Department of **Employment, Economic Development and Innovation**

Taking female mud crabs (*Scylla serrata*): assessment of risks and benefits

FRDC 2009/031

Final Report

Dr I W Brown

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Southern Fisheries Centre, Deception Bay, Queensland

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Australian Government
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OBJECTIVES:

1. Evaluate the risks and benefits of allowing the harvest of female mud crabs in Queensland.
2. Depending on (a), develop a plan for implementing a change to the single-sex harvest policy (SSHP) arrangement.

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE

1. A 4-day workshop of mud crab fishery stakeholders and interested parties provided a forum for in-depth discussion and debate about one of the most controversial management arrangements within Queensland's mud crab fishery.
2. Interactive management strategy modeling demonstrated convincingly that (on the basis of existing commercial catch and effort data) there is no biological or conservational justification for continuing to prohibit the harvest of female mud crabs in Queensland. To minimize the risk of recruitment overfishing it is recommended that the minimum legal size on female mud crabs be set at a point not below 16 cm CW.
3. Economic modeling demonstrated that significant economic advantage would result from permitting a controlled harvest of female crabs, potentially increasing the value of the commercial fishery (currently estimated at around AU$12 million annually) by as much as 25%.
4. By way of a formal risk assessment process, the forum agreed that, unless the management change was very carefully controlled and phased in, the greatest risk associated with changing the SSHP would be an increase in fishing effort which could lead to reduced profitability of individual businesses.
5. The forum agreed the any change to the SSHP would have to be done in such a way as to control the impact on female biomass, for example by the sale of a limited number of non-removable, non-transferable compliance tags. Proceeds from tag sales would offset the cost of tag administration and any necessary fishery-independent monitoring.
6. The forum agreed that the requirement for a reliable indicator of stock size is paramount. The annual fishery-independent mud crab monitoring survey is being phased out for financial reasons, and this Project has identified deficiencies in the commercial log-book catch and effort reporting system which casts doubt on the value of reported catch rates as an indicator of stock abundance.
7. While some of the deficiencies mentioned above are now being addressed, the responsible Minister is prepared to consider a change to the SSHP when more reliable indicators for catch/effort and stock abundance are established.

A Workshop was held at the Joondoburri Conference Centre (Bribie Island) during the first week of November 2009 to evaluate the risks and benefits of allowing the harvest of female mud crabs in Queensland.

Invitees to the Workshop, which was funded by the Australian Government's Fisheries Research and Development Corporation, included commercial and recreational crab fishers, GBRMPA, Qld Seafood Marketers' Association, local and interstate fisheries personnel, fisheries economics expert (Griffith Uni), population modelling expert (UK), fisheries scientists, social scientists, FRDC, fisheries managers, indigenous sector representative and compliance personnel.

Presentations were given on:

- Background to the single sex harvest policy
- Status of mud crab fisheries throughout tropical and subtropical Australia
- The economics of the Queensland mud crab fishery
- Management strategy evaluation (simulation) modelling of the Queensland mud crab fishery with different scenarios
- Market structure and opportunities

The Workshop was informed by a number of participants, in particular Professor Tor Hundloe who presented papers on economic modelling of the Queensland mud crab fishery, and Dr James Scandol, who conducted a number of management strategy evaluations (MSEs) using the Walters 'growth-type groups' or Gtg simulation Model.

The economic models, on the basis of current harvesting levels and projected increases in human population size and demand preferences, predicted substantial increases in the value of the mud crab fishery. The MSEs (which are not stock assessment models) indicated that, on the basis of the existing commercial catch-effort data set (adjusted for a 5% annual cryptic increase in effective fishing effort) and known or estimated population parameters, harvesting female crabs at conservative levels of minimum legal size would not impact adversely on the stock's sustainability.

The workshop undertook an assessment of possible risks associated with changing the single sex harvest policy (SSHP) for mud crabs, and considered ways to design an experiment or carefully monitored trial to determine the stock, economic, and social outcomes of such a major management change. The highest-ranking risk (perceived by the group) related to decreases in profitability resulting from increased production levels. This was followed in importance by the risks to resource sustainability from recruitment overfishing, and to equity in catch share resulting from activation of latent recreational and commercial effort. However it was agreed that in principle these risks could be managed provided a number of conditions were met. These conditions related principally to the need to control any phase-in of female harvest gradually to prevent a 'gold rush' mentality developing, which will be associated with negative socioeconomic and ecological consequences.

As agreed during the workshop, an account ('the Proceedings') was then prepared and circulated to all participants. This provided key stakeholder representatives with a comprehensive brief on the presentations, discussions and outcomes, to enable informed feedback to and consultation with their constituents. However the extent to which the represented stakeholders were adequately briefed appears to have been rather variable, primarily because the issues of the SSHP were 'rolled up' with a broader suite of questions relating to the management of Queensland's mud and blue swimmer crab fisheries, about which the peak recreational and commercial bodies were seeking comment from their membership

prior to the fishery review in mid-2010. As a result, the responses tended to be polarised and there was not a clear unanimous view expressed on the issue.

A series of analyses of catch-effort data from compulsory commercial logbooks and from the Department's Long-Term Monitoring Programme (LTMP) were conducted after the Workshop. Although not part of the Project plan, these were initiated as a result of questions arising from the Workshop participants about the reliability of the data used in the simulation modelling. Exploration of the logbook data and results of the analyses suggest that biases in the data (from a variety of sources, but principally the widespread use of more than the permitted number of pots) may be giving an over-optimistic view of the status of the East Coast mud crab resource. In particular, if a significant proportion fishers are reporting that catches are greater than they actually are, this will result in an overestimate of the productivity of the stock, and an underestimate of the impact of removing the SSHB. Declining stock density trends in the fishery-independent LTMP data series over the past decade are consistent with the commercial data trends, although the time series is too short to rule out the possibility that this could be part of a decadal-scale environmental cycle. Reliable commercial and recreational crab fishers also report that legal-sized mud crabs are becoming more and more difficult to catch.

In accordance with the Communications Plan agreed to at the Workshop, the Minister was informed of these facts. Although no public announcement has yet been made, it is understood that the Minister's view is that before any changes can be made to the SSHP, the issues relating to over-potting need to be addressed satisfactorily. Along with other issues relating to improving our ability to confidently monitor changes in the mud crab resource, finding solutions to the over-potting problem will represent a significant part of the review of the mud and blue swimmer crab fisheries.

2 Acknowledgements

The commitment and valuable input provided by all Workshop participants (for the complete list see Appendix 2) is recognised with extreme gratitude. Without their involvement the Project would not have been possible. James Scandol and Tor Hundloe are to be thanked in particular for their critically important modelling work. Roseann Waia provided logistic assistance and expert reporting prior to and during the Workshop; the Joondoburri Conference Centre staff were particularly helpful in arranging accommodation and catering services for the attendees, and staff and drivers of the RedAir shuttle service safely transported people to and from Brisbane Airport. Particular thanks are due to Prof Carl Walters (University of British Columbia) for his enthusiastic support for the project during its formative stages, and for continuing advice and assistance with the Growth-type Groups Model.

3 Background

This project has been developed as a direct result of approaches from industry about the need for a definitive answer to questions relating to one of the State's most controversial crab fishery management arrangements. An effective prohibition on harvesting female mud crabs in Queensland was instituted by Parliament in 1891 (without reference to stock sustainability) with minimum legal weights of 3 and 10 lb for male and female crabs respectively. Because of the unrealistically high minimum legal weight for females, this essentially limited the legal catch to male crabs, a situation that was formalised in the legislative changes outlined in Section 7.1. The single-sex harvest policy (SSHP) has been in place ever since, and in recent years has been the subject of considerable debate. While a great deal of new and valuable information on

mud crab populations has been acquired over the past two or three decades by researchers such as Fielder and Heasman (1978), Hill (1979, 1980, 1982), Heasman (1980), Hill *et al.* (1982), Williams and Hill (1982), Hyland *et al*. (1984), Heasman *et al*. (1985), Robertson (1989) (Queensland), Keenan *et al*. (1998), Knuckey (1996, 1999), Hay *et al*. (2005), and Webley and Connolly (2007) there remain many unanswered questions about the species' population dynamics and behaviour.

Particularly important (and scientifically interesting) is the question of spawning behaviour. Ovigerous female mud crabs are rarely seen in their normal estuarine habitat, and are known to migrate large distances offshore to hatch their eggs. This behaviour allows for significant spatial dispersal of propagules over the larval development period of 4-6 weeks. However the proportion of the reproductively-active female stock that undertakes this migration is unknown, and the ultimate fate of the migrating crabs is unclear. The SSHP has resulted in a severely skewed female-dominated sex ratio which may alter local-scale population dynamics to the extent that small male crabs are prevented from recruiting to their preferred habitat. This may occur through cannibalism or competition for food or burrow-space. While larger female crabs are very fecund, the fact that egg-bearing individuals of any size are so rarely seen makes it difficult to know precisely the reproductive status of large female crabs in the population. Have the largest females undergone their terminal moult and become reproductively inactive, as many maintain?

A better understanding of spawning behaviour could make it possible to predict the outcome of relaxing the SSHP. However it is unlikely that sufficient resources will be available in the foreseeable future to address any of the relevant issues with adequate rigour to allow this to happen. If industry and fishery managers are to be reliably informed as to whether continuation of the SSHP is scientifically justifiable, the only remaining option is to empirically test the efficacy of the SSHP by a controlled manipulative experiment (Walters 1997). Learning about the way an exploited stock functions by observing the results of management changes is a process known as adaptive management. Eminent fisheries scientists such as Prof Carl Walters (University of British Columbia) have long advocated this form of experimentation (Walters 2007a), and the strategy has already been applied in Queensland in the Great Barrier Reef Effects of Linefishing Programme (Mapstone *et al.* 2004).

Walters (2007b) has recently developed a stock assessment and policy simulation model for mud crabs based on a high-resolution age-sex structured sub-model that divides each age cohort into ‘growth-type groups’ (GTGs) that have persistently different growth curves. This work has been done with the collaboration of Dr Neil Gribble (Agri-Science Queensland’s Northern Fisheries Centre) and Dr Mark Grubert (NT Fisheries, Darwin) using catch-effort data and parameter estimates from the Gulf of Carpentaria (GoC) stock that were generated from a previous collaborative FRDC project (Hay *et al*. 2005). The GTG model indicated that, for the GoC stock, at least, fishing mortality (*F*) based on length-frequency data had previously been considerably over-estimated. Walters believes annual *F* to be less than 1.2 in the NT fishery and considerably lower than this in the Qld GoC fishery. Yield-per-recruit modelling indicates that yield could be increased by ~35% by reducing the minimum legal size (MLS) to 12 or 13 cm but MLS reduction could be risky, possibly leading to recruitment overfishing. Walters concludes that even complex integrated models based on length-frequency data are unlikely to be able to resolve the basic uncertainty about the magnitude of *F*, and recommends an experimental approach to address this issue. Some methods that may be appropriate include high-reward tagging, swept-area analysis (using estimates of effective attraction zone area from previous depletion experiments), and/or controlled collaborative fish-down experiments.

However before specific methods can be identified there is a need to gain broad-based support for conducting any sort of experimentation which would lead to a better understanding of the effects of the current regulations in Queensland.

4 Need

Nearly three decades ago Dr Burke Hill, reporting on Queensland's Mud Crab Fishery (Hill 1982) recommended a trial period allowing the take of females provided there was a monitoring programme in place to evaluate the result. Such a trial has not yet been implemented, and while much excellent work on mud crabs has been done in recent years, it is not sufficient to answer the 'big-picture' question of sustainability.

Information based on empirical data is needed to inform the Mud Crab Fishery Management Plan development process. At present there are many points of view about the relevance and need for the SSHP, but there is little hard evidence.

For some years industry has argued for a relaxation of the legislation, bringing it into line with that in NSW and NT. However without scientific evidence management is reluctant to change the status quo, and in turn FRDC has been unwilling to fund the necessary work because of a perception that the recommendations may not be implemented. DEEDI is now actively seeking ways to improve the profitability of the State's fishing industry, and a relaxation of the SSHP has been endorsed by all parties as one way to achieve this aim.

There are two primary issues that need addressing in relation to changing the SSHP – sustainability and profitability. The risks associated with both of these issues need to be determined objectively before a decision can be made to progress any investigation into the effects of the policy.

The project aligns closely with the DEEDI joint priorities of industry profitability and sustainability, and directly addresses QFIRAC Key R&D Topic #3 - A critical evaluation of management strategies to optimise the socio-economic value of portunid crab fisheries, particularly in terms of the potential value and/or ecological impact of altering the current single-sex harvest policy in Queensland.

5 Objectives

(a) Evaluate the risks and benefits of allowing the harvest of female mud crabs in Queensland.

(b) Depending on (a), develop a plan for implementing a change to the SSHP arrangement.

6 Methods

The workshop was divided into two parts. The first part related to an assessment of the potential risks and benefits that might flow from a change in the management arrangement. An initial scoping session presented information on (i) the current status of mud crab fisheries of other Australian states where there is no prohibition on the taking of females, (ii) markets and marketing arrangements for mud crabs, (iii) the economics of the mud crab fishery in

Queensland, and (iv) the likely sustainability outcomes of various management change scenarios using the Growth-type-group simulation model.

It was stressed that the workshop could only produce a fruitful outcome if all participants were totally objective, setting aside any traditionally-held views on the single-sex harvest policy, examining the available evidence and approaching the issues from the viewpoint of each of the key stakeholders.

Following the scoping session the workshop participants engaged in a risk assessment analysis, following the guidelines of the AS/NZS 4360 Risk Assessment Standard (Figure 1). As there is little published information available on processes that might be adopted specifically in situations such as this (i.e. risk-benefit analysis of a proposed management change) the methodology adopted was derived from a number of sources, all of which were ultimately based on the AS/NZS 4360 standard. Elements of the 'scale-intensity-consequence' analysis (SICA) developed as part of the Ecological Risk Assessment of the Effects of Fishing (ERAEF) were included. The ERAEF process was developed by CSIRO following some earlier pioneering work by Dr Rick Fletcher and others addressing Commonwealth-managed fisheries' reporting requirements for the Department of the Environment, Water, Heritage and the Arts. The inclusion of a 'scale' (both spatial and temporal) dimension in the 'likelihood' assessment was done because of the conceptual difficulty of assessing the likelihood of an event without the inclusion of some (at least qualitative) measure of the geographical scale over which the event posing a potential risk may occur.

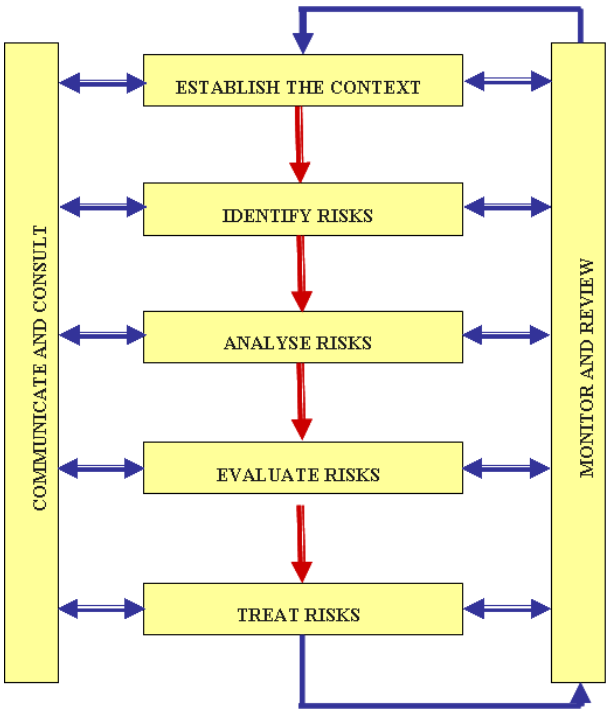

Figure 1. Risk assessment process flowchart as specified in the AS/NZS 4360 risk assessment standard.

Conduct of the risk-assessment and analysis was based to a large degree on the process adopted by ANU researcher Katherine Daniell (Daniell 2007), who was contracted to the Hornsby Shire Council to undertake a community-based risk assessment as a precursor to the

development of the Lower Hawkesbury Estuary Management Plan (LHEMP). The five principal steps in the risk-assessment process, (excluding the Scoping component), were:

1. Identification of Sectors (ensure that we have identified all actual or potential users or beneficiaries of the resource)

2. Identification of Asset Categories or Values (how does each sector perceive the resource to be of value?).

3. Risk identification (what are the risks associated with each of the asset categories or values? Note that this relates to a likely *change* from the current state – i.e. how would a given *change* to the SSHP pose a risk to the particular value in question?).

4. Risk scoring: What would be the consequence of a given change in the SSHP arrangement to the asset value in question, and how likely would be its occurrence in terms of frequency and geographical extent? Additional qualitative information was also sought on (a) perceived knowledge uncertainty (how confident are we in our understanding of the underlying systems and processes?) and (b) management challenge (how confident are we in our ability to manage the risk?).

5. Risk evaluation: This was done by spreadsheet, using the following simple formula to combine spatial (L_s) and temporal (L_t) scales into a single likelihood score L (noting that both had been rated on a 1-5 scale) and derive the final risk score R from likelihood (L) and consequence (C):

   $L = (L_s \times L_t) / 5$ and

   $R = (L / 5) \times C$

   which further simplifies to

   $R = (L_s \times L_t \times C) / 25,$

   where R is calculated risk standardised to a 1-5 scale. It is important to note that although the risk values are numeric, they have no units and are simply a convenient quantitative expression of the relative ranks of the various risks.

Scoring sheets and associated risk scoring tables used during the breakout-group and plenary sessions are provided in Appendix 3.

Following this risk assessment and evaluation of the economic and other benefits that may be expected to flow from a change to the SSHP, the workshop was asked to formulate an agreed position (with whatever caveats and preconditions were deemed necessary) on whether any future change to the SSHP should be considered.

Progress to the second part of the Workshop was dependent upon the outcome of the risk and benefit assessments. The aims of the Project clearly stated that if the Workshop decided at this point that the risk of changing the SSHP under any circumstances was completely unacceptable, the process would terminate forthwith.

However an agreement was reached (given certain preconditions) to progress some level of female mud crab harvest. As a result, the Workshop then faced the tasks of (a) developing a

strategy that would provide the greatest community benefit at a risk level that is realistically manageable, and (b) developing a communication strategy to ensure that the process would not be derailed politically as a result of conflicting advice from key stakeholder groups.

7 Results

This chapter contains an account of the Workshop and its immediate outcomes (Sections 7.1 - 7.9), and subsequent project-related activities, including further stakeholder consultation and Ministerial briefings (Section 7.10). The names of presenters are shown where material was presented by people other than the PI. Where relevant, discussion points and questions are included.

7.1 History of the SSHP in Queensland

This part of the Scoping process is an account of the legislative history of the mud crab single sex harvest policy (SSHP), dating back to the early 1860s when the first fisheries laws were introduced in the state. The dot-point details below were extracted by Mr R Honey from the Parliamentary Papers (Hansard) collection at the John Oxley Library, Brisbane.

- In 1863 the first fisheries laws were introduced in Queensland whereby fish were 'regulated' by weight.
- In 1891 the first law pertaining to crabs was introduced. The minimum legal weights were 3 lb (1.4 kg) for males and 10 lb (4.5 kg) for females.
- In 1913 a Parliamentary Committee was appointed to change the existing law regulating fish by weight to regulations on the basis of size (linear measurement). The Committee's report was submitted on 31 May 1913.
- The Committee recommended a size of 5 inches (= 12.7 cm; presumably carapace width) for male crabs. Because it could not envisage the linear size of a 10 lb female crab, and as it assumed (without any biological evidence for the need) that the past restriction was to protect the females completely, it recommended a complete prohibition on the taking of female crabs.
- In 1926 the MLS was increased to 6 inches (~15 cm) for male crabs (reason not known), where it has stayed ever since.

7.2 Research-based recommendations

The first significant research findings on mud crabs in Queensland resulted from a comprehensive PhD study by Mike Heasman into their general biology and fishery. This work, reported in 1980, suggested (*inter alia*) that there were '*ample grounds to seriously review present [single-sex harvest] legislation*'. This was based principally on the conclusion that the productivity of the fishery was highly unlikely to be recruitment-limited.

Following on from Heasman's work, an investigation of the Queensland mud crab fishery was carried out by the QDPI Fisheries Research Branch, with funding from the Fishing Industry Research Trust Account. The report on this work (Hill 1982) commented that '*Despite the difficulties of sampling [fishery-independent surveys] there is sufficient information now available on mud crabs in Queensland for a management scheme to be drawn up provided that the managers establish clear objectives. The scheme should have a sound biological base but will*

require careful working out to satisfy the various interests of the different groups who currently exploit mud crabs'.

Among the report's recommendations were:

- Retain the existing 150 mm size restriction on male mud crabs.
- Consider a trial period during which females of 150 mm or larger could be taken. This trial should be undertaken only if a monitoring program to evaluate the results is instituted during the trial.

The National Mud Crab Workshop (Terrigal, NSW; 1993), attended by researchers and fishery managers from NSW, Qld, NT and WA, concluded that

- There appears to be no biological justification for a total prohibition on taking female mud crabs,

and recommended that

- There should be a uniform legal minimum size for mud crabs throughout Australia.

In 1993 Dr M Coates (University of Central Queensland) prepared a report to the Queensland Commercial Fishermen's Association (Rockhampton Branch) on the advisability or otherwise of allowing the take of female mud crabs (Coates 1993). This review of arguments for and against concluded that '*most evidence suggests that removing females through fishing would decrease the brood stock, which could result in a decrease in the number of new recruits into the population. This, in turn, could result in a reduced number of legal-sized male crabs entering the fishery. If recruitment were reduced below a certain level a population crash could result*'.
and recommended that:

- The prohibition on the taking of female mud crabs should stay in place.
- Further research on reproduction and recruitment needs to be carried out.
- A program monitoring the fishery is desirable.

7.3 Status of mud crab fisheries in Australia

Mud crab fishery situation statements from each of the States were presented to the Workshop by Phil Gaffney (Qld), Mark Grubert (NT), Steve Montgomery (NSW) and Ian Brown (on behalf of Danielle Johnston, WA). These reports can be found in Appendix 4. An overview of the principal comparative features of the fishery in each State at the present time are summarised in Table 1.

7.4 Some observations on the Queensland catch-effort data series

Queensland's commercial mud crab logbook data are sometimes said to be unreliable, not giving a true picture of the status of the stock, particularly since the Investment Warning announcement in September 2003. There have also been changes over the years in the way the data have been recorded. For example in the early 1990s a number of crabbers reported a cumulative catch over periods of weeks and sometimes months, without any corresponding accumulated effort data. This 'bulking' makes analysis of catch rates almost impossible, and necessitates the removal of the un-usable data from the series. Fortunately the incidence of this type of reporting diminished in the late 1990s and had little effect on gross catch rate (kg/day)

estimates thereafter. The data sets used in the GTG modelling have been filtered to exclude all records where the fishing start and end dates differed.

Table 1. Comparison of principal features of mud crab fisheries (management and status) between Australian States.

FEATURE	Queensland	Northern Territory	New South Wales	West Australia**
Single-sex harvest policy	Yes	No	No	No
Commercial MLS Male (mm)	150 CW	140 CW	85 CL*	150 CW
Commercial MLS Female (mm)	n.a.	150 CW	85 CL	150 CW
Recreational MLS Male (mm)	150 CW	130 CW	85 CL	150 CW
Recreational MLS Female (mm)	n.a.	140 CW	85 CL	150 CW
Seasonal closures	No	No	No	No
Commercial pot limit	50	60	10 + 10 dillies	Specified by exemption (permit)***
Recreational pot/apparatus limit per person	4	5	1 + 5 dillies	Hook, drop net (max. 10) or scoop net
Recreational bag limit (per person)	10	10	5	5
Commercial fishing units/licences current	431	49	217	6
Commercial catch 2008 (t)	1025	412	107	5.8
Commercial effort 2008 (fishing days)	38000	11122	15000	118
Commercial CPUE 2008 (kg/fishing day)	27	37	7	24-73 est.
Est. recreational annual catch (t)	600-800	65 (+ 70 indigenous****)	30-60	21 est.
Monitoring arrangements	Compulsory daily logs; annual fishery independent survey; limited 'research' logs.	Demographic data collected from comm. samples monthly at Darwin.	Port-based monitoring of comm. catch demographics and catch rates.	Logbooks; No regular monitoring programme

* 85 mm carapace length approximates 130 mm carapace width.
** Brown mud crabs (*Scylla olivacea*, both male and female) are subject to a MLS of 120 mm.
*** Ranges from drop nets only (zero pots) to 300 pots
**** estimated in survey year 2000-01

The data suggest that in the year prior to the investment warning there was an increase in both logged catches and effort (Figure 2). This may have been the result of rumours to the effect that such a warning was imminent, and a desire on the part of some crabbers to acquire more 'history' in the fishery. After the announcement, reported catches and effort dropped back to the levels of the three years from 2000 to 2002.

Queensland's mud crab fishery is very seasonal, with catches following a regular trajectory of highs during the warmer months of November to May and lows in the cooler months of June to October. Effort tracks catches seasonally, but changes in effort are not the sole determinant of catch, as catch rates also vary with great seasonal regularity (Figure 3).

This regularity in catch rates (CPUE) suggests that there have not been dramatic changes in the level of Queensland's mud crab stocks over the past couple of decades. However the apparent slight increase in CPUE over the past few years (evident also in the previous figures) is of interest. It suggests that either the stock has been growing or (more likely) there has been an increase in catchability or undocumented cryptic effort.

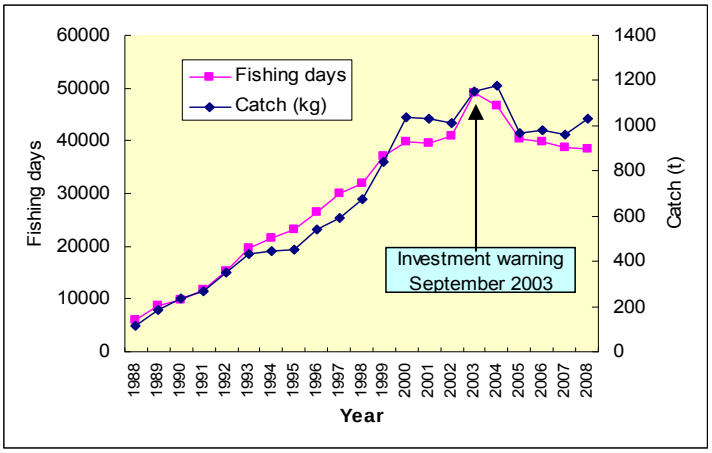

Figure 2. Annual catches (kg) and fishing effort (days) in the Queensland mud crab fishery, showing the effect of the investment warning.

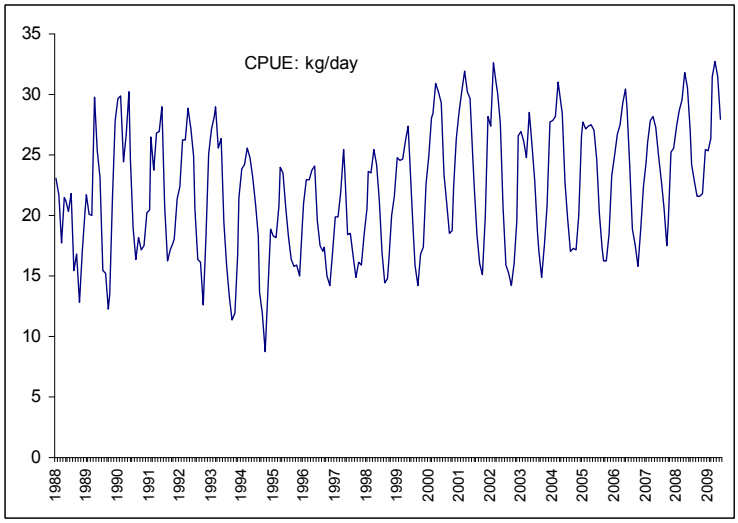

Figure 3. Seasonality in mud crab catch rates (kg/fishing day) for Gulf and East Coast combined.

The big question with fisheries management is whether the present level of fishing effort is producing the maximum (or optimum) sustainable yield. In some fisheries a graph of yield (i.e. catch) against effort will be dome-shaped. Low effort produces low yields, which is not unexpected. Increasing effort produces increasing yields, but beyond a certain point further increases in effort result in declining catches. That 'certain point' - the top of the 'dome' – is the level of effort resulting in maximum yields (in an ideal equilibrium system). However Prof. Carl Walters frequently makes the point that identifying the top of the effort-yield curve is not possible until the fishery is pushed beyond that point. On the basis of the commercial logbook data this doesn't appear to have happened yet (Figure 4). The trajectory is essentially linear, with little evidence of a downward curve. The effect of the Investment Warning can be seen, with a reduction in effort to around 4,000 fishing days p.a. and an associated catch of about 1,000 t.

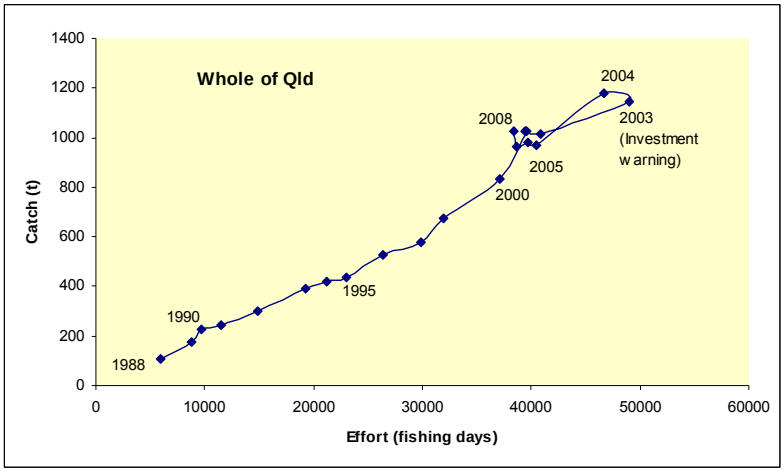

Figure 4. Effort-yield plot for the Queensland mud crab fishery over the two decades from 1988 to 2008, based on raw logbook data.

7.5 Queensland's Long-Term Monitoring Programme (Jason McGilvray)

Annual fishery-independent mud crab surveys commenced in 2000, with the aim of monitoring changes in catch rates and the length and sex-structure of local crab populations in the long term. Sampling has been conducted statewide (Figure 5) by separate LTMP teams in the north and south. The programme was reviewed in 2006 and an experiment carried out to determine the effect of varying soak-time of pots on crab catches and associated pot saturation effects. Because of this, no regular survey was done that year. Surveys recommenced in 2007 and continued to 2009, but due to budgetary constraints the survey appears unlikely to be funded in 2010.

Survey protocols:

- 17 locations (chosen on basis of productivity from commercial logs)
- 4 fixed sites within each location
- 20 pots set per site
- Sites and locations remain the same each year
- Tide and lunar phase kept constant between years
- Standard pot design and bait type
- Soak time kept constant (6 hrs in the north and 12 hrs in the south)

All mud crabs caught during the surveys are counted, sexed and measured. In addition, bycatch species are identified and counted, and separately enumerated if they are species of particular conservation significance. Environmental variables (water temperature and salinity) have also been recorded.

In 2008 the Commercial Fisher Monitoring Logbook (CFML) was introduced to address the issue of seasonal variation, which cannot be obtained from the 'temporal snapshot' LTMP surveys. On one day each fortnight, a select group of participating crab fishers records the numbers of crabs of each sex caught, along with location and effort data (including soak-time estimates). It is proposed that this programme will continue through 2010, and consideration will

be given to incorporating some of the detailed reporting processes into the fishery-wide compulsory logbook.

