing grounds and mangrove areas

1998 Update for the Queensland Gulf of Carpentaria.

This section updates the summary provided to the CRAB MAC Mud Crab working group meeting on the 17 September 1998 (above). At that time only logbook data up to 1996 had been reliably entered onto the QFMA logbook database, therefore the summary covered the 1988-1996. The data for 1997-98 has reduced reliability, due to problems with data entry, hence this update must considered as provisional. The data appears to show a marked drop in catch and CPUE in the northern Gulf hence was brought to the notice of CRAB MAC as a preliminary analysis only, not as part of the summary.

A full year of data is not available for 1998 therefore total annual catch will be under-estimated, however the catch per unit effort (crab per pot-lift or crabs per day) will be comparable with previous years. Cpue has been used an adequate index to the underlying crab abundance in this update although it is recognised that factors such as fisher experience and motivation will affect catch rates.

Table 7. Annual Catch per unit effort for mud crab from the North East Queensland Gulf of Carpentaria.

Lat.	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
11	0.00	0.00	0.00	0.00	0.25	0.20	0.15	0.56	0.94	1.00	0.30
12	0.00	0.00	0.00	0.00	0.61	0.50	0.67	0.78	0.71	0.69	0.41
13	0.00	0.89	0.62	0.70	0.00	0.47	■	0.70	0.56	0.82	0.48
14	0.00	0.74	0.69	0.00	0.60	0.87	1.06	0.00	0.23	0.44	0.63
15	0.00	0.41	0.26	0.32	0.84	0.42	0.62	0.45	0.51	0.48	0.17
16	0.00	0.62	0.69	0.31	0.70	0.30	0.39	0.37	0.53	0.61	0.44
17	0.02	0.63	0.46	0.37	0.43	0.31	0.24	0.43	0.62	0.60	0.78

Note. cpue in crab per lift; ■ this point was an outlier, originally an order of magnitude higher than any other value in the table.

The trajectories of these data, from Weipa in the north (11 deg) to Karumba in the south (16-17 deg) are presented in following graphs. A comparison of the cpue in 1997 and 1998 shows that a remarkable change in crab abundance has occurred. In the north eastern Gulf there has been a dramatic drop in crab abundance but in the central Gulf (Archer River) and in the far south of the Gulf there has been an increase. Overall the catch for the eastern Gulf will be down on last year's record high. These data are supported by anecdotal information gained from Queensland Gulf fishers at the 1998 annual general meeting of the QCFO and from a series of amateur and indigenous fishers along the Gulf coast at the 1998 October Gulf ZAC meeting.

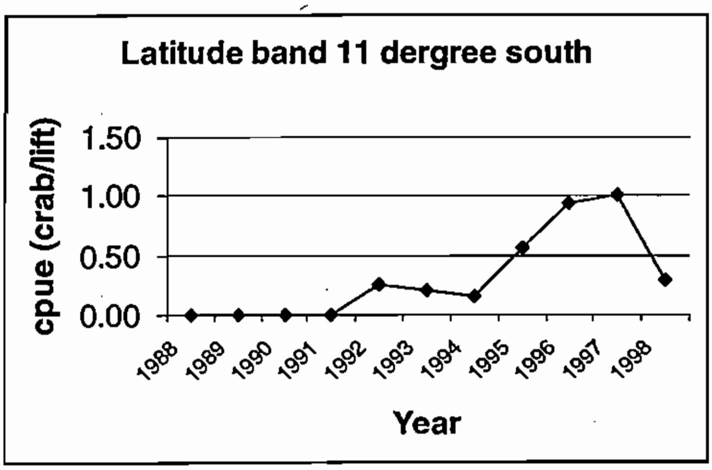
A number of explanations have been put forward by local fishers. The rainfall and consequent river run-off was unusually high and sustained in the first few months of 1998. One theory is that the adult crabs were "washed out by the fresh" then moved along the coast, sequentially attempting to re-enter a river system. Because the northern rivers kept running for an unusually long time, the crabs had all moved down the coast into the southern end of the Gulf where they were finally caught. Hence a reduced catch in the north and an increased catch in the south.

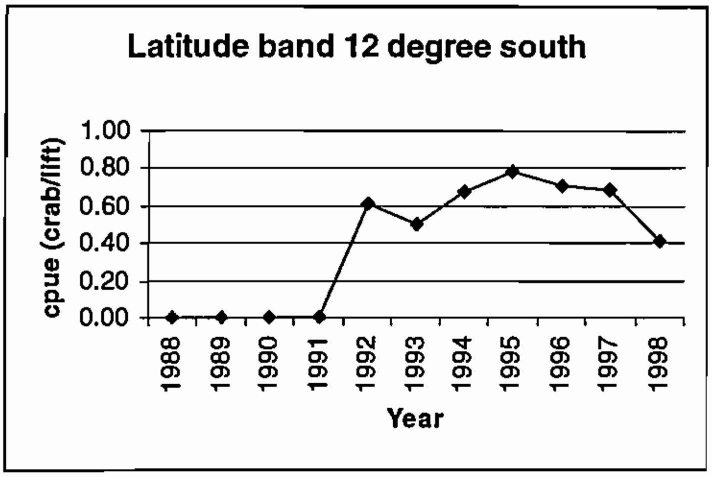
A second explanation is that two years ago a big wet, which also had high sustained rainfall, stopped recruitment of the juveniles back into the northern rivers. The effect of this recruitment failure has taken two years to show up in the catch. Presumably there was no recruitment failure in the south or indeed a similar mechanism to that proposed for the adults operated and the recruits were concentrated in the southern end of the Gulf. Again the result would be a reduced catch in the north and an increased catch in the south.

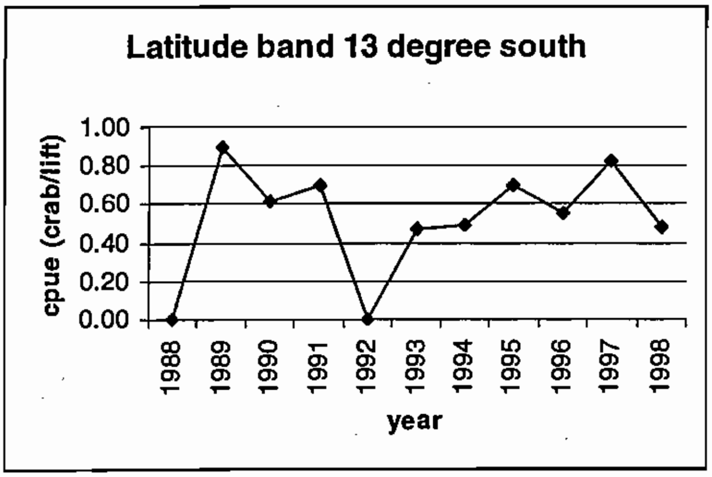
Fishers definitely believe that environmental/climate fluctuations are the cause of changes in crab abundance, however a third possibility is that the high catches made in the northern Gulf over the previous three years were not sustainable and it has taken three years to deplete the previously unfished "reserve". This does not explain the increase in abundance in the southern Gulf but the two phenomena may not be linked.

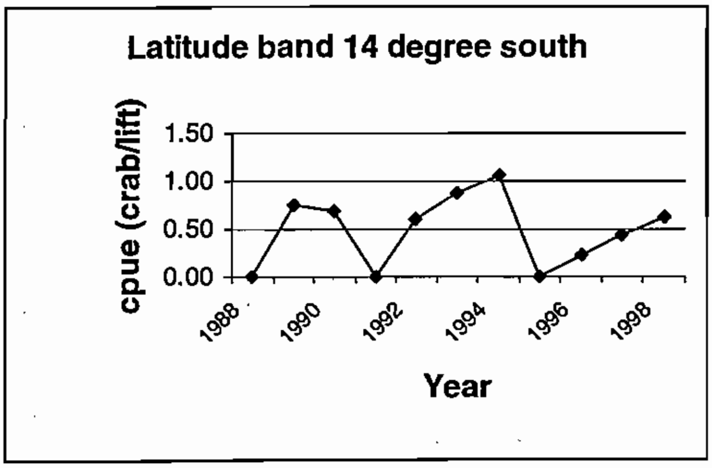
If the fishers are correct then next years catch will return to previous levels, given that rainfall is "normal" (ie, not the same as 1998). If the juvenile recruitment scenario is correct then there has been another recruitment failure in 1998 (due to the rainfall and river flow) and catches will be again reduced in two years time. It should be noted that long-term weather forecasts are for big wets over the next few years, hence further reduced catches in the Northern Gulf would be predicted under either fishers' scenario.

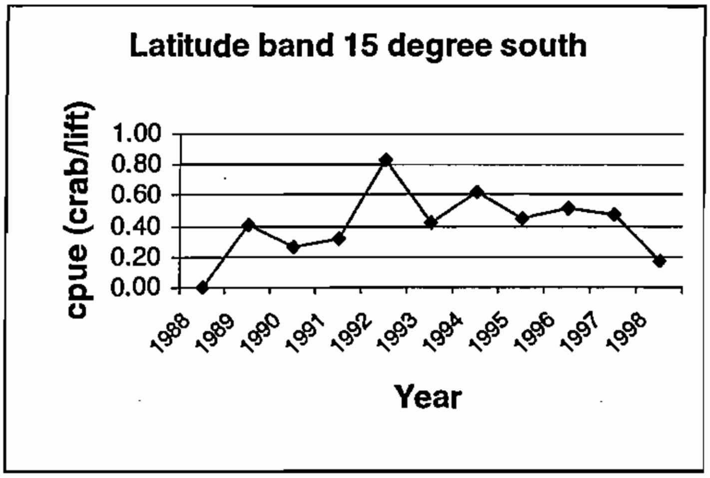
If there has been a depletion of the northern part of the stock then it will take a number of years before catches return to the average for the Gulf; catches will not return to the very high levels of an unexploited stock.




