FRDC 1999/125

Tropical Resource Assessment Program (Qld inshore fish stocks):

Phase I, Collation and assessment of available fisheries information.

Phase II, Model application and validation.

Editor Dr Neil A Gribble

Contibuting authors:

Dr Neil A Gribble, Rod Garrett, Karina Magro, Jeff Bibby, Dr Vickie Hall, Stirling Peverell, Jason Stapley and David Welch.

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This publication provides the final report for FRDC project 1999/125

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Cover Photographs: Top panel, Barramundi, *Lates calcarifer (photo: E. Grant)*;
Bottom panel , the black-tip reef shark, *Carcharhinus melanopterus (photo: J. Stapley)*

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Structure of report

Due to the length and complexity of the project the final report has been broken up into five major sections.

Section 1. Adaptive management in a tropical fishery: Summary and Interpretation.

Section 2. Technical report of TRAP Phase I, which summarises:
- Collation of historic logbook information Gulf
- Collation of historic logbook information East Coast
- Collation of historic research information
- Proceeding of National Stock Assessment Expert Workshop

Section 3. Technical report of TRAP Phase II, N3 observation program

Section 4. Technical report of TRAP Phase II, N9 observer program

Section 5. Benefits, Outcomes and Conclusions

Appendices

	Appendix 1	Intellectual Property
	Appendix 2	Program Staff
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	Appendix 5	(Section 2)
	Appendix 6	(Section 3)
	Appendix 7	(Section 4)

Acronyms

AFFS	Agency for Food and Fibre Sciences
AFZ	Australian Fishing Zone
ASFB	Australian Society for Fish Biology
BACI	"before, after, control, impact" model
CFISH	commercial fishery catch and effort logbook database
CLIMPROD	FAO modelling software
CPUE	Catch per unit effort
CRC	Co-operative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CW	Carapace Width
DEH	Department of Environment and Heritage, Commonwealth
DPI&F	Department of Primary Industries and Fisheries, Queensland
EA	Environment Australia
ECOFISH	North Queensland Non-government organisation fostering sustainable fishing
Emsy	effort corresponding to MSY
EPBC	Environment Protection and Biodiversity Conservation Act, 1999
FAC	Fishing Advisory Committee
FAO	Food and Agriculture Organisation of the United Nations
FL	Fork Length
FRDC	Fisheries Research and Development Corporation
GBRMPA	Great Barrier Reef Marine Park Authority
GOC	Gulf of Carpentaria
GOCCFA	Gulf of Carpentaria Commercial Fishermen Association
GVP	Gross Value of Product
INFO FISH	Queensland recreational tag and release program
LCF	length at caudal fork
MAC	Management Advisory Committee
MLS	minimum legal size
MSY	Maximum Sustainable Yield
N3	Queensland Gulf of Carpentaria fishery from shore out to 7 nautical miles
N9	Queensland Gulf of Carpentaria fishery 7 to 25 nautical miles offshore
NFC	Northern Fisheries Centre
NHT	National Heritage Trust
NSF	Northern Shark Fishery
NT	Northern Territory
QCFO	Queensland Commercial Fisherman's Organisation
QDPI	Queensland Department of Primary Industries
QFISH	Queensland Recreational and Commercial Fishery catch and effort logbook database (DPI&F)
QFJA	Queensland Fisheries Joint Authority
QFMA	Queensland Fisheries Management Authority
QFS	Queensland Fisheries Service, DPI&F

QLD	Queensland
QSIA	Queensland Seafood Industry Association
RA	Released Alive
RAP	GBRMPA Representative Area Program
RD	Released Dead
RFISH	Recreational Fishery catch and effort logbook database (DPI&F)
SCFA	Standing Committee on Fisheries and Aquaculture
SEANET	Australian Non-government organisation fostering sustainable fishing
SFC	Southern Fisheries Centre
SUNFISH	Queensland Recreational Fishing Organisation
SUNTAG	Queensland recreational tag and release program
TL	Total Length
TRAP	Tropical Research Assessment Program
VMS	Vessel Monitoring System (Satellite based)
VPA	Virtual Population Analysis
WA	Western Australia
ZAC	Zonal Advisory Committee

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1999/125 Tropical Resource Assessment Program (Qld inshore fish stocks)

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Objectives:

1. Evaluate the effectiveness of the Management Plan for the Gulf Inshore Fishery (1999).
2. To assess the effect of a large reduction and spatial redeployment of fishing effort on the population dynamics of exploited tropical inshore finfish species.
3. To identify species composition of the Queensland Gulf inshore shark fishery and report on the impact of increased effort on shark stocks in the new N9 fishery.
4. To provide a model for the analysis of management plans as a contribution to development and review process for tropical inshore fisheries.

Non-technical Summary :

The evaluation of the "adaptive management" concept (Walters 1986) carried out for the Queensland Gulf of Carpentaria inshore finfish fishery, via the comparison of Tropical Resource Assessment Program, Phase I and Phase II data, identified a major challenge:

- Given high inter-annual variation (typical of tropical fisheries) then a relatively long the data time-series was required to identify statistically significant trends, in this case at least 3 to 5 years.
- Stability of the management/political regime over this longer period was unlikely; resulting in changes to management outside the Gulf Plan and beyond the control of the researchers, and thus leading ultimately to a confounding of variables.
- Therefore, either the management regime being assessed needed remain stable for long enough to pick-up resultant change in stock statistics, or any management intervention had to result in relatively short-term "dramatic" change that was much greater than the background variation; i.e., were unambiguous.

The timing for the current evaluation was dictated by the passing of Queensland legislation for the 1999 Management Plan for the Gulf of Carpentaria Inshore Finfish Fishery. The subsequent period has been highly unstable politically as the Queensland State and Commonwealth "Environment" legislation was undergoing fundamental changes. Fishery Management needed to react to these political/legislative changes, outside the original terms of the 1999 Gulf Plan, and beyond the control and scope of the evaluation.

In more general terms; in tropical fisheries with high natural (inter-annual) variation in population parameters, it may not be possible to establish realistic timeframes to allow statistically valid evaluation of the effects of management initiatives, or of any contingent "adaptive" responses.

Reporting against Outcomes achieved (from TRAP Phase II proposal).

1). *The Queensland Gulf inshore net fishermen embrace the concept of co-operative fisheries research through an observer program.*

(a) The TRAP N9 observer program has been transferred from research to operational status under the QFS Long Term Monitoring program, with the TRAP temporary biologist/observer currently being upgraded to a permanent employee.

(b.) The refinements to stock assessments recommended by the national stock assessment workshop of TRAP Phase I were carried out; in particular the observer data set was used in the Virtual Population Analysis (Pope cohort analysis) of the Gulf Barramundi stock.

An additional refinement was the partial validation of logbook information; in particular the identification of three boats that were submitting major quantities of catch and effort "mis-information". By observing the actual catch rates from vessels fishing alongside the boats in question it was possible to discount these logbook reports. Information quality was improved, which has meant that assessments based on this information were also improved.

(c.) The stock and fishery assessments produced by TRAP feed directly into the Gulf Management Advisory Committee and the advisory committee of the Gulf Queensland Fisheries Joint Authority. These assessments are also integrated into QFS biannual fisheries "Condition and Trend" reporting, and are now part of the QFS Long-Term Monitoring Program reporting process.

An unforeseen but crucial management need and subsequent use of the TRAP assessments was for the Ecological Assessment of the Gulf of Carpentaria Inshore Finfish Fishery, produced by QFS for Environment Australia to fulfil the requirements of the EPBC Act. At stake were permits to export product from the fishery; in a real sense its financial viability.

A further indirect improvement to fisheries management has been the acceptance of the effectiveness of fisheries observers by both management and industry, with observers now being considered for all Queensland fisheries.

(d.) Stock and fishery assessments, staff-time, and project resources from TRAP Phases I and II significantly assisted the Gulf of Carpentaria Commercial Fishermen's Association in producing:

- Operational Code of Conduct for the Gulf fisheries, and an
- Environment Management Plan (industry sponsored).

Furthermore, two of our major industry partners, Gary Ward and Claudine Ward, received the national Fisherman of the year (2002) award and national fisheries Environmental award (2003) respectively, for this work on advancing sustainable fishing in the Queensland Gulf of Carpentaria.

These are tangible examples of where the Gulf fishing community had real ownership of the research outputs, and using this knowledge and support, is now leading Australian tropical fisheries in responsible and sustainable management of their fish resources. This has been all the more remarkable, as the Gulf of Carpentaria is considered remote, logistically difficult, and even "hazardous".

The Gulf fishing community acknowledged the important supportive role provided by TRAP through its nomination of the TRAP Team for a successful 2001 QDPI Client Service Award.

(2) *Documentation of biological information on priority fish species is carried out to fill gaps identified by FRDC Project 92/145 and FRDC Project 95/049. This will include information on species composition, number caught, and population structure (length frequency) of the catch. This information will be summarised and published with the project annual reports.*

The Tropical Resource Assessment Program has been outstandingly successful in collecting and collating historic logbook and research data from the North Queensland coastal gill-net fishery into two parallel 22-year time-series. On their own these collated data represent a pivotal management tool, given high inter-annual variation in the commercial fish catch means that slow underlying trends in the recovery of the stock can only be identified when a long-term time-series is examined. A 2-3.5% annual increase in biomass over a long period can be "lost" where short-term inter-annual variation is in the order of 20%.

Sections 3 and 4 of this report, which are the technical reports from the N3 and N9 observers, combined with the data appendices in section 5, document species composition of catch and bycatch, number caught, and population structure (length frequency) of the major targeted species of the Queensland Gulf Inshore set net fishery.

(3) *An evaluation of the effort reduction initiatives of the Gulf Inshore Finfish Fishery Management Plan (1999) is carried out in terms of their effect on stock dynamics*.

The Gulf Plan called for a Government/Industry funded buy-back of endorsements, reducing fishing effort by 30%. Contingent on this reduction was to be the progressive closure to commercial fishers of a number of environmentally sensitive rivers. In the event, State Government funding constraints meant that no money was available for the buy-back, hence only a very small reduction of effort occurred through the Industry contribution, and therefore there were no spatial closures (due to the Plan itself).

The evaluation showed that while there had been a steady rebuild of the "indicator" Gulf Barramundi stock since the early 1980's, there had been no significant impact on this recovery trajectory by the 1999 Gulf Plan, (as yet).

(4) *The results of the project are useful to and are incorporated in future Management Plans for tropical inshore fisheries, in particular the Queensland Tropical East Coast Inshore Fishery Management Plan.*

As documented in this and previous reports, the progress results and stock assessments from TRAP Phase I were instrumental in the formulation of the 1999 Management Plan for the Gulf Inshore Finfish Fishery. TRAP Phase II interim reports, briefings, and collated data have been incorporated in:

(a.) QFS Bycatch Action Plan for Gulf inshore set net fisheries,
(b.) National Plan of Action for Shark,
(c.) Ecological Assessment of the Gulf of Carpentaria Inshore Finfish Fishery for EA,
(d.) National Oceans Office, Northern Area Planning process, and,
(e.) ongoing deliberations of Inshore Finfish MAC for the Queensland East Coast Inshore Fishery Management Plan.

Keywords: Adaptive management, fish stock assessment, fisheries observers.

Acknowledgements

Section 1 and 2

Barramundi Assessment
The authors would like to acknowledge the contributions Lew Williams, Jim Higgs and Clare Bullock (QFS) who assisted in providing the CFISH catch and effort data, recreational catch data (RFISH and Charter Boat logbook) and Long Term Monitoring data. Dr David Die (Rosendial School of Marine and Atmospheric Science) developed the biomass dynamic model used here. Malcolm Haddon (University of Tasmania) and Clive Turnbull (QFS) provided helpful comments during discussions on fitting data to the biomass dynamic model.

Threadfin Salmon Assessment
The authors would like to acknowledge the contributions of Lew Williams and Clare Bullock (QFS) who assisted in providing the CFISH catch and effort data. Michael O'Neill (AFFS, SFC) and Clive Turnbull (AFFS, NFC) provided helpful comments during discussions on attempting to fit data to the biomass dynamic model and analysis of the data. Professor Norm Hall (Murdoch University), kindly undertook independent review of this assessment and the methods used. The Threadfin Salmon assessment was markedly improved following Professor Halls' appraisal and we are grateful for his considered input.

Shark Assessment
Stuart Hyland, QFS for the additional observer data from the CRC REEF B4.5 Coastal Fisheries Monitoring. Special thanks to those skippers and fishing vessels that participated in the observer programs, allowing the collection of data on the catch (and bycatch). Without their co-operation the collection of such invaluable data would not have been possible.

Adaptive Management Evaluation
The authors acknowledge the comments and support of Prof Joe Baker, Gulf MAC Chair, and Mark Doohan (QFS). Mark had the unenviable task of managing the Queensland inshore net fisheries during the TRAP Phase II period. Special thanks to the Ward and Lollo families and to the Gulf of Carpentaria Commercial Fishermen's Association for their support throughout the TRAP project. Without their active co-operation this project would not have been possible.

Section 3 and 4
The Authors wish to thank the operators for their goodwill and assistance with data collection. The data gathered across the Gulf fisheries are critical to ensuring long-term sustainability of the finfish resources of Northern Australia.

Section 5
The Authors wish to thank Olivia Whybird for editing and review of the overall document and of ensuring compliance for FRDC proformas.

Background

Original Proposal

This project introduces a new era in tropical fisheries management in Australia. The Queensland Fisheries Management Authority (QFMA) are to put in place a Management Plan for the Gulf of Carpentaria Inshore Fishery in the 1999 fishing season. A successful management plan will; ensure sustainability of the fishery resources, promote the long-term viability of fishers, and foster rational exploitation of a new sector (inshore shark). This will be one of the first dedicated fishery Management Plans for tropical fisheries, Australia-wide, and will provide a "test-bed" for other such plans in the future, particularly the Management Plan for the Queensland Tropical East coast Inshore Fishery.

TRAP (Phase I), FRDC Project (95/049), gave regular research updates to the Tropical Finfin Management Advisory Committee (Tropical Finfish MAC) which were incorporated in the Gulf Inshore Fishery Plan. Therefore it is possible for the first time to create an integrated "Before and After" assessment of the initiatives provided in such management plans. TRAP (Phase I) has provided the "before" data times-series and the proposed project would give the complementary "after" perspective.

The Gulf Management Plan calls for;

(a) a reduction of the fishing effort by approximately 30%, via buy-back of N3 endorsements,
(b) redeployment of effort, via a new offshore N9 license which will require surrendering two N3 endorsements, and
(c) further reduction in effort by closure of some rivers in the fishery.

Such a reduction in effort represents a significant "signal" that will be injected into population dynamics of the target species and will resonate through subsequent year's catch and effort data. The effects of this signal can be analysed in two ways; firstly as a measure of the success or otherwise of the management initiatives, and secondly as a tool for stock assessment of target species.

Walters (1986) describes a system of "adaptive management" of fisheries resources whereby management is seen as an adaptive process, learning from the response of the fishery to controlled changes to management regimens. The effect of a large reduction in effort combined with a spatial redeployment of some of the remaining effort in the Gulf inshore fishery will provide a unique opportunity to:

(a) monitor the effectiveness of the Gulf Management Plan initiatives by tracking the change in population dynamics of the target species, and,
(b) test the effectiveness of the Walters (1986) concept in a tropical fishery by assessing the effect of changes in fishing effort on the target species populations and providing this as feedback to the Tropical Finfish MAC for incorporation of plans under development.

Update on the project background

The Queensland Fisheries Management Authority (now the Queensland Fishery Service) put in place the legislated Queensland Gulf of Carpentaria Inshore Finfish Fishery Management Plan (the Gulf Plan) in 1999. The major objectives of the Gulf Plan were to;

- Maintain inshore finfish stocks at sustainable levels,
- Protect spawning target species,
- Minimise the effects of fishing on protected wildlife,
- Provide a recreational fishery that gives economic and social benefits to local, regional and State economies, and to,
- Satisfy the traditional or customary needs of Aborigines and Torres Strait Islanders.

This plan called for a reduction in commercial fishing effort by over 30% via an endorsement buy-back, followed by closure of some rivers to commercial fishing. There was a division of the inshore net fishery into an N3 and N9 component, with the N3 endorsement fishing from shore to 7 nautical miles and the N9 from 7 nautical miles out to 25 nautical miles offshore. The new N9 endorsement recognised that there had been a progressive increase in the tonnage of offshore species being caught (identified in TRAP Phase I), primarily shark and mackerel, targeted by a small number of operators.

The current report provides the first assessment of the GOC fishery since the implementation of the 1999 Gulf Plan, along with a preliminary assessment of the East Coast fishery. The overall aim was to test the effectiveness of the management plan in meeting its objective of maintaining inshore finfish stocks at sustainable levels and so provide feedback to allow the Gulf Management Advisory Committee (previously the Tropical Finfish Management Advisory Committee) to make changes to the Gulf Plan if necessary. The latter process follows the concept of adaptive management advocated by Carl Walters (1986). Assessment of the situation before and after the enactment of the Gulf Plan was provided by the two phases of the Tropical Resource Assessment Program (TRAP Phase I and II).

TRAP Phase I (FRDC Project 95/049) was responsible for collating and assessing all of the available stock assessment information for the inshore gill net fishery in tropical North Queensland. Another aspect of the project was to generate stock assessment models describing the population dynamics of tropical Barramundi and king salmon in particular. The status of the inshore gillnet fishery and recommended management initiatives were provided to the northern Tropical Finfish Management Advisory Committee through regular research updates. These project outputs were instrumental in the formulation of the 1999 Gulf Inshore Finfish Management Plan.

TRAP Phase II (FRDC Project 99/125) gave the corresponding "after" perspective, primarily through a fishery observer program. The TRAP observer program was integrated with the FRDC funded "Effects of Inshore Gillnetting" project (FRDC 97/206), with the ongoing observer program set-up for the Queensland Gulf N9 fishery under the 1999 Gulf Plan, and with the QDPI "Long Term Monitoring" program also begun in 1999. All projects utilised fisheries observers to collect accurate research data, which complemented and extended the TRAP Phase I database. This research time-series paralleled the fishery-dependent QFISH commercial logbook database, which combined historic plus current records.

Observers operating within a supportive commercial fishery was the only cost-effective way to collect the "validated" field data required, given the remoteness of the Gulf. The alternative was to undertake extensive independent surveys in this difficult isolated area of northern Queensland. The latter would have been expensive and extremely difficult logistically, if not impossible.

Fisheries Management and policy changes during the life of the project

State

A major reorganisation of Queensland fisheries management agencies occurred in 2000-2001. The Queensland Fisheries Management Authority (QFMA) was absorbed by QDPI into the Queensland Fisheries Service (QFS), and lost its independent board. The fishery Management Advisory Committees (MACs) now operated under the QFS and were also reorganised at this time. The northern Tropical Finfish MAC was disbanded, and its responsibilities for Gulf of Carpentaria fisheries assumed by Gulf MAC. The northern East Coast inshore fisheries, became part of the portfolio of the East Coast Inshore Finfish MAC. [Editor: In February 2004 QDPI was reorganised again as the Department of Primary Industries and Fisheries (DPI&F), and the QFS has become the Fisheries Buisness Group].

Gulf MAC was responsible for reviewing the Queensland Gulf of Carpentaria Inshore Finfish Fishery Management Plan (1999) hence the TRAP project fed progress reports and briefings primarily into and through the Gulf MAC. The role of TRAP co-investigators in the new MAC structure was similar to the previous structure with Rod Garrett as a member and Dr Neil Gribble as an adviser on stock assessment; that is direct communication of project outputs to management and industry was maintained.

In 2001 the N9 Fisheries observer reported the capture and mortality of four dolphin (*Tursiops*) in commercial nets. This prompted a review event under the Queensland Gulf of Carpentaria Inshore Finfish Fishery Management Plan and a stakeholder Bycatch Workshop was run which developed and a Bycatch Action plan (2002). Because of its strategic database and observer experience in the Gulf inshore fisheries, the TRAP project team was requested/required to participate and help formulate the action plan.

One recommendation from the Bycatch Action Plan was the testing and monitoring the effectiveness of Dolphin "Pingers" (acoustic warning beacons fitted to the nets) and the N9 observer took on this role. At the time there was an NHT funded project building suitable devices specially adapted to Queensland conditions and the Gulf N9/N3 fishers volunteered to trial them, (with the assistance and monitoring by TRAP observers). Collaboration between projects was ensured, as Geoff McPherson and Dr. Neil Gribble were co-investigators on the NHT project as well as on the TRAP project.

On the East Coast although there was no Inshore Finfish Fishery Management Plan (the relevant MAC was and still is formulating this Plan), concern from conservation groups prompted the Commonwealth and Queensland Governments to proclaim dugong (*Dugong dugong*) sanctuary areas along the coast. Sanctuaries were sited in areas where there was a perceived risk of dugong mortality from the inshore commercial fishery nets; i.e. the Barramundi fishery. Coincidentally there was a re-zoning of the Far Northern Section of the Great Barrier Reef Marine Park, which also closed a number of prime Barramundi fishery areas. These spatial closures and the resultant reduction in "effective" fishing effort, represent a confounding factor when comparing the Gulf and East Coast catch statistics.

Finally, the QDPI Fisheries Group, the original lead agency for the TRAP project, was reorganised in 2001 into the Queensland Fisheries Service (QFS) and the Agency for Food and Fibre Sciences (AFFS) Fisheries and Aquaculture research unit. Most project research staff and the project management were assigned to AFFS but a number of co-investigators went to QFS. This included one of the TRAP fisheries observers (N9) and the QFISH commercial logbook section. [Editor: since writing the department became the Department of Primary Industries and Fisheries (DPI&F), QFS became the Fisheries Business Group, and fisheries research staff from AFFS are now located in the Sustainable Fisheries Program, Animal Science group, Delivery Business Group].

QFS has subsequently refocussed its priorities, concentrating on the Queensland East Coast, GBR World Heritage Area, in particular the trawl and reef-line fishery management plans. QFS has also reassigned resources to manage the implication of area closures resulting from the Marine Representative Areas Program put forward by GBRMPA

Commonwealth

The State policy changes reflect changes that occurred at the Federal Government level. Fished species went from an exempt status under the old Act to the status where a fishery taking these species required assessment of its Ecological Sustainability under the Environment Protection and Biodiversity Conservation Act, 1999 (EPBC Act).

In December 1998 the Commonwealth Government launched Australia's Oceans Policy, which established the broad principles and actions required

to achieve ecologically sustainable development in Australia's Exclusive Economic Zone.

> "*The Policy includes principles for ecological sustainability and a range of measures for delivering ecologically sustainable fisheries. The goal is to use, conserve and enhance resources so that ecological process and ecosystem functions are maintained, or enhanced, for the benefit of present and future generations, whilst taking into account both long-term and short-term economic, environmental and social equity considerations*." (Environment Australia Guidelines, 2001).

This Policy commitment is underpinned by two legislative requirements:

1. *that all Commonwealth managed fisheries undergo strategic environmental impact assessment before new management arrangements are brought into effect;* and (of relevance to State Fisheries),

2. *that all fisheries based on export of marine species undergo assessment to determine the extent to which management arrangements will ensure the fishery is managed in an ecologically sustainable way.*

These requirements were set out in the EPBC Act and included timeframes within which the assessments were required. Initially these were due to be completed by 2003 but this deadline has been progressively delayed to 2004.

The result of the EPBC Act was a profound change in the industry and management requirements from the TRAP program. Due to foresight, essential information had been collated or collected as part of TRAP and its allied projects for assessment of the sustainability of both target and by-catch species for the Queensland Inshore Finfish Fishery (see Roelofs 2003).

Community

Even at the community level there were profound changes. Due to a shift in State Government policy, compulsory membership in the Queensland Commercial Fisherman's Organisation (QCFO) now known as the Queensland Seafood Industry Association (QSIA) was no longer supported. On the East Coast this led to a reduction in the QSIA membership and the formation of a number of voluntary industry representative associations. In the Cairns and northern region, ECOFISH took over this function. In the Gulf region, the Gulf of Carpentaria Commercial Fishermen's Association took on the representation role, but maintained its links with the QSIA.

In parallel to the EPBC Act reporting process, the Gulf of Carpentaria Commercial Fishermen's Association formulated and produced a Code of Conduct and an industry sponsored Environmental Management Plan (see Roelofs 2003; Appendix 3&4). The TRAP project and TRAP staff individually, encouraged, facilitated funding and provided fisheries

assessment information to the Association both directly and through the SEANET fisheries extension officer. TRAP support has continued into the current application by the Gulf of Carpentaria Commercial Fishermen's Association for Marine Stewardship Council certification for their fishery.

In recognition of this collaborative relationship, the Gulf of Carpentaria Commercial Fishermen's Association nominated the TRAP program team for a successful 2001 DPI Client Service Award.

Climatic changes.

During the period of TRAP Phase II, Northern Australia has gone through one of the worst droughts on record. Given that the recruitment of many Gulf species is driven by the inundation and river flows caused by the monsoonal wet season, a prolonged drought can be expected to impact stock dynamics. Documenting these relationships was well beyond the scope of the original grant proposal so Ms Jackie Balston was encouraged to begin a MSc project (James Cook University) looking at the effects of climate on fisheries productivity, using the TRAP dataset. This project is progressing and is allied to a Coastal CRC program researching the effect of river flow on coastal fish productivity.

Post-Plan issues considered by the Management Advisory Committee

Several major issues arose after the adoption of the 1999 Gulf Plan from within the fishery while others had their origins in overlapping jurisdictions; all have required a co-ordinated response to be made from the fishery management agency and the operators on the fishing grounds.

1. **Fishery accreditation under the Commonwealth EPBC Act 1999** Schedule 4 reporting provisions of the Environmental Protection and Biological Conservation Act require that the Gulf inshore finfish fishery demonstrate the ecological sustainability of net fishing. Roelofs (2003) have presented a detailed assessment to Environment Australia (now Commonwealth Department of Environment and Heritage), which awaits release for public comment. The assessment gives prominence to the effectiveness and thoroughness of elements of the Plan in meeting sustainability expectations. These measures include the on-board Fishery Observer programs, whose genesis was TRAP, in monitoring target and bycatch, in the reporting of incidental capture of proscribed species, and in assessing the utility of acoustic warning devices (pingers) to diminish interactions with protected wildlife species in fishing operations. The Observer approach developed by TRAP is likely to serve as a model for other fisheries in Australia, and its introduction made mandatory for fishery accreditation, especially for proving compliance with the “Part 13” protected species provisions of the EPBC Act. The N9 user-pays system for

funding the Observer scheme also demonstrates an approach appropriate elsewhere in Australia.

2. **Indigenous sector inclusion in fishery management arrangements**
In 2001, a national survey was conducted of recreational and Indigenous fishing across Australia, and the results recently reported by Henry and Lyle (2003). This signal publication characterized and quantified for the first time the importance and use made of fishery resources by these two sectors, and highlighted in particular the relevance of Indigenous needs in considerations about resource access and management. As part of an initiative across northern Australia, a framework for formal recognition of Indigenous inclusion in decisions on Queensland fisheries was enunciated in an Aboriginal and Torres Straits Islander Fishing Strategy (Smyth 1999). The Queensland Government's current Cape York Partnership initiative extends the movement towards Indigenous engagement in stewardship and use of fishery resources, and opens the door to future co-management arrangements. The protocols developed by TRAP for resource monitoring and assessment are easily extended to the Indigenous custodians of Sea Country, and technology transfer is occurring with a number of communities especially in the Western Peninsula Area. Such developments build on the success of Indigenous management of the Black Jewfish fishery in the Northern Peninsula Area described by Phelan (2002), where an overexploited resource has undergone stock rebuilding as a consequence of fishery intervention by Indigenous communities working co-operatively with Fisheries Management to achieve a common goal.

3. **Sustainability of shark and grey mackerel**
Meeting requirements of the National Plan of Action for Sharks and Rays has given Queensland Fisheries Service the mandate to progress on actions that will ensure the sustainability of sharks and rays in Queensland waters. The Commonwealth DEH fishery audit process (under the EPBC Act) has given impetus to establishing complementary arrangements between neighbouring jurisdictions where resources may be shared. Queensland has declared its prohibition on shark finning in non-target shark fisheries; other initiatives promoted by Gulf MAC for sharks include controlling the harvest of sharks through the issue of authorisations to target shark from the Queensland Fisheries Joint Authority (QFJA) to N9 fishers, and setting bycatch limits of shark product for other Gulf commercial and recreational fishers, at quantities that match closely those in force in the Northern Territory. Critical characterisation of exploited shark resources is underway with N9-QFJA Fishery Observer and Research Project Observer programs, the latter funded through FRDC Project on Sustainability of Northern Sharks and Rays, Phase 2. Such activities build on and extend the fishery-dependent data collection procedures developed in TRAP.

The status of grey mackerel as a QFJA species to be managed under Queensland law was confirmed in mid 2003. Subsequently, Gulf MAC has proposed that harvest of these mackerel in the Gulf N9 and N3 fisheries be controlled through limited QFJA authorities to target grey mackerel, and bycatch limits be set for fishers without such permits. Further, it is

proposed that the licence-holders fund and participate in a Fishery Observer program that collects biological and fishery information on the species that is necessary for assessing the status, condition and use of Gulf of Carpentaria grey mackerel stocks. In addition to providing a set of protocols for the Observer program, TRAP provides a blueprint for assessing the impact of the grey mackerel fishery management arrangements.

4. **Bycatch Action Plan for Queensland's Gulf inshore fisheries**
The genesis for this plan arose from a Ministerial direction to Queensland Fisheries Service to respond to reported cetacean mortalities in the N9 fishery during 2000. Developed through a Gulf-wide consultative process involving all three fishery sectors, the Plan is a strategic document that embraces all Gulf inshore net and line fisheries. A particular focus is on the incidental catch of species of conservation concern, and in developing methods to minimize the capture of non-target species in legal fishing gear and with apparatus lost or discarded in other fisheries. Establishing levels of cryptic mortality in fish released after capture is a national research initiative, fundamental to making accurate stock assessments, and includes key target species in Gulf waters such as the Barramundi. The Gulf Bycatch Action Plan is a cornerstone of the Queensland application for fishery accreditation under the EPBC Act (Roelofs 2003), and is integral to the industry Code of Conduct and Environmental Management System adopted by the Gulf of Carpentaria Commercial Fishermen's Association. Fishery Observer programs such as that currently operating in the N9 fishery serve to validate activities relating to the Gulf Plan and to judge the likely effectiveness of the measures when taken up on the fishing grounds.

5. **National Oceans Office's Northern Planning Area**
This recent commonwealth initiative engages many stakeholders in developing a framework for gaining knowledge about marine resources and for their future management. The Scoping Study phase of the Planning exercise has provided funding to define current understanding of fishery resources in profiles of key species/species groups, and to identify priorities for further investigation that will lead to a better understanding of the ecosystem. The 1999 Gulf Plan is scheduled for review in 2005; this timetable will allow GulfMAC and Queensland Fisheries Service to consider the results of the Northern Planning Area exercise as well as the outcomes of the Commonwealth DEH fishery accreditation application. Data obtained on Gulf fishery resources through TRAP and its more recent derivatives have already contributed significantly to meeting the requirements of both Commonwealth activities; the outputs from the program will have a vital role in setting directions for a new management plan for Gulf fisheries through the next decade.

Need

The project addresses the following needs:

1. To gather biological information on priority fish species to fill gaps identified by FRDC Project 92/145 and FRDC Project 95/049. Currently the commercial catch and effort logbooks record only common name categories of catch by daily weight (kg/day or kg/hour}. Information on true species composition, number caught, and population structure (length frequency) can only be gathered by expensive fishery independent sampling or a more cost-effective observer program (as proposed). This basic knowledge is critical to any effective management of complex multi-species tropical fisheries.

2. To evaluate the effort reduction initiatives of the Gulf Inshore Fishery Management Plan (1999) in terms of their effect on stock dynamics, as a test-bed for future Management Plans for tropical inshore fisheries, in particular the Queensland Tropical East coast Inshore Fishery Management Plan.

3. To Involve commercial fishers in the collection and ownership of research data that will be used in the management of their fishery.

And provides a unique opportunity to:

1. Apply and test the concept of "adaptive management" (Walters 1986) where management is seen as an adaptive process, learning from the response of the fishery to controlled changes to management regimens. The lessons learned from the Gulf Inshore Fishery Management Plan (1999) can be applied to Queensland Tropical East coast Inshore Fishery Management Plan as it is developed; if the effects of the Gulf Plan are properly documented.

2. TRAP Phase I (FRDC 95/049) has collated and validated historic and current catch/effort data for the Gulf, together with the available recreational and research data, to give a 16 year time-series of population dynamics of the target species of the inshore fishery. Building on the population dynamics models developed as part of TRAP (Phase I), the logical extension to the program is to use these tools to track the effects of proposed changes to management.

Objectives

Project Objectives TRAP Phase II:

4. Evaluate the effectiveness of the Queensland Fisheries Management Authority's new Management Plan for the Gulf Inshore Fishery (1999).
5. To assess the effect of a large reduction and spatial redeployment of fishing effort on the population dynamics of exploited tropical inshore finfish species.
6. To identify species composition of the Queensland Gulf inshore shark fishery and report on the impact of increased effort on shark stocks in the new N9 fishery.
7. To provide a model for the analysis of management plans as a contribution to development and review process for tropical inshore fisheries.

(see section 2 in this document for the objectives and summary of TRAP Phase I)

Planned Outcomes

Reporting against Outcomes achieved (from TRAP Phase II proposal).

1). *The Queensland Gulf inshore net fishermen embrace the concept of co-operative fisheries research through an observer program.*

(a) The TRAP N9 observer program has been transferred from research to operational status under the QFS Long Term Monitoring program, with the TRAP temporary biologist/observer currently being upgraded to a permanent employee.

(b.) The refinements to stock assessments recommended by the national stock assessment workshop of TRAP Phase I were carried out; in particular the observer data set was used in the Virtual Population Analysis (Pope cohort analysis) of the Gulf Barramundi stock.

An additional refinement was the partial validation of logbook information; in particular the identification of three boats that were submitting major quantities of catch and effort “mis-information”. By observing the actual catch rates from vessels fishing alongside the boats in question it was possible to discount these logbook reports. Information quality was improved, which has meant that assessments based on this information were also improved.

(c.) The stock and fishery assessments produced by TRAP feed directly into the Gulf Management Advisory Committee and the advisory

committee of the Gulf Queensland Fisheries Joint Authority. These assessments are also integrated into QFS biannual fisheries "Condition and Trend" reporting, and are now part of the QFS Long-Term Monitoring Program reporting process.

An unforeseen but crucial management need and subsequent use of the TRAP assessments was for the Ecological Assessment of the Gulf of Carpentaria Inshore Finfish Fishery, produced by QFS for Environment Australia to fulfil the requirements of the EPBC Act. At stake were permits to export product from the fishery; in a real sense its financial viability.

A further indirect improvement to fisheries management has been the acceptance of the effectiveness of fisheries observers by both management and industry, with observers now being considered for all Queensland fisheries.

(d.) Stock and fishery assessments, staff-time, and project resources from TRAP Phases I and II significantly assisted the Gulf of Carpentaria Commercial Fishermen's Association in producing:

- Operational Code of Conduct for the Gulf fisheries, and an
- Environment Management Plan (industry sponsored).

Furthermore, two of our major industry partners, Gary Ward and Claudine Ward, received the national Fisherman of the year (2002) award and national fisheries Environmental award (2003) respectively, for this work on advancing sustainable fishing in the Queensland Gulf of Carpentaria.

These are tangible examples of where the Gulf fishing community had real ownership of the research outputs, and using this knowledge and support, is now leading Australian tropical fisheries in responsible and sustainable management of their fish resources. This has been all the more remarkable, as the Gulf of Carpentaria is considered remote, logistically difficult, and even "hazardous".

The Gulf fishing community acknowledged the important supportive role provided by TRAP through its nomination of the TRAP Team for a successful 2001 QDPI Client Service Award.

(2) *Documentation of biological information on priority fish species is carried out to fill gaps identified by FRDC Project 92/145 and FRDC Project 95/049. This will include information on species composition, number caught, and population structure (length frequency) of the catch. This information will be summarised and published with the project annual reports.*

The Tropical Resource Assessment Program has been outstandingly successful in collecting and collating historic logbook and research data from the North Queensland coastal gill-net fishery into two parallel 22-year time-series. On their own these collated data represent a pivotal

management tool, given high inter-annual variation in the commercial fish catch means that slow underlying trends in the recovery of the stock can only be identified when a long-term time-series is examined. A 2-3.5% annual increase in biomass over a long period can be "lost" where short-term inter-annual variation is in the order of 20%.

Sections 3 and 4 of this report, which are the technical reports from the N3 and N9 observers, combined with the data appendices in section 5, document species composition of catch and bycatch, number caught, and population structure (length frequency) of the major targeted species of the Queensland Gulf Inshore set net fishery.

(3) *An evaluation of the effort reduction initiatives of the Gulf Inshore finfish Fishery Management Plan (1999) is carried out in terms of their effect on stock dynamics*.

The Gulf Plan called for a Government/Industry funded buy-back of endorsements, reducing fishing effort by 30%. Contingent on this reduction was to be the progressive closure to commercial fishers of a number of environmentally sensitive rivers. In the event, State Government funding constraints meant that no money was available for the buy-back, hence only a very small reduction of effort occurred through the Industry contribution, and therefore there were no spatial closures (due to the Plan itself).

The evaluation showed that while there had been a steady rebuild of the "indicator" Gulf Barramundi stock since the early 1980's, there had been no significant impact on this recovery trajectory by the 1999 Gulf Plan, (as yet).

(4) *The results of the project are useful to and are incorporated in future Management Plans for tropical inshore fisheries, in particular the Queensland Tropical East Coast Inshore Fishery Management Plan.*

As documented in this and previous reports, the progress results and stock assessments from TRAP Phase I were instrumental in the formulation of the 1999 Management Plan for the Gulf Inshore Finfish Fishery. TRAP Phase II interim reports, briefings, and collated data have been incorporated in:

(a.) QFS Bycatch Action Plan for Gulf inshore set net fisheries,
(b.) National Plan of Action for Shark,
(c.) Ecological Assessment of the Gulf of Carpentaria Inshore Finfish Fishery for EA,
(d.) National Oceans Office, Northern Area Planning process, and,
(e.) ongoing deliberations of Inshore Finfish MAC for the Queensland East Coast Inshore Fishery Management Plan.

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Structure of report

Due to the length and complexity of the project the final report has been broken up into five major sections.

Section 1. Adaptive management in a tropical fishery: Summary and Interpretation.

Section 2. Technical report of TRAP Phase I, which summarises:
- Collation of historic logbook information Gulf
- Collation of historic logbook information East Coast
- Collation of historic research information
- Proceeding of National Stock Assessment Expert Workshop

Section 3. Technical report of TRAP Phase II, N3 observation program

Section 4. Technical report of TRAP Phase II, N9 observer program

Section 5. Benefits, Outcomes and Conclusions

Appendices

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Acronyms

AFFS	Agency for Food and Fibre Sciences
AFZ	Australian Fishing Zone
ASFB	Australian Society for Fish Biology
BACI	"before, after, control, impact" model
CFISH	commercial fishery catch and effort logbook database
CLIMPROD	FAO modelling software
CPUE	Catch per unit effort
CRC	Co-operative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CW	Carapace Width
DEH	Department of Environment and Heritage, Commonwealth
DPI&F	Department of Primary Industries and Fisheries, Queensland
EA	Environment Australia
ECOFISH	North Queensland Non-government organisation fostering sustainable fishing
Emsy	effort corresponding to MSY
EPBC	Environment Protection and Biodiversity Conservation Act, 1999
FAC	Fishing Advisory Committee
FAO	Food and Agriculture Organisation of the United Nations
FL	Fork Length
FRDC	Fisheries Research and Development Corporation
GBRMPA	Great Barrier Reef Marine Park Authority
GOC	Gulf of Carpentaria
GOCCFA	Gulf of Carpentaria Commercial Fishermen Association
GVP	Gross Value of Product
INFO FISH	Queensland recreational tag and release program
LCF	length at caudal fork
MAC	Management Advisory Committee
MLS	minimum legal size
MSY	Maximum Sustainable Yield
N3	Queensland Gulf of Carpentaria fishery from shore out to 7 nautical miles
N9	Queensland Gulf of Carpentaria fishery 7 to 25 nautical miles offshore
NFC	Northern Fisheries Centre
NHT	National Heritage Trust
NSF	Northern Shark Fishery
NT	Northern Territory
QCFO	Queensland Commercial Fisherman's Organisation
QDPI	Queensland Department of Primary Industries
QFISH	Queensland Recreational and Commercial Fishery catch and effort logbook database (DPI&F)
QFJA	Queensland Fisheries Joint Authority
QFMA	Queensland Fisheries Management Authority
QFS	Queensland Fisheries Service, DPI&F

QLD	Queensland
QSIA	Queensland Seafood Industry Association
RA	Released Alive
RAP	GBRMPA Representative Area Program
RD	Released Dead
RFISH	Recreational Fishery catch and effort logbook database (DPI&F)
SCFA	Standing Committee on Fisheries and Aquaculture
SEANET	Australian Non-government organisation fostering sustainable fishing
SFC	Southern Fisheries Centre
SUNFISH	Queensland Recreational Fishing Organisation
SUNTAG	Queensland recreational tag and release program
TL	Total Length
TRAP	Tropical Research Assessment Program
VMS	Vessel Monitoring System (Satellite based)
VPA	Virtual Population Analysis
WA	Western Australia
ZAC	Zonal Advisory Committee

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1999/125 Tropical Resource Assessment Program (Qld inshore fish stocks)

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Objectives:

1. Evaluate the effectiveness of the Management Plan for the Gulf Inshore Fishery (1999).
2. To assess the effect of a large reduction and spatial redeployment of fishing effort on the population dynamics of exploited tropical inshore finfish species.
3. To identify species composition of the Queensland Gulf inshore shark fishery and report on the impact of increased effort on shark stocks in the new N9 fishery.
4. To provide a model for the analysis of management plans as a contribution to development and review process for tropical inshore fisheries.

Non-technical Summary :

The evaluation of the "adaptive management" concept (Walters 1986) carried out for the Queensland Gulf of Carpentaria inshore finfish fishery, via the comparison of Tropical Resource Assessment Program, Phase I and Phase II data, identified a major challenge:

- Given high inter-annual variation (typical of tropical fisheries) then a relatively long the data time-series was required to identify statistically significant trends, in this case at least 3 to 5 years.
- Stability of the management/political regime over this longer period was unlikely; resulting in changes to management outside the Gulf Plan and beyond the control of the researchers, and thus leading ultimately to a confounding of variables.
- Therefore, either the management regime being assessed needed remain stable for long enough to pick-up resultant change in stock statistics, or any management intervention had to result in relatively short-term "dramatic" change that was much greater than the background variation; i.e., were unambiguous.

The timing for the current evaluation was dictated by the passing of Queensland legislation for the 1999 Management Plan for the Gulf of Carpentaria Inshore Finfish Fishery. The subsequent period has been highly unstable politically as the Queensland State and Commonwealth "Environment" legislation was undergoing fundamental changes. Fishery Management needed to react to these political/legislative changes, outside the original terms of the 1999 Gulf Plan, and beyond the control and scope of the evaluation.

In more general terms; in tropical fisheries with high natural (inter-annual) variation in population parameters, it may not be possible to establish realistic timeframes to allow statistically valid evaluation of the effects of management initiatives, or of any contingent "adaptive" responses.

Reporting against Outcomes achieved (from TRAP Phase II proposal).

1). *The Queensland Gulf inshore net fishermen embrace the concept of co-operative fisheries research through an observer program.*

(a) The TRAP N9 observer program has been transferred from research to operational status under the QFS Long Term Monitoring program, with the TRAP temporary biologist/observer currently being upgraded to a permanent employee.

(b.) The refinements to stock assessments recommended by the national stock assessment workshop of TRAP Phase I were carried out; in particular the observer data set was used in the Virtual Population Analysis (Pope cohort analysis) of the Gulf Barramundi stock.

An additional refinement was the partial validation of logbook information; in particular the identification of three boats that were submitting major quantities of catch and effort "mis-information". By observing the actual catch rates from vessels fishing alongside the boats in question it was possible to discount these logbook reports. Information quality was improved, which has meant that assessments based on this information were also improved.

(c.) The stock and fishery assessments produced by TRAP feed directly into the Gulf Management Advisory Committee and the advisory committee of the Gulf Queensland Fisheries Joint Authority. These assessments are also integrated into QFS biannual fisheries "Condition and Trend" reporting, and are now part of the QFS Long-Term Monitoring Program reporting process.

An unforeseen but crucial management need and subsequent use of the TRAP assessments was for the Ecological Assessment of the Gulf of Carpentaria Inshore Finfish Fishery, produced by QFS for Environment Australia to fulfil the requirements of the EPBC Act. At stake were permits to export product from the fishery; in a real sense its financial viability.

A further indirect improvement to fisheries management has been the acceptance of the effectiveness of fisheries observers by both management and industry, with observers now being considered for all Queensland fisheries.

(d.) Stock and fishery assessments, staff-time, and project resources from TRAP Phases I and II significantly assisted the Gulf of Carpentaria Commercial Fishermen's Association in producing:

- Operational Code of Conduct for the Gulf fisheries, and an
- Environment Management Plan (industry sponsored).

Furthermore, two of our major industry partners, Gary Ward and Claudine Ward, received the national Fisherman of the year (2002) award and national fisheries Environmental award (2003) respectively, for this work on advancing sustainable fishing in the Queensland Gulf of Carpentaria.

These are tangible examples of where the Gulf fishing community had real ownership of the research outputs, and using this knowledge and support, is now leading Australian tropical fisheries in responsible and sustainable management of their fish resources. This has been all the more remarkable, as the Gulf of Carpentaria is considered remote, logistically difficult, and even "hazardous".

The Gulf fishing community acknowledged the important supportive role provided by TRAP through its nomination of the TRAP Team for a successful 2001 QDPI Client Service Award.

(2) *Documentation of biological information on priority fish species is carried out to fill gaps identified by FRDC Project 92/145 and FRDC Project 95/049. This will include information on species composition, number caught, and population structure (length frequency) of the catch. This information will be summarised and published with the project annual reports.*

The Tropical Resource Assessment Program has been outstandingly successful in collecting and collating historic logbook and research data from the North Queensland coastal gill-net fishery into two parallel 22-year time-series. On their own these collated data represent a pivotal management tool, given high inter-annual variation in the commercial fish catch means that slow underlying trends in the recovery of the stock can only be identified when a long-term time-series is examined. A 2-3.5% annual increase in biomass over a long period can be "lost" where short-term inter-annual variation is in the order of 20%.

Sections 3 and 4 of this report, which are the technical reports from the N3 and N9 observers, combined with the data appendices in section 5, document species composition of catch and bycatch, number caught, and population structure (length frequency) of the major targeted species of the Queensland Gulf Inshore set net fishery.

(3) *An evaluation of the effort reduction initiatives of the Gulf Inshore Finfish Fishery Management Plan (1999) is carried out in terms of their effect on stock dynamics*.

The Gulf Plan called for a Government/Industry funded buy-back of endorsements, reducing fishing effort by 30%. Contingent on this reduction was to be the progressive closure to commercial fishers of a number of environmentally sensitive rivers. In the event, State Government funding constraints meant that no money was available for the buy-back, hence only a very small reduction of effort occurred through the Industry contribution, and therefore there were no spatial closures (due to the Plan itself).

The evaluation showed that while there had been a steady rebuild of the "indicator" Gulf Barramundi stock since the early 1980's, there had been no significant impact on this recovery trajectory by the 1999 Gulf Plan, (as yet).

(4) *The results of the project are useful to and are incorporated in future Management Plans for tropical inshore fisheries, in particular the Queensland Tropical East Coast Inshore Fishery Management Plan.*

As documented in this and previous reports, the progress results and stock assessments from TRAP Phase I were instrumental in the formulation of the 1999 Management Plan for the Gulf Inshore Finfish Fishery. TRAP Phase II interim reports, briefings, and collated data have been incorporated in:

(a.) QFS Bycatch Action Plan for Gulf inshore set net fisheries,
(b.) National Plan of Action for Shark,
(c.) Ecological Assessment of the Gulf of Carpentaria Inshore Finfish Fishery for EA,
(d.) National Oceans Office, Northern Area Planning process, and,
(e.) ongoing deliberations of Inshore Finfish MAC for the Queensland East Coast Inshore Fishery Management Plan.

Keywords: Adaptive management, fish stock assessment, fisheries observers.

Acknowledgements

Section 1 and 2

Barramundi Assessment
The authors would like to acknowledge the contributions Lew Williams, Jim Higgs and Clare Bullock (QFS) who assisted in providing the CFISH catch and effort data, recreational catch data (RFISH and Charter Boat logbook) and Long Term Monitoring data. Dr David Die (Rosendial School of Marine and Atmospheric Science) developed the biomass dynamic model used here. Malcolm Haddon (University of Tasmania) and Clive Turnbull (QFS) provided helpful comments during discussions on fitting data to the biomass dynamic model.

Threadfin Salmon Assessment
The authors would like to acknowledge the contributions of Lew Williams and Clare Bullock (QFS) who assisted in providing the CFISH catch and effort data. Michael O'Neill (AFFS, SFC) and Clive Turnbull (AFFS, NFC) provided helpful comments during discussions on attempting to fit data to the biomass dynamic model and analysis of the data. Professor Norm Hall (Murdoch University), kindly undertook independent review of this assessment and the methods used. The Threadfin Salmon assessment was markedly improved following Professor Halls' appraisal and we are grateful for his considered input.

Shark Assessment
Stuart Hyland, QFS for the additional observer data from the CRC REEF B4.5 Coastal Fisheries Monitoring. Special thanks to those skippers and fishing vessels that participated in the observer programs, allowing the collection of data on the catch (and bycatch). Without their co-operation the collection of such invaluable data would not have been possible.

Adaptive Management Evaluation
The authors acknowledge the comments and support of Prof Joe Baker, Gulf MAC Chair, and Mark Doohan (QFS). Mark had the unenviable task of managing the Queensland inshore net fisheries during the TRAP Phase II period. Special thanks to the Ward and Lollo families and to the Gulf of Carpentaria Commercial Fishermen's Association for their support throughout the TRAP project. Without their active co-operation this project would not have been possible.

Section 3 and 4
The Authors wish to thank the operators for their goodwill and assistance with data collection. The data gathered across the Gulf fisheries are critical to ensuring long-term sustainability of the finfish resources of Northern Australia.

Section 5
The Authors wish to thank Olivia Whybird for editing and review of the overall document and of ensuring compliance for FRDC proformas.

Background

Original Proposal

This project introduces a new era in tropical fisheries management in Australia. The Queensland Fisheries Management Authority (QFMA) are to put in place a Management Plan for the Gulf of Carpentaria Inshore Fishery in the 1999 fishing season. A successful management plan will; ensure sustainability of the fishery resources, promote the long-term viability of fishers, and foster rational exploitation of a new sector (inshore shark). This will be one of the first dedicated fishery Management Plans for tropical fisheries, Australia-wide, and will provide a "test-bed" for other such plans in the future, particularly the Management Plan for the Queensland Tropical East coast Inshore Fishery.

TRAP (Phase I), FRDC Project (95/049), gave regular research updates to the Tropical Finfin Management Advisory Committee (Tropical Finfish MAC) which were incorporated in the Gulf Inshore Fishery Plan. Therefore it is possible for the first time to create an integrated "Before and After" assessment of the initiatives provided in such management plans. TRAP (Phase I) has provided the "before" data times-series and the proposed project would give the complementary "after" perspective.

The Gulf Management Plan calls for;

(a) a reduction of the fishing effort by approximately 30%, via buy-back of N3 endorsements,
(b) redeployment of effort, via a new offshore N9 license which will require surrendering two N3 endorsements, and
(c) further reduction in effort by closure of some rivers in the fishery.

Such a reduction in effort represents a significant "signal" that will be injected into population dynamics of the target species and will resonate through subsequent year's catch and effort data. The effects of this signal can be analysed in two ways; firstly as a measure of the success or otherwise of the management initiatives, and secondly as a tool for stock assessment of target species.

Walters (1986) describes a system of "adaptive management" of fisheries resources whereby management is seen as an adaptive process, learning from the response of the fishery to controlled changes to management regimens. The effect of a large reduction in effort combined with a spatial redeployment of some of the remaining effort in the Gulf inshore fishery will provide a unique opportunity to:

(a) monitor the effectiveness of the Gulf Management Plan initiatives by tracking the change in population dynamics of the target species, and,
(b) test the effectiveness of the Walters (1986) concept in a tropical fishery by assessing the effect of changes in fishing effort on the target species populations and providing this as feedback to the Tropical Finfish MAC for incorporation of plans under development.

Update on the project background

The Queensland Fisheries Management Authority (now the Queensland Fishery Service) put in place the legislated Queensland Gulf of Carpentaria Inshore Finfish Fishery Management Plan (the Gulf Plan) in 1999. The major objectives of the Gulf Plan were to;

- Maintain inshore finfish stocks at sustainable levels,
- Protect spawning target species,
- Minimise the effects of fishing on protected wildlife,
- Provide a recreational fishery that gives economic and social benefits to local, regional and State economies, and to,
- Satisfy the traditional or customary needs of Aborigines and Torres Strait Islanders.

This plan called for a reduction in commercial fishing effort by over 30% via an endorsement buy-back, followed by closure of some rivers to commercial fishing. There was a division of the inshore net fishery into an N3 and N9 component, with the N3 endorsement fishing from shore to 7 nautical miles and the N9 from 7 nautical miles out to 25 nautical miles offshore. The new N9 endorsement recognised that there had been a progressive increase in the tonnage of offshore species being caught (identified in TRAP Phase I), primarily shark and mackerel, targeted by a small number of operators.

The current report provides the first assessment of the GOC fishery since the implementation of the 1999 Gulf Plan, along with a preliminary assessment of the East Coast fishery. The overall aim was to test the effectiveness of the management plan in meeting its objective of maintaining inshore finfish stocks at sustainable levels and so provide feedback to allow the Gulf Management Advisory Committee (previously the Tropical Finfish Management Advisory Committee) to make changes to the Gulf Plan if necessary. The latter process follows the concept of adaptive management advocated by Carl Walters (1986). Assessment of the situation before and after the enactment of the Gulf Plan was provided by the two phases of the Tropical Resource Assessment Program (TRAP Phase I and II).

TRAP Phase I (FRDC Project 95/049) was responsible for collating and assessing all of the available stock assessment information for the inshore gill net fishery in tropical North Queensland. Another aspect of the project was to generate stock assessment models describing the population dynamics of tropical Barramundi and king salmon in particular. The status of the inshore gillnet fishery and recommended management initiatives were provided to the northern Tropical Finfish Management Advisory Committee through regular research updates. These project outputs were instrumental in the formulation of the 1999 Gulf Inshore Finfish Management Plan.

TRAP Phase II (FRDC Project 99/125) gave the corresponding "after" perspective, primarily through a fishery observer program. The TRAP observer program was integrated with the FRDC funded "Effects of Inshore Gillnetting" project (FRDC 97/206), with the ongoing observer program set-up for the Queensland Gulf N9 fishery under the 1999 Gulf Plan, and with the QDPI "Long Term Monitoring" program also begun in 1999. All projects utilised fisheries observers to collect accurate research data, which complemented and extended the TRAP Phase I database. This research time-series paralleled the fishery-dependent QFISH commercial logbook database, which combined historic plus current records.

Observers operating within a supportive commercial fishery was the only cost-effective way to collect the "validated" field data required, given the remoteness of the Gulf. The alternative was to undertake extensive independent surveys in this difficult isolated area of northern Queensland. The latter would have been expensive and extremely difficult logistically, if not impossible.

Fisheries Management and policy changes during the life of the project

State

A major reorganisation of Queensland fisheries management agencies occurred in 2000-2001. The Queensland Fisheries Management Authority (QFMA) was absorbed by QDPI into the Queensland Fisheries Service (QFS), and lost its independent board. The fishery Management Advisory Committees (MACs) now operated under the QFS and were also reorganised at this time. The northern Tropical Finfish MAC was disbanded, and its responsibilities for Gulf of Carpentaria fisheries assumed by Gulf MAC. The northern East Coast inshore fisheries, became part of the portfolio of the East Coast Inshore Finfish MAC. [Editor: In February 2004 QDPI was reorganised again as the Department of Primary Industries and Fisheries (DPI&F), and the QFS has become the Fisheries Buisness Group].

Gulf MAC was responsible for reviewing the Queensland Gulf of Carpentaria Inshore Finfish Fishery Management Plan (1999) hence the TRAP project fed progress reports and briefings primarily into and through the Gulf MAC. The role of TRAP co-investigators in the new MAC structure was similar to the previous structure with Rod Garrett as a member and Dr Neil Gribble as an adviser on stock assessment; that is direct communication of project outputs to management and industry was maintained.

In 2001 the N9 Fisheries observer reported the capture and mortality of four dolphin (*Tursiops*) in commercial nets. This prompted a review event under the Queensland Gulf of Carpentaria Inshore Finfish Fishery Management Plan and a stakeholder Bycatch Workshop was run which developed and a Bycatch Action plan (2002). Because of its strategic database and observer experience in the Gulf inshore fisheries, the TRAP project team was requested/required to participate and help formulate the action plan.

One recommendation from the Bycatch Action Plan was the testing and monitoring the effectiveness of Dolphin "Pingers" (acoustic warning beacons fitted to the nets) and the N9 observer took on this role. At the time there was an NHT funded project building suitable devices specially adapted to Queensland conditions and the Gulf N9/N3 fishers volunteered to trial them, (with the assistance and monitoring by TRAP observers). Collaboration between projects was ensured, as Geoff McPherson and Dr. Neil Gribble were co-investigators on the NHT project as well as on the TRAP project.

On the East Coast although there was no Inshore Finfish Fishery Management Plan (the relevant MAC was and still is formulating this Plan), concern from conservation groups prompted the Commonwealth and Queensland Governments to proclaim dugong (*Dugong dugong*) sanctuary areas along the coast. Sanctuaries were sited in areas where there was a perceived risk of dugong mortality from the inshore commercial fishery nets; i.e. the Barramundi fishery. Coincidentally there was a re-zoning of the Far Northern Section of the Great Barrier Reef Marine Park, which also closed a number of prime Barramundi fishery areas. These spatial closures and the resultant reduction in "effective" fishing effort, represent a confounding factor when comparing the Gulf and East Coast catch statistics.

Finally, the QDPI Fisheries Group, the original lead agency for the TRAP project, was reorganised in 2001 into the Queensland Fisheries Service (QFS) and the Agency for Food and Fibre Sciences (AFFS) Fisheries and Aquaculture research unit. Most project research staff and the project management were assigned to AFFS but a number of co-investigators went to QFS. This included one of the TRAP fisheries observers (N9) and the QFISH commercial logbook section. [Editor: since writing the department became the Department of Primary Industries and Fisheries (DPI&F), QFS became the Fisheries Business Group, and fisheries research staff from AFFS are now located in the Sustainable Fisheries Program, Animal Science group, Delivery Business Group].

QFS has subsequently refocussed its priorities, concentrating on the Queensland East Coast, GBR World Heritage Area, in particular the trawl and reef-line fishery management plans. QFS has also reassigned resources to manage the implication of area closures resulting from the Marine Representative Areas Program put forward by GBRMPA

Commonwealth

The State policy changes reflect changes that occurred at the Federal Government level. Fished species went from an exempt status under the old Act to the status where a fishery taking these species required assessment of its Ecological Sustainability under the Environment Protection and Biodiversity Conservation Act, 1999 (EPBC Act).

In December 1998 the Commonwealth Government launched Australia's Oceans Policy, which established the broad principles and actions required

to achieve ecologically sustainable development in Australia's Exclusive Economic Zone.

> "*The Policy includes principles for ecological sustainability and a range of measures for delivering ecologically sustainable fisheries. The goal is to use, conserve and enhance resources so that ecological process and ecosystem functions are maintained, or enhanced, for the benefit of present and future generations, whilst taking into account both long-term and short-term economic, environmental and social equity considerations*." (Environment Australia Guidelines, 2001).

This Policy commitment is underpinned by two legislative requirements:

1. *that all Commonwealth managed fisheries undergo strategic environmental impact assessment before new management arrangements are brought into effect;* and (of relevance to State Fisheries),

2. *that all fisheries based on export of marine species undergo assessment to determine the extent to which management arrangements will ensure the fishery is managed in an ecologically sustainable way.*

These requirements were set out in the EPBC Act and included timeframes within which the assessments were required. Initially these were due to be completed by 2003 but this deadline has been progressively delayed to 2004.

The result of the EPBC Act was a profound change in the industry and management requirements from the TRAP program. Due to foresight, essential information had been collated or collected as part of TRAP and its allied projects for assessment of the sustainability of both target and by-catch species for the Queensland Inshore Finfish Fishery (see Roelofs 2003).

Community

Even at the community level there were profound changes. Due to a shift in State Government policy, compulsory membership in the Queensland Commercial Fisherman's Organisation (QCFO) now known as the Queensland Seafood Industry Association (QSIA) was no longer supported. On the East Coast this led to a reduction in the QSIA membership and the formation of a number of voluntary industry representative associations. In the Cairns and northern region, ECOFISH took over this function. In the Gulf region, the Gulf of Carpentaria Commercial Fishermen's Association took on the representation role, but maintained its links with the QSIA.

In parallel to the EPBC Act reporting process, the Gulf of Carpentaria Commercial Fishermen's Association formulated and produced a Code of Conduct and an industry sponsored Environmental Management Plan (see Roelofs 2003; Appendix 3&4). The TRAP project and TRAP staff individually, encouraged, facilitated funding and provided fisheries

assessment information to the Association both directly and through the SEANET fisheries extension officer. TRAP support has continued into the current application by the Gulf of Carpentaria Commercial Fishermen's Association for Marine Stewardship Council certification for their fishery.

In recognition of this collaborative relationship, the Gulf of Carpentaria Commercial Fishermen's Association nominated the TRAP program team for a successful 2001 DPI Client Service Award.

Climatic changes.

During the period of TRAP Phase II, Northern Australia has gone through one of the worst droughts on record. Given that the recruitment of many Gulf species is driven by the inundation and river flows caused by the monsoonal wet season, a prolonged drought can be expected to impact stock dynamics. Documenting these relationships was well beyond the scope of the original grant proposal so Ms Jackie Balston was encouraged to begin a MSc project (James Cook University) looking at the effects of climate on fisheries productivity, using the TRAP dataset. This project is progressing and is allied to a Coastal CRC program researching the effect of river flow on coastal fish productivity.

Post-Plan issues considered by the Management Advisory Committee

Several major issues arose after the adoption of the 1999 Gulf Plan from within the fishery while others had their origins in overlapping jurisdictions; all have required a co-ordinated response to be made from the fishery management agency and the operators on the fishing grounds.

1. **Fishery accreditation under the Commonwealth EPBC Act 1999** Schedule 4 reporting provisions of the Environmental Protection and Biological Conservation Act require that the Gulf inshore finfish fishery demonstrate the ecological sustainability of net fishing. Roelofs (2003) have presented a detailed assessment to Environment Australia (now Commonwealth Department of Environment and Heritage), which awaits release for public comment. The assessment gives prominence to the effectiveness and thoroughness of elements of the Plan in meeting sustainability expectations. These measures include the on-board Fishery Observer programs, whose genesis was TRAP, in monitoring target and bycatch, in the reporting of incidental capture of proscribed species, and in assessing the utility of acoustic warning devices (pingers) to diminish interactions with protected wildlife species in fishing operations. The Observer approach developed by TRAP is likely to serve as a model for other fisheries in Australia, and its introduction made mandatory for fishery accreditation, especially for proving compliance with the “Part 13” protected species provisions of the EPBC Act. The N9 user-pays system for

funding the Observer scheme also demonstrates an approach appropriate elsewhere in Australia.

2. **Indigenous sector inclusion in fishery management arrangements**
In 2001, a national survey was conducted of recreational and Indigenous fishing across Australia, and the results recently reported by Henry and Lyle (2003). This signal publication characterized and quantified for the first time the importance and use made of fishery resources by these two sectors, and highlighted in particular the relevance of Indigenous needs in considerations about resource access and management. As part of an initiative across northern Australia, a framework for formal recognition of Indigenous inclusion in decisions on Queensland fisheries was enunciated in an Aboriginal and Torres Straits Islander Fishing Strategy (Smyth 1999). The Queensland Government's current Cape York Partnership initiative extends the movement towards Indigenous engagement in stewardship and use of fishery resources, and opens the door to future co-management arrangements. The protocols developed by TRAP for resource monitoring and assessment are easily extended to the Indigenous custodians of Sea Country, and technology transfer is occurring with a number of communities especially in the Western Peninsula Area. Such developments build on the success of Indigenous management of the Black Jewfish fishery in the Northern Peninsula Area described by Phelan (2002), where an overexploited resource has undergone stock rebuilding as a consequence of fishery intervention by Indigenous communities working co-operatively with Fisheries Management to achieve a common goal.

3. **Sustainability of shark and grey mackerel**
Meeting requirements of the National Plan of Action for Sharks and Rays has given Queensland Fisheries Service the mandate to progress on actions that will ensure the sustainability of sharks and rays in Queensland waters. The Commonwealth DEH fishery audit process (under the EPBC Act) has given impetus to establishing complementary arrangements between neighbouring jurisdictions where resources may be shared. Queensland has declared its prohibition on shark finning in non-target shark fisheries; other initiatives promoted by Gulf MAC for sharks include controlling the harvest of sharks through the issue of authorisations to target shark from the Queensland Fisheries Joint Authority (QFJA) to N9 fishers, and setting bycatch limits of shark product for other Gulf commercial and recreational fishers, at quantities that match closely those in force in the Northern Territory. Critical characterisation of exploited shark resources is underway with N9-QFJA Fishery Observer and Research Project Observer programs, the latter funded through FRDC Project on Sustainability of Northern Sharks and Rays, Phase 2. Such activities build on and extend the fishery-dependent data collection procedures developed in TRAP.

The status of grey mackerel as a QFJA species to be managed under Queensland law was confirmed in mid 2003. Subsequently, Gulf MAC has proposed that harvest of these mackerel in the Gulf N9 and N3 fisheries be controlled through limited QFJA authorities to target grey mackerel, and bycatch limits be set for fishers without such permits. Further, it is

proposed that the licence-holders fund and participate in a Fishery Observer program that collects biological and fishery information on the species that is necessary for assessing the status, condition and use of Gulf of Carpentaria grey mackerel stocks. In addition to providing a set of protocols for the Observer program, TRAP provides a blueprint for assessing the impact of the grey mackerel fishery management arrangements.

4. **Bycatch Action Plan for Queensland's Gulf inshore fisheries**
The genesis for this plan arose from a Ministerial direction to Queensland Fisheries Service to respond to reported cetacean mortalities in the N9 fishery during 2000. Developed through a Gulf-wide consultative process involving all three fishery sectors, the Plan is a strategic document that embraces all Gulf inshore net and line fisheries. A particular focus is on the incidental catch of species of conservation concern, and in developing methods to minimize the capture of non-target species in legal fishing gear and with apparatus lost or discarded in other fisheries. Establishing levels of cryptic mortality in fish released after capture is a national research initiative, fundamental to making accurate stock assessments, and includes key target species in Gulf waters such as the Barramundi. The Gulf Bycatch Action Plan is a cornerstone of the Queensland application for fishery accreditation under the EPBC Act (Roelofs 2003), and is integral to the industry Code of Conduct and Environmental Management System adopted by the Gulf of Carpentaria Commercial Fishermen's Association. Fishery Observer programs such as that currently operating in the N9 fishery serve to validate activities relating to the Gulf Plan and to judge the likely effectiveness of the measures when taken up on the fishing grounds.

5. **National Oceans Office's Northern Planning Area**
This recent commonwealth initiative engages many stakeholders in developing a framework for gaining knowledge about marine resources and for their future management. The Scoping Study phase of the Planning exercise has provided funding to define current understanding of fishery resources in profiles of key species/species groups, and to identify priorities for further investigation that will lead to a better understanding of the ecosystem. The 1999 Gulf Plan is scheduled for review in 2005; this timetable will allow GulfMAC and Queensland Fisheries Service to consider the results of the Northern Planning Area exercise as well as the outcomes of the Commonwealth DEH fishery accreditation application. Data obtained on Gulf fishery resources through TRAP and its more recent derivatives have already contributed significantly to meeting the requirements of both Commonwealth activities; the outputs from the program will have a vital role in setting directions for a new management plan for Gulf fisheries through the next decade.

Need

The project addresses the following needs:

1. To gather biological information on priority fish species to fill gaps identified by FRDC Project 92/145 and FRDC Project 95/049. Currently the commercial catch and effort logbooks record only common name categories of catch by daily weight (kg/day or kg/hour}. Information on true species composition, number caught, and population structure (length frequency) can only be gathered by expensive fishery independent sampling or a more cost-effective observer program (as proposed). This basic knowledge is critical to any effective management of complex multi-species tropical fisheries.

2. To evaluate the effort reduction initiatives of the Gulf Inshore Fishery Management Plan (1999) in terms of their effect on stock dynamics, as a test-bed for future Management Plans for tropical inshore fisheries, in particular the Queensland Tropical East coast Inshore Fishery Management Plan.

3. To Involve commercial fishers in the collection and ownership of research data that will be used in the management of their fishery.

And provides a unique opportunity to:

1. Apply and test the concept of "adaptive management" (Walters 1986) where management is seen as an adaptive process, learning from the response of the fishery to controlled changes to management regimens. The lessons learned from the Gulf Inshore Fishery Management Plan (1999) can be applied to Queensland Tropical East coast Inshore Fishery Management Plan as it is developed; if the effects of the Gulf Plan are properly documented.

2. TRAP Phase I (FRDC 95/049) has collated and validated historic and current catch/effort data for the Gulf, together with the available recreational and research data, to give a 16 year time-series of population dynamics of the target species of the inshore fishery. Building on the population dynamics models developed as part of TRAP (Phase I), the logical extension to the program is to use these tools to track the effects of proposed changes to management.

Objectives

Project Objectives TRAP Phase II:

4. Evaluate the effectiveness of the Queensland Fisheries Management Authority's new Management Plan for the Gulf Inshore Fishery (1999).
5. To assess the effect of a large reduction and spatial redeployment of fishing effort on the population dynamics of exploited tropical inshore finfish species.
6. To identify species composition of the Queensland Gulf inshore shark fishery and report on the impact of increased effort on shark stocks in the new N9 fishery.
7. To provide a model for the analysis of management plans as a contribution to development and review process for tropical inshore fisheries.

(see section 2 in this document for the objectives and summary of TRAP Phase I)

Planned Outcomes

Reporting against Outcomes achieved (from TRAP Phase II proposal).

1). *The Queensland Gulf inshore net fishermen embrace the concept of co-operative fisheries research through an observer program.*

(a) The TRAP N9 observer program has been transferred from research to operational status under the QFS Long Term Monitoring program, with the TRAP temporary biologist/observer currently being upgraded to a permanent employee.

(b.) The refinements to stock assessments recommended by the national stock assessment workshop of TRAP Phase I were carried out; in particular the observer data set was used in the Virtual Population Analysis (Pope cohort analysis) of the Gulf Barramundi stock.

An additional refinement was the partial validation of logbook information; in particular the identification of three boats that were submitting major quantities of catch and effort “mis-information”. By observing the actual catch rates from vessels fishing alongside the boats in question it was possible to discount these logbook reports. Information quality was improved, which has meant that assessments based on this information were also improved.

(c.) The stock and fishery assessments produced by TRAP feed directly into the Gulf Management Advisory Committee and the advisory

committee of the Gulf Queensland Fisheries Joint Authority. These assessments are also integrated into QFS biannual fisheries "Condition and Trend" reporting, and are now part of the QFS Long-Term Monitoring Program reporting process.

An unforeseen but crucial management need and subsequent use of the TRAP assessments was for the Ecological Assessment of the Gulf of Carpentaria Inshore Finfish Fishery, produced by QFS for Environment Australia to fulfil the requirements of the EPBC Act. At stake were permits to export product from the fishery; in a real sense its financial viability.

A further indirect improvement to fisheries management has been the acceptance of the effectiveness of fisheries observers by both management and industry, with observers now being considered for all Queensland fisheries.

(d.) Stock and fishery assessments, staff-time, and project resources from TRAP Phases I and II significantly assisted the Gulf of Carpentaria Commercial Fishermen's Association in producing:

- Operational Code of Conduct for the Gulf fisheries, and an
- Environment Management Plan (industry sponsored).

Furthermore, two of our major industry partners, Gary Ward and Claudine Ward, received the national Fisherman of the year (2002) award and national fisheries Environmental award (2003) respectively, for this work on advancing sustainable fishing in the Queensland Gulf of Carpentaria.

These are tangible examples of where the Gulf fishing community had real ownership of the research outputs, and using this knowledge and support, is now leading Australian tropical fisheries in responsible and sustainable management of their fish resources. This has been all the more remarkable, as the Gulf of Carpentaria is considered remote, logistically difficult, and even "hazardous".

The Gulf fishing community acknowledged the important supportive role provided by TRAP through its nomination of the TRAP Team for a successful 2001 QDPI Client Service Award.

(2) *Documentation of biological information on priority fish species is carried out to fill gaps identified by FRDC Project 92/145 and FRDC Project 95/049. This will include information on species composition, number caught, and population structure (length frequency) of the catch. This information will be summarised and published with the project annual reports.*

The Tropical Resource Assessment Program has been outstandingly successful in collecting and collating historic logbook and research data from the North Queensland coastal gill-net fishery into two parallel 22-year time-series. On their own these collated data represent a pivotal

management tool, given high inter-annual variation in the commercial fish catch means that slow underlying trends in the recovery of the stock can only be identified when a long-term time-series is examined. A 2-3.5% annual increase in biomass over a long period can be "lost" where short-term inter-annual variation is in the order of 20%.

Sections 3 and 4 of this report, which are the technical reports from the N3 and N9 observers, combined with the data appendices in section 5, document species composition of catch and bycatch, number caught, and population structure (length frequency) of the major targeted species of the Queensland Gulf Inshore set net fishery.

(3) *An evaluation of the effort reduction initiatives of the Gulf Inshore finfish Fishery Management Plan (1999) is carried out in terms of their effect on stock dynamics*.

The Gulf Plan called for a Government/Industry funded buy-back of endorsements, reducing fishing effort by 30%. Contingent on this reduction was to be the progressive closure to commercial fishers of a number of environmentally sensitive rivers. In the event, State Government funding constraints meant that no money was available for the buy-back, hence only a very small reduction of effort occurred through the Industry contribution, and therefore there were no spatial closures (due to the Plan itself).

The evaluation showed that while there had been a steady rebuild of the "indicator" Gulf Barramundi stock since the early 1980's, there had been no significant impact on this recovery trajectory by the 1999 Gulf Plan, (as yet).

(4) *The results of the project are useful to and are incorporated in future Management Plans for tropical inshore fisheries, in particular the Queensland Tropical East Coast Inshore Fishery Management Plan.*

As documented in this and previous reports, the progress results and stock assessments from TRAP Phase I were instrumental in the formulation of the 1999 Management Plan for the Gulf Inshore Finfish Fishery. TRAP Phase II interim reports, briefings, and collated data have been incorporated in:

(a.) QFS Bycatch Action Plan for Gulf inshore set net fisheries,
(b.) National Plan of Action for Shark,
(c.) Ecological Assessment of the Gulf of Carpentaria Inshore Finfish Fishery for EA,
(d.) National Oceans Office, Northern Area Planning process, and,
(e.) ongoing deliberations of Inshore Finfish MAC for the Queensland East Coast Inshore Fishery Management Plan.

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Section 1. Adaptive management in a tropical fishery: Summary and Interpretation.

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Appendix 4 (Section 1) - David J Welch, Rod N Garrett and Neil A Gribble (2003 Draft), Fisheries uncertainty: a tropical Australian data-poor fishery, Proceedings 2003 Wakefield Symposium……..… CD

1.1 Introduction (Section 1)

The objectives of the second phase of the TRAP project were to firstly evaluate the effectiveness the 1999 management plan for the Queensland Gulf of Carpentaria Inshore Finfish Fishery. The second and third objectives were linked to this evaluation by assessing the effect on the major stocks of the plan's proposed reduction in fishing effort, river closures, and the splitting of the fishery into inshore (N3) and offshore (N9) endorsements.

The basis of the assessment was the then 16-year time-series of fishery dependent and independent data compiled by the first phase of TRAP. As of 2002 this is now a 22-year data time-series. The assessment tools were to be the population dynamics models developed by an Expert Stock Assessment Workshop, again as part of the first phase of the TRAP project.

As noted in the general preamble, the over-riding aim was to explore the concept of adaptive management, advocated by Carl Walters (1986), by testing the effectiveness of initiatives in the 1999 Fisheries management plan and providing feedback to allow the Gulf Management Advisory Committee to make "adaptive" changes to the plan if necessary.

In this section of the report we will deal with each species identified in TRAP Phase I as suitable for stock assessment modelling:

Barramundi (as the primary target hence indicator species).

King salmon

and to track the effect of dividing the fishery into N3 and N9 endorsements, we will assess the changes in the catch of :

Shark (a "generic" logbook category).

1.2 Methodology (Section 1)

The analysis was originally designed to follow the general outline (for design of adaptive management experiments) suggested in Walters (1986):

1. Systematic evaluation of existing data.
   TRAP Phase I collated two parallel historic data time-series, both fishery dependent and fishery independent data available for the major target species of the inshore gillnet or "set-net" fishery.

2. An accounting system for overall value
   TRAP Phase I developed suitable stock assessment models for estimating the overall trajectory of stock recovery, which was used as the indicator of "value" of replicate management initiatives (primarily for the main target species, Barramundi). In this case the Gulf and East Coast inshore fisheries were taken as the "replicates" and compared.
3. Models for the propagation of uncertainty.
   It was planned to use a "before, after, control, impact" (BACI) design to explore the uncertainty in the data. That is; to compare the trajectory of stock recovery in the Gulf prior to the introduction the Gulf Plan to that after its introduction, but standardised against similar trajectories generated from the East Coast data where there was no Fisheries Management Plan introduced. That is, data from TRAP Phase I compared with data from TRAP Phase II for the Gulf versus East Coast. Any uncertainty due to environmental or market forces should have been seen in both datasets, hence cancel each other out, but major differences should have been attributable to the effects of the Gulf Fisheries Management Plan.

4. Methods for calculating the cost-effectiveness of reducing uncertainty.
   Walters (1986) suggested Monte Carlo simulation of the expected performance of each plan, accompanied by feedback management, to give estimates of future management performance.

5. Mechanisms for generating alternative plans (or modifications).
   The management advisory committee (Gulf MAC previously Tropical Fin Fish MAC) planned major reviews of the 1999 Queensland Gulf of Carpentaria Inshore Fishery Management Plan, at five year intervals. This provided the "mechanism" for generating modifications or major new initiatives. [In reality the 3 monthly meetings of the MAC were the actual mechanism for introducing changes in the fishery, where the need was recognized from the regular reports generated by the TRAP project].

The national stock assessment workshop, held as part of TRAP Phase I (see section 2, this report), had evaluated the available data on the Queensland Gulf of Carpentaria fish stocks and recommended that the data on the Barramundi stock, as the major target species, was most amenable to stock assessment. Lack of data or lack of contrast in the data available reduced the usefulness of assessment of the other fished species, taken mainly as bycatch in the Barramundi fishery.

Following these recommendations, the Barramundi stock (dynamics) was used as the main indicator species in the analysis of adaptive management. Treadfin salmon was also investigated, to provide a contrast and add a perspective on the effect the plan had on the major bycatch/byproduct species in the inshore fin fish fishery.

Changes in the shark catch in the Gulf were assessed separately. The national stock assessment workshop noted that data for this commercial category was almost intractable due to lack of species identification. However, a major initiative of the Queensland Gulf of Carpentaria Inshore Fin-fish Fishery Management Plan had been to introduce controls on this component of the fishery, hence an evaluation was necessary.

Again, following the workshop recommendations fisheries observers were used to obtain species identification and preliminary biological information on the commercially exploited shark species. We were not confident enough in the dataset to model the dynamics of individual species, given that most had spatial distributions that included Northern Territory and even Indonesian fisheries and their respective harvests. Therefore, we attempted a much more restricted descriptive evaluation of the effect of the N3/N9 split on the local fishery using only the commercial logbook data.

1.3 Summary of the Gulf Barramundi Stock status

1.3.1 Background

The distribution of Barramundi, *Lates calcarifer*, extends throughout the Indo-West Pacific from the Arabian Sea and the Middle East, to the Malaysian Archipelago, Indonesia, Papua New Guinea, northern Australia, China and Taiwan (Grey 1987; Rod Garrett, Northern Fisheries Centre, pers. comm.). The distribution of Barramundi extends east as far as Tahiti where it has been introduced for aquaculture and has reportedly escaped into the wild (Rod Garrett, Northern Fisheries Centre, pers. comm.). Within Australia, Barramundi are found in coastal rivers and estuaries north of approximately 26 °S (Grey 1987; Garrett 1995). It is highly prized as both a table fish and a sportfish. Commercial, recreational and Indigenous fishers take the species, with many communities in remote areas of northern Australia benefiting from sport fishing tourism, as well as being the centres for commercial operations. In Queensland the management arrangements for the East Coast fishery and the Gulf of Carpentaria (GOC) fishery are different and so each fishery is treated separately here.

At a 1997 stock assessment workshop held in Cairns (see section 2), two biomass dynamic models were developed for the Queensland Barramundi fisheries. Only the GOC fishery data (1981 – 1996) was applied to these models due to the lack of contrast in the East Coast CPUE data at that time. Both models suggested that biomass of Barramundi was low at the beginning of the time series with a gradual re-building of the stocks at a rate of 1 – 2% per year (Section 2, Gribble 1998).

Given such a gradual underlying change in the stock biomass, and the inter-annual variability inherent in tropical species, it is critical to have the perspective of a long time-series to be able to track the status of a stock and to see the effect of management initiatives.

1.3.2 Biology and Ecology

Barramundi are generally found in freshwater, estuarine and coastal marine habitats, congregating during summer months in the estuaries and tidal flats at the mouths of rivers and creeks to spawn. Spawning tends to be associated with the full and new moon, generally on the incoming tide, and when temperatures are between 27 and 33 °C (MacKinnon *et al.* 1986; Kailola *et al*. 1993). Estuarine salinities of 28 to 32 ‰ are required for both successful fertilisation and embryonic development (Garrett 1995). Early juveniles inhabit brackish lagoons and swamps and may migrate to freshwater environments as they grow and/or as the lagoons dry up or shrink (Russell and Garrett 1983; Russell and Garrett 1985). Being protandrous hermaphrodites, the Barramundi starts out life as a male, then at a certain stage of its life, makes the change to female (Moore 1979; Davis 1982). In Queensland waters, males can mature between 45 to 75 cm

total length (TL), then later change sex, becoming females between 55 and 95 cm TL or larger (Garrett 1995). This has important implications for management, as the larger females need to be retained in the spawning biomass to ensure adequate egg production. Barramundi are a fairly long-lived species by tropical standards, living to over 25 years of age (Garrett 1995) and recruiting to the fishery after approximately three to five years (Davis 1987; Garrett 1995).

With the onset of the first substantial rains of summer, male Barramundi of breeding size move from their upstream habitats to estuaries where spawning aggregations are formed with female fish (Davis 1987). Therefore, recruitment of mature Barramundi into the fishery may be affected by the degree of flushing in the upstream habitats. Poor rainfall and/or poor or restricted river run-off may not permit the downstream migration to the potential spawning stock and recruitment to the fishery. In years of high rainfall following several seasons of low rainfall or drought, an abundance of recruits may enter the fishery in coastal waters. Further, when rains come at the right time spawning success and subsequent recruitment to the population is enhanced. These fish will usually recruit to the fishery 3 – 5 years later (Ian Halliday, unpublished data). The sex change, spawning aggregation behaviour and downstream migration aspects of the Barramundi life history provide challenges for the successful management of this species.

1.3.3 Fishery Management

In 1981 management strategies were implemented for both the GOC and East Coast Barramundi fisheries following concerns that stocks were in decline due to increased fishing pressure through the 1970's.

Historic strategies implemented included:

- a temporal closure during November, December and January, that banned the taking of Barramundi and all river set netting operations during this period,
- restrictions on foreshore netting in the GOC and the East Coast south to Cape Flattery,
- restrictions on gill net mesh size and on total gill net length,
- reduction in commercial effort by limited licence regimes for both the GOC and East Coast fisheries, with entry based on historical and financial involvement as well as demonstration of professional standards of operation,
- compulsory monthly logbook entries of commercial catch and effort,
- introduction of an amateur bag limit,
- protection of nursery habitats,
- increase in legal minimum size.

Current management of the Queensland Barramundi fisheries includes:

- East Coast management arrangements introduced in 1991.

- Gulf of Carpentaria Inshore Fishery Management Plan implemented in 1999 (N3 and N9 fisheries).
- Minimum legal size limit of 58cm TL for East Coast and 60cm TL for the Gulf of Carpentaria (GOC).
- Maximum legal size limit of 120 cm TL (introduced in ~1985).
- A closed season to protect spawning stock; Nov-Jan for the East Coast and Oct-Jan for the GOC (Garrett and Williams 2002). The GOC closure is timed each year to lunar cycles.
- Recreational in possession limit of five Barramundi per person.
- Spatial closures on the East Coast in zones designated as Dugong Protection Areas.
- Spatial closures in the Gulf (some for recreational fishing only; some for Indigenous fishing only) (Garrett and Williams 2002).

Research and Monitoring

- QFS Long Term Monitoring Program in the Qld GOC and Qld East Coast.
- QFS compulsory commercial fishing logbooks (CFISH) with daily records.
- QFS bi-annual recreational fishing surveys (RFISH) since 1997.
- QFS N9 fishery observer program
- FRDC TRAP Phase II N3 fishery observer program (QDPI, AFFS)
- CRC Monitoring tasks (**Coastal CRC**: Fitzroy River; **Reef CRC**: World Heritage Area streams).

Commercial fishing

In the State of Queensland, the GOC and East Coast fisheries are managed as separate entities. The commercial fisheries for Barramundi are primarily set net fisheries and fishing operations are generally individual family operations, with the apparent absence of any real influence of major seafood companies in the harvest. Product is sold throughout Australia mostly in frozen fillet form but also whole, with frozen fillet worth $10 - $11 per kg to the fisher (Williams 2002). Since 1998 the annual GVP for the commercial fisheries has been between $5.1 and $6.7M.

During 2001 the total commercial catch for the Gulf of Carpentaria and the East Coast was 720t and 220t respectively. Since 1981 the GOC catch has been between 325t and 760t, and since 1989 the number of boats reporting catch each year has ranged from 81 – 98 boats. On the East Coast a much higher number of boats report catch of Barramundi and since 1989 has ranged from 202 to 239 boats per year. East Coast catch of Barramundi, however, is lower than the GOC catch and since 1985 has been between 122t and 275t per year. The vast majority of this catch (95%) is taken north of Bundaberg.

Recreational fishing
The recreational Barramundi fishery in Queensland represents a multi-million dollar tourist industry, with many fishers travelling from other States. It includes a private sector and charter sector. Barramundi are caught using hook and line while the Indigenous fishery can use hook and line, nets, and traps (Garrett 1995). Historical information on catch and effort for the recreational fishery is very limited. Since 1997 bi-annual recreational catch data has been collected using telephone surveys and a voluntary diary system (RFISH) by QFS staff. Estimates of catch from the RFISH program for the East Coast were 130 – 168t in 1997 and 127 – 164t in 1999, and for the GOC 44 – 57t and 47 – 61t for 1997 and 1999 respectively (derived from RFISH estimates and Williams 2002). Estimates from the Queensland charter boat logbook database are that Barramundi catch from both the East Coast and GOC are relatively trivial averaging 1.7t and 0.4t respectively over the last four years.

1.3.4 Fishery assessment

Commercial catch and effort data since 1981 has been recorded using two different sets of logbooks. The early logbooks were used from 1981 - 1990 and the current database was introduced in 1988. Overlap occurred from 1988 to 1990 and any discrepancies between databases were reconciled by the QDPI Tropical Resource Assessment Program (TRAP) to provide a continuous time series for modelling exercises (Magro *et al*. 1997; Gribble 1998). Reliable records from the East Coast were only available from 1985. An important assumption in using the number of boat days as a measure of effort is that individual boats are fishing with similar intensity in any given year. This assumption was validated by Magro *et al.* (1997), however may be changing due to the introduction of hydraulic net-reels for deploying and recovery of inshore nets.