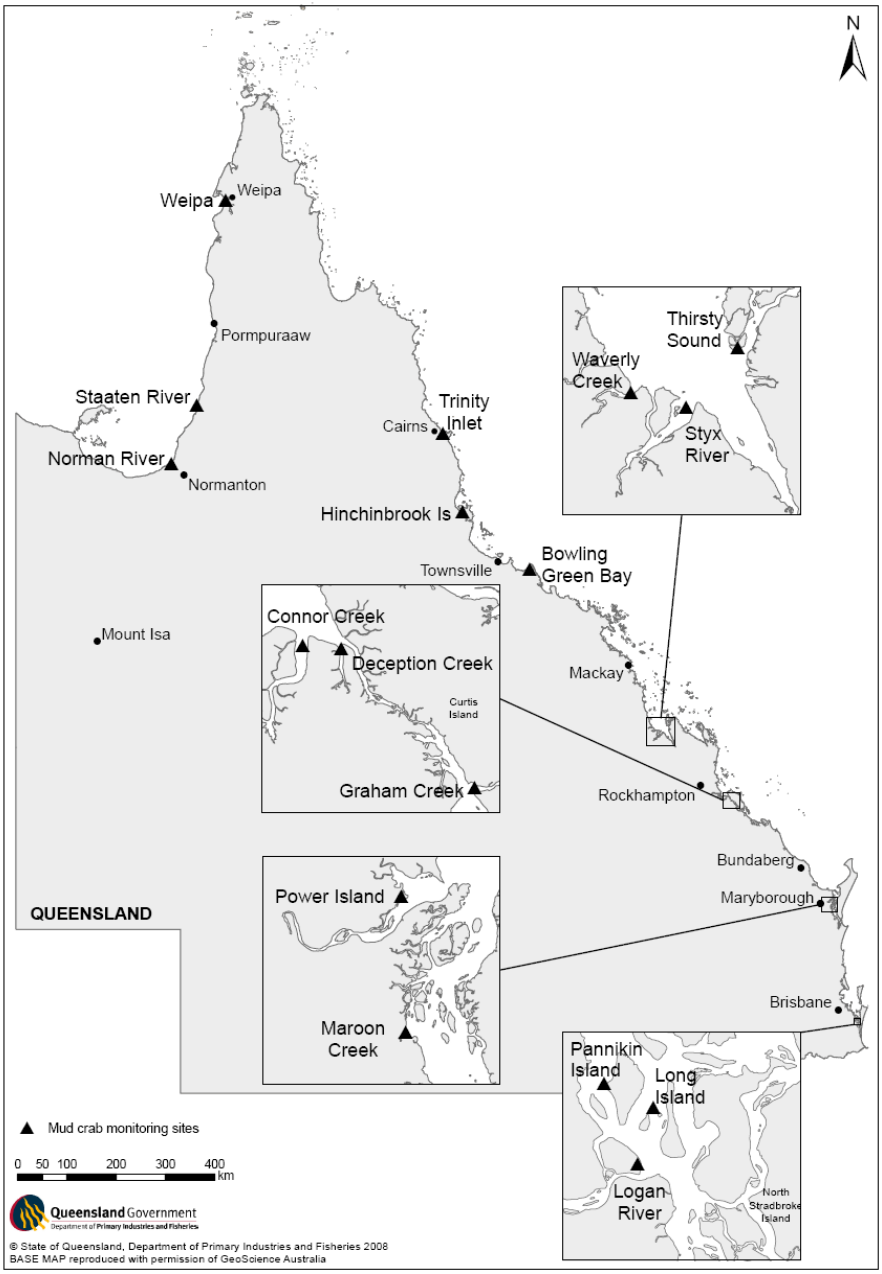

Figure 5. Location of sampling sites occupied during the annual mud crab surveys by the QPIF Long-Term Monitoring Programme.

Annual trends in the LTMP results for three of the sampling areas are shown in Figure 6. There was a lack of consistency between the representative locations (Graham Ck – Gladstone, Weipa – Gulf of Carpentaria, and Trinity Inlet – north Qld) and additional analysis is needed to determine whether there are any significant broad regional trends.

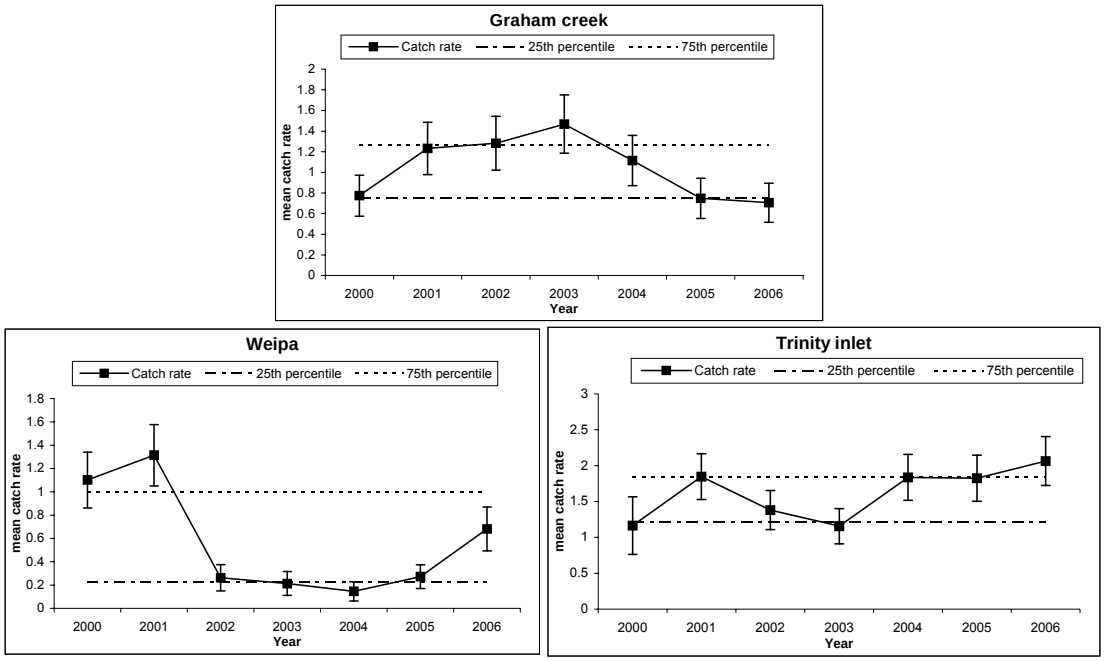

Figure 6. Mud crab catch-rate (CPUE) trends at three of the LTMP sampling locations over the period 2000-2006.

7.6 Market status (James Fogarty)

Background information on the state of current and potential markets for mud crabs was presented by James Fogarty, President of the Queensland Seafood Marketers' Association.

As far as overseas markets for mud crabs are concerned, a few years ago Taiwan had been favoured, followed by Singapore and Malaysia. However in recent times the strength of the Australian dollar has made it very difficult for us to compete in those markets. There has also been a problem with consistency of supply, the bigger markets rapidly losing interest if supply becomes erratic. Today we're focussed almost exclusively on domestic markets, with almost all of Queensland's mud crab catch going interstate, principally to the Sydney Fish Market (SFM). Very little of our product is actually sold in Queensland.

Most mud crabs that *are* sold in Queensland are frozen product from PNG. There may ultimately be a competitive risk from this source, as PNG is currently negotiating with Biosecurity Australia to enable the introduction of live mud crabs into Australia.

A-grade crabs go to wholesalers or direct to restaurants. The market price for A-grade male crabs range from $30 to $35/kg, while females (from NT) bring $35-$40. In high-end Sydney restaurants prices can be as high as $80- $90/kg. Demand for males is less than for females, because of the Asian preference for females which are said to have 'sweeter' flesh. B-grade crabs tend to be sold to Chinese and Vietnamese restaurants for chilli crab dishes which are very popular. The Queensland post-harvest sector would prefer not to see B-grade crabs on the market (as has been done in NT).

Northern Territory A-grade crabs set the market price in Sydney, and female crabs (from NT) usually command $5-10/kg more than males. Demand for A-grade always exceeds supply, particularly round Christmas time. Queensland has a competitive advantage at that time of the year because of access difficulties in NT during the wet season. This is one reason for the demand for (imported) frozen product in regional Queensland centres such as Mackay.

Conclusions:

- Imported crabs supplement supply on local domestic markets, as availability is limited throughout most of year because of high prices in Sydney and Melbourne.
- The product's value to the stakeholder is probably higher in NT than it is in Qld.
- The Qld Seafood Marketers' Association believes that female crabs from Queensland would compete favourably with those from NT – prices more affordable, fishermen would be better off as a result of increased catch rates, and reduced unit production costs.
- Quality crabs would be available throughout the year.
- Sustainability is not a problem in NT so it shouldn't be in Qld.
- Minimising the amount of B-grade crabs on the market would be advisable.
- Indications from the marketplace are that market prices would not be adversely influenced by increased supply. Demand continues to be very high in the southern States.

Discussion:
Question re. NT recreational crabbers' ability to take soft crabs – should be same rule for commercial and recreational sectors, as a B-grade crab released by a commercial fisher will be immediately taken take by a recreational fisher. Response: there *is* a market for B-grades, but QSMA would support a push to discourage or prohibit the take of B-grades.

Question re. supply and demand – if another 300 t of crab comes onto the market, wouldn't there be a drop in price? Issue of B-grade – should sell product in its most valuable form. Response: if it is decided to harvest (some) females, it would be wise to phase in the change during winter when females from NT are in shorter supply. Market situation indicates that there could be an initial decrease in price, but it would rise again in a relatively short time.

Question re. impact of aquaculture crabs coming on the market. Response: although the technology is there, a lot of issues (e.g. cannibalism by large crabs on smaller ones) still need to be addressed. We're nowhere near commercial hard crab production yet.

7.7 Sustainability - Gtg modelling (James Scandol[1])

7.7.1 Summary

This section summarises the methods and outcomes of modelling analyses that were done to support the assessment of risk and benefits associated with harvesting female mud crabs in Queensland. Three modelling approaches were used: examination of catch and effort relationships; visually-oriented population modelling with the Walters Growth Type Groups (GTG) population model; and, the use of indicator-based projections with a parallel GTG population model. Patterns within the catch and effort data and the results of the GTG modelling do not indicate that either the Gulf of Carpentaria or East Coast mud crab stocks are heavily fished. Removal of the single sex harvest policy (SSHP) will cause impacts on the biomass of female crabs and the larger females will inevitably be removed from targeted populations. These changes are, however, not dissimilar to the effects of fishing on mud crab populations in the NT and NSW or other fished crab populations in Queensland. Modelling suggests that removal of the SSHP with current input controls will likely increase the long-term commercial catch to around 50% above the current level (and the recreational catches could be expected to

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respond similarly). This increase in catch is likely to be associated with a 30-40% reduction in the vulnerable female biomass (assuming a 16 cm MLS for females).

Due to the highly variable and environmentally-driven nature of recruitment in these fisheries, any risk-management strategy associated with changes to SSHP should be associated with a robust and credible monitoring program capable of detecting unacceptable impacts on the spawning stocks. Controlling the initial harvest of female crabs by distributing a known number of tags for experimental purposes will dramatically reduce the risks associated with changes to SSHP. The significant uncertainties associated with the effectiveness of input controls will be replaced with a reasonably accurate and unbiased estimate of total female catch (in numbers, weight and length composition). Using tags to control the total female harvest will also enable strategies to be implemented that have a relatively small and managed impact on the spawning stock.

7.7.2 Background

James Scandol of Zetafish Pty Ltd was engaged to complete a model-based analysis of the capacity of the Queensland mud crab stocks to withstand the additional fishing pressure that would result from a removal of the single sex harvest policy (SSHP). This modelling work was to be completed using the tools and algorithms developed by Canadian fisheries scientist Carl Walters (Walters 2007b). The 2-6 November 2009 mud crab workshop associated with FRDC Project 2009/031 enabled extensive interaction between commercial and recreational fisheries, QDPI (now DEEDI) scientists, managers and compliance officers as well as other key stakeholder groups such as GBRMPA and representatives from NSW and the NT.

Preliminary results of the initial modelling work were presented at the workshop and additional analyses were completed based upon suggestions made at the workshop. This report summarises the key results of the modelling work and outlines the issues raised with respect to this work. It was emphasised to all workshop participants that the modelling was not a definitive stock assessment of the mud crab stocks in Queensland (which is probably not possible), but rather an interpretation of the industry-provided catch and effort data using accepted models of fish population dynamics and known biological processes (such as individual growth). These models enable potential outcomes from changes to the SSHP upon key indicators to be assessed. The inability of such models to make precise predictions of mud crab populations and fishery harvests was made very clear to workshop participants.

7.7.3 Modelling framework

The modelling was done using three related approaches: examination of commercial catch and effort data; application of the compiled Walters GtgModel model to calibrate a size-structured population model to monthly catch and effort records; extension of the GtgModel in R to enable quantitative comparison of alternative options for the removal of the SSHP. These modelling approaches are outlined in more detail below.

7.7.3.1 Catch and effort data

Fisheries population models (such as the GtgModel) are calibrated to observed patterns in catch, effort and, in some cases, the length frequency distribution of catches. This calibration means that the catch and effort data play a key role in any historical reconstruction of the stock. These models also make the assumption that the observed catch rate (catch/effort or CPUE) is proportional to the vulnerable biomass. This assumption is known to be compromised if, *inter*

alia, fishing effort has become more efficient over the history of the fishery. This phenomenon is well documented in many fisheries and can result from increasing efficiency of methods and/or increasing real effort per unit of reported effort (for example fishers using more pots per day, but only reporting the number of days fished in their logbooks). There has been no study of this so-called "effort creep" in the Queensland mud crab fishery, but it is not unreasonable to assume that it has occurred. Effort creep has the potential to show that a stable CPUE time series is in fact trending downwards.

This analysis did not consider the possibility of over-reporting of catches (which was identified to be a problem following the conclusion of the workshop). If over-reporting had occurred, it would have led to the overestimation of stock productivity. This issue is discussed in more detail in the concluding comments of this section.

The following model was applied to simulate the effect of effort creep in the Queensland mud crab fisheries (for both the Gulf of Carpentaria and East Coast stocks)

$$E_y^* = E_y \cdot \exp\left(\delta \cdot \left(y - 1988\right)\right)$$

This convenient equation used δ to represent an approximate percentage annual rate of change in efficiency. The overall effect of 21 years (1988-2008) of such change will also be reported.

7.7.3.2 The Walters GtgModel

The GtgModel (or growth type groups model) is an age-structured population model that enables representation of the significant variation in length at age seen in most fish populations (Walters and Martell, 2004). This model is documented in detail elsewhere (Walters 2007) and readers should refer to this documentation for a detailed definition of the algorithms used. An Excel-based equilibrium version of the model structure was also available.

7.7.3.3 Option evaluation with GtgR

Due to the difficulty of modifying the algorithm within the GtgModel (which was compiled with Visual Basic 6), the simulation and projection algorithm was rewritten in the statistical and graphical software R (R Development Core Team, 2009). The algorithm used in the R version was based on an instantaneous rather than discrete harvest algorithm, therefore there were slight divergences in the estimated catch time-series after about 200 time steps. Such differences do not make important changes to the indicators used in this analysis.
The option evaluation model projected the fitted population dynamics for number of years. The most common projection period was 4 years, but some projections to 12 years were also done. Rather than report the absolute values of indicators or variables that the model uses (such as vulnerable biomass or catch), indicator ratios are reported. These are:

> The *short-term indicator ratios* were defined as the ratio of the average value of an indicator (such as projected catch) over the next 4 years, (in this case 2009-2012) to the average value of that indicator over the last 4 years of the simulation (in this case 2005-2008).
> The *long-term indicator ratios* were defined as the ratio of the average value of an indicator (such as projected catch) over the next 9-12 years of an indicator (in this case 2017-2020) to the average value of that indicator over the last 4 years of the simulation (in this case 2005-2008).

These projections required several assumptions of varying credibility. The intra-annual variation in recruitment and catchability was assumed to continue for the projection period, the future recruitment variability was assumed to be zero, and the monthly effort was assumed to be the

average of the last 3 years (2006-2008). Other projected effort and recruitment scenarios were also considered.

7.7.4 Results

7.7.4.1 Catch and effort data

Two data sets from Queensland commercial mud crab fisheries were considered in this analysis: catch and effort data from the Gulf of Carpentaria (GC) and the Queensland East Coast (EC). These data sets are assumed to represent the two recognised stocks that are harvested in the state. Interactions between the fisheries in the Northern Territory and New South Wales are not considered. Commercial catch data are represented in tonnes and the effort data (reported days fished) has been re-scaled by 1/500 to meet the numerical requirements of the GtgModel. Effort is therefore reported as arbitrary "effort units" (eu).

The structure of the GtgModel did not enable quantitative inclusion of recreational catch data as the model captured the dynamics of the stock using the relationship between catch and effort (technically the model was conditioned on catch). Recreational catches (Table 2) could either be considered as a time independent process similar to natural mortality or as a time-dependent process such as commercial fishing mortality. Regardless of this interpretation, the resulting effect of recreational fishing on population models is to require a re-scaling of the underlying biomass or production estimates to compensate for this additional fishery. The magnitude of this extra biomass or production depends upon the extent to which the fishery is "fished down". For example, if the fishery is in a highly productive state, there may only need to be small increase in the modelled biomass or productivity to support the recreational fishery; in contrast a heavily fished stock with low productivity may require a significant increase in the modelled biomass or productivity.

Consider the case of an increase in modelled biomass (represented by α) that will be required both before and after the management change. The following equation illustrates why ratio-based indicators (*I*) may be so little affected by consistent recreational fisheries:

$$I \approx \frac{\alpha \cdot B_{future}}{\alpha \cdot B_{past}} \approx \frac{B_{future}}{B_{past}}$$

This model breaks down if the re-scaling of the modelled biomass (α) required to compensate for the recreational fishery is very different before and after the proposed management change. There are no reasons to suggest why this would be the case for this fishery unless the recreational fishery changes in a disproportionate manner to the commercial fishery.

Table 2 Annual estimates of the recreational harvest of mud crabs in Queensland (assuming average weight = 1 kg) from the RFISH surveys.

Year	Catch Estimate
1997	800 t
1999	1 100 t
2002	990 t
2005	700 t

Figures in the Appendix to this section summarise the catch and effort data used in the subsequent analyses for the Gulf of Carpentaria fishery (Figure 7 and Figure 8) and the East

Coast fishery (Figure 9 and Figure 10). Note that it takes an overall increase in the efficiency of effort of almost three times to create a “fish down” in the East Coast fishery over 20 years (Figure 12). This change represents a plausible, but very significant increase, in actual effort applied within a hand-hauled pot fishery. Such an increase in efficiency would have to represent an upper limit in effort creep that could likely occur.

Other scenarios that were evaluated included using an efficiency factor of δ=10%. This scenario indicated a very significant fish-down from the corrected CPUE data. However, the GtgModel could not be robustly fitted to these times series because catches were at historically high levels from an extremely small relative biomass.

7.7.4.2 The Walters GtG model

The Ggt Model modelling reported here used the same biological parameters that Neil Gribble and Carl Walters had applied when the model was first developed for the Gulf of Carpentaria mud crab fishery. Table 3 summarises these parameters and their values. The only alteration was the application of a re-scaled length to weight coefficient (to better correspond to existing observations).

Table 3 Summary of the parameter values used in the GtgModel and the GtgR simulations.

Parameter	Value
Number of growth type groups	5
Maximum number of age groups	48 months
Length to weight co-efficient	0.0002143 kg/cm^{-3}
Von Bertalanffy growth co-efficient (k)	0.06667 /month
Von Bertalanffy growth asymptotic length (L∞)	18 cm
Co-efficient of variation of L∞	10 %
Length at 50% vulnerability	10 cm
Standard deviation of length at 50% vulnerability	0.5 cm
Minimum length at maturity	12.6 cm
Monthly survival rate (exp[-M])	0.9
Historical minimum legal length	15 cm

The results from the GtgModel are presented as ‘screen shots’ (Figure 13 to Figure 16). As the GtgModel was designed primarily as a visual tool for model fitting and policy exploration, there was no available option to export simulation results for additional analysis (without revising and re-compiling the model). Therefore these types of analyses were completed with GtgR modelling tools.

Figures in the Appendix (Section 7.7.6) illustrate the patterns generated by the GtgModel when fitted to the Gulf of Carpentaria (GC: Figure 13 and Figure 14) and East Coast (EC: Figure 15 and Figure 16) catch and effort datasets. Note that after simulation year 2008, the population is projected rather than calibrated. Two characteristics of the model can be noted from these figures for the calibration period 1988-2008. Firstly, the correspondence between the observed and estimated catches is particularly good (which is not unexpected given the extensive parameterisation of recruitment and catchability) and that variation in recruitment can drive increases in catches (e.g. the pulse of recruitment between 2000-2002 in Figure 11). Secondly, the expansion of the commercial harvest has not led to any historical decline in egg production.

Two alternative futures are modelled after 2008 in panes (a) and (b) of Figure 13 and Figure 15. If the SSHP is retained, then catch, egg production and fishing mortality remain relatively stable in both stocks (assuming stable recruitment and effort). On the other hand, if SSHP is removed, then catches increase by essentially doubling, and egg production declines to a lower level (particularly in the East Coast fishery, Figure 15). Although there may a future trend implied from these figures, these require assumptions about future recruitment and future effort and are not just based upon underlying changes to stock status resulting from the removal of the SSHP. Any modelled projections of such populations must therefore be interpreted with care.

One caveat is that the fit of the model to the data involves significant statistical variation. There are a multitude of combinations of parameter values which provide a valid representation of the population and the fishery (though with varying probabilities). Figure 14 and Figure 16 illustrate the variability associated with accepted simulations from the Markov Chain Monte Carlo algorithm from both the Gulf and East Coast fisheries.

Any future trends implied to any of the indicators could easily be masked by statistical variation in the models. It was beyond the scope of this project to undertake a full uncertainty analysis of this fishery (which should also consider model structure uncertainty), and it is still informative to report the mean of any patterns that are generated by the model. Any interpretation of such results should, however, keep Figure 14 and Figure 16 in mind. Using ratios of indicators (rather than the indicators themselves) will reduce the effect of such variation on the results.

7.7.4.3 Option evaluation with GtgR

The following results for the GtgR analysis are fully deterministic and based upon the best fit of the model to the data and represent the mean responses to the indicators identified. Using ratio indicators, any systematic bias that crosses the before-after interval is essentially cancelled out. This will reduce the variance of the results in comparison to Figure 14 and Figure 16, but it doesn't remove the need for assumptions about future effort and recruitment.

Four ratio-based indicators are presented in these results: commercial catch; egg production; vulnerable male biomass and vulnerable female biomass. Commercial catch includes the harvest of male and, if SSHP is removed, female crabs above the minimum legal length (MLS). Egg production is strongly linked to the spawning biomass (of female crabs) but is more loosely linked to recruitment via the non-linear stock recruitment relationship. If the biomass is not heavily fished down (as is the case in the results presented here), then recruitment will not be strongly coupled to egg production. This relationship will be further masked by the significant recruitment variability that is present in this system. Vulnerable biomasses are the fraction of the total biomass vulnerable to the fishery based upon the current selectivity (regardless of the MLS). Vulnerable biomass is therefore less prone to changes in MLS than commercial catches.

All comparative projections with GtgR were completed in parallel with a "control" (or status quo) of retaining the SSHP and a 15 cm MLS on male crabs and keeping the effort the same as the average for the last 3 years. For example, when an option results in the catch ratio indicator having a value of 1.5, it suggests that catches would have increased 50% compared to retaining the status quo. The fact that the control case does not exactly equal one on the graphs is due to residual effects of the pre-projection period (see Figure 17).

This section presents the results of various options for altering SSHP. General results are presented for both the Gulf and East Coast fisheries but the more specific results (such as the sensitivity analyses) have only been presented for the East Coast fishery as the indicator-based results are similar between the two fisheries.

Based upon discussions at the Nov 2009 workshop, the options that were considered and compared are the status quo versus removal of SSHP with a 15, 16, 17 or 18 cm MLS for female crabs (the MLS of male crabs would remain at 15 cm).

7.7.4.4 Short-term indicator results

The initial 4-year period after a proposed management change is of key importance to this fishery because there will be transient effects that are likely to have biological, social and economic consequences. In particular, if SSHP is removed, the sudden availability of female crabs is likely to increase both commercial and recreational effort and cause a short-term (1-2 years) fish down of the female stock as the larger female crabs are removed. This effort response is probably the most difficult aspect of this fishery to predict. Three scenarios will be considered: (1) effort remains the same as the average of the last three years; (2) effort is double the average of the last three years; (3) effort is double the average for two years, then stabilises to 1.5 times the average.

Results for the Gulf and East Coast fisheries are presented. These scenarios assume that there is no recruitment variability for this four year period and the indicator is calculated as the ratio of the indicator 4 years after the management change to the indicator 4 years before the change.

Figure 15 to Figure 20 all indicate that increasing the MLS of female crabs results in a progressively smaller effect on all indicators. With a 15 cm MLS and constant effort, initial catches are essentially double (as expected) but then decline if only the larger crabs are retained (Figure 17). Similarly, egg production and the female vulnerable biomass have the largest impact at a 15 cm MLS. The male vulnerable biomass is only slightly affected for both the Gulf and East Coast fisheries by such a change.

Doubling the projected fishing effort causes an increased affect on all indicators compared to the constant effort scenario. Catches are now over double for the East Coast fishery (Figure 19) and almost triple for the Gulf fishery (Figure 16) during the period 4 years after the proposed management change. Having the projected effort double for only two years, then decrease to 1.5x (scenario 3) reduced the effect of the management change on all indicators but only by a small amount because, as expected, most of the impacts occurred almost immediately after the proposed change was introduced. A 15 cm MLS and increased effort scenarios suggested a short term 20% drop in the vulnerable female biomass in the Gulf fishery (Figure 16) and a 40% drop in the East Coast fishery (Figure 19).

Due to the similarity of these results for both the Gulf and East Coast fisheries, only the more responsive East Coast fishery will be reported hereafter. From the visual analysis of the catch and effort data presented above (Figure 12), it is evident than when the East Coast stocks have a 5% effort creep factor applied, there has been an expected fish-down of the stocks which results in management options having greater impacts on the modelled stock than would likely occur in the more stable Gulf fishery. Furthermore, only the effort doubling scenario will be reported hereafter as this is likely to reflect an upper limit to the increase in effort applied to the fishery.

7.7.4.5 Long-term indicator results

This analysis extends the projection scenario to 12 years and defines a new indicator ratio based upon the system state from 9-12 years after the management option has been applied. Figure 19 illustrates the results for the East Coast fishery when projected effort is constant and Figure 20 when projected effort is double (for the whole 12 years).

As expected the longer-term catches are not double the simulated catches when SSHP was initially removed, but have stabilized to around 1.6 x (for a 15 cm MLS). The vulnerable male

and female biomasses are slightly lower, as is egg production, from the SSHP control. These changes are not surprising because after the transient effects of the management change have passed, the population will stabilise. Similar, but larger effects were noted using the effort doubling scenario (Figure 20).

The most interesting result this second scenario is the difference between a 15 and 16 cm MLS for female crabs. Using a 16 cm MLS rather than a 15 cm for females makes almost no change in long-term catches (both about 1.5x), but the larger MLS generates a significant improvement to egg production and vulnerable biomass (for both males and female). This is not an unusual result in fisheries population dynamics and is analogous to the adoption of $F_{0.1}$ as the target reference point in many fisheries rather than F_{max}.

7.7.4.6 Recruitment effects

The previous analyses assumed that recruitment would remain stable over the next 12 years. This is a highly unlikely assumption; rather there will be recruitment variability in the population. Two extreme scenarios are used to bracket the possible consequences to changes in recruitment over time. The first scenario assumed that annual recruitment decreased by 50% over 12 years, and the second scenario assumed that it increased by 50% over 12 years. Results are presented in Figure 21 and Figure 22 respectively.

Decreasing recruitment by 50% over 12 years caused a significant decrease in all indicators from the (previously considered) constant recruitment scenarios. Such an extreme change resulted in the vulnerable female biomass decreasing to 60% of the baseline if the SSHP was retained and decreasing to 40% with a 16 cm MLS on female crabs (Figure 21). Increasing recruitment by 50% had the expected opposite effect, where catches were almost doubled for the 15 and 16 cm MLS options, whilst the long-term impact on the vulnerable female biomass for a 16 cm MLS was negligible compared to the current harvesting strategy (Figure 22).

These results illustrate that the changes to key indicators from recruitment processes can easily exceed the possible changes that result from the removal of the SSHP. This has important ramifications for the design of sampling programs used to measure the impact of alterations to the SSHP.

7.7.4.7 Modelling catch controls on female crabs

Workshop participants suggested that the female harvest might best be controlled by issuing limited numbers of tags. This strategy requires the model to represent the harvest of female crabs in a much more controlled manner than would be using input controls alone. The GtgR model was modified so that female fishing pressure was controlled directly (though still subject to monthly variation in catchability) rather than calculated from mean catchability and fishing effort (as is the male catch). This fishing pressure resulted in a catch of female crabs that was compared with the recent four year history of male crab catch (see Figure 25). This Figure illustrates that as fishing pressure increases the catch of female crabs (relative to male catch) increases and that the MLS applied to female crabs has a very significant effect on the catch (as expected). If the decision was made to harvest females at a level of around 40% of the historical male catch, then using a 16 cm MLS for females, this would suggest a fishing pressure of around 0.04 /month (indicated by the vertical line on Figure 25).

The indicator response diagrams were then prepared for this level of fishing pressure. Figure 26 illustrates that overall increase in catch using a 16 cm MLS will be slightly greater than 30% (due to the reduction in male crab catch in the control simulation). Egg production may decrease around 20%, there will be hardly any effect on the vulnerable male crabs and a 10% decrease in vulnerable female biomass is indicated. With recent commercial catches at between 800-850 t/year, 40% translates in to a female catch of 320-340 t/year.

7.7.5 Discussion

There are multiple lines of argument that can be put forward to suggest why the Queensland mud crab stocks could sustain the harvest of female crabs. These arguments include:

- The mud crab fisheries in the Northern Territory and NSW do not have a SSHP, yet neither fishery illustrates any strong evidence of overfishing.

- That there are no characteristics of the biology, ecology or harvesting methods of mud crabs that would usually be associated with a susceptibility to overfishing. For example: individuals have high growth rates and spawn large numbers of eggs; mud crabs are broadcast spawners so the stock-recruitment relationships are likely to be spatially de-coupled; adults live in spatially complex estuarine environments where there are logistical constraints to fishing effort; adults are not known to form spawning or migratory aggregations that can be easily targeted by highly efficient fishing methods such as trawls or seines; the licensed fishing methods have gear saturation effects and physical constraints that will likely provide a ceiling to actual fishing effort. This is not to say that recruitment overfishing is impossible with such biological and fishery characteristics, simply much more unlikely.

- The spawning biomass of many fish and most shellfish stocks is protected with a MLS and not a SSHP (which is impossible for most species anyway). The effectiveness of MLSs as a strategy to protect spawning stocks is further enhanced by the low discard mortality rates associated with crab potting. The current MLS of 15 cm if applied to females may be too low to effectively protect the spawning biomass in southern Queensland. The length at initial maturity appears to vary from 12-15 cm (depending upon latitude) so a MLS greater than 15 cm is probably justified for female crabs in Queensland. Modelling suggests that a 1 cm increment of MLS may have little impact on long-term yields but will help protect spawning stocks.

- Neither of the catch and effort time series from the Gulf of Carpentaria nor the East Coast indicate that the male mud crab stocks have been significantly depleted, even with quite aggressive scenarios of effort creep. If anything, the East Coast stock may simply have been fished down to a more productive level. The state of the female mud crabs stocks should be very similar to their unfished state (which will be associated with low levels of productivity). The strength of this line of argument is, however, compromised if there has been increasing over-reporting of commercial catches. This was not analysed in the modelling study, but has the potential to over-estimate the current state and productivity of the stocks. As a rule of thumb, if there has been over-reporting by 10%, then the stock's productivity will be 10% lower than that indicated here.

The modelling integrates some (but certainly not all) of these observations and indicates that removing the SSHP will cause an initial fish-down of female crabs, but that this transient effect would stabilise into an increased yield of around 50% from the current level (and the recreational sector could be expected to have a similar response). This scenario assumes that fishing effort is similar or greater than present. The model indicates that removal of the SSHP and a 16 cm MLS for females could cause a 30-40% reduction in the vulnerable female biomass (as expected) and up to a 50% reduction in egg production (which doesn't necessarily translate into a 50% reduction in recruitment). Projected production and biomass patterns are highly dependent upon future patterns of recruitment, but the entire modelling study is prone to the potential biases identified if catches have been over-reported.