Latitude band 12 degree south
cpue (crab/lift)
1.00
0.80
0.60
0.40
0.20
0.00
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
Year


Latitude band 13 degree south
cpue (crab/lift)
1.00
0.80
0.60
0.40
0.20
0.00
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
year


Latitude band 14 degree south
cpue (crab/lift)
1.50
1.00
0.50
0.00
1988
1990
1992
1994
1996
1998
Year


Latitude band 15 degree south
cpue (crab/lift)
1.00
0.80
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0.40
0.20
0.00
1988
1989
1990
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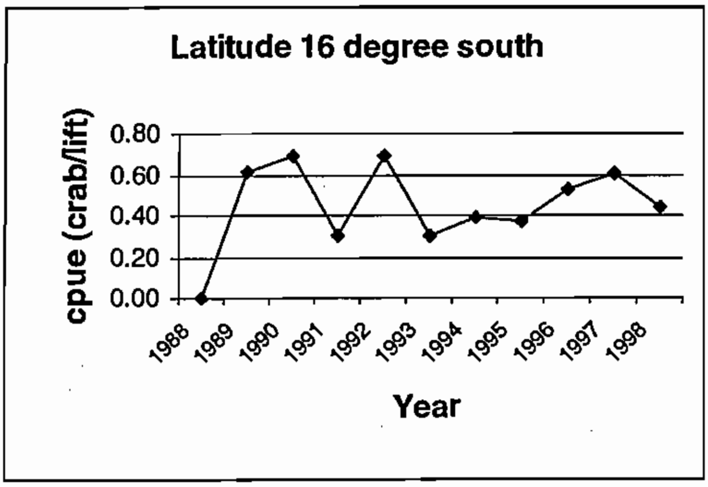
1995
1996
1997
1998
Year


Latitude 16 degree south
cpue (crab/lift)
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0.40
0.20
0.00
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
Year

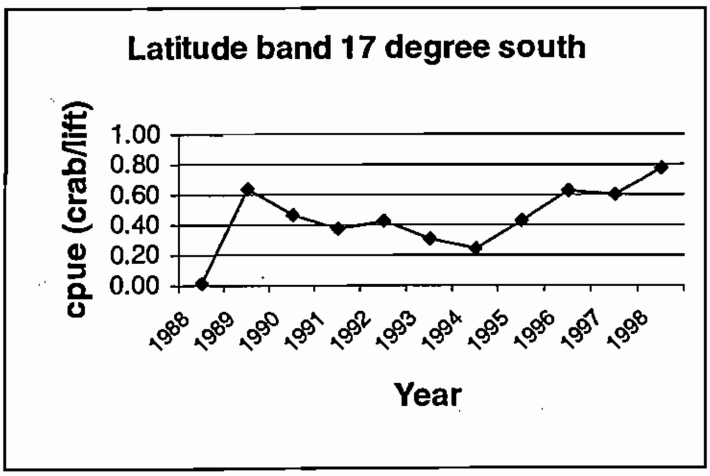
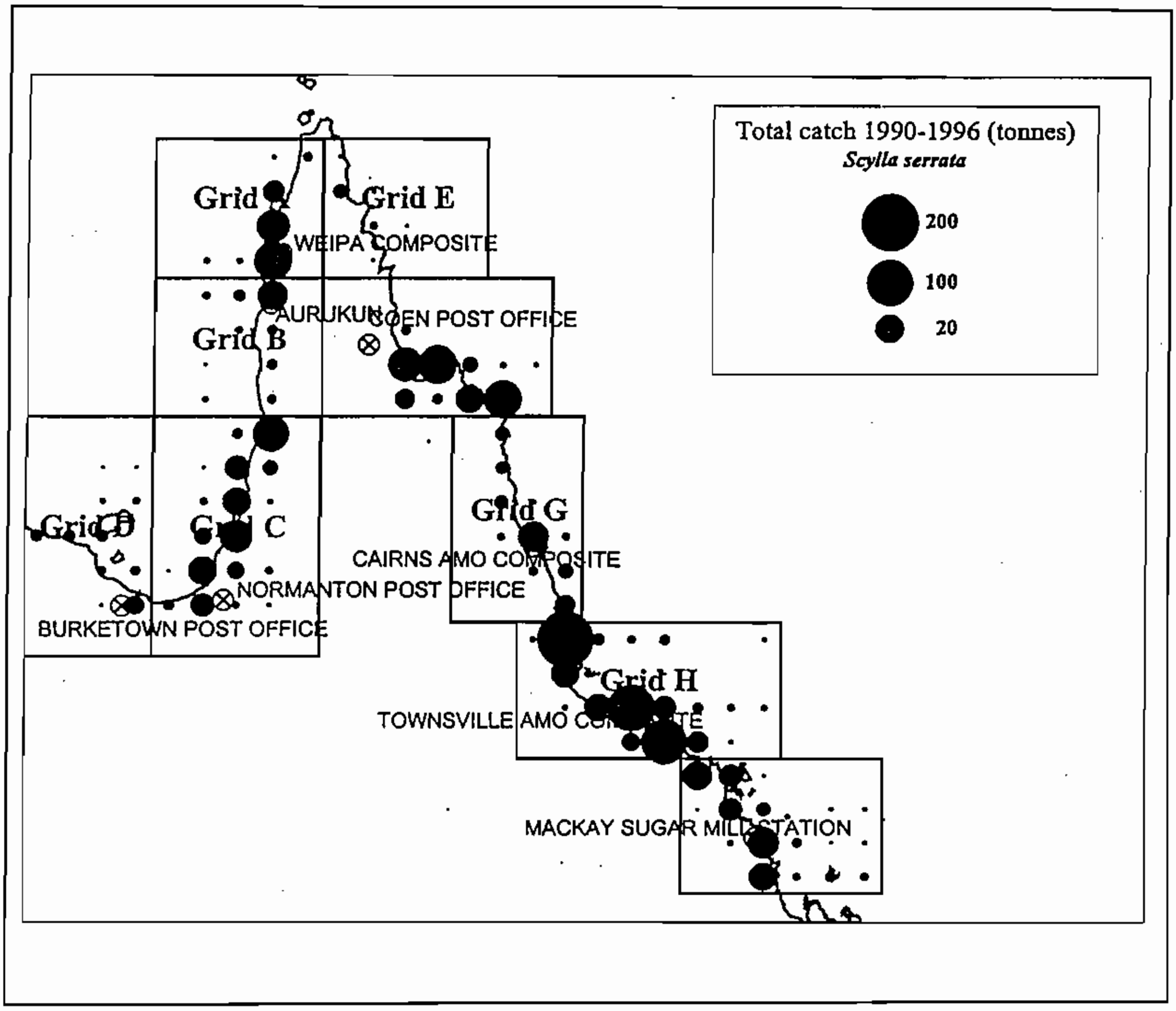
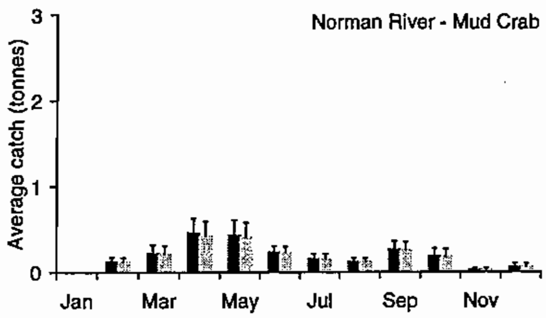

Latitude band 17 degree south
cpue (crab/lift)
1.00
0.80
0.60
0.40
0.20
0.00
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
Year

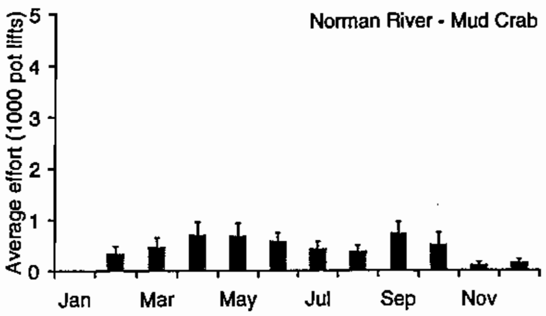
Figure 10. Commercial crab catch by latitude

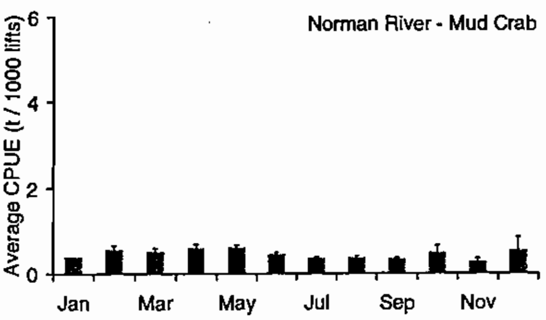


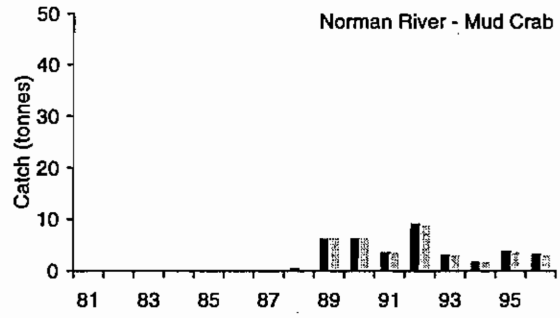
Appendix 1. Distribution of commercial logbook catch and effort data by major river systems.

