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Review of the Sustainability of Fishing Effort in the Queensland East Coast Trawl Fishery

Queensland Government
Department of Primary Industries and Fisheries

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1 Executive Summary

The General Effort Review represents a comprehensive assessment, using available data and information, of the ecological sustainability of current levels of effort in Queensland's East Coast trawl fishery.

A comprehensive analysis of the sustainability of principal and permitted species indicates that overall the current levels of effort applied to these species in the Fishery Area are ecologically sustainable.

Significant reductions in effort in terms of days fished (approximately 40%) and effort units (approximately 32%) used in the fishery have been achieved since 1996 and the introduction of the Plan in November 1999. This reduction in fishing effort is mirrored by a significant reduction in the number of vessels in the fleet, from approximately 1400 licenced operators in early 1980's to 800 vessels at the introduction of the Plan to 520 as of May 2004.

The decline in boat numbers is considered a positive for the fishery as over capitalisation and an excessive number of licences were identified prior to the Plan as being negative in relation to long-term sustainability and viability.

A small degree of under-utilization of effort units occurs in the fishery. However, the majority of licence holders have used 100% of their allocation in at least one year since 1999. The under-utilisation of individual effort allocations is at acceptable levels (approximately 16%). The total amount of effort considered appropriate for the fishery is capped via the individual allocations; any unused effort represents a benefit to the fishery.

Since the introduction of the Plan (2000 to 2003) average boat size has increased. It is not considered to be a negative trend for sustainability of the fishery. The increase is primarily a result of a reduction in the number of vessels between 10 and 40 hull units (HU); it is not due to an increase in the number of larger vessels.

The majority of EUs have been transferred from medium to large boats. The total change in EU holdings within the fleet is not considered to be a reflection of adverse conditions for small operators.

Tracking temporal changes in effort creep is pivotal to effective management of the fishery to ensure the fishing effort remains sustainable. Current estimates put average "effort creep" between 0.2 and 1.6% per year since 1989, depending on the sector of the fishery. These estimates of effort creep are used in the stock assessments of principal species and to standardise Catch per Unit Effort (CPUE) estimates.

Significant changes in where effort is applied in the fishery have occurred from 1996 to present. An overall shift in effort away from the tiger/endeavour prawn, saucer scallop and banana and bay prawn sectors has occurred. This effort has moved into the eastern king prawn sector with a 6% increase in the proportion of total fishing effort from the ECTF after the implementation of the plan. Minor spatial changes within each major sector have also occurred primarily in response to small-scale spatial variability in productivity.

Model predictions for the eastern king prawn fishery indicated that eastern king prawn biomass was at or below a stable exploitable biomass from 1991 –1999, moving above the stable exploitable biomass in 2000-2001. A further assessment, incorporating 2002 and 2003 data should be completed before effort-based management of the EKP is considered. This assessment and subsequent development of management options should be completed in cooperation with NSW Fisheries. Alternative, or complementary management arrangements such as spawning closures should also be investigated.

The stock assessment model for saucer scallops advocates between 6,300 and 11,700 nights directed towards scallops depending on the model and management target used. In 2002, approximately 7,400 nights were used in the scallop sector, which is substantially lower than the historical average (approximately13,600 nights). Using the Beverton-Holt model above, a precautionary target of 3/4 EMSY would advocate a significant increase in allowable effort (approximately 1,400 nights).

Stock assessments of Tiger/endeavour prawn stocks in north Queensland were based on the results of the surplus production model. Both Tiger and Endeavour Prawn stocks were identified as fully exploited. However, these stocks should be re-assessed using a more dynamic model when the required biological data becomes available.

Stock assessments are not currently available for the remaining target species. It is considered that the biological data available for reef king prawns, bay prawns, black tiger prawns, Moreton Bay bugs and squid are insufficient to conduct a robust stock assessment for these species. Preliminary analysis of these species has not identified any sustainability concerns. However, the 70% cpue indicators identified in the Plan have been found inadequate for some species and need to be replaced with a more suitable assessment method.

Sustainability of the permitted fish was assessed using a 'Productivity – Susceptibility Assessment Process (PSA) adapted from previous models developed by the CSIRO. Although the PSA identified several species at 'True High Risk' and 'Probable High Risk' from trawling, the management arrangements currently in place are anticipated to offset any sustainability concerns. The PSA also identified data deficiencies for many of the permitted species leading to them being classified in higher risk categories.

The GER highlights the need for further research focused on the biology and ecology of the permitted species, continued refinement of existing stock assessments and the development of stock or fishery assessments for the remainder of the principal species in the fishery. The continued building of data and information on the principal and permitted species and bycatch in the fishery and continued refinement of fishing gear technology in particular BRDs is critical to the on-going ecological sustainability of the fishery.

As the understanding of stock dynamics improves, the DPI&F's ability to determine appropriate effort and or catch targets will be enhanced. Currently the management of effort in the fishery is at the scale of the entire East Coast with the exception of the cap in effort in the Great Barrier Reef World Heritage Area. The concept of single stock management, either via area based effort caps, species based effort caps or stock based endorsements, will form the basis of a two-year feasibility assessment of smaller scale management in the fishery. The DPI&F is committed over the next three years to the feasibility assessment. This assessment will be conducted through TrawlMAC and take into account the outcomes of stock assessments. DPI&F emphasises that this study will be a feasibility assessment and will be conducted over the next few years involving consultation with Industry and other key stakeholders.

The Plan has not introduced any form of effort management on the beam trawl fishery. Given the observed reduction in catch and effort, management intervention in this sector of the fishery does not appear to be a significant priority but requires continual review.

A qualitative analysis of bycatch indicated that the precautionary management measures in place are adequate to ensure that the impacts on the bycatch species in the fishery area are sustainable. A more comprehensive quantitative analysis may be available when the results of current research projects, in particular the Seabed Biodiversity Mapping Project due for completion in 2007, are published.

Overall, the economic section of the review indicates that profitability in 2002/03 was more positive than in years prior to the Plan. It is not possible to conclusively state the factors that have caused this result. More detailed modelling is required to determine the link between the reductions in effort and boats and increasing profitability in the remaining fleet.

The reduction in effort in the fishery has been significant and a major contributor to the current sustainability of the principal and permitted species and bycatch taken or impacted on by the fishery.

In 2000 the State and Commonwealth Governments implemented a structural adjustment scheme (buy-back) that removed 99 licenses from the fishery. This adjustment scheme involved a contribution of $10 million from each jurisdiction and an equivalent reduction in effort (5% of Effort Units) as the industry contribution. The adjustment scheme and the effort reductions resulting from boat replacements, licence transfers and effort unit transfers has resulted in the meeting of agreed and legislative effort reductions by the end of 2003. The agreed and legislative targets were a 15% reduction up front and an annual reduction that accounted for effort creep. Although the effort management system in the Plan has achieved its' intended purpose to date, it requires review in order for the system to be effective in the future and not impede effort trading within the industry.

2 Introduction

The *Fisheries (East Coast Trawl) Management Plan 1999* (the Plan) was first gazetted in November 1999 to consolidate aspects of trawl fishery management and provide a basis for further development of the fishery towards ecological sustainability and economic viability.

Since that time, the Plan has undergone significant review and change. There are several sections within the Plan that require formal reviews of the fishery. The first of these was the review of permitted fish (other than principal fish) that was completed by the QFS (now Department of Primary Industries & Fisheries (DPI&F)) in 2001. This General Effort Review (GER) is the second major review under the Plan.

2.1 Reason for the General Effort Review

The Effort Management System (EMS) that was introduced under the Plan in 2001 represents the single most significant management regime in the trawl fishery and probably the largest operational change in a fishery in Queensland's history. The EMS is discussed in detail below. Although the EMS was introduced following extensive consultation, negotiation and modelling, it represented a new direction for fisheries management in Queensland and was therefore surrounded with some uncertainty.

The GER represents a formal review of the current levels of effort resulting from the EMS. The purpose of the GER is therefore to allow the DPI&F to determine whether fishing effort in the fishery is ecologically sustainable.

2.2 Commonwealth/State Agreements regarding Fishing Effort

Immediately prior to the introduction of the EMS, the State and Commonwealth Governments implemented a structural adjustment scheme (buy-back) that removed 99 licenses from the fishery. This adjustment scheme involved a contribution of $10 million from each jurisdiction and an equivalent reduction in effort (5% of Effort Units) as the industry contribution.

Given the significant monetary investment, the appropriate management of fishing effort to achieve ecological sustainability was a focal point of negotiations at that time. The GER and any subsequent legislative amendments arising from the Review are intended to ensure that the initial reduction and subsequent management of effort are sustainable over the long-term.

2.3 Ecological Sustainability

"Ecologically Sustainable Development" (ESD) is defined in the Fisheries Act 1994 as:

"Using, conserving and enhancing the community's fisheries resources and fish habitats so that—
The ecological processes on which life depends are maintained; and
The total quality of life, both now and in the future, can be improved."

There are many tools in fisheries management that play an active role in assessing the impact that fisheries have on the sustainability of target and non-target species specifically and ecosystems in general. These include specific tools such as stock assessments and risk assessments as well as general principles for resource management such as the Precautionary Principle and intergenerational equity.

The Precautionary Principle is particularly important in fisheries as the assessment of sustainability impacts is often conducted in an information poor environment. The Precautionary Principal is defined in the Fisheries Act 1994 as:

"The principle that, if there is a threat of serious or irreversible environmental damage, lack of scientific certainty should not be used as a reason to postpone measures to prevent environment degradation, or possible environmental degradation, because of the threat."

The GER has collated available information to allow for an assessment of fishing effort against sustainability criteria, cognizant of the definitions above.

2.4 Objectives of the Review

Terms of Reference for the GER were developed by the DPI&F prior to the commencement of the Review. These terms of reference were subsequently reviewed and amended by the stakeholder steering committee.
Where practical the sustainability of species was assessed using (but not limited to) review events outlined in Schedule 2 of the Plan and in accordance with the principles of ecological sustainable development.

The terms of reference determine that the objective of the General Effort Review is to provide a fully comprehensive assessment of the ecological sustainability of principal and permitted species and bycatch impacted by the fishery and review the economic performance of the fishery since the introduction of the Plan. The review does not extend to the assessment of the sustainability of overall ecosystem functioning in the fishery areas due to the lack of available data.

2.5 Structure of the GER

The GER has been a comprehensive review of many aspects of the fishery. This report summarises the:

- Change in fleet profile since introduction of the Plan;
- Spatial change in fishing effort since introduction of the Plan in 1999; including changes in beam trawl fishing effort and changes in Moreton Bay fishing effort;
- Sustainability of principal species;
- Sustainability of permitted species;
- Sustainability of bycatch; and
- Economic performance of the fleet.

There are three levels of information reported in the GER. The first is the research material and published data that forms the basis of most of the information used in the Review. Citations and publications are listed in the 'Reference section' at the end of this report, for the purposes of transparency. It is anticipated that stakeholders will not need to refer to the majority of references, unless it is to gain a detailed understanding of the technical and scientific aspects of the GER.

This report is the second component of the GER. The Report represents a comprehensive analysis and summary of the available information. It is acknowledged that the GER Report is extremely comprehensive and at times complex, and may be challenging for some stakeholders to fully understand. This is a result of the technical nature of the issues that have been discussed. Every effort has been made to ensure that information presented in the report is correct and provided in sufficient detail.

Finally, a Discussion Paper that summarizes the issues covered by the GER has been developed. It is envisaged that the Discussion Paper will be of most value to the majority of individual stakeholders, while the GER Report may be of value to key stakeholder groups who are interested in the detailed analyses and methods used in the Review.

The discussion paper also contains several policy statements or recommendations at the conclusion of each section. These have been included to ensure transparency so that stakeholders can be clear as to the DPI&F's interpretation of the available information. These statements do not represent Government Policy and may be subject to change as more information, such as feedback from stakeholders becomes available through the consultation process.

2.6 Development of the GER

The Department of Primary Industries & Fisheries formerly the Queensland Fisheries Service (QFS) and the Agency for Food and Fibre Sciences (AFFS) have developed the GER Report and Discussion Paper. A stakeholder-based Steering Committee and the Trawl Management Advisory Committee (TrawlMAC) have overseen this process to ensure transparency and provided constructive comment that has enhanced the quality of the Review.

2.7 Consultation

The Plan states that if the Review concludes that fishing effort in the fishery is not ecologically sustainable, the Plan must be amended before 2006. The role of the GER Report and Discussion Paper is to provide information to managers and stakeholders on which to base consideration of management options. It is important to note that these documents are only the first stage in stakeholder consultation regarding any possible amendment to the Trawl Plan.

The DPI&F and TrawlMAC will consider feedback to the GER before recommending management changes. Stakeholders will be further consulted regarding proposals for legislative amendment through the Regulatory Impact Statement/Public Benefit Test process. In this way, it is envisaged that the management of the fishery can be progressed to achieve ecological sustainability in a manner that maintains economic viability of the catching and processing sector and ensure social well being.

3 Background on the East Coast Trawl Fishery

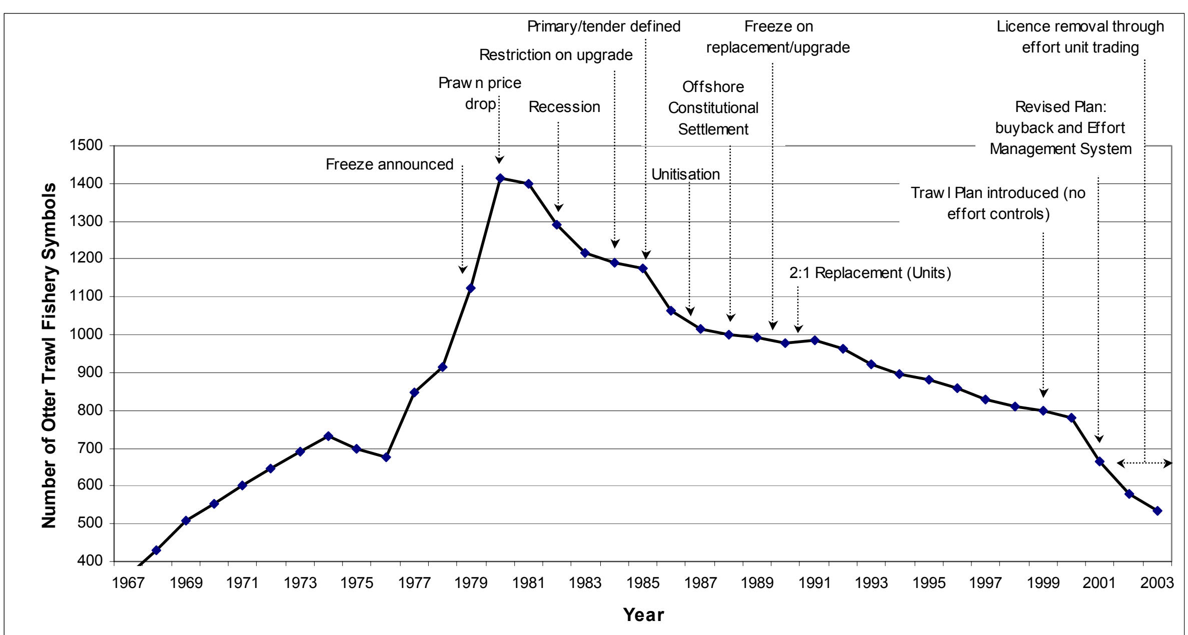
3.1 Changes in Fleet Profile – Otter Trawl

3.1.1 *Purpose*

The ECTF is a complicated fishery with vessel characteristics and fishing gear varying depending on the principal species being targeted. Any effective management arrangements need to take into account not only the temporal changes in the number of boats, their catch and effort but also any significant changes in fishing equipment.

3.1.2 *Changes in the number of vessels*

Significant changes in the number of otter trawl vessels licenced to operate in the fishery have occurred since the late 1960's (Figure 2.1).



Between the late 1960's and the early 1980's, licence numbers increased by over 250% to peak at just over 1,400 vessels (Figure 2.1). Management arrangements introduced since that time saw a reduction of approximately 30% in vessel numbers over a 10-year period.

Even with the reduction leading up to the early 1990's the number of licences and associated fishing effort in the otter trawl fleet were considered inappropriate in terms of long-term ecological sustainability and economic viability. The decreasing trend in vessel numbers due to management initiatives introduced prior to the Plan continued until 2000 when the first major amendments to the Plan were introduced.

A further reduction in vessel numbers of approximately 45% occurred between 1990 and 2003 (Figure 2.1). Licence numbers at the end of 2003 (527) were the lowest in over 30 years. Overall, the Plan has resulted in a reduction of about 33% in the number of licences. Interestingly, the structural adjustment scheme and the subsequent reduction in licences through effort trading have each been responsible for approximately half of this reduction, with the remainder resulting from licence holders surrendering their trawl endorsement after selling off their effort unit holdings.

3.1.3 *Change in size of vessels*

Figure 2.2 shows the variability in the distribution of Hull Units (HU) across the ECTF fleet. The post Plan HU distributions are marked by a modal shift towards vessels of larger holdings. Actual numbers of vessels in each of the HU classes have either decreased or remained unchanged. This restructure is in accordance with DPI&F policy expectations.

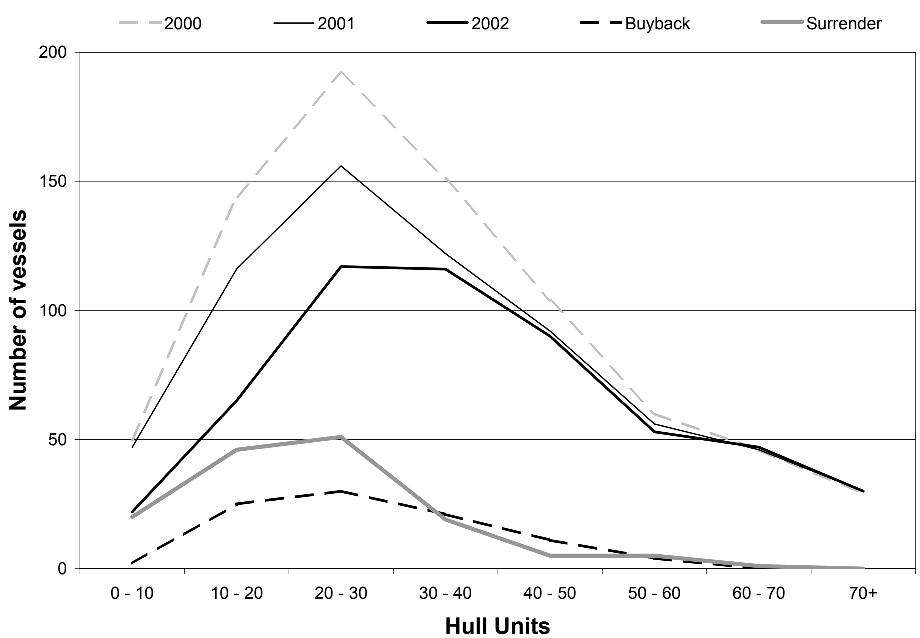


Figure 2.2. Changes in the hull unit profile of the fleet for vessels included in the buyback, licence and effort unit surrenders and for the years 2000 to mid-2003.

The modal shift in HU distribution was primarily caused by a reduction in the number of vessels in the HU classes between 10 and 40 HU. There have been a disproportionate number of vessels in these size classes removed from the fishery via the Buyback and through the process of licence holders surrendering the T1 fishery symbol after selling off their effort unit holdings (Figure 2.2).

The number of vessels in the 20-30 HU class decreased by approximately 60% between 2000 and 2002. Over the same period vessel numbers in10-20 HU class decreased by approximately 30%. Notably there has not been a commensurate increase in the number of larger vessels (>60 HU) since 2000. The observed changes in the HU profile of the fleet have purely been a result of the attrition of smaller vessels rather than the addition of larger boats.

3.1.4 *Technological development of the otter trawl fleet*

Methods

Data from this section were derived from two sources; the Fisheries Research and Development Corporation (FRDC) project number 1999/120: Reference point management and the role of catch-per-unit effort in prawn and scallop fisheries; and from the "Gear description forms" contained in the DPI&F OT08 Trawl fishery logbook, which was released in late 2002.

The data series on the types of devices and technologies adopted by fishers, and when they were adopted, was obtained from a purposely-designed survey of 344 past and present fishing vessel owner/operators selected randomly from the entire trawl fleet of 900 vessels that had fished during 1997 and 1998. The questionnaire considered a number of different vessel characteristics thought to affect fishing power. The 344 interviews represented a response rate of 85% of the 406 operators who were initially contacted. Overall, the sample included vessels that collectively accounted for about 40% of each sector's total catch between 1989 and 1999.

It is important to note the further back in time that the project sought information from licence holders through the interviews, the less reliable the information was likely to become. The reason for this was because the early observations (those prior to 1970) were based on the recollections of a very small number of operators who were still available for interview, and also due to a less precise recollection over time. Observations from more recent years (i.e. 1980-2000) were likely to be more accurate because they were based on larger sample sizes (i.e. more interviewees) and presumably, more accurate recollections.

These data were supplemented for 2003 by returns from the "Gear description forms". At this stage the gear data from this source are only indicative of the fleet in 2003, but will become a useful tool for tracking changes in the fishery as fishers are required to submit a new form when significant changes are made or when they start a new logbook.

Rates of change for certain technologies have been calculated by fitting a linear regression of the parameter with fishing year as the independent variable. The rate of change was then taken as the fitted regression coefficient. Technologies included in this section were based on those found to have a significant effect on catch rates by O'Neill et al (In Press). As mentioned previously, data prior to 1970 is thought to be less reliable and has been excluded from the analyses. The rate of change has been calculated for the three main sectors (eastern king prawn, scallop fishery and the northern tiger/endeavour) of the East coast trawl fishery (ECTF) over the last 30 years. It also compares and contrasts the three main sectors.

Results

Propeller Nozzles

The adoption of propeller nozzles has continued at a steady rate throughout the fishery after first being introduced in the late 1970's. The rate of adoption was comparable between sectors being adopted at a rate of 2% of the fishery per year ($P < 0.001$, $R^2 = 0.98$). The 2003 values in the time series seen in Figure 2.3, which are the only data points after the implementation of the Plan, indicate that the post plan rate of uptake of propeller nozzles in the ECTF have continued as per the pre plan trends.

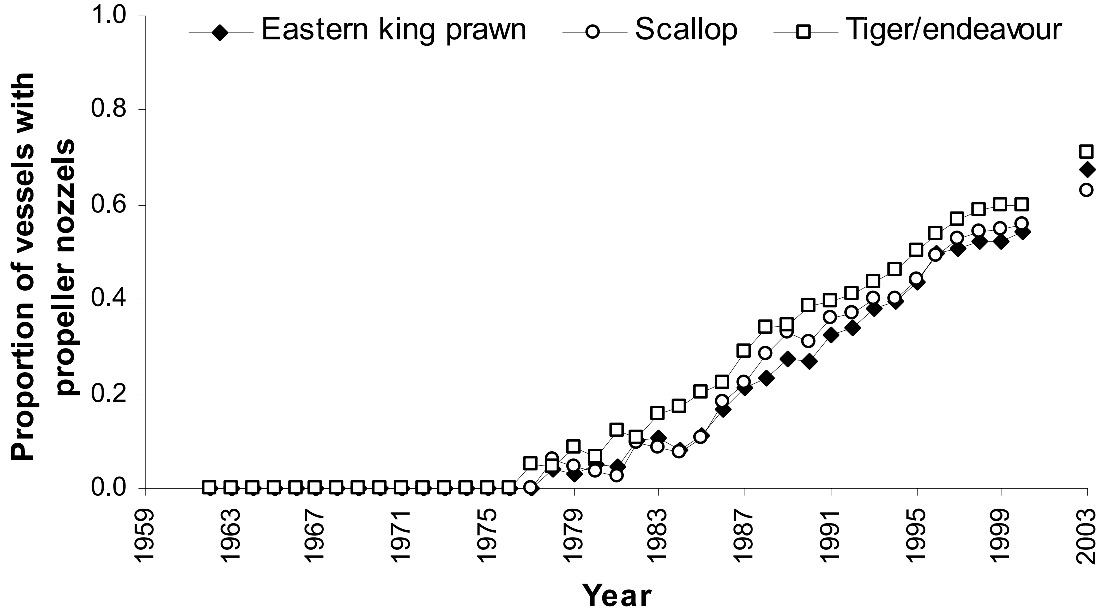


Figure 2.3. Long-term trends in the proportion of vessels using propeller nozzles in the ECTF.

Currently, 67% of vessels are using propeller nozzles across the entire ECTF, 67% in the eastern king prawn sector, 63% in the scallop sector and 70% in the tiger/endeavour prawn sector.

Try gear

Try gear began to be adopted in the tiger/endeavour prawn sectors in the late 1970s; by 1988 it was used on about 50% of vessels (Figure 2.4). By 2000 about 71% of vessels in the tiger/endeavour prawn sectors reported using the device.

The adoption of try gear in the scallop and eastern king prawn sectors occurred later and by 1984 it was still only used by about 5% of vessels. Since then there has been a steady increase in usage with about 64% of vessels in the scallop and eastern king prawn fisheries using try gear in 2000.

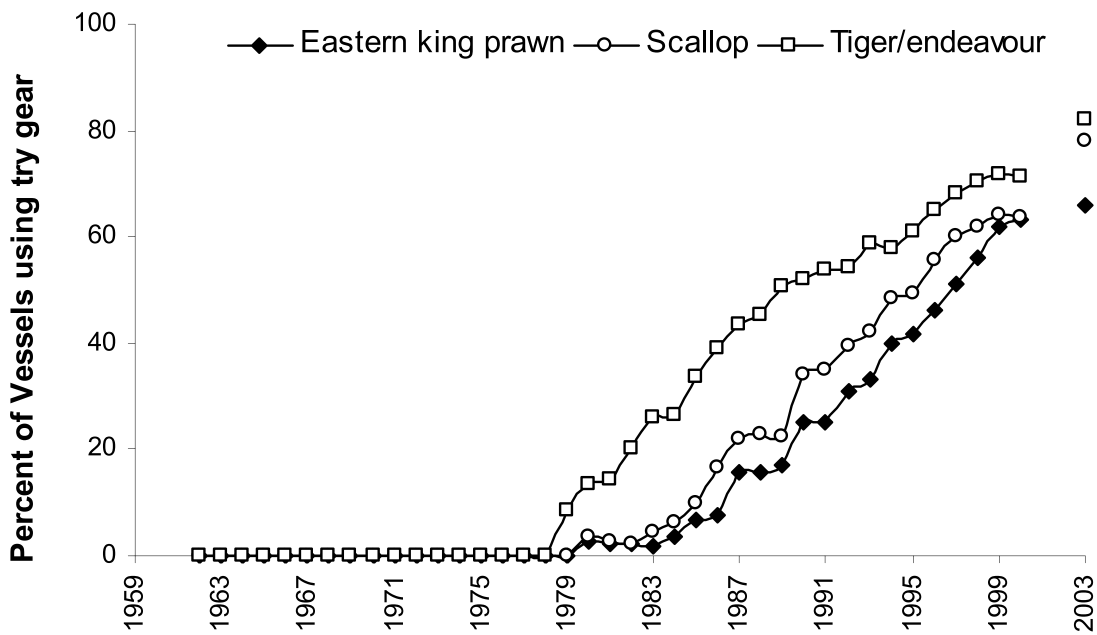


Figure 2.4. Long-term trends in the proportion of vessels using try gear in the ECTF

The rate of adoption of try gear across the entire ECTF was 3% per year ($P < 0.001$, $R^2 = 0.99$). Vessels have been adopting try gear after the implementation of the plan, with the rate of uptake higher in the tiger/endeavour prawn and scallop sectors (Figure 2.4). In 2003 73% of fishers in the ECTF reported using try gear, 66% in the eastern king prawn sector, 78% in the scallop sector and 82% in the tiger/endeavour prawn sector.

Propeller Pitch and Diameter
The average propeller pitch and diameter in the ECTF have displayed steady increases from the early 1970's onward. Average propeller pitch increased at a rate of 0.43 inches per year ($P < 0.001$, $R^2 = 96\%$) in the eastern king prawn, 0.39 ($P < 0.001$, $R^2 = 93\%$) inches per year in the scallop and 0.44 ($P < 0.001$, $R^2 = 97\%$) inches per year in the tiger/endeavour prawn sector. Data for 2003 indicate that this steady rate of increase is being maintained after the implementation of the plan with an increase in all sectors between 2000 and 2003 (Figure 2.5).

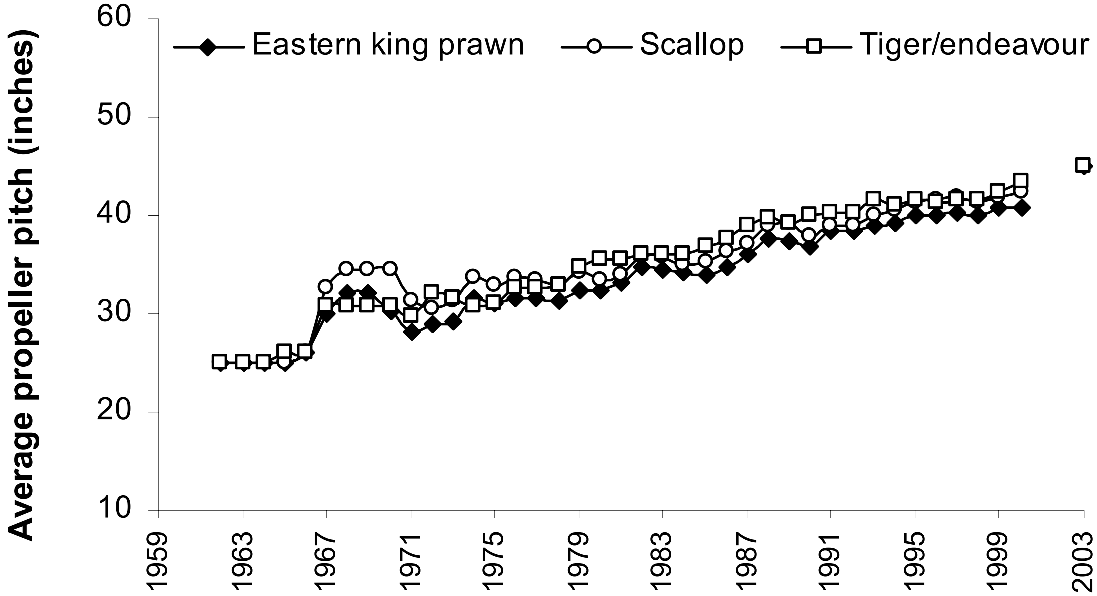


Figure 2.5. Average propeller pitch by sector in the ECTF.

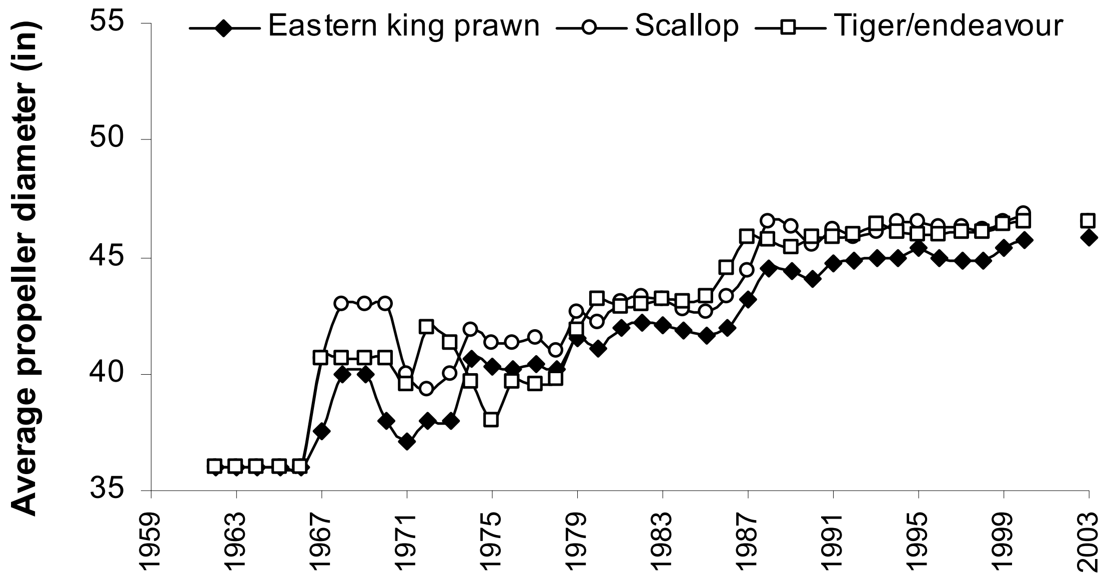


Figure 2.6. Average propeller diameter by sector in the ECTF.

Average propeller diameter increased at a slightly lower rate than propeller pitch. Average propeller diameter increased at a rate of 0.25 inches per year ($P < 0.001$, R^2 = 92%) in the eastern king prawn, 0.23 ($P < 0.001$, R^2 = 84%) inches per year in the scallop and 0.25 ($P < 0.001$, R^2 = 82%) inches per year in the tiger/endeavour prawn sector. Data for 2003 (shown in Figure 2.6) indicate that this steady rate of increase has halted after the implementation of the plan with no marked increase in any sector between 2000 and 2003.

Trawl speed

Trawl speed displayed the largest difference between sectors of all the parameters measured. This reflects the changes in fishing techniques and equipment used to target each major species in the ECTF since the early 1970's (Figure 2.7). The rates of increase for each sector are shown in Table 2.1. The tiger/endeavour prawn sector displayed a significantly higher rate of increase in trawl speed compared to the other two sectors with the scallop vessels displaying the lowest rate of increase of the three sectors.

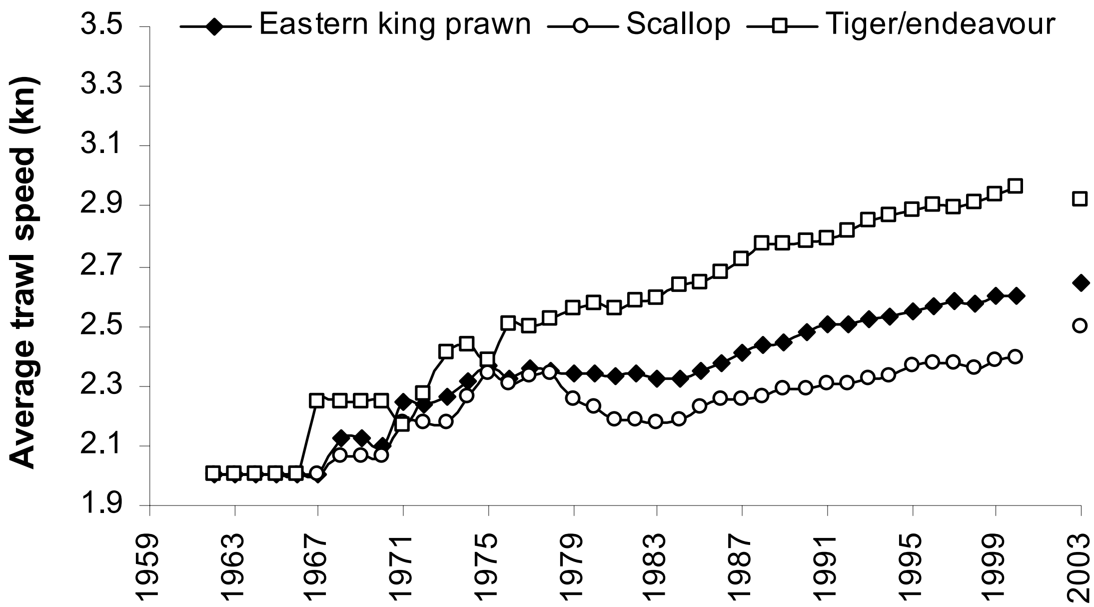


Figure 2.7. Average trawl speed by sector in the ECTF.

Table 2.1. Rate of increase in trawl speed by fishery sector.

Sector	Rate of increase per year (knots)	Standard Error	Lower 95% CI	Upper 95% CI
Eastern king prawn	0.01294461	0.000742019	0.011429	0.01446
Scallop	0.006966605	0.00115812	0.004601	0.009332
Tiger/endeavour prawn	0.022456478	0.000967643	0.02048	0.024433

The 2003 data in Figure 2.7 show that increases in trawl speed are still occurring in the two of the three sectors after the implementation of the plan. The tiger/endeavour prawn sector was the only sector to display a reduction in trawl speed. This apparent reduction in average trawl speed may be due to a movement of vessels with different trawl speeds in or out of the tiger/endeavour prawn sector rather than an actual decrease in trawl speeds across the fishery.

The distributions of trawl speeds by sector for the 2003 season are displayed in Figure 2.8. This figure illustrates the difference in trawl speeds between the tiger/endeavour prawn and the scallop sectors. There is also a marked contrast in trawl speeds between the eastern king prawn shallow and the eastern king prawn deep sectors. This reflects the differing sizes of net head rope lengths towed in the two eastern king prawn sectors with shallow water areas restricted to 44m head rope length and deep water areas allowed 92m head rope length.

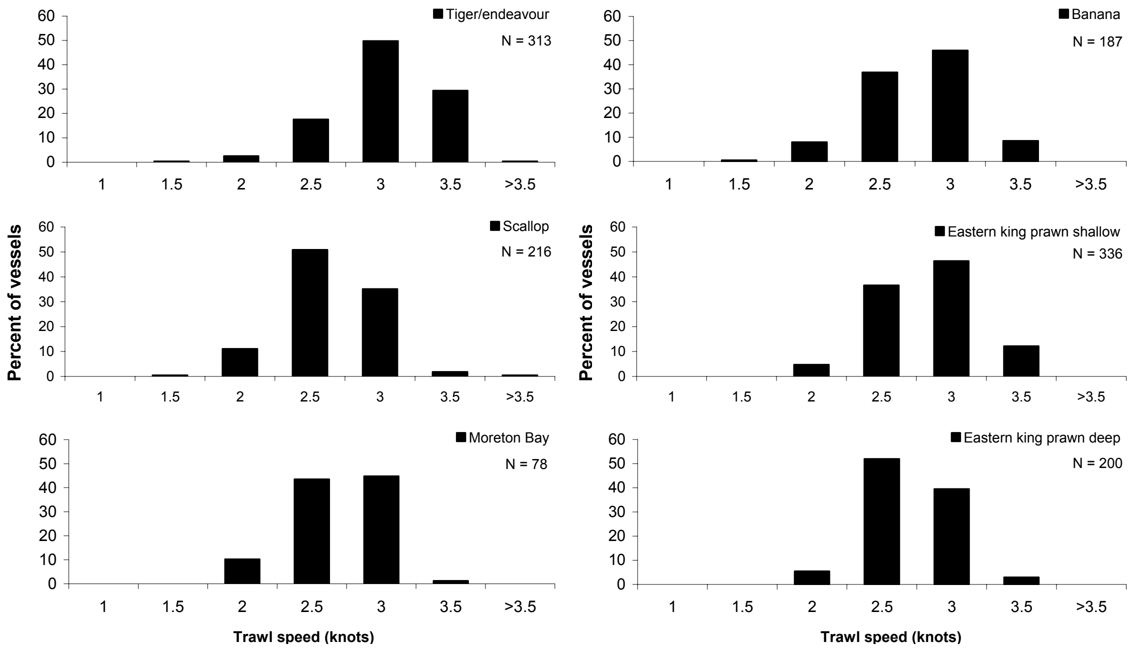


Figure 2.8. The distribution of trawl speeds by sector for the 2003-fishing season. (Source OT08 logbooks).

Engine power

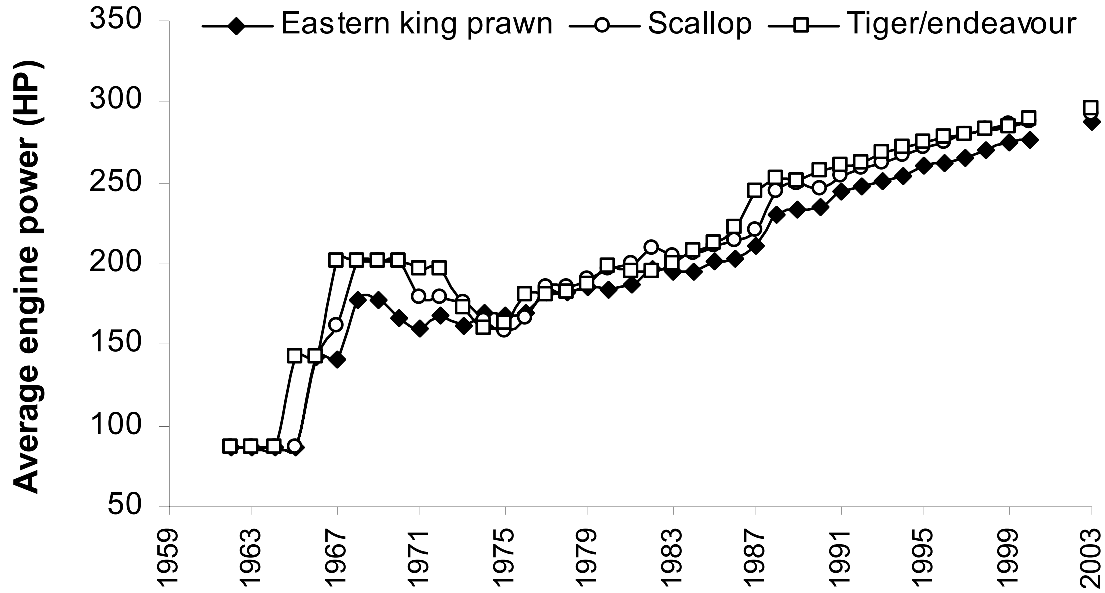


Figure 2.9. Average engine power by sector in the ECTF.

The temporal trends in average engine power in the ECTF are displayed in Figure 2.9. Differences in the rates of increase between the sectors were not statistically significant at the 5% probability level with an overall rate of increase in engine power of 4.25 Hp per year ($P<0.001$, $R^2 = 90\%$) across the entire ECTF. Changes in engine power are still occurring post plan with increases in HP experienced between 2000 and 2003.

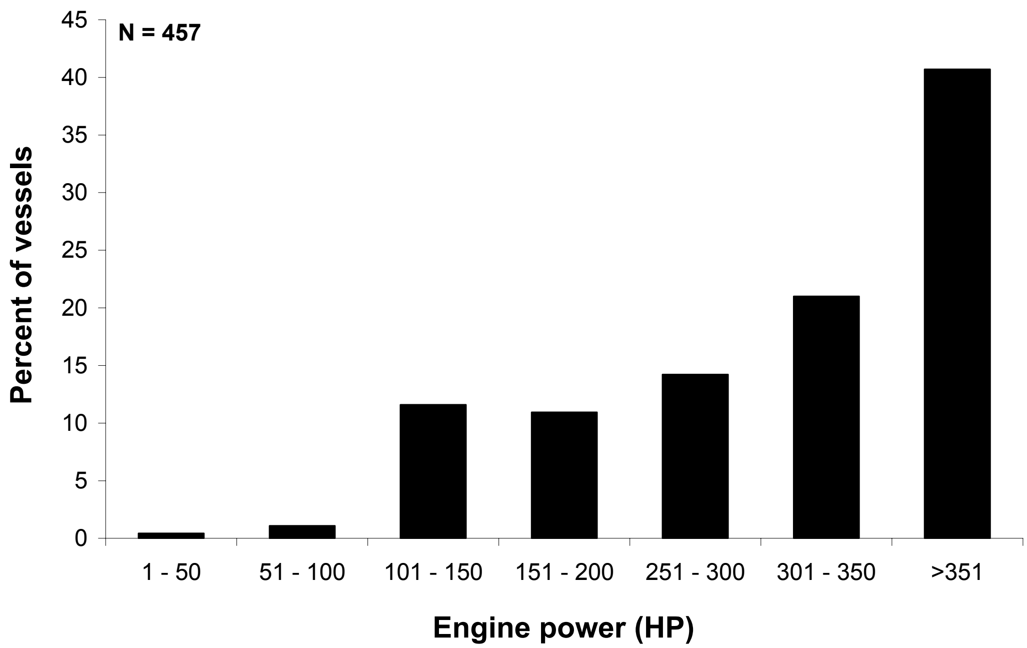


Figure 2.10. Distribution of engine power in the ECTF.

The 2003 average of 280 ± 4 HP is perhaps not indicative of the actual engine power distribution within the fleet. The engine power distribution is highly skewed towards larger engine power vessels with 40% of vessels with an engine power greater than

350 HP (Figure 2.10). 13% of vessels are at the maximum engine capacity of 300 continuous brake kW (402HP).

Gearbox reduction ratio
Figure 2.11 shows the trends in average gearbox reduction ratio for the ECTF. There were no significant differences between the sectors in terms of the rate of increase in average reduction ratio per year. The overall rate of increase in average reduction ratio was 0.03 per year (P>0.001, R^2 = 84%). Data derived for the 2003 fishing season indicate that there have been negligible changes in the average reduction ratio for the ECTF since the implementation of the Plan.

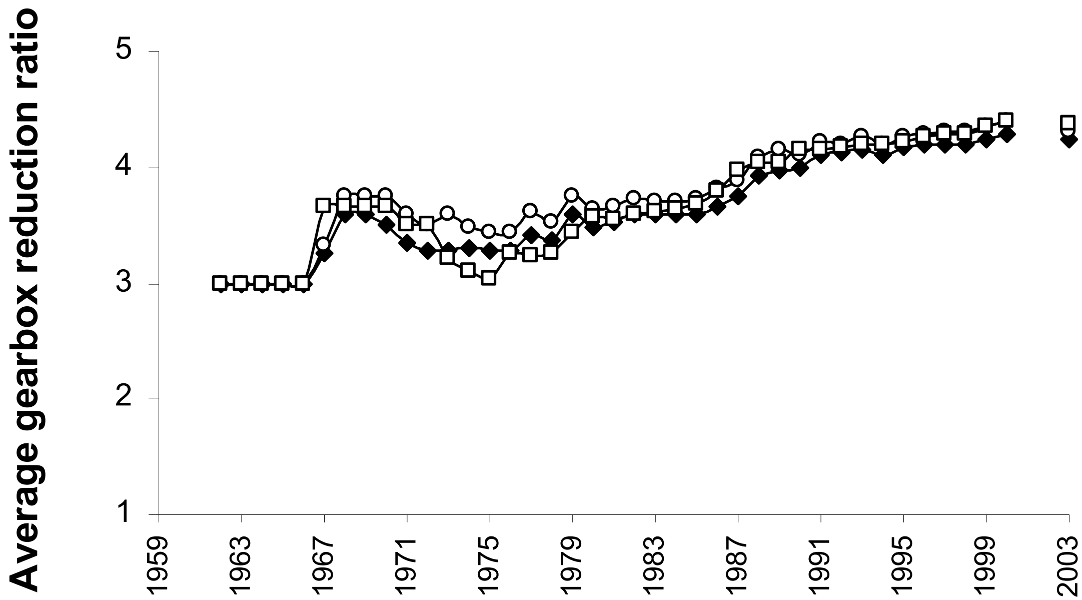


Figure 2.11. Average gearbox reduction ratio by sector in the ECTF.

Fuel capacity
The long-term trends in average fuel capacity are shown in Figure 2.12. The average fuel capacity increased from between 3000 and 5000 in the early 1970's to between 11000 and 12000 in 2003. The average rate of increase was 313 litres per year (P<0.001, R^2 = 91%) with the differences in the rate of increase between sectors shown in Table 2.2.

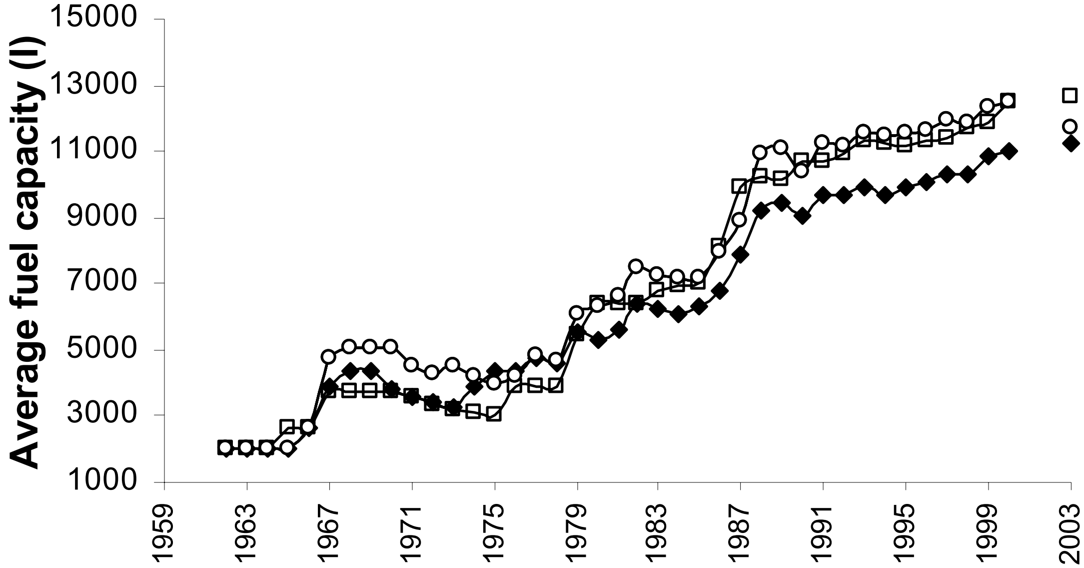


Figure 2.12. Average fuel capacity by sector for the ECTF.

Table 2.2. Rate of increase in fuel capacity by sector.

Sector	Rate of increase per year (litres)	Standard Error	Lower 95% CI	Upper 95% CI
Eastern king prawn	277.6435	10.62401	255.9464	299.3406
Scallop	313.9486	17.13636	278.9515	348.9457
Tiger/endeavour prawn	347.5815	15.76801	315.3789	379.784

The average fuel capacity for each sector for the 2003 fishing season was 11254, 11746 and 12625 for the eastern king prawn, scallop and tiger/endeavour prawn sectors respectively.

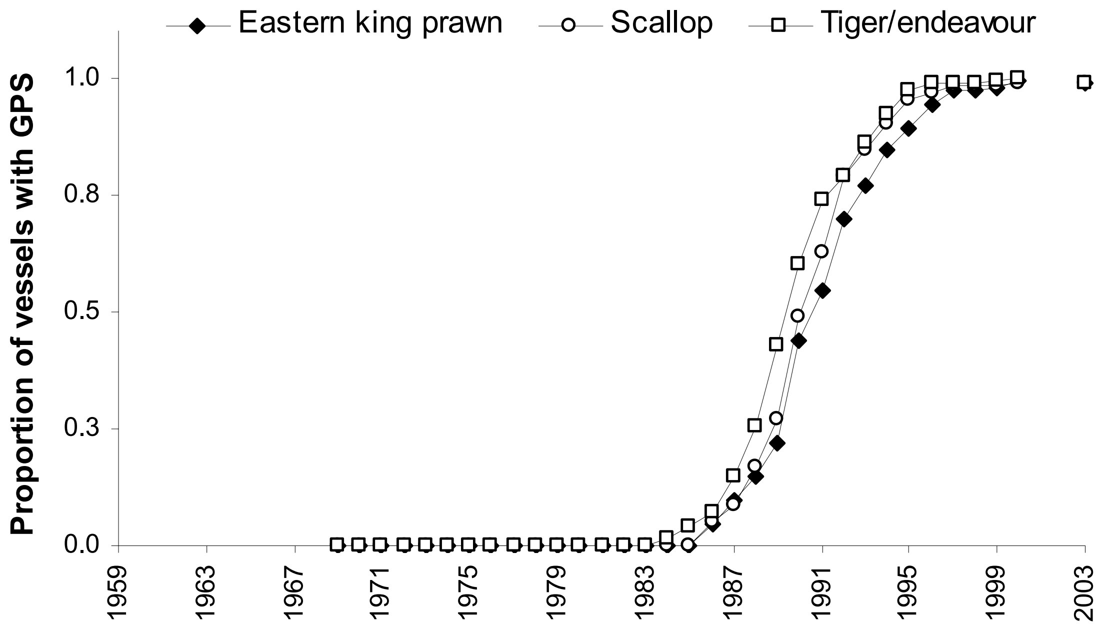


Figure 2.13. Long-term trends in the proportion of vessels using GPS in the ECTF.

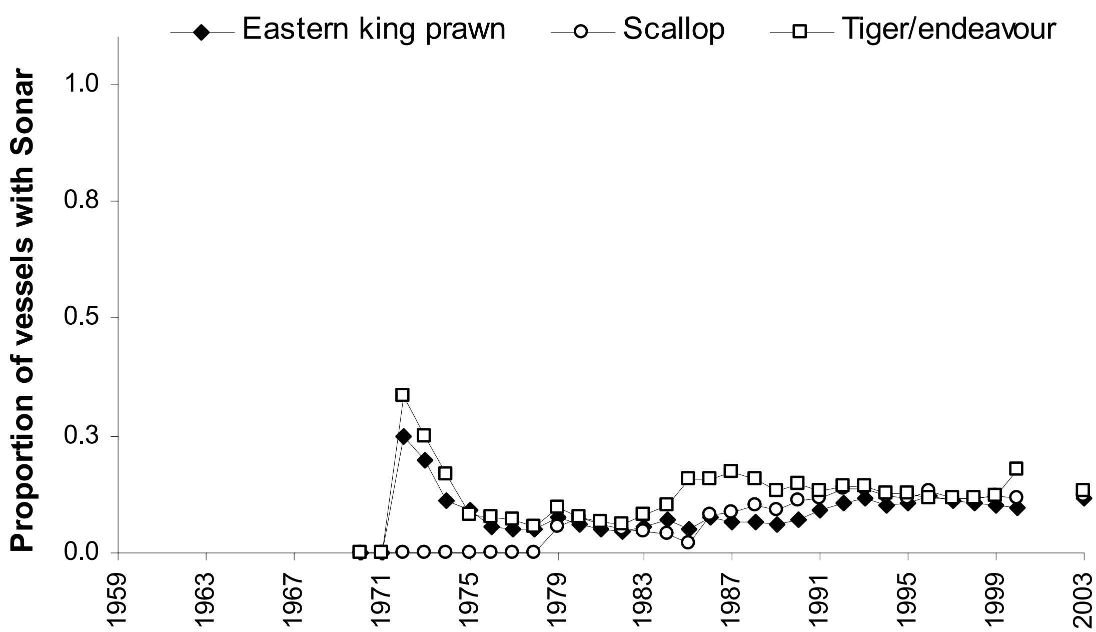


Figure 2.14. Long-term trends in the proportion of vessels using Sonar in the ECTF.

The rate at which fishers adopted certain navigational technologies is provided in Figures 2.13 and 2.14. Almost all operators have adopted GPS, across all sectors. In contrast however, few fishers (around 10%-15%) have adopted sonar even though the technology has been available for many years.

GPS began to be adopted in 1986 and by 1998 was used by almost every operator. GPS offered fishers improved spatial accuracy for trawling, with a precision of about ±50m. In 1994 operators started to use DGPS which improved their precision to a maximum achievable ±1m, depending on the level of subscription the individual operator paid for. Since the United States removed the imprecision of the GPS satellite signal in 1999 (initially implemented for military defence), the difference between GPS and DGPS has been significantly reduced. Both GPS and DGPS now offer similar precision and therefore there is no real need for fishers to adopt DGPS.

The long-term adoption of sonar is shown in Figure 2.14. The proportion of vessels utilizing sonar has been relatively low, after its initial uptake in the early 1970s sonar usage has varied between 10-20% of the fishery. Little variation between the sectors in terms of sonar usage is evident.

Net size

The long-term trends in average total net head rope length are shown in Figures 2.15, 2.16, 2.17, and 2.18. Total head rope lengths in each sector are affected by restrictions on net size, and indirectly by regulations on vessels size. For example, the maximum total combined foot and head rope lengths are restricted to 88 m in depths less than 50 fathoms (fm) and 184 m rope in depths greater than 50 fm [Fisheries (East Coast Trawl) Management Plan 1999]. These equate to a maximum total allowable total head rope length of about 44 m (22 fm) and 92 m (45 fm) in the shallow and deep water, respectively. Total head rope lengths for the most commonly used gear types (triple and quad gear) have plateaued and stabilized since the early 1980s. In the tiger/endeavour prawn (Figure 2.17) and shallow water eastern king prawn sectors (Figure 2.19), average total head rope length has stabilized at, or just under, the maximum allowable of 22 fm since the early 1980s. In the deep-water eastern king prawn sector the average total head rope length of triple gear has remained relatively stable at about 35 fm since the early 1980s. This is well below the maximum (92 m or 45 fm) that fishers can tow in the deep water, and is probably a result of limitations on vessel size. Few, if any operators in the deep water appear to be towing the maximum allowable net sizes. The average size for 2003, which has been acquired through the OT08 gear description forms, is lower than that for previous years at 29 fm indicating a reduction in net size in that sector after the implementation of the plan.

The average total net head rope length used to target saucer scallops has also remained relatively unchanged since the early 1980s at 25fm and 26fm for quad gear and triple gear respectively. This is below the maximum allowable head rope length of about 54.5m (27fm).

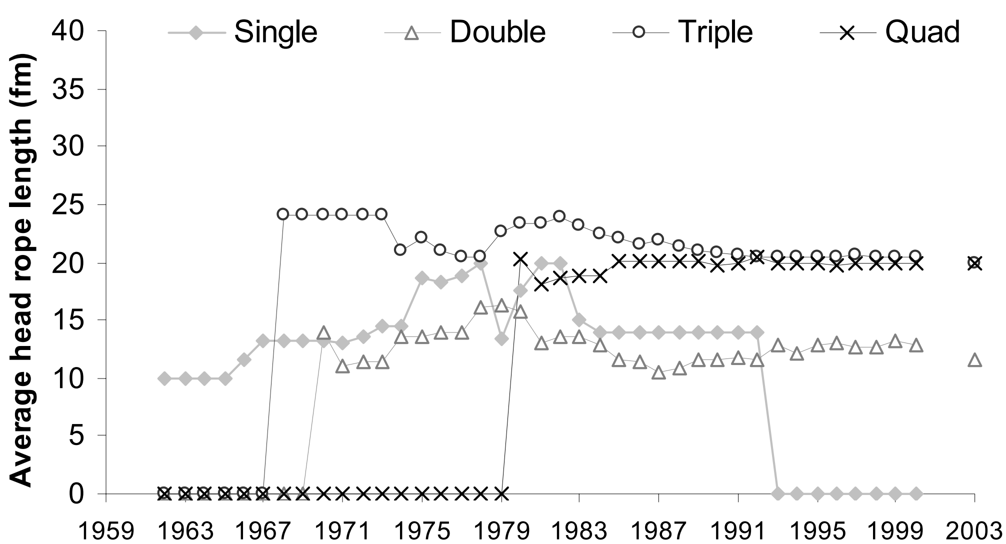


Figure 2.15. Average total head rope length in the shallow water eastern king prawn sector.

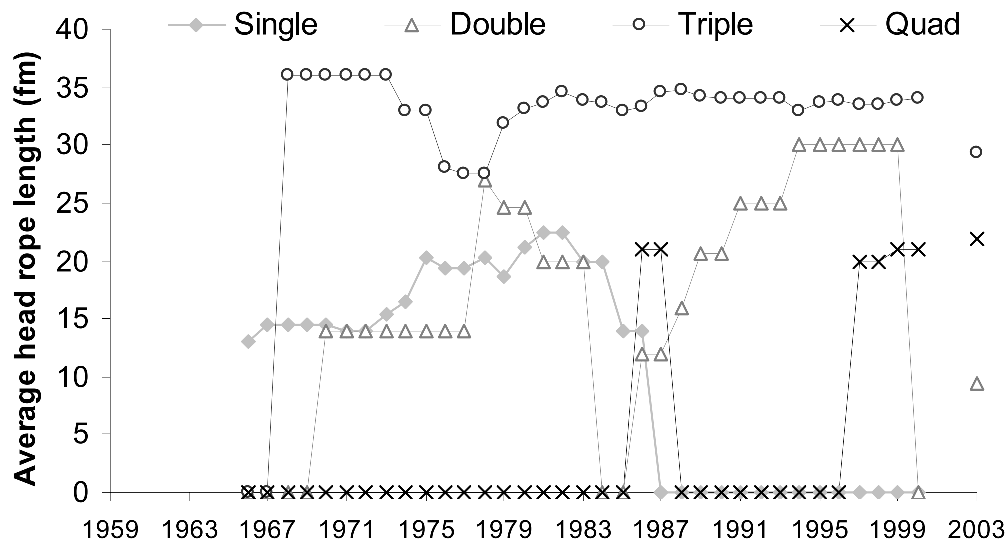


Figure 2.16. Average head rope length in the deep-water eastern king prawn sector.