Rather than over-emphasise the utility of such forecasts (which require a lot of assumptions), it is more valuable to discuss the options for changing the SSHP and the strategies that could be used to ensure that any such changes to not result in negative outcomes for the stocks and the fisheries. An adaptive management process should be developed that ensures that the potential outcomes of removing the SSHP can be measured and that strategies are in place for acting upon any unacceptable outcomes. Application of fishery-independent monitoring programs (such as LTMP) will improve our understanding of any impacts upon the stock and the subsequent credibility of any decisions taken.

The option identified at the workshop of using single-use crab tags to control the total harvest of female crabs for both the commercial and recreational sectors has several advantages over conventional input controls. Firstly, managing total female removals rather than just relying on the coarse effectiveness of input controls is a much more risk-averse approach to rescinding the SSHP. Any alterations to SSHP will be more easily reversed if the social, economic or biological outcomes are deemed to be unacceptable. Secondly, by quantifying the total removals (rather than just the commercial catches), any monitoring signals in the abundance and length composition of females will be more easily associated with changes to SSHP rather than being confounded by unreported recreational catch.

If the number of tags distributed reflects a relatively minor increase (discussions indicated a 20-40% increase) in total catch, then the impacts on the female biomass will likely be relatively small although this impact will be greater if the model was biased because of over-reporting. Indeed, measuring such changes may well be below the statistical power of the LTMP design. Measuring impacts such as “recruitment overfishing” is notoriously difficult in the best of circumstances and alternative, more practical, performance indicators may have to be adopted. One suggestion is to use the length measurements of female crabs to ensure that internationally accepted conventions on protecting the spawning biomass are being achieved (such as ensuring that each female has, on average, the opportunity to spawn once or twice).

Question on importance of recruitment; cannibalism, with large females eating small crabs in captivity. Maybe increased productivity if the big animals are taken out? Notice in own crab pots large females always eating smaller crabs. Response: Yes, the model deals with this issue in a parallel way as recruitment compensation. Because of the complexity of behavioural and other dynamics, the only way to address such questions is with a well-designed field-scale experiment.

Question: How important to the model results is the reliability of the initial input catch-effort data? Response: It is very important, but the three model scenarios (with inbuilt effort-creep) are likely to capture the underlying patterns of catch and effort.

7.7.6 Appendix: Figures

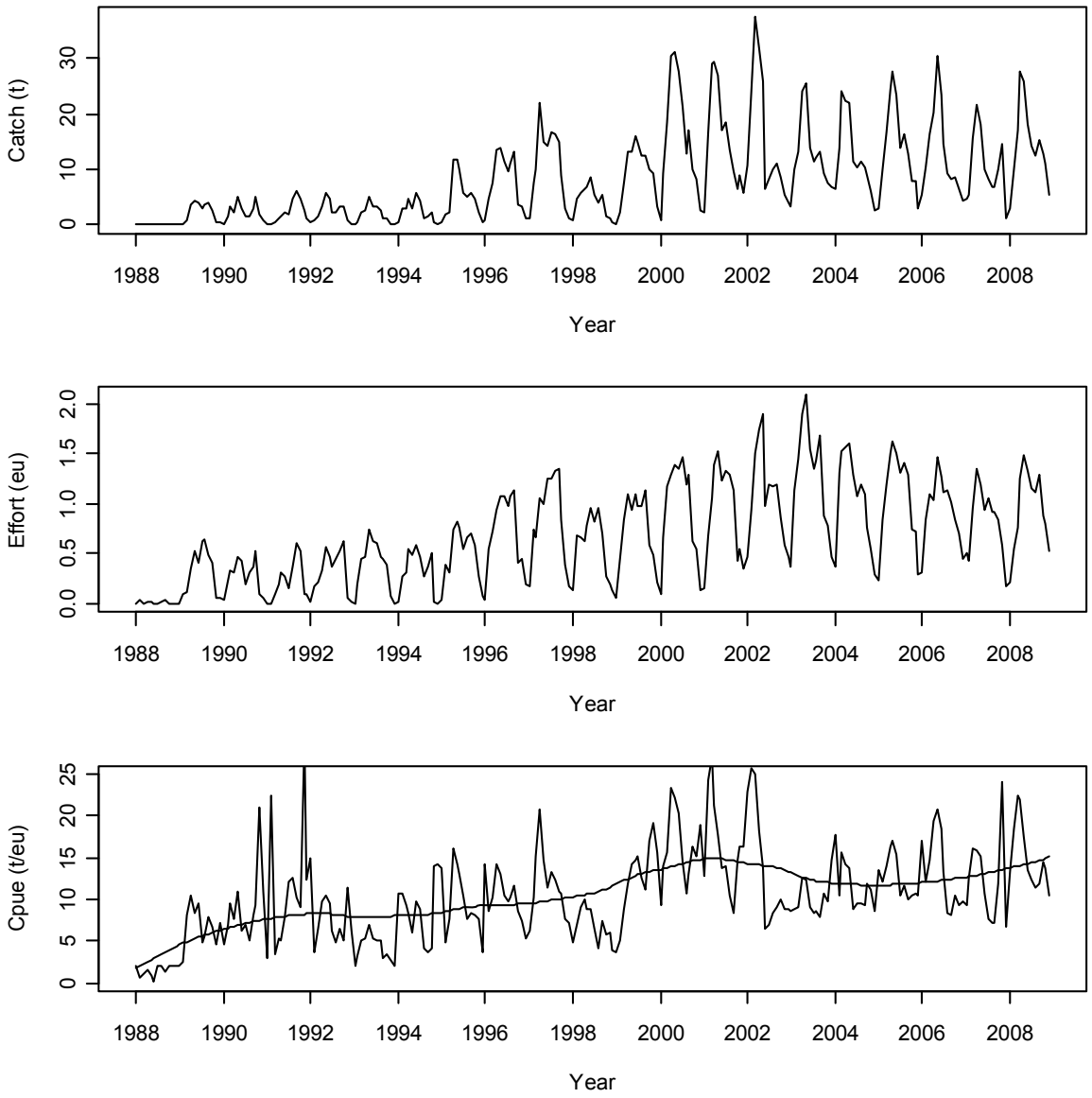

Figure 7. Time series plots of the monthly catch, effort and catch per unit effort (CPUE) for the Gulf of Carpentaria mud crab fishery with no correction to the data for "effort creep". Tick marks on horizontal axis represent the start of the calendar year. A Loess smoother has been fitted to the CPUE data to highlight the long-term trend which indicates that CPUE actually increased.

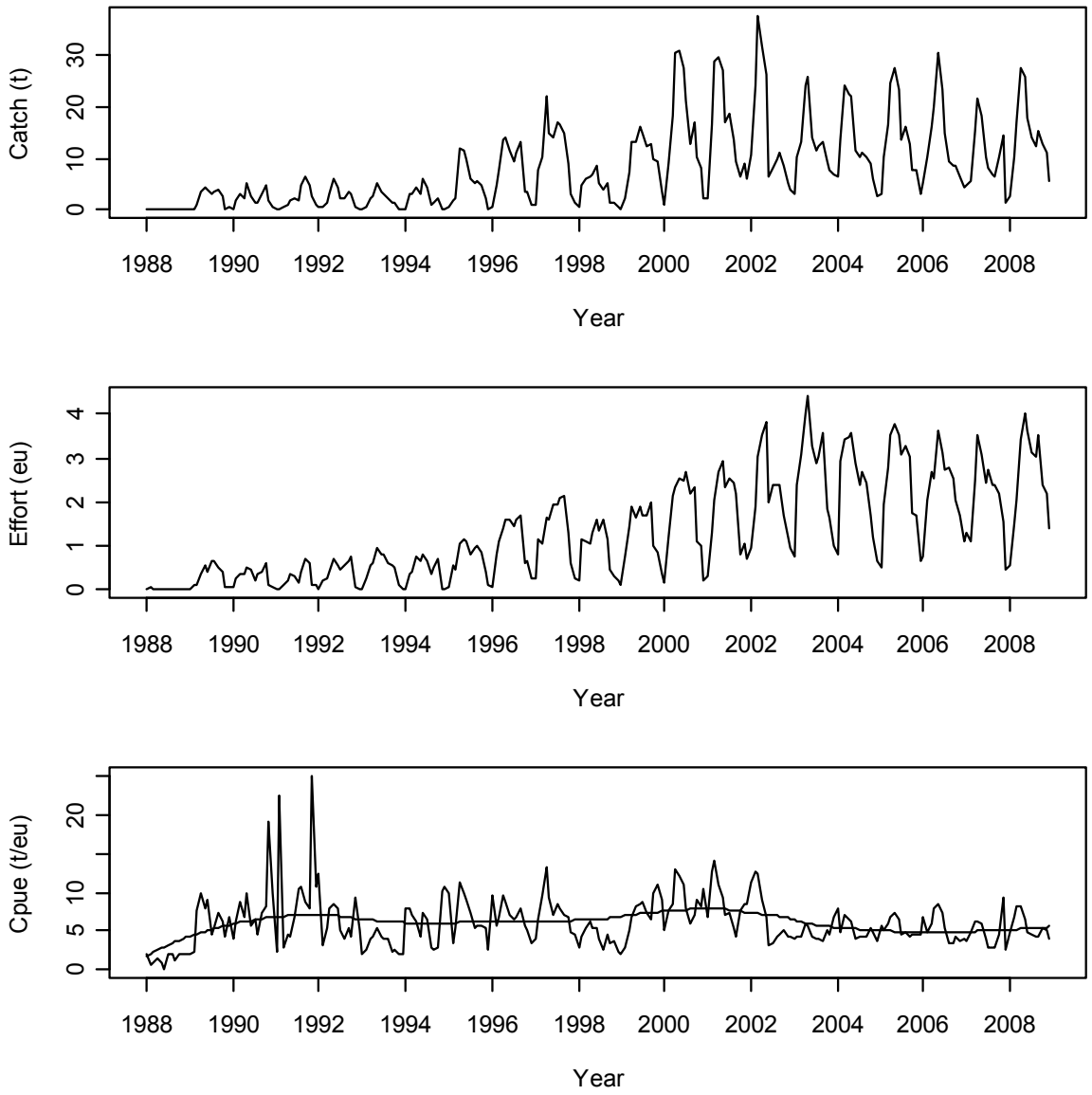

Figure 8. Time series plots of the monthly catch, effort and catch per unit effort (CPUE) for the Gulf of Carpentaria mud crab fishery with a 5% effort creep factor applied (a unit of effort in 2008 was 2.7x more efficient that 1988). Tick marks on horizontal axis represent the start of the calendar year. A Loess smoother has been fitted to the CPUE data to highlight the long-term trend which indicates that CPUE declined in 2002 but has been stable since 2004.

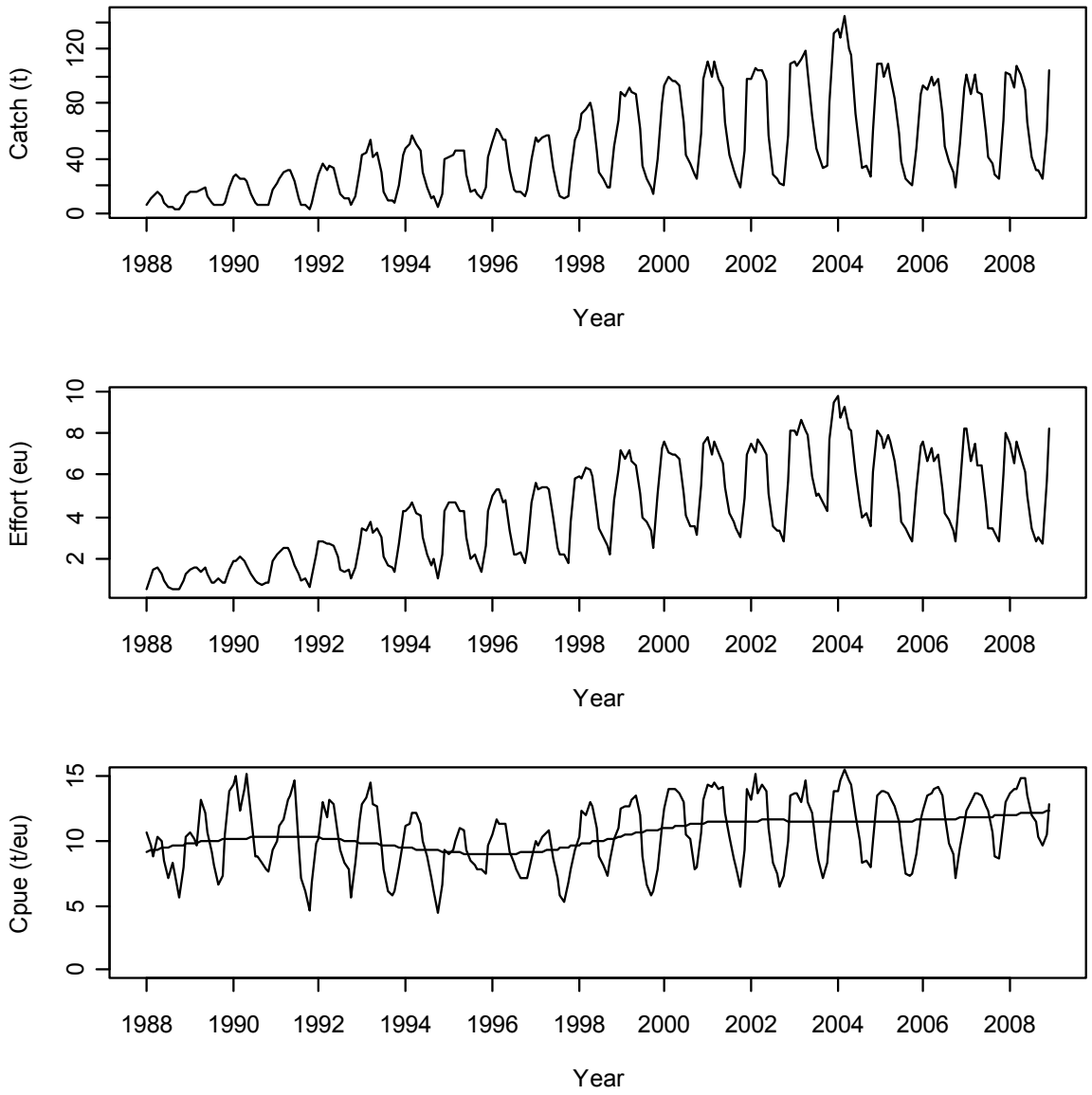

Figure 9. Time series plots of the monthly catch, effort and catch per unit effort (CPUE) for the Queensland East Coast mud crab fishery with no correction to the data for "effort creep". Tick marks on horizontal axis represent the start of the calendar year. A Loess smoother has been fitted to the CPUE data to highlight the long-term trend which indicates that CPUE was stable or slightly increased.

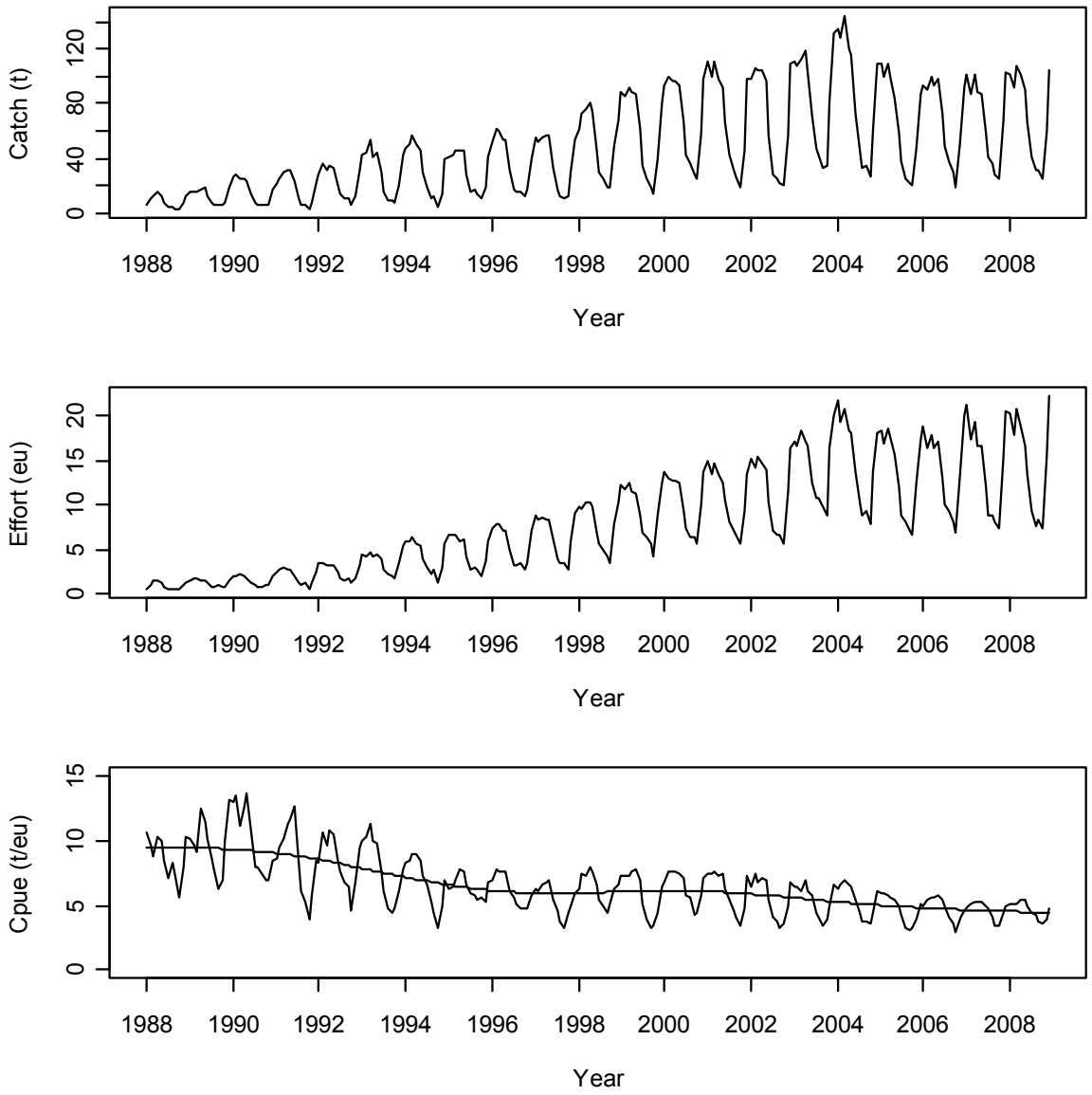

Figure 10. Time series plots of the monthly catch, effort and catch per unit effort (CPUE) for the East Coast mud crab fishery with a 5% effort creep factor applied (a unit of effort in 2008 was 2.7x more efficient that 1988). Tick marks on horizontal axis represent the start of the calendar year. A Loess smoother has been fitted to the CPUE data to highlight the long-term trend which indicates that CPUE has declined to around half the initial CPUE.

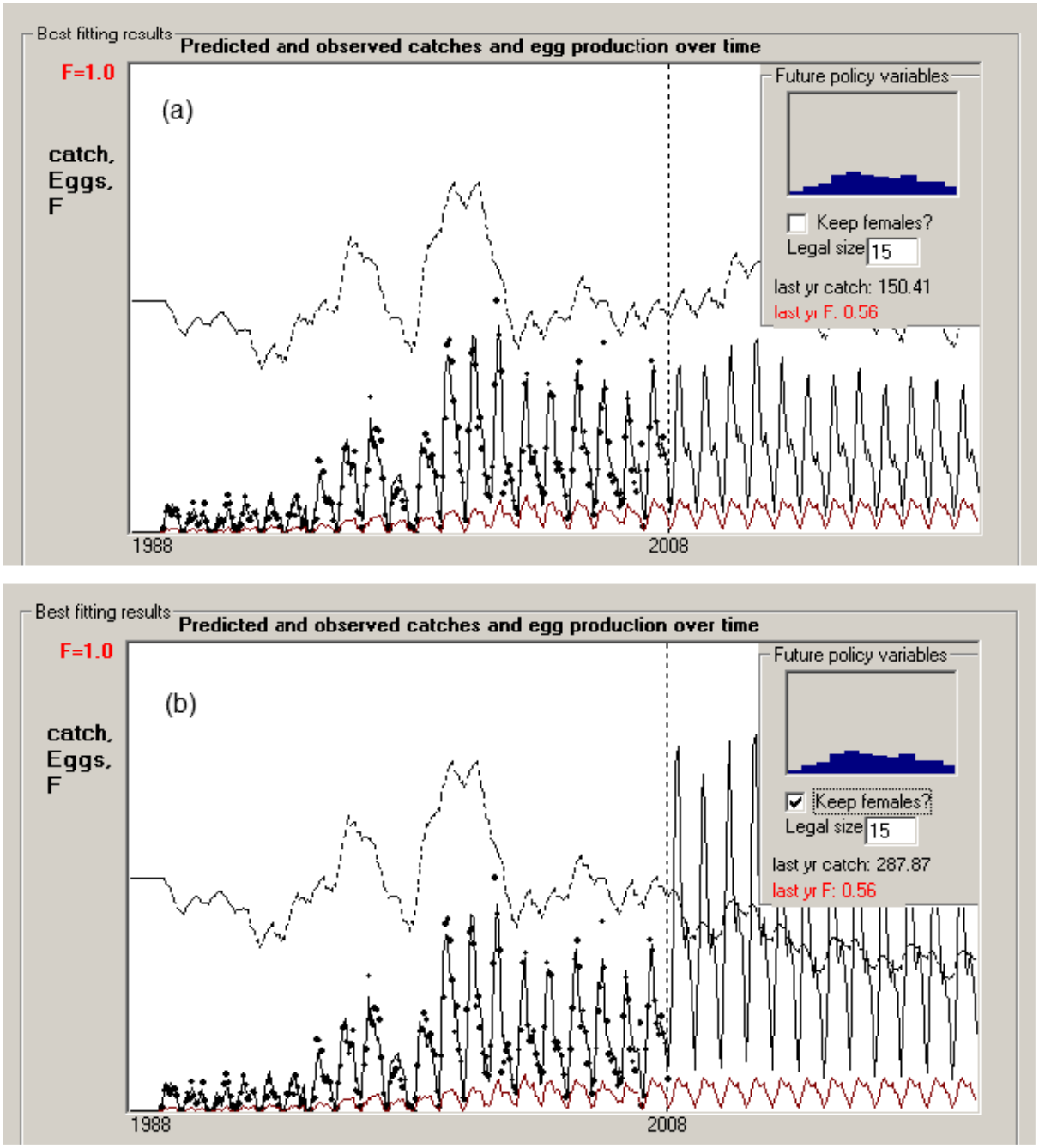

Figure 11. Screen shot of the GtgModel fitted to the Gulf of Carpentaria dataset with 5% effort creep. The series represent: egg production (upper dashed line); estimated catches (middle solid line); observed catches (dots) and fishing mortality (lower red line). Upper pane (a) illustrates 12 year projection from 2008 with current SSHP in place. Lower pane (b) illustrates 12 year projection after removal of the SSHP (with a 15 cm MLS for harvested female crabs).

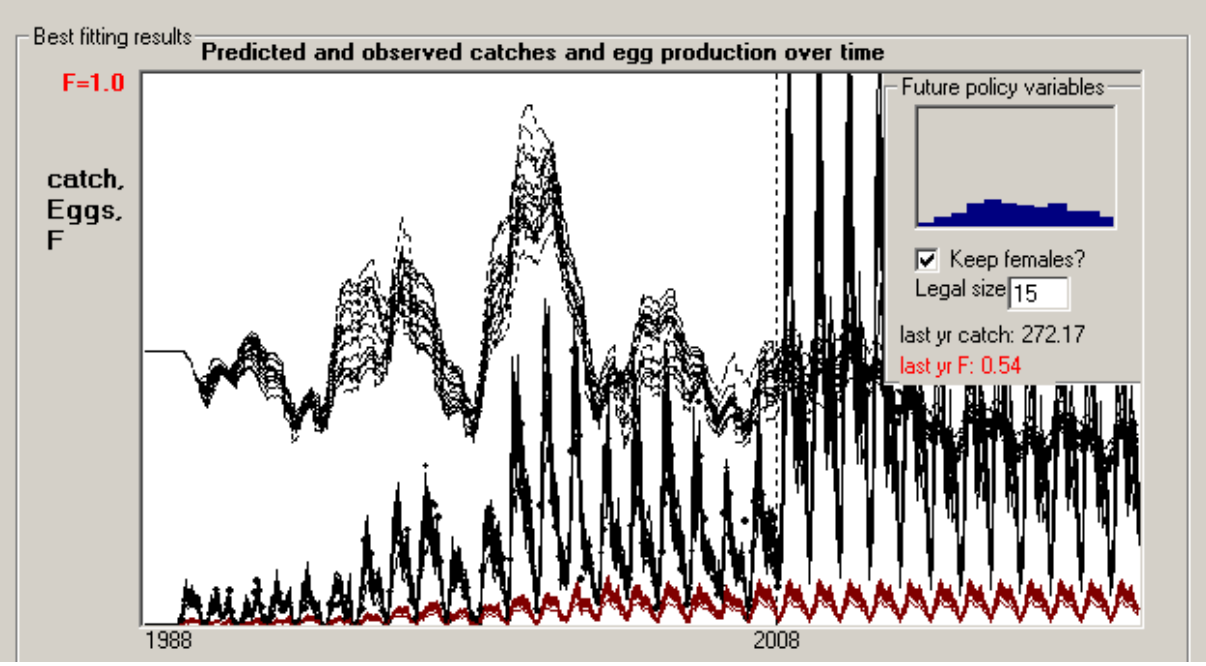

Figure 12. Screen shot of the GtgModel fitted to the Gulf of Carpentaria dataset with 5% effort creep. The series represent: egg production (upper dashed line); estimated catches (middle solid line); observed catches (dots) and fishing mortality (lower red line). This image includes a samples of simulations whose parameter values were accepted as part of the MCMC sampling and illustrates the variability associated with the modelling.

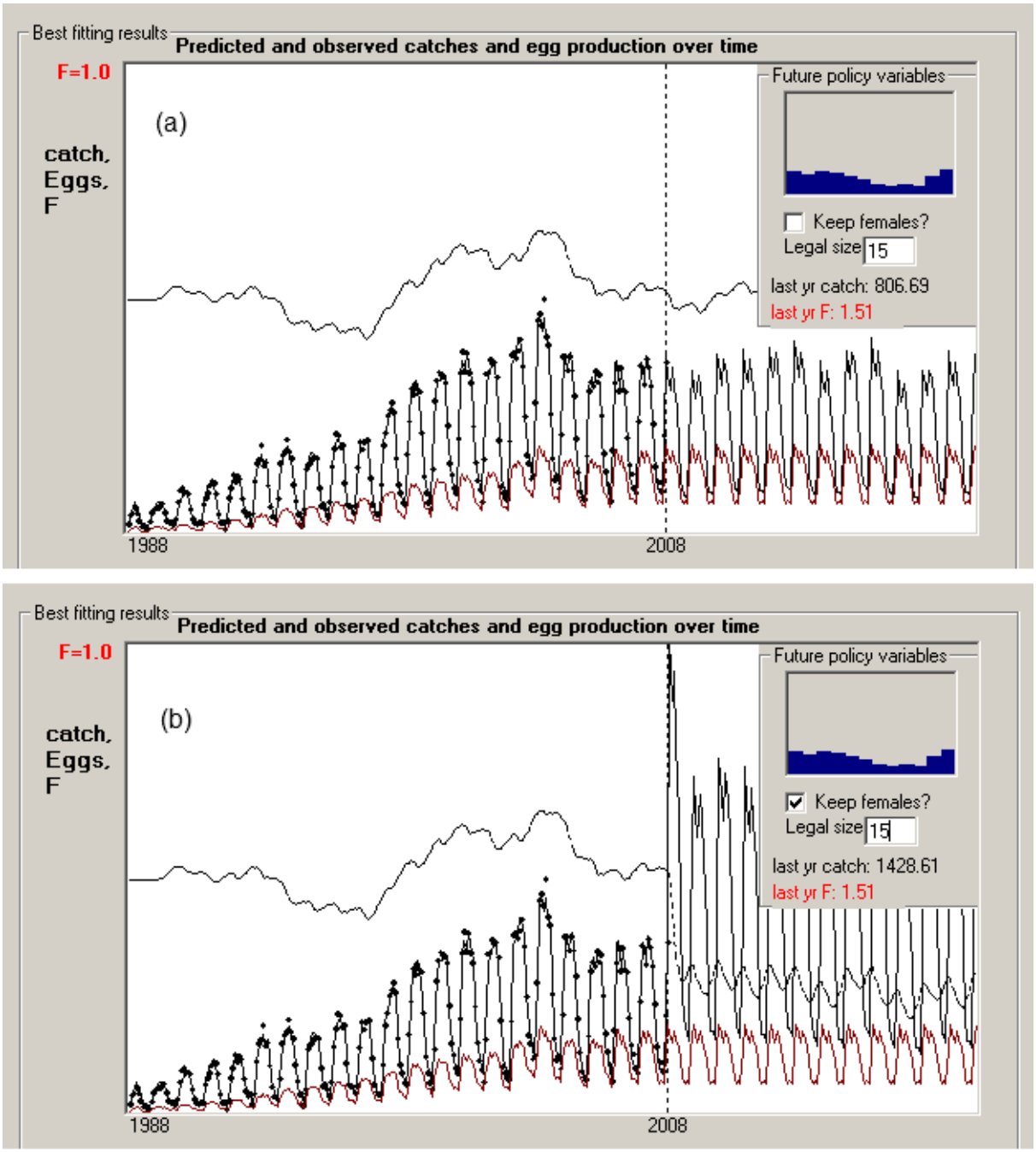

Figure 13. Screen shot of the GtgModel fitted to the East Coast dataset with 5% effort creep. The series represent: egg production (upper dashed line); estimated catches (middle solid line); observed catches (dots) and fishing mortality (lower red line). Upper pane (a) illustrates 12 year projection from 2008 with current SSHP in place. Lower pane (b) illustrates 12 year projection after removal of the SSHP (with a 15 cm MLS for harvested female crabs).

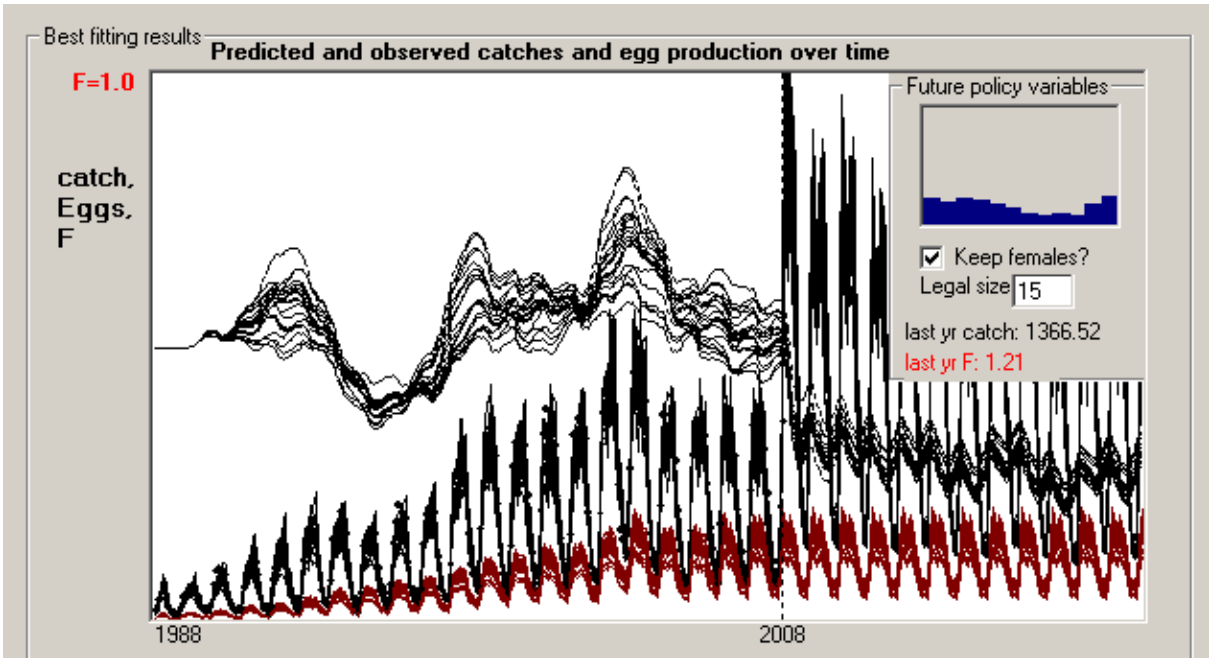

Figure 14. Screen shot of the GtgModel fitted to the East Coast dataset with 5% effort creep. The series represent: egg production (upper dashed line); estimated catches (middle solid line); observed catches (dots) and fishing mortality (lower red line). This image includes samples of simulations whose parameter values were accepted as part of the MCMC sampling and illustrates the variability associated with the modelling.