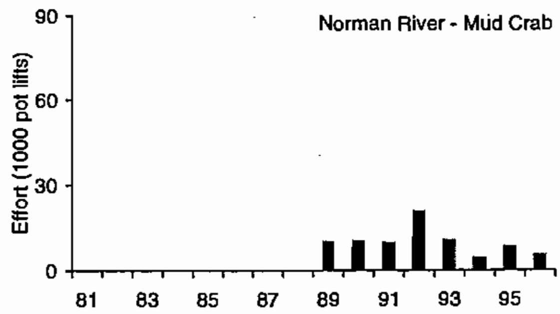
Gulf, Norman River

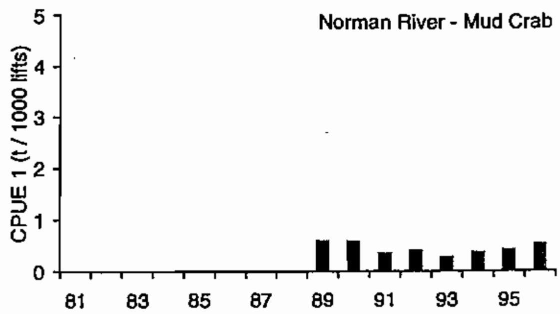






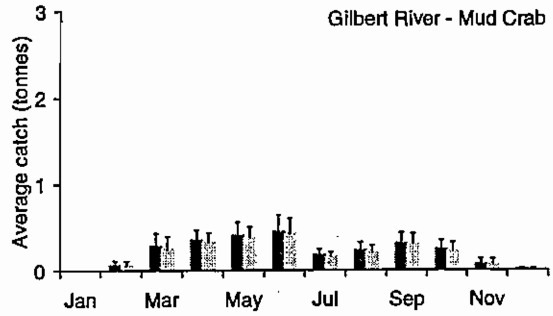


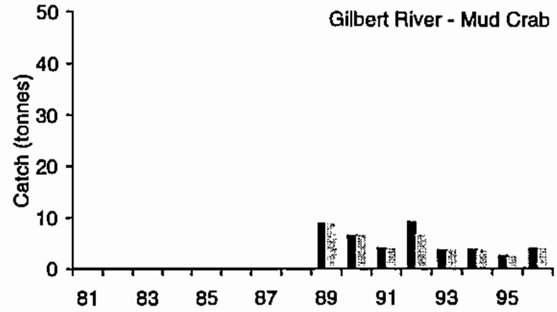


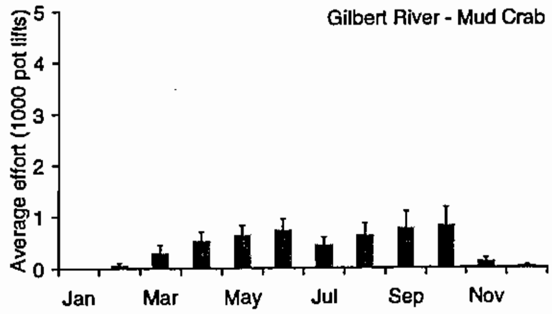


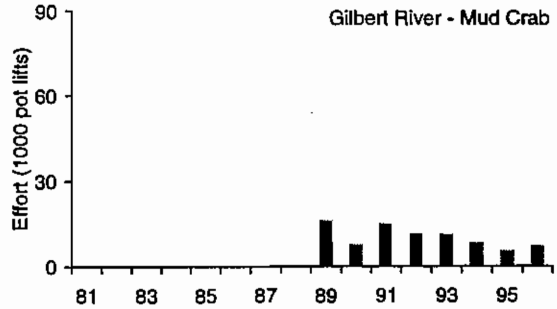
Note. Black bar represents all crab catch reported, Grey bar represents crab catch associated with pots.