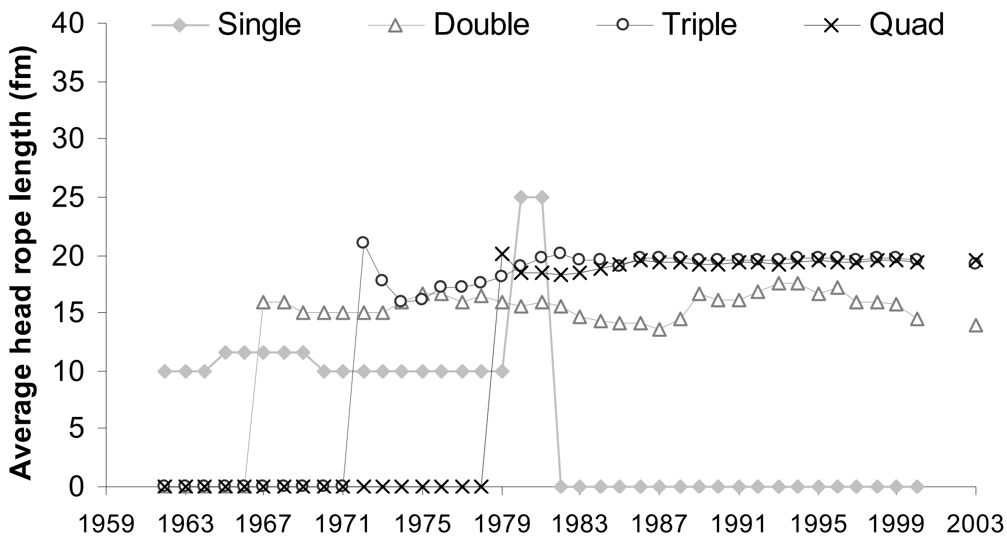


Figure 2.17. Average head rope length in the Tiger/Endeavour prawn sector.

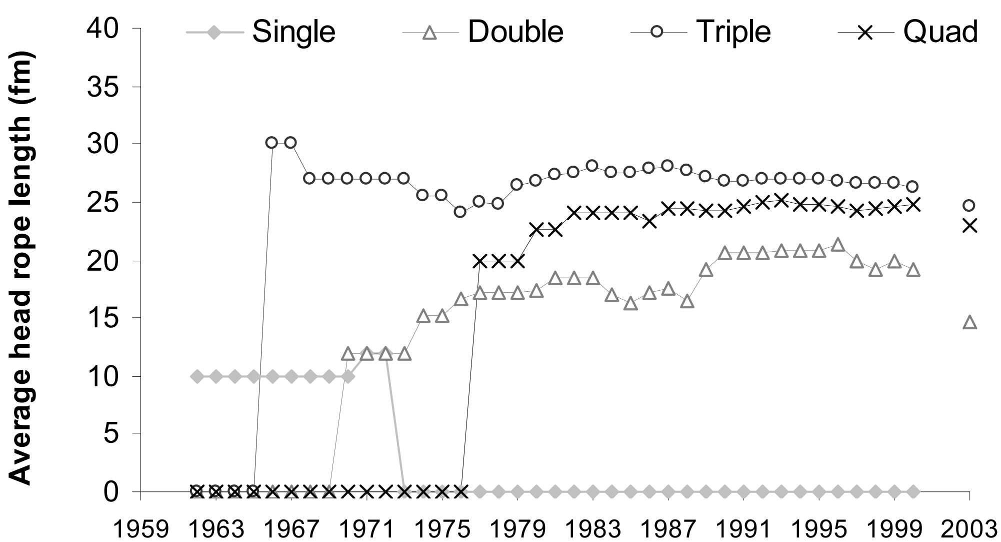


Figure 2.18. Average head rope length in the Saucer scallop sector.

3.1.5 *Temporal Comparison of Relative Fishing Power between Different Sectors*

Although a wide range of input controls have been in place in the ECTF for decades, it is generally argued that the fishing power of an average vessel in the fleet has continued to increase due to technological advances in fishing gear, vessel performance, navigation systems and telecommunications. Generalised linear regression (McCullagh and Nelder, 1989) have been used to examine the effects of these technologies on catches in the four major sectors of the Queensland east coast trawl fisheries and to quantify the average annual rate of increase in fishing power. The sectors are the:

- North Queensland tiger/endeavour prawn sector, which mainly targets brown tiger prawns (*P. esculentus*) and grooved tiger prawns (*Penaeus semisulcatus*);
- Scallop sector, which mainly targets Amusium balloti;
- Shallow water (< 50 fathoms) eastern king prawn sector; and
- Deep-water (> 50 fathoms) eastern king prawn sector, which target *Penaeus plebejus*.

The differences in relative fishing power increases between sectors, in terms of the technological influences have also been examined.

Methods
The analyses were based on logbook catch and effort data in each sector over 11 years from 1989 to 1999. The data consisted of the daily catch of each individual vessel. The spatial resolution of catches recorded from the Queensland east coast were based on 30 minute x 30 minute latitudinal and longitudinal grids. In order to omit the less reliable data, only data from vessels that had fished on more than four days in any month were used in the analyses, similar to the criterion used by Robins et al. (1998) and Bishop et al. (2000). The tiger prawn sector's catch is based upon more than one main target species. To remove the effect of non-directed fishing in these sectors, only tiger prawn catches greater than 20 kilograms per day were used.

The analysis considered a number of different vessel characteristics thought to affect fishing power. Data on the historical development and adoption of vessel/fishing technologies were collected through personal interviews of vessel owners or skippers. Interviews were completed for 344 past and present operating vessels, selected randomly from the entire trawl fleet of 900 vessels that had fished during 1997 and 1998. The 344 vessels represented a response rate of 85% of the 406 vessel operators who were contacted. Overall, the sample included vessels that collectively accounted for about 40% of each sector's total catch between 1989 and 1999. Vessel owners or skippers were asked to provide written records of vessel characteristics for the interview. Changes in the following characteristics and the date of each change were recorded for each vessel:

- Skippers (owner operated, relative of owner, or non-relative);
- Vessel length, engine power (HP), average trawl speed (knots), fuel capacity (litres), propeller size (inches) and the presence or absence of a propeller nozzle;
- Navigation equipment (presence or absence of global positioning systems (GPS) and plotters, and computer mapping software);
- Presence or absence of try-gear [try-gear is a small (1-3 fathom) net used for frequent 10-20 minute sampling of trawl grounds];
- Use of bycatch reduction devices (presence or absence);
- Type of otter board types (Bison, Flat, Kilfoil, Louvre or other less common types) and size (total board area = board length x width);

    Trawl net configurations -
    Number of nets (single, double, triple, quad or five nets);
    Total net head rope length (fathoms) combined for all nets; and
    Net mesh size (mm); and

- Type of ground chain (fixed drop chain, drop chain with sliding rings, drop rope and chain combined, looped chain or other less common configurations) and chain size (mm).

The analysis used a generalised linear model (GLM) with normally distributed errors on the log scale (McCullagh and Nelder, 1989). The response variable was based on individual vessel catches, summed over a unit of time for a spatial area. Therefore, throughout this paper we report on changes in fishing power affecting the catch. However, because fishing effort is included in our analysis as an explanatory variable, the findings are pertinent to both catch and catch rates. A detailed description of the statistical methodology is outlined in O'Neill et al (In Press).

Results

Summary of fishing gears and technologies

Section 3.1.4 provides a summary of the changes in fishing vessels, gears and technologies from 1989 to 1999. The maximum allowable size of vessels in all trawl sectors throughout this period was, and remains at, 20 metres. The average length of vessels remained unchanged and larger vessels generally operated in the deep-water eastern king prawn sector than in the other sectors. The size of nets used in each sector remained relatively constant (Figures 2.16, 2.17, 2.18, and 2.19). Generally, fishing vessels used the maximum amount of net permissible in the tiger prawn and shallow water eastern king prawn sectors (22 fathoms head rope length), and in the saucer scallop sector (37 fathoms of head rope). Although the maximum amount of net used in the deepwater eastern king prawn sector is 45 fathoms of head rope length, the average length of nets used was only about 35 fathoms. This may be due to restrictions on vessel size and engine power preventing vessels from effectively towing 45 fathoms of net.

In contrast to the relative consistencies in average vessel and net size, there have been some significant changes that may affect the swept area capacity of vessels within each sector. For example, substantial increases in engine size occurred across all sectors (Figure 2.19b); restricted to 400 HP. Interestingly, only minor increases in average trawl speed occurred over the same period (Figure 2.19c). The adoption of GPS increased markedly from 1988 and by 1992 the majority of fishing effort expended in the fishery was with the aid of GPS (Figure 2.19h). The use of computers with advanced mapping software, such as CPLOT™, to display and precisely record the GPS latitudinal and longitudinal positions on detailed coastal maps began around 1994 (Figure 2.19i). By the 1999 fishing season, about 65% of the north Queensland tiger prawn, 40% of the eastern king prawn and of the scallop fleets were using computer-mapping software. Other significant changes to have occurred include higher gear box ratios (Figure 2.19d), greater use of propeller nozzles (Figure 2.19e), larger vessel fuel capacities (Figure 2.19f), greater use of try gear in the eastern king prawn and scallop sectors (Figure 2.19g), and the gradual adoption of by-catch reduction and turtle exclusion devices (Figure 2.19j). In the tiger prawn sectors, there has been a significant change away from using standard flat otter-boards to other board types such as Bison, Louvre and Kilfoil (Figure 2.19l).

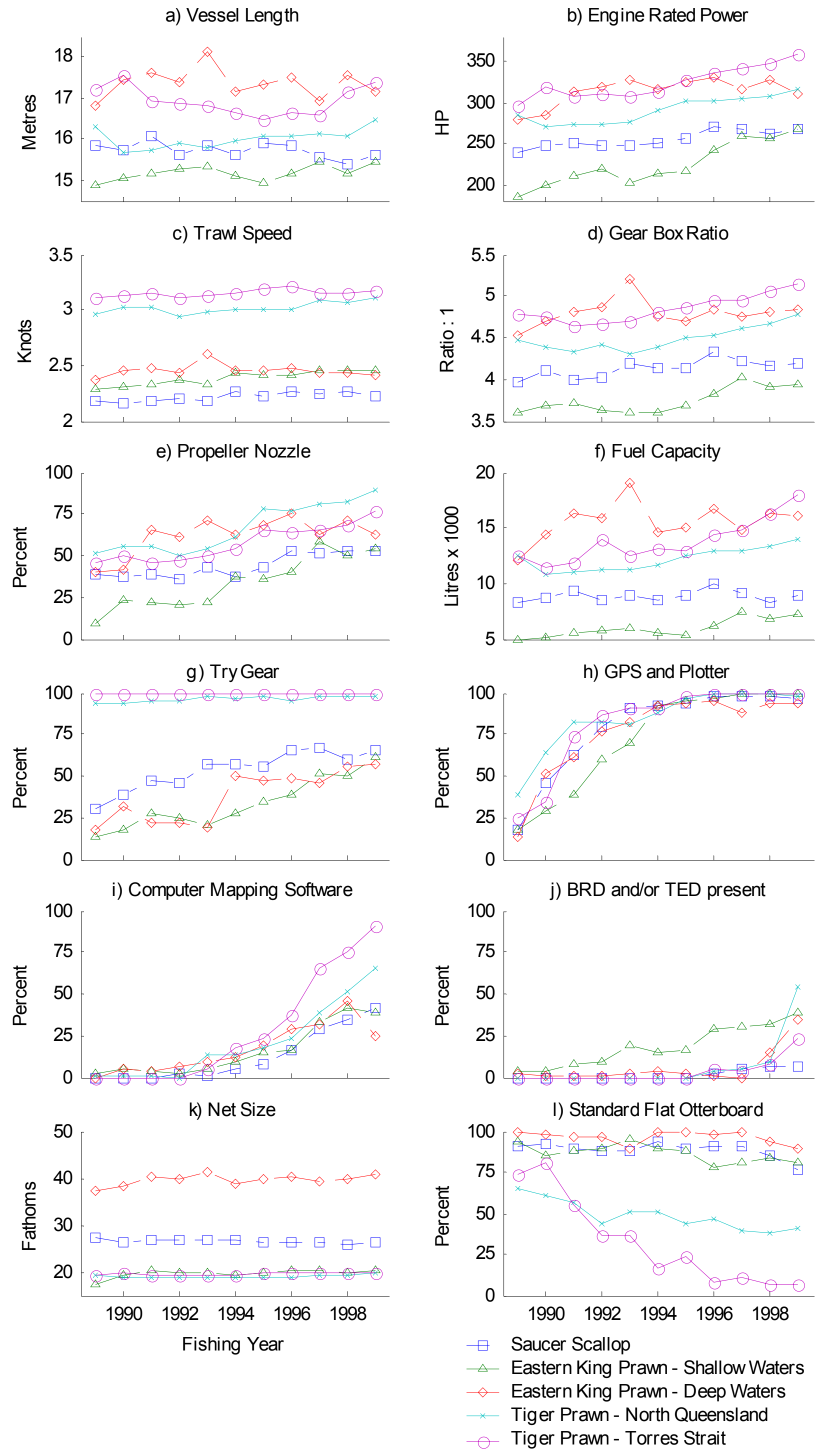


Figure 2.19. Summary of average fleet characteristics by fishing year and trawl sector. Plots a, b, c, d, e, f and k are weighted means according to the number of days fished by each vessel in each fishing year and sector. Plots g, h, i, j and l represent the percent of fishing effort (boat days) in each fishing year and sector using that particular device.

Table 2.3 contains the regression parameter estimates for fishing effort, and the various gears and technologies for the five sectors. For each sector, fishing effort was the most significant variable influencing catch. Parameter estimates for fishing effort were all significantly greater than 1 ($p<0.05$), which suggests that catch rates increase with the period spent fishing during each lunar phase period (i.e. the ratio between catch and a day of effort is not 1:1).

A number of positive effects on catch were identified in each sector. For the Tiger/endeavour prawn sector, engine horsepower, trawl speed, gearbox ratio, kort nozzle, global positioning systems, computer mapping software and sonar usage had a significant positive effect on catch. In the shallow water eastern king prawn sector, vessel length, engine horsepower, bycatch reduction devices (BRD) and turtle exclusion devices (TED) had significant positive effects. In the deep-water eastern king prawn sector, the use of kort nozzles, vessel fuel capacity, BRD and TED use, and net size (total head rope length) had a positive affect. In the scallop sector, engine horsepower, propeller size, try-gear, BRD and TED use, and ground chain size had a positive effect on catch.

Navigation technologies including GPS, computer mapping software, and sonar were only significant in the Queensland tiger prawn sector. In this sector, the use of GPS resulted in 4%, computer-mapping software 4%, and sonar 10% higher average catches of tiger prawns.

For all sectors analysed there was no evidence of highly correlated gear and technology ($\boldsymbol{\beta}_3$) parameters. Table 2.4 lists the parameter correlations greater than 0.3. These correlations were only moderate and generally involved highly significant parameters ($p<0.01$). Having identified these correlations, then removing any of these parameters from the analysis had little effect in the sense that the inferences on remaining parameters were unchanged. In addition, removing any of the listed correlations from the analysis resulted in little change from the overall average fishing power estimates, suggesting that the correlations listed in Table 2.4 were not of a significant magnitude.

Table 2.3. Parameter estimates (β_2 and β_3) and standard errors in parenthesis from the generalised linear model analysis (natural log transformed), for each trawl sector. The bold parameters indicate the most important covariate effects on fishing power. NS indicates the parameter was not significant and excluded from the analysis (p>0.05). * Indicates the gear type was grouped under other less used types.

Summary of Analysis	Eastern King Prawn (Shallow)	Eastern King Prawn (Deep)	Tiger/endeavour prawn	Saucer Scallop
Regression Mean Square	48.785	21.960	102.371	59.050
Residual Mean Square	0.945	0.319	0.745	0.578
Regression df, Residual df	320,7192	420, 4216	269, 10867	455, 14011
R^2	68.3	86.0	76.7	76.1
Parameter estimates				
Fishing Effort (days)	1.161	1.147	1.070	1.150
Vessel length	0.707	-0.548	-0.213	NS
HP	0.496	-0.142	NS	0.146
Trawl speed	-0.468	-0.334	NS	-0.083
Gear box ratio	-0.993	-0.172	0.192	NS
Propeller size	NS	NS	NS	0.416
Propeller nozzle (present)	-0.055	0.044	0.053	NS
Fuel capacity	NS	0.108	0.149	NS
Skipper type (4 levels)				
Mixed	0	0	0	0
Non-related to owner	0.124	-0.146	-0.121	0.068
Owner operated	0.021	-0.094	-0.090	0.102
Related to owner	-0.246	-0.102	0.020	0.1223
Try gear (present)	-0.109	NS	NS	0.154
GPS	NS	NS		NS
Absent			0	
GPS and Plotter			0.040	
Computer Mapping	NS	NS	0.037	NS
Sonar	NS	NS	0.100	NS
BRD and/or TED (present)	0.070	0.058	NS	0.100
Trawl gear – number of		NS	NS	NS
Single	0.293			
Double	0			
Triple	0.148			
Quad	0.754			
Five	0.359			
Net size – for all nets	NS	0.381	NS	0.065
Mesh size	-0.474	NS	-0.524	-0.323
Ground gear				
Drop chain	0	0	0	0
Drop chain with sliding	0.003	-0.008	-0.025	0.055

Looped chain	-0.220	-0.051	*	0.065
Drop rope and chain	-0.091	0.078	0.052	*
Others less used types	-0.334	0.046	0.208	0.187
Ground gear – chain size	0.525	NS	-0.095	0.089
Otter boards			NS	
Others less used types	0	0		0
Bison	*	*		0.784
Louvre	*	*		0.754
Standard flat	-1.894	3.131		0.244
Kilfoil	*	*		-3.112
Otter board size				
Other less used types	-0.132	1.939	0.022	0.209
Bison board size	*	*	0.088	-0.033
Louvre board size	*	*	0.057	-0.044
Standard flat board size	0.486	1.015	0.077	0.1374
Kilfoil board size	*	*	0.050	1.157

Table 2.4. Generalised linear model β_3 parameter correlations between the different vessel characteristics, for each trawl sector. Correlations larger than 0.3 are listed.

Parameter estimates	Correlations
Eastern King Prawn (Shallow)	
Trawl speed and Propeller nozzle	-0.355
Gear box ratio and Skipper (Non-related to owner)	-0.348
Trawl gear (Triple nets) and Standard flat board	0.351
Eastern King Prawn (Deep)	
Ground gear (Drop chain with sliding rings) and Net size	-0.523
Ground gear (Looped chain) and Skipper (Owner operated)	0.314
Fuel capacity and Propeller Nozzle	-0.444
Gear box ratio and Skipper (Related to owner)	0.408
Gear box ratio and Ground gear (Looped chain)	0.514
Gear box ratio and Fuel capacity	-0.451
HP and Ground gear (Drop rope and chain)	-0.319
Otter board size (Standard flat) and Net size	-0.508
Otter board size (Standard flat) and Vessel length	-0.391
Otter board size (Standard flat) and Gear box ratio	-0.324
Otter board size (Standard flat) and HP	-0.346
Tiger/endeavour prawn	
Ground gear chain size and Otter board size (Others types)	-0.386
Ground gear chain size and Otter board size (Bison)	-0.453
Ground gear chain size and Otter board size (Lourve)	-0.468
Ground gear chain size and Otter board size (Standard flat)	-0.475
Ground gear chain size and Otter board size (Kilfoil)	-0.471
Vessel length - Fuel capacity	-0.436
Gear box ratio and Fuel capacity	-0.402
Ground gear (Drop chain with sliding rings) and Mesh size	0.429

Estimates of Fishing Power

Estimated increases in average relative fishing power were higher in the shallow water eastern king prawn sector compared with the other sectors (Table 2.5 and Figure 2.20). For the 11-fishing year period 1989 to 1999 average relative fishing power increased by 27% in the shallow water eastern king prawn sector. Increases in average relative fishing power was comparatively small (less than 6%) for the deep-water eastern king prawn, north Queensland tiger prawn and saucer scallop sectors. Figure 2.21 compares average annual catch rates calculated from the observed data with the fishing power standardised values. Although average annual catch rates showed considerable between-year variation for each fishing sector, the standardised catch rates tended to show a slight long-term decline.

Table 2.5. Percent change in average fishing power from 1989 to 1999 (95% confidence intervals shown in parentheses), for the shallow water (< 50 fm depth) eastern king prawn, the deep-water (> 50 fm depth) eastern king prawn, the Tiger/endeavour prawn and the saucer scallop trawl sectors. Note the percent change represents the difference from the base reference year 1989, which was set at 0. The linear increase is the regression slope of the fishing power changes from 1989 to 1999.

Fishing Year	Eastern King Prawn (Shallow)	Eastern King Prawn (Deep)	Tiger/endeavour prawn	Saucer Scallop
Linear increase %	1.591 (0.553, 2.694)	0.326 (-0.069, 0.728)	0.613 (-0.236, 1.466)	0.226 (-0.684, 1.126)

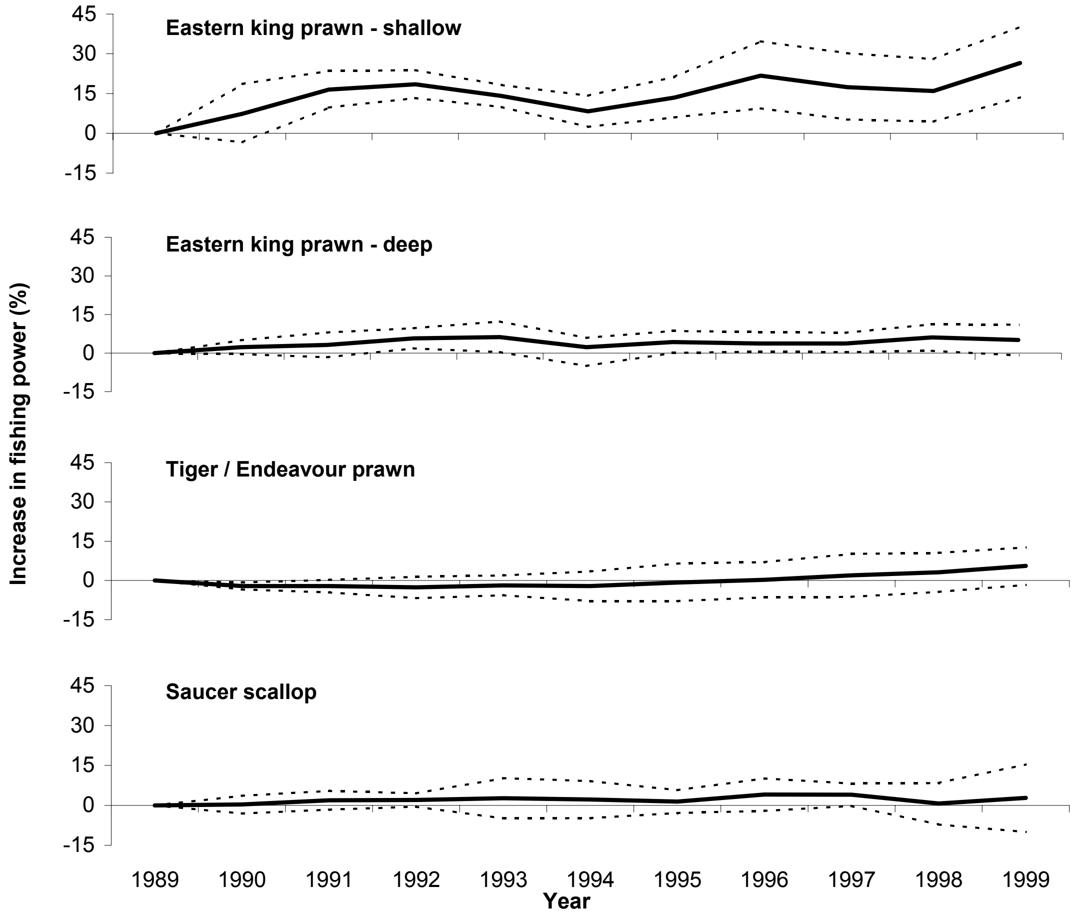


Figure 2.20. Percent change in average fishing power from 1989 to 1999 (dashed lines indicate 95% confidence intervals) for the shallow water (< 50 fm depth) eastern king prawn, the deep-water (> 50 fm depth) eastern king prawn, the Tiger/endeavour prawn and the saucer scallop trawl sectors. Note the percent change represents the difference from the base reference year 1989, which was set at 0. The fishing years represent the period from November through to October for the eastern king prawn and saucer scallop sectors, and March through to February for the tiger prawn sectors.

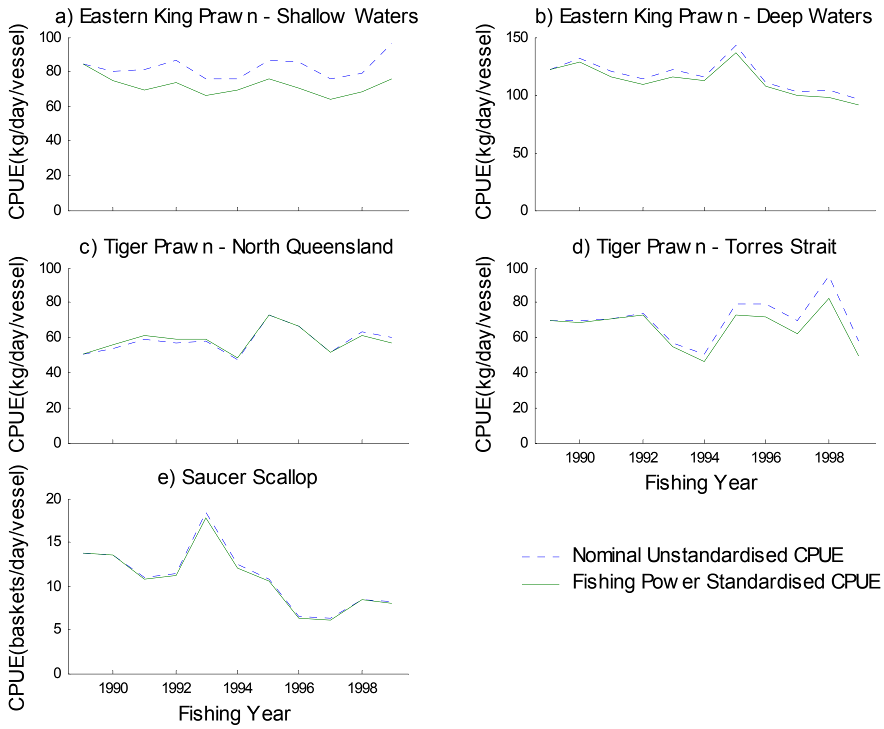


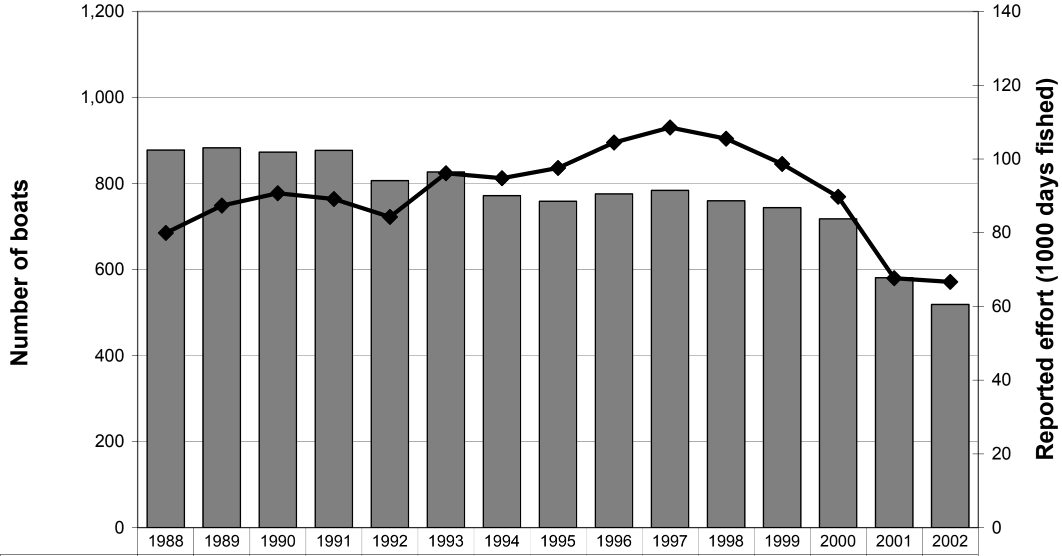
Figure 2.21. Comparison of nominal un-standardised (raw data) and fishing power standardised annual average catch rates (CPUE = catch-per-vessel day).

3.1.6 *Fishing Effort*

Fleet usage of effort in the fishery

Figure 2.22 shows the historical fishing effort in the ECTF, expressed as days fished, and changes in total number of vessels fishing since 1988 (source: CFISH database). Reported effort in the ECTF increased steadily from 1988 to 1997 with a pre plan (1996 to 1998) average of 106,165 ± 1219 days. Fishing effort reached a peak in 1997 of 108,530 days before a rapid decline to the post plan average of 67,151 ± 495 days, an effective reduction of 37%. The number of vessels operating in the fishery was roughly correlated with the fishing effort in each year with a 42% reduction achieved between 1989 and 2002.

The vessel replacement policy, vessel buy-back scheme, effort unit trading system and cap in total effort during 2001 have contributed significantly to the obvious decline in the number of boats and days fished from 2000 to 2001. Minimum trading in effort units occurred during 2002, which is not surprising considering the significant changes in the fleet and trading which occurred following the introduction of the effort unit system and transfer penalties in 2001. These limited transfers have resulted in a small number of vessels leaving the fishery.



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Boats	878	883	873	877	807	827	772	759	776	784	760	744	718	581	519
Days ('000s)	79.9	87.4	90.7	89.2	84.3	96.1	94.8	97.6	104.5	108.5	105.5	98.6	89.7	67.6	66.7

Figure 2.22. Annual number of reported days fished and number of reporting vessels. Note: The marked changes in annual days fished shown in Figure 2.5 illustrates why CPUE may be a more appropriate measure of the status of each stock, rather than total annual harvests.

VMS Fishing Effort (2001-2003)
Table 2.6 shows the number of effort units used per month between January 2001 and June 2003, inclusive. Small fluctuations in effort usage occur month to month, however, temporal patterns in effort usage are similar among years (Figure 2.23).

Table 2.6. Effort unit usage per month between January 2001 and June 2003.

	2001			2002			2003		
Location	GBRMP	Other [a]	Total	GBRMP	Other [a]	Total	GBRMP	Other [a]	Total
Allocation	2,983,319			2,941,460			2,925,321		
January	87,253	110,856	198,109	96,408	70,534	166,942	69,787	96,262	166,049
February	62,325	84,597	146,922	67,383	86,557	153,940	50,847	63,214	114,061
March	224,650	72,057	296,707	206,256	67,139	273,395	202,525	84,821	287,346
April	170,438	66,530	236,968	171,331	72,028	243,359	164,580	56,681	221,261
May	202,814	64,431	267,245	189,554	61,408	250,962	208,255	59,436	267,691
June	190,262	50,711	240,973	217,568	35,112	252,680	230,864	49,581	280,445
July	203,172	48,173	251,345	230,951	44,580	275,531	208,933	37,331	246,264
August	182,167	63,558	245,725	217,955	34,924	252,879	219,933	41,437	261,370
September	131,714	46,811	178,525	175,310	33,611	208,921	166,387	33,390	199,777
October	92,663	18,235	110,898	130,171	12,491	142,662	134,025	11,552	145,577
November	188,082	106,353	294,435	181,038	98,634	279,672	156,034	108,956	264,990
December	71,168	86,268	157,436	84,482	87,139	171,621	75,131	86,643	161,774
TOTAL	1,806,708	818,580	2,625,288	1,968,406	704,158	2,672,564	1,887,301	729,304	2,616,605

[A] 'Other' refers to areas in the ECTF but not in the GBRMP area.

The effects of the northern and southern closures are reflected in the monthly effort unit usage displayed in Table 2.6. The first closure period for the two regional closures is from 15 December to 1 March (northern closure) and 20 September to 1 November (southern closure). Marked reductions in fishing effort can be seen in the GBRMP during the northern closure period, and the areas outside the GBRMP for the southern closure period. (Table 2.6)

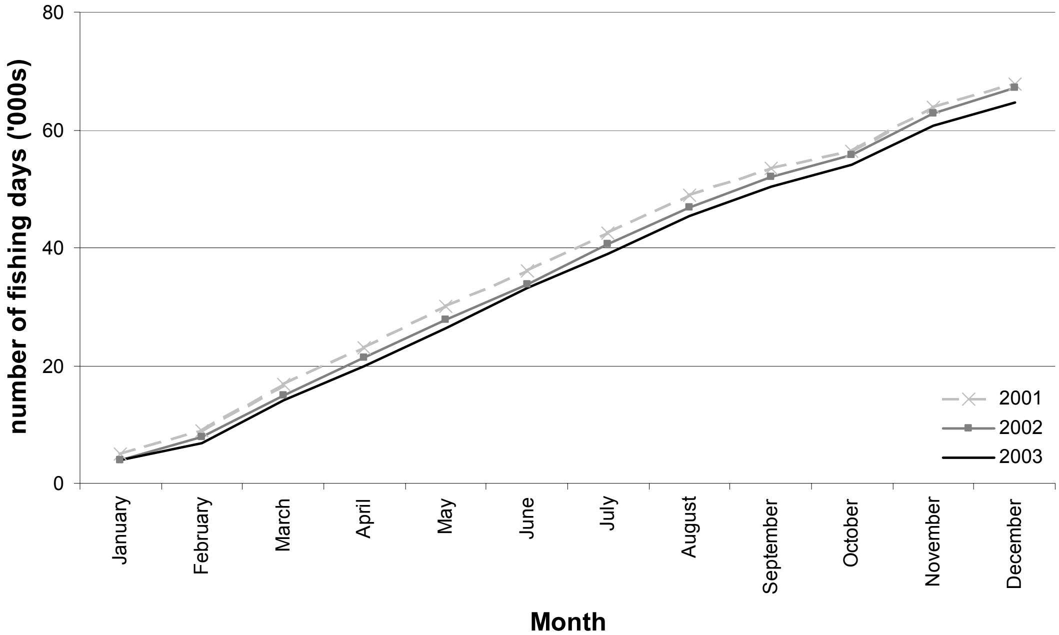


Figure 2.23. Cumulative monthly use of effort units for 2001, 2002 and 2003 in the entire East Coast trawl fishery.

Percentage of effort used by individuals each year

In terms of number of licences, proportion of total fishery effort and proportion of total fishery catch, the T1 and T1/M1 fleet is the most significant component of the ECTF. Figure 2.24 shows the use of EU by this sector of the fleet. The majority of fishers used a large proportion of their allocation in both 2001 and 2002. Grid ‘E’ in Figure 2.24 identifies those fishers who used more than 80% of their available effort in both years, this group accounts for 61% of the fleet. Approximately 80% of the fleet used more than 60% of their allocated effort in both years. The average usage per licence was 76.7 ± 1.3% and 83.4 ± 1.1% in 2001 and 2002 respectively.

Fishers rarely under utilised allocated effort in both years (few data points in Grids ‘A’ and ‘B’). As noted above, 61% of the fleet utilise more than 80% of their allocated effort, furthermore a large number of the fleet utilised 100% in at least one year. Grids marked F and G identify the few individuals that used a large proportion of their allocated effort in one year but a very small proportion in the other year.

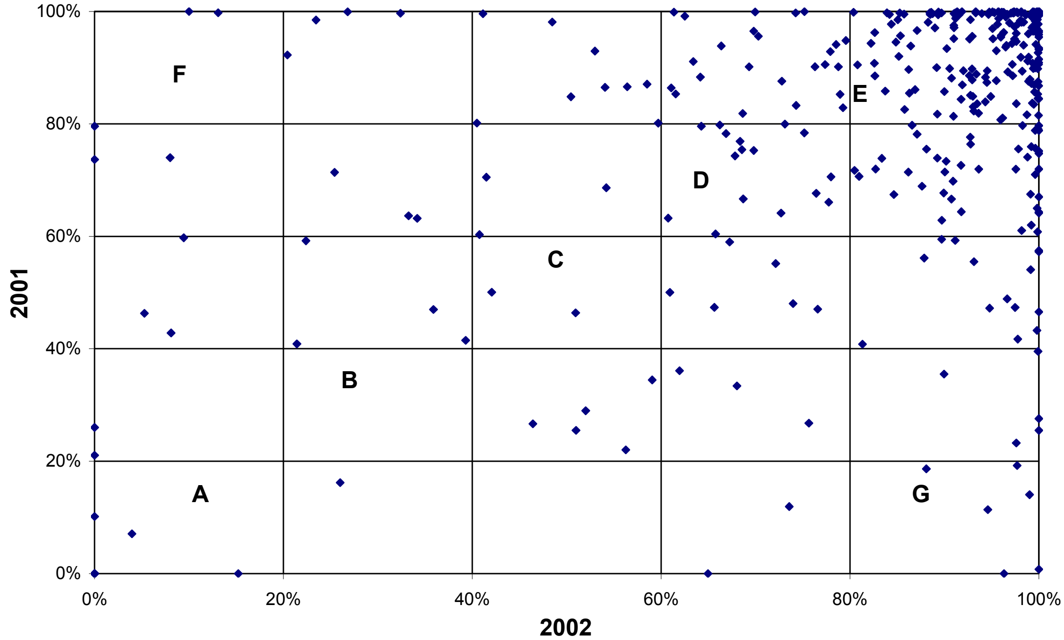


Figure 2.24. Individual use of effort units between 2001 and 2002 (T1/M1 fleet).

Changes in individual effort unit holding

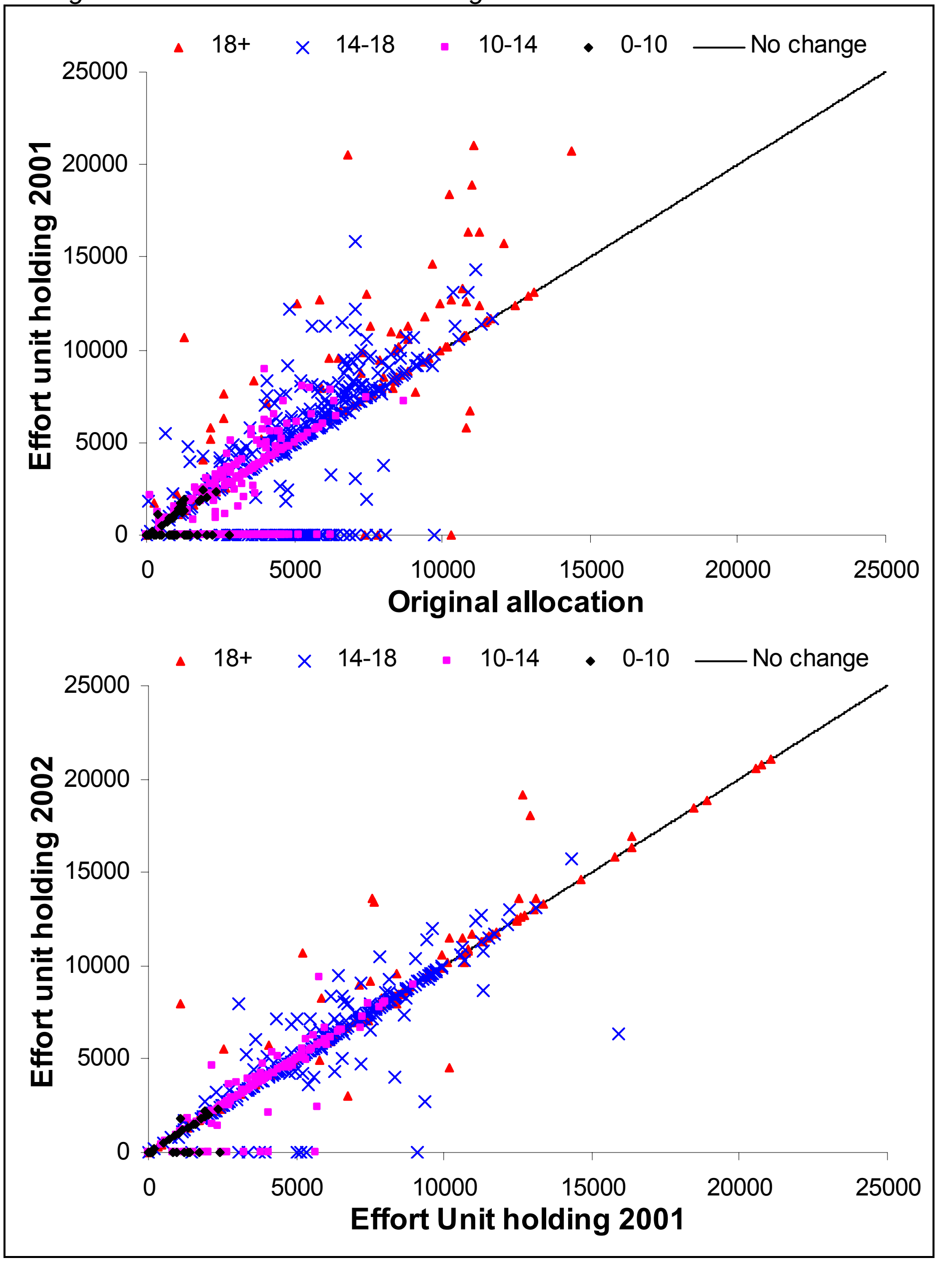


Figure 2.25. Individual trends in effort unit holding (by boat length).

Changes in effort unit holding per boat from the original allocation to 2002 are shown in Figure 2.25. Vessels that lie along the diagonal traded no effort units. Vessels above the line gained effort units. There was a significant decrease in the volume of effort unit trading from 2001 to 2002. The larger vessels in the fleet (>18m and 14 to 18m) were predominantly the vessels that increased their effort unit holdings in 2001. Very few large vessels (>18m) sold effort units. In contrast the majority of vessels that sold 100% of their effort units ranged in size from <10m and 10 to 14m. Large boats also have the greatest "spread" of data in terms of effort unit holdings; ranging from almost zero to over 20,000 EU. This is likely the result of larger vessels requiring larger EU holdings to gain parity in terms of nights with smaller vessels.

Tables 2.7 and 2.8 summarise the proportion of vessels by boat length category that changed their EU holding in 2001 and 2002. Transfer of EU occurred in all length categories, with the greatest increase in EU holdings occurring in vessels larger than 14m.

Table 2.7. Relative change in effort holding by boat length in 2001.

Length class	DECREASE	NO CHANGE	INCREASE
0-10	46%	25%	30%
10-14	52%	19%	29%
14-18	26%	31%	43%
18+	9%	42%	50%

Table 2.8. Relative change in effort holding by boat length in 2002.

Length class	DECREASE	NO CHANGE	INCREASE
0-10	16%	81%	4%
10-14	10%	83%	7%
14-18	10%	76%	14%
18+	9%	71%	20%

3.1.7 *Discussion*

The introduction of the Fisheries (East Coast Trawl) Management Plan 1999 (the Plan) has resulted in the most significant changes to the structure of the east coast otter trawl fleet in the history of the fishery. In addition to this, these changes have occurred in a relatively short time frame. The shift in fleet profile commenced with the trawl structural adjustment scheme, which actively removed 99 licences from the fishery prior to the commencement of the 2001 fishing season.

Since the implementation of the Effort Management System (EMS) in January 2001, fishers have been restricted by the total number of days that they are allowed to trawl in any given year. This has placed even greater emphasis on expected catch rates and market prices when a fisher considers whether or not to fish.

The EMS introduced tradeable effort units, which has created a market within the fishery that is not based on fish. Under this system, fishers have the flexibility in making business decisions whether to buy, sell or use their effort unit allocation.

Since its introduction the plan has resulted in effort reductions in three ways, through the initial allocation of effort units, through the trawl structural adjustment scheme and through surrender provisions placed on effort unit trading and vessel replacements. Overall there has been a significant reduction in both the number of boats and the number of nights fished, with all but the M2 boats in Moreton Bay resulting in a reduction in fishing effort.

Even though all boats have undergone a significant reduction in the effort they are permitted to apply to the fishery, effort is not being used to capacity within the trawl fleet. Some stakeholders have suggested that this is an indication that effort allocations are too high and that this unused effort presents a serious concern to the fishery. It is important to note that the fishery is highly variable both temporally and spatially. Seasonality of target species and the fact that saucer scallops and king prawns are traditionally caught at the end of the year causes fishers to retain nights until the end of the season to maximize profits. This retention of nights for use late in the season can result all of the allocated nights not being used if unforeseen circumstances occur. For example, unforeseen events such as illness, refits, strong winds, etc., late in the season can result in boats having nights remaining at the end of the season.

The overall fleet characteristics have also undergone significant changes since the implementation of the plan. Data on certain attributes of vessels indicate that the average size of vessels has increased since the implementation of the plan. In addition to this there has been an increase in the proportion of boats with propeller nozzles, the proportion of boats using try gear, the average engine power of boats, average trawl speeds and the average propeller pitch per boat. Factors, which have not increased markedly, include propeller diameter, fuel capacity, gearbox reduction, the use of GPS and sonar.

The analysis of fishing power indicated that annual changes in average fishing power differed between the sectors. Fishing power in the shallow water eastern king prawn sector had the highest rate of increase, which was not surprising given the large increase in average engine size in this sector. Increases in the number of vessels using global positioning systems and computer mapping software also contributed to increased fishing power in the tiger prawn sector. In the deep-water eastern king prawn sector average fishing power increases were surprisingly low. For this sector it was found that larger nets (net head rope lengths) were associated with larger catches, but management controls, for example over vessel and engine size, may have resulted in indirect limitations to the size of nets that fishers tow, and thus restricted fishing power.

Fishing power increased at a greater rate in the shallower, inshore fisheries (shallow eastern king prawn and tiger prawn sectors), possibly because vessels in these sectors originally had less technological capital investment, and therefore, the greatest potential for technology transfer and improvement in fishing power. Average annual fishing power increases were lowest in the scallop sector. This is at least partially due to the higher catch rates and fishing power in the scallop sector being associated with a relatively low average trawl speed of about 2.2 knots. At speeds greater than this, catch rates of scallops would be expected to decline. This was in marked contrast to the prawn sectors, where higher catches were taken at speeds of at least 3 knots.

A number of important factors affecting catches of prawns and scallops were identified, particularly factors relating to the searching capacity of vessels. The regressions indicated that catch rates improved the longer the vessel spent at sea. The models' parameter estimates for fishing effort were all significantly greater than 1 and were similar to those reported by Bishop et al. (2000) and Robins et al. (1998). This implies that catch per day of fishing effort does not have a simple interpretation. Catch rates from vessels that undertook short trips were not directly comparable with those from vessels that undertook longer trips. Within a trip, search time is probably important in identifying high catch areas and the vessels that remained longer during trips tended to be those that experienced higher than average catches. Therefore, a more representative average catch rate index for each sector should be estimated by using the number of days fished in each trip as a covariate as in prediction from a generalised linear model.

Holistically, trawl fishing power on the Queensland east coast has increased by 4% - 27%, depending on the sector, over the past 11 years. Monitoring of fishing power and the standardisation of average catches is an essential task, as trawl operators will continue to improve fishing efficiency and reduce operating costs. Even with ongoing monitoring of fishing power, it is often not possible to determine when effective changes have been made in the fishery until after the event. However, with the recent introduction of satellite vessel monitoring systems (VMS) and electronic catch and effort reporting systems (ECERS), catches in the future will be analysed in real-time together with information on vessel and trawl gear specifications. This will enable up to date stock assessments to be provided to managers and more responsive decisions made on managing the trawl fisheries. This is especially important since the Queensland Trawl Fishery is managed on the basis of inputs, such as limiting fishing days, therefore, changes in fishing power need to be monitored in real-time.

Caution needs to be exercised when assessing the cause of the changes to the fishing fleet after the implementation of the plan. 98 T1 and 1 T3 symbols were removed from the fishery by the trawl structural adjustment scheme and a further 147 surrendered since the beginning of 2001. It is difficult to determine whether the fishery is still developing technologically or whether the average parameter estimates mentioned above have increased because the boats removed from the fishery had low values of key parameters.

The increase in the average size of boats in the fishery was not due to small boats being replaced by larger boats, but as a result of the disproportionate removal of small boats from the fishery. The smaller vessels that have been removed from the fishery may have been less technologically advanced and therefore the increases in factors such as engine power, propeller nozzles and propeller pitch are more likely attributable to the vessels removed from the fishery rather than any significant increase in the vessels that remain in the fishery.

Although there has been a disproportionate reduction in small boats, the data presented above show that the majority of boats that have bought effort units to increase their allocation have not been amongst the largest size class. Boats of all size classes have been active in both buying and selling effort units.

3.2 Spatial Changes in Fishing Effort

3.2.1 *Purpose*

In order to effectively assess the sustainability of the East Coast Trawl Fishery (ECTF) a comprehensive understanding of the spatial and temporal trends in fishing effort is required. The ECTF is a highly complex fishery in terms of spatial area, principal and permitted species, bycatch composition and ecosystem dynamics. This complexity is such that in order to have confidence in maintaining or ensuring the sustainability of the fishery, an in-depth understanding of the spatial and temporal trends in effort and the factors that may cause them is required. This section examines the spatial and temporal changes in fishing effort and gross value of production (GVP) within the ECTF after the implementation of the plan.

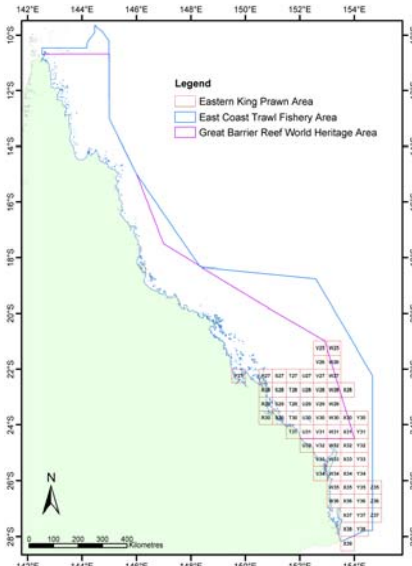
3.2.2 *Methods*

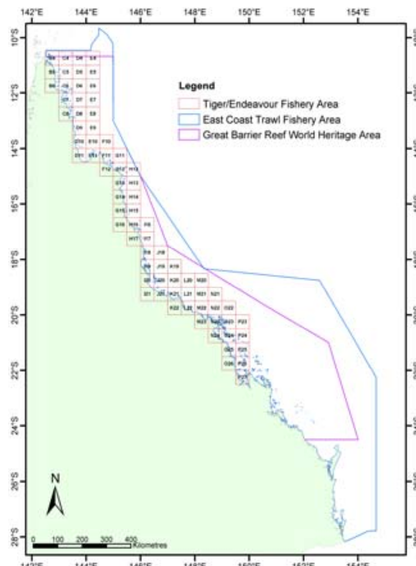
Trends in the fishing effort of the East Coast Trawl Fishery (ECTF) fleet were analysed by aggregating all effort to the 6nm CFISH sites contained in the compulsory daily logbooks. In order to identify any fishery-wide trends or intra-sectoral shifts in effort, the fishery was divided into 5 sectors: eastern king prawn, tiger/endeavour prawn, saucer scallops, red spot king prawn and bay and banana prawns. An examination of the fishery as a whole was also completed.

The fishery sectors were defined through examining the 30nm reporting Grids more commonly associated with catch from the major trawl fishing sector. Maps of the fishery sector areas are shown in Figure 3.1. King prawns were split north and south by red spot prawn and eastern king prawn. Data that fell outside the East Coast Trawl Fishery area due to incorrect location reporting was excluded from the analysis.

The five fishery sectors are not finite and are based on species distributions with a large degree of overlap. The overlap of distributions results in a number of target species being caught in the same sector at the same time. Therefore the addition of the total effort in each sector will not yield the total trawl effort for that year.

The general dispersion of fishing effort in each sector was measured by taking the average number of logbook sites that have been fished at certain levels annually. This has been done within each species sector to determine if there have been any marked shifts in fishing patterns within or between the sectors. It must be noted that even though there has been a reduction in each sector, this may have been biased by the





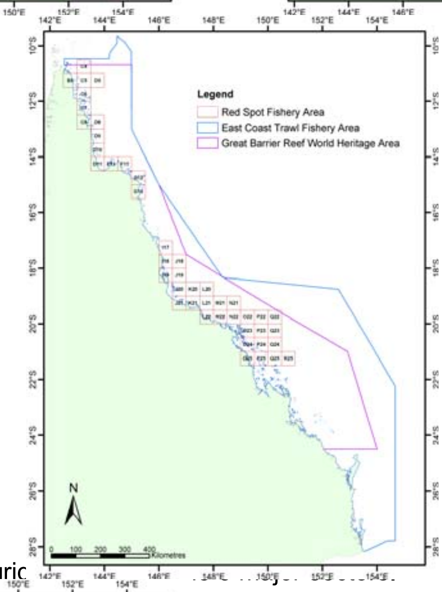
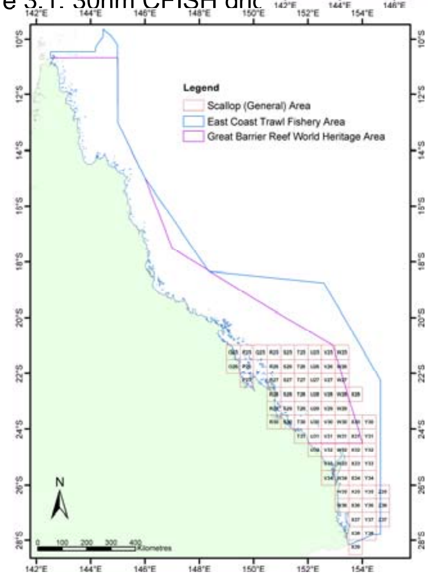
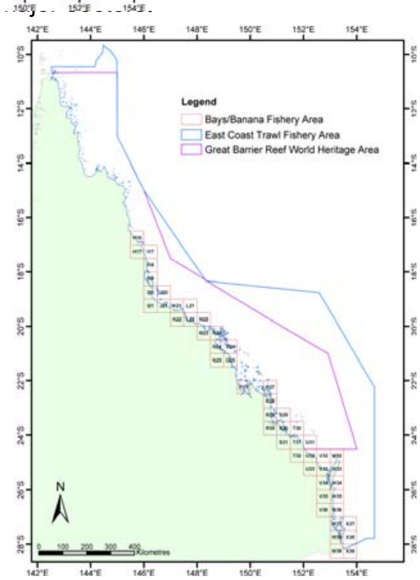


Figure 3.1. 30nm CFISH gric





number of sites, which are no longer available to be fished through the addition of closed areas in the plan.

After allocating fishing effort to a particular sector, or sectors, the trends were analysed using the average annual effort for the pre plan years of 1996 to 1998 and the post plan years of 2001 and 2002 for each 6nm site.

As fishers report at various spatial scales (latitude and longitude, 30nm grid or 6nm site), a standard scale needed to be used (Table 3.1). All reported locations were adjusted to 6nm site scale. Days fished and GVP ($AUD) were extracted for each 6' site from within the CFISH data set between 1996 and 2002 inclusive. Data reported by latitude and longitude was included in the 6nm site data. The aggregated 6nm site data were then summarised for the entire 30nm grid within which they fell, providing a proportion of total effort by 6nm site within each 30nm grid.

Table 3.1. Percent of effort reported by each spatial scale.

Period	Lat-Longs	Sites	Grids	Nulls
Pre-Plan (1996-1998)	11%	35%	54%	0%
Post-Plan (2001-2002)	26%	58%	14%	2%

Although the method of using the historic pattern within each 30nm grid to allocate catch and effort to the 6nm site may mask any changes after the implementation of the plan, this effect is minimized by the fact that the percent of effort reported by 30nm grid has been reduced by 40% after the implementation of the plan (Table 3.1).

The fished 6nm sites were compared visually using GIS plots. A comparison of the GVP for the sites pre and post plan has also been completed. In an attempt to remove the masking effects of any infrequently fished sites, all sites with less than 10 fishing days or a GVP of less than $5000 per period have been removed from the analysis.

GVP was estimated based on whole wet weight estimates of landed product with weights multiplied by estimated average price per kilo ("Beach Prices") for Principal and Permitted Trawl species. "Beach Prices" of Queensland seafood currently used have been based on information collected from a variety of sources by Mr Lew Williams (A&MU, DPI&F), circa early-2002 (Table 3.2).

As seafood prices change within the market place through time, between fishers and geographic regions, the final GVP figure should only be used as a notional representation of the Value of landed product.

Table 3.2. Beach prices used to calculate GVP.

Category	**Species-group**	**AUD $/kg**
Principal species	Prawn - King	$ 12.00
	Prawns - Tiger	$ 15.00
	Prawns - Endeavour	$ 12.00
	Prawns - Banana	$ 9.00
	Prawns – Bay	$ 5.50

	Prawns - Other	$ 6.50
	Scallops - Saucer	$ 20.00
	Scallops - Other	$ 18.00
	Bugs	$ 12.00
	Squid	$ 5.00
Principal species - average		**$ 12.50**
Permitted species	Balmain Bugs	$ 10.00
	Barking Crayfish	$ 12.00
	Blue Swimmers	$ 5.00
	Red Spot Crabs	$ 2.00
	Pinkies	$ 2.00
	Cuttlefish	$ 5.00
	Octopus	$ 5.00
	Mantis Shrimp	$ 5.00
	Syngnathids	$ 150.00
	Shark	$ 6.00
Permitted species - average		**$ 6.50**

3.2.3 *Entire ECTF*

Dispersion of effort

In terms of the area of the fishery utilised by the East Coast trawl fleet, a total of 2116 6nm sites were trawled pre plan and 1953 sites trawled post plan. The distribution of effort by site is shown in Table 3.3. The reduction of effort in the fishery after the implementation of the plan resulted in there being fewer sites that received high levels of effort. The number of sites, which received 51 nights of effort or more in the post plan period reduced from 573 (27%) pre-plan to 251 (13%) post-plan. This has lead to a more uniform distribution of trawling throughout the fishery.

Table 3.3. Distribution of effort by 6nm site for the ECTF.

Average annual fishing effort (days)	Number of Sites (pre plan)	Number of Sites (post plan)
1: 509	1543	1702
51: 200	455	218
201: 500	100	25
501: 1000	11	6
1001: 3200	7	2

Changes in spatial patterns of effort

A plot of the average annual effort by 6nm site is shown in Figure 3.2. Universal reductions in effort have occurred across the fishery. With the exception of a small number of sites, there has generally been either a reduction or no change in the effort. The largest reductions appear to have occurred close to the coast in the shallow areas of the fishery. In contrast the deeper, offshore and generally more remote grids appear to have had no change or an increase in effort in the post plan period.