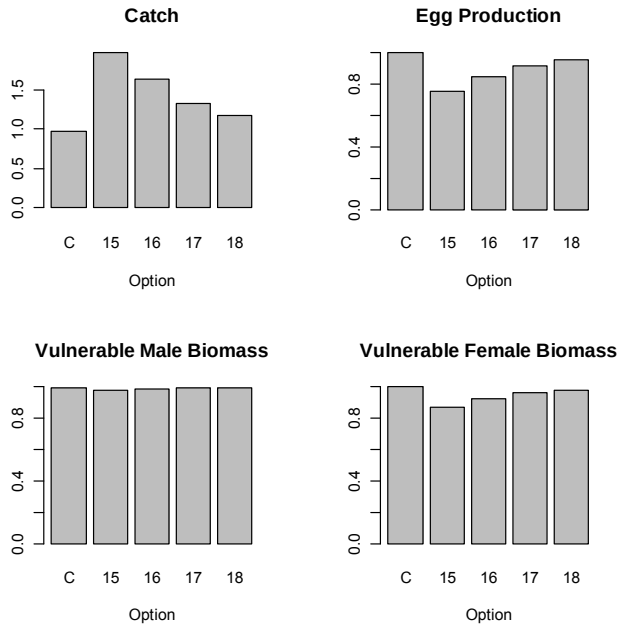

Figure 15. Results for the indicator ratios for the Gulf of Carpentaria mud crab fishery with a 5% effort creep factor applied. Four short-term projection indicator ratios are reported: commercial catch, egg production and vulnerable male/female biomass. Five management options are considered: the status quo (C) where the SSHP is retained as well as alternative MLSs (15 to 18 cm) for female crabs if the SSHP is rescinded. Projected effort is constant at the same level as the average of the last three years (2006-2008).

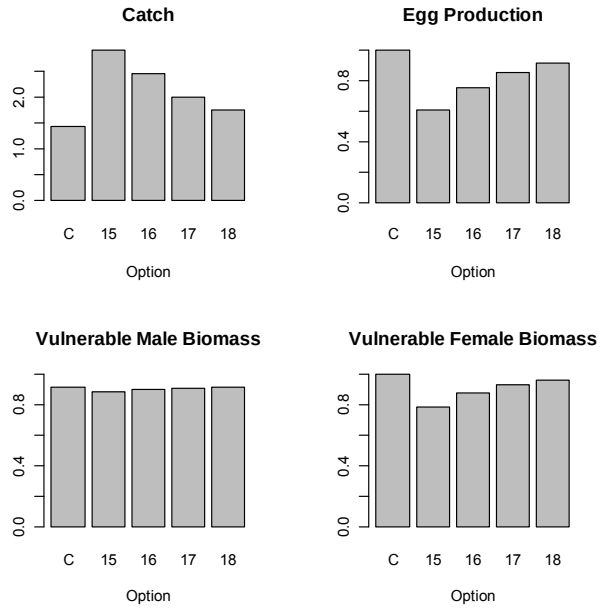

Figure 16**.** Results for the indicator ratios for the Gulf of Carpentaria mud crab fishery with a 5% effort creep factor applied. Four short-term projection indicator ratios are reported: commercial catch, egg production and vulnerable male/female biomass. Five management options are considered: the status quo (C) where the SSHP is retained as well as alternative MLSs (15 to 18 cm) for female crabs if the SSHP is rescinded. Projected effort is constant at double the level as the average of the last three years (2006-2008).

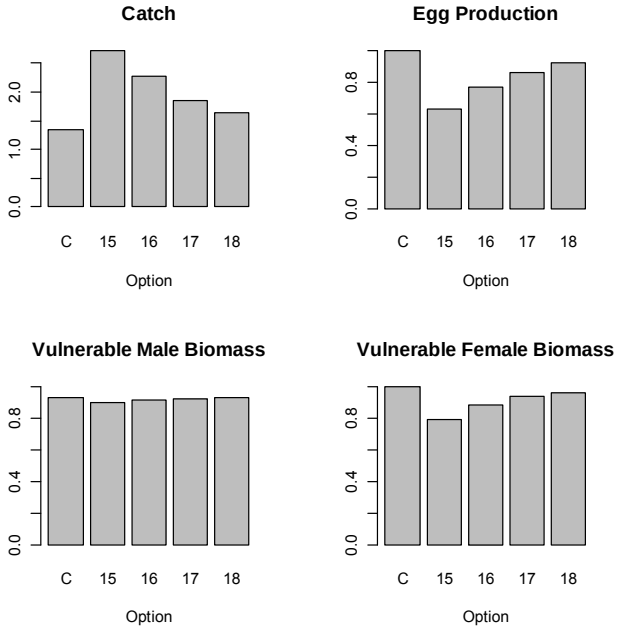

Figure 17. Results for the indicator ratios for the Gulf of Carpentaria mud crab fishery with a 5% effort creep factor applied. Four short-term projection indicator ratios are reported: commercial catch, egg production and vulnerable male/female biomass. Five management options are considered: the status quo (C) where the SSHP is retained as well as four alternative MLSs (15 to 18 cm) for female crabs if the SSHP is rescinded. Projected effort is double the level as the average of the last three years (2006-2008) for two years, then is reduced to 1.5x that average for the remainder of the projection period.

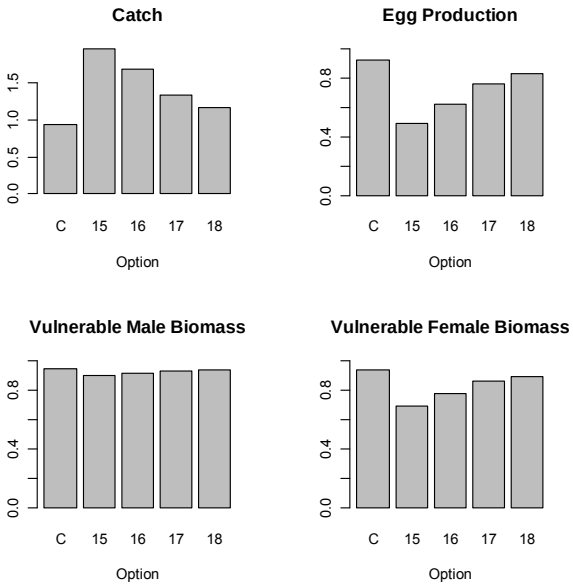

Figure 18. Results for the indicator ratios for the East Coast mud crab fishery with a 5% effort creep factor applied. Four short-term projection indicator ratios are reported: commercial catch, egg production and vulnerable male/female biomass. Five management options are considered: the status quo (C) where the SSHP is retained as well as four alternative MLSs (15 to 18 cm) for female crabs if the SSHP is rescinded. Projected effort is constant at the same level as the average of the last three years (2006-2008) during the projection period.

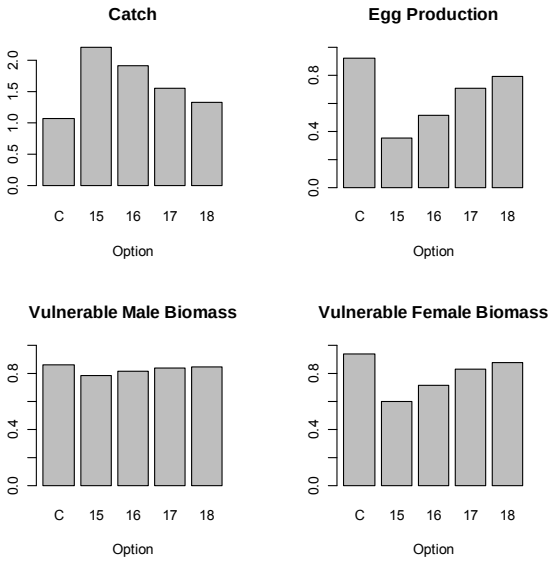

Figure 19. Results for the indicator ratios for the East Coast mud crab fishery with a 5% effort creep factor applied. Four short-term projection indicator ratios are reported: commercial catch, egg production and vulnerable male/female biomass. Five management options are considered: the status quo (C) where the SSHP is retained as well as alternative MLSs (15 to 18 cm) for female crabs if the SSHP is rescinded. Projected effort is constant at double the level as the average of the last three years (2006-2008) during the projection period.

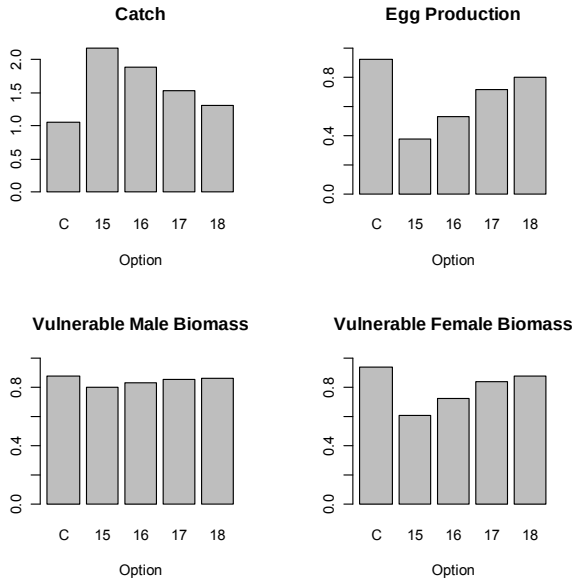

Figure 20. Results for the indicator ratios for the East Coast mud crab fishery with a 5% effort creep factor applied. Four short-term projection indicator ratios are reported: commercial catch, egg production and vulnerable male/female biomass. Five management options are considered: the status quo (C) where the SSHP is retained as well as four alternative MLSs (15 to 18 cm) for female crabs if the SSHP is rescinded. Projected effort is double the level as the average of the last three years (2006-2008) for two years, then reduces to 1.5x that average.

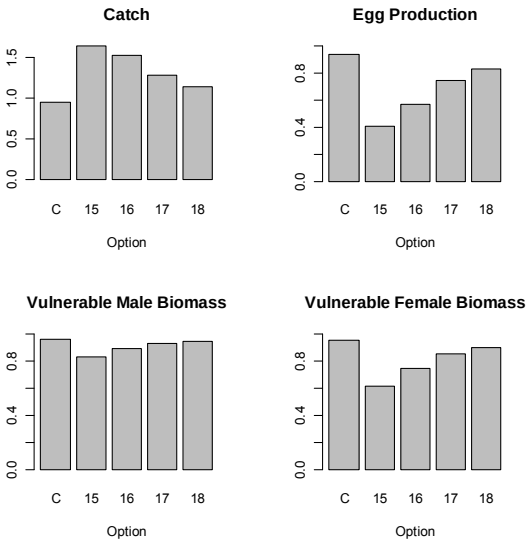

Figure 21. Results for the long-term indicator ratios for the East Coast mud crab fishery with a 5% effort creep factor applied. Four long-term projection indicator ratios are reported: commercial catch, egg production and vulnerable male/female biomass. Five management options are considered: the status quo (C) where the SSHP is retained as well as alternative MLSs (15 to 18 cm) for female crabs if the SSHP is rescinded. Projected effort is constant at the same level as the average of the last three years (2006-2008) during the projection period.

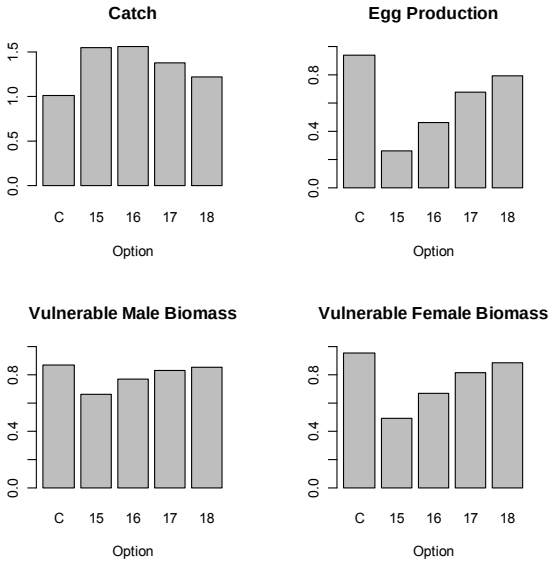

Figure 22. Results for the long-term indicator ratios for the East Coast mud crab fishery with a 5% effort creep factor applied. Four long-term projection indicator ratios are reported: commercial catch, egg production and vulnerable male/female biomass. Five management options are considered: the status quo (C) where the SSHP is retained as well as alternative MLSs (15 to 18 cm) for female crabs if the SSHP is rescinded. Projected effort is constant at double the average of the last three years (2006-2008) during the projection period.

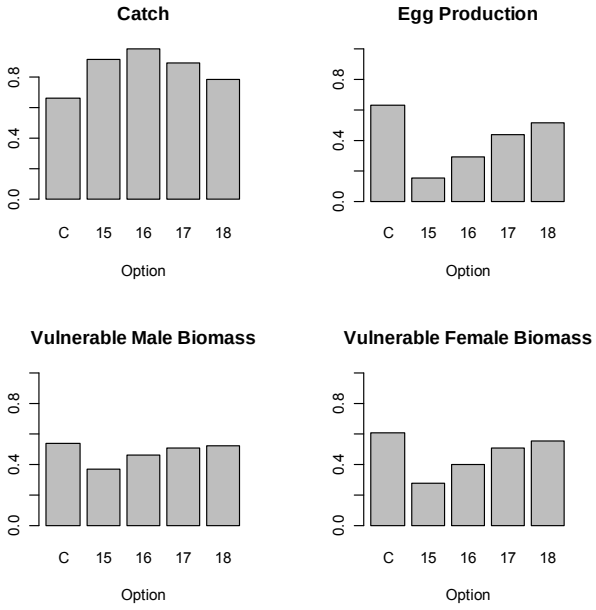

Figure 23. Results for the long-term indicator ratios for the East Coast mud crab fishery with a 5% effort creep factor applied. Four long-term projection indicator ratios are reported: commercial catch, egg production and vulnerable male/female biomass. Five management options are considered: the status quo (C) where the SSHP is retained as well as alternative MLSs (15 to 18 cm) for female crabs if the SSHP is rescinded. Projected effort is constant at double the average of the last three years (2006-2008) and recruitment is systematically decreased by half over the 12 year projection period.

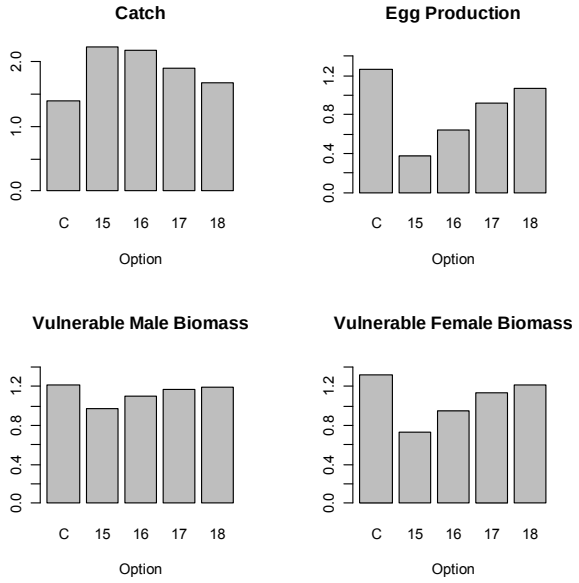

Figure 24. Results for the long-term indicator ratios for the East Coast mud crab fishery with a 5% effort creep factor applied. Four long-term projection indicator ratios are reported: commercial catch, egg production and vulnerable male/female biomass. Five management options are considered: the status quo (C) where the SSHP is retained as well as alternative MLSs (15 to 18 cm) for female crabs if the SSHP is rescinded. Projected effort is constant at double the average of the last three years (2006-2008) and recruitment is systematically increased by half over the 12 year projection period.

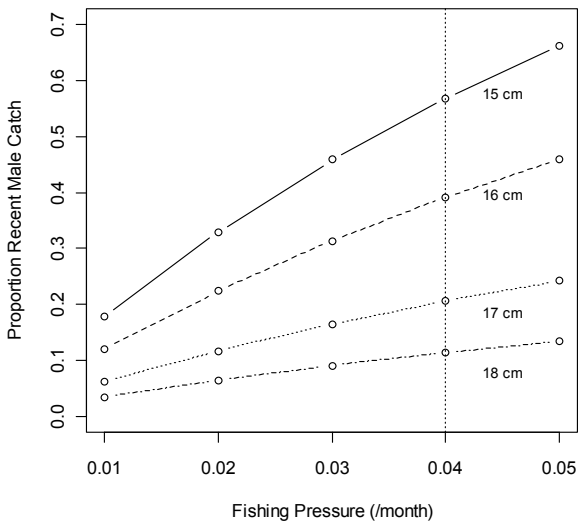

Figure 25. The relationship between the fishing pressure on females crabs and the proportion of recent male catch (last four years) that such fishing pressure generates. The underlying model is for the East Coast mud crab fishery with a 5% effort creep factor applied. Projected effort on male crabs is the same as the average of the last three years (2006-2008) and recruitment is kept constant over the 12 year projection period. The vertical line at fishing pressure = 0.04 indicates that harvesting female crabs with a 16 cm MLS would generate a female harvest of around 40% of the recent male catch.

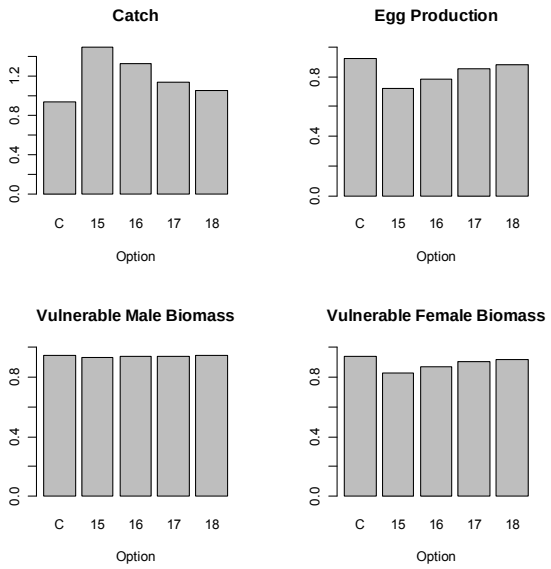

Figure 26. Results for the short-term indicator ratios for the East Coast mud crab fishery with a 5% effort creep factor applied. Four long-term projection indicator ratios are reported: commercial catch, egg production and vulnerable male/female biomass. Five management options are considered: the status quo (C) where the SSHP is retained as well as alternative MLSs (15 to 18 cm) for female crabs if the SSHP is rescinded. Projected effort on male crabs is the same as the average of the last three years (2006-2008) and recruitment is constant over the 4 year projection period. Fishing pressure on female crabs has been controlled at 0.04/month (see previous figure) to generate a female catch of around 40% of the recent male catch.

7.8 Economics of the Queensland mud crab fishery (Tor Hundloe)

7.8.1 Introduction

Mud crabs are a highly-priced seafood delicacy in Australia. They are not generally available in fresh seafood shops or restaurants but are typically sold in what could be termed niche markets. The Sydney Seafood Market is the major conduit between fishers and wholesalers/retailers in Australia. The Melbourne market is significant although not as important. Brisbane and the South East Queensland (which includes the Gold Coast and the Sunshine Coast) is a large but diverse market. Outside these capital cities, the closer the retail outlet is to sub-topical and tropical fishery ports where crabs are landed the more likely it is that mud crabs are on sale. The exception to this are specialised seafood shops and restaurants in tourism areas and high-income suburbs in any of the capital cities.

Mud crabs were not always a high-value commercial seafood. Until the rather dramatic expansion of residential living in the coastal areas of Queensland, mud crabs were a prime target of keen recreational fishers who wished to supplement their diet with little effort. During the season (the warmer months – those with an “r” in their name – in the subtropical part of the state and year-round in the tropical areas) a feed of crab was a less costly seafood meal than fin fish caught by line. Crab pots, more likely-than-not home-made, or a long piece of strong wire with a hook, were the only equipment needed. Bait for the pots was any sort of meat waste. Both male and female crabs were taken notwithstanding the legal situation. This was a period when the Australian population was about half of what it is today and the pressure on the resource was far less than it is today.

The day of the mud crab as a working-man's cheap meal gradually came to an end as the mangrove-lined creeks and rivers of the Gold Coast became canal estates, the Moreton Bay islands changed from small farming communities to suburbs, and the coastal cities from Brisbane to Cairns extended their residential areas. To further diminish fishing grounds and – importantly – access to the grounds, industrial development (for example, airports and shipping terminals) extended as trade expanded. This is obvious at all the major ports up the length of the Queensland coast.

This is not to imply that massive crabbing areas were lost, although that was the case on the Gold Coast. However, the gradual loss of favourite areas combined with a significant change in the style of residential accommodation on the coast (from the "beach shack" to modern brick homes) saw the "old-time" crabbers, who were in reality the average "mum, dad and kids" family of the 1950s, 1960s and early 1970s, move on or change their lifestyles. Crabbing stopped being a popular pursuit for most people. Those who retained their like of the sweet crab meat came to purchase it from retail outlets which increasingly found that they could sell crabs and at a high price. A small number continued their crabbing, often travelling further afield to set their pots.

The other significant demographic and economic factors were the advent of the two-income family and the decrease in leisure time. The weekends were taken up with the sporting activities of the children and home and yard maintenance. Crab-fishing and other leisure activities suffered as a result. However, the two-income family could afford mud crabs as an occasional "treat" purchased from those fresh seafood outlets which sold them, or as a restaurant meal. As a restaurant meal the diner had no idea of the sex of the crab or where it was caught – and, we can assume, did not care as long as the meal was enjoyable.

The point of the above piece of potted history is that the form and cost of a mud crab meal changed dramatically, from an inexpensive food acquired with relative ease by modern "hunter-gatherers", to a high-priced, specialty seafood. Key economic fundamentals changed in the eras we are discussing. These we discuss next. They give us a pointer to what we could expect if the supply of mud crabs were to increase substantially, as would be the case with the legal harvest of female crabs (jennies) in Queensland.

Today mud crabs are describes as an "icon" seafood by the Queensland commercial fishing industry. The crabs are thought of in the same terms in the Northern Territory. Presenting mud crabs in this way is aimed at installing a keen interest in them by tourists. This is a good strategy in as much as a meal or two of an "icon" dish at a relatively high price is not a major financial sacrifice for someone who has paid $2,000 plus in airfares on the long distance haul to Australia from Europe or the U.S.A. Crab meal is a very small marginal outlay for the tourist, and as a "one-off" experience the meal can be priced relatively highly without affecting demand.

A similar consumer psychology applies to the crab-fishers of old who are richer now but remain nostalgic for a crab meal. As a rare meal it will be able to be highly priced without choking off demand. One remembers "treats" of one's youth, or more generally a bygone era, and is willing to pay good money to indulge in a little nostalgic dining.

It can be noted that there exists, particularly in yet-to-be-developed coastal regions of Queensland, "old-style" crab fishers who would not entertain paying $30 to $50 per kilo for a commercially-caught crab. The number of these people is gradually diminishing, however it is estimated that 43% of the total harvest of crabs in Queensland is taken by recreational fishers (Department of the Environment and Water Resources, August 2009) and hence there must remain a significant number of these people.

The amateur catch has a dampening affect on the price of mud crabs in the retail shops. Imagine a situation where keen mud crab fanciers no longer had the prospect of catching their own and as a consequence entered the market to purchase crabs. All other things being equal, a shift in demand would push up prices, and substantially.

7.8.2 Current supply and price structure

Let us turn to the existing data on mud crab fishing. The Queensland commercial catch in recent years has fluctuated between approximately 800 and 1,100 tonnes. However, CPUE has remained relatively constant at approximately 25kg/day (23-26kg/day). However, if a longer term perspective is taken we notice a dramatic increase in the commercial catch over the past 20 years. There has been a four to five-fold increase in catch since 1988, when it was in the order of 230 tonnes. Notwithstanding this very large change, CPUE (kg/boat day) has remained relatively constant ranging between 17 and 26kg/day. We cannot over-emphasise the dramatic change in the quantity of mud crabs put on the market. We would expect such an increase in supply to have a significant affect in decreasing market prices.

Expectations and reality do not always coincide and this is a case were they don't. Mud crab prices in constant dollar terms (adjusted for inflation) have remained relatively stable in most markets. We should note in summary that population growth generally, and in South East Queensland particularly, over the past 20 years would have increased demand. Population growth has been closer to two-fold than four or five-fold. Hence, it does not explain the relative constant price of the crabs. Demand has increased faster than the increase in supply.

The value of the Queensland catch on the beach (wharf) has been in the order of $9-16 million per year in recent years. This equates to a price to the fishers of between $10 to $20/kg on average. However fishers selling into a variety of markets (from Melbourne in the South to local ones such as Townsville and Cairns in the North) tend to have their own specific clearing price, which fluctuates throughout the year.

While the Sydney Fish Market is used by some as the benchmark, there are those who (through whatever reason) supply local markets and accept a lesser price per kg (partly compensated by significantly reduced transport and commission costs).

The average value of Northern Territory mud crabs is higher than Queensland, at $16-20/kg. These are averages across the year and seasonal fluctuations, long-run droughts, and key annual events (Christmas and Chinese New Year) have significant effects on daily/weekly prices.

The Sydney Fish Market prices are generally higher than those in Queensland, whether that be in the major South-East Queensland market (Brisbane, the Gold and Sunshine Coasts) or major coastal cities such as Cairns, Townsville and Mackay. In fact, Sydney prices to the fisher can be double that of local Queensland markets. Give the cost of freight, in the vicinity of $5/kg from far North Queensland, a premium is needed in the Sydney market for Queensland suppliers. Yet the difference between $20 (noted above) and $40 per kilo, reducing to $35/kg with freight taken into account, and to about $32 with commission paid, is large. However, a price of $40/kg is not the average (see Table 4) but rather a high price achieved by some fishers at some times.

There is an unanswered question as to why more crabs are not put on the Sydney market. Sydney market prices for mud crabs, at various periods of the year, over the past three years are presented in Table 4. Over the years 2006/07 to 2008/09, 68 percent of the crabs sold in the Sydney Fish Market are caught in Queensland ($\bar{x}$ = 155,420 kg).

The Sydney market, more so than the Queensland market, shows distinct seasonal variations (Table 5).

Table 4. Average mud crab prices at Sydney Fish Market: 06/07 to 08/09

Year	Male	Combined	Females	Difference
2006/07	$21.50	-	$27.00	$6.5
2007/08	$22.00	-	$30.5	$7.5
2008/09	$22.50	-	$30.00	$7.5
2006/07 - 2008/09	-	$25	-	-

Table 5. Season variation in market prices

Price	Months	Prices: (Males, per kg)	Prices: (Females, per kg)	Approximate price differential
Very High	Aug, Sept, Oct	$31.20 to $32.20	$32.70 to $36.15	$4.90
High	Nov, Dec, Jan, Feb	$23.80 to $29.20	$27.60 to $34.20	$10.2
Low	March, April, May, June	$15.30 to $18.30	$23.00 to $26.30	$8.00
Switching	July	$25.20	$29.80	$4.60

Brief mention is warranted of the Melbourne market. The average price of mud crabs is lower in Melbourne than Sydney. The Melbourne market relies on both domestic products and imports from Papua New Guinea.

The price on the beach (or the price to a fisher at the fish market) is one thing. Between the beach and the final buyer is usually a wholesaler and a retailer. A retailer could expect to pay between 50% and 100% of the price that a fisher gets and the public could expect to pay between 50% to 100% of what the retailer pays. Using the lower mark-up, a kilo of crab earning the fisher $20 will sell in the fresh seafood outlets for $45.

There is a far more exaggerated price increase in the restaurant trade, however the customer is purchasing a completely different product in a restaurant – the ambience of the setting, the company and the skills of the chef. One of the common errors made by non-economists in comparing seafood prices is to focus on restaurant prices.

Mud crabs are an expensive – in fact, very expensive – food. The flesh of a mud crab represents about one quarter of its weight. This means that crab meat costs in the order of $150 per kg at retail level. Compare this to $25 for prime t-bone steak or $50 for eye-fillet. However, it is not unusual to see “crab meat” (usually not identified) selling for as little as $25 in seafood outlets. This is likely to be the meat of crabs which have not sold quickly.

It is not surprising that, with the exception of coastal tourist areas and suburbs with high average incomes, mud crabs are not found in fresh seafood outlets and restaurants. A random survey undertaken for this project, along the eastern seaboard of Australia (Brisbane to Melbourne with

the capital cities, including Sydney, excluded) resulted in not one establishment south of the Queensland border selling mud crabs. The survey was undertaken in October 2009, well after the commencement of the Moreton Bay mud crab "season" and crabs were certainly available from North Queensland. This result should not be taken to indicate that mud crabs would not be sold in this coastal area in the Christmas period. The demand increases then. However, the survey was undertaken during the NSW school-holiday period and coastal towns (and their seafood eateries and restaurants) were doing good business.

As with any luxury item a "choke" price is eventually reached where demand drops off dramatically. For mud crabs sold by wholesalers to retailers this is in the order of $45/kg in Brisbane, except at peak demand time when a retail price of $60/kg or a little more can be achieved. As noted previously, the Sydney markets is able to accommodate a higher price at all times of the year. A price per kilo of $60 retail is the national choke price. This is one point in the demand curve.

It is worth noting that mud crabs can range in quality not just weight; for example, appearance can count in the eyes of the consumer – this applies to cooked crabs where some are shiny red and others a "dirty" brown and less attractive. A more particular quality difference of relevance for this research is the real or perceived difference in taste between male (buck) and female (jenny) crabs. Crab connoisseurs are adamant that the females have a sweeter flesh. In localities where there are significant Vietnamese residents jennies are much sought after due to this taste difference.

Given this we should note that if jennies were to be caught and sold in Queensland in any quantity there is likely to be a price difference between bucks and jennies depending on the location of the retail outlet. Where there were significant numbers of Asian buyers at either individual or central markets this price differential would be obvious. We have not been able to establish the premium for jennies except at the Sydney Fish Market. However, if there was a large increase in female crabs in the market it would not be surprising to see a greater drop in the price for bucks (based on today's prices) then any decrease in the price of jennies. We shall come to this matter below.

What happens when we harvest females?

It is now time to focus directly on what is likely to happen to price of mud crabs if female mud crabs were to be caught in Queensland and put on the market. We know from both inductive and deductive logic that the demand curve for a normal good is downward sloping which means that any increase in supply or shift in the supply curve will decrease price. What we need to measure is the price elasticity (and other elasticities) of mud crabs. Let me explain this in lay terms.

First, we can commence with what economists call "own price elasticity". This is written as "e". In English it is a measure of the "percentage change in quantity demanded given a one percent change in price". The change in price can be the consequence of various influences, but here we are contemplating an increase in supply. This can be shown graphically (see Figure 27 below). Elasticity is a measure of responsiveness to some change in circumstance.

To illustrate responsiveness, consider petrol, alcoholic drinks and tobacco products. The evidence is that over a significant price range, there is very little change in quantity demanded of these products. I expect that those of us who recall petrol prices at half their present price – probably only 10 years ago – are still purchasing the same amount of fuel as we did then. Then there is strong evidence that people "hooked" on nicotine will keep purchasing tobacco products regardless of significant price increases. And the same with alcohol. It is a consequence of own price inelasticity of these goods that governments tax them – apply "sin taxes" – given the public policy goal of increasing the public purse. If these products were price elastic, a tax would lead to significantly decreased demand and the objective of generating revenue would be thwarted.