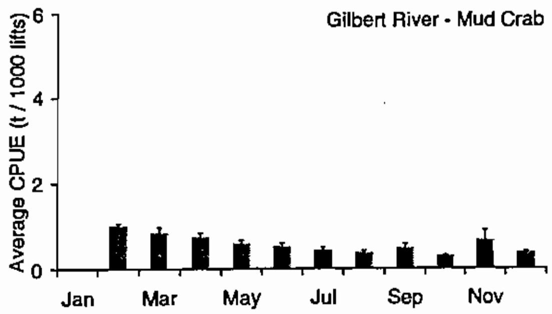
Gulf, Gilbert River

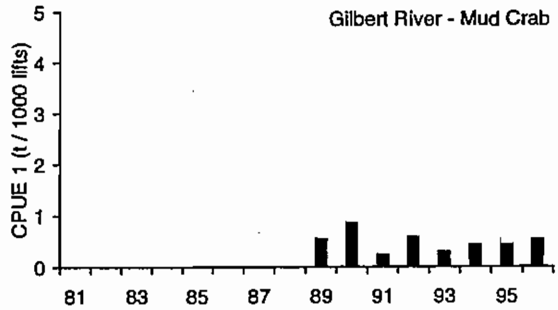




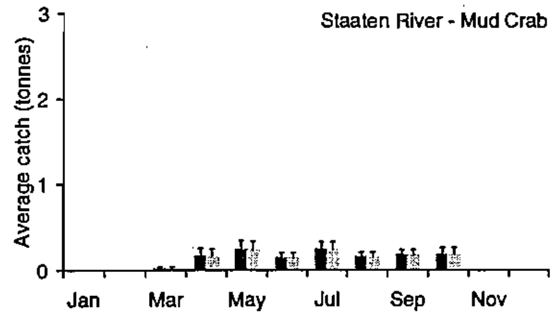


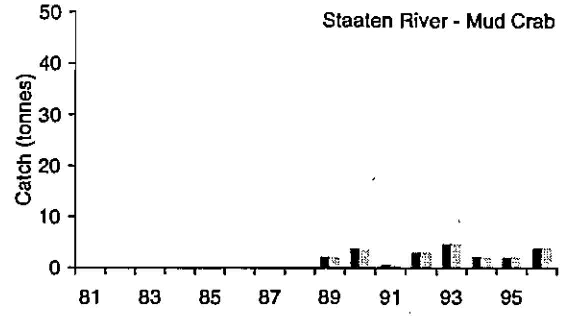


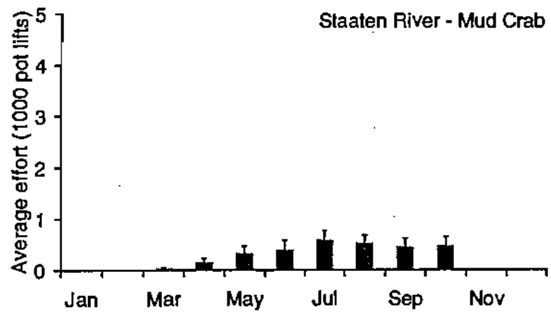


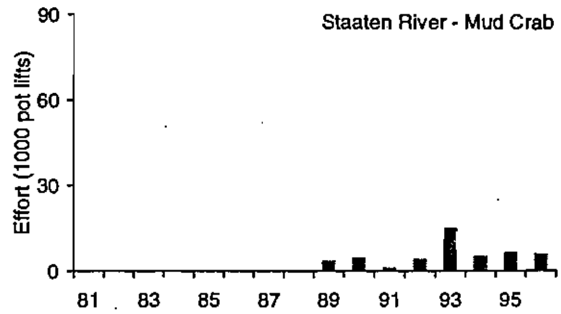


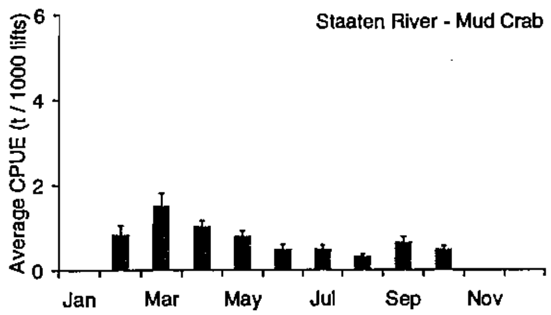
Gulf, Staaten River

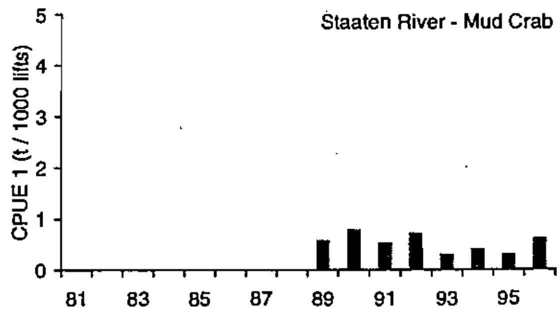




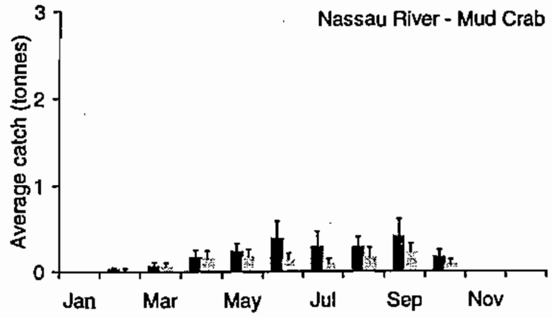


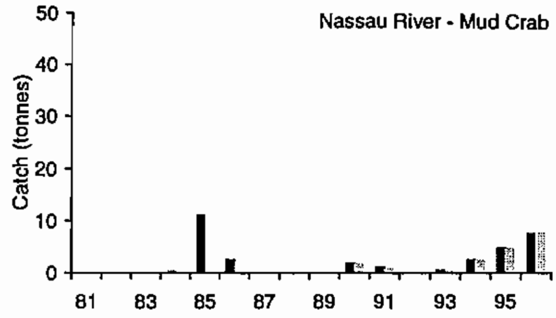


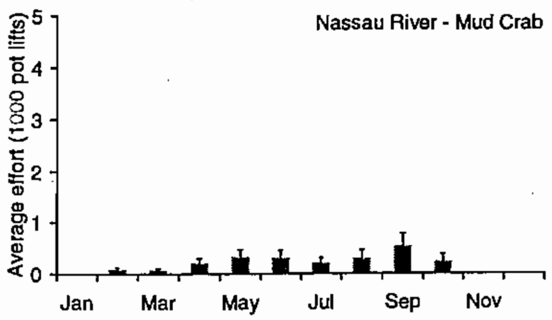


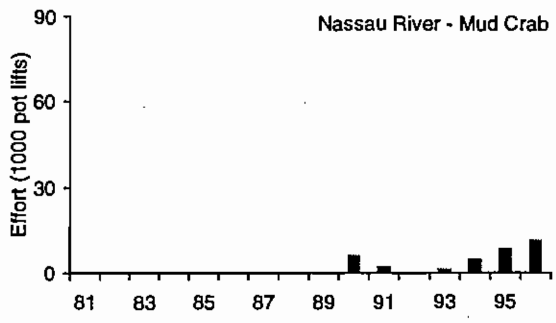


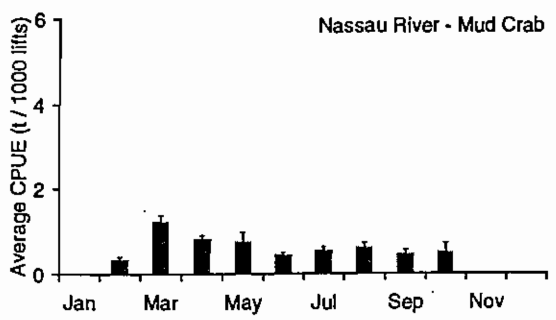
Gulf, Nassau River

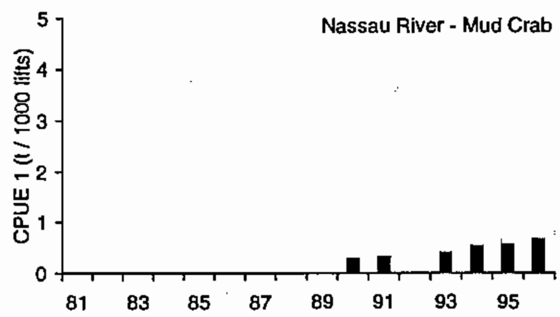




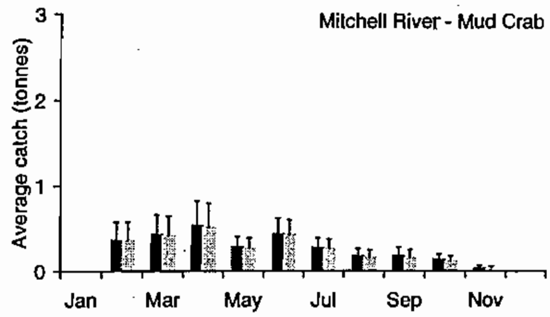


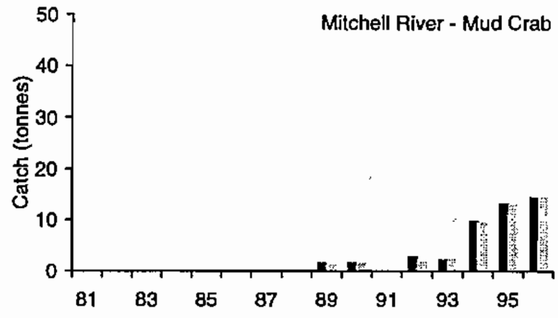


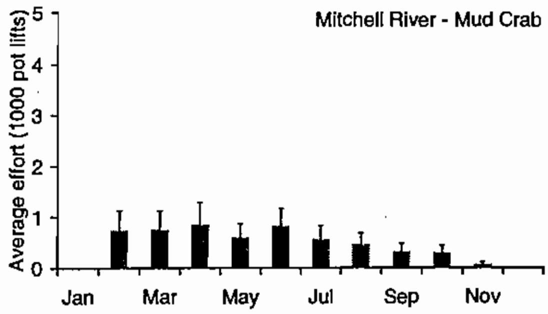


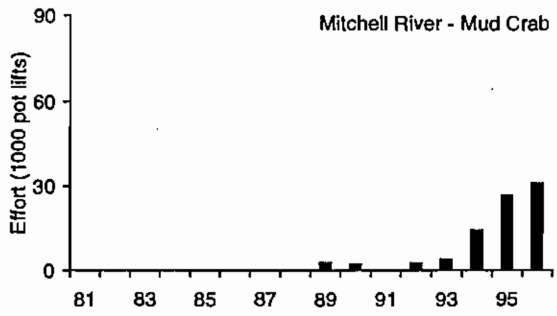


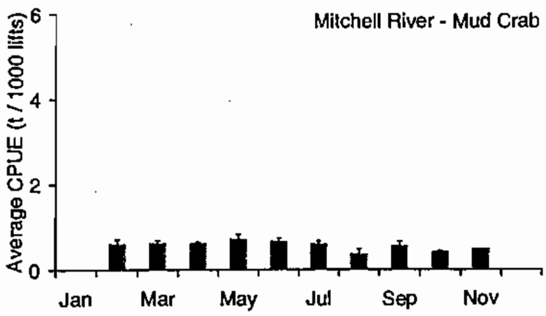
Gulf, Mitchell River

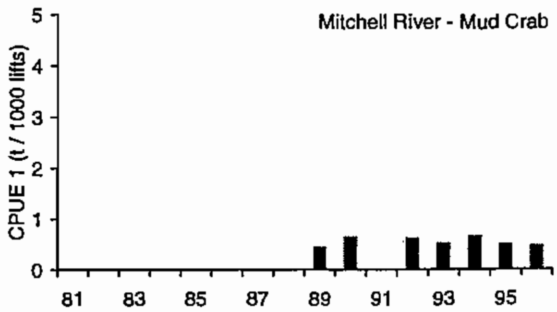




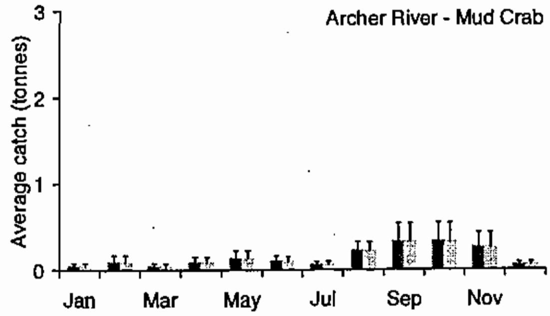


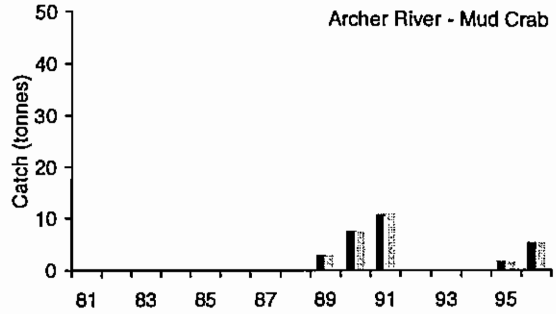


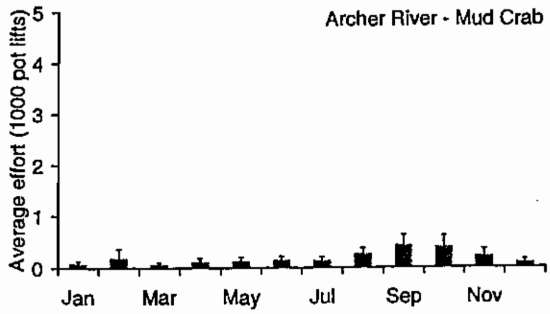