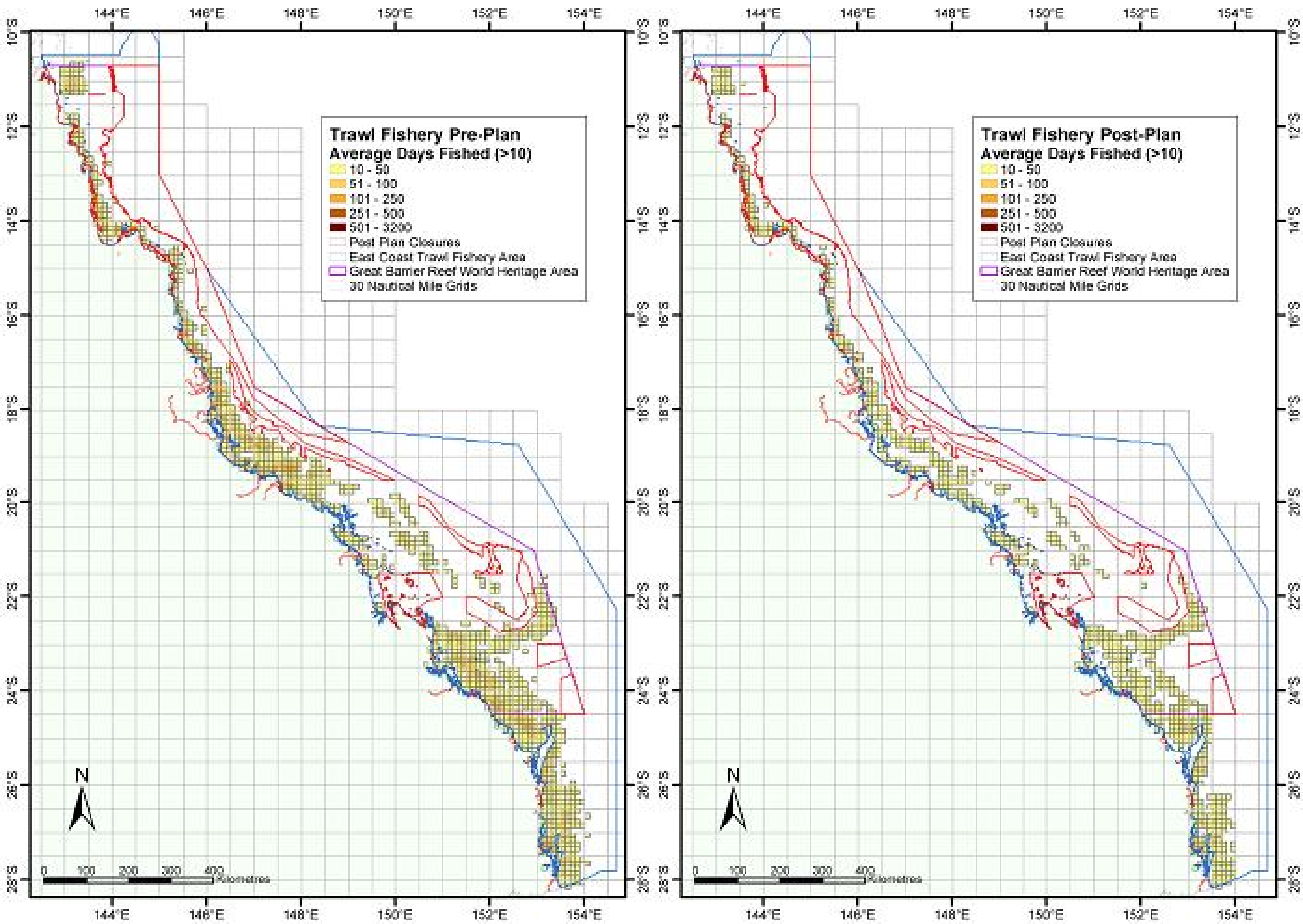


Figure 3.2. Average days fished per year for the ECTF from 1996 to 1998 (Pre-Plan) and 2001 to 2002 (Post-Plan). Note 6nm sites with < 10 days were excluded from the analysis.

Table 3.4. Change in effort by 6nm site for the ECTF since the introduction of the Plan.

Change in average annual fishing effort (days)	Number of Sites
-2400: -2001	1
-2000: -1501	0
-1500: -1001	0
-1000: -501	6
-500: -251	27
-250: -101	143
-100: -21	488
-20: 20	1704
21: 50	47
51: 100	7
101: 250	3

The change in fishing effort by site is summarised in Table 3.4. Major reductions in effort were recorded in 665 (28%) sites, 1704 (70%) had only a minor change or no change at all and 57 (2%) had a major increase. Looking at the fishery as a whole the change in the distribution appears to reflect what would be expected under a holistic decrease in effort, with relatively uniform reductions across all sites and few major changes in the patterns of fishing effort. Although this scale identifies some apparent patterns, a finer scale approach is required to determine if patterns are evident within or between the major sectors of the fishery.

Changes in the patterns of annual gross value of production (GVP) per 6nm site for ECTF generally replicated those for effort (Figure 3.3 and Table 3.5). The uniform reduction in effort was reflected in the GVP per site although there were localized areas of increased GVP scattered throughout the fishery and in the offshore areas to the south.

Figure 3.3. Changes in annual fishing effort and GVP derived from the ECTF.

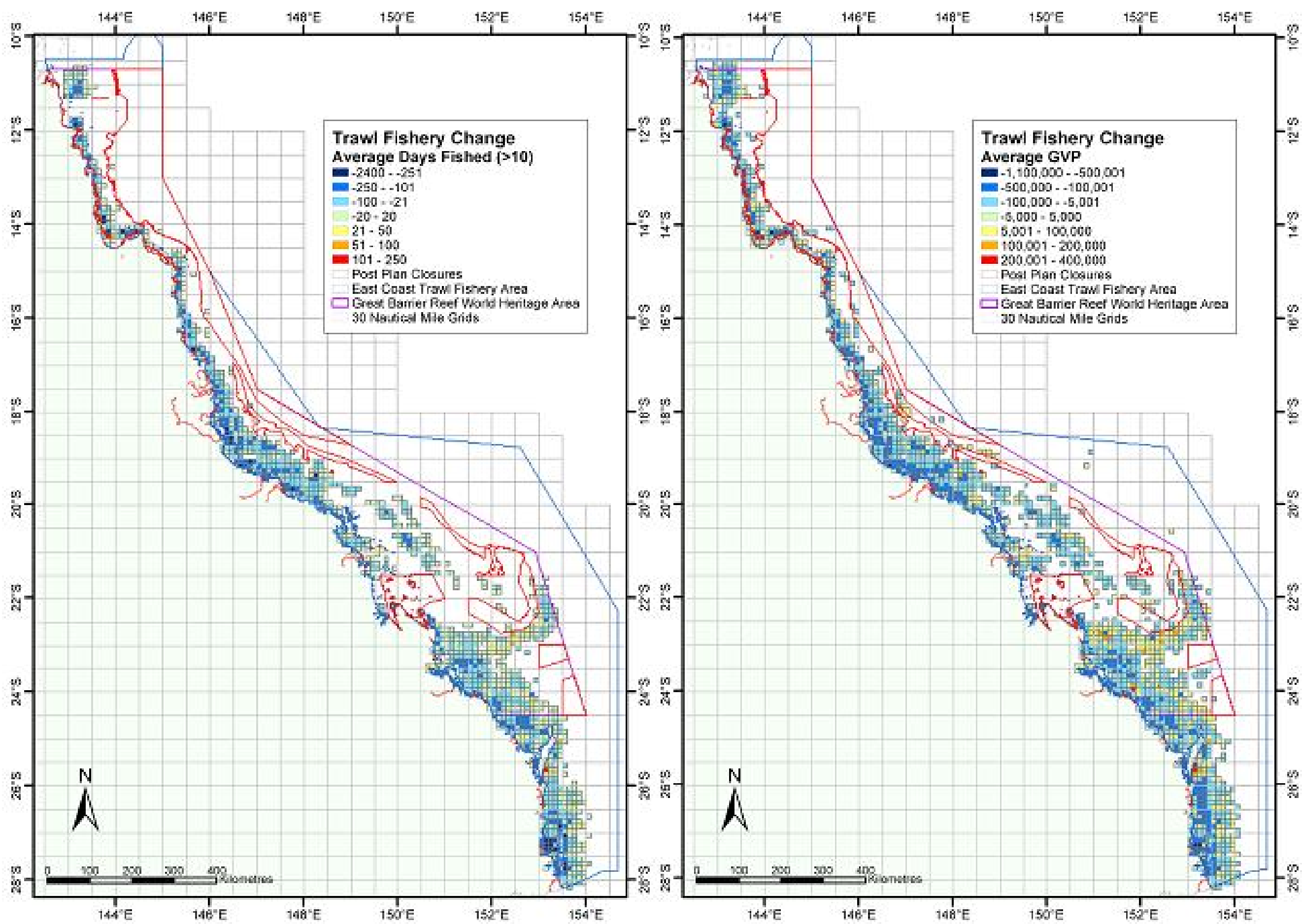


Table 3.5. Changes in GVP per 6nm site for the ECTF.

Change in average annual GVP (AUD)	Number of Sites
-1,100,000: -500,000	9
-500,000: -100,001	234
-100,000: -5,001	855
-5,000: 5,000	1044
5,001: 100,000	265
100,001: 200,000	14
200,001: 400,000	5

Effort by sector

The annual effort by sector is shown in Table 3.6. The tiger/endeavour prawn fishery had the highest levels of effort pre plan with an average of 38251 + 504 nights per year. This was reduced to 22351 + 771 nights per year post plan. The largest reduction occurred in the Banana and Bay prawn sector with a reduction from 24356 + 920 pre plan to 11641 + 261 post plan. Red spot kings and scallops also had marked reductions after the implementation of the plan.
Annual scallop effort was reduced from 15305 + 1836 to 8755 + 3359 nights per year, with only 5396 nights fished in 2002. Red spot king prawns had an annual average fishing effort comparable with eastern king prawns before the plan with 20990 + 797 and 22839 + 676 nights per year respectively. However, after the implementation of the plan, red spot king prawn effort was reduced to 14272 + 1948, contrasting with eastern king prawns which had the lowest reduction after the plan with 19535 + 211 nights per year.

Table 3.6. Summary of annual changes in effort (fishing days) by sector in the ECTF.

Year	Eastern King	Tiger/Endeavour	Scallops	Red Spot King	Bay/Banana
1988	11861	39035	6543	20884	19500
1989	17479	36266	7876	15799	23639
1990	19104	31743	17300	13915	19196
1991	20892	30068	11517	15580	24059
1992	20426	25436	10870	17113	20647
1993	19726	35155	16477	15251	19883
1994	18431	39345	12341	14698	20501
1995	18939	35111	19785	18061	18261
1996	22690	38400	12972	22583	22540
1997	21750	39040	18928	20199	25008
1998	24078	37312	14016	20187	25520
1999	19365	37848	13146	18227	25019
2000	18720	34972	15039	15756	16813
2001	19746	21580	12114	12324	11902
2002	19324	23121	5396	16220	11380

3.2.4 *Eastern King Prawns*

Dispersion of effort

The eastern king prawn sector of the fishery accounted for 20.0 + 0.71 % of the effort per year before the implementation of the plan and 26.3 + 0.03 % after the implementation of the plan. In terms of the area utilised by the eastern king prawn sector, 760 of a total 2116 of the 6nm sites trawled by the ECTF were accounted eastern king prawn effort pre plan with 709 of the 1953 sites post plan.

The distribution of effort by site is shown in Table 3.7. The eastern king prawn sector is marked by a relatively uniform distribution of effort with 695 (98%) sites receiving 200 nights of effort or less in the post plan era. The effort pattern has moved towards less effort in fewer sites after the implementation of the plan with a reduction in the number of sites receiving greater than 50 nights per year. No eastern king prawn sites received greater than 500 nights per year after the implementation of the plan.

Table 3.7. Distribution of effort by 6nm site for the eastern king prawn sector.

Average annual fishing effort (days)	Number of Sites (pre plan)	Number of Sites (post plan)
1: 50	634	622
51: 200	103	73
201: 500	22	14
501: 1000	1	0
1001: 3200	0	0
TOTAL	837	712

Changes in spatial patterns of effort

A plot of the average eastern king prawn effort by 6nm site is displayed in Table 3.8. Several changes in effort patterns are apparent in the eastern king prawn sector. Firstly there is generally a large reduction in effort in the shallower inshore areas particularly from the NSW border to Caloundra. This contrasts with a very large increase in effort in the sites to the north east of the wide bay bar in the Southern Fraser Island region.

The deeper offshore areas in the eastern king prawn sector particularly those in the deepwater net area have received greater levels of effort after the implementation of the plan. The Swain Reefs and the areas east of Lady Elliot Island have received significantly more effort with 8 sites receiving between 51 to 100 more nights per year. This increase is exacerbated by the fact that the ECTF has received an overall 36% reduction in fishing effort since the start of 2001. Considering this overall reduction in effort large localized increases in effort would be unexpected.

Table 3.8. Changes in GVP per 6nm site for the eastern king prawn sector.

Change in average annual fishing effort (days)	Number of Sites
-1,100,000: -500,000	0
-500,000: -100,001	21
-100,000: -5,001	235
-5,000: 5,000	502
5,001: 100,000	117
100,001: 200,000	5
200,001: 400,000	2

Changes in the patterns of annual GVP per 6nm site for the eastern king prawn sector roughly reflected those for effort (Figures 3.4 and 3.5). 256 (29%) sites had significant reduction in GVP, 502 (57%) had little or no change and 127 (15%) had a significant increase in GVP.

Shallow water sites between the NSW Border and Caloundra have generally been reduced in value by between $5,000 - $500,000 per site. Increases in effort from the Southern Fraser Island Area mentioned above yielded increases in GVP for 6 sites of between $5,001 and $400,000 per site. The overall pattern was marked by reduced GVP in the shallow water areas with increased or no change in GVP for the deeper offshore areas.

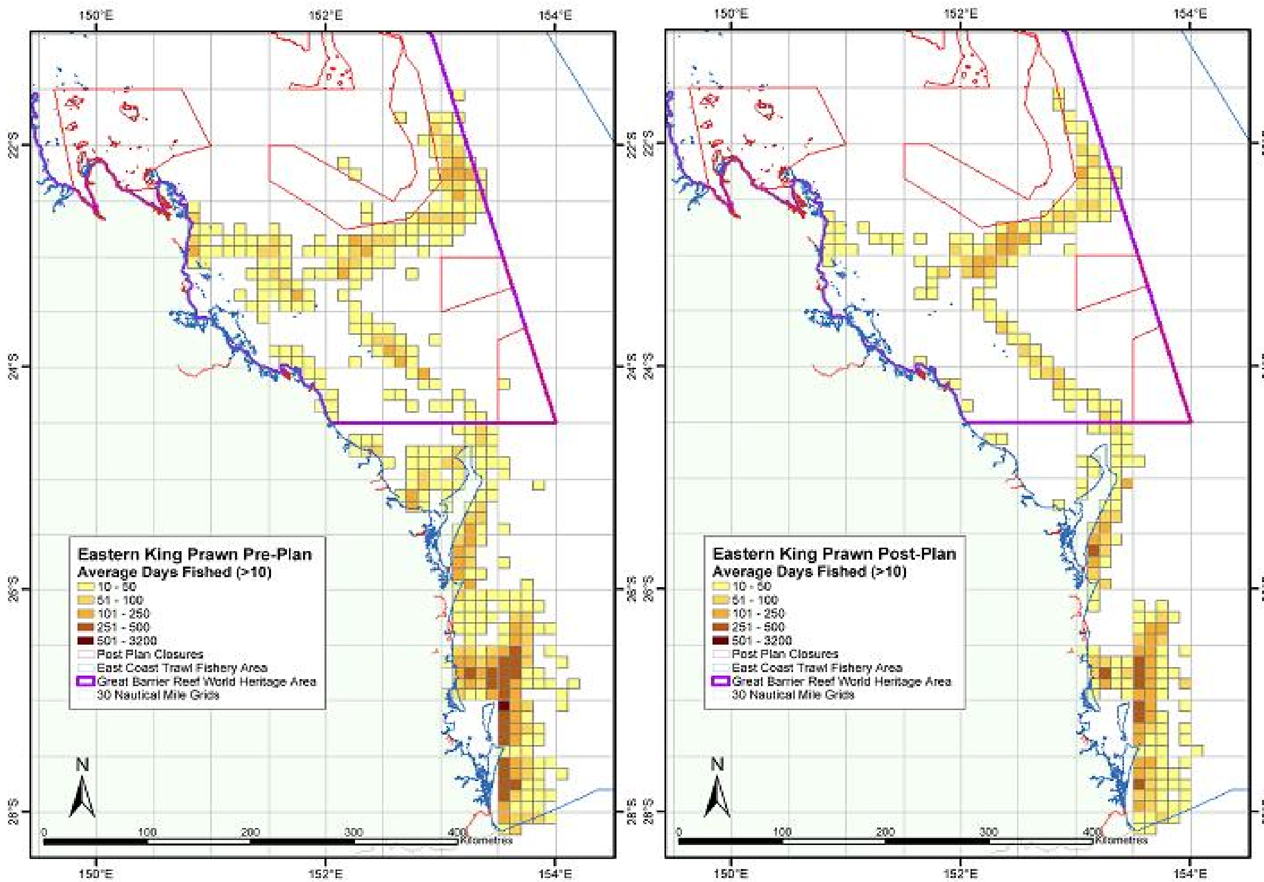


Figure 3.4. Average days fished per year for the Eastern King Prawn sector (< 10 days excluded).

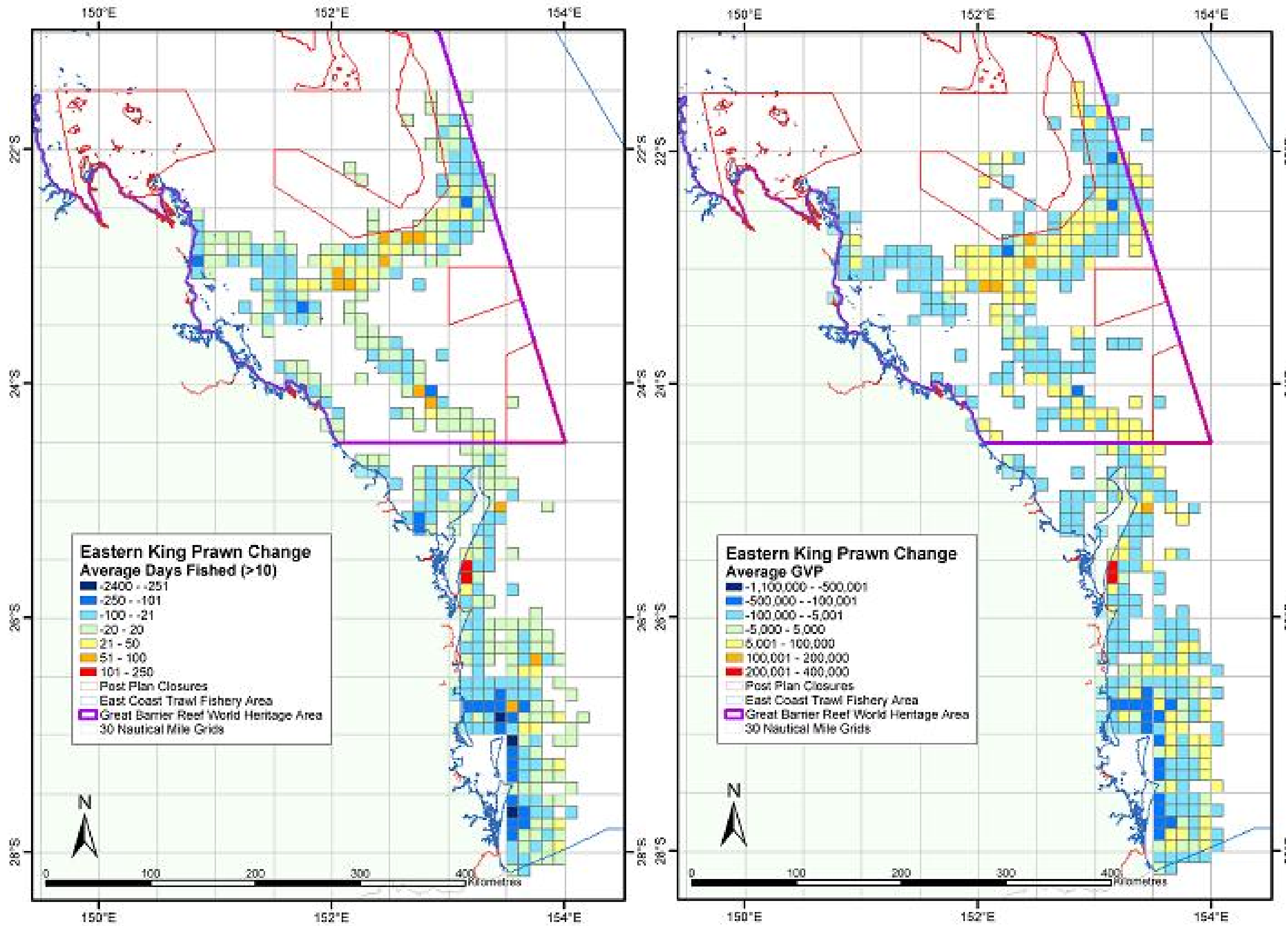
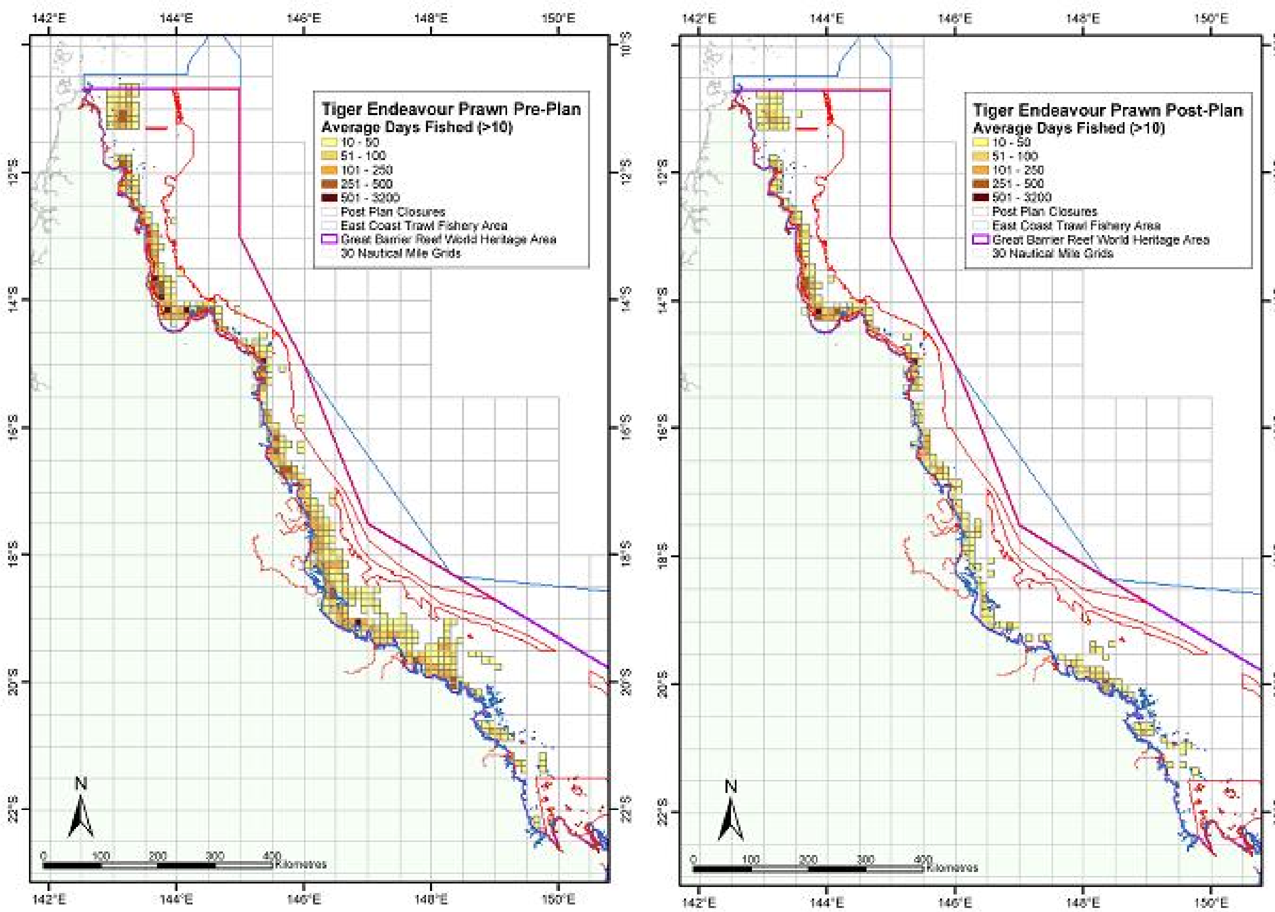


Figure 3.5. Changes in annual fishing effort and GVP derived from the Eastern King prawn sector (< $5000 excluded).

3.2.5 *Tiger / Endeavour prawn*

Dispersion of effort

The Tiger/endeavour prawn sector of the fishery received 33.6 ± 0.52 % of the total east coast trawl fishing effort per year before the implementation of the plan and 30.0 ± 1.32 % after the implementation of the plan. The area of the fishery utilised by the Tiger/endeavour prawn sector was reduced from 837 of a total 2116 sites trawled by the ECTF in the pre plan period with 712 of the 1953 sites trawled in the post plan period. The distribution of effort by site is shown in Figure 3.6.



The Tiger/endeavour prawn sector showed a similar distribution of effort to the eastern king prawn sector with 700 (98%) sites receiving 200 nights of effort or less in the post plan era (Table 3.9). The effort pattern in the Tiger/endeavour prawn sector has also moved towards less effort in fewer sites after the implementation of the plan. The Tiger/endeavour prawn sector has reduced the number of sites receiving more than 50 nights per year with only 2 sites receiving more than 500 nights per year after the implementation of the plan.

Table 3.9. Distribution of effort by 6nm site for the tiger/endeavour prawn sector.

Average annual fishing effort (days)	Number of Sites (pre plan)	Number of Sites (post plan)
1: 50	639	633
51: 200	153	67
201: 500	39	10
501: 1000	5	2
1001: 3200	1	0
TOTAL	837	712

Changes in spatial patterns of effort

A plot of the average Tiger/endeavour prawn effort by 6nm site is displayed in Figure 3.6. No major patterns are apparent in the Tiger/endeavour prawn sector. With the exception of a slight increase in effort in the Mackay area and two sites in Princess Charlotte Bay, there has generally been a large reduction in the effort in all Tiger/endeavour prawn sites.

The change in fishing effort by site is shown in Table 3.10. A major reduction in fishing effort occurred in 254 (27%) sites, 671 had only a minor change and significant increases in effort only occurred in 9 (1%) sites. The Tiger/endeavour prawn sector reflects the expected changes in the patterns of effort with uniform reductions across all sites with few major changes in the patterns of fishing effort.

Table 3.10. Change in effort by 6nm site for the tiger/endeavour prawn sector.

Change in average annual fishing effort (days)	Number of Sites
-2400: -2001	0
-2000: -1501	0
-1500: -1001	0
-1000: -501	1
-500: -251	11
-250: -101	54
-100: -21	188
-20: 20	671
21: 50	7
51: 100	0
101: 250	2

Changes in the patterns of annual (GVP) per 6nm site for the Tiger/endeavour prawn sector reflected those for effort (Table 3.11 and Figure 3.7). 411 (44%) sites had a significant reduction in GVP, 472 (50%) had little or no change and 52 (6%) had a significant increase in GVP. Spatial changes in GVP per site were marked by a general decreased GVP with localized increases in GVP present in the areas around Princess Charlotte Bay.

Table 3.11. Changes in GVP per 6nm site for the Tiger/endeavour prawn sector.

Change in average annual GVP (AUD)	Number of Sites
-1,100,000: -500,000	4
-500,000: -100,001	80
-100,000: -5,001	327

-5,000: 5,000	472
5,001: 100,000	49
100,001: 200,000	1
200,001: 400,000	1

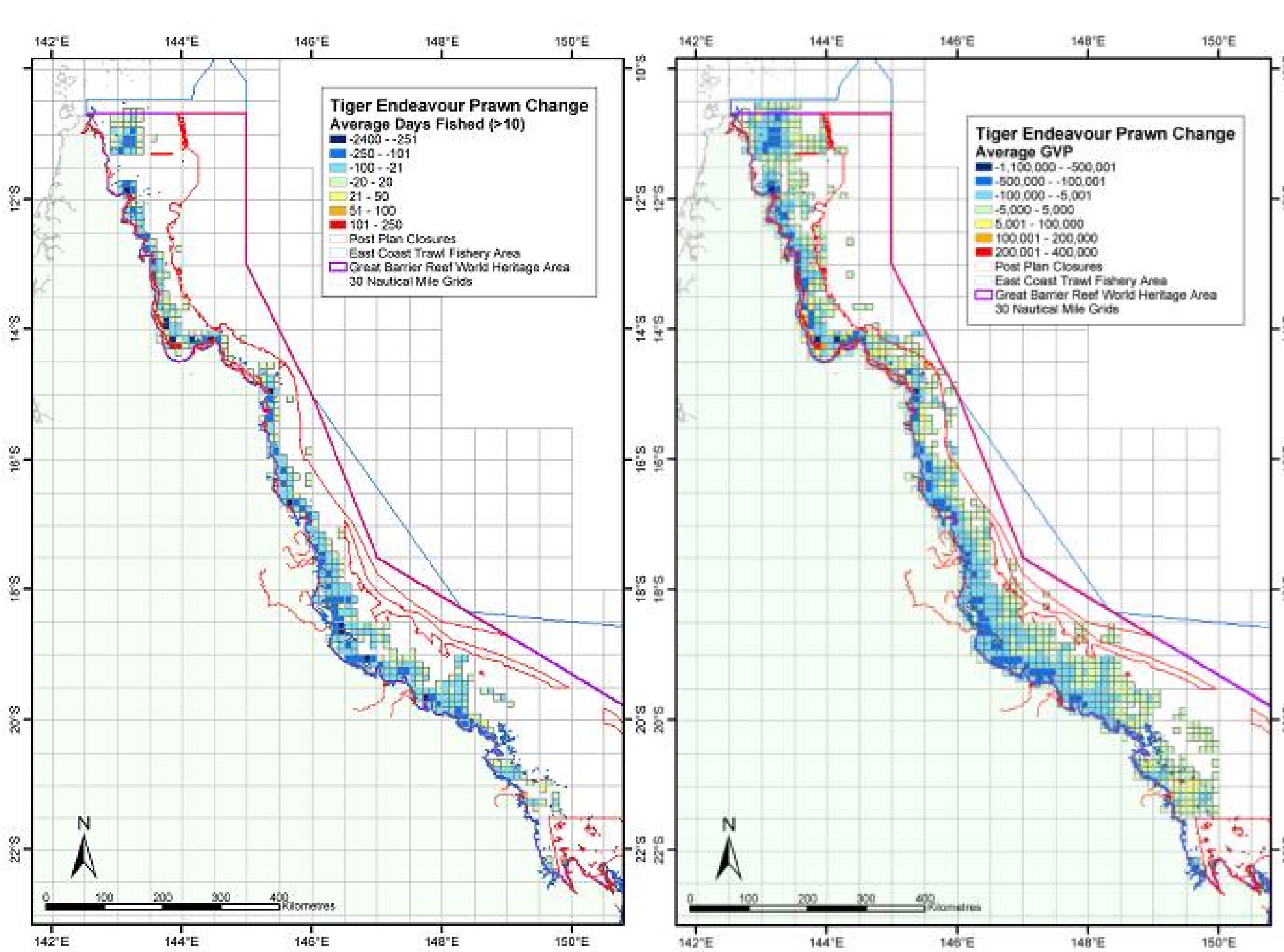


Figure 3.7. Changes in annual fishing effort and GVP derived from the tiger/endeavour prawn sector (< $5000 excluded).

3.2.6 *Saucer Scallops*

Dispersion of effort

The saucer scallop sector of the ECTF fishery received 13.4 ± 1.44 % of the trawl effort per year before the implementation of the plan and 11.7 ± 4.40 % after implementation. In terms of the area of the fishery utilised by the saucer scallop sector, 536 of a total 2116 of the 6nm sites trawled by the ECTF pre plan compared to 464 of the 1953 sites post plan. This equates to a 13% reduction in the fishery area after implementation of the Plan.

The distribution of effort by site is shown in Table 3.12. The saucer scallop sector displayed a much smaller distribution than all of the prawn sectors except Banana and bay prawns with all sites receiving 200 nights of effort or less in the post plan era. The effort pattern in the saucer scallop sector after the implementation of the plan has seen

a marked reduction in both the number of sites fished and the number of nights fished per site.

Table 3.12. Distribution of effort by 6nm site for the saucer scallop sector.

Average annual fishing effort (days)	Number of Sites (pre plan)	Number of Sites (post plan)
1: 50	424	427
51: 200	104	37
201: 500	8	0
501: 1000	0	0
1001: 3200	0	0
TOTAL	536	464

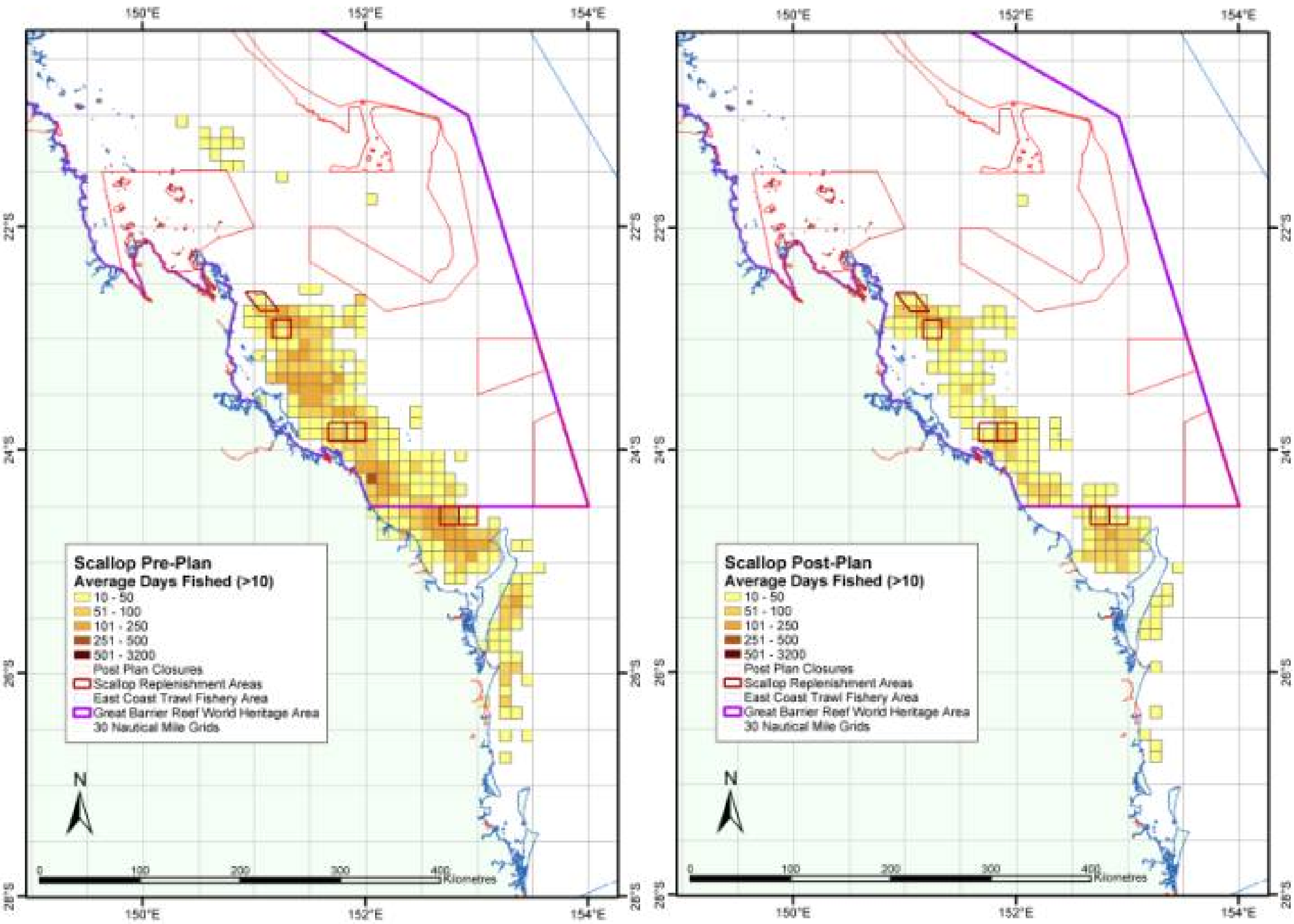


Figure 3.8. Average days fished per year for the saucer scallop sector (< 10 days excluded).

Changes in spatial patterns of effort

A plot of the average saucer scallop effort by 6nm site is displayed in Figure 3.8 and spatial changes in fishing effort are summarised in Table 3.13. The saucer scallop sector effort is marked by a major reduction across the entire sector. With the exception of an increase in effort of between 51-100 nights in one site north of Yeppoon, there has generally been a large reduction in the effort in most saucer scallop sites.

The most significant reductions in effort have occurred around the scallop replenishment area in Hervey Bay, to the east of Seventeen Seventy and off Cape Capricorn. A total of 18 sites in these areas have had a reduction in effort of between 101 and 250 nights per site.

Table 3.13. Change in effort by 6nm site for the saucer scallop sector.

Change in average annual fishing effort (days)	Number of Sites
-2400: -2001	0
-2000: -1501	0
-1500: -1001	0
-1000: -501	0
-500: -251	0
-250: -101	25
-100: -21	121

-20: 20	467
21: 50	6
51: 100	1
101: 250	0

Major reductions in effort occurred in146 (23%) sites, 467 (75%) had only a minor change or no change at all and 7 (2%) had a significant increase in effort (Table 3.13).

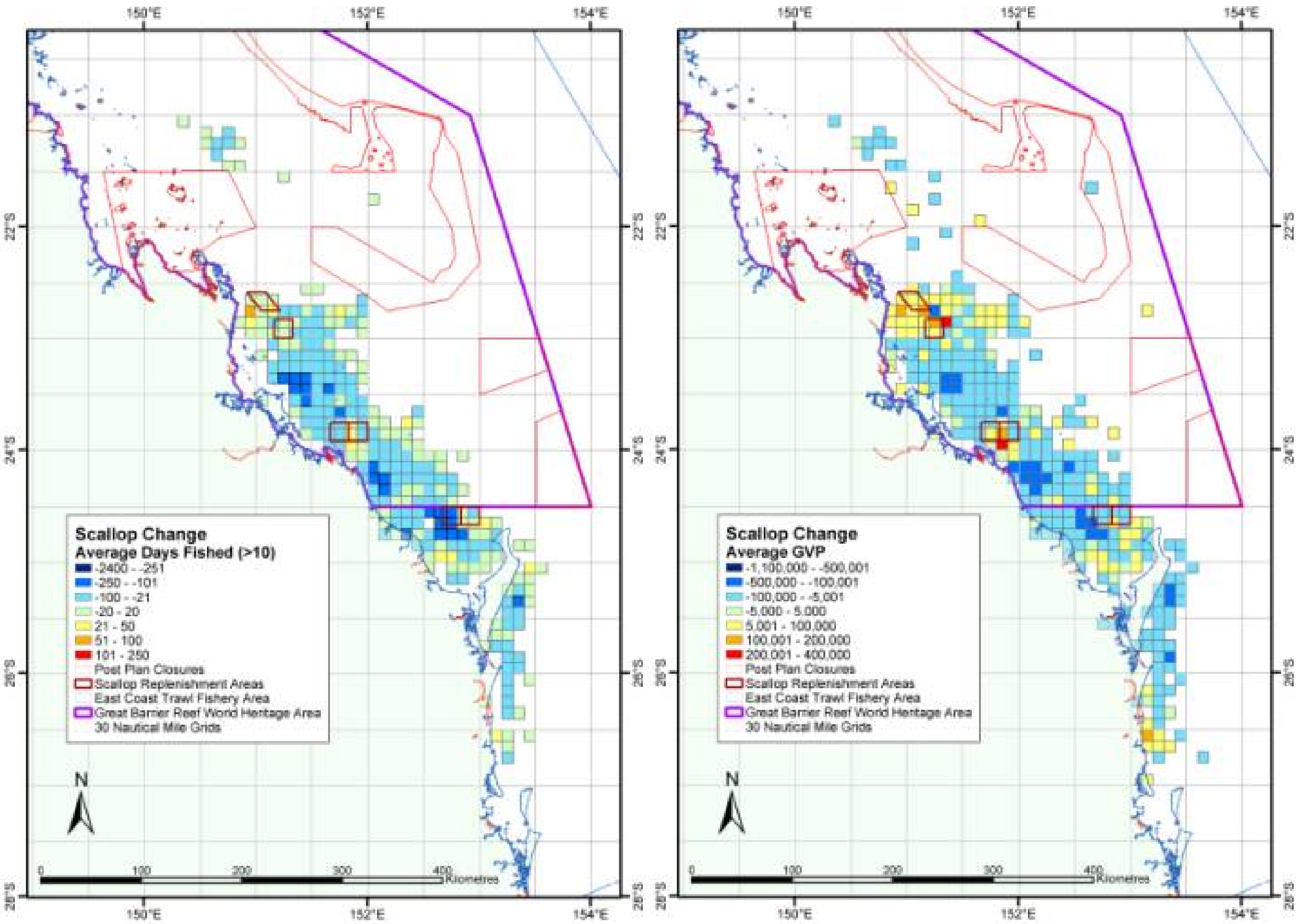


Figure 3.9. Changes annual fishing effort and GVP derived from the saucer scallop sector (< $5000 and < 10 days excluded).

Table 3.14. Changes in GVP per 6nm site for the Saucer Scallop sector.

Change in average annual GVP (AUD)	Number of Sites
-1,100,000: -500,000	0
-500,000: -100,001	22
-100,000: -5,001	190
-5,000: 5,000	344
5,001: 100,000	57
100,001: 200,000	5
200,001: 400,000	2

Changes in the patterns of annual (GVP) per 6nm site for the saucer scallop sector did not reflect those for effort (Figure 3.9 and Table 3.14). 212 (34%) sites had a significant reduction in GVP, 344 (55%) had little or no change and 64 (10%) had a significant increase in GVP. The spatial patterns of reduced effort did not reflect the GVP per site.

Although the overall pattern was a reduction in GVP, there were marked areas of increased GVP near Yeppoon, Gladstone, Hervey Bay and the Sunshine Coast.

3.2.7 *Red spot king prawns*

Dispersion of effort
The Red spot king prawn sector of the fishery accounted for 18.4 ± 0.92% of the effort per year before the implementation of the plan and 19.2 ± 2.80% after the implementation of the plan. In terms of the area of the fishery utilised by the Red spot king prawn sector, 727 of a total 2116 of the 6nm sites trawled by the ECTF were recorded as Red spot king prawn effort pre plan with 684 of the 1953 sites post plan.

The distribution of effort by site is shown in Table 3.15. The Red spot king prawn sector showed a similar distribution of effort to the eastern king prawn sector with 679 (99%) of sites receiving 200 nights of effort or less in the post plan era. The effort pattern in this sector is comparable with all other sectors mentioned above, having shifted to less fishing effort in less sites after the implementation of the plan. The Red spot king prawn sector has reduced the number of sites receiving greater than 50 nights per year with no sites receiving greater than 500 nights per year after the implementation of the plan.

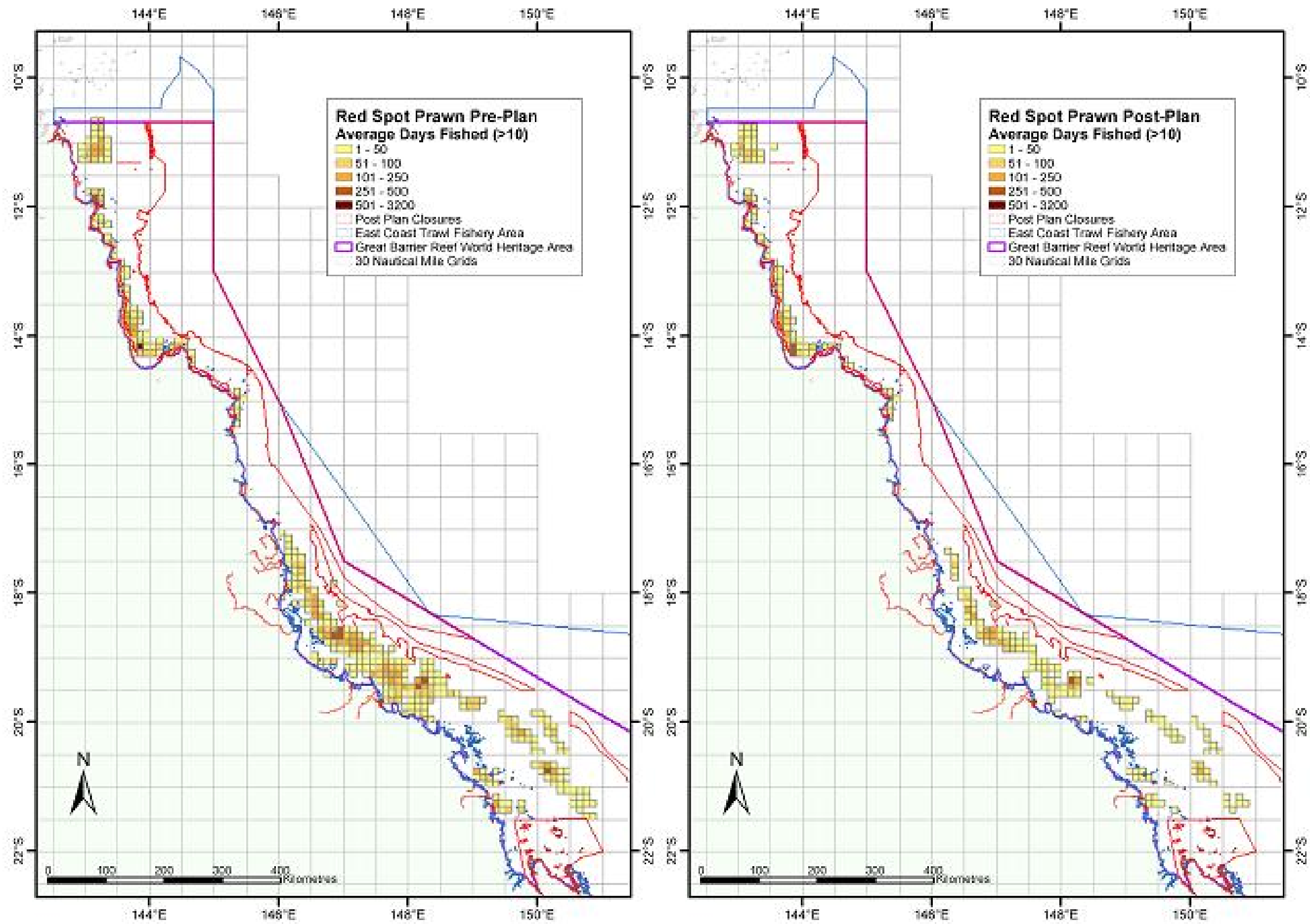
Table 3.15. Distribution of effort by 6nm site for the Red spot king prawn sector.

Average annual fishing effort (days)	Number of Sites (pre plan)	Number of Sites (post plan)
1: 50	604	638
51: 200	105	41
201: 500	17	5
501: 1000	1	0
1001: 3200	0	0
TOTAL	727	684

Changes in spatial patterns of effort
A plot of the average Red spot king prawn effort by 6nm site is displayed in Figure 3.10. Widespread reductions in effort have occurred in the Red spot king prawn sector. With the exception of an increase in effort in one site in the Princess Charlotte Bay area, there has generally been either a small reduction or no change in the effort in Red spot king prawn sector sites.

Figure 3.10. Average days fished per year for the Red spot king prawn sector (< 10 days excluded).

Table 3.16. Change in effort by 6nm site for the Red spot king prawn sector.



Change in average annual fishing effort (days)	Number of Sites
-2400: -2001	0
-2000: -1501	0
-1500: -1001	0
-1000: -501	0
-500: -251	2
-250: -101	23
-100: -21	132
-20: 20	655
21: 50	10
51: 100	0
101: 250	1

Changes in fishing effort by site are summarised in Table 3.16. It is apparent that 157 (19%) sites had a major reduction in effort, 655 (80%) had only a minor change or no change at all and 11 (1%) had a major increase. There has been an overall uniform reduction in effort across most of the Red spot king prawn sector with few major shifts in the patterns of fishing effort.

Table 3.17. Changes in GVP per 6nm site for the Red spot king prawn sector.

Change in average annual GVP (AUD)	Number of Sites
-1,100,000: -500,000	0
-500,000: -100,001	6
-100,000: -5,001	209
-5,000: 5,000	558
5,001: 100,000	49
100,001: 200,000	1
200,001: 400,000	0

Changes in the patterns of annual (GVP) per 6nm site for the Red spot king prawn sector generally reflected those for effort (Table 3.17 and Figure 3.11). A significant reduction in GVP occurred in 215 (26%) sites, 558 (68%) had little or no change and 50 (6%) had a significant increase in GVP. Spatially the GVP has declined in the majority of sites with a small number of sites with increased GVP scattered across the entire sector. Increases in GVP were also present in the areas in the far north of the ECTF.

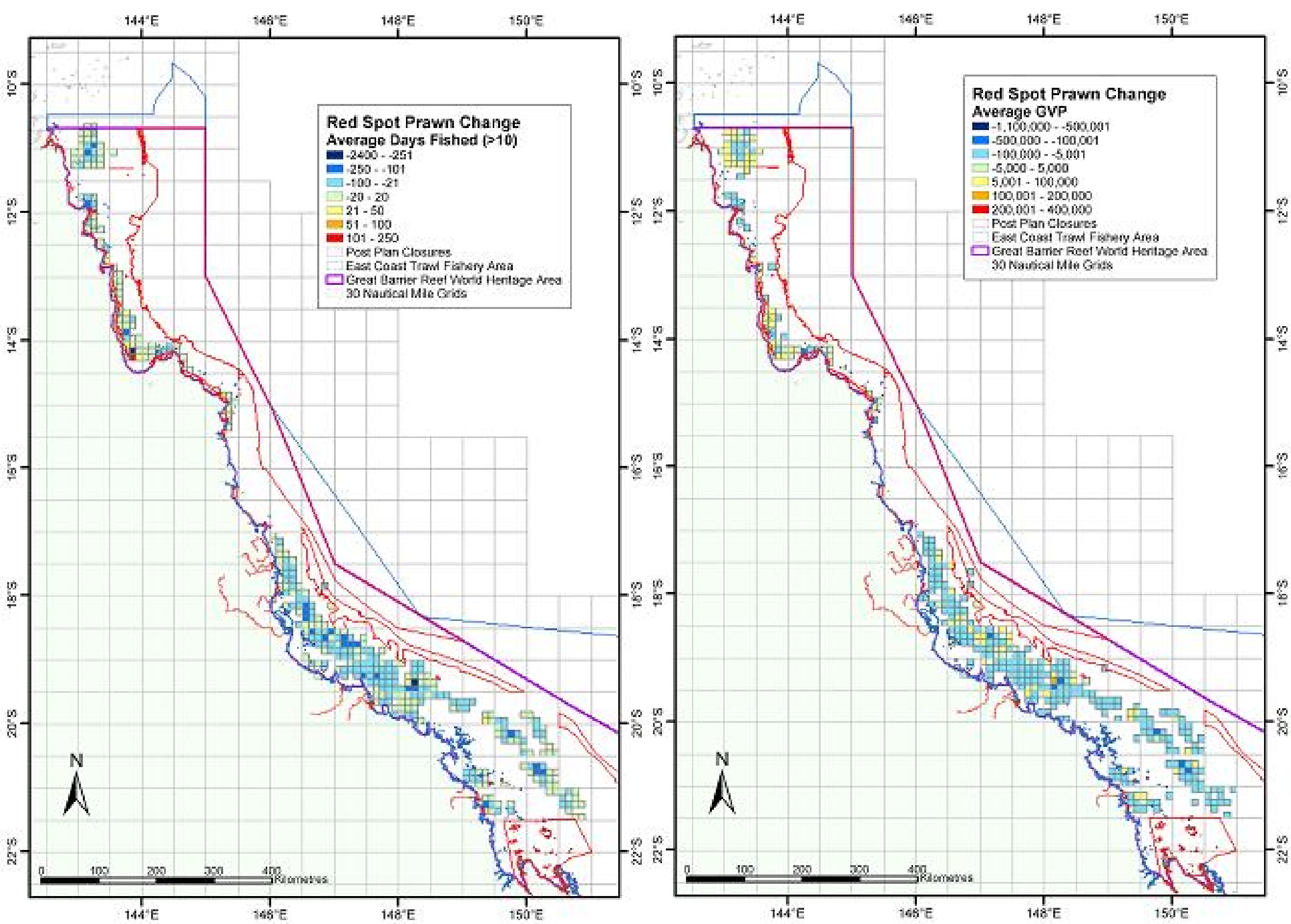


Figure 3.11. Changes in annual fishing effort and GVP derived from the Red spot king prawn sector (< $5000 and < 10 days excluded).

3.2.8 *Banana and Bay Prawns*

Dispersion of effort

The Banana/Bay prawn sector of the fishery received approximately 21.3 ± 0.61% of the total effort in the east coast trawl fishery per year before the implementation of the plan and 15.6 ± 0.20% after the implementation of the plan. In terms of the area of the fishery utilised by the Banana and bay prawn sector, 447 of a total 2116 of the 6nm sites trawled by the ECTF were recorded as Banana/Bay prawn effort pre plan with 310 of the 1953 sites post plan. This is by far the least area of all the sectors used in terms of 6nm sites, furthermore the greatest proportional reduction (30%) in sites fished post plan of all the sectors.

The distribution of effort by site is shown in Table 3.18. The changes in the dispersion of effort varied significantly between the Banana/Bay prawn sector and the other 4 main sectors. Although the proportion of sites (301 (97%)) of sites which received 200 nights of effort or less in the post plan era were comparable, there was a higher incidence of sites with greater than 201 nights fished than in the other sectors.

Table 3.18. Distribution of effort by 6nm site for the Banana/Bay prawn sector.

Average annual fishing effort (days)	Number of Sites (pre plan)	Number of Sites (post plan)
1: 50	385	281
51: 200	44	20
201: 500	9	6
501: 1000	4	2
1001: 3200	5	1
TOTAL	447	310

Changes in spatial patterns of effort

Broad-scale reductions in effort have occurred in the Banana/Bay prawn sector (Figure 3.12). With the exception of a small number of sites south of Yeppoon, there has generally been either a reduction or no change in the effort in Banana/Bay prawn sector sites. The largest reductions occurred within Moreton Bay.

Figure 3.12. Average days fished per year for the Banana/Bay prawn sector (< 10 days excluded).

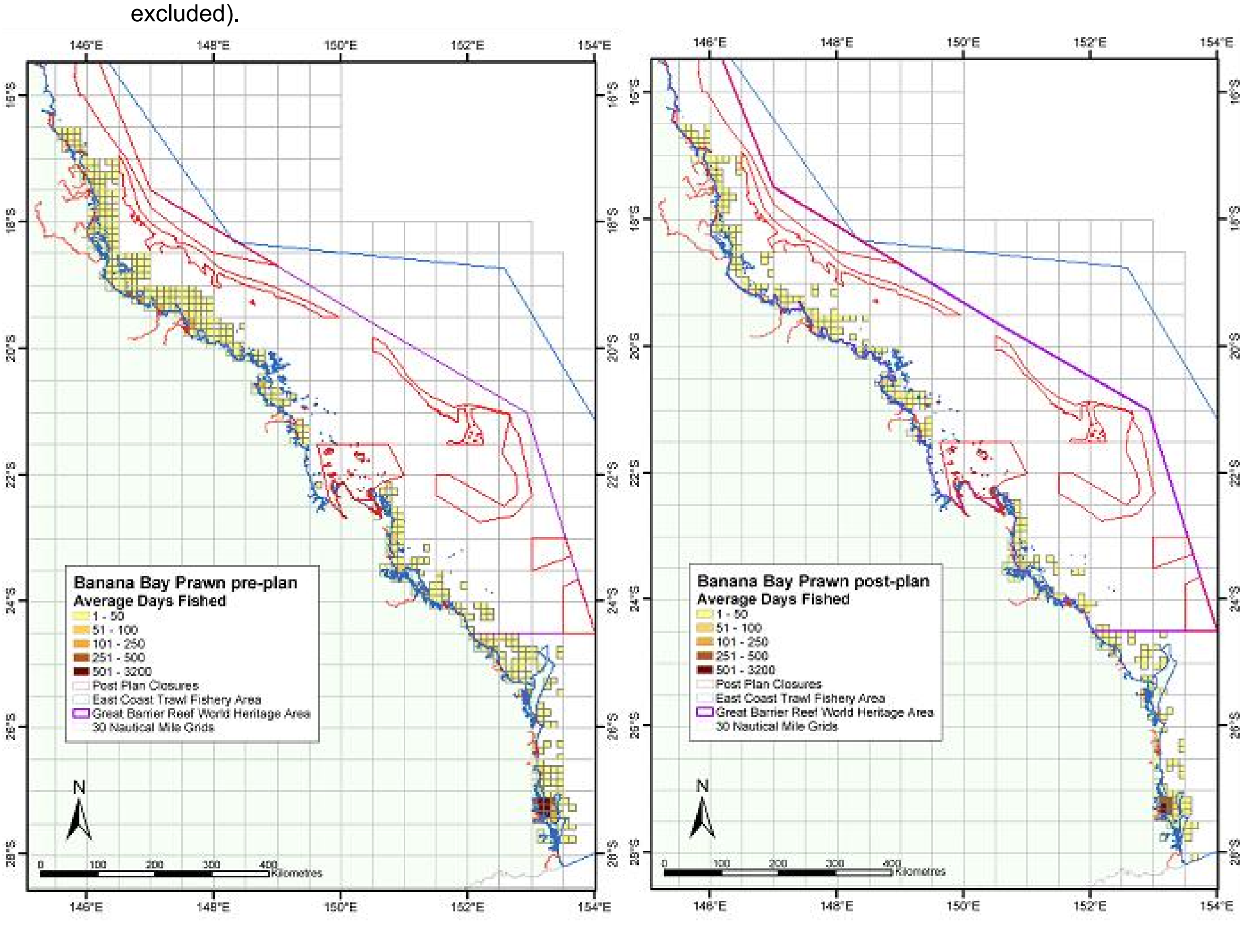


Table 3.19. Change in effort by 6nm site for the Banana/Bay prawn sector.

Change in average annual fishing effort (days)	Number of Sites
-2400: -2001	1
-2000: -1501	1
-1500: -1001	1
-1000: -501	3
-500: -251	6
-250: -101	14
-100: -21	78
-20: 20	402
21: 50	6
51: 100	0
101: 250	0

Changes in fishing effort by site are summarised in Table 3.19. Significant reductions in effort occurred in 104 (20%) sites, significant increases in effort occurred in 6 (1%) sites and 402 (79%) had only a minor change or no change at all in effort. The Banana/Bay prawn sector reflects the expected changes in the patterns of effort with uniform reductions across all sites with few major changes in the patterns of fishing effort.

Changes in the patterns of annual (GVP) per 6nm site for the Banana/Bay prawn sector generally reflected those for effort (Table 3.20 and Figure 3.13). 161 (31%) sites had a significant reduction in GVP, 332 (65%) had little or no change and 19 (4%) had a significant increase in GVP. The uniform reduction in effort was reflected in the GVP per site although there were localized areas of increased GVP south of Yeppoon and north of Mackay.

Table 3.20. Changes in GVP per 6nm site for the Banana/Bay prawn sector.