1.3.5 Historical Catch and Effort

Gulf of Carpentaria
There was a steady decline in catch in the GOC from 1981 to 1994 when catch was down by 45% of 1981 levels. Catch has increased fairly rapidly since 1994 and in 2001 was back to 1981 levels (Figure 1.1). The corresponding effort steadily declined from 1981 to the mid-nineties and has been fairly stable since. Throughout the time series CPUE has shown an increase, particularly since 1986 (Figure 1.1). These trends would suggest that the fishery is not currently under threat from overfishing at current effort levels.

East Coast
Catch of Barramundi from the Queensland East Coast is presented for the period 1985 to 2001. Catch has been variable and the last three years have recorded the highest catches during the period of logbook records (Figure 1.2). Effort has also been variable but has declined over the time series to relatively stable levels over the last 5 years. Similar to the GOC, the CPUE

trend has shown a steady increase over the time series (Figure 1.2), suggesting that current effort levels are not threatening the stock.

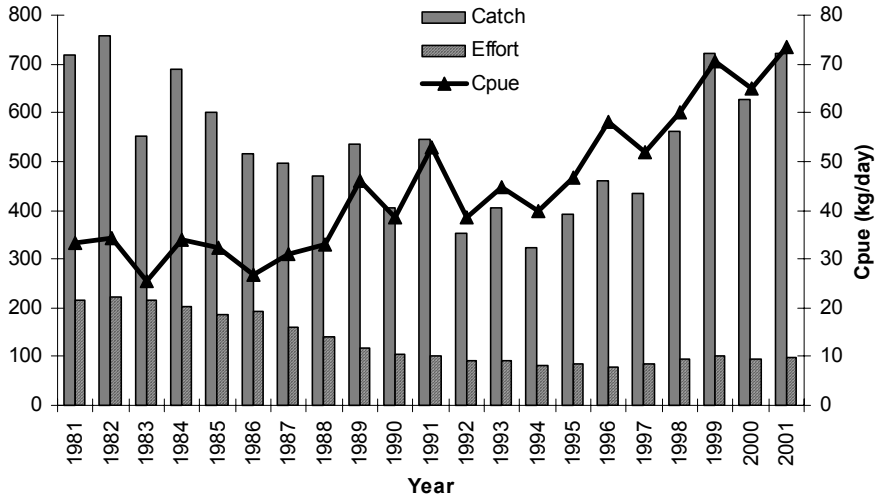

Figure 1.1 - Catch (tonnes), effort (boat days) and CPUE for the Queensland Gulf of Carpentaria Barramundi set net fishery from 1981 to 2001. (Source: QFS CFISH database).

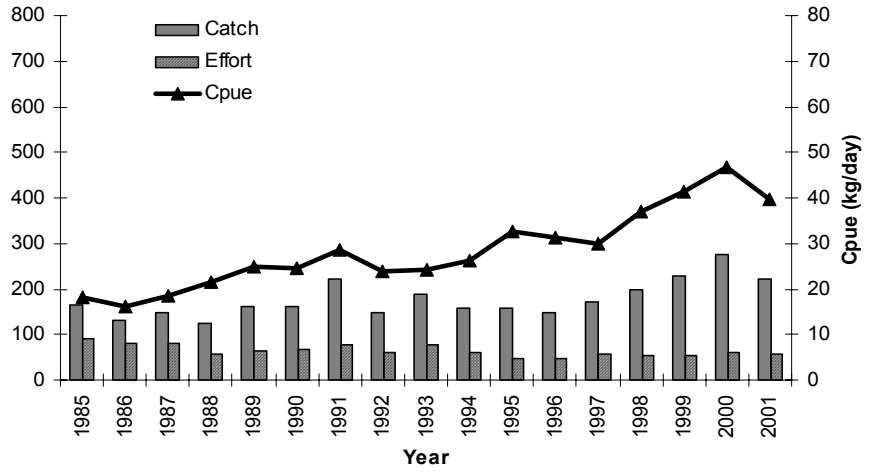

Figure 1.2 - Catch (tonnes), effort (boat days) and CPUE for the Queensland East Coast set net Barramundi fishery from 1985 to 2001 (Source: QFS CFISH database)

1.3.6 Stock assessment modelling

Biomass Dynamic model
(see also Die *et al*. Appendix 3)
Biomass dynamic models are used to describe the dynamics of a fished population in terms of biomass using the previous year's biomass, growth in biomass in that year and catch. These models use some measure of relative stock size (eg. CPUE) to model the population. We used a non-equilibrium model developed by Dr David Die (see Gribble 1998, Welsh *et al*. 2002 for details) and fitted it to catch-per-unit-effort (CPUE) data. The model uses monthly data to account for seasonal differences and incorporates random recruitment seasonally. The model describes change in biomass as:

$$B_{y,t+1} = B_t + (r_y)p_t - C_t$$

where p_t = 1/6 for 9 ≤ t ≤12 and 1 ≤ t ≤ 2, and p_t = 0 elsewhere, B = biomass, C = catch, and r_y represents the random annual recruitment. The predicted CPUE was calculated by the model,

$$CPUE_{pred} = qB_t$$

where q is the catchability coefficient.
The parameters of the final model were q, the initial biomass (B_0), and the r_y for each year of the time series.

This model was first developed at a stock assessment workshop held in Cairns in 1997 (see Section 2) and was fitted to data from the Queensland GOC Barramundi fishery for the years 1981 – 1996 (see also Die *et al.* in Appendix 3). We fitted the model again using the same data the with the addition of data for the subsequent years, 1997 – 2001. The model was not used for the East Coast Barramundi data at 1997 workshop due to the lack of contrast in the CPUE, catch, and effort over the time series available (1985 – 1996). After scanning the dataset with the 5 years of extra data, we felt that there was sufficient variability in CPUE to also apply the East Coast data to the biomass dynamic model. This also provided a between comparison the stock dynamics in the Gulf, with the stock enhancement initiatives of the 1999 management Plan, and the East Coast stock that did not have a change in management in 1999.

Calculation of CPUE

We used daily catch and effort data obtained from the QFS CFISH commercial logbook database for the years 1988 – 2001. Historic data from earlier years were obtained through TRAP Phase I (see Gribble 1998). We used geometric means of CPUE data as they are typically log-normally distributed (Haddon 2001). We calculated geometric means of CPUE using the back-calculated value of the equation:

$$CPUEa = \frac{\sum_{i=1}^{n} \log \frac{C_i}{E_i}}{n}$$

where C_i is the unique observation of catch, E_i is the corresponding observation of effort (days fished), and n is the total number of observations for any given month. That is, the geometric mean of CPUE is given by:

$$eCPUEa = \exp(CPUEa)$$

Using this equation, estimates of CPUE for months during 1981 – 1996 correlated well with the estimates of CPUE used for the initial workshop analyses (see Gribble 1998). Estimates of CPUE from the closed fishing season (November through January) were excluded from the model for both the GOC and the East coast data. Observations where effort was greater than 31 days in any given month were also excluded. This was consistent with the methods used at the Cairns workshop (see Gribble 1998).

Cohort Analysis

Cohort analysis is a version of Virtual Population Analysis (VPA) and was developed by Pope (1972). Like VPA it uses commercial catch at age in numbers to follow fish cohorts throughout their lives. The model used in this analysis incorporates estimates of natural mortality and catch to back-calculate cohort size and ultimately provide estimates of fishing mortality (F) and population size by age class. We used Pope's cohort analysis on Barramundi data to estimate trends in relative population size for comparison with estimates from the biomass dynamic model. We did this using an Excel spreadsheet developed by FAO (Lassen and Medley 2001). Sufficient data was only available for GOC to be used in the analysis.

Appropriate catch-at-age data was not available however a reasonable time-series of fishery-independent length frequency data was available from 1982 – 1994, 1997 (Hall *et al*. 1998) and 1998 – 2001 (QDPI, TRAP observer program). An estimate of 'relative age' was calculated using the von Bertalanffy equation and the parameters estimated by Davis and Kirkwood (1984). This is an indirect measurement of age and therefore assumes consistent growth patterns through the time series and equal selectivity across age classes. The latter, in particular, is unlikely to be true therefore the use of 'relative age' here should be treated with caution. Catch-at-age estimates for the analysis were derived using commercial

catch records (CFISH), mean weight of the commercial catch (TRAP observer program) and yearly 'relative age class' proportions. Averaging across the previous three years for 1995, and the following three years for 1996 estimated age frequencies for the missing years (1995 & 1996).

1.3.7 Model outputs

Gulf of Carpentaria

Biomass Dynamic model

The model tracked the monthly decrease in CPUE fairly well for the first 6 years of the time series and tended to underestimate the decrease in monthly CPUE afterwards, although there was slight improvement in the final five years of the time series (Figure 1.3). The model suggested a very slowly declining population when fitted to the historic data (1981 – 1987) and a steadily increasing population from 1988 – 2001. Over the entire time series the resulting overall trend has been an increase in exploitable biomass at an average annual rate of 3.5% of the initial (1981) biomass (Figure 1.4).

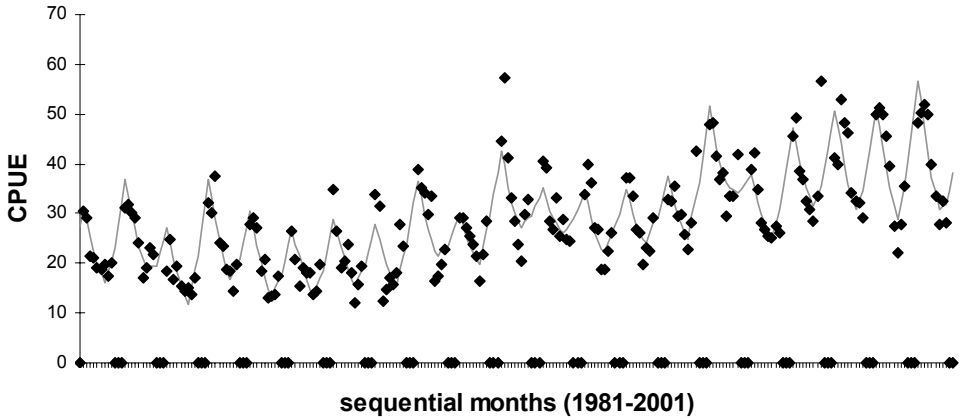

Figure 1.3 - The model fitted to the observed monthly CPUE (kg/day) data for Gulf of Carpentaria Barramundi over the time series 1981 – 2001. The grey line represents predicted CPUE and dots (♦) represent observed CPUE.

During the first 10 years of the time series the monthly exploitable biomass fluctuated between 300 and 1,000t (Figure 1.4). During the last ten years of the time series the model estimated that the stock fluctuated between 550 and 1,400t, which reflects rebuilding in the stock. The model estimated that the current (2002) exploitable biomass is approximately 1,100t (Figure 1.4) and suggested that the stock in 2002 is still increasing.

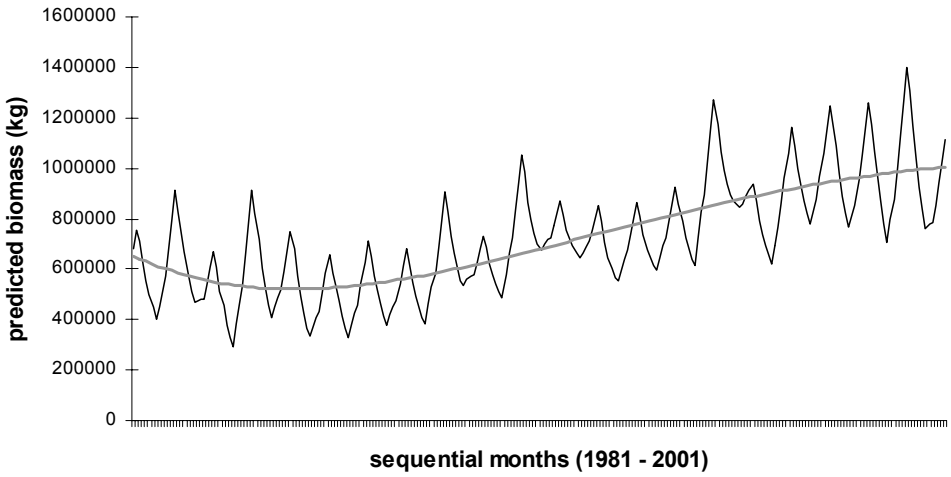

Figure 1.4 - Exploitable biomass of Gulf of Carpentaria Barramundi predicted by the model (thin line) showing monthly fluctuations over the time series 1981 – 2001. A polynomial curve is fitted to the predicted data to emphasise the overall trend (grey line).

Cohort analysis

It appeared that the cohort analysis did not estimate stock biomass very well early in the time series. However, it is important to note that the overall trend in the estimates of stock biomass from the cohort analysis was consistent with the predictions from the biomass dynamic model for the GOC Barramundi. The cohort analysis estimated that the stock has increased at an average annual rate of 13% since 1986 (Figure 1.5).

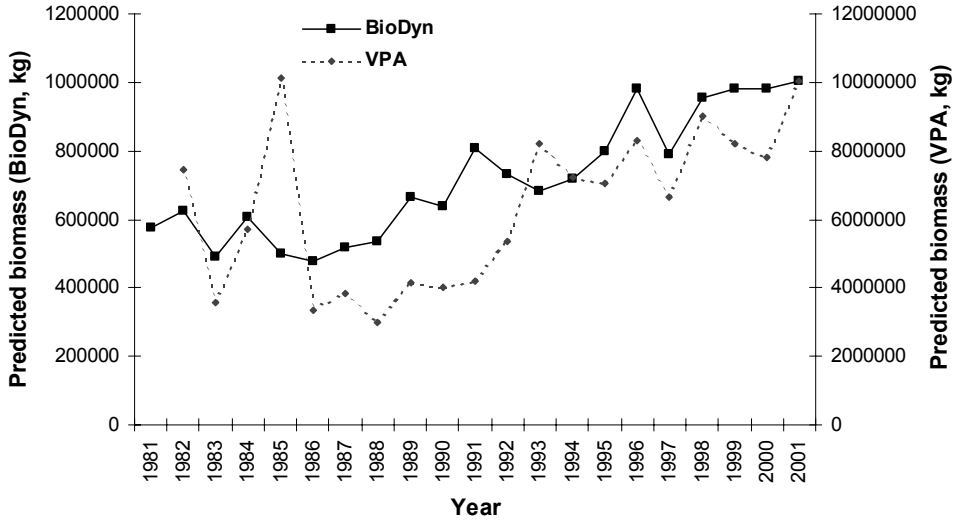

Figure 1.5 - Comparison of the estimated biomass from the biomass dynamic model (solid line) and the cohort analysis (dotted line) of the GOC set net Barramundi fishery from 1981 - 2001.

In terms of the recommendations of Carl Walters (Walters 1986) for adaptive management, the agreement of two different models utilising two independent data sources (fishery dependent and fishery independent data

time-series) gives a robust starting point for "An accounting system for overall value" in assessing the Gulf Inshore Fin Fish Management Plan.

East Coast

The biomass dynamic model tracked the observed monthly CPUE reasonably well, however it tended to underestimate the decrease in monthly CPUE in all years throughout the time series 1985 – 2001 (Figure 1.6).

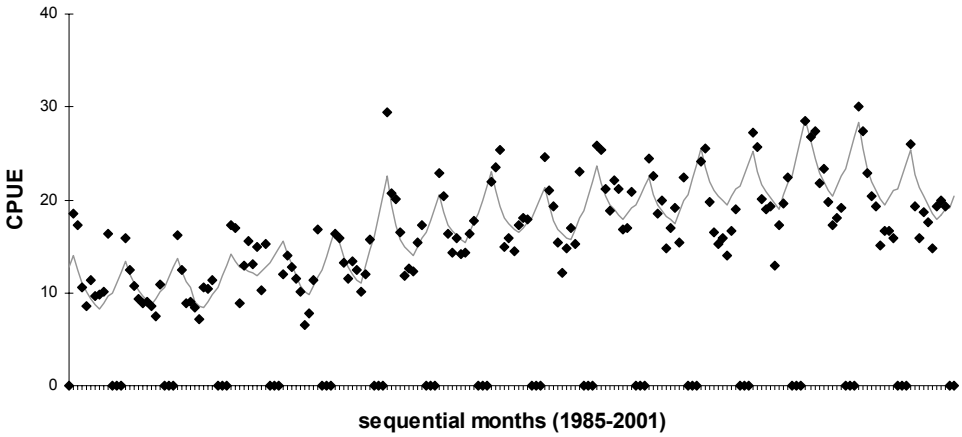

Figure 1.6 - The model fitted to the observed monthly CPUE (kg/day) data for East Coast Barramundi over the time series 1985 – 2001. The line represents predicted CPUE and dots (♦) represent observed CPUE.

The model suggested a steadily increasing population from 1985 – 1999 at an average annual rate of 8%. Notably, over the 1999 – 2001 period, the predicted average exploitable biomass apparently decreased by 13% (Figure 1.6). During the full time series the monthly exploitable biomass fluctuated between 200 and 600t. The model estimated that the current (2002) exploitable biomass is approximately 450t (Figure 1.7) and suggests that the stock is in slight decline from 1999 levels. It is possible that the apparent stock decline was due to reduced fishing efficiency observed following the implementation of revised East Coast management measures in 1999, unrelated in any way to the Gulf management plan.

These measures included the closure of some traditionally productive Barramundi fishing areas with the introduction of Dugong Protection Areas and the northern re-zoning of the Great Barrier Reef Marine Park. For the apparent decline to be explained by the closures, the CPUE (and predicted underlying biomass) should stabilise over the next year or two. Catch and effort from the fishery should be monitored closely over the next few years to assess the stabilisation of CPUE. Monitoring will also reveal if the closures eventually cause an increase in production from edge effects of the closed areas effectively acting as fish sanctuaries.

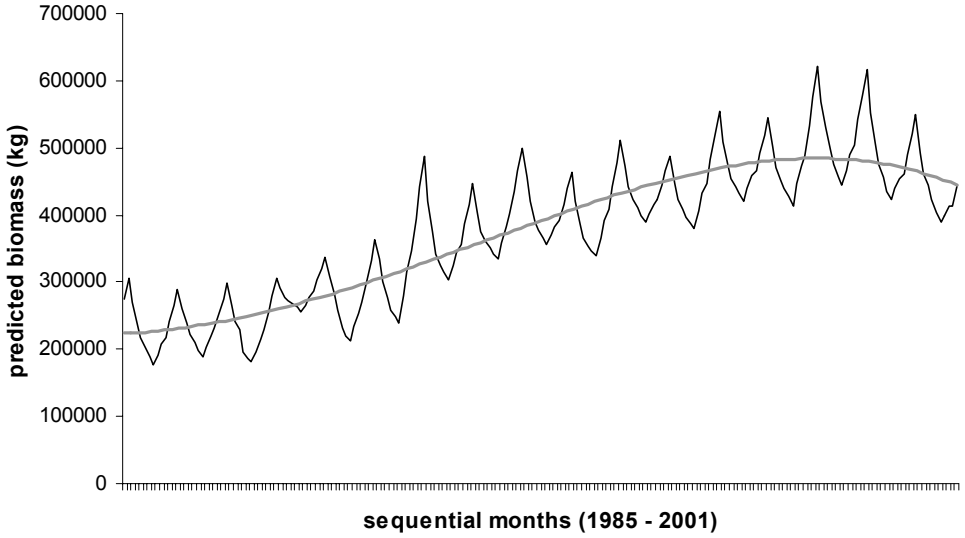

Figure 1.7 - Exploitable biomass of East coast Barramundi predicted by the model (thin line) showing monthly fluctuations over the time series 1985 – 2001. A polynomial curve is fitted to the predicted data to emphasise the overall trend (bold line).

1.3.8 Effect of the 1999 Gulf fisheries management Plan.

The assessment suggests that Barramundi stocks in the Queensland Gulf of Carpentaria (GOC) and on the Queensland East Coast have been slowly increasing from 1981 and 1985 respectively, into the new millennium. This apparent recovery is probably a result of effort restrictions and seasonal closures implemented from 1981, following a reported drop in stock numbers during the 1970's. Current stocks in the GOC appear to be healthy and current levels of fishing effort appear to be sustainable.

The 1999 Gulf fisheries management plan does not seem to have had a dramatic impact on the trajectory of this recovery. There is no indication from the raw data nor from the modelling of any increase in the rate of recovery, which was the expectation of the MAC when formulating the plan. Possible reasons for this are dealt with in the discussion at the end of the section.

East Coast Barramundi stocks appear to follow the same general trend as the GOC, however a recent decline in estimated biomass may be an artefact due to spatial closures (Dugong sanctuary areas plus rezoning of the far northern section of the GBR) implemented on the East Coast since 1999. If so, then it is likely that current levels of fishing effort on the East Coast are also sustainable, however the stock should be closely monitored given the recent trend.

In the GOC fishery the similarity in the trend in estimates from both the cohort analysis and the biomass dynamic model, based on fishery independent and fishery dependent data respectively, indicates that the underlying assessment of the stock dynamic is robust.

BACI analysis of the "value of replicate management plans"

As noted in the methods section it was hoped to be able carry out a BACI analysis (Before, After, Control, Impact) using the pre and post 1999 Gulf data compared to similar data from the East Coast. That is, catch data with and without the changes due to the 1999 Gulf Inshore Fisheries Management Plan. This form of analysis is particularly powerful for detecting changes between time-series where an impact affects the trajectory of only one of the series but normal fluctuations (e.g. attributable to seasonal or gross climatic changes) effect both equally.

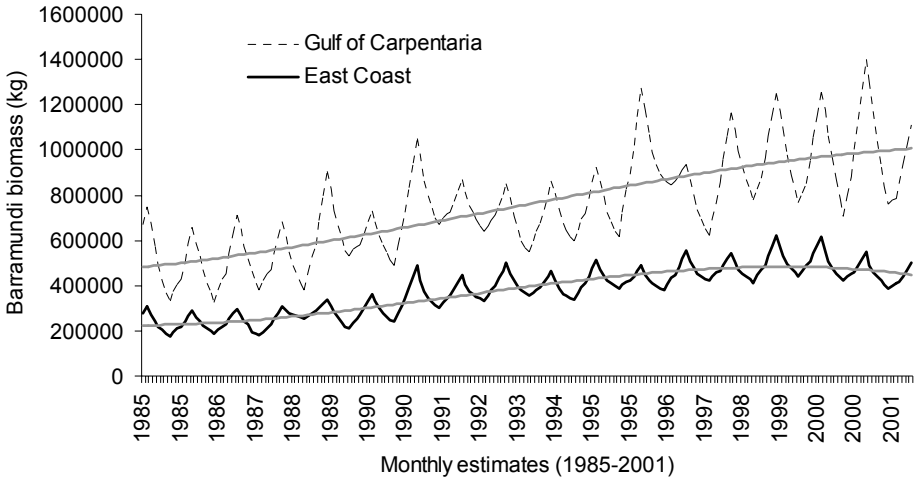

Figure 1.8 - Comparison of Gulf and East Coast Barramundi estimated biomass (Biomass dynamic model)

Time-plots of both Gulf and East Coast Barramundi biomass estimates (Figure 1.8) show seasonal intra-annual fluctuations which were roughly in synchrony but the magnitude of the swings in the Gulf estimates was much higher than on the East Coast. There was an overall upward trend through both time-series but with an obvious divergence between the slopes in the later years.

The trend across the difference between biomass estimate time-series (Figure 1.9), 1985 to 2001, again showed high intra-annual variability, which indicated that either the phase or the magnitude (or both) of the individual series did not cancel out. There was also a residual increase in the "difference" between the two series through time, indicating that the rate of growth in the biomass of the Gulf stock consistently exceeded that of the East Coast, with the gap widening with time; i.e., standardising the Gulf against the East Coast did not fully de-trend the data. Again, this will confound a simple BACI comparison of the effect of the 1999 Gulf Fisheries plan (see Table 1.1) making interpretation difficult.

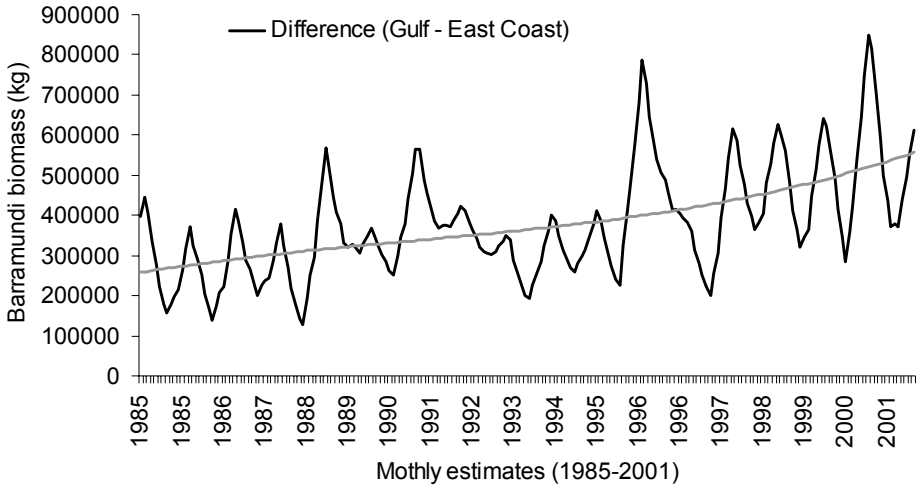

Figure 1.9 - Difference in estimated biomass trajectories (Die *et al.* model) between the Gulf Barramundi stock (Impact) and the East Coast Barramundi stock (Control), before and after the introduction of the Gulf Fisheries management plan in 1999.

Table 1.1 - BACI analysis comparing the mean and variances of differences between the estimated Barramundi biomass for the Gulf (Impact) and the East Coast (Control), for the period 1985 to 1998 (Before Gulf plan) compared with 1999 to 2002 (After Gulf plan).

t-Test: Two-Sample Assuming Unequal Variances		
	Before, 85-98	**After,** 99-02
Mean	348956.4	506282.6
Variance	13594201588	19954087438
Observations	168	36
Hypothesized Mean Difference	0	
Df	46	
t Stat	(-) 6.242	
P(T<=t) one-tail	6.2668E-08	
t Critical one-tail	1.679	
P(T<=t) two-tail	1.25336E-07	
t Critical two-tail	2.013	

To make the analysis orthogonal, the data set was reduced to 3 years prior and 3 years after the introduction of the Gulf Fisheries management plan. A similar t-test analysis of the means (Table 1.2) was run on the difference between the biomass estimates from the Gulf and East Coast.

Table 1.2 - BACI analysis comparing the mean and variances of differences between the estimated Barramundi biomass for the Gulf (Impact) and the East Coast (Control), for the period 1995 to 1998 (Before) compared with 1999 to 2002 (After).

t-Test: Two-Sample Assuming Unequal Variances		
	Before, 95-98	**After,** 99-02
Mean	447964.6	506282.6
Variance	19867720768	19954087438
Observations	35	36
Hypothesized Mean Difference	0	
Df	69	
t Stat	(-) 1.741	
P(T<=t) one-tail	0.043	
t Critical one-tail	1.667	
P(T<=t) two-tail	0.086	
t Critical two-tail	1.9954	

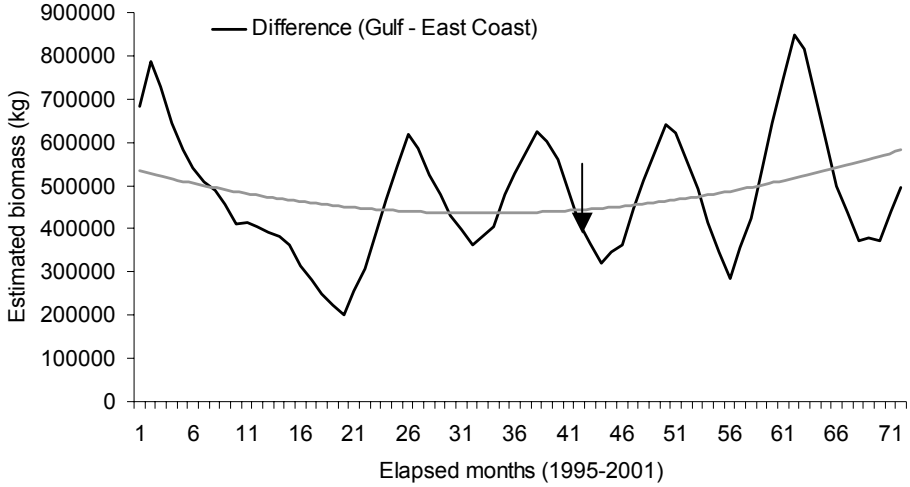

Figure 1.10 - Difference in estimated biomass trajectories (Die *et al.* model) from the Gulf Barramundi stock (Impact) and the East Coast Barramundi stock (Control), before and after the introduction of the Gulf Fisheries management plan in 1999 (Arrow**)**

As with the full data-set there was considerable intra-annular variation (Figure 1.10), and the underlying trends are still present (see previous comments) though not as marked (Figure 1.9.). In both the full and reduced data sets, Table 1.1 and 1.2 respectively, the one-tailed t-test was significant at the 0.05 level. The BACI analysis therefore indicates that there was a significant difference between the trajectories of the Gulf and East Coast Barramundi biomass.

Interpretation of BACI results

Political realities have the unfortunate ability of over-running experimental designs, which is what happened during the course of this project. The Gulf Plan called for a Government/Industry funded buy-back of endorsements, reducing fishing effort by 30%. Contingent on this reduction would be progressive closure to commercial fishers of a number of environmentally sensitive rivers. In the event, State Government funding constraints meant that no money was available for the buy-back, hence only a very small reduction of effort occurred through the Industry contribution, and therefore there were no spatial closures.

Ironically, on the East Coast the high-profile of Dugong conservation led to declaration of coastal Dugong sanctuary areas, which effectively closed a number of highly productive inshore fin-fish fishery areas and led to a the "buy-out" of a number of inshore net fishery endorsements. This was combined with a major re-zoning of the far northern section of the Great Barrier Reef Marine Park, which again effectively closed a number of highly productive inshore areas. The process is continuing with the proposed inshore spatial closures on the Queensland East Coast under the GBRMPA Marine Representative Area Program (RAP) initiative.

In terms of the original BACI design the Gulf "Impact" area was only lightly impacted but the East Coast "Control" was extensively impacted, which meant that although there was a statistically significant outcome it could not be interpreted as due solely to the 1999 Gulf Management Plan. This confounding of variables effectively reduced the analysis to a simple "before and after" comparison of the Barramundi stock on Gulf coast.

Given that both the Gulf and East Coast fisheries have been subject to ad-hoc changes, at a number of levels of management, over the life of the project (and that process is ongoing) it was not considered productive to forecast the expected performance of management plans that were in a state of flux. As Walters (1986) notes; "This (Monte Carlo simulation) approach will provide a conservative estimate of future management performance since it does not account for future innovations…", or in this case, changes to management plans out of the control of the researchers.

1.4 Summary of the Northern Queensland Threadfin and Blue Salmon Stock

1.4.1 Background

The threadfin salmon species taken in Queensland's inshore net and recreational line fisheries comprise the king salmon, *Polydactylus macrochir*, and the blue salmon, *Eleutheronema tetradactylum*. The distribution of king salmon salmon extends throughout tropical coastal waters of Australia and New Guinea and is recorded from Indian waters. The blue salmon is known from the same regions and throughout south-east Asia (Kailola *et al*. 1993). Within Australia king salmon are found from Broome in the west to the Noosa River on the east coast, while blue salmon extend from the Exmouth Gulf in the west to the Mary River on the Queensland east coast. Threadfins are found predominantly in foreshore areas and also in coastal rivers and estuaries (Kailola *et al*. 1993). Threadfin salmon share similar habitats as the main target species of the inshore net fisheries, Barramundi, however Barramundi predominantly occupy coastal rivers and estuaries.

Threadfin salmon are highly prized as both table fish and sportfish particularly in the Gulf of Carpentaria (GOC) and the Fitzroy River on the east coast. Preliminary genetic analysis has suggested that distinctly different populations of each species occur on the different fishing grounds in Queensland (Garrett 1997). In Queensland waters the management arrangements for the East Coast fishery and the GOC fishery are different and so each fishery is treated separately here. There is no evidence to suggest that there are genetic differences between salmon stocks of the Queensland GOC and Northern Territory or Western Australia. The assessment presented here is therefore incomplete as it only takes into account Queensland state waters and it is likely that GOC blue and king salmon stocks are in fact part of the same stock straddling at least two state boundaries.

1.4.2 Biology and Ecology

Threadfin salmon are generally found in estuarine and coastal marine habitats, congregating in large schools during autumn and spring months in foreshore areas and in tidal flats at the mouths of rivers (Garrett 2002; Garrett and Williams 2002). Age and growth information has only been collected from the GOC for king salmon. Garrett (1997) estimated maximum size and age in the GOC to be 120.5cm length at caudal fork (LCF) and 14 years for king salmon, and 69.4cm LCF and 7 years for blue salmon. Stanger (1974) reported similar results for blue salmon from the east coast. Both species were shown to exhibit greater growth during winter months. Kailola *et al.* (1993) reported that king salmon live longer than 20 years and attain 170cm-fork length (40+kg), however failed to cite the source of the data.

Both species are protandrous hermaphrodites changing from male to female during their life cycle. This has important implications for management, as the larger females need to be retained in the spawning biomass to ensure adequate egg production. Sex change in female king salmon occurs across a broad size range with length at 50% maturity estimated to be 95.4cm LCF, at which size the fish are 6 – 10 years old (Garrett 1997). Male king salmon are estimated to reach maturity from 28cm LCF however no estimate of the size at which 50% of males are mature was provided. In female blue salmon, sex change occurs within a narrower range with length at 50% maturity estimated to be 54.3cm LCF, which corresponds to approximately 4 years of age (Garrett 1997). Garrett (1997) reported that male blue salmon begin to reach maturity at approximately 24cm LCF however no estimate of the size at which 50% of males are mature was provided. Spawning for both species appear to occur during the months of late winter/early spring (Garrett 1997).

1.4.3 Fishery Management

As noted previously, in 1981 management initiatives were implemented for both the GOC and East Coast commercial Barramundi fisheries following concerns that stocks were in decline due to increased fishing pressure through the 1970s. Barramundi are the primary target species of these fisheries but other species such as threadfin salmon are also targeted depending on factors such as season, market forces and catch rates of individual species. The strategies employed effectively included all species taken by the inshore gillnet fishery.

Historic management strategies included:

- a temporal closure during November, December and January, that banned the taking of Barramundi and all river set netting operations during this period,
- no foreshore netting in the GOC and the East Coast south to Cape Flattery during the seasonal closure,
- restrictions on gill net mesh size and on total gill net length,
- reduction in commercial effort by limited licence regimes for both the GOC and East Coast net fisheries, with entry based on historical and financial involvement as well as demonstration of professional standards of operation,
- compulsory monthly logbook entries of commercial catch and effort of the GOC Barramundi,
- protection of nursery habitats by spatial closures.

It is not possible to assess how these management arrangements affected the catch and effort for threadfin salmon stocks due to the lack of relevant data for the period before and after the implementation of the Plan. Hindcasting using the available historic data (TRAP Phase I) via an appropriate biomass dynamic model was the only avenue available.

Current management of the Queensland threadfin salmon fishery includes:

- Gulf of Carpentaria Inshore Fishery Management Plan implemented in 1999.
- King salmon minimum legal size (MLS) limit of 40cm total length (TL) for East Coast and 60cm TL for the Gulf of Carpentaria.
- Blue salmon minimum legal size limit of 40cm TL for East Coast and 40cm TL for the Gulf of Carpentaria.
- Recreational in-possession limit of 5 king salmon and 20 blue salmon in the GOC only.
- Spatial closures for net fishing on the East Coast in zones designated as Dugong Protection Areas and areas zoned as closed to fishing the GBRMPA rezoning of the far northern section of the GBR.
- Spatial closures in the Gulf (some for recreational fishing only; some for indigenous fishing only) (Williams 2002).

The GOC Inshore Fishery Management Plan included changes to the MLS and recreational bag limits as well as the negotiation with industry for spatial closures. A breakdown in these negotiations has meant that these closures have not been fully implemented however some foreshore areas have been closed to commercial fishing as part of a re-allocation of the threadfin salmon resource. There are no obvious effects of the changes in the Plan on total catch and effort for the GOC with the change observed in these estimates being within the variability of other years. However, in the year after 1999 there was a substantial drop in the number of vessels reporting catch of king salmon (20%), and a smaller fall in vessels reporting catch of blue salmon (11%) (see Table 1.3). A more detailed spatial and temporal analysis of catch and effort would be required to elucidate the effects, if any, of the implementation of the Plan.

Commercial fishing

The Queensland commercial inshore gillnet fishery is a multi-species fishery of which Barramundi is the most valuable species and threadfin salmon represent an important component. The fishery targets threadfin salmon as they form large schools in foreshore areas. In the GOC, hand hauled set nets have traditionally been used by operators, however the use of power-assisted net haulers (net reels), which allows automated net retrieval, is reported to have increased in the fishery by at least 10% since 1998 (S. Peverell, pres com, TRAP). Net reels greatly improve the efficiency of fishing activity in two ways: faster retrieval means more sets can be employed in a given period of time thereby improving catch quantities, and product discarding is likely to be significantly decreased. The latter point relates to the tendency for threadfin to spoil or die quickly in the nets due to necrosis in the warm tropical waters. Using net reels, catch rates of over 500 king salmon per hour/500m net have been recorded in the GOC. This equates to approximately 2.15t whole weight (Peverell and Gribble, in Section 3). Net reels are also used on the east coast, but the level of operation is uncertain. In the State of Queensland, the GOC and east coast commercial net fisheries are managed as separate entities.

During 2001, the total commercial catch of king salmon from the Gulf of Carpentaria and for the East Coast was 463t and 77t respectively. The total commercial catch of blue salmon from the Gulf of Carpentaria and the East Coast for 2001 was 62t and 132t respectively. Since 1989 the number of

boats reporting catch of threadfin salmon each year in Queensland has been stable and has ranged from 69 – 96 boats in the GOC, and 195 – 275 boats on the east coast (QFS CFISH database) (Table 1.3).

Table 1.3 - Number of vessels and associated catch (tonnes) that reported landings of king and blue salmon from the GOC and the east coast for the years 1989 – 2001 (Source: QFS CFISH database).

	Gulf of Carpentaria				East Coast			
	King salmon		Blue salmon		King salmon		Blue salmon	
Year	Vessels	Catch (t)	Vessels	Catch (t)	Vessels	Catch (t)	Vessels	Catch (t)
1989	96	306	75	46	195	74	221	108
1990	94	435	73	64	199	93	214	99
1991	87	477	75	45	222	115	242	133
1992	76	389	71	63	219	82	235	109
1993	91	333	71	59	242	110	275	134
1994	84	218	69	82	226	93	246	132
1995	85	248	70	73	200	73	227	105
1996	84	286	71	84	216	87	225	97
1997	87	241	76	50	228	83	242	114
1998	92	330	85	66	212	83	203	78
1999	95	346	75	58	208	95	205	91
2000	76	305	67	39	224	105	232	94
2001	87	463	73	62	217	77	250	132

Recreational fishing

Threadfin salmon are caught by recreational anglers using hook and line while the Indigenous fishery can use hook and line, nets, traps and spears (Garrett 1995; Garrett 2002; Garrett and Williams 2002). Historical information on catch and effort for the recreational fishery is extremely limited and there are currently no estimates of total catch for Queensland (Garrett 2002; Garrett and Williams 2002). The QFS RFISH program will be providing estimates for these species from 2001 surveys with the release of the National recreational and Indigenous fishing survey in late 2002 (J. Higgs, QFS, pers com). These estimates will greatly improve predictions of the status of the stocks and should be incorporated into future assessments of threadfin salmon stocks.

Research and Monitoring

- QFS compulsory commercial fishing logbooks (CFISH) with daily records of catch and effort.
- QFS bi-annual recreational fishing surveys (RFISH) since 1997 (since 2001 for threadfin salmon species).
- QFS N9 fishery observer program in the GOC.
- FRDC TRAP Phase II N3 fishery observer program (QDPI, AFFS)(completed June 2002)
- CRC Monitoring tasks since 2000 (Coastal CRC: Fitzroy River; Reef CRC: World Heritage Area streams).

1.4.4 Commercial fishery assessment

Catch and Effort
Prior to the introduction of the QDPI Logbook program in 1988 the historic data on threadfin salmon was patchy (see section 2, TRAP Phase I report). Compulsory recording of commercial catch and effort logbooks (CFISH) has been enforced by the QFMA, now QFS, since 1988. Catch from 1988 for the GOC, however, has not been reported here for either King or Blue threadfin species due to incomplete recording of information in logbooks for that year.

It should also be noted that "suspect" records for three vessels in the GOC fishery were excluded from the data set due to very dubious records of catch and effort. These records only influenced the data for the years 1999, 2000 and 2001. The records for the vessels concerned were excluded from the entire time series. This decision made a significant impact on the analysis of catch levels. For example, in 2001 excluding the catch of the three vessels decreased the total Gulf catch of king salmon by 39% and blue salmon by 80%. Such catches were unachievable in the small area supposedly fished and the tonnage involved could not have been processed nor shipped given the resources of the operators concerned.

Caveat: An underlying concern for the QFS logbook program is that it is largely unvalidated, apart from the 1999 to 2002 period when TRAP observers were present in the Gulf fishery.

King salmon; Gulf of Carpentaria
Catch of king salmon in the GOC has been variable throughout the time series ranging from 218t in 1994 to 477t in 1991. Total catch decreased rapidly between 1991 and 1994 and has steadily increased since 1991 by about 16% per year. Catch in 2001 was similar to 1994 levels (Figure 1.11). Effort levels rose from around 8000 days in the early years to average around 4500 days each year since 1994. Effort in 2001 showed an increase to over 5500 days. The catch-per-unit-effort (CPUE) was variable in the first 6 years of the time series but has shown a steady increase since 1994. Jumps in CPUE in some years (1996, 1998 and 2001) may be due to changes in fishing operations, eg. increased use of net reels on boats however information on gear changes by individual operators is not available for this to be validated (Figure 1.11). Other factors may be increased targeting due to changing market prices.

King Salmon; East Coast
Catch, effort, and CPUE of king salmon on the east coast has been relatively stable throughout the time series. Catch increased between 1988 and 1991 from 64t to 115t per year but since 1992 has been relatively stable at around 85t per year with small peaks in 1993 and 2000, although catch dropped in 2001 by 30% from 2000 levels. Effort peaked in 1993 at 5600 days and since 1995 has been stable at 3000 – 3500 days (Figure

1.12). The CPUE was relatively stable to 1994 with a sudden increase by 24% in 1995, since when CPUE has been stable (Figure 1.12).

Catch and Effort

Total annual commercial catch of blue salmon has been low relative to king salmon in the Gulf of Carpentaria and on the east coast. This is due to market forces showing a preference for king salmon particularly during the early years of the time series, as well as the smaller size of blue salmon compared to its' larger relative. As noted earlier the last three years of the data time-series contained dubious logbook entries and records for the vessels concerned were excluded from the entire time series.

Blue salmon; Gulf of Carpentaria

Catch of blue salmon in the GOC has been relatively stable throughout the time series with peaks in the mid-nineties. Although the lowest catch of 39t was recorded in 2000 this was followed by a catch of 62t in 2001. Reported effort levels and CPUE have both been relatively stable since 1991 (Figure 1.13).

Blue salmon; East Coast

Catch, effort, and CPUE of blue salmon on the east coast have been relatively stable throughout the time series. There were minor peaks in catch in 1991, 1993, 1994, 1997 and 2001 of 133t, 134t, 132, 114t and 132t respectively. Effort increased slowly to a peak of 6500 days in 1993 and has been relatively stable since 1995 ranging from 3200 – 4200 days (Figure 1.14). Similar to east coast king salmon, the CPUE was stable during the early years of the time series until it jumped by 39% in 1994, since when CPUE has again been stable (Figure 1.14).

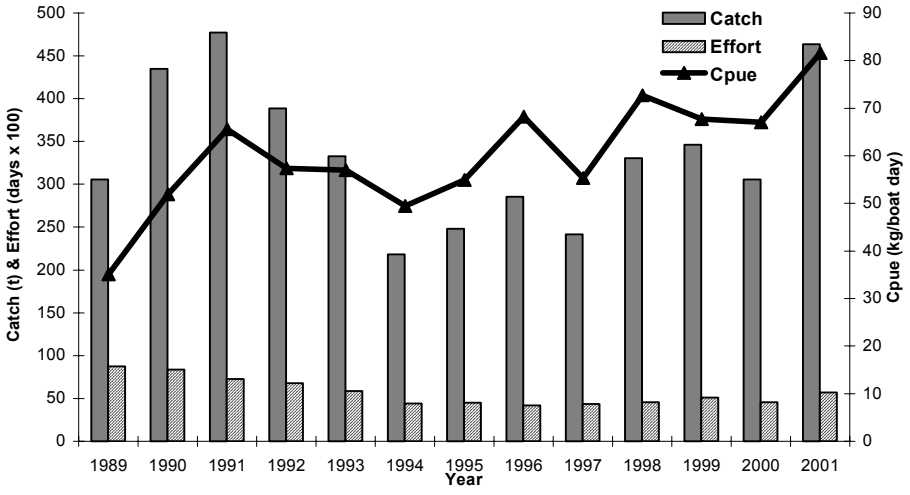

Figure 1.11 - Catch (tonnes), effort (boat days) and CPUE for king salmon from the Queensland Gulf of Carpentaria inshore net fishery from 1989 to 2001 (Source: QFS CFISH database).

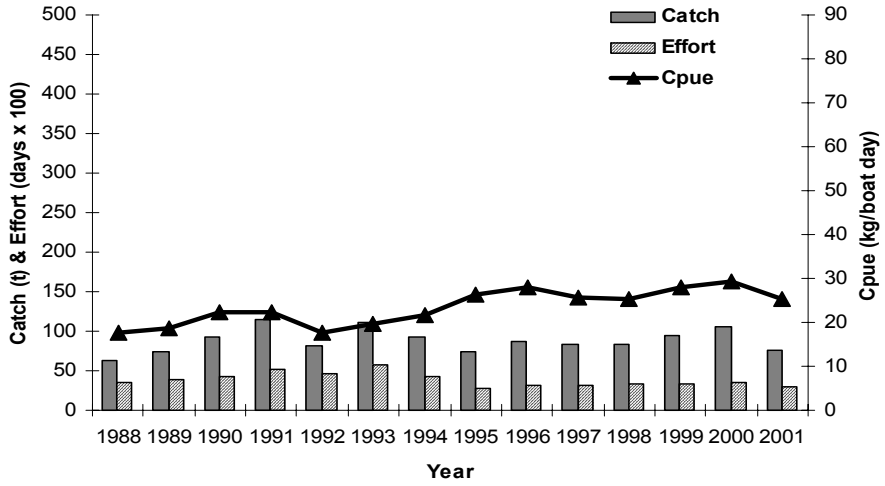

Figure 1.12 - Catch (tonnes), effort (boat days) and CPUE for king salmon from the Queensland East Coast inshore net fishery from 1989 to 2001 (Source: QFS CFISH database).

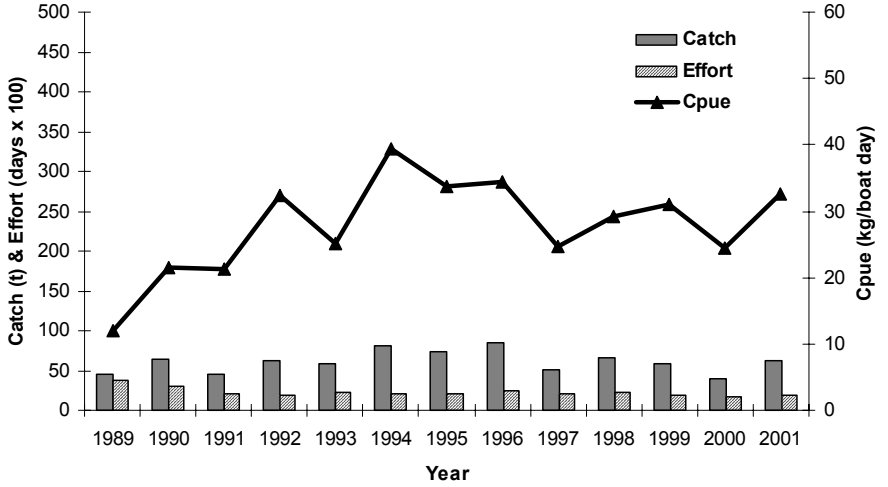

Figure 1.13 - Catch (tonnes), effort (boat days) and CPUE for blue salmon from the Queensland Gulf of Carpentaria inshore net fishery from 1989 to 2001 (Source: QFS CFISH database).

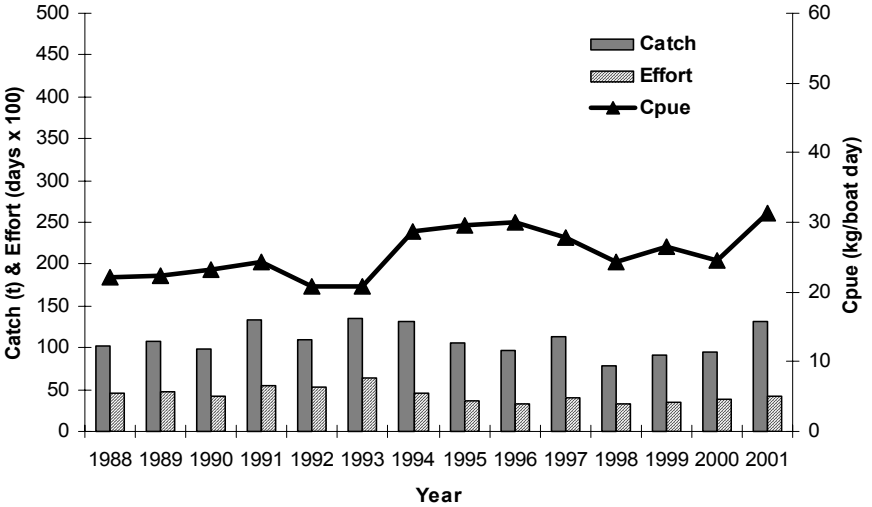

Figure 1.14 - Catch (tonnes), effort (boat days) and CPUE for blue salmon from the Queensland east coast inshore net fishery from 1988 to 2001 (Source: QFS CFISH database).

1.4.5 Summary of catch and effort

Overall, trends in catch, effort and CPUE for both species of threadfin salmon do not show any signs that would indicate that stocks in either the GOC or on the East Coast are currently under threat. This is indicated by stable levels of reported commercial fishery effort since the mid-nineties with CPUE stable or increasing during the same period. However, due to the schooling nature of the species any decline in the abundance of the stocks may not be reflected in changes in CPUE due to the efficiency of targeting individual schools (hyperstability). Further, effort creep may be a factor for the GOC inshore net fishery, particularly since 1998 and particularly for king salmon. Also, catch rates in the GOC tend to be more variable than on the east coast for both king and blue salmon. This observation may reflect inter-annual variability of the ecosystem in the Gulf as well as market-driven considerations by the fishers. A major problem is the high incidence of wastage of fish due to the tendency of both threadfin species to die or 'spoil' quickly through flesh necrosis once netted. Therefore reported catch is an underestimate of total commercial catch, and by how much it is an underestimate is an important question that requires attention. The introduction of net reels may increase the proportion of fish that are marketable but will still not reflect the fishing mortality rate.

1.4.6 Stock assessment modelling / Biomass dynamic models

Attempts were made to fit standardised commercial catch rate data for the GOC king salmon to several non-equilibrium biomass dynamic models using observation error estimation methods. The monthly model developed for Barramundi by Dr David Die (see Gribble 1997 and Die *et al*. in Appendix 3) was tuned for use with the GOC king salmon data. The model was only able to obtain a very poor fit to the observed data due to strong inter-monthly variability. Subsequently, two simple models were developed; an annual Schaefer model and an annual Pella & Tomlinson model. Two estimates of the catchability co-efficient, q, were incorporated into the models to attempt to account for the increased efficiency likely to be introduced to the fishery with the increased use of net reels since 1998 (S. Peverell, QFS, NFC, pers com).

In each case, the predicted index of CPUE was unreliable with the resulting estimates of biological parameters being unrealistic. Estimates of Maximum Sustainable Yield (MSY) and effort corresponding to MSY (Emsy) were also highly unrealistic and this is likely to be due to failure of the data rather than the models (Hilborn 1979). That is, there needs to be sufficient variability in stock size and fishing effort to reliably estimate the parameters of the model (Hilborn and Walters 1992).

The data sets for blue salmon and east coast king salmon showed histories of effort and CPUE at least as stable as that shown by the GOC king salmon and so no attempt was made to model these data. It should be noted however that the schooling behaviour of both blue and king salmon could influence the relationship between catch rate data and the relative abundance of the fished stock, therefore due caution should exercised in the use of catch rate information as the sole indicator of stock status.

1.4.7 Effect of the 1999 Gulf Inshore Fin Fish fisheries management Plan

As noted above, the trajectory for both king and blue salmon in the Gulf was relatively flat with little contrast through time between high and low CPUE. Furthermore there is no evidence of a dramatic change in the stock biomass following the introduction of the effort reduction in the 1999 management plan. The catch appears to be increasing slightly in the years following 1999 despite a slight reduction in effort. This could be explained by the progressive introduction of mechanically assisted net reels into the inshore fishery, rather than any effect from the management plan. Again, "effort creep" is a possible confounding variable not envisioned in the experimental design and beyond the control of the researchers.

As noted above, no stock assessment model was applicable to the threadfin data due the lack of any real "information content" in the data time-series; a simple straight-line fit with a slight upward slope would have been the most parsimonious description of the stock dynamics over the full time-series. Given this situation no attempt was made at BACI analysis or any further Monte Carlo modelling.

A further review of this fishery was presented at the 2003 Wakefield Symposium, Alaska Sea Grant; (Welsh *et al.* 2003 Draft, in Appendix 4) and the paper will be published in the proceedings.

1.5 Summary of the Northern Queensland Shark Stock

1.5.1 Background

Sharks have been fished commercially off northern Australia from the early 1970s. Between 1974 and 1986 a pelagic gillnet fishery was operated by vessels from Taiwan, with the majority of effort concentrated north of the Wessel Islands off the Northern Territory. Catches of shark and other species reached a peak of about 10,000 t in 1977. With the declaration of the Australian Fishing Zone (AFZ), a catch quota of 7,000 t processed-weight was implemented for a maximum of 30 licensed foreign gillnetters. Concerns about the incidental capture of dolphin saw a regulation introduced in May 1986 banning the use of gillnets longer than 2.5 km. At the time, the foreign vessels had been using gillnets up to 20 km long. The restriction effectively rendered foreign fishing uneconomic and, despite some attempts to switch to longlining as an alternative, the vessels from Taiwan had ceased shark fishing in the AFZ by mid-1986.

Until February 1995 the Northern Shark Fishery (NSF) was managed under complementary Commonwealth and State or Territory controls. Responsibilities changed as a result of Offshore Constitutional Settlement agreements establishing three separate Commonwealth–State/Territory Joint Authorities, which manage the fishery under State or Territory law. As a result, the NSF no longer exists as a management entity, but agreements between the Commonwealth and the State or Territory, and those between adjacent State or Territory management agencies, place particular obligations on those governments to cooperate on matters of mutual interest.

Two species of black-tip shark (*Carcharhinus tilstoni/limbatus* and *C. sorrah*) are the principal northern commercial species. These represent shared or "straddling" stocks across a number of State, Territory or Joint Authority jurisdictions. Hammerhead sharks (Sphyrnidae) and mackerels (grey mackerel, *Scomberomorus semifasciatus* and Spanish mackerel, *Scomberomorus commerson*) formed a significant part of the historic catch. The TRAP N9 observer (see Section 4) and projects such the FRDC "Sustainability of Northern Sharks and Rays; Phase I" (Rose *et al.* 2002) have shown that the current catch composition is actually much more varied and a wider assortment of shark species are taken. Shark fishing takes place mainly in inshore areas around the perimeter of the Gulf of Carpentaria and across to the Goulburn Islands, Van Diemen Gulf, Fog Bay and Joseph Bonaparte Gulf. The major fishing method is pelagic gillnetting, with most activity in waters adjacent to the Northern Territory.

Across the northern region there is growing interest in the fishery, and markets are developing for a range of shark products other than flesh, including fin, cartilage, livers and skin. Dried shark fin fetches from A$100 to A$200 per kilogram on Asian markets (2003 prices). In the 1998 about 230 t of black-tip shark were recorded as taken within Gulf of Carpentaria

waters of Queensland with an estimate of 400 t of grey mackerel and 220 t of Spanish mackerel taken in inshore waters (source Lew Williams, QDPI Supervising Fisheries Economist; Rik Buckworth, NT Fisheries unpublished data).

Shark are often taken as bycatch of handline, longline, haul net, bait net and Barramundi fishing in northern Australia. There were also significant catches of shark from the Northern Prawn Fishery (NPF), which operates throughout much the same region as the NSF. A study published in 1991 by the Northern Territory Department of Primary Industry and Fisheries showed an annual NPF catch of at least 100 t of black-tip shark. Currently there is a moratorium on shark take by the NPF but historically this catch must have impacted stocks.

Australia allows access by traditional Indonesian fishers to a limited area of the AFZ off northwestern Western Australia. The extent of the catches taken by these vessels and by Indonesian vessels operating illegally in Australian waters is unknown. Indications are, however, that the species composition of the catch taken by Indonesian vessels is different from that taken by domestic shark vessels (I Strobuski CSIRO pers com).

A review workshop held in 1997-98 (R Buckworth NT Fisheries unpublished data) found that the sustainable yield for black-tip shark is at least 2,000 t per year for the Northern Territory, Queensland and Western Australia shark fisheries combined.

1.5.2 Biology and Ecology

The national stock assessment workshop, organised as part of TRAP Phase I, identified the total lack of any species identification in the historic Gulf shark data as a major problem. Only the logbook category of generic "shark" had been (and still is) recorded. TRAP Phase II, N3 and N9 fisheries observers were tasked to provide at least the species composition of the Gulf shark catch, as the first step in assessing the status of the stocks.

During 2002 the observed N9 shark catch (72.9% of the total catch) comprised 10 species of whaler sharks, 1 species of weasel shark and 3 species of hammerheads (Table 1.4). Whalers contributed 64.9% and hammerheads 7.9% of the total observed catch numbers.

During the overlapping period the N3 observer reported the take of 28 species/genera of sharks and rays.

Table 1.4 - Species composition of Gulf N9 shark catch, observed during 120 days of fishing effort in 2000-2003.

Species	Common name
Carcharhinidae spp	Whaler shark (dominated by C. tilstoni & C. sorrah)
Carcharhinus albimarginatus	Silvertip shark
Carcharhinus amblyrhynchoides	Graceful shark
Carcharhinus amboinensis	Pigeye shark
Carcharhinus brevipinna	Spinner shark
Carcharhinus cautus	Nervous shark
Carcharhinus dussumieri	Whitecheek shark
Carcharhinus fitzroyensis	Creek whaler
Carcharhinus leucas	Bull shark
Carcharhinus limbatus	Common blacktip shark
Carcharhinus macloti	Hardnose shark
Carcharhinus sorrah	Spot-tail shark
Carcharhinus tilstoni (43.42%)	Australian blacktip shark
Carcharhinus tilstoni/limbatus (16.36%)	Blacktip shark spp.
Galeocerdo cuvier	Tiger shark
Rhizoprionodon acutus	Milk shark
Rhizoprionodon oligolinx	Grey sharpnose shark
Rhizoprionodon taylori	Australian sharpnose shark
Hemigaleus microstoma	Weasel shark
Hemipristis elongates	Snaggletooth shark
Anoxypristis cuspidate	Narrow sawfish
Eusphyra blochii	Winghead hammerhead
Sphyrna lewini	Scalloped hammerhead shark
Sphyrna mokarran	Great hammerhead shark
Stegostoma fasciatum	Leopard shark

Percentage Composition of Queensland Gulf shark catch

As the N9 fishery is a "targeted" shark fishery, the species identification and CPUE data were more accurate and representative than data collected on shark caught as bycatch in the N3 fishery.

The river/estuary/foreshore nature of the Gulf N3 "Barramundi" fishery meant the species composition of sharks caught from this variety of habitats was more extensive than from the deeper-water offshore N9 fishery (Tables 1.4 and 1.5). The identification of the largest group caught in the N3 fishery, Carcharhinus spp (Figure 1.15), was problematic in the field particularly early in the project. Increasing observer skill and the knowledge gained from bringing specimens and photographs back to the laboratory for detailed taxonomic analysis, meant that this group was reliably "back-identified" as mainly *C. Leucas*. The high proportion of the *C. Leucas* in the catch is consistent with that observed previously from the Gulf by Haliday *et al.* (2001), and is consistent with the known biology and inshore/brackish-water habitat preference of *C. leucas* (Last and Stevens 1994).

Table 1.5 - Species composition of Gulf N3 shark catch, observed during 130 days of fishing effort in 2001-2002.

Species	Common name
Eusphyra blochii	Winghead hammerhead shark
Carcharhinus amboinensis	Pigeye shark
Carcharhinus tilstoni	Australian blacktip shark
Anoxypristis cuspidate	Narrow sawfish
Carcharhinus leucas	Bull whaler shark
Pristis microdon	Freshwater sawfish
Pristis zijsron	Green sawfish
Negaprion acutidens	Lemon shark
Carcharhinus amblyrhynchoides	Graceful shark
Carcharhinus brevipinna	Spinner shark
Rhizoprionodon taylori	Australian sharpnose shark
Sphyrna lewini	Scalloped hammerhead shark
Carcharhinus cautus	Nervous shark
Pristis clavate	Dwarf sawfish
Carcharhinus limbatus	*Common black tip shark
Rhizoprionodon acutus	Milk shark
Rhizoprionodon oligolinx	Grey sharpnose shark
Stegostoma fasciatun	Leopard shark
Sphyrna mokarran	Great hammerhead shark
Carcharhinus melanopterus	Blacktip reef shark
Carcharhinus macloti	Hardnose shark
Sphyrnidae sp.	Hammerhead shark
Scyliorhinidae sp.	Catshark
Hemigaleus microstoma	Weasel shark

In the N9 fishery the largest proportion of the observed catch was Black tip whaler sharks (*Carcharhinus tilstoni / limbatus* complex plus *C. sorrah*), Figure 1.16. Again this was consistent with the known biology and habitat preference of the species, and with previous studies of the offshore Gulf shark fishery (Rik Buckworth, NT Fisheries pers com 2003).

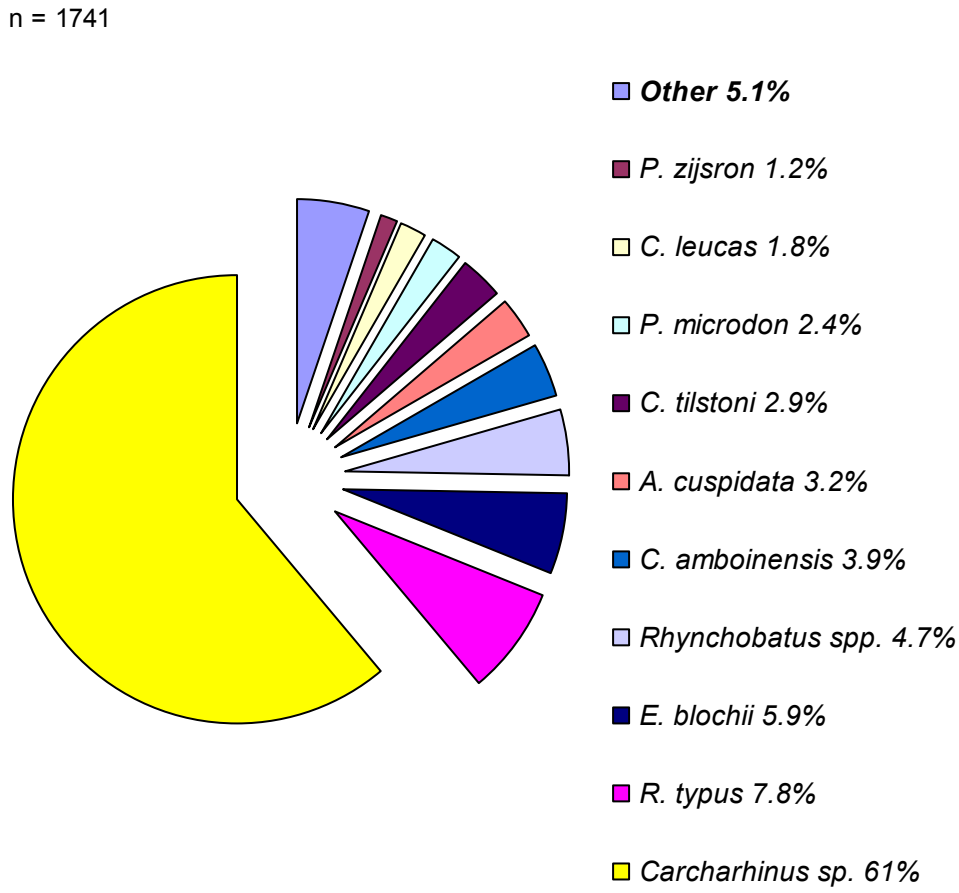

Figure 1.15 - Proportion of shark species in the catch of the Gulf N3 inshore gill nets, based on 130 days of fisheries observer data over 3 years (see section 3). Note: *Carcharinus sp* category (61%) was subsequently identified as mainly *C. leucas* (Bull whaler shark).

Hind-casting the historic percent composition of the Queensland Gulf shark catch from the current data is speculative at best. In previous stock assessments the assumption was made that the majority of sharks taken were the "commercially important" Black tip whaler (Rik Buckworth, NT Fisheries pers com 2003). Based on the observed differences in species composition between N3 and N9 fisheries and on the broad range of species taken overall, such assumptions were probably overestimates.

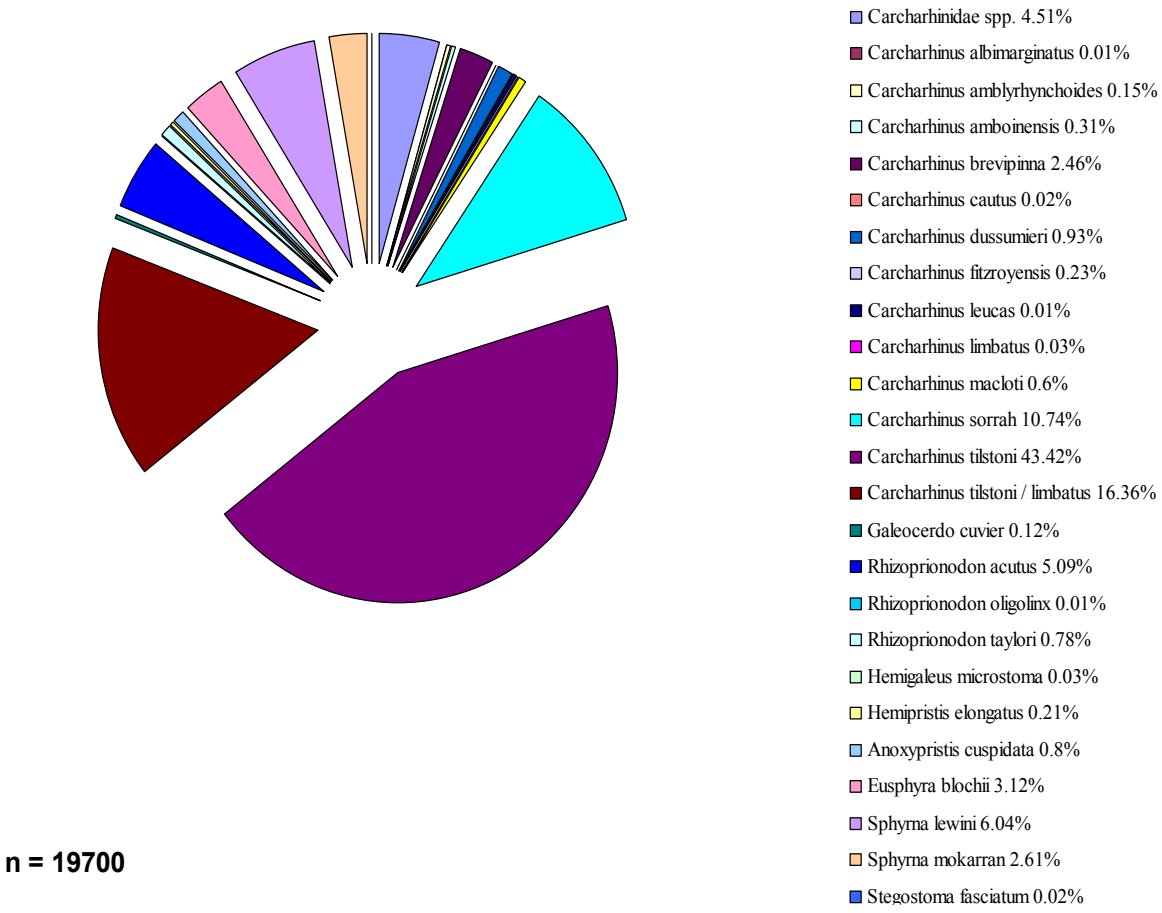

Figure 1.16 - Proportion of shark species in the catch of the Gulf N9 offshore gill nets, based on 130 days of fisheries observer data over 3 years (see section 4).

Historic Catch

A composite time-series of Gulf shark catch was derived from historic (1981-1988) and current (1989-2002) Gulf N3 and N9 catch and effort logbook data (Figure 1.17.), however a number of caveats need to be applied to these data:

- The historic data in particular was un-validated and is the least reliable of the series as shark was not the target species and the market for shark products only gradually developed over this period;
- The current data are also un-validated and in 1995 was subject to an apparent rapid increase in catch, probably triggered by fears that entry into the new N9 fishery would depend on past logbook history. To counter this "apparent" 100 tonne increase in one year, the 1995 outlier was replaced with an average was taken of the year before and the year after.
- Years 2000-2002 were filtered to remove records of one family group who were recording obviously incorrect overestimates of their catch. These logbook records are currently being investigated for breaches of compliance (see also the Barramundi and Theadfin assessments).

In both the N3 and N9 logbooks, across the full time-series, only the generic "Shark" is entered with no species information given.

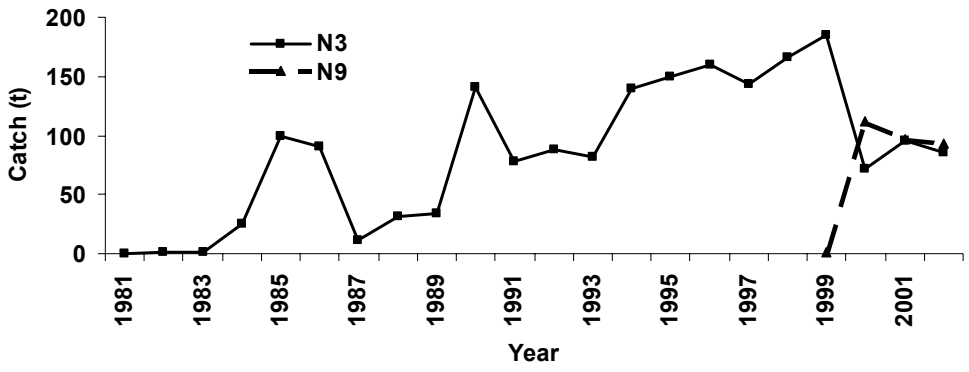

Figure 1.17 - Historic Queensland Gulf of Carpentaria Shark catch 1981-1988

The underlying profile of the composite catch data for the Gulf N3 endorsement was of a classic developing fishery. As the market developed and diversification occurred across from the Barramundi fishery, the catch steadily increased. The majority of the catch in the early 1990's came from N3 fishers specialising in shark/mackerel. Since the introduction of the 1999 Management Plan there has been a plateau in the N3 catch (Figure 1.17.), but the combination of the N3 plus the N9 catch gives a considerable increase in the total shark take from the Queensland Gulf of Carpentaria (see Figure 1.21.)

The current (compulsory) catch and effort logbook data

Similar caveats as applied to the historic data-set need to be applied to the current QFISH logbook information; Figure 1.18 and Figure 1.19. These data are for a commercial category with no species information recorded; they are recorded at thirty nautical mile spatial-grid resolution (with a voluntary six nautical mile grid option available); and they are un-validated except for the last 3 years of the time series when research fisheries observers from TRAP Phase II were operating (see Sections 3 and 4). In the case of the N9 fishery, part of the apparent increase in catch is due to the inclusion of harvest data previously recorded from the same area but through the Commonwealth rather than Queensland logbook program.

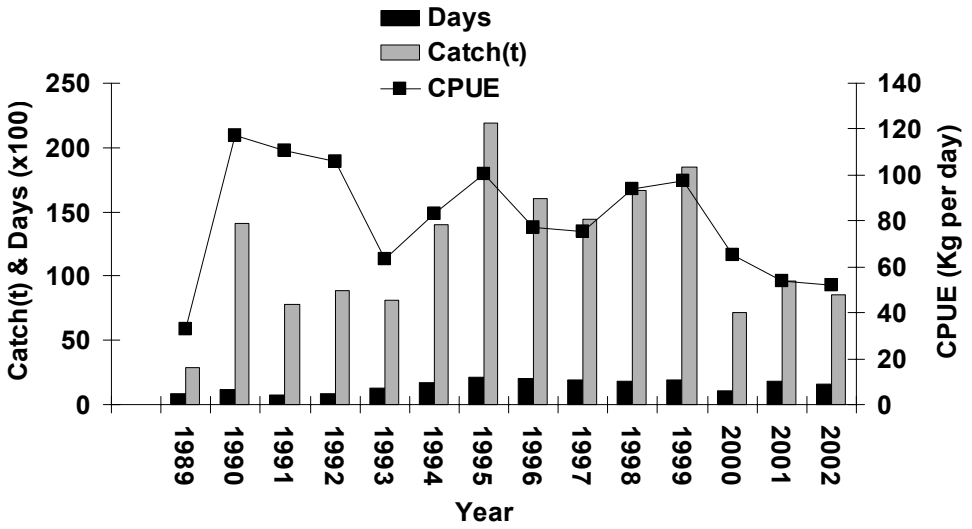

Figure 1.18 - Catch (tonnes), effort (boat days) and CPUE for SHARK from the Queensland Gulf of Carpentaria N3 inshore net fishery from 1989 to 2001 (Source: QFS CFISH database).

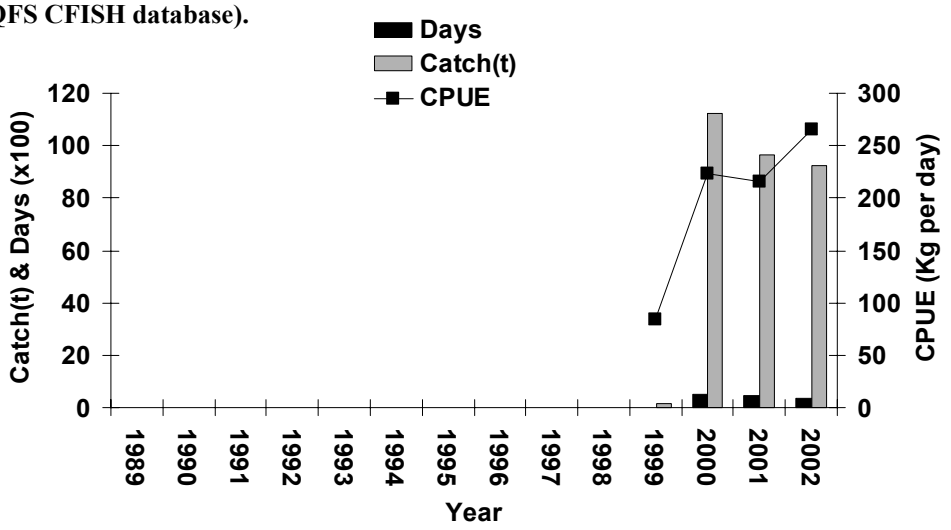

Figure 1.19 - Catch (tonnes), effort (boat days) and CPUE for SHARK from the Queensland Gulf of Carpentaria N9 inshore net fishery from 1989 to 2001 (Source: QFS CFISH database).

Combining the CPUE time-plots for the N3 and N9 endorsements gives a better indication of the effect of introducing the new endorsement (Figure 1.20 and Figure 1.21.).

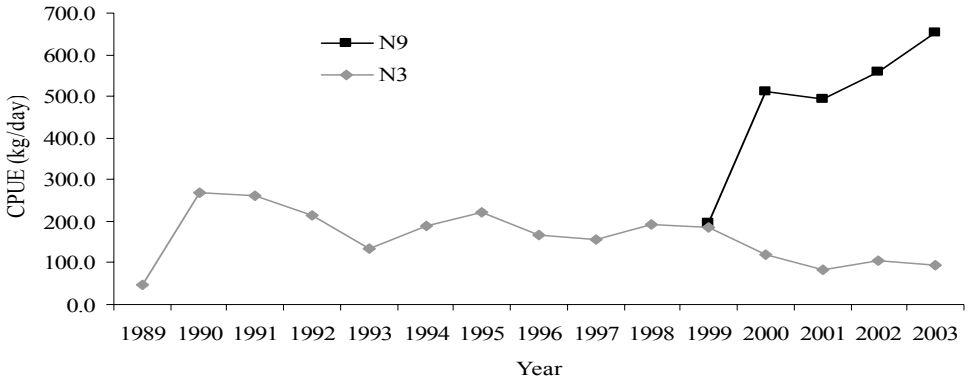

Figure 1.20 - Non-standardised CPUE in kg per day fished for SHARK from the Queensland Gulf of Carpentaria N3 and N9 endorsements from 1989 to 2003 (Source: QFS CFISH database).

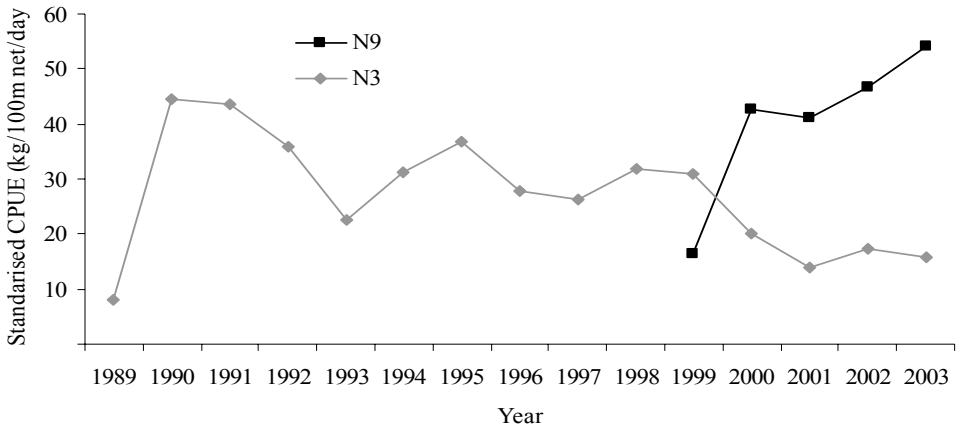

Figure 1.21 - Standardised CPUE in "kg per 100m net per day fished" for SHARK from the Queensland Gulf of Carpentaria N3 and N9 endorsements from 1989 to 2003 (Source: Standardised QFS CFISH database).

An N9 endorsement is entitled to set 1200 m of net compared to the 600 m for an N3 endorsement; hence a direct comparison on "days fished" from the logbook records is somewhat misleading. This can be corrected by using a rough standardisation to per 100 meters of net, assuming each fisher sets the maximum allowable amount of net (almost invariably entered into the logbooks, see Section 2). The use of hydraulic net reels in the N9 fishery (and the spread of this technology to the N3) represents a further increase in fishing efficiency, which is unquantifiable at present.

There was a decrease in the N3 CPUE for shark following 1999, most likely due to a reduction in the effective effort as the dedicated and more efficient shark operators transferred to the N9 fishery. Combining the CPUE for both N3 and N9 however, suggests the overall CPUE for shark in the Queensland Gulf of Carpentaria has not decreased since the introduction of the 1999 Gulf Management Plan, nor has the total catch. (see Figure 1.21 & 1.22).

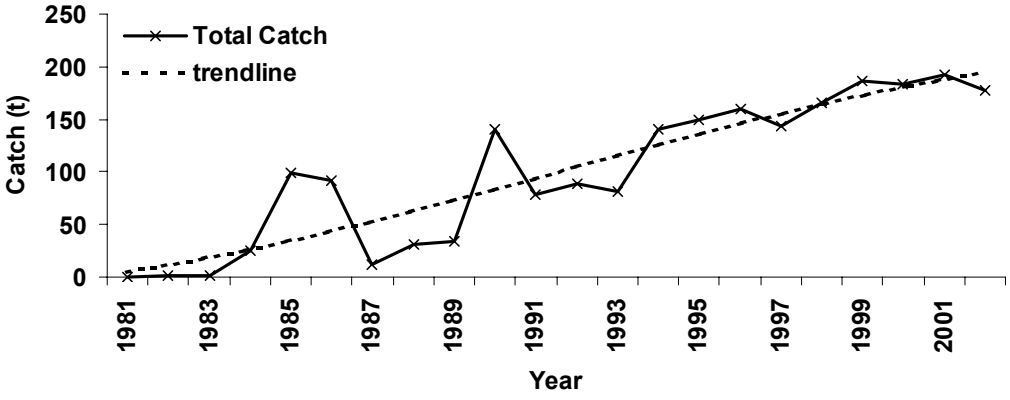

Figure 1.22 - Combined shark catch for both N3 and N9 inshore fishery endorsements in the Queensland Gulf of Carpentaria (Note: The 1995 outlier has been replaced by the average of 1994 and 1996, see text. Dashed line is the indicative trend line).

1.5.3 Effect of the 1999 Gulf Inshore Fin Fish fisheries management Plan

The split into a Gulf N3 and N9 endorsement has been effective in that the catch of shark in the inshore waters appears to have plateauxed, or at least the rate of increase has significantly slowed (Figure 1.17.). Predictably the catch of shark increased in the new dedicated shark/mackerel N9 fishery, as was intended under the Queensland Gulf Inshore Finfish Fishery Management Plan. The trajectory of the overall catch is still increasing (Figure 1.22.) which will need to be monitored by the Gulf MAC and the Gulf Queensland Fisheries Joint Authority. The latter authority integrates the management of the Northern Territory, Commonwealth, and Queensland fisheries, and is ultimately responsible for Gulf-wide "straddling" stocks such as pelagic shark and mackerel.

1.5.4 Update of the 1989-2003 Commercial Logbook Shark Data

During early 2004 the conversion ratio applied to change shark fillet and trunk weights to whole weight in the CFISH database were modified. This means that the historic data is no longer compatible with the current CFISH data. Data based on the new conversion rates has been provided for completeness, although shark catches are subtly different the trends have remained the same. Caveats need to be applied to the current QFISH shark catch logbook information when analysis is undertaken. They are:

- The logbook data are un-validated except for the 3 years 2000 to 2002 when research fisheries observers from TRAP Phase II were operating in both N9 and N3 fisheries.
- These data are for a commercial shark category with no species information recorded; they are recorded at thirty nautical mile spatial-grid resolution (with a voluntary six nautical mile grid option available).
- The 1995 peak in catch was probably triggered by fears that entry from the N3 into the proposed N9. fishery would depend on past logbook history. To counter this apparent 150 tonne increase in one year, the 1995 outlier was replaced with an average was taken of the year before and the year after (Figure 1.23).
- Records were filtered to remove of one fisher family group who were recording obviously incorrect overestimates of their catch. These logbook records are currently being investigated for breaches of compliance (see also the 2002 Barramundi and Theadfin assessments (Welch *et al.* 2002a and b)).

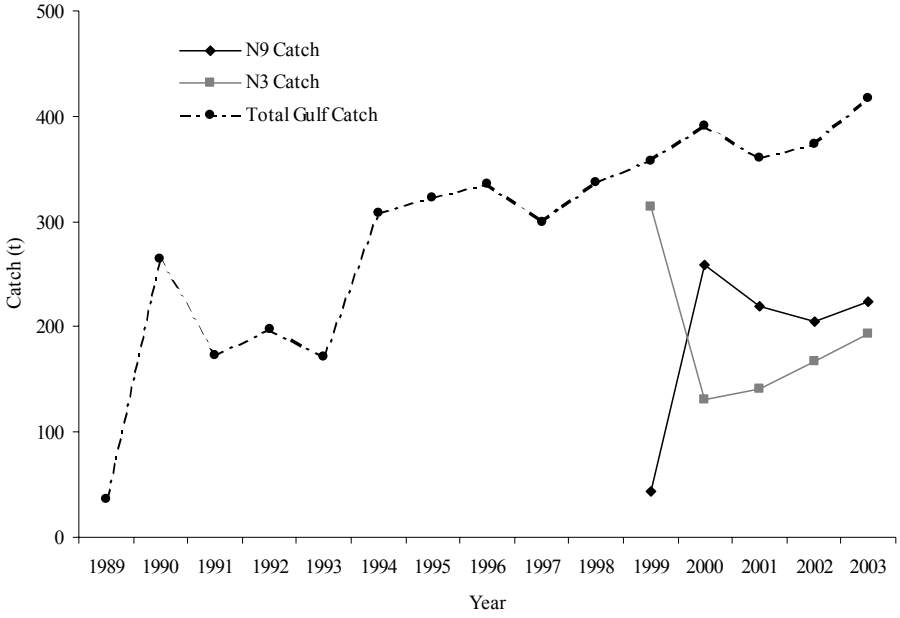

Figure 1.23 – Catch (tonnes) of Queensland Gulf shark fishery and the N3 and N9 components, which commenced in 1999. (Source: QF CFISH database) Note: the 1995 outlier was replaced with an average was taken of the year before and the year after.

1.6 Discussion (Section 1)

The Tropical Resource Assessment Program has been outstandingly successful in collecting and collating historic logbook and research data from the North Queensland coastal gill-net fishery into two parallel 22-year time-series. On their own these collated data represent a pivotal management tool, given high inter-annual variation in the commercial fish catch means that slow underlying trends in the recovery of the stock can only be identified when a long-term time-series is examined. A 2-3.5% annual increase in biomass over a long period can be "lost" where short-term inter-annual variation is in the order of 20%. This is particularly so in the assessment of Barramundi stocks, arguably the key commercial and recreationally important species in the North Queensland inshore fishery.

These data time-series, and the population dynamics models derived from them, have also been used effectively in the adaptive management of the Queensland Gulf fisheries, although not quite in the way Carl. Walters (1986) envisaged. As events unfolded, the process was not strictly formal but an evolutionary series of management decisions by Gulf MAC, made possible through the regular feedback of assessment results from the TRAP project. This flexible management response was driven by necessity as the Queensland State and Commonwealth legislative environment was undergoing fundamental changes throughout the duration of TRAP Phase II project (see the Preamble at the beginning of this report).

Addressing each of the objectives of the project:

- Evaluate the effectiveness of the Queensland Fisheries Management Authority's Management Plan for the Gulf Inshore Finfish Fishery (1999).

As noted in the Barramundi stock assessment, political realities have the unfortunate ability of over-running the best-intentioned experimental designs. The Gulf Plan called for a Government/Industry funded buy-back of endorsements, reducing fishing effort by 30%. Contingent on this reduction was to be the progressive closure to commercial fishers of a number of environmentally sensitive rivers. In the event, State Government funding constraints meant that no money was available for the buy-back, hence only a very small reduction of effort occurred through the Industry contribution, and therefore there were no spatial closures (due to the Plan itself).

Hence the evaluation showed that while there had been a steady rebuild of the "indicator" Gulf Barramundi stock since the early 1980's, there had been no significant impact on this recovery trajectory by the 1999 Gulf Plan.

- To assess the effect of a large reduction and spatial redeployment of fishing effort on the population dynamics of exploited tropical inshore finfish species.

Up to the date of this report there had been a relatively small reduction in the number of boats and fishing effort in the fishery (see above), which must be counter-balanced by the gradual increase in “effective effort” by the increasing use mechanically assisted net-reels to improve fishing efficiency. Therefore the probable effect of a reduction and redeployment of fishing effort will have been small. The Before-After-Control-Impact (BACI) analysis highlighted that apparent statistical differences between comparable 18-year biomass trajectories of the Gulf versus the East Coast were most likely due to changes in the management of the East Coast fishery rather than due to the 1999 Gulf Plan per se.