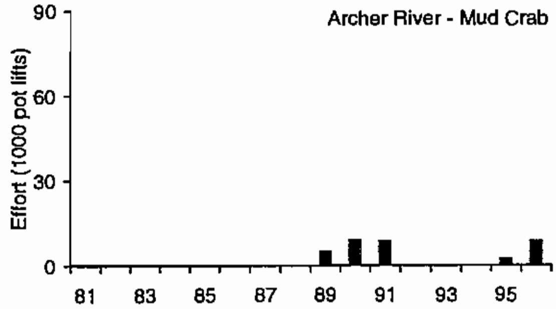


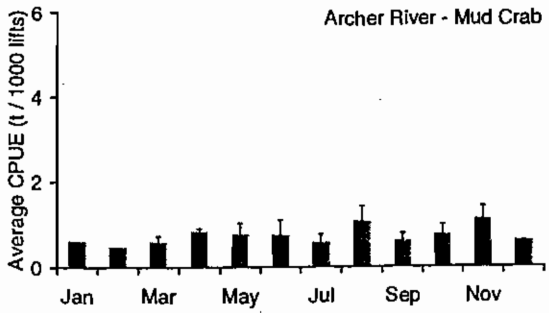
Gulf, Archer River

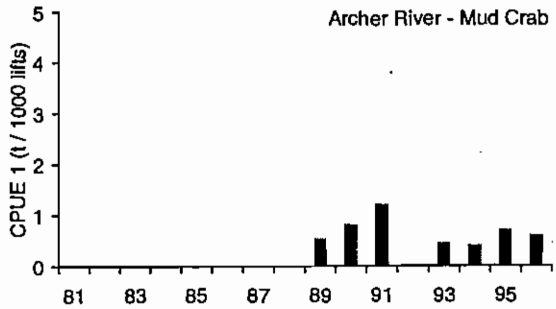




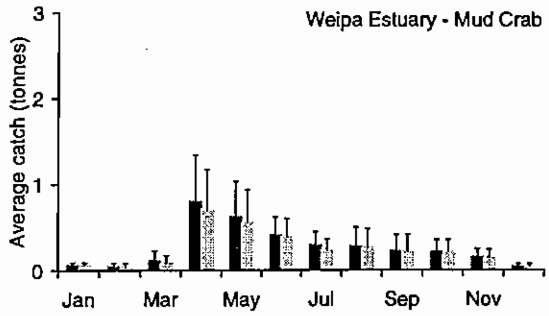


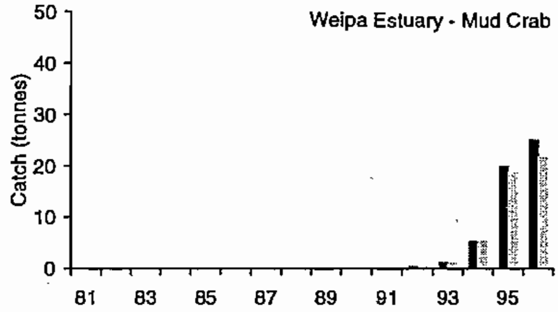


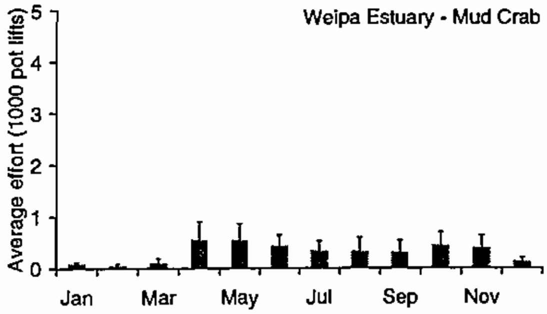


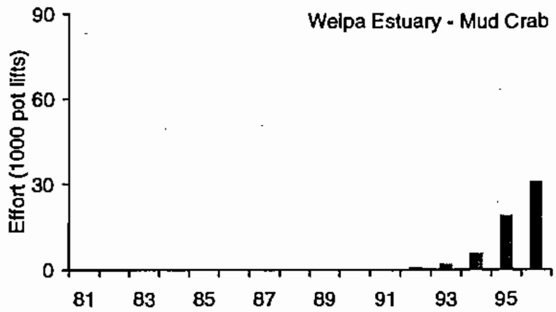


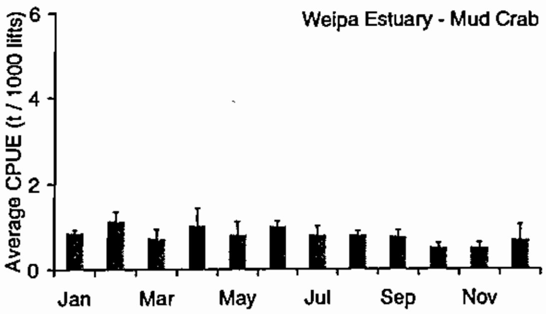
Gulf, Weipa Estuary

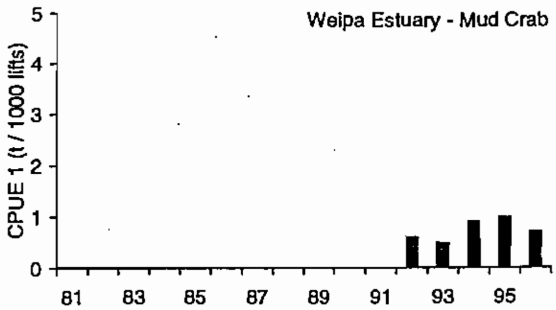




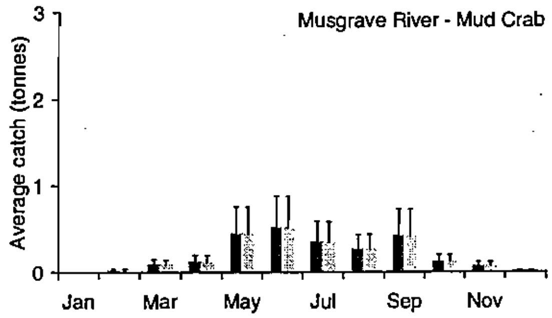


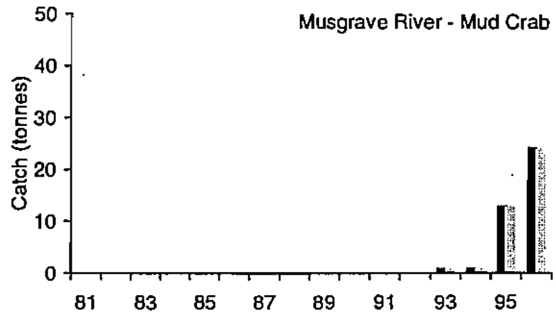


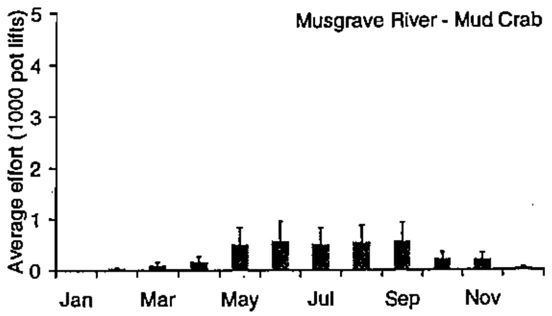


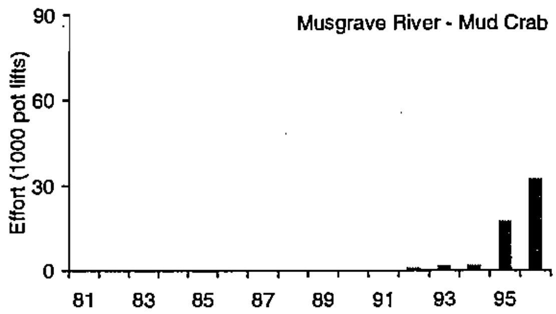


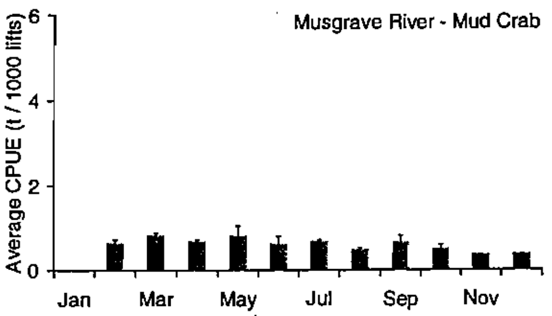
East, Coast Musgrave River

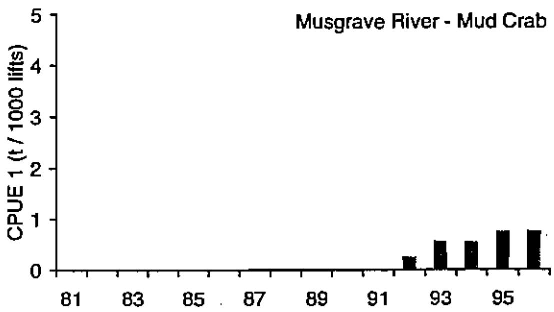




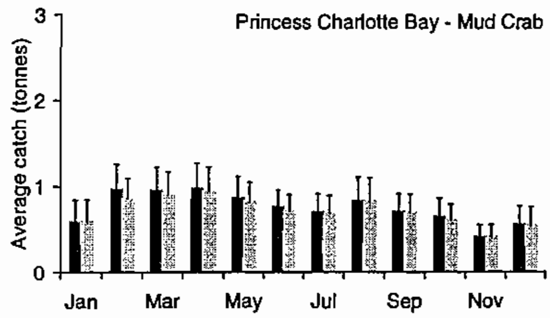


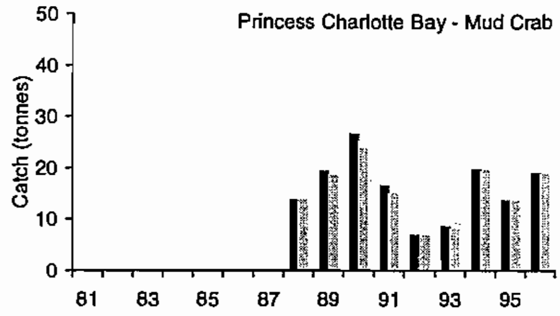


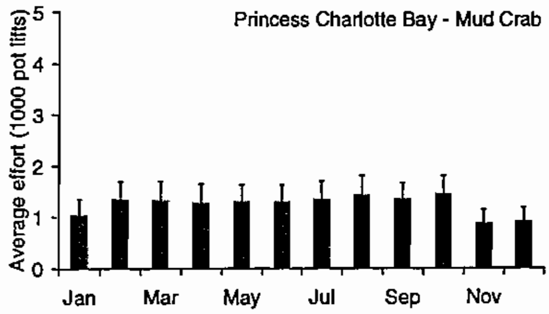


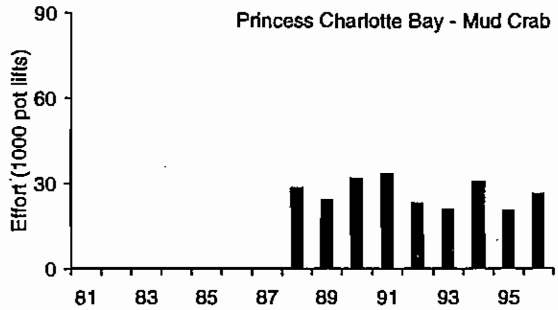


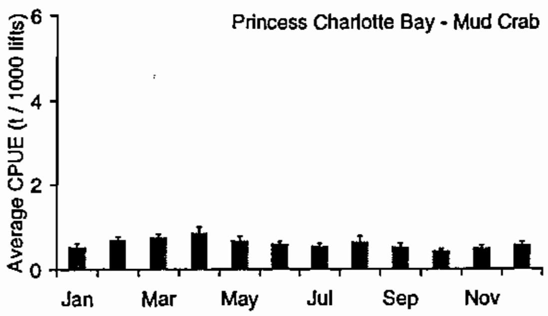
East Coast, PCB

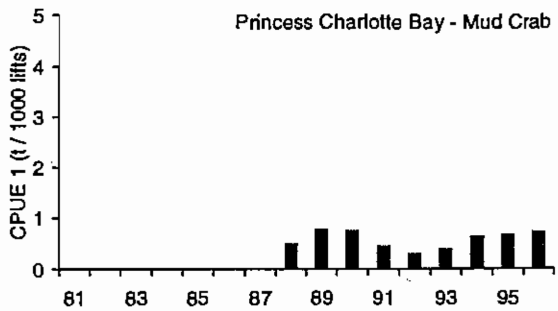




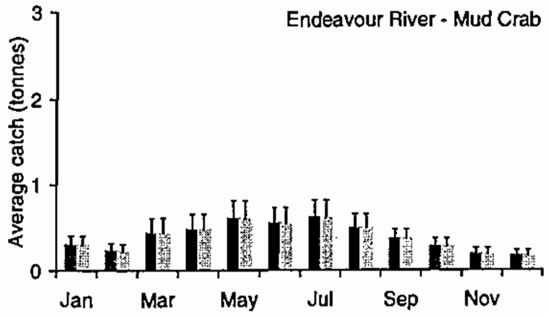