Change in average annual GVP (AUD)	Number of Sites
-1,100,000: -500,000	1
-500,000: -100,001	18
-100,000: -5,001	142
-5,000: 5,000	332
5,001: 100,000	18
100,001: 200,000	1
200,001: 400,000	0

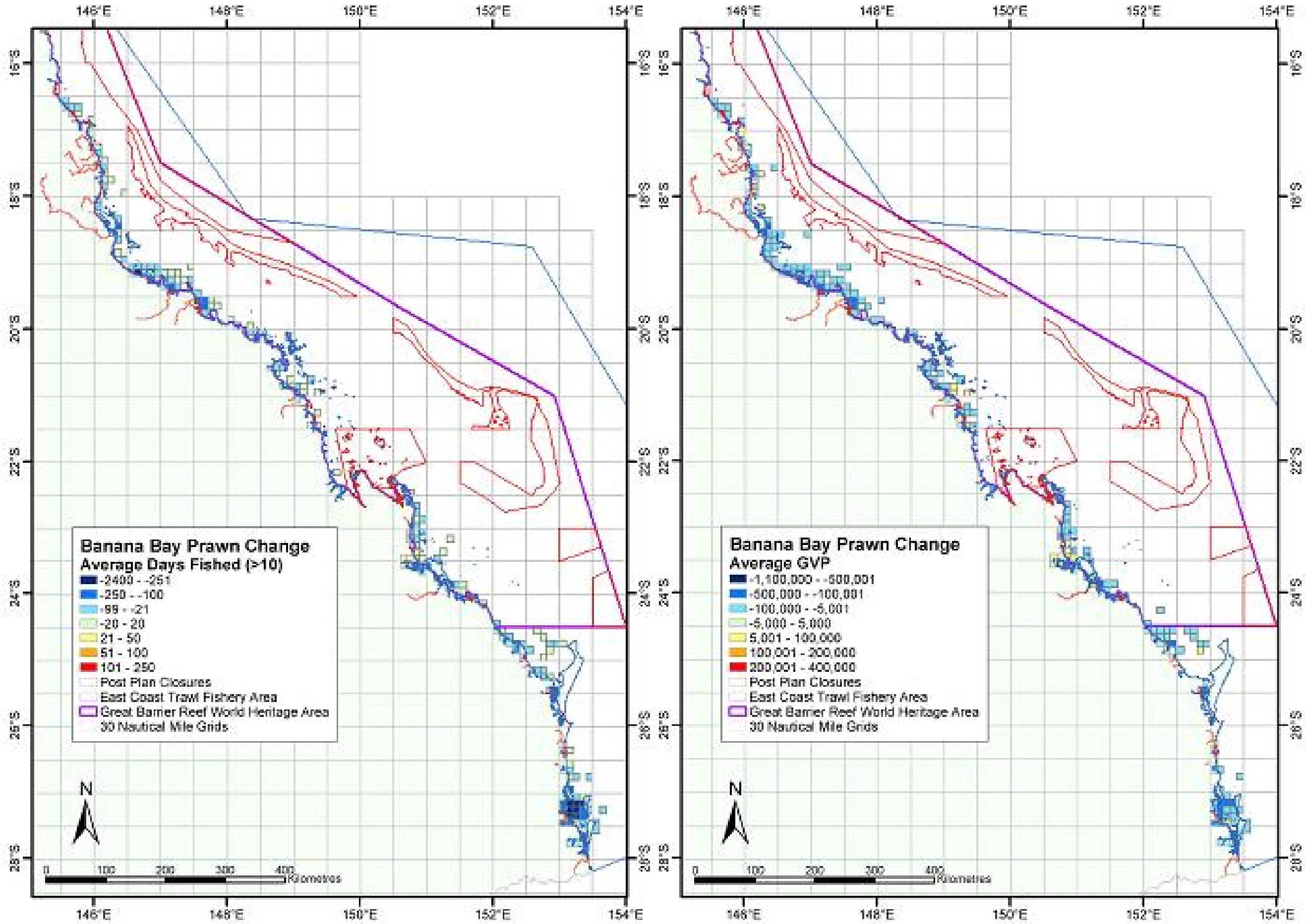


Figure 3.13. Changes in annual fishing effort and GVP derived from the Banana/Bay prawn sector (< $5000 and < 10 days excluded).

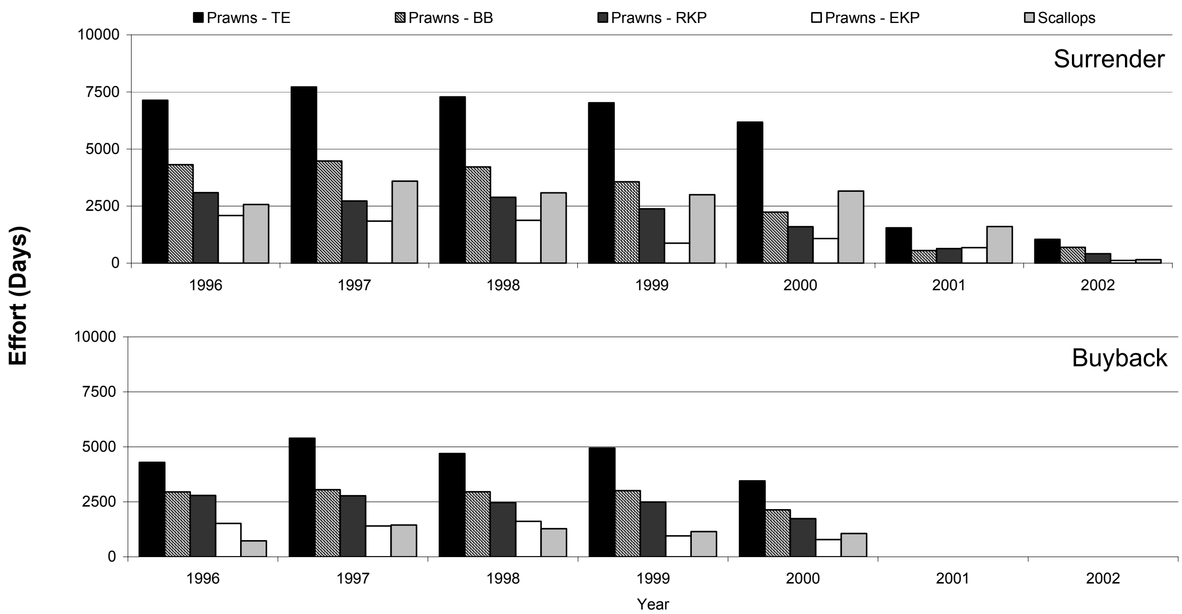
3.2.9 *Effort for vessels no longer in the fishery*

Vessels have been removed from the fishery via two major processes, the structural adjustment scheme or buyback and the surrender of T1 endorsements after all effort units have been sold from a licence. Figure 3.14 shows the effort by sector for the vessels that have been removed from the fishery. In comparing this removed effort it must be noted that the effort from the buyback has been completely removed from the fishery, whereas the effort from the surrendered T1 vessels has been redistributed throughout the fishery via the process of effort unit trading.

For both the buyback and surrendered vessels, the Tiger/endeavour prawn sector was the most actively fished with an average level of effort before the plan of 7380 ± 174 and 4793 ± 320 nights per year for the surrendered and buyback vessels respectively. The eastern king prawn sector had the least amount of effort before the plan with 1509

± 59 nights per year for the buyback vessels and 1938 ± 76 nights per year for the surrendered vessels. The effort removed from the scallop sector via the buyback was the lowest of all sectors with an average annual effort of 1150 ± 217 nights per year before the plan.

Figure 3.14. Annual effort for vessels removed from the fishery via the Structural adjustment scheme or by surrendering their T1 endorsement.



3.2.10 *Great Barrier Reef World Heritage Area*

Fishing effort in the Great Barrier Reef World Heritage area (GBRWHA) was reduced by 38% from a pre plan average of 73068 ± 1540 fishing days to 45205 ± 757 fishing days post plan (Table 3.21). In terms of the average proportion of total ECTF effort used within the GBRWHA, a reduction of 3.4% occurred within the GBRWHA with the level dropping from 64.2 ± 1.1% to 60.8 ± 1.6% after the implementation of the plan. The proportion of vessels operating in the GBRWHA was also significantly reduced from 71.8 ± 0.4% to 67.5 ± 1.5%.

Table 3.21. Annual effort and GVP in the GBRWHA and ECTF.

Year	Boats			Days fished			GVP (Million $AUD)		
	GBRWHA	ECTF	%	GBRWHA	ECTF	%	GBRWHA	ECTF	%
1988	738	941	78.4%	60,883	84,144	72.3%	88.2	110.4	79.9%
1989	702	950	73.8%	58,349	92,340	63.1%	79.9	111.9	71.4%
1990	689	950	72.5%	58,857	95,304	61.7%	87.8	124.6	70.4%
1991	690	958	72.0%	59,188	95,360	62.0%	85.2	115.6	73.7%
1992	633	883	71.6%	53,500	89,171	59.9%	77.3	111.1	69.5%
1993	648	908	71.3%	65,817	101,755	64.6%	111.8	146.7	76.2%
1994	608	866	70.2%	65,270	101,150	64.5%	89.3	125.1	71.4%
1995	608	852	71.3%	69,219	104,443	66.2%	116.3	153.4	75.8%
1996	629	874	71.9%	72,652	111,203	65.3%	106.3	144.9	73.3%
1997	635	876	72.4%	75,919	116,204	65.3%	94.8	130.7	72.5%
1998	604	850	71.0%	70,634	114,011	61.9%	104.3	146.2	71.3%
1999	582	839	69.3%	67,316	107,007	62.9%	96.5	129.0	74.7%
2000	564	798	70.6%	59,168	96,541	61.2%	72.5	105.5	68.7%
2001	447	677	66.0%	44,449	75,042	59.2%	72.9	105.4	69.1%
2002	422	611	69.0%	45,962	73,621	62.4%	81.0	108.4	74.7%

Although there was a significant reduction in the proportion of the total ECTF effort used in the GBRWHA, there was no significant change in the proportion of the total GVP taken from the GBRWHA with 72.4 $\pm$ 0.6% of GVP pre plan and 71.9 $\pm$ 2.8% of GVP taken from within the GBRWHA post plan.

3.2.11 *Discussion*

After the implementation of the plan and the subsequent reduction in effort through the structural adjustment scheme, there was an overall uniform reduction in effort across the entire fishery area. However, a sector-by-sector analysis showed some significant inter-sectoral patterns after the implementation of the Plan.

An overall shift in effort away from the tiger/endeavour prawn, saucer scallop and banana/bay prawn sectors have occurred. This effort has moved predominantly into the eastern king prawn sector resulting in a 6% increase in the proportion of total fishing effort after the implementation of the plan. Minor spatial changes within each major sector have also occurred.

The eastern king prawn sector had the most obvious changes in effort with a reduction in the shallower inshore areas and an increase in the deeper offshore areas. The shallow water sites are traditionally targeted in the summer months when eastern king prawn recruits migrate offshore from the Great Sandy Straits and Moreton Bay (Courtney et al 2002). Care must be taken in the interpretation of these trends with such a short time series. The eastern king prawn recruits to the Moreton Bay fishery in October/November each year with larger prawns recruiting to the offshore areas in the following 2 to 3 months (Courtney et al 2002).

Seasonally late recruitment from Moreton Bay in 2002 could account for the low effort in the shallow water areas around Moreton Island and Caloundra.

The variability in effort applied to the deeper sites within the deepwater net area compared to the shallow sites from the NSW border to Caloundra may be influenced by the effect of the annual southern closure on these areas. The inshore areas are closed for six weeks per year with the deepwater net area open to fishing year round. However, the southern closure only accounts for the variability between the two areas, it does not account for the increase in effort in the sites within the deepwater net area after the implementation of the plan.

The tiger/endeavour prawn and red spot king prawn sectors showed a uniform reduction in effort across all sites. This is the expected fleet behaviour when individual operators all have their effort scaled down proportionally. It also indicates that a large proportion of the fleet target these sectors annually. Of note however was the 3% shift of effort out of the tiger/endeavour prawn sector, the shift presumably toward the eastern king prawn sector.

A large reduction in the effort within the saucer scallop sector was identified, with negligible localized increases in some sites. The localized increases in effort correspond with the scallop replenishment areas and presumably are a result of boats either working along the closure boundaries of the closed areas or the large pulses of effort that occur when the areas are opened to fishing.

The saucer scallop GVP didn't correlate well with the effort within the fishery. Again the areas around the scallop replenishment areas were higher than expected. As noted above the rotation of the replenishment areas causes a large pulse of effort as boats work in areas closed that have been closed for extended periods. Catches in these areas have been known to exceed 150 baskets a night for several nights, resulting in significant localized increases in GVP.

The area off the Sunshine Coast also experienced large increases in GVP. This increase resulted from an unusual settlement of scallops in this area in early 2001. A small number of boats experienced a short period of increased catches of around 100 baskets per 24-hour period (B. Logan pers. com.). The increase in GVP was prominent, as scallops are generally not caught in this area.

The banana and bay prawn sector also displayed a large decrease in both overall effort and effort within each site. The higher incidence of sites with greater than 200 nights a year is presumably caused by the schooling nature of the banana prawn, resulting in the aggregation of the fleet targeting small areas with high prawn densities. Another cause of this high level of effort per site could be that a large proportion of the bay prawn effort is within Moreton Bay. In this area, a significant proportion of the total trawl effort is undertaken in a relatively small number of sites.

3.3 Temporal changes in Catch and effort in Moreton Bay

3.3.1 *Purpose*

Currently there are 38 otter trawl vessels (M2 fishery symbol) licenced to fish in Moreton Bay only and an additional 53 otter trawl vessels (M1/T1 fishery symbol) licenced to fish in Moreton Bay and the general T1 fishery area. Currently the number of M2 vessels is managed through a 2 for 1 boat replacement policy.
Fishing effort in the east coast trawl fishery has been capped under the *Fisheries (East Coast Trawl) Management Plan 1999* (the Plan). The number of nights that can be fished in Moreton Bay is capped through the allocation of M1/T1 and M2 fishery symbols. Each of the 38 vessels with an M2 symbol can fish up to 260 days per year (9,880 nights), M1/T1 holders can potentially use all of their allocated nights in Moreton Bay (8089 nights) resulting in more than 17,600 nights of fishing effort annually. Through effort unit trading by the M1/T1 holders, this level can potentially reach more than 23,000 nights if M1/T1 holders increase their effort unit holding to 260 nights. Typically M1/T1 holders have been using approx 43% of their allocation in Moreton Bay, however there is the potential for this to increase significantly. The potential for significant increases in effort needs to be considered when developing an alternative system for the management of the M2 fleet.

The purpose of this section is to assess the status of the two trawl fisheries within Moreton Bay. The historic catch and effort in Moreton Bay has been analysed and compared with the vessels currently operating in the M1/T1 and M2 fisheries. This will provide baseline information required to develop a system for management of the otter trawl fishery in Moreton Bay and revise the current M2 vessels 2 for 1 boat replacement policy.

3.3.2 *Methods*

All Moreton Bay trawl data were extracted from the CFISH database for the years 1996 to 2002. At the time of production of this report the complete catch records for 2003 were not available. The nature of the 30nm grids and 6nm sites in the Moreton Bay area and the significant effort occurring in the shallow eastern king prawn fishery just east of Moreton Island make it difficult to determine which trawl fishing has occurred inside or just outside Moreton bay. The logbook grids in the Moreton Bay area are shown in Figure 3.15.

Spatial resolution of catch records
From 1996 to 2002 the spatial resolution at which catch data has been recorded is highly variable. In 1996 fishers were required to only report catch at the 30' grid resolution, this contrasts to present requirements where catch is recorded at either 6nm grid or a specific latitude and longitude. The highlighted 6nm sites are the areas where it becomes difficult to identify whether the fishing has occurred in Moreton Bay or outside (Figure 1). Cases where fishers have not recorded at the 6nm site resolution result in effort being incorrectly attributed either inside or outside Moreton Bay. For example, if a vessel worked in the shallow water eastern king prawn grounds in grid W37 site 15, which is clearly outside Moreton Bay but only puts "W37" in the logbook, this effort is attributed within Moreton Bay as the centre of Grid W37 is in the centre of the bay. This can lead to some effort from larger T1 and T2 vessels being allocated within Moreton Bay when the fishing actually occurred outside. This discrepancy is more prevalent in the years before 2000 when 6nm reporting was not compulsory.
As versions prior to the OT07 logbook did not differentiate between beam and otter trawl fishing it is difficult to differentiate between these two fishing methods prior to the start of 2000 when the OT07 logbooks were introduced to the fishery. To address this issue only vessels that did not have a beam trawl symbol were used in the catch per unit effort analyses. This may result in the exclusion of only a small amount of catch as only 3 licences have both an M1/T1/M2 and T5 symbols.

Species resolution of catch records

Fishers label catch based on the dominant species caught. For example, 'Bay prawns' are made up of a suite of species including school, clicker, coral and small king prawns. Catch recorded as 'Tiger prawns' may contain small kings and banana prawns but are predominantly tiger prawns, and similarly for catch recorded as 'King prawns' (i.e. may contain small tigers and bananas). For the purposes of this report fishing catch and effort has been aggregated into 4 principal species groups: King prawns, Tiger prawns, Bay prawns and Squid. The years 1996 to 2002 have been broken into two periods: 1996 to 1998 is the Pre Plan period and 2001 and 2002 represents the post plan period. The years 1999 and 2000 have been excluded because of the structural change undertaken by the fishery in the years immediately preceding and following the implementation of the Plan.

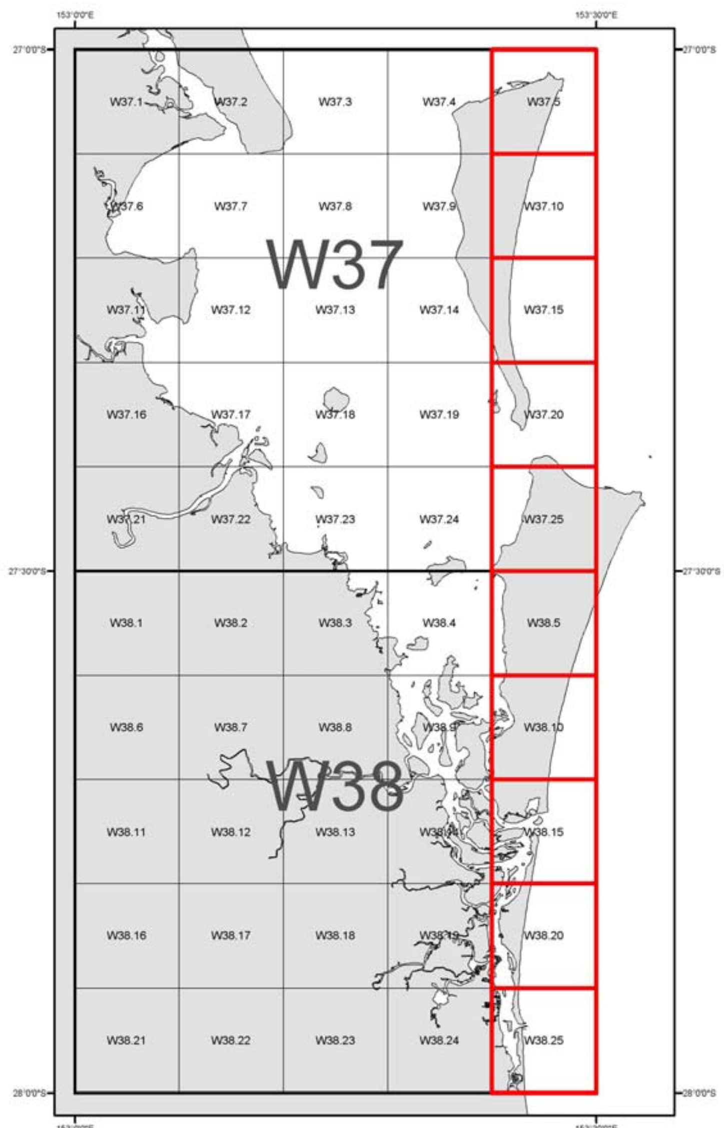
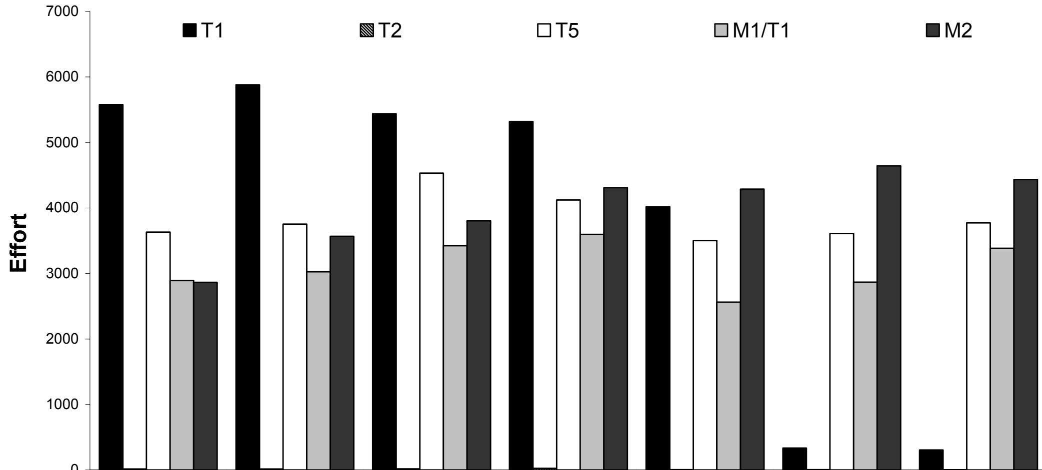


Figure 3.15. 30' and 6' logbook grids in the Moreton Bay area. 6' grids outlined in red are excluded from the analysis.

3.3.3 *Results*

3.3.4 *Fishing effort and number of boats*

The annual fishing effort in Moreton bay has been reduced from an average of 16146 ± 648 nights per year before the Plan to 11677 ± 219 nights after the Plan. By fishery there has only been significant reductions in the T1 and T2 fishery symbols that can no longer fish in Moreton Bay. The M2 vessels have increased their average annual effort from 3412 ± 282 nights per year pre plan to 4539 ± 105 nights per year since the implementation of the Plan (Figure 3.16). The M1/T1 symbol vessels have seen no significant change in the amount of effort in the Bay with an annual average of 3114 ± 160 nights fished pre plan and 3126 ± 259 nights post plan. The T5 symbol vessels have maintained a relatively constant level of effort with an average of 3971 ± 282 nights and 3691 ± 82 nights per year before and after the Plan respectively. The minor amount of T1 and T2 effort in the 2001 and 2002 seasons (Figure 3.16) is the discrepancy due to errors in the recording of catch location as discussed in the methods section.

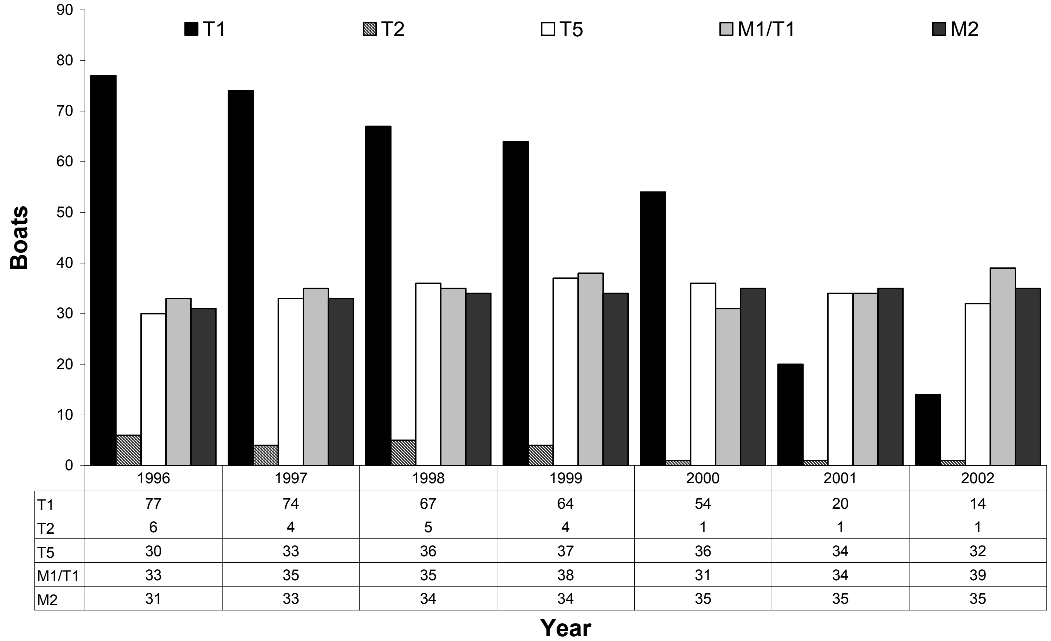


	1996	1997	1998	1999	2000	2001	2002
T1	5578	5882	5441	5320	4019	334	305
T2	15	13	17	23	6	4	1
T5	3630	3753	4531	4122	3502	3609	3772
M1/T1	2891	3026	3425	3596	2561	2867	3384
M2	2864	3568	3805	4308	4289	4645	4434

Year

Figure 3.16. Annual Effort by fishery symbol in Moreton Bay. M1/T1 and M2 symbols in this figure refer to boats that were allocated an M1/T1 or M2 symbol when the new symbols were created.

The number of vessels fishing in Moreton Bay each year has reduced from an average of 178 ± 0.7 pre-plan to 123 ± 1.5 after the implementation of the Plan (Figure 3.17). As with effort, the reductions are caused by the elimination of T1 and T2 boats from Moreton Bay, not a reduction in the activity of M1/T1 or M2 boats. The M1/T1 symbol boats increased from an average of 34 ± 0.7 to 37 ± 2.5 boats fishing per year and the active M2 symbol boats increased from 33 ± 0.9 to 35 ± 0.0 boats fishing per year after the Plan.



	1996	1997	1998	1999	2000	2001	2002
T1	77	74	67	64	54	20	14
T2	6	4	5	4	1	1	1
T5	30	33	36	37	36	34	32
M1/T1	33	35	35	38	31	34	39
M2	31	33	34	34	35	35	35

Figure 3.17. Annual changes in the numbers of **active** boats by fishery symbol. M1/T1 and M2 symbols in this figure refer to boats that were allocated an M1/T1 or M2 symbol when the new symbols were created.

3.3.5 *M1/T1 Effort unit holding*

Table 3.22 summarises the changes in effort unit holding for the M1/T1 symbol holders since the implementation of the Plan. It is apparent that although the average holding per licence has increased considerably, the number of M1/T1 symbol holders has decreased. The total M1/T1 effort unit holding increased in the first quota year, but has decreased in the following two years.

Table 3.22. M1/T1 effort unit holding per year.

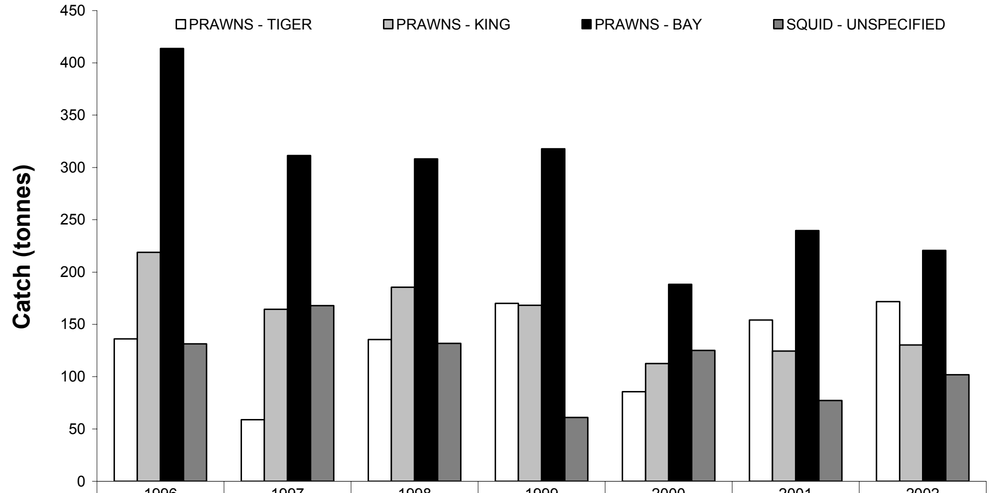
Year	Initial	2001	2002	2003
M1/T1 licences	59	59	56	53
Total nights	7098	8054	7865	7573
Total Effort Units	167623	191977	191903	185554
Average Effort Units ± S.E.	2841 ± 205	3254± 220	3427 ± 231	3501± 246

At the end of the 2001 season 8880 nights (8054 nights + 826 steaming nights) were available to be fished in Moreton Bay by M1/T1 licences. Of these, 2867 (32%) were fished within Moreton Bay. At the end of the 2002 season the M1/T1 fishery had a total of 7865 nights available to be fished plus an additional 224 steaming nights. Of these 8089 available nights, 3384 (42%) were fished in Moreton Bay. This represents a significant increase in the proportion of total M1/T1 effort units being applied to the Bay.

3.3.6 *Annual catch by species*

The annual catch by species for Moreton Bay is shown in Figure 3.18. The annual catches for all species except tiger prawns declined after the implementation of the Plan.

Tiger prawn catches displayed high inter-annual variation with the highest catch of 171 tonnes in 2001. Average annual catches have increased after the Plan: pre plan annual catch of 110 ± 25 tonnes (low average catch due primarily to a low catch in 1997) compared to a post plan annual catch of 163 + 9 tonnes. The annual king prawn catch also showed high inter annual variation with a decrease in annual catches after the implementation of the plan from 190 + 16 to 127 + 3 tonnes per year.



	1996	1997	1998	1999	2000	2001	2002
PRAWNS - TIGER	136.2	58.9	135.6	170.1	85.7	154.1	171.7
PRAWNS - KING	218.8	164.4	185.5	168.2	112.7	124.5	130.3
PRAWNS - BAY	413.8	311.4	308.3	317.9	188.3	239.7	220.7
SQUID - UNSPECIFIED	131.3	167.9	131.9	61.0	125.1	77.2	101.8

Year

Figure 3.18. Annual catch by species group in Moreton Bay.

Annual catches of bay prawns had the largest reduction after the Plan, with catches decreasing from an average of 345 + 35 to 230 + 10 tonnes per year. Squid catches were reduced from an average of 144 + 12 to 90 + 12 tonnes per year.

3.3.7 *Monthly catch and effort by species*

All boats

The monthly catch and effort of tiger prawns is shown in Figure 3.19. Tiger prawn catches typically peak in March with lowest catches recorded during July and August. Average monthly tiger prawn catches have increased following the implementation of the Plan with an average monthly catch of 9.2 + 1.8 tonnes pre plan and 13.6 + 2.9 tonnes post plan. The monthly average number of nights on which tiger prawns were caught decreased marginally after the implementation of the Plan with 600 + 51 pre plan and 554 + 63 nights post plan.

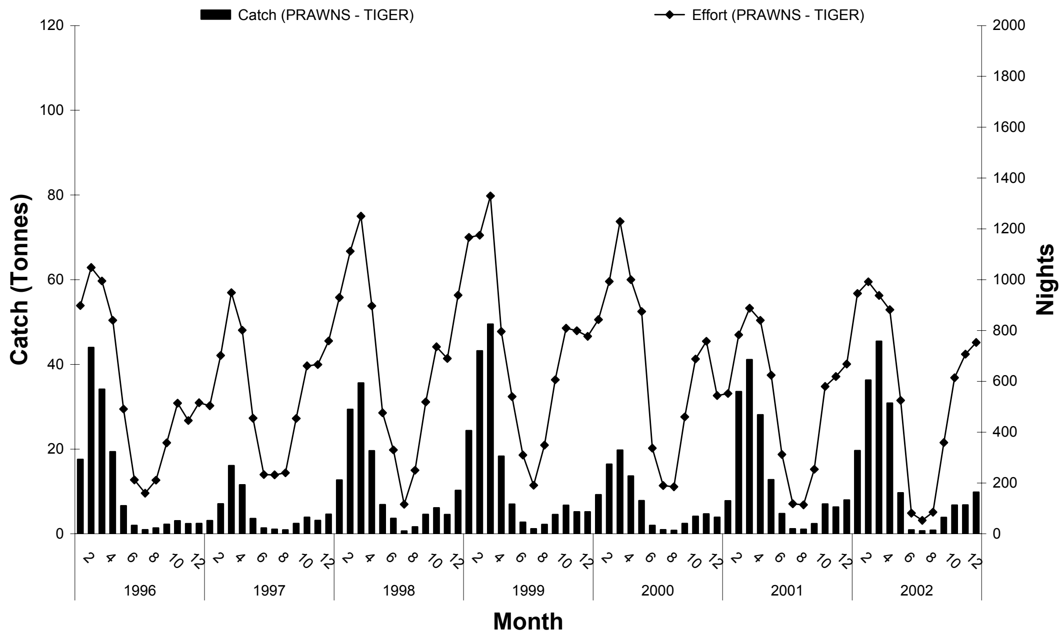


Figure 3.19. Monthly Catch and Effort of tiger prawns for all vessels in Moreton Bay.

Monthly catches of king prawns in Moreton Bay steadily increase from October, peak in January and decrease gradually to a minimum in June - July (Figure 3.20). The average monthly catch of king prawns has decreased significantly after the implementation of the Plan decreasing from an average of 15.8 ± 2.2 tonnes to 10.6 ± 1.8 tonnes per month. The average number of nights on which king prawns were caught also decreased notably after the Plan. An average of 734 ± 74 nights were fished per month before the Plan with 502 ± 59 nights per month fished post plan.

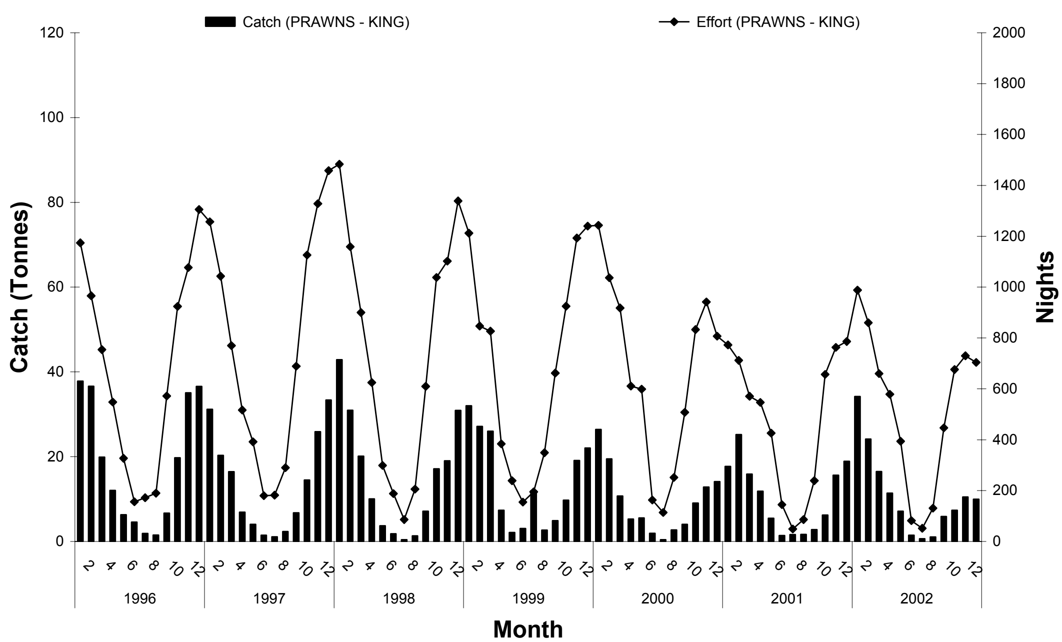


Figure 3.20. Monthly Catch and Effort of king prawns for all vessels in Moreton Bay.

Catches of Bay prawns tend to be caught more consistently throughout the year with no one or two-month period consistently experiencing large catches (Figure 3.21). Catches of bay prawns have decreased more than the other target species with average monthly catches decreasing from 28.7 + 4.0 to 19.1 + 3.4 tonnes per month after the Plan. The average number of nights on which bay prawns were caught also decreased significantly after the Plan. An average of 824 + 72 nights were fished per month before the Plan decreasing to 523 + 60 nights per month fished post plan.

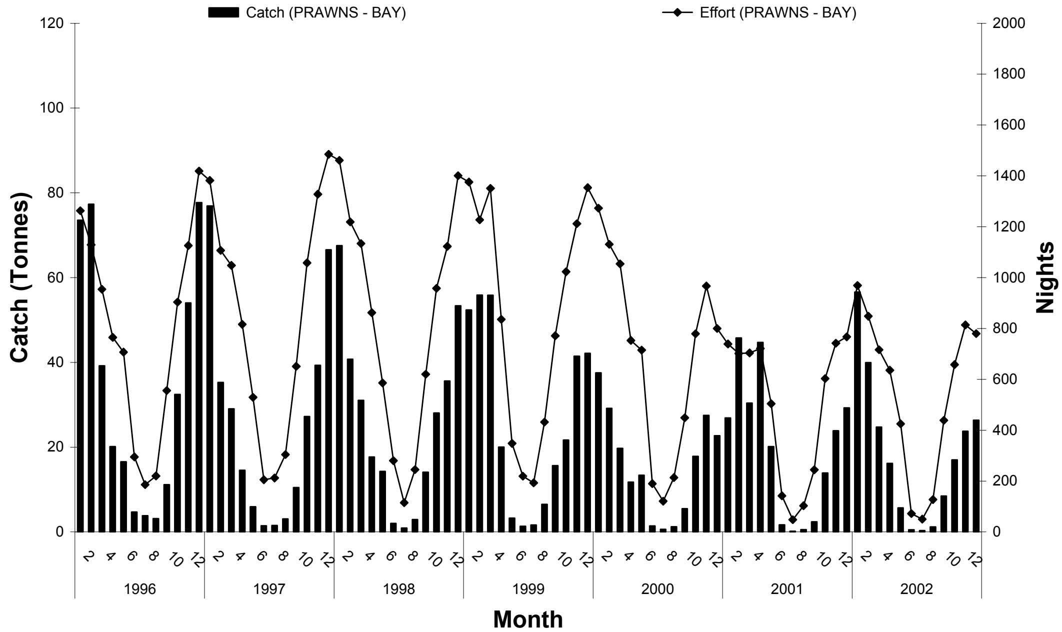


Figure 3.21. Monthly Catch and Effort of bay prawns for all vessels in Moreton Bay.

Monthly squid catches are highly variable with no consistent seasonal patterns present, however in general, highest catches are reported February to April (Figure 3.22). Average monthly catches of squid have also decreased after the Plan with a pre plan average of 11.9 + 2.0 tonnes and a post plan average of 7.5 + 1.7 tonnes. The average number of nights on which squid were caught also showed high variations and no consistent seasonal patterns, decreasing from 468 + 32.6 to 378 + 42.2 nights per month after the Plan.

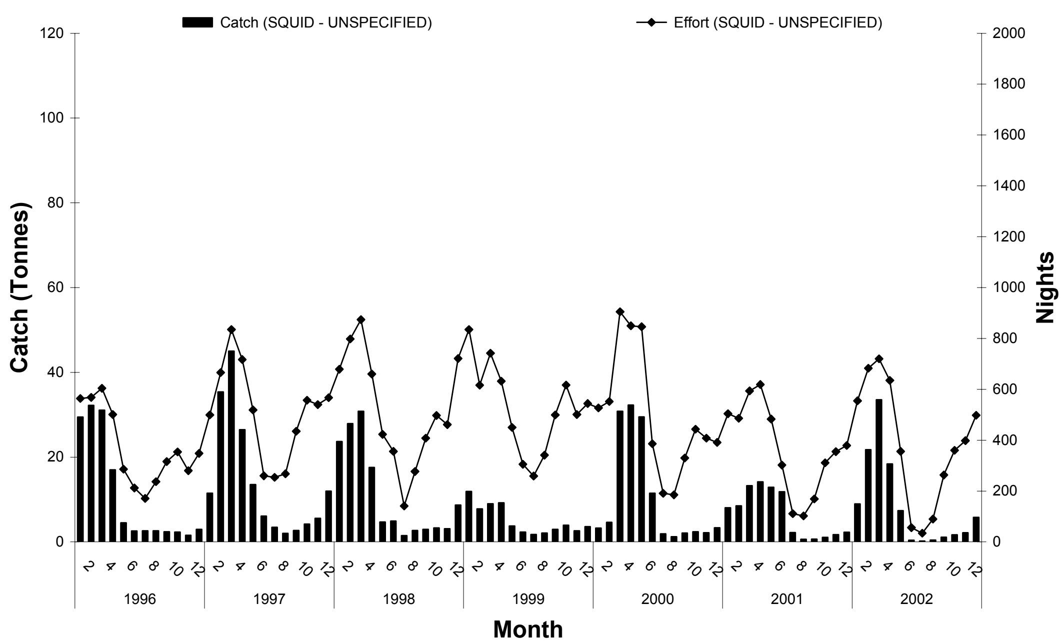


Figure 3.22. Monthly Catch and Effort of squid for all vessels in Moreton Bay.

Current M1/T1 and M2 vessels

The monthly catch and effort by symbol for boats that **currently** hold an M1/T1 or M2 symbol are included in this section. These data are relevant for comparing the relative catches of boats that have fished in Moreton Bay before and after the management changes introduced by the Plan.

The monthly tiger prawn catch and effort for M1/T1 and M2 symbol boats are shown in Figure 3.23. The average monthly catches for the two fisheries are similar. The M1/T1 fishery averaged 2.4 ± 0.5 tonnes and 6.5 ± 1.5 tonnes before and after the Plan respectively. The M2 fishery averaged 2.4 ± 0.4 tonnes and 6.6 ± 1.2 tonnes before and after the Plan respectively. In terms of the number of nights on which tiger prawns were caught, the M2 boats have maintained a higher average fishing effort per month before and after the implementation of the Plan than the M1/T1 vessels. The M2 fishery has increased in average effort directed at tiger prawns from 187 ± 15 nights per month pre plan to 330 ± 34 nights per month after the Plan, an average increase of 143 nights per month. The M1/T1 fishery has also increased in average effort targeted at tiger prawns with a 143 ± 15 nights per month before and 216 ± 29 nights per month after the Plan, an average increase of 73 nights per month.

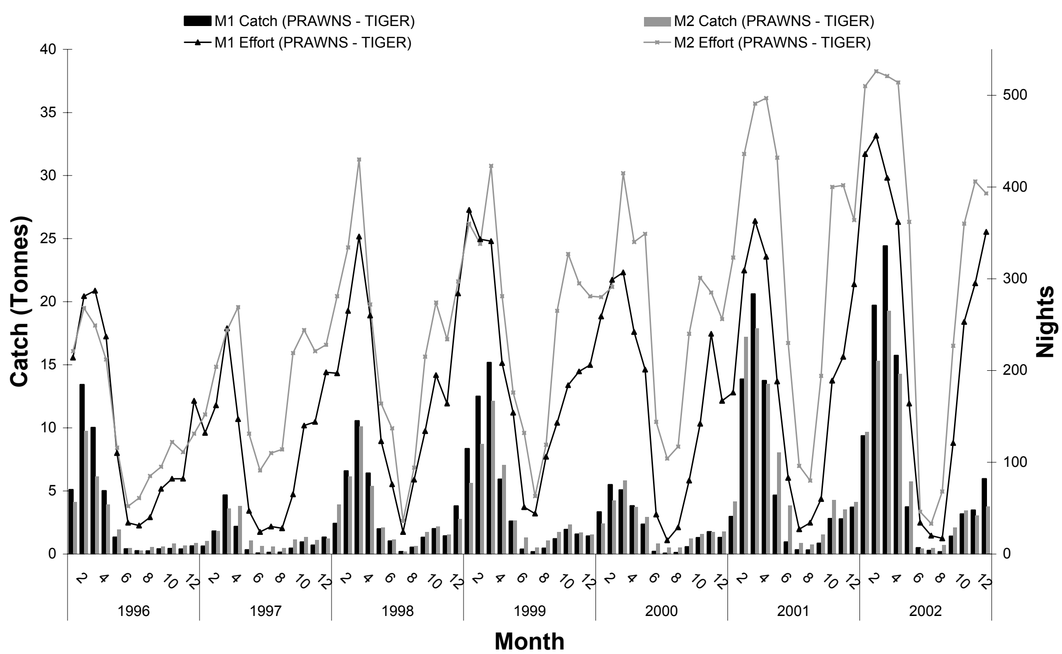


Figure 3.23. Monthly Catch and Effort of tiger prawns for current M1/T1 and M2 vessels in Moreton Bay.

The monthly king prawn catch and effort for M1/T1 and M2 symbol boats is shown in Figure 3.24. The M1/T1 fishery showed no significant change averaging 4.1 ± 0.6 tonnes and 4.4 ± 0.9 tonnes before and after the Plan respectively. In contrast, the M2 fishery increased from an average of 3.5 ± 0.5 tonnes to 4.8 ± 0.8 tonnes before and after the Plan respectively.

In terms of the number of nights on which king prawns were caught, the M2 boats have maintained a higher average fishing effort per month before and after the implementation of the Plan than M1/T1 vessels. The M2 fishery has increased in average effort directed at king prawns from 213 ± 20 nights per month pre plan to 292

+ 33 nights per month after the Plan, an average increase of 79 nights per month. The average effort targeted at king prawns in the M1/T1 fishery has not changed significantly: 179 + 21 nights per month before and 191 + 25 nights per month after the Plan, an average increase of 12 nights per month.

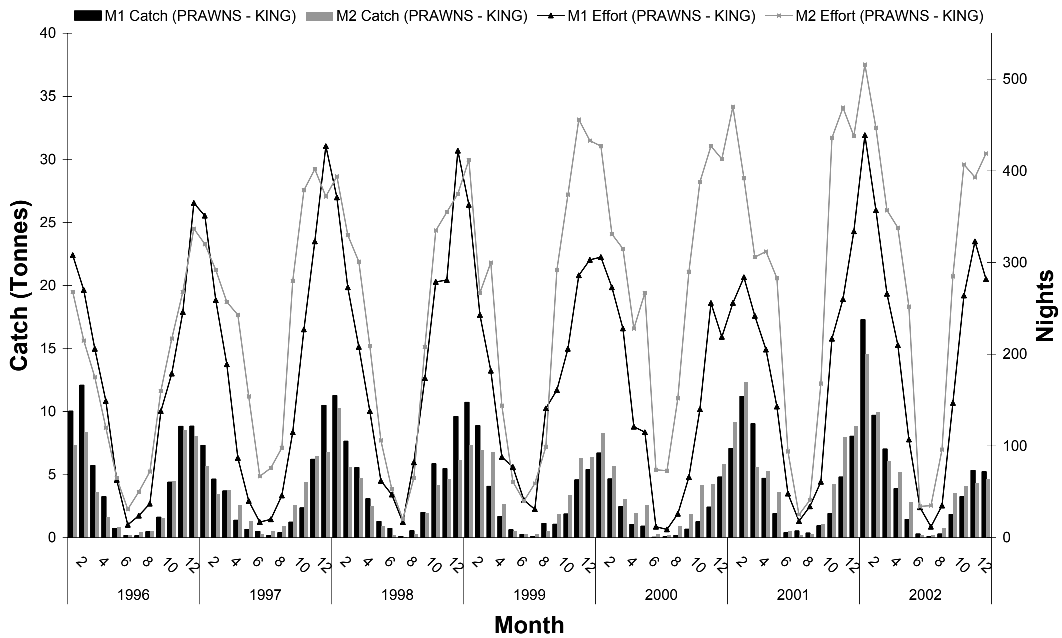


Figure 3.24. Monthly Catch and Effort of king prawns for current M1/T1 and M2 vessels in Moreton Bay.

The monthly bay prawn catch and effort for M1/T1 and M2 symbol boats is shown in Figure 3.25. There was no significant change in the catch of bay prawns by the M1/T1 fishery with an average of 8.0 + 1.3 tonnes and 7.9 + 1.5 tonnes before and after the Plan. In contrast, the M2 fishery increased from an average of 8.6 + 1.1 tonnes to 12.0 + 2.0 tonnes before and after the Plan respectively.

In terms of the number of nights on which bay prawns were caught, the M2 boats have again maintained a higher average fishing effort per month before and after the implementation of the Plan. The M2 fishery has increased in average effort directed at bay prawns from 260 + 19 nights per month pre plan to 334 + 34 nights per month after the Plan, an average increase of 74 nights per month. The average effort targeted at bay prawns in the M1/T1 fishery has remained constant with 208 + 22 nights per month before and 202 + 28 nights per month after the Plan, an average decrease of 6 nights per month.

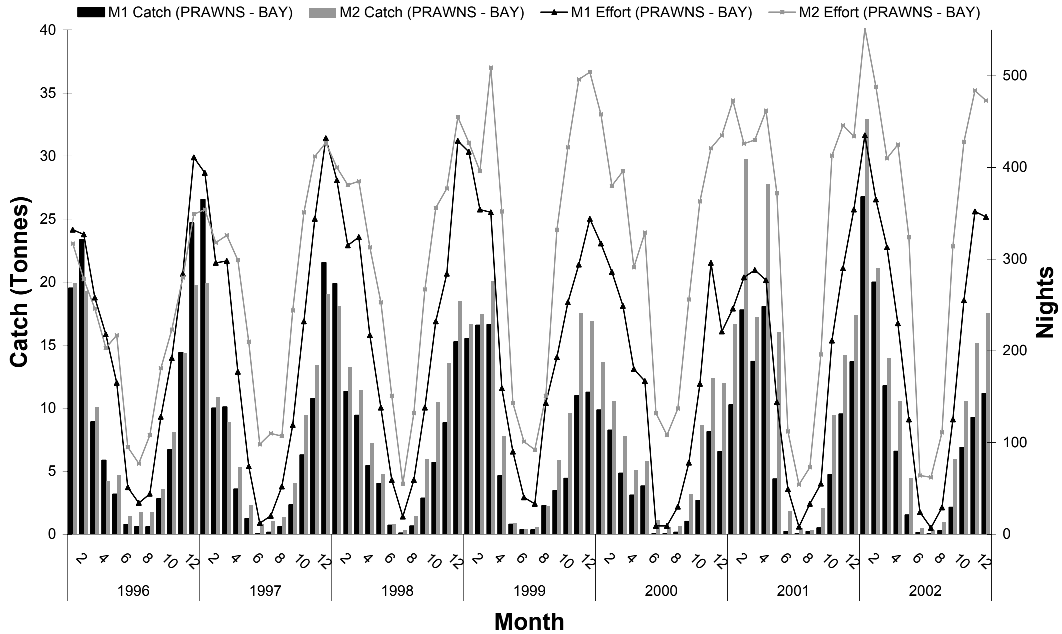


Figure 3.25. Monthly Catch and Effort of bay prawns for current M1/T1 and M2 vessels in Moreton Bay.

The monthly squid catch and effort for M1/T1 and M2 symbol boats are shown in Figure 3.26. In contrast to prawn species the average monthly catches for the two fisheries are significantly different. The M2 fishery recorded a higher proportion of the total catch. The M1/T1 fishery averaged 2.7 ± 0.5 tonnes and 2.7 ± 0.7 tonnes before and after the Plan respectively. The M2 fishery averaged 3.3 ± 0.5 tonnes and 4.6 ± 1.0 tonnes before and after the Plan respectively.

In terms of the number of nights on which squid were caught, the M2 boats have maintained a higher average fishing effort per month before and after the implementation of the Plan than the M1/T1 vessels. The M2 fishery has increased the average effort directed at squid from 149 ± 9 nights per month pre plan to 235 ± 23 nights per month after the Plan, an average increase of 86 nights per month. The M1/T1 fishery has also increased the average effort targeted at squid from 108 ± 11 nights per month before and 137 ± 19 nights per month after the Plan, an average increase of 19 nights per month.

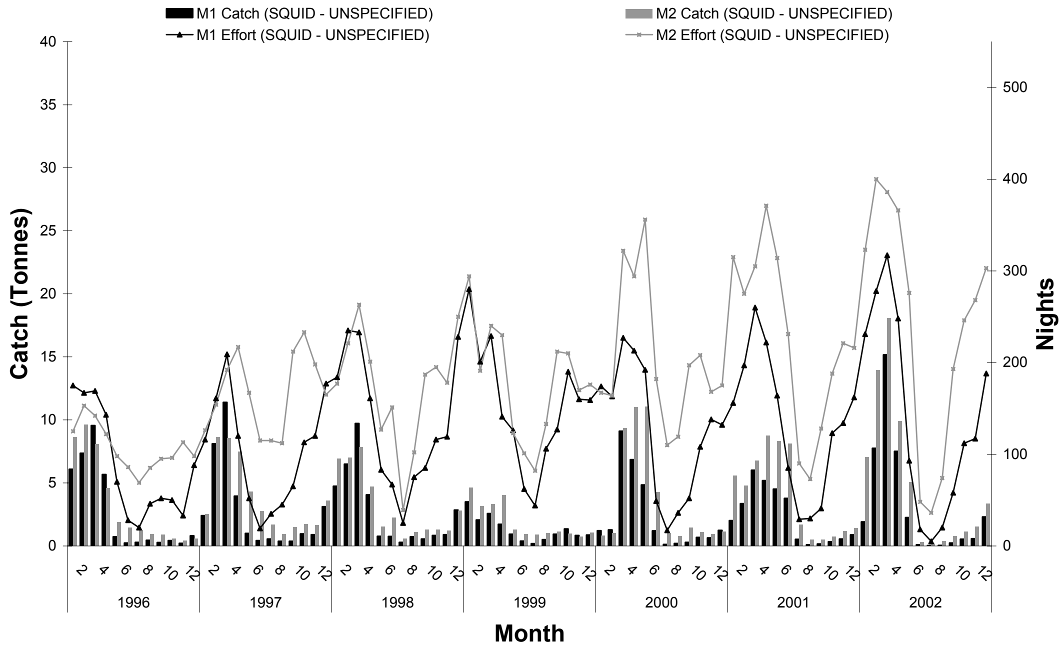


Figure 3.26. Monthly Catch and Effort of squid for current M1/T1 and M2 vessels in Moreton Bay.

3.3.8 *Annual trends in catch per unit of effort (CPUE)*

The monthly CPUE for tiger prawns is shown in Figure 3.27. M1/T1 symbol boats have higher catch rates of tiger prawns. The overall catch rate of tiger prawns in Moreton Bay for both fisheries have increased since the implementation of the Plan (Figure 3.27).

Each year there are two significant pulses in the monthly CPUE of tiger prawns, with a small increase in catch rates in October followed by the main increase in catch rates generally in March. The average monthly CPUE for tiger prawns for the M1/T1 fishery has increased from 12.6 ± 1.6 to 23.0 ± 3.2 kg per boat night since the Plan. The M2 fishery has also increased with a pre plan monthly average of 10.8 ± 1.2 kg per boat night increasing to 16.9 ± 2.0 kg per boat night after the Plan.

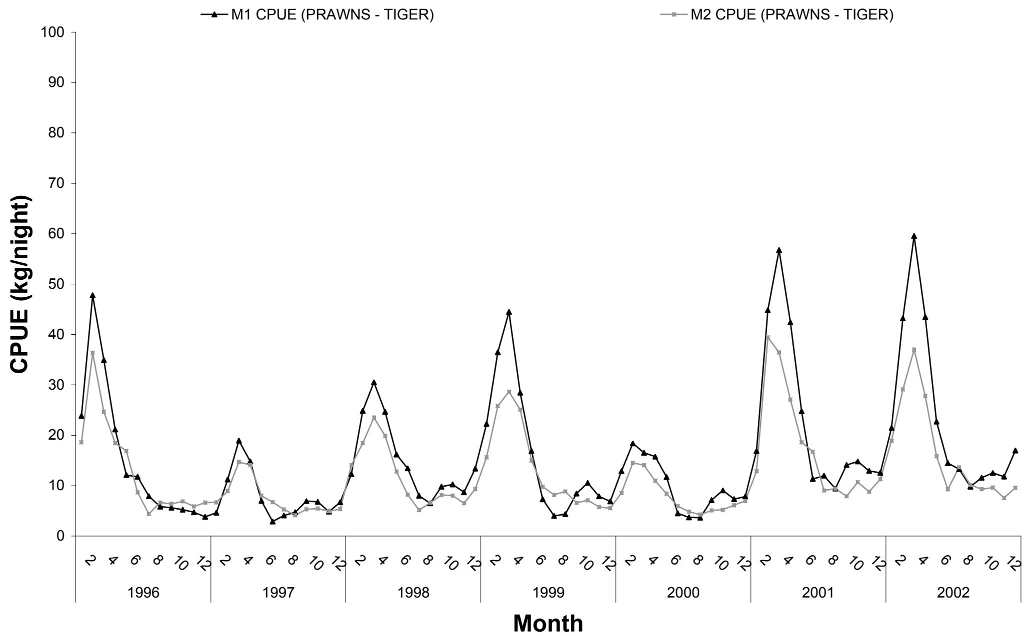


Figure 3.27. Monthly catch per unit of effort of tiger prawns for current M1/T1 and M2 vessels in Moreton Bay.

Similar to tiger prawn CPUE, M1/T1 boats had generally higher catch rates of king prawns than M2 boats. However, in contrast to the tiger prawn CPUE, king prawn catch rates have not increased significantly since the implementation of the Plan (Figure 3.28). King prawn CPUE did not display any clear seasonal trends among years. The average monthly CPUE for king prawns for the M1/T1 fishery remained unchanged at 19.3 $\pm$ 1.5 and 19.3 $\pm$ 2.0 kg per boat night before and after the Plan respectively. There has been no significant change in king prawn CPUE in the M2 fishery with a pre plan monthly average of 14.0 $\pm$ 1.3 kg per boat night before the Plan and 13.8 $\pm$ 1.4 kg per boat night after the Plan.

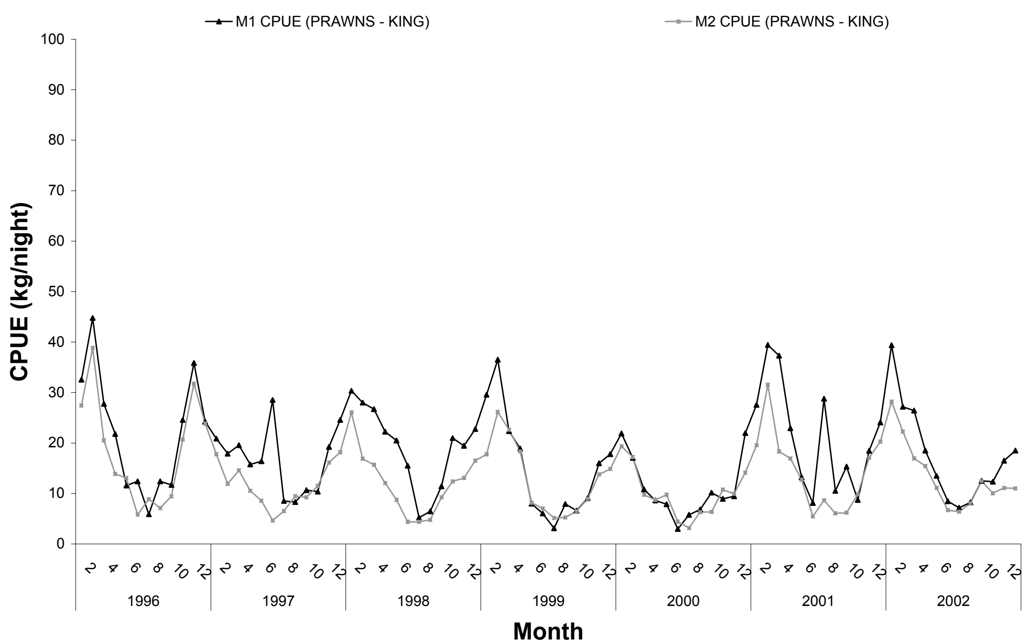


Figure 3.28. Monthly catch per unit of effort of king prawns for current M1/T1 and M2 vessels in Moreton Bay.

The average monthly CPUE for bay prawns is shown in Figure 3.29. Unlike the other prawn species, M1/T1 and M2 boats generally had comparable catch rates of bay prawns both pre and post plan. The average monthly CPUE for bay prawns in the M1/T1 fishery did not change significantly (29.3 ± 2.9 and 28.3 ± 4.0 kg per boat night before and after the Plan respectively). Similarly there was no significant change in the bay prawn CPUE for the M2 fishery (pre plan monthly average of 28.6 ± 2.8 kg per boat night before the Plan and 28.8 ± 3.7 kg per boat night after the Plan).

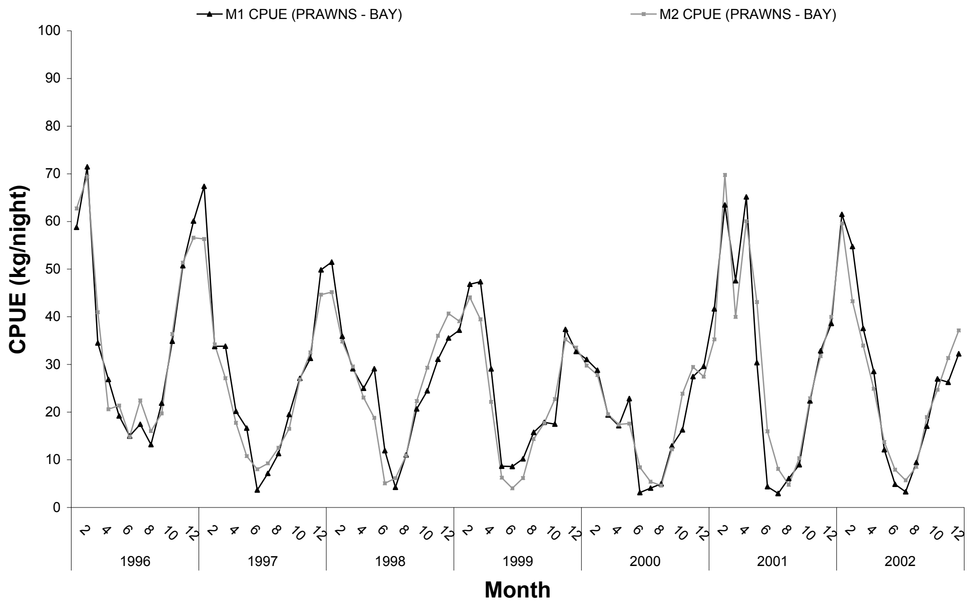


Figure 3.29. Monthly catch per unit of effort of bay prawns for current M1/T1 and M2 vessels in Moreton Bay.