On the Queensland northern East Coast, in contrast to the relative in-action on the Gulf Coast, the high profile of Dugong conservation led to declaration of coastal Dugong sanctuary areas. The declaration effectively closed a number of highly productive inshore fin-fish fishery areas and led to a the Government funded "buy-out" of a number of inshore net fishery endorsements. These closures coincided with a major re-zoning of the far northern section of the Great Barrier Reef Marine Park, which again effectively closed a number of highly productive inshore areas. The latter process is continuing with the proposed inshore spatial closures on the Queensland East Coast under the GBRMPA Marine Representative Area Program (RAP) initiative, coming into force in 2003-2004.

- To identify species composition of the Queensland Gulf inshore shark fishery and report on the impact of increased effort on shark stocks in the new N9 fishery.

The fisheries observers, recommended by the TRAP Phase I national stock assessment workshop and built into legislation via the 1999 Queensland Gulf Inshore Finfish Fishery Management Plan, proved highly successful in documenting species composition of the Queensland Gulf inshore shark fishery. This information has been used subsequently by our allied shark sustainability projects, “Sustainability of Northern Sharks and Rays Phase I and II (FRDC 2001/077 and 2002/064)”, the EA fisheries sustainability assessment required under the EPBC Act, the QFS Bycatch Action Plan for the Gulf, the National Plan of Action for Shark, and the National Oceans Office scoping study for the Northern Planning Area. Arguably this component of the project has been the most cost-effective and successful baseline data gathering exercise run by QDPI in the Gulf.

- To provide a model for the analysis of management plans as a contribution to development and review process for tropical inshore fisheries.

Addressing the final objective has been the most interesting and challenging component of the project. As noted in the Preamble and Barramundi stock assessment, the original methodology was based on the concepts put forward by Walters (1986), but for all practical purposes was overwhelmed

by political events. The alternative "pragmatically opportunistic" process was a series of reactive and proactive management responses to rapidly emerging political issues and to concerns identified from the 'real-time" TRAP II fisheries observer data. Few if any of these issues or concerns could have been foreseen at the experimental design or planning stages of the current project.

Therefore the evaluation of "adaptive management" theory (Walters 1986) in the Queensland Gulf of Carpentaria, inshore finfish fishery highlighted a mismatch of temporal scales:

- Given high inter-annual variation (typical of tropical fisheries) then a relatively long the time-series was required to identify statistically significant trends, in this case at least 3 to 5 years,
- Stability of the management/political regime over this longer period was unlikely, resulting in changes to management outside the Gulf Plan and beyond the control of the researchers, and leading ultimately to a confounding of variables.
- Either the management regime being assessed needed to be unchanged for long enough to pick-up resultant changes in trends, or the magnitude of the management intervention had to result in relatively short-term changes that were much greater than the background variation; i.e., were unambiguous,

The magnitude of the change due to management intervention (the signal) measured against the background variation in the data (the noise) determines both the length of the data time-series required for trend analysis, and the ultimate robustness of the conclusions. In the event the impact of a reduced-scale intervention from the 1999 Gulf Plan was minor and a series of ex-plan reactive and proactive management adjustments were made during the evaluation period. The resultant low "signal to noise ratio" was simply too confounded and complex, hence the analysis must be considered inconclusive at this time.

The practical application of adaptive management as a "pragmatically opportunistic" process did appear to work however, responding flexibly to continuous monitoring of the resource. Future evaluation therefore needs to shift from assessing the impact of an "event", such as the 1999 Gulf Plan, to the more realistic assessment of the effectiveness of a continuously adaptive "process".

Proposing any alternate assessment model or methodology is difficult against a background of instability in Fisheries policy at the Commonwealth, State, and Community levels (see Preamble for detail). There has even been a change in the climate, with northern Australia experiencing the worst drought in a hundred years during the period covered by TRAP Phase II project.

This brings to mind the quote "*Cherish change only the flux is real*" (author unknown) as generally appropriate for tropical fisheries.

1.7 Conclusion (Section 1)

The evaluation of the "adaptive management" concept (Walters 1986) carried out for the Queensland Gulf of Carpentaria inshore finfish fishery identified a major problem:

- Given high inter-annual variation (typical of tropical fisheries) then a relatively long the data time-series was required to identify statistically significant trends, in this case at least 3 to 5 years.

- With hindsight, the stability of the management/political regime over this longer period was unlikely, resulting in changes to management outside the Gulf Plan and beyond the control of the researchers, and thus leading ultimately to a confounding of variables.

- Therefore, either the management regime being assessed needed to remain stable for long enough to pick-up resultant change in trends, or any management intervention had to result in relatively short-term changes that were much greater than the background variation; i.e., were unambiguous.

The timing for the current evaluation was dictated by the passing of Queensland legislation for the 1999 Management Plan for the Gulf of Carpentaria Inshore Finfish Fishery, but the subsequent period has been highly unstable as the Queensland State and Commonwealth "Environment" legislation was undergoing fundamental changes (see Preamble). Fishery Management needed to react to these political/legislative changes, outside the original terms of the 1999 Gulf Plan, and beyond the control and scope of the evaluation.

In more general terms; it may not be possible to establish realistic timeframes to allow statistically valid evaluation of the effects of adaptive management in tropical fisheries with high natural (inter-annual) variation in population parameters.

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Section 2. TRAP Phase I

Technical report of TRAP Phase I, which summarises:

- Collation of historic logbook information Gulf
- Collation of historic logbook information East Coast
- Collation of historic research information
- Proceeding of National Stock Assessment Expert Workshop

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2.1 Introduction (Section 2)

This report collates and reviews the models and parameter estimates produced in TRAP phase I (FRDC 95/49), "Tropical Resource Assessment Program: Development of management tools describing stock dynamics and exploitation in North Queensland Fisheries", as the transition to TRAP phase II (FRDC 99/125) "Tropical Resource Assessment Program: Model application and validation".

The national expert-group stock assessment workshop run under TRAP phase I, reviewed the available time-series of catch and effort data from the Queensland Gulf of Carpentaria and Tropical East Coasts (see Gribble 1998 and summary in following section). Although a fifteen year series was covered, data was limited in its quality, completeness, and in the compatibility of the logbook information from different periods. The target species for the majority of the series was Barramundi with other species taken as by-catch, until the later years when changes in fishing operation and gear allowed the identification of shark and mackerel as separate fisheries, i.e. as targeted fish stocks. Mud crab was always considered a separate fishery as the majority of the catch was recorded from pots rather than the set gill-nets. The result was that the best data sets, with the longest time-series, were for Barramundi and Mud crab. Hence the workshop concentrated on stock assessment models for these species.

Problems highlighted by both the TRAP Annual reports (phase I) and the stock assessment workshop were the lack of validation by independent observers of the logbook information and the lack of verification/error-checking of this data as it was entered into the QFMA database. TRAP phase I addressed the first of these problems with a pilot observer program and the second by spending considerable time and resources on verification of the data from original logbook records (see Magro *et al.* 1997 and 1998). The problem of incomplete compatibility between the historic dataset, 1981-1988, and the current dataset, 1988-1996, remains.

There was a more recent problem, identified in the QFMA database records since 1996-97. A flaw in the data-entry screens written for a new operating system did not give the correct geographic position for catch and effort under certain circumstances. For the purposes of modelling only the time-series of 1981-1996 from the Gulf of Carpentaria and 1984-1996 from the East Coast were considered, although for mud crab there had been disturbing changes in CPUE reported anecdotally and despite its unreliability the full time-series had to be analysed for trends at least.

Models were developed first for the Gulf of Carpentaria, where the best data were available, then transferred to the Queensland East Coast where appropriate. This coincided with the needs of the fishing industry and management, (Tropical Finfish Management Advisory Committee), where stock assessments were needed for the formulation of a management plan for the Gulf inshore fisheries (implemented April 1999) and a management plan for the East Coast inshore fisheries (currently being formulated). Mud crab data analysis has been presented to Crab MAC for a Gulf mud crab fishery management plan (again, currently being formulated).

Parameter estimates for models were derived from the above catch and effort time-series and from a parallel time-series of research data complied from a

sequential/over-lapping but unrelated series of one to three year research projects (see Hall *et al.* 1998). Again data quality is less than optimum as the sampling design was not consistent across all the projects. It was possible however to find consistent elements across the projects, which allowed certain sites and the catch of certain size nets to be followed for the fifteen years.

For completeness the collated catch and effort data tables for the Gulf and East Coasts, together with the collated research data are presented in Appendix 5 a, b and c of this report.

2.2 Summary of the 1997 TRAP Stock Assessment Workshop (Expert Group): findings & recommendations

2.2.1 Barramundi (*Lates calcarifer*)

Gulf of Carpentaria coast

The commercial fishery logbook data had shown a continuing decline in catch and effort over the 15-year time series with the 1996 catches down 45% on those of 19981. The catch per day per boat (CPUE) had remained relatively stable over the same time period. Traditionally if the CPUE, as an index of underlying abundance of the fish, is stable and fishing effort is declining then the fishery is not considered to be under threat. Barramundi is an economically valuable fish, however, and it was difficult to see why this resource was not being fully exploited. It was considered possible that the fishing effort was only transferring into other fisheries as the number of available barramundi fell; ie effort was tracking the falling number of fish hence giving apparently stable CPUE.

Two Biomass dynamic models were developed at the workshop for this fishery by Dr Malcolm Haddon (Uni of Sydney) and Dr David Die (CSIRO) (see also section on Biomass dynamic models). Both these models indicated that the biomass of barramundi was very low at the beginning of the data time-series (between 25% and 50% of virgin biomass, depending on the model) with a gradual rebuilding of the stock over the last 15 years. David Die's seasonal model indicated the increase in stock biomass was at a rate of around 1% to 2% per year (25% to 30% of initial 1981 biomass) and the current biomass was estimated at 700 to 1000 tonnes. Malcolm Haddon's model indicated a higher current biomass of around 4500 tonnes but this had been rebuilt from a higher initial biomass at around the same rate as the Die model; i.e. at 1% to 2% per year. Both biomass estimates were consistent with previous equilibrium state CLIMPROD modelling, which gave a estimate of Maximum Sustainable Yield (MSY) at between 300 and 400 tonnes (TRAP, 1996 Annual Report). All modelling exercises for the Gulf stock have produced stock biomass predictions with very wide confidence intervals.

East Coast

Barramundi catch and effort data for the East Coast was not as free from anomalies (errors or mis-identification/confusion at data entry) as the data for the Gulf. The catch and effort logbooks indicated a relatively stable trend in annual catch of Barramundi between 1984 and 1996. The minimum and maximum annual catches were observed in 1988 (87 tonnes) and in 1985 (180 tonnes). The overall trend was a gradual decline punctuated by minor peaks in 1987, 1991 and 1992 at 156, 170 and 139 tonnes respectively. The CPUE was relatively stable over the 12 year period from 1985 to 1996, with a CPUE of 15 kg / boat day in 1985 and a virtually unchanged CPUE of 14 kg / boat day in 1996. The highest monthly CPUE was usually observed at the beginning of the fishing season, particularly from 1992 to 1996.

The lack of contrast in these data, due to the apparently stable CPUE and a consistent decline in catch and fishing effort, did not lend itself to population dynamics modelling. Transfer of the Gulf fishery models to the East Coast was considered an (future) alternative.

2.2.2 Mud crab (*Scylla serrata*)

Gulf Coast
Total catch of mud crabs in the Queensland Gulf of Carpentaria has increased each year since 1994, as has fishing effort, but CPUE has remained relatively stable over this period. The catch and effort for mud crabs in the southern Gulf (Karumba region) has remained steady, with a slight increase in CPUE over the period 1994 to 1997. However, catch and effort for mud crabs in the northern Gulf (Weipa region) has increased four-fold over 1994 to 1997, but again CPUE has remained relatively stable.

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; i.e. north of Weipa.

East Coast
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 (1988-97) 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 in some years. 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.

There is a wider spatial disparity in catches and a greater 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. Due to lack of stock dynamics information in the logbook data no population dynamics models were proposed for either the Gulf or East Coast mud crab stocks (see Recommendations and Habitat-alias model).

2.2.3 Shark (non-specific)

Gulf Coast
The shark catch increased steadily over the 15-year time-series analysed. “Shark” has also increased as a proportion of the total fish catch and increasingly has been targeted using hydraulic net reels (“reel boats”). Although the gill nets used have the same mesh as for the barramundi fishery there are significant changes in the methodology employed hence shark can be considered as a fishery in its own right. Overlaps occur, however, as shark can be caught as bycatch in a gillnet set to catch barramundi and therefore is a component of the barramundi fishery. There were a number of problems in the database, the most importantly the lack of species

identification beyond generic "Shark Trunks" or "Shark fillets". Without species information it is not possible to perform a true stock assessment. A mixture of unknown species (such as this fishery) will give a mixture of recruitment strategies, growth rates, and natural mortalities, with each species reacting differently to fishing pressure. The second problem was the apparent inclusion in some years of catch and effort data from offshore commonwealth-endorsed shark boats. Allowing for the removal of the latter outliers, the CPUE appears to be flat with little contrast that would be useful for modelling.

East Coast
Shark (mainly Family Carcharhinidae) was the second most important commercial category of fish caught in the East Coast inshore fishery, representing 16 % of the total cumulative catch recorded. The database suffers the same limitations as for the Gulf inshore shark fishery and very little analysis could be attempted.

2.2.4 Grey mackerel (*Scomberomorus semifasciatus*)

Gulf Coast
The recent expansion of this fishery (increase in catch and effort) in the Gulf was driven by only a few major fishers. Although the catch has doubled, the catch per unit effort has remained stable. Seasonality in the fishery is very marked, both on the Gulf and East Coast. A possible explanation is the interaction of this fishery with the availability of barramundi; fishers target barramundi when these are most abundant, but at other times target grey mackerel. Overall, there is very little contrast or population dynamics information in these data (see recommendations).

East Coast
There were problems with logbooks reporting of generic "Mackerel" and Grey Mackerel on the East Coast. No Grey Mackerel catch was reported between 1985 and 1987, although 15% to 19 % of the total netfishing catch was Grey Mackerel during 1988 to 1990. Mackerel catch (excluding "Grey Mackerel" category) increased from 12 tonnes in 1991 to 71 tonnes in 1996; this may represent increased targeting of Mackerel species, using different commercial nets. The effort data is not truly comparable as the East Coast logbook "04" net category covers ring-netting and inshore gill-nets but the Gulf "04" category includes only gill-netting.

2.2.5 Workshop Recommendations
[Response to recommendations in italics].

- **Statistically standardise the fishing effort recorded in the QFMA commercial catch and effort database.** Presently only the number of days fished per boat (boat days) are recorded, which does not capture the difference in fishing power between boats or fishers; i.e. one days fishing for a large boat may constitute more "effort" than one day for a much smaller boat. This requires access to the QFMA license database and a way of linking the catch/effort with the details of the boat across the full 15 year time-series of data.
  ***[Access to relevant databases was negotiated and** a painstaking method of manual linking of catch and effort records to boat table information was begun. This process is particularly difficult for the historic data set but will be completed by July 1999]*.

- **Validate data that fishers are entering into logbooks and characterise the data currently in the QFISH database**. A number of questions were raised as to the accuracy of the catch effort data in the QFISH commercial logbook database for a number species. In the case of barramundi it was pointed out that the performance criteria might have led to over reporting of effort in the early 1980's (to justify the continuation of a fishers license). Catch was verified at the time with buyer's returns. Conversely there may be an under-reporting of effort in recent years due to non-compliance with management regulations that have limited both mesh size and net length. Gaining access to private logbooks of long-term fishers and a limited on-boat observer program was recommended for validating existing data.
  [A pilot observer program was instituted (Magro et al. 1997 and 1998) and limited anecdotal data was collected. A rapport with fishers was established which will be built on during TRAP phase II].

- **Determine the past history of catch and effort in the barramundi fishery, particularly during the 1970's and early 1980's.** Population models based on the commercial catch and effort data indicate that a very large drop in biomass occurred prior to the start of the dataset in 1981. This is consistent with the introduction of severe management restrictions on commercial fishing effort, which were put in place from 1981. Interview and/or questionnaires of long-term fishers were recommended in conjunction with the limited observer program.
  [A pilot observer program was instituted (Magro et al. 1997 and 1998) and limited anecdotal data was collected. The history according to the older fishers, although somewhat varied, was not inconsistent with an excess of effort in the late 1970's with a resultant over-exploitation of the stock].

- **Collate a parallel time-series of available (historic) research data.** There have been a number of short-term (1 to 3 years), roughly sequential research projects on inshore fish species, both in the Gulf and on the East Coast. Although not continuous these data could be integrated with the commercial catch and effort data for such species to give a more comprehensive view of the stock dynamics.
  [The TRAP 1998 annual report (Hall et al. 1998) details the available time-series of fishery-independent research 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 Colombia, Canada, 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, workshop participants recommended that a similar technique might be applied in Queensland.
  [A model for habitat alias of mud crab abundance was devised using satellite imagery to determine the area of potential habitat (Helmke et al. 1998, Gould et al. 1999)].

- **Analyse mud crab CPUE by grouping data by catchment/river system.** It was recommended that allocating the catch/effort data into the different catchments would be a better reflection of where crabs are caught (i.e.,

incorporate information on their habitat) and possibly show latitudinal trends in population dynamics.
[Allocation of catch and effort into catchments has been carried out and is now the basis for mud crab assessments (Helmke et al. 1998)]

- **Gather shark catch data for all elements of the fishery not just from the inshore gillnet component.** A number of problems with the shark data were identified, primarily the lack of species identification and that a number of other fisheries may exploit the same shark stock (or stocks). The recommendation was to obtain the shark catch information from all fisheries and determine the total annual catch for the "unit stock". This is an intractable problem for analysis of all current data, without species information it is not possible to identify what catch statistics from the offshore commercial shark fishery overlap with the inshore gill net data.
[*TRAP investigators have supported and are involved as co-investigators in a Northern Australia shark study proposal to FRDC (lead agency CSIRO) which will gather some of the required data]*.

- **There was little stock assessment information in the Grey Mackerel logbook data hence assessing this stock will require fishery independent surveys**. There is a recently completed FRDC funded research program on Grey Mackerel (Cameron and Begg, 92/144 and 92/144.02) which has examined stock identification, reproduction, age/growth and gill net selectivity for both the Gulf and East Coast stocks. *[Current Northern Territory joint project - a desk top fishery assessment is in progress using available information to identify knowledge gaps and to preliminary model the integrated fishery assessment for the Gulf of Carpentaria (2003-2004)]*

2.3 Computer Models

2.3.1 CLIMPROD Models

The FAO "CLIMPROD" software is interactive in that it allows choice and assistance with decision making when fitting surplus production models to fisheries catch and effort data (Fréon *et al.* 1993). The program allows the inclusion of an environmental variable (in this case rainfall) which can affect either the abundance or the catchability of the target species. A description of the models, and the variables produced in the output, is discussed in Fréon *et al.* (1993).

The Gulf coast Barramundi catch and effort data represented a 15 year time-series, 1981-1996, and a parallel rainfall data set was available through the Met Bureau. These data were adequate for CLIMPROD and allowed a "climate" variable to be added to the models. Rainfall was chosen as the environmental correlate due to the effect of the monsoonal "wet" season alternating with the dry winters in the Gulf of Carpentaria. Data from grid "C" in the southern Gulf was modelled as two stocks of Barramundi have been identified (Keenan 1994), a small northern stock and a larger southern stock where the majority of the catch was taken.

The East Coast Barramundi catch and effort data for 1985-96 represented a sufficiently long and complete dataset to be submitted to CLIMPROD procedures, although inclusion of lag times (allowance for dominant year classes) reduced the set to below 12 years and degraded the reliability of the models. Genetic studies have shown that the East Coast Barramundi were all from a number of stocks (Shaklee *et al.* 1993, Keenan 1994); however for the purposes of CLIMPROD modeling, these were assumed to behave in the same way. Rainfall data from logbook grid "H" was used as the environmental correlate as 40% of the Barramundi catch and 60% of the mud catch were reported from this grid.

The results of the modelling exercise are presented initially as a straightforward application of the basic Schaefer production model with no environmental correlate. This is a standard model for calculating Maximum Sustainable Yield (MSY) for exploited fish stocks and the decision routines of CLIMPROD suggested that this was most appropriate procedure for the dataset.

Queensland Gulf of Carpentaria

Basic Schaefer production model for the Queensland Gulf of Carpentaria commercial catch and effort data

A fit of the standard Schaefer Model to the data was poor with only 14 % (Box 1) of the variance in the abundance explained by the simple model (Figure 2.1 and Figure 2.2). The predicted Maximum Sustainable Yield (MSY) was 349 tonnes per annum but with a 95 % confidence interval of 292 to 411 tonnes (Figure 2.3). This compares favourably with the observed annual yields from Grid C over the 15 years of records, with a minimum annual catch of 153 tonnes and a maximum annual catch of 422 tonnes. The Maximum Sustainable Effort (Emsy) was predicted at 18 000 boat days with a 95 % confidence interval of 12 000 to 23 000 boat days (Figure 2.3). Again this was within the range of the observed minimum annual effort of 6 088 boat days and maximum annual effort at 14 927 boat days. Both the MSY and EMSY

predictions appear biologically reasonable given the data used, but the confidence intervals are very wide, which indicates caution should be used when trying to apply the results.

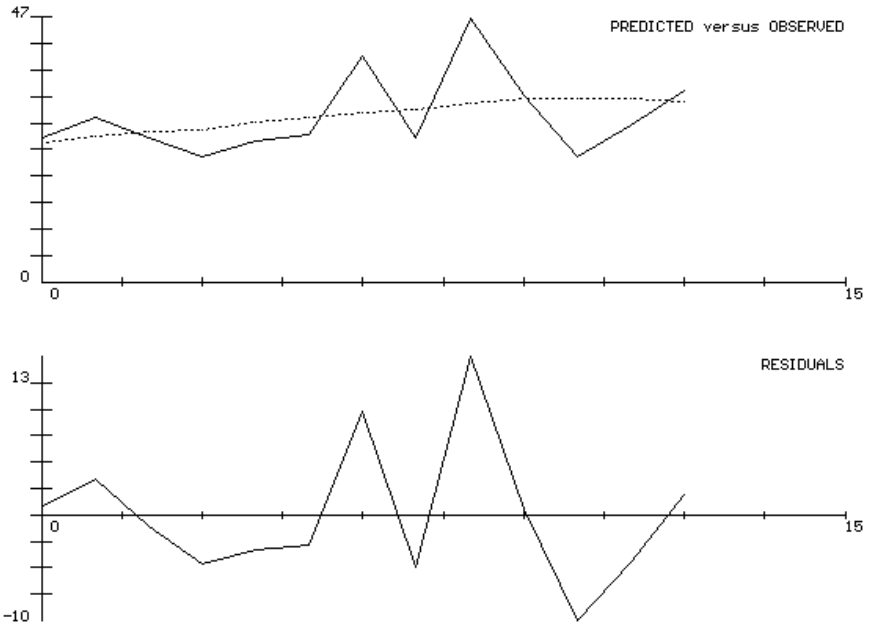

Figure 2.1 - Fit of predicted values from a Schaefer Model (dotted line) with observed catch (tonnes) for Barramundi caught in Grid C.

Box 1 - Schaefer Model _ Output from CLIMPROD

Model	CPUE=a+b.E
Coefficient a	40.357
Coefficient b	-1.175
S.a.	8.056
S.b.	0.714
Min_E	6.088
Max_E	14.926
Nb_years	15
Nb_exploit	3
Variance	48.915
Var.residuals	41.954
r^2	14
T_jackknife	Bad
r^2_Jackknife	0

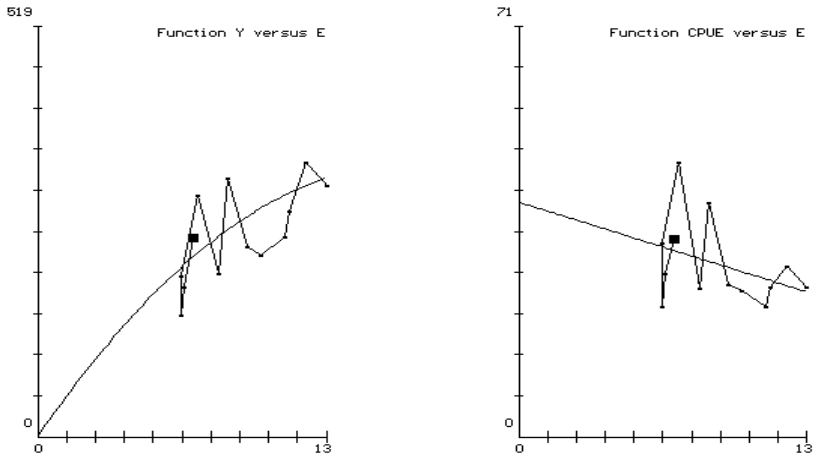

Figure 2.2 - Fit of Schaefer curve to the observed Barramundi catch (Y in tonnes) and effort (E in boat days x 1000) data for Grid C

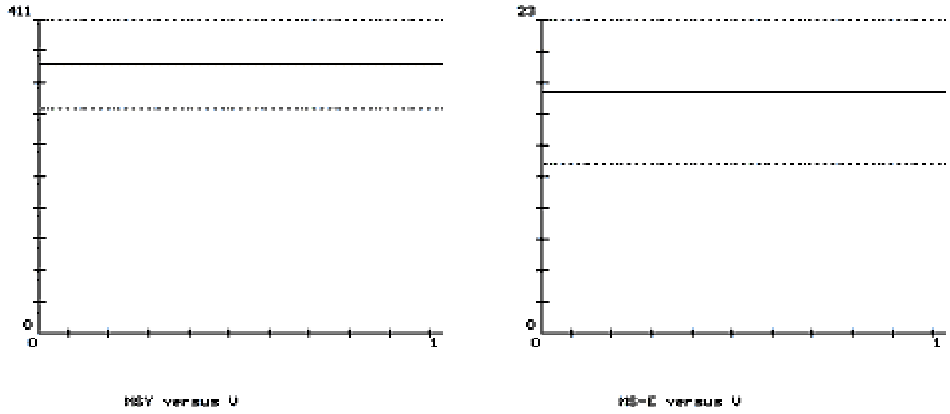

Figure 2.3 - Estimated Maximum Sustainable Yield (MSY) and Maximum Sustainable Effort (EMSY) for Barramundi in Grid C, using a Schaefer Model with no adjustment for rainfall (V).

The Mixed Model including rainfall effects

The fit of a Mixed Model appears better than the Schaefer Model with 41 % of the variance accounted for by the model (Box 2). However, jackknife analysis (repeated removal of samples and recalculating of results) shows a very poor result, suggesting that the model fit was most likely coincidental rather than due to an underlying relationship (Figure 2.4 and Figure 2.5). This is borne out in the model predictions where the confidence intervals of MSY and EMSY are extremely wide and include negative tonnes caught and negative days fished (Figure 2.6). Biologically, the results are not reasonable and suggest that the simpler model with fewer parameters would be a better choice given the available data.

Box 2 – Mixed Model (Output from CLIMPROD)

Model	CPUE=(a.V^(1+b)+c.V^(2+b)).exp(d.V^b.E)
Coefficient a	40.190
Coefficient b	0.172
Coefficient c	-6.963
Coefficient d	-0.0039
s_a	48.122
s_b	0.387
s_c	58.618
s_d	0.0418
Min_E	4.891
Max_E	14.926
Nb_years	15
Nb_exploit	3
Age_rec	5
Climatic_infl	abundance_catchability
Begin	1 years
End	10 years
Variance	37.578
Var.residuals	22.177
r^2	41
T_jackknife	bad
r^2_Jackknife	0

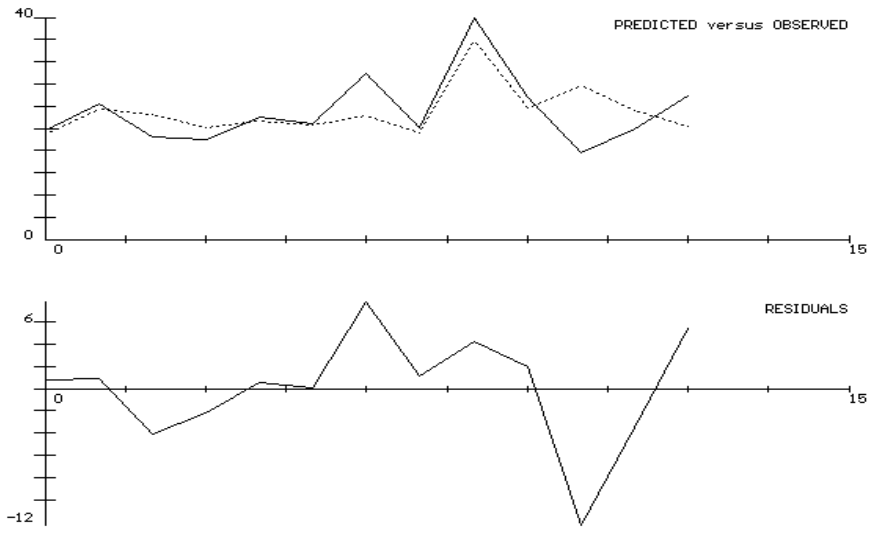

Figure 2.4 - Fit of predicted values from a Mixed Model (dotted line) with the catch (tonnes) for Barramundi caught in Grid C.

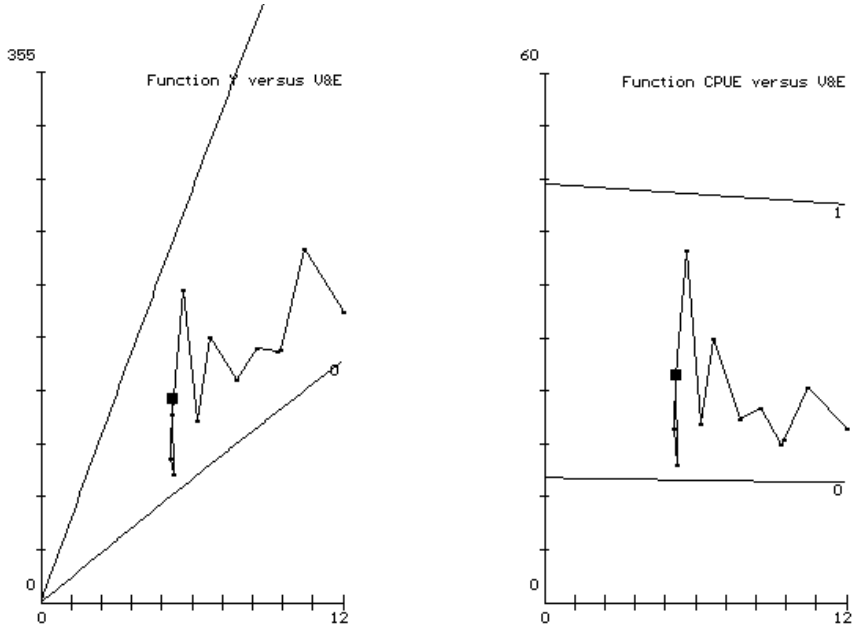

Figure 2.5 - Fit of Mixed Model to the observed catch (Y in tonnes) and effort (E in boat days x 1000) data.

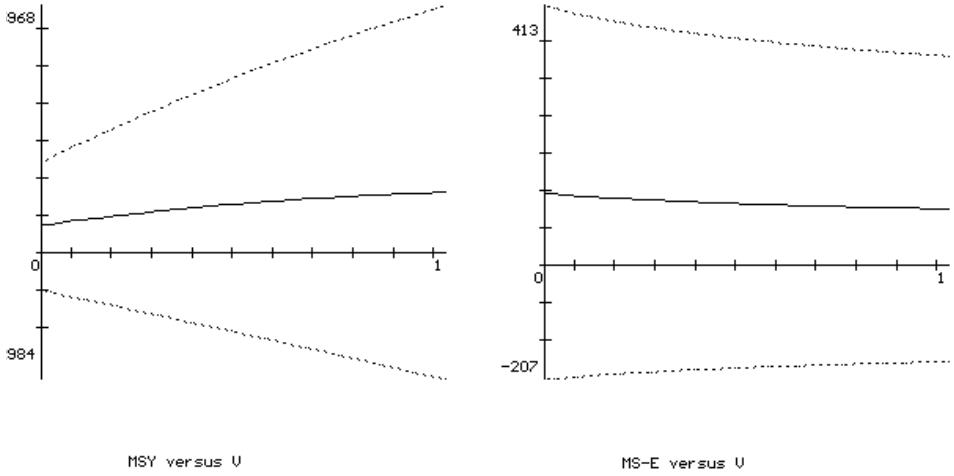

Figure 2.6 - Estimated Maximum Sustainable Yield (MSY) and Maximum Sustainable Effort (EMSY) using a Mixed Model with adjustment for rainfall (V) affecting both abundance and catchability.

Gulf Mud Crab

CLIMPROD requires at least 12 years of catch, effort and environmental data to adequately utilise its in-built 'decision assistance' routines. Although there was a 15 year combination of historic and current logbook records for Mud Crab, only the last seven years of data could be assigned reliably to potting (see explanation in Appendix 5a). It was possible, however, to fit models manually within CLIMPROD over the shorter time series. There was no information to suggest a genetic stock differentiation between the grids, and catches were not obviously dominated by a single grid, as were Barramundi, hence analysis was performed for the entire Gulf from 1989 to 1995. The process was unproductive for a number of the simpler models because of the very high 1995 catch, which was much greater than observed in the previous six years. None of the models could adequately handle a large variation in catch and effort over such a short time span. The inclusion of rainfall data did not improve the fit nor did it allow predictions of an MSY or EMSY.

Tropical East Coast

The basic Schaefer production model for the Queensland Tropical East Coast commercial catch and effort data

A fit of the Schaefer Model to the data was poor with only 10 % (Box 1) of the variance in the abundance explained by the simple model (Figure 2.7 and Figure 2.8). The predicted Maximum Sustainable Yield (MSY) was 182 tonnes per annum but with a 95 % confidence interval of 139 to 226 tonnes (Figure 2.9). This compares favourably with the observed annual yields over the 12 years of records, with a minimum annual catch of 89 tonnes and a maximum annual catch of 180 tonnes. The Maximum Sustainable Effort (EMSY) was predicted at 17 250 boat days with a 95 % confidence interval of 11 500 to 23 000 boat days (Figure 2.9). The range of the observed minimum annual effort was 5903 boat days and maximum annual effort was 11624 boat days. As noted in the 1997 Annual Report, Database section, the net fishery logbook data for the East Coast was complex as a number of different net types (set net, drift net, ring net, tunnel net, seine and bait nets) were included under the inshore set net fishery category. It was not possible to make the assumption that Barramundi was the target species of the fishery although it was a major component of the catch. Therefore the number of boat days of effort was probably overestimated leading to conservative predictions from the model. Both the MSY and EMSY predictions appear biologically reasonable given the data used, but the confidence intervals are very wide, which indicates caution should be used when trying to apply the results.

Box 3 - Schaefer Model _ Output from CLIMPROD

Model	CPUE=a+b.E
Coefficient a	21.33
Coefficient b	-0.64
S.a.	3.131
S.b.	0.37
Min_E	5.90
Max_E	11.624
Nb_years	12
Nb_exploit	2
Variance	7.11
Var.residuals	6.405
r^2	10
T_jackknife	Bad
r^2_Jackknife	0

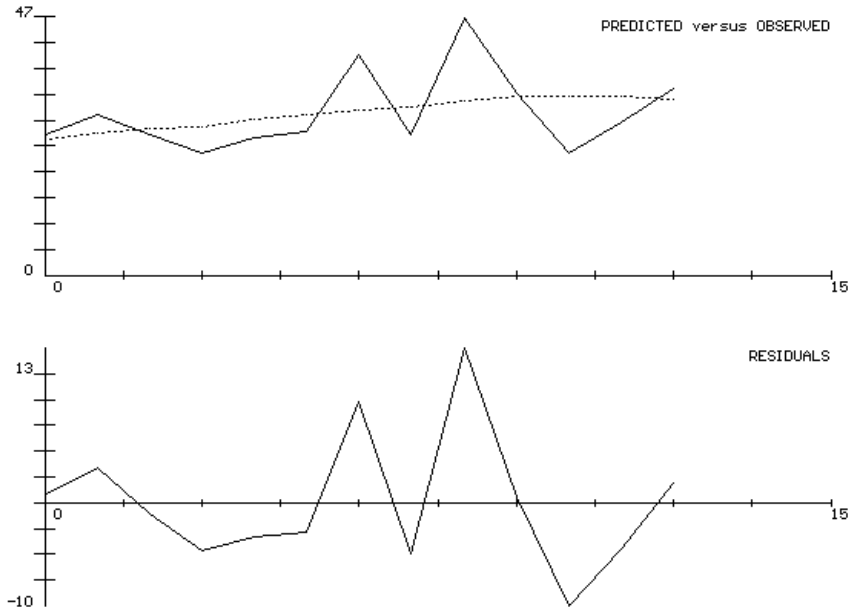

Figure 2.7 - Fit of predicted values from a Schaefer Model (dotted line) with observed catch (tonnes) for Barramundi caught on the Queensland East Coast.

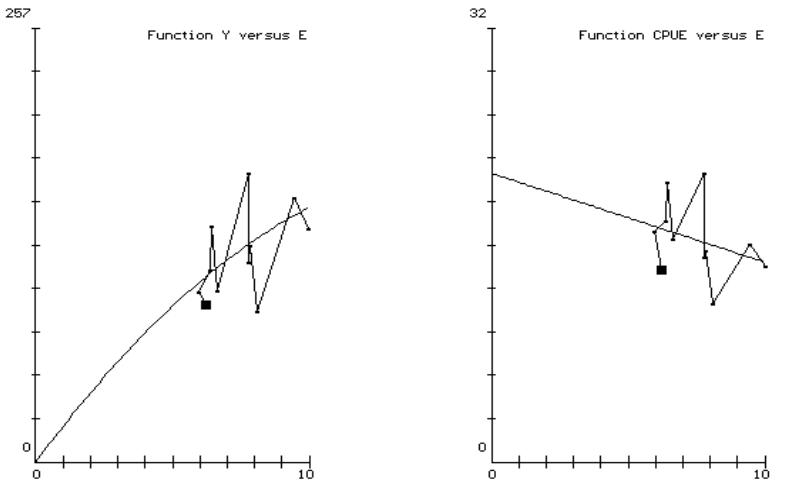

Figure 2.8 - Fit of Schaefer curve to the observed Barramundi catch (Y in tonnes) and effort (E in boat days x 1000) data for the Queensland East Coast.

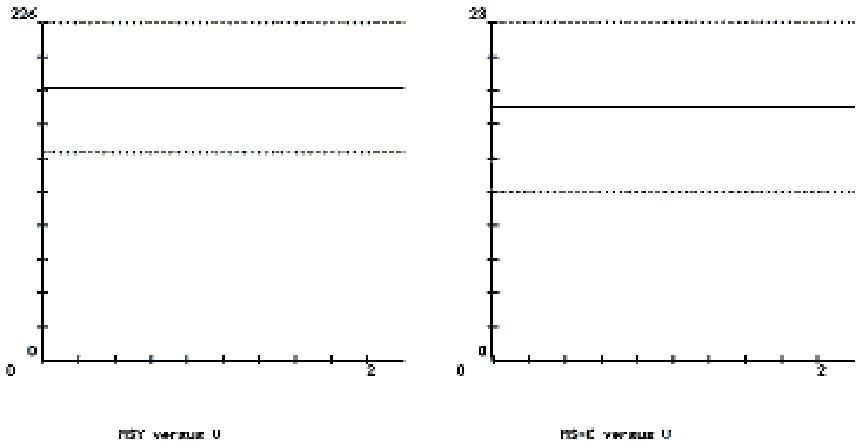

Figure 2.9 - Estimated Maximum Sustainable Yield (MSY) and Maximum Sustainable Effort (EMSY) for Queensland East Coast Barramundi using a Schaefer Model with no adjustment for rainfall (V).

East Coast Mud Crab
CLIMPROD requires at least 12 years of catch, effort and environmental data to adequately utilise its in-built 'decision assistance' routines. Although there was a 12 year combination of historic and current logbook records for Mud Crab, only the last seven years of data could be assigned reliably to potting. As with the Queensland Gulf of Carpentaria logbook information the Tropical East Coast dataset was effectively too short to apply the CLIMPROD package.

2.3.2 Biomass dynamic production models

Two models were proposed for the Gulf barramundi stock, based on the 1981-1997 commercial logbook catch and effort database. Both were variants of "biomass dynamic" surplus-production models, which unlike CLIMPROD do not assume that the stock is in equilibrium. Dr M Haddon, Uni of Sydney (now at AMC), proposed a standard yearly model and Dr David Die, CSIRO, proposed a more complex seasonal model. Both models had difficulty fitting the two sections of the time-series consistently; i.e. 1981-1988 and 1988-1997. It was recommended that if possible the models be run again in the future using standardised effort data (by vessel sequence number), which should make the two periods of the data more consistent. Both models were implemented in EXCEL™.

Malcolm Hadden Model.
Description: Biomass dynamic model, yearly recruitment.
This was a simple Biomass dynamic, stock production model wherein there were two data series; historical 1981 -1988 and the current 1988-1997. The former has monthly data while the latter has daily data. There appeared to be inconsistent implications from each of these series. The historic data suggested a declining population (from the model) while the current data suggested a growing population.

If the effort imposed on the gulf Barramundi stock had decreased (in the early 1980's) and stayed steady then the resultant fishing mortality (F) had declined to a level that permitted rebuilding. If the level of effort stayed constant then we should not be surprised that the stock has continued to recover, albeit very slowly (Figure 2.11).

Also, there were peaks in CPUE in 1990 and 1991 and four and five years later there were further peaks, which is suggestive of cyclic trends (Figure 2.10). The model predicts that the CPUE should be even higher in 1997 but if there are cyclic environmental driving forces then CPUE may in fact drop in 1997 (Editors note: The complete data for 1997 showed a drop in catch but CPUE remained stable).

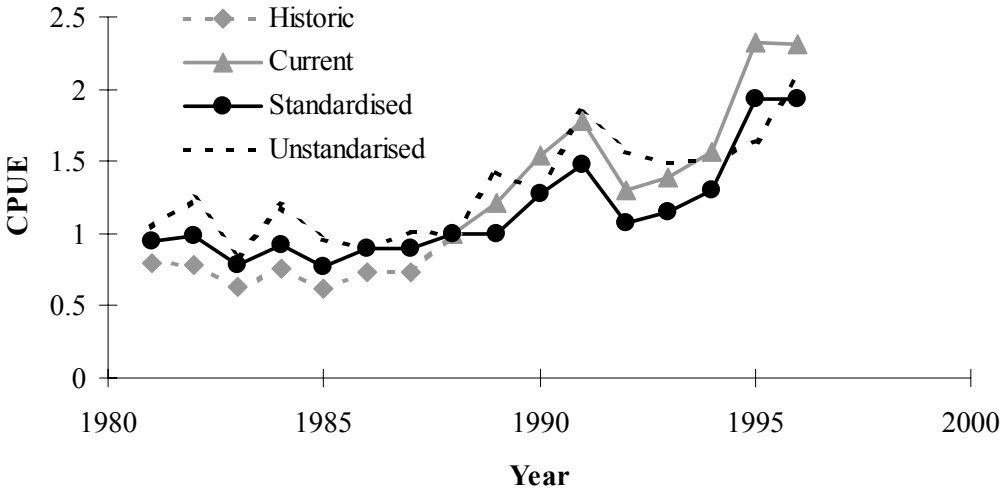

Figure 2.10 - Yearly catch per unit effort data for Barramundi in the Queensland Gulf of Carpentaria

Note: The raw data is given as the **Historic** and **Current** lines; the validated but unstandardarised data is given as the Unstandardised line; and the two data sets standardised according to an experimental general linear model incorporating month (cf rainfall), year, and grid is given as Standardised Together. All lines follow similar trajectories and parsimony would suggest the simplest line would be adequate to describe the underlying trends.

Model parameters

	Unstandardised	Standarised
r	2.18059658	2.838058917
K	12864.17781	12529.92264
B0Est	**3974.171923**	**3631.07148**
p	14.68015826	16.22300012
q	0.005687809	0.000133714
qc	0.007958659	0.000149688
Bcurr	**4546.423283**	**6386.237145**
Bcurr/K	0.353417323	0.509678897
MSY	1483.134903	1732.471735
B0/K	0.308933224	0.289792012
LogLikehood	13.21409262	11.73837246
Ssq	0.179595187	0.215976667

Note: Percentage increase in biomass of from the initial 1981 stock = (Bcurr-BOEst/BOEst *100)

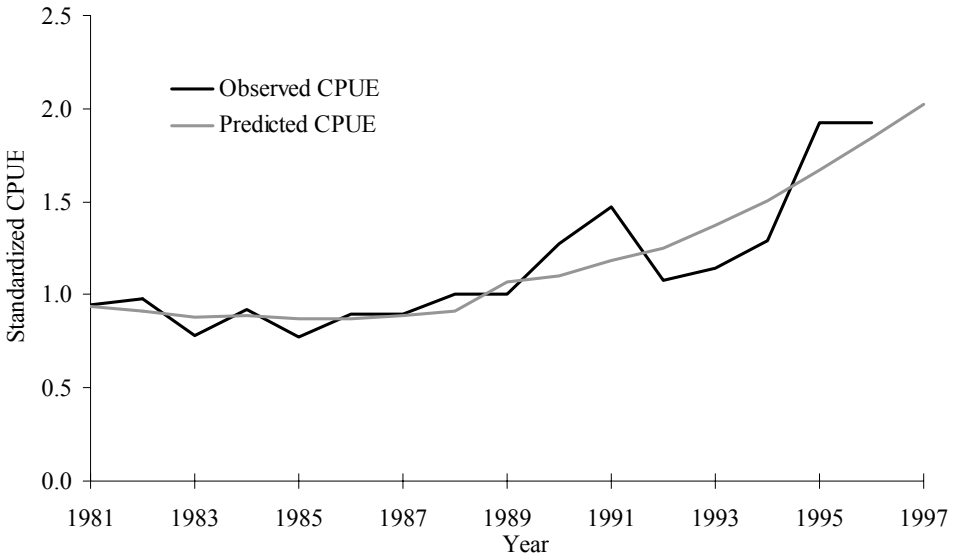

Figure 2.11 - Fit of the Biomass dynamic model to yearly catch per unit effort data for Barramundi catch in the Gulf of Carpentaria.

David Die Model

Description: Biomass dynamic model, recruitment driven, assuming growth occurs in every month.

$$B+1=Bi-Ci+ ri \text{ and } cpue = B * q$$

where B is biomass, C is catch, r is recruitment, q is catchability.

Model Parameters

Run 1. (all data)

B	**782218.2117**	B/k	0.478304822
r	1.186006772		0.479856115
k	1635396.876		
q	2.28277E-05		
ssq	0		

Run 2.

B	**683398.7661**	(≈700 tonnes)
r	0	0.479856115
k	0	
q	4.0312E-05	
ssq	2.919642239	

Editors note: Includes 1989 data, which was an unusual year in the pattern of monthly data.

The model tracks the monthly CPUE reasonably well over the historic dataset and in the most recent years, but has difficulty in the period when the two datsets overlap (Figure 2.12). This is most likely due to data problems at that time rather than reflecting underlying patterns in the relative biomass of the Barramundi stock.

Overall the model tracks the trajectory of the combined cpue datasets and predicts a similar scenario to Dr Haddon's model but is more conservative in its predictions of biomass.

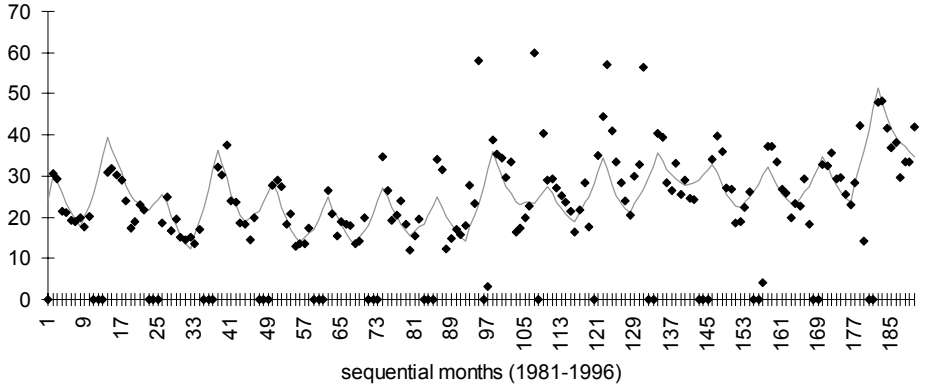

Figure 2.12 - Fit of seasonal Biomass dynamic model to monthly catch per unit effort data for Barramundi.

Note: Filled diamonds are the observed CPUE and the line is the predicted CPUE (cf biomass) according to the model.

This model has been applied to a number of divergent datasets and is to be published by Dr Die and myself, with co-authors in an appropriate scientific journal.

2.3.3 Preliminary "life-table" models

(integrating research results with the results from Biomass Dynamic production models based on the logbook CPUE data).

(1) Estimation of abundance for barramundi stocks in the Gulf of Carpentaria

The total biomass of barramundi present in the Gulf of Carpentaria has been estimated from CPUE data to be 700 – 1000 tonnes by Die, and 4546 - 6386 tonnes by Hadden (Gribble 1998). A rough estimate of the abundance of barramundi in a particular size-class was calculated by combining the CPUE estimates by Die and Hadden with the research size-frequency data (pooled over time) and probability of capture estimates (Table 2.1). The resulting relationships between size-class and abundance were diminishing exponential (Figure 2.13) and described by the following equations:

700 tonnes: $y = 6.8x10^{8}\ e^{-0.137x}$ ($r^2 = 0.998$)
1000 tonnes: $y = 9.7x10^{8}\ e^{-0.137x}$ ($r^2 = 0.998$)
4546 tonnes: $y = 4.4x10^{9}\ e^{-0.137x}$ ($r^2 = 0.998$)
6386 tonnes: $y = 6.2x10^{9}\ e^{-0.137x}$ ($r^2 = 0.998$)

where y = abundance of barramundi and x = size-class (cm).

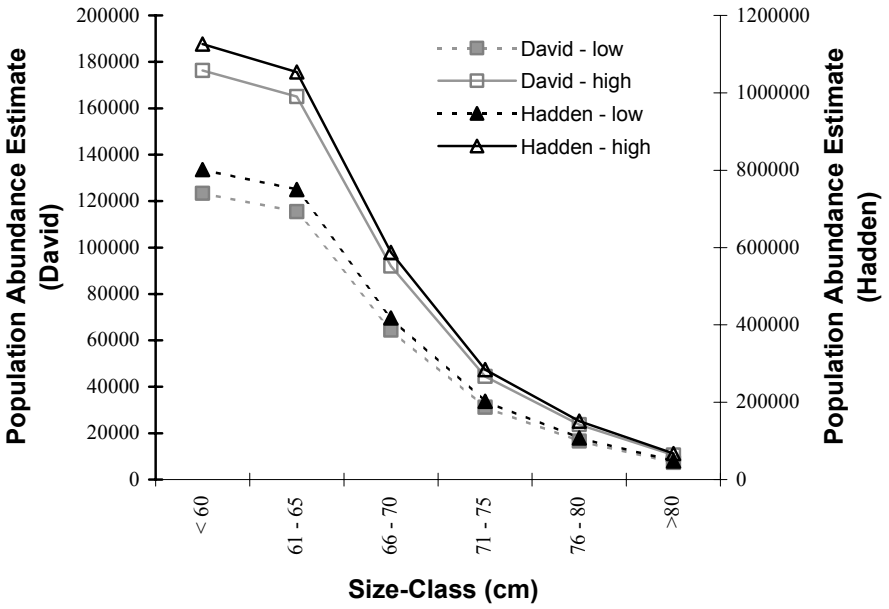

Figure 2.13 - Size-specific abundance estimates for barramundi in the Gulf of Carpentaria. (Open symbols were not used in the regression analysis).

The rate of decline in abundance with an increase in size was the same for all population weights; i.e. the form of the curves were similar. This relationship was significantly different from zero (Regression Analysis: t-stat = $-34.27_{(0.05,\ 3df)}$. P = 0.000). In contrast, the intercepts differed both between and within the two models. There was approximately a 30% difference between the lower and upper estimates for each model, and a greater than 5-fold differences between intercepts among models. The critical parameter was the estimate of total biomass derived from the biomass dynamic models. This estimate needs to be confirmed before further modelling of virtual populations (VPA).

Parameter Estimates.

Appendix 5c details the methods and parameter estimates made for :

- Size frequency distributions of catch.
- Mesh selectivity.
- Age class distribution of catch/population
- Allometric relationship of length to weight
- Growth relationship of length to age (Davis 1984)
- Total mortality.
- Ratio of male to female.

An outline of the formulas used to estimate population abundance of barramundi in each size class for the Gulf of Carpentaria is given in Table 2.1.

Table 2.1 An outline of the formulas used to estimate population abundance of barramundi in the Gulf of Carpentaria. Values have been based on weight estimates of the population provided by Die and Hadden (see Biomass Dynamic models).

DIE									
Size-Class (cm)	Percent Frequency (PF)	Weight Estimate of Population (WEP, tonnes)		Average Weight (tonnes)	Estimate of Population Abundance (PE)		Probability of Capture (PC)	Adjusted Estimate of Population Abundance	
		700	1000		700	1000		700	1000
≤60	23	161	230	0.0015	107333	153333	0.85	123433	176333
61 – 65	30	210	300	0.002	105000	150000	0.90	115500	165000
66 – 70	23	161	230	0.0025	64400	92000	1.00	64400	92000
71 – 75	12	84	120	0.0031	27097	38710	0.85	31161	44516
76 – 80	7	49	70	0.0037	13243	18919	0.75	16554	23649
>80	5	35	50	0.0066	5303	7576	0.60	7424	10606
HADDEN									
Size-Class (cm)	Percent Frequency (PF)	Weight Estimate of Population (WEP, tonnes)		Average Weight (tonnes)	Estimate of Population Abundance (PE)		Probability of Capture (PC)	Adjusted Estimate of Population Abundance	
		4546	6386		4546	6386		4546	6386
≤60	23	1046	1469	0.0015	697053	979187	0.85	801611	1126065
61 – 65	30	1364	1916	0.002	681900	957900	0.90	750090	1053690
66 – 70	23	1046	1469	0.0025	418232	587512	1.00	418232	587512
71 – 75	12	546	766	0.0031	175974	247200	0.85	202370	284280
76 – 80	7	318	447	0.0037	86005	120816	0.75	107507	151020
>80	5	227	319	0.0066	34439	48379	0.60	48215	67730
FORMULA	N = 1692 Size frequency from 1983 – 1992 and 1997 – 1998	$\frac{PF}{100} * WEP$		$\frac{\sum \text{Wt of Size - Class}_i}{\text{\# Fish in Size - Class}_i}$	$\frac{\text{WEP in Size - Class}_i}{\text{Average Weight in Size - Class}_i}$		**Error! Reference source not found.**	$PE \pm [PE * (1 - PC)]^*$	

* Fish < 66 cm in length, operator is positive as fish numbers are underestimated, fish > 70 cm in length, operator is negative as fish numbers are overestimated.

2.3.4 Mud crab "habitat alias" models

Basic model

It is possible to estimate total crab abundance using catch data from the commercial logbook records and the total area of mangrove habitat. The steps in this form of analysis are simple and relatively straightforward.

1. Estimate the total area of mud crab habitat in Albatross Bay estuaries. For this study, mud crab habitat was taken as the area of mangrove identified from satellite imagery (Danaher 1995), 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. The length of stream adjacent to mangrove areas was calculated from AUSLIG maps of creek systems.

   A_m = Area of mangrove (km^2)
   A_r = Area of river (km^2)
   $A = A_m + A_r$

2. Estimate the weight of crabs taken per pot lift and the number of pot lifts in the Weipa region. This information was calculated from QFMA QFISH logbook information (Figure 2.14).

   C = average annual catch between 1989 and 1997 (tonnes)
   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. Divide the area of mangrove habitat by the drawing area of a crab pot and multiply this by the average weight of crabs taken per lift. This would give the potential harvest (tonnes) of legal sized male mud crabs in the population, assuming that assumes that a legal sized mud crab weighs about 1 kg.

   PA = number of pot areas
   $= A_m/A_p$ (method 1)
   $= A/A_p$ (method 2)

   Potential harvest = C/(E*L)*PA

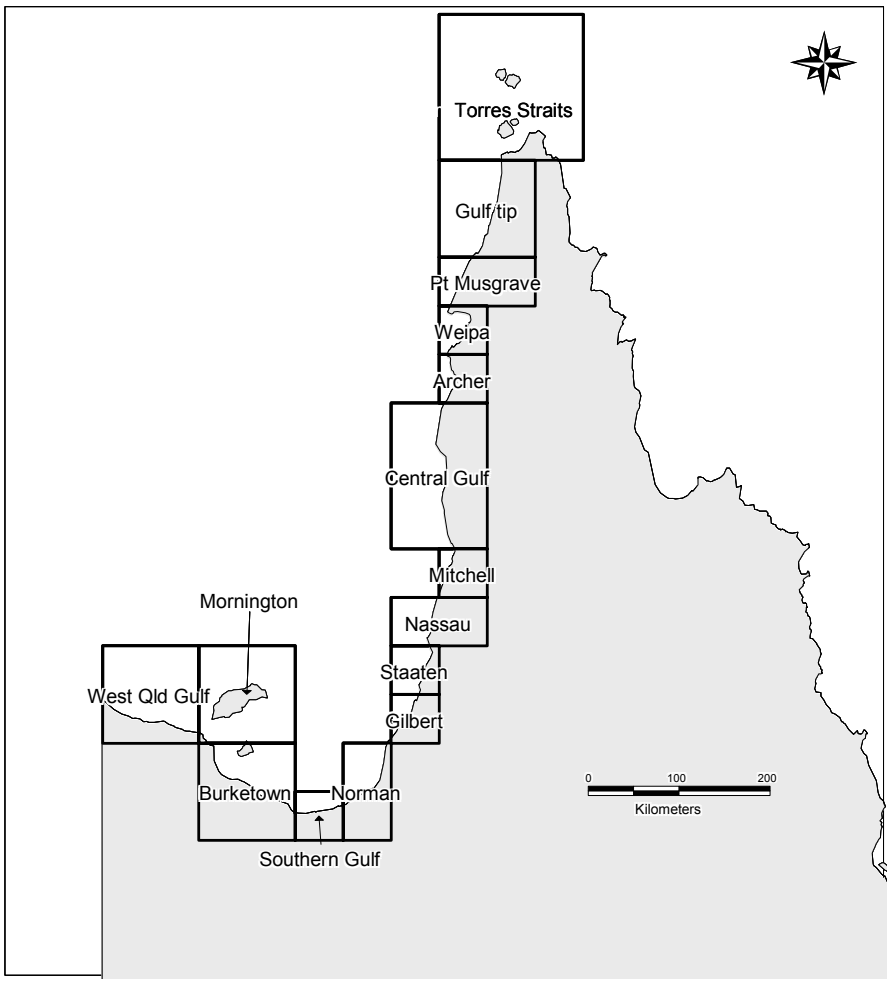

Figure 2.14 - Commercial log book grids used to calculate mud crab abundance in the Gulf of Carpentaria.

It should be stressed that this is a first pass estimate only. The yearly catch of mud crabs can alter between years but the area of habitat is unlikely to do so, therefore this method will not indicate dynamic changes in mud crab stocks.

To address these yearly changes, a mud crab abundance estimate for each river catchment can be calculated via the "catch-curve" method (Ricker 1975) for the period of March to September in each year. The recruitment of a new year-class has finished by March and the spawning migration of females begins in October (Dr Ian Knuckey, NT Fisheries, pers com). Changes in the crab population between these months should be relatively free of immigration/emigration artefacts, therefore any depletion should be caused by the fishing effort and hence reflected in declining CPUE. This decline can be used to determine the initial abundance.

A second consideration is that the area of stream and mangroves measured for this method does include all possible mud crab habits hence will be an underestimate of the total habitat area and consequently the total abundance of mud crabs.

A more accurate assessment can be made with fishery-independent surveys in a number of typical mud crab habitats (eg, mangrove stream, foreshore mudflats, and salt marshes). These surveys could establish the potential "carrying capacity" of each mud crab habitat type in any one year. Satellite imagery could then give the total area of each habitat type and hence an estimate of the total "potential" number of crabs in that year.

Fishery independent "Depletion" survey models

Leslie model

$$\frac{c_t}{f_t} = qN_t$$

where
c_t is catch (number of untagged crabs caught each day) for that time (*t)*
f_t is effort (pot lifts) during time (*t)*
q is the catchability — the fraction of the population taken by 1 unit of effort
N_t is the population at time *t.*
t is the time (days)

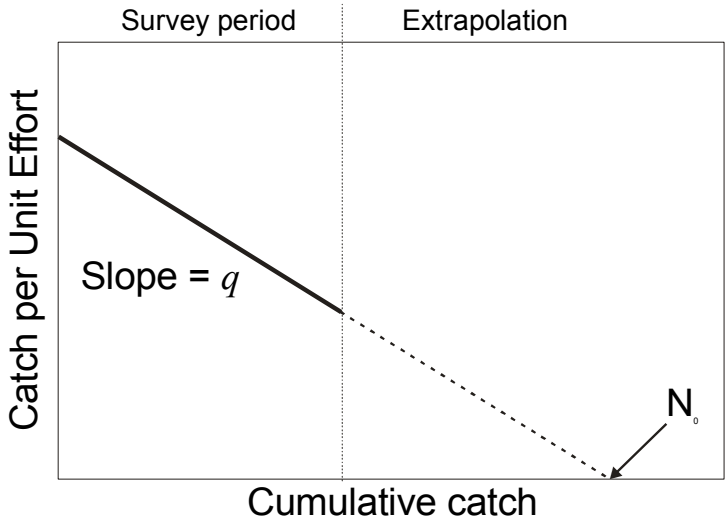

Figure 2.15 - Diagrammatic representation of the Leslie Method

Catch per unit effort is plotted against cumulative catch over a known time interval (Figure 2.15). The resulting fitted straight line (usually descending) gives an initial population estimate at the point where the line cuts the cumulative catch axis (Figure 2.15). The slope of the line estimates catchability.

An example of the application of this model is in the 1998 Weipa Mud crab baseline survey 1. (Helmke, Gribble, and Gould. 1998).

2.4 Discussion (Section 2)

Recurring issues throughout TRAP (phase I) were the paucity or poor quality of the catch and effort data in the logbook database, the difficulty of working with un-standarised fishing effort recorded simply as days-fished, and the need to follow individual boats or groups of boats through the data time-series. An interesting aspect of the data, which was highlighted for a number of species, was the lack of contrast in the catch-per-unit effort data; i.e. there were no dramatic increases or decreases in the CPUE time-series, rather relatively stable trajectories. This could be due to healthy stocks with stable underlying stock biomass, or it could be due to hyperstability where commercial CPUE is maintained by serially fishing down aggregations. In the latter case, fishery-independent methods or observer programs can give information on the actual state of the stock. Only in the case of Gulf barramundi was there sufficient contrast in the CPUE and the data quality to attempt modelling the population dynamics.

The CLIMPROD modelling of the Gulf of Carpentaria "Grid C" and the Tropical East Coast "Grid H" Barramundi catch and effort gave predictions of Maximum Sustainable Yield (MSY) and effort (MSE) that were above the current exploitation levels by a comfortable margin, but there are a number of confounding factors that need to be considered. Firstly, even the simplest production model requires a contrast in the data, from under-exploitation to over-exploitation of the stock, to allow sustainable yields to be estimated. As noted earlier the Gulf Barramundi data describe a simple decline of catch and effort with little such contrast, which limits the reliability of the standard equilibrium models. The wide confidence intervals about the predictions given by CLIMPROD are an indication of this limitation. The inclusion of annual rainfall data to the standard production models did not increase the fit nor the reliability of the CLIMPROD models. An assessment of the Northern Territory Barramundi Fishery also found that environmental variables made little difference in the fit of stock assessment models (Walters, 1996). In the southern Gulf, this result may have been due to a lack of temporal resolution in the precise timing of the seasonal rains during the year. Detailed time series modelling of rainfall and river run-off data against monthly catch and effort may give a better understanding of the influence of rainfall and river run-off on Barramundi recruitment and stock abundance. However, a simple time-delay model (using a 5 year lag time) of rainfall and catch devised by Mr Lou Williams, Senior Fisheries Economist for QDPI Fisheries (pers com), was highly successful at predicting catches for three out of five years but has been increasing inaccurate over the last two years. Environmental forcing factors affecting the life cycle and recruitment of barramundi, which requires both fresh water and marine habitats and undergoes a sex-change from male to female, are likely to be complex.

The two forms of Biomass dynamic model developed for Barramundi suggested an underlying scenario of a slowly rebuilding stock, (see section on Biomass dynamic Models). Both forms required that the initial biomass

was relatively low, suggesting a heavy fish-down had occurred in the 1970's and early 1980's. The introduction of draconian management measures by the Government Fisheries agency in the early and mid 1980's, supports the case that fish numbers were under pressure at this time. The measures included making the fishery limited entry, reducing the number of fishers by two thirds, limiting the amount of net that could be set, and introducing a closed season over the summer spawning. Fishers who were in the inshore fishery in the seventies have stated that barramundi were becoming harder to catch (compared to earlier), but the TRAP pilot observer program found that a number of fishers believe that the management measures were brought in to restrict the east coast fishers access to the Gulf stocks (Magro *et al*. 1998). They contend that there was too many fishers setting too much net rather than a major reduction in the barramundi biomass; the effect on CPUE would be the same, however, with more fishers taking fewer fish each. This is really a moot point, as excessive effort would drive down the biomass in any case.

The life-table model based on research data also supports the scenario of a slowly rebuilding barramundi stock. For 150mm mesh nets the length frequency histogram of barramundi caught in 1981 is not significantly different ($P < .05$, Kolmogrov-Smirnov test) to that of fish caught in 1996-1997. There has been no decrease in the size of fish, all size classes were consistently present in all year samples (i.e. no missing year classes), and the size and ratio of females to males had not changed beyond the limits of year to year variation. The age/length trajectories predicted by the model, although the differing in absolute values depending on the initial biomass estimate, indicate that the population is following the standard pattern of reduction in numbers with increasing size/age class. Mortality (rate of decrease) is highest in the younger/smaller year classes, slowing as fish become older and larger. These tables together with the research derived parameter estimates are the first steps towards a full VPA analysis of the Gulf barramundi stock.

A combination of the seasonal biomass dynamic model and the life-table model give the tools required to track changes in the Queensland Gulf of Carpentaria barramundi stock in response to the fishing effort reduction required under the 1999 Gulf Inshore Set-net Fishery Management Plan (QFMA 1999). Validation of these models and the monitoring of the changes to the stocks, as a test of adaptive management strategies (Walters 1986), is the objective of TRAP (phase II).

The second series of models developed were the mud crab "habitat alias" models which are to be further developed through a joint WA, NT, and Qld Fisheries research program. Funding is to be sought from FRDC in 2000 for a 5 year research proposal to survey various habitats in each state to determine the abundance of mud crabs, and therefore the importance of that habitat to maintaining the stocks. These estimates will be combined with satellite imagery to give an overall estimate of mud crab resources across northern tropical Australia.

2.5 Documents produced and distributed under TRAP Phase I

2.5.1 Project reports

- Tropical Resource Assessment Program: FRDC Project 95/049 Annual report 1996 (Gulf Inshore Fishery)., Magro, Gribble and Bibby pp 55

- Tropical Resource Assessment Program: FRDC Project 95/049 Annual report 1997 (Tropical East Coast Inshore fishery)., Magro, Gribble, and Bibby. pp 55

- Tropical Resource Assessment Program: FRDC Project 95/049 Annual report 1998 (Research data compilation)., Hall, Gribble, and Peverell. pp 84.

- Tropical Resource Assessment Program: Fisheries Stock Assessment Workshop. (Expert Group)., Cairns 28-31 Oct 1997. Gribble pp54.

Sub-project reports

- Tropical Resource Assessment Program: Summary of Mud Crab distribution in Queensland., Gribble and Helmke pp 37

- Tropical Resource Assessment Program: Inshore Fishery Observer program. Peverell, Gribble, and Hall. pp 48

- Report on Barramundi sustainability indicators to Tropical Finfish MAC. pp20.

Related project reports
(These are projects that were spin-offs from the main program)

- Weipa Mud crab baseline survey 1. Helmke, Gribble, and Gould. (Funded through the QFMA) pp 60.

- Weipa Mud crab baseline survey 2. Gould, Helmke, Peverell and Gribble (Funded through an NHT community grant)

2.5.2 Formal Presentations (extension)

- 1996. Preliminary results and advice were provided to QCFO and QFMA, including TRAP personnel delivering presentations at Tropical Finfish MAC, Gulf of Carpentaria ZAC and QCFO meetings. Copies of annual report supplied to steering committee members and information distributed the organisations they represent.

- 1997. Preliminary results and advice were presented to the Tropical Finfish MAC, Gulf of Carpentaria ZAC and QCFO meetings. TRAP personnel also provided data and advice to a 'straddling stocks' workshop in Darwin, Northern Territory, and to the follow-up Queensland Fisheries Joint Authority Fishing Advisory Committee (QFJA FAC) meeting in Cairns. Two presentations by TRAP staff were made at the Australian Society for Fish Biology (ASFB) Annual Conference, held in Darwin (18th and 19th July, 1997). One paper covered a method of allocating effort in the catch/effort database; the second paper presented some of the biological parameters estimated from the research database. Copies of annual report were supplied to steering committee members and information distributed the organisations they represent.

- 1998. Two formal presentations of the ongoing results from TRAP were made during 1998; one to the Gulf Zonal Advisory Committee, and a second to the CRAB Management Advisory Committee. An in-house presentation was made at Northern Fisheries Centre for peer review of the collation of research data. Copies of annual report were supplied to steering committee members and information distributed the organisations they represent.

- 1999. Two formal presentations were made; to the SCFA Research Committee, Mini-symposium of Stock Assessment Experts, Queenscliff, August, and at the Scientific Assessment session of the Northern Fisheries Council meeting Cairns, July.

- 2003. Formal presentation at the 18th Lowell Wakefield Fisheries Symposium, Anchorage, Alaska 'Fisheries uncertainty: a tropical Australian data-poor fishery' (Sea Grant Proceedings Report)

- 2004. Formal presentation at the 2004 ASFB National Conference. 'Adaptive management in a tropical fishery: the north Queensland Barramundi case study'

All reports have been provided to each member of the steering committee for dissemination through their respective organisations; QDPI Fisheries Condition and Trend Unit, Charter Boat Operators/Recreational Fishers, QCFO, and QFMA. Summary analysis. Copies of all reports were made available through a co-investigator, Mr Rod Garrett, and principal investigator Dr Neil Gribble, to the Tropical Finfish Management Advisory Committee and its Stock Assessment Group, respectively, for consideration in formulating Inshore Set-Net Fishery management plans.

2.6 References (Section 2)

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Section 3. Technical report for TRAP Phase II, N3 Fishery Observer Program

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3.1 Introduction N3 Fishery Observer Program

The Tropical Resource Assessment Program (TRAP) Gulf of Carpentaria (GOC) N3 inshore setnet Fishery Observer Program were conducted from July 1998 to October 2001. During this period 233 observer days was recorded. The Fisheries Observer was required to liase with commercial fishers and organise sea time convenient to both parties. A field diary was maintained for all days whilst in the field. Entries included anecdotal evidence on the history of the fishery, fishers concerns about present management arrangements, technical detail on operation, and temporal factors influencing catch rates. Technical detail on fishing operations included information on net size, mesh drop, net length, net soak time, location and date. Other detail on the netting conditions was also recorded, including the presence or absence of jellyfish, water clarity and tidal or flood current. The GOC was also categorised into north, south, and western regions. The northern region encompasses the western side of Cape York Peninsula north of the Mitchell River. The southern region encompasses the rivers and creeks extending from the Mitchell into the southern GOC to Spring creek. The western GOC incorporates all drainage systems from the Leichardt River to the Queensland - Northern Territory border (Figure 3.1).

3.1.1 Fishery Observer Duties

Whilst in the field, the Fishery Observer not only performed research tasks but also was actively involved in daily fishing operations, in order to get a "feel" for the fishery. Therefore, a practical experience in the workings of the industry was a basic requirement for the Fishery Observer to successfully integrate into the day to day running of the fishing operations. Inshore fishing vessels are small and are usually family-run enterprises. There was no room for passengers on these boats and the Fishery Observer was expected to pull his/her weight.

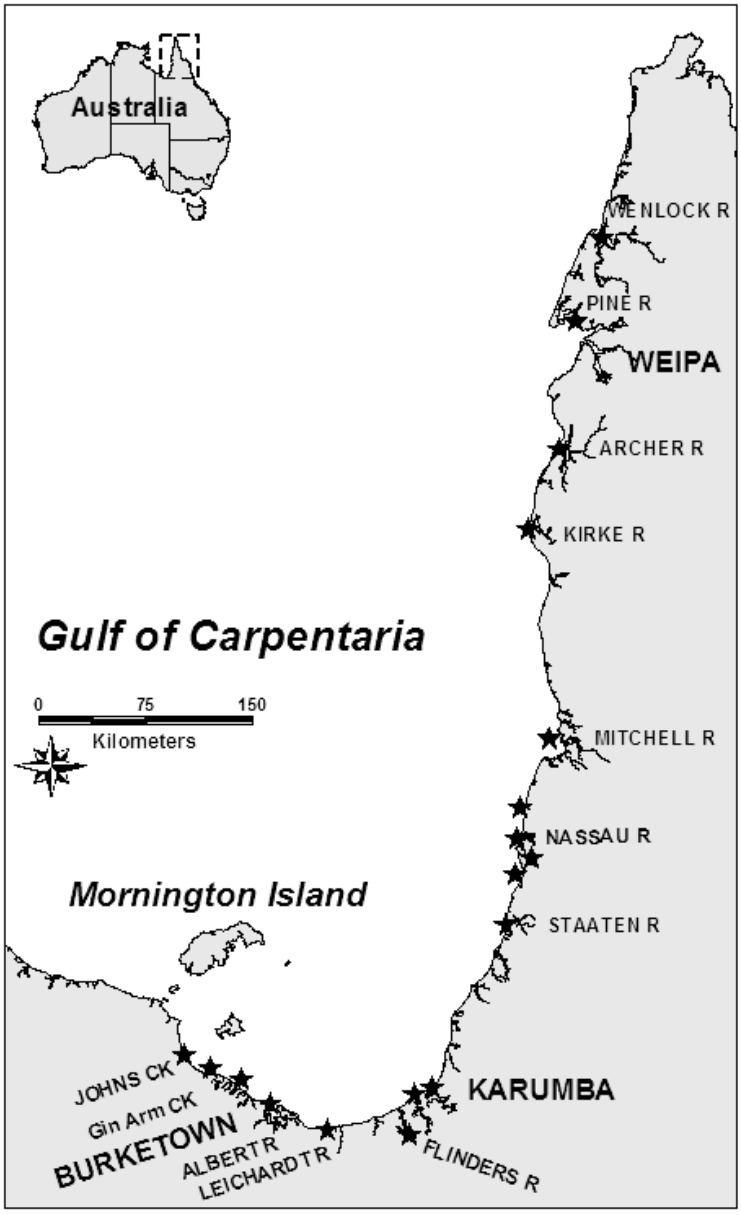
3.1.2 Industry Placement

A difficult challenge for the Fishery Observer was organising vessels to monitor during normal fishing operations. Accepting a Fishery Observed aboard was voluntary, but the majority of GOC commercial fishers were sceptical, viewing researchers as a possible threat to their livelihood. Good "people skills" were essential; hence a flyer on the project background and objectives was distributed as a first step, then presentations were delivered at industry meetings, and a report sent to the participating fisher within a short period of time following each observer trip. Word-of-mouth then convinced other fishers to allow the Fishery Observer on board.

Consequently, access to commercial fishing operations had to be conducted on an opportunistic basis. Developing contacts whilst in the field was the most successful method of obtaining boat access. A personal introduction given by the participating fishers to other fishers was often the key to further cooperation. At each introduction the Fishery Observer project

protocols were outlined, to the fisher, which was to observe, record and report. It was stressed that the Fishery Observer did not have the legislative authority to enforce fishery regulations (i.e. his/her role was not as a policeman).

Figure 3.1 - TRAP N3 Fishery Observer Program survey sites, GOC 1999 - 2001



3.1.3 Sampling period

Commercial fisher participation in the TRAP N3 Fishery Observer program was undertaken voluntarily whilst the TRAP N9 Fishery Observer program is legislated as part of N9 permit requirement. Both the programs were restricted by the seasonal barramundi closure set each year in summer based on three and a half lunar cycles beginning 7 days prior to the first major spawning moon, usually the October full moon.

3.1.4 Gear

The survey was centred on commercial gill netting operations with gear regulated under the Queensland Fisheries Act 1994, and the GOC Inshore Fisheries Management Plan 1999. In most instances monofilament net of a minimum and maximum mesh size of 162.5mm and 245mm respectively was deployed. The gear is classified as a set net and depending on the depth can fish the entire water column. An N3 licence is permitted to use 360m of net inside a river or 600m net along the foreshore or offshore. Unless the fisher holds two licences he/she is not permitted to operate gear on the foreshore and river simultaneously. In the GOC a gear attendance rule applies along with seasonal and spatial closures.

3.1.5 Confidentiality

The Fishery Observer was privy to valuable information concerning the performance of the fishers surveyed. It was a gentleman's agreement between the Fishery Observer and the fishers that any specialised fishing techniques, locations or site-specific fish numbers caught would not be published without prior approval. It is essential that a good working relationship between scientists and fishers be maintained for the benefit of industry, researches, and resource managers.

3.2 Methods (Section 3)

3.2.1 Sampling Protocols

Data ranking

One of the primary objectives of the Fishery Observer project was to obtain length frequency data for all species caught in the N3 net operations. This created problems where the Fishery Observer was restricted to the mother vessel and could not attend net "robs" or checks. The data therefore had to be rated on its degree of accuracy. For this reason each record was allocated a reliability rating of one through to three, as listed below.

1 - Fishery Observer identified animal and obtained length measurement
2 - Fishery Observer identified animal and estimated length.
3 - Fisher observed and identified animal with or without measurement

By adopting the above method, time was available for the Fishery Observer to record more length and weight frequency data from as many specimens as possible. As well, placing a reliability rating on each record allowed for those fish that were mutilated by shark, crocodile or crabs to be recorded, but could be discounted if need be in subsequent analyses. All fishers surveyed were sufficiently skilled in identifying the common fish species found in their area of operation. During periods of intense workloads, the Fisheries Observer took a sub-sample of length measurements and the remaining catch was identified to species and counted.

Measuring length

Taking a length measurement of a fish requires little explanation, although there are three possible measures that can be made: standard (SL), fork (FL), and total length (TL). The measuring board used by the Fisheries Observer was 1.2 m long with a white background and black engraved numbering at 1 cm intervals. The fish were placed firmly against the headpiece of the measuring board, ensuring the animal's mouth was closed. Often when an animal was partially frozen and had had its throat cut the length measurement was difficult to obtain. Where possible the animal was then left to thaw before measuring or a rating category of 2 was assigned to that fish. The caudal fin length measurement (fork or tip) was taken to the nearest 0.5 cm grouping. Where damage had occurred to the caudal fin a category rating of 2 was assigned. Confidence in total length measurements are important to the Fishery Observer in analysis of the number of legal sized fish available to the fishery, and to the commercial fisher in determining legally take.

Fillet length frequency data was collected for a number of target species. The skin off the fillet was measured after the fillet had been processed. The shoulder of the skin was placed at the headpiece of the measuring board and with a sweeping motion of the palm along the skin, it was spread out evenly along the board. A measurement was then taken where the skin had left the caudal peduncle.

Measuring weight
Fish were weighed using a set of 10 kg Super Samson™ scales. The scales were hung in an accessible area free from disruption to crew aboard the fishing vessel. Fish were weighed whole and all measurements were taken to the nearest 0.01 kg. Weight measurements were recorded for only a select group of commercially important species (see Anon 1988). The size of the catch and the prevailing weather conditions governed how many fish the Fishery Observer weighed. All fish weighed had had been bled prior to weighing, so whole weights are only an approximation of the true live weight.

Fillet weight measurements could only be taken during times of processing. A weight was obtained after the fillet had been removed and trimmed for packaging. Both wet fillets were then placed in a prawn basket and weighed using the same scales as those used for obtaining whole weight of a fish. Whole weight and subsequent fillet weight of the same fish were recorded.

Species identification
The Fishery Observer undertook species identification whilst out in the field, with only difficult or unfamiliar species taken back frozen to the laboratory for later examination. Most species caught in the N3 inshore set net fishery were easily identified. A comprehensive set of identification keys such as Food and Agriculture Organisation (FAO) Species Identification Sheets for Fisheries Purposes (e.g. Compagno, 2001) were then used to positively identify the animal. Photographs were taken for the animals that could not be transported back to the lab for identification or which were released alive. All animals were keyed down to at least genus level.

3.2.2 Data Analysis

Fishery Observer Catch per unit of effort (CPUE)
Commercial fishing hours were recorded for the total amount of net in the water for the period of observation. In some locations where the net was left high and dry because of the range in the tide, actual hours the net was in the water was recorded. The fisher paradigm is that the net had to have a minimum of 50% water coverage and a depth of greater than 0.2 meters before it began to fish. Recording actual fishing hours as opposed to fishing days as a measure of fishing effort was extremely important as net shots in the western GOC can remain dry for up to 12 hours in a day. Approximate length of net set was also recorded.

Fishers in most cases do not fish with the maximum amount of net entitled to them. The quality of the net set is dependent on fishing conditions (presence of jellyfish, weed, etc) and the amount of fish movement expected. The catch per unit of effort for each site was averaged for combined soak times and the amount of net standardised to 500m. CPUE is presented as fish per hour per 500m of net.

3.3 Observed Technical and Catch Information

3.3.1 Constraints on analysis and interpretation of Fishery Observer data

Observer coverage of the fleet
The program was voluntary with fishers inviting the research observer on board their vessel and only nominal payment involved, usually to cover food and sundries. The coverage of the fleet (and number of sets) was relatively low compared to compulsory compliance observer programs, but formed a representative sample of the species caught and of typical CPUE rates achieved within the fishery. Approximately 9% of the active licences took part in the program and 144 days of fishing was observed.

Economics
Fishers draw on knowledge gained from decades of practical experience to conduct their fishery operation. The commercial fisher has to possess knowledge of the target animal's biology, behaviour, and habitat requirements if they are to remain viable in the fishing industry. Depending on the season and the market value of the product at the time, fishers will change the target of their operation. Commercial fishers target particular species because they provide the greatest financial return for the least amount of effort. Barramundi have a high market value and are the preferred species, however, during the winter months of June, July and August, fishers diversify into other fisheries, such as mackerel, shark and king salmon, in an effort to maintain a viable income.

The barramundi fishery was described by fishers as being a 'hit miss affair' over the winter months, where the fish are scattered and often difficult to locate. Magro *et. al*. (1997) reported a decrease in the catch of barramundi over winter and attributed this to the fish dispersing from estuaries and foreshores after the spawning season. This reduces the catchability of the fish and explains the fishers' need for diversification to other species that can provide a better financial return.

A number of experienced GOC commercial fishers commented that there is very little skill associated with setting a gillnet, the skill lies in where the gillnet is set. Under conditions where the fish are scattered, the experienced fishers move their nets at least every 24 hours to maintain a high catch rate. It was observed that gillnet "sets" were placed in strategic locations and positions in bends, gutters, deep holes and flats of rivers and foreshores. The majority of fish were always caught in one or two nets rather than over the full complement of gillnets.

Water clarity
Working under clear water conditions reduces the catching ability of gillnets considerably as the nets are visible to the fish. Barramundi and king salmon were observed avoiding the nets by jumping over or swimming parallel to them. Anecdotal reports from fishers suggest a net constructed out of 40 ply (light, fine mesh) will catch more fish than a net constructed

out of 80 ply under these fishing conditions. However, the trade off between fishing with lighter nets over heavier nets is the damage factor larger fish have on lighter nets. A large barramundi, king salmon or shark has the power and weight to swim through a lightly constructed net (40 ply), breaking meshes as it struggles through. This was observed on the Bynoe River foreshore where a barramundi with a total length of 120cm was landed but had nearly escaped by breaking several 40 ply meshes.

The high catch rates of barramundi seen in the early part of the season are a result of high numbers remaining after the spawning migrations, and the water being “dirty”. High flow events caused from torrential rain in the Wet season increases the turbidity in the creeks and rivers and along the foreshores. During the winter months or “Dry” when the rain is absent or not as heavy, the strength and direction of the wind can influence the clarity of the water by blowing dust from the mudflats over the rivers and foreshore. This event was witnessed in the Bynoe River where the wind was blowing from the southeast at 15 to 25 knots. Within 24 hours the water clarity had turned from being relatively clear to a cloudy grey and the catch rates of fish improved.

Tidal regime

A number of experienced GOC commercial fishers commented that "fishing the river" over the full range of a 2.8m tide was “a waste of time”. The neap tides are the preferred tides to work the river as the tidal current is reduced and the net can fish effectively. During the period of the surveys only two sets of neap tides were experienced and both produced excellent catch rates of barramundi. When a strong current is fished, the nets are under a lot of strain and in some instances rise to the surface “surfing”. The pressure on the net is so great that the lead line cannot hold the net against the bottom or hang in mid water properly. The fishing efficiency of the net during this period is drastically reduced, with the net only fishing effectively a small percentage of the soak time usually when the current stream drops on the low or high tide.

It was observed during the Bynoe River and Nassau River surveys that when a gill net is under considerable strain from the current it tends to vibrate, producing a “humming” or “drumming” sound. The nets exhibiting this behaviour had very poor catch rates and often did not catch anything. Under these conditions, the nets were estimated as only fishing effectively for 4 hours (during slack water) over a 12 hour soak time. Some fishers believe in sinking the net through the use of pinion weights, or sand filled bottles. The net is still under extreme pressure and a lot of effort is exerted by the fisher in working his nets in these conditions for often very little return.

Foreshore fishers do not experience the severe tidal currents of the river, just the lack of water at low tide. In part of the GOC the nets are often left exposed for up to 12 hours out of a 24 hour soak time. It is self-evident why this might have an effect on net efficiency, and must be factored into

catch per unit effort (CPUE) calculations generated from CFISH logbook data. (Note the CFISH record days

Jellyfish

There are two types of jellyfish that are of concern to the fishers. One species is referred to as "blubber" (*Catostylus* sp.) and the other is the box jellyfish (*Chironex fleckeri*). Both of these species possess stinging nematocysts that make handling these animals extremely difficult, and in latter dangerous to health, hence capture of either species is avoided by fishers where possible.

Jellyfish in large numbers and sizes in nets cause a lot of heartache and unnecessary effort for commercial inshore set net fishers. Anecdotal reports from commercial fishers suggest north East Coast fishery only experience jellyfish in difficult numbers every six to seven years, whereas the Gulf fishers have to deal with the animals on a yearly basis (Eric Lilo, GOC and EC Commercial Fisher, pers com). Over the duration of the surveys, jellyfish were encountered at all locations in the Gulf, however they only caused problems for commercial fishes in the Nassau River and Bynoe River. In some instances the jellyfish (*Catostylus* sp.) were as large as 20 cm across and weighed in excess of several kilograms.

Jellyfish concentrations are only considered by GOC fishers to be a problem in areas of high tidal current, including estuaries and foreshore gutters. River nets are normally hung in a fashion that allows for them to sit loosely in the water even in high flow conditions. The net is designed to act as a "shock absorber' rather than a "trampoline" in catching fish (Eric Lilo, GOC and EC Commercial Fisher, pers com). When a fish hits a loose net it rolls, picking up more meshes and entangling itself further. The mass of jellyfish caught in the meshes compounds the pressure created from the tide and the net becomes taunt and stretched. As well, fish appear to be able to identify the net from the vibrations/sound produced by the taunt net in the water and avoid capture.

Once the jellyfish have been removed from the net, the fisher is still left with the problem of jellyfish slime from the tentacles and body coating the meshes. Fine silt sticks to the stinging slime, colouring the net brown and possibly making it visible to fish. This was observed in the Nassau River where two days of turbid water and weeks of fishing among jellyfish coated the net meshes with a fine brown silt layer. Under clear water conditions, the nets were very highly visible when viewed from above the water surface and the catch rate was affected accordingly.