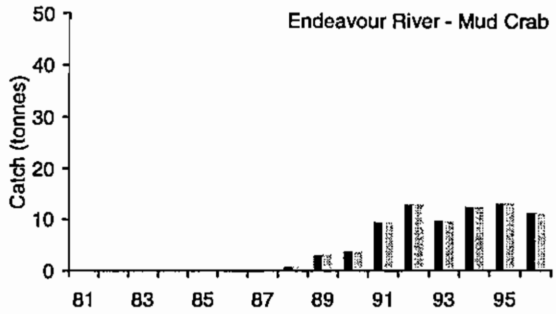


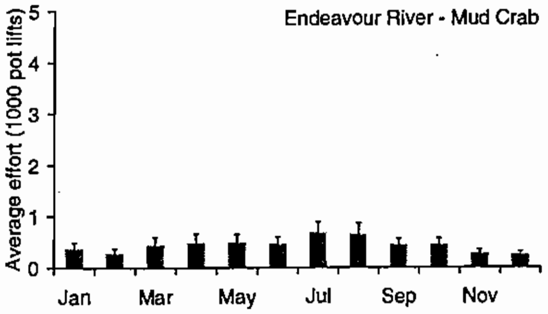


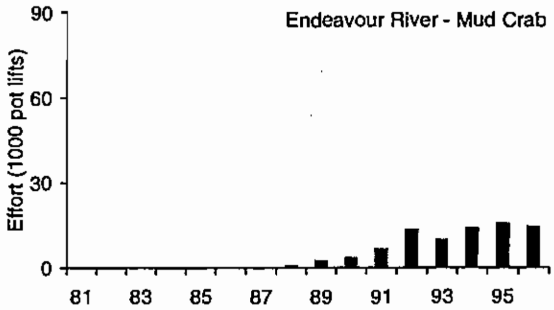


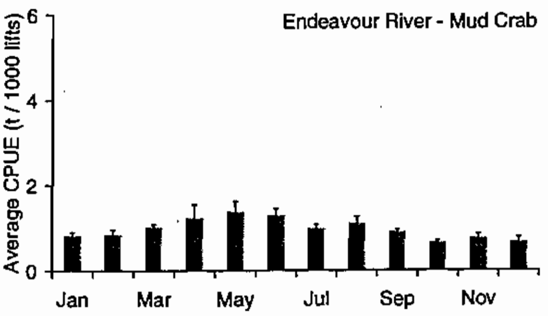
East Coast, Endeavour River

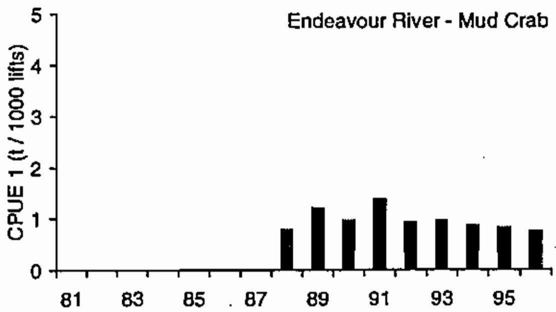




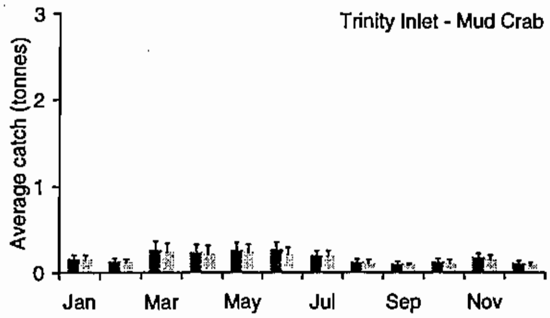


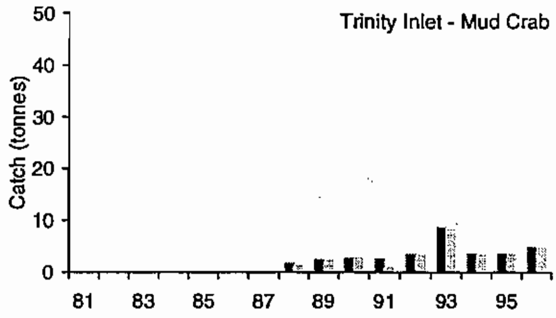


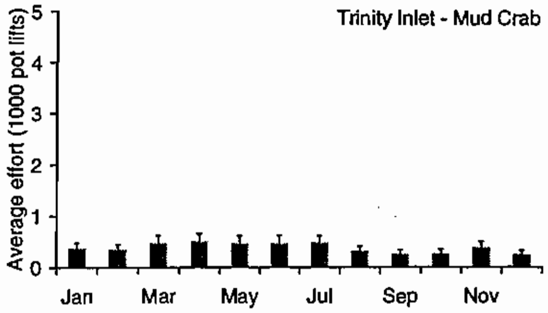


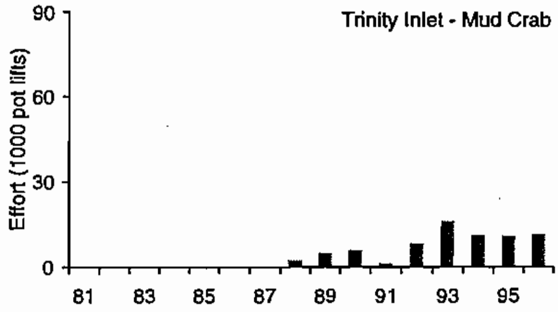


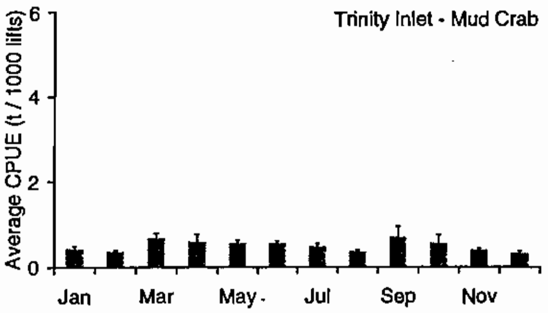
East Coast, Trinity Inlet

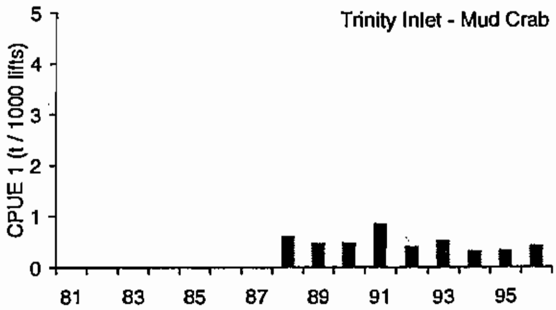




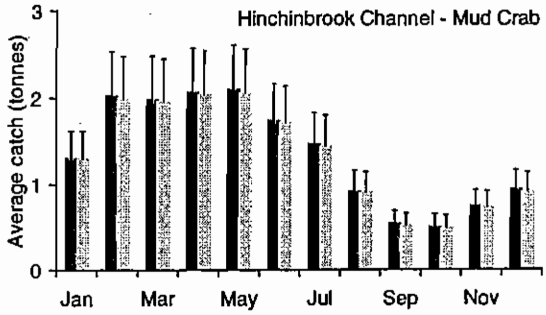


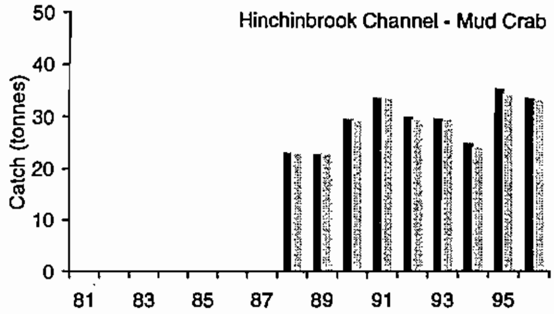


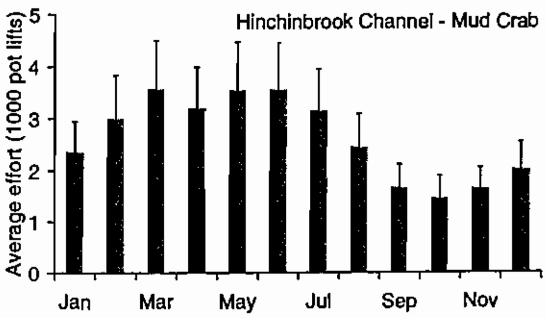


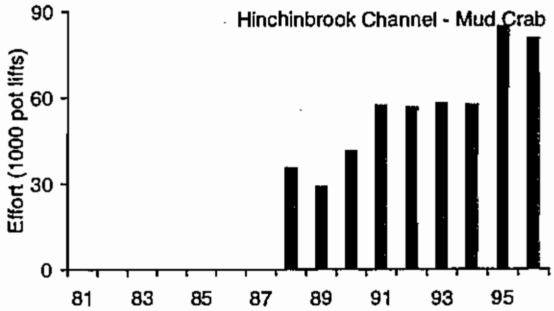


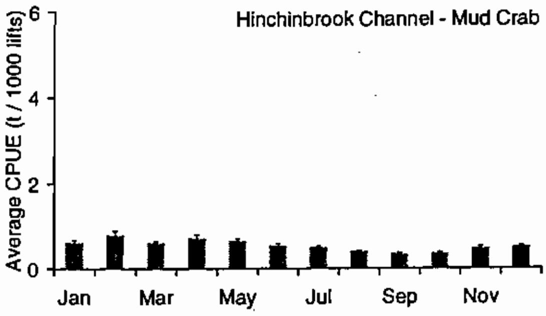
East Coast, Hinchinbrook

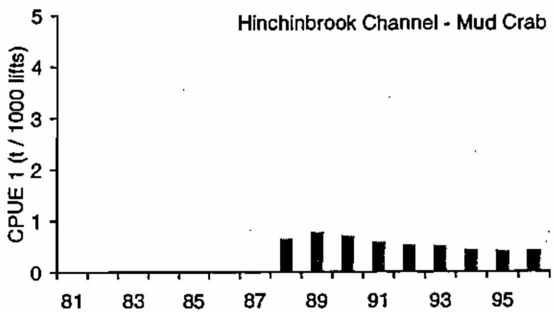




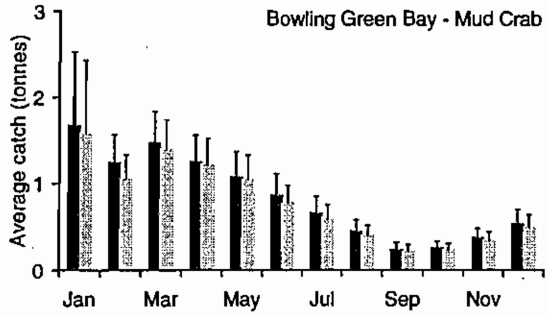


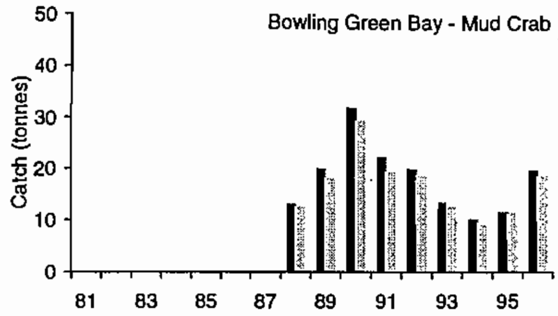


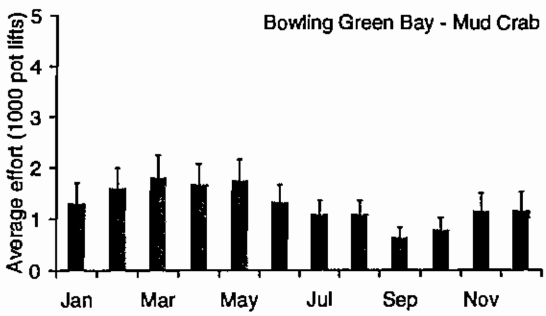


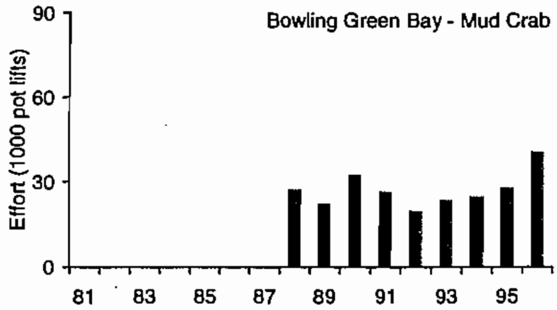


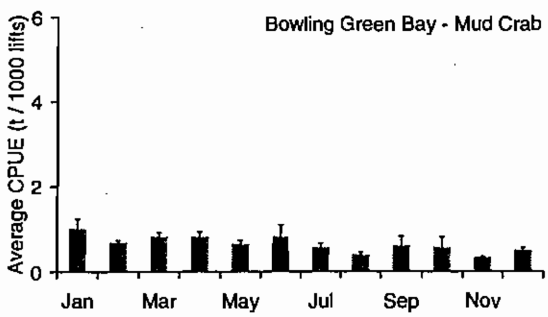
East Coast, Bowling Green Bay