The average monthly CPUE for squid for M1/T1 and M2 boats were generally similar with M2 CPUE (Figure 3.30). Squid CPUE was similar to the monthly catches in Figure 3.22 in that there were no discrete seasonal patterns. The average monthly CPUE for squid for the M1/T1 fishery decreased from 19.6 ± 2.5 to 15.1 ± 2.7 kg per boat night before and after the Plan respectively. There was also a reduction in squid CPUE in the M2 fishery with a pre plan monthly average of 22.0 ± 2.9 kg per boat night before the Plan and 15.7 ± 2.5 kg per boat night after the Plan.

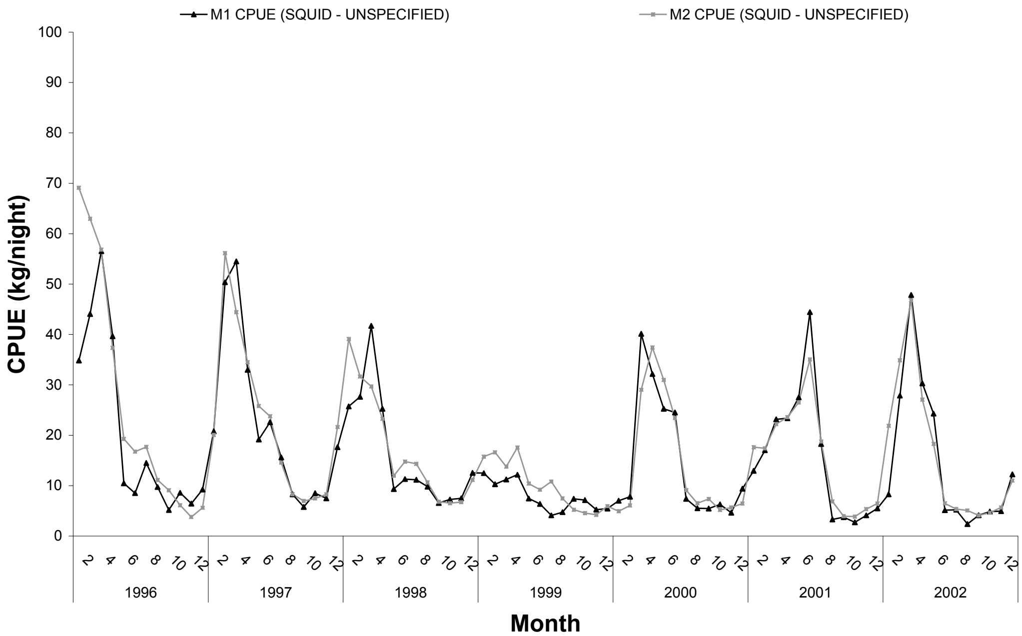


Figure 3.30. Monthly catch per unit of effort of squid for current M1/T1 and M2 vessels in Moreton Bay.

3.3.9 *Discussion*

The implementation of the Plan has resulted in significant changes to the Moreton Bay otter trawl fishery. With a reduction in the number of boats able to fish within the area, a similar reduction in both fishing effort and associated catches were predicted in the short term. The most notable of the changes in catch and CPUE is that of tiger prawns. Despite a 27% reduction in effort, the average annual catch of tiger prawns has increased by 53 tonnes per year. This increase in tiger prawn catch was due to significant increases in CPUE in both the M1/T1 and M2 fisheries.

In general, annual catches have reduced in line with the decrease in effort. Average catch rates have remained relatively stable with squid the only species of the 4 major species or species groups where catch rates reduced considerably. The reason for this reduction is unclear, however squid are an aggregating species and generally only caught in large numbers during the day. The trend in reduced catch rates may be an indication that fishers have reduced the number of days spent trawling specifically for squid, as a result of increased tiger prawn catches.

It should be noted when interpreting the overall catch reductions, that a number of 'offshore' catches had been included in the years before 2000. Prior to the implementation of 6nm reporting in the trawl fishery, a number of offshore catches reported in 30nm grids may have been included in Moreton Bay. This may result in larger apparent annual catch reductions than those that actually did occur.

Although the allocation of the M1/T1 and M2 symbols restricts the number of vessels in Moreton Bay, it does not allow for any control over the level of fishing effort within the Bay. A total of 53 M1/T1 and 38 M2 fishery symbols are currently attached to licences. M2 licences are able to fish approximately 260 days per year with the current weekend closures in Moreton Bay. M1/T1 symbol holders are subject to fishing restrictions based on their effort unit holding, however no restrictions exist on the number of these effort units the M1/T1 symbol holders can use within Moreton Bay. Although the actual proportion of the total M1/T1 nights used in Moreton Bay has been approx. 43%, in 2002 M1/T1 symbol holders could have fished a total of 8089 nights in Moreton Bay. As discussed earlier, M1/T1 vessels have increased their total effort unit holding and the proportion of those effort units used in Moreton Bay so the potential remains for much higher effort from M1/T1 vessels in the future.

With M2 symbol boats able to fish 260 nights per year and M1/T1 boats potentially able to apply to the Bay all of their current allocation of effort, approximately 17,600 nights may be fished in Moreton Bay annually. This number can increase to maximum of 23,000 nights annually if all M1/T1 boats increase their effort unit holding to 260 days. It is unlikely that this level will ever be reached given the seasonal nature of the species within Moreton Bay and the generally poor catches in the winter months, however the increasing levels of effort for boats currently fishing in Moreton Bay needs to be monitored. Significant increases in fishing effort or fishing efficiency, in terms of effort creep, without appropriate management responses could undermine the ecological sustainability and/or economic viability of the Moreton Bay fishery.

3.4 Spatial and Temporal Changes in Fishing Effort – River and Inshore Trawl Fishery

Fleet Profile

The number of licences endorsed to fish in the river and inshore beam trawl fishery has been reduced from 222 in 1996 to 157 in 2003. The T5 fishery symbol has traditionally been the largest in terms of number of fishery symbols issued and the T7 symbol the smallest (Figure 4.31). Reductions in numbers of vessels generally occurred prior to the plan being introduced with negligible reductions in the post plan period. The largest reduction in the number of fishery symbols issued occurred in 1997-1998 when 57 fishery symbols were removed from the fishery.

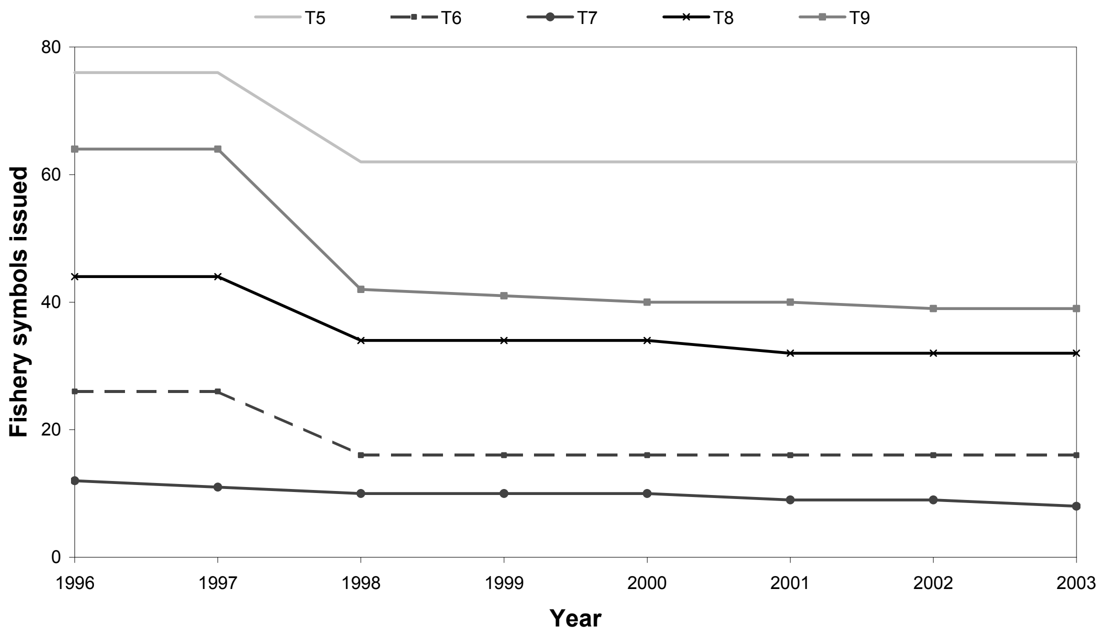


Figure 4.31. Number of fishery symbols issued per year for the River and Inshore trawl fishery.

General catch trends

Prawn catches in the beam trawl fishery have displayed high intra-annual variation with the highest catch of 541 tonnes in 1998 (Figure 4.32). Effort in the fishery displayed a steady increase from 4348 days in 1998 to 9084 days in 1998 before decreasing again between 1998 and 2002.

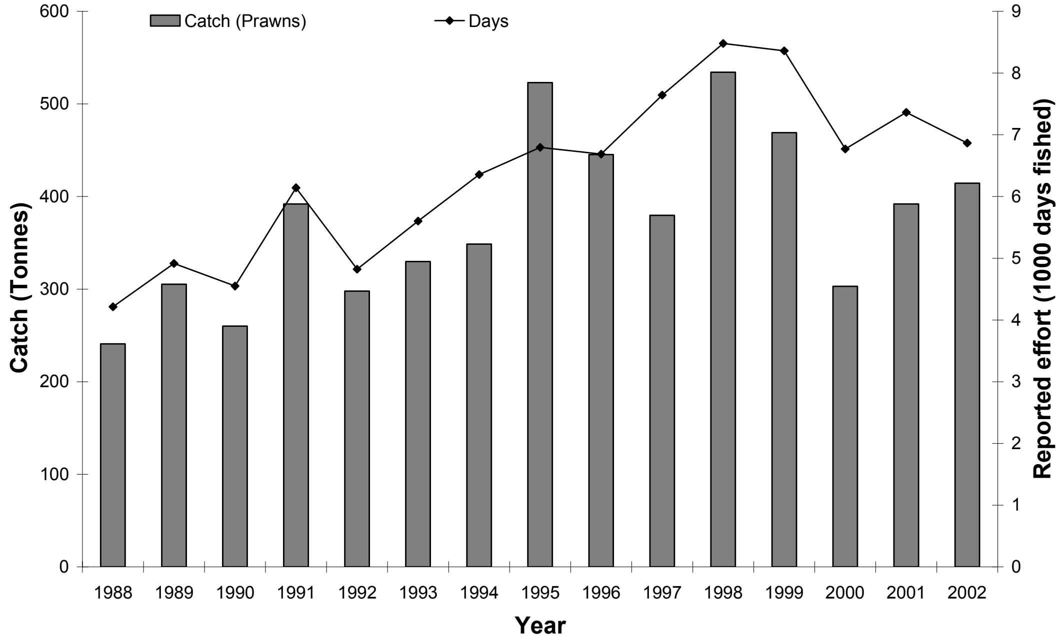


Figure 4.32. Changes in prawn catch and effort in the beam trawl fishery.

Annual catch and effort figures for non-prawn species are shown in Figure 3.33. This category includes a suite of species with squid (22%), Moreton bay bugs (15%) scallops (15%) and blue swimmer crabs (12%) the most dominant in the catches. Recorded catches of non-prawn species are marked by a recent reduction in catches with a decline from 18 tonnes in 1995 to 8 tonnes in 2002. However this reduction in catches was not accompanied by a reduction in the number of days on which non-prawn species were reported.

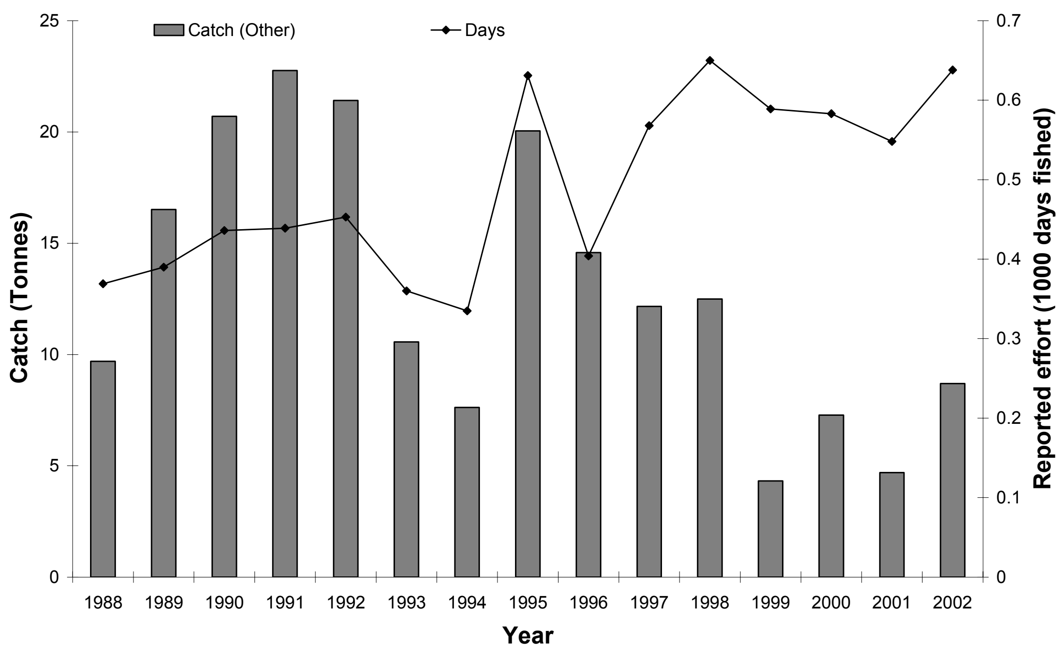


Figure 3.33. Changes in other species catch and effort in the beam trawl fishery.

Effects of the Plan on the Beam trawl fishery

Since the introduction of the Plan in late 1999 and subsequent management changes in 2000, there has been a 12% reduction (mean catch (t) ± SE: pre-plan 466t ± 45; post-plan 407t ± 11) in annual total catch. Table 3.23 outlines the pre and post plan average catches by fishery area. The largest total reduction in catch was in the T5 fishery area with the post plan catches 45 tonnes lower than the pre plan levels. Proportionally, the T6 fishery area experienced the largest reduction with a post plan reduction of 75%.

Table 3.23. Average annual prawn catch by area pre and post plan.

Area	Pre Plan		Post Plan	
	Average	S.E.	Average	S.E.
T5	278707.0	15638.7	233122.2	6319.5
T6	7141.3	1890.5	1767.7	847.5
T7	74053.8	27103.4	63655.4	10638.0
T8	51847.0	6546.6	51048.6	10577.2
T9	36369.3	832.2	26710.4	7752.2

The average number of boats working in each fishery area also reduced after the implementation of the plan (Table 3.24). The average number of boats was reduced in all fishery areas with the largest reduction in the T8 fishery area. The total number of boats licenced to fish in each area is outlined in Figure 4.31.

Table 3.24. Average annual number of boats by beam trawl area pre and post plan.

Area	Pre Plan		Post Plan	
	Average	S.E.	Average	S.E.
T5	50.0	1.0	49.5	0.5
T6	9.0	0.6	6.5	0.5
T7	9.3	0.9	7.5	0.5
T8	22.7	0.7	18.5	0.5
T9	20.3	0.7	17.5	0.5

Total effort in the beam trawl fishery reduced by 10% (mean effort (days) $\pm$ SE: pre-plan 7575 days $\pm$ 533; post-plan 6805 days $\pm$ 267) after the implementation of the plan. Reductions occurred in all fishery areas with the largest reduction in the T5 fishery of 195 days (Table 3.25). The effort reductions reflected the catch reductions with the T6 fishery also having the largest proportional reduction of 290%.

The historic proportion of the total effort for each fishery is displayed in Figure 3.34. There is no indication of a shift in the proportion of effort in each fishery area. The only marked proportional change has been caused by a reduction in effort in the T6 fishery area. The T5 fishery area has traditionally been the largest in terms of effort, with (mean effort (% of days) $\pm$ SE: pre-plan 59.8% days $\pm$ 1.6; post-plan 63.5 days $\pm$ 2.6).

Table 3.25. Average annual effort by beam trawl area pre and post plan.

Area	Pre Plan		Post Plan	
	Average	S.E.	Average	S.E.

T5	4511.7	209.4726	4316.5	10.5
T6	257.0	26.0832	65.5	20.5
T7	730.7	164.5664	638.0	74
T8	1536.3	201.5311	1362.0	270
T9	539.3	33.74578	423.0	46

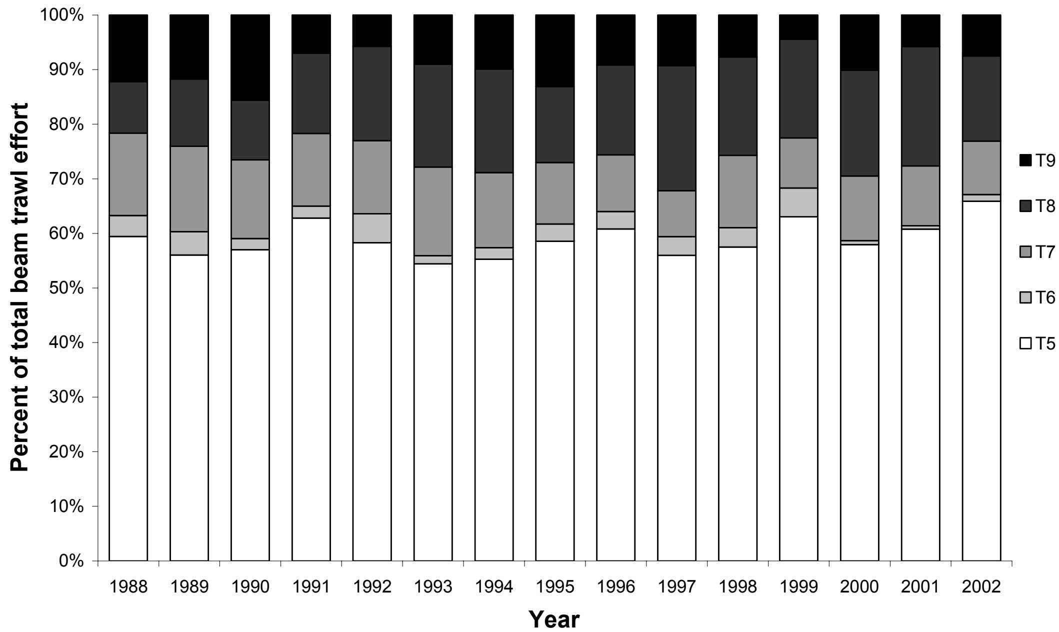


Figure 3.34. Percent of beam trawl effort by fishery symbol.

The large reduction in catch and effort in the T6 fishery has been caused by a shift of effort of those operators into the C1 fishery targeting Mud and Blue swimmer crabs.

Figure 3.35 shows the increase in effort of the T6 endorsement holders in the C1 fishery. From 1999 onwards the effort of these endorsement holders in the C1 fishery has increased by 290% and 80% for catches of blue swimmer and mud crabs respectively.

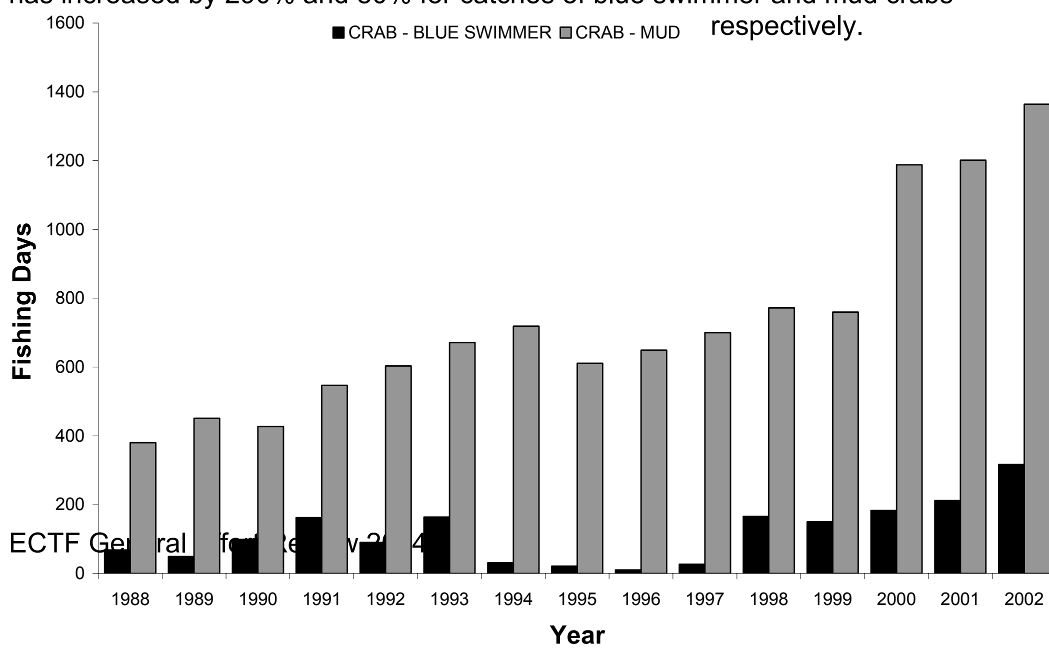


Figure 3.35. Annual days fished in the C1 fishery by T6 endorsement holders (N=16).

Discussion

Despite the fact that there were no specific effort reduction strategies for these fishery symbols written into the plan, both catch and effort in river and inshore trawl fishery have been reduced since its implementation. This has not been reflected by the number of vessels endorsed to participate in the fishery, as there have been negligible reductions in the post plan period.

A static number of licences within the fishery accompanied by decreasing levels of both catch and effort indicate that fishers may be utilizing other fishery symbols thereby moving effort out of the trawl fishery. This is reflected in the T6 fishery with fishers clearly opting to put more fishing effort into the Mud and Blue swimmer crab fishery than their traditional trawl fishery.

Although the general effort within the fishery has been reduced, the number of days on which catches of non-prawn species have been reported has remained at the same, or even higher levels than before the implementation of the plan. This statistic is most probably caused by the OT07 logs in which it became a requirement to report catches of “Permitted species.” This new logbook was introduced in 1999 and can perhaps explain why catches of non-prawn species have been reduced without a proportionate decrease in the number of days fished. This could be accounted for if fishers are actually catching less but recording small catches of species they had not previously been able to report.

4 Sustainability of Principal Species

4.1 Purpose

In order to maintain sustainable production over time in the East Coast Trawl Fishery (ECTF), quantitative assessments of key stocks are required. Stock assessments are used to assess the effects of current and proposed future management arrangements on the actual or potential production of the stock. This section examines the available stock assessments for target species in the ECTF. Where stock assessments have not been completed a summary based on data available for that species is presented.

4.2 Source

Information on the stock assessments of principal species have been extracted from the following reports:

Turnbull C, Gribble, N (2002) ‘Current Assessment of the northern Queensland Tiger and Endeavour prawn stocks.’ Department of Primary Industries, Queensland, Information Series QI03014.

O’Neill M, Courtney A, Good N, Turnbull T, Yeomans K, Staunton Smith J, Shootingstar C (In press) ‘Reference point management and the role of catch-per-unit effort in prawn and scallop fisheries.’
Fisheries Research and Development Corporation Final Report, FRDC 1999/120.

4.3 Summary

AFFS Fisheries biologists used a variety of stock assessment models to test management responses to the reference point of 70% of the average historic catch rate. The 70% reference points result in sustainable levels of fishing, but were not considered valid because they can trigger at high population sizes and cause inappropriate changes in fishing effort. Similarly, catch rates for low population sizes may not necessarily fall below the 70% catch rate trigger. In general, it was identified that reference points targeting fishing effort to $2/3E_{MSY}$ or $3/4E_{MSY}$:

- Maintained populations above the size, which supports maximum sustainable yield, but not exceedingly;
- Resulted in lower risks of under or overfishing; and
- Improved catches and catch rates at lower fishing effort than currently present.

The stock assessments suggest all three eastern king prawn, tiger prawn and saucer scallop populations were fished to levels that support maximum sustainable yields, but eastern king prawn population sizes prior to 2001 may have been much lower than this. Eastern king prawn and saucer scallop results were sensitive to the assumed spawner-recruitment relationships and fishing power increases. Due to a short time series, the tiger prawn assessment lacks contrast; in that catch and effort for the whole time-series was centred around the top of the yield curve. The assessment of this species may benefit from a monthly delay difference model, which utilizes available biological data as per the eastern king prawn assessment.

Uncertainty still clouds the ideal reference point for the eastern king prawns and saucer scallops. This problem remains for most fisheries; reference points depend on knowledge of how many prawns or scallops are in the ocean and management having clear target goals for fishing e.g. high catch rates. New types of data are essential to improve the stock assessments, such as spatial indices of abundance collected through fishery independent sampling and vessel monitoring systems (VMS). More accurate and robust reference points may exist using these data, rather than model-based reference points. These pieces of information will aid in refining the stock assessment, defining more accurate reference points and strengthening future management decisions.

4.4 Methods

Delay Difference Modelling

The Deriso-Schnute delay difference model was used to assess Australia's eastern king prawns (Deriso 1980; Schnute 1985; Quinn and Deriso 1999; Dichmont 2001). The model simplified the mathematics of population age structures so that population biomass followed a single delay difference equation, and prawn growth was approximated by the Brody growth curve. The model analysed the available time-series of standardised monthly-catch-rates, in order to estimate harvest rates and therefore calculate monthly population biomass and numbers of prawns. This model captured the monthly dynamics of the prawn population, the seasonality of the fishery, and estimated spawning and recruitment trends. It contained biologically meaningful parameters for prawn growth, natural mortality, and recruitment and allowed realistic variations in these parameters. The model also allowed for some of these parameters to be estimated directly from standardised catch rate data as a proxy for the relative abundance of the species.

Age Structured Modelling

An age-structured biomass model was used to calculate monthly population biomass and numbers of saucer scallop. This model was first documented within the Proceedings of the southeast Queensland Stock Assessment Workshop 1998 (Dichmont et al 1999), and has been considerably enhanced to calculate and simulate reference points. The model used an age structured approach that considered the survival of 1,2,…,48 month old scallop. This model allowed for the change in size selectivity with varying minimum legal sizes throughout the year and incorporated fishery independent survey estimates of scallop numbers.

Surplus Production Model

The simplest time dynamic fisheries population models are those that consider only a single indicator of population size, usually biomass. These models ignore age or size structure and do not explicitly consider growth and recruitment. They are called biomass dynamic (or surplus production) models and take several variations on the traditional logistic models of ecology. The most commonly used of these is the Schaefer form of the surplus production model. Only two main parameters are to be estimated which makes it easy to apply. These are the intrinsic population growth rate (r) and the population carrying capacity (K; virgin stock size). This model is well described by Punt (1993), Prager (1994) and Haddon (2001). It relies on the standardised catch per unit effort index being proportional to the trend in stock abundance.

The eastern king prawn and scallop modelling used standardised catch rates from the fishing years 1989 to 2001. The model for the tiger and endeavour prawns used the total catch for each species category for each stratum (north and south of 16^0S) based on all records. This type of model requires a long time-series of catch and CPUE data that covers periods of low and high fishing effort and preferably includes the developmental period of the fishery.

Reference Points

On completion of the base assessments, the performances of different reference points were tested for the eastern king prawn and saucer scallops through a series of simulations (Table 4.1). As the tiger/endeavour prawn assessment was not completed under the FRDC project, this species will not be further analysed in this manner. The simulations for each trawl sector included decision analysis procedures, to demonstrate the performance of each management system and reference point. The approach of testing reference points was streamlined to allow management responses to be modelled ahead of time, so that the results can be used to help develop alternative and improved management systems. The algorithm used for the simulations was similar to the forward projection methodology used by Richards et al. (1998) and the management strategy evaluation approach by Punt et al (2001a). The expected median outcomes and probabilities indicating risks of overfishing are presented.

To evaluate potential reference points the monthly delay difference (for eastern king prawns) or age-structured (for scallops) models were used to operate the possible or hypothetical dynamics of the populations. This component of the simulations can be labelled as the “operating model”. It captures the temporal dynamics of the stocks and allows for stochastic variations (uncertainty) in all parameters. The other component of the simulations is the “assessment model”. This represents our real life process to assess the state of the stocks (i.e. using CPUE reference points every year or stock assessment models every two years). The structures of both the operating and assessment models were the same, but they differ in that the operating model functions on random variations in all parameters (e.g. spawner-recruitment, natural mortality etc). The assessment-model parameters, updated every two years, represent an estimate of the average dynamics of the population, and so it includes error in judgement to apply appropriate fishing strategies.

Table 4.1. The catch rate and fishing mortality reference points that were examined through simulation and provided in the management performance sections. Their link to fisheries management is defined under the management strategy evaluation (MSE) below. $cpue_t$ were the average catch rates in the current review periods described in the Queensland east coast trawl management plan (QECTMP); 60%cpue, 70%cpue, and 80%cpue were the percentage of the average catch rates from the reference review periods between 1988 and 1997 (QECTMP 2002).

Target Species	Limit Reference Points	Upper Reference Points	Limit Review (Months)	Upper Review (Months)	Simulation Framework
Eastern King Prawns	$cpue_t$ < 60%cpue $cpue_t$ < 70%cpue $cpue_t$ < 80%cpue	$cpue_t$ > 97.5 percentile None	Nov to Feb or[1] May to Aug	Nov to Feb and[2] May to Aug	Delay Difference Model
Saucer Scallop	$cpue_t$ < 60%cpue $cpue_t$ < 70%cpue $cpue_t$ < 80%cpue	$cpue_t$ > 97.5 percentile None	Nov to Feb	Nov to Feb	Age Structured Model
Eastern King Prawns Saucer Scallop	$cpue_t$ < 60%cpue $cpue_t$ < 70%cpue $cpue_t$ < 80%cpue	$cpue_t$ > 97.5 percentile None	Annual	Annual	Surplus Production Model
Eastern King Prawns Saucer Scallop	F_{MSY} 3/4 F_{MSY} 2/3 F_{MSY}	N/A	N/A	N/A	Delay Difference and Age Structured Models

or[1] indicates that a low average eastern king prawn catch-rate in either limit review period can trigger management; and[2] indicates that a high average eastern king prawn catch-rate in both upper review periods is required to trigger management. The other sectors have single review periods.

The results of using different reference points were summarised in a management strategy evaluation (MSE) framework (Smith 1994 and Punt et al 2001). Management strategy evaluation involved assessing the consequences of a range of management strategies and presented the results in a way which lays bare the trade-offs in performance across a range of management objectives (Smith 1994). The approach does not define a final fishing strategy or decision. It only provides information on which to base management choices, given a set of management objectives. To fully understand the structure of the MSE results herein, the following key elements and definitions were used:

The ***fishing strategies*** were the number of vessel days allowed in the fishery each fishing year. A number of initial fishing strategies were examined. For example, the eastern king prawn starting test fishing effort ranged from 45000 to 15000 days, at 5000-day intervals.

The ***management strategies*** were the decisions on how fishing effort was changed in response to a triggered limit reference point. The management strategies tested were:

1. **Pre plan** or "control": no reference points or management interventions, effort at the average level before the implementation of the plan.

2. **Moderate two-way**: if the lower catch-rate limit reference point was triggered, fishing effort was reduced by 10%; if the upper catch rate limit reference point was exceeded, fishing effort was allowed to increase by 5%.

3. **Heavy two-way**: if the lower catch-rate limit reference point was triggered, fishing effort was reduced by 30%; if the upper catch-rate limit reference point was exceeded, fishing effort was allowed to increase by 15%.

4. **Moderate one-way**: if the lower catch-rate limit reference point was triggered, fishing effort was reduced by 10%; no increases in fishing effort allowed.

5. **Heavy one-way**: if the lower catch-rate limit reference point was triggered, fishing effort was reduced by 30%; no increases in fishing effort allowed.

6. **Fishing mortality (F) based**: fishing effort was altered every two years according to the reference point estimates of Maximum Sustainable Yield (MSY), ¾ MSY and 2/3 MSY. These three MSY control rules manage fishing effort at population sizes above half the biomass that supports MSY ($0.5B_{MSY}$).

The **management objectives** ranged from biological sustainability to industry sustainability to management activity and accuracy. A number of different performance measures were used to gauge each fishing strategy and management strategy against the management objectives.

Two quantitative measures of biological sustainability were used: (i) The risks (probabilities) over a 20-year period of management that the stock size will fall below 20% of the virgin (unfished) population biomass. The 20% value is not meant to represent the threshold of recruitment overfishing, but rather to indicate that the stock has been substantially fished down. (ii) The risks (probabilities) over a 20-year period of management that the stock size will fall below the long-term equilibrium population biomass that results from fishing the stock at maximum sustainable yield (B_{MSY}).
Three quantitative measures of industry sustainability were used:

1. The median total catch over the 20-year period of management.
2. The median variation in total catch over the 20-year period of management (average coefficient of variation).
3. The median of the resulting total fishing effort over the 20-year period of management.

Three quantitative measures for management performance were used:

1. The average number of CPUE reference point triggers over the 20-year period of management.
2. The distribution of population sizes when CPUE reference points trigger, expressed as a ratio of virgin biomasses.
3. Proportion of triggers accurately detecting population sizes below 20% of virgin biomass or the biomass that supports MSY (B_{MSY}).

4.5 Eastern King Prawns

Catch Statistics

The offshore eastern king prawn harvest, excluding Moreton Bay, consistently averaged 1719 t in Queensland and 848 t in New South Wales between the 1989 and 2000 fishing years (Figure 4.1). Total catches in 2001 increased notably to 2404 t and 1063 t from Queensland and New South Wales waters respectively. Fishing efforts applied to eastern king prawns between 1989 and 2001 were consistent, averaging 20739 nights in Queensland and 20439 nights in New South Wales. Average monthly standardised-catch-rates in Queensland and New South Wales were stable between 1989 and 2000, but increased in 2001 (Figure 4.2). In Queensland waters monthly standardised-catch-rates peaked at an average of 124 kgs for the 2001 fishing-year between February 2001 and April 2001. Standardised catch rates for the same months in New South Wales were 58 kgs.

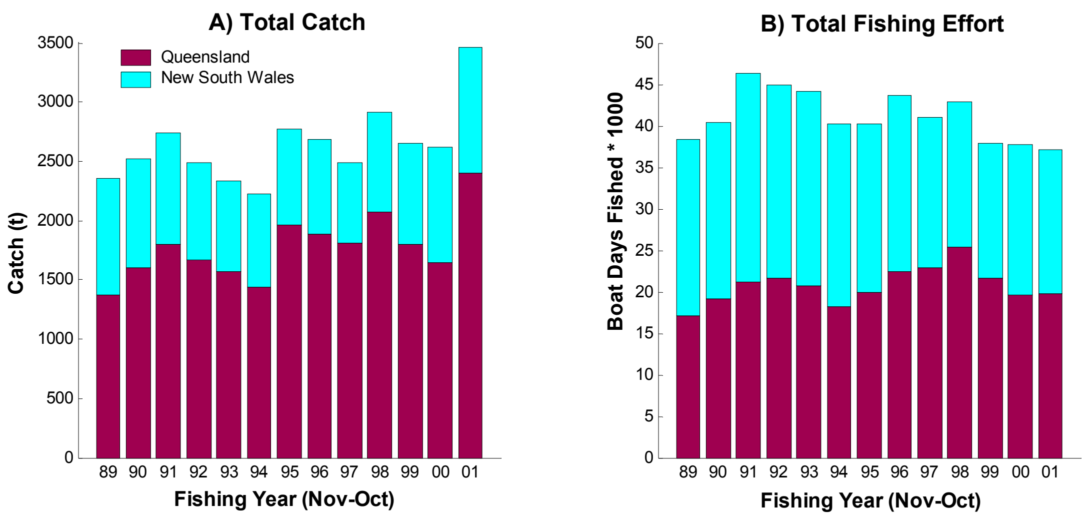


Figure 4.1. Queensland and New South Wales eastern king prawn catches and fishing effort from 1989 to 2001; note the large total catch taken in 2001.

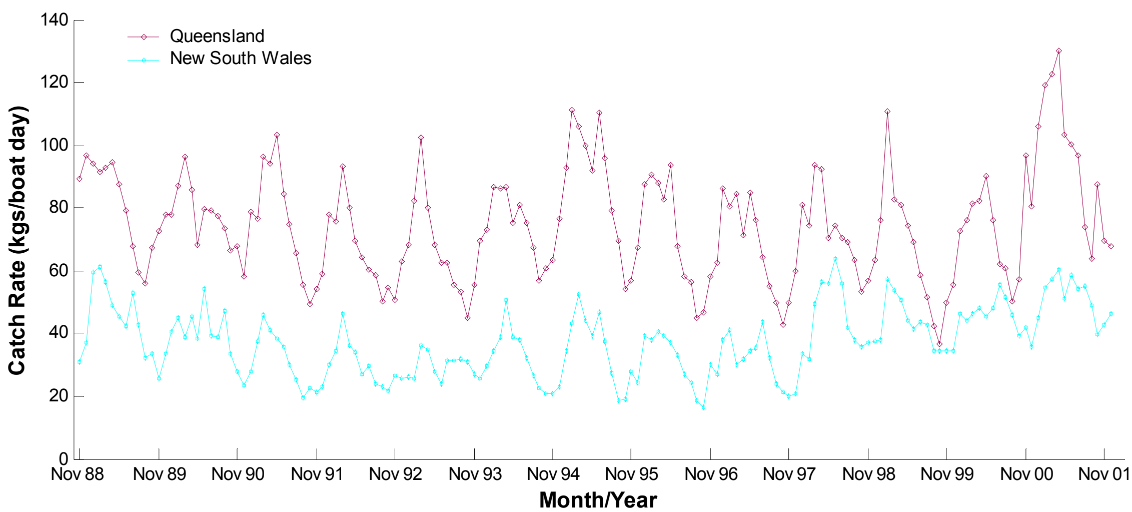


Figure 4.2. Queensland and New South Wales monthly-standardised catch rates from November 1988 to December 2001; note the similar cycles between states and the high catch rates reported in Queensland for 2001.

Biological Inputs

In most stock assessment models, published independent estimates of biological parameters are incorporated in order to calculate the dynamics of populations. These biological inputs from relevant studies on the species are used to calculate average prawn growth, average prawn weight, average prawn size at first recruitment to the fishery and one month prior, natural mortality and the relative monthly spawning pattern. These biological parameters are deterministic, and the model sensitivity to these is reported as part of the stock assessment. These parameters represent the best knowledge and are treated as the base case against which the model sensitivities are measured. The measure of relative spawning was calculated by analysing the histological stages of female prawns, where prawns staged as mature or ripe indicated spawning. Generally the relative amount of spawning was greatest between May and October. These parameters are not included here but can be found in O'Neill et al (In press).

CPUE inputs

Queensland eastern king prawn catches were retrieved from the Queensland Fisheries Service QFISH database. The fishing-year for eastern king prawns was defined as starting in November and ending in October, to match the cycle of fishing and recruitment to the fishery (Courtney et al 1997).

New South Wales (NSW) catches were collated for all eastern king prawn landings taken from only ocean prawn trawling. The NSW commercial catch records manager supplied these data. Monthly eastern king prawn catches and days fished were extracted separately for each trawler that reported catches of eastern king prawns.

The fishing power standardisation process involved calculating a weighted average catch rate (kilograms of prawns per boat night) based on the number of standardised days fished in each state. The numbers of standardised days were calculated by multiplying the reported number of boat days in each fishing year and month by the average changes in fishing power (Section 3.1.5). The overall average change in fishing power for the combined Queensland and New South Wales sectors was assumed to be the weighted average between the deep and shallow water estimates.

Stock Assessment

The stock assessment used two modelling approaches - a monthly delay difference model and an annual surplus production model (Figure 4.3 and Figure 4.4 respectively). The delay difference model compared three monthly rates of natural mortality (M) and fishing power (Section 3.1.5), with their respective 90% confidence intervals (Figure 4.3). These plots were structured accordingly:

The first row of plots (A, B, and C) resulted from assuming M=0.20 month^{-1}, which, based on the literature, is likely to be the most accurate estimate of natural mortality. The model used to generate plot C was considered to most accurately reflect reality and was therefore used as the base case model.

The second row of plots (D, E, and F) resulted from assuming a comparatively low rate of natural mortality (M=0.12 month^{-1}) derived from and equal to the 90th percentile on a normal distribution with mean 0.2 and standard deviation of 0.05 (25%).

The third row of plots (G, H, and I) assumed a relatively high rate of natural mortality (M=0.28) equal to the upper 90th percentile on a normal distribution with mean 0.2 and standard deviation of 0.05 (25%).

The first column of plots resulted from incorporating a value of zero for the annual rate of increasing fishing power (i.e., no annual effort creep) in the assessment and the stock-recruitment relationship.

The second column of plots resulted from incorporating relatively low levels of annual increase in fishing power. The annual increases were the lower 90% confidence interval of the estimate of fishing power increase for each year and therefore varied between years. Because the estimates of annual increase in fishing power differ between the shallow water and deep water sectors of the eastern king prawn fishery (see Section 3.1.5), estimates used in the models were weighted to take account of the relative distribution of effort throughout the entire fishery (including both New South and Queensland effort). These estimates of the increase in fishing power were incorporated in both the assessment and the spawner-recruitment relationship.
The third column of plots resulted from using the annual median estimates of increase in fishing power, and again weighted to take account of the spatial distribution of fishing effort. These estimates are likely to be the most accurate estimates of annual increase in fishing power because they were derived directly from the fishing power analyses presented in Section 3.1.5. The estimates were incorporated in both the assessment and the spawner-recruitment relationship.

Note the purpose of comparing different outputs was to highlight the dependences of certain biological parameters on estimates of fishing power. The base-case results should always be used to compare dependences.

The model generally predicted that biomass, expressed as a ratio to virgin exploitable stock biomass size, was stable between 1989 and 2000 (Figure 4.3). There was a notable increase in 2001 that reflected the increased reported catches and catch rates at that time. Even though the predicted biomasses were stable, under some scenarios (particularly column C) the model indicated the biomass was consistently below B_{MSY} (Figure 4.3). The stock-recruitment curves (Figure 4.5) and model were used to estimate the equilibrium virgin stock size (B_0), the population size that supports maximum sustainable yield (B_{MSY}), and the management quantities of maximum sustainable yield (MSY).

Details on the catch data used in the spawner-recruitment curves are outlined in O'Neill et al (In press). Ninety-two percent of the historic daily catch records from 1970 to 1987 were recorded from between Fraser Island in the north and the New South Wales border to the south (Moreton Bay excluded), with about 75% of data from these grids during the recruitment period and 60% during the spawning period after 1987. Only results from the Beverton-Holt form of the spawning-recruitment relationship were reported because they were very similar to those obtained using the Ricker curve. The measure of steepness is defined as the average productivity of recruitment at 20% of virgin spawning stock size (Haddon 2001). This measure is a proxy for the productivity of the stock and therefore the ability to withstand higher fishing pressure. Steepness declined with increasing fishing power (Figure 4.5 and Table 4.2) indicating that increases in fishing power lead to an inability of the stock to recover from higher fishing effort. Estimates of MSY were comparable ranging from 2,380 to 2,612 tonnes across all models (Table 4.2 and Table 4.3). However, the equilibrium estimates of fishing effort (E_{MSY}, ¾E_{MSY} and 2/3E_{MSY}) were reduced substantially when annual increases in fishing power were included in the modelling (Table 4.2).

Results for the surplus-production model are provided in (Table 4.3). Due to the lack of contrast in the annual catch rates, the estimate for the model's population-growth parameter (r) was very high at 2.4. Values above one generally indicate that the stock has high intrinsic rate of increase, and as a result high levels of E_{MSY} were calculated, contrasting with the steepness values calculated using the delay difference model.

Additional sensitivity analysis on the delay difference model showed that higher MSY was related to lower rates of natural mortality, but lower MSY was calculated for slower prawn growth rates or higher natural mortality rates (Table 4.4).

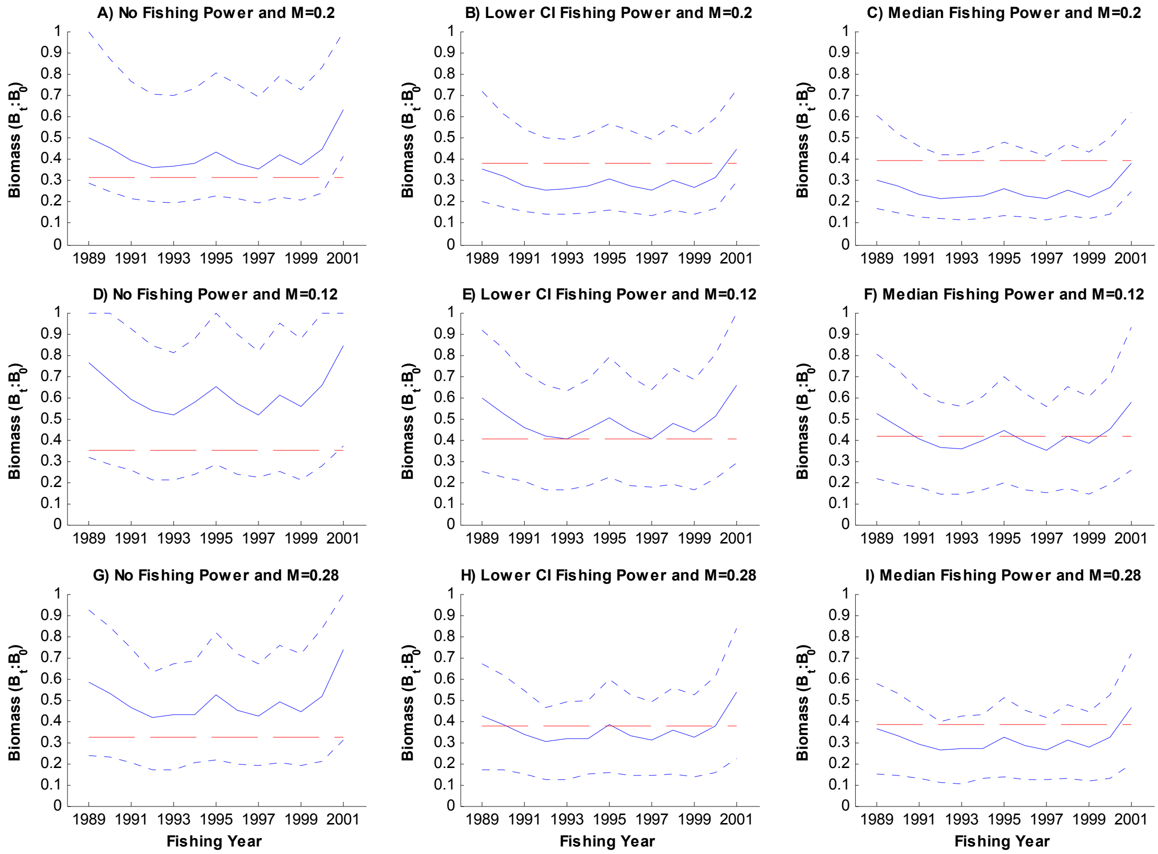


Figure 4.3. The monthly delay difference model predicted stable exploitable biomasses for the eastern king prawns between 1989 and 2000 fishing years, with a notable increase in 2001 (dotted lines represent the 90th percentiles). The results were presented for variations in fishing power, natural mortality and stock-recruitment. The dashed line shows the biomass reference point for maximum sustainable yield (BMSY). The dotted lines represent the 90 percent confidence intervals.

Figure 4.4. The annual surplus production model predicted stable exploitable biomasses for the eastern king prawns between 1990 and 2000 fishing years (dotted lines represent the 90th percentiles). The dashed line shows the biomass reference point for maximum sustainable yield (B_{MSY}).

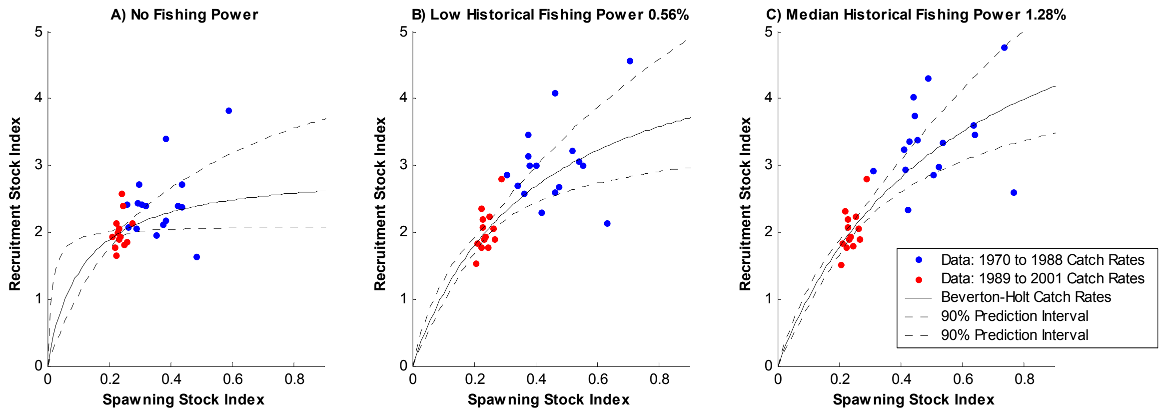


Figure 4.5. Eastern king prawn spawner-recruitment relationships assuming A) no fishing power increases, B) the lower 90% confidence interval for changes in the fishing power and C) the actual (best knowledge) estimate for changes in the fishing power. Note the rate of fishing power change listed on B) and C) were assumed proportional rates applied to the fishing years 1970 to 1988, based on the 1989 to 1999 trend in fishing power. One-year autocorrelations were non-significant at -0.072; the relationships were fit using a weighted log-likelihood.

Table 4.2. Eastern king prawn spawner-recruitment parameters and the delay-difference equilibrium management quantities for the base case biological parameters and three levels of fishing power. Numbers within brackets refer to the standard error and T statistic for the spawner-recruitment parameters and 90% confidence intervals for the Management parameters.

Parameters	No Fishing Power	Lower CI Fishing Power	Median Fishing Power
Spawner-Recruitment			
α	0.0384 (0.0175; 2.19)	0.0743 (0.0119; 6.22)	0.0839 (0.0098; 8.56)
β	3.3896e-9 (0.7134e-9; 4.75)	1.8676e-9 (0.4634e-9; 4.03)	1.4595e-9 (0.3682e-9; 3.96)
Steepness	0.56 (0.45:0.68)	0.40 (0.32:0.48)	0.37 (0.31:0.45)
Management			
MSY (tonnes)	2530 (1797:3392)	2704 (1802:3982)	2612 (1694:4065)
E_{MSY} (2001 nights)	47487 (24697:71215)	31744 (15809:74513)	25664 (15477:67447)
3/4 E_{MSY} (2001 nights)	35615 (18523:53411)	23808 (11857:55885)	19248 (11607:50585)
2/3 E_{MSY} (2001 nights)	31626 (16448:47429)	19516 (10529:49626)	17109 (10318:44964)

Table 4.3. Summary of the parameters estimated from the surplus production model.

Parameter	Estimate (90% Confidence Interval)
Population Growth Rate r	2.395 (1.819:2.922)
Management Quantity	
MSY (tonnes)	2609 (2553:2729)
E_{MSY}	44381 (41124:49862)
¾ E_{MSY}	33286 (30843:37397)
2/3 E_{MSY}	29587 (27416:33238)

Table 4.4. Additional delay-difference sensitivities based on varying the prawn growth parameter (ρ) and natural mortality (M).

Parameter; Fishing Power (FP)	MSY (tonnes)	E_{MSY} (2001 nights)
Slow Prawn Growth ρ=0.55; median FP	2162	26081
Slow Prawn Growth ρ=0.55; lower CI FP	2090	32226
Natural Mortality M=0.12; lower CI FP	3193	50104
Natural Mortality M=0.28; lower CI FP	2437	30677

For both the delay difference and surplus production model stock assessments there was no evidence to suggest the models were inadequate for the data or that the use of lognormal errors were inappropriate. An analysis of the residuals showed that the models predicted the standardised catch rates quite well, although the monthly delay difference model tended to slightly under estimate six of the monthly peak catch rates present in the time series. The standardised residuals for these large catch rates were all less than four, indicating they were not extreme. The influence of these data points had little effect on the log-likelihood or upon the estimation of the parameters. For example, removing or slightly increasing their effect resulted in little change in the parameter estimates, suggesting the model captured these observations reasonably well and that it did accurately model the year to year and month to month patterns of eastern king prawns catch rates.

Reference Point Simulations

The reference points examined by the two models are provided in Table 4.1. A large number of results were generated from these simulations, especially as a result of considering the different assumptions made about recruitment. For example, recruitment was estimated with and without stock-recruitment relations, and with and without the application of annual increases in fishing power. The results presented in this section focus on the performance of reference points through the delay difference model using the spawner-recruitment relationship with median fishing power (base case) (Figure 4.5C). Definitions used to interpret the simulations and results from all simulations and summarised forecasts for five-year and 20-year periods are outlined in O'Neill et al (In press). The simulations assess the consequences of using different reference points and management strategies and the subsequent results are presented in such a way as to allow the reader to evaluate the trade offs in performance. The results do not define a final reference point, management strategy or the status of the eastern king prawn stock, but rather they provide expected outcomes that may be used by decision makers to help select appropriate reference points to achieve the management objectives.

Biological Performance
The model simulations suggested that higher biomass trajectories would be attained using 2/3 F_{MSY} and ¾ F_{MSY} reference points (Figure 4.6). The 80% CPUE reference point, under the heavy one-way management intervention, would also result in relatively high biomass trajectories. Retaining the pre plan average effort, or adopting F_{MSY} as a reference point generally resulted in relatively low biomass trajectories.

The probability trajectories for the biomass falling below 20% of the virgin stock biomass (B_0) and B_{MSY} were lowest under the 80% CPUE using a heavy one-way management strategy. Conversely, the probability of the biomass falling below 20% B_0 was highest when the F_{MSY} reference point was used.

Only the 2/3 F_{MSY} reference point and the 80% CPUE used under the heavy one-way management strategy ensured the biomass was above B_{MSY} with greater than 50% confidence. The other strategies and reference points failed this.

Industry Performance
The simulations indicate that using F_{MSY} as a biological reference point would likely to lead to several detrimental conditions upon industry. For example, over the 20-year period forecast, catch trajectories declined, effort trajectories significantly increased, catch rate trajectories declined and annual catch variation increased (Figure 4.7). In contrast, trajectories associated with the 2/3 F_{MSY} and ¾ F_{MSY} reference points resulted in increased catches, lower effort and higher CPUEs, although a significant drop in catch would likely result in the first five years.

The CPUE reference points under the heavy one-way management scenario all resulted in similar catch trajectories, with the 80% CPUE resulting in the highest trajectories for catch rate and the lowest trajectories for effort (Figure 4.7).

Management performance
The number of triggered CPUE reference points was higher for the 80% CPUE reference point and lower for the 60% CPUE reference point (Figure 4.8). In other words, the higher the CPUE reference point the more likely it is to trigger. The CPUE reference points resulted in one to three corrections in fishing effort, over the 20 year forecast period, depending on the response mechanism (moderate or heavy) and the reference point (60%, 70% or 80% CPUE). Generally, the ¾ and 2/3 F_{MSY} reference points resulted in one significant correction in fishing effort (Figure 4.7).

The CPUE reference points typically triggered at low biomass levels ranging between 10% and 40% of virgin stock size (B_0) (Figure 4.9). All simulations of the CPUE reference points highlighted they can falsely trigger at large biomasses (Figure 4.9). The simulations were based on the base-case model stock assessment where the spawner-recruitment curve incorporated the median estimates of fishing power increase and indicate that the CPUE reference points were based on catches when the population biomass was at 25-30% B_0. Consequently, the management performance of the CPUE reference points often fails to trigger at low biomasses around 20% B_0 (Table 4.5). For example, the 70% moderate one-way management strategy only correctly triggered for 32% of the annual biomasses that were below 20% B_0 (Figure 4.9). Even lower accuracy resulted from using the 60% CPUE reference point. The accuracies were extremely low if CPUE reference points were used to manage biomasses around B_{MSY} (Table 4.5). No significant quadratic effects of changing trigger accuracy were found for different levels of fishing effort ($p>0.05$).

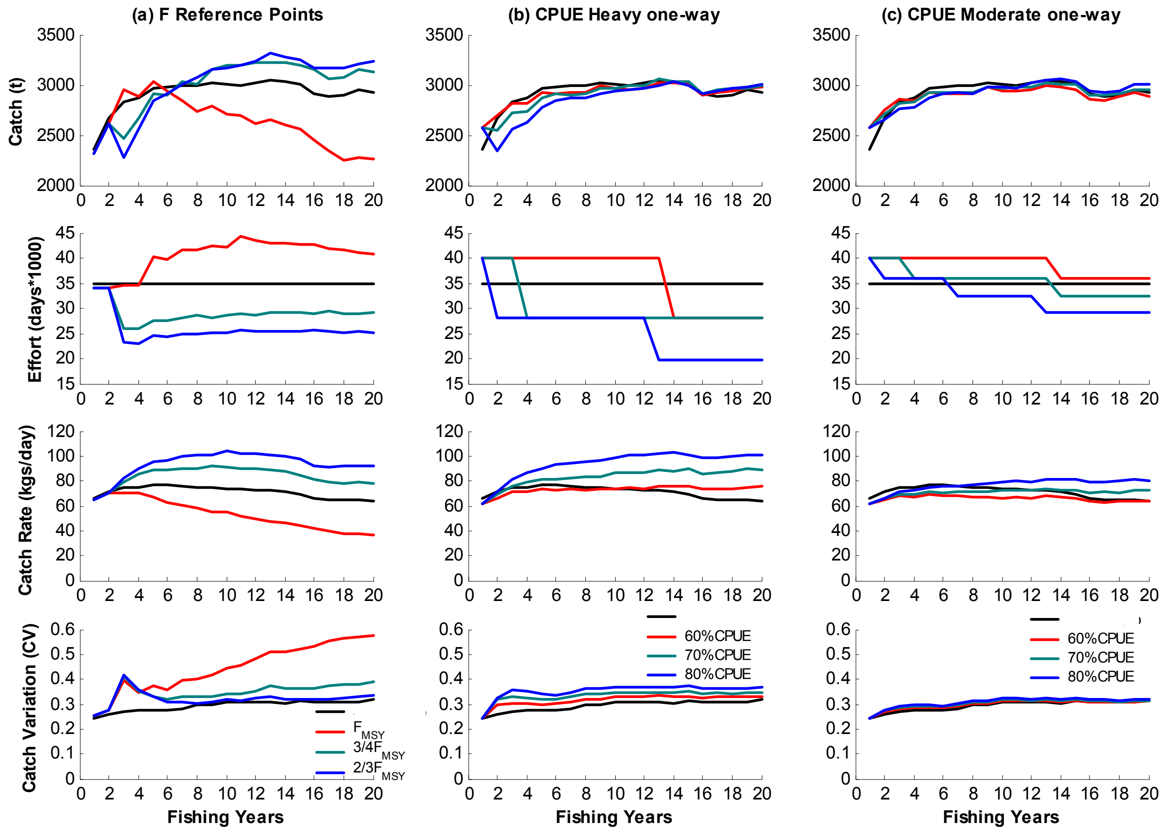


Figure 4.6. The expected biological outcomes for eastern king prawns from managing fishing effort according to, (a) fishing mortality, (b) heavy one-way catch-rate, and (c) moderate one-way catch rate reference points. The first two rows of plots illustrate the outcomes in relation to virgin population size (B_0). Outcomes on the bottom two rows were measured against the population size which supports maximum sustainable yield (B_{MSY}). Lower probabilities (or risks) of the population sizes falling below $0.2B_0$ and B_{MSY} were for fishing efforts managed at 2/3 of MSY effort or 80% heavy one-way catch-rates. Probabilities at 0.5 represent the population sizes at $0.2B_0$ and B_{MSY} (equal to one) respectively. The one-way and two-way catch-rate management strategies performed alike. The results assume Beverton-Holt recruitment; pre plan represents 35000 days of fishing effort with no management changes.