Jellyfish not only affect net fishing efficiency but also create extra work for fishers. The task of "robbing" or pulling a gill net under these conditions is extremely difficult and dangerous. Protective clothing is required to avoid stings from the jellyfish nematocysts and a majority of fishers wear gloves, long sleeve shirts, wet weather gear, aprons and safety glasses. Even so it is not uncommon to be stung around the eyes, neck and forearms.

Weed and slime
Weed and brown slime was recorded affecting fishing operations in both foreshore and estuarine areas. Removing this material from nets is time consuming and tedious, so some fishers buy high-powered water jets specifically for cleaning their nets. Weed in the net creates unnecessary weight and pressure while slime discolours the net mesh reducing catchability.

The aftermath of fishing among weed was experienced during a survey of the Bynoe River foreshore where three panels of net had been affected. The weed was entangled around the net knots and removal could only be achieved by drying and shaking the mesh. Observations on catch rates between the clean and dirty panels were possible and it was evident that the clean panels were catching more fish, although statistical analysis was beyond the scope of the present study.

Predation on net catches
The financial cost of loss of fish caught in nets to predators is two-fold. The loss of product directly affects the fishers' income while the net damage incurred affects its catchability. The three predators caused the most problems for commercial net fishers in the three year survey were sharks, crocodiles, and mud crabs.

Crocodiles (*Crocodylus porosus*) were observed taking fish from the nets in the Gin Arm River, crushing and shaking the fish. The attacks only occurred during the night and early morning. Bruising and puncture holes often rendered fish unfit for processing (Plate 3.1). In economic terms when a fisher looses four barramundi over a 24 hour soak time, which is not uncommon along the western coast of the Gulf, he has effectively lost A$120 worth of fillets (2002 prices) and the associated costs of repairing damaged gear. This issue highlights a significant data gap in "effective effort" calculations for stock assessment modelling for target species such as barramundi and king salmon. Large holes in the net were observed on several occasions, caused by large crocodiles or sharks, which would have reduced the catching efficiency markedly. The GOC fishers Code of Conduct (Ward 2001) covers the handling and live release of protected species caught in nets, such as crocodiles and sawfish.

Mud crabs (*Scylla serrata*) were observed to cause product damage, especially along the foreshore net shots. Mud crabs of various sizes were observed eating the eyes and tails of moribund or struggling fish. Crab predation mainly affects the sale of whole product where physical scarring renders the product unsaleable. Crab attack by breaking the skin also accelerates the spoiling time for product caught during warm water conditions.

Predation of product by sharks was an issue for net fishing operators especially along the northern foreshores of the GOC. Sharks can cleanly remove a fish from a net, leaving behind the head but in many cases also

damage the fishing gear. This leaves the fishers with the time consuming task of net repair, lost fishing time and loss of saleable product.

Fishing pressure and other disturbances

Currently the fishers on the Queensland Gulf coast tend to self-regulate the total fishing pressure on a particular river system, by employing a gentleman's agreement between fishers. A fisher will not fish over another's nets and will not set further up the river than the fisher already there. This is made easier by the fact that their fishing grounds cover a vast, relatively undisturbed area, isolated from development and the other fishing sector competitors. By having such a large fishing area, sections of foreshore and rivers can be left undisturbed for weeks on end.

However, it is possible to fish a local area to a point where catch rates drop off dramatically; when this occurs, a fisher will shift his netting operators elsewhere. Anecdotal reports from fishers suggest that this moving of nets early in the season is not as important as later in the season because the fish are continually moving in and feeding. During the latter part of the season, June through until October, many fishers share a practice that a stretch of river should be left undisturbed for approximately two weeks after it has been fished (Eric Lollo, GOC and EC Commercial Fisher, pers com). This is to allow further fish to recruit into the area and for those fish remaining to adjust back into normal behavioural patterns. This practice was conducted at all of the rivers surveyed where fishers removed their nets after a 24 hour soak time, even if a good catch rate was experienced.

A comment made by a number of fishers during the Fishery Observer surveys was that not enough research has been conducted into the effects environmental disturbances such as boat traffic, mining pollution, urbanisation, and poor catchment management practices.

Net length

Observations revealed that fishers when recording their information in CFISH logbooks, especially for those fishers possessing two or more endorsements, often overestimated net length. The full complement of net (see Section 3.2.1) was often recorded when the amount of net used was dependent on the fishing conditions and how many fish were being caught in the area. The commercial fisher is limited in how much product he or she can process and adjusts the amount of fishing effort (net length and soak time) accordingly. The commercial fishers reasons for overestimating net length, and hence fishing effort, was that they feared they would lose their full entitlement of net if the logbooks suggested they could produce reasonable catch rates from less net.

3.3.2 N3 Fishery catch composition

The N3 fishery catch comprises many species dominated primarily by barramundi and king salmon (Figure 3.2). The Fishery Observer program has identified a total of 98 species form 53 families within the N3 fishery catch (Table 3.1). The species composition between survey sites did not vary dramatically over the duration of the program. Seasonal conditions varied between years, and these had profound effect on the abundance of species although species composition remained the same. The Kirke River catch per unit of effort of blue salmon and narrow sawfish was down by 91% and 100% respectively for the 2000 and 2001 fishing seasons. A change in fishing conditions between the two consecutive years was suggested to be the cause, with a change in water clarity implicated.

The N3 fishery catch composition can be broken down to approximately 91% of fish numbers caught being of marketable value and 9% presently being viewed as uneconomical to process (Figure 3.3). The top five marketable species make up 78% of the total catch and are highlighted in order of numbers caught in Figure 3.2. Market forces change over time with creative marketing, consumer tastes and preferences driving the change.

Presently, very little within the N3 fishery is considered bycatch, that is that part of the catch that interacts with set net fishing gear and is discarded (Eric Lollo and Gary Ward, GOC Commercial Fishers, pers com). Catfish (*Ariid* spp.) (71%) and bony bream (*Nematolosa* spp.) (16%) dominated the non-marketable catch (9% of the total catch in N3 catches observed in 1991- 2001), (Figure 3.4). Other species in the bycatch category included several species of sharks, rays and finfish such as wolf herring (*Chirocentrus dorab*). The incidental capture of Commonwealth or State legislated species accounted for less than 0.1% of the observed total catch and is discussed in Section 3.3.9.

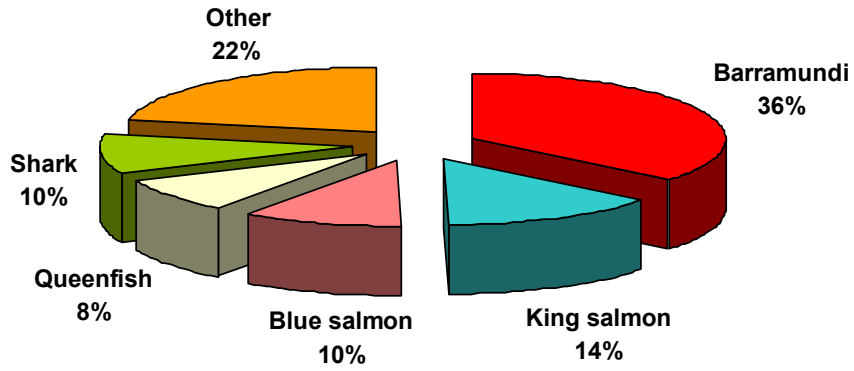


Figure 3.2 - N3 Fishery species composition of marketable catch, based on observed landings 1999-2001

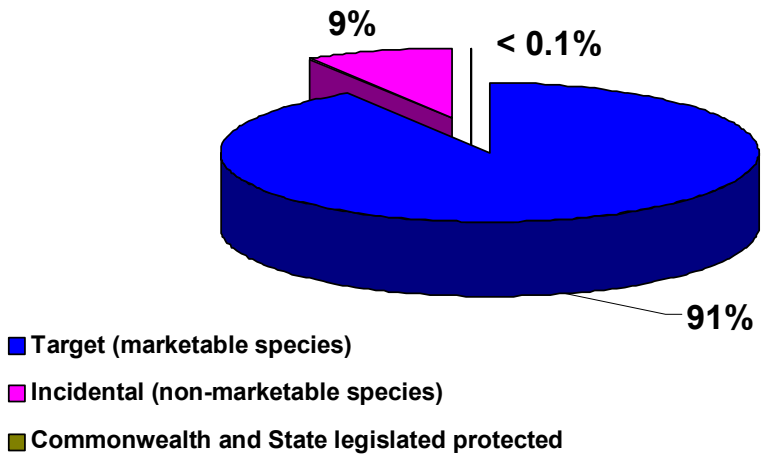


Figure 3.3 - Summary of N3 fishery resource, based on observed landings 1999-2001

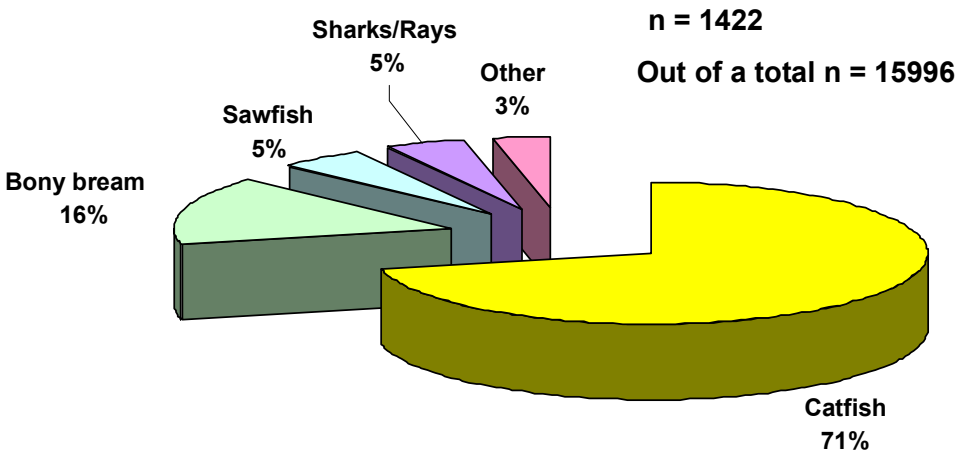


Figure 3.4 - Species composition of non-marketable catch in the N3 Fishery, , based on observed landings 1999-2001

Table 3.1 – Catch species composition recorded in the N3 Fishery Observer program 1999 – 2001

FAMILY	Species	Common name
Ariidae	Ariidae sp.	Catfish
	Arius thalassinus	Golden catfish
	Cinetodus froggatti	Small mouthed salmon catfish
Carangidae	Carangidae sp.	Trevally
	Carangoides gymnostethoides	Bludger trevally
	Gnathanodon speciosus	Golden Trevally
	Parastromateus niger	Black pomfret
	Scomberoides commersonnianus	Queenfish
	Trachinotus blochi	Snub-nosed dart
Carcharhinidae	*Carcharhinus amblyrhynchoides*	Graceful shark
	Carcharhinus amboinensis	Pigeye shark
	Carcharhinus brevipinna	Spinner shark
	Carcharhinus cautus	Nervous shark
	Carcharhinus fitzroyensis	Creek whaler
	Carcharhinus leucas	Bull shark
	Carcharhinus limbatus	Common blacktip shark
	Carcharhinus macloti	Hardnose shark
	Carcharhinus melanopterus	Blacktip reef shark
	Carcharhinus sp.	Whaler shark
	Carcharhinus tilstoni	Australian blacktip shark
	Negaprion acutidens	Lemon shark
	Rhizoprionodon acutus	Milk shark
	Rhizoprionodon oligolinx	Grey sharpnose shark
	Rhizoprionodon taylori	Australian sharpnose shark
Centropomidae	*Lates calcarifer*	Barramundi
Chanidae	*Chanos chanos*	Milkfish
Chelonidae	Chelonidae sp.	Sea turtle
Chirocentridae	*Chirocentrus dorab*	Wolf herring
Clupeidae	*Nematalosa come*	Saltwater bony bream
	Nematalosa sp.	Saltwater bony bream
Coryphaenidae	*Coryphaena hippurus*	Dolphinfish
Crocodylidae	*Crocodylus porosus*	Saltwater crocodile
Dasyatidae	Dasyatidae sp.	Stingray
Dasyatidae	*Himantura uarnak*	Long-tailed Stingray
Drepanidae	*Drepane punctata*	Sicklefish
Elopidae	*Elops australis*	Giant Herring
	Elops hawaiensis	Torres Strait Herring
Ephippidae	*Ephippides* sp.	Sicklefish
	Platax teira	Teira batfish
Ginglymostomatidae	*Nebrius ferrugineus*	Tawny shark
Gobiidae	*Rhinogobius* sp.	Goby
Haemulidae	Haemulidae sp.	Brown morwong / Sweetlip
Haemulidae	*Pomadasys kaakan*	Large-banded / Golden grunter
Harpodontidae	*Harpodontidae sp.*	Lizardfish
Hemigaleidae	*Hemigaleus microstoma*	Weasel shark
Hydrophiidae	Hydrophiidae sp.	Sea snake
Leptobramidae	*Leptobrama muelleri*	Beach salmon
Lobotidae	*Lobotes surinamensis*	Jumping cod

FAMILY	Species	Common name
Lutjanidae	*Lutjanus argentimaculatus*	Mangrove jack
	Lutjanus johni	Fingermark
	Lutjanus russelli	Moses perch / Fingermark
Monodactylidae	*Monodactylus argenteus*	Diamond-fish / Butterfish
Mugilidae	*Liza vaigiensis*	Diamond-scaled mullet
	Valamugil buchanani	Buchanan's mullet
	Valamugil seheli	Blue-tailed mullet
Myliobatidae	*Aetobatus narinari*	Eagle ray
	Myliobatidae sp.	Eagle ray
Platycephalidae	Platycephalidae sp.	Flathead
	Platycephalus indicus	Bar-tailed flathead
Plotosidae	Plotosidae sp.	Eel-tailed catfish
Polynemidae	*Eleutheronema tetradactylum*	Blue Salmon
	Polydactylus macrochir	King Salmon
Portunidae	*Scylla serrata*	Mud crab
Pristidae	*Anoxypristis cuspidata*	Slimy/Narrow sawfish
	Pristidae sp.	Sawfish
	Pristis clavata	Dwarf sawfish
	Pristis microdon	Freshwater sawfish
	Pristis zijsron	Green sawfish
Rhinobatidae	*Rhinobatos batillum*	Common Shovelnosed ray
	Rhinobatos typus	Giant Shovelnosed ray
Rhinopteridae	*Rhinoptera neglecta*	Cownose ray
Rhynchobatidae	*Rhynchobatus djiddensis*	White spotted guitarfish
Scatophagidae	*Scatophagus argus*	Spotted scat
Sciaenidae	*Nibea soldada*	Silver jewfish
	Nibea squamosa	Jewelfish
	Protonibea diacanthus	Black jew
	Sciaenidae sp.	Jewfish
Scombridae	*Scomberomorus commerson*	Spanish Mackerel
	Scomberomorus semifasciatus	Grey Mackerel
Scyliorhinidae	*Atelomycterus* sp.	Banded catshark
Scyliorhinidae	Scyliorhinidae sp.	Catshark
Serranidae	*Epinephelus coioides*	Estuary cod
Soleidae	Soleidae sp.	Soles
Sparidae	*Acanthopagrus berda*	Pikey bream
Sphyraenidae	*Sphyraena jello*	Slender barracuda
	Sphyraena sp.	Barracuda, Sea pike
Sphyrnidae	*Eusphyra blochii*	Winghead hammerhead shark
	Sphyrna mokarran	Great hammerhead shark
	Sphyrnidae sp.	Hammerhead shark
Stegastomatidae	*Stegostoma fasciatun*	Leopard shark
Tetraodontidae	Tetraodontidae sp.	Pufferfish
Toxotidae	*Toxotes chatareus*	Archerfish

3.3.3 N3 Fishery target species, length frequency

The N3 inshore fishery has two primary target species, barramundi (*Lates calcarifer*) and king salmon (*Polydactylus macrochir*). Secondary target species include blue salmon (*Eleutheronema tetradactylum*), queenfish (*Scomberoides commersonnianus*), jewel (*Nibea squamosa*) and black jew (*Protonibea diacanthus*). Fishers target aggregations of these "secondary species" when environmental and economic conditions are favourable for those species and not for the primary target species.

A component of the "offshore" N3 fishery (7 nautical mile offshore limit) primarily targets shark (*Carcharhinus* spp.) and grey mackerel *(Scomberomorus semifasciatus*) using mechanical net hauling devices. Known as net reel boats, this operation developed from the traditional hand hauled net fishery is an extremely productive technique when targeting seasonal aggregations of grey mackerel. Very little biological data have been collected for these secondary target species, and this gap was identified as a priority for investigation by the attendees at the Gulf of Carpentaria Set Net Bycatch Action workshop (see Roelofs 2003), held in Karumba under the auspices of the Gulf Inshore Fin Fishery Management Advisory Committee (Gulf MAC).

The N3 fishery is regulated under the QLD Fisheries and Regulation ACT 1994 and the GOC Finfish Management Plan 1999 where a size restriction applies to a number of commercial target species (Table 3.2). The net selectivity of the gear deployed by the fishers was observed to be very specific in the size classes it targets. Over 85% of the total catch of both the primary and secondary target species was of legal size in the period observed. In the case of barramundi and king salmon, 96% and 86% respectively of the total catch number were legal. Data could be not recorded on the fate of the non-legal size classed fish however Halliday *et al.* (2001) discuss this mortality in detail for the Gulf of Carpentaria and the East Coast of Queensland.

Table 3.2 - Regulated species observed caught in the N3 Fishery 1991 – 2001 showing size limits, % of each species under legal size, and the total number of fish captured.

Species	Barramundi	King salmon	Blue salmon	Queenfish	Jewel	Black jew
Size regulation (TL cm)	>60 & <120	>60	>40	>45	>45	>60 & <120
Non-legal	4%	14%	12%	0%	3%	10%
Legal	96%	86%	88%	100%	97%	90%
Number measured	4157	389	278	357	271	62
Total n	5382	2013	1515	1210	454	71

3.3.4 Barramundi fishery

Length frequency

Length frequency data was collected for 4157 barramundi surveyed in three regions of the Gulf. The surveyed mesh sizes ranged between 165mm to 200mm mesh. 200mm mesh was only recorded on 8 occasions out of a total of 473 net sets. The length frequency histogram for the three regions portrays the same modal distribution, centred on the 65cm to 80cm size classes. A Kolmogarov – Smirnov two sample test carried out on the three regional data sets revealed no significant difference in the modal distributions with p values of 0.165, 0.165 and 0.819 respectively (Table 3.3). The curves show a normal distribution, suggesting that fishing pressure has not skewed the population towards larger or smaller size cohorts and reflecting strongly the net selectivity characteristic of the gear deployed.

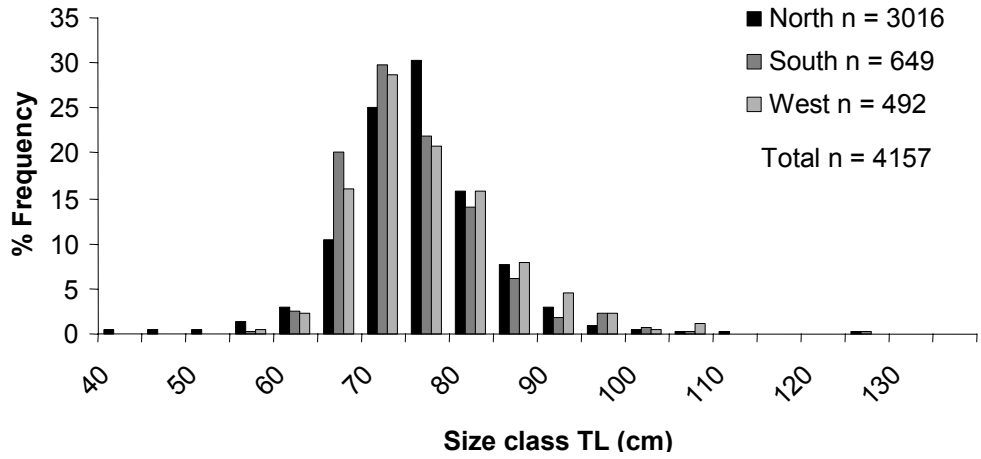


Figure 3.5 - Length frequency histograms for barramundi recorded in the three regions of the Gulf of Carpentaria from 1999 to 2001

Table 3.3 - Kolmogorov - Smirnoff test for barramundi length frequency data recorded for the three regions of the Gulf of Carpentaria 1999 - 2001

Regions	df	Chi-squared	P-value
North – South	2	3.6	0.165
North – West	2	3.6	0.165
South - West	2	0.4	0.819

Fishery Observer CPUE

The catch per unit effort for the three regions varied dramatically. Factors that can influence fisher CPUE include tidal flow and levels, water clarity, water temperature, presence of jellyfish or predators, and fisher knowledge (see Section 3.3.1). The highest CPUE was 31.25 barramundi per hour/500m net recorded in the western Gulf of Carpentaria. The southern Gulf of Carpentaria recorded a low average observed CPUE in comparison to the northern and western regions of the Gulf (Table 3.4). CPUE of barramundi in the southern Gulf along the foreshores is extremely low over the winter months. The Fishery Observer surveys undertaken in the southern Gulf, however, were predominantly with commercial fishers

targeting king salmon along the foreshore flats (in response to low Barramundi catches, see 3.1.1).

Table 3.4 highlights the significant variation that can arise in an area when using CPUE as a measure for fish abundance. The variation in the maximum and minimum values for the western Gulf is approximately 30 barramundi per hr/500m net. A thorough understanding of the fishery and the factors effecting the catching efficiency of the net need to be considered when using CPUE as an indicator of abundance of the fish.

Table 3.4 - Average CPUE (barramundi per hour/500m net) for observed set net locations for the three regions of the Gulf as surveyed by the TRAP Fisheries Observer, pooled for 3 years.

Region	n - sites	max CPUE	min CPUE	average CPUE
North	26	27.4	0.24	4.00
South	5	2.08	0.01	1.17
West	12	31.25	0.60	9.10

3.3.5 King salmon fishery

Length frequency

The king salmon fishery is essentially made up of mixed size classes as portrayed in Figure 3.5. In the southern and northern regions of the Gulf the line graph reveals a bell shaped curve dominated by the 90cm to 105cm size classes in the south, and the 75cm to 90cm size classes in the north. Further data need to be collected for the western GOC for comparison. In all three regions of the GOC it is evident that smaller size classes (fork length – 20cm to 60cm) are being captured in the fishery. King salmon of less than 65cm fork length made up only 13.9% of the observed total catch in 1999 – 2001, and were observed to be bridled by the mouth rather then entangled or meshed.

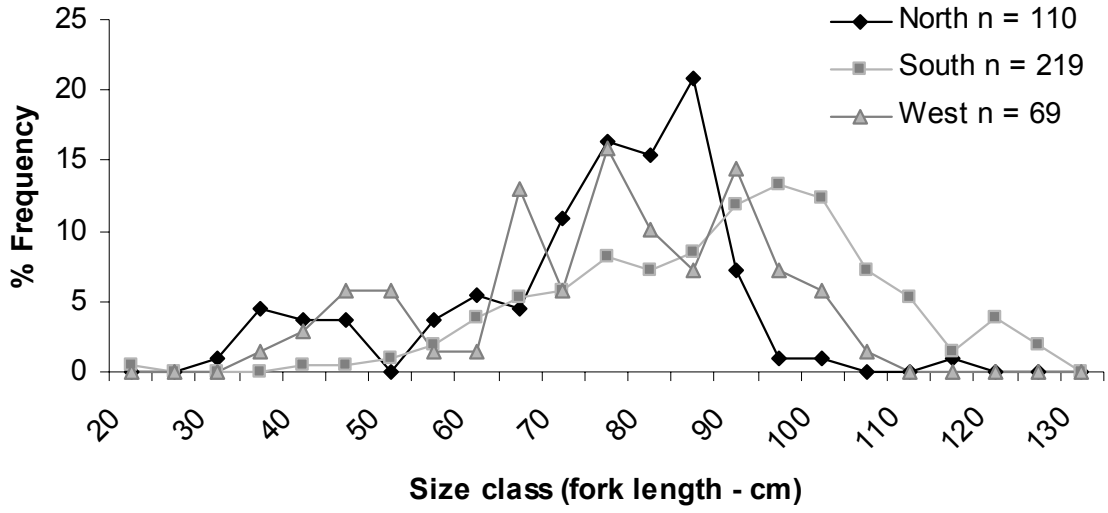


Figure 3.6 - Length frequency plots for king salmon (*Polydactylus macrochir)* recorded in the three regions of the Gulf of Carpentaria from 1999 to 2001.

3.3.6 Morphometric relationships in barramundi and king salmon

Microsoft Excel and Statistix software were used to analyse the morphological relationships of barramundi and king salmon for the Gulf of Carpentaria. Records were taken from the Gin Arm River, Albert River and Bynoe River (Figure 3.1). All of the relationships analysed were significant with an average r^2 value greater than 0.9 (see Appendix 6).

3.3.7 Hydraulic net reels

The Fishery Observer surveys were concentrated in the traditional hand hauled net fishery and only limited observations possible in the inshore net reel operations. Inshore net reel operations are conducted from modified vessels up to 7meters in length. The boat length allows the fishers to maintain the operation under a tender vessel licence and their shallow draft provides greater access to shallow waters. Only two nights fishing was recorded in the offshore N3 fishery on a net reel vessel. This is a limitation of the N3 fishery data set where, in comparison, a comprehensive data set exists for the rivers and foreshores regions. The observed catch per unit of effort of one net reel shot was calculated at 511 king salmon per hour/500m net. The average whole weight for the product was 4.2kg. This equates to approximately 650kg of fillet product per hour per 500 m of net.

The advantages of net reel fishing over hand hauling are profound. In the example provided above the water temperature was 39^{o}C and the air temperature was in excess of 35^{o}C. All fish were handled professionally, and only one fish being identified as spoilt, not being fit for processing. A professional net reel operation will have chilled brine water for the immediate cooling of product once hooked from the net and the fisher is always in attendance of the net. The net is hauled onto the drum as the fish are caught, allowing fishers to concentrate all of their effort in maintaining product quality. This is a significant advantage over traditional hand hauled netting where under the same conditions as mentioned above the fisher would likely have lost large quantities of product to heat and necrosis (muscle deterioration) due to the delay in retrieving catch from the net and getting catch to the processing table.

The N3 net reel operations have been operating on a small scale for approximately 20 years, and were previously recognised as operating in the offshore areas targeting grey mackerel and shark. Foreshore areas are now being targeted through the use of smaller vessels with shallow drafts targeting seasonal aggregations of king salmon and barramundi. This fishing technique is becoming more widely accepted especially as the demand for fresh whole fish is expanding. Net reel operations have the capacity to increase effort within the fishery without stepping outside the boundaries of the regulations. Under the current logbook system (daily effort) net reel fishing effort cannot be assessed accurately as multiple net shots can be deployed in a single day, targeting a greater geographical area and multiple species.

3.3.8 Shark fishery

Sharks, rays and chimaeras are represented by an estimated 923 – 1117 species and 55 families (Compagno and Cook 1995). They occupy niches in marine, hypersaline and freshwater habitats and are most numerous in tropical and subtropical environments (Last and Stevens 1994).

Elasmobranches are generally long lived, produce few offspring and mature later than most bony fishes (Walker 1998). This life history strategy makes them more vulnerable to overexploitation (Bonfil 1996). Elasmobranch exploitation is escalating in response to increased demand in shark products (Rose 1994), and, as a result, more international attention is being focused on shark (Bonfil 1994).

On an opportunistic basis the TRAP Fisheries Observer recorded shark and ray catch in the N3 Fishery by species, total length, and sex. A total of 33 species from 11 families was recorded. The family Carcharhinidae (whaler shark) dominated the catch (71%), with bull sharks (*Carcharhinus leucas*) and Pinkeye sharks (*Carcharhinus amboinensis*) being the most common species recorded early on in the season, during the runoff period (January, February and March) and Australian blacktip sharks (*Carcharhinus tilstoni*) later in the winter months.

A comprehensive data set on species composition of the catch exists for the N9 fishery (see Section 4). A comparison of the two species lists reveals there is an overlap in the catch composition of the two fisheries.

A total of 37 species of sharks and rays from 12 families were recorded in the N9 fishery. Like the N3 fishery the Carcharhinidae family dominated the species composition (17 species). The total catch was dominated by *Carcharhinus tilstoni/limbatus* (43%) followed by *Carcharhinus sorrah* (15%). Both of these species are regarded as highly desirable for marketing 98% and 97% being fully processed respectively.

With respect to finning within both fisheries it was observed that very little product is wasted with a total of 85% of the catch being fully processed, 6% part processed, 3% released alive and 5% discarded. 8 species, mainly made up of rays were all released alive with *Mobula eregoodootenkee* (Pigmy devilray) recording only 44% frequency of alive release. Of the 6% part processed animals *Rhynchobatus djiddensis, Eusphyra blochii* and *Sphyrna mokarran* dominated the catch. These shark are large and scavenge from the net often being entangled by their flat winged head. These animals are marketable at the Sydney fish markets as trunked product (Ian Stockton NSW District Fisheries Officer personal communication, 2002).

Table 3.5 - Chondrichthyan species list for the N3 Fishery Observer Program 1999 - 2001

FAMILY	Species	Common name	% frequency of occurrence
Carcharhinidae	*Carcharhinus amblyrhynchoides*	Graceful shark	0.74
	Carcharhinus amboinensis	Pigeye shark	3.61
	Carcharhinus brevipinna	Spinner shark	0.74
	Carcharhinus cautus	Nervous shark	0.21
	Carcharhinus fitzroyensis	Creek whaler	0.05
	Carcharhinus leucas	Bull shark	1.70
	Carcharhinus limbatus	Common black tip shark	0.21
	Carcharhinus macloti	Hardnose shark	0.05
	Carcharhinus melanopterus	Blacktip reef shark	0.11
	Carcharhinus sp.	Whaler shark	59.31
	Carcharhinus tilstoni	Australian blacktip shark	2.65
	Negaprion acutidens	Lemon shark	0.85
	Rhizoprionodon acutus	Milk shark	0.11
	Rhizoprionodon oligolinx	Grey sharpnose shark	0.16
	Rhizoprionodon taylori	Australian sharpnose shark	0.32
Ginglymostomatidae	*Nebrius ferrugineus*	Tawny shark	0.05
Hemigaleidae	*Hemigaleus microstoma*	Weasel shark	0.05
Myliobatidae	*Aetobatus narinari*	Eagle ray	0.05
	Myliobatidae sp.	Eagle ray	0.11
Pristidae	*Anoxypristis cuspidata*	Slimy\Narrow sawfish	7.00
	Pristidae sp.*	Sawfish	0.37
	Pristis clavata	Dwarf sawfish	0.69
	Pristis microdon	Freshwater sawfish	2.39
Rhinobatidae	*Rhinobatos batillum*	Common Shovelnosed ray	0.16
	Rhinobatos typus	Giant Shovelnosed ray	7.27
Rhinopteridae	*Rhinoptera neglecta*	Cownose ray	0.64
Rhynchobatidae	*Rhynchobatus djiddensis*	White spotted guitarfish	4.30
Scyliorhinidae	*Atelomycterus* sp.	Banded catshark	0.05
	Scyliorhinidae sp.	Catshark	0.05
Sphyrnidae	*Eusphyra blochii*	Winghead hammerhead shark	5.52
	Sphyrna mokarran	Great hammerhead shark	0.11
	Sphyrnidae sp.	Hammerhead shark	0.05
Stegastomatidae	*Stegostoma fasciatun*	Leopard shark	0.32

*several of these individuals were subsequently identified as *Pristis zijsron*, Green sawfish

3.3.9 Endangered or threatened species

As part of the TRAP mandate, all observations on interactions between commercial fishing operations and threatened and endangered marine megafauna were documented (see Section 4). Both programs identified the two fisheries have limited interaction with endangered or threatened species that are listed under State and Commonwealth legislation. Animals observed within the area of commercial fishing activity with significant conservation listing included Irrawaddy dolphin (*Orcaella brevirostris*) and a number of marine turtles.

Conservation listings of species encountered in the N3 Fishery and the relevant legislation are listed in Table 3.6. It should be noted that under the Queensland Conservation of Nature Act 1992, all native animals are protected, irrespective of the conservation status they possess. From the N3 Fishery, three groups of animals (sawfish, marine turtles and the saltwater crocodile) with a conservation status of threatened or endangered were encountered in 1999 - 2001.

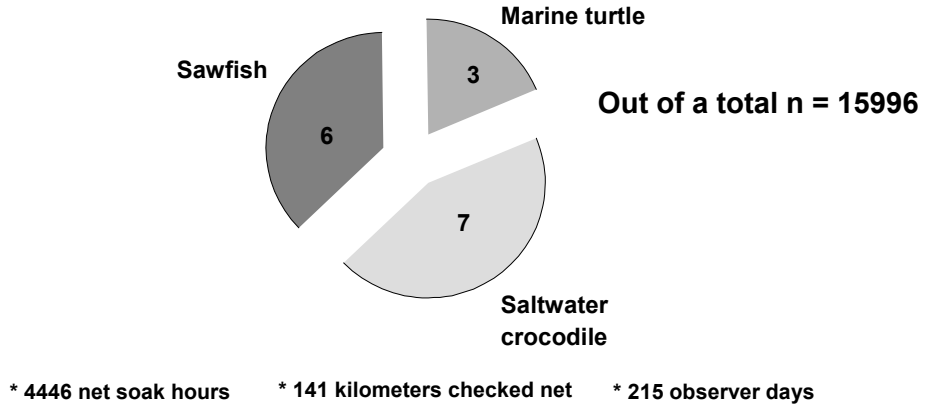


Figure 3.7 - Commonwealth and State Legislated species with a conservation status of threatened or endangered, captured within the N3 fishery (Number of animals caught of each group in centre of pie-chart segment).

All three marine turtles captured in the N3 Fishery through the Fishery Observer program 1999-2001 were released alive. This is made possible when fishers perform regular net checks and follow the procedures outlined under the Endangered Species and Awareness Course (QSIA). The species of marine turtle most commonly observed by fishers are the green turtle (*Chelonia mydas*) and the loggerhead turtle (*Caretta caretta*). In the past, fishers have actively participated in turtle tagging programs overseen by the Environmental Protection Agency (Dr. Col Limpus, QPWS, Principal Research Scientist pers comm April 2002).

The N3 Fishery Observer data reveal crocodile entanglement to be minimal however there was considerable interaction observed (Plate 3.1). From seven saltwater crocodile, *Crocodylus porosus* captures three were released alive with the largest measuring approximately 3.5m total length. All *C.*

porosus mortalities were attributed to drowning where the animal's shoulders were 'wedged' in the meshes. Juvenile saltwater crocodiles were observed to be more vulnerable to 'wedging' especially animals in the 1.2 to 1.5m size class. No interactions were observed between fishing operations and the freshwater crocodile *Crocodylus johnstoni*. The incidental capture of a saltwater crocodile is a reportable action under the Queensland Nature Conservation Act 1992.

Plate 3.1 - Crocodile attacks on fish in nets are a common occurrence in the GOC inshore set net fishery

There are five species of sawfish that overlap in habitat range with the N3 Fishery. Presently only one of these species, the freshwater sawfish (*Pristis microdon*) is currently listed as having a high conservation status (threatened – EPBC Act 1999).

The N3 Fishery Observer established that the interaction between the N3 fishery and the freshwater sawfish was limited to the wet season monsoon months when the rivers are in flood. From the evidence provided to date (Peverell 2002 in press) the species has gained a measure of protection since the GOC set net regulations in 1981 introduced a seasonal closure for barramundi (Mitchell 1982).

In an effort to further reduce the incidental capture of these animals and other species of sawfish, the Karumba branch of QSIA has adopted a 'Handling and Release Procedures Document for Sawfishes' (Peverell, 2002) (Appendix 6). The document was developed in collaboration with several N3 fishers in response to growing concern over the sustainable management of this family internationally and within the section of endangered and threatened marine species of Environment Australia.

This document has been incorporated into the GOC inshore set net fishery code of conduct (Ward 2001) and the environmental management plan for the Gulf (Ward 2003), and the fishers have been participating in a tag and release program steered by QDPI and endorsed by Environment Australia, World Wide Fund for Nature, SUNFISH and ECOFISH. Logistical support is also being supplied by Infofish Services coordinated by Bill Sawynok.

Table 3.6 - Status of GOC N3 Fishery species under various protection legislation

Species	State legislation	Commonwealth legislation	International (IUCN)
Freshwater sawfish *Pristis microdon*	N/A	Vulnerable	Critically Endangered
Dwarf sawfish *Pristis clavata*	N/A	N/A	Endangered
Green sawfish *Pristis zijsron*	N/A	N/A	Endangered
Slimy sawfish *Anoxypristis cuspidata*	N/A	N/A	Vulnerable
Saltwater crocodile *Crocodylus porosus*	Vulnerable	N/A	N/A
Green turtle *Chelonia mydas*	Vulnerable	Vulnerable	Endangered
Loggerhead turtle *Caretta caretta*	Endangered	Endangered	Endangered

Note 1. Dolphins are notifiable under Commonwealth Cetacean legislation
2. All "native animals" are protected under Nature Conservation Act 1999.

3.3.10 Recreational fishery data

The waters of the GOC support fish and crab stocks that are important to recreational fishers. A survey undertaken by Gulf Local Authorities Development Association (GLADA) in 1999 into the socio-economic trends within the Gulf tourism industry revealed the region is visited by approximately 100,000 tourists annually with 90% identifying recreational fishing as their main purpose for their visit (Kehoe, 1999). The report also identified visitors to the Normanton, Karumba and Burketown regions being equally proportioned from Queensland and interstate.

Recreational fishing in the Gulf of Carpentaria is increasing at a rapid rate as access improves and fishing locations become more widely known. Of concern is that very little information has been documented on the catch statistics and economics behind this very important sector (Helmke 1999). As recreational fishing develops further within localised areas such as Topsy Creek, south of the Mitchell River or Dina Island situated on the Staaten River, there is a greater need to monitor this impact if fish and crab stocks are to be sustainable managed. Recreational fishers travelling into these once isolated fishing locations are very well equipped; note in plate 3.2, the large freezer unit on the four wheel drive vehicle. A freezer of this size can hold up to 500kg of frozen product.

Anecdotal reports have suggested as many as one in four legal barramundi caught in the Staaten River during the peak of the tourist season (June through to September) show some form of interaction with line fishing. Reported observations include torn jaws, large lacerations, and gill and eye damage. These reports are supported by similar observations made whilst surveying the Nassau River, although no quantitative data were recorded. The TRAP Fisheries Observer obtained recreational catch data from the Nassau River and the Kirke River (Tables 3.7 and 3.8) on an opportunistic basis.

Nassau River

According to direct observation and anecdotal reports from the commercial shore based fishers taken in 1998 - 2000 the Nassau River has received constant growth in recreational pressure. This is largely attributed to a change in ownership and management of the nearby cattle grazing property, where there is a strong interest in encouraging tourism. Several advertisements promoting the station as a preferred fishing location have been published in prominent fishing magazines/papers in 2001.

There are two types of recreational fishers visiting the Nassau River; lure fishers with the sole desire to catch barramundi, and bait fishers only interested in grunter, threadfin salmon, black jew and fingermark. Most of the bait fishers are from interstate, and lack skills in the techniques required when lure fishing for barramundi.

Table 3.7 - Recreational catch data for the Nassau River, 1999 and 2000.

N° fishers	Effort (hrs)	Method	Barra	King Salmon	Mangrove Jack	Finger-mark	Barra CPUE (Legal fish/hr/fisher)
2	10	Lures	5				0.25
2	9.5	Lures	10				0.53
3	9.5	Lures	3	1	1	1	0.11
2	10	Lures	14				0.65
5	0.5	Lures					0
2	4.5	Lures	4	1		1	0.44
3	2	Lures	6				1.0
2	3.5	Lures	6				0.86
2	1.5	Lures	3				1.0
1	1.5	Lures	2				0.67
1	0.5	Lures	2				2.0
1	0.5	Bait				1	N/A
2	3	Lures	6				0.5
Average 2000							0.67
4	4.5	Lures	22				0.67
4	5.5	Lures	21				0.05
4	2.5	lures	7				0.30
4	5.5	lures	30				0.55
4	2.5	lures	6				0.10
4	8	lures	14				0.13
4	5.5	lures	13				0.23
4	2	lures	4				0.38
Average 1999							0.30

Table 3.8 - Recreational catch statistics recorded for the Kirke River 2001

Trip (n)	Effort (hrs)	No of Fishers	Catfish	Mangrove Jack	Fingermark	Flathead	King salmon	Barramundi	CPUE barra/hr/fisher	Gear type
1	2	3	0	0	0	0	0	9	1.50	Lure & Fly, braid
2	3.5	2	0	0	0	0	0	5	0.71	Lure, monofilament line
3	5.5	2	0	0	0	0	0	4	0.36	Lure, braid
4	3.5	2	0	0	0	0	0	1	0.14	Lure, braid
5	1.5	4	0	0	0	0	0	3	0.50	Lure, braid
6	1.5	2	0	0	0	0	0	3	1.00	Lure & Fly, monofilament line
7	2	2	0	0	0	0	0	15	3.75	Lure, braid
8	2	2	0	0	0	0	0	32	8.00	Lure, monofilament line
9	1.75	2	0	1	0	0	0	19	5.43	Lure, braid
10	1.75	4	0	0	0	0	0	8	1.14	Lure & Fly, braid
11	3.5	4	0	0	0	1	1	4	0.29	Lure
12	1.75	4	0	0	0	0	0	17	2.43	Lure, braid
13	3	2	0	0	0	0	0	25	4.17	Lure
14	4.5	2	0	0	0	0	0	11	1.22	Lure
15	1.75	2	0	0	0	0	0	1	0.29	Lure
16	2.5	2	0	0	0	0	0	5	1.00	Lure
17	1.25	4	0	1	1	0	0	7	1.40	Lure
18	3	2	5	0	0	0	0	14	2.33	Lure
								Average	1.98	

The results presented in Table 3.7 were provided by the same fishing party whilst fishing in September 1999 and 2000. The average legal barramundi catch per unit of effort was higher in the second year (2000 – 0.67 fish/hr/fisher), than in 1999 (0.30 fish/hr/fisher). It was suggested by the fishers the reason for the improved catch rates was because they had a better understanding of the system and what fishing techniques would work best the second time round.

The numbers of legal barramundi caught were greater in 2000 with 90% of the total barramundi catch being legal in comparison to 1999 where 38% of the catch was legal. The recreational fishers advised that they altered their gear and fishing technique in 2000, and directed a majority of their fishing effort to around the rock walls along the river bank which held larger fish along with deploying larger and deeper diving lures. This is a clear example of how technology and knowledge of an area can bring more specific pressure being placed on a resource.

Other species recorded during the survey included fingermark (*Lutjanus johni*), queenfish (*Scomberoides* sp.) and estuary cod (*Epinephelus* sp.).

Kirke River

Recreational catch composition and fishing effort was recorded for a group of experienced fishers during September 2001. The Kirke River is recognised as being a very productive fishery area and differing from other river systems within the GOC (Sheppard *et al*. 2001).

Site specific data was not recorded, however the fishers concentrated their efforts upstream of the Kirke lake system and at the river mouth. The dominant method employed by the fishers was lure casting and trolling (Table 3.8). Barramundi was also captured on fly fishing apparatus. A total of eighteen fishing trips were recorded with fishers concentrating their efforts in the early morning and late afternoon.

All fishing trips recorded barramundi with the highest barramundi catch per unit of effort being 8.00 fish/hr/fisher and the lowest 0.14 fish/hr/fisher. The average barramundi catch per unit of effort was 1.98 barramundi/hr/fisher. No length measurements were recorded. Fishery Observer diary records of conversations made with the recreational fishing party suggest the catch was predominantly of undersized fish in the 45cm to 60cm total length size classes.

Other species recorded included fingermark, mangrove jack, catfish, king salmon and flathead. This species composition is consistent with that recorded in the commercial net fishery (Table 3.1 and 3.2), see also Sheppard *et al* (2001).

3.3.11 Summary Gulf recreational fishery

On both survey occasions, in the Nassau and Kirke, barramundi was the preferred angler target species and from a total of 138.75 recreational hours a total number of 386 barramundi was recorded. The average barramundi catch per unit of effort for the combined trip data was 1.27 fish/hr/fisher. The barramundi catch rates recorded in the TRAP Fishery Observer program are high compared to catches of 0.1 – 0.15 fish/hr/fisher in Trinity Inlet near Cairns (Helmke *et al*. 2000), 0.33 fish/hr/fisher in the Bohle River near Townsville (Lunow and Garrett, in press) and 0.18 fish/hr/fisher in the Norman River, Gulf of Carpentaria (Helmke, *et al. 2*000) for the same season.

Russell and Hales (1990) calculated that the overall recreational CPUE for barramundi in the freshwater reaches of Princess Charlotte Bay was 0.09. These authors commented that the CPUE was greater in the freshwater reaches of the Bay compared to the estuarine systems. This was attributed to an increase in species diversity in estuarine systems and competition with commercial fishery activity. Of interest, the overall recreational barramundi CPUE of 1.27 recorded in the N3 program is 14 times greater than that for Princess Charlotte Bay.

The Princess Charlotte Bay survey of Russell and Hales (1990) was calculated over a broader range of fishing abilities than the brief N3 survey, and took into consideration temporal and seasonal variation. Even so, the recreational barramundi CPUE in the Gulf is likely to be higher than that for east-coast drainage systems. This is based on the data supplied from INF0 FISH services where the CPUE for barramundi in the Weipa region was higher than that for the remainder of the State (Figure 3.8).

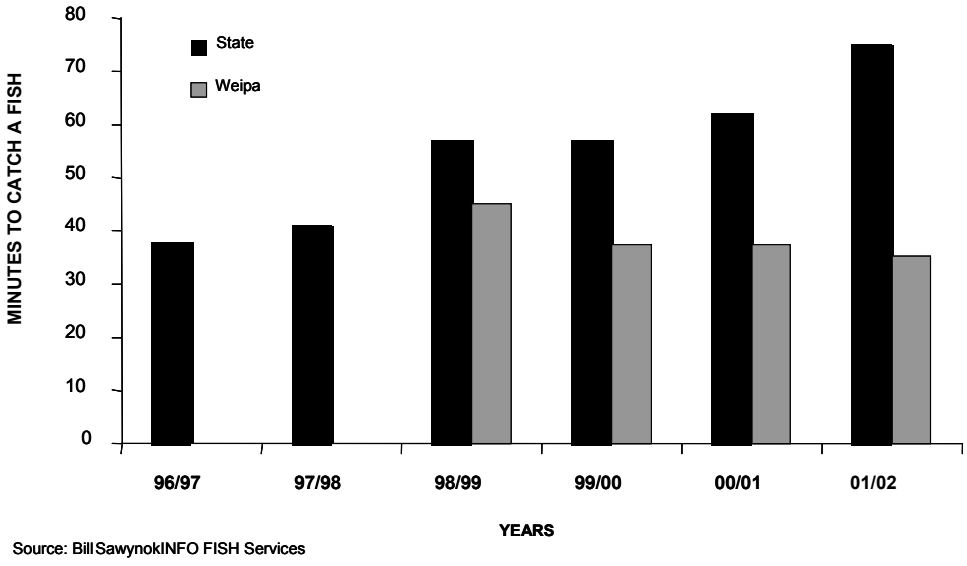


Figure 3.8 - CPUE comparing the Weipa region to the remainder of the State

The TRAP project team has not been able to get a true indication on the recreational take of barramundi or other species in the GOC. This is obviously an area for future work.

Plate 3.2 - Recreational fishing is a favourite activity for Gulf tourists, note the size of the freezer unit, Topsy Creek 2001.

3.4 Ancillary studies

A number of additional studies were possible because the TRAP Fishery Observer was present in the fishery and/or that a small amount of extra effort and resource could value-add to the basic program. Although these studies were not covered in the original proposal, they cost the FRDC no extra funding and optimised the value to the stakeholders.

3.4.1 Mud crab fishery

A discussion paper was released in October 1999 on the first stage in the development of a Queensland mud crab fishery management plan. Stock assessment of this valuable commercial and recreational species will be essential in formulating and testing management strategies for this plan.

Two mud crab biomass assessment projects have been conducted in the Weipa region in recent years (Gould *et al.* 2001, and Helmke *et al.* 1998). In 2000, a major Qld/NT initiative on estimating abundance of Gulf mud crabs commenced with FRDC 2000/142 the "Methods for monitoring abundance and habitat for northern Australian mud crab *Scylla serrata*" funded by FRDC for 3 years.

As part of TRAP a small-scale pilot exercise on mud crabs was undertaken as a precursor for the FRDC mud crab project. The TRAP N3 Fishery Observer undertook a mud crab depletion survey along a 1.2km stretch of uniform bank in Corduroy creek, one of the major tributaries leading into the Nassau River, during October 2000. The bank of the creek was clearly defined and was well supported by a 5m riparian band of mangroves. Behind the mangroves was an extensive salt sand/mud pan. Corduroy creek had been potted heavily in the lead up to the survey, by the resident commercial fishers who had reported excellent catch rates in the system earlier in the season. The survey was conducted over a 5 day period using 40 crab pots and fresh fish frames for bait. The pots were pulled twice a day with all crabs being tagged, sexed and measured (to the nearest 0.5 mm carapace width (CW)) before being returned to the water. Only the ratch rates of untagged crabs from subsequent days of the survey were counted in the analysis; i.e. the tagged crabs were the equivalent of 'depleted' crabs. The crab pots were spaced every 30m. No crab pots drifted outside the study site, and only two incidences were recorded of pots dragging, caused by drifting logs. Reduced tidal flow over the neap tides also assisted in reducing the effects of pot drifting during the survey.

Mud crab sex ratio

The sex ratio of mud crabs recorded in Corduroy creek in the survey period, was dominated by the male juvenile and sub-adult size classes (Figure **3.9**). The size classes greater than 15cm CW showed a distinct change in the sex ratio, being relatively even in distribution. Heavy commercial crabbing earlier in the season is most likely the cause of this distinct shift in the crab population's sex ratio above legal taking size.

Mud crab size frequency

The size frequency information for both male and female mud crabs showed a bi-modal size distribution (Figure 3.9). This characteristic was more distinct in the female size frequency data, with the two dominant size classes being 11cm and 14cm CW respectively. Lunow and Garrett (1999b) and Helmke *et al*. (1998) reported similar size class distributions in mud crab populations of other north Queensland river systems. It is thought that this bi-modality could be a result of female crabs of the spawning size class >12cm (Hill 1982) being under represented at this time of the year due to off shore spawning migration. The time of the survey corresponds with this migration, as female mud crabs spawn during the later months of winter - early spring (Tracy Hay, NT fisheries, pers com).

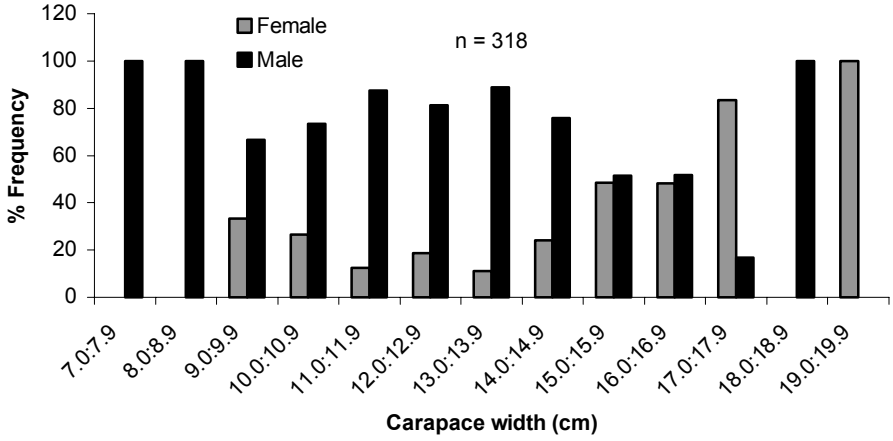


Figure 3.9 - Size and sex ratio of Mud Crabs, *S. serrata*, Corduroy Creek off the Nassau River, October 2000

Pot selectivity could also have an effect on the sex and size class distribution of mud crabs represented in the survey. Juvenile to sub-adult male mud crabs and female crabs can be expected to dominate the catch statistics in an area heavily potted. Territorial and more aggressive behaviour displayed by male mud crabs should bias against the catch rate of female mud crabs of similar size class. Female mud crabs become more abundant in the larger size classes where the sex ratio clearly becomes more evenly distributed; i.e. when legal male crabs are removed by commercial and recreational potting.

For mud crabs tagged during the survey, the recapture data was dominated by the male size classes 10cm to 14cm CW (Figure 3.9). This was expected as 66% of the tagged crabs were from these size classes. This finding offers further support for the behavioural traits of male sub-adult crabs being more aggressive and dominant in comparison to female crabs of the same size class. A similar situation was observed in Northern Territory and interpreted by Prof Carl Walters (1996) as a fishery nearing full exploitation. Walters noted that because of the rapid growth of smaller crabs these could replenish legal-sized crabs as they were harvested. Therefore it is possible to harvest the legal-sized component of a crab

population, estimated at any one time in the season, without crashing the fishery. Walters stated that for the Northern Territory; "The mud crab fishery probably takes a high proportion 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 past seasons" (Walters 1996, Executive summary).

Mud crab CPUE

The average catch per unit of effort (CPUE – crabs per pot lift) for untagged mud crabs was 1.21 crabs per pot lift with a legal CPUE of 0.08 crabs per pot lift. The highest CPUE for both legal and total catch was recorded on the first day (Table 3.9).

Table 3.9 - Mud crab survey results for the Corduroy Creek off the Nassau River, October 2000

Day	Pot lifts	Cleanskin	Legal	Recapture	CPUE (crabs/pot lift)	Legal CPUE (crabs/pot lift)	Total Crabs
1	80	144	14	21	1.8	0.18	165
2	80	72	4	91	0.9	0.05	163
3	80	71	2	93	0.89	0.025	164
4	80	99	6	74	1.24	0.075	173

Note: cleanskin refers to untagged crabs

Mud crab population estimate

The population estimate for Corduroy creek, during the survey period, using the Maximum likelihood/Bayes procedure (Carl Walters, UBC, fisheries centre, pers. comm.) for combining CPUE data on unmarked crabs with mark recapture data in depletion experiments was 421 crabs. This estimate had a maximum likelihood probability of 82%. The legal mud crab abundance using the same method was estimated at 33 crabs, 8% of the total population.

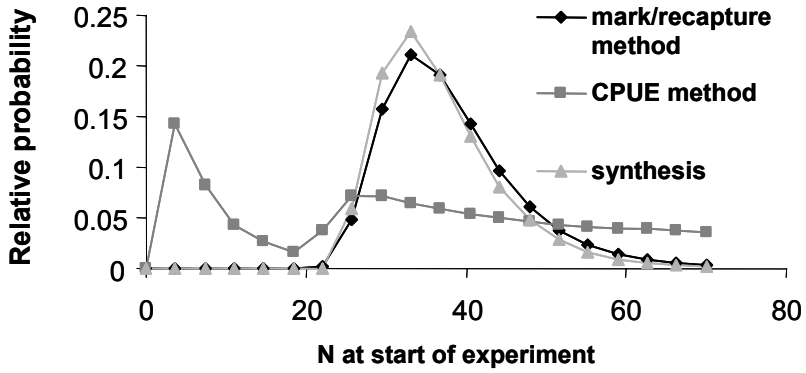


Figure 3.10 - Estimate of the total number of mud crabs *S. serrata* in Corduroy Creek off the Nassau River, using both CPUE of unmarked crabs (probability CPUE) and depletion (probability mark) methods (Carl Walters, UBC, Fisheries Centre, pers com)

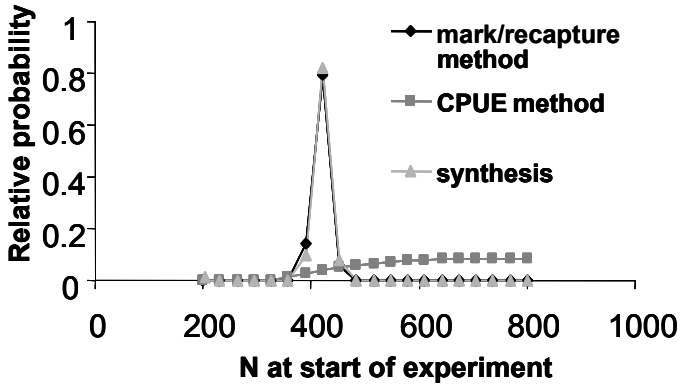


Figure 3.11 - Estimate of the number of legal mud crabs, *S. serrata* in Corduroy Creek off the Nassau River, using both CPUE of unmarked crabs (probability CPUE) and depletion (probability mark) methods (Carl Walters, UBC, Fisheries Centre, pers com)

3.4.2 Acoustic net alarms to reduce interactions with protected wildlife

The acoustic alarms or "pingers" as they are more commonly referred to which were used in this trial are of low frequency (3 kH) pulsating every second. The alarms are of a frequency that can be heard by dugong and cetaceans warning them of the presence of an underwater obstruction. (Geoff McPherson, Northern Fisheries Centre, pers. comm.)

The use of pingers within the N3 fishery was feasible with the strong support and interest shown by the commercial fishers. The Gulf Fishery Management Plan 1999 recommends the reduction in interactions with protected wildlife species, and EA accreditation under the EPBC Act also requires the use of bycatch reduction techniques.

During the study pingers were placed approximately every fifty metres of net and hung from the head rope. The purpose of these pingers is to alert

cetaceans and dugong to the presence of the set nets, they are not intended to be a deterrent. During the 1999-2001 survey operations, the Fishery Observer in the N3 fishery sighted no dugongs. Dolphins were sighted although no captures were recorded.

In 2001 acoustic alarms (pingers) were placed on the foreshore net sets of one endorsement holder for a period of six days totalling fifty fishing hours. There was no change in the species composition between the pinger nets (Table 3.10) and non-pinger nets. A total of 21 species from 18 families were recorded with the most dominant catch being barramundi (44% of catch numbers). Dolphins were observed surfacing in the mouth of the river approximately two hundred metres from one net. There was a noticeable increase of 54% in the catch rate of barramundi whilst the pingers were being trialed. This may have been more to do with the location of the nets and other external factors such as environment and fishing gear rather than the pingers themselves.

Table 3.10 - Species list for western GOC set nets using acoustic "pinger" alarms 2001

FAMILY	*Species*	Common name
Ariidae	*Ariidae* sp.	Catfish
Carangidae	*Scomberoides commersonnianus*	Queenfish
	Parastromateus niger	Black pomfret
Carcharhinidae	*Carcharhinus* sp.	Whaler shark
	Carcharhinus amboinensis	Pigeye shark
Centropomidae	*Lates calcarifer*	Barramundi
Dasyatidae	*Dasyatidae* sp.	Stingra
Haemulidae	*Pomadasys kaakan*	Large-banded / Golden grunter
Lobotidae	*Lobotes surinamensis*	Jumping
Lutjanidae	*Lutjanus johni*	Fingermark
Mugilida	*Liza vaigiensis*	Diamond-scaled mullet
Polynemidae	*Polydactylus sheridani*	King
	Eleutheronema tetradactylum	Blue
Portunidae	*Scylla serrata*	Mud crab
Pristidae	*Pristis zijsron*	Green sawfish
Rhinobatidae	*Rhinobatos typus*	Giant Shovelnosed ray
Rhynchobatidae	*Rhynchobatus djiddensis*	White spotted guitarfish
Scatophagidae	*Scatophagus argus*	Spotted
Sciaenidae	*Nibea squamosa*	Jewelfish
Serranidae	*Epinephelus coioides*	Estuary cod
Sphyraenidae	*Sphyraena* sp.	Barracuda, Sea pike

3.4.3 Mortality of Target species in gillnets

Processed product has to be of a high standard to be accepted by the wholesaler, an important issue if top prices and successful markets are to be secured. Data were collected on the mortality of fishes meshed in the nets during net robs conducted over one trip in the N3 fishery. Species were identified and their condition in the net was categorised into alive, dead or unknown status. “Unknown” was only used when the Fishery Observer was unable to collect the information directly because there was too many fish

to handle or the Fishery Observer was attending other net robs. The status of 1214 specimens was recorded. Net mortality was kept to a minimum, with a majority of specimens pulled from the net alive (58%), making them eligible for the whole fish trade (Table 3.11). Net checks were conducted on a regular basis, approximately every 6 to 12 hours. It is possible to extend the soaktimes of the nets during winter when the water temperatures are below 26^{o}C. During the summer months shorter soaktimes have been observed; every 4 hours.

It was observed that fish captured in gill nets are either entangled or meshed. Barramundi, *Lates calcarifer*, recorded the most significant survival percentage at 80%, followed by *Pomadasys kaakan* (grunter) at 56% (Table 3.11). The mortality of barramundi 9% was due to net entanglement where meshes bind the fish's operculum and cannot be opened to enable water flow through the gills. The high percentage of blue salmon mortality is difficult to understand as only one to two net meshes within the fishes mouth 'bridle' most of these fish. Being meshed in the mouth might restrict the respiratory functioning of the gills causing death. Mortality may be a result of the species being more susceptible to physiological (eg. capture stress) or environmental factors (eg. water temperature).

Table 3.11 - Set net mortality for all species captured western Gulf of Carpentaria 2001

Species	%Alive	%Dead	%Unsure	Total
Ariidae sp.	65	9	26	23
Carcharhinus amboinensis	0	0	100	1
Carcharhinus sp.	37	0	63	19
Dasyatidae sp.	0	0	100	1
Eleutheronema tetradactylum	10	30	60	108
Epinephelus coioides	33	0	67	3
Lates calcarifer	80	9	11	564
Leptobrama muelleri	0	100	0	2
Liza vaigiensis	33	0	67	3
Lobotes surinamensis	0	0	100	1
Lutjanus johni	0	0	100	1
Nematalosa sp.	0	0	100	4
Nibea squamosa	50	17	33	12
Parastromateus niger	25	25	50	4
Plotosidae sp.	0	100	0	1
Polydactylus sheridani	39	30	30	227
Pomadasys kaakan	56	7	37	112
Pristis zijsron	50	50	0	6
Protonibea diacanthus	0	80	20	5
Rhinobatos typus	50	0	50	2
Rhynchobatus djiddensis	100	0	0	1
Scatophagus argus	91	9	0	22
Scomberoides commersonnianus	25	10	64	67
Scylla serrata	100	0	0	24
Sphyraena sp.	0	0	100	1
Total	58	15	26	1214

3.5 Benefits of Fishery Observer program to stakeholders

3.5.1 Bycatch review

The Gulf of Carpentaria net fishery bycatch action plan workshop was held in Karumba on the 20th and 21st April 2002. The workshop was represented by all industry stakeholders including commercial fishing, conservation, recreational fishing, indigenous, industry liaison (SEANET, QDPI net Fishery Observer programs) and Resource Management (Environment Protection Agency, QDPI Senior Resource Manager). The bycatch action plan was developed in response to confirmed cetacean mortalities in the N9 fishery and the possibility this fishery was a key threatening process to the long-term viability of protected marine megafauna. The workshop was established as part of the consultation phase in developing management strategies designed to further monitor and minimise bycatch mortalities within the set net fisheries of the Gulf.

The TRAP project through the N3 Fishery Observer program and management role of the N9 Fishery Observer program was able to provide significant contributions to the discussions of the proposed actions by Environment Australia and Queensland Fisheries Service. The data presented are documented in Section 2 (N3 fishery catch composition) and 3 (N9 fishery catch composition). The data provided in Fishery Observer programs is "real time" and gives an accurate account of the operations within the fishery. Some 38 proposed actions were debated and a number of actions have already being implemented or are in the process of being implemented. Many of the proposed actions were outside the scope of the workshop to implement, and since have been developed by the Gulf Management Advisory Committee. [The Draft Bycatch Action Plan has subsequently been published as an appendix in the Ecological Assessment: Gulf of Carpentaria Inshore Finfish Fishery, Roelofs 2003).

3.5.2 Client Services Award

The N3 and N9 Fisheries Observer programs have been fundamental components of successful completion of the TRAP project objectives. Professional relationships have been established between project staff and commercial fishers within both fisheries. The true success of this project was evaluated when the Queensland Seafood Industry Association Karumba Branch nominated the TRAP program for a QDPI Client Services Award in 2001. The client service award was won on merit in competition to other service delivery programs within QDPI. The Department's Queensland Fisheries Service identified the advantages of the Fishery Observer program as a management tool, and have adopted this approach as part of its long term monitoring program of barramundi and Spanish mackerel stocks in the Gulf of Carpentaria and along the East Coast of Queensland. The TRAP program has been instrumental in showcasing the concept of adaptive management in fisheries where "real time" information can be documented independently outside the scope of the commercial logbook program, as in the case of the reporting of protected marine megafauna.

3.5.3 Value adding to commercial catch

Unfortunately, barramundi fishers have not seen any significant rise in the price of their frozen fillet product for several years. With Australia's free trade policy Gulf fishers compete with what they believe to be inferior imported product such as nile perch (*Lates niloticus*) as well with other Australian seafood products. Because of this issue, some Gulf fishers are now processing and selling whole fish rather than the traditional trays of fillets. With barramundi, this technique involves the fish found alive in the nets being brain spiked (ike jime), bled by cutting a gill, having their stomachs removed, and then the whole fish placed in brine before being packed in ice (Plate 3.2) then transported rapidly to East Coast and interstate markets via a nearby port.

Within the N3 fishery, significant investment has been outlaid by a number of fishers to enhance the quality and quantity of fresh fish being marketed out of the Gulf. Mr. Lew Williams, Senior Fisheries Economist for QDPI, gave an important seminar on the state of the fishing industries in terms of trade at the 2000 general annual meeting of the GOCCFA Inc. The "take home message" from Mr Williams' seminar was that fishers are having to work harder and longer these days for the same financial returns, and the operating costs continually increase at a higher rate than the price of their product.

It is beneficial for some larger operators to switch primarily from frozen fillet to gutted whole fish, especially for low fillet ratio species such as Queenfish. The financial returns to the fisher are greater and it gives the wholesalers marketing the fish an edge over imported frozen product. A whole gutted barramundi is worth more than the same fish royal filleted (i.e. belly flap not included), based on a market value of $11.50kg for fillet and $7.00kg for whole fish in 2001. Therefore a minimum legal sized barramundi (TL = 60cm, average whole weight = 2.4kg) is worth an extra $4.40 and a maximum sized barramundi (TL = 120cm, average weight = 18.1kg) is worth an extra $35.10. This is calculated on the observed fillet ratio of 42%. The less the fillet-to-whole weight conversion ratio is, the greater the trade off is between fresh fish and fillet marketing.

Marketing whole fish also gives the fishers the opportunity to value add non-target species, which might otherwise be discarded as byproduct such as Queenfish (*Scomberoides commersonniaus*), Shark, Grunter (*Pomadasys kaakan*) and Black Pomfret (*Parastromateus niger*). This may encourage the fishers to continue net fishing for longer during the season as opposed to diversifying into other enterprises such as the crab or line fishery when the barramundi fishing slows down during winter. Another advantage to fishers of the fresh fish market is the short turnaround in payment because the fresh product is sold immediately whereas frozen fillet product can be held for market for months at a time.

Plate 3.3 : Two essential stages in the wild caught fresh fish production;
1 - packing of product into 500kg ice bins ready for transport and
2 - the fast transport of product to port

3.5.4 Protected wildlife species

It is evident that the N3 fishery have an interaction, albeit limited, with marine mega-fauna protected under the Commonwealth EPBC Act and Queensland Conservation of Nature Act 1992. These animals include marine turtles, freshwater sawfish (*Pristis microdon*), Saltwater crocodile (*Crocodylus porosus*), Irrawaddy dolphin (*Orcaella brevirostris*) and potentially Dugong (*Dugong dugong*). The species of marine turtle most commonly observed by fishers are the Green turtle (*Chelonia mydas*) and the Loggerhead turtle (*Caretta caretta*).

The incidental capture of protected species is a reportable offence. A number of issues pertaining to the responsibility and procedure for the reporting of such interactions by N3 fishers is currently being reviewed under the GOC Bycatch Action Plan. The TRAP Fishery Observer program provided documented catch composition and frequency of occurrence information during the consultation phase for this plan. During this process, the success of the Fishery Observer program was clearly demonstrated and it is highly recommended that such a program continue if accurate and timely catch data on protected species is to be recorded in the future.

3.5.5 Contributions to Fishery Management and other management orientated programs

The TRAP Fishery Observer program has demonstrated positive applications as a management tool for both Queensland Fisheries Service and fishery scientists. The project has provided significant and timely contributions to the ongoing management of the N3 and N9 fisheries. This is reflected in the Department of Primary Industries client services award the project received at the end of 2001. The project has also provided valuable logistical and technical support for other projects and initiatives within the GOC, which will further benefit industry and management alike. These include;

1. QFS Barramundi Long Term Monitoring Program – the concept of utilising Fishery Observers as part of the QFS Long Term Monitoring

program was based on the success of the TRAP Fishery Observer program.

2. GOC Inshore Finfish Code of Conduct – the TRAP project team assisted in the formation of this document and Environmental Management System. [Both Gary and Claudine Ward, prominent commercial fishers in the Gulf and collaborators with the TRAP program, were awarded National Fisherman of the Year 2002 and Rural Woman of the Year 2003 respectively, based on their contributions to environmental sustainability in the Gulf fishery].

3. Value Adding through the development of fresh fish trade – addressing bycatch issues within the fishery was one of the key elements requiring attention as set out under the GOC inshore finfish management plan. The fishery is multi species, and increasing the value of non-target species through the fresh fish trade allowed for low value species to become economically viable to target. The Fishery Observer program aided in the early development of this diversification through market knowledge sharing and extension service delivery.

4. FRDC 2001/077: Sustainability of Northern Sharks and Rays Phase I – the Fishery Observer program provided valuable species composition and industry knowledge to develop and drive this successfully funded national project. Of particular importance is the recognition the project received for its identification and need for future research into the life history of sawfish.

5. FRDC 2000/142: Methods for monitoring abundance and habitat for northern Australian mud crab *Scylla serrata* –technical knowledge on the limitations of the proposed sampling regime were established through a pilot survey undertaken by the Fishery Observer.

6. QFS N9 Fishery Observer Program – the concept of a Fisheries Observer to monitor the N9 fishery was incorporated into the 1999 Gulf Inshore Finfish Management Plan, and was based on the TRAP I pilot N3 Fishery Observer program.

7. Evaluation of acoustic alarms – validation of the field trial data could only be made possible through the cooperation of the N3 Fishery Observer program. The data and observations made by the Fishery Observers aided in the design and successful transition of the program into the N3 and N9 fisheries.

8. NHT Freshwater Elasmobranches (Thorburn *et al.* 2003) - the industry contacts and field expertise of the TRAP Fishery Observer facilitated the remote area sampling carried out by this joint CSIRO/DPI&F/NT/WA study

9. NOO Key species status report (Anon, 2004) – Data collected and the experience gained by the TRAP Fishery Observer was utilised in the chapters on Shark, Sawfish, Mud crab, Mackerel and Barramundi.

10. Northern Australia's Operational Plan for the Sustainable Use of Shark resources (2004) – the Queensland component of the plan was based on the species composition and fishery data collected by the TRAP phase I and II.

11. Cornerstone for commonwealth DEH ecological assessment of GOC Inshore Fishery (Roloefs, 2003)

12. Sustainability assessments for target and bycatch sharks and rays (Stobustski *et al*., in prep) in GOC and East Coast (Gribble et al. 2004a and b) - possible only due to the TRAP Fishery Observer identification of species being captured in the shark fishery.

13. Release procedures for sawfish developed and workshops for industry (see Appendix 6)

3.6 References (Section 3)

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Section 4. Technical report of TRAP Phase II, N9 observer program

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4.1 Introduction

The TRAP II project, fisheries observer program, documented the catch and bycatch from commercial N9 Fishers in the Gulf of Carpenteria (GOC). This report provides summarised information collected from observed vessels in 2000, 2001, and 2002. Observer trips were conducted at various times during each season. Trips encompassed all areas within the N9 Fishery area (total Fishery area 40,600km^2, Figure 4.1). In addition to the N9 observer surveys, an opportunity arose to conduct an observer survey in QFJA waters after the N9 Fishery closed. The information collated from that cruise is presented in a separate report.

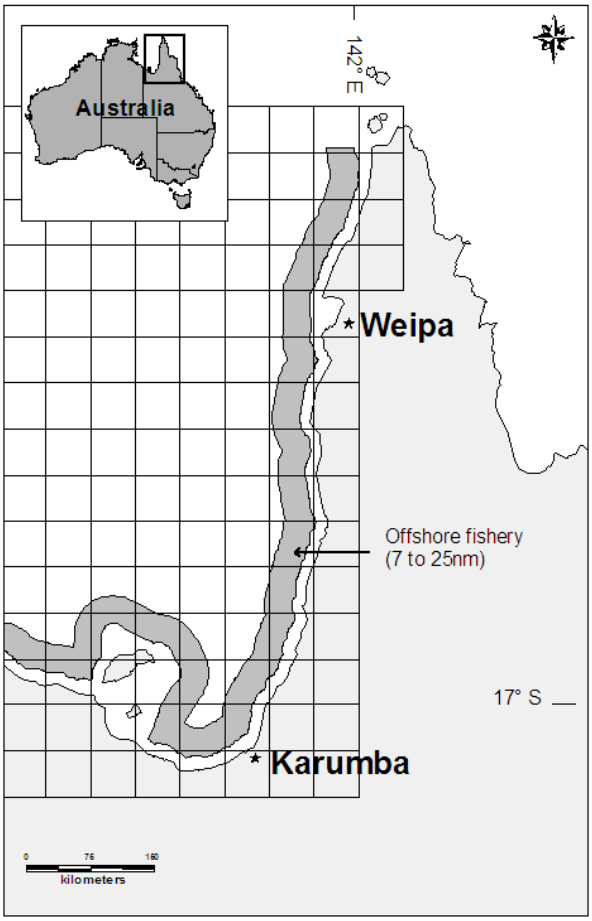


Figure 4.1 - Locality map of the Gulf of Carpentaria and Cape York Peninsula showing the N9 fishery areas and major towns.

4.2 Collaborative work

Under the umbrella of the TRAP N9 observer program a number of ancillary research projects were made possible, or given that the observer data was available additional analysis was possible. The major ancillary collaborative project were:

- SUSTAINABLITY INDEX - The N9 observer information has been utilised for a relative sustainability risk index for shark in the Gulf of Carpentaria.
- ACOUSTIC DEVICES - During the 2002 fishing season trials were conducted using Lien (Cairns) 3 kHz and an American style acoustic warning device, '10 kHz AirMar Pingers' for the Dolphin Bycatch Mitigation experiments (see Section 4.8.1).
- SAWFISH - During the season, information on sawfish (Pristidae) was collected to assist in the collaborative FRDC project. The sawfish captured in the N9 Fishery was examined due to its international conservation status (ICUN, 2002 red listed as endangered), however the narrow sawfish is not listed on the *EPBC* species list. From the 45 specimens of narrow sawfish (*Anoxprisits cuspidata*) captured, 28 specimens were dissected, examined and samples taken for genetic profiling and age determination, and 12 specimens were tagged and released. The remaining 5 specimens were not sampled due to communication breakdowns during processing times. The data from the N9 observer program will assist in the collation of life history and abundance data on Gulf sawfish, and in managing this resource. The FRDC Project will be completed in 2005.
- NET BUOYS - During observer operations, some fishers experimented with various buoys sizes to examine overall net buoyancy. Some of the traditionally used styrene buoys (300mm diameter, buoyancy rating of 14kg) were replaced with Scanmarin inflatable buoys (810mm diameter, buoyancy rating of 270kg), usually every fourth buoy. This increased the fishing efficiency of the net by distributing the mesh evenly throughout the water column at all times. With traditional styrene buoys, the net tended to collapse in sections once laden down with fish specimens, especially large shark species. The more time the net was on the bottom, the higher the chance of hooking-up on the sea floor and capturing unwanted benthic bycatch species. Thus the use of larger buoys resulted in a win-win situation increasing fishing efficiency and potentially reducing net maintenance, and benthic habitat and bycatch interactions. This practise is beginning to be adopted by most fishers.

4.3 Historical Gulf Catch and CPUE

A Commonwealth / N3 endorsement began targeting shark with power-assisted devices (hydraulic net reels) in the early 1980's, but these devices was not accepted by all Gulf fishers. The full potential of these devices began to be realised in the early 1990's; initially targeting sharks more than three nautical miles offshore. During these activities the potential of thee grey mackerel stock was discovered and exploitation expanded by the early to mid 1990's. Once the ready availability of grey mackerel was realised, the popularity of the power-assisted devices rose along with the targeting of grey mackerel, especially since the mid to late 1990's (Figure 4.2 and 4.3).

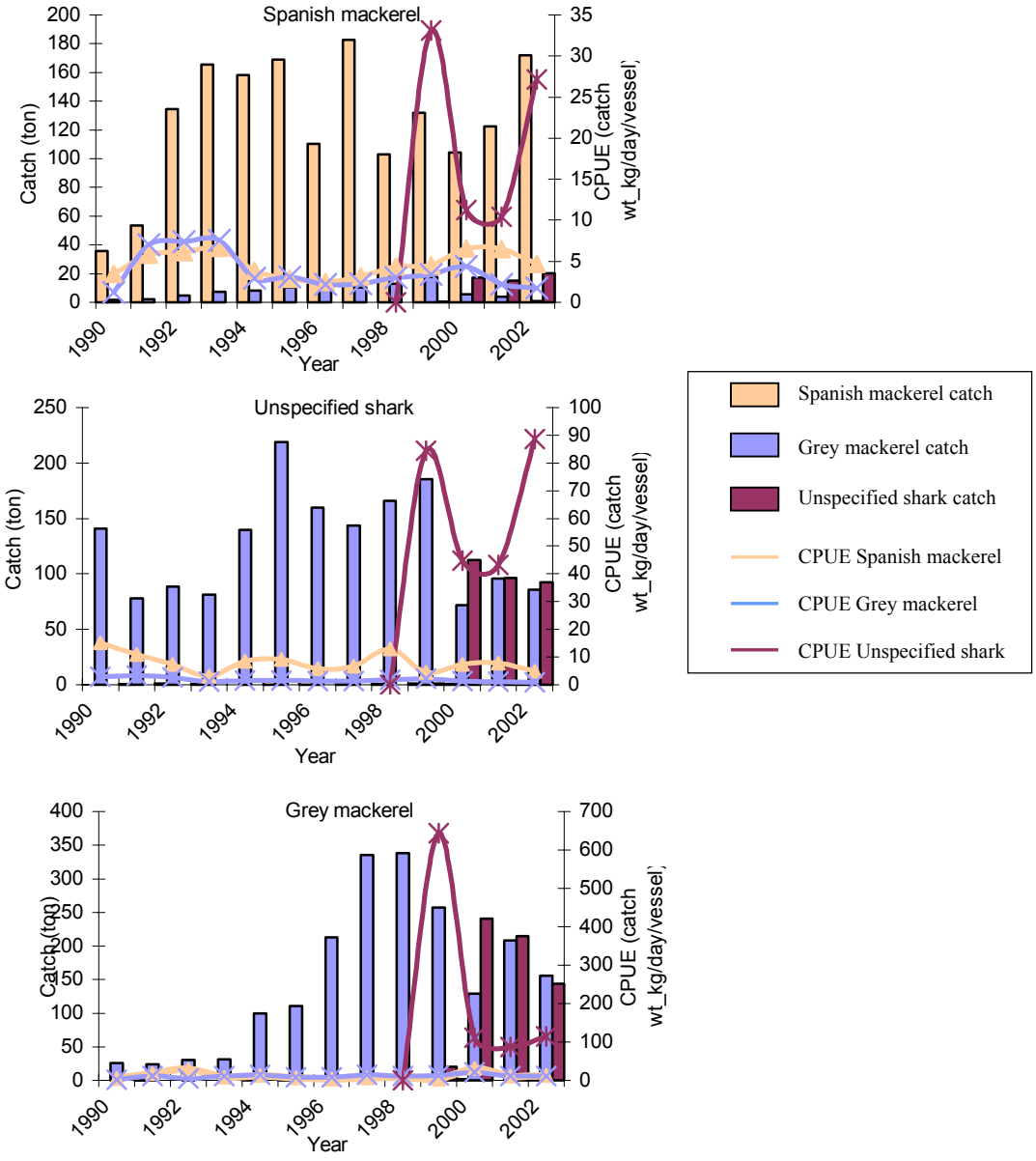


Figure 4.2 - Annual Catch and CPUE of Spanish mackerel, grey mackerel, and sharks in Queensland (CFISH)

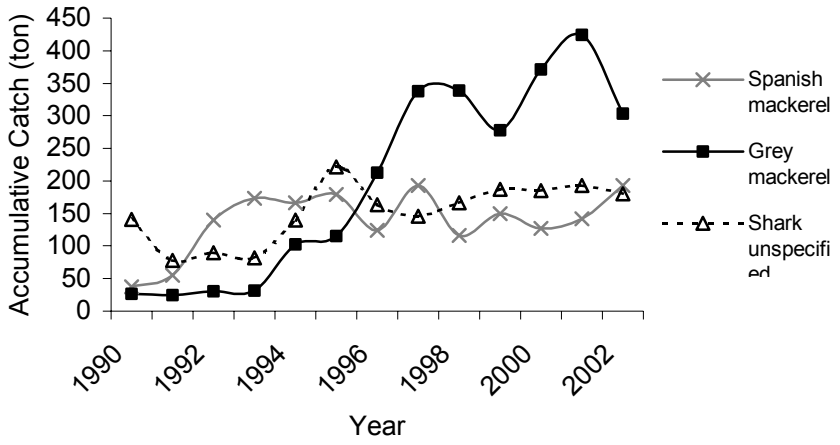


Figure 4.3 - Accumulative Annual Catches for the Gulf Fisheries

Historical CFISH database records from the Gulf annual commercial grey mackerel gillnet catch indicates a huge increase in landings from 1994 onwards (Figure 4.2 and 4.3). The 2002 Gulf annual catch was over 300t and GVP of $1.81m, while the average for 2000 to 2002 was 365ton/yr and GVP of $2.2m/yr (CFISH). The N9 Fishery contributed an average of ~54% of the annual grey mackerel catch for the state over the last three years (~45%/yr was contributed by N3). The total annual tonnage captured in the N9 for 2002 dropped by ~70-80t from the 2000 and 2001 years, and was probably due to one vessel not operating in that fishery, as the CPUE remained consistent. The Line Fishery log book catches indicated few grey mackerel were captured annually, ranging between 0.07 to 5.5t/yr between 1990 to 2002 (1.6t/yr or ~0.5%/yr contribution for the last 3 years).

Spanish mackerel Gulf Line catches increased noticeably from 1992 and from this time onwards the total Spanish mackerel catches have remained between 103-190t per annum (Figure 4.2). Prior to 1992, less effort days were put into the Line Fishery which resulted in lower annual yields, as similar CPUEs were recorded throughout the time series examined (Figure 4.2). The 2002 season produced a high annual catch of 190t and GVP of $1.35m, while the average for the last 3 years was 153t/yr and GVP of $1.06m/yr (CFISH). The N9 Fishery contributed an average of ~12% of the Gulf Spanish mackerel annual catch over the last three years, whereas the Line Fisheries contributed an average of ~86%. Prior to the N9 Fishery (1999) the Line Fishery contributed an average of 93.3% of the Spanish mackerel annual catch. Excluding 1990 and 1991, the historic Gulf Line total annual catches before the introduction of the N9 Fishery ranging from 103-182t, which are similar to post N9 Fishery total Gulf annual catch levels (ranging between 126t to193t).

The average annual tonnage of shark captured over the years (1990-present) has an average annual catch of ~150t (ranged from 80-220t/yr), with gillnet fisheries contributing ~99% of the annual catch. However, the historic annual catches of shark have been consistently above 140t/yr since 1994, but prior to 1994 averaged 98t/yr (CFISH, Figure 4.2). The 2002

Gulf annual catch was 180t and GVP of $1.08m, while the average for the last 3 years (2000 to 2002) was 185ton/yr and GVP of $1.11m/yr.

These data support the anecdotal reports of the effort shift into the offshore waters and the uptake of power assisted net haul devices. Sharks in these offshore areas can be captured all year round in substantial numbers, whereas the inshore / estuary sharks are reported, by Fishers and the Tropical Resource Assessment Program Observer, to be mainly captured in substantial numbers at the beginning of each fishing season.

To provide an indicator of effort, the N9 Fishery in 2002 was distributed amongst 6 endorsements (0 in 1997), there are 105 primary and 155 tender vessel endorsements in the Line Fishery (same in 1997) and 90 in the N3 (105 in 1997). Currently ~15% of the N3 endorsements take substantial amounts of grey mackerel (Gary Ward, President, Gulf of Carpentaria Commercial Fishing Association, pers. comm.) and as a result capture more Spanish mackerel and sharks compared to when targeting barramundi. The ability of N3 endorsements to fish offshore and target offshore species, with and without power-assisted devices, is increasing with each season.

4.4 Observed Technical and Catch Information

In the N9 observer program only one vessel has been boarded at the same time each season. Fixed temporal observer trips should also produce spatial similarities, as it has been observed that fishers target particular areas as the season progresses. This type of temporal and spatial coverage of the N9 Fishery area should produce an accurate annual catch composition, which would also allow seasonal comparisons of the annual data sets.

However, in terms of effort analysis, this strategy does not take into account spatial variation in habitat nor the effectiveness of each Fisher. The catch information was standardised by grouping the observer data from all vessels into 30 minute grids. Assuming that the fishing gear used amongst the N9 vessels is the same, the knowledge of the fishers is the same and the habitat within the grids is consistent.

The general fishing procedure for N9 vessels was to begin setting the net late in the afternoon and usually to conduct two shots per night, with the majority of shots being conducted at night. The fishers conducted day shots as ‘feeler shots’ to locate potential new fish aggregations and to supplement the catch, predominately when night catches were low. The fishing techniques usually involved attaching the anchor and danbuoy to the end of the net, running the net down-wind and then securing it to the bow of the vessel. The approximate offshore position of the danbouy was used as the location of the net-set, with the setting direction to the end of the net with the vessel attached. Fishing depth was estimated from electronic equipment onboard the vessels, along with vessel drift. Once the net was set and in position, the movement of the vessel from its net set position was recorded as drift. The general drift direction was observed to swing with the wind.

4.5 Collective Summary of Observer Trips conducted between 2000 to 2002

During 2000 to 2002 the following general observations were recorded:

Endorsements operating -	varied with each season, from 4 to 5 vessels out of the 6
N^{o} of endorsements observed -	10 observer surveys conducted
Observed months-	February, March, July, August, September and October
Days observed fishing-	107 (CFISH days = 1616, total observer cover was 6.6%)
Net type -	162.5mm mesh, 35-40 ply, 80-85 drop
Average net length -	1161m (900 to 1200m)
Net sets observed -	198
Average soak time -	4.8 hours (1.8 to 17.1 hours)
Average drift -	1.8nm (0.1 to 8.0nm, n=116 sets)
Average depth fished -	21.2m (13 to 37m, n=116 sets)
Protected species -	3 greensea turtles (2RA[*] and 1RD[#]) and 5 dolphins (5RD[#])
Bycatch mitigation trials -	Acoustic warning devices trailed from mid 2001 onwards, AirMar pingers used for 2002 seasons and trials are continuing.
Total catch composition -	34,448 specimens see Figure 4.4 (94 species from 39 families)
Average set catch composition -	174 specimens/set, 11.5 spp/set (0 to 28 species/set)

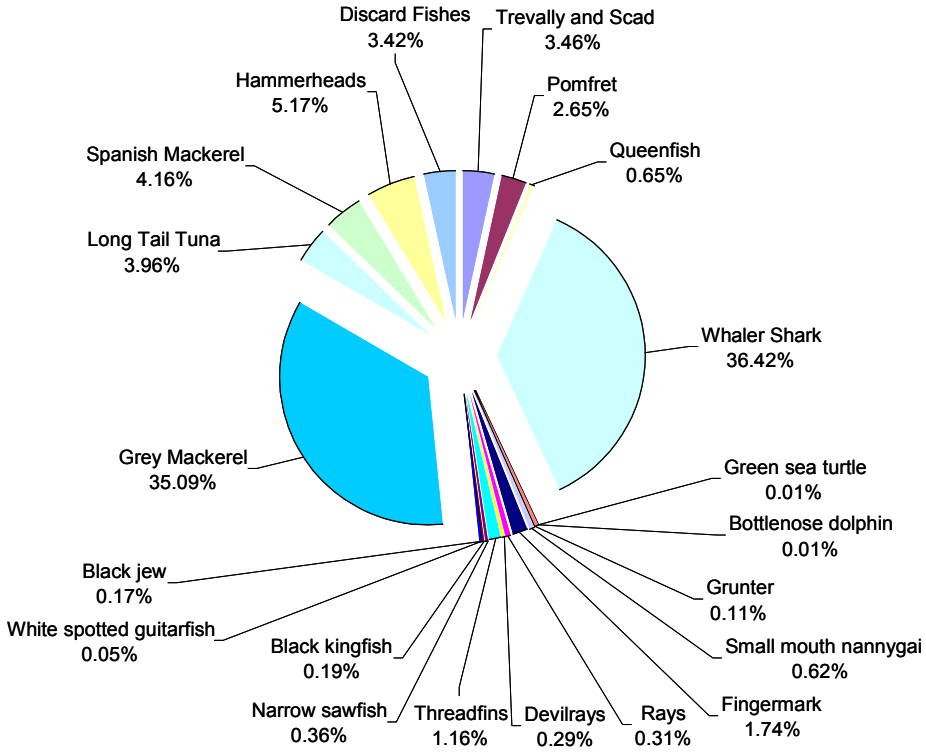
Fate of catch composition:

- Processed: 82.4%
- Partly processed: 2.3% (i.e. fins removed and the rest of the carcass discarded)
- Released dead: 13.1% (chiefly unmarketable specimens)
- Released alive: 2.9% (chiefly unmarketable specimens)

[*]RA = Released Alive
[#]RD = Released Dead

During the observer surveys from 2002 size distribution samples were collected from most species encountered, generally all specimens or particular species of interest were measured for each net set. The sizes of sharks and main byproduct / bycatch specimens captured in the fishery over the years is presented in Appendix 7 (Figure 2 and 4).