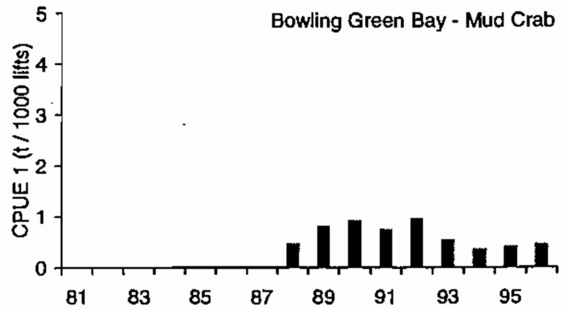




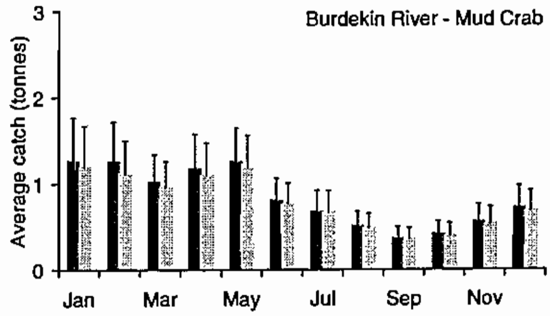


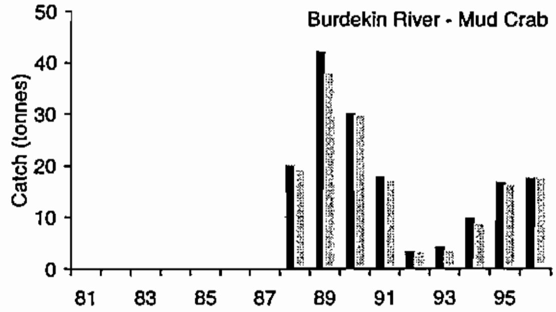


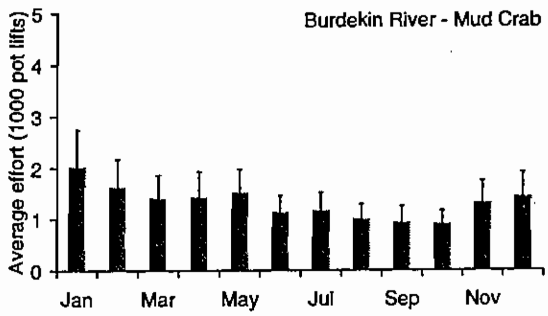


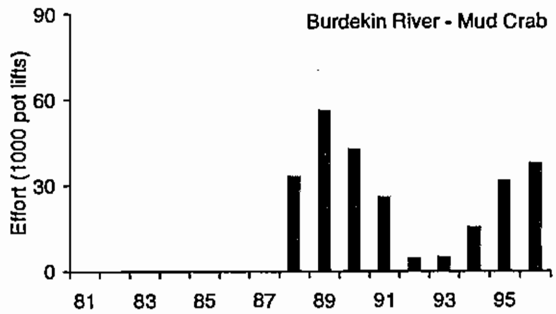


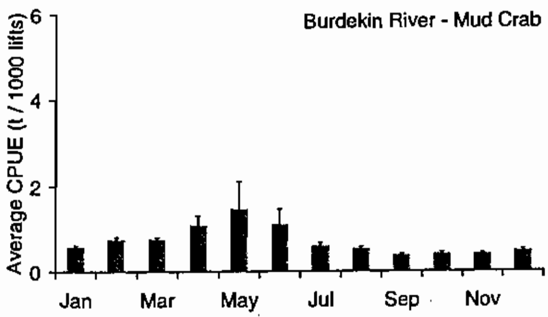
East Coast, Burdekin River

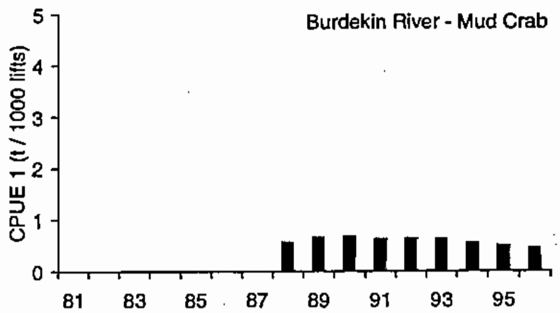












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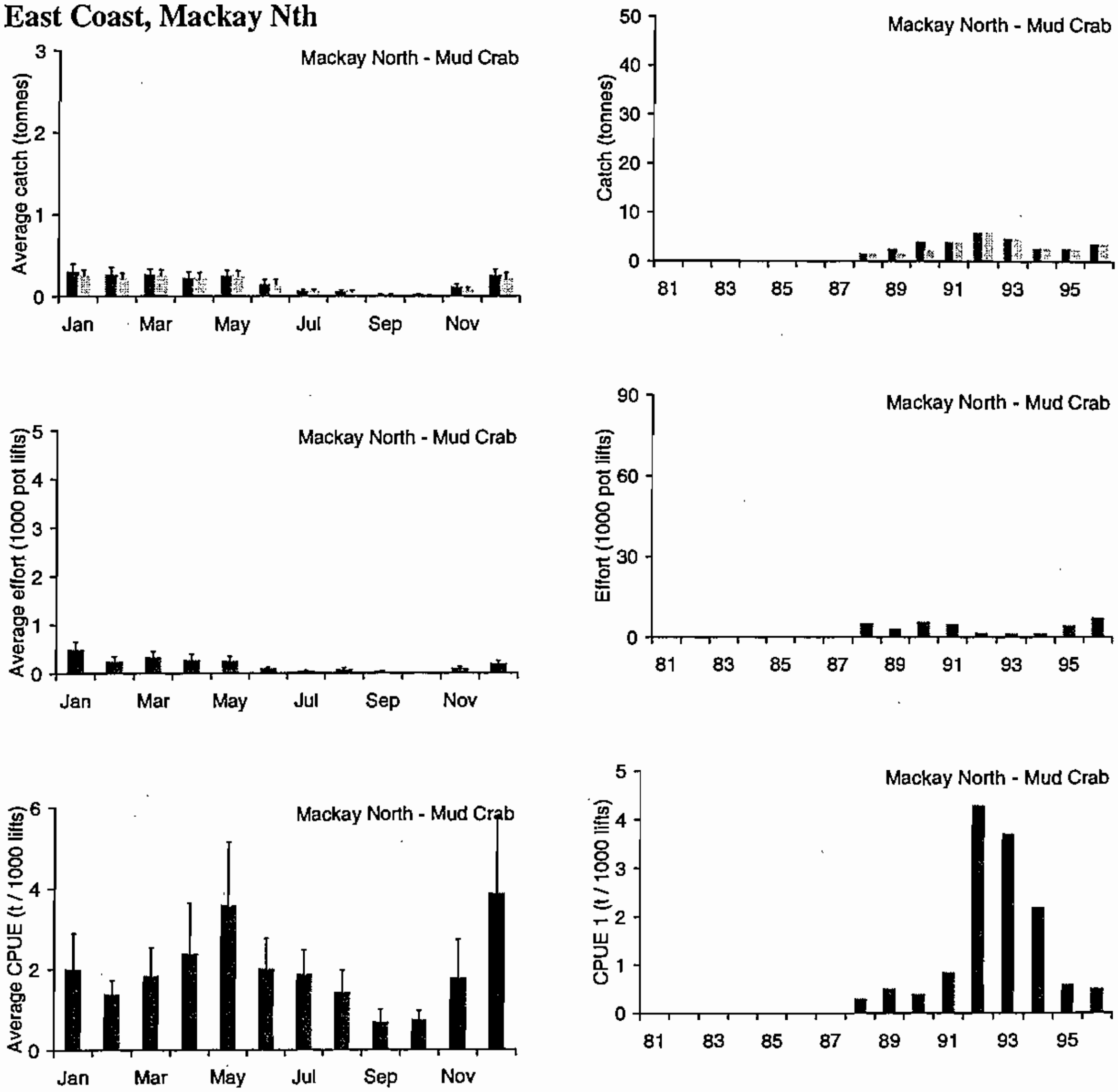

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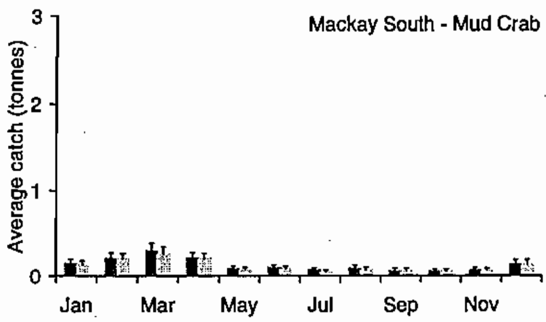

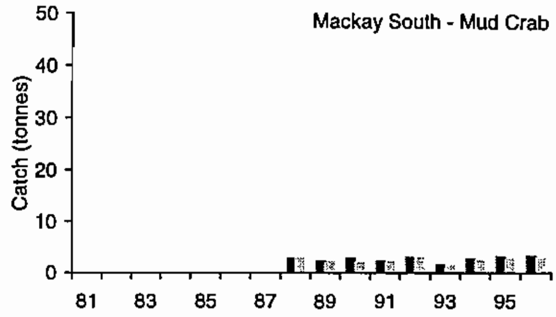

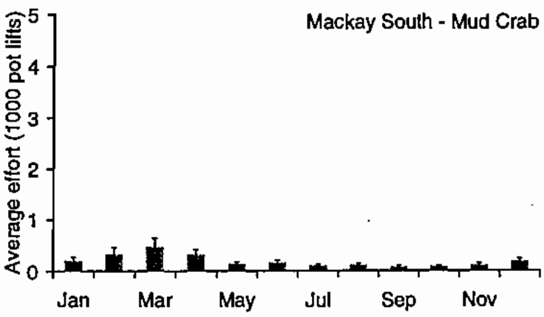

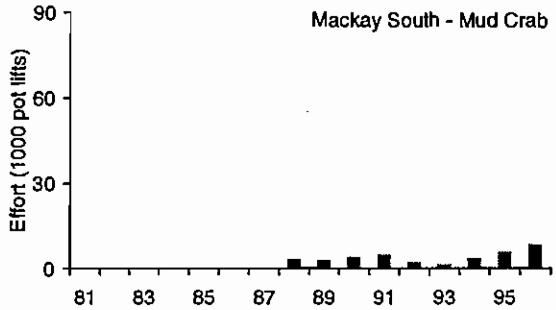

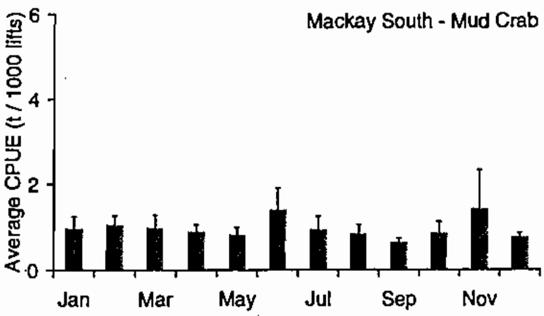

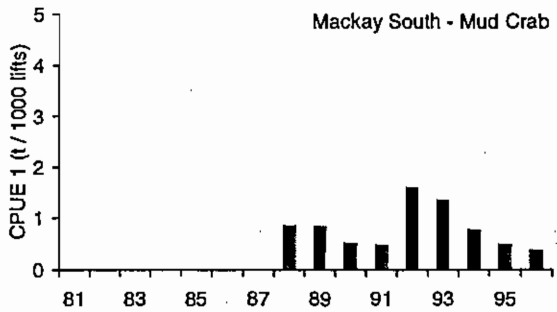

Appendix V Letter of Support from NSW Fisheries for Research Directions Endorsed at Workshop

NSW FISHERIES

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	ACTION OFFICER
1	C. Calogeras
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Mr Chris Calogeras
A/Assistant Director of Aquatic Resource Management
Fisheries Division
Dept. Primary Industry and Fisheries
DARWIN NT 0801

Dear Mr Calogeras Chris

Thank you for your letter of 24 June 1999 concerning the research directions for mud crabs endorsed by the Mud Crab Workshop held in Darwin in May.

Whilst NSW currently has no major concerns regarding our mud crab fishery, and consequently no pressing priority to allocate resources to research on this species, I am happy to endorse the priorities put forward by the workshop. They appear to be sensible and of general importance to the future research and management of Australia's mud crab resources.

I am particularly pleased to see your mention of research designed to examine the appropriateness of regional size limit regulations because there is some evidence in NSW that the current size limit may not be appropriate. I look forward to any new research undertaken that may assist in examining this issue more thoroughly.

Yours sincerely

John Glaister 21/7/99

DR JOHN GLAISTER
Director of Fisheries

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