Before considering the available evidence relating to the own price elasticity for mud crabs, we should note that there are a range of factors, each having a measure of elasticity attached to it then, that influence demand, supply and price of mud crabs. We can start by considering what economists call "shifts" in demand and supply curves. Both demand and supply can expand (the curves shift outwards) or contract (the curves shift inwards) and one "scissor" of the pair of the scissors can shift in the opposite direction to the other – and hence cancel an expected price change. For example, at Christmas time when there is an increase in demand for mud crabs if there is a corresponding increase in supply (which is unlikely) the price could remain constant. It is because there is not an increase in supply that price increases.

Aggregate demand shifts according to conventional drivers. The most obvious is human population growth. The significant increase in human population in south-east Queensland in recent years, an increase of approximately 75,000 people per annum, has led to an increase in demand for mud crabs – all other things being equal (which they have been to date). As population in this region of Australia is forecast to continue to increase, and at a higher rate than elsewhere in Australia, we can look forward to an increase in demand for mud crabs based on this one driver.

Without any other influences, if the supply of mud crabs increased and kept in pace with the population growth in key markets, there would be no decrease in price. The opening up of the Queensland fishery to the harvest of jennies is one way – the only way – an increase could happen. If we could estimate the demand for mud crabs per capita for a specific regional market (say, south-east Queensland), we could calculate the level of increased supply which would be required so not affect price. Unfortunately, there are no readily available data on demand for mud crabs on a regional scale. The last comprehensive seafood consumption survey in south-east Queensland was done by the author in the early 1980s. This is a major impediment in analysing seafood values in Queensland. As noted previously, the only comprehensive data are available from the Sydney Fish Market.

Another conventional force that shifts the demand curve outwards is an increase in income. As we get richer – even if it is only by a few percentage points per year – we are likely to purchase more of many goods (often the high priced ones). As income growth is not changing dramatically in Australia, at around 3% on average, we should expect nothing more than a 2% to 4% increase in demand for mud crabs per annum, all other things being equal. One the basis of income increases over the long run, supply of mud crabs could increase in line with it without affecting price.

Yet another driver of shifts in demand is what economists call "taste". Taste is not the actual flavour of food but a more general change in attitude towards a good or service. Where we have recent survey data on seafood consumption (eg. Melbourne) we discover that demand for seafood in general has increased dramatically over the past generation. This is a consequence of two major factors: the much greater number of Asians in our society, and the promotion of seafood as healthy food (the Omega 3 factor). While we do not have any evidence of this being a trend positively influencing mud crab demand, it is likely to be the case.

If we put together population growth, the increase in income and a change in taste favouring seafood, we have a sound basis to explain an increase in mud crab consumption in Australia. These three factors would have forced up the price of mud crabs had there not been a corresponding increase in supply over the past years.

There has been a dramatic increase in supply of mud crabs in Queensland over the past 20 years, from about 230 tonnes per annum to nearly 1,100 tonnes per annum. Had there not been an increase in demand there would have been an equally dramatic decrease in price assuming unity or near-unity demand elasticity. This price decrease has not occurred, and this is the best evidence we have at present to suggest that the retail price for mud crabs is not responsive to

supply changes, at least over the price range we have experienced in recent years. Hence, it has been to the fishing industry's advantage to increase supply. A further increase in landings of mud crabs, in this case by including jennies, is unlikely to drive down prices, except marginally.
There are two other factors which need consideration if female mud crabs are going to be put on the market. The first is that there will be an incentive by both full-time and part-time crabbers (of whom there seem to be many – the average income of a Queensland commercial crabber is in the order of $40,000) to work harder at Christmas and other peak times to make the most of the high beach prices (in the order of $30 to $40/kg). To the extent that this dampened demand, and only marginally, it would disadvantage the full-time (12 months a year) crabber who relies on peak period prices to earn a profit at the end of the year.

The second factor is that if the commercial fishers are permitted to take jennies, it could be expected that recreational crabbers will also be allowed to take jennies. If amateurs are allowed to take female crabs – within the existing controls – this should not be a problem, but the temptation for illegal sales on the black market could surface and if the sales were significant there could be a marginal impact on commercial fishers' incomes.

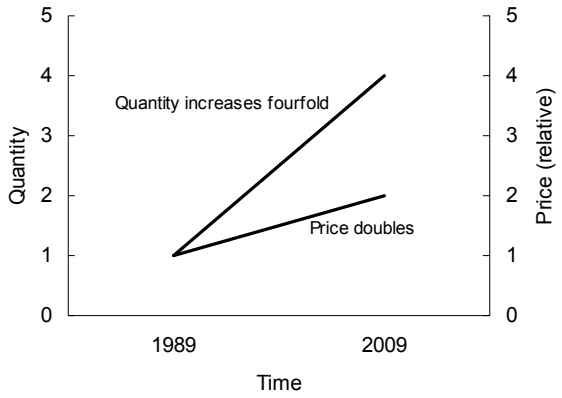

Figure 27 Queensland record catch and beach price

7.8.3 Demand and supply relationships

Figure 28 illustrates shifts in both demand and supply. In this hypothetical case the (presumed) simultaneous movements result in an immediate return to the previously equilibrium price but at the higher quantity of crabs supplied. In this example the increase in supply and the resulting drop in price are compensated for by an increase in demand. See Steps 1, 2 and 3. In the following Box 1 the major drivers of shifts in demand are described.

Both the expected increase in the number of consumers (population growth) and the expected income in per capita (disposable) affects the retail price of mud crabs. If we take South-east Queensland as an example, in a year hence the population will be in the order of 103.75% its present number. Population growth, whether in South-east Queensland or Australia generally will grow arithmetically in line with immigration policies but as new migrants have offspring the natural birth rate will accelerate the growth.

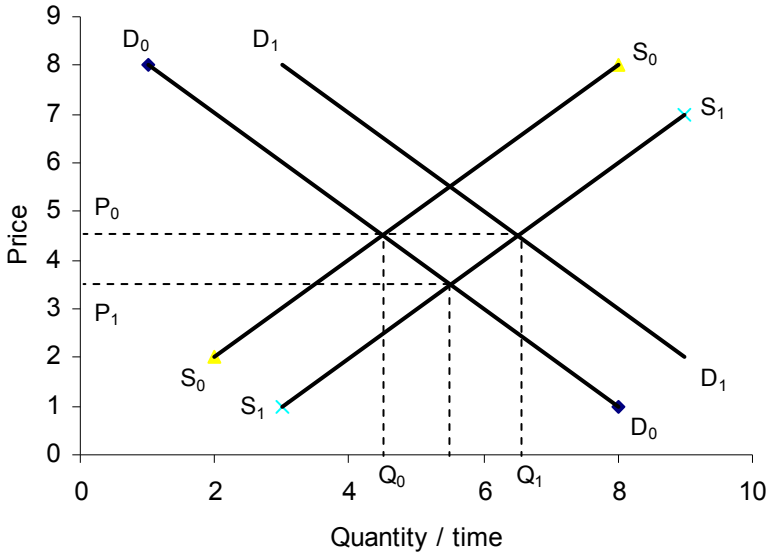

Figure 28. Demand and supply shifts

BOX 1: DEMAND INCREASES DUE TO MAJOR DRIVERS

Income

1a. Change in household income (I) will shift the demand curve. Increase in income (for normal goods) leads to increase in demand, which leads to increase in price (all other things being equal)

1b. The increase in average income in Australia in 2010 expected to be 2.7%

1c. We can predict an annual increase between 2% and 4%, say 3%

Population

2a. Change in population (i.e. the number of consumers)
Increase in population leads to increase in demand, which leads to an increase in price (all other things being equal)

2b The increase in the Australian population varies by location, and is driven by migration policy, not the birth rate

2c. In SEQLD, the annual population growth at present approximates 3.75%

Preferences

3a. Change in "taste" (preferences) will shift the demand curve

3b. Health concerns drive up demand for seafood

The average income will be 103% (or thereabouts) of the present income. On the basis of these changes, the demand for mud crabs would have shifted outwards. At today's prices, we would expect a 6.8% (cumulative) increase in demand for mud crabs. With population and income

increases driving demand into the future it would take not much more than 10 years for demand to have doubled – at present prices, assuming supply increased in line with demand increases.

The formulae for both income elasticity of demand and population elasticity of demand are presented in Boxes 2 and 3.

BOX 2: INCOME ELASTICITY OF DEMAND

(e = elasticity = responsiveness to a change Δ =change. I = income)

$$e_d^I = \frac{\%\Delta Q^d}{\%\Delta I}$$

Where $\Delta I = \frac{I_1 - I_0}{\overline{I}}$ (the idea of an ARC)

By substitution, $$e_d^I = \frac{\%\Delta Q^d}{\%\Delta I} = -\frac{Q_1 - Q_0}{\frac{\overline{Q}}{\frac{I_1 - I_0}{\overline{I}}}}$$

$$= -\frac{Q_1 - Q_0}{I_1 - I_0} \times \frac{\overline{I}}{\overline{Q}}$$

It is now appropriate to return to the issue of *own price elasticity of demand*. Given that we only have comprehensive data from the Sydney Fish Market our analysis will be based on that. In using these data, the fluctuations in price and quantities have been smoothed-out and the general shape of a demand curve for both male and female mud crabs have been estimated.

The own price elasticities have been estimated on the basis of a long-term increase in crabs put on the market, with an approximate fifty-fifty split between males and females. Market clearing prices for both sexes are estimated to decline, but not significantly. The own price elasticity for female mud crabs is in the order of e = -3.

BOX 3: POPULATION ELASTICITY OF DEMAND

$$e_d^{Pop} = \frac{\%\Delta Q^d}{\%\Delta^{Pop}}$$

Where $\Delta^{Pop} = \frac{Pop_1 - Pop_0}{\overline{Pop}}$

By substitution, $$e_d^{Pop} = \frac{\%\Delta Q^d}{\%\Delta^{Pop}} = \frac{Q_1 - Q_2}{\frac{\overline{Q}}{\frac{Pop_1 - Pop_0}{\overline{Pop}}}}$$

$$= \frac{Q_1 - Q_0}{Pop_1 - Pop_0} \times \frac{\overline{Pop}}{\overline{Q}}$$

This means that a 100% increase in female crabs on the market would decrease price by 33.3%. On this basis, by changing the mix of Queensland caught and sold mud crabs from 100% male to 50% male: 50% female, there would be in the order of a $11 million gain in total revenue to the commercial industry BEFORE the decrease in the price of male crabs AND the decreases in the price of female crabs are taken into account. With regard to the latter, if there was no decrease in demand for female crabs as more and more entered the market we could expect in the order of $16.5 million in total revenue to the industry plus $8.25 income from male mud crabs. This is a total of $24.75 million for the sale of the equivalent number of crabs (in total) from Queensland at present. However, this is unrealistic as the own price elasticities suggests that the outcome for a

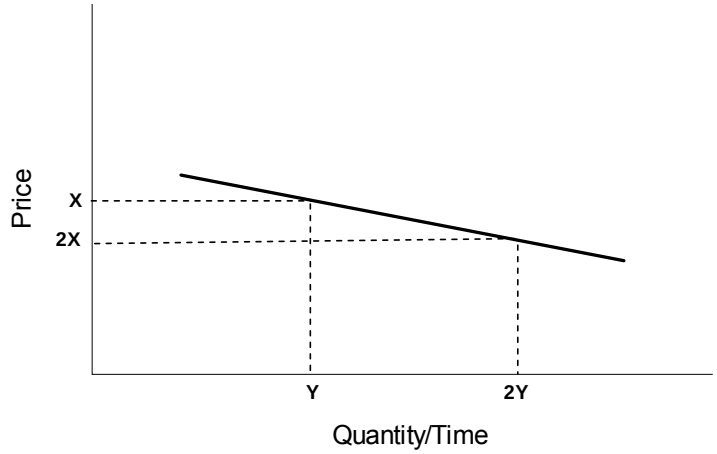

Figure 29 Representation of demand curve for female mud crabs showing a supply increase.

50:50 split would be $11 million for females plus $8.25 million for males, giving a total of $19.25 million. This is $4.25 million ABOVE the total revenue earned today ($15 million) with no Queensland caught jennies allowed on the market.

In the long term, and assuming that harvesting some female crabs does not result in recruitment overfishing, as the total catch is allowed to expand its MSY (or MEY) level of the total revenue for the fishery could be expected to more than double.

In both Figure 29 and Figure 30, a doubling of mud crabs on the market is shown. Given the relatively small number of female crabs presently sold, the relationship between increased supply and the impact on the average price is a reasonably realistic assessment of the situation a 50:50 mix if male/female crabs are on the market. For illustrative purposes the male crab graph is drawn with a doubling of males sold. This will not occur – in fact, male crabs numbers sold are likely to go through an initial decrease as the more valuable females replace them, but should eventually settle down to a quantity which reflects the price differentials.

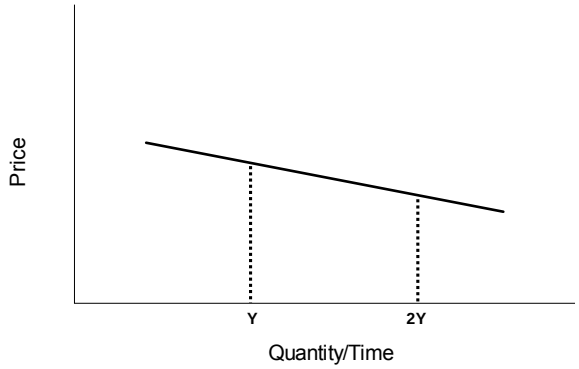

Figure 30 Representation of demand curve for male mud crabs showing a supply increase

7.8.4 Discussion

Question: Effect of change in people's tastes and culinary adventurousness – significant over the past decade or so but will it continue? And big period of affluence in the '90s – neither of these influences will happen again – will this have a discounting effect on price elasticity? Comment: Taste has changed, but don't know if it will or won't continue. Latest world financial problems haven't really affected prices. The major question is whether the dramatic culinary shift will continue. However migration-driven factors will continue. Taste was left out of the equation (as was inflation) – if positive, the increase would be more than 7% p.a.

Q: Sydney market driven by Asian population – if females were allowed to be taken, would demand increase in Qld? Response: Yes, if Brisbane reflects Sydney market. Need to discuss what markets would be targeted if there was a trial experimental fishery allowing female capture and it would also be important to factor in production costs, particularly with regard to freight costs.

7.9 Risk Assessment

The first two steps in the risk assessment process (identification of sectors and asset categories or values) were carried out by three breakout groups, convened by Drs Wayne Sumpton, Neil Gribble and Mark Grubert. Each group comprised about seven participants and as far as possible contained a cross-section of organisations and expertise areas represented at the Workshop.

7.9.1 Sector and Asset Category (Value) identification

This brief exercise aimed to ensure that all sectors and community groups which have an interest in the mud crab fishery or resource are identified.

Having identified the Sectors, the next step was to list the various ways each Sector perceives the resource to be valuable. It required re-focussing participants' views to those of different sectors and thinking 'outside the square'.

In full-group session the results from the breakout groups (each assembled on separate flip-charts with the aid of Post-it notes) were compiled into a single list (Table 6).

Table 6. List of Sectors and associated Asset Categories or values identified by the three breakout groups.

SECTOR	ASSET CATEGORY (VALUE) / ISSUE
Commercial	Profitability Sustainability (economic and stock) Equity in catch share (Latent effort) Continuity in supply to the public Local product benefit Black marketing Lifestyle (cultural history)
Recreational	Resource sustainability Equity in catch share Quality of recreational experience Cultural history (social) Environmental stewardship Personal food supply Black marketing
Conservation	Preservationists (pristine environmental wilderness) Sustainability (ecosystem, ecological role, TEP species and stock) Bycatch Stewardship
Indigenous	Cultural heritage (traditional knowledge) Maintain food supply (subsistence) Care for sea country Business opportunity (development)
Wholesale/retail (incl. restaurants)	Continuity in quality and quantity Stability of supply Profitability
Mud crab consumers	Continuity in quality and quantity Stability of supply Price affordability (choke point) Preference for local product
Fishing gear support businesses	Profitability and sales Participation Access to the resource Education and promotion
General public (non-users)	Local income and local economy Aesthetics (e.g. float pollution) Environmental concerns Tourism Community diversity and vibrancy
Tourism operators (+charter)	Profitability Sustainability (stock and economics) Quality of experience Transfer of knowledge and education Culinary experience (exposure to the product)
Government (State and ATO)	Employment (compliance) Tax revenue Public/political perception Stewardship
Interstate mud crab industry	Inter-state competition Market share and price elasticity Cross-jurisdictional sustainability (stock)
Aquaculture	Broodstock value Market (established)

It should be noted that in some instances 'values' were identified that would be better categorised as issues or possible risks (e.g. 'black marketing'); these have been left in the table above. The text highlighted in red were duplicated assets (identified by more than one group) that in the opinion of the Workshop could be deleted from the list.

It was perceived that with the time available the risks associated with all 26 listed assets (after removal of duplicates) would not be able to be evaluated effectively. Therefore the listed Assets were initially assigned by the Workshop into A or B priorities (Table 7), on the understanding that the lower priority assets would not be subject to further analysis. A second prioritisation followed, reducing the initial list of 13 to the six considered the most important (Table 8).

Table 7. Ranked asset categories

Asset Category	Rank 1	Rank 2
Profitability	A	A
Sustainability (economic and stock)	A	A
Equity in catch share (activation of latent effort)	A	A
Quality of recreational experience	A	A
Environmental stewardship	A	A
Care for sea country	A	A
Continuity in supply to the public	A	B
Black marketing	A	B
Continuity in quality and quantity	A	B
Price affordability (choke point)	A	B
Local income and local economy	A	B
Public/political perception	A	B
Inter-state competition	A	B
Local product	B	
Lifestyle (cultural history)	B	
Personal food supply	B	
Environmental preservation (pristine wilderness)	B	
Bycatch	B	
Education and promotion	B	
Aesthetics (e.g. float pollution)	B	
Community diversity and vibrancy	B	
Employment (compliance sector)	B	
Tax revenue	B	
Broodstock value	B	
Cross-jurisdictional sustainability (stock)	B	

7.9.2 Risk identification

The task of identifying risks associated with each of the Asset Categories was conducted in a plenary session. It was pointed out that the risks were those relating to the likely *change* from the current state (i.e. those which might arise in the event of a change in management arrangements). They should be considered as the risks associated with the 'base level' change – i.e. simply opening up the harvest of female crabs to all sectors at the same MLS as males (150 mm), without any phase-in period. The reason for this was to avoid complications arising from pre-empting risk management processes that may ultimately be required.

The identified risks (shown in Table 8) were related primarily to (a) the effects of increasing catches and fishing effort on the profitability of individual businesses; (b) the potential for overfishing to occur and jeopardise the long-term sustainability of the stock and the industry; (c) the possible activation of latent effort or fishing capacity in either or both the commercial and recreational sectors, and an associated increase in the likelihood of intra- and/or inter-sectoral interactions leading to a decline in the quality of the (recreational) fishing experience; (d) negativity of public perception about changing a currently conservatively-managed fishery; and (e) concern amongst the indigenous community about the State's commitment to caring for Sea Country.

Table 8. Risks associated with asset categories

Asset Category	Risks	Comments
Profitability per business	1. Increase in harvest effort; 2. Increase in supply; 3. Decrease in demand	1. Increase in effort as a result of the higher profits associated with an increase harvest (now retaining females) fishers who would have otherwise participated at a lower level, will now be catching more; activation of latent effort. In time the uptake will affect CPUE. The same principle applies to both the recreational and commercial sectors; 2. As a result of an increase in supply the overall price per kg could decrease?
Sustainability (economic and stock)	1. Recruitment overfishing	1. Which includes the removal of excessive numbers of spawning females; 2. The activation of extra effort could increase the risks associated with ghost fishing, and including TEP species interactions.
Equity in catch share	1. Acitivation of recreational latent effort; 2. Activation of commercial latent effort; 3. Escalating conflict between/within sectors	
Quality of recreational experience	1. Decreased quality of experience (due to the increase in participation numbers)	1. With regards to the experience, the quality of the fishing experience (which may diminish due to the extra numbers participating); the latent effort factor of this risk is covered in the equity of catch share.
Environmental stewardship	1. Negative public perception about our ability to manage the fishery	1. We currently have a handle on the sustainability of the fishery through the prohibition on taking females, and through the removal of the SSHP this may change?
Care for sea country	1. Compromising sea country management	1. Thre recreational and commercial impact of taking female mud crabs on Indigenous sea country.

7.9.3 Indicative scenario modelling (James Scandol)

Using the GTG model it is possible to estimate the likely consequences of changing the MLS or the SSHP (i.e. the management environment). The standard indicators are (i) catch (males and females), (ii) biomass (spawning, vulnerable), and (iii) egg production.

An example of a model output from the Gulf of Carpentaria data set indicates relatively low fishing pressure on the GOC stock. Results are highly variable, and dependent on future recruitment variability (assumed here to be constant). The following graphs show the indicative results of decreasing the MLS on catch (Figure 31) and vulnerable female biomass (Figure 32).

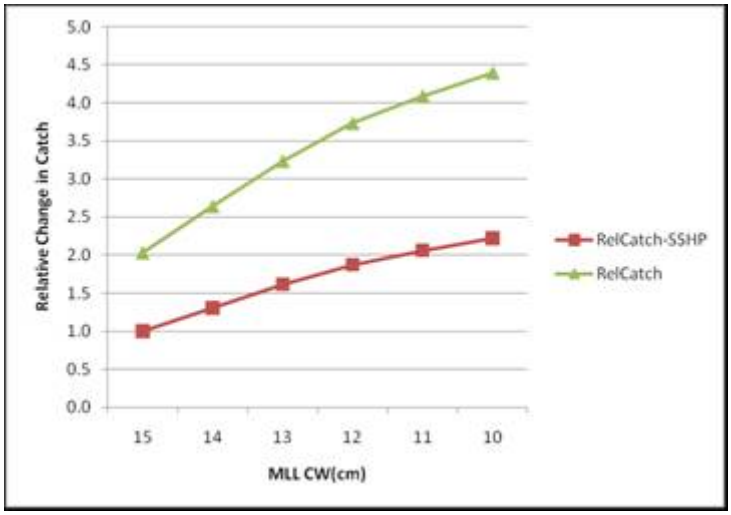

Figure 31. Relative change in catch (or dollar value) with reducing minimum legal size (ratio of next 4 yr to previous 4 yr), under SSHP (red line) and without SSHP (green line)

Both graphics assume that both commercial and recreational fishing effort remains constant. The relative values are derived from the ratio of the indicator values for the four-year window following the management change to those of the four-year window prior to the change. Decreasing the size limit by 1 cm under the SSHP results in an increase in catch of about 20%, and (naturally) no change in the female spawning biomass. If the SSHP is removed and females can be taken, the MLS reduction would double the catch, but reduce the female spawning biomass. It needs to be remembered that these forecasts are for a short term and don't capture the possible effects on recruitment and subsequent biomass and future catches, which may take several years to become evident.

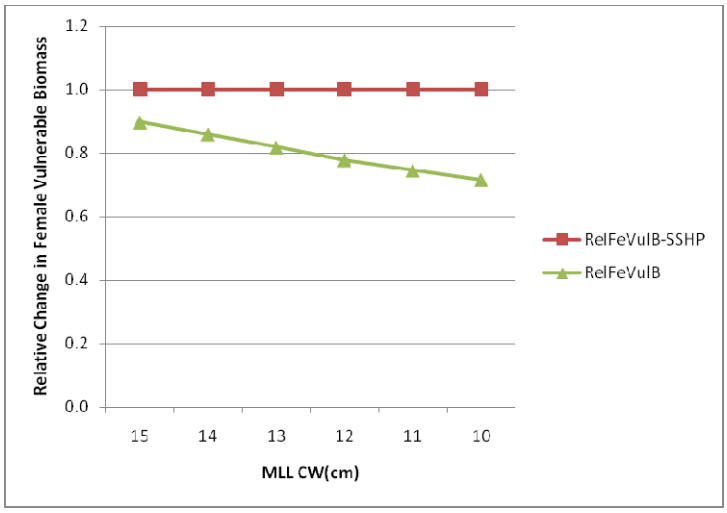

Figure 32. Relative change in vulnerable female biomass with reducing minimum legal size (ratio of next 4 yr to previous 4 yr) under SSHP (red line) and without SSHP (green line).

7.9.4 Risk scoring

Risk scoring was carried out by the same three breakout groups that had initially identified the Sectors and Asset Categories. The risks were allocated haphazardly among groups such that each group had a separate set of risks to score, with the exception that two groups scored Risk #1 (recruitment overfishing) independently. The latter provided a measure of consistency between groups, albeit for only one risk.

Each group recorded its scores with reference to the scoring tables provided (see Appendix 2). It was reiterated that risk scores were to relate to the *change* from the current management state. Following the exercise the sheets were returned in plenary session and the data transcribed to an Excel spreadsheet which had been set up to calculate the likelihood and risk values.

The eleven key risks identified previously were ranked in descending order (Table 9), together with associated knowledge uncertainty and management effectiveness scores.

Table 9. Tabulated scores for risks. Note that Risk 1 was scored by two groups independently.

Group	Risk No.	Risk	Asset Category	Consequence	Scale (temporal) (1-5)	Scale (spatial) (1-5)	Knowledge uncertainty	Management effectiveness	Liekelihood (calculated)	Risk value (calculated)
NG	6	Increase in total harvest effort	Profitability per business	4	5	4	3	4	4	3.2
WS	1	Recruitment overfishing	Sustainability (economic and stock)	4	3	4	3	5	2.4	1.92
NG	1	Recruitment overfishing	Sustainability (economic and stock)	4	3	4	3	4	2.4	1.92
WS	3	Activation of latent recreational effort	Equity in catch share	3	4	4	3	5	3.2	1.92
WS	4	Activation of commercial latent effort	Equity in catch share	3	4	4	3	5	3.2	1.92
MG	10	Negative public perception re. ability to manage fishery sustainably	Environmental stewardship	3	3	4	4	4	2.4	1.44
WS	5	Escalating conflict between & within sectors	Equity in catch share	2	4	4	3	5	3.2	1.28
MG	9	Decreased quality of experience due to increase in particpation numbers	Quality of recreational experience	3	3	3	4	5	1.8	1.08
WS	2	Ecological sustainability' (Risk added by group)	Sustainability (economic and stock)	2	3	4	3	5	2.4	0.96
NG	8	Decrease in demand	Profitability per business	4	2	3	4	5	1.2	0.96
NG	7	Increase in supply	Profitability per business	2	2	3	5	5	1.2	0.48
MG	11	Compromising sea country management	Care for sea country	1	1	1	5	3	0.2	0.04

Interestingly the greatest risk was that of an increase in fishing (harvest) effort on profitability of individual businesses. Recruitment overfishing, activation of commercial latent effort and activation of recreational latent effort were all considered equal risks, with respect to sustainability (overfishing) and equity in catch share (latent effort). 'Middle level' risks included (i) public perception that we might be jeopardising our stewardship of the environment; (ii) increased likelihood of 'social' interactions on the fishing grounds because of increased numbers of fishers

(both recreational and commercial); and (iii) decreased quality of recreational/fishery experience for the same reason. The least risky of the key issues, according to the scoring process, were those relating to (i) a reduction in ecosystem sustainability, (ii) declining demand impacting on profitability, (iii) over-supply of the market, again potentially affecting prices and therefore profitability, and (iv) negative perceptions regarding possible compromises to indigenous sea country management processes.

7.9.5 Comparison of risks and benefits

Following the risk scoring exercise there was considerable discussion, particularly in relation to comments on the economics of the fishery from Prof. Hundloe, and concerns about the likely erosion of the initial profitability gains by increasing input costs. An example from the blue swimmer crab fishery was given, indicating that input costs have risen 35-40% while the beach price had only risen about 15%.

Recently accessed SFM data for 2006/7 and 2008/9 show that the shortfall in NSW landings due to the flood period was compensated for by Queensland product. If we assume (as a result of removing the ban on taking females) that the harvest of males and females is the same, we would have to allow for a decrease in the price of males, because of the premium on females. Taking these into account, we have two extreme price-structures (high and low), both of which show a net benefit to the industry which is currently worth $10-15 million p.a. The pessimistic (low-price) scenario would provide for a $1.5 million p.a. benefit, while the optimistic (high-price) scenario would provide for a $4.25 million benefit each year. These modelled figures are based on data from the SFM, where two-thirds of Queensland's production goes. Even the optimistic scenario is conservative, so we should expect to see a benefit of at least 10%. And this is beach-price only, without any in-built multiplier effects. As a rough guide, we could approximately double this to include multipliers. Nor does it factor in any change in demand over time.

7.9.6 Risk management and experimental design

Having identified the major risks associated with opening up the harvest of female crabs at a minimum legal size of 150 mm CW, discussion focussed on potential available means of reducing and managing those risks. It was agreed that a number of pre-conditions to any trial period or adaptive management experiment would be necessary in order to gain the support of all stakeholder groups present. It was noted that there were divergent opinions on the issue. A communication from the invited Indigenous representative, who unfortunately at the last minute was unable to attend the workshop, was brought to the group's attention. He conveyed the opinion of the South East Queensland Traditional Owners' Alliance (SEQTOA) that female mud crabs should not be harvested. This view appears not to be based on any particular cultural attribute, but rather to the belief that 'it was the right thing to do'. Other workshop attendees noted that, by way of contrast, indigenous groups in other parts of the State (particularly in the north) take female as well as male mud crabs.

The overall aim of the trial or experiment would be to determine the stock, economic and social impacts of permitting the harvest of (some) female mud crabs. Three specific objectives were identified:

1. To measure changes in recruitment (to the fishery), sex ratio and population size structure.
2. To measure changes in process and markets.

3. To document changes in social indicators such as community acceptance and competition within and between sectors, taking into account issues of equity of catch share.

An initial discussion identified a number of things that would need to occur for such a trial or experiment to be developed: (i) all stakeholder groups would need to endorse (or at least accept) the proposed course of action, (ii) the process should be overseen by a Steering Committee involving all key stakeholder groups, (iii) a communication strategy will be needed to inform the Minister and demonstrate widespread acceptance of the plan across sectors resulting from appropriate consultation, (iv) the trial or experiment would need to be on a broad enough scale to effectively address the objectives above, and (iv) the process would need to be effectively cost-neutral to government and industry alike over the period of the trial or experiment.

Moving towards an in-principle resolution, agreement was indicated from representatives of the following key stakeholder groups:

1. East Coast Crab Fishers' Association Inc., *provided*
   - the issue of excess fishing capacity is addressed
   - there are control mechanisms in place to inhibit cross-fishery transfers (activation of latent effort), and
   - catches are managed and validated, and effort is controlled.

2. Queensland Seafood Industry Association, *on the basis* of the provisos in the above paragraph.

3. Sunfish Queensland, *provided*
   - the adaptive management experiment preceding any long-term change to the SSHP was fully reversible – i.e. the in the event of any detrimental effect becoming evident, the SSHP would be reinstated.

It was generally agreed that there would need to be some way of regulating the numbers of female crabs that could be taken, both by commercial and recreational fishers. The most likely approach to this, and possibly the most acceptable from the compliance point of view, was seen to be through the distribution of non-removable tags which would be required to be attached to each female mud crab in possession. This would apply to the recreational and commercial sectors alike. It was also agreed that the precautionary measure of having a higher MLS for females would be appropriate. A figure of 160 mm (for female crabs) was considered appropriate, as any MLS greater than that would start impacting on the benefits (particularly economic) of permitting female harvest.

Next was the question of the scale of the proposed trial or experiment. The two logical options were (i) State-wide, and (ii) regional. No resolution was reached on the question of regional boundaries, but it was agreed that the regions would have to be large enough to provide for the amount of additional take (of females) to be large enough to make a measurable difference to the demography of the local mud crab population, even if the difference was minimal.

A re-definition and re-focussing of the agreed pre-conditions resulted in the following:

- Impact on female vulnerable biomass to be controlled by the issue of a limited number of non-removable compliance tags.
- Tags are to be non-transferable.
- Tags will be sold at a nominal price, the return to be considered a 'research levy' to cover the cost of tag administration and any additional fishery-independent monitoring required.
- State-wide allocation of tags to the commercial fishery to be in proportion to 'recent history' (say 20% {of the average of the last two years' catch of males crabs?}).