The shark catch (see Figure 4.4) was dominated by the blacktip shark species group and the spot-tail sharks, contributing 25.1% and 4.6% to the total catch. The dominant finfish species were grey mackerel and Spanish mackerel, which contributed 35.1% and 4.2% respectively. Longtail tuna was the dominant discarded species, which contributed 4.0%.



Discard Fishes includes: Catfish, Milkfish, Herring, Sole, Porcupine fish, Sickle fish, Batfish, Sailfish, Black marlin, Beach salmon, Emperor, Jumping cod, Tarpon, Halibut, Little jewfish, Bonito, Mackerel tuna, Short mackerel, Spotted mackerel, School mackerel, Cod, Barracuda, Grinner and Pufferfish.

Figure 4.4 - Percent Contribution for the Total Observed Catch during 2000, 2001 and 2002

4.6 Yearly Summaries

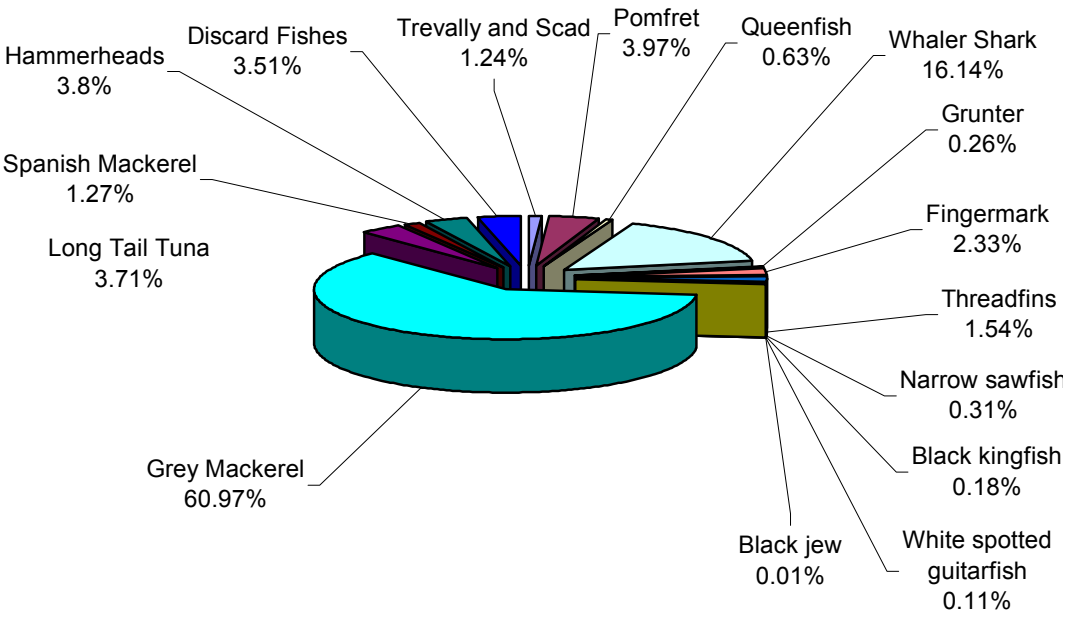
4.6.1 Summary of Observer trips conducted in 2000

Endorsements operating -	5 endorsements, all were operating
N^{o} of endorsements observed -	4 endorsements (fifth endorsement was observed as part of N3 TRAP Observer Program earlier in the year before this program started)
Observed months -	August, September and October
Days observed fishing -	30 (CFISH days fished = 639, observer cover = 4.7%)
Net type -	162.5mm mesh, 35-40 ply, 80-85 drop
Average net length -	1190
Net sets observed -	64
Average soak time -	4.3
Percent anchor attached to net -	43.8%
Average drift -	1.9 (0.1 to 8.0nm, n=6)
Average depth fished -	nil
Protected species -	1 greensea turtles (1RA*)
Bycatch mitigation trials -	nil
Total catch composition -	14834 specimens see Figure 4.5 (69species from 32 families)
Average set catch composition -	232 specimens/set, 13.5 spp/set (3 to 27species/set)

Fate of catch composition -

- Processed: 84.8%
- Partly processed: 0.3% (i.e. fins removed and the rest of the carcass discarded)
- Released dead: 12.8% (chiefly unmarketable specimens)
- Released alive: 2.1% (chiefly unmarketable specimens).

*RA = Released Alive



Discard Fishes includes: Catfish, Herring, Sole, Bottlenose dolphin, Black marlin, Devil rays, Eagle rays, Cownose ray, Mackerel tuna, Short mackerel, Spotted mackerel and a Grinner.

Figure 4.5 - Percent Contribution for the Total Observed Catch in 2000

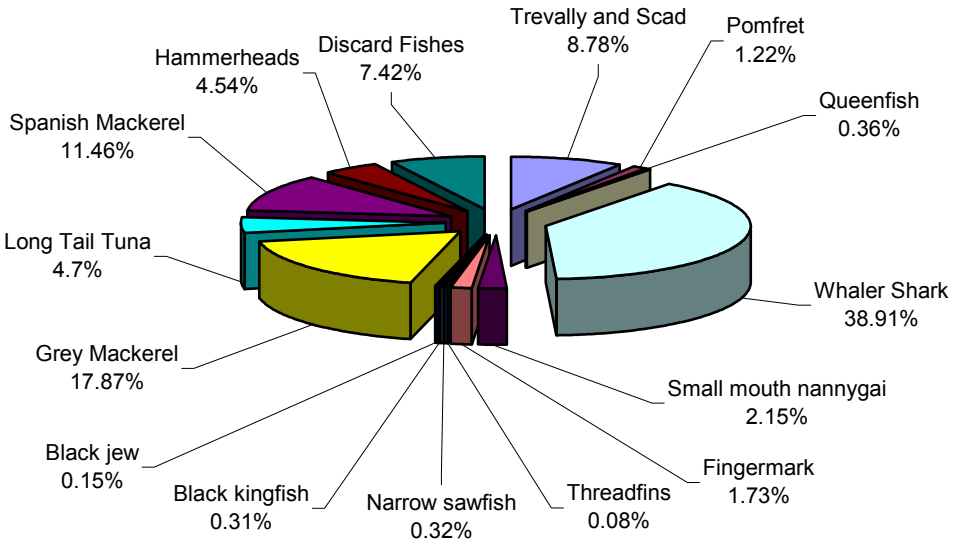
4.6.2 Summary of Observer trips conducted in 2001

Endorsements operating:	5 endorsements, four were operating and one was partially operating
N° of endorsements observed:	4 endorsements
Observed months:	February, March and August
Days observed fishing:	41 (CFISH days fished =494, observer cover=8.3%)
Net type:	162.5mm mesh, 35-40 ply, 80-85 drop
Average net length:	1110
Net sets observed:	77
Average soak time:	5.1
Percent anchor attached to net:	45.5%
Average drift:	1.9 (0.1 to 5.8nm, n=47)
Average depth fished:	21.2 (13 to 37m, n=59)
Protected species:	2 greensea turtles (1RA* and 1RD#) and 4 dolphins (4RD#)
Bycatch mitigation trials:	Acoustic warning devices (Lien pingers)
Total catch composition:	9934 specimens see Figure 4.6 (72species from 32 families)
Average set catch composition:	131 specimens/set, 11.1 spp/set (0 to 28 species/set)

Fate of observed catch composition:

- Processed: 76.0%
- Partly processed: 4.7% (i.e. fins removed and the rest of the carcass discarded)
- Released dead: 15.7% (chiefly unmarketable specimens)
- Released alive: 3.7% (chiefly unmarketable specimens).

*RA = Released Alive
#RD = Released Dead



Discard Fishes includes: Catfish, milkfish, greensea turtle, wolf herring, tongue sole, blackspotted whipray, leopard ray, bottlenose dolphin, torres strait herring, dusky batfish, teira batfish, butterfly ray, sailfish, black marlin, beach salmon, oxeye herring, manta ray, pygmy devilray, whitespotted eagle ray, banded eagle ray, ornate eagle ray, tropical halibut, cownose ray, whitespotted guitarfish, leaping bonito, mackerel tuna, short mackerel, longjawed mackerel, slender barracuda, spotted-tailed grinner, starry pufferfish.

Figure 4.6 - Percent Contribution for the Total Observed Catch in 2001

4.6.3 Summary of Observer trips conducted in 2002

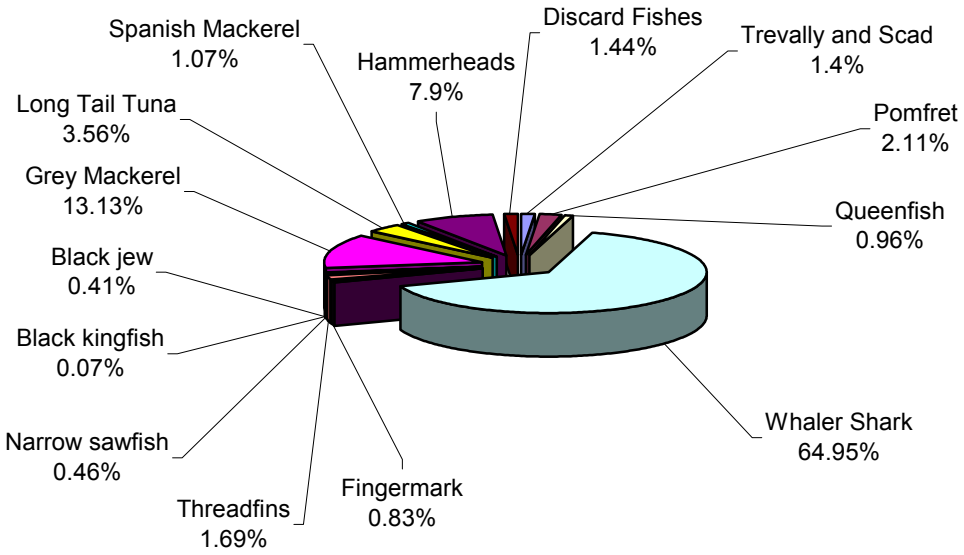
Endorsements operating -	6 endorsements, three were operating, two were partially operating and one was out of the fishery
N^{o} of endorsements observed -	3 endorsements (additional QFJA observer trip was conducted)
Observed months -	July, August and October
Days observed fishing -	36 (CFISH days fished =483, observer cover=7.5%)
Net type -	162.5mm mesh, 35-40 ply, 80-85 drop
Average net length -	1195
Net sets observed -	57
Average soak time -	4.8
Percent anchor attached to net -	100%
Average drift -	1.6 (0.1 to 3.9nm, n=54)
Average depth fished -	21.3 (13 to 32.1m, n=57)
Protected species -	1 dolphins (1RD$^{\#}$)
Bycatch mitigation trials -	Acoustic warning devices (AirMar pingers)
Total catch composition -	9680 specimens see Figure 4.7 (72species from 32 families)
Average set catch composition -	171 specimens/set, 9.8 spp/set (0 to 24species/set)

Fate of catch composition:

- Processed: 85.1%
- Partly processed: 2.8% (i.e. fins removed and the rest of the carcass discarded)
- Released dead: 10.1% (chiefly unmarketable specimens)
- Released alive: 2.0% (chiefly unmarketable specimens).

$^{\#}$RD = Released Dead

Detail of the species composition and catch statistics for 2002 is provided in Appendix 7 on the CD attached at the end of this document.



Discard Fishes includes: Catfish, Herring, Sole, Bottlenose dolphin, Black marlin, Devil rays, Eagle rays, Cownose ray, Mackerel tuna, Short mackerel, Spotted mackerel and a Grinner.

Figure 4.7 - Percent Contribution for the Total Observed Catch in 2002

4.7 Shark Catch and Biology

The blacktip whaler species grows to ~2000mm TL and matures ~1100mm TL (Last & Stevens 1994), thus the observed catch was dominated by immature specimens and very few mature specimens were captured. Of the male blacktips sexed (n=2881), only ~1.9% of them were mature. Other species of whaler sharks captured possess different growth characteristics, body profiles and varied biological characteristics (size at maturity, behaviour, etc). These characteristics contribute to the varied size ranges captured for each species in the Gulf (Appendix 7 Figures 1 to 4). For example, the milk shark (*R. acutus*, 4.2% of the whaler shark catch) is a small growing species with a maximum attainable size of 1.8m TL with a slender body (Stobutzki *et al.* 2003). The specimens captured in 2002 were mostly mature, as approximately 96% of them were male and had a median size of 659mm FL, many of these milk sharks were bridled across their opened mouths by the gillnet. Other small growing species of whaler sharks encountered and captured the same way included, the whitecheek shark (*C. dussumieri*, median 621mm FL, all mature and ~68% male), hardnose shark (*C. macloti*, median 635mm FL, all mature and ~80% male) and the Australian sharpnose shark (*R. taylori*, median 550mm FL, all mature and ~33% male). This method of capture was also apparent for some small teleost bycatch species, such as blue salmon and some trevallies. The other whaler shark species captured were gilled or entangled in the net meshes due to their large sizes and broad body shape. Overall the fishing gear used in the N9 Fishery appears to be effective at targeting whaler sharks between 550 and 800mm FL.

Hammerhead sharks contributed a low percentage of the shark catch (10.8%) in 2002 (19.1% in 2000 and 10.5% in 2001), however these specimens can achieve larger maximum sizes than most whaler shark species; with the exception of the tiger shark (*G. cuvier*, Stobutzki, *et al.* 2003). In practical terms the numbers of hammerheads captured was low, but in general, it takes fewer hammerheads to fill fillet cartons for market than whalers. The median size of hammerhead sharks captured was greater than that of whaler sharks captured (840mm FL compared to 611mm FL).

Note that the smallest hammerhead shark species captured (Winghead hammerhead, *E. blochii*, max. attainable size of 1850mm TL, median size captured 1034mm FL), ~93% were mature and predominantly female and were only partly processed, due to its poor quality flesh (excessive "bloodlines") and is reported as a species with potentially high mercury levels (Last and Stevens 1994). Whereas the remaining two hammerhead shark species captured and processed were predominantly immature specimens:

- 93% of the scalloped hammerhead (*S. lewini*) and
- 99.5% of the great hammerhead (*S. mokarran*), respectively.

This included specimens from birth sizes upwards, as umbilical scars were present on the smallest specimens. These two hammerheads species can

attain very large maximum sizes, the scalloped hammerhead can attain 4.5m TL and great hammerhead 6m TL (Stobutzki *et al.* 2003). The observed median sizes captured were 740mm and 930mm FL, respectively.

The scalloped hammerhead contributed 57.8% of the hammerhead catch observed in 2002. Comparatively this hammerhead species occurred less in 2000 (53.5% of the hammerhead catch) and 2001 (38.1% of the hammerhead catch).

Very few 'finable', small and extra large, whaler and hammerhead sharks were captured, as only 3.8% of the total shark catch was partly processed. Of this, 75.7% were the winghead hammerhead (*E. blochii*), which has unmarketable flesh (see above), however this species has very large fins to its body size.

A wide range of species and sizes of sharks are captured in the N9 Fishery and this may be due not only to the mesh net utilised in the fishery, but also behaviour and anatomical differences between the species. Apart from the traditional 'meshing' of whalers due body shape (typically fusiform) and body depth relationships, preliminary indications have shown some behavioural patterns may contribute to the capture of additional whaler and hammerhead shark species. The gillnets utilised selected whaler sharks generally between 550 to 800mm which were meshed, however some small whaler sharks were bridled across their opened mouths and large sharks were usually longitudinally rolled up in the net. Also, head shape may influence vulnerability of hammerhead sharks to capture in the nets. The broad lateral blades of their head may initially limit interactions with gillnets, ie meshing, but may not aid them in avoiding entanglement after the initial contact with the mesh net. In general larger specimens appear more likely to break free of the light ply of the net used in this fishery (35 to 40 ply), unless the head and/or foot rope were involved in the entanglement. This may explain why relatively few massive shark specimens (>2.2m FL) were captured during the observed trips.

Very large specimens do inhabit these waters and the areas regularly fished in the Gulf (Last and Stevens 1994). Destroyed sections of gillnet (by large animals) was regularly observed during surveys. Fishers noted that particular areas in the Gulf are known for large sharks, but are rarely fished when good catches are occurring elsewhere. Fishing practices and the fishing gear used in the N9 Fishery appear to select against the capture of large shark species, thus partially protecting mature sharks.

To date, there has been limited investigation into the biology of sharks in the Gulf, however there has been some work done on *C. tilstoni* and *C. sorrah* (Davenport and Stevens 1988; Stevens and Wiley 1986; Stevens *et al.* 2000). From this work a divergence of opinions has arisen over the likelihood that distinct pupping and nursery areas exist in the Gulf (John Stevens, CSIRO, pers. comm.). The observer program has not addressed these concerns, however collation of birth size, and litter size and sex information began in 2002, although still limited.

4.8 Byproduct / Bycatch

The byproduct / bycatch in the 2002 N9 Fishery net shots was dominated by grey mackerel (48.4% of the byproduct / bycatch numbers) all of which was processed. Approximately 25% of the grey mackerel captured were measured and they ranged from 379 –1040mm TL. However, the majority measured were between 750mm to 900mm TL and their average size was 822mm TL (Appendix 7 Figure 6 and 7). According to Cameron and Begg (2002) age structure of grey mackerel, the 2002 observed grey mackerel captured in the N9 Fishery were between <1 to <12 years of age. The average age for the average size (822mm TL) captured during these 2002 N9 Fishery observer trips was estimated to be >1 to <3 years old. These authors found a large variation in age to size which could be explained by the initial very fast growth rate and slightly different sex specific growth curves. The previous research for Gulf grey mackerel suggested that male greys grew faster but reached a smaller theoretical maximum length than females (♂L_∞=973, 95% CI, n=322; ♀L_∞=1364, 95% CI, n=154). In addition, during N9 Fishery observer trips numerous anecdotal reports from fishers who have fished both the Gulf and East Coast, have suggested that grey mackerel in the Gulf reach a smaller maximum size compared to those on the East Coast.

Further, Cameron and Begg (2002) found that the majority of maturing/ripe fish were captured between September and January in the Gulf. The majority of samples were obtained from one month (October contributed 62.9% of the samples) while the remaining months had limited samples and no samples were obtained between March and April. The estimated length at first maturity was not clearly established, as the smallest greys sampled (550mm FL, ~2 yrs old, n=3) were found to be capable of spawning. The previous research showed that Gulf and Arafura Sea grey mackerel are genetically different from the East Coast greys, however they suggested that finer stock structure may exist. As only four polymorphic loci were analysed which greatly reduced the power to identify genetic variation and true stock structure. Previous research on Gulf grey mackerel from Cameron and Begg (2002) provides a good baseline information, however further work into the biology and life cycle is required to provide information to manage the grey mackerel resource across northern Australia.

Longtail tuna (*T. tonggol*) was the next major contributor to the bycatch / byproduct total, contributing 13.1% of the numbers. Longtail tuna is a regulated species and under any fishery symbol in Queensland a maximum of ten may be in possession (*Fishery Regulation* 1995). Thus during the observer trips no longtail tuna were processed and the majority were returned deceased. My general observations are that ‘small-scaled’ species have poor survivability to net capture and handling, whereas most ‘large-scaled’ and most benthic species seem to be more resilient. Small-scaled species are fish such as Scombridae (mackerels and tunas) and Polynemidae (threadfins), large-scaled animals include Haemulidae

(grunters), Lutjanidae (snappers) Sciaenidae (croakers) and Serranidae (emperors), and benthic animals include guitarfish, rays and sawfish. Most small-scaled fish specimens were observed to succumb quickly, however the small-scaled carangids (trevally, queenfish, pomfret) were seen to be reasonably hardy.

If soak times were long (>6-8hrs) nearly all species were observed to dead in the net, except for some benthic species. Also, in particular areas of the Gulf many of these specimens were observed to be bitten by sharks cruising along the net. Many of the larger sized tiger, big eye and bull sharks have been observed visiting the nets on many occasions. For these reasons many N9 Fishers conduct short soak times to increase product quality and reduce predation along the net. This in turn increases the potential survival of bycatch specimens.

The composition of the ray catch was low and can be attributed to the selective nature of the mesh-nets used. Gillnets of the type deployed are selective towards fusiform body shapes as opposed to dorsoventrally flattened body shapes. All rays captured (0.8% of the byproduct / bycatch numbers) were returned to the sea alive.

4.9 Observer CPUE

Whaler, hammerhead, mackerel and protected species average CPUEs from fishing seasons 2000, 2001 and 2002 are presented in Table 4.1. Note that the effort calculated for 2000 was from the last 7 weeks of the fishing season, whereas the 2001 and 2002 data was collected throughout the fishing season. This limited CPUE data collected from the observer trips provides snap-shots during the year for the specimens captured, however these CPUEs can vary spatially and temporally. Generally observer trips have occurred at different times for each season and fishing has occurred in different locations, however there has been some overlaps in locations as each Fisher has their preferred fishing grounds.

Table 4.1 - Annual comparison of Observed CPUE* of Major Fish Groups and Species Captured in the N9 Fishery

Season	No of Sets	Whaler	Hammer-heads	Grey Mackerel	Spanish Mackerel	Dolphins	Turtles
2000	65	4.3	1.0	13.6	0.4	0.000	0.002
2001	76	4.7	0.6	2.4	1.5	0.004	0.003
2002	57	9.5	1.2	1.9	0.2	0.002	0.000
Average	66	6.16	0.93	5.97	0.70	0.002	0.002

* N^{o} of specimens captured / hour / 500m of net

The primary role of this project was to determine what bycatch is captured in the N9 Fishery and this has involved changing the observer trips each season to encompass possible spatial and temporal shifts in species compositions in the Gulf, thus establishing a complete catch composition throughout the season and across the N9 Fishery area (some 40,600km^2). A degree of standardisation was established however, as eache vessel was observed at the same time each season to provide a consistent temporal snapshot.

4.9.1 Observer/Commercial CPUE for Whalers, Hamerheads and Grey and Spanish Mackerel

Due to likely spatial and temporal variations in catch rates, annual log book catches for the N9 fishers are included for a relative comparison with the data collected on the observer cruises. Average log book CPUEs from the fishing seasons 2000, 2001 and 2002 for whaler, hammerhead, mackerel and protected species are presented in Table 4.2.

Table 4.2 - CFISH Log Book CPUE* of Major Fish Groups and Species Captured

Season	Sharks	Grey Mackerel	Spanish Mackerel
2000	44.79	111.93	11.25
2001	43.18	86.58	10.41
2002	88.57	114.98	27.14
Average	58.85	104.50	16.27

*Catch wt (whole kg) / day / vessel

The observed catch rates varied greatly in all the areas fished (Table #), but, as discussed earlier, grey mackerel and whaler sharks dominated the catches for the trips observed. On average 6.0 grey mackerel and 6.2 whaler sharks were caught per hour per 500 meters of net. In contrast, low catches of hammerhead sharks and Spanish mackerel were observed. Note that the observed catch rates for these species / groups varied between observed years (Table 4.1) and with the averaged annual log book catch rates (Table 4.2).

The annual log book catch rates for grey and Spanish mackerel in 2002 were higher than those of previous years (2000 and 2001) but the observed catch rates did not reflect this information. This apparent contradiction would most probably be due to observed 'patchy' catches of these specimens throughout the year. This 'patchiness' may be attributed to time of year, area fishing, success in locating stocks, condition of fishing net and weather conditions. For example, during the 2000 season all observer trips were conducted at peak times of grey mackerel capture which placed a bias on the observer results.

Not all of the N9 endorsements fished during the 2002 season and those which did fish, did not utilise the full fishing season. Some operators possess multiple endorsements (NT and/or Commonwealth) and only enter the N9 Fishery when conditions are favourable or market driven. Fisher knowledge and the technology and efficiency in the N9 Fishery vessels are improving all the time which increases CPUE, however operational hurdles exist in these offshore fisheries which contributes to decreased fishing time and effort. This is mainly due to weather conditions and the exposed nature of this offshore fishery. As such, compared to inshore gillnetting operations, operational expenses are high and fishing has to be productive to maintain such operations. For example the 2002 fishing season was no exception with many vessels having downtime, as only three out of the six N9 endorsements fished throughout the season. Two of these were dual endorsed and fished Commonwealth and NT waters during 2002, this usually occurs during the N9 closure and for a short time at the beginning of each season. The length of down time in the N9 Fishery, during the season, depends on the vessel refit schedule and location (one vessel undergoes refits in Darwin), catch rates, extent of the wet season, sea conditions and unexpected breakdowns. This also has impacts on organising observer surveys on board these vessels and requires flexibility in observer trip schedules.

Table 4.3 - Standardised Temporal CPUE* Snapshot of one N9 fishing vessel

Season	No of Sets	Whaler	Hammer-heads	Grey Mackerel	Spanish Mackerel	Dolphins	Turtles
2000	17	7.9	2.7	7.1	0.7	0	0
2001	23	9.0	0.6	6.4	2.9	0	0
2002	29	11.5	1.8	0.5	0.2	0	0

* N^{o} of specimens captured / hour / 500m of net

4.10 Critical Issues

During the three years of observing, two types of notifiable species (*Tursiops and Chelonia*) interactions were observed. These species are not listed as 'vulnerable, rare or endangered' but are a notifiable species under the *Nature Conservation Act* 1992. Under the Commonwealth *EPBC Act* 1999, when dolphins and other small cetaceans are unintentionally caught in fishing nets, penalties do not apply provided that live animals are released immediately and the capture is reported as soon as possible to relevant authorities. All notifiable species were reported to State authorities and QFS.

Numerous dolphin pods were observed throughout the trips, inshore and offshore.

- Three Greensea turtles (*Chelonia mydas*) were captured, two of which were released unharmed. These are listed as 'vulnerable'. Of the three turtle two were released unharmed and one was released deceased.
- Five Bottlenose dolphins (*Tursiops aduncus*) were captured, all were released deceased.
  - One of these interaction was observed in 2002 with a bottlenose dolphin (*Tursiops aduncus*) and N9 fishing gear with pingers attached. The dolphin was captured while AirMar 10kHz pingers were being trialed and it was captured in the top portion of the net next to one of these pingers.
  - One of the dolphins was a juvenile, which potentially drowned prior to being captured due to violent sea conditions.
  - The remaining three mature dolphins were captured in one area off Cape Keerweer towards the end of the season, which instigated the Pingers trials using Lein alarms and then Airman pingers.

4.10.1 Notes on Dolphin Pingers

Best practise for deploying the Dolphin alarms or pingers, to maintain appropriate spacings and retain pingers, was to deploy them with the net buoy and attached to the head rope of the net. This also placed the pinger at a suitable operating depth under the water surface. Retrieval of the pingers was compromised in some situations, however. During observer trips in 2002, two pingers were lost when they were attached to buoys that were incorrectly attached to the head rope of the net. The only way to prevent this is by permanently attaching the pingers onto the net near the head rope or foot rope for the life of the net, but this technique will depend on the fisher and net drum capability.

Acoustic output of the devices with water temperature was not known. With the water temperature extremes in the Gulf of Carpentaria, the battery performance and acoustic propagation of different frequencies are yet to be considered. Preliminary analyses to date indicate that the acoustic devices do not affect shark catch. The frequency of each device is above the frequency response known for sharks and most fish species (Geoff

McPherson, DPI&F pers comm). Industry operator's and observer assessments confirm this observation.

At this stage the uncertainty lies with the unknown ambient biological noise levels (background noise). Future work may involve behavioural tests with dolphins and trialing alternative pingers with different frequencies, for example the successful multi-frequency dolphin alarms used in European Fisheries. Acoustic tracking systems being developed by DPI&F for marine mammals around nets, with and without acoustic devices, is viewed as the next step to determine alarm/pinger effectiveness.

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Section 5. Planned Outcomes and Conclusions

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Rod Garrett

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5.1 Benefits and Adoption

5.1.1 Benefits

1. Collection and collation of basic fishery and biological information to assist in the effective management of a tropical multi-species fishery, on both the Gulf and East coast of northern Queensland,

2. A "before and after" assessment of the effort reduction initiatives put forward in the 1999 Gulf Inshore Finfish Fishery Management Plan. The problems documented give a measure of the effectiveness of such effort reductions for consideration in future modifications to the Plan.

3. A timely assessment of short to medium-term effects of the Management Plan for the Gulf Inshore Finfish Fishery, as input to the Draft Management Plan for the East Coast Inshore Fishery which is currently being formulated by the Gulf MAC.

4. An assessment of the Walters (1986) concept of "adaptive management" as an appropriate tool or otherwise in the management of tropical inshore fisheries.

5.1.2 Adoption of project recommendations - adaptive management to TRAP interim reports

Regular reporting by TRAP research staff, initially to the Tropical Finfish MAC then later to the reorganised Gulf MAC, elicited a series of management responses:

TRAP N9 observer reported 4 dead dolphins caught in N9 nets.

- This triggered a review event in the management plan leading to stakeholder "Bycatch workshop" which developed a "Bycatch Action Plan (2002)".

TRAP observers identified Grey mackerel as a major component of N9 catch (also taken in the N3 fishery) but this species was not listed as either a State or Commonwealth controlled species under the OCS agreement that set up the Gulf of Carpentaria Queensland Fisheries Joint Authority (QFJA).

- By default Grey mackerel was a Commonwealth regulated species. In 2001 the Gulf QFJA issued special permits to allow the N9 fishers to take QFJA species (eg. Shark and Grey Mackerel).
- Gulf MAC is currently setting up complementary arrangements to allow N3 fishers to legally take Grey Mackerel, either as a target or bycatch species. Proposed is a separate access right in the N3 fishery to take Grey Mackerel (through a QFJA permit),

limited by entry criteria plus requirement for an industry-funded observer and satellite VMS.

TRAP observers identified shark as a significant component of the N3 catch, even after the split of the inshore fishery into the offshore N9 (shark/mackerel) and inshore N3 (Barramundi) endorsements.

- Gulf MAC is currently setting an "in possession" limit on the N3 endorsements of 550 kg of shark product, including fin (with 10:1 ratio flesh to fin allowed).

TRAP observers reported increasing use of hydraulic Net reels in the N3 fishery, increasing the effective effort (i.e., effort creep).

- Gulf MAC has proposed that only 600 m of net be allowed on N3 net reel boats. Also these boats will be subject to the conditions for taking Grey Mackerel in the N3 fishery (see above).

TRAP observers identified the protected freshwater sawfish (*Pristis microdon*) as a component of the inshore catch and alerted both Gulf MAC and the Gulf of Carpentaria Commercial Fishermen's Association.

- TRAP N3 observer and Gulf inshore fishers developed a method of live release for sawfish and this was included in the Gulf of Carpentaria Commercial Fishermen's Association, Code of Conduct.
- Gulf Mac funded shark and bycatch species identification workshops (run by the TRAP N3 observer) to raise the awareness of this problem with Gulf fishers and to ensure methods of live release were known and used.

TRAP N3 observer assisted with development of fresh fish marketing to the East Coast from the Gulf fishery.

- Brain-spiking freshly caught fish, "Ikejima", then road-transporting them on ice to the East Coast from Karumba has grown in popularity. The quality of this non-frozen product is increased, as is the price received from the buyers. This practice may alter the spatial distribution of fishing effort around major coastal towns in the tropical north with good road or air connections.

At the Commonwealth management level the existence of fisheries observers in the Gulf inshore fishery was a positive factor in sustainability assessments under the EPBC Act. If they had not already been present they would have been made a requirement.

5.2 Further Development

The Tropical Resource Assessment Program generated a number of initiatives that will be developed further in the future:

- Incorporation of fisheries observers (a key initiative of the TRAP methodology) into the monitoring the major Queensland fisheries and developing workable policy and procedures. The success of the TRAP observers has added support to calls from management, and some sections of industry, for observer validation of logbook data. [Note: It was interesting that once the potential of remote area fisheries observers had been demonstrated, management identified many more "essential" tasks they could carry out. The difficulty was to avoid compromising research aims with tasks that were primarily to ensure compliance; i.e., policing the fishery. Our philosophy as researchers was to work with fishers to solve common problems, and to avoid any "them and us" confrontations.]

- Adaptive Management in tropical fisheries will need to be more process oriented and appropriate assessment methodology developed. It was obvious from the current study that management was "adapting", sometimes rapidly, to changes in the fishery. In most cases these adaptations were reactive and ongoing, hence could not have been predicted nor incorporated in the original design of the analysis.

- The use of mechanically assisted net-drums to set and retrieve inshore gill-nets is expanding through the N3 "Barramundi" fishery in the Gulf. The effect of this technology on the effective fishing effort, and hence on future stock assessments, requires further study.

- Grey Mackerel was identified as a component of the both N9 and N3 catch that was increasing but very little information is available on the stock dynamics or sustainability of this species. Again there is a need for further study, in this case on the basic biology, stock structure, and distribution of this species.

5.3 Planned Outcomes

5.3.1 Performance indicators (from original proposal)

(1). The Gulf inshore net fishermen embrace the concept of co-operative fisheries research through an observer program.
(a.) Junior biologists will gain relevant experience with remote operators,
(b.) Stock assessments will be refined using the data the biologists collect,
(c.) Management will be improved with better stock assessments, and
(d.) Fishers will have a real ownership in the research that ultimately governs how their fishery will be managed. The measurement of this indicator will be the number of fishers that agree to become involved in the project.

(2) Documentation of biological information on priority fish species is carried out to fill gaps identified by FRDC Project 92/145 and FRDC Project 95/049. This will include information on species composition, number caught, and population structure (length frequency) of the catch. This information will be summarised and published with the project annual reports.

(3). An evaluation of the effort reduction initiatives of the Gulf Inshore Fishery Management Plan (1999) is carried out in terms of their effect on stock dynamics.

(4) The results of the project are useful to and are incorporated in future Management Plans for tropical inshore fisheries, in particular the Queensland Tropical East coast Inshore Fishery Management Plan.

5.3.2 Outcomes

1). *The Gulf inshore net fishermen embrace the concept of co-operative fisheries research through an observer program.*

Junior biologists will gain relevant experience with remote operators.

As noted in the discussion, this component of has been the most successful part of the project with both the N3 and N9 fisheries observers being accepted fully by the Gulf fishing community.

Stirling Peverell (N3 observer) has enrolled in a part-time MSc on the distribution and biology of Gulf Sawfish with James Cook University, based on data collected as a fisheries observer and with the continuing co-operation of Gulf fishers in his sawfish tag and release program. The observer skills and rapport he developed during TRAP is currently being utilised as the Shark fisheries observer with FRDC 2002/064.

The N9 observer program has been transferred from research to operational status, under the QFS Long Term Monitoring program, with the TRAP temporary biologist/observer, Jason Stapley, currently being upgraded to a permanent employee.

(b.) *Stock assessments will be refined using the data the biologists collect,*

The refinements to stock assessments recommended by the national stock assessment workshop of TRAP Phase I were carried out, in particular the observer data was used in the Virtual Population Analysis (Pope cohort analysis) of the Gulf Barramundi stock

An additional refinement was the validation of logbook information, in particular the identification of three boats that were submitting major quantities of catch and effort "mis-information". By observing the actual catch rates from vessels fishing alongside the boats in question it was possible to discount these logbook reports. Information quality was improved which meant that assessments based on that information were also improved.

(c.) *Management will be improved with better stock assessments,*

The stock and fishery assessments produced by TRAP feed directly into the Gulf Management Advisory Committee, the advisory committee of the GulF Queensland Fisheries Joint Authority, are integrated into QFS biannual fisheries "Condition and Trend" reporting, and are now part of the QFS Long-Term Monitoring Program.

An unforeseen but crucial management need and subsequent use of the stock and fishery assessments produced by TRAP were for the Ecological Assessment of the Gulf of Carpentaria Inshore Finfish Fishery, produced by QFS for Environment Australia to fulfil the requirements of the EPBC Act. At stake were permits to export product from the fishery; in a real sense its financial viability.

A further indirect improvement to fisheries management has been the acceptance of the effectiveness of fisheries observers by both management and industry, with observers now being considered for all Queensland fisheries.

(d.) *Fishers will have a real ownership in the research that ultimately governs how their fishery will be managed.*

Output in the form of stock and fishery assessments, staff-time, and project resources from TRAP Phase's I and II significantly assisted the Gulf of Carpentaria Commercial Fishermen's Association in producing:

- Code of Conduct for the Gulf fisheries, and
- Environment Management Plan (industry sponsored).

Furthermore, two of our major industry partners, Gary Ward and Claudine Ward, received the national Fisherman of the year (2002) award and national fisheries

Environmental award (2003) respectively, for this work on advancing sustainable fishing in the Queensland Gulf of Carpentaria.

These are tangible examples of where the Gulf fishing community had real ownership of the research outputs, and using this knowledge and support is now leading Australian tropical fisheries in responsible and sustainable management of their fish resources. This has been all the more remarkable, as the Gulf of Carpentaria is considered remote, logistically difficult, and even "hazardous".

The Gulf fishing community acknowledged the important supportive role provided by TRAP through its nomination of the TRAP Team for a successful 2001 QDPI Client Service Award.

(2) *Documentation of biological information on priority fish species is carried out to fill gaps identified by FRDC Project 92/145 and FRDC Project 95/049. This will include information on species composition, number caught, and population structure (length frequency) of the catch. This information will be summarised and published with the project annual reports.*

Sections 3 and 4 of this report, which are the technical reports from the N3 and N9 observers, combined with the data appendices in section 5, document species composition of catch and bycatch, number caught, and population structure (length frequency) of the major targeted species in the catch of the Queensland Gulf Inshore set net fishery.

(3) *An evaluation of the effort reduction initiatives of the Gulf Inshore Fishery Management Plan (1999) is carried out in terms of their effect on stock dynamics*.

Section 1 of this report provides the evaluation of the effort reduction initiatives of the Gulf Inshore Fishery Management Plan (1999) in terms of their effect on stock dynamics of key Gulf species; the Barramundi, Threadfin salmon and shark stocks.

(4) *The results of the project are useful to and are incorporated in future Management Plans for tropical inshore fisheries, in particular the Queensland Tropical East Coast Inshore Fishery Management Plan.*

As documented in this and previous reports, the progress results and stock assessments from TRAP Phase I were instrumental in the formulation of the 1999 Management Plan for the Gulf Inshore Finfish Fishery.

TRAP Phase II interim reports, briefings, and collated data have been incorporated in:

(a.) QFS Bycatch Action Plan for Gulf inshore set net fisheries,
(b.) National Plan of Action for Shark,
(c.) Ecological Assessment of the Gulf of Carpentaria Inshore Finfish Fishery for EA,
(d.) National Oceans Office, Northern Area Planning process, and,
(e.) ongoing deliberations of Inshore Finfish MAC for the Queensland Tropical East Coast Inshore Fishery Management Plan.

Appendix 1 – Intellectual Property

Intellectual Property and/or valuable information arising from the research

No commercial saleable information has been generated by the project. Intellectual property is as per funding contract.

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Appendix 3 (Section 1)
Draft journal article

A monthly biomass dynamic model applicable to short-lived and long-lived tropical stocks

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Running title: A monthly biomass dynamic model

Keywords: Shrimp, barramundi, environmental effects, seasonal dynamics, recruitment

Summary

Biomass dynamic models were developed as simple representations of the annual dynamics of harvested stocks. They relate the change in a biomass index to the catch removed, the surviving biomass and the rate of biomass growth. We have generalized these models to seasonal dynamics by incorporating the impacts of both fishing and the environment into monthly stock dynamics.

We apply these models to data from a gillnet fishery for barramundi (*Lates calcifer*) in northern Australia and a trawl fishery for shrimp (*Penaeus subtilis*) in northeastern Brazil. For barramundi we assume the biomass growth occurs only through the wet season. Likelihood profiles suggest that the initial biomass and catchability can be precisely estimated with this model. For shrimp we assume that the seasonal pattern of recruitment is determined by the seasonal rainfall pattern. The short data series does not allow for precise estimation of initial biomass, but catchability is estimated with reasonable precision.
We suggest that these models are useful to explain seasonal dynamics and to evaluate within-season management measures such as fishing closures, even though the long term productivity of the stock can not be considered.

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Introduction

Biomass dynamic models (Hilborn and Walters, 1992; Punt and Hilborn, 1996) are simple representations of the dynamics of fish stocks that seek to explain changes in stock biomass. Because of their simplicity and modest data requirements, these models are ideally suited for obtaining estimates of reference points for fishery management, such as estimates of maximum sustainable yield (MSY), and the ratio of current biomass to the biomass at the level that produces MSY. These models have been widely applied to temperate (Chen and Montgomery, 1999), and tropical (Haddon, 1998, ICCAT 2001a, 2001b) fisheries. In general, they express the change in annual biomass as a function of the previous year's biomass, the growth in biomass and the harvest. The growth in biomass is often modelled as a function of the previous year's biomass and some parameters that define the productivity of the stock. The biomass growth functions often contain an expression that implicitly assumes that density-dependence mechanisms determine biomass growth. In this paper we add the effects of environmental variables to the biomass function. A special case also considered is where only environmental variables determine biomass growth. In contrast, Punt and Hilborn's (1996) definition of biomass dynamics explicitly exclude the effects of environmental variables on the biomass function.

Biomass dynamic model have always been applied to annual data because they have mainly been used for long-lived temperate stocks, and because most temperate animals have an annual reproductive cycle with short recruitment period (Haddon, 1998; Chen and Montgomery, 1999). The most common source of data for these models is annual catch-per-unit-of-effort; however, they can be used with any other index of relative abundance (eg from census data, tagging). Unfortunately, when used with annual data these models require a moderate to long time series, with enough contrast in biomass for the model to accurately supply parameter estimates. Fisheries in tropical areas rarely have such long time-series of annual data, and they often target species that recruit continuously throughout the year.

This paper develops a general formulation for monthly biomass dynamic models and applies it to two tropical fisheries to demonstrate its applicability to a broad range of fishery assessment problems.

Methods

The concept of biomass dynamics can be applied to seasonal dynamics, especially if no attempt is made to draw conclusions about the long-term productivity of the stock. In this respect seasonal biomass dynamic models are analogous to other models of population dynamics such as monthly yield-per-recruit or Thomson and Bell models (Sparre and Venema, 1992), which seek to represent the dynamics only of stocks that recruit continuously.

Let's assume that monthly biomass changes B_{t+1} -B_t are a function of growth in biomass $g(B_t)$ and catch C_t, where growth in biomass encompasses both the effects of recruitment, individual somatic growth and natural survival.

$$B_{y,t+1} = B_{y,t} + g(B_{y,t}) - C_{y,t} \qquad (1)$$

This formulation was used by Punt and Hilborn (1996) to define annual biomass dynamics, and only differs in that t here denotes month (t = 1,2,…12), to accommodate monthly biomass changes. These authors use the name "biomass-dynamic function" to describe $g(B_t)$, and we follow their nomenclature. Note that to make this notation consistent with calendar years, $B_{y,1} = B_{y-1,12} + g(B_{y-1,12}) - C_{y-1,12}$.

Although seasonal environmental changes are less intense in the tropics than elsewhere, many tropical stocks maintain annual cycles. In short-lived species such as shrimp, recruitment and egg production tend to occur within a period of few months coinciding with the onset of the wet or dry seasons (Dall et al., 1990, Munro 1990). We therefore hypothesise, that within a season, the environment shapes the timing of recruitment. The magnitude of annual recruitment, however, is most likely to be the product of both environmental forcing and parental stock size. We now propose to extend the biomass growth model above by separating the annual effects y from the seasonal (for convenience we consider only monthly time units) effects t:

$$g\left(B_{y,t}\right) = h\left(B_{y-1}, E_{y-1}\right) p\left(E_t\right) \quad , \qquad (2)$$

where $h\left(B_{y-1}, E_{y-1}\right)$ represents the effects of the previous year parental biomass and environmental conditions, and where $p\left(E_t\right)$ represents a function of the state of the environment E_t in month t.

The term $h\left(B_{y-1}, E_{y-1}\right)$ may take the form of a stock-recruitment relationship that includes the effects of both parental stock size and environmental forcing on annual recruitment such as the functions used by Laloe (1988), Laloe and Samba (1991), Freon et al. (1992) in their equilibrium production models. These functions incorporate environmental forcing on catchability and/or carrying capacity. Alternatively, the biomass-dynamic function can be one of the traditional surplus production

functions used in annual biomass dynamic models that do not incorporate the effects of the environment (Punt and Hilborn (1996). A special case of a biomass-dynamic function would be one where the stock is only a function of an unknown set of environmental variables, and then $h(E_y)$ can be treated as a random variable $E_y(\mu_y, \sigma)$ where μ_y can be treated as fixed factors in the estimation.
Substituting equation (2) in (1) results in,

$$B_{y,t+1} = B_{y,t} + h(B_{y-1}, E_{y-1})\, p_t - C_t \quad , \qquad (3)$$

On the other hand $p(E_t)$ represents the pattern of annual change in biomass within a season. A simple case is to define a growing season and a non-growing season, so that production is just a function of month of the year t ; constant during the growing season and zero during the non-growing season,

$$\begin{aligned} &for \quad t_1 > t > t_2 \quad ; \quad p_t = \frac{1}{t_2 - t_1} \\ &\text{otherwise} \quad ; \quad p_t = 0 \quad . \end{aligned} \qquad (4)$$

It must be noted that $p(E_t) = 0$ does not mean that there is no growth but rather than growth and mortality balance out.
A more elegant way to model the above case would be to make p_t the cyclical function of month, such as,

$$p_t = a + b\cos(ct + d) \quad , \qquad (5)$$

where $a \geq b\cos(ct+d)$, $\sum_1^{12} p_t = 1$ and $a,\ b,\ c$ and d are parameters defining respectively, the cycle, amplitude and timing of the seasonal cycle. Similar cyclical models have been used successfully to model lunar cycles of spawning in subtropical crustacea (Courtney et al., 1996).
On the other hand, for simplicity, $p(E_t)$ may be related to the magnitude of a single environmental variable that may be considered to be an index of the main processes of environmental change,

$$p_t = \frac{E_t}{\sum_1^{12} E_t} \quad . \qquad (6)$$

We used an observation error procedure (Punt and Hilborn, 1996) to fit the catch-per-unit-of-effort estimated from the model $\hat{U}_{y,t}$ to the observed catch per unit of effort $U_{y,t}$. This procedure assumes that the model incorporates all factors controlling seasonal changes in biomass, and that the lack of fit between observed and estimated catch per unit of effort is

due to measurement error in the observed catch-per-unit-of-effort. Given that the model considers that annual biomass growth is a random variable, it seems flexible enough to warrant the use of an observation error procedure:

$$U_{y,t} = q\, B_{y,t}\, e^{\eta_{y,t}} \quad , \qquad (7)$$

where q is the catchability coefficient and $\eta_{y,t}$ is the observation error in year y and month t.
Substituting equation (7) into equation (3) leads to,

$$U_{y,t+1} = U_{y,t} + \left(h'(B_{y-1}, E_{y-1})\, p_t - q\, C_t\right) e^{\eta_{y,t}} \quad , \qquad (8)$$

where for convenience we denote $h'(B_{y-1}, E_{y-1})$ as the product of q and $h(B_{y-1}, E_{y-1})$. We then estimated model parameters by maximum likelihood as suggested by Punt and Hilborn (1996).

Log-likelihood profiles were then used to estimate approximate confidence intervals for model parameters. Model error is therefore not considered directly, but this does not mean that it is not an important part of the variance associated with equation (8). In the following section special cases of equation (8) are applied to two real data sets. The models used for each application are chosen to illustrate the general properties of equation (8), and therefore do not represent an attempt at incorporating all the error sources in the estimation process. If alternative formulations of equation (8) were to be considered in a particular application model error would have to be incorporated into the estimation process, possibly through Monte Carlo model selection and/or bootstrapping.

Applications
We now present two case studies of the above seasonal model where the functions $p(t)$ and $h(y)$ have been adapted to fit the particular characteristics of the stock.

a) Gulf of Carpentaria barramundi
The Gulf of Carpentaria barramundi (*Lates calcifer*) fishery in northern Queensland, Australia has pronounced seasonality in catches and catch rate associated with the fish's annual migration when the coastal plains flood. During the wet season the fish migrate inland to colonise the streams and billabongs (seasonal lakes) flooded by the monsoonal rains. At the end of the season, they swim back towards the sea. They are targeted in the estuaries by the gillnet fishery which operates from February to November. Catch rates are highest at the beginning of the fishing season (Griffin, 1997). It is thought the juveniles recruit to the population and adults grow most in weight during the wet season.

This fishery is managed as a unit stock by limited entry and strict gear controls (QFS 2002). All fishers record daily catch and fishing effort data in a compulsory logbook. Monthly data on catch, effort and catch-per-unit-

of-effort for 1981-1996 were obtained from the Queensland Fish Management Authority. These data were fitted to a simple biomass dynamic model where growth in biomass varies seasonally and between years:

$$B_{y,t+1} = B_{y,t} + h(B_y)\, p_t - C_t \quad , \qquad (9)$$

where $h(B_y)$ is the annual biomass growth, considered to be a random variable and where p_t defines the seasonal pattern of biomass growth. Biomass growth was assumed to be constant during the growing season (September to February) and zero at other times,

$$\begin{aligned} &\text{for} \quad 1 \le t \le 2 \text{ and } 8 \le t \le 12 \quad ; \quad p_t = \frac{1}{6} \\ &\text{otherwise} \qquad\quad ; \quad p_t = 0 \quad . \end{aligned} \qquad (10)$$

Equation (8) can be simplified for the barramundi:

$$U_{y,t+1} = U_{y,t} + \left(h'(B_y)\, p_t - qC_t\right) e^{\eta_{y,t}} \quad , \qquad (11)$$

where for convenience we denote $h'(B_y)$ as the product of q and $h(B_y)$.

The barramundi model therefore contains 18 parameters, the $h'(B_y)$ for each year of the time series, q and the initial biomass, $B_{1981,1}$ ($= U_{1981,1}/q$).

b) Brown shrimp fishery of northeastern Brazil

The shrimp fishery of northeastern Brazil harvests a mixed stock comprised of brown shrimp *Penaeus subtilis*, white shrimp *P. schmitti* and sea-bob *Xiphopenaeus kroyeri*. The artisanal and industrial vessels fish between the mouths of the Panaiba river and the border of French Guyana. Most of the catch of *P. subtilis*, the most valuable species, comes from the industrial fishery where it represents 90% of the landings. This species is the focus of this example.

Brown shrimp spend their early lives as juveniles in the rivers, and on migrate to the open sea at the onset of the wet season. The adults found in the marine waters of mud banks outside the river mouths are the main target of the fishing fleet. The commercial vessels are Florida-type shrimp trawlers, most of which are based in Belem, the main fishing port. Landings and catch rates peak at the beginning of the fishing season, when coastal rainfall is highest.

The fishery used to be managed through a limited-entry system and a seasonal closure between December and January. The seasonal closure was recently replaced by a total allowable quota and a closed area off the mouth of the Amazon river. Landing reports detailing catches by commercial category and days at sea are provided by all vessels on return to port. Data on monthly catch and effort for 1991-1994 were obtained

from the *Centro de Pesquisa e Extensao Pesqueira da Regiao Norte do Brasil* (CEPNOR), and monthly rainfall data for Belem were obtained from the Brazilian Institute of Meteorology (Fig. 1).

This data were fitted to a simple biomass dynamic model incorporating seasonal growth in biomass and random growth in annual biomass. Growth in biomass was assumed to follow the monthly rainfall pattern $r_{y,t}$:

$$B_{y,t+1} = B_{y,t} + h(B_y)\, p_{y,t} - C_t \quad ,$$

$$\text{where} \quad p_{y,t} = \frac{r_{y,t}}{\sum_t r_{y,t}} \quad , \qquad (12)$$

and $h(B_y)$ is the annual biomass growth, considered to be a random variable.

To demonstrate how useful this model can be to provide management advice we calculated the effects of extending the seasonal closure in the Brazilian shrimp fishery and estimated historical fishing mortality during the period of our data by the ratio of the catch to the biomass. The resulting time series of fishing mortality was modified only by setting the mortality in February in each year to zero. This new mortality time series was then used together with the estimates of initial biomass and annual biomass growth factors to recalculate the time series of biomass and catch. The difference between observed catches and calculated catches was used as a measure of the effects of increasing the length of the closure to the month of February.
Equation (8) can be simplified for the brown shrimp:

$$\hat{U}_{y,t+1} = U_{y,t} + \left(h'(B_y)\, p_{y,t} - qC_t\right) e^{\eta_{y,t}} \qquad (13)$$

The shrimp model contains 6 parameters, the $h'(B_y)$ for each year of the time series, q and the initial biomass, $B_{1991,1}$ (= $U_{1981,1}/q$).

Results

a) Gulf of Carpentaria barramundi

The model explains 85% of the variation in monthly catch-per-unit-of-effort (Fig. 2), and predicts that the harvestable biomass of the barramundi stock oscillates between 300 and 1200 tons per month (Table 1). The catchability coefficient for one day of gillnet fishing is estimated to be 0.00004. The model seems to explain well the seasonal rate of decrease in catch-per-unit-of-effort for the first 6 years of the time series; however, for the next 10 years it underestimates the seasonal fall in catch per unit of effort. The estimates of annual growth in biomass oscillate between 300 and 900 tons.

The likelihood profiles suggest (Fig. 3) that the initial biomass and catchability are estimated with similar precision because their 95% confidence limits are betwen 0.000038 and 0.000046 for q, and between 700 and 800 tons for biomass.

b) Brown shrimp fishery of northeastern Brazil

The model explains 87% of the variation in monthly catch-per-unit-of-effort (Fig. 4) and predicts that the harvestable biomass of the shrimp stock oscillates between 300 and 1400 tons per month. The catchability coefficient for one day at sea is estimated to be 0.00015. The annual growth in biomass oscillates between 1300 and 3200 tons (Table 1). The likelihood profiles suggest that q is better estimated than the initial biomass (Fig. 4). The 95% confidence limits for the biomass are wide - between 900 and 1600 tons - whereas the same limits for q are between only 0.00012 and 0.00017.

Observed catches during the month of February represent, on average, 4.5% of the annual catch. Eliminating fishing mortality in the month of February for all years and maintaining fishing mortality in all other months to the levels estimated in the biomass model, reduced the predicted annual catch by only 0.3%. This is the result of the larger biomass giving increased catches in the remaining months, partially compensating the loss of February's catch.

Discussion

Biomass dynamic models try to describe the dynamics of stock biomass as a balance between the removal of biomass by harvesting and the growth of stocks. These models track annual changes in biomass by assuming that stock growth is a function of carrying capacity and the stock's annual growth rate. This implicitly assumes that there is a functional dependence between stock size and subsequent recruitment, leading to increases in the relative growth in biomass as the stock is reduced to levels below its virgin biomass. Although modeling the underlying relationship between stock size and recruitment is difficult, especially when only short annual time series are available, it is clear that for most fished stocks recruitment tends to be lower at low spawning stock sizes (Myers and Barrowman, 1996).

Biomass dynamic models do not have to be restricted to describing annual changes in biomass; we have shown that they can describe seasonal dynamics. In theory, these seasonal models can be simple generalizations of the annual model and retain the functional relationship between annual stock growth and stock size. Alternatively they may describe only seasonal dynamics, without attempting to model long-term productivity. The two case studies presented here do the latter, helping us explain how biomass changes within a season, but not giving us any insight in the reasons for changes in the annual growth rates of stocks. We believe this is a useful strategy, since estimates of annual recruitment produced by these models can, when more data become available, be used in "a posteriori" analysis to define relationships with environmental variables or even stock size. However, exploratory analysis of the influence of environmental variables on stock abundance will often lead to a "nominally statistically significant relationship" (Myers, 1998). That is why such relationships should be retested in the future before too much confidence is put on their value to explain the dynamics of stocks.

In the two case studies presented here, we were unable to either estimate or incorporate in the model functional relationships between stock size and recruitment. This limits the usefulness of these models to providing advice on seasonal stock dynamics. No comments can be made on the possible mechanisms that determine the long-term stock fluctuations or the long-term levels of productivity. This is not necessarily a limitation of the models, but rather of the data. In both cases the time series were short (less than 20 years) and did not show large changes in annual average abundance, even if seasonal changes in biomass were large. Under such conditions the data has no information on how the average annual biomass may change as a function of stock size.

Seasonal models are essential to developing appropriate seasonal closure strategies in tropical shrimp trawl fisheries (Die and Watson, 1991; Die and Watson, 1992; Watson et al., 1993; Somers and Wang, 1997). Our seasonal model of brow shrimp predicts that a seasonal closure in February would lead to a small decrease in catch. This effect of the closure is a direct result of the increases in biomass resulting from the cessation of fishing during part of the recruitment period, however, our model did not consider

the effects of effort redistribution which are often associated with the imposition of seasonal closures. These redistribution effects were shown to be significant in the assessment of such closures by Watson et al. (1993) and could be easily incorporated into our model by modifying the fishing mortality time series.

Understanding seasonal dynamics can also be the first step in disentangling the processes that control the annual dynamics of shrimp trawl fisheries. Wang and Die (1996), for instance, used a weekly model to estimate annual recruitment and then establish spawning-stock recruitment relationships for two shrimp stocks. As Haddon (1998) points out, fisheries for short-lived species tend to be "recruitment-driven", and a very large part of the stock biomass disappears every year and is replaced by recruitment. He interprets biomass dynamic models in such case as analogous to stock-recruitment models. Haddon argues that in biomass dynamic models, biomass growth does not have the same meaning as it does in abundance-structured models. In our model, biomass growth is the combination of new individuals joining the fishable population (recruitment) and the change (growth or loss) in biomass of those already present in the population.

After a cohort's biomass reaches its peak it declines even in the absence of fishing. In our model this decline is subsumed in the biomass growth term. Thus the seasonal biomass growth patterns from our model cannot be interpreted as the pattern of recruitment to the fishing grounds. During the months when increases in the biomass of the main cohort are substantial, our monthly biomass growth term will overestimate recruitment, and the converse also applies. This means that the seasonal pattern of biomass growth estimated from our model will have more pronounced peaks than the true pattern of recruitment.

Our model makes some strong assumptions about fishing processes, one being that catchability (the portion of the stock removed by one unit of fishing effort) remains constant between months and between years. There is now clear evidence that catchability changes are more the norm than the exception. Some of these changes can be accounted for by standardising effort by fleet and area factors. In some tropical trawl fisheries, such standardisation has shown that fishing power increases as much as 5% per year (Robins et al., 1998; Bishop et al. 2000), increasing catchability by over 25% in five years. In these fisheries, catchability can also change significantly within a season, and there is a suggestion that catchability may be directly proportional to abundance in some shrimp stocks (Die and Ellis, 1999). Examination of the residuals for both the barramundi and shrimp applications shows that the observed seasonal drop in catch per unit of effort is slightly greater than the drop estimated by the model, suggesting a possible change in catchability.

The three- to four-fold changes in monthly biomass predicted by the fit to the barramundi data cannot be interpreted to represent changes in biomass of the whole stock. Such long-lived species don't normally show such

seasonal changes in biomass because of the presence of many the age groups contributing to the total biomass; instead these changes are more likely to reflect the migration of fish in and out of the fished area and not a real change in the total biomass of the stock. In addition, the fit of the barramundi data underestimates seasonal catch-per-unit-of-effort decreases in the last few years. This may indicate an increase in catchability in recent years, but this does not necessarily invalidate our model. If possible, such changes should be accounted for by standardising fishing effort before using it in the biomass dynamic model. Alternatively additional parameters can be incorporated in the model to account for trends in catchability, provided that the data warrant increasing the model's complexity. Haddon (1998), for example, incorporated a parameter that accounted for an annual increase in catchability in an annual biomass-dynamic model for an Australian prawn trawl fishery.

Rainfall can be a useful indicator of the seasonal environmental changes that affect shrimp fisheries; for example annual rainfall determines recruitment strength in the fishery for *Penaeus merguiensis* in northern Australia (Vance et al., 1985) and the pattern of seasonal abundance in *Penaeus aztecus* in Mexico (Solana-Sansores and Arrreguin-Sanchez, 1992). In Brasil and more recently in northern Australia (AFMA 2002), however, the effect of rainfall on annual shrimp production does not appear to be consistent. Castello and Moller (1978) found a negative correlation and D'Incao (1984) a positive one, between rainfall and catch in the Lagoa dos Patos, Rio Grande do Sul. Most authors agree, however, that the seasonal pattern of rainfall is correlated with the timing of shrimp recruitment, and this is the basis for our seasonal model. Although we did not use lagged terms in our model, using lagged environmental variables is a natural extension of the formulations we propose.

Although the seasonal rainfall patterns successfully explained additional catch-per-unit-of-effort variation in the shrimp data, they did not do so for the barramundi data. A simpler model, incorporating a six month period of constant biomass growth, was not improved by incorporating rainfall information. This result seems to conflict with Griffin's (1997) view that recruitment in barramundi is correlated with the total monsoonal rainfall. It must be remembered, however, that in our model recruitment is only one of the components of biomass growth and that barramundi is a much longer-lived species than the shrimp. Recruitment and somatic growth are dependent on the surviving stock size of several age groups, and it is unlikely that rainfall alone is a good index of all the environmental processes that may affect such a wide range of age groups. What is clear is that the six monthly period chosen for our model does represent a period during which environmental conditions in northern Australia are favorable to both recruitment and somatic growth. This is consistent with what has been observed in other tropical floodplain fishes (Bayley, 1988). Alternatively the linear model incorporating rainfall and biomass growth tested for Barramundi may have been too simple to capture the dynamics of this stock and more complex models that nest environmental and population factors in the biomass growth function may provide a better fit

to the data; e.g. more complex models may have to explicitly incorporate lagged effects between the environmental variables and biomass growth.

In conclusion, we believe that the seasonal biomass models we gave presented are useful in describing seasonal dynamics, especially of short-lived species. If a long time series is available (> 20 years) they can be part of a model with both seasonal and annual dynamics, and can then be used to assess the long-term productivity of fished stocks and can be used to estimate reference points such as MSY. If only short time series are available, they can provide insight into the design of seasonal management measures such as fishing closures.

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TABLE 1: Parameter estimates from monthly biomass dynamic models. Growth in biomass $h'(B)_y$ and the initial biomasses $B_{1981,1}$ $B_{1991,1}$ are in tons. q is the catchability coefficient.

Barramundi fishery in the Gulf of Carpentaria, Northern Australia

	1981	1982	1983	1984	1985	1986	1987	1988
$h'(B)_y$	674	379	757	469	461	515	422	641
	1989	1990	1991	1992	1993	1994	1995	1996
$h'(B)_y$	312	659	298	258	365	422	691	879
q	0.00004	$B_{1981,1}$	752					

Brown shrimp fishery in Northern Brazil

	1991	1992	1993	1994
$h'(B)_y$	1344	2655	3229	2157
q	0.00015	$B_{1991,1}$	1198	

Figures (*Die et al.)*

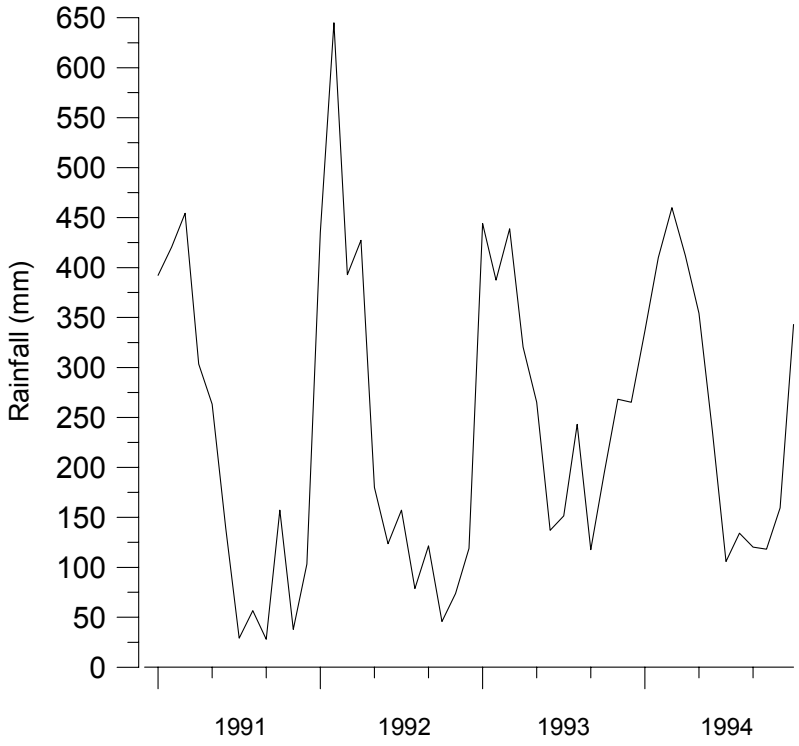

Fig. 1: Monthly rainfall in Belem, Para, Brazil. The monthly proportion of rainfall in a given year is used as P_t in the biomass dynamic model of the brown shrimp fishery.

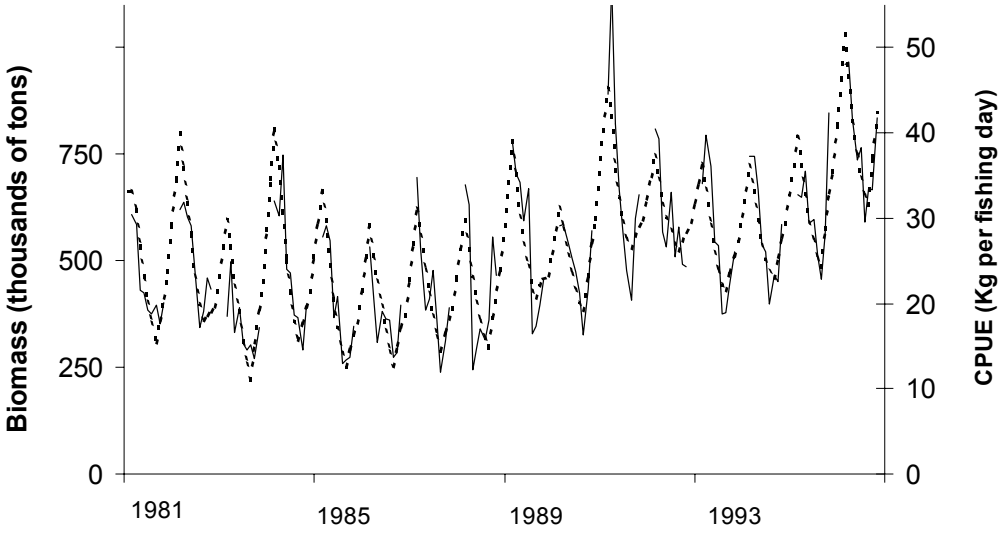

Fig. 2: Observed (full line) catch-per-unit-of-fishing-effort (kg per day) from the Barramundi fishery in the Gulf of Carpentaria, Australia. Dashed line represents the catch-per-unit-of-fishing-effort and the biomass estimated from a monthly biomass dynamic model that assumes that biomass growth only occurs during September to February.

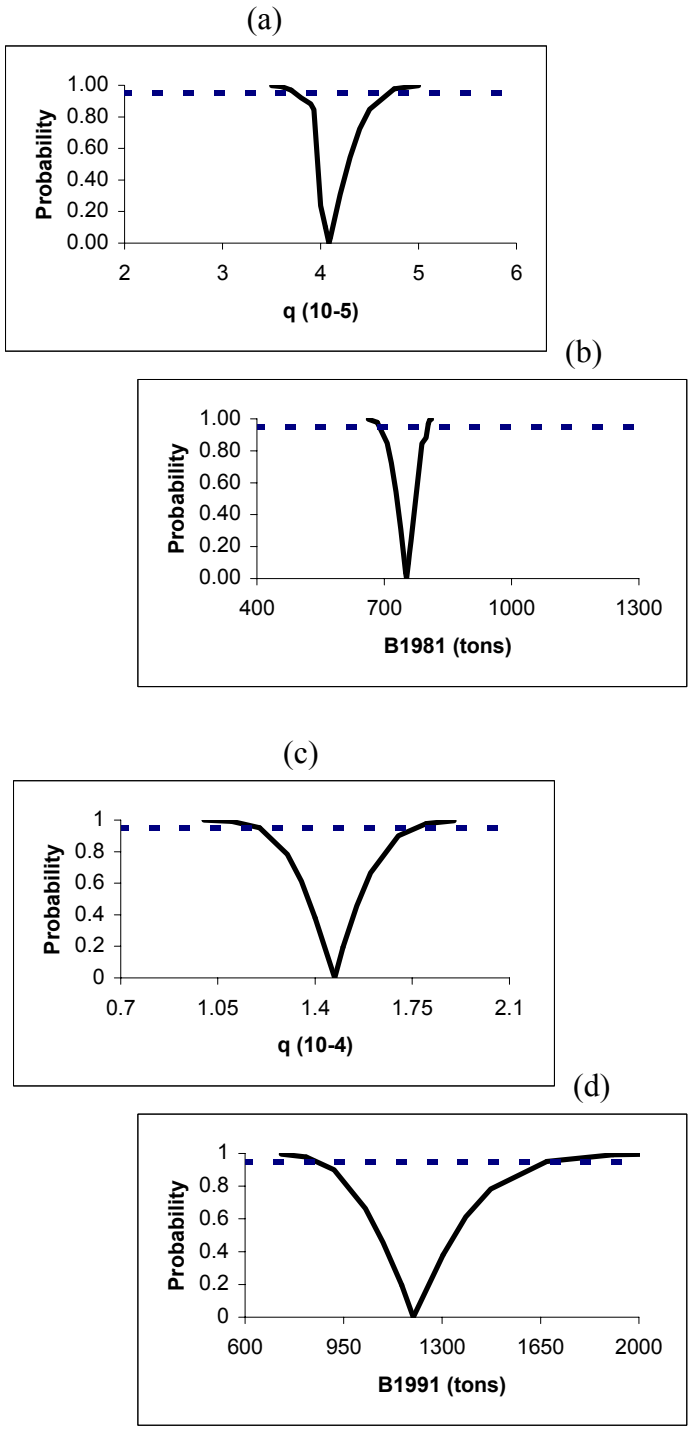

Fig. 3: Likelihood profiles for parameters estimated for biomass dynamic model: (a) barramundi catchability, (b) barramundi initial biomass, (c) shrimp catchability (d) shrimp initial biomass. All graphs are scaled to +/- 50% of the best estimate to allow for comparisons of the precision of different parameter fits. Broken lines represent the 95% confidence limits.

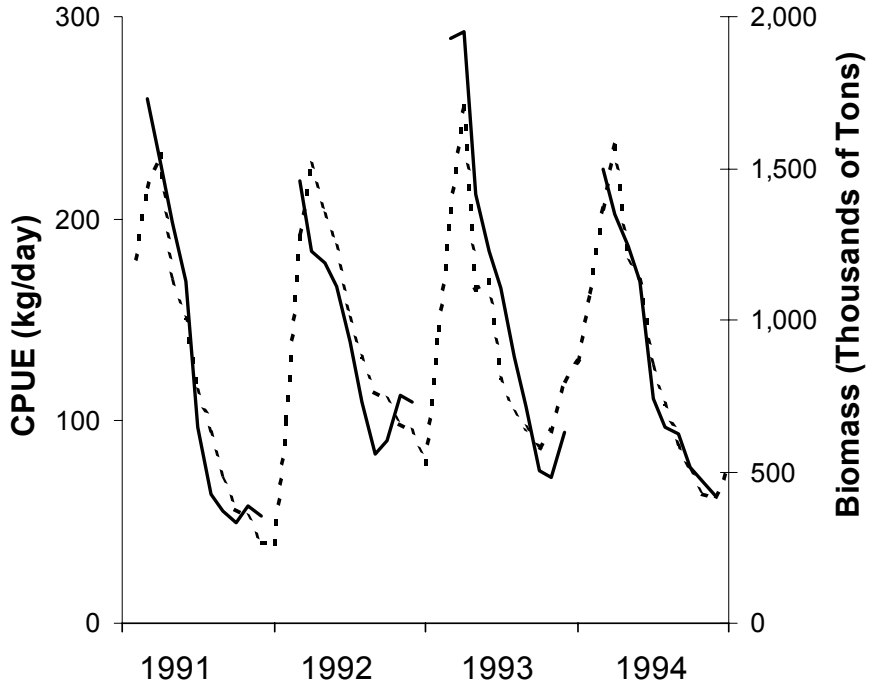

Fig. 4: Observed (full line) catch-per-unit-of-fishing-effort (kg per day) from the Northeastern Brazil shrimp fishery. Dashed line represents the catch-per-unit-of-fishing-effort and biomass estimated from a monthly biomass dynamic model that assumes that the seasonal pattern of biomass growth follows the rainfall pattern in Belem, Para, Brazil.

Appendix 4 (Section 1)
Draft journal article

Fisheries uncertainty: a tropical Australian data-poor fishery

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Abstract

Many fisheries the world over have been managed under data-limited situations with varying success. Unfortunately, and inevitably, this still occurs in many fisheries due to a plethora of factors including the development of new fisheries, lack of monitoring and enforcement resources and vast coastlines with multiple access points to name a few. One example of a data-limited fishery is the commercial inshore gillnet fishery of northern Queensland, Australia. One of the main species taken in the fishery is the king threadfin, *Polydactylus macrochir*. Commercial catch and effort of king threadfin has only been reported since 1988 and trends indicate that they are currently not under threat. Both species however exhibit strong schooling habits and so are prone to rapid stock decline, known as hyperstability. Further, estimation of stock size using models has not been possible. More robust assessments that would minimise this uncertainty are hampered by a number of data issues including limited biological data, no monitoring data, un-validated commercial logbook data with evidence of gross mis-reporting and effort creep. These are the types of characteristics that have led to sudden and dramatic over-exploitation of fished stocks around the world. In a new era of fisheries management and under the guise of the precautionary principle, fisheries managers are adopting a number of different management strategies that are risk averse in data-limited and uncertain situations. We highlight the king threadfin fishery as an example of a data-poor fishery in an assessment poor environment, and provide precautionary options relevant to fisheries faced with challenges similar to those confronted by the Queensland king threadfin fishery in northern Australia.

Introduction

Many fisheries the world over have been managed under data-limited situations with varying success. In developed nations most fisheries are considered to be data-rich due to a long history of operation of fishing fleets and documentation of their harvest performance (eg. Atlantic bluefin tuna – Fromentin 2003). In contrast, there are also data-poor fisheries that still confront fisheries managers due to a plethora of factors including the development of new fisheries (Great Barrier Reef live fish trade - Mapstone et al 2001; Namibia orange roughy – Boyer et al 2001) a lack of resource monitoring and fishery enforcement (Gribble and Robertson, 1998), and vast coastlines with multiple access points to name a few (see Parma et al, 2003).

However, despite having very good time series of catch and effort data, well-developed population models and current biological information most of these fisheries are over-exploited or have already collapsed (Safina, 1995). With such a poor record for even data-rich fisheries, the application of the Precautionary Principle demands managers adopt conservative management strategies. This approach is called for when the level of uncertainty is high, particularly in data-limited situations. Indeed, many of the examples of fisheries failures can be attributed to the perceived need for more information delaying the need for better management (see Walters, 1998). For fisheries where data are poor or lacking (or both) there is an inherent danger that stock collapse is imminent. These situations can no longer be used as an excuse to carry on regardless with the recommendation that more research is required. History tells us that if we wait for that data, we do so at ecological peril. The development in recent years of several management options that are considered risk-averse (New Zealand Ministry of Fisheries 2002) now make it easier for managers to fulfill their responsibility to act appropriately and address concerns of risk and uncertainty in fisheries. This is not to say that the manager's job is an easy one, because the social and economic issues that must be considered in this process (Garcia, 1994) often present conflicting objectives.

In Australia the majority of catch from wild domestic fisheries is exported overseas. The introduction of the Commonwealth of Australia's Environment Protection and Biodiversity Conservation (EPBC) Act 1999 requires that all fisheries that are managed by the Commonwealth or that export their product, are to demonstrate ecological sustainability. Subsequent to the introduction of this Act, stock assessments of target species have been initiated for a number of Australian fisheries, which in some cases represents the first formal assessment of the fishery. We carried out one such assessment on the threadfin (Family Polynemidae) fish stocks, an important component of a valuable multi-species commercial net fishery, in tropical Queensland waters (Welch et al 2002). While undertaking this assessment it became apparent to us that many data deficiencies and uncertainties existed in the available database for the fishery. These uncertainties were circumstances that reportedly preceded fisheries stock collapses for other species elsewhere in the world, suggesting a potential high risk for king threadfin stocks. Further, the ecological relationships among the suite of species taken in the multi-species fishery were unknown, which means that there may also be high risk to other species and possibly to the sustainability of the entire fishery.

What is a data-limited fishery?

In a fisheries context, a 'data-limited' status is not necessarily easily defined. Of course the amount of data available for any one stock or fishery will vary but it is also likely that the perception of what constitutes "data-limited" will also vary. For example, in developed industrialized fishing nations, "data-limited" may mean that there is uncertainty in the stock-recruitment relationship or in the structure of an age-structured model. In other fisheries the term may mean that information about catch, effort, species biology or even the species composition of the catch is lacking. It is also important to evaluate not only data quantity but also data quality. Whitworth et al (2003) state: "*The quality of data should reflect the probability of making a serious management mistake."* While they were referring to the collection of new data it also applies to available or historic data. To provide clarification in terminology and application, we have adopted a standardized definition of what constitutes a data-limited fishery. Restrepo et al (1998) provided some guidance in categorizing fish stocks according to their level of data richness. In this paper we use, and expand upon, their attempt to provide a framework for defining the potential differing levels of data-limitation (Table 1). As noted by Restrepo et al (1998), multi-species fisheries are likely to be of mixed data richness.

The Queensland Gulf of Carpentaria threadfin fishery: an example of a data-limited fishery

In northern Queensland, Australia, the inshore commercial net and recreational line fisheries target many different species on both the east coast and in the Gulf of Carpentaria (GOC). The GOC and the northeast coast represent vast areas that are very remote from human habitation and are largely inaccessible; management of these fisheries is implemented from Brisbane, the state capital, some 2,500 km away. The inshore net fishery is divided into two components: the inner 'N3' fishery which operates in rivers and offshore to a 7 nautical mile limit, and the outer 'N9' fishery which operates in the 7 – 25 nautical mile band (Figure 1). The main target species is the centropomid barramundi, *Lates calcarifer*. The second most valuable catch component in these inshore fisheries is made up of two polynemid species: the king threadfin, *Polydactylus macrochir*, and the fourfingered threadfin, *Eleutheronema tetradactylum*. The threadfins are tropical shallow water species found through most of the Indo-Pacific region predominantly in foreshore areas, but also in coastal rivers and estuaries (Kailola et al 1993). Threadfins share similar tidal habitats with the barramundi, however *L. calcarifer* predominantly occupy coastal rivers and estuaries. Threadfins are highly prized as both table fish and sportfish, and are taken by commercial, recreational and Indigenous fishers. The king threadfin is favoured over the fourfingered threadfin due to its larger size, better eating qualities and market price, and its greater abundance. The Queensland commercial inshore net fishery was recently valued at approximately AU$12M GVP (Williams, 2002) making this a significant contribution to the economy of coastal Queensland. For the purpose of this article we will only discuss the Gulf of Carpentaria king threadfin, due to similarities in the net fisheries issues for both the Queensland northeast coast and the GOC, as well as similarities in the fishery for the two threadfin species.

Biology and Ecology

King threadfin congregate in large schools during the southern hemisphere autumn and spring months in foreshore areas and in tidal flats at the mouths of rivers (Garrett, 2002; Garrett and Williams, 2002). Garrett (1997) estimated maximum size and age of *P. macrochir* in the GOC to be 120.5cm length at caudal fork (LCF) and 14 years.

King threadfin are protandrous hermaphrodites changing sex from male to female during their life cycle. This has important implications for management, as the larger fish, which are predominantly females, need to be retained in the spawning biomass to ensure adequate egg production. Sex change in female king threadfin occurs across a broad size range with length at 50% maturity estimated to be 95.4cm LCF (114.9cm TL), at which size the fish are 6 – 10 years old (Garrett, 1997). This author estimated male king threadfin reached maturity from 28cm LCF (34.7cm TL), but gave no estimate of the size at which 50% of males became mature. Spawning appears to occur during the months of late winter/early spring (Garrett, 1997).

Commercial fishing

The Queensland inshore commercial fishery targets different species depending on factors such as season, market forces and catch rates of individual species. The fishery targets threadfins on a seasonal basis, when they form large schools in foreshore areas. In the GOC, hand hauled set nets have traditionally been used by commercial fishers, however the use of power-assisted net haulers (net reels) is reported to have increased in the fishery by at least 10% since 1998 (S. Peverell, fishery observer, DPI, NFC, pers com, 26 June, 2002).

Compulsory logbook recording of commercial catch and effort has been in effect in Queensland since 1988 however, the first year is considered a learning period and so is not presented. The average annual catch of GOC king threadfin for the period 1989-2002 was 344t and during 2001 and 2002, the total commercial catch of king threadfin from the Gulf of Carpentaria was 463t and 444t respectively. Since 1989 the number of boats reporting catch of threadfins each year in the GOC has ranged from 69 – 96 boats (QFS CFISH database) (Table 2).

It should be noted that records for three vessels in the king threadfin GOC fishery were excluded from the data set due to very dubious records of catch and effort. For example their records showed estimates of consecutive daily catch that would have been physically impossible to process (Jason Stapley, fishery observer, DPI, NFC, pers com). These records only influenced the data for the years 1999, 2000, 2001 and possibly 2002. However, rather than exclude only those years, the records for the vessels concerned were excluded from the entire time series. This decision made a significant impact on the analysis of catch levels. For example, excluding the catch of the three vessels in 2001 decreased the total reported catch of Gulf king threadfin by 39%!

Catch of king threadfin in the GOC was high early in the time series dropping through the early 1990's as effort decreased. Effort has been relatively stable since 1994 at around 4500 fishing days with an increase in 2001 and 2002 to around 5400 days. Catch has increased since 1994 due to an increasing trend in CPUE (Figure 2). Peaks in CPUE in some years (1996, 1998 and 2001) may be due to changes in fishing operations. For example, increased use of net reels by some commercial fishers may have resulted in higher catch rates. Unfortunately, information on gear changes by individual operators is not currently available and so the effect of gear change on catch rates cannot be quantified. Increased targeting of threadfins due to changing market prices may also have contributed to increased catch rates of threadfins in some years.

**Recreational and Indigenous fishing

Threadfins are popular sportfish species and are caught by recreational anglers using hook and line while the Indigenous fishery uses hook and line, nets, traps and spears (Garrett, 1995; Garrett, 2002; Garrett and Williams, 2002). Historical information on catch and effort for both these fishery sectors is extremely limited and a report released in July 2003 provided the first ever estimates of catch in Australia (Henry and Lyle, 2003). However, these authors presented data only for the entire state of Queensland in total numbers and combined for the two species of threadfins: Recreational catch ≈ 103,000 fish per year; Indigenous catch ≈ 12,000 fish per year.

**Research and Monitoring

Fisheries-dependent data have been collected from the GOC commercial fishery since 1988 through compulsory commercial fishing logbooks with daily records of catch and effort. Only recently, fisheries observers have been placed on vessels in the GOC net fishery and the information collected has focused on catch composition and length frequency data. Some catch-per-unit-effort (CPUE) data was also collected from a limited number of vessels for use as a general comparison to logbook records (Gribble et al, in prep). It is planned to include threadfins in a fishery-independent monitoring program (Queensland Department of Primary Industries Long-term monitoring program) to collect size, age and growth information from fished barramundi stocks. Research on threadfins in Australia has documented growth, feeding and reproduction (eg. Stanger, 1974), and age, growth and genetics (Garrett, 1997). It is also intended to include threadfins in the program of biennial recreational fishing surveys in Queensland that estimate annual recreational catch (Jim Higgs, Queensland Fisheries Service, pers com).

**Management

Management decisions for the GOC in the past have been driven by consideration for the main target species only, the barramundi, with little regard for the multi-species nature of the fishery. In 1981, management initiatives were implemented for both the GOC and east coast commercial barramundi fisheries following concerns that stocks were in decline due to increased fishing pressure through the 1970s. The strategies employed effectively included all species taken by the inshore gillnet fishery. For the GOC these strategies included:

- a temporal closure during November, December and January, that banned the taking of barramundi and all river set netting operations during this period,
- no foreshore netting during the seasonal closure,
- restrictions on gill net mesh size and on total gill net length,
- reduction in commercial effort by limited license regimes with entry based on historical and financial involvement as well as demonstration of professional standards of operation,
- compulsory monthly logbook entries of commercial catch and effort, and
- protection of barramundi nursery habitats through area closures.

Since the implementation of these management arrangements, the biomass of barramundi in the GOC has increased annually (Welch et al, 2002a). It is not possible however, to assess the effect of these initiatives on catch and effort for threadfins due to the lack of relevant data for the period before the implementation of the GOC Plan. In 1999, further management measures were implemented in the GOC fishery, including changes to the king threadfin minimum legal size (MLS) and recreational bag limits as well as the negotiation

with industry for spatial closures. Concurrent with buy-back of licenses by government a lower than expected financial contribution to the buy-back scheme has meant that these closures have not been fully implemented, however some foreshore areas have been closed to commercial fishing as part of a re-allocation of the threadfin resource. While there are no obvious effects of the 1999 changes in management on total threadfin catch and effort, in the years after 1999 there was a drop by 20% in the number of vessels reporting catch of king threadfin (Table 1). Detailed spatial and temporal analysis of catch and effort has not been carried out to elucidate the effects, if any, of the implementation of the Plan.

Stock assessments

Stock assessment of Queensland threadfin resources was first attempted in 1997 (Gribble 1998), and then in 2002 (Welch et al 2002). In order to estimate current and past trends in relative biomass of GOC king threadfin, attempts were made to fit different non-equilibrium biomass dynamic models to standardized commercial catch rate data using observation error estimation methods (Haddon 2001). A monthly model developed for barramundi (Die, unpublished data) at a stock assessment workshop (see Gribble, 1998 and Welch *et al*, 2002a) was used with the GOC king threadfin data. The model provided only a very poor fit to the observed data due to strong inter-monthly variability in CPUE. Subsequently, two simple models were used; an annual Schaefer model and an annual Pella & Tomlinson model. Two estimates of the catchability co-efficient, q, were incorporated into the models to attempt to account for the increased efficiency likely to be introduced to the fishery with the increased use of net reels since 1998 (S. Peverell, QFS, NFC, pers com, 2002). In each case, the predicted index of CPUE was unreliable with the resulting estimates of the biological parameters r and K being unrealistic. Estimates of Maximum Sustainable Yield (MSY) and effort corresponding to MSY (E_{msy}) were also highly unrealistic and this is likely to be due to failure of the data rather than the models (Hilborn, 1979). That is, there was not sufficient variability in CPUE and fishing effort to reliably estimate the parameters of the model (Hilborn and Walters, 1992) and therefore stock size.