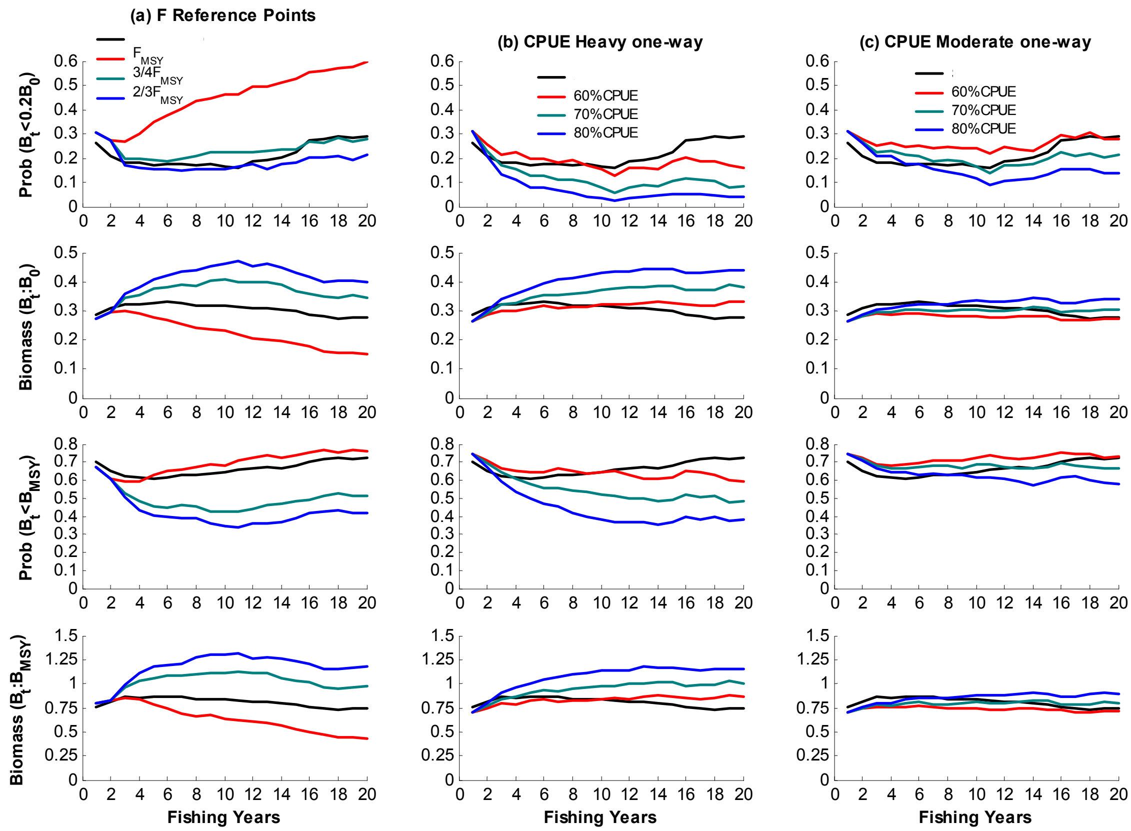


Figure 4.7. The expected industry outcomes from fishing eastern king prawns and managing fishing effort according to, (a) fishing mortality, (b) heavy one-way catch-rate, and (c) moderate one-way catch-rate reference points. Industry outcomes were measured against median total catches, fishing effort, catch-rates and variation in total catches (coefficient of variation). Generally, the management strategies of ¾ and 2/3 of MSY fishing effort produced larger catches and catch-rates in the long term. Variations in total catches were similar for all management strategies, but much larger for fishing at MSY. The one-way and two-way catch-rate management strategies performed alike. The results assume Beverton-Holt recruitment; pre plan represents 35000 days of fishing effort with no management changes.

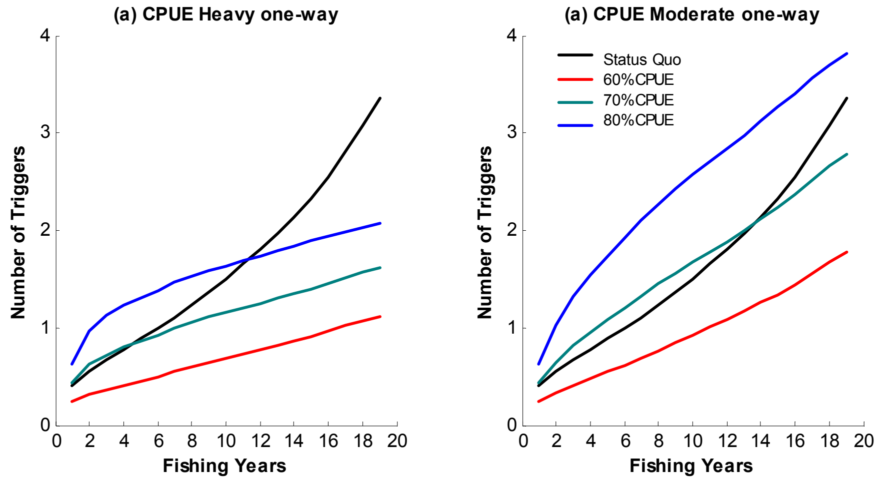


Figure 4.8. The average cumulative number of management changes (limit catch-rate triggers) for the (a) heavy one-way catch-rate, and (b) moderate one-way catch-rate reference points. Generally over twenty years, between one and two catch-rate triggers will occur under the heavy one-way management strategy, but up to three or four may occur under moderate one-way management strategy. Again, the one-way and two-way catch-rate management strategies performed alike. The results assume Beverton-Holt recruitment; pre plan represents the number of catch-rates falling below 70%CPUE for 35000 days of fishing effort with no management changes.

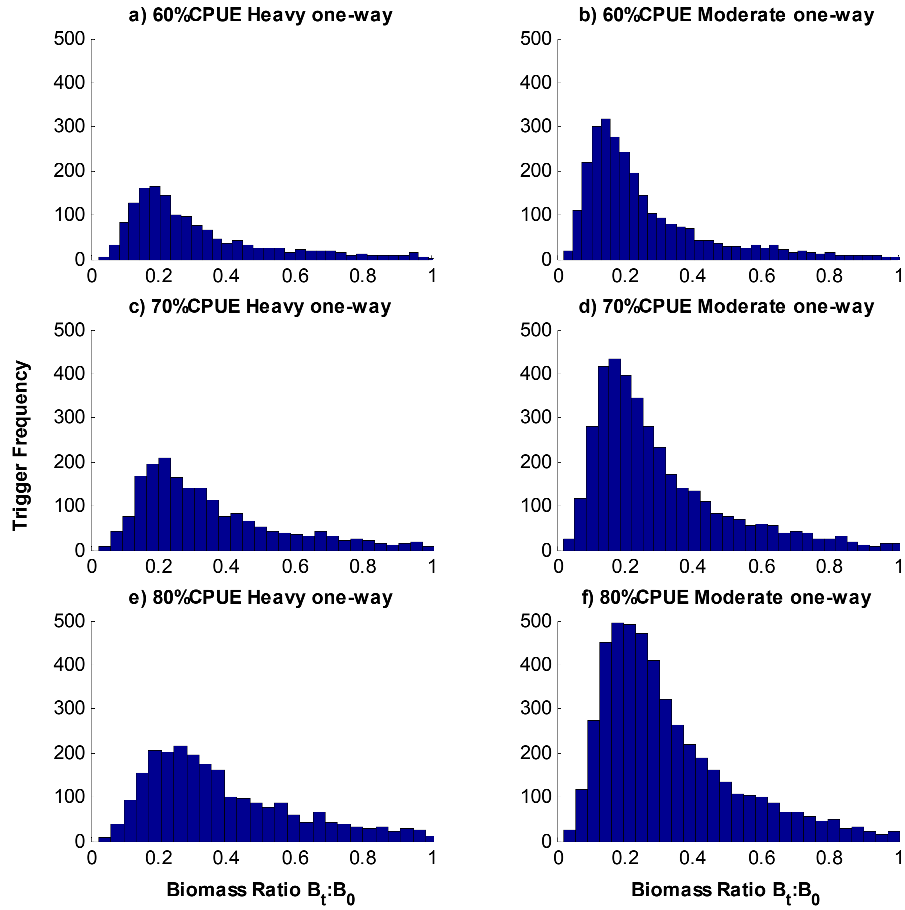


Figure 4.9. The distribution of CPUE reference points triggering under a range of exploitable biomasses, expressed as a ratio of virgin biomasses. The results are shown from the monthly delay difference model for 45,000 test-fishing days of effort, assuming Beverton-Holt recruitment. The catch-rate reference points triggered more frequently under the moderate one-way management strategy and trigger at marginally lower population sizes due to the slow response of this management strategy to change fishing effort.

Table 4.5. The accuracy of catch-rate reference points for 45000 test-fishing days of effort, assuming Beverton-Holt recruitment. The higher probabilities for the 80% CPUE and moderate one-way management strategy indicate better accuracy measured against the biomass reference levels of $0.2B_0$ and B_{MSY}.

Reference Point	Management Strategy	Proportion of Triggers Accurately detected when Bt < 0.2B0	Proportion of Triggers Accurately detected when Bt < BMSY	Actual Biomass (Bt/B0) at Trigger		
				5%ile	Median	95%ile
60% CPUE	Heavy one-way	0.14	0.09	0.10	0.24	0.75
60% CPUE	Moderate one-way	0.24	0.15	0.07	0.19	0.67
70% CPUE	Heavy one-way	0.22	0.12	0.11	0.29	0.80
70% CPUE	Moderate one-way	0.32	0.21	0.09	0.24	0.71
80% CPUE	Heavy one-way	0.32	0.17	0.13	0.33	0.84
80% CPUE	Moderate one-way	0.43	0.27	0.10	0.27	0.74

4.6 Saucer Scallops

Catch Statistics

Saucer scallop harvest varied greatly between the 1989 and 1996 (Figure 4.10). Total catch from these fishing years averaged 962 t meat, with the smallest catch of 397 t taken in 1989 and the largest catch of 1738 t taken in 1993. After the 1996 fishing year total catches averaged 791 t meat, with catches ranging between 623 t and 1045 t. Fishing efforts applied to saucer scallops between 1990 and 2001 were relatively consistent, averaging 13583 nights with a range of 9729 and 16772 nights. Fishing effort for the 2002 fishing year was significantly less at 7436 nights. Average monthly standardised-catch-rates show a downward trend between 1989 and 2002, but were stable from 1998 (Figure 4.11). Monthly standardised-catch-rates peaked at an average of 21 baskets for the 1993 fishing-year between November 1992 and April 1993. Standardised-catch-rates averaged only six baskets for the 1996 and 1997 fishing years. Since 1998 standardised-catch-rates average about eight baskets. Note the spike in the February 2001 catch rate of 15.5 baskets and the January 2002 catch rate of 18.6 baskets. This corresponded to the rotational opening of the spatial closures. Caution should be applied calculating annual catch rates for 2001 and 2002, as they would be bias upwards due to the rotational closure effects (Jebreen et al. 2003).

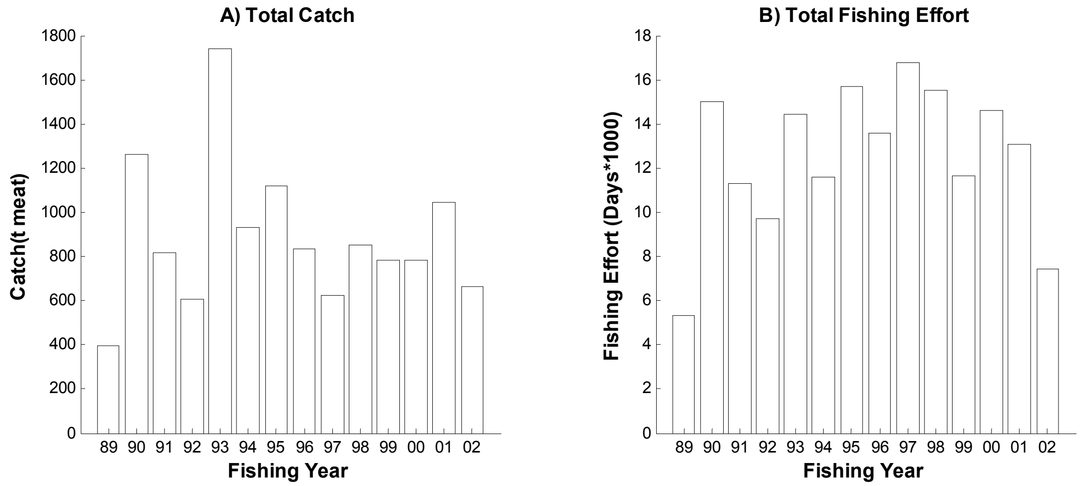


Figure 4.10. The saucer scallop total catch and fishing effort reported from 1989 to the 2002 fishing-year. The statistics represent all catches south of 22.5 degrees.

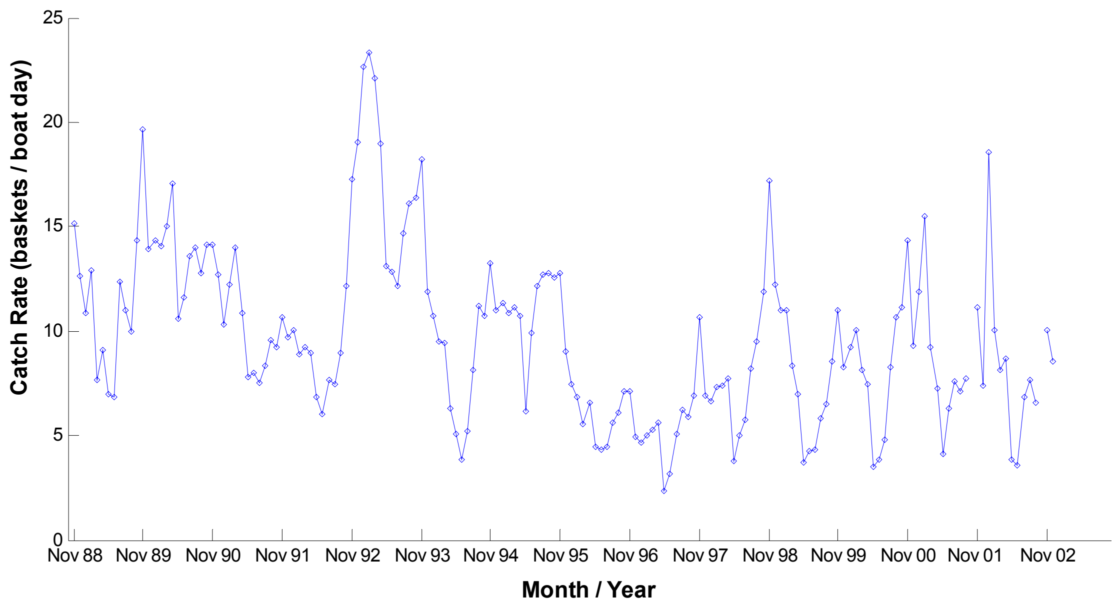


Figure 4.11. Monthly-standardised saucer scallop catch rates from 1989 to 2002; note the seasonal patterns in catch rates and the overall gradual decline. The gaps in catch rates relate to the October seasonal closure. The February 2001 catch rate of 15.5 baskets and the January 2002 catch rate of 18.6 baskets relate to the rotational opening of the spatial closures.

Biological Data and Management

As with eastern king prawns a range of parameters were used to calculate average rates of scallop growth and natural mortality, weight, size at maturity, fecundity and monthly variation in spawning activity. These biological parameters are deterministic and the model sensitivities to the parameters are reported as part of the stock assessment. These parameters are based on previous research studies and were assumed to most accurately reflect the true biological parameters for the scallop population. As such, they were treated as the base case against which the model sensitivities were measured.

The growth curve was based on a weighted average of the parameters reported by Dredge (1981). The weightings were based on the number of recaptured tagged scallops from a series of tag-recapture experiments. The model considered the management-imposed seasonal variations in minimum legal size and also the slight differences between the regulated shell height measures (90 mm and 95 mm) and those applied by fishers, which equate to about a 2 mm reduction in the actual size of scallops that can be retained. The incidence of scallops with histologically mature and spent gonads was used to indicate relative spawning activity (Dredge 1981), with the relative amount of spawning generally greater between April and August. This study also found that 75% of scallops were mature at a shell height of ≥ 90mm. Logistic regression on these data, using the mid points of the size categories, approximated maturity across the ages. No significant exponential relationship existed between shell height and fecundity (Dredge 1981). These reproductive fecundity data were combined with the population estimates from the stock assessment model to calculate spawning stock sizes. The scallop meat-weight relationship was based on data collected from October in 2000 and 2002. Although the relationship was adjusted each month for changes in meat-weight condition, it did not take account of soaking procedures that are sometimes used by processors to increase meat-weight by 5-10% (Williams 2002).

To enable a more complete analysis of the stock assessment and reference points, historical changes in management were included. Management of the saucer scallop fishery through three spatial closures commenced in April 1989 given concerns about the sustainability of the fishery. These closures were implemented for seven months between April and October 1989 and were assumed to have negligible effect on the assessment as they were removed after “industry had shown unwillingness to comply with these closures” (Queensland Fisherman, December 1989). As a result of declines in catch rates in 1996/1997, the closures were re-introduced in February 1997. The closures were generally referred to as “scallop replenishment areas” and were fixed in place until 2001, where management, as a result from industry pressure, began a rotational strategy of opening and closing these areas to trawling. Fishery independent estimates of scallop numbers in the closures were included to account for the closure effect of changing the exploitable proportion of the stock. Minimum legal scallop sizes have also experienced a history of change. From 1988 to December 1999 minimum legal sizes were set at 90mm from November to April and 95mm for May to October inclusive. In January 2001 sizes changed to 90mm from January to April, and 95mm for May to December, inclusive.

CPUE inputs

As with eastern king prawns, all Queensland saucer scallop catches were extracted from the Queensland Fisheries Service QFISH database. Only catches south of -22 degrees were included in the stock assessment. This latitudinal range was chosen to minimize the mixture of mud scallop (*Amusium pleuronectes)* in catches that can occur north of -22.5 degrees (Dichmont et al 1999). The fishing-year for saucer scallops was defined from November through to October and based on information about the life cycle, size at recruitment and the seasonal variation in fishing effort.

Stock Assessment

The saucer scallop stock assessment used two modelling approaches - a monthly age-structured model and an annual Schaefer surplus production model (Figures 4.12, 4.13, and 4.14). The age-structured model compared three monthly rates of natural mortality (M) and 3 levels of annual increase in fishing power (Section 3.1.5), with their respective 90% confidence intervals (Figures 4.12 and 4.13). These plots were structured accordingly:

1. Figure 4.12A resulted from assuming M=0.09 $month^{-1}$, which, based on the literature, is likely to be the most accurate estimate of natural mortality and from incorporating the median estimate for annual fishing power increase. The model was considered to most accurately reflect reality and was therefore used as the base-case.

2. Figure 4.12B resulted from assuming a lower rate of natural mortality (M=0.07 $month^{-1}$) equal to the 2.5^{th} percentile on a normal distribution with mean 0.09 and standard deviation of 0.01.

3. Figure 4.12C assumed a relatively higher rate of natural mortality (M=0.11) equal to the upper 97.5 percentile on a normal distribution with mean 0.09 and standard deviation of 0.01.

4. Figure 4.13A resulted from assuming no annual increase in fishing power (i.e., no annual effort creep) in the assessment of the stock-recruitment relationship. Figure 4.13A and B also assumed natural mortality at M=0.09 $month^{-1}$. The effect of changing fishing power should be compared against Figure 4.12A (i.e. median annual fishing power increases).

5. Figure 4.13B resulted from incorporating relatively higher levels of annual increase in fishing power. The annual increases were the upper 90% confidence interval of the annual increases in fishing power, which varied between years. These estimates of the increase in fishing power were incorporated in both the assessment and the spawner-recruitment relationship.

Note the purpose of comparing different outputs was to highlight the influence of estimates natural mortality (M) and fishing power. The results should be compared against the base-case results.

The age-structured model generally predicted that biomass, expressed as a ratio to virgin exploitable stock biomass size, declined between 1989 and 1997 (Figure 4.12 and Figure 4.13). The biomass was notably below B_{MSY} in the 1997 fishing-year and this reflected the low catch rates reported at that time. Since 1998, the predicted biomasses varied around B_{MSY} for all scenarios. In comparison to these results, the

Schaefer surplus production analysis also predicted declining biomasses between 1989 and 1997 (Figure 4.14). The biomasses from 1994 to 1999 were judged to be below B_{MSY} (estimated as ½ virgin stock size in this model). The biomass in 2001 increased and was above B_{MSY}. The confidence intervals on the model estimates were quite large.

The monthly age-structured model and Beverton-Holt spawner-recruitment curve (Figure 4.15) were used to estimate the equilibrium virgin stock size (B_0) and the population size that supports maximum sustainable yield (B_{MSY}) (Table 4.6). The yield estimates and the steepness of the Beverton-Holt curve were very similar to those derived from the Ricker spawner-recruitment relationship. Details on the catch data used in the spawner-recruitment curves are outlined in O'Neill et al (In press). Only about 5% of all daily catch records were from 1978 to 1987. However, in order of 700 to 1,000 days of fishing were still recorded in each of the years from 1978 to 1981.

Estimates of equilibrium management quantities across four different minimum legal sizes show that MSY was similar, but smaller assuming Ricker recruitment compared to Beverton-Holt (Table 4.7). Although, in terms of equilibrium levels of fishing effort at E_{MSY}, the estimates were smaller for the less conservative 90mm size limit compared to the larger size limit of 95mm. Additional sensitivity analysis on the age-structured model showed that higher E_{MSY} was related to higher rates of natural mortality or no fishing power increases, but lower E_{MSY} was calculated for slower scallop growth rates or higher fishing power increases (Table 4.8). Management quantities from the surplus-production model are provided in Table 4.9. The estimate for the model's population-growth parameter (r) was high at 1.2. Values above 1 generally indicate that the stock has high intrinsic rate of increase, and as a result higher levels of E_{MSY} were calculated.

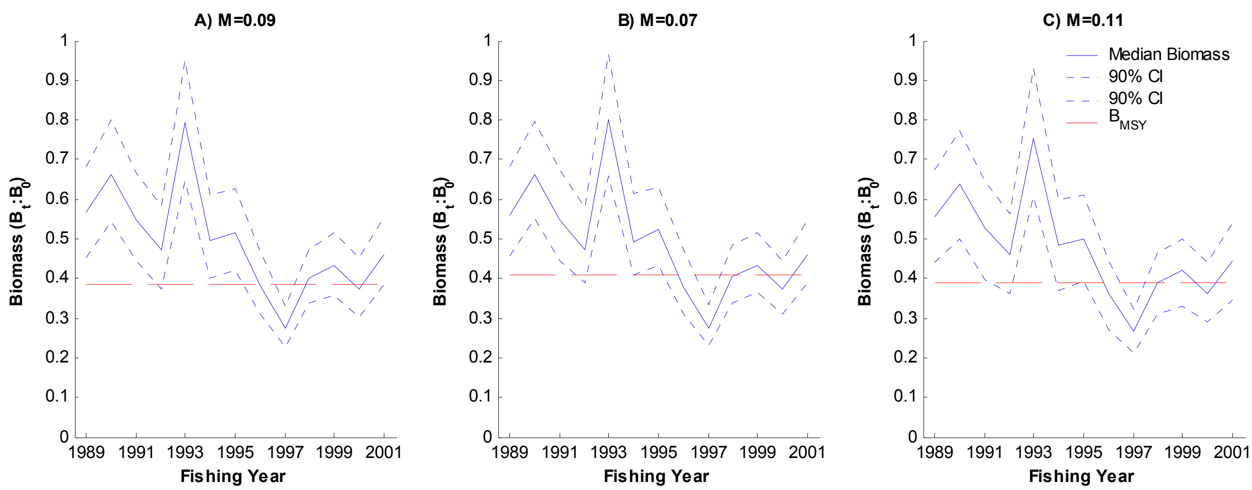


Figure 4.12. The monthly age-structured model predicted declining exploitable biomasses for scallops between 1989 and 1997. Since 1997, biomasses varied around the biomass reference point for maximum sustainable yield (B_{MSY} the dashed red horizontal line). Results are presented for three estimates of natural mortality (M) and the model assumed the median annual estimate of increasing fishing power. B_{MSY} was calculated using the Beverton-Holt spawner-recruitment curve (Figure 4.15). The dotted lines represent the 90 percent confidence intervals.

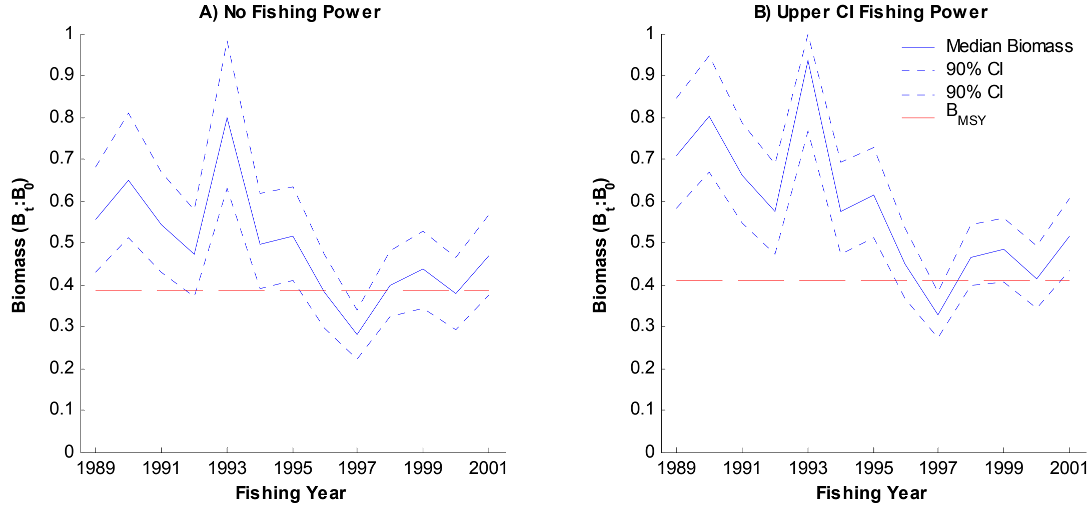


Figure 4.13. Biomass estimates from the monthly age-structured model for two different estimates of the annual increase in fishing power. The model incorporated a single estimate of natural mortality (M=0.09). Trends in the exploitable biomass were similar to those in Figure 4.12A.

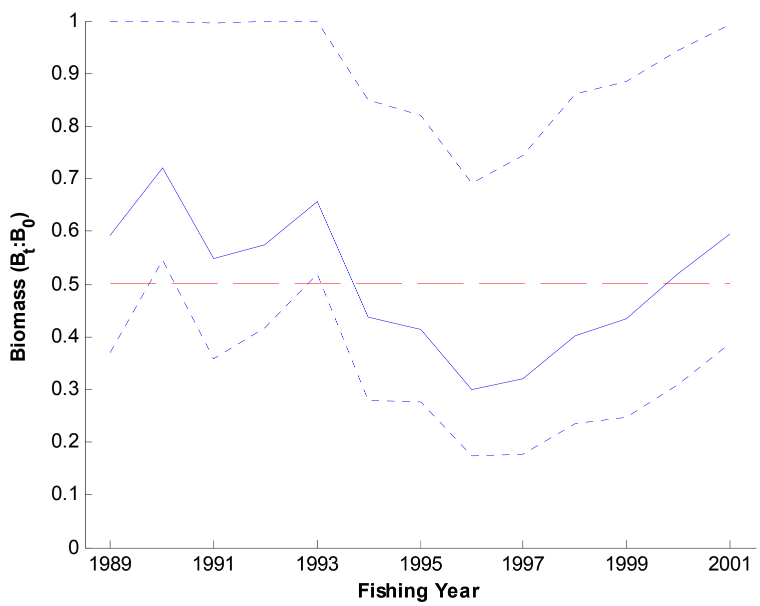


Figure 4.14. The annual surplus production model predicted declining exploitable biomasses for the scallop fishery between 1989 and 1997 fishing years (dotted lines represent the 90th percentiles). The model predicted increasing biomass since 1997. The dashed red horizontal line shows the biomass reference point for maximum sustainable yield (B_{MSY}).

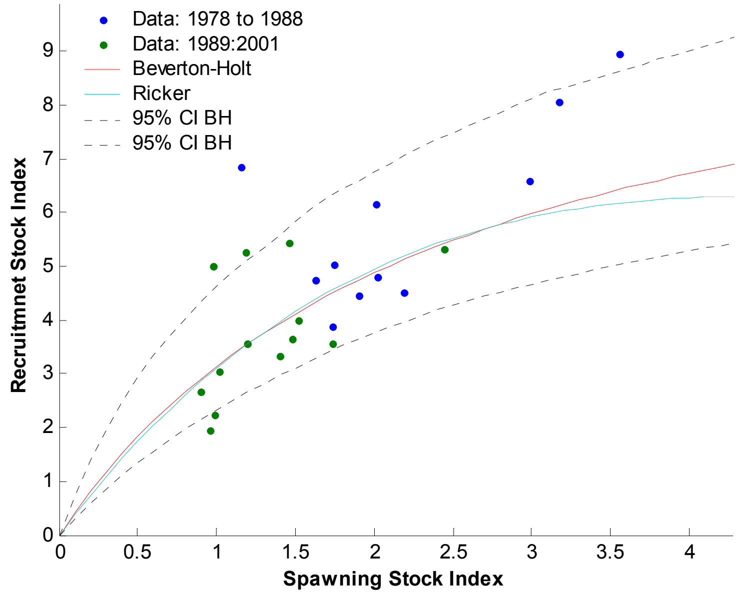


Figure 4.15. Scallop spawner-recruitment relationships assuming the Beverton-Holt form (red line) and the Ricker form (green line). Curves fitted using a weighted log-likelihood and incorporate the median estimates of annual increases in fishing power. Two-year autocorrelations were non-significant at -0.235.

Table 4.6. Saucer scallop spawner-recruitment parameters. Numbers within parentheses refer to the parameter standard error and T statistic for α and β, and 90% confidence intervals for steepness.

Spawner-Recruitment Parameters	**Beverton-Holt**	**Ricker**
α	226500.826 (62651.237; 3.62)	3.902e-6 (6.312e-7; 6.18)
β	9.185e-10 (4.657e-10; 1.97)	2.274e-15 (1.108e-15; 2.05)
Steepness	0.32 (0.23:0.52)	0.30 (0.22:0.4)

Table 4.7. Scallop equilibrium management quantities as calculated from the monthly age-structured model using two forms of the spawner-recruitment relationship and median annual increases in fishing power. The quantities were calculated for four different minimum legal shell-sizes. Numbers in parenthesis are 90% confidence intervals.

Management Quantities	Beverton-Holt	Ricker
Current Size Limit – Jan-Apr 90mm, May-Dec 95mm		
MSY (millions of shell)	50 (10:150)	44 (5:130)
MSY (tonnes meat)*	658 (131:1923)	599 (69:1714)
E_{MSY} (2001 nights)	11709 (4681:32385)	9437 (3366:20805)
$3/4E_{MSY}$ (2001 nights)	8782 (3511:24289)	7078 (2524:15604)
$2/3E_{MSY}$ (2001 nights)	7806 (3121:21590)	6292 (2244:13870)
Size Limit – 90mm all year		
MSY (millions of shell)	50 (10:152)	45 (5:132)
MSY (tonnes meat)*	650 (129:1895)	590 (68:1679)
E_{MSY} (2001 nights)	10934 (4422:29699)	8853 (3190:18790)
$3/4E_{MSY}$ (2001 nights)	8201 (3316:22274)	6640 (2393:14093)
$2/3E_{MSY}$ (2001 nights)	7289 (2948:19799)	5902 (2127:12527)
Size Limit – 95mm all year		
MSY (millions of shell)	49 (9:149)	44 (5:130)
MSY (tonnes meat)*	666 (132:1948)	605 (70:1731)
E_{MSY} (2001 nights)	12287 (4852:35668)	9821 (3432:22476)
$3/4E_{MSY}$ (2001 nights)	9215 (3639:26751)	7366 (2574:16857)
$2/3E_{MSY}$ (2001 nights)	8192 (3235:23780)	6547 (2288:14985)
Size Limit – Nov-Apr 90mm, May-Oct 95mm		
MSY (millions of shell)	50 (10:150)	44 (5:131)
MSY (tonnes meat)*	653 (130:1910)	592 (68:1695)
E_{MSY} (2001 nights)	11254 (4551:31182)	9123 (3273:19571)
$3/4E_{MSY}$ (2001 nights)	8441 (3413:23387)	6842 (2455:14678)
$2/3E_{MSY}$ (2001 nights)	7503 (3034:20789)	6082 (2182:13048)

Table 4.8. Additional management calculations, from the scallop age-structured model, based on varying the monthly rate of natural mortality (M) and fishing power increases. These results relate to the current minimum legal size of 90mm Jan-Apr, and 95mm May-Dec, assuming Beverton-Holt recruitment.

Management Quantities	M=0.07, Median estimates of annual increase in Fishing Power	M=0.11, Median estimates of annual increase in Fishing Power	M=0.09, No annual increase in Fishing Power	M=0.09, Annual increase in Fishing Power =upper 90% CI
MSY (millions of shell)	47	52	50	46
MSY (tonnes meat)*	639	671	661	600
E_{MSY}	8053	12386	136970	9886
$3/4E_{MSY}$	6040	9289	10273	7415
$2/3E_{MSY}$	5369	8257	9131	6591

Table 4.9. Summary of the parameters estimated from the Schaefer surplus production model.

Parameter	**Estimate (90% Confidence Interval)**
Population Growth Rate *r*	1.203 (0.548:1.728)
Management Quantity	
MSY (tonnes meat)*	1149 (941:1217)
E_{MSY}	15251 (11289:19199)
¾ E_{MSY}	11438 (8467:14399)
2/3 E_{MSY}	10168 (7526:12800)

For both the age-structured and surplus production model stock assessments there was no evidence to suggest the models were inadequate for the data or that the use of lognormal errors were inappropriate. The models predicted the standardised catch rates quite well, although the monthly age-structured model did slightly under estimate three of the monthly peak catch rates present in the time series. The standardised residuals for these large catch rates were all less than four, indicating they were not extreme. The influence of these data points had little effect on the log-likelihood or upon the estimation of the parameters. For example, removing or slightly increasing their effect resulted in little change in the parameter estimates, suggesting the model captured these observations reasonably well and that it did accurately model the year to year and month to month patterns of saucer scallop catch rates. The surplus production fit to the annual time series tended to over estimate standardised catch rates from 1990 to 1992, to compensate for the large catch rates in 1993. Although, from 1993 the model generally captured the trend in catch rates.

Reference Point Simulations
The reference points examined by the two models are provided in Table 4.5. A large number of results were generated from these simulations, mainly as a result of the various stock-recruitment possibilities and the range of minimum legal size regulations. The results presented in this section focus on the performance of reference points

through the monthly age-structured model using the Beverton-Holt spawner-recruitment relationship (which assumes median annual increases in fishing power) and the current size limit (i.e. the base-case) (Figure 4.12A). Results from all simulations, including summarised forecasts for five-year and 20-year periods are outlined in O'Neill et al (In press). The simulations assess the consequences of using different reference points and management strategies and the subsequent results are presented to allow the reader to evaluate the trade offs in performance. The results do not define a final reference point, management strategy or the future status of the scallop fishery, but rather they provide expected outcomes that may be used by decision makers to help select appropriate reference points to achieve the management objectives. It is important to note that the management objectives for the scallop fishery are yet to be defined.

Biological Performance

The model simulations suggested that higher biomass trajectories would be attained using the 80% CPUE reference point, under the heavy one-way management intervention (Figure 4.16). After 20 years, these biomass trajectories levelled at above $1.5B_{MSY}$ or 0.6-0.7 B_0. The 2/3 F_{MSY}, ¾ F_{MSY}, and other CPUE reference points, also resulted in relative increases in biomass and the 20-year biomass trajectories levelled at 1.25-1.5 B_{MSY} or 0.5-0.5 B_0. Returning to the pre plan level (13,000 fishing nights), or adopting F_{MSY} as a reference point generally resulted in relatively lower biomass trajectories falling below B_{MSY} after 20 years.

The probability trajectories for the biomass falling below 20% of the virgin stock biomass (B_0) and B_{MSY} were lowest under the CPUE reference points using a heavy one-way management strategy. Conversely, the probability of the biomass falling below 20% B_0 was highest with pre plan fishing effort and when the F_{MSY} reference point was used.

All the 2/3 F_{MSY}, ¾ F_{MSY}, and CPUE reference points and management strategies ensured the biomass was above B_{MSY} with greater than 60% confidence. The F_{MSY} and pre plan strategies failed this.

Industry Performance

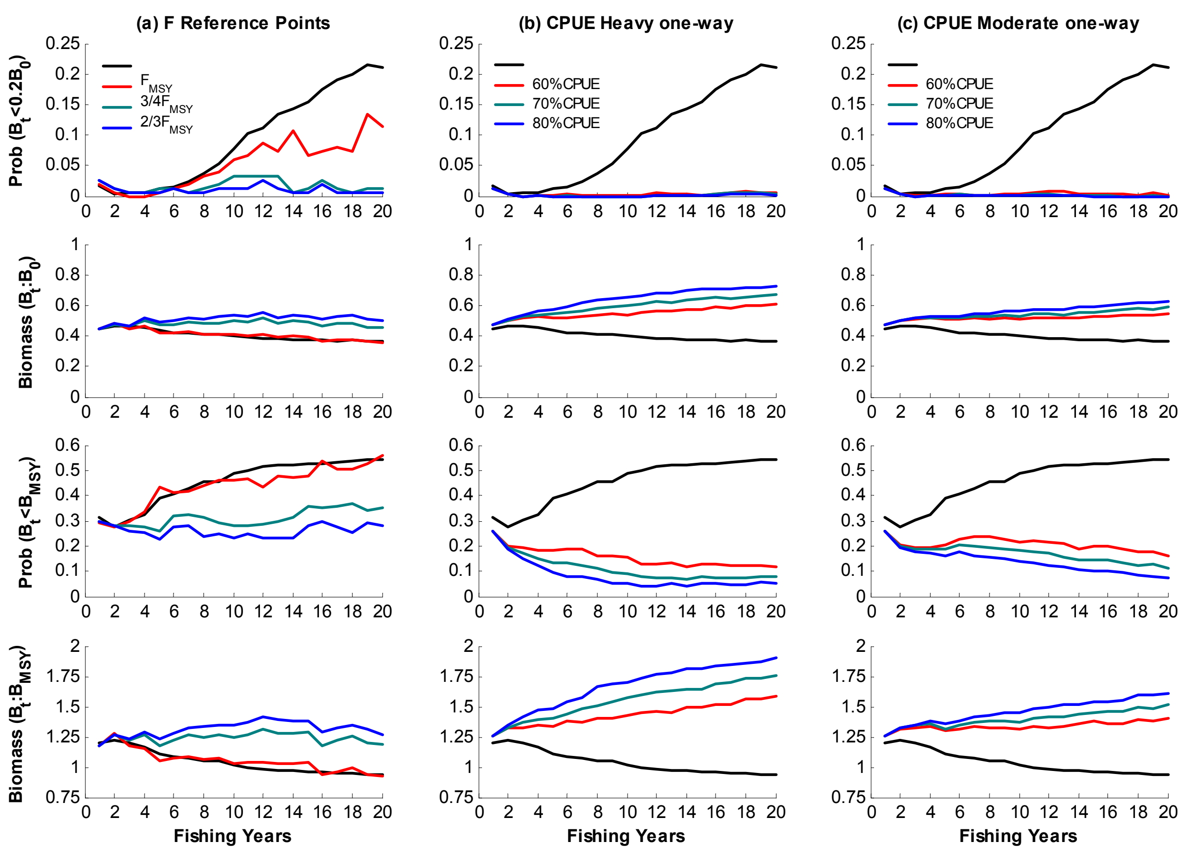
The simulations indicate that pre plan fishing effort would likely lead to the best scallop catches for industry (Figure 4.17). Fishing according to the $3/4F_{MSY}$ and $2/3F_{MSY}$ reference points also produced similar catches after about ten years. Although, a drop in catch would likely result from the lower fishing effort applied in the first five to ten years. The CPUE reference points all resulted in lower catch trajectories after 10 to 20 years, but the 80% CPUE under the heavy one-way management scenario resulted in the highest trajectories for catch rate and the lowest trajectories for fishing effort. Pre plan fishing effort and the F_{MSY} reference point resulted in higher fishing effort and the lowest catch rates. The variations in total catches (CV) were smallest for the $3/4F_{MSY}$ and $2/3F_{MSY}$ fishing strategies. Overall, the catch-rate reference points, with annual management responses, appear to reduce fishing effort effectively even though the biomass trajectories are above $0.5B_0$ or $1.25B_{MSY}$ (Figure 4.16).

Management performance

The number of triggered CPUE reference points was higher for the 80% CPUE reference point and lower for the 60% CPUE reference point (Figure 4.18). In other words, the higher the CPUE reference point the more likely it was to trigger. The CPUE reference points resulted in three to eight corrections in fishing effort, over the 20 year forecast, depending on the response mechanism (moderate or heavy) and the reference point (60%, 70% or 80% CPUE). Generally, the ¾ and 2/3 F_{MSY} reference points resulted in one significant correction in fishing effort (Figure 4.17).

The CPUE reference points triggered at a wide range of biomasses, but typically ranged between 30% and 60% of virgin stock size (B_0) (Figure 4.19). All simulations of the CPUE reference points highlighted they can falsely trigger at large biomasses. The management performance of the 70% and 80% CPUE reference points often accurately triggered at low biomasses around 20% B_0 (Table 4.10). For example, the 70% moderate one-way management strategy only correctly triggered for 70% of the biomasses that were below 20% B_0. Lower accuracy resulted from using the 60% CPUE reference point. The accuracies were again lower if CPUE reference points were used to manage biomasses falling below B_{MSY} (Table 4.10).

Figure 4.16. The expected biological outcomes for saucer scallops from managing fishing effort according to, (a) fishing mortality rates, (b) heavy one-way catch-rate, and (c) moderate one-way catch rate reference points. The first two rows of plots illustrate the outcomes in relation to virgin population size (B0). Outcomes on the bottom two rows were measured against the population size which supports maximum sustainable yield (BMSY). Low probabilities (or risks) of the biomass falling below 0.2B0 were obtained for the 60-80% CPUE reference points, and for the ¾MSY and 2/3MSY reference points. Similar results were obtained in relation to the biomass falling below BMSY when effort was managed using the 60-80% CPUE reference points. Probabilities at 0.5 represent the population sizes at 0.2B0 and BMSY (equal to one) respectively. The one-way and two-way catch rate management strategies performed alike. The results assume Beverton-Holt recruitment and median estimates of the annual increase in fishing power. Simulations for pre plan and the fishing mortality reference points commenced at 13,000 nights of fishing effort. Simulations for the CPUE reference points commenced at 10,000 nights of fishing.



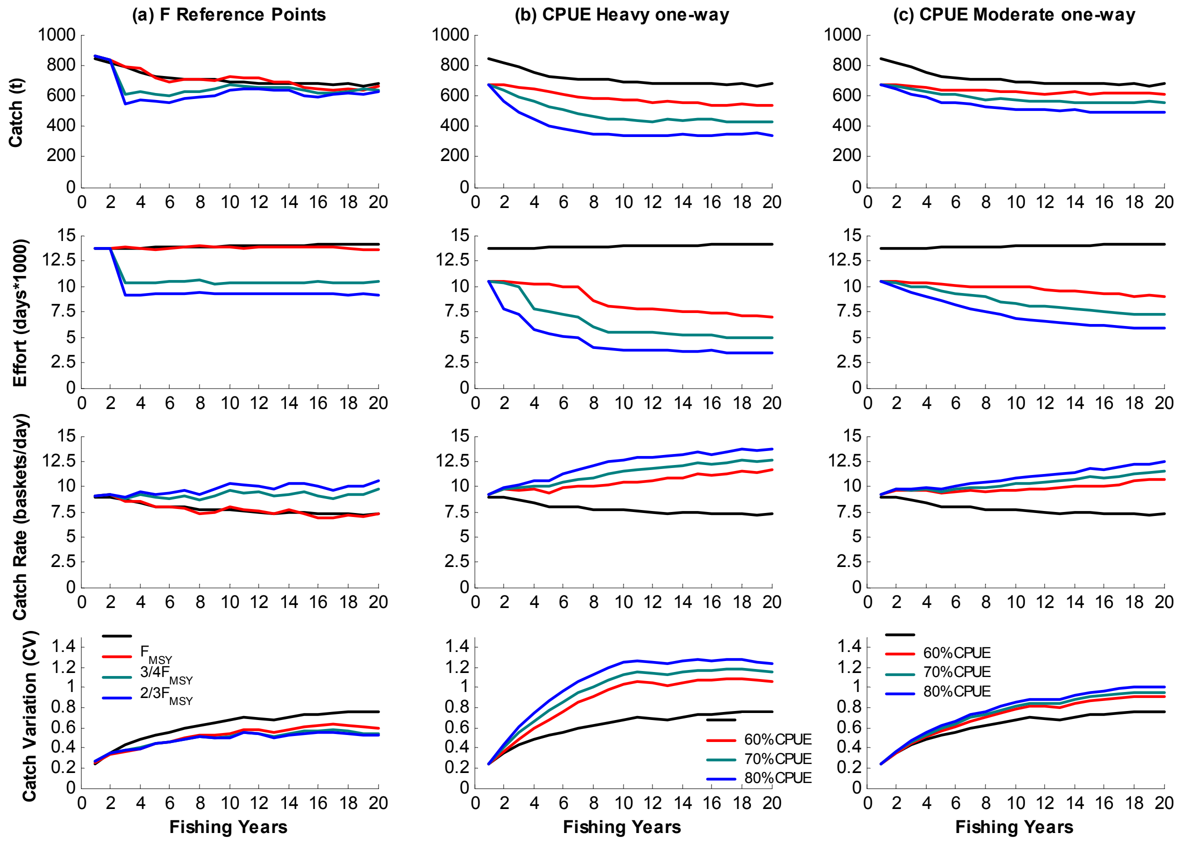


Figure 4.17. The expected industry outcomes from forecasting fishing effort in the scallop fishery according to, (a) fishing mortality, (b) heavy one-way catch-rate, and (c) moderate one-way catch-rate reference points. Industry outcomes were measured against total catches, fishing effort, catch-rates and variation in total catch (coefficient of variation). The management strategies of ¾MSY and 2/3 of MSY fishing effort resulted in equivalent long-term total catches, lower fishing effort and lower catch variations than returning to the pre plan fishing effort. However, the heavy one-way catch-rate reference points produced higher catch-rates in the long term. The one-way and two-way catch-rate management strategies performed alike. The forecasts assumed Beverton-Holt recruitment and the median annual increases in fishing power. Simulations for pre plan and the fishing mortality reference points started at 13,000 nights of fishing effort. Simulations for the CPUE reference points commenced at 10,000 nights of fishing.

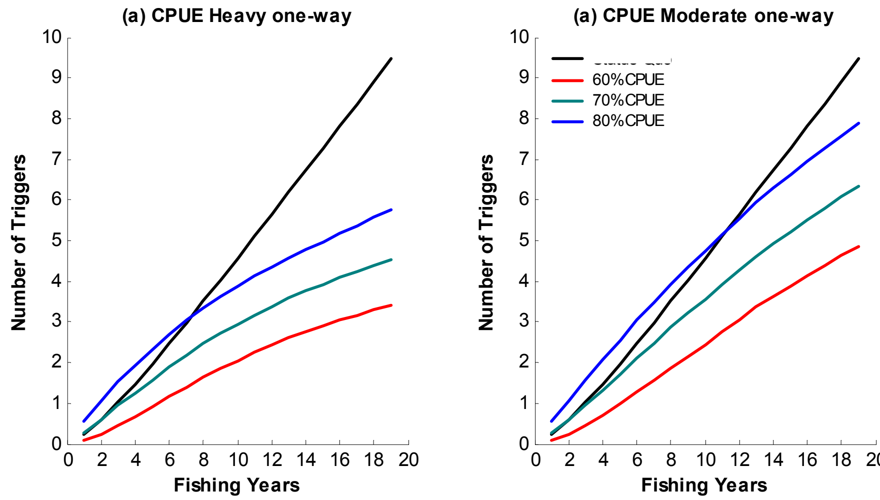


Figure 4.18. The average cumulative number of management changes (limit catch-rate triggers) for the (a) heavy one-way catch-rate, and (b) moderate one-way catch-rate reference points. Generally over twenty years, between three and six catch-rate triggers will occur under the heavy one-way management strategy, but up to six or eight may occur under the moderate one-way management strategy. Again, the one-way and two-way catch-rate management strategies performed alike. The results assume Beverton-Holt recruitment and median fishing power increases. Simulations for pre plan levels commenced at 13,000 nights of fishing effort and represents the number of catch rates falling below 70% CPUE. Simulations for the CPUE reference points commenced at 10,000 nights of fishing.

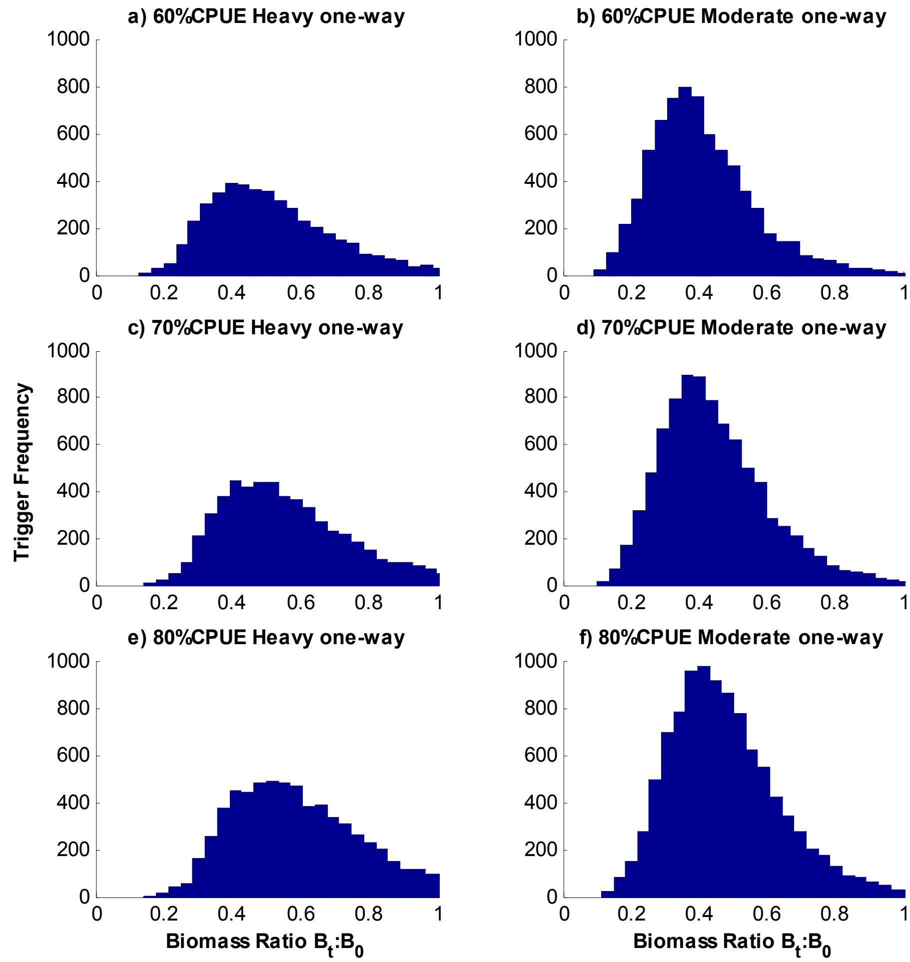


Figure 4.19. Distribution of the exploitable biomasses, expressed as a ratio of virgin biomasses, at which the catch-rate reference points triggered. The results are shown from the monthly age-structured model for 15,000 test-fishing days of effort, assuming Beverton-Holt recruitment. The catch-rate reference points triggered more frequently under the moderate one-way management strategy and trigger at marginally lower population sizes due to the slow response of this management strategy to change fishing effort.

Table 4.10. The accuracy of six catch-rate reference points measured from the monthly age-structured model for 15,000 test-fishing days of effort. The higher probabilities for the 80% CPUE and moderate one-way management strategy indicate better accuracy measured against the biomass reference levels of $0.2B_0$ and B_{MSY}.

Reference Point	Management Strategy	Proportion of Triggers Accurately detected when $B_t < 0.2B_0$	Proportion of Triggers Accurately detected when $B_t < B_{MSY}$	Actual Biomass (B_t/B_0) at Trigger		
				5%ile	Median	95%ile
60% CPUE	Heavy one-way	0.46	0.24	0.27	0.49	0.84
60% CPUE	Moderate one-way	0.64	0.39	0.20	0.39	0.70
70% CPUE	Heavy one-way	0.60	0.33	0.30	0.53	0.89
70% CPUE	Moderate one-way	0.70	0.50	0.23	0.42	0.74
80% CPUE	Heavy one-way	0.80	0.47	0.33	0.56	0.90
80% CPUE	Moderate one-way	0.83	0.62	0.25	0.46	0.77

4.7 Tiger / Endeavour prawns

The time-series of data available is relatively short and does not contain the developmental period of the fishery. This makes it difficult to fit surplus production models which require information from periods of low and high fishing effort. As it was not possible to obtain stable and biologically sensible fits to the tiger and endeavour prawn data for the south stratum only the fits for the north stratum have been presented.

Tiger Prawns North

The north stratum was modelled using three effort creep scenarios. The estimates of effort creep used in scenario's 2 and 3 were obtained from analyses conducted as part of FRDC Project 1999/120 **Reference point management and the role of catch-per-unit effort in prawn and scallop fisheries** (O'Neill et. al. in press). The 0.6 percent per year estimate of the annual change in fishing power is the linear fit of the yearly estimates of changes in fishing power. The fishing power analysis was only conducted on data for the north stratum for tiger prawn catch.

Effort creep scenario's used in the model:

1. Estimate effort creep (qinc) from the catch and CPUE data. This is the least preferable method as changes in catch rates and changes in fishing power tend to be confounded.
2. Use the linear fit of the fishing power analysis (0.6 percent per year increase in fishing power). This is better than scenario 1 and should be used whenever reliable information on changes in fishing power is available.
3. Yearly effort creep increments for the years 1989 to 1999 and a 0.6 percent annual increase was assumed for the reaming years. This is the best option as it makes full use of all the available data on changes in fishing power.

Scenario's 1 and 2 were run as a check on the sensitivity of the model to the values of effort creep used in the model.

Although scenario three gave the best fit (highest log likelihood) all three resulted in similar fits and parameter estimates (Table 4.11). When change in fishing power was estimated from the model (scenario 1) a value of 0.02 percent was obtained which is much lower than the 0.06 percent annual change in fishing power estimated by the FRDC study.

Table 4.11. North stratum tiger prawn model results. Qinc is the annual change in fishing power.

effort scenario	3	2	1
r	1.88	1.77	1.78
K	2,635	2,819	2,833
Bzero	1,196	1,222	1,191
q0	4.49003E-05	4.38626E-05	4.60011E-05
qinc	annual increments	1.006	1.002
LogLike	14.279	13.848	13.910
MSY	1,239	1,248	1,259
Emsy2001	19,150	18,640	18,910

Table 4.12. Bootstrap results for the tiger prawns in the north stratum. The 'median' is the middle value of the bootstrap estimates, the 'lower' and 'Upper' the 95% confidence interval of the bootstrap estimates.

parameter	Lower	optimal	Median	Upper
r	1.30	1.88	1.93	2.82
K	1,895	2,635	2,596	4,223
MSY	1,227	1,239	1,249	1,400
Emsy2001	15,800	19,150	19,123	23,637
Average catch 1988 to 2000			1,195	
tiger effort			16,429	
total effort			19,011	

Table 4.12 shows that the estimate of Maximum Sustainable Yield (MSY) for the north stratum is about 1,249 tonnes and that based on the current model, we are 95% confident that the true estimate lies between 1,227 and 1,400 tonnes. The average annual catch for the years 1988 to 2001 (1,195 t) is close to the median MSY estimate, which indicates that the fishery is fully exploited. Consistently fishing at or above MSY could result in a decline in prawn stocks. It is generally considered that fishing should be conducted at about 10% back from MSY to ensure that stocks are not overfished and to maximise the economic efficiency of the fleet.

Emsy (2001) is the fishing effort, standardised to 2001 days of effort, required to catch the Maximum Sustainable Yield. The estimate of Emsy for the north stratum is 19,150 days with a 95% confidence range of 15,800 to 23,637 days (Table 4.12). Although the annual effort based on all records (19,123 d) is slightly higher than Emsy the average effort targeted at tiger prawns, 16,429 days, is below Emsy and is closer to the lower confidence limit.

Figure 4.20 shows the fit of the model CPUE against the observed CPUE. The model fairly closely simulates the observed CPUE. Based on the trends in the CPUE data and the bootstrap biomass estimates (Figure 4.21) there is no evidence of a decline in the average stock size over the last ten years.

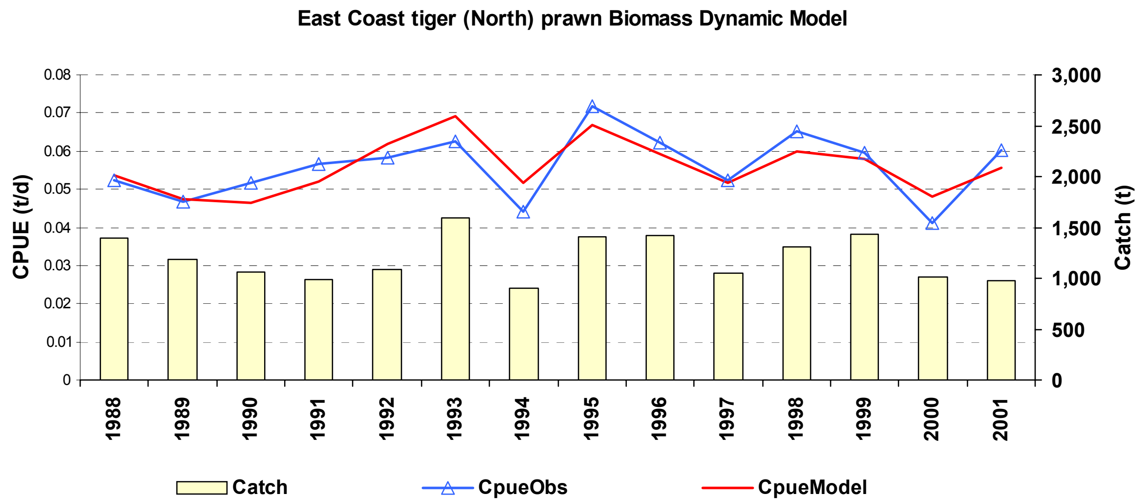


Figure 4.20. Tiger prawn model fit for the north stratum using effort creep scenario 3.