- Same principle to be applied to the recreational sector, based upon the results of Rfish surveys.
- The minimum size of females allowed to be taken will be 160 mm carapace width.
- If the regional-scale option is adopted it will need to be done at a spatial scale appropriate to the objectives of the experiment.
- Purchasers of tags will be required to provide some level of catch reporting (for the commercial sector this will be over and above existing logbook requirements).

The upsides and downsides of each of the two spatial options (State-wide and Regional) were identified (see box below).

State-wide Option	
Pros • Best to detect possible recruitment overfishing • Better economic data • Better social data • Involves everyone • More equitable • More cost-effective, easier compliance • Best represents potential management change • Good (cost-neutral?) funding base • Consistent with National Competition Policy (NCP) • Risk-averse differential size limit M/F	*Cons* • Significant political risks • Acceptability • Greatest scale = greatest impact (+ve & -ve) • Confounded by temporal processes (environment change, drought etc.) • Does not allow for before-after-control-impact (BACI) design • Significant administrative overheads
Regional Option	
Pros • Lesser scale -> lesser impact • Staged approach easier (+/- regions, +/- participation) • Greater political acceptability • Better statistical replication (more chance of detecting an effect); BACI design possible. • Quasi spatial control • Utilises local expertise (both sectors) • More community engagement and awareness opportunities	*Cons* • Unlikely to be cost-neutral (may require external funding) • More prone to environmental variation • Greater compliance risk • Lesser scale -> lesser impact, resulting in less rigorous data (biological, economic & social)

Options for involvement or participation of recreational and commercial sectors in the potential experiment, at both spatial scales, were canvassed:

Recreational Participation Options	
State-wide • Total participation • Nomination by peak bodies • Self-nomination • Nominal tag cost (research levy) • Reflects distribution of Queensland population • Ground-truthing with creel surveys	*Regional* • Nomination by peak bodies by region • Self-nomination by region • Reporting by region • Catch control by region • Ground-truthing with creel surveys
Commercial Participation Options	
State-wide • All licence-holders to participate • Tags allocated to licence-holders on basis of recent catch history (to date of Workshop) • Participation optional	*Regional* • Must have recent catch history in the region up to date of Workshop • Offer open to all in region • Regions to be defined in terns of logbook grids • Tag allocations not transferable between regions

7.9.7 In-principle support agreement

The following statement was drafted by the workshop participants to reflect the background and consensus decision on the way forward:

1. A workshop was held on Bribie Island from 2-6 November 2009 to evaluate the risks and benefits of allowing the harvest of female mud crabs in Queensland.

2. Workshop participants included commercial and recreational crab fishers, GBRMPA, Qld Seafood Marketers' Association, local and interstate fisheries personnel, fisheries economics expert (Griffith Uni), population modelling expert (UK), fisheries scientists, social scientists, FRDC, fisheries managers and compliance personnel.

3. Presentations were given on:
    a. Background to the single sex harvest policy
    b. Status of mud crab fisheries throughout Australia
    c. Economics of the Queensland mud crab fishery
    d. Modelling research of the Queensland mud crab fishery
    e. Market structure and opportunities

4. Following this the workshop undertook a risk-assessment process under Australian-New Zealand Standards, and {considered the} design {of} an experiment {or monitored trial} to determine the stock, economic, and social outcomes of permitting the harvest of female mud crabs.

5. Once the proceedings of the workshop are available, peak industry bodies and other key stakeholders will be invited to provide their views on the proposed experiment.

6. Government will then need to consider what approach will be taken.

7.9.8 Communication strategy

Richard Stevens (FRDC Board) facilitated the next session, which was dedicated to the development of a communication strategy. This was seen as essential in order to ensure that the Minister and MPs, key stakeholder groups and the general public are completely conversant with what is being proposed by way of the adaptive management trial.

7.9.8.1 Objective

To ensure proper understanding and awareness of the female mud crab adaptive management experiment.

7.9.8.2 Target audience

- Minister, Cabinet members, and MPs in coastal electorates.
- Key stakeholders – commercial, recreational, indigenous, conservation (and others?).
- Key Government agencies and NGOs – e.g. GBRMPA, DERM, WWF, DEWHA.
- Media specialists (selected people in the papers and TV such as fishing writers, fishing radio and television)
- Wider community

7.9.8.3 Key message

A carefully planned and controlled experiment is to be conducted to determine the stock, economic, and social outcomes of permitting the harvest of female mud crabs.

7.9.8.4 Communication methods

- Ministerial press release, supported by key stakeholder press releases (need to coordinate approaches and timing)
- Circulate to licensed crab fishers, other stakeholders
- Senior scientists available for 'one on one' interviews with the media (Need to have answers which are not too technical regarding sex ratios, sustainability, measurements etc)
- Call centre (business information centre can be provided with scripts (call centre) to relay basic information quickly. If they require more information they can then refer to the fisheries management officer.
- Rolling media releases
- Radio
- Regional newspapers
- Website

The quantity of information to be released, and its staging will need to be advised. The Department's communications staff will assist with this.

7.9.8.5 Action plan

- A senior DPI person to have ongoing carriage of the process.
- A steering committee will have to be established (involving all key stakeholder groups) to manage the experiment directly.
- A management advisory group will look at the surrounding management content.
- A timeline will need to be drawn up by the Steering Committee.

Workshop members queried how long it would be before the information and decisions of the Workshop could be released, as there is considerable apprehension surrounding the subject. It was recommended that:

a) A report from this workshop will be written and circulated to all workshop participants.

b) Brief the minister of the outcomes of the recommendations from the workshop (and the extent of decisions),

c) The workshop statement will have to gain consensus from everybody present at the workshop.

d) Representatives of key stakeholder groups need to discuss the Workshop outcomes with their constituents (at this stage expert level advice followed by peak body support). Expert advice would be based on the biology and economics from the workshop. There must be agreement before moving forward, with no divergent views, and confidence with the message being proposed otherwise the momentum will be lost.

7.10 Post-Workshop activities

7.10.1 Analysis of LTMP dataset

Fishery-independent monitoring information presented at the Workshop suggested that although there was a great deal of variability in adjusted mean catch rates within regions, the time-series trajectories in three main areas indicated a fairly static population density. However further analyses were undertaken after the Workshop by Principal Biometrician Dr D Mayer to more closely examine some of the main effects and interactions. The composite binomial-conditional gamma GLM accounted for year, soak time and regional effects, as well as the effects of a subtle change in pot design. The latter occurred when the manufacturer of the original 'Munyana' design went out of business, and another gear manufacturer fabricated a set of replacement pots based on the same design. While there did not appear to be any difference between the two designs, the new pots consistently caught significantly less than the old pots in simultaneous trials.

The conditional adjusted catch rates showed downward trends over the 10-year survey period in all five areas (Gulf of Carpentaria, North Qld, Gladstone, Hervey Bay and Moreton Bay; Figure 33). Alternative generalised linear models were examined, which produced slightly different results, and there is some evidence of cyclicity although the time-series is far too short to be certain that the effect is real. Overall there is some reason to be concerned about the implications of these findings, and to reinforce the particular value of fishery-independent data-sets. However the modelled reduction of around 5% is very similar to that shown by the east coast commercial logbook data with the application of an annual 5% effort 'efficiency' factor (see Figure 10).

The size data collected as part of the LTMP surveys was investigated to test the commonly-held belief that the single-sex harvest policy has resulted in a preponderance of large female crabs in the population. LTMP carapace width data were grouped into three regions (Gulf of Carpentaria, North Queensland and South Queensland) which are relatively lightly, moderately and heavily fished, respectively. The proportion of legal-sized male crabs in the population was lowest in the southern part of the State, somewhat higher in North Queensland, and highest in the Gulf (Figure 34). This is in general accordance with the scenario of an imbalance in sex ratio with increasing fishing pressure, but the curious situation with the Gulf data warrants some explanation. The data indicate that above minimum legal size, the proportion of male crabs in the population increases progressively to unity at 20 cm CW, suggesting that there are no very large females in the population. This is counterintuitive assuming relatively light fishing pressure and reasonable compliance with the prohibition on taking female crabs. It would be expected that, in a situation of minimal fishing pressure on the vulnerable female stock, the ratio of males to females should not

be more than about 1:1 (50%). This raises the question as to whether the fishery-independent survey is sampling the population effectively. A plausible explanation (N. Gribble, *pers. comm*.) has to do with the species' aggressive behaviour, where large male crabs actively exclude females (even of similar size) from entering the pot. Thus in areas where large males are still abundant the pot samples may be seriously underestimating the local abundance of large females.

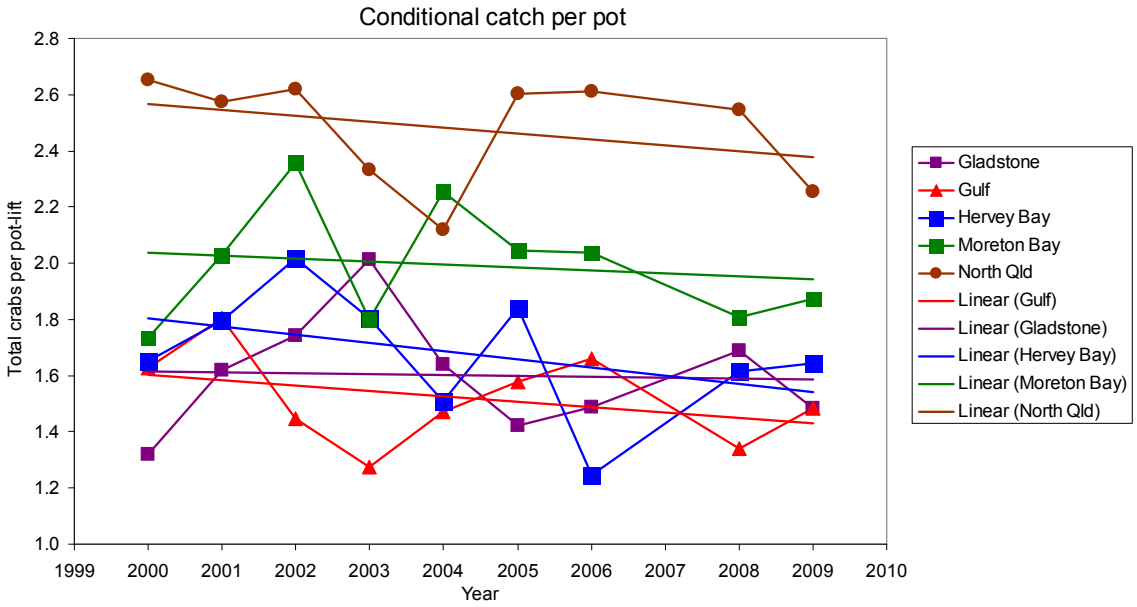

Figure 33. Trends in (modelled) adjusted mean catch rates for each of the five main LTMP mud crab survey areas

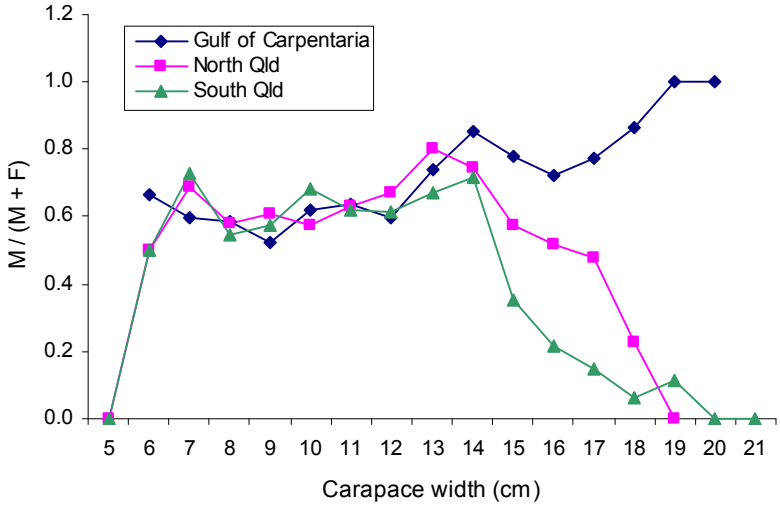

Figure 34. Size-related differences in the sex ratio, portrayed as the proportion of male mud crabs in the sample, in three broad regions subject to different levels of fishing pressure. Data from LTMP database.

7.10.2 Qld catch disposals

At the November Workshop there was some discussion about the 'fate' of the Queensland mud crab catch – how is the product distributed and where does it go? Conventional wisdom has it that almost all of Queensland's 1000 t+ logged commercial catch is sold on the domestic market, most going to NSW, particularly the Sydney Fish Market (SFM), and some to Victoria. Much of Professor Hundloe's economic modelling was based on the market situation at SFM, as the independent processors he'd interviewed were loath to reveal useful details of their target markets and price structures.

Recently we were advised that SFM actually handles only about 130-180 t per year of mud crab from Queensland. There is evidently a small quantity air-freighted to overseas markets from north Queensland, but what happens to the remaining 800 t or so is unclear. Is it all sold locally in Queensland? Is there indeed another 800 t caught? This raises the possibility that the State's commercial mud crab catch may be overstated.

New arrangements driven by Safe Food Queensland have led to the phasing out of the previous Seafood Buyers' Licence, which appears to mean that there is no easily followed paper trail along the distribution chain for seafood products in this State. As a result, it is not possible to verify the total commercial catch without recourse to commercial dealers' receipts, which creates difficulties if the identity of the dealers is not known.

7.10.3 Logbook data quality

This led to an investigation of the commercial logbook data, summaries of which are used in the Department's Annual Status Reports for the Mud Crab Fishery.

When the 2008 mud crab catches by vessel were ranked, the top producer had logged a quantity of crabs that, following some simple calculations, appeared extraordinarily high. On further investigation, other departmental staff established that this person had consistently over-stated his daily catch, and when contacted, was unable to produce any documentary evidence to support his logbook records. This is one example of possibly a number of cases where - either intentionally or otherwise - the catch data in the logbook system may be erroneous and potentially biasing catches upward. It is often said that as soon as there is a rumour (whether correct or not) of an impending Investment Warning, there will be a calculated strategy on the part of some operators to inflate their catches. This is done in order to maximise their catch history and ensure that they are in the best position if a quota system is introduced or there is a compulsory buy-back of licences as part of a latent effort reduction scheme. Unfortunately it is not known how prevalent this activity is, nor what effect it has had on the catch-effort statistics. However it is unlikely that this over-reporting was occurring systematically early in the history of the fishery, well before any mention was made of an investment warning. It is also possible that some fishers under-reported their catches which would reduce the potential bias.

It is also widely recognised that many mud crab fishers use more than the permitted number of crab pots (currently 50). Clearly they do not record the actual number of pots set if the permitted number is exceeded. The consequence of this is that effective effort is greater than reported effort, by an unknown amount. Individual fishermen have suggested that the numbers of pots being deployed by a significant part of the fleet could be as high as 100 or more (at least twice the permitted number) under an individual fishery symbol.

The Investment Warning-related inflation of catches and the efficiency increases resulting from the use of excess fishing apparatus have a similar and mutually-reinforcing effect on catch rates or CPUEs, currently considered one of the best available indicators of the status of Queensland's mud crab stocks. In both cases the effects are to inflate reported catch rates, leading potentially to an unjustifiably optimistic view of the status of the fishery. Catch inflation is an issue that needs to be dealt with through forensic accounting, paper-trail auditing processes, and the use of range-checks at the point of data entry and other quality control processes. Effort creep resulting from excess gear use, on the other hand, requires on-water monitoring.

It should be remembered that the management strategy evaluations based on the Gtg simulation model in Section 7.7 are not stock assessments - a point made repeatedly by James Scandol during the course of the Workshop. The simulations assume that the base catch-effort data are correct, and that the observed increases in both catch and CPUE are due to increases in catching 'efficiency' rather than a biologically untenable long-term crab population growth in the face of increasing effort. These 'efficiencies' are almost certainly due in the main to the effort creep effects described above. To account for this biasing effect, the MSE modelling incorporated a more or less arbitrary (but quite significant) 5% p.a. increase in catching efficiency over the logbook period. Statistical analyses using a Mixed Model in Genstat were carried out on the commercial logbook data to investigate the effects of inter-annual and seasonal factors and between-vessel differences on the average annual catch rate.

Four statistical models were compared to judge the effect of including vessel (or operator) on the annual mean catch rate. In all cases the input data (relating only to CAAB codes for 'mud crabs' and 'giant mud crabs') and only for the East Coast, were for the entire logbook period (1988-2009) and aggregated to monthly total catches (kg) and effort (in fishing days). A subsidiary Access query log-transformed the monthly catch and effort data, then 'adjusted' the effort data by applying the instantaneous rate formula

$$X' = X \times e^{(r.\Delta t)}$$

where X' = efficiency-adjusted catch rate, X = reported catch rate, r is the applied annual efficiency increase rate (in this case 5%), and Δt the number of years elapsed since 1988.

The four models were as follows:

Model I: generalised log-linear, with 'boat' as a factor. Restricted to boats logging ≥ 500 fishing days over the logbook period.

Model II: generalised linear mixed model, with 'boat' as a random effect. Restrictions as above.

Model III: generalised log-linear, with no 'boat' effect. Restrictions as above.

Model IV: generalised linear mixed model, with 'boat' as a random effect. No boat restrictions.

The adjusted mean annual catch rates for Models I-III were very similar in absolute values as well as in the general trend (Figure 35), indicating that the more computer-efficient treatment of 'boats' as a random rather than fixed effect has little impact on the final result. Having established this, it was then possible to include all vessels in the analysis (Model IV) which had previously been impossible because of data capacity limitations. Not surprisingly, the inclusion of the 'low effort' operators in the analysis reduced the absolute adjusted values to some extent (Figure 35) but the form or trajectory of the time-series was very similar to that of the subset of 'high effort' operators.

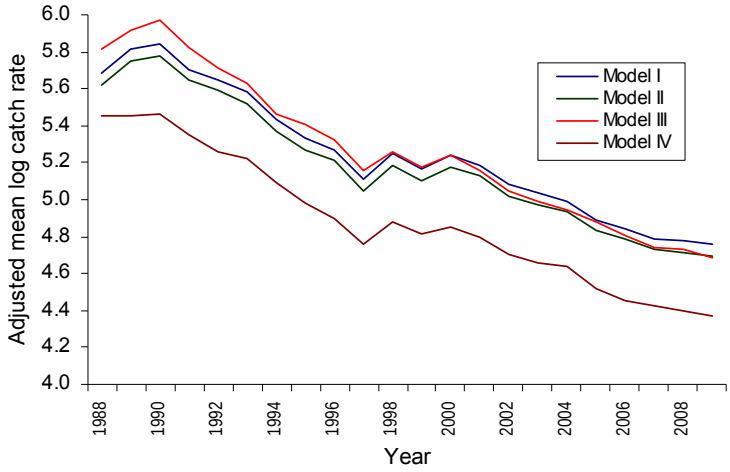

Figure 35. Time trajectory of adjusted mean (log) catch rates for the East Coast mud crab fishery as derived from four models (see text for explanation).

Of some concern is the fact that all models showed a downward trend in the adjusted means, from about 5.4 (fleet-wide) in 1988 to 4.4 in 2009. This, in conjunction with similar trends in the LTMP fishery-independent dataset (see Section 7.10.1) indicates that there may be an issue with the status of the mud crab resource, given that over the past 6 years there has been a progressive decrease in reported commercial effort (number of fishing days). These analyses used the same (5%) annual estimate of efficiency increase (over the entire logbook period) as was used in the MSE models in Section 7.7. However a possibly more accurate scenario may be that the over-potting and catch inflation issues did not begin in a significant way until a year or two prior to the official announcement of the Investment Warning. If this was the case, the rate over the last decade may have been much higher, potentially in the order of 10%.

This highlights the real need for far better and reliable systems and processes to track changes in the mud crab stock than are currently available, although the observed 18% decline in apparent abundance over the 2-decade period may simply be a reflection of increasing exploitation pressure on a highly productive resource. As a rule of thumb, a reduction in the standing stock to 60-70% of its unfished biomass is acceptable, and even with the notional 5% annual effort creep factor included, the standing stock over the past 20 years has been reduced to only about 80% of its level at the beginning of the logbook period.

7.10.4 Stakeholder consultation and responses

Following the November Workshop, the Proceedings (on which this report is based) were produced and circulated to all major stakeholder representatives to enable them to take the outcomes to their constituents for discussion. This would then enable an informed view to be made from each of the stakeholder groups. It should be noted that all stakeholder representatives at the Workshop agreed to the consensus view detailed in the 'Woorim Agreement' (Section 7.9.7) that - subject to a number of caveats - the Workshop participants were supportive of the establishment of a carefully-controlled trial or adaptive management experiment.

The two major groups (Sunfish Queensland and the Queensland Seafood Industries Association) approached this consultation by way of questionnaires to their members. Both questionnaires were

far broader than the specific issue of the single-sex harvest policy, and had been designed to cover a number of questions relating (potentially) to the management of portunid crab fisheries in Queensland, in view of the likely management review to be undertaken in 2010. There is little evidence that any of the detail of the background, discussion, or resolutions of the Workshop were conveyed to the stakeholder groups' members for consideration, but rather a 'show of hands' on simplistic questions to do with changes to the size limits and harvesting female crabs. In fact it appears unlikely that very few people responding to these questionnaires had even been made aware by their respective organisations that a Workshop had taken place. In contrast, some individuals and groups not directly associated with these 'peak bodies' but nevertheless attuned to the need for informed, evidence-based comment, took the trouble to consult with industry members and (presumably) make them aware of the proceedings of the Workshop. A summary of the consultation responses is given in Table 10. The full set of (essentially unedited) individual responses follows in Sections 7.10.5 - 7.10.8.

Table 10. Summarised responses from key stakeholder groups represented at the Workshop.

Sector/organisation	Source	Response
Commercial: Queensland Seafood Industries Association	Responses from pre-Workshop QSIA survey of members.	Opinion divided and polarised, 50% in favour, 39% opposed and 10% undecided. Concerns re. possible effects on market/profitability, increasing recreational effort and black marketing. If changes are made, the process will need to be carefully controlled (e.g. quotas, ratios or tags).
Commercial: East Coast Crabfishers Industry Network Inc.	Post-Workshop meetings (Brisbane, Maryborough, Cairns) and phone contact with members.	Positive, and generally supportive of some relaxation of SSHP. However concerns about long-term stock sustainability and market impact. Any policy change would need to be done in a controlled and responsible way, in context of other mgmt reforms, mgmt of excess fishing capacity, and provision of reliable data for monitoring effects.
Recreational: Sunfish Qld Inc.	Post-Workshop state-wide questionnaire on aspects of BSC and MC fisheries – 25 responses.	Negative – 16 totally opposed, 9 wanted 'more science'. Actual science rather than modelling seen as necessary – good data required, rather than good models with poor quality data. Have always been opposed to taking of female m/c, and will continue opposition to any project aimed at supporting the take of female m/c (resources should be used more effectively elsewhere).
Recreational: independent (T Fuller, prev. CrabMAC rec. rep)	Post-Workshop feedback from newspaper articles and many (126) phone calls.	Opinion divided – 60% in favour, 40% opposed. One-third of those in favour wanted current size and bag limit to remain; two-thirds wanted some form of 'conditional' take (e.g. ratio of max. 2 females per male). Supporters were mainly younger and in smaller communities; opposers older and in larger communities (higher fishing pressure).
Environmental: GBRMPA	Review of Workshop proceedings	Supported the outcomes of the Workshop without being specific or expressing any particular caveats.
Indigenous: South East Queensland Traditional Owners'Association	Pre-workshop consultation with various south-Qld indigenous groups.	Strong negative feedback from SEQTOA Board and Gold Coast Aboriginal Association. Expressions of 'concern about the matter' (presumably negative) also conveyed from Sunshine Coast, Brisbane and Quandamooka Traditional Owner groups.

7.10.5 Commercial sector

7.10.5.1 Queensland Seafood Industries Association (industry peak body)

Ian
Please find attached the QSIA C1 Issues Paper Report following industry input in 2009. As you can see, this question regarding female mud crabs is included in the report and will no doubt be used to inform the future management arrangements for this important fishery later this year.

Warm regards
Winston Harris
Chief Executive Officer

From: AN ANALYSIS OF RESPONSES TO THE QSIA ISSUES PAPER ON THE BLUE SWIMMER AND MUD CRAB FISHERIES

Question 4 - Taking female mud crabs

The responses are also divided on the issue of the taking of female mud crab – with 50% agreeing, 39% disagreeing and 10% undecided on the proposal.

Comment:
There was support for the proposal based on its use in other States and the increase in catch and profitability of the industry. However, there were downsides mentioned, namely that the increase in supply could lower the current market prices of mud crabs, so that more effort on the fishery might not increase overall value; increased recreational effort would also result and the dangers of increased black marketing exists. Caution was recommended and that any change should be based on good science and perhaps limited to certain sizes and/or quotas.

Commonly, a view was expressed as why rock the boat given a currently healthy industry. With regard to the suggested size limit, (Q.4a) those who supported the taking of females suggested MLSs ranging from 150 mm to 200 mm, while others felt it should be based on science as to when females no longer mate and breed.

With regard to alternative management arrangements (Q.4b) three suggestions were mentioned with the most common one being a quantitative limit in terms of numbers of female crabs per day of 5 to 25 per day, or a ratio of 10% females to male catch, or a seasonal Individual Transferable Quota (ITQ, e.g. 2 tonnes). The other suggestions were a limited seasonal take of females from July to January each year, or a limited take around Easter and Christmas; with a further suggestion of a tag system to allow the take of limited numbers of females with the revenue from tags being used for research and monitoring.

7.10.5.2 East Coast Crabfishers Industry Network Inc.

East Coast Crabfishers Industry Network Inc. "On the Job" in North Queensland.

Gents,

Good roll up and feed back on the Female Mud Crab Project at these two meetings, plus other small group discussions with fishers in Cairns.

Attendance by commercial, recreational, sunfish, Gary & Claudine Ward from Gulf Fisherman's and even the local newspaper, we are expecting an article on the meetings deliberations. Also ran our potential solutions meetings in conjunction with this discussion, as it provided a good lead in to the topic. We have now conducted these sessions in Brisbane @ our AGM and in Maryborough plus other phone contact.

General feed back to the proposed Female Mud Crab Project arrangements was positive, however "With great caution" being a very common theme in how this should be approached, and avoiding a "gold rush" must be one of the primary considerations for the commercial sector especially.

We will provide a formal written response by January 10th.

Regards
Bruce

12th January 2010
Dear Ian

Having conducted consultation within our membership and crab industry participants generally, East Coast Crabfishers Industry Network Inc wishes to provide a formal response to the proposed female mud crab harvesting project.
Our findings have been that there is generalised support for the taking of female mud crabs, however most fishers express strong concerns in relation to future sustainability of stocks and the ability of the market to absorb the additional product without significantly impacting on price. The concept of a precautionary approach was strongly supported and the proposed management concepts outlined at the Bribie Island workshop were conveyed to industry participants and were met with mostly favourably responses.

As such we wish to provide a positive response to the proposal, but reaffirm our initial qualifiers that;

The science must support the taking of female mud crabs without detrimental effects to economic viability of industry participants and ecological sustainability of stocks.

The taking of female mud crabs be managed in a controlled and responsible way and that the implementation of the project coincides with the introduction of wider management reforms for the mud crab fishery, (The C1 fishery review), including a process for managing the current excess fishing capacity of the fleet and the provision of accurate management data.

We thank you for the opportunity to contribute to this project and remain available for more detailed discussion if required.

Regards
Bruce Sutton
Secretary, East Coast Crabfishers Industry Network Inc.

Hi Ian

Since we had our meeting at Taylors Beach, a lot of the local people, commercial and recreational have contacted me about the project.

Some have been concerned but when I explained to them how it will basically work everyone has gone away happy. Actually there has been no negative comments towards the scheme.

The main concern I see is about there being open slather. Nobody wants over exploitation of the industry.

Ian I think it was a job well done.

Thank you
Regards
David Perkins

7.10.6 Recreational sector

7.10.6.1 Sunfish Queensland

Hi Ian

We sent a questionnaire state-wide to gauge opinion on the single sex harvest policy of mud crabs as well as other important aspects of both the sand crab and mud crab fishery. The results are in our newsletter which I have also attached.

There was no support for the removal of the SSHP. Sixty-five percent were completely opposed and the remaining thirty-five percent wanted more science. Some were quite specific; they, like me, required actual science and not modelling. Over the last few years we have seen too many reports come out of Fisheries Qld (aka DPI&F, QPI&F) that were based on reasonable models with poor or questionable data inputs.

Sunfish Qld still holds that the apparent purpose of removing the Single Sex Harvest Policy is to add support to part of an inefficient and uneconomic commercial fishing sector especially in the South east corner of the state.

Sunfish Queensland and its member organizations representing the interests of recreational fishing are totally opposed to this proposal & this has been our position for many years. We are also opposed to any research proposals aimed at supporting the take of female mud crabs when there are more important areas of research where the money & resources could be more effectively used.

Regards

Judy Lynne
Executive Officer
SUNFISH Queensland Inc

Extracted from Sunfish's **sf magazine** January 2010, p. 15 (Crab Questionnaire analysis):

Sunfish Qld ran an email questionnaire on current recreational crabbing & asked for comments on existing & suggested changes as a prelude to the review next year of the Crabbing by Fisheries Queensland. The total response was 25 replies & came from anglers state wide. Although the sample was small there were some very definite trends & some very practical suggestions.

The next step by Sunfish will be to formulate a draft submission for circulation to our members for comment.

A general overview of the 11 questions were as follows:

Q1 75% considered the crab sizes were OK, 25% thought sand crabs should be larger.
Q2 65% said no taking of female mud crabs, 35% wanted more science.
Q3 80% said they agreed with no "on water" possession of crab meat, 20% were unsure.
etc.

7.10.6.2 Non-Sunfish affiliated recreational fishers

Transcribed from fax recd 8 Feb from Trevor Fuller.

Ian
This is the result, in brief, prior to our workshop at Bribie Is. Since then I have had lots of contact with fishers and views still vary but mostly due to lack [sic] of biological misunderstanding.

Will continue to monitor and survey general community with the objective of people being able to make informed decisions.

Will be doing a 3-hr talkback on radio in Townsville this Saturday 13th Feb '10 (transmission goes all over the top end).

Regards
Trevor Fuller

Response to 'Take female crabs' in media (Trevor Fuller) Published in *Townsville Bulletin* and *Sunday Mail* (Brisbane), inviting public comment on 'Take' vs 'not take' female mud crabs.

Total response – 126 calls plus personal contacts. Calls from Townsville, Hinchinbrook, Burdekin, Bowen, Mackay, Mt Isa, Cairns, Brisbane & Weipa.

Results: (122 recreational and 4 commercial fishers)

Take female crabs –	no controls	26
	conditional take	47
No take -		49

Re. 'no controls' – same as male crabs 15 cm + bag limit.
Conditional take = ratio of female to male crabs (support max. 2 fem: 1 male)
'No take' – strong views on leaving 'as is'.

Demographics:
'Support take' by mostly under 45 yr-old fishers
Strong support 'no take' over 45 yr-old fishers
Smaller communities (low [fishing] pressure) support conditional take
Major centres, high take areas, strongly against take of female crabs.

7.10.7 Indigenous stakeholders

Hi Ian,

I am sorry that I wont be attending the workshop this week as I have a heavy workload of Cultural Heritage Management. I waited until this morning for someone to fill in for me this week down here, but there is nobody available or suitable.

I have informed the full board of SEQTOA members of the workshop and the intentions of it, the Traditonal Owners do not support the FRDC 2009/031 Taking Female Mud Crabs for any Commercial Harvesting or for Recreational purposes. The (SEQTOA) members have been delegated by our different groups and we all have our own Decision Making processes in place. I, as Chairperson of the Ngarang-Wal Gold Coast Aboriginal Association Incorporated took this issue to our membership/traditional owners down here and there was a unanimous decision not to Harvest the Female Mud Crab or change any Current Laws regarding Recreational crabbing.

The Sunshine Coast, the Brisbane and the Quandamooka Traditional Owners asked me as their Delegate @ this level to convey their message of concern in this matter.