Uncertainties of the Queensland GOC king threadfin fishery

In Queensland fisheries assessments, commercial CPUE is used as an indicator of trends in the status of a fish stock under the assumption that CPUE is proportional to stock size (Williams, 2002). In the GOC fishery trends in catch, effort and CPUE of king threadfin do not show any signs that would indicate that stocks in the GOC are currently under threat. However, various factors can influence the relationship between catch rate data and the relative abundance of the fished stock. Due to the schooling nature of the species any decline in the abundance of the stocks may not be reflected in changes in CPUE due to the efficiency of targeting individual schools (hyperstability) (Hilborn and Walters 1992). Also, it was reported that an increase in inter-annual variation in the frequency and size of schools on the inshore fishing grounds has recently occurred and that operators now regularly target deeper water offshore populations of adult fish (Williams, 2002). The expansion into new areas in deeper water has been possible through the use of hydraulic net reels and may explain increases in catch in the last two years.

Effort creep may also be a factor affecting catches and catch rates for the GOC inshore net fishery, particularly since 1998, with the introduction of net reels and their uptake by a growing number of operators. Net reels greatly improve the efficiency of fishing activity in two ways: faster automated net retrieval means

more sets can be employed in a given period of time thereby improving catch rates, and product discarding is likely to be significantly decreased. Using net reels, catch rates of over 500 king threadfin per hour/500m net have been recorded in the GOC (Gribble, unpublished data). This equates to approximately 1.5t total weight. The introduction of net reels may increase the proportion of fish that are marketable but the fishing mortality rate will still not be reflected accurately by the reported catch.

Significant discarding of product is reported to occur both at the net and on processing boats due to the tendency of threadfin to die and 'spoil' quickly in the nets from necrosis in the hot (> 30° C) tropical waters. Therefore reported catch is an underestimate of total commercial catch, and by how much is a critical uncertainty. This also means that post-release mortality is likely to be high. Uncertainty also exists in the reported levels of catch and effort because only rudimentary validation of GOC logbook CPUE has been carried out (Gribble, unpublished data). Further, there is compelling evidence that catch reporting by particular vessels has been extremely inflated in some years. With rigid error checking of the logbook database, significant mis-reporting will be revealed. The accuracy of other records, however, cannot be ascertained without proper validation using fisheries observers and/or audits using product receipts. Further, current commercial logbook entry requirements mean that there is no distinction made in recording effort between targeting and incidental catch. That is, current measures of effort are not likely to be proportional to fishing mortality. A further uncertainty exists in recreational and Indigenous catch of GOC king threadfin.

The MLS of 60cm total length (TL) for Gulf king threadfin does not allow 50% of females to spawn at least once before becoming vulnerable to the fishing gear. In particular the larger, older females recruit to the fishery well before the estimated size of 50% female maturity of 114.9cm (TL) (Garrett, 1997). Very few fisheries-independent age and length samples of threadfins have been collected, even for monitoring purposes, and the last dedicated collection program occurred nearly a decade ago (Garrett 1997). Examination of the data set for both threadfin species indicates poor sample sizes in the lower and upper age classes, and from only a small number of samples, genetic work has indicated the possibility of separate sub-stocks within the GOC (Garrett, 1997). This observation, coupled with the species seasonal schooling behavior when they are targeted indicates there is potential risk of localized depletions of sub-stocks. From only preliminary analyses estimation of the size of the GOC threadfin stock has not been possible (Gribble 1998; Welch et al 2002). A summary of these data deficiencies and uncertainties are presented in Table 3.

**Options for the GOC threadfin fishery*

Based on the definitions provided in Table 1, and given the uncertainty in the available data set, we consider that the Queensland GOC king threadfin fishery is data-poor. The uncertainties present in the fishery are many and varied. Individually, each represents a potential risk of rapid stock depletion, but collectively this risk is greatly increased. Such a situation demands the implementation of precautionary management arrangements and the Precautionary Principle would assist managers in doing this. In addressing concerns of the GOC king threadfin fishery, there are two aspects that must be considered. The first is the issue of dealing with the uncertainty in the short term; the second is the issue of data uncertainty over the longer-term. For both scenario's, the range of appropriate options available under the circumstances must be investigated.

Precautionary fishery management options

The high level of uncertainty and the data issues associated with the GOC king threadfin fishery suggest a high risk of detrimental effects to the stock and therefore to the ecosystem. It is under these circumstances that the Precautionary Principle should be applied. In recent years, several different management strategies have been promoted as being risk-averse and suitable for situations of uncertainty. Here we discuss some of these options with particular reference to their suitability for the GOC king threadfins.

***Setting reference points

Setting reference points is a management strategy which has received much attention in recent years. A limit reference point represents an upper (or lower) limit for the safe exploitation of a fished stock while a target reference point represents the level of exploitation that takes into account uncertainty (Caddy and McGarvey, 1996). Under this scenario, the target reference point is determined by the level of precaution deemed to be required in managing the particular stock. This approach could be applied for the GOC king threadfin, with the major limitation being that the only quantitative estimates that could be used as reference points for the fishery involve the use of catch and/or CPUE. However, these variables are notoriously unreliable as fishery indicators and given the uncertainties in the GOC inshore net fishery, their use as reference points in this fishery are likely to be unsuitable.

Quota systems

The use of quota systems has been an increasing trend in recent years. In data-poor fisheries, the quota (Total Allowable Catch - TAC) can be scaled downwards to create a buffer to compensate for uncertainty. The level of scaling can be empirically determined or 'guessed'. Frederick and Peterman (1995), using allowable harvests based on point estimates, used a simulation model to estimate the optimal adjustment and showed that by incorporating uncertainty into the simulations large adjustments to harvest levels are often needed. They also argued against arbitrary adjustments to account for uncertainty. Further, it is likely that an adaptive quota management framework that is highly responsive will perform better in uncertain situations (Sladek Nowlis and Bollerman, 2002). Individual Transferable Quota's (ITQ's) are a preferred approach as they negate the 'race for fish' attitude that can occur with a TAC, but good monitoring procedures need to be in place as ITQ's also encourage under-reporting of catch and high-grading (Hilborn and Walters 1992).

Currently no quota system operates for the GOC king threadfin or any other species taken in the inshore fishery. Quota management systems rely on estimation of MSY or an alternative, and so assessments of stocks need to be more accurate (Walters and Pearse, 1996); however it is likely that we will never be able to reliably estimate stock size even for data-rich fisheries (Walters, 1998). The New Zealand Ministry of Fisheries has developed a conservative strategy for data-limited situations by using a method for determining an alternative to MSY. Maximum Constant Yield (MCY) is defined as "..the maximum constant catch that is estimated to be sustainable.." (New Zealand Ministry of Fisheries, 2002). MCY represents the average catch that can be taken from a stock taking into account the natural variability inherent in the particular stock. As long as the catch is below this range of natural variability it is considered to be sustainable. Caution with the use of MCY should be exercised however as using the MCY strategy at low stock sizes involves high risk because a larger proportion of the stock is being removed. Walters and Pearse (1996) state that with uncertainty, quotas need to be

conservative possibly to the point of cutting economic gain. This would certainly be the case with the GOC king threadfin fishery as the use of the MCY strategy would result in a 46% reduction in current reported commercial catch!

Quota management can be a robust conservative strategy for a data-limited fishery, however implementation and enforcement in such a vast and isolated region as the GOC may make them prohibitive. One solution may be an expansion of the on-board fishery observer program through industry funding.

Spatial and temporal closures

Marine protected areas (MPAs) have been increasingly used globally as a conservation and fisheries management strategy. Many authors advocate MPA's as insurance in situations of persistent uncertainty (eg. Lauck et al 1998). This concept has merit, however it relies on guesswork to some extent as optimal design of MPA's is not fully understood and will likely vary for different species and different fisheries. Several authors recognize this and suggest that MPA's should be implemented in an adaptive management framework (eg. Sainsbury, 1991; Carr and Raimondi, 1999). In a fisheries context, the effectiveness of MPAs has been demonstrated using model simulations. For example, Holland (2003) demonstrated that area closures could increase both the productivity and profitability for the Canadian Georges Bank multispecies groundfish fishery. In real data situations, temporal and spatial closures have been effective in protecting spawning aggregation for red hind in the US Virgin Islands (Beets and Friedlander, 1999) and in maintaining fisheries yield in adjacent fishing grounds (Russ and Alcala, 1996). In the GOC a temporal closure in place during the spawning season of barramundi appears to have contributed to an increase in the stock size of this species (Welch et al 2002a). A number of spatial closures have been implemented in the GOC, however threadfins are mobile schooling species and these areas are currently very small in terms of the available fishing area. Further, they are predominantly located in estuaries and river mouths to ensure protection of barramundi spawning and nursery areas. As part of fishery management programs, to protect king threadfin stocks effectively using MPA's in the GOC, it is likely that several larger foreshore and offshore areas would need to be included, enforcement of these areas guaranteed, and their effectiveness carefully monitored. A precautionary approach to setting up MPA's in the GOC would involve a spatial arrangement of areas covering a representation of different habitat types. As a conservative strategy for short-term management of GOC king threadfin, MPA's are likely to represent the strategy that are the least resource demanding in terms of their implementation. Their effectiveness however is likely to be reliant on the level of enforcement that is imposed (Gribble and Robertson 1998).

Other strategies

Input controls such as those already implemented in the GOC inshore net fishery, although less highlighted in the literature as precautionary measures, can be adjusted to allow for uncertainty. Examples include effort controls such as reductions in net length, changes to mesh sizes, or a reduction in the number of fishing licenses. For the GOC inshore net fishery, effort creep has been identified as a potentially problematic issue. Therefore the banning of net reels may represent a realistic precautionary management option both from an implementation and an enforcement perspective.

Improving future assessments

Data Collection and Data Use

In terms of addressing data issues, it is worth noting that data-limited fisheries often arise because of certain characteristics of the fisheries themselves. Such fisheries may be new or developing, may be of low value, or the cost of data collection may be prohibitive due to the geographic spread and remoteness of the fishing grounds, and a multiplicity of access points. These characteristics are relevant to the GOC king threadfin fishery and therefore it is unlikely that more information will be available in the short term. It may therefore be prudent to make better use of the existing data (Hall, 2003a). For example, the very recent estimates of threadfin catch from the recreational and Indigenous sectors provided by Henry and Lyle (2003) are provided as total numbers of both species grouped together and are for the entire state. Unfortunately these figures are not comparable to the known commercial catch for each threadfin species from the GOC, which is expressed in weight. If we assumed that the proportion of each threadfin species in the catch from the recreational and indigenous sectors can be apportioned similarly to the catch composition in the commercial sector in both the GOC and east coast, and use an estimate of average weight of fish per species, we can derive an estimate of GOC king threadfin catch by weight for these sectors of the fishery. The typical weight of king threadfin specimens taken in the GOC commercial fishery is 3kg (Garrett 1997); applying this value suggests the annual recreational and indigenous harvest would be in the order of 207t.

Industry monitoring and provision of data

Where fishery characteristics make centralized management difficult, Parma et al (2003) advocate working with the fishers so that they are involved at all stages of management including monitoring and enforcement. This puts more ownership back into the fishery and Parma et al (2003) showed this to be an effective approach in South America. The importance of involvement of stakeholders in the processes of management is recognized in Australia as it is compulsory under Australian Commonwealth legislation in the *Fishery Act 1994*. In the GOC the industry has been an active partner in the development of recent management plans. A problem that exists for the GOC is that it is a remote area that is not easily accessed and the fishery has a large number of operators spread over a very large area and several operators are unwilling participants in the management process. In fact, strong evidence exists of some operators mis-reporting catch in the GOC. With any industry-collected data, caution will always need to taken in the used data. However there is potential within the GOC for improved involvement of industry and industry-funded monitoring may be pragmatic.

Data proxies and parameter estimation

Problems with data deficiencies or missing data can be reduced by using information from other studies that can be related to the stock in question. These meta-analyses have provided proxy values or ‘rules of thumb’ techniques for estimating parameters. For example, Hoenig’s (1983) estimator provides an estimate of natural mortality derived using an approximation method that is a function of the longevity of the species. Existing estimates of maximum age for king threadfin (Garrett 1997) could be used to estimate natural mortality for GOC *P. macrochir* using this method. Myers et al (1999) carried out a meta-analysis of stock-recruitment parameters to show that at low population sizes the number of spawners produced by each spawner per year is fairly constant across species. Also, Restrepo et al (1998) summarized possible proxies for MSY-related

parameters for data-moderate or data-poor fisheries. These types of methods for estimating data and parameters could be applied to GOC king threadfin as further assessment methods are employed.

To avoid having to use inadequate data or where data are missing, Hall (2003b) suggests simplifying model assumptions. Another technique he mentions for use in fishery applications are treating missing data as an extra model parameter to be estimated when fitting the model to the available data. The use of any of these techniques requires careful consideration as they may introduce a higher degree of uncertainty than with the original inadequate or even missing data values. Also, the implementation of particular management strategies may negate the need for, and therefore costs of, additional data collection (Whitworth et al 2003). For example, by making an uncommon and/or low value species in a multi-species fishery a 'no-take' species the collecting of data for stock assessment may no longer be required. This type of strategy however is likely to result in increased targeting on other species. These are all simple but probably under-utilized strategies for improving the assessment of data-poor fisheries, and there is certainly scope to apply many of these strategies to future threadfin assessments.

Multi-species considerations

Traditionally, management of multi-species fisheries has relied on species-specific assessments without much consideration of inter-specific relationships and hence the flow-on effects of fishing for particular species. In meeting ESD requirements and the availability of greater computer power, there has been a growing impetus in recent years towards investigating ecosystem-oriented assessment and management, which attempts to account for relationships among target and non-target species (eg. ECOSIM, ECOPATH). Developments of these methods are progressing slowly due to the lack of understanding of these complex relationships among species. Despite the challenges brought by the data-intensive requirements of multi-species approaches, consideration of the effects of fishing on all species groups is now mandatory in Australian fisheries.

An important aspect of the king threadfin salmon fishery in the GOC is the multi-specific nature of the entire inshore net fishery of which it is a component. The species predominantly taken in the inshore net fishery, which operates out to 7 nautical miles, are: barramundi (*L. calcarifer*), king threadfin (*P. macrchir*), and four-fingered threadfin (*E. tetradactylum*), with small quantities of grunter (*Pomadasys kaakan* and *P. argenteus*) and triple tail cod (*Lobotes surinamensis*) (Williams, 2002). A more offshore net fishery, that is licensed separately, also operates in the GOC in the band 7 – 25 nautical miles from shore, targeting tropical shark (~ eight species) and grey mackerel (Broadbarred king mackerel, *Scomberomorus semifasciatus*) (Williams, 2002). The ecological relationships among all these species are not understood and to date have not received consideration. Barramundi in particular also represent an iconic species across northern Australia due to a valuable sportfishing industry, their fine table quality and their significance in indigenous folklore. The ecological consequences of a collapse in GOC king threadfins might affect ecosystem balance and may negatively impact upon barramundi stocks, or stocks of other target species. Another realistic consequence of a collapse in king threadfins would be a shift in effort to other species within the fishery. Currently barramundi stocks are thought to be increasing under current management arrangements (Welch et al 2002a), four-fingered threadfin stocks are considered at high risk due to uncertainty (Welch et al 2002b), and no monitoring or assessment has been undertaken for the other species (Williams 2002). Barramundi are a high trophic level predator, and their increasing numbers could impact on the other target species via recruitment

processes, juvenile and adult predator-prey relationships or competition. It is also possible that increased targeting of alternative species would have negative impacts on those stocks resulting in further negative impacts on the entire net fishery. An example of this has occurred in the adjacent offshore net fishery in the GOC where shark was the main target species until a sudden change in targeting occurred in only the last few years (Williams, 2002). Since then effort has shifted to grey mackerel resulting in very large catches of this species and management concern over the sustainability of these catches (Garrett and Begg 2003). Alternatively, a decline in total catch of any of the other target inshore species may result in increased targeting of king threadfin.

The consequent social and economic effects for the GOC fishery and the GOC community of a collapse in king threadfins are also unknown, and are likely to be significant. The barramundi is a major draw card for sportfishers from around the world for a thriving and valuable sportfish industry in the GOC, of which threadfins are a component.

Development of multi-species approaches are occurring slowly using model simulations. These methods are data-intensive and so far, fishery-specific. Although the potential relationships among species in the GOC are certain to be complex and data-intensive, that does not mean that we should not attempt to consider the interrelationships in assessment for management. Single-species assessments are likely to be the only approach for the present for data-poor fisheries (most fisheries) such as the GOC inshore net fishery. But we can still put assessment of this fishery into a multi-species framework, if only rudimentary. Assuming there are ecological linkages among the species targeted in the GOC (likely), then it is also likely that some basic fishery indicators will also be linked among the species. Such indicators include fisheries-dependent (catch, CPUE) and fishery-independent information (size, age). Even in data-poor fisheries these types of information are already collected or can be collected relatively easily. Fishery-independent data represent the most reliable indicators and such data are not currently available for any species other than barramundi; the inclusion of other inshore species in the monitoring program is an urgent challenge for Queensland fisheries management.

**Conclusions*

Contrary to much of the literature on data-limited fisheries examples this paper highlights a data-limited fishery prior to affirmative management actions. The king threadfin fishery in the multi-species GOC fishery, although having been in operation for over 15 years, is still in an early assessment stage. This is, in part, due to a lack of institutional resources necessary to adequately carry out assessments. The fishery is data poor and, given the level of uncertainty involved, is considered to be at risk. It may well be that, contrary to indications outlined above, king threadfin populations in the GOC are healthy and stable, and clearly without data collection there is no sure way to elucidate the answer to this question. In the absence of information and resources necessary to carry out more formal analyses, precautionary management should be adopted in the short-term until greater certainty in stock levels can be established. However, any long term management arrangements considered for king threadfin should also consider the multi-species nature of the fishery. Care must be taken in this process to ensure appropriate and precautionary management for the GOC inshore net fishery is implemented. This includes consideration of factors that will impact on the effectiveness of implementation, monitoring, as well as the ability of management to reduce exploitation rates.

Longer-term strategies should be developed to improve the data quantity and data quality of threadfins preferably within a risk assessment framework to optimize data collection in a resource-limited management environment. The high

levels of uncertainty however require that implementation of improved data collection, appropriate levels of resource monitoring and precautionary management initiatives be carried out as soon as possible and in a structured way. When carried out against clearly stated and quantifiable objectives simulation modeling is a useful tool in assessing different management strategies under uncertainty (Smith et al 1999; Milner-Gulland et al 2001; Hoyle 2002) and ideally this approach would be used for the GOC. Simulations can also be useful in the whole process for improving data collection and assessments (Restrepo et al, 1998).

Long-term data acquisition on the ecological relationships among targeted species will help the sustainable management of the fishery, however the complexity of such relationships means that management for sustainability must proceed for the moment in the absence of this knowledge. In Australia the Commonwealth EPBC Act is promoting ecosystem-based management, and since many of Australia's fisheries can be considered data-poor, this approach may be prohibitive. It is more likely that simple alternatives for assessment and management will be the only option for data-poor multi-species fisheries and these alternatives should be explored and adopted to the greatest extent possible. Ultimately, these types of techniques will improve the success of achieving the goal of sustainability in our fisheries, under what are usually resource-limited conditions.

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Table 1. Fishery attributes used to define fisheries based on their data availability (and data quality).

	Data-rich	Data-moderate	Data-poor
Reliable MSY-related quantities	Yes	limited	No
Stock size estimate	Yes	Yes	No
Control rules	F_{msy}, B_{msy}, etc	$F_{35\%}$, $B_{35\%}$, proxies, etc	M, average catch, etc
Stock assessments	sophisticated	Simple - sophisticated	minimal
Uncertainty	Accounted for	Reasonable characterization	Qualitative
Life history characteristics	Yes	Yes	Unreliable or limited
Fishery parameters (eg. selectivity, fishing mortality)	Yes	Yes	Unreliable or limited
Fishery-dependent data (eg. logbook catch & effort)	Yes	Yes	Unreliable or limited
Fishery-independent data (eg. Monitoring)	Yes	Available or limited	No
Data time series	>20 years	Generally >20 years	Generally <20 years
Data quality	High	High-moderate	Moderate-poor

Table 2. Number of vessels and associated catch (tonnes) that reported landings of king threadfin from the GOC for the years 1989 – 2002 (Source: QFS CFISH database).

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Number of vessels	96	94	87	76	91	84	85	84	87	92	95	76	87	83
Catch (t)King threadfin	306	435	477	389	333	218	248	286	241	330	346	305	463	444

Table 3. Summary of data issues associated with the Queensland GOC king threadfin fishery.

Fishery information	Known situation
CPUE stability	Targeting of schools and expansion of fishing grounds
Effort creep	Apparent through gear technology improvements
Discarding	Reported to be high – no estimates
Post-release mortality	Likely to be high
Logbook reporting requirements	Lack of detail – CPUE estimates dubious
Commercial logbook data	Rudimentary validation
Mis-reporting of catch	Apparent
Recreational catch	Unknown
Indigenous catch	Unknown
Minimum legal size	Too small based on limited maturity data
Fisheries independent monitoring data	None
Age and growth	Out-dated and poorly understood
Genetic sub-stocks	Possible localized depletion
Stock size	Unknown

Appendix 5a (Section 2)

Gulf of Carpentaria Inshore Fishery

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Barramundi: Preliminary analysis of catch and effort data

The catch and effort logbooks indicate a significant and steady decline in Barramundi catch from 730 tonnes in 1981 to 412 tonnes in 1995 (y = 718 - 26x, r^2 = 0.7919, n = 15). The minimum annual production was 336 tonnes in 1992 and the maximum annual catch was 756 tonnes in 1982. The general decline was punctuated by minor peaks in 1984, 1989 and 1991 at 661, 520 and 502 tonnes respectively.

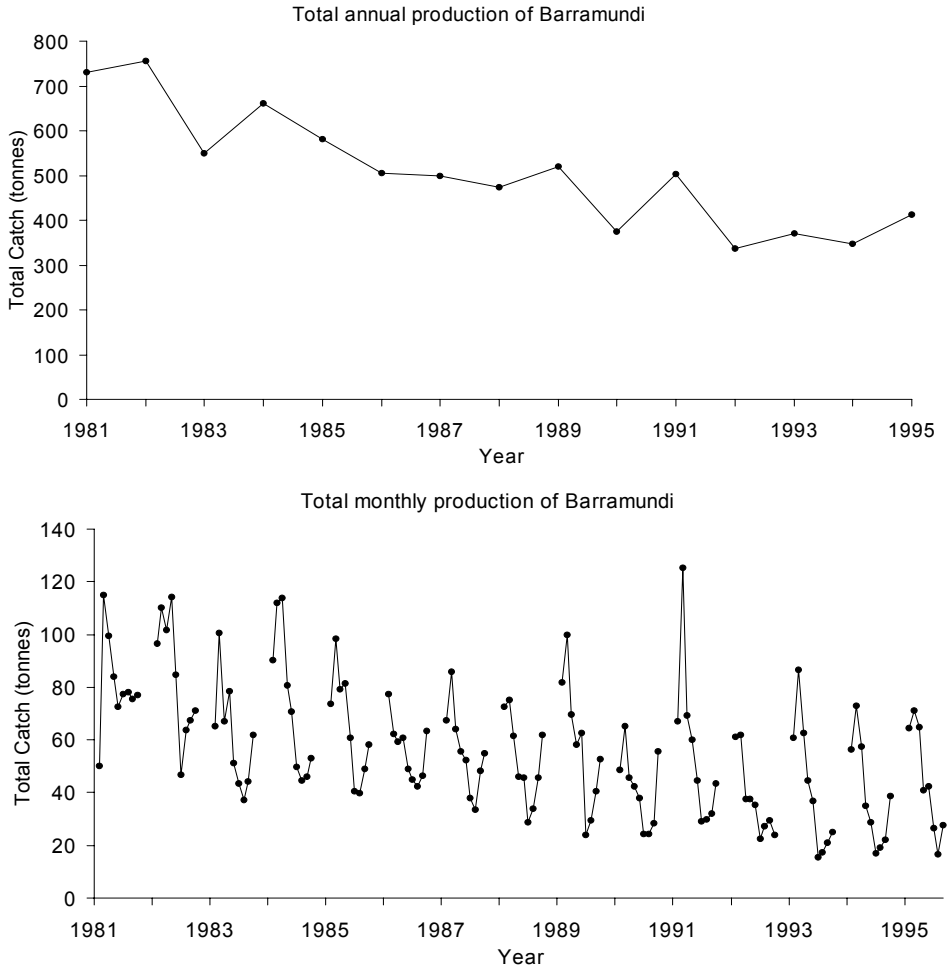

Figure 1: Annual production (tonnes) of Barramundi (*Lates calcarifer*) in the Gulf of Carpentaria from 1981 to 1995.

The monthly catches within each year indicate similar patterns with higher total catch during March and April (Table 1 and Figure 1). Barramundi are usually taken in greater quantities during this time of the year because they are still frequenting estuaries and coastal foreshores after the spawning season. The decreased catch during the winter months occurs when Barramundi have dispersed from these areas and have reduced catchability. There is an increase in the Barramundi catch during September and October when they commence to aggregate for spawning.

The catch and effort logbooks indicate a significant and steady decline in effort from 19 644 boat days in 1981 to 11 552 boat days in 1995 (Figure 2

y = 20.805 - 0.781y, r^2 = 0.8901, n = 15). Although the total annual effort has fluctuated with minor peaks in 1983 and 1986 at 19 708 and 17 497 boat days respectively, the total annual effort has fallen as low as 9 138 boat days in 1992 (Table 1).

The monthly effort within each year indicate similar patterns where the total effort is highest during March and April. However, the decline in effort during the winter months was not as dramatic as the decline observed in catch. This is likely because fishers are able to offset declining Barramundi availability by catching other species (Tables 3, 4 and 5). There was a slight increase in effort during September and October when Barramundi are beginning to aggregate for the spawning. The total monthly effort for each year is listed in the Table 1.

Table 1: Total annual Barramundi catch (kg) and effort from total number of boat days, total number of boats and average number of days fished per boat for each year.

Year	Total catch	Total days	Number of boats	Days per boat
1981	729 588	19 644	132	149
1982	756 230	19 543	120	163
1983	549 767	19 708	114	173
1984	661 057	17 553	104	169
1985	581 084	16 491	96	172
1986	506 190	17 497	98	179
1987	499 888	15 846	104	152
1988	473 866	14 294	104	137
1989	519 844	12 742	107	119
1990	375 670	12 167	97	125
1991	502 244	10 652	89	120
1992	336 516	9 138	84	109
1993	370 472	10 519	93	113
1994	347 721	11 025	93	119
1995	412 088	11 552	91	127

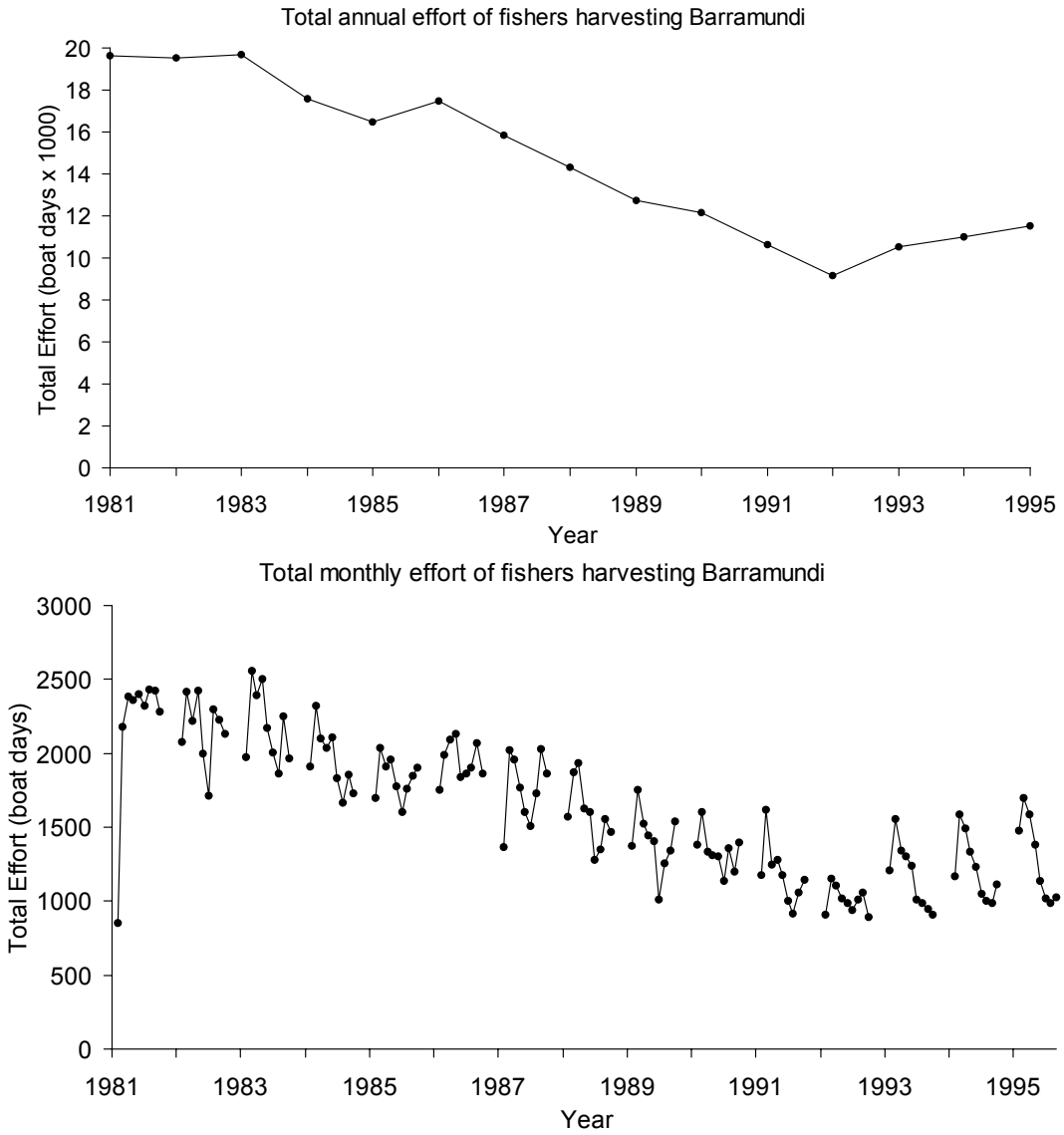

Figure 2: Total annual effort (boat days) for Barramundi fishers in the Gulf of Carpentaria from 1981 to 1995.

An important assumption in using the number of boat days as a measure of effort is that individual boats are fishing with similar intensity in any given year. This assumption can be evaluated by comparing the number of boats and the average number of days per boat among years. The total number of boats operating each year was highest at 132 boats in 1981 and declined to 91 boats in 1995 (Table 1). The lowest number of boats operating in the fishery occurred in 1992 when only 84 boats were recorded. There was an average of 75 boats operating in any one month during the 15 years of logbook recording. The most boats to operate in any month occurred in June 1981 when 110 boats lodged returns. The number of boats operating in a month was lowest at 49 in October 1992.

The average number of days fished per boat for each month over the 15 years are given in the Table 9. There appears to be similar levels of effort in terms of the average number of days fished per boat per month excluding the three months of November, December and January which constitute the annual closed season. Although the numbers of days fished

prior to 1989 appears higher than in the later seven years, this is probably a result of the differences between the historic and current databases (monthly versus daily returns). However, the minimum and maximum average number of days fished per boat per month over the 15 years were 15 and 27 respectively. This indicates boats were fishing for a similar number of days during each calendar month of the Barramundi fishing season. Boats can be assumed to be operating with relatively similar levels of fishing effort in terms of the number of days fished per month which justifies the use of boat days as a measure of fishing effort.

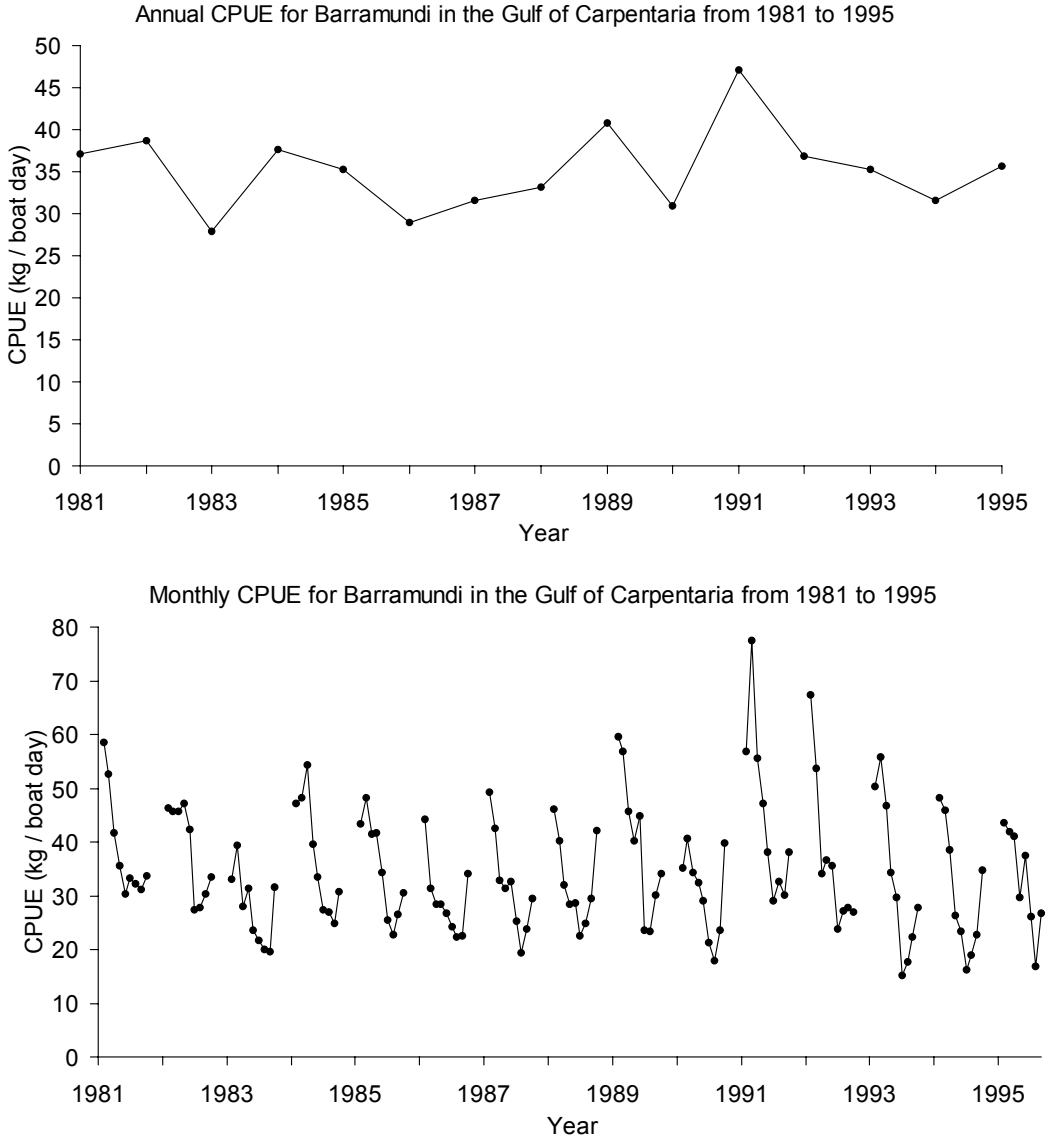

Figure 3: Annual CPUE (kg / boat day) for Barramundi in the Gulf of Carpentaria from 1981 to 1995.

There were some catches of Barramundi during November, December and January, which normally constitute the annual closed season. However, the maximum catch for any month between November to January was 3 tonnes Table 6. This catch was associated with a collective 100 boat days Table 7 from four boats, Table 8. The catch and effort during November to January

were much lower compared with the remaining nine months. The catches in November and January may have resulted from the closed season beginning or ending within those months; the dates of the closed season have changed from year to year. Alternatively, incorrect dates may have been recorded on the logsheets. The numbers of boats and days fished during November to January were higher from 1988 to 1995. During these months and years, the effort was extracted for all set net fishing irrespective of whether Barramundi was caught and it was likely that species other than Barramundi were being targeted (Tables 3, 4 and 5). However, the total catch for all months was included in the annual totals, but the catches for November to January were not included in the monthly time series.

The CPUE appears to have remained relatively stable over the 15 year period from 1981 to 1995 (Figure 3). The CPUE was 37 kg / boat day in 1981 and was virtually unchanged at 36 kg / boat day in 1995. The CPUE reached minor peaks in 1982, 1984 and 1989 at 39, 38 and 41 kg / boat day respectively, and was highest at 47 kg / boat day in 1991. CPUE decreased to lower values in 1983 (28 kg / boat day), 1988 (33), 1990 (31) and 1994 (32). The highest monthly CPUE was usually observed at the beginning of the fishing season. This higher CPUE is due in part to the greater seasonal availability of Barramundi at this time, the seasonal rains allowing recruitment of fish from river habitats and the seasonal closure from November to January. CPUE increases at the end of the year, following lower catches in the middle of the year and the aggregating behaviour of Barramundi at this time of the year.

Comparison of catch and effort among grids

The Gulf of Carpentaria was divided into statistical grids for the voluntary and compulsory catch-effort logbook programs (Figure 10 and 11).

Grid C was the most significant area in the Gulf of Carpentaria in terms of total Barramundi production, producing 4 146 tonnes from 1981 to 1995. This was 54 % of the total production from the Gulf over the 15 year period. Lower total catches were observed in grids B, D and A with 2 276, 1 017 and 184 tonnes respectively. However, the proportion of catches varied from year to year among grids. A comparison of the total annual Barramundi catch is given in Figure 4. The most productive area, Grid C near Karumba, produced 58 % of the annual total in 1981 (422 tonnes) and 61 % of the total annual production in 1995 (250 tonnes). However, production in Grid C declined to 153 tonnes in 1993, which was only 41 % of the annual total for that year. Grid B was the second most productive grid with total annual catches ranging from 258 tonnes in 1982 to 78 tonnes in 1992. These catches were 34 and 23 % respectively of the annual totals in these years. Grid D contributed less than 20 % of the total production of Barramundi in any given year. The total annual catch in Grid D ranged from 120 to 29 tonnes, in 1984 and 1989 respectively, which were 18 and 6 % of the annual totals for those years. Grid A produced less than 6 % of

the annual totals for each year and production ranged from 32 tonnes in 1987 to two tonnes in 1989. Nil production was reported for Grid A in 1990 and 1991.

Closer examination of the monthly rainfall, production, effort and CPUE for Grid C, near Karumba, is given in Figure 5. Heavy rainfall occurred during the closed season in 1991 after nine years of lower rainfall. The rainfall effectively increased the catch by driving fish out of the river systems, making available many more fish for harvest. The effect of the flooding seemed to last only two to three months and the catches were down to the levels of previous years by May. The 1991 rainfall may have been responsible for the increase in catch at the beginning of the 1992 year with the inclusion of small fish flushed out during the previous wet season. However, there was no similar explanation for the high catch in Grid C during 1989.

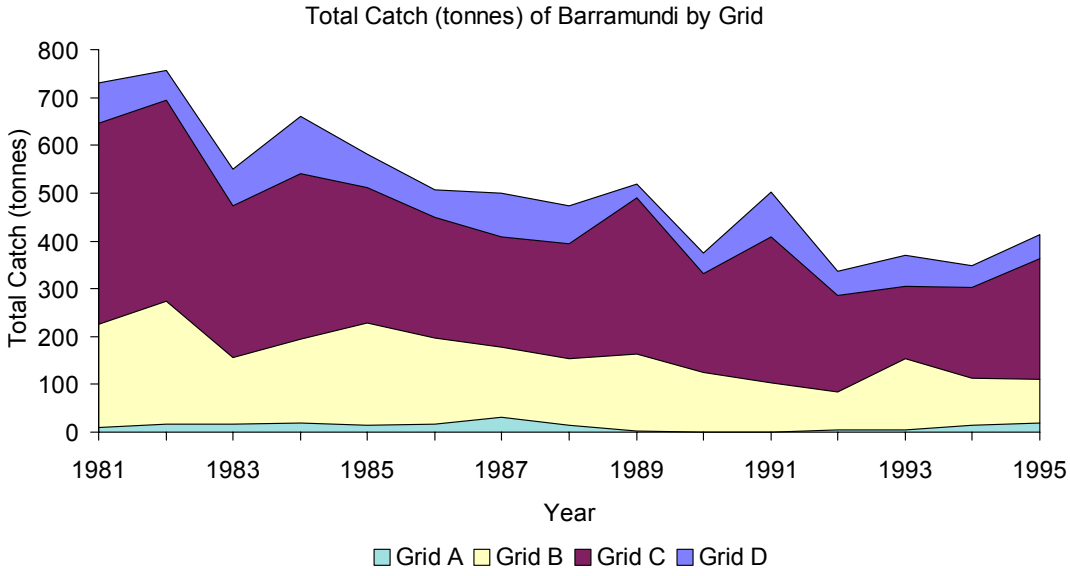

Figure 4: Comparison of the annual production (tonnes) of Barramundi among four spatial grids from the Gulf of Carpentaria from 1981 to 1995.

The total annual rainfall, Barramundi production, effort and CPUE are given for each grid in the Summary Figure and Tables (Grid A, Figure 12; Grid B, Figure 13; Grid C, Figure 14; and Grid D, Figure 15). The high rainfall from Grid C observed in 1991 did not occur throughout the Gulf. Therefore, the effect of rainfall on stocks appears to be localised and may depend on the amount and timing of rainfall. The impact will be further influenced by behaviour of the stocks, such as the release of landlocked Barramundi recruiting into the fishery and the location of fish aggregations. Heavy rainfall associated with cyclone activity, wind and river run-off can decrease fishing effort and catchability of the fish.

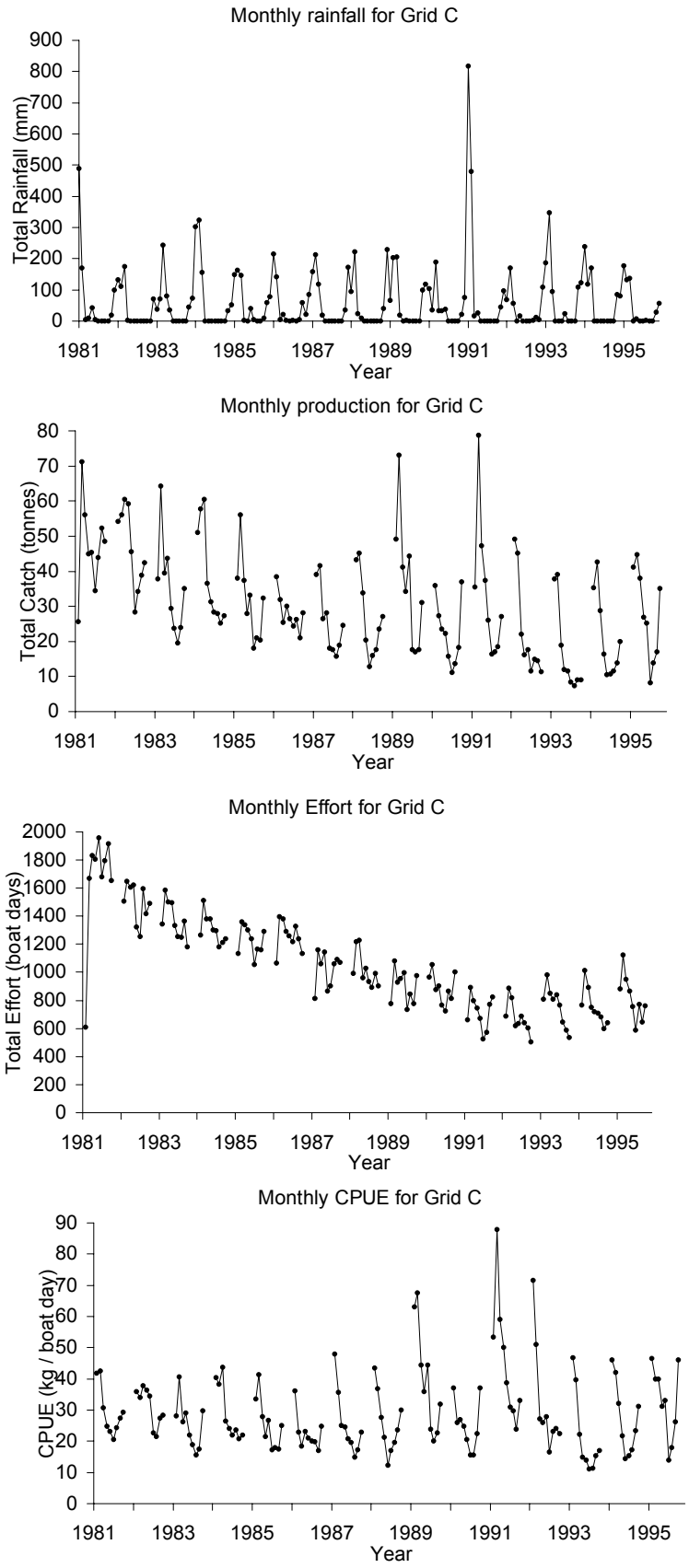

Figure 5: Monthly rainfall (mm), production of Barramundi (tonnes), effort (boat days) and CPUE (kg / boat day) in Grid C, near Karumba, in the Gulf of Carpentaria from 1981 to 1995.

Mud crab: Preliminary analysis of catch and effort data

The catch and effort logbooks indicate an increase in the total annual mud crab catch from 389 kg in 1981 to 55 tonnes in 1995 (Figure 6). The total annual production has fluctuated markedly between 2 tonnes in 1988 and 58 tonnes in 1995. The total annual catch, however, has remained above 20 tonnes from 1989 to 1995 (Table 2). The total catches from records where pot information was available closely approximated the combined catch of mud crab from pots and where the effort was not identified.

The monthly catches within each year indicate similar patterns where the total catch was highest during the winter months (Figure 6 and Table 10). The average mud crab catch was highest for May, June and October at 2 921, 2 724 and 2 700 kg respectively. The highest monthly catches of mud crab were recorded in October 1985 (12 382 kg) and May 1995 (10 215). Lower average catches of 470 and 323 kg were observed during December and January. The monthly mud crab catches for each year from 1981 to 1995 are listed in Table 10.

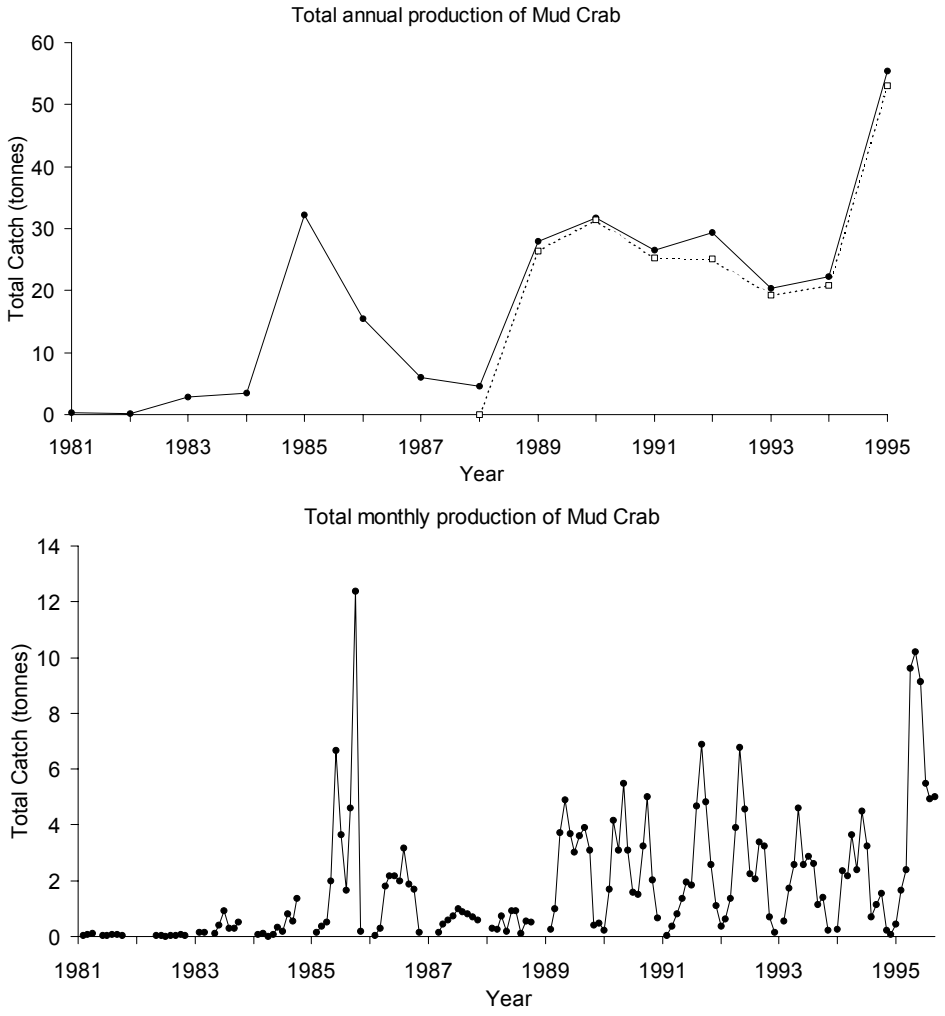

Figure 6: Annual production (tonnes) of mud crab *(Scylla serrata)* in the Gulf of Carpentaria from 1981 to 1995. The dotted line indicates data associated with pot information.

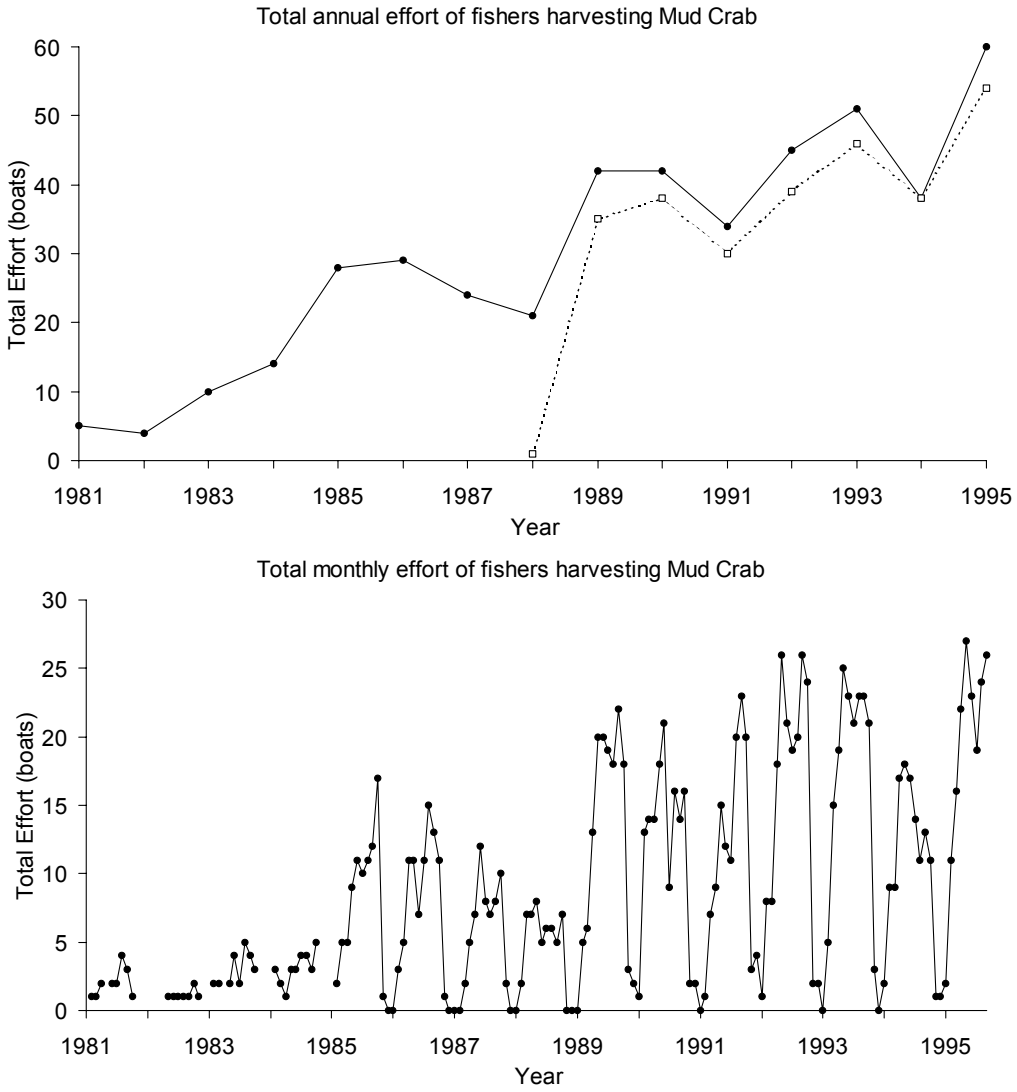

Figure 7: Total annual effort (number of boats) for mud crab in the Gulf of Carpentaria from 1981 to 1995. The dotted line indicates data associated with pot information.

The reporting of mud crab was not a mandatory requirement in the Barramundi / Set Gillnet Production Returns from 1981 to 1988. Fishers voluntarily listed mud crab and associated catches. Consequently, the reported catch of mud crab may not reflect the true catch of mud crab in the years prior to 1989. For example, the annual total mud crab catch is extremely low in 1981 and 1982 (Table 2), the first two years of the Barramundi / Set Gillnet Production Returns.

The number of boat days was not an appropriate measure of fishing effort for mud crab. The historic database has recorded days fishing in association with the Set Net Fishery. Mud crab catches from pots were recorded but the pot information was not required in the logbook at the time. The current database, however, contains individual records on potting activity, including the number of pots and pot lifts. The only standard measure of effort between the historic and current database was the total number of boats that recorded mud crab catches in any given year. There was a significant and steady increase in the total number of boats from five boats in 1981 to 60 boats in 1995 (Figure 7, $y = 1.8 + 3.5x$, $r^2 = 0.8548$, $n = 15$). The number of boats recording potting information closely

approximates the total number of boats that were reporting mud crab from 1989 to 1995. Therefore, the total catches of mud crab can be represented from the data associated with pot information from 1989 onwards.

The monthly crabbing effort in each year follows a similar pattern where the total effort was highest during the winter months (Figure 7 and Table 11). An average of 10 to 12 boats recorded mud crab during the winter months between April and October (Table 11). The average number of boats recording mud crab was less in February (5 boats) and March (6 boats) when fishers were more likely to be concentrating their fishing effort on catching Barramundi. The most number of boats reporting mud crab in any one month was 26 boats in both May 1992 and September 1994.

Table 2: Total annual mud crab catch (kg) and effort from total number of boat days, total number of boats and average number of days fished per boat for each year.

Year	Total catch	Total days	Number of boats	Days per boat
1981	389	314	5	63
1982	198	186	4	46
1983	2 804	409	10	41
1984	3 460	492	14	35
1985	32 160	1 650	28	59
1986	15 398	1 838	29	63
1987	5 935	981	24	41
1988	4 525	889	21	42
1989	28 008	9 544	42	227
1990	31 814	9 670	42	230
1991	26 472	5 821	34	171
1992	29 383	7 069	45	157
1993	20 321	8 622	51	169
1994	22 232	6 538	38	172
1995	55 424	10 663	60	178

An important assumption in using the number of boats as a measure of effort is that individual boats were fishing with similar intensity for any given month in any given year. However, this was likely to be untrue as the average number of days fished per boat increased dramatically from 63 days per boat in 1981 to 178 days per boat in 1995 (Table 2). A minimum of 35 days per boat was recorded in 1984 and the maximum of 230 days per boat in 1990. This indicates boats were fishing with different intensity in terms of the number of fishing days in any given year. Therefore, the number of boats was not an appropriate measure of effort. The implication of this finding is that analysis of catch and effort is more appropriate using

just the detailed potting data available from 1989 to 1995.

The total annual catch of mud crab associated with potting activity was relatively stable between 1989 and 1994, at 26 and 21 tonnes respectively (Figure 8). There was a dramatic increase to 53 tonnes in 1995. The total number of pots, as a measure of fishing effort, followed the total catch, with stable effort from 1989 (51 097 pots) to 1994 (49 024) and an increase to 94 951 pots in 1995. CPUE appears to be declining over the period from 0.62 kg / pot in 1990 to 0.35 kg / pot in 1993. These values represent both the maximum and minimum respectively from the seven years of data. CPUE begins to increase in 1993 and reaches 0.56 kg / pot in 1995. The increase in CPUE may indicate an increase in stock abundance, or fishers were targeting previously unknown mud crab populations. This can be investigated by observing the catch and effort data from the four grids.

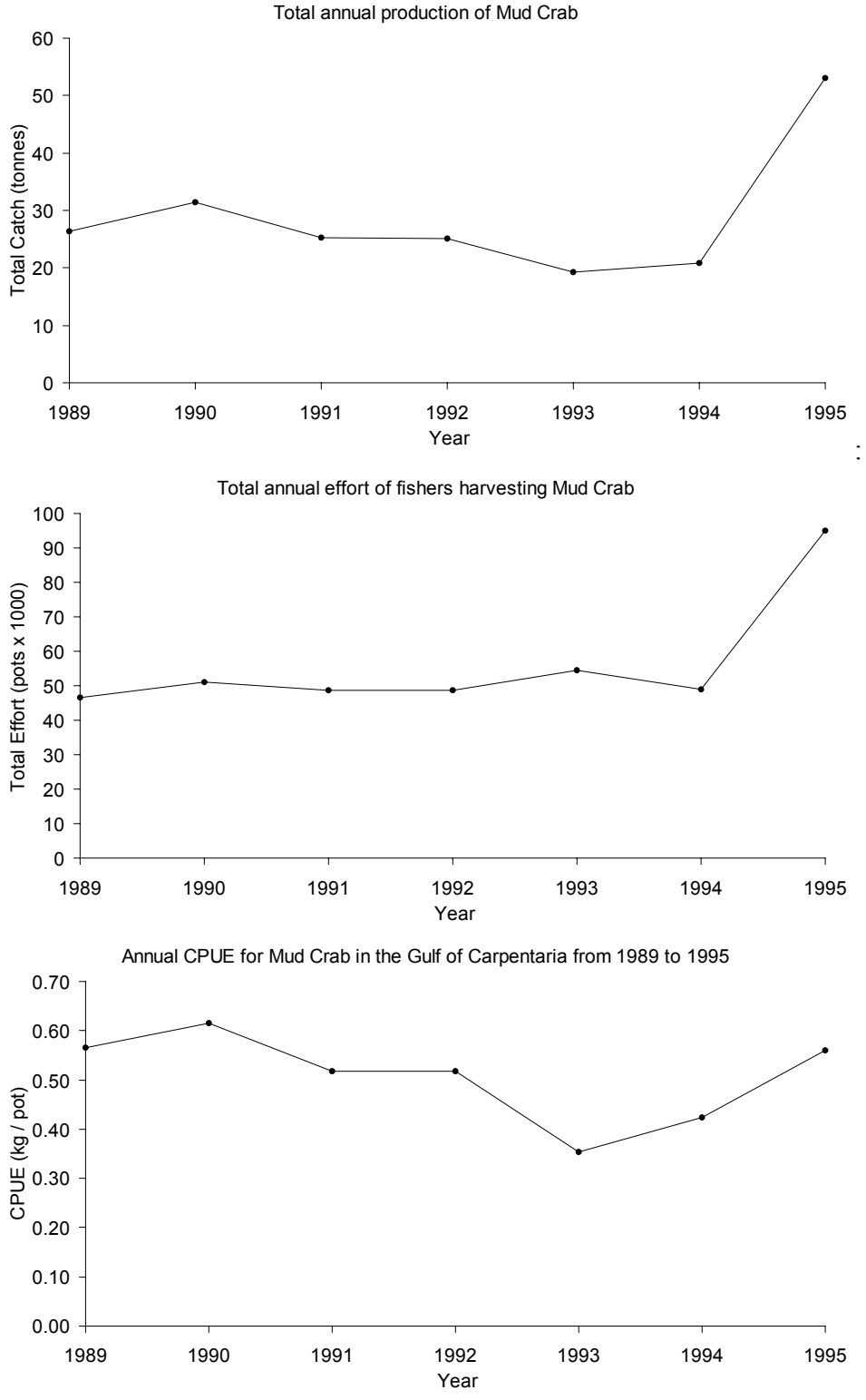

Figure 8: Annual production (tonnes), effort (pots x 1000) and CPUE (kg / pot) for mud crab in the Gulf of Carpentaria from 1989 to 1995.

Comparison of catch and effort among grids

The Gulf of Carpentaria was divided into statistical grids for the voluntary and compulsory catch-effort logbook programs (Figure 10 and 11).

The highest total catch of mud crab was observed in Grid C with 187 tonnes, which was 68 % of the total production from all grids over the 15 year period. Lower total catches were observed in Grids A, B and D with 45, 32 and 10 tonnes respectively. The annual catches, however, varied among the four grids (Figure 9). The most productive area, Grid C near Karumba, produced a maximum of 32 tonnes in 1985, which was above 99 % of the annual total for that year (Table 2). Grid C produced over 50 % of the annual total catch for all years except 1991 and 1995. The recorded catches for 1991 and 1995 in Grid C were 11 and 20 tonnes, which were 47 and 36 % of the total Gulf production for those years. Although, the annual catch from Grid A was lower then 6 tonnes prior to 1995, Grid A produced 33 tonnes in 1995 which was 60 % of the total annual Gulf catch for that year.

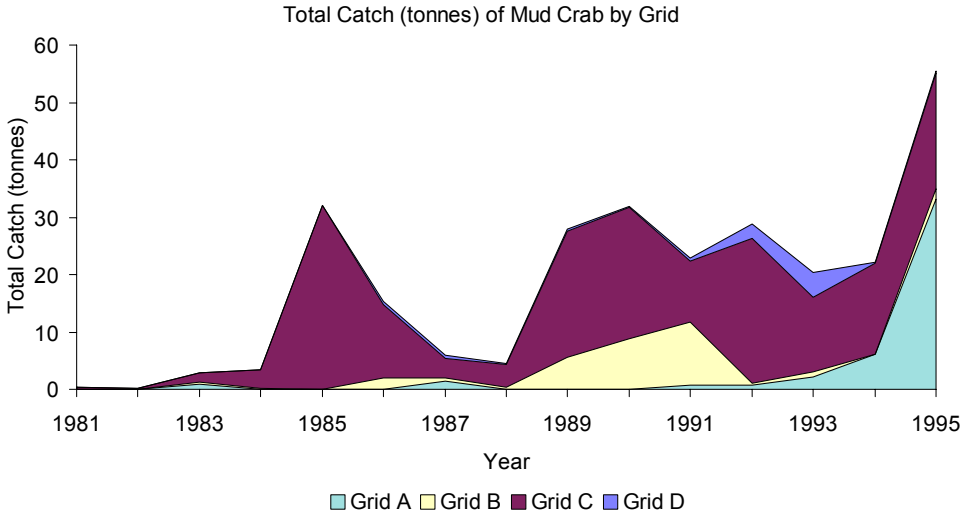

Figure 9: Comparison of the annual production (tonnes) of mud crab among four spatial grids from the Gulf of Carpentaria from 1981 to 1995.

The total annual rainfall, mud crab production, effort and CPUE are given for each grid in the Summary Figures and Tables (Grid A, Figure 16; Grid B, Figure 17; and Grid C, Figure 18). Closer examination of the monthly rainfall, production, effort and CPUE for each grid indicates a large variability in the catch and effort among years. There was a high correlation between the catch and effort in each grid. High catches accompanied high levels of effort, although whether catch or effort determined the relationship could not be concluded. CPUE follows different trends among the four grids. There was an increasing CPUE in Grid A, a relatively stable CPUE in Grid C, and CPUE decreased in Grids B and D. A decline or increase in CPUE may reflect changes in mud crab

abundance. However, as the distribution of mud crab is patchy and animals are concentrated in certain habitats, the patterns observed here may also reflect the efficiency of fishers to target the aggregations. Misleading CPUE may result from very low levels of catch and effort because they may not accurately reflect the whole population. A large sample size is usually required when sampling sparsely distributed populations, and the number of fishers reporting mud crab in some grids (such as grids B and D) may be insufficient to accurately reflect stock abundance.

SUMMARY FIGURES AND TABLES FOR THE GULF.

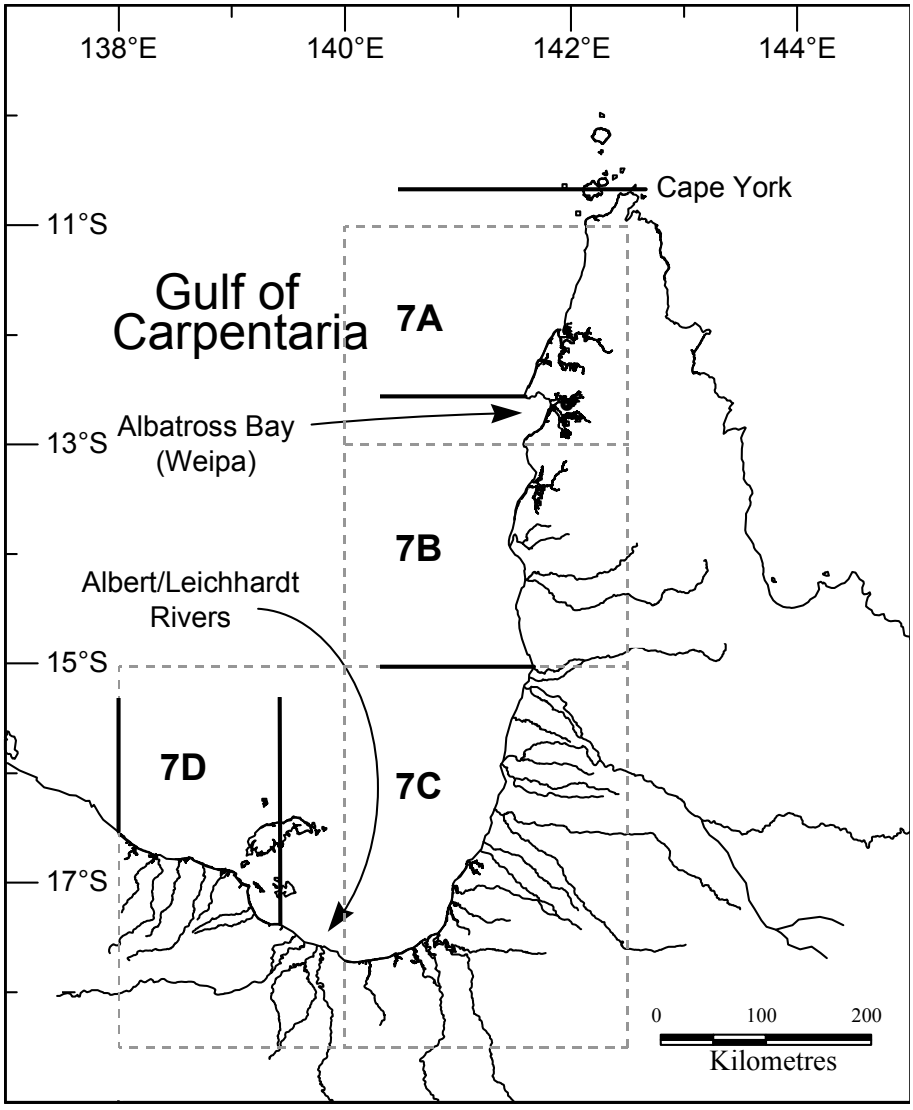

Figure 10: Map of the Gulf of Carpentaria showing the boundaries used in the GN01 Logbook between 1981 and 1982 (solid lines). The dotted lines represent the four grids used for this report.

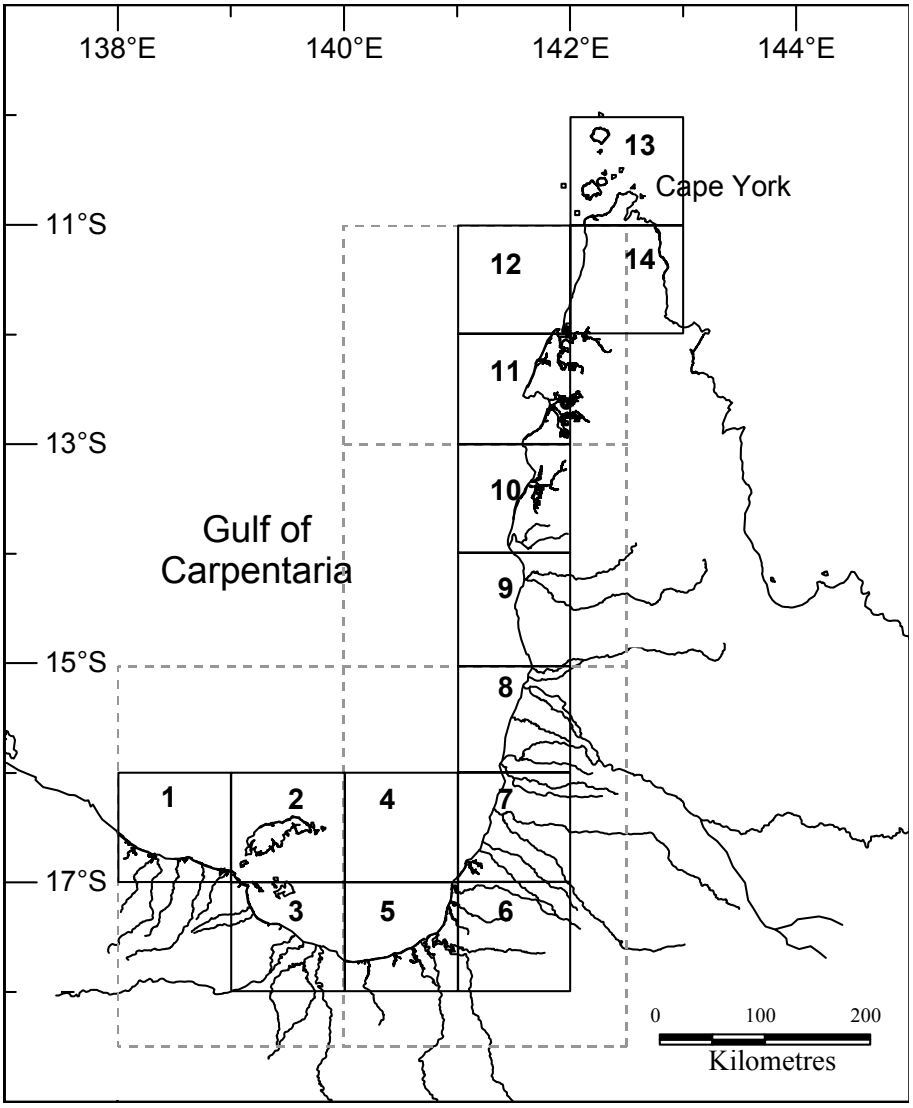

Figure 11: Map of the Gulf of Carpentaria showing the fishing grounds used in the GN02 Logbook between 1983 to 1987 (solid lines). The dotted lines represent the four grids used for this report.

Table 3: Minor commercial categories, and their associated total catch (kg) between 1981 and 1995, from the Gulf of Carpentaria identified from commercial catch and effort logbook data that were not included in analyses. * indicates values represent total number of animals.

Common name	Scientific name	Species code	Total catch (kg)
Stripey Bass	Lutjanus carponotatus	346011	5.5
Cuttlefish	Cuttlefish	602000	10
Oysters	Oysters	653000	20
Crustacea	Crustacea	700000	2
Banana Prawn	Penaeus merguiensis	701901	20
Painted Lobster	Panulirus ornatus	703015	160
Crocodile		992200	254*
Dugong		991300	42*

Table 4: Minor commercial categories from the Gulf of Carpentaria identified from commercial catch and effort logbook data that were reassigned to other categories to avoid ambiguity.

Original common name	Original scientific name	Original sp. code	Total catch(kg)	Assigned common name	Assigned sp. code
Cobbler	*Gymnapistes marmoratus*	287018	158	Fork-tailed Catfish	188000
Silver Whiting	*Sillago sihama*	330006	10	Whiting	330900
Summer Whiting	Cfish Code 116	330800	1002	Whiting	330900
Amberjack	*Seriola dumerili*	337025	200	Trevally - other	337000
Giant Trevally	Cfish Code 31*4*	337801	102	Trevally - other	337000
Great Trevally	Cfish Code 321	337803	60	Trevally - other	337000
Kingfish Species	Family Carangidae	337805	26	Trevally - other	337000
Pumpkin head	Family Carangidae	337900	40694	Trevally - other	337000
Jobfish	*Pristipomoides typis & multidens*	346901	195	Sea Perch - other	346000
Snapper	*Chrysophrys auratus*	353001	379	Sea Perch - other	346000
Malabar Sea Perch	*Lutjanus erythropterus*	346005	33	Saddle-tail Snapper	346007
Sea Perch	*L. erythropterus & L malabaricus*	346911	242	Saddle-tail Snapper	346007
John Snapper	*Lutjanus johnii*	346909		Mangrove Jack	346015
Grunter or Javelin Fish	*Family Haemulidae*	350900	272	Grunter	350800
Lesser Spangled Emp.	*Lethrinus choerorynchus*	351001	128	Emperor - other	351000
Spangled Emperor	*Lethrinus nebulosus*	351008	9	Emperor - other	351000
Sweetlip-Other	Cfish Code 226	351800	73	Emperor - other	351000
Jewfish	*Argyrosomus hololepidotus*	354001	335426	Black Jew	354003
Silver Jew	Cfish Code 153	354800	1486	Black Jew	354003
Sea Mullet	*Mugil cephalus*	381002	20	Mullet	381000
Mud Mullet (flat-tail)	*Liza subviridis*	381007	2	Mullet	381000
Queen Salmon	Cfish Code 115	383800	90	Threadfin Salmon	383000
Pigfish	*Bodianus vulpinus*	384001	66	Tuskfish / Wrasse	384000
Maori	*Ophthalmolepis cyanogramma*	384019	114	Tuskfish / Wrasse	384000
Tuskfish	*Family Labridae*	384800	219	Tuskfish / Wrasse	384000
Yellowfin Tuna	Cfish Code 305	441002	49	Mackerel	441000
School Mackerel	*Scomberomorus queenslandicus*	441014	2608	Mackerel	441000
Spotted Mackerel	*Scomberomorus munroi*	441015	312	Mackerel	441000
Grey Mackerel	*Scomberomorus*	441018	445799	Mackerel	441000

	semifasciatus				
Salmon Mackerel	*Grammatorcynus bicarinatus*	441025	49	Mackerel	441000
Mackerel-Other	Cfish Code 305	441800	325932	Mackerel	441000
Spanish Mackerel	*Scomberomorus commerson*	441902	906742	Mackerel	441000
Bait - Other (Scad)		402C	1140	Baitfish	599920
Crabs	Crabs	702000	1189	Black Mud Crab	702001
Mud Crab Claws	Cfish Code 609	702800	127	Black Mud Crab	702001
Black Tipped Shark	*Carcharhinus melanopterus*	018036	2929	Shark	901034
Family Rhinobatidae	Family Rhinobatidae	027000	125	Shark	901034
Shark Fins And Tails		141C	183	Shark	901034
Family Pristidae	Family Pristidae	25000	5458	Shark	901034
Mixed / Other		401C	15235	Others	999999
Mixed Fish	Family Mixed Fish Families	599000	208234	Others	999999
Mixed Reef A	Mixed Reef A	990006	95830	Others	999999
Mixed Reef B	Mixed Reef B	990007	1986	Others	999999

Table 5: Minor commercial categories from the Gulf of Carpentaria identified from commercial catch and effort logbook data that were pooled with 'Others' for analyses and their associated total catch (kg) from 1981 to 1995. * indicates the species name for tailor and wings were probably incorrectly assigned.

Common name	CSIRO name	Species code	Total Catch (kg)
Others	Commercial group: Unknown (Other fish)	999999	807214
Queenfish	Scomberoides spp	337905	131647
Fork-tailed Catfish	Family Ariidae	188000	83697
Black Pomfret	*Parastromateus niger*	339001	57104
Trippletail	*Lobotes surinamensis*	348001	55756
Trevally – other	Family Carangidae	337000	41082
Mullet	Family Mugilidae	381000	23498
Ray	Common name: Rays	990001	16399
Rock Cod	Epinephelus spp and Cephalopholis spp	311909	9591
Sand Crab	Ovalipes spp	702901	4858
Black Kingfish	*Rachycentron canadum*	335001	4643
Sea Gar	Family Hemiramphidae	234000	4444
Emperor – other	Family Lethrinidae	351000	4281
Tailor *	*Pomatomus saltatrix*	334002	4124
Mangrove Jack	*Lutjanus argentimaculatus*	346015	3969
Golden Trevally	*Gnathanodon speciosus*	337802	3420
Coral Trout	Commercial group: Coral Trout	311905	2714
Red Emperor	*Lutjanus sebae*	346004	2607
Whiting	*Sillago sihama*	330900	2422
Black Trevally	*Siganus spinus*	337800	2239
Bait Fish		599920	2032
Yellow-finned Bream	*Acanthopagrus australis*	353004	1799
Sea Perch – other	Family Lutjanidae	346000	1568
Longtail Tuna	*Thunnus tonggol*	441013	1140
Barracuda	Family Sphyraenidae	382000	1111
Skins	Common name: Skins	990008	1080
Red Throat Emperor	*Lethrinus miniatus*	351009	1059
Wing *	*Pteraclis velifera*	342006	831
Saddle-tail Snapper	*Lutjanus malabaricus*	346007	821
Threadfin Salmon	Family Polynemidae	383000	761
Moses Sea Perch	*Lutjanus russelli*	346012	620
Milkfish	*Chanos chanos*	142001	515
Tuskfish / Wrasse	Family Labridae	384000	399
Barramundi Cod	*Cromileptes altivelis*	311044	320
Flathead	Family Platycephalidae	296000	141
Luderick	*Girella tricuspidata*	361007	91

Table 6: Summary of the total Gulf of Carpentaria Barramundi catch (kg) by year and month in the Gulf of Carpentaria from 1981 to 1995.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	252	50085	114789	99412	84162	72750	77289	78104	75687	77058		
1982		96424	110033	101605	114217	84621	46852	63691	67375	71093	320	
1983		65349	100504	66889	78368	51231	43506	37195	44127	62053	547	
1984		90115	112012	113962	80693	70594	49911	44644	46043	53083		
1985		73526	98310	79381	81323	60890	40595	39973	48843	58243		
1986		77498	62324	59242	60715	49095	44838	42422	46597	63459		
1987		67422	86002	64226	55459	52325	37993	33560	48186	54716		
1988	733	72398	75210	61613	46176	45867	28750	33738	45807	61833	1740	
1989	60	81743	99707	69582	58099	62811	23780	29444	40358	52580	1680	
1990	330	48552	65095	45593	42435	37870	24187	24466	28253	55520	3368	
1991	35	66894	125115	69296	60142	44646	28984	29909	32015	43508	1700	
1992		61130	61797	37620	37532	35276	22347	27424	29437	23953		
1993		60667	86616	62782	44598	36738	15388	17380	21108	25195		
1994	32	56214	72866	57630	35029	28810	16917	19126	22248	38794	55	
1995		64301	71055	64962	41056	42536	26596	16684	27578	57289	30	

Table 7: Summary of the total number of boat days fished by year and month in the Gulf of Carpentaria from 1981 to 1995.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	6	855	2179	2386	2362	2400	2318	2432	2424	2282		
1982		2078	2413	2219	2425	2000	1712	2295	2228	2130	43	
1983		1972	2559	2392	2506	2169	2005	1866	2253	1967	20	
1984		1913	2319	2101	2037	2109	1828	1662	1858	1727		
1985		1698	2037	1914	1955	1780	1600	1758	1845	1906		
1986		1752	1987	2090	2133	1837	1860	1901	2072	1866		
1987		1367	2024	1958	1767	1603	1508	1725	2032	1862		
1988	12	1567	1869	1932	1628	1603	1276	1353	1556	1469	30	
1989	51	1373	1754	1525	1444	1402	1013	1258	1339	1541	36	6
1990	14	1379	1604	1332	1313	1300	1137	1360	1199	1398	100	31
1991	2	1178	1615	1247	1277	1173	999	914	1061	1143	19	24
1992	18	906	1150	1106	1022	989	938	1009	1061	891	37	11
1993		1206	1552	1346	1299	1241	1010	987	945	907	11	15
1994	22	1167	1585	1494	1335	1234	1050	1004	983	1114	21	16
1995	13	1474	1695	1584	1382	1136	1020	988	1028	1216	16	

Table 8: Summary of the total number of boats by year and month in the Gulf of Carpentaria from 1981 to 1995.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	1	53	96	109	107	110	98	107	103	94		
1982		95	101	104	108	94	80	93	95	91	1	
1983		85	96	97	101	90	84	81	88	81	1	
1984		78	90	92	92	91	80	73	75	68		
1985		74	81	81	81	77	69	70	79	82		
1986		77	78	83	88	76	75	75	81	77		
1987		69	83	84	78	76	72	74	89	81		
1988	1	72	79	80	77	64	64	60	68	62	1	
1989	2	68	79	73	74	70	58	61	69	70	2	1
1990	3	72	73	69	68	67	64	66	65	63	4	1
1991	2	63	75	73	71	66	57	57	57	57	2	2
1992	1	53	61	67	69	60	62	55	61	49	4	1
1993		66	70	68	73	64	59	61	56	50	2	1
1994	3	59	72	77	73	59	55	61	56	4	1	
1995	1	72	78	74	71	69	61	59	63	60	4	

Table 9: Summary of the total number of days fished per boat by year and month in the Gulf of Carpentaria from 1981 to 1995.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	6	16	23	22	22	22	24	23	24	24		
1982		22	24	21	22	21	21	25	23	23	43	
1983		23	27	25	25	24	24	23	26	24	20	
1984		25	26	23	22	23	23	23	25	25		
1985		23	25	24	24	23	23	25	23	23		
1986		23	25	25	24	24	25	25	26	24		
1987		20	24	23	23	21	21	23	23	23		
1988	12	22	24	24	21	25	20	23	23	24	30	
1989	26	20	22	21	20	20	17	21	19	22	18	6
1990	5	19	22	19	19	19	18	21	18	22	25	31
1991	1	19	22	17	18	18	18	16	19	20	10	12
1992	18	17	19	17	15	16	15	18	17	18	9	11
1993		18	22	20	18	19	17	16	17	18	6	15
1994	7	20	22	19	18	18	18	18	16	20	5	16
1995	13	20	22	21	19	16	17	17	16	20	4	

Figure 12: Annual rainfall (mm), production of Barramundi (tonnes), effort (boat days) and CPUE (kg / boat) in Grid A, near Weipa, in the Gulf of Carpentaria from 1981 to 1995.

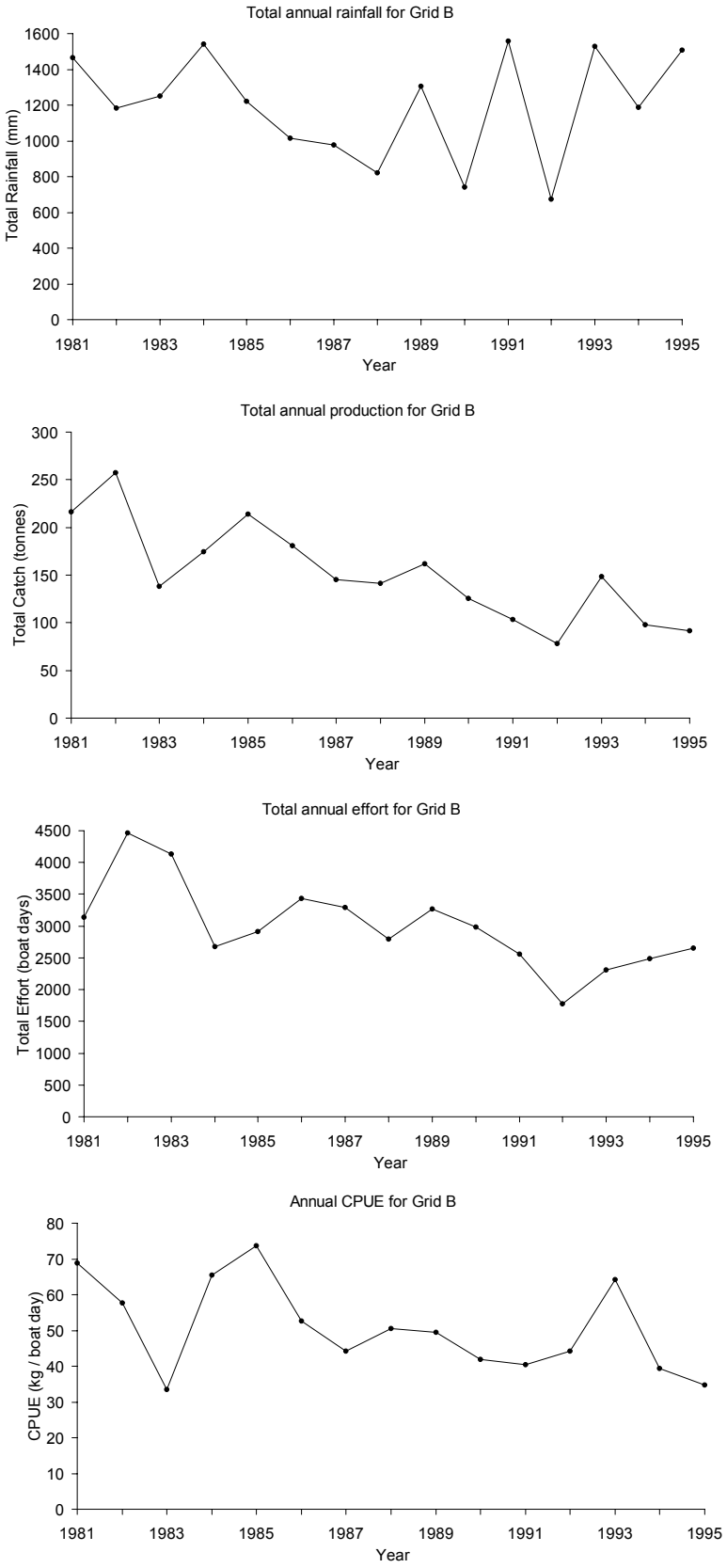

Figure 13: Annual rainfall (mm), production of Barramundi (tonnes), effort (boat days) and CPUE (kg / boat) in Grid B, near Kowanyama, in the Gulf of Carpentaria from 1981 to 1995.