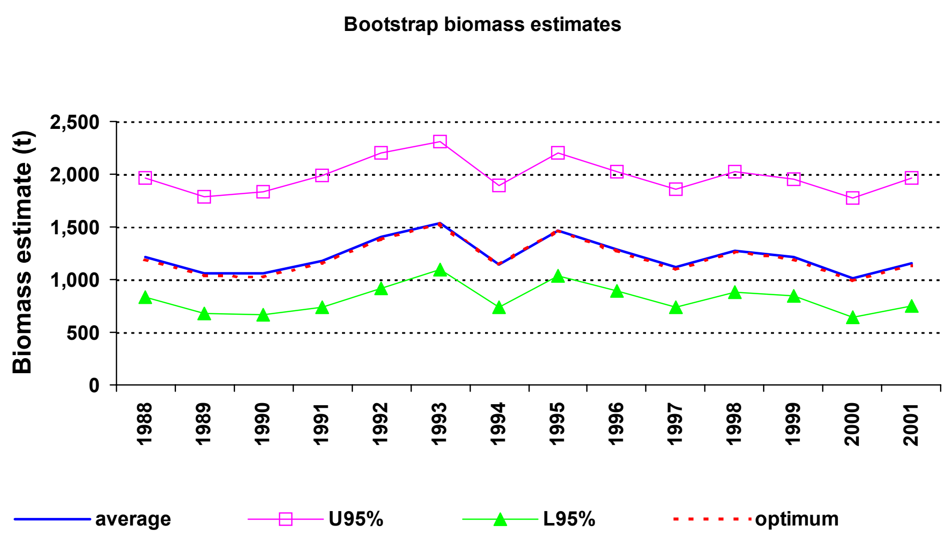


Figure 4.21. Tiger prawn bootstrap biomass estimates.

The plot of catch and effort against the model yield curve (Figure 4.22) also indicates that the tiger prawn stock in the north stratum is fully exploited as catch and effort for the whole time-series is centred on the top of the curve, which is MSY. The curve is based on the median parameter estimates from the bootstrap results. The model would be improved if we had data from periods of low fishing effort i.e. the left hand side of the curve.

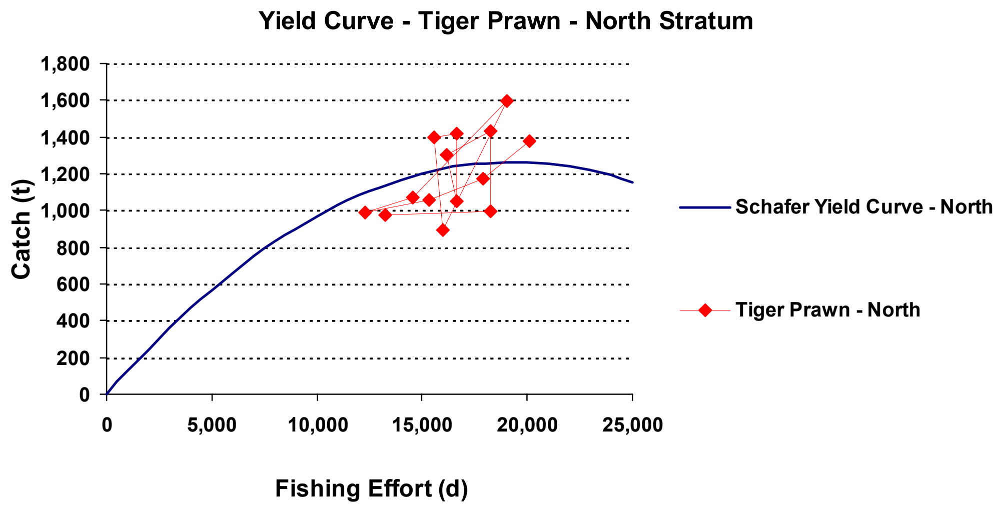


Figure 4.22. Annual catch and effort plotted over the Schafer Yield Curve for tiger prawns in the north stratum.

Endeavour Prawns North

As catches of tiger and endeavour prawns almost always occur together, we assumed that the changes in fishing power estimated by the FRDC study for tiger prawn sector also applied to endeavour prawns.

Table 4.13. North stratum endeavour prawn model results.

Parameter	estimate
r	0.18
K	23,000
Bzero	8,605
q0	4.98184E-06
qinc	annual increments
LogLike	12.420
MSY	1,053
Emsy2001	16,808

Although a good fit in terms of the log likelihood (Table 4.13) could be obtained the model parameter estimates of r, and K, Bzero are not realistic. The r and K parameters are correlated and the model consistently tries to make K (carrying capacity) extremely large and r (biomass growth) extremely small. This represents a population with a high carrying capacity, however, a low ability to replace itself. This is biologically not realistic as prawn stocks are short lived and have high growth and reproductive rates. Although this scenario is unlikely to be representative of the population, it does result in a precautionary model for the stock.

The plot of model CPUE against observed CPUE in Figure 4.23 also shows that the model is not fitting well to the data. As the log likelihood increases the model CPUE tends to flatten and poorly reflected the observed CPUE. This may be due to endeavour prawns being a secondary target species to tigers. Therefore years of high endeavour catch may be due to increased effort directed at tiger prawns although the catch rates of endeavour prawns are average or lower than average in that year.

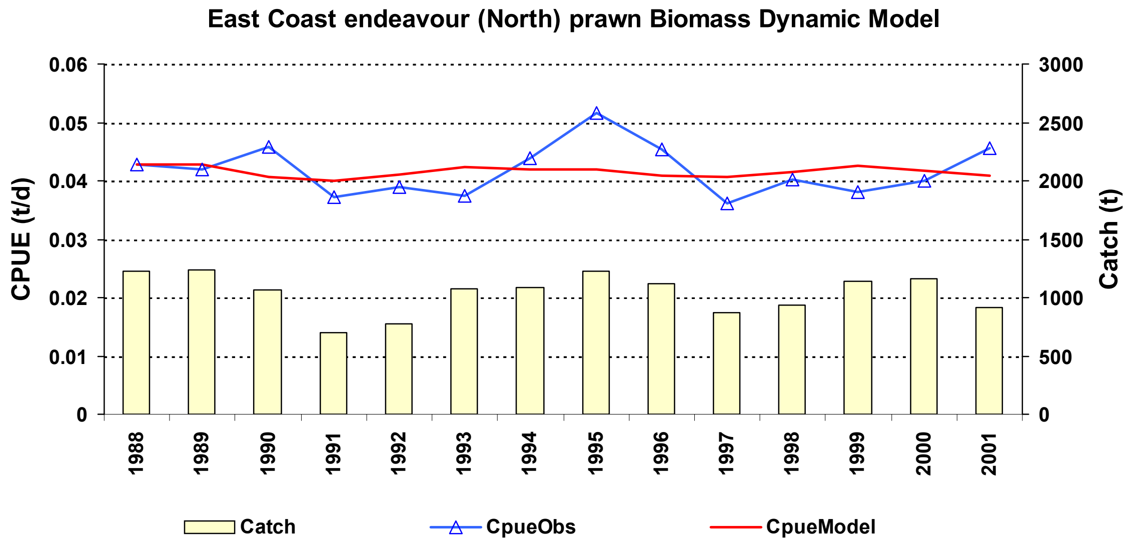


Figure 4.23. Endeavour prawn model fit for the north stratum.

Although estimates of the r, K and Bzero parameters are obviously not realistic the estimated MSY (Figure 4.23) is similar to the average catch over the times-series (1,039 t). While the average effort targeted at endeavour prawns (16,027 d) is lower than the estimate of Emsy the total effort in the north (19,123 d) is higher than Emsy.

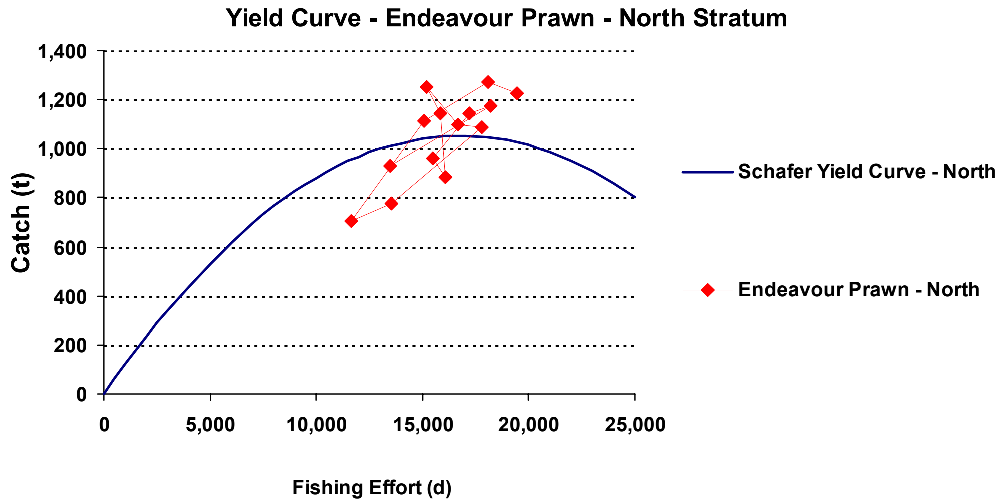


Figure 4.24. Annual catch and effort plotted over the Schafer Yield Curve for endeavour prawns in the north stratum.

Notwithstanding the previously mentioned problems with the results of the endeavour model, it is possible to infer that the MSY and Emsy estimates suggest that the fishery is fully exploited. This is also illustrated in Figure 4.24, which shows that catch and effort for most years is centred about the top of the yield curve.

4.8 Discussion

Reference Points

The comparison of data based (catch-rates) and model based reference points has provided a basis for Queensland and New South Wales trawl managers, and their relevant committees, to consider sustainable levels of fishing effort, reference points and their response mechanisms. The reference points and management responses considered here are only small subsets of the full range of possibilities. The results quantified the trade offs of various management in relation to reference points, and will help set target management objectives for fishing eastern king prawns and saucer scallops. The results do not define a final reference point, management strategy or the future status of the stocks, but rather they provide expected outcomes that may be used by decision makers to help select appropriate reference points to achieve the target objectives. The relevance of this work to management is very high, especially since the management objectives for trawling will continue to be revised. The current objectives in all three trawl-sectors do not define any reference points, together with management responses, that could be used to restrict fishing effort to levels that are sustainable. This research is timely and provides a starting point for discussion of potential reference points and management strategies. The continuation of this work is required for these trawl sectors to achieve sustainable management.

The results across the trawl sectors suggest that for biomasses at B_{MSY} or below, the $2/3E_{MSY}$ target fishing effort tended to ensure future biomasses would increase above B_{MSY} with greater than 50% confidence over 20 years, total catches would not be reduced, catch rates would increase, the variation in total catches would be minimised and that only one major change to fishing effort would occur. Alternately if biomasses were above B_{MSY}, fishing effort at $3/4E_{MSY}$ would also achieve the expected outcomes above. It should be noted that any stock assessment is prone to uncertainties and error. For this reason, target fishing at E_{MSY} has high risk and performs poorly in relation to outcomes for sustainability, industry stability and management.

The simulations also show that catch-rate reference points can restrict fishing effort to levels that are sustainable, but cannot accurately manage these prawn and scallop trawl-sectors. The catch-rates can trigger at high population sizes, resulting in inappropriate changes in fishing effort. Similarly low population sizes may not necessarily trigger the reference point. These results occurred primarily due to the observed variation in catch rates and uncertainty in measuring prawn or scallop catchability (q). Even after standardising the catch rates for changes in fishing power, it does not appear that catch-rate reference points are precise enough to correctly warrant a change in fishing effort. The simulations do assume that catch rates are proportional to abundance, however for a given population size catch rates can still vary 20-30%. In addition, many different factors can affect commercial catch rates, and even if it was possible to allow for these factors the catch rate reference point are not fully predictable with abundance. When selecting an appropriate average catch rate to use as a trigger point there is a trade off between ensuring accurate detection of low biomasses with reduction of inappropriate triggering at high biomass levels.

Fishing at about $2/3E_{MSY}$ or $3/4E_{MSY}$, with revisions for increases in fishing power and new assessments appears to be better management, than modifying effort using the current 70% CPUE limit reference points defined in the east coast trawl management plan. These fishing mortality reference points ($2/3E_{MSY}$ or $3/4E_{MSY}$) appear more effective at maintaining the stocks safely above B_{MSY}, resulting in lower risks of under or overfishing, improved yields and catch rates at lower fishing effort. The stock assessments are prone to uncertainties and error, but changes in fishing effort are likely to result from more justified reasons and eliminate any catch rate reference point triggers that can occur by chance. The catch rate reference points will work to ensure the effort is sustainable, but not necessarily to ensure the stocks are at B_{MSY}; long-term reduced yields may result. The results do conflict with the suggested alternative to model based reference points, that data based approaches should be preferred (Hilborn 2002). But the role of catch rates as reference points is still unclear. Observation of linear trends in recruitment and spawner CPUE, such is done for setting the Queensland spanner crab total allowable catch, may be a more robust practice in conjunction with stock assessments every two years. Additional simulations, and clear management target objectives, are required to examine this catch rate and other strategies in more detail.

All simulations show that the continuation of pre plan levels of fishing effort will introduce long-term risks of overfishing in the sectors examined. Future alternate levels of fishing will depend on the target objectives for each trawl sector. When detailed management targets have been defined, simulations using these targets, as mathematical objective functions will help define clearer sustainable fishing effort. For example, Francis (1993) defined an objective function to maximise average catch, and searched for a management option subject to the condition that the probability of the population biomass falling below 20% of the virgin biomass in any year was less than 10% (Francis 1997). Another example is the target objective defined for Australia’s Northern Prawn Fishery. It was defined as “In determining milestones and performance measures for the fishery, NORMAC agreed that from 2002 and thereafter (annually) NORMAC will use the NPFAG accepted assessment model to estimate the performance of the previous years stock relative to spawner target levels. The agreed target is a 70+% chance that the spawner population at the end of 2006 will be above or at spawner target levels. NORMAC will utilise the advice of the NPFAG (majority) to provide the advice to assess performance against the target. If the agreed target is not projected to be reached, NORMAC will recommend appropriate effort adjustment measures for implementation in 2004” (NORMAC 51, 2001). The target spawner level was S_{MSY}, which is related to B_{MSY}. This target example is probably more appropriate than the first, given that MSY is now consider more to be a limit reference point (Garcia and Staples 2000). Many multiple objective functions could be defined and for example could combine the two above to cover both limit and target reference points.

Irrespective of future management objectives for the prawn and scallop sectors, all simulations here show that with reduced levels of fishing, higher biomasses, higher catch rates, and equivalent annual catches will result. The perception by many people that more nights of fishing effort equals more total catches does not hold true in the long-term; however, for a single vessel total catch is maximised by the number of nights fished, but not catch rates. Note that the results were highly dependent on the shape and magnitude of the spawner-recruitment relationship. Additional simulations assuming alternate spawner-recruitment relationships are provided in O'Neill et al (In press). Generally, these results refer to higher steepness in the spawner-recruitment curve, and therefore lower risks associate with higher fishing effort. Tracking future changes in fishing power is an essential ongoing requirement for these fishing-effort (input controlled) managed fisheries.

Uncertainty still clouds the ideal reference fishing point for the eastern king prawns and saucer scallops. This problem remains for most fisheries, as reference points depend on our knowing how many fish are in the ocean (Hilborn 2002). New types of data are essential to improve the accuracy of stock assessments, such as spatial indices of abundance collected through fishery independent sampling and VMS. More accurate and robust reference points may exist using these data. These pieces of information will aid in refining the stock assessment, interpretation of results, defining reference points and strengthen future management decisions.

The northern Queensland East Coast stocks of tiger and endeavour prawns are currently fully exploited, with both catch and effort at the top of the yield curve. No detrimental trends are apparent in the logbook catch and effort data at this time.

A number of caveats need to be applied to the assessment however, the data time-series is relatively short and does not contain the developmental stage of the fishery, hence the current level of the stock is uncertain beyond that it is stable and currently full-exploited. Turnbull and Gribble (2002) hypothesize that the stocks may have been fished down heavily in the past and the current productivity may be relatively low.

The logbook categories of "Tiger" and "Endeavour" are actually suites of up to three species that are morphologically similar. Tigers can be mixtures of *Penaeus semisulcatus*, *P. esculentus*, and *P. monodon*, while Endeavours include *Metapenaeus endeavouri* and *M. ensis*. The assessment was made on the grouped "category" data, which might mask stock changes in individual species. Both species groups are known to aggregate to a greater or lesser degree which may make CPUE a poor indicator of underlying abundance, hence may lower the power of current assessment models based on CPUE time-series.

4.9 Stock Assessment and Future Development

The stock assessments presented are the most comprehensive attempt to evaluate the status of eastern king prawns and saucer scallops. The assessments were based on monthly time steps and captured the seasonal patterns in fishing effort and catches. The models brought together the biological relationships on prawn and scallop growth rates, natural mortality and spawning. They also included estimates of fishing power increases, historical catch rates prior to the compulsory logbook system implemented in 1988, and spawner-recruitment relationships. In addition, the outcomes from these monthly models were compared along side the more simplistic annual surplus production models. It should be noted that the assessments were based on limited data and a large degree of uncertainty in relation to the estimated spawner-recruitment relationships still remains. It was even highlighted in the review of the 2001 assessment of tiger prawns in the Northern Prawn Fishery, that with 30 years of catch and effort data, the fishery was still only considered to have limited/moderate data (Deriso 2001).

Eastern King Prawns

The results for eastern king prawns indicate the 2001 biomass was at about B_{MSY}. Biomasses prior to 2001 were calculated to be below B_{MSY}. The stable biomass trends between 1989 and 1997 were similar to those calculated in 1998, but they were not scaled to virgin stock size (B_0) (Dichmont et al 1999). The spawner-recruitment relationships were used to define the status of the eastern king prawns in relation to virgin stock sizes (B_0) and the biomasses (B_{MSY}) that support maximum sustainable yields. Sensitivities of assuming different spawner-recruitment relationship were reported utilising the historical pre-1988 and post-1987 catch rates and assuming three different rates of fishing power increases; confirming past comments that there appears to be some decline in recruitment of eastern king prawns to the offshore ocean fishery (Williams 2002). The results across the sensitivity analyses suggested current levels of fishing effort are probably too high to promote higher biomasses in the future. However, the results are uncertain and depended on the historical pre-1988 assumptions on fishing power increases, and that the standardised catch rates from November to February and May to August are linearly related to recruitment and spawning biomasses respectively. It is unlikely that the assumed historical fishing power increases were constant through time at the 1989 to 1999 rate of increase, but were likely to vary over the entire history of the recorded catch rates.

Historical changes in the management of prawns in Queensland appear to have had little effect of increasing catch rates of eastern king prawns. Research surveys conducted in 1982-83 and 1983-84 identified new deep water fishing grounds in southern and central Queensland (Potter and Dredge 1985). Coinciding with these findings the net head rope length increased in size significantly for the offshore deep waters. Whilst at the time the authors were cautious in promoting the newly discovered fishery as economically viable, the changes in management suggest that interest from a number of fishers probably led to the introduction of the new regulations regarding net sizes. Also worthy of note is the primary motivation for the exploratory study:

"…if new grounds and resources were discovered, then some fishing effort might be diverted from the adjacent continental shelf trawl fisheries…..there is a general belief that the east coast prawn fishery is over capitalised with too many vessels working on the established grounds.." (Potter and Dredge 1985).

The above statement seems to be reflected in the declining standardised catch rates indices used in the spawner-recruitment relationships. Post 1988 catch rates seem to be dramatically lower compared to pre 1988. This contrast was even evident in the unstandardised catch rates spawner-recruitment indices. It seems that the eastern king prawn sector experienced increased fishing effort during the 1970-80's. Since 1989, catch rates have remained relatively constant.

The results as they stand, provide the first credible hypothesis on the state of eastern king prawns. We are certain that these results and others in the future will need to be discussed in detail, as they should, but most probably to defend against the notion that the burden of proof lies with those who would claim it is safe to keep fishing at current or harder effort levels (Walters and Martell 2002). However, the stock assessment still needs further work:

- Fishing power and catch rate standardisation is of very high importance for eastern king prawns. Fishing gear and technology information on the pre-1988 vessels, which recorded catch rates, are needed. The data will reduce the uncertainty in the spawner-recruitment relationship and more clearly define the status of the trawl sector. A more elegant method for including the pre-1988 catch rates into the assessment would be preferred, but difficult given no data on total catch or total fishing effort exists.
- Spatially separate monthly standardised-catch-rates may improve accuracies of E_{MSY}. This will take into account the spatial distribution of fishing, but maybe difficult to develop given the uncertain spatial accuracy of the monthly catch reporting of eastern king prawns in New South Wales.
- Fishery-independent eastern king prawn recruitment surveys on the offshore fishing grounds should be of high importance to improve estimates of prawn abundance (Courtney et al 2002), and would also help with on-going catch-rate standardisation (i.e. monitoring fishing power increases). The importance of having a catch rate index that is linearly related to abundance cannot be over-emphasised. This can be improved by including survey estimates (Punt et al 2001a).
- Since aging of Penaeid prawns is not possible at this time, size-graded prawn catches should be recorded, validated and used in the stock assessment (O'Neill et al 1998).
- Update, review and collaborate estimates of natural mortality M, especially in terms of M changing with prawn size, will improve accuracies of the calculated management related quantities (e.g. E_{MSY}).
- Investigate the use of statistical priors on the spawner-recruitment steepness to improve accuracies of management related quantities (e.g. *Penaeus esculentus* and *P.semisulcatus* from Dichmont 2001 or Ye 2000).
- Seasonal closures to protect juvenile recruiting eastern king prawns should be investigated to increase spawning stock sizes.
- Finally, collaborative stock assessment and management should commence with Queensland and New South Wales; especially to set target levels of fishing effort.

Saucer Scallops

The stock assessment results for saucer scallops are timely. Queensland scallop processors, scallop fishers and the fishery's managers have identified a strong need to evaluate the suite of management arrangements in the fishery that have accumulated over the last 20 years. Prior to 2001, saucer scallop landings were valued at about $30 million annually (Williams 2002). During 2002 and 2003 there was a significant drop (30-40%) in catch and fishing effort. In March 2003, the Queensland Seafood Marketers' Association (QSMA) and the Queensland Seafood Industry Association (QSIA) called a special scallop management crisis meeting with DPI management and researchers to discuss the current state and nature of the trawl sector. From this meeting an industry scallop working group was formed. This working group has since called for the reduction in scallop minimum legal sizes to 90mm all year, the removal of daylight closures on scallop grounds and the abolition of the replenishment areas to improve catches and supplies of scallops to processors. This has created a strong need to determine the status of the saucer scallops and how management should be optimised to ensure the biological and economical sustainability of the fishery.

The biomass of saucer scallops was estimated at about B_{MSY} in 2001. In 1997, the biomass was notably below B_{MSY}, confirming the decline estimated in 1998 (Dichmont 1999). The results also confirm the comments the resource is fully exploited (Williams 2002). Estimates of E_{MSY} from the age-structured model varied between one to two thousand nights less than the 13000 nights fished in 2001. The estimates of E_{MSY} were at least one thousand nights less for the smaller 90mm size limit, compared to the larger 95mm size limit examined. The spawner-recruitment relationships were used to define the status of the saucer scallops in relation to virgin stock sizes (B_0) and the biomasses (B_{MSY}) that support maximum sustainable yields. Sensitivities of assuming different spawner-recruitment relationship were reported utilising the historical pre-1988 and post-1987 catch rates and assuming three different rates of fishing power increases. These results were sensitive to the shape of the spawner-recruitment curve, but not overly fishing power increases. It should be noted that management changes have potentially had an effect on the pre-1988 historical catch rates of scallops. Larger minimum shell size restrictions would have a negative effect on catch rates. However, from 1978 onwards fishers changed from primarily twin otter gear set ups to triple and quad nets. This change in configuration allowed fishing to be more safely conducted in areas with rougher bottoms and fast flowing tidal currents (Mike Dredge, personal communication 2001). There is also anecdotal evidence that this change in configuration led to higher catch rates overall. In addition, increases in net length from 40 metres (head rope) to 109m (combined head rope and footrope) introduced in 1983 may have been expected to also increase catch rates. However, this is not evident from spawner-recruitment relationships, which shows the catch rates spawner-recruitment indices general dropping. The increase in minimum shell size from 80mm in 1981 to 85mm in 1985 may have impacted on reported declining catch rates. As would the 1989 change to a seasonal minimum shell size of 95mm from May to October, and 90mm in the other months. However, the weighted log-likelihood used to fit the spawner-recruitment curves would allow for these significant effects of management changing catch rates.

There is still a strong need to determine how the trawl management changes including the allocation of trawl nights have affected the distribution of fishing effort, and how the management measures should be optimised to ensure the biological and economical sustainability of the trawl sector. To achieve this, economic data on the fishery are required. In addition, the assumed biological parameters on scallop natural mortality and growth need to be updated and corroborated. These parameters are currently based on tagging studies undertaken between 1976 and 1978, and may be biased as a result of non-tag-reporting issues (Dredge, 1985a&b). Additional small tagging studies were carried out in 1993 and 1997 to estimate scallop growth, genetics and fishing mortality, but these data were not designed to estimate natural mortality (Dredge pers. comm.). However, to further improve the current assessment the following is also needed:

Additional fishing power and catch rate standardisation is of very high importance. Even though the effect of fishing power on the spawner-recruitment curve was not dramatic as for eastern king prawns, fishing gear and technology information for the pre-1988 vessels are needed. The data will reduce the uncertainty in the spawner-recruitment relationship and more clearly define the status of the trawl sector.
The full-scale fishery-independent saucer scallop surveys provided excellent data for the assessment between 1997 and 2000. The survey scale was reduced to only the replenishment areas after 2000. The full-scale survey should be used to improve estimates of scallop abundance and to help with on-going monitoring of fishing power (Dichmont et al 2000). The importance of having a catch rate index that is linearly related to abundance cannot be over-emphasised. This can be improved by including survey estimates (Punt et al 2001a).

Tiger / Endeavour prawns

As there is currently no mechanism for managing the fishery on a regional basis future stock assessments will use a General Linear Model (GLM) that accounts for year, month, area, vessel and associated byproduct catch will be used to produce standardized catch rates indices for the entire tiger/endeavour prawn fishery. The north/ south stratums used in this analysis are based on management arrangements that have now changed. In addition there are smaller scale regional effects that need to be considered in the standardization process.

Further work is required on the problem of identifying records that indicate targeted endeavour fishing. The use of a GLM to standardise the CPUE data with associated tiger catch as a co-factor in the model may help with this problem.

A delay difference model that utilizes available biological information on stocks structure and growth rates could also be used as an alternate model of the fishery. This model however requires detailed information on the species split by area and time so that the commercial catch categories can be accurately partitioned into species. Information on the species split at the start of the season is being provided at a coarse level (30 minute grids) by the Prawn Long Term Fisheries Monitoring Surveys. Future development of the east coast tiger and endeavour models will benefit from the review by David Die, in March 2003 of the Torres Strait tiger prawn model as the current east coast models are based on the Torres Strait model.

4.10 Target species without stock assessments

4.10.1 *Penaeus monodon*

Introduction

Penaeus monodon (also known as the black tiger prawn or leader prawn) is a small component of the East Coast Trawl Fishery in terms of contribution to total landings but significant in terms of broodstock supply to prawn hatcheries for aquaculture.

Irregularity of supply of black tiger prawns (BTP) is a major concern to the prawn aquaculture industry and was a prime driving factor for a comprehensive collaborative research project between Queensland and the Northern Territory that was funded by the Fisheries Research and Development Corporation (FRDC 99/199, Gribble et al 2002[1]).

The project had seven objectives:

1. Collate fisheries information currently available on *P. monodon* across northern Australia from grey literature, fisheries databases, research projects, and from indigenous communities;
2. Define the distribution of adult *P. monodon* stocks and habitats;
3. Define the distribution of juvenile *P. monodon* stocks and habitats;
4. Determine seasonal patterns in *P. monodon* population dynamics (abundance, population structure);
5. Identify *P. monodon* biology (recruitment, movement, growth, reproduction) in Queensland;
6. Examine alternative capture techniques and the associated stress testing of caught broodstock, in particular for inshore and shallow water habitats, which may contain useable quantities of currently unexploited broodstock; and

[1] Unless otherwise quoted, all results and conclusions referred to in this section are sourced from Gribble et al 2002. It should be noted that the Report generated by this research is extremely large, so only brief summaries are provided here.

7. Conduct an economic cost/benefit analysis of various fishing patterns, capture techniques and handling protocols.

A variety of methods were employed in the study, including examination of commercial and research log books, fishery independent trawl surveys, collation of data on abiotic factors (water quality, rainfall etc), oppurtunistic sampling using alternate fishing methods (cast nets, traps, electro-fishers etc) and anecdotal information from commercial, recreational and indigenous fishers.

Generally, Gribble et al (2002) found that BTP in northern Queensland (where they are required as broodstock) are at the limit of their geographic range. This contributes significantly to annual variation in supply. Testing of alternate fishing methods did not result in the identification of another fishing apparatus that would be economically viable. The research team was also unable to discover any fishing grounds for BTP that are currently unexploited.

<u>Methods</u>

Gribble et al (2002) used different research methodologies/analyses to address each of the 7 objectives for the research project. This resulted in an extremely comprehensive report that provides stand-alone chapters that address each objective. Full details of the methods used are not provided here, however, the following is a summary (see Gribble et al (2002) for further detail).

Objective 1 – Information collation and Review:

- Literature sources;
- Anecdotal information;
- Research surveys (conducted previously as part of other projects).

Objective 2 – Adult BTP stocks and habitats:

- Commercial logbook information;
- Research logbook information;
- Research surveys using beam trawl gear;
- Water quality assessments;
- Habitat associations (depth, seagrass, associations with other species).

Objective 3 – Juvenile BTP stocks and habitats:

- Research surveys using cast nets;
- Opportunistic sampling using alternate gear (small beam trawl, fyke net, scoop net, Drag net, electro-fishing);
- Information from recreational fishers;
- Abiotic information (water quality, rainfall, water flow).

Objective 4 – Seasonal patterns in BTP population dynamics:

- Seasonal abiotic information (water quality, rainfall, water flow);
- Seasonal changes in BTP abundance and size (primarily commercial data).

Objective 5 – Biology of BTP:

- Tag-release-recapture work using individuals sourced from sampling regimes above and donated by commercial and recreational fishers;
- Morphological examination of all samples to determine sex and maturity.

Objective 6 – Alternative capture methods:

- Traps (Munyara and opera house traps);
- Nets (lift and trammel);
- Beam trawl.

Objective 7 – Economic review:

- Commercial catch data;
- Broodstock market information;
- Literature review.

Results

Distribution

BTP were found to be a rare occurrence in commercial catches outside of their main distribution from Cairns to Cardwell with 74% of all reported BTP catches less than 20kg per day. However, daily catches were reported as high as 520kg per day signifying that extremely large catches are possible albeit on a sporadic basis. Within the main area, small-scale sampling demonstrated that their distribution was patchy and centred around several "hot-spots" (Figure 4.25).

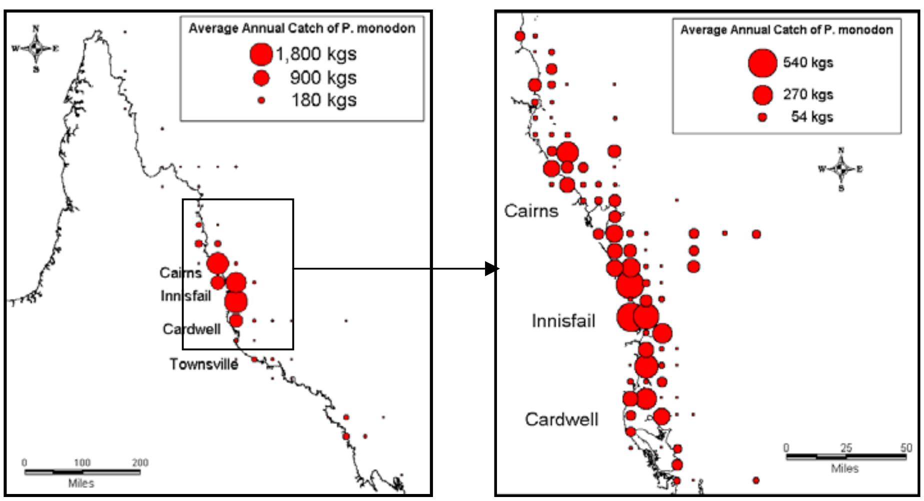


Figure 4.25. Distribution of BTP catches.

Abundance and catch rates

Low abundances for BTP were found throughout the study. That is, catch rates of BTP were significantly lower those for banana prawns (*P. merguiensis*), which inhabit the same types of habitats (up to 1:50). Figure 4.26 shows the daily catch of BTP for the fishery as recorded in logbooks. In this regard, the project raised concerns that there was no specific provision in commercial logbooks for fishers to record the capture of BTP. This means that some proportion of the historical catch is likely to have been reported simply as "tiger prawns".

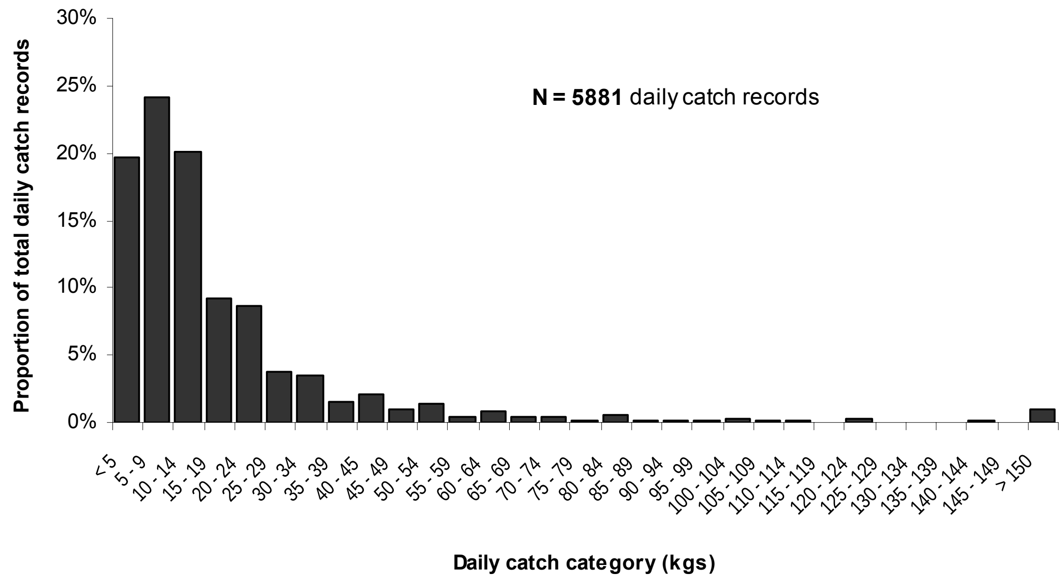


Figure 4.26. Distribution of reported daily BTP catches in the East Coast Trawl Fishery, 1988 to 2001. Values are daily catch of P. monodon (kgs) per vessel.

This figure serves to demonstrate the pronounced tendency towards extremely low daily catches of BTP. However, the long tail to the right of the figure does indicate that large daily catches are experienced at times. These trends are supported by data from the research logbooks, which also show that the majority of total trawls resulted in low catch per unit area but that high catch rates were achieved (Figure 4.27). Similarly, 295 out of 360 research trawls failed to capture any BTP.

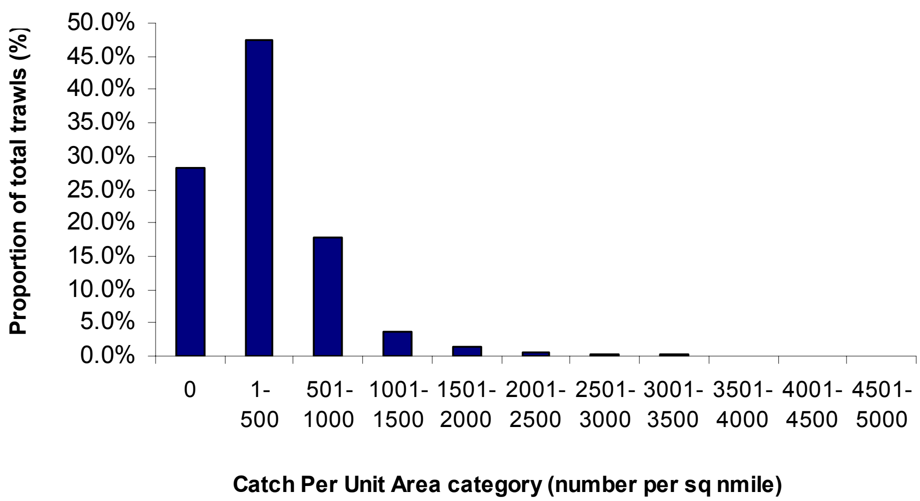


Figure 4.27. Catch Per Unit Area Frequency class distribution for P. monodon recorded in research logbook survey April 2000 to September 2000. Catch records included were recorded as numbers of P. monodon for each trawl.

Gribble et al (2002) also compared the total catch of BTP per year with the total catch of banana prawns. Figure 4.28 shows that while banana prawn catches were significantly higher than those for BTP, the yearly harvest trends followed a similar pattern. Gribble et al concluded that the same annual processes therefore might influence the total biomass for both species. However, BTP are typically caught as a byproduct of trawling for banana prawns. The possibility that the similarities in catch trends is more a product of banana prawn catch and effort, rather than reliance by both species on similar conditions, should not be discounted.

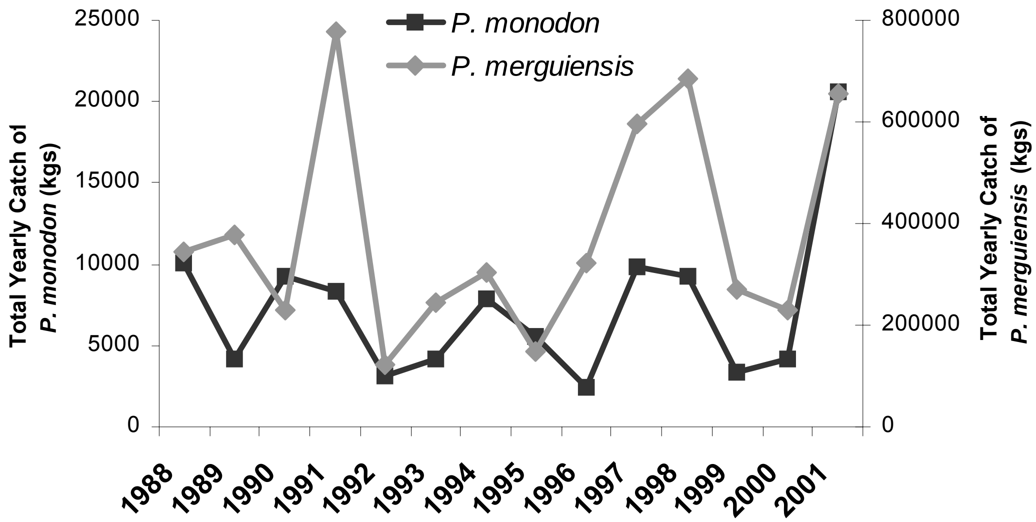


Figure 4.28. Annual reported commercial catch of *P.monodon* and *P.merguiensis* in the East Coast Trawl Fishery between 1988 and 2001.

Juvenile Habitat

Sampling found that BTP make use of all sections of estuary habitat from the upper tidal (freshwater) to the lower tidal (saltwater) reaches. Different stages of the juvenile lifecycle predominantly used different areas within the estuary, with a general trend of animals moving progressively towards the mouth as they mature.

BTP were also observed preferring structural habitat, such as peg roots from mangroves. Gribble et al (2002) concluded: "Throughout the life cycle of P. monodon, the most important and fragile habitats are the estuarine habitats that include the upper, middle and low estuarine reaches of small, medium and large river systems. The fact that they depend upon all three parts (upper, middle and lower estuarine) of a system means that riparian/estuarine habitat degradation is a real threat to the continuing supply of broodstock to aquaculture."

Recruitment Movement and Growth

This component of the study was addressed via a tag-recapture program. Just over 2,000 BTP were tagged, with a recapture rate of 4.7%. Unfortunately, this low number of recaptures (95) makes it difficult to draw inferences about the population.

The growth of BTP was found to be fairly typical of most penaeid prawns, with growth continuing up to a maximum of three years and females attaining a larger size than males.

Unlike other penaeid prawns, BTP recaptures did indicate a strong homing behaviour, with a number of BTP that were released away from their capture site (up to 70km), only to be recaptured at the original location.

Based on a significant pulse in recruitment in late winter/early spring, it was estimated that the "effective spawning period" for BTP of July/early August. Lower levels of recruitment were detected throughout the rest of the year, with some suggestion of a second, weaker pulse in September to November.

Alternative Capture Methods
Non-trawl methods for the commercial harvesting of prawn species are often advocated as more sustainable methods of production.

None of the alternative gear types tested produced catch rates of any penaeid prawns comparable to trawl methods. The catch rates of BTP from these methods were found to be uneconomical in terms of the number of person hours required to catch a commercial quantity of BTP.

Seasonal patterns in BTP population dynamics
Assessments of BTP abundance compared to abiotic factors showed a low number of very weak trends and were unable to identify a single factor that could be used in a predictive capacity.

Economic review
Gribble et al (2002) encountered difficulty in assessing the economics of the BTP sector as a whole due to the low number of participants and the unknown (underestimated) take of BTP for non-broodstock purposes. What was clear, however, was that a large proportion of the aquaculture prawn industry is completely reliant on the supply of BTP from the trawl fishery.

The capture and retention of BTP while conducting normal trawl operations for banana prawns and the recent trend of exporting live BTP to overseas markets were identified as factors that have potential to disrupt supply to prawn hatcheries.

Sustainability
The Report found significant variability in the total catch and catch rate of BTP in the commercial fishery. However, this data did not indicate an overall decline in catches over the available time-series. Added to this, BTP were found to be an "r-selected" species in that it is short-lived and highly fecund. Despite the fact that no single abiotic factor could be identified that drives BTP catches, Gribble et al advocate that recruitment success is more a function of prevailing environmental conditions than spawner abundance.

Gribble et al (2002) (page 164) concluded: "Although not validated, this reported commercial catch suggested that the species is reasonably sustainable at current levels of fishing effort".

Management Considerations and Responses

Logbooks – The recommendation that BTP be included as a specific catch category in commercial logbooks was implemented in January 2003 with the release of the OT08 log. This is expected to facilitate more complete reporting, which will in turn allow more robust and accurate analysis.

Catch allocation – As stated above, it is widely accepted that a certain level of BTP is taken incidentally as part of banana prawn trawling operations. Gribble et al found that 10 – 15% of the reported commercial catch of BTP is supplied to the aquaculture industry. This means that the vast majority of BTP captured are sold as frozen product, constituting a "waste" to the aquaculture industry.

In most circumstances, and during the first part of the year, this is not generally an issue as the specialised broodstock collectors are able to meet the limited demand from hatcheries at that time. However, later in the year when catches of BTP become more scarce, and demand from the hatcheries grows that situations of undersupply can occur. This is particularly the case in low catch years. Some consideration therefore needs to be given to mechanisms that would ensure a sufficient proportion of BTP is taken by fishers who have the capacity and infrastructure to supply the aquaculture industry.

The DPI&F has commenced addressing this issue in two main ways:

- In late 2002, a gear restriction area was declared between Cairns and Port Douglas. This prevents vessels from trawling in the area unless they use small gear characteristic of broodstock collectors. This management regime was not introduced solely for the benefit of BTP supply, but has been well received by broodstock collectors and the Australian Prawn Farmers Association.

  A proposal for a similar restricted area between Cairns and Innisfail is being developed by Industry. While the benefits of such an area to the aquaculture industry are easily identifiable, they must also be balanced against the potential impacts on the wider trawl sector.

- Since the introduction of a major seasonal closure north of Mackay from 15 December to 1 March each year, the DPI&F has adopted a policy of issuing permits to allow recognised broodstock collectors to continue to trawl in order to minimise interruptions to supply.

Habitat degradation – Gribble et al (2002) reported that protection of riparian vegetation is likely to be a significant factor in continued supply for BTP to the aquaculture industry. In this regard, the DPI&F maintains an effective system of marine protected areas (Fish Habitat Areas) as well as blanket protection for all marine plants. The marine habitats in these areas are protected from development for the prime benefit of fish stocks that rely on them. Figure 4.29 shows the Fish Habitat Areas that have been declared in the area from Port Douglas to Cardwell. The areas cover the majority of the large estuary systems in this area.

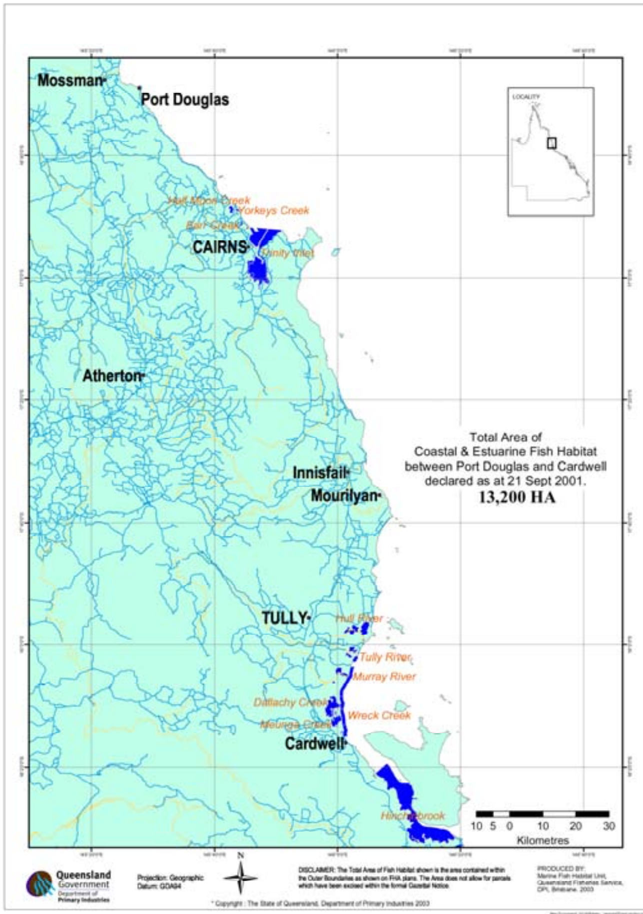


Figure 4.29. Fish habitat areas between Port Douglas and Cardwell.

Industry cooperation – In order to ensure, as far as possible, that the optimal benefit for both the trawl fishery and the aquaculture industry is realised, closer collaboration between the two sectors is required. While the DPI&F would undoubtedly have a role to play in this, it is not a regulatory function of the Government to force communication. Rather, the relevant industry groups need to liaise effectively to resolve several issues in the fishery such as the temporal disparity between BTP availability and demand from hatcheries, retention of the bulk of BTP for sale as frozen product and the trend of exporting live BTP to overseas aquaculture industries.

4.10.2 *Reef King Prawns*

Reef King Prawns (RKP), or northern king prawns are an assemblage consisting of red spot king prawn (Penaeus longistylus) and blue-legged king prawn (*P. latisulcatus*). This sector of the fishery has an approximated Gross Value of Production of $5.7m per annum (Williams 2002). While this is not large compared to other prawn sectors such as Tiger and Eastern King Prawns, it is a significant component of the overall fishery.

The Plan contains a CPUE based review event based on the CPUE in given periods of the year being maintained above 70% of the historic CPUE. The issues associated with using this type of review event have been discussed and acknowledged earlier in this chapter with regard to the eastern king prawn and saucer scallop sectors. However, until the outcomes of this effort review can be actioned, the 70% CPUE review event remains the only method available for routine assessment of RKP.

Both of the RKP species have been combined to assess the Red Spot King CPUE review event. The CPUE of the two species have been added, as they were not differentiated in logbooks prior to 1999.

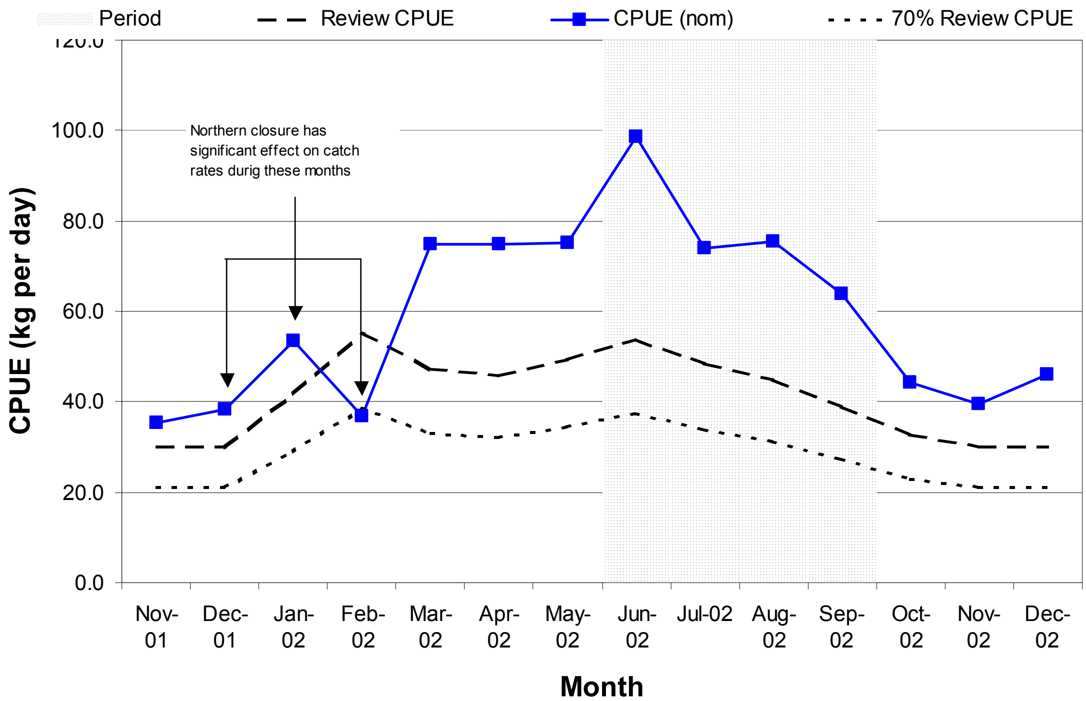


Figure 4.30. Monthly CPUE (nominal) for Reef King Prawns (Otter Trawl). Stippled areas of the graph represent the Trigger Review Periods.

The nominal CPUE of Reef King Prawns harvested by the ECTF for 2001/2 is well above the 70% trigger CPUE during the review period (Figure 4.30). Catch rates dropped below the 70% trigger level in February; however this is outside the review period of June to September. In this regard, it is likely that the Northern Trawl Closure from December to January has affected catch rates in the early months of the year since the introduction of the Plan. The reported annual CPUE for 2002 is only slightly less than that reported in 1996 (highest reported since logbooks started in 1988). In 2002 there was 26% less effort than in 1996, which resulted in only a 5% reduction in catch (DPI&F, unpublished data).

It should be noted that this data is not standardised and therefore does not include an assessment of the increase in fishing power. However, due to the location of this fishery, it is likely that the majority of vessels taking RKP are essentially part of the larger Tiger/Endeavour prawn sector. Section 2.3.5 of this report summarises the fishing power increases (effort creep) in the ECTF. While it is difficult to speculate on the effect that certain technological advancements over the past decade have had on RKP catch rates, it is possible to infer that effort creep may be similar to that of the Tiger/endeavour prawn sector. Effort creep in the tiger/endeavour prawn sector was found to be 0.613% (95% C.I. -0.236 : 1.466) per year with a total effort creep between 1989 and 1999 of 5.5% (95% C.I. -1.7 : 12.6). A comparison of the CPUE review event for Tiger/endeavour prawns with and without effort creep (QFS 2003) showed that standardising the data did not make a significant difference in terms of the Review Event. This is also likely to be the case for RKP, especially given that the nominal CPUE is significantly higher than the historic CPUE, let alone the 70% reference point.

The apparently healthy CPUE for RKP indicates that there should be no sustainability concerns as to the level of effort applied to the assemblage. This is supported by the short-lived, rapid growth characteristics exhibited by RKP and the fact that significant inter-reef areas are now closed under the Plan. These closures prevent further expansion of the fishery for these species and provide a level of spatial refuge. It is also worth noting that further closures to inter-reef zones are likely to be implemented in the near future as part of the GBRMPA Representative Areas Program. This will provide an extra level of protection to these species.

However, it should be acknowledged that the analysis of CPUE above does not represent a rigorous, scientifically defensible stock assessment. This highlights the need for formal stock assessment on all exploited prawn stocks.

4.10.3 *Bay Prawns*

Bay prawns are an assemblage consisting of greasy prawns (*Metapenaeus bennettae*) School prawns (*Metapenaeus macleayi*) and a mixture of sub adults of other prawn species. This sector of the fishery has an approximated Gross Value of Production of $1.4m per annum (Williams 2002). While this is not large compared with the value of ECTF, it is a significant component of the fishery within Moreton Bay.

As with the other principal species, Bay prawns are subject to a CPUE based review event under the Plan. To date this is the only method available to assess this assemblage. The monthly CPUE of Bay prawns in the ECTF has remained consistently above the 70% review CPUE level during the trigger review periods (Figure 4.31). The CPUE dropped to below the 70% review CPUE for the months of May to August, however these months fall outside the review period of 1 November to February 28.

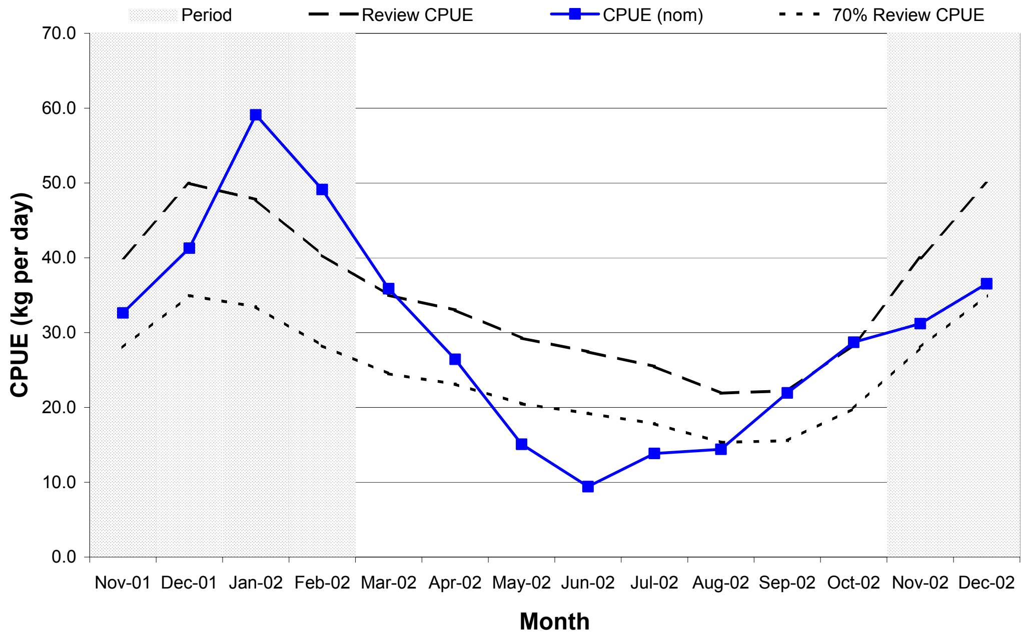


Figure 4.31. Monthly CPUE (nominal) for Bay Prawns (Otter Trawl). Stippled areas of the graph represent the Trigger Review Periods.

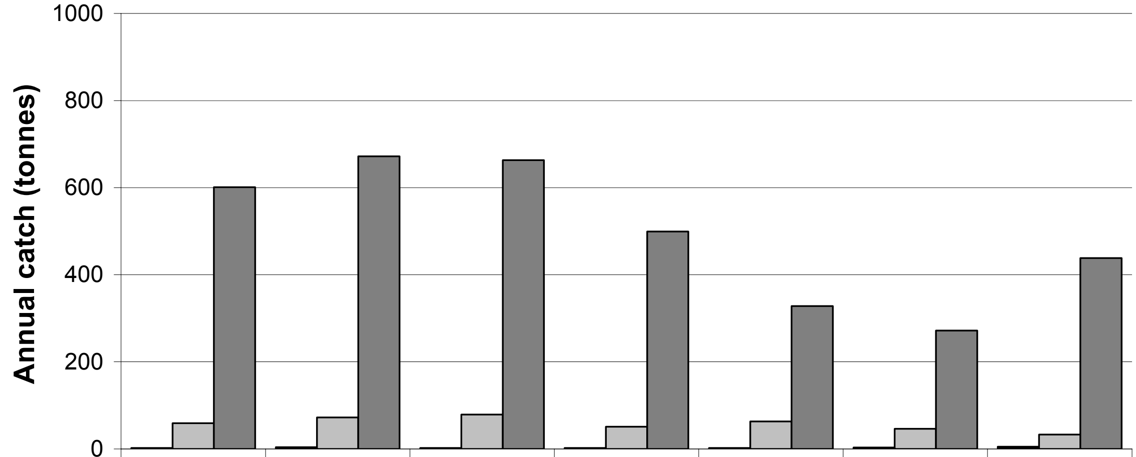
The data used for this analysis has not been standardised to include an assessment of potential increases in fishing power. It is difficult to speculate on the effect that certain technological advancements over the past decade have had on Bay prawns given that the fishery is dominated by catches in Moreton bay, and this area was not separated under by O'Neill et al (In press). Given the nature of the regulations in Moreton Bay, with a maximum vessel length of 14m and a maximum net head rope length of 16.25m (8 fathoms), one may assume that the parameters which lead to increases in fishing power may not be able to increase significantly.

The apparently healthy CPUE for Bay prawns indicates that there should be no sustainability concerns as to the current level of effort applied to the assemblage. However, as with Reef King Prawns, it should be acknowledged that the analysis of CPUE above does not represent a rigorous, scientifically defensible stock assessment, again highlighting the need for formal stock assessment on all exploited prawn stocks.

4.10.4 *Moreton Bay Bugs*

Two species of Moreton Bay bugs are harvested in the ECTF, *Thenus indicus* (mud bug) and *T.orientalis* (reef bug). It is legal to target bugs, however the majority of their harvest is incidental. The species group is a by-product of prawn and scallop trawling (Courtney 2002). Consequently, any changes in the fishing patterns for the primary target species will also be reflected in the reported harvests of Bugs. Improved reporting methods since 1998 have resulted in improved differentiation of Balmain Bugs (*Ibacus spp*.) from Moreton Bay Bugs (*Thenus spp*.) within the CFISH system.

Figure 4.32 shows a decline in Bugs from 1998 to 2001. This may largely be due to reductions in fishing effort rather than a population decline (Courtney 2002). It is also likely that data early in the time series includes Balmain Bugs, thereby overemphasising the significance of the decline in total catch. Furthermore, the steady catch rates during 1998 to 2001 period indicate that declines are not the result of a decrease in abundance (Figure 4.33, DPI&F unpublished data). Industry in general considers that the progressive introduction of Bycatch Reduction Devices (BRDs), in particular Turtle Excluder Devices (TEDs), between 1999 and 2000 have significantly contributed to the decline in catch.



	1996	1997	1998	1999	2000	2001	2002
MB	2	4	2	2	2	3	5
EC	59	72	79	51	63	46	33
GBRMP	601	672	663	499	328	272	438

Year

Figure 4.32. Annual regional catch of all bugs 1996 - 2002 (Otter Trawl).

The GBRMP region produces 84-92% of reported catch. Total catch of bugs decreased significantly from 1998 to 2001(59 % decline) in the GBRWHA. Reported catches have increased (48 % increase) in 2002, however they have continued to decline in the EC region (south of GBRWHA). Anecdotal evidence and preliminary logbook data indicate improved catches again in 2003.