Thank You and Kind Regards

Tony Dillon
0414537688.

7.10.8 Environmental stakeholders (GBRMPA)

Australian Government
Great Barrier Reef
Marine Park Authority

Dr Ian W Brown
Senior Principal Fisheries Scientist
Fisheries Queensland
Southern Fisheries Centre
PO Box 76
DECEPTION BAY QLD 4508

Dear Dr Brown

Risk assessment for the harvest of female mud crabs

I write to lend my endorsement for the recent risk assessment and workshop you held at Bribie Island to evaluate the risks and benefits of allowing the harvest of female mud crabs in Queensland

I understand that:

- a rigorous risk assessment to AS/NZ 4360 standard was undertaken at the workshop;
- the workshop assembled and involved a broad set of stakeholders and people with the most appropriate detailed knowledge to input to the risk assessment; and
- the workshop proposed the development and implementation of a well-designed, controlled and effectively monitored adaptive management experiment of sufficient spatial scale to provide statistically robust information to guide longer term management.

Thank you for the opportunity for staff of the Great Barrier Reef Marine Park Authority to contribute to and participate in the workshop.

Yours sincerely

11/1/2010

Peter McGinnity
General Manager
Environment and Sustainability Branch

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7.10.9 Ministerial briefing and outcome

A critical element of the Communication Strategy was that the Minister consider the results of the research workshop, including stakeholder responses and a summary of the resulting views on the workshop draft proceedings. The Minister considered these results and stakeholder views and has advised that any change to the single sex harvest policy would be reconsidered when concerns relating to effort (over-potting) in the fishery have been addressed. It is intended that this issue will be addressed in the forthcoming review of the mud and blue swimmer crab fisheries to be conducted by Fisheries Queensland.

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8 Discussion

The Workshop in November 2009 achieved its stated aim of bringing together experts in the field of mud crab biology, stock assessment, fishery economics and a broad range of industry and stakeholder group representatives, managers and compliance personnel to examine the long-standing question of whether or not it is advisable to harvest female mud crabs.

Following a series of very informative presentations by Dr James Scandol on a management strategy evaluation based on the Walters GtgModel, and by Professor Tor Hundloe on the economics of the mud crab fishery, a risk assessment was undertaken to identify and rank the major risks that the Workshop participants believed may be associated with a relaxation of the SSHP. The top-ranking perceived risk was to the profitability of individual fishing businesses as a result of increases in fishing effort. It was felt that unless the process was managed with particular care, and despite the evidence of the Gtg and economic modelling, the advantages to opening up the female sector of the fishable population to exploitation would attract a 'gold rush' of new operators, result in higher levels of between-sectoral interaction, and while there may be initial short-term gains in profitability, these may be dissipated over time.

The three next highest (and equal) ranking risks were recruitment overfishing and activation of commercial and recreational latent effort of fishing capacity. Clearly the concern about recruitment overfishing had not been allayed completely by the management strategy evaluation modelling. In addition, the widely-held view that above a certain size or age female mud crabs lose their capacity to reproduce was challenged by advice from Dr David Mann (staff member of the DEEDI Aquaculture Research Centre at Bribie Island) that large female crabs sourced from Moreton Bay had been used as broodstock.

The remaining lower-ranked risks included negative public perception relating to concerns about environmental stewardship, Sea Country management, and ecosystem sustainability; escalating conflict between and within sectors; and decreased quality of experience due to increased participation numbers.

Economic modelling demonstrated that there were substantial gains both to the individual operator and to the State's economy by allowing the harvest of female mud crabs. On the basis of existing market arrangements, and assuming that the biological system would sustain such a scenario, the net benefit to the industry (currently between $10 and $15 million p.a.) could rise from between $1.5 million and $4.25 million p.a.

It is important to note that, after evaluation of risk management options and potential experimental designs for trial, the Workshop participants agreed that there was no scientific reason why female mud crabs should not be harvested at some appropriate level, and that subject to a number of conditions or caveats a carefully-controlled and reversible experiment would be appropriate. The concerns expressed in the risk assessment part of the Workshop were real, but it was agreed that they could potentially be managed adequately and reduced to an acceptable level. While not overtly expressed by the participants at the time, there was probably an underlying concern about the reliability of the data that had been used for the management strategy evaluation and to some extent the economic modelling. The latter was a particular issue for Prof. Hundloe in that so little reliable information (even anecdotal) is available on the economic structure of most of Queensland's fisheries. It was acknowledged that the commercial logbook data may be deficient in certain areas, and recreational data on mud crab catch and effort are sparse and probably even less reliable, but apart from the relatively short LTMP time-series there was little else to inform the process.

The stakeholder consultation phase following the Workshop was generally less effective than it could have been. Possibly because of the need for the recreational and commercial peak bodies to canvas the views of their membership on a broad range of issues relating to the management of the Queensland's blue swimmer crab and mud crab fisheries, the question of harvesting female crabs was not well supported by explanatory information or background material, and tended to be presented as a bland question requiring a 'yes' or 'no' answer. This was a disappointing development, as it means that the large majority of commercial and recreational fishers were not adequately briefed by their respective organisations. On the other hand, genuine attempts to inform all interested parties and gain their views were made by a particular recreational fisherman long associated with crab fishery management in Queensland, and by a recently-formed industry group representing a number of commercial crab fishers on the East Coast. It is suggested that a process be developed for more intensively briefing a representative section of the commercial and recreational fishery and seeking perhaps a more informed response. This could take the form of a mailout of information (e.g. a hard copy of this Report's Non-Technical Summary and an electronic copy on CD of the entire report), together with a confidential anonymous questionnaire.

Investigations into the logbook data after the Workshop had concluded revealed deficiencies in the data quality assurance area, some of which are now being addressed. However the problem of over-potting remains, as there seems to be no way to account for it retrospectively. Reliable industry sources suggest that some operators could be using at least twice and perhaps three times the permitted number of pots in order to make an adequate living. If widespread, such actions could have seriously biased catch rates and led to erroneous conclusions regarding the sustainability of the mud crab resource. This problem would have been exacerbated by a tendency to inflate catches as a result of the Investment Warning. A number of suggestions relating to these and other related issues of data usefulness, reliability and quality are given in the Section 12. Nevertheless it is important to recognise that the decline in CPUE relates only to legal-sized male crabs. Populations of female crabs should be near virgin state unless there is significant illegal harvesting of female crabs or if gamete limitation (insufficient males to fertilise all the females) is reducing the stock's reproductive potential. There are broader questions about whether a 'fish-down' of female crabs, which would result from the removal of the SSHP, would result in reduced recruitment. If there are depensatory effects - such as females excluding males from burrow sites - then the large stock of mature females may be inhibiting productivity. If there are not large numbers of females in the stock, this raises the question of whether there has been a change in the underlying population dynamics, such as an increase in natural mortality.

9 Benefits

The outstanding benefit of this project is that an expert group of people was convened for a significant length of time to discuss one particular issue relating to the management of Queensland's mud crab fishery. It was agreed that there is no biological justification for maintaining the single-sex harvest policy and that some form of carefully-controlled experimental approach to phasing in as agreed level of female harvest is appropriate.

There are financial benefits to be gained from harvesting female crabs, which would add considerably to the value of the fishery.

While not a planned Project activity, additional analysis and investigation of the base dataset which had been used in the MSE modelling has brought to light certain deficiencies in quality assurance procedures that are now being addressed. These will certainly improve the quality of the data in future.

10 Further Development

There is a need to further investigate the possibility that there has been a real decline in mud crab stock abundance on the East Coast, or whether the observed downward trajectory is simply part of a longer-term environmental cycle.

A number of changes to the data reporting process need to be introduced, and the procedures for improving data quality need to be implemented.

While there are many areas of research that could improve our understanding of the species' interesting reproductive biology and behaviour, no further research is needed to justify the harvest of female mud crabs. What is needed is a more reliable system for tracking changes in the population abundance of the State's mud crab stocks. Once this is achieved, the way will be clear for changing the SSHP under a carefully-controlled adaptive management process.

11 Planned outcomes

It is anticipated that the outcomes from the Workshop will contribute very significantly to the development of new management arrangements for the State's portunid crab fisheries, to be developed during a review scheduled to commence in 2011.

The Workshop in-principle agreement to pursue a controlled and carefully-monitored phasing-in of some level of female harvest should be part of the new Mud Crab Harvest Strategy. However it is recognised that the methodology of such a phase-in cannot be determined until the broader issues of management philosophy (e.g. input or output controls) have been agreed upon.

12 Conclusions and Recommendations

1. It has been shown that *in principle* there is no justification for pursuing the single-sex harvest policy for mud crabs in Queensland (or elsewhere). However until such time as a reliable indicator of stock abundance is developed it would not be wise to allow the take of female crabs.

2. When such an indicator becomes available, a minimum legal size for female crabs of 160 mm CW (spine-to-spine) should be set to minimise the risk of overexploitation

3. Transition to a both-sex harvest arrangement should be done by way of a controlled adaptive management experiment, allowing for immediate policy reversal should there be any indication of undesirable or unsustainable ecological, economic or social consequences.

4. The take of female crabs should be carefully controlled, preferably by a system of compliance tags sold to commercial or recreational crab fisher wishing to participate in the experiment.

5. The experiment should be carried out at a regional (rather than State-wide) level

6. Recent exploratory analyses of the commercial logbook data have revealed errors that may have biased catch-rate estimates upward and led to over-optimistic assessment of the state of the mud crab resource. Analyses of the 10-yer annual Long-Term Monitoring Programme (LTMP) mud crab survey dataset have shown significant declines in at least two of the six surveyed regions, and possible declines in another two. However this fishery-independent survey will not be conducted in 2010, and its future thereafter is in doubt because of insufficient financial resources. Specific recommendations relating to these issues are as follows:

    - Continue the LTMP mud crab surveys, at least on a biennial basis. Consideration might be given to an alternative and potentially less costly strategy where commercial operators do the survey with their own vessels and gear, but under LTMP protocols and with an LTMP staff member on board as observer/data collector.

    - Review the mud crab logbook format and instruction set so that the most appropriate data are obtained (with reliability) from the fishery and fishermen know precisely what information they must provide.

    - Review CEFISH mud crab data quality control processes to ensure (a) range-checks for data input screens are established and used, (b) periodic basic statistics are calculated to detect anomalies, and (c) procedures are established to follow-up and rectify such anomalies.

    - Institute a statistically robust process for validating logbook data using (if necessary) the Fisheries Observer Programme, or alternatively a reliable industry observer.

    - Ensure that whenever changes are made retrospectively to the logbook data, these corrections are themselves logged and communicated to all staff concerned with analysis of the data.

    - Review the process for determining fishery ‘history’ to ensure that honest and conscientious fishermen are not disadvantaged as a result of reporting ‘errors’ (whether intentional or otherwise) by others.

    - Introduce some form of Catch Disposal Record into the Mud Crab Fishery. While the CDR was developed for quota-managed fisheries it is sorely needed in the mud crab fishery. It is most unfortunate that we have no idea where our fishermen sell the bulk of their extremely valuable mud crab catch. Most importantly, it is essential to have some sort of paper-trail that can be used to verify the magnitude of the reported catch.

    - Better inform a broad sector of the commercial and recreational fisheries of the outcomes of the Workshop, and canvas their opinions on the establishment of a (reversible) adaptive management process to enable a properly monitored and controlled test of the effects of allowing some harvest of female crabs.

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Appendix 1 Intellectual property

There are no intellectual property issues associated with this research, as it is all in the public domain and for the public good.

Appendix 2 Personnel engaged on project

The following table lists the names of all people officially invited to participate in the Workshop. Those who were unable to attend are indicated by asterisks.

Surname	First name	Affiliation/expertise area
Bateman*	Dave	Recreational (Sunfish)
Brooks	Kate	Social Research Program, FRDC
Brown	Ian	Research, CrabMAC
Dillon*	Tony	Indigenous & QFIRAC
Doohan	Mark	Compliance/Enforcement
Exten	Rick	Compliance/Enforcement & CrabMAC
Fogarty	James	Marketing Qld Seafood Marketers' Assocn)
Fuller	Trevor	Recreational
Gaffney	Phil	Management
Gardner*	Michael	President, QSIA
Gribble	Neil	Research (DPI&F, NQ)
Groves	Jim	Deputy D/G, Fisheries (DPI&F)
Grubert	Mark	Research (NT)
Grunske	Mark	Commercial crabber (GOC)
Harris*	Winston	QSIA, Executive Officer
Hundloe	Tor	Fisheries economics
Jackson	Peter	Industry (QSIA Crab subcommittee)
Johnston	John	Sunfish south (per Dave Bateman)
Lightowler*	Mark	DPI&F, Fishery Management
Lynne	Judy	Sunfish
Mayer	David	DPI&F, biometrics
McGilvray	Jason	LTMP (crabs)
Montgomery	Steven	Research (NSW)
Nash	Warwick	Research (DPI&F, Science Leader)
Stevens	Richard	FRDC Board
O'Neill	Michael	DPI&F, stock assessment
Owens	Randall	Conservation (GBRMPA)
Perkins	Dave	Commercial crabber (north) & CrabMAC
Riesenweber	Tony	Commercial crabber (south)
Scandol	James	Modelling
Sumpton	Wayne	DPI&F, Research
Sutton	Bruce	Commercial crabber (south)
Tobin	Renae	Social researcher, JCU
Waia	Roseann	DPI&F, Minutes Secretary
Yarroll	Ian	DPI&F Fishery management
Garland	Anna	DPI&F, data management

* did not attend

Appendix 3 Risk scoring tables

Consequence should be scored first, and should reflect the impact of the event, action or activity on whatever asset or value is being investigated, at the highest level of likelihood. This is because the introduction of a 'likelihood' element may have a significant moderating effect on the consequence. It's important not to be influenced subconsciously by Likelihood when scoring Consequence.

Consequence scoring					
	Insignificant	Minor	Moderate	Major	Catastrophic
Score	1	2	3	4	5
Description	Little or no measurable impact. Can't differentiate from background variability.	Impacts relatively small, most reversible in the short term (<3 yr)	Impacts significant, but effects may or may not be reversible in the short term	Impacts very significant, mostly irreversible in the short term	Extreme and long-lasting detrimental effects, possibly irreversible even in the long term.

Likelihood will not be scored, but calculated automatically in the spreadsheet from the two Scale components (temporal and spatial). We assume that the conventional Likelihood index is equivalent to the Temporal Scale, as in most examples the scoring guides are the same for both.

Temporal scale is scored on the basis of probable frequency (how often is the event likely to occur?) using the following guide:

Temporal Scale (=Likelihood) scoring					
	Rare	Unlikely	Possible	Likely	Almost certain
Score	1	2	3	4	5
Description	Occurs only in exceptional circumstances.	Could happen, but not often expected.	Expected to occur about half the time.	Probably occurs under most circumstances.	Expected to occur in most circumstances.

Spatial scale is scored on the basis of how geographically widespread the event is expected to occur, using the following guide:

Spatial Scale level scoring					
	Insignificant	Minor	Moderate	Major	Catastrophic
Score	1	2	3	4	5
Description	Effect is highly localised and probably not detectable.	May affect one or two centres of production on the EC.	Expected to affect two or three of the major centres of production throughout Queensland	Likely to affect most East Coast and GoC stocks/fisheries	Widespread effect highly probable, with influence extending to all Australian mud crab resources/fisheries.

Knowledge Uncertainty is not used directly in the estimation of risk, but is a useful indicator of how robust (or rubbery) our risk values might be. This quantity should be scored thus:

Knowledge Uncertainty scoring					
Score	1	2	3	4	5
Description	Very well documented and described. Available information considered excellent, with expert agreement.	Processes described and documented. Good information available, verified by expert input.	Limited information, but strengthened by expert knowledge. Differences of opinion exist.	Primarily perception-based, but some isolated supporting information exists.	Based only on perception. No information to support opinion.

Management Challenge is also not used directly, but it will provide some guidance on the likely capacity of current and projected management arrangements to address the issue or satisfactorily manage the risk.

Management Challenge scoring					
	Excellent	Good	Satisfactory	Poor	Unsatisfactory
Score	1	2	3	4	5
Description	Systems already in place capable of mitigating the risk	Systems in place for risk mitigation. Improvement opportunities have been identified but not yet actioned.	Adequate provisions are in place to manage the risk.	Risk management system has been subject to major change or is in the process of being implemented. Effectiveness cannot be confirmed.	No system or process currently exists (or is being planned) to manage risks of this type.

Appendix 4 Mud Crab State fishery situation statements

4.1 Northern Territory (Mark Grubert)

4.1.1 History of fishery

The commercial Northern Territory (NT) Mud Crab Fishery was formally established in 1980, with 61 licences issued and no restriction on pot numbers. Licence numbers peaked at 112 in 1982 but were capped at 55 in 1985, at which point the number of pots per licence was set at 60 (with no change since); Darwin Harbour and surrounding creeks were permanently closed to commercial crabbing; and a minimum legal size (MLS; i.e. 130 mm for both sexes) was imposed. The maximum number of licences was further reduced to 49 in 1998, where it has remained since.

It was not until the 1990s that the commercial harvest exceeded 200 tonnes (see table below). Berried female crabs were protected in 1993 and the MLS for females increased to 140 mm in 1996. The annual harvest increased rapidly through the late 1990's and peaked at 1139 tonnes in 2001. The decline in catch thereafter resulted in an increase in the MLS for commercially harvested mud crabs in May 2006 to 140 mm for males and 150 mm for females. The recreational MLS remains 10 mm below that of the respective commercial MLS.

Year	Catch (t)	Pot lifts	CPUE (kg/pot lift)	Pot days	CPUE (kg/pot
1990	134	464,620	0.29	9,283	14.45
1991	143	415,178	0.34	9,284	15.41
1992	193	519,588	0.37	9,285	20.76
1993	226	554,214	0.41	9,286	24.36
1994	199	625,282	0.32	9,287	21.43
1995	264	659,829	0.40	9,814	26.93
1996	573	880,644	0.65	11,328	50.56
1997	595	947,076	0.63	11,998	49.59
1998	528	1,042,877	0.51	13,030	40.55
1999	758	982,500	0.77	13,292	57.01
2000	1038	983,524	1.06	14,337	72.38
2001	1139	1,016,412	1.12	14,424	78.98
2002	739	1,066,160	0.69	15,373	48.09
2003	393	950,413	0.41	13,497	29.12
2004	425	953,660	0.45	13,606	31.24
2005	304	776,897	0.39	11,885	25.61
2006	266	680,179	0.39	10,628	25.02
2007	320	637,863	0.50	10,199	31.38
2008	412	678,794	0.61	11,122	37.05

The commercial harvest has increased every year since 2006 and is estimated to approach 600 tonnes in 2009. Effort during this period has been relatively stable, but of course the CPUE has increased.

There has been considerable spatial expansion and contraction in the fishery over the years as evident by fluctuations in the number of grids fished. There is also a strong negative correlation between the annual number of grids fished and CPUE since 1995 (Ward et al., 2007), indicating that fishers concentrate on a small number of highly productive grids when possible, then as catch rates fall, spread out in search of other productive areas.

4.1.2 Description of fishing grounds:

The NT commercial Mud Crab Fishery operates in tidal waters between the Queensland and Western Australian borders, with most activity concentrated in the Gulf of Carpentaria. Some fishers also operate along the North Arnhem coast, Van Diemen Gulf, Chambers Bay, and the west coast down to the Victoria River region. Crabbing operations are confined to coastal and estuarine areas, predominantly on mud flats. Commercial crab fishing is not permitted in Darwin Harbour, most creeks adjoining Shoal Bay, Leaders Creek and the waterways of Kakadu National Park.

Most recreational, Indigenous and Fishing Tour Operator (FTO) effort is concentrated around population centres. For example, Coleman (2004) reported that 74% of the recreational catch of mud crabs occurs in the Darwin Harbour/Shoal Bay area.

4.1.3 Quantity and value of catch:

In 2008, the NT commercial mud crab sector caught 412 tonnes, valued at more than $8.24 million. The value of the harvest has been as high as $10-12 million in some years.

Parallel surveys in 2000/01 highlighted the importance of the mud crab resource to recreational and Indigenous fishers who harvested 82 000 and 86 500 crabs (with a combined weight of about 135 tonnes) in a 12-month period, respectively (Henry and Lyle, 2003). The mud crab harvest by FTO clients is relatively small, in the order of 700-900 crabs per annum.

4.1.4 Type of operation:

Commercial mud crab fishers in the NT typically use 4 to 6 metre aluminium vessels powered by four stroke outboard motors between 100 and 150 hp. These vessels may be open or semi-enclosed with forward or tiller control.

4.1.5 Markets

Mud crabs are premium seafood, with strong demand for live product from the Sydney and Melbourne markets. Live mud crabs are transported to Darwin from around the NT coast (at least weekly) then cleaned, sorted by size, sex and condition, and air freighted to southern markets. Northern Territory mud crabs have previously been exported to Singapore, China and the United States of America.

4.1.6 Management philosophy and regulations:

The management objective for the NT Mud Crab Fishery is to ensure the continued sustainability of the fishery. This is achieved through input controls, gear limits and size limits (see “History” section for details). There are some spatial closures (which usually apply to all commercial fisheries) but no temporal closures. Pots must be <0.5 m3 in volume and no more than 1 metre in any one dimension (all sectors). Commercial crabbers must only use pots with a mesh size no less than 45 mm high x 60 mm wide.

Management arrangements for the commercial sector will soon be changed to enable unitisation of the fishery. Many fishers believe that running one 60 pot licence is not profitable but running two (i.e. 120 pots) is too difficult and expensive. They consider that checking 90 pots is both achievable and profitable. Under the new scheme, each existing 60 pot licence will become two 30 pot units (with no change in the number of licences). Fishers will not be allowed to operate with less than 60 pots (2 units) but will be able to lease multiples of 30 pots (1 unit) above this figure. Unitisation will be of most benefit to those who fish by themselves. It will also reduce the likelihood of over-potting, which has been a problem in the past. Penalties for over-potting will also be increased.

Recreational mud crab fishers are subject to the same gear controls (in terms of markings and dimensions) as commercial fishers and most use collapsible nylon mesh pots (as opposed to wire mesh pots used by industry). Dillies may also be used, but must not be made of entanglement material. A gear restriction of five pots (or dillies) per person applies, with a maximum of 10 pots per vessel (if two or more people on board). Mud crabs may also be harvested by a hand spear, hand-held hook, hook and line, hand net, cast net or drag net. Recreational catch and gear controls also apply to FTO clients.

4.1.7 Monitoring arrangements and procedures:

A commercial mud crab monitoring program has been in place since the early 1990s and is only made possible through the assistance of a number of mud crab fishers and processors. Almost all mud crabs caught in the Territory are transported to Darwin where Fisheries Group staff coordinate their monitoring activities with product delivery. Between 100 and 200 crabs (contingent on availability) are sampled from several regions on a monthly basis and information such as carapace width, weight, sex, and mating success is collected. This data is then summarised in annual status reports and used in regular stock assessments (see below).

An airline freight validation program was in place for over a decade and showed good agreement between commercial catches and freight records. However, the program was discontinued in 2008 due to its time consuming nature and low priority status.

4.1.8 Assessment arrangements and procedures:

Stock assessments of the NT Mud Crab Fishery are conducted at intervals of no more than four years (e.g. 1997, 1999, 2000, 2004 and 2007). Most assessments have involved an independent fisheries scientist (from interstate or overseas) working in conjunction with the Fisheries Group of DRDPIFR.

In the most recent assessment, Ward et al. (2007) examined the effect of the 10 mm increase in the MLS for the commercial sector (which came into effect on 1 May 2006) using data to

December 2006. Their analyses suggested that a 10 mm increase was warranted and protected approximately four times as many small crabs as a 5 mm increase in MLS. They also stressed that, at the time, insufficient time had elapsed since the increase in the MLS (i.e. just eight months) to detect any change in recruitment. A more appropriate interval would be 18-24 months (in line with the life history of the species).

4.1.9 Research work current, recently completed or proposed:

The Fisheries Group of DRDPIFR has an active mud crab research program with several individual and/or collaborate projects recently completed, underway or planned. Completed projects include the "2007 Mud Crab Workshop: Revision of the National Strategy for Mud Crab Research" (Grubert et al., 2008); "Use of a durometer to differentiate between soft- and hard-shelled mud crabs (*Scylla serrata*)" (manuscript submitted to Asian Fisheries Science); and "Ageing of mud crabs (*Scylla serrata*) using lipofuscin" (on hold and unpublished).

The latter study suggested that lipofuscin volume fraction was not correlated with age in *Scylla serrata*. However, recent works on other *Scylla* species have reported a positive correlation. We now consider that high temperatures (30-35ºC) during storage may have lead to lipofuscin degradation and we will repeat the trial using different methodology if and when resources allow. Current projects include "Evaluating the environmental drivers of mud crab (*Scylla serrata*) catches in Australia" (in conjunction with Griffith University and others); "A collaborative recruitment forecasting programme for the Northern Territory Mud Crab Fishery" (a partnership with the NT Seafood Council); and "Improving the accuracy of effort estimates in the NT Mud Crab Fishery" (using temperature and depth dataloggers). The 2009/2010 Recreational Fishing Survey will also provide estimates of the recreational catch and harvest of mud crabs (results due late 2010).

The Fisheries Group has also recently submitted a collaborative FRDC proposal entitled "Improving gear selectivity in Australian mud crab fisheries" which aims to reduce the retention of undersized mud crabs and non-target species through the use of escape vents or different mesh sizes.

4.1.10 References:

Coleman, A. P. M. (2004). The National Recreational Fishing Survey: The Northern Territory. Fishery Report 72. Northern Territory Department of Business, Industry and Resource Development. Fishery Report No. 72.

Grubert, M. A., Brown, I. W., Gribble, N. A. and Neville, D. (2008). 2007 Mud Crab Workshop: Revision of the National Strategy for Mud Crab Research. Northern Territory Department of Regional Development, Primary Industry, Fisheries and Resources. Fishery Report No. 93.

Henry, G. W. and Lyle, J. M. (2003). The National Recreational and Indigenous Fishing Survey. FRDC Project 99/158. NSW Fisheries Final Report Series No 48.

Ward, T. M. Schmarr, D. W. and McGarvey, R. (2007). Northern Territory Mud Crab Fishery: 2007 Stock Assessment. Report to Northern Territory Department of Primary Industries and Mines. SARDI Research Report Series No. 244.

4.2 Queensland (Phil Gaffney and Anna Garland)

Mud Crab Fishery profile 2008	
Species targeted Mud crab (*Scylla serrata*)	**Fishery season** All year round
Total harvest from all sectors Approximately 1676 t[i]	**Commercial licences active in 2008** 531 as of December 2008[ii]
Commercial harvest 1025 t	**Commercial licences accessing the fishery in 2008** 431
Recreational harvest (2005) 638 t	**Fishery symbol** C1
Indigenous harvest (2001) 12 t[iii]	**Monitoring undertaken** Commercial logbooks (CFISH), fishery independent monitoring
Charter harvest 1.2 t	**Accreditation under the EPBC Act** Expires 21 August 2012
Commercial Gross Value of Production (GVP) Approximately $16.4 million	**Logbook validation** Yes–completed May 2007
Sector contribution to total catch Predominately commercial	**Quota managed** No

Comment: Mud crab will be assessed as a part of the QPIF stock status reporting program roll out in 2009–10.

Table 1 History of the Queensland commercial mud crab fishery – catch & effort statistics.

Year	Licences	Days	Catch (t)	CPUE (kg/day)
1998	436	30909	676	21.19
1999	448	37057	838	22.62
2000	464	39574	1035	26.14
2001	488	39452	1029	26.09
2002	481	40753	1014	24.89
2003	499	48934	1149	23.49
2004	496	46701	1178	25.22
2005	424	40412	969	23.97
2006	425	39557	983	24.86
2007	423	38413	963	25.06
2008	431	38002	1025	26.97

[i] Total harvest estimate for 2008 includes the recreational harvest estimate from 2005, based on the assumption that the subsequent years of catch would be similar.

[ii] Approximately one third of C1 licences have been removed through the ongoing latent effort process.

[iii] The indigenous estimate is derived from the 2000-01 National Recreational and Indigenous Fishing Survey (NRIFS). There are no indications to suggest that harvest levels will have changed significantly between 2001 and 2008.

4.2.1 History of development and management of the Fishery

Crabs comprised an important dietary component for aboriginal communities along the Queensland coast before and after European habitation. The earliest records of European involvement in the crab fishery date back to the establishment of the penal settlement on the shores of Moreton Bay in the 1820s. Convicts caught crabs along with other marine animals to supplement food production in the settlement. The subsistence harvesting of crabs soon developed into small-scale commercial operations during the latter part of the 19th century, first in Moreton Bay and then beyond, to cater for the needs of Queensland's expanding population. By the turn of the century a recognised crab fishery had emerged.

A range of management measures has evolved over the life of the mud crab fishery to provide restraints on fishing effort and to ensure sustainable management of the mud crab resource and its habitat. A timeline of the history of the fishery and the management arrangements introduced is provided in Table 2 **Historical timeline of the Queensland Mud Crab Fishery management arrangements**.

Table 2 Historical timeline of the Queensland Mud Crab Fishery management arrangements

Time Frame	History and management
Pre-European settlement	Aboriginal communities harvested mud crabs for subsistence needs.
1820s	Convicts caught crabs on the shores of Moreton Bay along with other marine animals to supplement food production.
Late 1800s 1890s Early 1900s	Small-scale commercial operations were established to cater for the needs of Queensland's expanding population. Growth extended beyond Moreton Bay to population centres along the coast. Minimum weight restrictions were introduced: 3 pounds (~ 1.4 kg) for male mud crabs and 10 pounds (~ 4.5 kg) for female mud crabs. A recognised mud crab fishery emerged.
1913	Harvesting female mud crabs was prohibited (this restriction continues to apply). The minimum weight restriction for male mud crabs was converted to a minimum size limitation: 5 inches (12.5cm) carapace width (CW).
1927	The minimum 'size' for male mud crabs was increased to 6 inches (15cm) CW (this restriction continues to apply).
1976	Where the carapace of a crab is damaged alternative underside measurements must be used: 4.6cm from joint of the claw to the joint of the last walking leg (this restriction continues to apply). The possession of crab meat and claws separate from carapace was prohibited
1984	Limited entry arrangements were introduced into the commercial mud crab fishery. Gear and in possession limits were implemented in the recreational fishery: a maximum of four apparatus and an in possession limit of 10 legal size male crabs.
1991	A limit of fifty crab pots was introduced for each commercial fishing operation. Previously this limit applied to each licensed master fisherman involved in the operation (this restriction continues to apply).
2008	Policy process to remove latent effort in the fishery

4.2.2 Fleet size

Table 1 above.

4.2.3 Description of fishing grounds

The Queensland Mud Crab Fishery occurs in all waters adjacent to the State of Queensland, including the waters of the east coast of Queensland and waters of the Gulf of Carpentaria (Figure 1). Effectively it covers the majority of Queensland tidal waters, except closed waters.

As of April 1999, waters of the Torres Strait were excluded from Queensland jurisdiction and managed collectively, by the Commonwealth, the State of Queensland and Torres Strait Island Communities through the Protected Zone Joint Authority.

Figure 1 Boundary and regional delineations of the Mud Crab Fishery.

4.2.4 Quantity and value of catch

The majority of mud crabs are taken commercially (61%), with just over a third of the total harvest retained by the recreational sector (38%). Compared with the harvest by the commercial and recreational sectors, the annual harvest of mud crabs by the Indigenous and charter sectors is considered very low (less than 1%).

4.2.5 Commercial Catch

Table 1 above

4.2.6 Recreational catch

Results from the 2005 Recreational Fisheries Information System (RFISH) diary survey indicates that approximately 638 000 mud crabs were harvested in 2005 and approximately 2.3 million mud crabs were released (Table 3). These estimates equate to a recreational harvest of approximately 638 t – a decrease from the 2002 estimate of 874 t. The recreational harvest represents approximately 41% of the estimated total annual harvest of mud crabs.

The 2001 National Recreational and Indigenous Fishing Survey (NRIFS) (Henry and Lyle 2003) indicated that Queensland recreational fishers take the largest proportion of the national mud crab

harvest at 71%, and that they primarily used pots and traps to harvest mud crabs. QPIF are currently planning a state-wide recreational survey that will provide accurate recreational catch estimates.