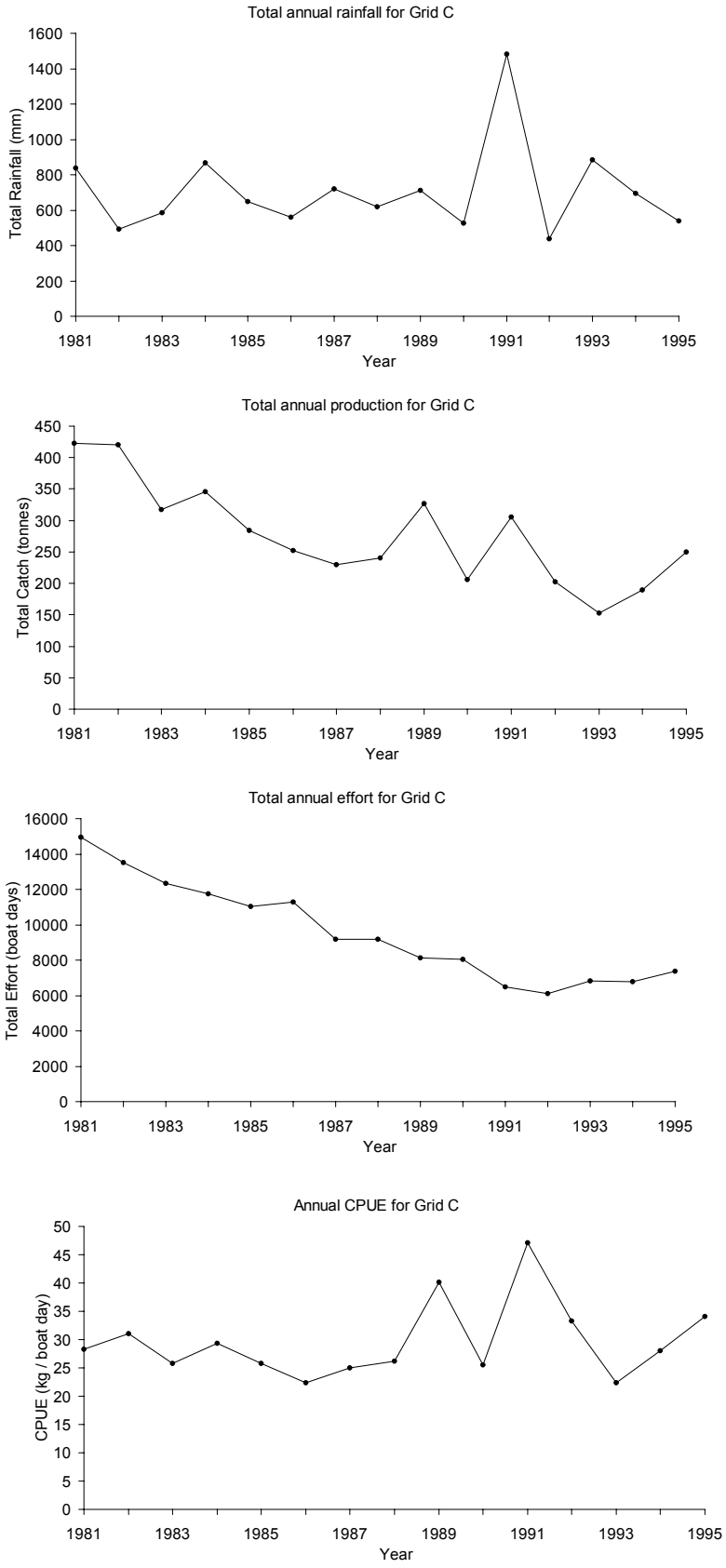

Figure 14: Annual rainfall (mm), production of Barramundi (tonnes), effort (boat days) and CPUE (kg / boat) in Grid C, near Karumba, in the Gulf of Carpentaria from 1981 to 1995.

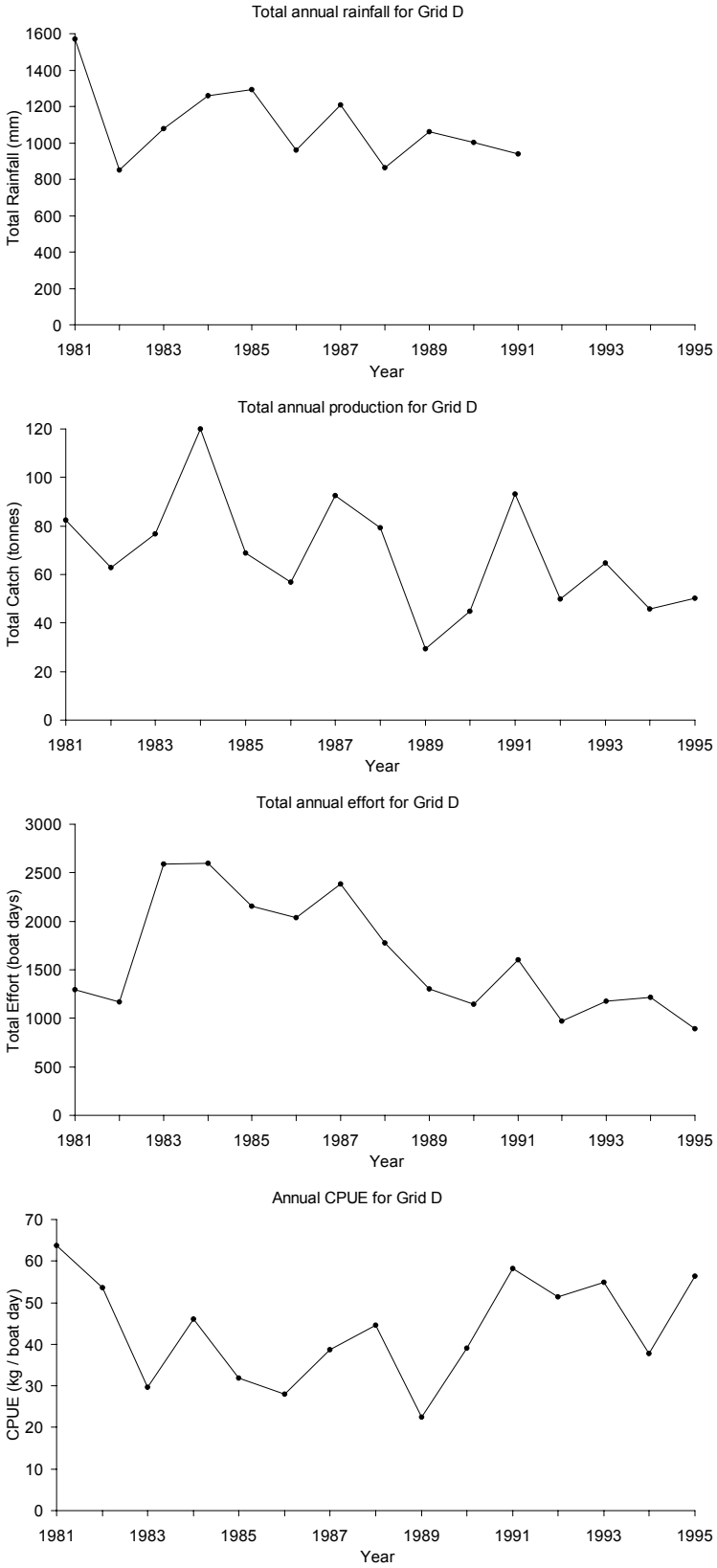

Figure 15: Annual rainfall (mm), production of Barramundi (tonnes), effort (boat days) and CPUE (kg / boat) in Grid D, near Mornington Island, in the Gulf of Carpentaria from 1981 to 1995.

Table 10: Summary of the total Gulf of Carpentaria mud crab catch (kg) by year and month in the Gulf of Carpentaria from 1981 to 1995.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981		19	65	95		41	31	58	57	21		
1982					24	35	6	21	19	73	20	
1983		142	142		113	401	916	286	284	517		
1984		80	96	15	71	334	168	792	549	1352		
1985		132	383	525	2002	6660	3632	1676	4596	12382	170	
1986		20	303	1814	2192	2165	1999	3183	1887	1694	140	
1987			145	437	594	751.5	998	896	824	702	585	
1988		280	274	752	186	915	915	127	542	533		
1989		256	977	3715	4898	3680	3009	3600	3908	3101	389	475
1990	217	1683	4165	3090	5505	3092	1597	1511	3240	5024	2017	673
1991		45	354	815	1352	1971	1847	4690	6876	4814	2592	1116
1992	360	612	1374	3897	6769	4564	2246	2066	3388	3239	703	165
1993		571	1723	2593	4595	2589	2869	2599	1160	1412	210	
1994	276	2354	2175	3640	2382	4509	3224	698	1140	1537	211	85
1995	439	1643	2388	9618	10215	9153	5507	4938	5003	4097	2114	308

Table 11: Summary of the total number of boats by year and month in the Gulf of Carpentaria from 1981 to 1995.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981		1	1	2		2	2	4	3	1		
1982					1	1	1	1	1	2	1	
1983		2	2		2	4	2	5	4	3		
1984		3	2	1	3	3	4	4	3	5		
1985		2	5	5	9	11	10	11	12	17	1	
1986		3	5	11	11	7	11	15	13	11	1	
1987			2	5	7	12	8	7	8	10	2	
1988		2	7	7	8	5	6	6	5	7		
1989		5	6	13	20	20	19	18	22	18	3	2
1990	1	13	14	14	18	21	9	16	14	16	2	2
1991		1	7	9	15	12	11	20	23	20	3	4
1992	1	8	8	18	26	21	19	20	26	24	2	2
1993		5	15	19	25	23	21	23	23	21	3	
1994	2	9	9	17	18	17	14	11	13	11	1	1
1995	2	11	16	22	27	23	19	24	26	21	8	3

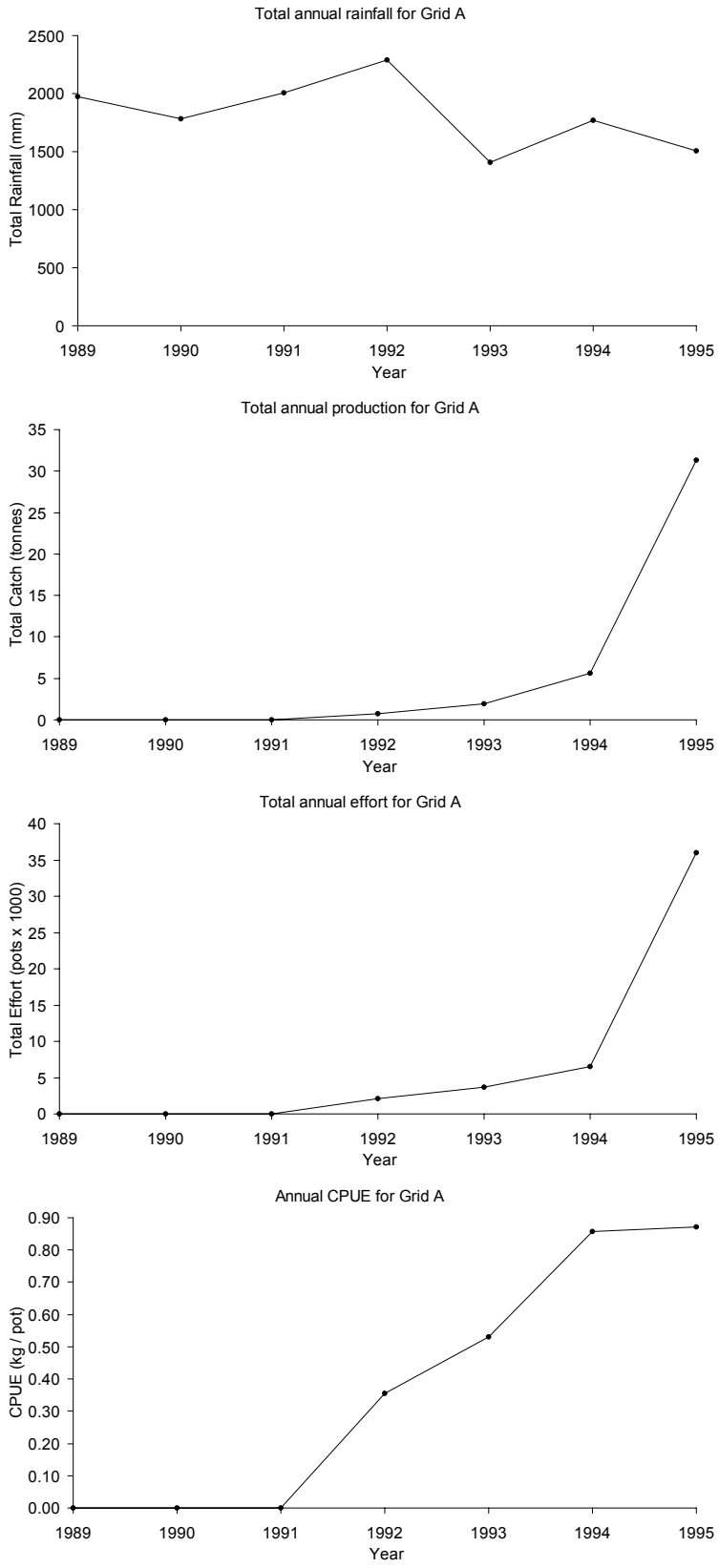

Figure 16: Annual rainfall (mm), production of mud crab (tonnes), effort (pots x 1000) and CPUE (kg / pot) in Grid A, near Weipa, in the Gulf of Carpentaria from 1989 to 1995.

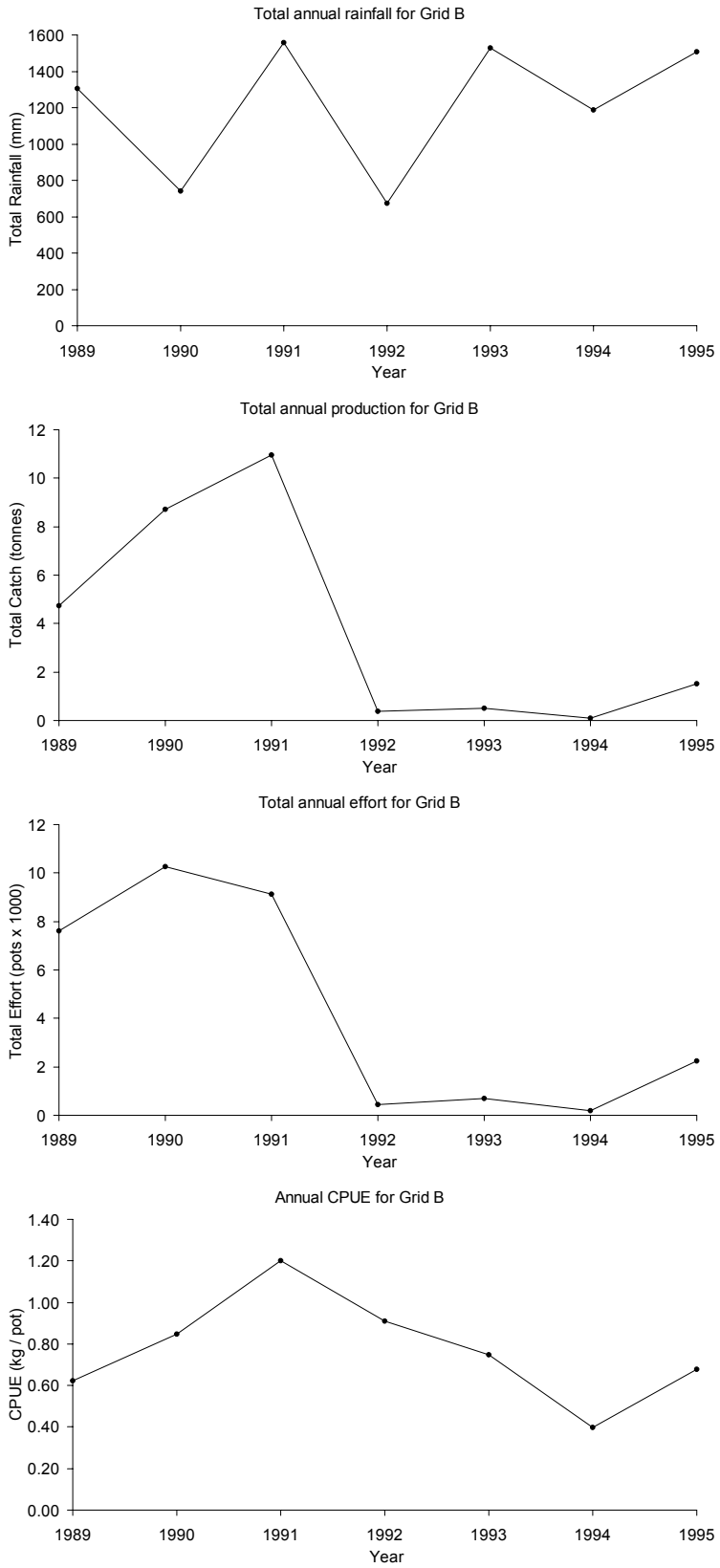

Figure 17: Annual rainfall (mm), production of mud crab (tonnes), effort (pots x 1000) and CPUE (kg / pot) in Grid B, near Kowanyama, in the Gulf of Carpentaria from 1989 to 1995.

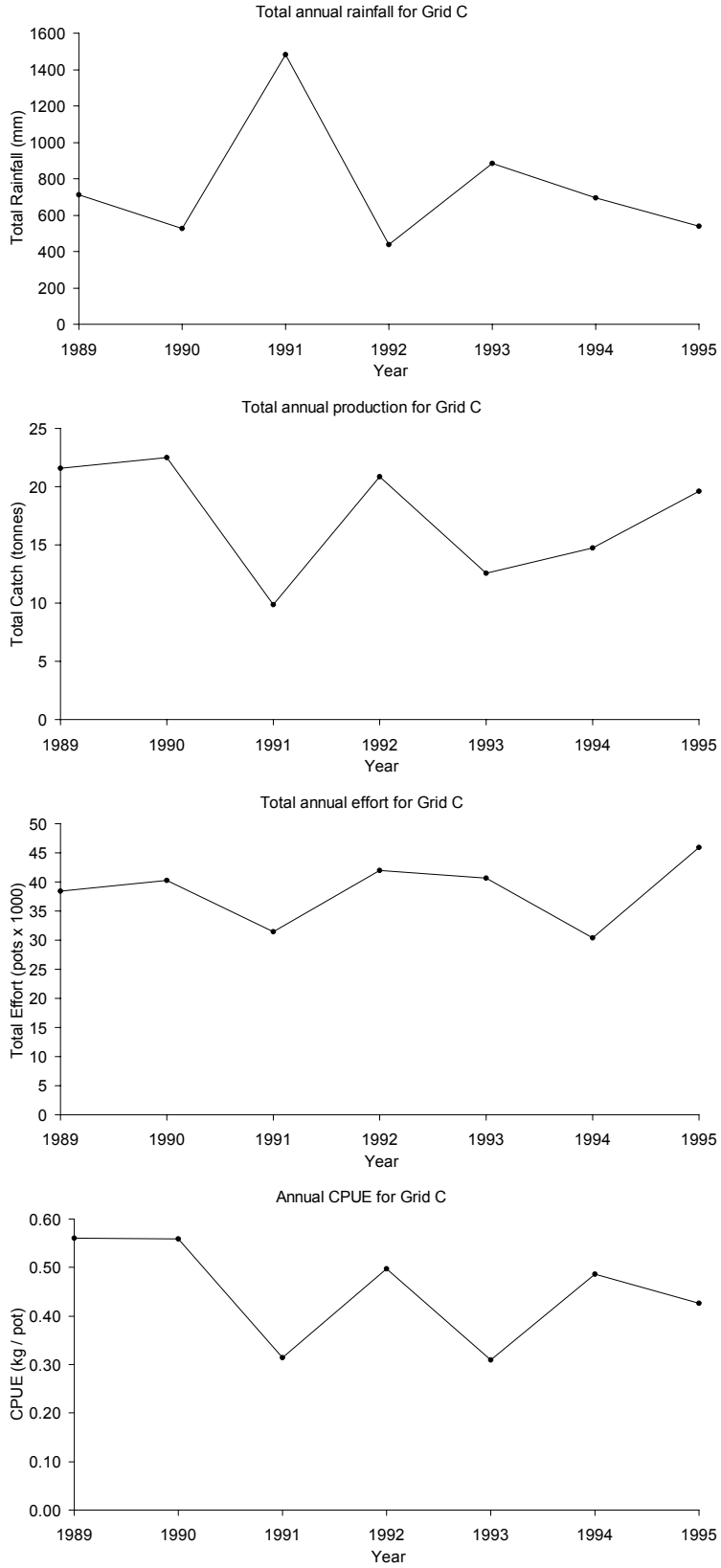

Figure 18: Annual rainfall (mm), production of mud crab (tonnes), effort (pots x 1000) and CPUE (kg / pot) in Grid C, near Karumba, in the Gulf of Carpentaria from 1989 to 1995.

Appendix 5b (Section 2)

East Coast Inshore Fishery

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Preliminary analysis of Tropical East Coast catch and effort data

The catch and effort logbooks indicate a relatively stable annual catch of Barramundi between 1985 and 1996 (Figure 1; $r^2 = 0.3212$, n = 12). The minimum and maximum annual catches were observed in 1988 (87 tonnes) and in 1985 (180 tonnes). The overall trend was a gradual decline punctuated by minor peaks in 1987, 1991 and 1992 at 156, 170 and 139 tonnes respectively (Table 1 and Figure 1).

The monthly catches within each year indicate similar patterns with pronounced higher catches during February and March (Figure 1 and Table 7). Barramundi are usually taken in greater quantities during this time of the year because they are still frequenting estuaries and coastal foreshores after the spawning season. The decreased catch during the winter months occurs when Barramundi have dispersed from these areas and have reduced catchability. There was no consistent increase in the Barramundi catch during September and October, as observed in the Gulf of Carpentaria Set Net Fishery (Magro *et al.* 1997). This is probably due to spawning with the associated aggregations of adult fish occurring later in the year on the East Coast (R. Garret QDPI, pers com.). The total monthly catch for each year is listed in Table 7.

Table 1: Total annual Barramundi catch (kg) and effort from total number of boat days, total number of boats and average number of days fished per boat for each year.

Year	Total catch	Total days	Number of boats	Days per boat
1985	179 607	11 624	127	92
1986	138 199	9 531	109	87
1987	156 614	9 737	145	67
1988	89 048	7 597	209	36
1989	128 395	8 248	189	43
1990	118 455	7 820	174	45
1991	171 503	8 024	199	40
1992	101 257	6 143	192	32
1993	140 030	6 777	184	37
1994	114 019	6 417	156	41
1995	100 521	5 903	150	39
1996	92 984	6 582	175	38

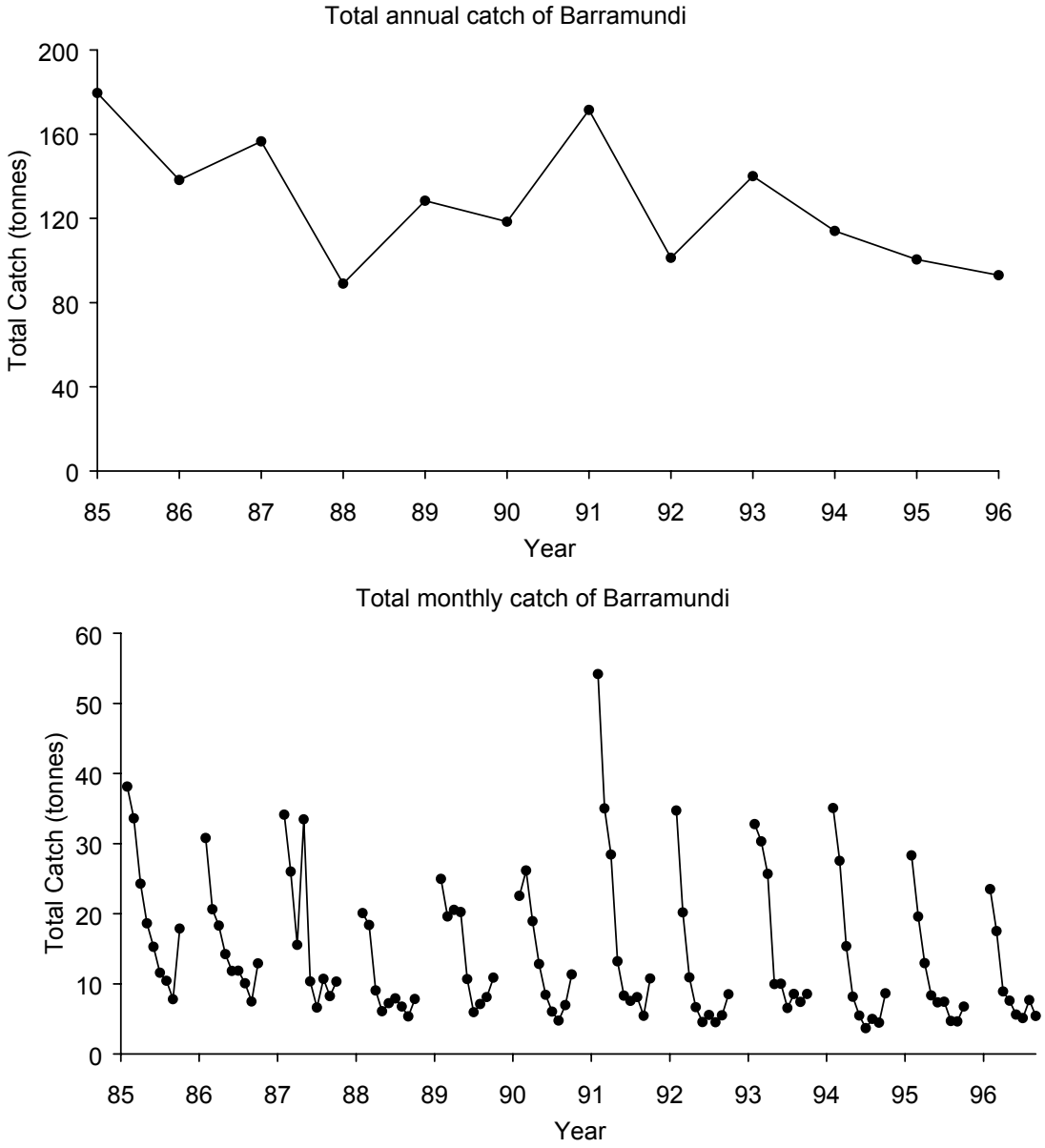

Figure 1: Annual catch (tonnes) of Barramundi (*Lates calcarifer*) in north-east Queensland from 1985 to 1996, by year and by month.

The catch and effort logbooks indicate a significant and steady decline in effort from 11 624 boat days in 1985 to 6 582 boat days in 1996 (Figure 2, $y = 10.63 - 0.4251x$, $r^2 = 0.7975$, $n = 12$). The patterns of monthly effort within each year were similar with the total effort highest during February and March (Figure 2 and Table 8) then declining in later months. The apparent decline in effort during the winter months, however, was not as dramatic as the decline observed in catch. This was likely because fishers are able to offset declining Barramundi availability by catching other species (Tables 4, 5 and 6). There was no dramatic increase in effort during September and October, as has been observed in the Gulf of Carpentaria Set Net Fishery. The total monthly effort (measured in boat days) for each year is listed in Table 8.

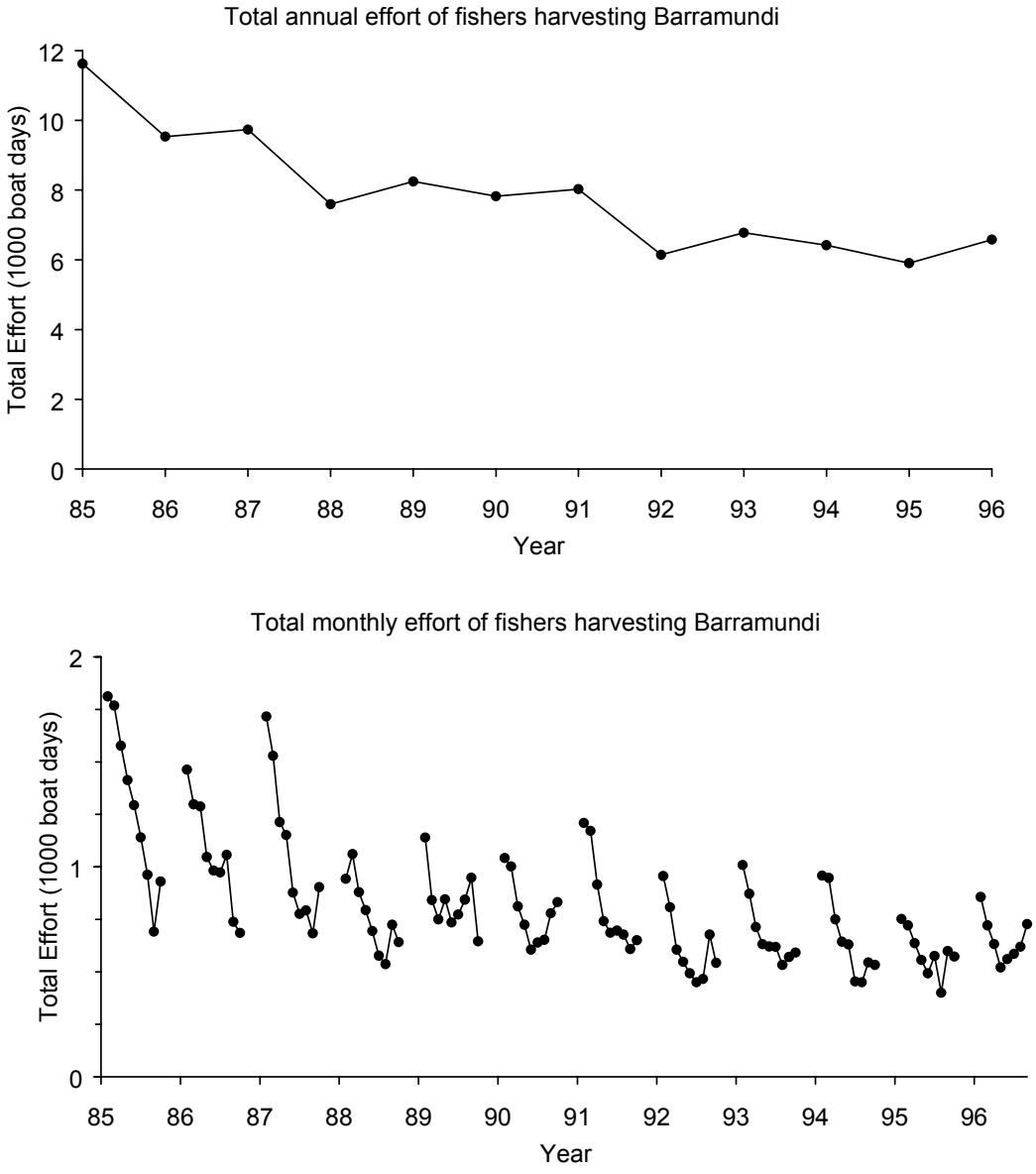

Figure 2: Total annual effort (boat days) for Barramundi fishers in north-east Queensland from 1985 to 1996.

An important assumption in using the number of boat days as a measure of effort is that individual boats are fishing with similar intensity in any given year. This assumption can be evaluated by comparing the number of boats and the average number of days per boat among years. The total number of boats operating each year was highest at 209 boats in 1988 and declined to 150 boats in 1995 (Table 1). The lowest number of boats operating in the fishery occurred in 1986 when only 109 boats were recorded. There was an average of 87 boats operating in any one month during the 12 years of logbook recording (calculated for the months from February to October). The most boats to operate in any month occurred in February 1991 when 130 boats lodged returns (Table 9).

The average number of days fished per boat for each month over the 12 years is given in Table 10. There appears to be a marked difference in the average number of days fished per boat per month (excluding the three months of November, December and January which constitute the annual closed season). The number of days fished prior to 1988 is greater than in the later nine years. This was probably a result of the differences between the historic and current databases (monthly versus daily returns). However, the minimum and maximum average number of days fished per boat per month over the 12 years were 5 and 19 days respectively. This indicates the number of days in which boats were fishing during each calendar month of the Barramundi fishing season were not entirely dissimilar. Boats can be assumed to be operating with relatively similar levels of fishing effort in terms of the number of days fished per month which justifies the use of boat days as a measure of fishing effort.

There were some catches of Barramundi reported during November, December and January which normally constitute the annual closed season. However, the maximum catch for any month between November to January was 1.9 tonnes. This catch in December 1985 was associated with a collective 33 boat days (Table 8) from two boats (Table 9). The catch and effort during November to January were much lower compared with the remaining nine months. The total Barramundi catch for all months was included in the annual totals, but the catches for November to January were not included in the monthly time series.

The CPUE was relatively stable over the 12 year period from 1985 to 1996 (Figure 3). The CPUE was 15 kg / boat day in 1985 and was virtually unchanged at 14 kg / boat day in 1996. The CPUE reached peaks in 1991 and 1993 at 21 and 20 kg / boat day respectively. CPUE was lowest in 1988 (12 kg / boat day). The highest monthly CPUE was usually observed at the beginning of the fishing season, particularly from 1992 to 1996. This higher CPUE is due in part to the greater seasonal availability of Barramundi at this time because of the seasonal closure from November to January and the wet season rainfall allowing recruitment of fish from river habitats.

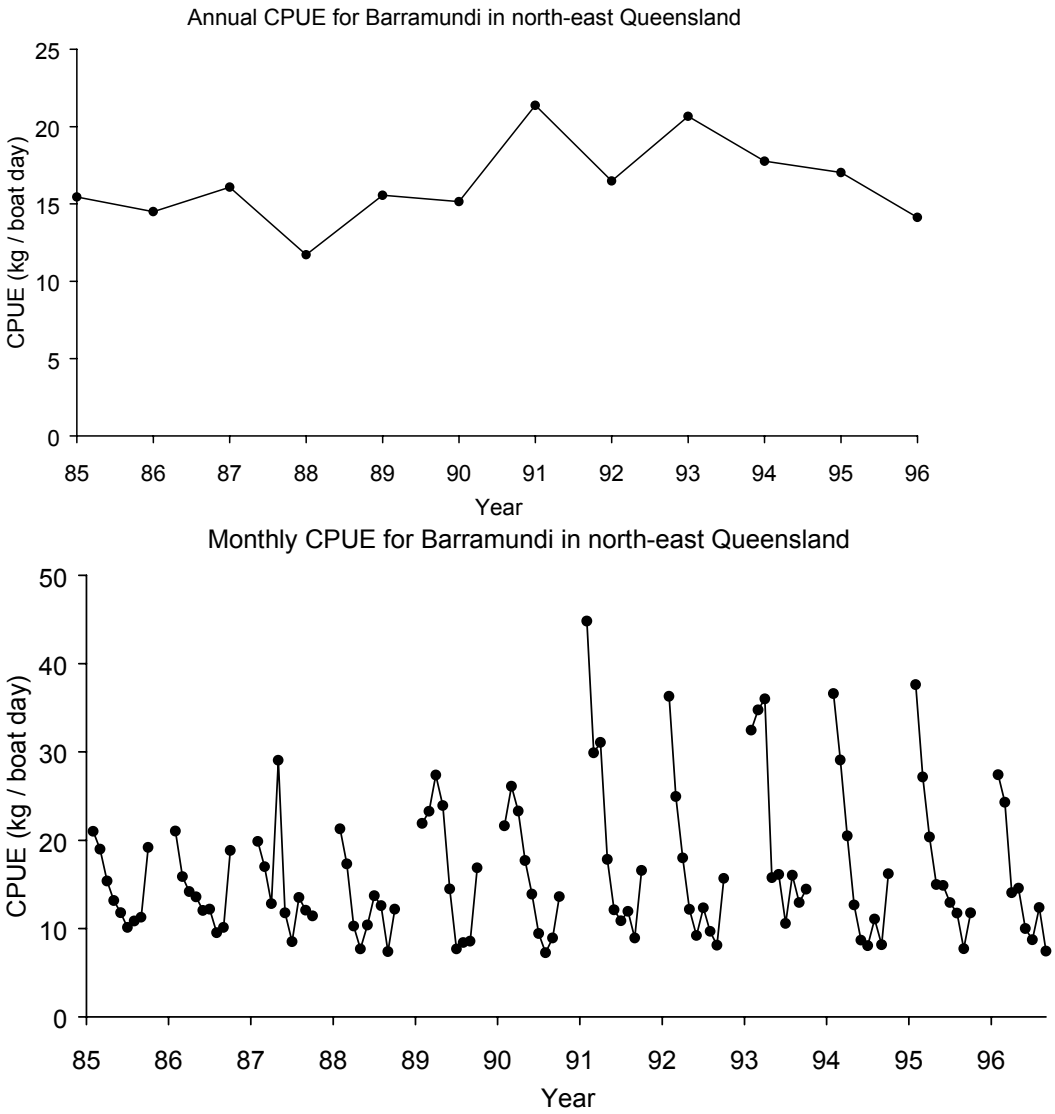

Figure 3: Annual CPUE (kg / boat day) for Barramundi in the north-east Queensland coast from 1985 to 1996.

Comparison of catch and effort among grids

The Gulf of Carpentaria was divided into statistical grids for the voluntary and compulsory catch-effort logbook programs (Table 3 and Figures 9 and 10).

Grid H around Townsville was the most significant area in the north-east Queensland coast in terms of total Barramundi production, producing 534 tonnes from 1985 to 1996. This was 35 % of the total production along the north-east Queensland coast over the 12 year period. Lower total catches were observed in grids F, G, I and E with 400, 239, 279 and 54 tonnes respectively. These tonnages represent 27%, 16%, 18% and 4 % of the total production along the north-east Queensland coast over the 12 year period. A comparison of the total annual Barramundi catch is given in Figure 4. The most productive area, Grid H produced 44 % of the total annual production in 1986 (61 tonnes). However, production in Grid H was lowest in 1993, which was only 23 % (32 tonnes) of the annual total for that year.

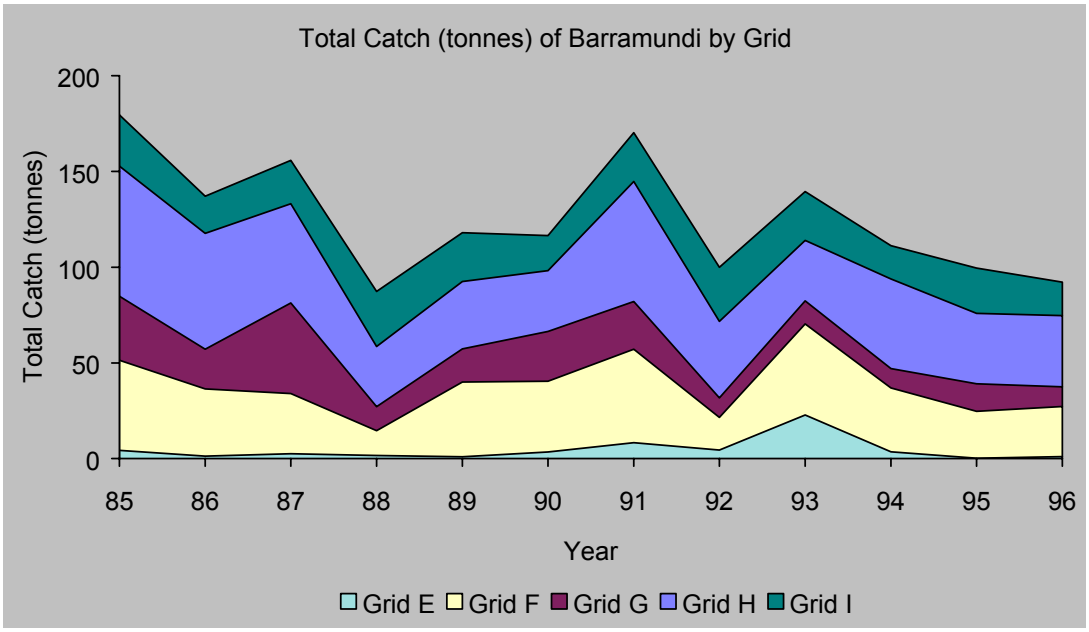

Figure 4: Comparison of the annual production (tonnes) of Barramundi among five spatial grids along the north-east Queensland coast from 1985 to 1996.

Mud Crab: Preliminary analysis of catch and effort data

The catch and effort logbooks indicate an increase in the annual catch of Mud Crab from 21 tonnes in 1985 to 116 tonnes in 1996 (Figure 5). The annual catch was highest in 1990 at 146 tonnes (Table 2). The total catches from records where pot information was available closely approximated the combined catch of Mud Crab from pots and where the effort was not identified.

The monthly catch indicates similar patterns among years with higher catches during the mid year (Figure6 and Table 11) The highest monthly catches of Mud Crab were recorded in March, April and May 1991 with 66, 69 and 64 tonnes respectively. The monthly Mud Crab catches for each year from 1985 to 1996 are listed in Table 11.

The reporting of Mud Crab catch was not mandatory until the MIXED logbook was introduced in 1988. Consequently, in the years prior to 1989 the reported catch of Mud Crab may not reflect the true catch of Mud Crab; the extremely low catches in 1985 to 1987 may be an under estimate

The number of boat days was not an appropriate measure of fishing effort for Mud Crab and only the current database contained information on potting activity, including the number of pots and pot lifts. The only standard measure of effort between the historic and current database was the total number of boats that recorded Mud Crab catches in any given year. The number of boats recording potting information closely approximates the total number of boats that were reporting Mud Crab from 1988 to 1996 (Figure 6) There was an average of 122 boats operating each year in the Mud Crab fishery between 1988 to 1996. This was much higher than the average of 42 boats from 1985 to 1987. This indicates a reliable

time series of only nine years duration for Mud Crab catches along the north-east Queensland coast.

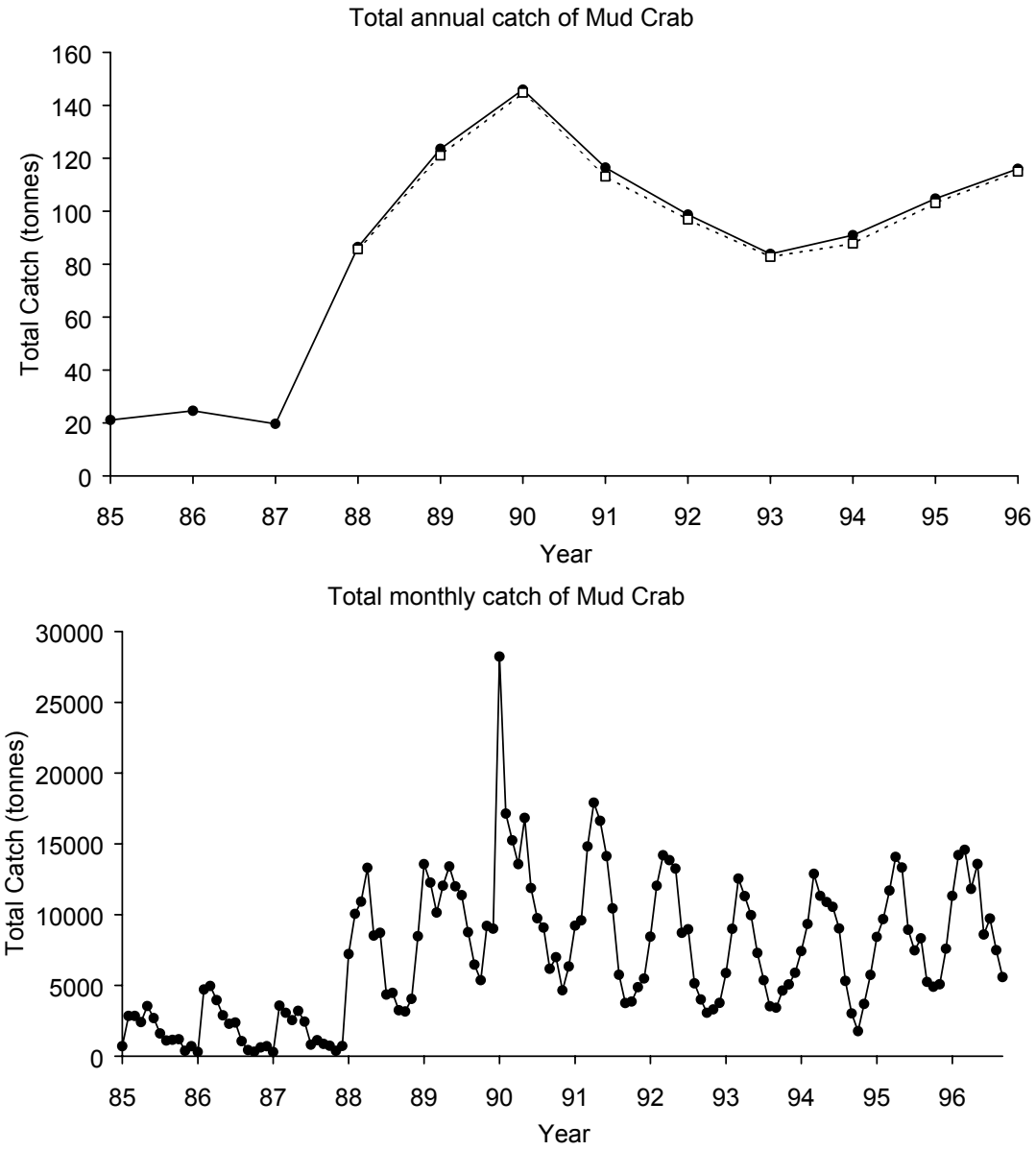

Figure 5: Annual catch (tonnes) of Mud Crab *(Scylla serrata)* in the north-east Queensland coast from 1985 to 1996.

The monthly effort follows a similar pattern where the total effort was highest during the winter months in each year (Figure 6 and Table 12). The total monthly effort for each year is listed in Table 12. An average of 42 boats recorded Mud Crab each month (from 1988 to 1996). The number of boats recording Mud Crab was lowest in November 1992 and November 1994 (17 boats). The most number of boats in any one month was April 1991 when 69 boats reported Mud Crab.

Table 2: Total annual Mud Crab catch (kg) and effort from total number of boat days, total number of boats and average number of days fished per boat for each year.

Year	Total catch	Total days	Number of boats	Days per boat
1985	21 141	2 436	47	51
1986	24 595	2 756	44	62
1987	19 698	2 087	35	59
1988	86 476	9 534	132	72
1989	123 560	9 932	118	84
1990	145 853	9 929	127	78
1991	116 439	9 878	135	73
1992	98 728	7 634	109	70
1993	83 888	8 418	122	69
1994	90 950	8 579	110	77
1995	104 731	9 009	118	76
1996	115 978	10 456	129	81

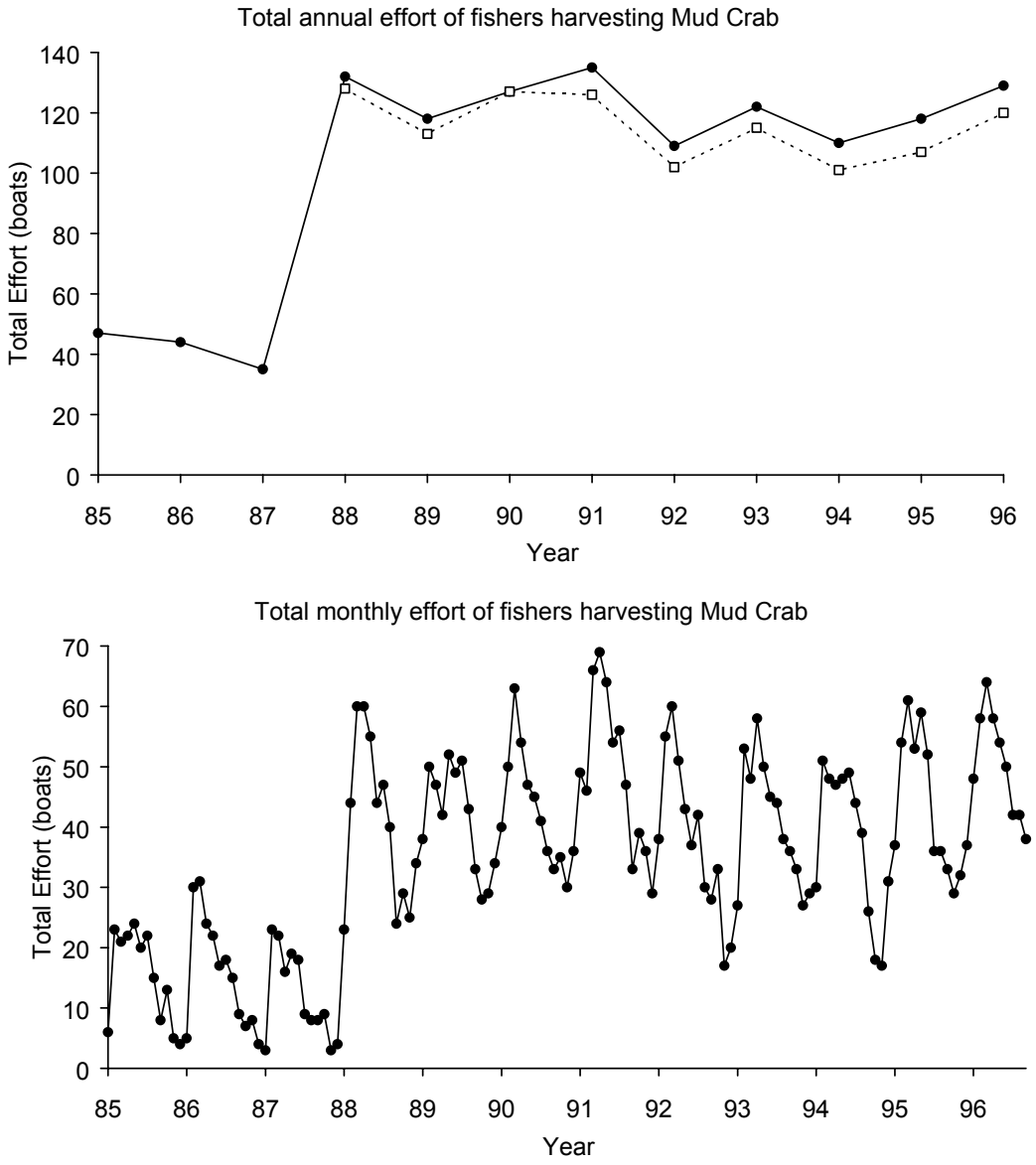

Figure 6: Total annual effort (number of boats) for Mud Crab in the north-east Queensland coast from 1985 to 1996. The dotted line indicates data associated with pot information.

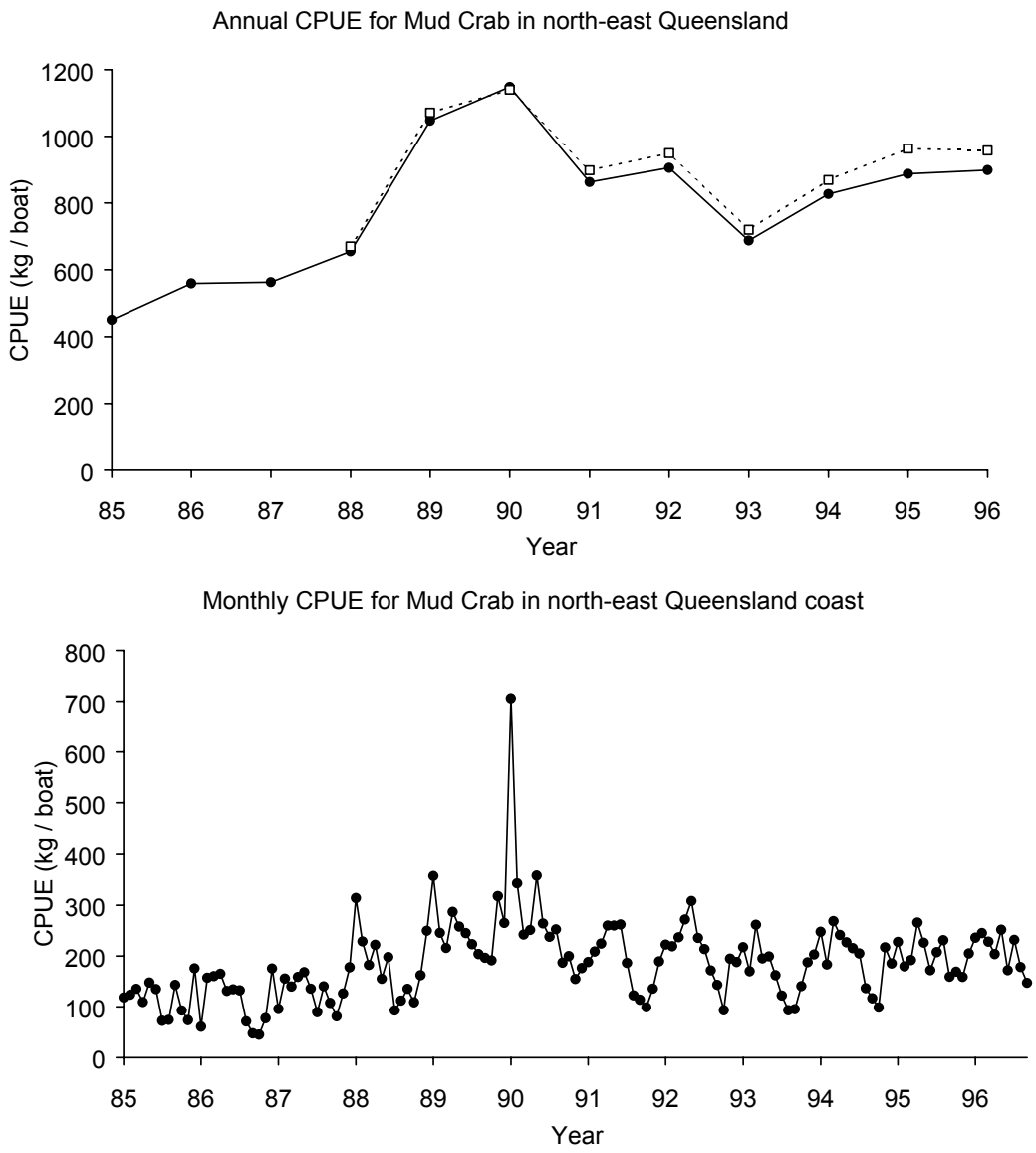

Figure 7: Annual CPUE (kg / pot) for Mud Crab along the north-east Queensland coast from 1985 to 1996.

An important assumption in using the number of boats as a measure of effort is that individual boats were fishing with similar intensity for any given month in any given year. A minimum of 51 days per boat were spent harvesting Mud Crab in 1985 and 84 days per boat was the maximum observed in 1989 (Table 2) On average, 71 days were fished per boat each year between 1985 and 1996. This indicates boats were fishing with relatively similar intensity in terms of the number of fishing days in any given year.

CPUE was highest in 1990 at 1 148 kg per boat (Figure 7). 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.

Comparison of catch and effort among grids

The highest total catch of Mud Crab was observed in Grid H (Townsville area) with a cumulative 631 tonnes, which was 61 % of the total production from all grids over the 12 year period. Lower total catches were observed in Grids F (232 tonnes) and I (116 tonnes) representing 23 and 11 % respectively of the total production over the period. Grids I and E accounted for less than 5 % of the 12 year production total. The annual catch varied minimally among the five grids (Figure 8). The most productive area, Grid H, was produced a maximum of 99 tonnes in 1990 and an average of 52 tonnes of Mud Crab each year from 1985 to 1996. Grid F, Princess Charlotte Bay, produced an average of 24 tonnes from 1988 to 1996; Grid I, the area representing the Mackay ZAC produced an average yearly catch of 12 tonnes from 1985 to 1996.

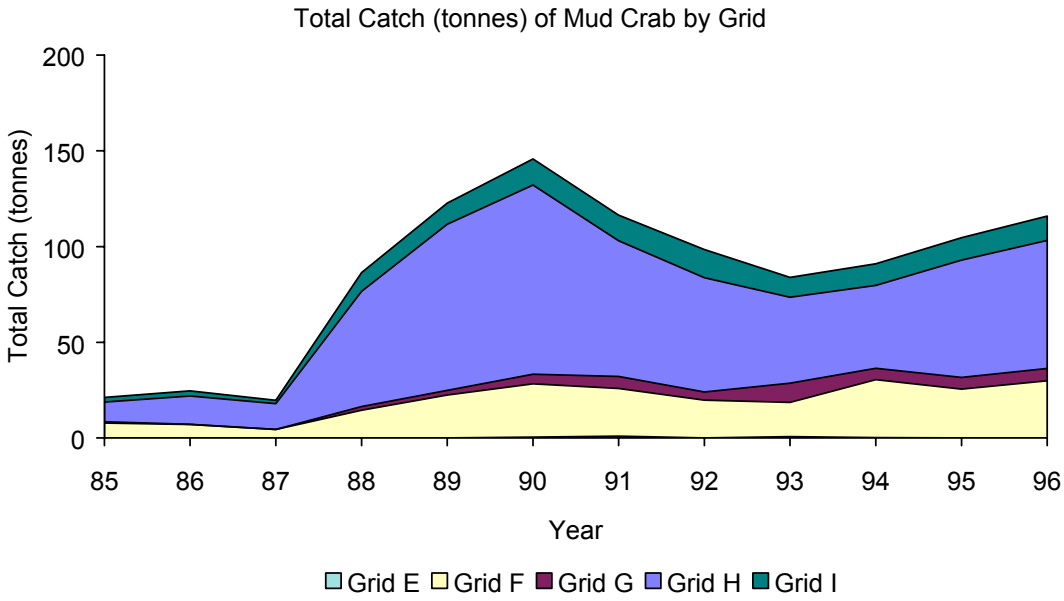

Figure 8: Comparison of the annual production (tonnes) of Mud Crab among five spatial grids along the north-east Queensland coast from 1985 to 1996.

SUMMARY TABLES AND FIGURES FOR THE TROPICAL EAST COAST

Table 3: Latitude and Longitude reference points for spatial grids assigned for the north Queensland Set Net Fishery by TRAP.

Geographic Area	Grid	Latitude (ºS)	Longitude (ºE)	Area		
		Minimum	Maximum	Minimum	Maximum	(km^2)
North Gulf	A	11.00	13.00	140.00	142.50	60 468
Central Gulf	B	13.00	15.00	140.00	142.50	59 982
South-east Gulf	C	15.00	18.50	140.00	142.50	103 581
West Gulf	D	15.00	18.50	138.00	140.00	82 865
North-east Coast	E	11.00	13.00	142.50	145.00	60 468
Princess Charlotte Bay	F	13.00	15.00	142.50	146.00	83 975
Cairns	G	15.00	18.00	144.50	147.00	88 903
Townsville	H	18.00	20.00	145.50	149.50	93 521
Mackay	I	20.00	22.00	148.00	151.00	69 255

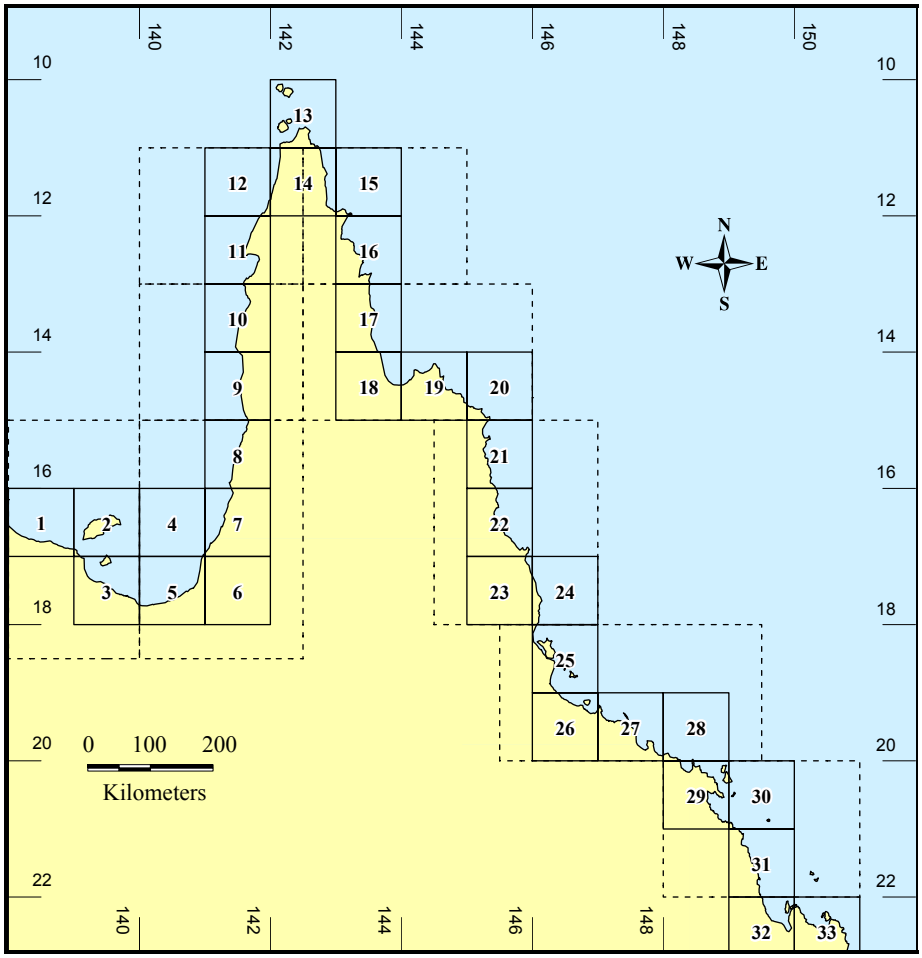

Figure 9: Map of the north Queensland coast showing the fishing grounds used in the GN02 logbook from 1983 to 1987 (——) and the spatial grids assigned for the north Queensland Set Net Fishery by TRAP (– – –).

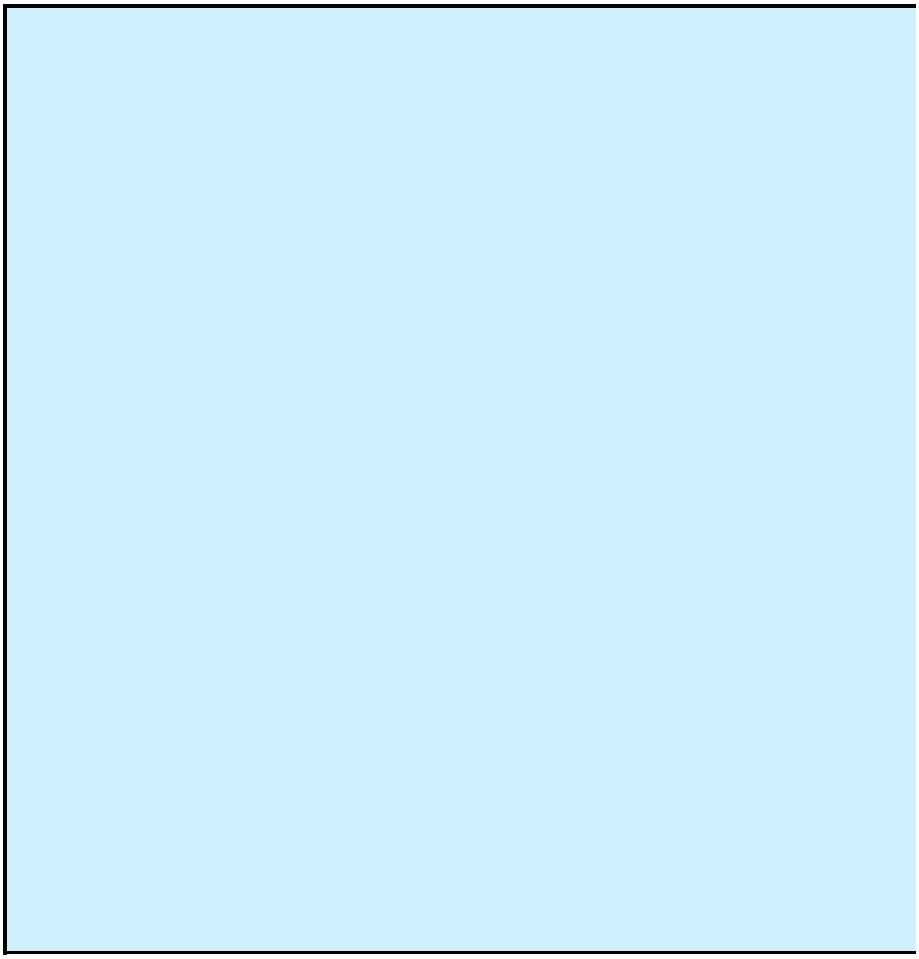

Figure 10: Map of the north Queensland coast showing the ZAC boundaries (——) and the spatial grids assigned for the north Queensland Set Net Fishery by TRAP (– – –).

Table 4: Minor commercial categories identified from commercial catch and effort logbook data from north-east Queensland that were not included in analyses, and their associated total catch (kg) between 1985 and 1996. * indicates values represent total number of animals.

Common name	Scientific name	Species code	Total catch (kg)
Squid		600000	118
Cuttlefish		602000	124
Oyster		653000	2 354
Moreton Bay Bugs	*Ibacus cilatus*	700000	926
Red Spot King Prawn	*Penaeus longistylus*	701303	1 261
Greasy Prawn	*Metapenaeus bennettae*	701340	50
Banana Prawn	*Penaeus merguiensis*	701901	508
Tiger Prawn	*Penaeus esculentus*	701902	2 748
Endeavour Prawn	*Metapenaeus endeavouri & M. ensis*	701903	1 493
King Prawn	*Penaeus latisulcatus*	701904	5 804
Western King Prawn	*Penaeus latisulcatus*	701910	2 335
Prawn - Unspecified		701000	7 657
Mixed Prawn		701907	549
Prawn - Mixed Bait		701920	332
Crab - Unspecified		702000	10 756
Spanner Crab	*Ranina ranina*	702002	1 777
Blue Swimmer Crab	*Portunus pelagicus*	702901	12 990
Lobster - Unspecified		703000	54
Tropical Rock Lobster	Panulirus spp	703015	730
Saucer Scallop	Amusium balloti	900204	412
Roe		902C	35
Skins		990008	25
Dugong		991300	42*
Crocodile		992200	64*
Nothing Caught		901C	0

Table 5: Minor commercial categories from north-east Queensland identified from commercial catch and effort logbook data that were reassigned to avoid ambiguity.

Original common name	Original scientific name	Original sp. code	Total catch (kg)	Assigned common name	Assigned sp. code
Shark	Family Carcharhinidae	3HARK	16	Shark	019900
Sting Ray	Family Arhynchobatidae	034000	211	Shark	019900
School Shark	*Galeorhinus australis*	018002	250	Shark	019900
Shark Fins		019901	951	Shark	019900
Sawfish	Family Pristidae	025000	1 814	Shark	019900
Ray	Family Arhynchobatidae	990001	7 137	Shark	019900
Shark	Family Carcharhinidae	901034	197 232	Shark	019900
Blue Pilchard	*Sardinops neopilchardus*	85002	54	Blue Pilchard	085002
Barramundi	*Lates calcarifer*	610002	482 174	Barramundi	310006
Diver Whiting	*Sillago maculata*	330004	56	Whiting	330900
Summer Whiting	*Sillago ciliata*	330800	36 735	Whiting	330900
Rainbow Runner	*Elegatis bipinnulatus*	337029	150	Trevally	337900
Amberjack	*Seriola dumerili*	337025	341	Trevally	337900
Yellowtail Kingfish	*Seriola lalandi*	337006	369	Trevally	337900
Kingfish	Family Carangidae	337805	515	Trevally	337900
Black Kingfish	*Rachycentron canadus*	335001	2 510	Trevally	337900
Golden Trevally	*Gnathanodon speciosus*	337802	5 968	Trevally	337900
Giant Trevally	*Caranx ignobilis*	337801	7 384	Trevally	337900
Snub Nosed Dart	*Trachinotus blochii*	337075	31	Dart	337904
John Snapper	*Lutjanus johnii*	346909	310	Fingermark Bream	346012
Grunter	Family Haemulidae	350900	609	Grunter	350800
Javelin Fish	Family Haemulidae	350000	340	Grunter	350800
Red Sweetlip	Family Lethrinidae	351000	187	Spangled Emperor	351008
Lesser Spangled Emperor	*Lethrinus choerorynchus*	351001	647	Spangled Emperor	351008
Jew Fish	Family Sciaenidae	354000	122	Black Jew Fish	354003
Silver Jew Fish	*Nibea soldado*	354800	622	Black Jew Fish	354003
Mulloway	*Argyrosomus hololepidotus*	354001	39 612	Black Jew Fish	354003
Sea Mullet	*Mugil cephalus*	381002	6	Mullet	381000
Fantail Mullet	*Mugil georgii*	381009	9	Mullet	381000
Sand Mullet (Blue-Tailed)	Family Mugilidae	381800	176	Mullet	381000
Jumping Mullet	*Liza argentea*	381004	1 019	Mullet	381000
Threadfin Salmon	CFISH Code 115	3873800	1 443	Salmon	383000
Venus Tuskfish	*Choerodon venustus*	980000	26	Venus Tusk Fish	384042
Bonito	*Sarda australis & Cybiosarda elegans*	441909	1 372	Mackerel	441800
Shark Mackerel	*Grammatorcynus bicarinatus*	441025	1 657	Mackerel	441800
School Mackerel	*Scomberomorus queenslandicus*	441014	9 417	Mackerel	441800
Spanish Mackerel	*Scomberomorus commerson*	441902	13 605	Mackerel	441800

Spotted Mackerel	*Scomceromorus munroi*	441015	62 632	Mackerel	441800
Mixed Reef B	Mixed Reef B	599901	1 230	Fish	599000
Mixed Reef A	Mixed Reef A	599900	5 511	Fish	599000
Non Finfish	Non Finfish	999999	206 799	Fish	599000
Bait - Ribbon Fish		403C	236	Bait Fish	599920
Bait - Other (Scad)		402C	13 380	Bait Fish	599920
Mud Crab	*Scylla serrata*	43D CRAB	43	Mud Crab	702001
Mud Crab Claws	Cfish code 609	702800	1 466	Mud Crab	702001

Table 6: Minor commercial categories from the north-east Queensland Set Net Fishery logbooks that were pooled with 'Others' for analyses.

Common name	CSIRO name	Species code	Total Catch (kg)
Fish	Family Mixed Fish Families	599000	326 632
Garfish	Family Hemiramphidae	234000	89 520
Whiting	Family Sillaginidae	330900	82 617
Flathead	Platycephalus spp	296000	55 859
Bream	Family Sparidae	353900	44 103
Black Jew Fish	Protonibea diacanthus	354003	40 440
Bait Fish	Temporary Bait Fish Code	599920	23 725
Jumping Cod (Trippletail)	*Lobotes surinamensis*	348001	16 269
Coral Trout	Plectropomus spp and Variola spp	311905	14 247
Mangrove Jack	*Lutjanus argentimaculatus*	346015	12 017
Catfish	Family Ariidae	188000	11 262
Yellowfin Bream	*Acanthopagrus australis*	353004	10 483
Bony Bream (Herring)	*Nematalosa erebi & N. vlaminghi*	599800	9 771
Black Trevally	*Signaus spinus*	337800	8 601
Cod	Epinephelus & Cephalopholis spp	311909	6 495
Pomfret	*Stromatoeides sinensis*	339900	4 861
Red Throat Emperor	*Lethrinus miniatus*	351009	2 213
Red Emperor	*Lutjanus sebae*	346004	2 107
Wolf Herring	*Chirocentris dorab*	087001	1 995
Salmon	Family Polynemidae	383000	3 421
Pike	Family Sphyraenidae	382000	1 908
Black Pomfret	*Parastromateus niger*	339001	1 870
Milkfish	*Chanos chanoa*	142001	1 583
John Dory	*Zeus faber*	363801	1 356
Snapper (Squire)	*Chrysophrys auratus*	353001	1 335
Wrasse	Labridae spp	384000	924
Spangled Emperor	*Lethrinus nebulosus*	351008	834
Fingermark Bream	*Lutjanus russelli*	346012	624
Large Mouth Nannygai	*Lutjanus malabaricus*	346007	542
Steelback	*Leptobrama mulleri*	357012	531
Butter Bream	*Monodactylus argenteus*	356002	446
Painted Sweetlip	*Diagramma pictum*	350003	428
Hardyhead	Family Atherinidae	246000	395
Sweetlip	Sweetlip	351800	389
Black Bream Luderick)	*Girella tricuspidata*	361007	318
Stripey Bass	*Lutjanus carponotatus*	346011	300
Wings	Mixed Fish Wings	599802	248
Parrot Fish	Choerodon spp	384901	197
Tusk Fish	Tuskfish (Labridae spp)	384800	192
Jewelfish	*Nibea squamosa*	599801	180
Pilchard / Sardine	Family Clupeidae	085000	178
Nannygai	*L. malabaricus & L. erythropterus*	346911	139
Tailor	*Pomatomus saltatrix*	334002	134
Spotted Scale Sea Perch	*Lutjanus johnii*	346030	134
Maori Wrasse	*Ophthalmolepis cyanogramma*	384019	124
Jobfish	Jobfish	346901	78
Yellow Tail Fusilier	*Caesio cuning*	346018	74
Blue Pilchard	*Sardinops neopilchardus*	085002	54
Western Blue Groper	*Achoerodus gouldii*	384002	49
Flounder	Flounder	461000	46
Venus Tusk Fish	*Choerodon venustus*	384042	42
Sea Perch	Family Lutjanidae	346000	12
Barramundi Cod	*Cromileptes altivelis*	311044	11
Bat Fish	Platax spp	362901	9

Table 7: Summary of the total north-east Queensland Barramundi catch (kg) by year and month from 1985 to 1996.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	15	38 102	33 598	24 271	18 627	15 273	11 562	10 448	7 797	17 868	170	1877
1986		30 800	20 629	18 281	14 239	11 833	11 879	10 069	7 477	12 919	72	
1987	964	34 110	26 013	15 552	33 446	10 330	6 613	10 714	8 244	10 319	310	
1988	109	20 084	18 398	9 050	6 106	7 232	7 922	6 760	5 361	7 818	204	4
1989	204	24 968	19 607	20 546	20 243	10 658	5 944	7 112	8 116	10 889	93	14
1990	88	22 553	26 164	18 923	12 817	8 421	6 025	4 740	6 954	11 341	429	
1991	262	54 176	35 009	28 432	13 208	8 315	7 572	8 099	5 441	10 772	199	20
1992		34 713	20 169	10 904	6 674	4 547	5 553	4 517	5 495	8 524	162	
1993	210	32 766	30 302	25 677	9 951	10 027	6 552	8 541	7 400	8 561	44	
1994	361	35 078	27 548	15 376	8 147	5 480	3 665	4 984	4 446	8 644	292	
1995	428	28 297	19 584	12 953	8 350	7 342	7 455	4 701	4 620	6 744	47	
1996		23 499	17 518	8 895	7 584	5 620	5 122	7 675	5 417	11 395	254	5

Table 8: Summary of the total number of boat days fished by year and month in north-east Queensland from 1985 to 1996.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	3	1812	1768	1577	1413	1294	1140	962	692	931		33
1986		1463	1298	1288	1047	982	973	1057	738	685		
1987	61	1716	1529	1213	1151	877	776	793	683	903	35	
1988	242	943	1061	879	794	694	577	537	724	641	297	208
1989	242	1139	842	750	846	735	773	844	948	645	290	194
1990	298	1042	1002	812	724	606	639	652	779	832	274	160
1991	208	1209	1171	915	741	686	696	677	609	650	250	212
1992	162	956	808	606	548	493	450	466	677	543	272	162
1993	213	1009	872	713	631	621	619	533	571	592	265	138
1994	142	958	947	750	643	630	454	450	545	533	204	161
1995	180	752	721	636	557	493	576	400	599	573	237	179
1996	193	857	721	632	521	561	586	620	727	680	315	169

Table 9: Summary of the total number of boats by year and month in north-east Queensland from 1985 to 1996.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	1	98	95	94	83	74	69	62	50	63	1	2
1986		89	78	72	74	62	59	58	53	51	1	
1987	3	102	93	84	86	61	61	60	55	66	3	
1988	26	110	120	105	90	92	87	87	87	84	45	36
1989	39	110	101	97	95	85	88	92	96	76	34	30
1990	34	108	113	102	86	82	79	77	80	95	44	33
1991	42	130	115	110	106	100	109	103	93	92	49	40
1992	39	118	108	90	92	86	88	87	87	88	46	28
1993	49	112	99	98	102	94	93	89	85	83	44	40
1994	32	96	94	87	79	90	67	68	76	67	34	31
1995	30	90	90	82	85	86	85	66	79	76	45	35
1996	40	93	90	87	74	84	89	94	93	87	56	38

Table 10: Summary of the total number of days fished per boat by year and month in north-east Queensland from 1985 to 1996.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	3	18	19	17	17	17	17	16	14	15		17
1986		16	17	18	14	16	16	18	14	13		
1987	20	17	16	14	13	14	13	13	12	14	12	
1988	9	8	9	8	9	7	7	6	8	8	6	6
1989	6	10	8	8	9	9	9	9	10	8	8	6
1990	9	10	9	8	8	7	8	8	10	9	6	5
1991	5	9	10	8	7	7	6	7	6	7	5	5
1992	4	8	7	7	6	6	5	5	8	6	6	6
1993	4	9	9	7	6	7	7	6	7	7	6	3
1994	4	10	10	9	8	7	7	7	7	8	6	5
1995	6	8	8	8	7	6	7	6	8	8	5	5
1996	5	9	8	7	7	7	7	7	8	8	6	4

Table 11: Summary of the total Mud Crab catch (kg) by year and month in north-east Queensland from 1985 to 1996.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	708	2 838	2 839	2 400	3 539	2 694	1 593	1 111	1 143	1 201	368	702
1986	304	4 712	4 961	3 954	2 877	2 281	2 376	1 067	426	314	616	700
1987	285	3 574	3 066	2 535	3 196	2 438	804	1 120	859	727	378	711
1988	7 223	10 054	10 928	13 309	8 516	8 707	4 350	4 469	3 239	3 155	4 047	8 476
1989	13 569	12 261	10 141	12 043	13 394	11 994	11 367	8 750	6 472	5 357	9 208	9 004
1990	28 231	17 137	15 260	13 571	16 832	11 872	9 737	9 085	6 164	6 988	4 639	6 337
1991	9 214	9 599	14 814	17 918	16 623	14 129	10 439	5 752	3 747	3 849	4 871	5 484
1992	8 440	12 041	14 194	13 857	13 247	8 714	8 969	5 138	3 997	3 065	3 306	3 760
1993	5 870	8 995	12 557	11 309	9 961	7 290	5 366	3 528	3 426	4 637	5 066	5 883
1994	7 426	9 340	12 879	11 327	10 884	10 542	9 018	5 318	3 025	1 766	3 684	5 741
1995	8 427	9 683	11 698	14 072	13 331	8 929	7 463	8 317	5 251	4 894	5 079	7 587
1996	11 320	14 210	14 588	11 812	13 585	8 585	9 728	7 484	5 591	5 723	5 343	8 009

Table 12: Summary of the total number of boats harvesting Mud Crab by year and month in north-east Queensland from 1985 to 1996.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	6	23	21	22	24	20	22	15	8	13	5	4
1986	5	30	31	24	22	17	18	15	9	7	8	4
1987	3	23	22	16	19	18	9	8	8	9	3	4
1988	23	44	60	60	55	44	47	40	24	29	25	34
1989	38	50	47	42	52	49	51	43	33	28	29	34
1990	40	50	63	54	47	45	41	36	33	35	30	36
1991	49	46	66	69	64	54	56	47	33	39	36	29
1992	38	55	60	51	43	37	42	30	28	33	17	20
1993	27	53	48	58	50	45	44	38	36	33	27	29
1994	30	51	48	47	48	49	44	39	26	18	17	31
1995	37	54	61	53	59	52	36	36	33	29	32	37
1996	48	58	64	58	54	50	42	42	38	36	41	39

Appendix 5c (Section 2)

Status of Research Data – Northern Queensland inshore fish stocks

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Status of Research Data – Northern Queensland inshore fish stocks

The QDPI Northern Fisheries Centre (NFC) has collected research data on the major species of the tropical north Queensland gillnet fishery on an irregular basis between 1979-1998 through various one to three-year research projects. Information has been collected from a number of rivers in the Gulf of Carpentaria and the East Coast of Queensland (Figure 1). Data recorded includes measurements of length, weight and age, and determinations of sex for fish caught in a range of mesh net sizes. The status of these data was assessed for both the Gulf of Carpentaria and East Coast inshore gillnet fisheries, with a particular focus on Barramundi and King Salmon.

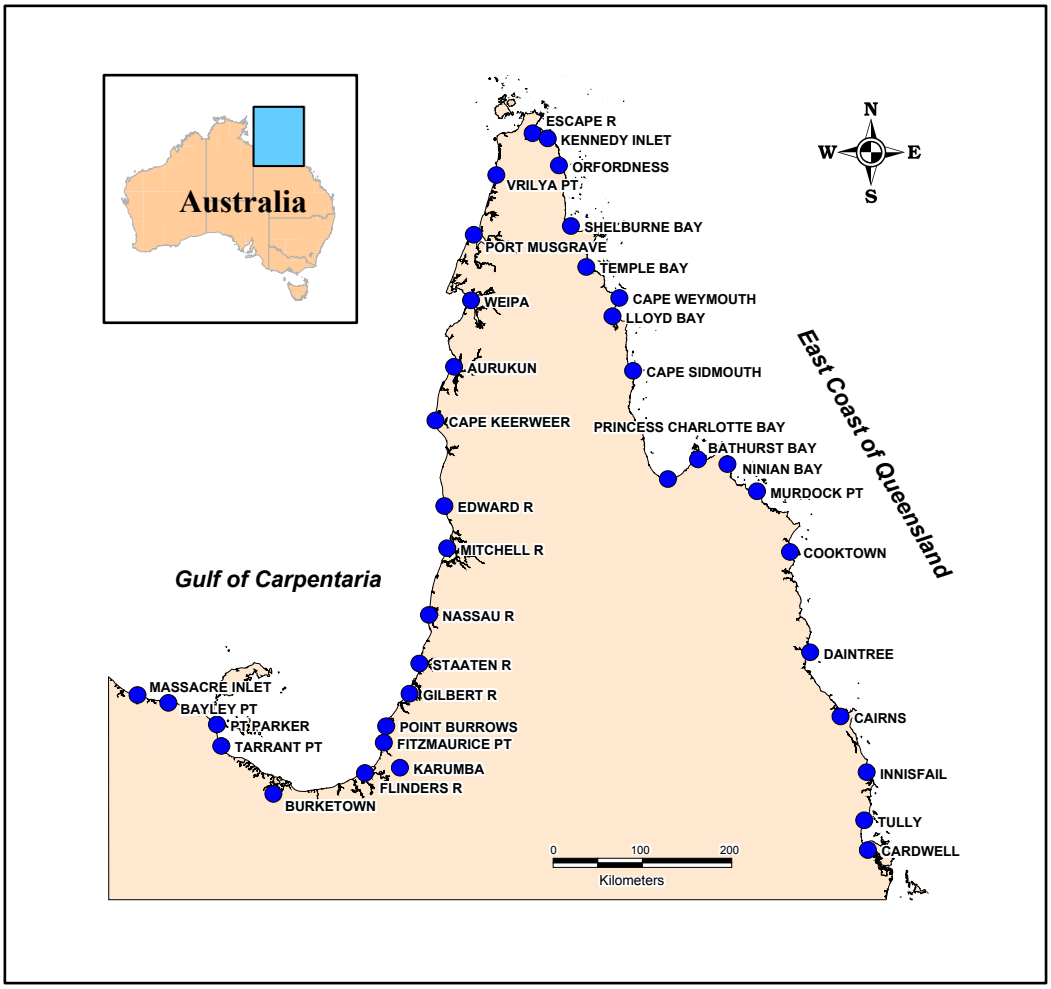

Figure 1 Map of study areas for the Gulf of Carpentaria and East Coast of Queensland.

Long-term patterns in the biology of barramundi caught in the Norman River

The majority of data collected for Barramundi over time stemmed from the Norman River, in the Gulf of Carpentaria for fish caught in 150mm mesh gill nets. These data were examined in further detail to provide (1) a descriptive summary of the data set, (2) size and weight frequency distributions to examine the status of fish stocks, and (3) pertinent biological information on Gulf Barramundi.

Summary of data for barramundi caught in 150 mm mesh gillnets

A total of 1735 barramundi were caught in 150mm mesh gillnets over 524 sampling days from the Norman River in the Gulf of Carpentaria. This collection of research data was spread over 17

years (1981 – 1998) and across 20 recorded sites along the Norman River (Table 1). The collection of fish within this spatial and temporal framework was sporadic. For example, on a temporal scale, sampling was highly irregular for months within years, for days within months and for hours within days, and on a spatial scale, variable for sites within rivers (Table 4, 5 ,6 and 7). These data are discussed in detail below.

The number of barramundi sampled over time was variable. A low number of fish (> 5% of total number) were sampled in 1981, 1982, 1990 and 1992, and a high number of fish (> 5% of total number) were sampled in the remaining years (Table 1). Similarly, fish numbers were highly variable between months (Table 1). There were generally fewer fish sampled in November, December and January (< 1% of total number), a higher number of fish sampled in February and April (> 15% of total number), and a moderate number of fish taken in the remaining months (>5% and < 15% of total number).

Table 1 Fish abundance and sampling effort for barramundi caught in 150 mm mesh gillnets along the Norman River in the Gulf of Carpentaria, over sites, years and months. (FN = % fish numbers; SD = %sample days).

AREA					
SITE	FN (%)	SD (%)	SITE	FN (%)	SD (%)
Foreshore, Bynoe	0.12	0.4	Jenny Lynd Ck	0.2	0.2
Foreshore	9.9	16.8	Baffle Island lower	0.3	0.2
Mouth	0.9	1.0	Baffle Island extra	0.1	0.2
Katoora Ck	0.2	0.4	Baffle Island upper	0.6	0.8
Six mile creek	0.1	0.2	11 Mile-Lower	6.5	1.0
Six mile Ck 3nm	0.1	0.2	11 Mile middle	2.7	0.4
Twin Creek	0.6	0.6	11 Mile upper	5.4	1.2
Walkers Ck	0.1	0.2	Glenore Weir	2.8	1.2
Walkers/Jenny Lynd Ck	0.1	0.2	Unspecified	69.6	75.2
TIME					
YEARS	FN (%)	SD (%)	MONTHS	FN (%)	SD (%)
1981	0.3	0.4	January	0.0	0.0
1982	1.0	0.6	February	16.2	16.2
1983	11.0	10.1	March	8.8	8.2
1984	12.0	10.9	April	16.9	12.0
1985	11.0	11.6	May	6.4	7.1
1986	7.8	8.6	June	13.4	11.8
1987	8.9	9.5	July	8.6	9.4
1988	8.3	12.2	August	7.6	8.4
1989	6.7	9.2	September	8.2	9.0
1990	4.0	5.9	October	12.2	16.8
1991	8.0	8.8	November	0.9	0.4
1992	3.3	5.0	December	0.08	0.8
1993	1.4	1.9	Total Number	1735	524
1997	10.6	3.8			
1998	6.7	1.5			

The sampling effort (number of days on which barramundi were sampled) for barramundi was also erratic over time (Table 1). Sampling effort was low (<5% of total days sampled) in 1981, 1982, 1983, 1997 and 1998, and for the months of November, December and January, high (> 10% of total days sampled) in 1983, 1985, 1988 and for the months of February and October (> 15% of total days sampled), and moderate (> 5% and < 15%) for the remaining months and years.

On a smaller spatial scale, sampling effort and number of barramundi sampled was unevenly spread over time among the 20 recorded collection sites along the Norman River (Table 1, 6 and 7). In most cases (>60%), the actual site of collection of barramundi was not specified until the early 1990s. Consequently, the site information is not suitable for spatial analysis within the Norman River catchment and will only be used to separate out individual data points.

The number of fish caught in a particular sampling event was closely associated (correlation coefficient = 0.637, $P_{(0.05,\ 138df)} = 0.000$) with sampling effort (number of days per month per year per site) (Figure 2). Over time, the median number of fish examined per day (grouped by months) was generally low (<7 fish per day) for all years except 1998 where the median value was 21 (Figure 3). Similarly, the range in number of fish caught per day was low (<5 fish per day) for all years except 1982, 1983, 1984, 1997 and 1998, where the range in the number of fish caught per day was high (8, 15, 11, 10 and 25 fish per day respectively, Figure 3).

On a spatial scale, the median number of fish caught per day was low (<7) for all sites except those at 11 Mile Creek (Figure 4). The median number of fish at the three 11 Mile sites was approximately three times greater than the number sampled at all the other sites (Figure 4). Variation in the number of fish caught per day was also evident among a small number of sites over time (Table 2). For example, approximately twice as many fish were taken per day in 1998 as compared with 1997 at the upper and lower reaches of 11 Mile Creek, and approximately 3.5 times as many fish were caught per day in 1984 as compared with 1982 and 1983 at Glenore Weir. In contrast, CPUE was uniformly low (1 – 5 fish caught per day) at all other sites (Table 2).

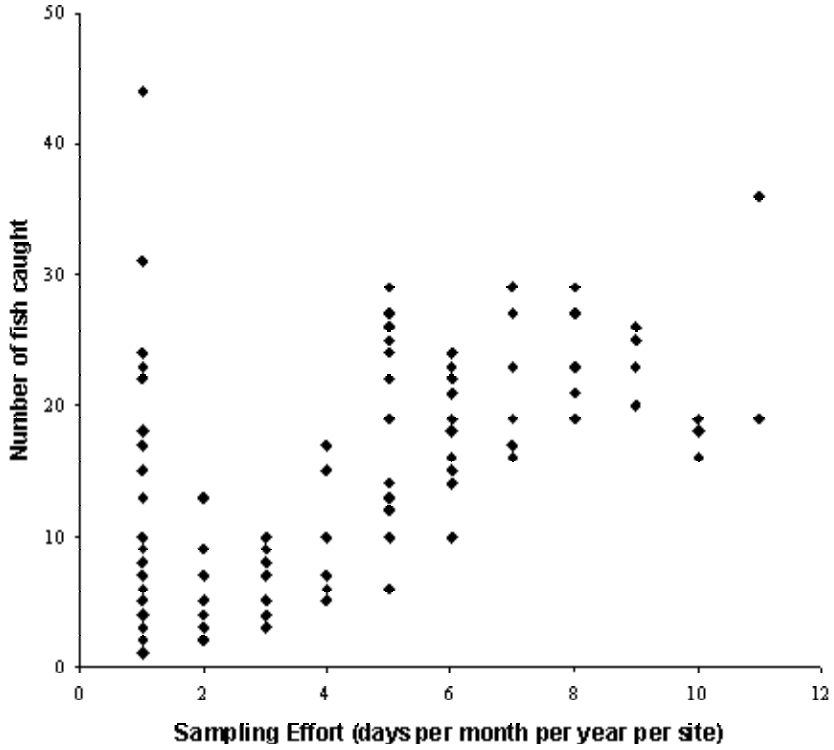

Figure 2 Scattergram of sampling effort (days per month per year per site) by number of fish sampled).

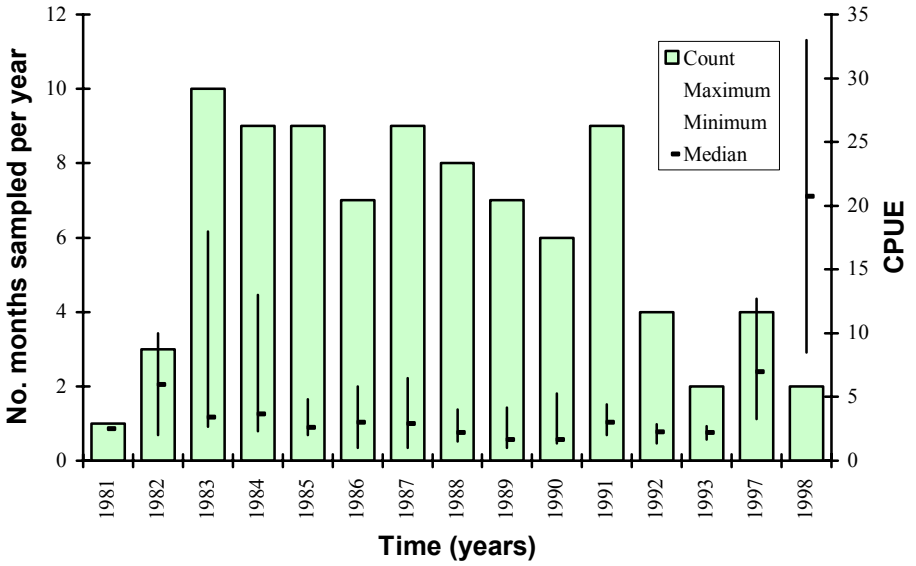

Figure 3 Description of catch per unit effort (number of barramundi sampled per day) among months and years. Grey bars represent the number of months over which sampling took place in each year, the solid vertical lines represent the maximum and minimum values for the number of fish sampled per day, and the solid horizontal lines represent the median value of number of fish sampled per day.

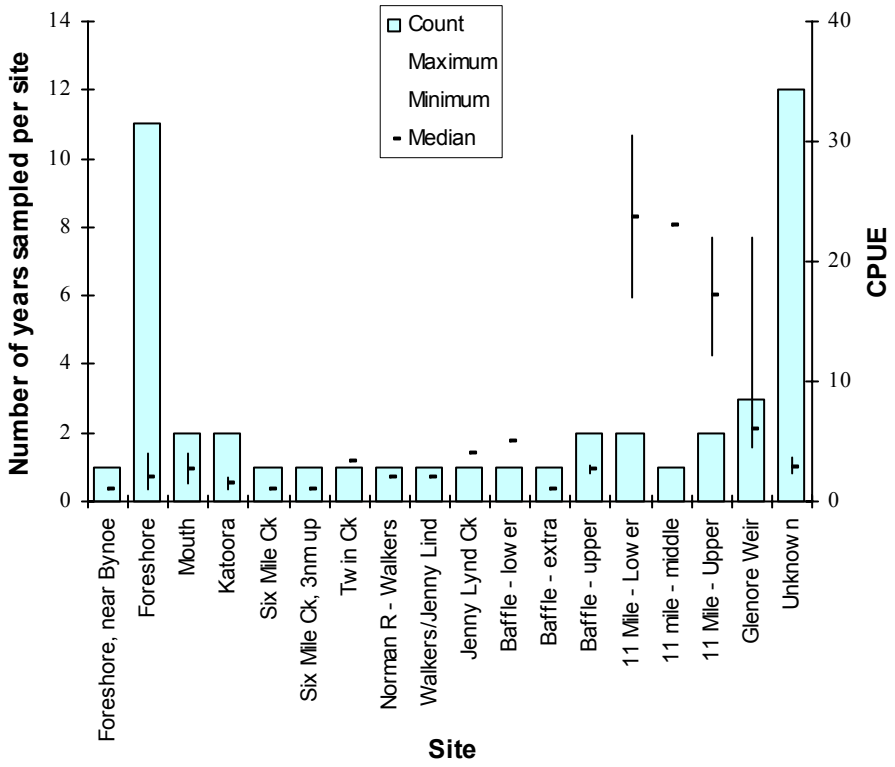

Figure 4 Description of catch per unit effort (number of fish caught per day) among sites grouped by years. Light grey bars represent the number of years over which sampling took place at each site, the solid vertical lines represent the maximum and minimum values for the number of fish caught per day, and the solid horizontal lines represent the median value of number of fish caught per day.

Table 2 Catch per unit effort over space and time for barramundi caught in 150 mm mesh gillnets in the Norman River.

SITE	YEAR														
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1997	1998
Foreshore, Bynoe						1									
Foreshore			3	1		1	1	2	1	2	2	2		4	3
Mouth											4	2			
Katoora Ck														2	1
Six mile creek			1												
Six mile Ck 3nm											1				
Twin Creek														3	
Walkers Ck														2	
Walkers/Jenny Lynd Ck														2	
Jenny Lynd Ck											4				
Baffle Is. lower															5
Baffle Is. extra														1	
Baffle Is. upper														2	3
11Mile-Lower														17	31
11 Mile middle														23	
11 Mile upper														12	22
Glenore Weir		6	5	22											
Unknown	3		4	3	3	3	3	2	3	2	3	2	2		

Size-frequency distributions over time

Yearly size-frequency distributions were constructed for barramundi caught in 150 mm mesh gillnets from the Norman River, pooled by site and month. Size-frequency histograms were not constructed for barramundi collected prior to 1983 nor between 1993 and 1996 due to the low number of fish caught in these years. In general, the size-frequency distributions for barramundi were relatively stable over time (Figure 5). For all years examined, the distributions were bell shaped and dominated by fish measuring between 55 and 70 cm in total length.

Mesh Selection

Gillnets are selective in the size of fish that they catch, negatively selecting for both small and large fish, and producing a normally distributed selection curve of the catch (Pauly 1984). Gill net selectivity has been clearly demonstrated for barramundi caught in the Norman River with 150 mm mesh gillnets since the size-frequency curves were all normally distributed (Figure 5). To estimate the selection curve of a 150 mm mesh gillnet, two gillnets of different mesh sizes were used to determine (1) the optimum length of capture, and (2) the probability of capture (Holt 1963). The gillnet sizes used for these estimates were 150 mm and 100 mm because they meet the assumptions of the analysis (i.e. both selection curves were normally distributed and had the same standard deviation, the optimum length was proportional to mesh size, and the tow nets had overlapping selection ranges). Barramundi caught in 1997 for research purposes were used in the analysis because they represented samples where the two gears have the same fishing power. The optimum lengths of capture for 100 mm and 150 mm mesh gillnets in 1997 were 45 cm and 67 cm respectively (Figure 6). Barramundi below 52 cm and above 84 cm in size have a less than 25% chance of capture while fish falling between 52 and 840 cm have a greater than 25% change of capture (Figure 6).

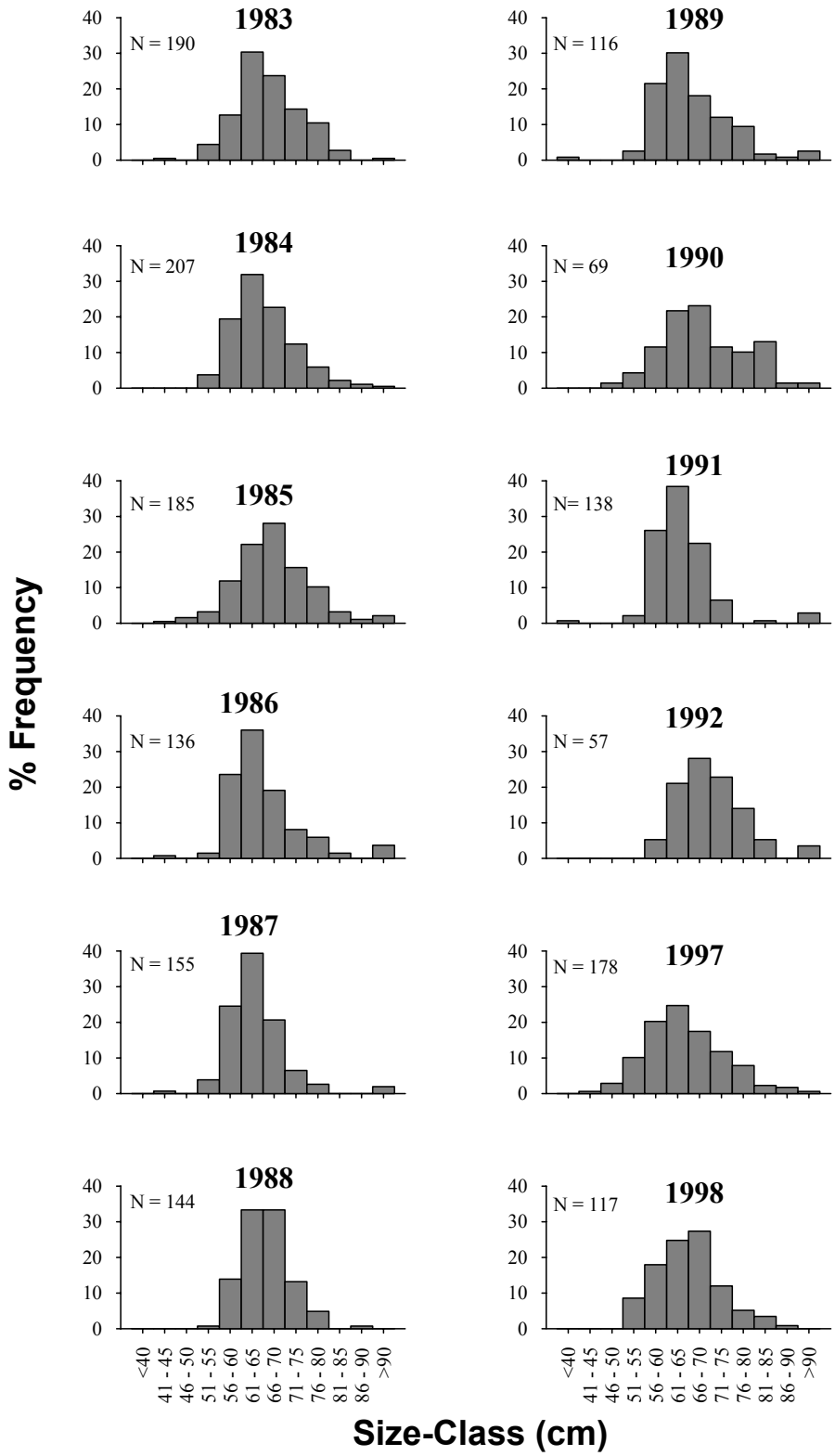

Figure 5 Size-frequency histograms for barramundi caught in 150 mm mesh gillnets in the Norman River, Karumba over time.

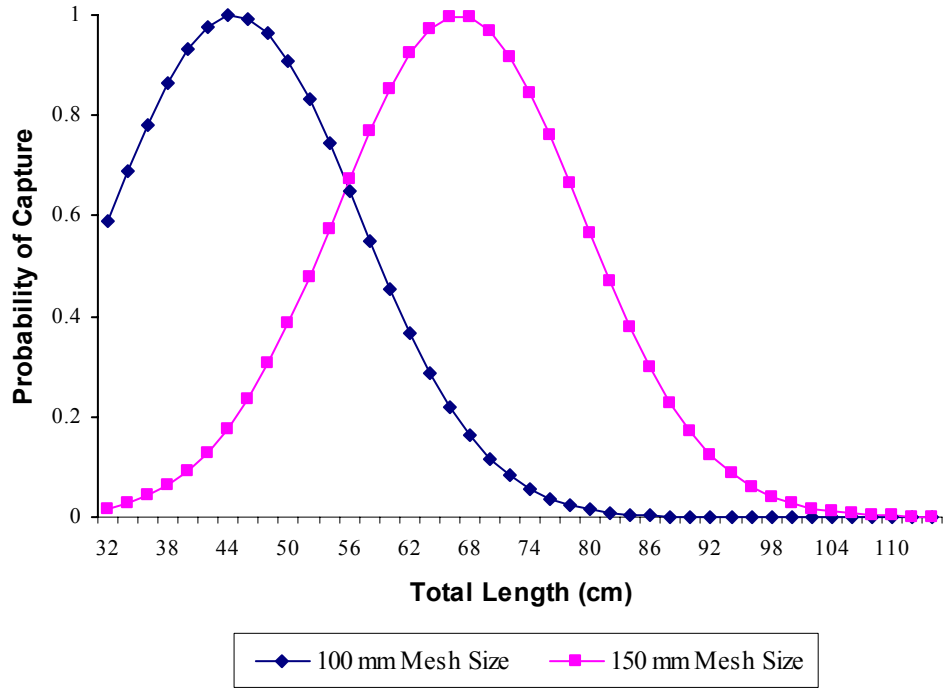

Figure 6 Probability of capture curves for barramundi from the Norman River caught in 100 mm and 150 mm mesh gillnets

An estimate of the true relative abundance in the 1997 population of barramundi caught in 150 mm mesh gillnets in the Norman River was calculated using the formula:

$$\text{True relative abundance in the population} = \frac{\text{relative abundance in sample}}{\text{probability of capture}} \quad \text{(Pauly 1984)}$$

For barramundi caught in 150 mm mesh gillnets, the relative abundance of smaller fish (<56cm) was under-estimated by approximately by 5 – 7.5% (Figure 7). In contrast, the relative abundance of larger fish (<64cm) was over-estimated by about 5% (Figure 7).

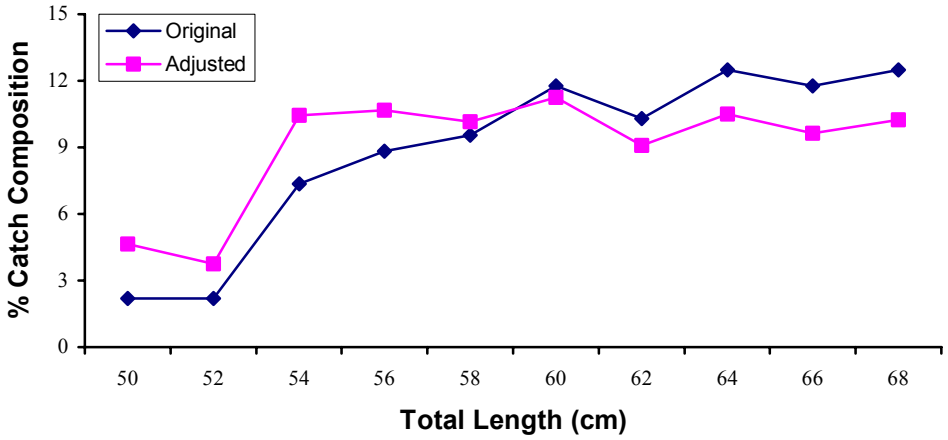

Figure 7 Percentage of catch composition for barramundi from the Norman River for both the original and adjusted samples collected with 150 mm mesh gillnets.

Age estimations of the catch

The von Bertalannffy growth curve models body length as a function of age. Using the von Bertalanffy parameter estimates form Davis and Kirkwood (1984) of l_∞=149; K = 0.125 and t_0=-1.27 for barramundi captured from the Norman River, the ages of barramundi caught in 150mm mesh gillnets were calculated. The ages of barramundi caught ranged from 7 months old to 22 years old. The dominant age-class was >3 – 4 year olds for all years investigated (Table 3).

Table 3 Percentage of barramundi from the Norman River belonging to each age-class over time.

	Age-Class (years)							
YEAR	≤ 1	>1 – 2	>2 – 3	>3 – 4	> 4 – 5	> 5 – 6	> 6	n
1983	0	1	14	54	25	6	1	190
1984	0	0	21	54	21	3	0	207
1985	0	2	14	48	28	5	3	185
1986	0	1	25	51	18	1	4	136
1987	0	1	23	63	11	0	2	155
1988	0	0	10	66	22	2	0	144
1989	1	0	19	52	21	4	3	116
1990	0	1	16	39	28	13	3	69
1991	1	0	21	66	9	1	3	138
1992	0	0	4	47	40	5	4	57
1997	0	2	29	44	18	4	2	178
1998	0	0	21	53	20	6	0	117

Age composition of length frequencies

The age composition for each size-class in each year was estimated for barramundi caught in 150 mm mesh gillnets from the Norman River, (Figure 8). Barramundi less than 40 cm in length consisted of young of the year or one year olds and barramundi greater than 90 cm in length consisted of fish older than 6 years. The age of barramundi increased at a rate of 10 cm increase in length for each year of age. However, in larger fish (>80 cm), yearly increments were observed for every 5 cm increase in length.

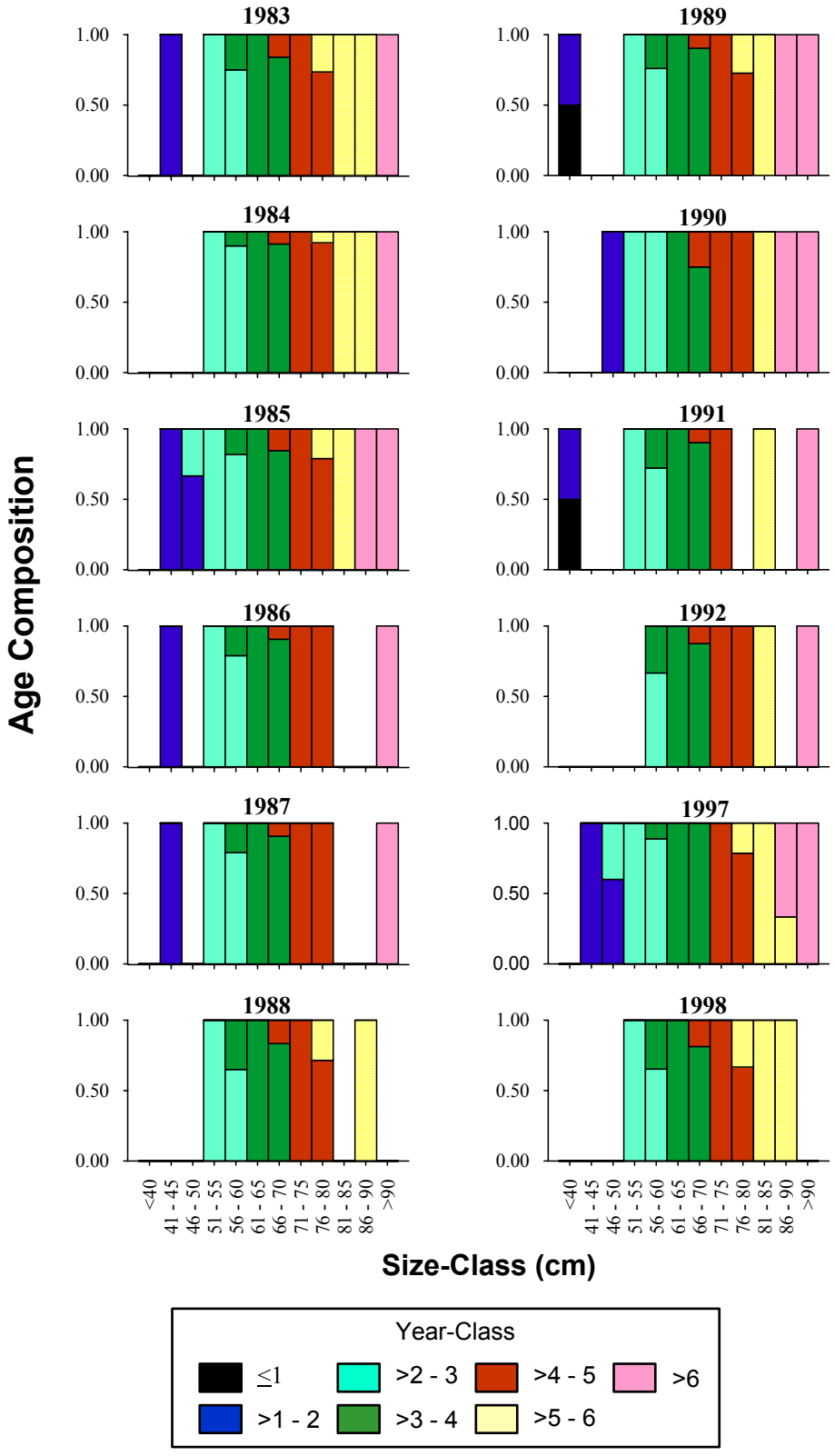

Figure 8 Age composition for each size-class over time for barramundi netted in the Norman River.

Weight estimates of the catch

The relationship between barramundi length and weight was established from the subset of the data on barramundi caught in 150 mm mesh gillnets from all sites within the Gulf of Carpentaria that had both length and weight measurements recorded. The resulting relationship between length and weight is reasonably well described (r^2=0.893) by the following equation: $y = 1\ E\text{-}0.5\ x^{2.951}$ (Figure 9). This relationship was then used to estimate the weight of each barramundi sampled in the Norman River. It has been assumed that the length/weight relationship of barramundi caught in the Norman River is the same as the relationship obtained for all Gulf barramundi.

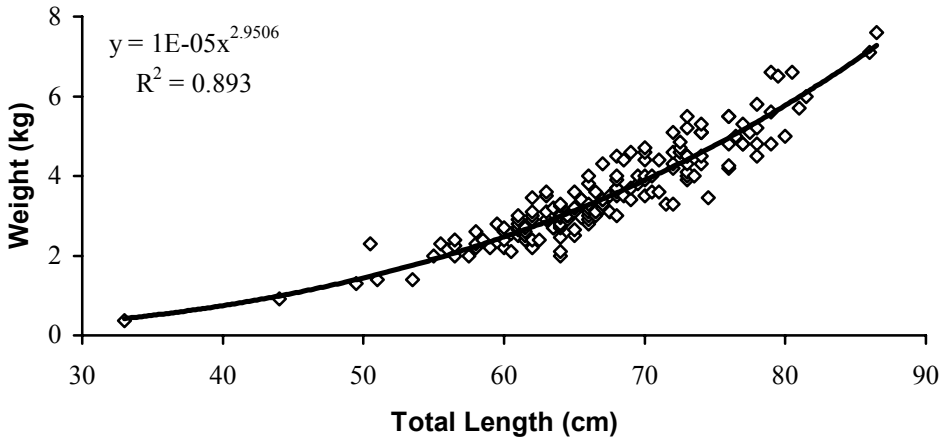

Figure 9 Relationship between total length (cm) and weight (kg) for barramundi caught in the Gulf of Carpentaria.

Composition of catch by weight

The total weight of barramundi caught between 1983 – 1992 and 1997 – 1998 in the Norman River is estimated at 4189 kg. The weight of individual barramundi ranged from 0.28kg to 20.17kg. The weight composition across size- and age-classes was dominated by fish 60 – 70cm in length (Figure 10) and >3 – 5 years old (**Error! Reference source not found.**), for all years. Fish smaller than 60cm in length and younger than 5 years of age constituted less than 21% of the total sample weight in all years (Figure 10 and **Error! Reference source not found.**). Similarly, the percentage of total sample weight for large fish (<70cm), and older than 5 years was also low for most years (< 30% and 50% for length and age respectively). The percentage of the total sample weight for large fish in 1990 and 1992 was high (55% and 61% respectively). However, low fish numbers most probably biases the weight composition for these years.

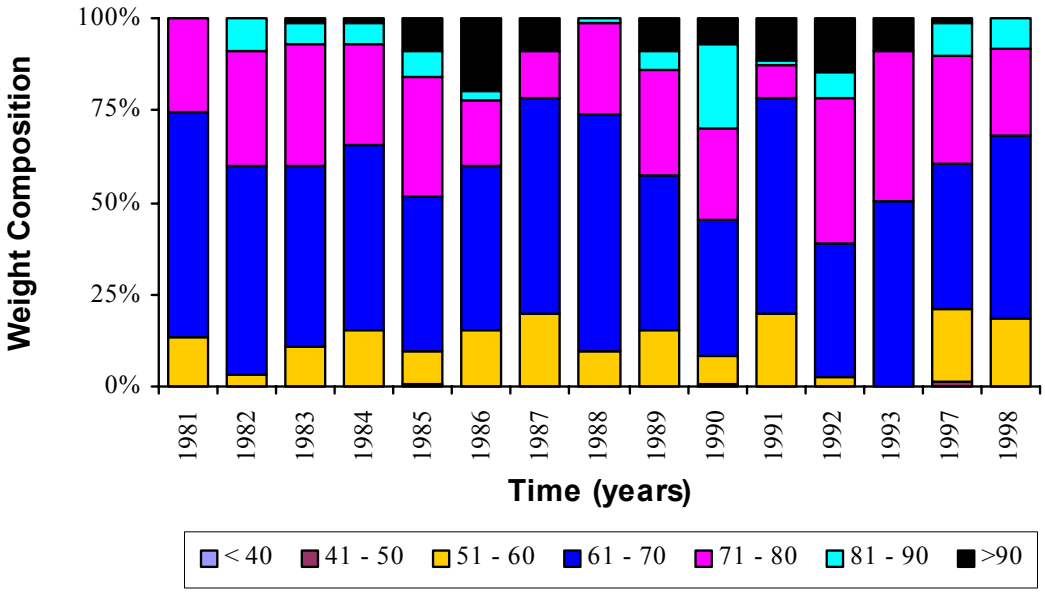

Figure 10 Weight composition across size-classes and years for barramundi sampled in the Norman River with 150 mm mesh gillnets.

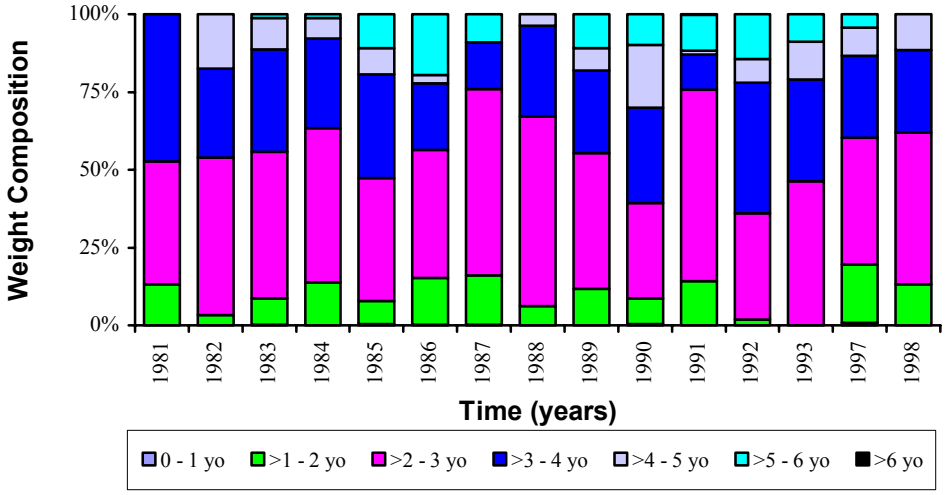

Figure 11 Weight composition across age-classes and years for barramundi sampled in the Norman River with 150 mm mesh gillnets.

Total Mortality Estimate

The total mortality for the research data was estimated using the linearized catch curve model based on length composition data (length converted catch curve, Pauly 1984). In this method, the von Bertalanffy growth equation is used to convert length into age. Values for the von Bertalanffy growth equation parameter, K, t_0 and l_∞ were taken from Davis (1984). Total mortality is then determined as the slope of the line from the following regression relationship:

$$\ln \frac{Catch\ (L1,L2)}{\Delta t\,(L1,L2)} = a - Z\left(\frac{t(L1)+t(L2)}{2}\right) \qquad \text{(Sparre } et\ al.\text{ 1989)}$$

Total mortality rose steadily over the first 6 years, starting at 1.2 in 1983 and peaking at 1.9 in 1987 and 1988 (Figure 12). After 1988, total mortality remained fairly low (<1.5) for all years with the exception of 1991, where Z rose to 1.8 (Figure 12). Total yearly rainfall for Normanton and CPUE data for Division C of the Gulf of Carpentaria (Magro *et al.* 1996) were overlaid on total mortality to see if there was any association between these variables (Figure 12). Environmental parameters and CPUE have been clearly related in other fisheries in the Gulf of Carpentaria (e.g. Banana Prawns, Williams 1997). For barramundi, the pattern in total mortality over time did not follow that of total rainfall, nor did it correspond to the CPUE data.

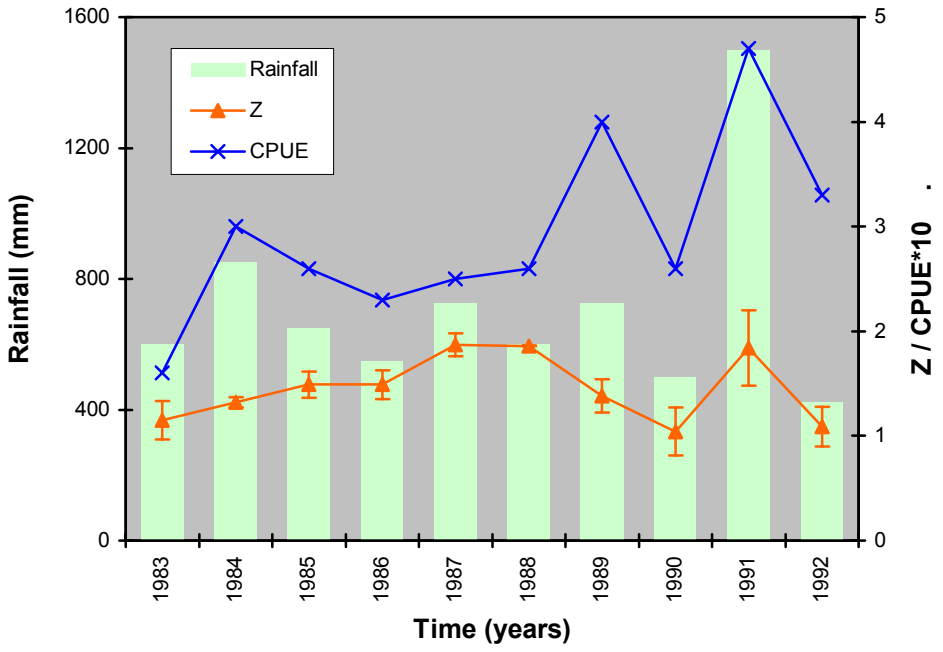

Figure 12 Overlay of total mortality and catch per unit effort (kg/boat days) on total rainfall over time. Source of data for total rainfall and CPUE is Magro *et al.* 1996.

Distribution patterns of male and female barramundi

The majority of barramundi sampled in 150mm mesh gillnets from the Norman River were recorded as male (82%). The proportion of males and females remained relatively stable over time with a slight increase in the female proportion in later years (Figure 13). The minimum and maximum lengths of male and female barramundi were also fairly consistent over time (Figure 14). Female lengths ranged from 46 to 77.5 cm and male lengths ranged from 32 to 58cm.

The size and age frequency distributions of male and female barramundi were examined for data pooled over time (Figure 15 and Figure 16). The shape of the distributions and the median values for both size and age were significantly different between males and females (Kolmogorov-Smirnov Two Sample Test: D=0.40 and 0.38 for age and size respectively, P<0.01; Median Test: $\chi^2_{(0.05,\ 1df)} = 9.3$ and 37.3 for age and size respectively, P<0.05). The overall median values for age and size were 3 years old and 66 cm respectively. Ninety-seven percent of the females sampled were older than 3 years and only 3% were younger than 3 years. Similarly, 83% of females were bigger than 66 cm and only 17% were smaller than 66 cm. In contrast, 79% of males were older than 3 years and 21% were younger than 3 years. There was an even distribution of males above and below 66 cm (48% and 52% above and below respectively). The differences in size and age frequency distributions of male and female barramundi reflect patterns in their life-history. Barramundi are protandrous hermaphrodites and change from male to female at around four years old (Davis 1984). Consequently, the smaller fish in the population are predominately males and the larger fish are female although some precocious females may occur (Davis 1984).

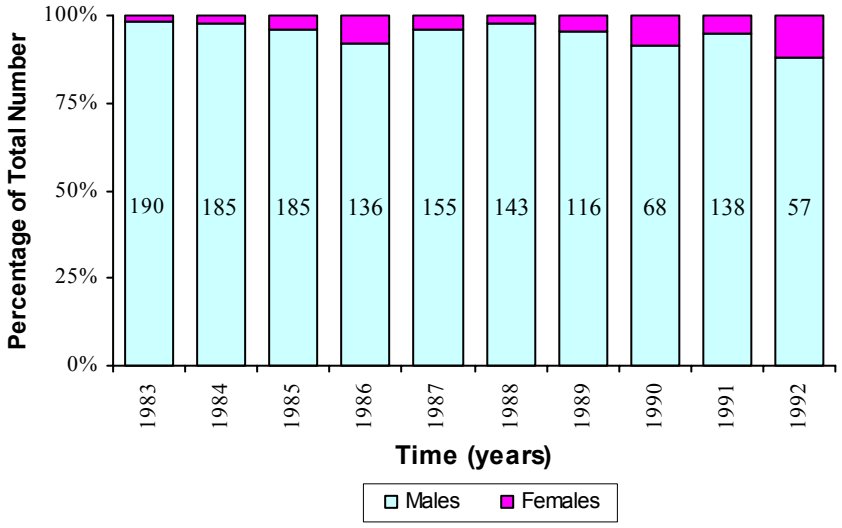

Figure 13 Percentage of male and female barramundi caught in 150 mm mesh gillnets from the Norman River over time. (Numbers in each bar represent the sample number).

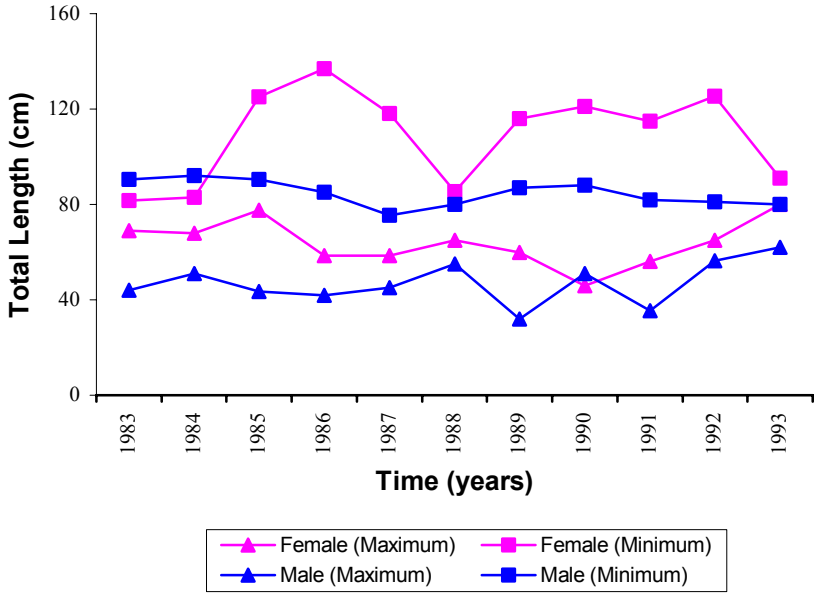

Figure 14 Maximum and minimum lengths of female and male barramundi caught in 150 mm mesh gillnets from the Norman River over time.

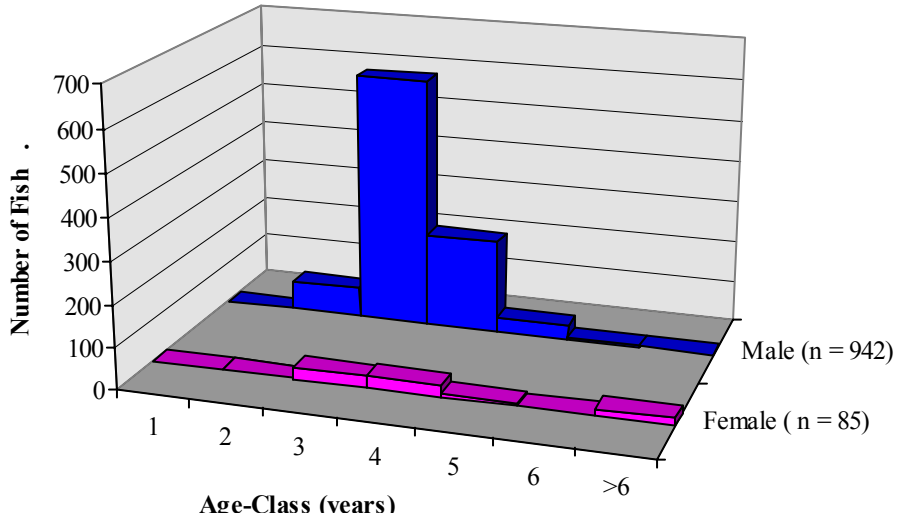

Figure 15 Age-frequency distribution of male and female barramundi in the Norman River for data pooled over years.

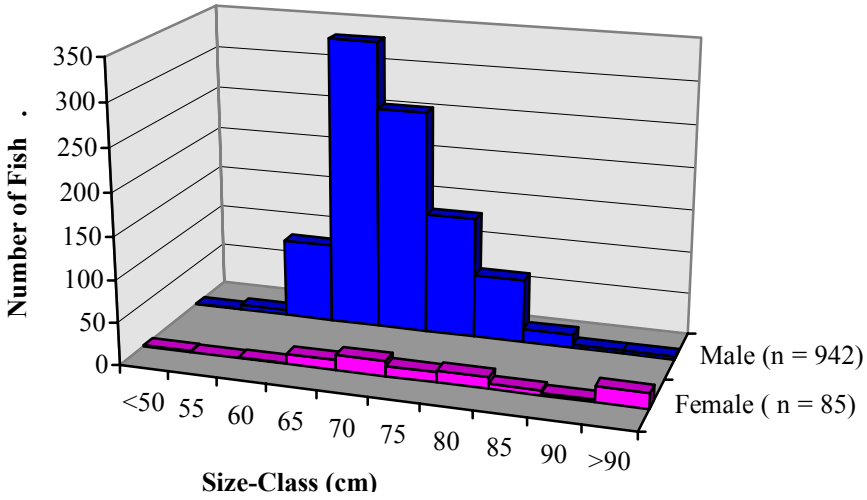

Figure 16 Size-frequency distribution for male and female barramundi pooled across years.

SUMMARY TABLES FOR RESEARCH DATA (Norman River).

Table 4 Number of barramundi caught over time in 150 mm gill nets along the Norman River, Karumba.

MONTH	YEAR															
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1997	1998	% Months
Jan																0.0
Feb			7	22	19	29	26	22	19	22	22	23	19		51	16.2
Mar			18	26	24		13	4	29		31	8				8.8
Apr			21	13	12	1	22	18	20	4	12	15		89	66	16.9
May		6	8	16	21		27	12		9	12					6.4
Jun			25	41	10	26	27		1	21	10	11		60		13.4
Jul		2	18	23	23	25	21	18	2		17					8.6
Aug	5		19	14	23	19	7	16			17			12		7.6
Sep			25	24	17	9	10	22	29	5	2					8.2
Oct			43	28	36	27	2	32	16	8	15		5			12.2
Nov		10	6													0.9
Dec														13		0.08
% Years	0.3	1.0	11.0	12.0	11.0	7.8	8.9	8.3	6.7	4.0	8.0	3.3	1.4	10.0	6.7	N = 17355

Table 5 Sampling effort (number of days) for barramundi caught in 150 mm gill nets along the Norman River, Karumba.

MONTH	YEAR															
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1997	1998	% Months
Jan																0.0
Feb			2	6	8	5	9	10	5	14	5	8	7		6	16.2
Mar			6	5	5		5	1	7		10	4				8.2
Apr			6	1	5	1	5	10	12	3	5	6		7	2	12.0
May		1	3	6	8		5	8		2	4					7.1
Jun			10	8	5	9	8		1	4	3	8		6		11.8
Jul		1	1	8	9	5	6	10	2		7					9.4
Aug	2		6	6	6	5	4	7			5			3		8.4
Sep			5	5	4	3	6	9	11	3	1					9.0
Oct			13	12	11	17	2	9	10	5	6		3			16.8
Nov		1	1													0.4
Dec														4		0.8
% Years	0.4	0.6	10.1	10.9	11.6	8.6	9.5	12.2	9.2	5.9	8.8	5.0	1.9	3.8	1.5	N =524

Table 6 Number of barramundi caught over time with 150 mm gillnets at recorded sites along the Norman River, Karumba.

SITE	YEAR														
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1997	1998
Foreshore, Bynoe						2									
Foreshore			14	3		6	8	40	7	43	18	25		4	3
Mouth											12	3			
Katoora														2	1
Six mile creek			1												
Six mile Ck 3nm											1				
Twin Creek														10	
Walkers														2	
Walkers/Jenny Lynd														2	
Jenny Lynd Ck											4				
Baffle lower															5
Baffle extra														1	
Baffle upper														7	3
11-Mile-Lower														51	61
11 Mile middle														46	
11 Mile upper														49	44
Glenore Weir		18	9	22											
General	5														
River										6	103	29	4		
Unknown			166	182	185	128	147	104	109	20			20		

Table 7 Sampling effort over sites and years for barramundi caught in 150 mm gillnets along the Norman River, Karumba.

SITE	YEAR														
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1997	1998
Foreshore, Bynoe						2									
Foreshore			5	3		5	7	20	5	20	9	12		1	1
Mouth											3	2			
Katoora														1	1
Six mile creek			1												
Six mile Ck 3nm											1				
Twin Creek														3	
Walkers														1	
Walkers/Jenny Lynd														1	
Jenny Lynd Ck											1				
Baffle lower															1
Baffle extra														1	
Baffle upper														3	1
11-Mile-Lower														3	2
11 Mile middle														2	
11 Mile upper														4	2
Glenore Weir		3	2	1											
River										4	32	12	2		
General	2														
Unknown			45	53	61	38	43	44	43	7			8		

Appendix 6 (**Section 3)**

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Appendix 6a Morphometric relationships of Barramundi and King Salmon

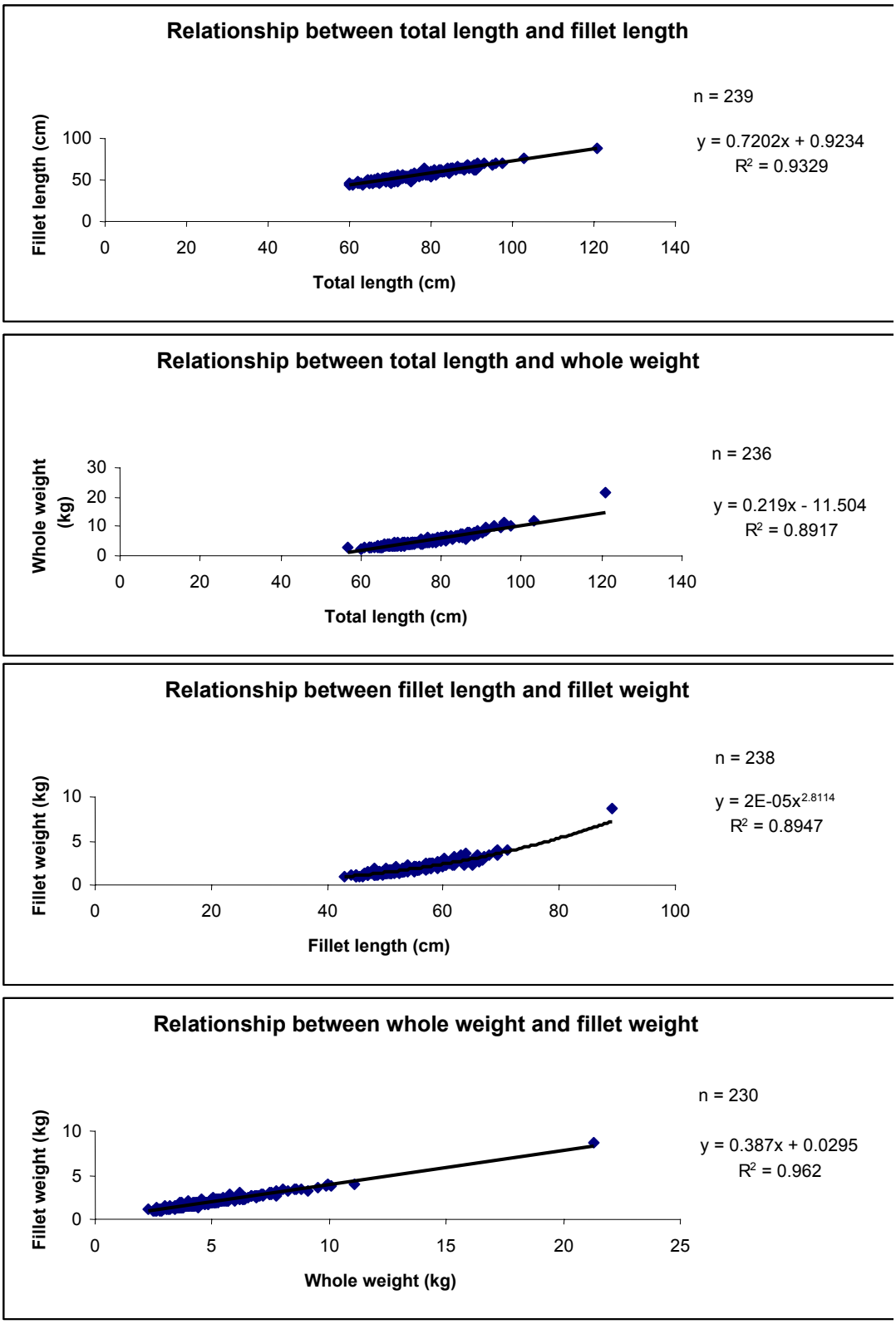
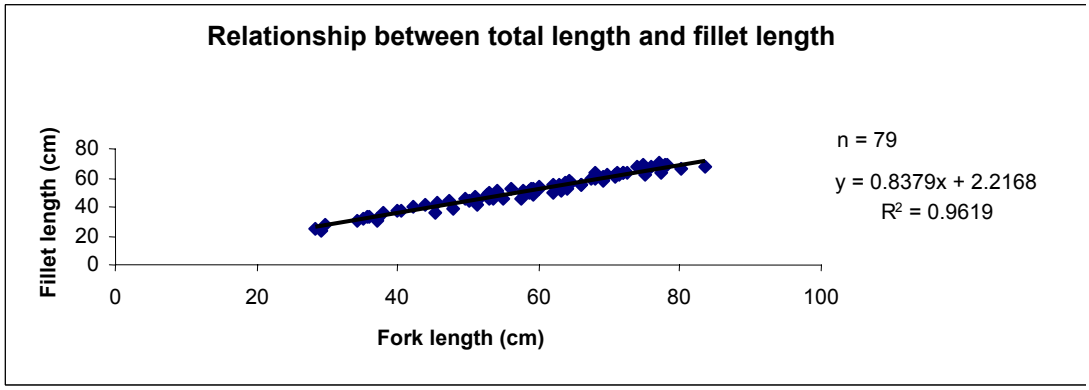
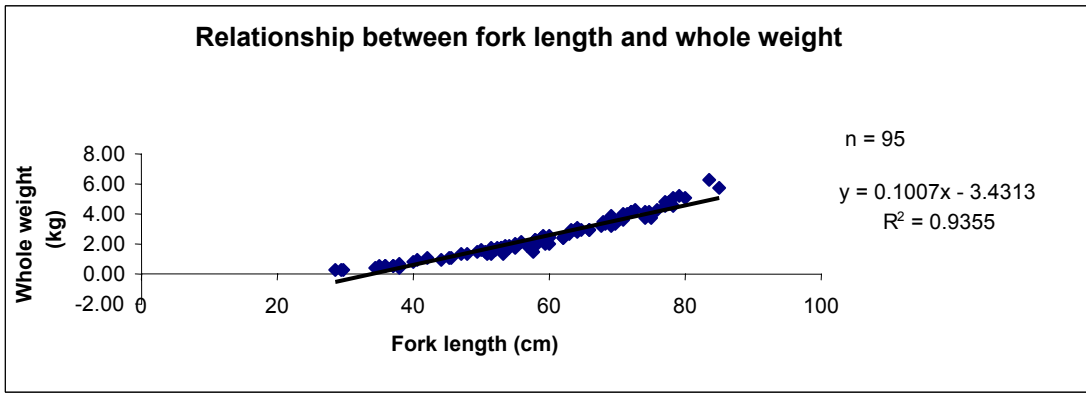
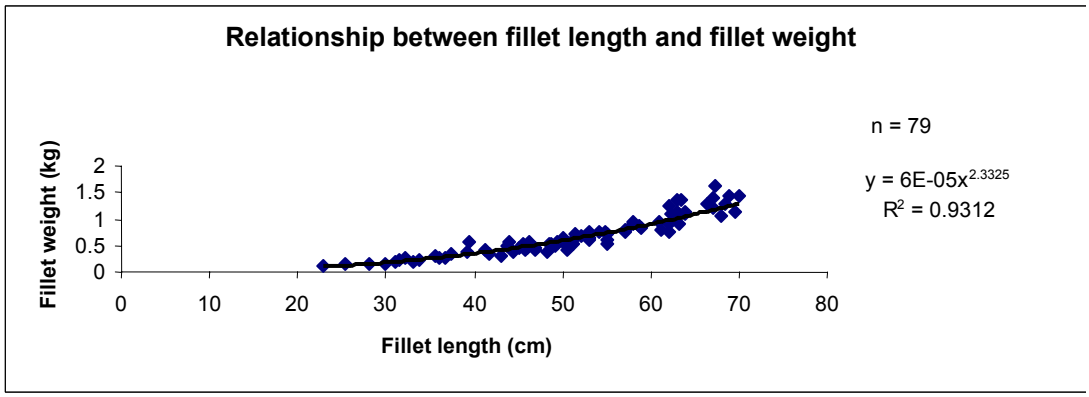


Figure 1: Relationships between several morphological measurements for Gulf barramundi (Lates calcarifer)







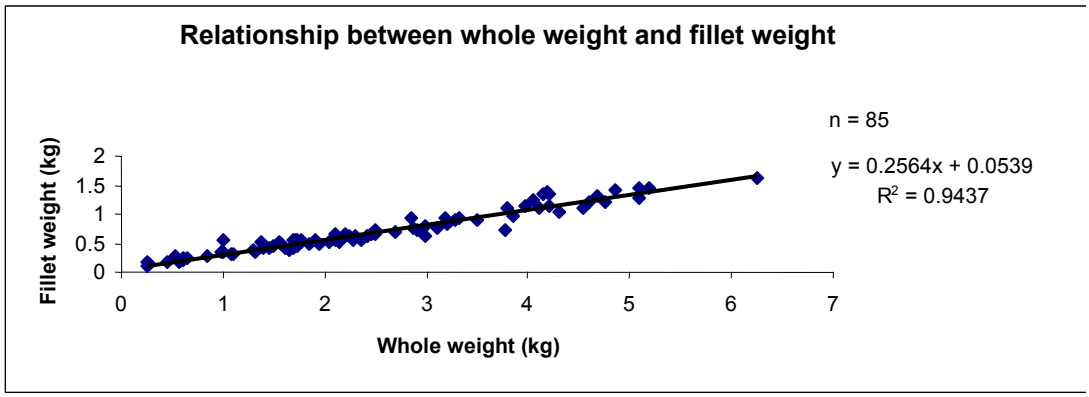


Figure 2: Relationships between several morphological measurements for Gulf king salmon (*Polydactylus macrochir*)

Appendix 6b. Gulf of Carpentaria N3 & N9 Sawfish Release Procedures

Sawfish (family Pristidae) have a cartilaginous skeleton that groups them with sharks and other elasmobranchs. They are members of the skates and rays order being characterised by their gill openings being on the ventral surface. These unique elasmobranchs inhabit estuarine and freshwater rivers, bays and lakes placing them at times in direct contact with commercial net fishermen of the Gulf of Carpentaria (GoC).

There are five species of sawfish inhabiting the waters of the GoC with the freshwater sawfish (*Pristis microdon*) listed under the Environmental Protection and Biodiversity Conservation Act (1999) as vulnerable. The International Union for Conservation of Nature (IUCN) has identified Pristidae as being endangered, and freshwater sawfish as critically endangered. The international distribution and abundance of Pristidae is declining rapidly and the GoC is considered to be one of the remaining known areas of healthy populations.

To maintain GoC fisheries biodiversity N3 & N9 commercial fishers have cooperatively assisted with the established code of fishing behaviour to reduce the impact of their fishing operations on all non target species. Components of the code can be found in the attached document.

- **Refrain from setting nets in known areas of large sawfish abundance**

Advantages: minimise the incidental catch and potential mortality of sawfish

- **Apply release procedures (attached) or other release procedures you consider more appropriate when dealing with captured sawfish**

Advantages: minimise the trauma and injury to sawfish caused by incidental catch

- **Participate in research programs monitoring the incidental capture of sawfish in gill nets**

Advantages: to further demonstrate the commitment of GoC set net fishermen to the principals of ecological sustainability.

- **Forward information on tagged or marked sawfish to Northern Fisheries Centre, Cairns**

Advantages: to help researchers and managers establish, piece together the life history and abundance of sawfish with the goal to identify equitable and sustainable management policies

Release Procedures

Sawfish like most marine animals when caught in a gill net will be highly stressed and in most instances quite lively. It is of utmost importance to remember when approaching a captured sawfish, to evaluate the situation before handling the animal how you could release it uninjured without placing yourself in extreme danger. Therefore a common sense approach prevails as you know your own capabilities when having to handle such a situation.

Sawfish are vulnerable to capture in gillnets because of their rostrum and numerous teeth. When adopting release procedures, keep in mind the position and the sideways action of the rostrum. If possible keep either in front or behind of the rostrum. Do not stand to the side of the rostrum even if you believe the animal is secured firmly in the net. If the sawfish is out of the water for any length of time ensure it is kept wet to reduce unnecessary stress and discomfort. Endeavour to release the sawfish away from set nets. Release procedures have been suggested for different size ranges.

Juveniles (60 to 150cm)

- generally light weight and easy to handle, restrain as you would any other fish of the same size and weight.
- net hook, cement trail or the back of a knife can be used to aid in untangling meshes.
- use common sense when determining whether it is feasible to handle the sawfish inside or outside the dinghy or boat.
- if exhausted make a conscious effort to swim and revive the sawfish before releasing it.

Sub Adults (150 to 350cm)

- at this size are powerful and heavy to handle.
- advisable to keep them out of your dinghy or boat.

Outside dinghy

- when approaching such a situation untangle the tail and mid section of the animal before tackling the rostrum.
- before attempting to untangle the rostrum secure the sawfish to avoid head shaking and tail slapping
- untangle the rostrum by standing in front, lever the rostrum over the gunnel of the dinghy and apply downward pressure.
- depending on the behavioural state of the sawfish at the time either use the suggested tools above or cut the meshes to avoid unnecessary contact.
- a second person can make for easy work with a higher degree of safety

Inside dinghy

- advisable to have a second person to assist.
- the sawfish will most likely thrash around for a short period of time avoid the rostrum and tail slapping.
- bend the first dorsal fin of the sawfish over and apply body weight, this will aid in subduing the animal
- the second person (standing in front of the rostrum) untangles the meshes using the suggested tools.
- a rope (slipknot) for the rostrum and the assistance of a second person should be sufficient to lift and release the sawfish with minimum stress and injury to yourself.
- if exhausted make a conscious effort to swim and revive the sawfish before releasing it.

Adults (350 to 700cm)

- at this size and larger sawfish are extremely dangerous.
- endeavour to beach the net in a safe area (photo 1).
- a second person is advisable.
- subdue the sawfish by placing downward pressure on the first dorsal fin or by placing body weight on the anterior mid section (photo 2).
- avoid the rostrum and tail slapping.
- standing in front or behind of the rostrum untangle the meshes using the suggested tools.
- using a slipknot around the tail drag the sawfish back into the water.
- keep nets in immediate area out of the water for as long as possible.

- where beaching the net is not practical (river set) attempt to cut the animal out of the net as you would a medium to large crocodile.

Additional information
All records of freshwater sawfish catches are important due to their conservation status. These captures should be reported along with any tagged sawfish (photo 3) from other species to the Northern Fisheries Centre, Cairns (07) 40350100. Record and forward onto the above centre any tag number (located beside the first dorsal fin) and sawfish length (bottom jaw to the tip of the tail).

Sawfish Photos

Photo 1: Beached sawfish

Photo 2: Secured sawfish

Photo 3: Tagged sawfish, note position of tag

Appendix 7(Section 4)

N9 fishery 2002 observed catch

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N9 fishery 2002 observed catch

This was the first full year of data available and a summary of this information is provided below.

Shark Catch

The observed 2002 shark catch (7052 specimens, 72.9% of the total catch) comprised 10 species of whaler sharks, 1 species of weasel shark and 3 species of hammerheads (Table 1). Whalers contributed 64.9% and hammerheads 7.9% of the total observed catch numbers. The observed shark catch fate was divided up into:

- Processed: 92%
- Partly processed: 3.8% (i.e. fins removed and the rest of the carcass discarded, chiefly unmarketable and small sharks)
- Released dead: 3.0% (chiefly small and unmarketable specimens)
- Released alive: 1.2% (chiefly small and unmarketable specimens).

Table 1 - Total Number of Sharks Captured during 2002 and their Fate

FAMILY	Species	Common name	N° Capture	P	PP	RD	RA
Carcharhinidae	*Carcharhinus amblyrhynchoides*	Graceful shark	11	11			
Carcharhinidae	*Carcharhinus amboinensis*	Pigeye shark	2	2			
Carcharhinidae	*Carcharhinus brevipinna*	Spinner shark	61	61			
Carcharhinidae	*Carcharhinus dussumieri*	Whitecheek shark	20		14	3	3
Carcharhinidae	*Carcharhinus macloti*	Hardnose shark	51		27	19	5
Carcharhinidae	*Carcharhinus sorrah*	Spot-tail shark	462	460			2
Carcharhinidae	*Carcharhinus tilstoni / limbatus*	Blacktip shark spp.	5403	5399			4
Carcharhinidae	*Galeocerdo cuvier*	Tiger shark	2			2	
Carcharhinidae	*Rhizoprionodon acutus*	Milk shark	261		19	176	66
Carcharhinidae	*Rhizoprionodon taylori*	Aus. sharpnose shark	9			9	
Hemugaleidae	*Hemipristis elongatus*	Snaggletooth shark	5	5			
Sphyrnidae	*Eusphyra blochii*	Winghead	205		205		
Sphyrnidae	*Sphyrna lewini*	Scalloped hammerhead	442	439	3		
Sphyrnidae	*Sphyrna mokarran*	Great hammerhead	118	114	3		1
		Total N° Captured	**7052**	**6491**	**271**	**209**	**81**
		Percentage of Fate		**92.04**	**3.84**	**2.96**	**1.15**

P= Processed PP= Partly Processed RA= Released Alive RD= Released Dead

Generally, during and after hauling / robbing the net the sharks were piled on the deck and barrelling (finned and trunked) began. When circumstances permitted the average sized shark trunks were placed in brine for at least ~24-36 hours, before being processed (filleted and skinned) and packed into 10-13kg cartons and snap frozen. The large shark trunks (>1.5m FL) were stored for ~27-48 hours depending on the vessel (mainly brine space), catch rates and sizes of species captured.

Specimens of the blacktip sharks, *Carcharhinus tilstoni* and *C. limbatus* were pooled in this report as the separation of these two species can only be identified by vertebrate counts, maturity status for their size (*C. limbatus* matures at a larger size than *C.*

tilstoni; Last and Stevens 1994) and/or electrophoretic or DNA testing. Thus visual identification between these two is usually not possible in the N9 Fishery as mainly small sharks were captured. However, *C. limbatus* is usually the rarer of these two species, with the two species found to occur in the approximate proportions of 1:300 in the Arafura Sea (Stevens and Wiley 1986).

A high percentage of sharks were processed (92%), while the remainder were either partly processed or discarded (Table 1), because of their:

- Size, too small or large, and/or
- Low market acceptability.

Shark species that were not processed for their fillets due to their small size included the whitecheek shark (*Carcharhinus dussumieri*), hardnose shark (*C. macloti*), milk shark (*Rhizoprionodon acutus*) and Australian sharpnose shark (*R. taylori*). These small species of whalers were never processed in the N9 Fishery but often partly processed, depending on the fisher. Shark species that were not processed for their fillets due to low market acceptability included the tiger shark (*Galeocerdo cuvier*) and winghead hammerhead shark (*Eusphyra blochii*).

Generally, marketable shark species less than 500mm FL and greater than 1500mm FL were partly processed. The largest blacktip whaler shark specimen captured in the 2002 season measured 1320mm FL (in 2001, 1931mm FL), which was processed. In 2002, the only observed shark specimens captured larger than 1500mm FL were the great hammerhead sharks (*Sphyrna mokarran*), which were processed up to 2000mm FL. All great hammerheads larger than 2000mm FL were partly processed. This species is one of the largest growing shark species captured in the N9 Fishery, and along with the tiger shark (*Galeocerdo cuvier*), the great hammerhead reaches a maximum reported size of 6000mm FL (Stobutzki, *et al.* 2003).

A high proportion of the shark catch was sexed (96.8%) and measured (80.1%) to establish information on sex ratios and length frequencies (Figures 1 to 5 and Table 2). When shark sexing and measuring was conducted, all sharks captured in the net sets were examined to reduce any bias. In 2002, whaler sharks captured ranged between 501 to 1486mm FL, with a median size of 611mm FL (Figure 3). The whaler sharks captured were dominantly immature specimens (~85% of all the male whalers sexed were immature) between 550 to 800mm FL (n=4883) and males contributed 58% (n=6061) of the whaler shark catch sampled. However the size ranges, median size and sex ratios of each whaler species captured varied greatly (Figure 1, 2 and 5). The hammerhead sharks captured ranged between 470-2180mm FL, with a median size of 840mm FL (Figure 3 and 4). Hammerhead shark specimens were mainly captured between 600mm to 1150mm FL (n=763) and males contributed 53.1% (n=765) of the hammerhead shark catch sampled. The size ranges, median size and sex ratios of each hammerhead species captured also varied greatly (Figure 3 to 5).

The whaler shark catch was dominated by one species complex, the blacktip whaler (*C. tilstoni/limbatus*), which contributed 86% of the whaler shark catch. A broad size range of this species was captured (501 to1320mm FL) and the median size was 605mm FL (n=4176). The grouped whaler shark results in Figure 1 were skewed by the blacktip

whaler biology characteristics, as this species complex dominated the whaler shark catch.

A large number of small whaler sharks were caught during the 2002 trips, which was reported by the crew to be more so this year than previous seasons. This report was supported by observer data as 75% of the blacktips captured were <700mm FL for 2002, whereas 62% were <700mm FL for 2001. Also the observed sampled size range of blacktips captured in 2001 was much larger than 2002 (501 to1320mm FL, median size was 605mm FL, n=4176, males contributing 53.3%, n=5206), 488 to 1931mm FL with a median size of 668mm FL (n=2510) with males contributing 42.3% (n=1260) of the blacktip whaler catch sampled in 2001.

Table 2 - Fork Length and Sex Ratio of Sharks Captured in 2002

Species	Common name	N° Measured	Median FL (±95% CI)	N° Sexed	Sex Ratio M:F
Carcharhinus amblyrhynchoides	Graceful shark	11	830 (35.4)	11	10:1
Carcharhinus amboinensis	Pigeye shark	2	983	2	
Carcharhinus brevipinna	Spinner shark	56	700 (36.3)	56	0.8:1
Carcharhinus dussumieri	Whitecheek shark	19	621 (15.0)	19	2.2:1
Carcharhinus macloti	Hardnose shark	51	635 (6.1)	51	4.1:1
Carcharhinus sorrah	Spot-tail shark	436	716 (8.0)	440	2:1
Carcharhinus tilstoni / limbatus	Blacktip shark spp.	4176	605 (3.3)	5206	1.2:1
Galeocerdo cuvier	Tiger shark	1	850	1	
Rhizoprionodon acutus	Milk shark	117	659 (4.6)	261	25.1:1
Rhizoprionodon taylori	Aus. sharpnose shark	9	550 (36.4)	9	0.5:1
Hemipristis elongatus	Snaggletooth shark	5	1050	5	0.7:1
Eusphyra blochii	Winghead hammerhead	203	980 (14.3)	204	0.2:1
Sphyrna lewini	Scalloped hammerhead	442	740 (16.9)	442	2.1:1
Sphyrna mokarran	Great hammerhead	118	930 (66.1)	118	1.7:1
		5646		**6825**	

FL= Fork Length (mm) CI= Confidence Interval

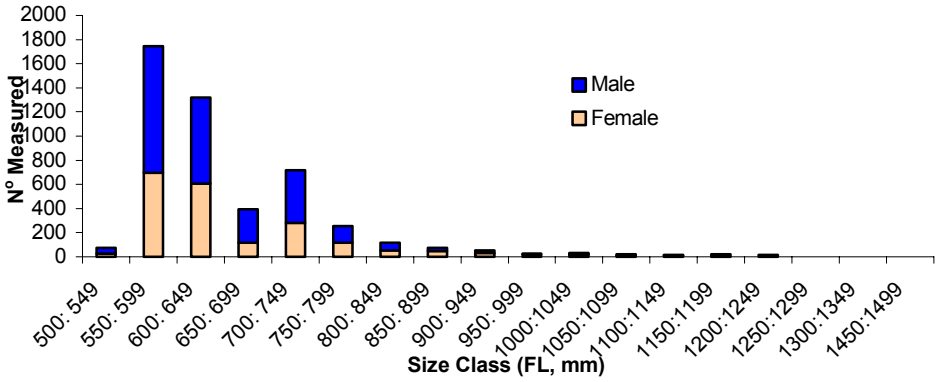

Figure 1 - Size Classes of Whaler Shark Specimens Sampled in 2002

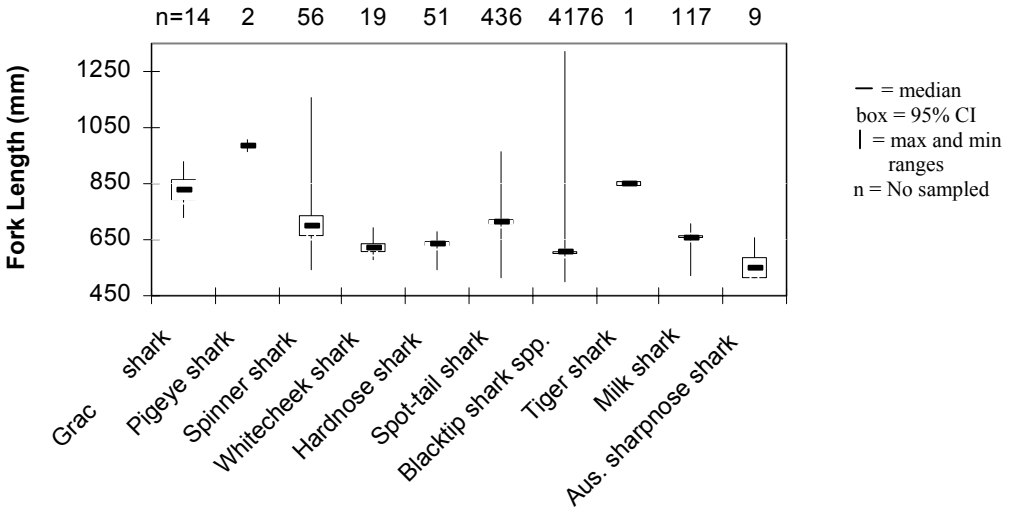

Figure 2 - Fork Length Range of Whaler Shark Specimens Sampled in 2002

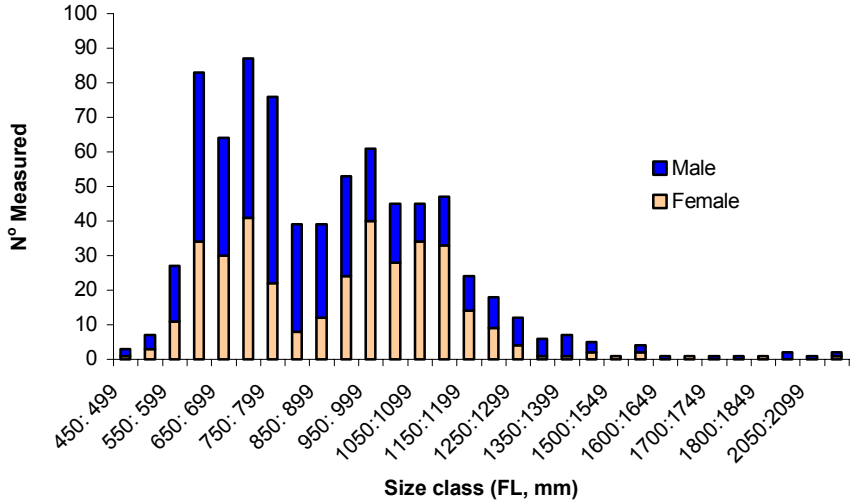

Figure 3- Size Classes of Hammerhead Sharks Specimens Sampled in 2002

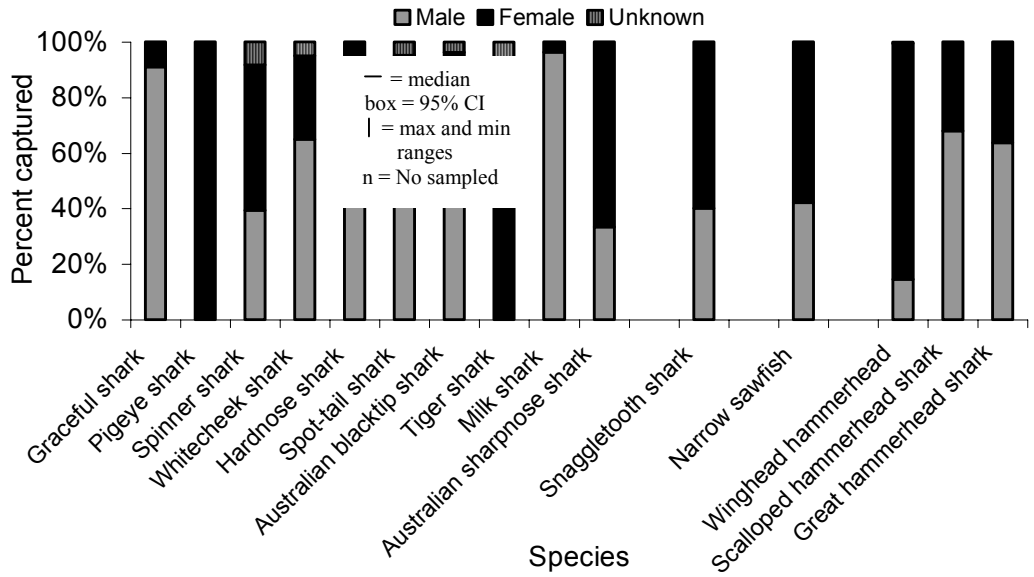

Figure 4 - Fork Length Range of Hammerhead Shark Specimens Sampled in 2002

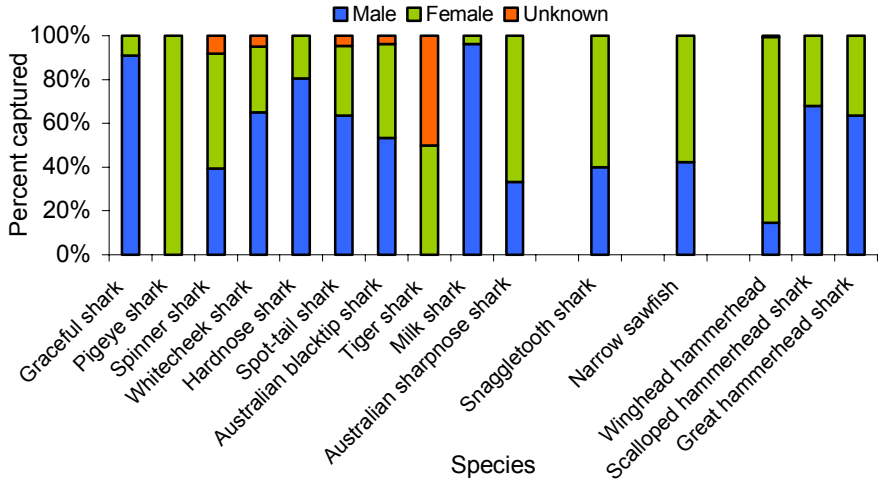

Figure 5 - Sex Ratios of Whaler and Hammerhead Shark Specimens Sampled in 2002

Of the 7052 sharks captured in the 2002 observer program, the blacktip complex (*C. tilstoni / limbatus*), the spot-tail (*C. sorrah*) and the scalloped hammerhead (*Sphyrna lewini*) contributed ~90% of the shark catch at 76.6%, 6.6% and 6.3% respectively. These dominant shark species are illustrated in Plate 1, and the biological characteristics of each species is presented in Table 3. In 2001 and 2000, the two most dominant species were the same as 2002.

Blacktip Shark
Carcharhinus tilstoni / limbatus
840mm FL

Spot-tail Shark
Carcharhinus sorrah
904mm FL

Scallop hammerhead Shark
Sphyrna lewini
~800mm FL

Plate 1 - Dominate Sharks of the Overall Catches in 2002

Table 3 - Biological Characteristics of the Major Shark Species Captured in 2002

	Australian blacktip *(Carcharhinus tilstoni)*	Spot-tail *(Carcharhinus sorrah)*	Scalloped hammerhead *(Sphyrna lewini)*
FL to TL relationships	TL = FL1.235 + 0.913 r^2=0.99	TL = FL1.196 + 4.715 r^2=0.99	TL = 1.30FL + 1.28 r^2=0.994
Max TL	2000	1600	4200
TL at Maturity	M 1100, F 1150	M 900, F 950	M 1400, F 1500
Age at Maturity	M 4, F 4	M 2, F 3	M 4, F 4
Growth (K y^{-1})	0.14-0.19	0.34-1.17	0.05-0.07
Reproduction	Viviparous	Viviparous	Viviparous
Mean Litter Size	3 (1-6)	3 (1-8)	17 (13-23)
TL at Birth	600	500	450-500
Gestation Period	10	10	9-10
Breeding Freq.	annual	annual	~
Young/yr	3	3	~
Birth Period	Jan	Jan	Oct-Jan
Habitat Range	inshore to about 150m deep	intertidal to at least 80m	inshore to at least 280m
Conservation Status	~	~	LR/nt
Distribution	Endemic	Indian & Western Pacific	Atlantic, Indian & Pacific

(Source: Davenport and Stevens 1988; Stevens and Lyle 1989; Stobutzki, *et al.* 2003)

2002 Byproduct / Bycatch

Observed fish byproduct / bycatch comprised 2628 specimens (27.2% of the catch) from 30 species in 16 families (Table 4). Grey mackerel (*Scomberomorus semifasciatus*) is currently considered as part of the target catch, however to keep trip and summary reports consistent and the shark catch separate, greys are placed in the byproduct / bycatch section. The byproduct and bycatch fate was divided up into:

- Byproduct: 66.6%
- Partly processed: 0%
- Released dead: 29.2% (chiefly unmarketable and regulated specimens)
- Released alive: 4.2% (chiefly unmarketable specimens).

Table 4 - Total Byproduct / Bycatch Caught in 2002

FAMILY	Species	Common name	No Capture	P	PP	RD	RA	Protected spp.	Reg spp.	Rec spp.
Ariidae	*Arius sp.*	Sea Catfish	3			2	1			
Carangidae	*Alectis ciliaris*	Pennantfish	2			2				
Carangidae	*Carangoides gymnostethus*	Bludger trevally	3			1	2			
Carangidae	*Caranx bucculentus*	Blue-spotted trevally	116			84	32			
Carangidae	*Caranx ignobilis*	Giant trevally	12			12				Y
Carangidae	*Megalaspis cordyla*	Finny scad	1			1				
Carangidae	*Parastromateus niger*	Black pomfret	204	135		46	23			
Carangidae	*Scomberoides commersonnianus*	Queenfish	93	84			9			Y
Carangidae	*Trachinotus blochii*	Snub-nosed dart	2				2			
Chirocentridae	*Chirocentrus dorab*	Wolf herring	7			7				
Cynoglossidae	*Paraplagusia sp.*	Sole	1			1				
Delpinidae	*Tursiops aduncus*	Bottlenose dolphin	1			1		Y		
Istiophoridae	*Makaira indica*	Black marlin	2			2				
Lutjanidae	*Lutjanus johni*	Fingermark	80	80						Y
Mobulidae	*Manta birostris*	Manta ray	2				2			
Mobulidae	*Mobula eregoodootenkee*	Pygmy devilray	2				2			
Myliobatidae	*Aetomylaeus nichofii*	Banded eagle ray	14				14			
Myliobatidae	*Aetomylaeus vespertilio*	Ornate eagle ray	2				2			
Polynemidae	*Eleutheronema tetradactylum*	Blue salmon	164			160	4			Y
Pristidae	*Anoxypristis cuspidata*	Narrow sawfish	45	30		3	12			
Rachycentridae	*Rachycentron canadus*	Black kingfish	7	7						Y
Rhinopteridae	*Rhinoptera neglecta*	Cownose ray	2				2			
Sciaenidae	*Protonibea diacanthus*	Black jew	40	40						Y
Scombridae	*Euthynnus affinis*	Mackerel tuna	10			10				
Scombridae	*Rastrelliger brachysoma*	Short mackerel	88			88				
Scombridae	*Scomberomorus commerson*	Spanish mackerel	104	104						Y
Scombridae	*Scomberomorus munroi*	Spotted mackerel	4	4						Y
Scombridae	*Scomberomorus semifasciatus*	Grey mackerel	1271	1267		3	1			Y
Scombridae	*Thunnus tonggol*	Long tail tuna	345			343	2		Y	
Synodontidae	*Saurida undosquamis*	Spotted-tailed grinner	1			1				
		No Captured	**2628**	**1751**	**0**	**767**	**110**			
		Percent		**66.63**	**0.00**	**29.19**	**4.19**			

P= Processed PP= Partly Processed RA= Released Alive RD= Released Dead Reg spp.= Regulated species
Rec spp.= Recreational Fishery species Y=yes

Bycatch mitigation trials were conducted using an American style acoustic warning device, 'AirMar pingers' which are high frequency (10kHz) warning devices designed to warn dolphins and whales (ie. echo-locating mammals) about the presence of a set meshnet. These warning devices were to assist in the Natural Heritage Trust (NHT) Research Project, investigating the 'effectiveness of active acoustic devices to reduce marine mammal bycatch in gillnet fisheries'. These dolphin bycatch mitigation experiments are being conducted by QFS, SeaNet, and University of Qld for Environment Australia (EA). The warning devices were placed every ~80-100m along the float-rope of the net, which was situated ~1.5m below the water surface.

During 2002 one bottlenose dolphin (*Tursiops aduncus*) interaction with N9 fishing gear was observed during the N9 observer trips and it was released deceased (Table 4). This interaction occurred when the 10kHz pingers were attached to the net and the dolphin was captured near a pinger. Under the Commonwealth *EPBC Act* 1999 and the Queensland *Nature Conservation Act* 1992, for all dolphins and other small cetaceans unintentionally caught in fishing nets penalties do not apply provided that live animals are released immediately and the capture (dead or alive) reported as soon as possible to relevant authorities. The dolphin interaction was reported to State authorities and no interactions with additional ‘protected’, or ‘endangered’, ‘vulnerable’ or ‘rare’ listed species was observed during the time onboard the N9 vessels during the 2002 fishing season.

A high proportion of the bycatch / byproduct was measured (30.7%) to establish information on length frequencies (Figure 6 and Table 5) and selectivity characteristics of the fishing gear for each species. When bycatch / byproduct measuring was conducted, all specimens captured in the net sets were examined to reduce any bias. Two large species captured (black marlin, *Makaira indica* and narrow sawfish, *Anoxypristis cuspidata*) are presented in an additional figure (Figure 7), due to their exceptional large size compared to the other byproduct / bycatch species captured.

Table 5 - Fork and Total Length of Byproduct and Bycatch Specimens Captured in 2002

Species	Common name	n	Avg FL	Min FL	Max FL	Avg TL (±95% CI)	Min TL	Max TL
Arius sp.	Sea Catfish	2	742	722	761	840 (39.2)	820	860
Alectis ciliaris	Pennantfish	1	189	189	189	211	211	211
Carangoides gymnostethus	Bludger trevally	2	535	530	540	621 (17.65)	612	630
Caranx bucculentus	Blue-spotted trevally	27	421	162	625	474 (73.8)	183	700
Caranx ignobilis	Giant trevally	12	891	780	960	990 (37.62)	875	1080
Megalaspis cordyla	Finny scad	1	306	306	306	330	330	330
Parastromateus niger	Black pomfret	61	344	220	460	379 (13.86)	240	505
Scomberoides commersonnianus	Queenfish	34	811	748	890	913 (13.27)	831	1000
Trachinotus blochii	Snub-nosed dart	2	672	624	720	788 (102.9)	735	840
Chirocentrus dorab	Wolf herring	3	444	418	490	496 (43.65)	468	540
Makaira indica	Black marlin	2	1857	1380	2334	2095	1600	2590
Lutjanus johni	Fingermark	9	634	514	671	662 (23.55)	591	699
Eleutheronema tetradactylum	Blue salmon	68	384	311	596	447 (13.52)	361	680
Anoxypristis cuspidata	Narrow sawfish	44				1871	1300	2310
Rachycentron canadus	Black kingfish	7	828	515	1146	910 (196.3)	550	1230
Protonibea diacanthus	Black jew	40				976 (21.9)	871	1220
Euthynnus affinis	Mackerel tuna	3	620	600	640	655 (28.29)	630	680
Rastrelliger brachysoma	Short mackerel	17	192	166	211	209 (7.08)	180	230
Scomberomorus commerson	Spanish mackerel	66	940	780	1160	1021	850	1240
Scomberomorus munroi	Spotted mackerel	2	600	495	705	678 (240.1)	555	800
Scomberomorus semifasciatus	Grey mackerel	318	725	338	940	817 (9.83)	379	1040
Thunnus tonggol	Long tail tuna	109	771	630	1050	828 (13.82)	680	1120
Saurida undosquamis	Spotted-tailed grinner	1	343	343	343	380	380	380

n= N° measured FL= Fork Length (mm) TL= Total Length (mm)

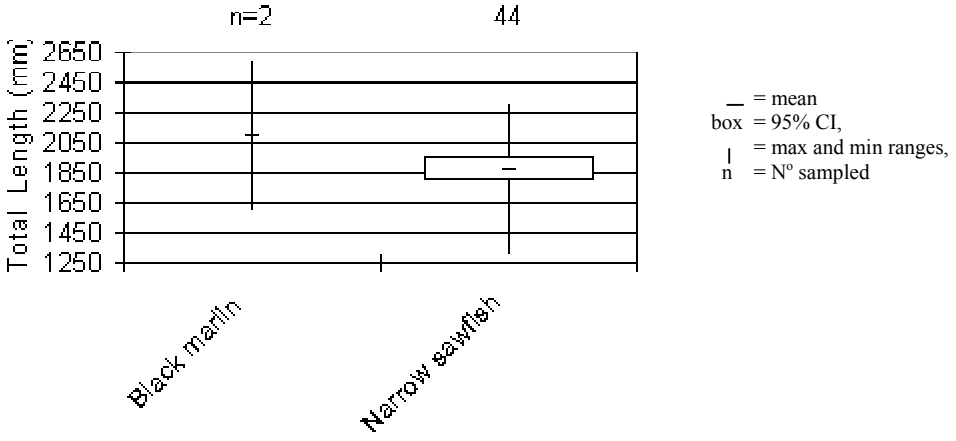

Figure 6 - Total Length Range of Byproduct and Bycatch Specimens Captured in 2002

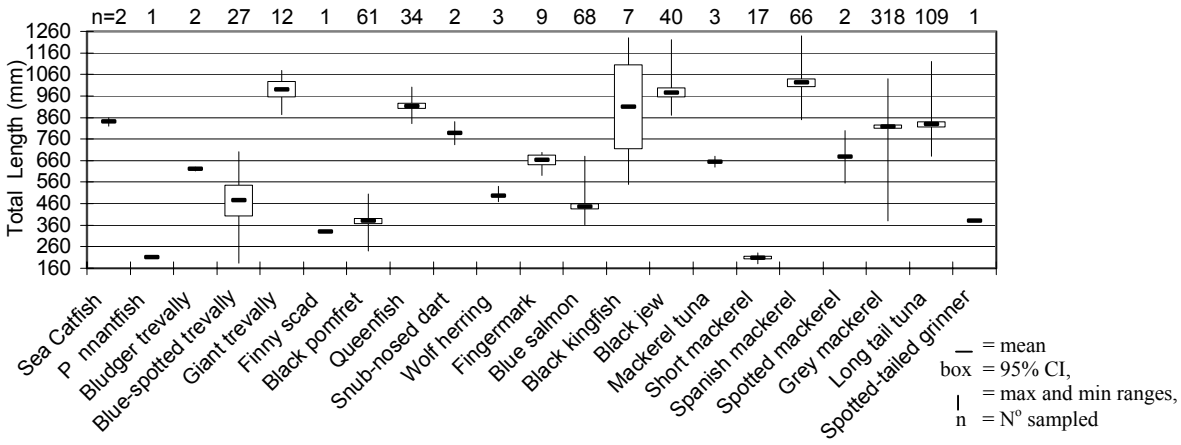

Figure 7 - Total Length Range of very large Byproduct and Bycatch Species in 2002

The fish byproduct was dominated by grey mackerel (*S. semifasciatus*) at 13.13% of the total catch, whereas Spanish mackerel (*Scomberomorus commerson*) contributed 1.07%. A sample of grey (25.0%) and Spanish mackerel (63.5%) were measured to establish selectivity characteristics of the fishing gear for these species (Figure 8), with the average size captured 817mm and 1022mm total length (TL), respectively. Byproduct fish were removed from the net, bled and placed in the brine tanks. The following morning the byproduct was processed (filleted), packaged into 10-13kg cartons and snap frozen. The discards were returned to the ocean alive nd/or deceased immediately during and after the net robs (Table 4).

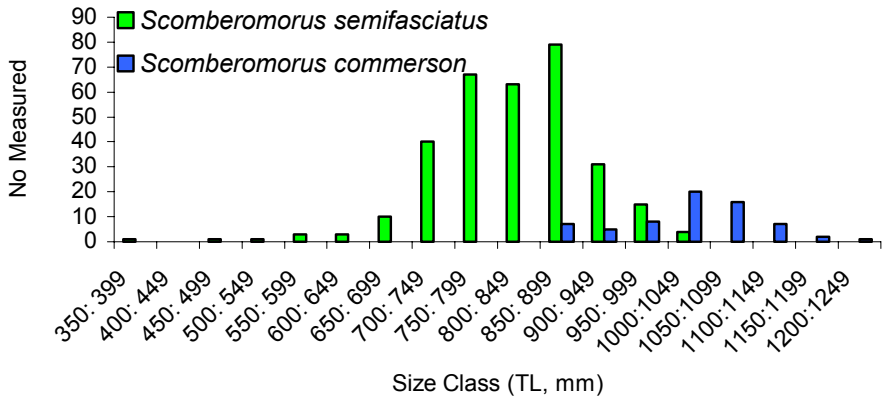

Figure 8 - Sample size distribution of grey and Spanish mackerel captured in N9 net sets observed during 2002

During the 2002 trips extensive sawfish research was conducted. In co-operation with the fishers, forty-five sawfish were captured and of these twelve were tagged and released and twenty-eight were examined with samples taken for genetics and aging work. No recaptures of the tagged animals were reported. The results will be incorporated into the collaborative FRDC Northern Australian sharks and rays sustainability project.

As noted earlier, not all of the byproduct / bycatch caught were processed, due to market size or species restrictions, however, 66.6% of the total byproduct / bycatch numbers captured were processed.