Table 3 Recreational catch of mud crab estimated from RFISH surveys (Source: DPI&F RFISH database 14 April 2008). Note: these figures do not include estimates of apportioned 'unspecified' crabs.

Statistic	1999	2002	2005
Number caught (millions)	3.512 ± 7.1%	3.880 ± 7.1%	2.762 ± 7.4%
Number released (millions)	2.518 ± 6.9%	3.006 ± 7.6%	2.124 ± 7.9%
Number retained (millions)	0.993 ± 6.9%	0.873 ± 6.3%	0.638 ± 7.4%
Estimated weight retained (tonnes)	993	873	638

4.2.7 Indigenous catch

The Indigenous harvest of mud crabs across northern Australia was estimated as part of the NRIFSiv. In 2001, an estimated 12 000 mud crabs were harvested by indigenous fishers from within the north Queensland communities surveyed. These estimates equate to an indigenous harvest of approximately 12 t. Such harvest levels would represent less than 1% of the estimated total annual harvest of mud crabs for the 2006 season. The main fishing methods used by indigenous fishers were found to be hand (58%) and spear (27%) fishing. There have been no updates to the survey and it is assumed that indigenous harvest has not altered significantly between 2001-08.

4.2.8 Type of operation

Crabs are taken in baited pots in estuary or near shore coastal waters, with pots usually checked on a daily basis. Pots are mostly collapsible trawl mesh pots, however some fishers use rigid wire pots.

The majority of boats operating in the fishery are usually small (<6m) and usually undertake day trips. A small number of larger commercial boats work in remote areas of the State, with product being flown out or transhipped to port via mother boats .

4.2.9 Markets

The majority of mud crabs are sold to local and interstate markets and are an important 'icon' species to the tourist and hospitality trade. There is a small live export trade to Asia from northern Queensland centres. Most often, the crabs are sold whole; either live or cooked and chilled. Fishers were paid between $10/kg and $20/kg for mud crabs in 2008 depending on the quality and

[iv] GW Henry & JM Lyle *The National Recreational and Indigenous Fishing Survey*, FRDC Project No. 99/158, Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, Australia, 2003.

availability of the product, the time of year and the product form. The average price paid to fishers was $16/kg.

4.2.10 Management arrangements and regulations

Queensland Primary Industries and Fisheries (QPIF), manages the Queensland Mud Crab Fishery in accordance with ecologically sustainable development (ESD) principles. The fishery is managed under the Queensland Fisheries Act 1994 and in accordance with the Queensland Fisheries Regulation 2008.

A range of input and output controls are in place to manage the harvest of mud crabs by commercial and recreational fishers (Table 4), including:

- a minimum legal size limit that applies to both commercial and recreational fishers (150 mm carapace width)
- a prohibition on taking female crabs
- apparatus restrictions (50 pots per licence for the commercial fishery and four pots per person for the recreational fishery)
- limited entry to the commercial fishery (C1 endorsement required)
- prescriptions on the size of the float that may be used
- closures (Eurimbula Creek and all adjoining waterways are closed to the harvesting of mud crabs, along with closures enforced through marine park zoning established under the Australian Government Great Barrier Reef Marine Park Act 1975 and the Queensland Marine Parks Act 2004).

Commercial operators are permitted to use traps and crab pots (with rigid or collapsible frames). In addition to pots and traps, recreational fishers are also permitted to use dillies.[v] Crab pots are defined as a fishing apparatus comprising a cage; dimensions of the pots vary but most are cylindrical and have two entrance funnels. Mud crabs are enticed into the pot or trap by bait attached to the inside of the apparatus. The most common baits used include fish and fish frames; however other meat and bones are also used. Both commercial and recreational mud crab fishers employ a similar technique when fishing with pots or traps. Pots are set on the substrate, generally in estuarine or near-shore coastal areas, and are checked daily or on each rising tide. The pots are hauled by hand to a dinghy or small boat, checked for mud crabs, rebaited, and then reset. When checking for mud crabs, the current management arrangements for the Queensland Mud Crab Fishery require that all undersize and female mud crabs are immediately returned to the water at the point of capture.

Consultation with stakeholders in this fishery occurs through many mechanisms:
On a strategic level the Queensland Fisheries Management Advisory Committee (QFMAC) considers the Mud Crab Fishery in the context of all Queensland fisheries and prioritises issues associated with it accordingly. Once fisheries management priorities have been determined, the department may establish a small number of Technical Advisory Groups (TAGs) to provide technical information that will assist QPIF to pursue these priorities (which may or may not impact the Mud Crab Fishery).

The Department may also establish technical working groups to generate information upon which to base decisions. These groups may be permanent or adhoc and can be fishery-specific or

[v] Inverted dillies or ‘witches hats’ are currently being phased out, and will be prohibited by April 2010.

broader. They may be established to provide advice to the Department or to inform the decisions of a body such a QFMAC.

The department consults directly with industry members through attendance at industry association meetings, port visits, newsletters and by other means. There are also legislated requirements for consultation; such as Regulatory Impact Statements (RIS) that ensure stakeholders in the fishery are consulted about significant changes in management arrangements.

Table 4 Summary of current management arrangements for mud crabs in Queensland.

Management arrangement	Commercial fishery	Recreational fishery
Number of Fishers	Limited Entry	Unlimited
Taking female crabs	Prohibited	Prohibited
Minimum size limit	15cm carapace width	15cm carapace width
In possession limit	N/A	Not more than 10 per person
No. of apparatus	Not more than 50 per crab fishery symbol	Not more than 4 per person
Apparatus marking	Owner's name or primary commercial fishing boat marking	Owner's surname and address
Float marking	Owner's primary commercial fishing boat marking	Owner's address
Float size	15cm in all dimensions	15cm in all dimensions
Age limit on using crab apparatus	N/A	Must be 15 yrs or over
Use of crab hooks	Prohibited	Prohibited
Possession of crab meat	Prohibited	Prohibited
Possession of crab claws separate from body	Prohibited	Prohibited

4.2.11 Monitoring arrangements and procedures

All commercial fishers in Queensland have a legal obligation to provide information about their fishing activity through the use of compulsory daily logbooks. This information must be submitted at the end of each month, whether or not fishing has been undertaken. Fishers must include a daily record of the location fished, an estimate of mud crab caught (in kg), an estimate of other crab species caught (excepting spanner crab which is prohibited), the total number of pots used, the total number of pot lifts, and any interactions with threatened or protected species.

4.2.12 Fishery independent monitoring

QPIF has monitored the statewide population of mud crabs, Scylla spp. since 1999 (Department of Primary Industries and Fisheries, 2005). The primary objectives of the fishery independent monitoring program are to collect length, sex and catch rate data to be used in determining the population status of the species (Department of Primary Industries and Fisheries, 2005). Sampling is undertaken in areas of known high commercial harvest and areas close to large human populations (assumed high recreational harvest).

In 2007, a review of the monitoring program was undertaken instead of the regular sampling activities. In 2008, sampling was again undertaken with all regions sampled successfully.

Additional data (fishery dependent) were collected by asking selected commercial fishers to fill in monitoring logbooks. These logbooks aimed to collect numbers of retained and released Scylla spp., as well as other bycatch, on a weekly basis, for a period of two months before and after QPIF sampling activities. Refer to the 2009 Mud Crab Fishery Annual Status Report for further details and analysis.

4.2.13 Fishery assessments

An assessment of the QLD Mud Crab Fishery under the EPBC Act was completed in 2007. As a result of that assessment, the Delegate of the then Minister for the Environment and Heritage declared the QLD Mud Crab Fishery an approved Wildlife Trade Operation under Part 13A of the EPBC Act and included product from the fishery on the List of Exempt Native Specimens. Annual Status Reports are submitted to the Department of the Environment, Water, Heritage and the Arts and report on all aspects of the fishery, including actions being taken to ensure the fishery remains sustainable

4.2.14 Current research

A FRDC-funded project investigating the effect of climate variability on mud crab stocks is being carried out by Griffith University researcher Jan-Olaf Meynecke. While links between climate and mud crab stocks in Queensland have already been examined and published, this project will build on this information by incorporating Northern Territory fishery data and some updated Queensland data.

4.3 New South Wales (Steven Montgomery & David Makin)

Commercial fishers operating in the New South Wales (NSW) estuary general fishery harvested 99% of total reported commercial landings of mud crabs in 2007/08. The NSW estuary general fishery is a multi-species multi-method fishery involving 649 fishing businesses state-wide, of which 217 are endorsed to trap mud crabs. Commercial catches of mud crabs in the estuary general fishery (Table 5) are ranked in the top ten species by weight (kg) and top five species by value (GVP 2007/08 $2.9 million). Mud crabs are also an important recreational species in NSW.

Table 5 NSW reported commercial wild harvest of Mud Crabs (Source: I&I NSW ComCatch 27-10-09 extract)

Fiscal Yr	GVP ($'000)[1]	Tonnes	EG[2] (tonnes)	% EG Trapping[3]	% EG Meshing[3]
1997/98	$2,050	139	139	82	8
1998/99	$1,818	135	134	93	4
1999/00	$1,871	165	165	94	4
2000/01	$1,871	146	146	94	5
2001/02	$1,724	120	120	95	4
2002/03	$2,606	145	145	93	7
2003/04	$1,932	109	108	94	5
2004/05	$1,964	103	103	96	3
2005/06	$2,656	115	115	96	3
2006/07	$2,735	109	109	94	4
2007/08	$2,916	107	107	95	4

[1] GVP ($'000) = estimated gross value of product at first point of sale for reported landings based on Sydney Fish Market average monthly price for mud crab

[2] EG = Estuary General Fishery

[3] EG Trapping and EG Meshing is the proportion of the total NSW commercial wild harvest reported by these method groups.

4.3.1 History of fishery

Mud crabs probably have been caught by Europeans in New South Wales since first settlement and long before that by indigenous peoples. Until 1977 catches were recorded collectively with blue swimmer crabs. The most accurate data on catches are from 1997-98, when changes made to the Monthly Return Forms improved the quality of the data being reported by fishers. Annual reported landings fell in most years from 1999-00 until 2004-05 but have remained stable since. The value of the fishery has increased over the past three years (Figure 2). Commercial landings are greatest in the summer months and least over winter (Figure 3).

4.3.2 Description of fishing grounds

The catch is taken from the shallow waters within estuaries along most of the NSW coast by the estuary general fishery. The estuary general fishery is regionalised (Figure 4) with access to the fishery in each region being determined by meeting a minimum shareholding for that region. Commercial landings of mud crabs are dominated by catches taken in estuary regions one, two, three and four (Figure 5).

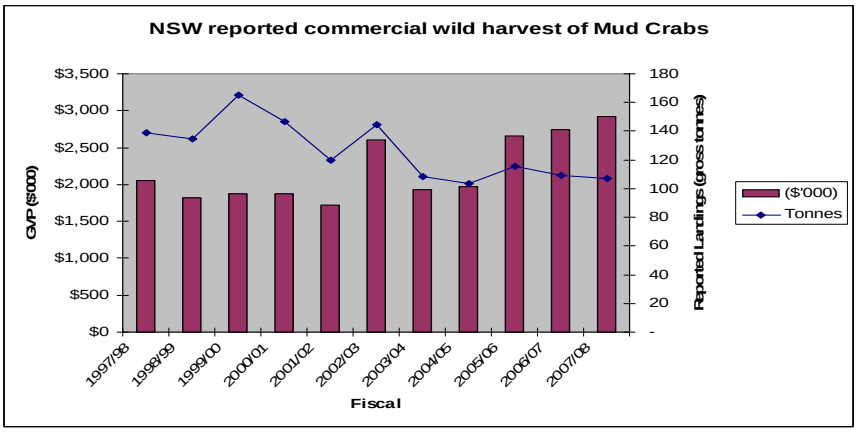

Figure 2 Annual reported commercial landings (tonnes) and value ($x000) of mud crab from NSW

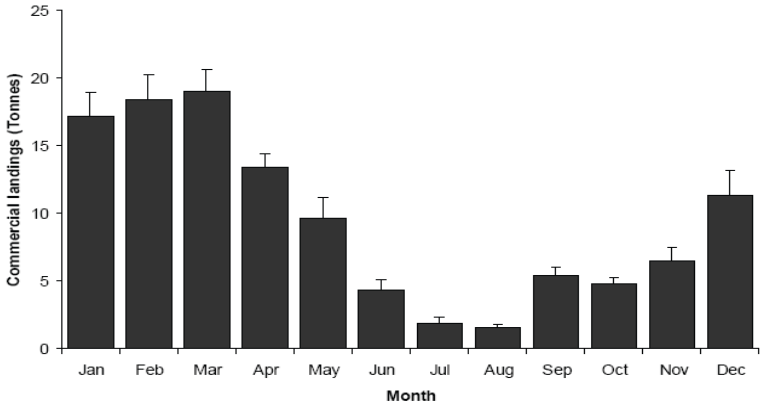

Figure 3 Mean (± SE) monthly reported commercial landings

4.3.3 Type of operation

Approximately 97% of the total commercial harvest of mud crabs in NSW is taken in traps. The remainder is bycatch in the flathead net fishery (Gray et al. 2004) and from the winter bottom set-net fishery (Gray 2002, Gray et al. 2005). Effort in the crab trap fishery is recorded on catch returns as the number of days fished. Total reported annual days fishing effort in the NSW mud crab trap fishery has ranged from 15,521 (2007/08) to 20,656 (1997/98) fisher days (Figure 6). From 2004/ 05 to 2007/08 the number of fisher days remained relatively stable whilst annual reported commercial landings has been stable since 2003/04, as has catch per unit effort (Figure 7).

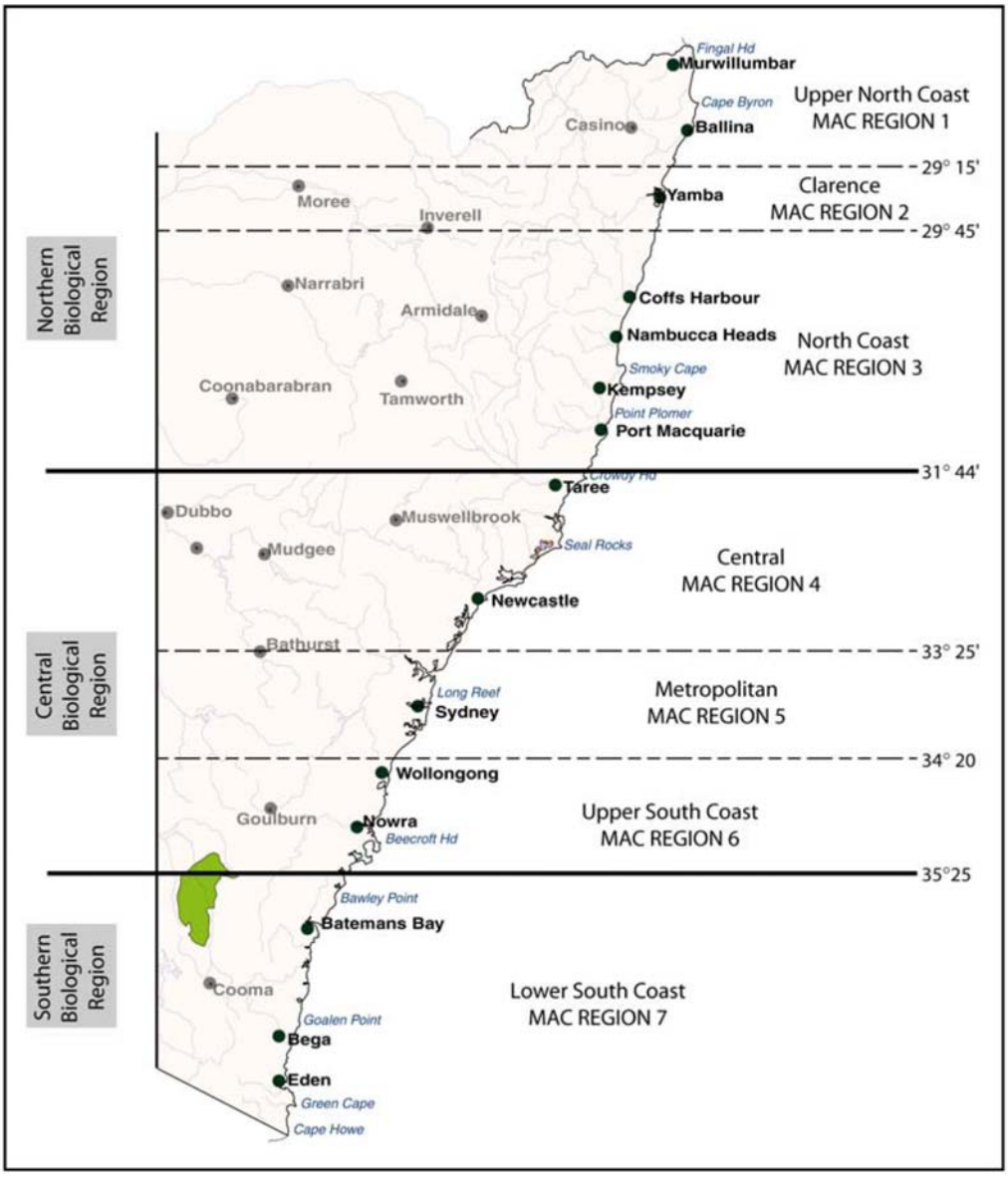

Figure 4 Map of NSW coast showing the seven regions used for zoning and the larger estuarine biological regions as defined by Pease (1999).

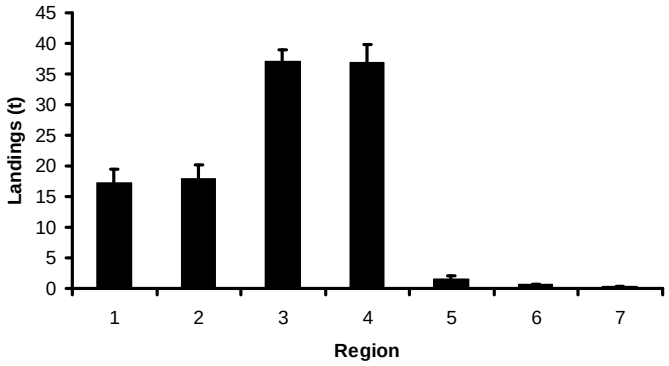

Figure 5 Five-year average reported landings of mud crabs for each of the seven management regions (see Figure 3). Standard errors are also shown.

Table 6 Number of Fishing Businesses having region specific shares and reported landings 2007-08 (Source: I&I NSW ComCatch 27-10-09 extract).

Region	FB with Mud Crab Trapping	Catch (t)
1	19	14
2	48	18
3	45	33
4	85	37
5	12	0
6	4	0
7	4	14

Tonnes: gross reported to nearest tonne

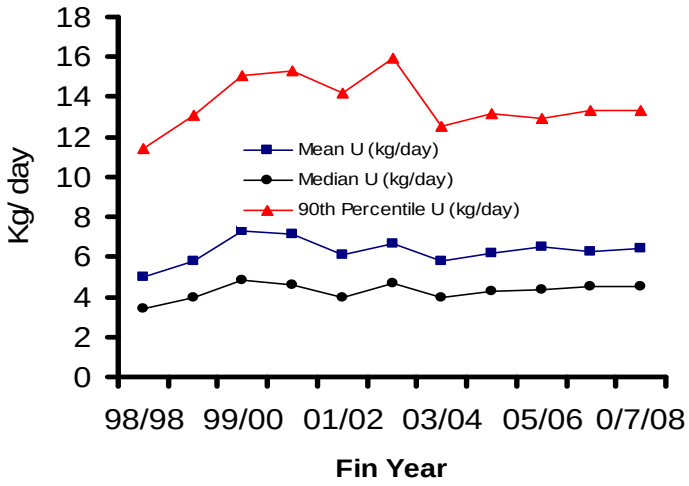

Figure 6 Reported commercial landings (line) and days effort (bars) in the NSW mud crab trap fishery.

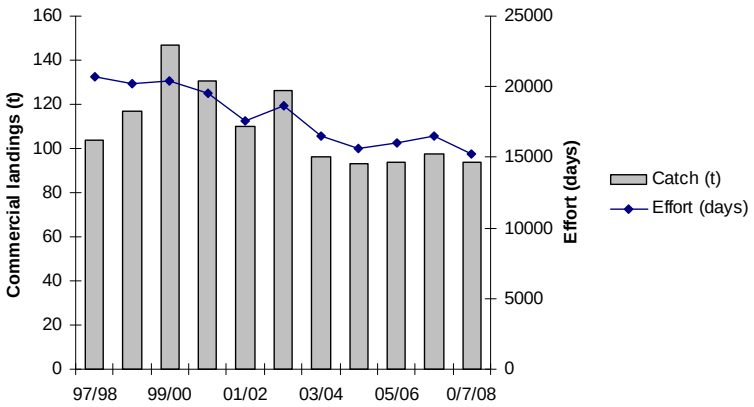

Figure 7 Commercial catch rates of mud crab harvested using crab potting for NSW. Three indicators are provided: (1) median catch rate from available monthly records; (2) sum of the catch divided by the sum of the effort; and (3) 90th percentile of the catch rate from available monthly records. Records with a zero catch rate (i.e no catch recorded are not included in the analyses (Source NSW DPI RAS)

4.3.4 Quantity and value of catch (commercial, recreational, indigenous)

Commercial: See above, for 2007/08 107 tonnes worth an estimated $2.9M at first point of sale

Recreational and indigenous catch: Data from the National Recreational and Indigenous Fishing Survey (Henry and Lyle, 2003) and onsite surveys undertaken by NSW DPI, suggest that the annual recreational harvest of giant mud crab in NSW is likely to lie between 30 and 60 t.

Illegal catch: Undefined, at approximately $27/kg on the legal market, compliance and anecdotal reports indicate that the illegal harvest for sale may be significant. In addition, theft of fishing gear also imposes a significant cost.

4.3.5 Markets (local, interstate, export; marketed product form)

Almost all the landings of mud crab in NSW are sold live to local markets. Prices in 2007-08 averaged over $27 per kg

4.3.6 Management

The mud crab fishery is managed by input controls. There has been a limited entry fishery since 1994. From February 2007 the NSW estuary general fishery became share managed. Share management provides a secure fishing access right for fishing businesses that hold shares and endorsements in a share managed fishery. Share management also provides a more flexible way to manage access to and harvesting from commercial fisheries. It also provides the necessary building blocks to improve industry viability and resource sustainability in the future. Management regulations applying to fishers harvesting mud crabs in the NSW estuary general fishery: commercial fishers harvesting mud crabs in NSW are restricted by input controls documented in the fisheries management act 1994 and the estuary general share management plan.

Input controls (commercial) include:

- A minimum legal size limit that applies to commercial and recreational fishers (85 mm carapace length)
- Prohibition on the taking of berried females
- Fishers operating traps are required to hold a trapping endorsement on their NSW commercial fishing licence. A trapping endorsement authorises the holder to mud crabs from estuarine waters within a region of the fishery using any of the following nets and traps: crab trap (maximum 10); hoop or lift net (maximum 10)
- Trap dimensions – not exceeding 1.2m in length, 1 meter in width and 0.5m in depth (or has a diameter not exceeding 1.6m at the top or bottom); consisting of mesh not less than 50mm; having not more than 4 entrance funnels none of which are on top of the trap (excluding any access doors for removing crabs from trap or baiting the trap).
- Recreational Fishing Havens and other Commercial Closed areas
- Marine Park Zoning (Marine Park Act 1997)

Input controls (recreational) include:

- Bag & size limits
- Minimum Legal Length (8.5 cm)
- Maximum Possession Limit (5)

- Maximum number crab traps (1) and (5) hoop or lift nets
- Prohibited to take or possess female crabs carrying ova
- Recreational closed areas
- Marine Park Zoning (Marine Park Act 1997)

4.3.7 Monitoring arrangements and procedures

NSW Mud crab research is restricted to port based monitoring (Richmond River, Clarence River and Wallis Lake) of commercial catches. Fishery dependent monitoring of sizes, sex ratio and catch rates is an effective way to monitor the trap fishery that enables changes in size/ sex structure of catches to be detected.

4.3.8 Assessment arrangements and procedures:

Scientist of the Wild Fisheries Program annually update data on catch, effort and catch per unit effort, size composition and any new biological information. This group then meets once per year together with representatives from QDPI&F and AFMA as the Resource Assessment Workshop (RAW) to review these information for more than 100 species and to determine whether a change in stock status is warranted. Then every two years this information is reported in 'Fisheries Resources NSW'. Any concerns with a species for the RAW annual review are referred to the Resource Assessment Review Committee (RARC) which comprises representatives from commercial and recreational fishing groups, the National Conservation Council, I&I NSW fisheries managers and scientists. If RARC agree with the concerns from RAW then the issue is passed on to the fisheries management division of I&I NSW.

4.3.9 Status of Fisheries Resources in NSW 2006/07

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/221012/Status-Of-Fisheries-Resources-In-NSW-2006-07.pdf
Giant Mud Crab - *Scylla serrata*
Status: Undefined
Could be susceptible to overfishing as NSW is the southern extent of their range, However there are no concerning trends in the fishery data.

4.3.10 Research work

We do no other research on mud crabs apart from monitoring and compiling these data together with catch and effort data for the most recent year.

4.4 Western Australia (Danielle Johnston)

4.4.1 History of fishery

The mud crab fishery is currently a small developing fishery in Western Australia with a total annual commercial catch of 6.5 tonnes in 2008. It is currently in an exploratory phase with a small number of commercial exemption holders (3) as well as aboriginal community exemption holders (3).

The mud crab resource is significant to the recreational and indigenous fishing sectors, although little data is available on recreational or customary fishing catch. The fishery has recently undergone a Developing Fishery Review in 2008 and the outcomes are being compiled.
It is understood that the majority of mud crabs caught in the fishery are green mud crabs (*Scylla serrata*), although due to the absence of this information in fishers' monthly (CAES) returns and the confusion over species identification it is possible that brown mud crabs (*Scylla olivacea*) may also be caught in relatively large numbers. One of the aboriginal communities, based on logbook returns, fish exclusively brown mud crabs however, again it is possible juvenile green mud crabs are also caught (and mis-identified as brown mud crabs).

Commercial fishing for mud crab in Western Australia commenced in 2003 with fishing generally occurring between March and November, with May-September fished consistently between years (with fishers avoiding the summer months due to poor conditions) (Figure 8). Catch was relatively low initially between 2003 and 2005 (ranging between 280 kg and 1142 kg) but increased significantly in 2006 to 10,651 kg (Figure 8). This was primarily due to substantial increases in effort (average increasing from 1790 potlifts in 2005 to 20,504 in 2006) and numbers of days fished (average increasing from 62 in 2005 to 204 in 2006). Catch per unit effort increased between 2003 and 2005 with greater knowledge of the fishery, but remained fairly constant between 2005 and 2006. Catch declined in 2007 to 5289 kg with a marked reduction in potlifts (6171) and approximately half the number of days fished. However, CPUE increased to its highest level to date at 0.86 crabs/potlift (Figure 8). Catch and effort for 2008 were slightly higher than 2007 with 6.5 t taken.

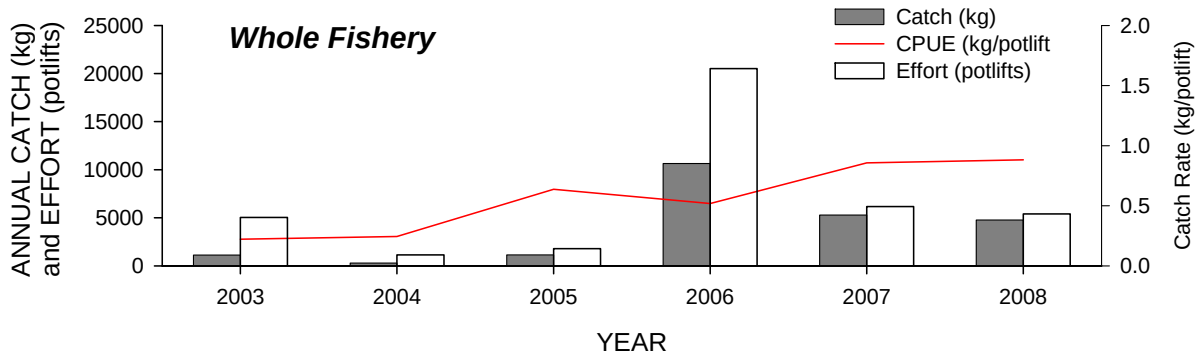

Figure 8 Catch and effort data for the Western Australian mud crab developing fishery, 2003 to 2008.

4.4.2 Fleet size

Six exemption holders: three commercial fishers and three indigenous communities.

4.4.3 Description of fishing grounds

Commercial fishing effort occurs in coastal and estuarine waters of the Kimberly region and is concentrated around York Sound, King Sound, Cambridge Gulf and Admiralty Gulf. Commercial operators generally fish on a part-time basis with the majority also operating other endorsements (barramundi licences, fishing boat charters).

The majority of commercial crabbing has occurred in York Sound with catches recorded in 2007 representing almost all the total catch taken for that year. Fishing in these waters has occurred in every year since the fishery commenced, whereas fishing has been relatively sporadic in other areas. Other important areas, in terms of number of years fished, has been Admiralty Gulf, however, catches have been relatively low. In contrast, relatively large catches have been taken in 2006 and 2008 in Cambridge Gulf, but no fishing has occurred in other years. King Sound has been fished the past 3 years in 2006, 2007 and 2008, although catches and CPUE have declined.

4.4.4 Quantity and value of catch

At present very little commercial and economic data is available as only one exemption holder fishes his licence consistently. Other exemption holders appear to have little interest in fishing (possibly due to the difficulties with fishing in such remote waters) and lease their entitlement to other operators. One aboriginal community, however, had been actively fishing and are reasonably good at submitting logbook returns. Based on the few data available, there doesn't appear to be large populations of mud crab in areas fished thus far. However, due to the vast distances of coastline and the remote location of this fishery, the logistical difficulties of operating in this region may have prevented good fishing areas from being located to date. Logbook data compliance continues to be a problem, with very few data submitted preventing an accurate assessment of mud crab stocks and their sustainability.

4.4.5 Type of operation

Mud crab fishers tend to fish remote waters for long periods of time in large motherships, using small dinghies to enter mangrove estuaries. Crabbers may travel vast distances to set pots and stay in the vicinity for several weeks before returning to unload catch. In this scenario, crabs are frozen and presumably sold to local markets. Alternatively, in the case of indigenous communities, they fish local mangrove estuaries in small boats (although details of fishing operations are not well known). Mud crabs are harvested using baited pots that are generally checked each daylight high tide. The majority of product is frozen (due to the length of fishing trips) and sold domestically, although live product may also be sold at premium prices.

4.4.6 Markets

See above. Mud crab are sold live and frozen to enable flexibility in sales targets and logistics. Current wholesale prices for live crabs are $25-$35/kg, frozen crabs return $25-$30/kg. The indigenous communities often use crabs in a barter system, rather than obtaining a dollar value.

4.4.7 Management philosophy and regulations

No spatial/seasonal closures or gear restrictions. Size limits for *Scylla serrata* (male and females150 mm CW) and *Scylla olivacea* (males and females120 mm CW). Ban on berried females. Recreational bag limits of 5 per person, or 10 per boat (2 or more people) (boat limit in King Sound is 20).

4.4.8 Monitoring arrangements and procedures

Compulsory CAES data collected and voluntary logbooks data (although poor compliance). No fishery independent monitoring. Sporadic basic analysis only.

4.4.9 Assessment arrangements and procedures

Infrequently. A recent review of the mud crab fishery was undertaken by the WA Department of Fisheries with submission to Developing Fisheries Review Committee in late 2008.

4.4.10 Research work current, recently completed or proposed:

There has been no fishery independent research undertaken on the mud crab fishery in Western Australia due to a lack of funding and resources devoted to this minor fishery. It is recognised that research funding is required to understand the basic biology and status of mud crab stocks in Western Australia. This is an issue that was highlighted in the recent Developing Fisheries Review. The mud crab is an iconic species in Western Australia and our lack of understanding of its biology and stocks needs to be rectified if scientists are to provide accurate and appropriate advice for effective future management.