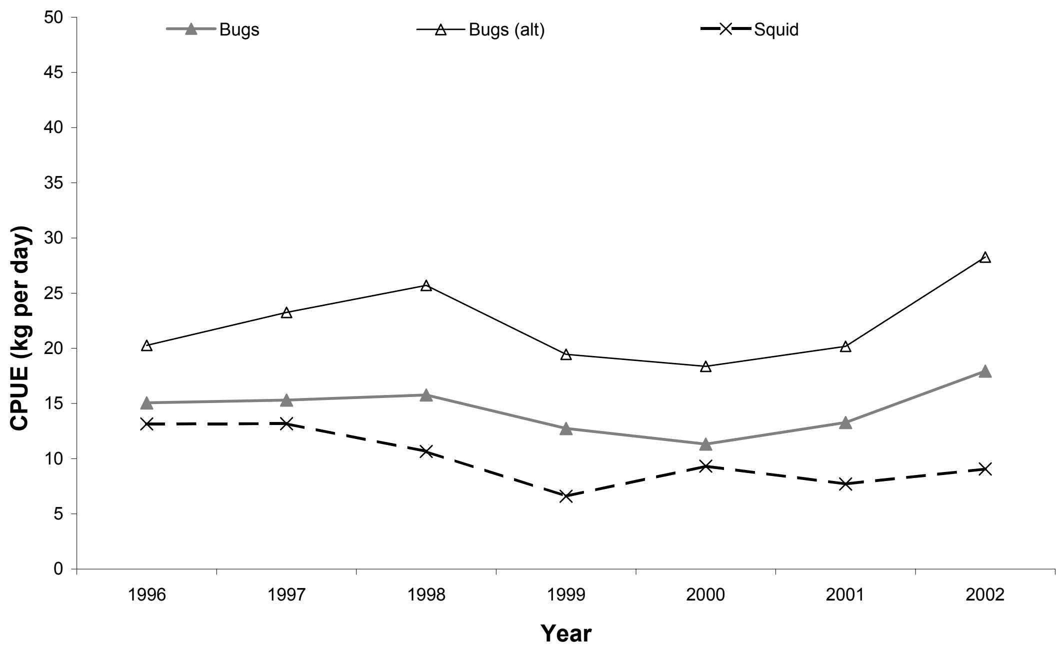


Figure 4.33. Annual cpue trends 1996 - 2002 for Bugs and Squid. Bugs (alt) uses the methods suggested by Courtney (2002).

In order to form some opinion about the status of bug stocks from catch rate data, Courtney (2002) considered that only data from certain grids where bug catches were high should be used. In analysing this catch data, all fishing effort from the relevant grids is used, rather than only effort data directly associated with bug capture. In this way, the CPUE data used simulate, as far as possible, the actual targeting of bugs. The difference between the two methods is highlighted in Figure 4.34.

Presently, the only formal mechanism for reviewing the status of bugs is via the 70% historic CPUE reference point contained in the Plan. The CPUE trigger was reached in January to February 2002 before increasing again. In general the CPUE is above the 1988-1997 levels (Figure 4.34) and well above the 70% trigger point.

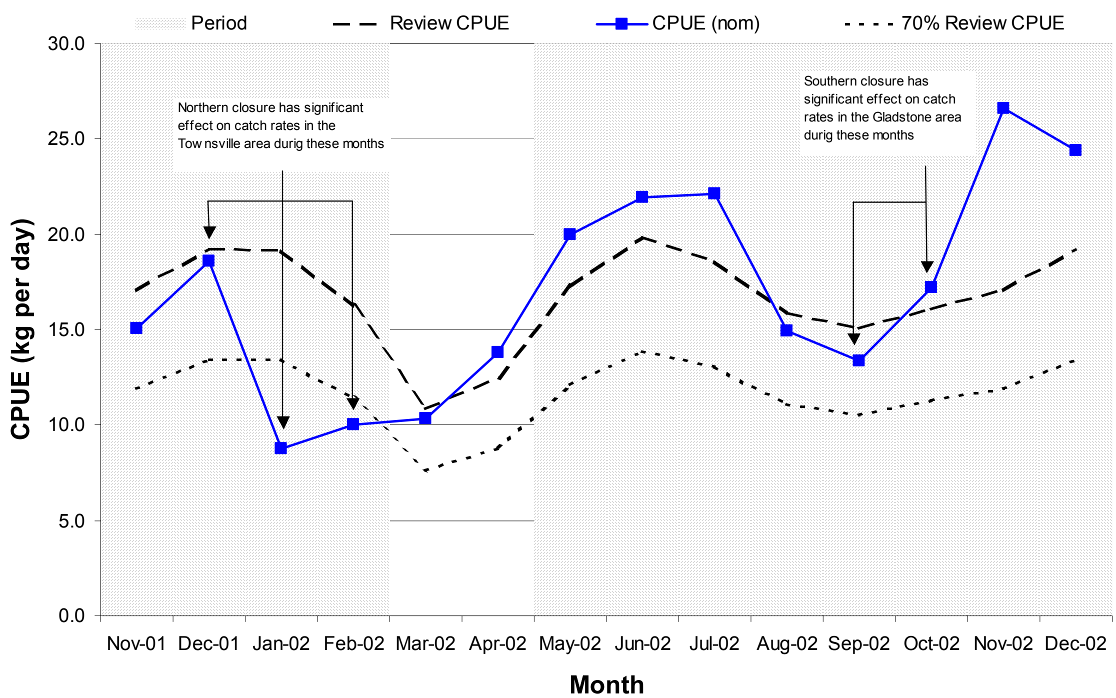


Figure 4.34. Monthly CPUE (alternate method) for Bugs (Otter Trawl). Stippled areas of the graph represent the Trigger Review Periods.

Courtney (2002) indicated that BRDs and in particular TEDs have impacted on bug harvests (and therefore CPUE). The quantification of the effect of TEDs and BRDs on catches is ongoing with AFFS investigating the effect of these devices on catch rates of principal, permitted and bycatch species.

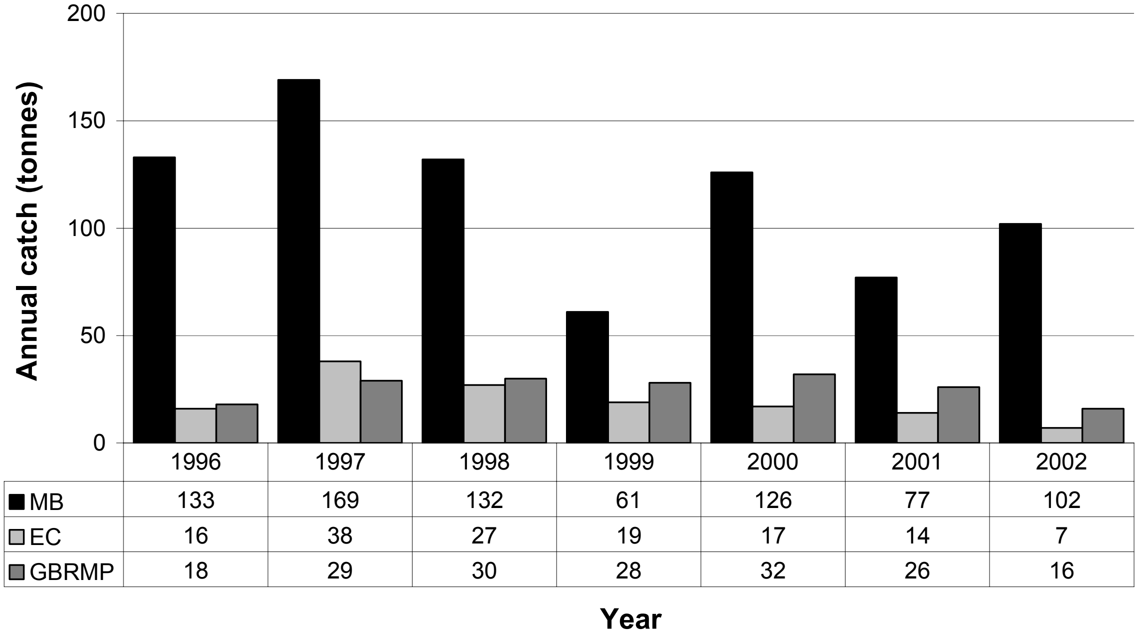
Courtney (2002) suggested that of the two areas identified for the alternate method, catches in the northern area fluctuated more due to changes in effort than a real CPUE decline. Bug catches in the southern area are principally associated with the annual reduction in minimum legal size of scallops, and therefore also largely a function of effort, with no evidence to suggest a real decline in CPUE. The major high catch area (Townsville) is affected by the northern trawl closure, which restricts all trawling north of Mackay between late December and March. The other major bug area (Gladstone) is similarly affected by the annual southern closure, which restricts all trawling south of Mackay in late September and October.

With total catches increasing since 2000 (Figure 4.32) and CPUE higher than the 70% trigger points except during months of poor effort associated with bug areas (January and February, Figure 4.34 and also Courtney 2002), it seems likely that the current levels of fishing effort should be considered sustainable. However, it may be useful to reassess the bug review periods to identify how best to monitor the stocks of bugs.

4.10.5 *Squid*

Squid (*Loliolus sp., Notodarus spp., Photololigo spp*. and *Sepioteuthis spp*.) are another group of principal species under the Trawl Plan for which there is little information to conduct a formal stock assessment. As with Moreton Bay bugs, while targeting of squid is legal, and undoubtedly does occur, the majority of its harvest is taken as a byproduct of prawn and scallop trawling.

Unlike all other principal species, the majority of the state's squid catch is taken from Moreton Bay (Figure 4.35).



	1996	1997	1998	1999	2000	2001	2002
MB	133	169	132	61	126	77	102
EC	16	38	27	19	17	14	7
GBRMP	18	29	30	28	32	26	16

Figure 4.35. Annual regional catch of all squid 1996 - 2002 (Otter Trawl).

As well as demonstrating the importance of Moreton Bay to squid catches, this figure demonstrates a gradual decline in total squid landings between 1996 and 2002.

As discussed above (Moreton Bay bugs), the use of CPUE data from logbooks to assess the status of a species (group) that is not actively targeted contains inherent risk and is generally to be avoided. The DPI&F has therefore developed preliminary business rules to assess the catch rates displayed by boats that have some "targeting" history for squid.

The following business rules were used to identify "squid target boats":

> Identify all annual squid catches for each licence landing 'squid' (defined as all species_codes like '600%' or like '620%'),
> In Moreton Bay (defined as Latitudes between 27.1 and 27.7 and Longitudes between 23 and 23.4),
> Since 1990 (inclusive).

Using the above annual licence catch subset, short list the top licences that average two tonnes (or more) per year of squid landings, in Moreton Bay, but also that fished in a post-plan year (defined for this exercise as 2001, 2002 and 2003).

This delivered 15 licences that have been used as "squid target boats". Monthly summaries of catch and effort associated with squid for these 15 boats were prepared to produce catch rate data below. These 15 boats accounted for between 10% and 40% of the overall squid landings for the whole fishery between 1996 and 2002 (Average = 23%). Annual catch rates for these boats are shown in Figure 4.36.

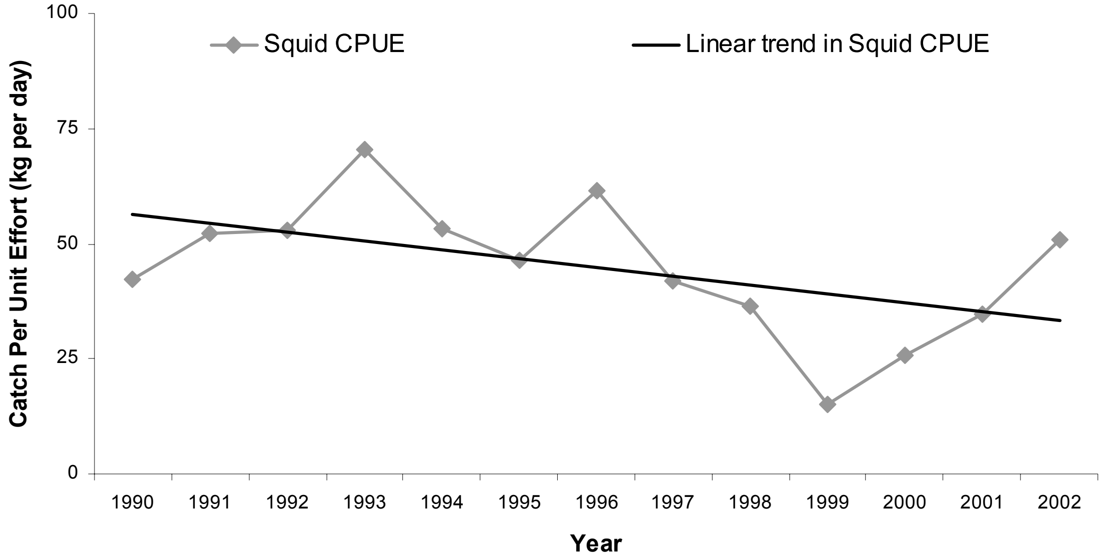


Figure 4.36. Annual catch rates (kg/day) of the 15 squid target vessels.

The regression line shows a slow decline in average catch rates for these boats between 1990 and 2003[2] (R^2 = 0.2). The inter-annual variation in catch rates is striking. There is evidence that in periods of high freshwater in-flow into Moreton Bay after rain events, squid aggregate in areas of the bay that remain more saline. Such aggregations obviously make squid more catchable at these times, meaning that squid harvest in the Bay is influenced by rainfall patterns. There is also the possibility that this data is a representation of the fact that, even amongst the identified boats, squid harvest may be a supplementary operation. Regardless of the interpretation, the progressive increase in catch rates since 1999 is encouraging.

Figure 4.37 shows the monthly catch rates for squid from the 15 boats displayed as pre-plan and post-plan years.

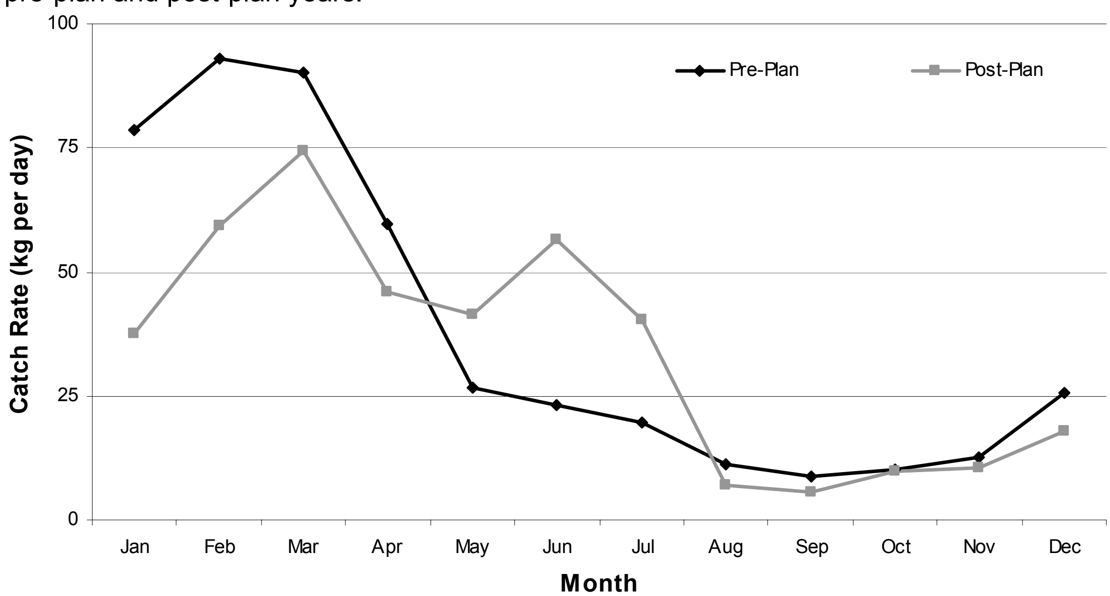


Figure 4.37. Monthly catch rates for pre-Plan (1996-1998 inc) and post-Plan (2001 & 2002) for squid target boats.

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[2] Noting that 2003 data is not yet complete and may therefore change the pattern marginally

This figure shows a decrease in catch rates during the high CPUE months of January to April in post-Plan years (≈ 150%). However, of interest is the significantly higher CPUE (≈ 200%) catch rates in the late autumn and early winter months post-Plan.

It is difficult to speculate on these trends. Advice from fishers is that prawn catches have improved in Moreton Bay since the reduction in the number of vessels that are licensed to fish there. It is possible that the reduction in CPUE in early months is indicative of these fishers choosing to fish for prawns rather than squid.

Similarly, the increased CPUE in the winter months may be an indirect result of the introduction of the Plan and the removal of winter whiting as a trawl species. Historically there has been very little fishing effort in Moreton Bay during winter months other than that directed towards winter whiting. Some trawl fishers in the Bay (M2 holders) are not subject to effort restrictions and it is possible that these fishers have substituted squid for winter whiting in these periods of low prawn catches.

5 Sustainability of permitted Species

5.1 Permitted Species Risk Assessment

5.1.1 *Executive Summary*

The results of the risk assessment indicate that it is unlikely that trawl impacts related to current fishing effort applied in the fishery pose a significant threat to the sustainability of any Permitted species retained in the QECTF.

Precautionary management measures already in place and proposed for introduction through legislative amendment will ensure that Permitted species are ecologically sustainable over the long-term in the East Coast Trawl fishery.

This part of the GER presents information about threats to sustainability of permitted fish from the trawl fishery. This Chapter is presented in two parts, and both must be considered to gain an understanding of the overall risk assessment.

The first part of the assessment (Productivity Susceptibility Assessment) simply analyses certain biological characteristics to assess the vulnerability of each species (or group) to trawl impacts in general.

The second part of the assessment (Discussion) includes the management arrangements that are relevant to each species to address some of the issues that become apparent from the PSA.

It is important that both parts are accounted for because a species that is given a "high risk" rating by the PSA is not necessarily at risk of unsustainable impacts in the East Coast Trawl Fishery because of the management arrangements that regulate it's take.

Relative "Risk"
It must also be noted that the PSA assesses the "risk" of unsustainability of the permitted species **against each other**. This means that a species (or group) that receives a "high risk" rating is not necessarily unsustainable but that it's biological characteristics make it more vulnerable to trawl-related impacts than other permitted species.

Key Outcomes
Blue Swimmer Crabs: 'Low Risk'. No sustainability concerns.

Red Spot Crabs: 'Moderate Risk'. No sustainability concerns.

Octopus: ' Moderate Risk' and 'Possible High Risk'. Species that are likely to be most encountered in the fishery are determined as a 'moderate risk', other lesser-known species determined as possible high risk. In possession limits reduce targeting of the species group. High discard survivability.

Pinkies: mix of 'Moderate Risk', 'Probable High Risk' and 'True High Risk' species. Dominant bycatch species. Subject to high fishing pressures. Temporal closures, permanent closures and RAP closures provide significant buffer against localised population depletions.

Cuttlefish: 'Possible high Risk'. Identified as a 'Possible High Risk' due to lack of knowledge. There are some indications that this may be over-precautionary. Methods to identify candidate "cuttlefish areas" should be considered.

Barking Crayfish: 'Probable High Risk'. Identified as a 'probable high risk' due to limited data on fishing mortality and longevity. No take on berried females and proposed MLS will increase sustainability.

Mantis Shrimps: 'Probable High Risk'. Very limited data on mantis shrimps have lead to a 'probable high risk' species rating. Low prices and few vessels fishing for mantis shrimps means they are likely to be able to sustain current fishing pressure. Further management intervention will be investigated through the Moreton Bay Review.

Balmain Bugs: 'True High Risk'. Ibacus chacei has been identified as a 'true high risk' species, with I. Brucei, and I. alticranatus as ' probable high risk' species. Proposed changes to the MLS will address the relative risk ratings among species.

Pipefish: 'True High Risk'. Detailed spatial data may be required identify key areas for pipefish and minimise the risk of overfishing. The Syngnathid WTO provides for the development of an observer program to verify catch data and identify key areas.

There exist significant data gaps in the life histories of the many of the Permitted Species in the East Coast trawl fishery.
It is important that the management regime be sufficiently precautionary to adequately address high levels of uncertainty in the responses of Permitted species to fishing effort.

Effort reduction in the fishery to date should be fully acknowledged for its contribution to the sustainability of Permitted Species. The substantial decreases in actual and potential effort have had a significant influence on the total amount of area swept by trawl nets as well as changing fisher behaviour.

Management measures such as spatial closures; TEDs, BRDs, MLS and trip limits are additional measures important to sustainable harvesting of Permitted Species and need to be considered fully in interpreting the broad-scale effects of fishing effort on Permitted Species populations.

In the RA process, uncertainties where there is no or limited data available have been acknowledged. Where this is the case, more effective use of observational information from fishers should be considered for inclusion in future risk assessments and as a first step in developing appropriate monitoring programs of non-target species. A rigorous process whereby this may be achieved requires further consultation with industry.

5.1.2 *Introduction*

In addition to the target species (prawns, squid, scallops and Moreton Bay bugs), the Plan allows for the retention of nine other types of seafood resources as byproducts of trawling, that currently have significant economic value (Figure 5.1). These are known as permitted fish and may only be retained as an incidental catch while targeting principal target species in the fishery.

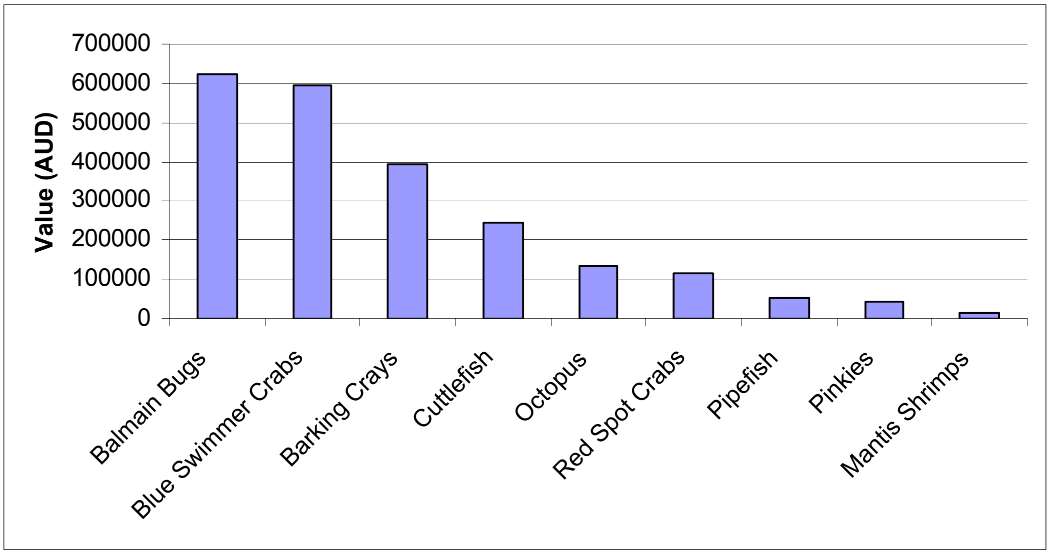

Figure 5.1. Average value of Permitted species landings in 2001/2002.

Since the inception of the Trawl Plan in 1999, concerns over sustainability of target, permitted and bycatch species have been addressed through significant management changes. These include:

- Protection of species susceptible to trawling through permanent closures over about one-third of the fishery area and over about 50% of the GBRWHA;
- Partial protection for these species through seasonal closures over about 60% of the fishery and nearly three-quarters of the GBRWHA;
- A vessel buy-back scheme removing 98 trawling licences and excess fishing capacity from the fishery;
- Introduction of an effort management system to provide the basis for further fishing effort reduction through licence trading arrangements;
- Mandatory use of bycatch reduction devices that minimise catch of non-target species by all trawlers operating in the fishery; and
- Removal of sharks, whiptails (*Pentapodus spp*.) and goatfish (*Upeneus spp*. and *Parapeneus spp*.) from the Permitted Species listed in the Trawl Plan in November 2001.

5.1.3 *Existing Management Arrangements*

Permitted fish species are subject to further specific management arrangements aimed at minimising target fishing for these species, thereby ensuring their populations are not overfished but contribute to the continued economic viability of the fishery.

In late 2001, Permitted fish management arrangements were subject to a major review under the Trawl Plan (i.e. the Permitted Species Review). The Permitted Species Review gathered and assessed available scientific and management information and the views of major stakeholders including the GBRMPA, the fishing industry and the community through a broad consultative process[3]. DPI&F has subsequently introduced a range of specific management initiatives for Permitted species to ensure that fishery interactions are sustainable. These are summarised in Table 5.1.

Table 5.1. Summary of existing management for Permitted Species.

Permitted Fish	Legislated Management Arrangements
Blue Swimmer Crabs	Minimum legal size 11.5cm measured “notch-to-notch”

[3] A regulatory Impact Statement was issued in relation to the Review.

(*Portunus pelagicus*)	Prohibition on retention of females In-possession limit: 100 in Moreton Bay 500 elsewhere
Barking Crayfish (*Linuparus trigonus*)	Prohibition on retention of ovigerous females
Balmain Bugs (3 *Ibacus* species)	Minimum legal size 10cm carapace width Prohibition on retention of ovigerous females
Cuttlefish (13 *Sepia*,1 *Metasepia* species)	In-possession limit of 66 L
Red Spot Crabs (*Portunus sanguinolentus*)	Minimum legal size 10cm measured "tip-to-tip" Prohibition on retention of females
Octopus (11 Octopus species)	In-possession limit of 66 L
Pipefish (2 Pipehorse species) (*Solegnathus hardwickii* and *Solegnathus dunkeri*)	Only two species may be retained In-possession limit of 50 individuals in total
Pinkies (10 *Nemipterus* species)	In-possession limit of 198 L
Mantis Shrimp (21 Stomatopod species)	In-possession limit of 15 L in Moreton Bay

5.1.4 *Assessment of Risk for Permitted Species*

The intent of the General Effort Review (this review) in relation to Permitted species is to assess whether the level of effort applied in the fishery is ecologically sustainable. In the Review, DPI&F has adapted the results of recent major research undertaken in Queensland and other Australian jurisdictions for incorporation into a formal risk assessment on Permitted species. Specific use is made of:

- The composition and biology of non-target species captured in the fishery researched by DPI&F AFFS;
- Recently developed scientific techniques for assessment of the relative sustainability of capture of non-target species against ecological attributes (Stobutzki et al. 2001); and
- A draft framework for the Ecological Risk Assessment of the Effects of Fishing (ERAEF) for Commonwealth-managed fisheries being developed by CSIRO Marine Research, Hobart (Hobday et al., CSIRO in prep.).

Relevant information from other credible sources has also been considered in the risk assessment including the advice of the trawling industry [Qld Seafood Industry Assoc.] and the GBRMPA.

The Permitted Species under assessment in this review are those potentially retained as byproduct in the fishery. Other non-target species, (bycatch) cannot be legally retained and are not considered in detail in this assessment.

5.1.5 *Method*

Risk Assessment Frameworks – What are the options?
DPI&F has considered appropriate Ecological Risk Assessment (ERA) models on which to base an assessment of the level of risk to Permitted Species associated with trawl effort in the fishery. Options include the:

- Western Australian Fisheries ESD-Risk Assessment Process;

- CSIRO Trawl Scenario Model[4] for assessment of the sustainability of trawl effort on benthic communities;
- CSIRO Risk Assessment process under development for the Northern Prawn Fishery; and
- Draft CSIRO ERAEF framework for Commonwealth-managed fisheries, (Hobday et al., CSIRO in prep.) that builds upon the work of Stobutzki et al. (2001) (see below).

The Review for Permitted species will consider two key questions:

- Does the distribution of fishing effort (and the activities associated with fishing effort) relative to the distribution of a species have a sustainable impact on the species? and
- Are the management measures currently in place and those proposed, likely to ensure sustainability through minimizing the risk of unsustainable impacts on a species?

In December 2003, DPI&F research, management, monitoring and assessment officers, industry and GBRMPA, AGDEH, Qld EPA, NQCC and QSIA representatives attended a stakeholder workshop to consider an appropriate conceptual framework on which to base a sustainability assessment of Permitted Species in the QECTF.

In view of the need for an assessment framework that could provide appropriate outcomes for sustainable management of the fishery, the peer reviewed method reported by Stobutzki et al. 2001 (Environmental Conservation **28**: 167-181) was selected. Its' previous use as a rigorous process ranking non-target species in order of concerns about their sustainability in another major Australian trawl fishery (the Northern Prawn Fishery) gave this method a major advantage over other ERA frameworks.

While, the method of Stobutzki et al. (2001) alone does not intend to provide a full ERA for even a single component of the QECTF ecosystem, it is being integrated into the multi-level ERAEF framework currently under development by CSIRO Marine Research in Hobart (Hobday et al., CSIRO, in prep.). The ERAEF framework outlines a process for assessing the relative significance of the attributes in the Stobutzki et al. (2001) method and provides a context for re-ordering specific analyses to achieve a staged and systematic ERA that more effectively uses the available information from scientific and industry sources to assess risk based on the:

- Intrinsic biological properties of species productivity (i.e. capacity to recover after depletion has occurred);
- Relative fishery interactions (i.e. susceptibility to capture or mortality); and
- Actual impact of the fishery on Permitted Species (i.e. removal rate).

Data Issues

Information regarding the biology, ecology and stock status of many of the Permitted species in the QECTF is limited in some instances. In December 2003, at the DPI&F stakeholder Workshop on Sustainability Assessment Frameworks there was general

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[4] The CSIRO "Mapping seabed biodiversity project" currently under way is acquiring data to test and refine the Trawl Scenario Model. DPI&F is awaiting preliminary outputs from that research to assist in assessing the likely impact and recovery of benthic communities subject to different levels of trawling effort. Results are not currently available, but are expected to be released following the General Effort Review at about the time of the General Review of the Plan commencing 2006.

agreement over the fundamental need for results from recent research on these species to be used in any assessment of sustainability of effort in the fishery. This would ensure outcomes that take into account scientific information on Permitted species and their biology are credible and provide a way forward for continued sustainable management of these species.

Data collected in DPI&F/FRDC Research Project (No. 2000/170), provide new information on key elements of the biology, population dynamics and exploitation of non-target species in the fishery including Permitted Species. The project conducted reviews of the biology and distribution of Permitted species; assessed their temporal and spatial distribution in the QECTF, and quantified key aspects of the population dynamics of several species. At the time of writing, the final project report has not been released however preliminary data and information provided by Dr J Haddy (NSW Fisheries) and Dr A Courtney and officers of DPI&F/AFFS have been used where appropriate in assessment procedures for Permitted species under this Review.

What is "sustainability"

Stobutzki et al. 2001 (p. 168) outlines a definition of "sustainability" that recognises its ecological aspects with respect to the assessment of susceptibility to trawl impacts and recovery from depletion of non-commercial bycatch species in the Northern Prawn Fishery. The DPI&F December 2003 Workshop discussed a need for this definition to be modified to better represent a broader context for considering commercially significant Permitted species in the QECTF as provided for in the objectives of the Trawl Plan. The Workshop agreed the Stobutzki et al. (2001) definition was appropriate to discarded bycatch species but where capture of certain species (Permitted species) occurred that there be given adequate recognition of these species having an economic benefit to the community and that only a limited number of the 66 Permitted species listed in Table 1 are actually retained in the fishery. To address this concern, the sustainability assessment of Permitted species in this Review has been based upon on the broader definition of "sustainability". The amended definition of "sustainability" with respect to Permitted species in the QECTF reads:

"The term sustainability of Permitted Species is used to mean optimisation of economic benefit while ensuring that the impact of the fishery on these species will not exceed the ability of the species to renew themselves".

Relative Sustainability Assessments

Stobutzki et al. (2001) describes a semi-quantitative framework for assessing the relative sustainability of bycatch species (i.e. their recovery capacity following population depletion and their susceptibility to capture or mortality due to trawling). It does not outline a full and comprehensive ERA method in itself and requires a process that provides inputs of species regarded by stakeholders as having moderate to high risk of not achieving an agreed operational management objective established for the fishery (Hobday et al., CSIRO in prep.). The further assessment of relative risk among moderate to high-risk species is necessary to assess which species (if any) are at risk of unsustainable impacts from trawling. Such species may require existing management arrangements to be evaluated as a minimum and perhaps require collection of more information as a priority to refine their risk rating. Further steps that could be taken include more detailed quantitative biological assessment of the species or additional management.

The relative sustainability assessment process in Stobutzki et al. (2001) when applied to Permitted Species, can help determine whether individual species or species groups are at risk from effort being applied unsustainably in the fishery - the focus of the Permitted species risk assessment in the current General Effort Review for the fishery.

Outputs of the DPI&F December 2003 Workshop provided a ranking system of Permitted Species attributes that reflect their productive capacity to recover after depletion and their susceptibility to trawl capture or mortality (Productivity and

Susceptibility in Appendix 1). Collectively, ranking species against various aspects of these attributes can be used to comprehensively assess the ecological sustainability of effort levels in the fishery since the Trawl Plan (i.e. the 2001 and 2002 effort years) and identify priorities for sustainable management of the fishery. To best achieve this, the ERAEF framework of Hobday et al., CSIRO (in prep.) currently under development has been used. The ERAEF framework integrates the work of Stobutzki et al. (2001) and has expanded it further into a step-wise process built specifically for rigorous ERA of Commonwealth-managed fisheries.

Procedures in the ERAEF framework are suitable for wider application in other fisheries and have been adapted for an ERA of Permitted Species in the QECTF to:

- Assess relative risks related to intrinsic biological properties of Permitted species,;
- Determine indices of interactions between trawl effort and Permitted Species;
- Identify which species are at potentially higher risk from unsustainable impacts;
- Demonstrate the efficacy of existing management arrangements for Permitted species; and
- Identify management actions required (e.g. acquire additional data or take other management actions) for species at relatively higher risk compared to other Permitted species.

A process model of stages of the ERAEF framework modified for risk assessment of Permitted Species in the General Effort Review is summarised in Table 5.2.

Table 5.2. Analyses identified in the ERAEF framework (Hobday *et al*., CSIRO in prep.) and considered in the risk assessment of Permitted species in the QECTF.

Stage in Process	Type of analysis	Species assessed
Scoping	Assembly of relevant fishery, biological and life history data and information	All Permitted (byproduct) species in the fishery
Level 1 Analysis (Qualitative)	Scale, intensity and consequence analysis (SICA) of indicators of key aspects of byproduct species' populations are based on expert judgment	No species were assessed for risk at this level due to the time and resource constraints required to complete the Review.
Level 2.1 Analysis (Semi-Quantitative)	Productivity – Susceptibility Analysis (PSA)	All Permitted (byproduct) species in the fishery
Level 2.2 Analysis (Semi-Quantitative)	Precautionary Risk Analysis	High risk species from the PSA are assessed for real compared to precautionary high risk status due to data deficiencies
Level 2.3 Risk Management Response (Qualitative)	Assessment of results of Level 2 analyses against management arrangements	Permitted species ranked high risk in the PSA, but will also include assessments of the efficacy of management arrangements specific to low risk species and the use of these species as reference points that could improve confidence in the relative assignment of moderate to high risk ratings for other

		Permitted species
Level 3 Analysis (Fully Quantitative)	For example Stock Assessment and Potential Biological Removal approaches	During this Review, no species has been assessed to this level

Productivity – Susceptibility Assessment
Productivity – Susceptibility Assessment (PSA) attributes and ranks used by Stobutzki et al. (2001) were reconsidered here as modified in the DPI&F Permitted Species Sustainability Assessment Workshop in December 2003 and since in consultation with Dr Alistair Hobday, CSIRO Marine Research, Hobart. There are eight sustainability attributes consisting of five attributes relating to the productive capacity of a species population to recover following depletion and three attributes relating to the susceptibility of a species to capture or mortality by trawling.

All attributes have been given equal weighting. The justification for the weightings proposed by Stobutzki et al. (2001) was not well documented in the assessment of finfish bycatch in the Northern Prawn Fishery. Weighted attributes have not been used in this risk assessment because there is currently no objective criteria for their development (A. Hobday, CSIRO, pers. comm., 2004). To ensure there is adequate precaution built into the assessment where insufficient data exists, a high-risk score of 3 is assigned from a range of scores of 1 to 3.

Precautionary Risk Analysis
Permitted species assessed to be “high-risk” in the PSA may be substantially at risk due to intrinsic biological characteristics or susceptibility to capture or mortality by trawling. Other species may be “high-risk” if they have received multiple precautionary “high-risk” ratings where existing knowledge about one or more of their attributes is data deficient. Species dealt with in this way or “precautionary high-risk species” [5] have been further assessed to determine whether their “high-risk” status is valid or due to a bias from allocating precautionary high-risk scores that dilute the contribution of lower risk scores (based on real data) in the total risk score. However, the DPI&F recognises the need to address data deficiencies for all precautionary high-risk species to refine their risk status in future assessments. The DPI&F is developing a five-year research plan for the East Coast fishery. This plan will identify information gaps and set research priorities.

Risk Management Response
Management arrangements that are appropriate to the productivity and susceptibility characteristics of the species serve as valuable reference points in gauging the efficacy of current management not only of high risk species, but also of other species assessed to be at lower risk and therefore requiring a lower level of management to achieve sustainability at current effort levels. The results of the PSA for other Permitted Species assessed to be at low to moderate risk are also considered in this assessment.

5.1.6 *Results*

Productivity – Susceptibility Assessment
Descriptions of the sustainability attributes and definition of their ranks are in Appendix 1. The significance of each attribute and the ranked scores for each Permitted species against each attribute are provided in the Tables below to assist in interpretation of the

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[5] Permitted species are regarded as precautionary high-risk species where they score one or more attributes as “high risk” due to data deficiency.

results of the analysis. A full summary of total productivity and susceptibility attribute scores and combined risk and score ratings for all Permitted species are given in Appendix 2.

Productivity Attributes

Ranks assigned to species /species group attributes equate to the following risk and productivity levels relative to other Permitted species.

Rank	**Productivity**	**Risk**
1	High	Low
2	Moderate	Moderate
3	Low	High

Likelihood of breeding before being captured

From research data, the size at first maturity and the size at which each species is captured in the fishery have been compared and an estimate made of the likelihood that each species/species group has bred before capture. Likelihood estimates have been ranked according to the rank definitions for Productivity Attribute 1: Likelihood of breeding before capture (Appendix 1). The results are in Table 5.3.

Table 5.3. Likelihood of breeding before capture.

Species	% Difference between length at capture and length at first maturity	Rank Score
Red Spot Crabs	Mean catch is: 29% > male size at first maturity Mean catch is: 44% > female size at first maturity	1
Pipefish *S. dunckeri*	The mean length at capture for *S. dunckeri* is 10.2% greater than the minimum length at first maturity	1
Blue swimmer crabs	The mean CW at capture for blue swimmer crabs is 14% greater than the length at first maturity	1
Barking crays	The mean CL at capture for barking crays is 21% greater than the length at first maturity	1
Pinkies (*N. celebicus* , *N. furcosus, N. metopias; N. nematopus; N. theodorei*)	The mean length at capture is 25% greater than the length at maturity	1
Pinkies (*N. aurifilum, N. hexodon, N. mesoprion, N. peronii, N. sp*)	The mean length at capture is ≤ 10% less than or ≤ 10% greater than the length at first maturity	2
Balmain Bugs (all 3 species)	Mean I. chacei catch is 70% < size at first maturity Mean I. brucei catch is 65% < size at first maturity I. sp.: nd	3
Pipefish *S. hardwickii*	The mean lengths at capture for *S. hardwickii* is 23% less than the length at first maturity	3
Cuttlefish	Uncertain	3
Octopus	Uncertain	3
Mantis shrimps	Uncertain	3

Maximum age
Trawl capture mortality of species capable of rapid regeneration over a relatively short timeframe is considered more sustainable than mortality of species requiring a relatively long period of time to reach sexual maturity. Maximum age data from the scientific literature have been ranked according to the rankings for Productivity Attribute 2 in Appendix 1. The results are in Table 5.4.

Table 5.4. Maximum age of Permitted Species.

Species	Maximum age (years)	Ranking
Cuttlefish [a]	1-2	1
Octopus [a]	1-2	1
Blue swimmer crabs [b]	3	2
Red spot crabs [c]	3.5	2
Mantis shrimps [a d]	2.5–4	2
Pinkies [e]	5	2
Solegnathus hardwickii [f]	5	2
Solegnathus dunckeri [f]	5	2
Ibacus chacei [g]	7	3
Ibacus brucei [g]	Uncertain	3
Ibacus sp. (? alticrenatus) [g]	Uncertain	3
Barking crays	Uncertain	3

Data Sources
a Dr. J. Haddy (NSW Fisheries, pers. comm. 2003)
b Sumpton et al. (2003)
c Courtney and Haddy 2003 in prep
d Dell and Sumpton (1999)
e Sainsbury and Whitelaw (1984)
f Connolly et al. (2001)
g Haddy, Courtney and Roy (2003 in prep.)

Fecundity
From information in the scientific literature, comparisons can be made among species of their annual reproductive capacity as a measure of recovery potential in the event that the fished population became depleted. Octopuses display two major reproductive modes, they either produce large numbers of small eggs that hatch as pelagic larvae (Group 1), or produce small numbers of large eggs that hatch as benthic juveniles (Group 2). Species have been ranked according to the rankings for Productivity Attribute 3: Annual fecundity (Appendix 1). The results are in Table 5.5.

Table 5.5. Annual fecundity estimates for Permitted Species.

Species	Maximum annual fecundity (x 10^3 eggs)	Ranking
Blue Swimmer Crabs	2000	1
Red Spot Crabs	1200	1
Pinkies[a]	500	1
Barking Crays	100	2
Octopus (Group 1) [b]	100	2
Ibacus brucei [c]	60	2
Ibacus chacei [c]	30	2
Ibacus sp. (?alticrenatus) [c]	15	2
Octopus exannulatus	5	3
Solegnathus hardwickii [d]	1	3
*Solegnathus dunckeri**	1	3

Octopus (Group 2) [b]	<1	3
Octopus (Group 3)	Uncertain	3
Mantis Shrimps	Uncertain	3
Cuttlefish	Uncertain	3

Data sources:

a Mohan and Velayudhan (1986)

b Group 1 species consist of *Octopus kagoshimensis*, and *O. marginatus*; Group 2 species consist of *Octopus australis* and *O. graptus* and (Dr J. Haddy, NSW Fisheries, pers. comm., 2003); Group 3 species consist of *Octopus sp*., *O. sp B*, *O. sp D, O. sp. G, O. sp. I* and *O. sp. J.*

c Haddy et al. (in prep.)

d assuming 5 broods are produced annually (Dunning et al. 2003)

* Assuming brood fecundity and number of broods produced annually is similar to *S. hardwickii*.

Reproductive Strategy

The logistic growth equation indicates that species with a potentially higher intrinsic rate of increase have the ability to recover from population depletion more rapidly than species with more gradual rates of regeneration. High numbers of offspring are produced by these species, a characteristic found in species that shed their gametes into the water column (i.e. broadcast spawners). Species with demersal eggs or those which exhibit parental care of eggs/offspring typically have fewer offspring and do not have the same capacity to recovery rapidly from depletion. Species have been ranked according to the rankings for Productivity Attribute 4: Reproductive strategy (Appendix 1). The results are in Table 5.6.

Table 5.6. Reproductive strategies used by Permitted Species.

Species	Reproductive Strategy	Ranking
Octopus (Group 1)* and *Octopus exannulatus* and pinkies	Broadcast spawners	1
Blue Swimmer crabs, Red Spot crabs, Balmain Bugs, Barking crays, Octopus (Group 2)*, cuttlefish and mantis shrimps	Demersal spawners or egg layers; guard or incubate eggs and/or young	2
Pipefish	Live-bearing/pouch brooder	3
Octopus (Group 3)	Uncertain	3

Notes:

* Group 1 species consist of *Octopus kagoshimensis*, and *O. marginatus*; Group 2 species consist of *Octopus australis*, and *O. graptus* (Dr J. Haddy, NSW Fisheries, pers. comm., 2003); Group 3 species consist of *Octopus sp., O. sp B, O. sp D, O. sp. G, O. sp. I* and *O. sp. J.*

Mortality Index

The recovery rate of a population is likely to be related to its fishing mortality rate (Stobutzki et al. 2001). The closer the average length of captured individuals is to the species maximum length, the lower is the fishing mortality of the population. Conversely, as mortality due to fishing increases, the average length of species in a population approaches the smallest length at which the species is caught (Stobutzki et al. 2001). A mortality index was calculated using minimum and mean length at catch data from research trawls in the QECTF and the known or inferred maximum length attained by the species from the scientific literature. Index values have been calculated using the formula:

Mortality Index = $(L_{max} – L_{ave})/ (L_{ave} – L_{min})$

and the range of estimates divided into thirds on a logarithmic scale for ranking purposes (Stobutzki et al. 2001). Species were assigned ranks accordingly (Appendix 1). Table 5.7 is a summary of the mortality index and rank scores for each species.

Table 5.7. Mortality index and rank scores.

Species	Index Value	Ranking
Sepia whitleyana	0.55	1
Sepia rex	0.66	1
Sepia opipara	0.91	1
Sepia papuensis	0.93	1
Sepia plangon	0.96	1
Sepia smithi	1.08	1
Nemipterus hexodon	1.15	1
Sepia limata	1.27	1
Nemipterus nematopus	1.32	1
Ibacus brucei	1.44	1
Nemipterus furcosus	1.67	1
Sepia rozella	1.70	1
Ibacus chacei	1.72	1
Portunus pelagicus	1.85	1
Nemipterus theodorei	2.11	1
Solegnathus hardwickii	2.60	1
Sepia pharaonis	2.66	1
Sepia elliptica	3.11	1
Nemipterus peronii	3.21	1
Odontodactylus cultrifer	4.30	1
Portunus sanginolentus	4.47	1
Octopus australis	8.02	2
Octopus cf. kagoshimensis	10.52	2
Quollastria gonypetes	11.94	2
Octopus exannulatus	13.04	2
Erugosquilla woodmasoni	17.43	2
Octopus marginatus	17.92	2
Belosquilla laevis	31.35	2
Solegnathus dunckeri	37.67	2
Octopus graptus	43.22	2
Oratosquillina interrupta	67.14	3
Linuparus trigonus	70.56	3
Odontodactylus japonicus	110.36	3

Data Deficient Species		
Carinosquilla australensis	dd	3
Carinosquilla carinata	dd	3
Carinosquilla multicarinata	dd	3

Dictyosquilla foveolata	dd	3
Harpiosquilla harpax	dd	3
Harpiosquilla melanoura	dd	3
Harpiosquilla sinensis	dd	3
Ibacus sp	dd	3
Kempina mikado	dd	3
Linuparus trigonus	dd	3
Metasepia pfefferi	dd	3
Miyakea nepa	dd	3
Nemipterus aurifilum	dd	3
Nemipterus celebicus	dd	3
Nemipterus mesoprion	dd	3
Nemipterus metopias	dd	3
Nemipterus sp	dd	3
Octopus sp	dd	3
Octopus sp B	dd	3
Octopus sp D	dd	3
Octopus sp G	dd	3
Octopus sp I	dd	3
Octopus sp J	dd	3
Oratosquilla anomola	dd	3
Oratosquillina quinquedentata	dd	3
Oratosquilla nepa	dd	3
Oratosquilla sp	dd	3
Oratosquilla stephensoni	dd	3
Sepia mestus	dd	3
Sepia mira	dd	3
Sepia sp	dd	3

Notes: dd = data deficient for minimum/maximum length at capture.

Productivity Summary
The productivity scores for Permitted species have been plotted in Appendix 3. In summary, the analysis indicates that the most productive Permitted species appear to be the pinkies [*Nemipterus furcosus* (Nf), *N. aurifilum* (Na*), N. nematopus* (Nn), *N. metopias* (Nme) and *N. theodorei* (Nt), *N. celebicus* (Nc), *N. hexodon* (Nh), *N. peronii* and *N. sp*], the Portunid crabs [*Portunus pelagicus* (Pp) and *P. sanguinolentus* (Ps), the cuttlefish *Sepia plangon* (Spl) and the Group 1 octopus [*O. kagoshimensis* (Ok) and *O. marginatus* (Om)].

Species with a moderate capacity to recover from population depletion are pipefish [*Solegnathus hardwickii* (Sh) and *S. dunckeri* (Sd)], cuttlefish Sepia species (Sl, So, Sph, Spl, Sw etc.) and *Metasepia pfefferi* (Mp), barking crays (Lt), Balmain bugs [*Ibacus chacei* (Ic) and *I. brucei* (Ib)], and Group 2 octopus [*Octopus australis* (Oa), *O. graptus* (Og) and *Octopus exannulatus* (Oe)].

Species assessed to have a relatively low capacity to recovery from depletion are the mantis shrimps (Ca, Cm, Df, Hs, Oan, Oq etc.), Group 3 octopus (O sp. O. sp.B, O. sp.D. and sp.J) and the unidentified Balmain bug *Ibacus sp*.. Relatively high levels of precaution have been used in assigning ranks to attributes of these species (Appendix 5), contributing to the their relatively high scores (low productivity status).

Susceptibility Attributes

Ranks assigned to species /species group attributes equate to the following risk and susceptibility levels relative to other Permitted species.

Rank	Susceptibility	Risk
1	Low	Low
2	Moderate	Moderate
3	High	High

Preferred Habitat

The habitat of recognised Permitted species is most likely to overlap where trawling occurs over softer sandy or muddy sediments, although some areas with harder substrates supporting attached plants and animals (benthos) may also coincide with trawl grounds. Increased susceptibility to capture by trawling occurs in these areas. Species are less susceptible to trawl capture where they also occur in areas dominated by rocky or coral reef as these habitats are not primarily targeted by trawling and occur mostly outside trawl grounds. Table 5.8 shows the relative sustainability rankings for Permitted species against Susceptibility Attribute 1: Preferred Habitat in Appendix 1.

Table 5.8. Preferred Habitat of Permitted Species.

Species	Habitat	Rank
Pipefish	Pipefish do not typically occur in the habitat of target trawl species but instead probably occur mainly outside of trawl grounds (Dunning et al. 2003). Pipefish appear to be captured near the edge of reef habitats (areas not typically trawled).	1
Blue Swimmer Crabs	Common in soft substrate areas, but also on sandbanks and in estuaries (these areas offer some protection from trawling)	2
Cuttlefish	Uncertain	3
Octopus	Uncertain but many species known to inhabit untrawlable habitat	3
Barking crayfish	Common in soft substrate areas (susceptible to trawling but in depths and areas that are not generally trawled due to an absence of target species).	3
Balmain Bugs	Common in soft substrate areas (susceptible to trawling)	3
Red Spot Crab	Common in soft substrate areas (susceptible to trawling)	3
Pinkies	Common in soft substrate areas (susceptible to trawling)	3
Mantis Shrimps	Common in soft substrate areas (susceptible to trawling)	3

Percentage of the permitted species range within the active fishery area

In the QECTF, 250 CFISH catch reporting (30*30 minute) grids occur entirely or partly within area of the fishery representing a total fishery area of 546,267 km2. Areas permanently closed to trawling (DPI&F[6] and GBRMPA closures combined), account for

[6] Nine grids are completely closed to trawling due to permanent DPI&F closures (grids D6, E6, F5, F6, E7, F7, E8, F8 and F9) representing approx. 9 x 3,087 km2 = 27,783 km2 or approx. 5% of the total fishery area.

172,089 km2, representing 32% of the total fishery area (DPI&F unpub.data, 2003). There are 241 grids open or partially open to trawling, representing a total area available to be fished (active fishery area) of 374,177 km2 or 68% of the total fishery area in 2002 (DPI&F unpub.data, 2003). Actual trawling occurs in only a small part of the area open to trawling due to high aggregation of effort.

The number of grids reporting catches of each Permitted spp in 2001 and 2002 is a surrogate for the range of the species within the fishery area. Spatial catch data was assessed using the interactive mapping and commercial catch grid query tools on the DPI&F CHRIS website[7]. The percentage of the Permitted species range estimated to be within the active fishery area removes areas of permanent closure in the species range from the analysis.

The percentage of the total fishery area less the area of permanent closures (the active fishery area) that overlaps with the species range was calculated and ranked according to the rank definitions in Appendix 1. Table 5.9 summarises the percentage of the active fishery area covered by the species range and sustainability rankings for Susceptibility Attribute 2: Percentage of the active fishery area within the species range.

Table 5.9. Percentage of the active fishery area within the Permitted species range.

Species	Percentage of active fishery area covered by the species range	Ranking
Cuttlefish	58	2
Blue Swimmer Crabs	57	2
Octopus	53	2
Pinkies	38	2
Pipefish	32	3
Barking Crays	31	3
Red Spot Crabs	30	3
Balmain Bugs	24	3
Mantis Shrimps	15	3

Post-capture survival of discards

Post-capture survival is based upon the observed condition/mortality of species landed onboard. Sources of information on the likelihood of post-capture survival of discarded Permitted species (on which sustainability rankings for this attribute are based) are:

- From catches during research trawls in the QECTF area (eg crab species appear to have relatively high post-capture survival compared to other trawled species: Hill and Wassenberg 2000; octopus are inferred to have a higher survival rate than other cephalopods (Hill et al. 1998); or
- From research trawls in other fisheries (eg 100% survival of Portunid crabs, 50% survival of stomatopods, but no survival of cuttlefish and nemipterids (pinkies) in the Torres Strait Prawn Fishery: (Hill and Wassenberg 1990), or
- Are anecdotal, based on research experience (eg there is generally high survival of Balmain bug discards (M. Dredge, DPI&F, pers. comm., 2003) and octopus discards (M. Dunning, DPI&F, pers. comm., 2004) in the QECTF, or
- Inferred from research aboard commercial vessels in other otter trawl fisheries (eg. pinkies [*Nemipterus theodorei*] were reported to have high post-capture mortality in the Queensland Stout Whiting Fishery: Dell et al (2003), or

[7] www.DPI&F.chrisweb.gov.au

- Inferred from research into similar species elsewhere (eg. Barking crayfish (*Linuparus trigonus*) are thought to be a robust crustacean with high post-capture survival prospects based on limited survival data on the spear lobster Linuparus somniosus (Wowor 1972).

Mortality due to selective predation of discards once they have been returned to the water is uncertain and has not been considered in the assessment. The results of the analysis were used to indicate the extent to which the management regime addresses sustainability through controls on harvesting (eg MLS limits). Table 5.10 contains estimates of post-capture survival for Permitted species against Susceptibility Attribute 3: Post-capture survival of discards in Appendix 1.

Table 5.10. Post-capture survival of discards.

Species	Likelihood of survival	Ranking
Blue Swimmer Crabs	High (>66%)	1
Balmain Bugs	High (>66%)	1
Red Spot Crabs	High (>66%)	1
Barking Crays	High (>66%)	1
Octopus	High (>66%)	1
Mantis Shrimps	Moderate (33-66%)	2
Cuttlefish	Low (<33%)	3
Pipefish	Low (<33%)	3
Pinkies	Low (<33%)	3

Susceptibility Score Summary

The susceptibility scores for Permitted species have been plotted in Appendix 4. In summary, the analysis indicates that the Permitted species least susceptible to capture or mortality from trawling appear to be the blue swimmer crab Portunus pelagicus (Pp); all octopus species [*Octopus australis* (Oa), *O.exannulatus* (Oe), *O. kagoshimensis* (Ok), *O. graptus* (Og), *O. marginatus* (Om), *Octopus sp*., *O. sp.B*, *O. sp. D, O. sp. G, O. sp. I,* and *O. sp. J*]. Balmain bugs (Ib, Ic, and I. sp.); Barking crays (Lt); the red spot crab *Portunus sanguiolentus* (Ps) and the pipefish *Solegnthus hardwickii* (Sh) and *Solegnthus dunckeri* (Sd) are moderately susceptible to trawl capture or mortality due to trawling. Species most susceptible to capture or mortality due to capture by trawling are the pinkies and mantis shrimps (all species).

Precautionary Risk Analysis

It is of note that in the high risk and moderate risk species categories (Appendix 2), there is representation of all three major taxonomic groups comprising the Permitted Species (there is only a single species in the low risk category). This suggests that the adaptation of the ERAF framework (Hobday et al. in prep.) and the attributes selected for assessment across the permitted species taxa (such as crustacean, finfish and cephalopods) in the QECTF are applicable and relevant. In interpreting the final levels of risk assigned to Permitted Species, it is important to recognise that the assessment has not inadvertently produced results that have a negative or positive bias toward any of the major taxa considered.

Four of the 63 Permitted species were assessed to be “true high risk” species: the Balmain bugs Ibacus chacei and Ibacus brucei, pipefish *Solegnathus hardwickii* and *S. dunckeri* (Appendix 5). There is sufficient scientific data available on which to base this classification. In contrast, forty-eight of the 66 Permitted species were classified as “precautionary high risk species” (i.e. precautionary high risk due to limited data, see Methods section). Twenty-three species are classified as “probable high risk” where ≤ 60% of their attributes rank “high risk” due to data deficiencies. A species is defined as “possible high risk” where >60% of their attributes rank “high-risk” due to data deficiencies. Twenty-two possible high-risk species have been identified (Appendix 5).

The relative total risk to Permitted Species’ groups from trawling related to productive capacity to recover from depletion and susceptibility to capture or mortality is plotted in Appendix 6. Before the effect of the existing mitigating management arrangements for the various groups of Permitted Species can be considered, key aspects of the overall risk associated with each group are discussed below.

Blue swimmer crabs are at low risk from trawling due to their extensive range covering more than 50% of the fishery area, high fecundity and expected high survival as discards. Red spot crabs are susceptible to trawl capture but like blue swimmer crabs are highly fecund, some animals having an opportunity to breed before capture. Octopus have relatively low to moderate productivity but their expected high survival as discards contributes to a moderate overall risk rating.
Pinkies are highly susceptible to capture by trawling but have relatively high fecundity and as broadcast spawners, their offspring are not likely to be affected by trawling during their pelagic early life stages.

Cuttlefish and mantis shrimps are assessed to be high risk, but this is mainly due to a high proportion of precautionary high-risk productivity rankings.

Despite being highly susceptible to capture by trawling, barking crayfish are susceptible to capture by trawling and moderate risk from trawling overall due to their likelihood of breeding before capture and moderate fecundity.

Balmain bugs (Ibacus chacei and I. brucei) are at the low end of high risk from trawling due to their low mortality index values and expected high survival when discarded. Ibacus sp. appears to be less productive than the other Ibacus species, but this may be due to data deficiencies in 60% of precautionary high-risk productivity rankings for this species (Appendix 5).

Pipefish scored high risk on five out of the eight attributes used in the PSA. They have relatively low productivity due to their low fecundity and the demersal pouch rearing characteristics of the adults. This also makes them susceptible to trawl capture around the margins of their preferred reefal habitats. Their low survival upon capture, places them at high risk from trawling.

5.1.7 *Discussion - Management Response to Risk*

Although information regarding non-target species is limited, the DPI&F has implemented strategies to improve fishery-dependent data collection. Logbooks in the trawl fishery have been significantly improved with the introduction of the OT08 log in early 2003; this includes mandatory reporting at fine spatial scale.

Blue Swimmer Crabs – Low Risk.

The blue swimmer crab (Portunus pelagicus) has relatively high capacity to recover from population depletion (i.e. high productivity). Blue swimmer crabs are generally regarded as being ubiquitous both within and outside the trawl grounds. When discarded, they are moderately robust. Therefore their discard mortality rates are relatively low. It is the only Permitted species assessed to be at ‘low risk’ of unsustainable impacts from trawling in the QECTF (Appendix 2).

In 2001, the Department of Primary Industries (Agency for food and Fibre Sciences) completed a major research project that assessed a number of key components of the Queensland Blue Swimmer Crab (BSC) stock (Sumpton et al 2003). While this project assessed the BSC fishery as a whole, it examined the impact of trawling on BSC in some detail.

In general, the Report emphasised that the biological characteristics of BSC afford considerable protection against overfishing. In summary, BSC are a rapidly growing, highly fecund species that reaches sexual maturity well before the minimum legal size.

Sumpton et al (2003) noted that further protection to BSC is afforded through the blanket protection of females. This is because virtually all mature females are inseminated providing for increased egg production. While a stock recruitment relationship for BSC has not yet been quantified in Queensland, it is possible to assume that facilitating increased egg production errs on the side of precautionary management.

The report also reviewed the sustainability of the minimum legal size (MLS) of BSC, concluding that there was considerable scope to reduce the MLS from 15cm to 14cm. This recommendation was partially based on the finding that 100% of male BSC reach maturity well below 15cm and even below 14cm.

For a MLS to be an effective management tool for ensuring appropriate levels of egg production, there must be an acceptable survival rate for undersized individuals that are caught incidentally and released. While it has been generally agreed that BSC are a robust species that should display high survivability, a need to quantify this has long been identified. Sumpton et al (2003) measured mortality rates among juvenile BSC for up to 8 hours after capture and simulated release. Results suggest a total mortality rate of approximately 7%. An experiment using adult BSC in Western Australia found similar results (Mellville Smith et al 2001).

Given these findings, MLS is an appropriate management tool for trawl-caught BSC because a significant proportion of released crabs are likely to survive.

BSC in the trawl fishery are further managed through “trip” limits of 100 crabs in Moreton Bay and 500 in the remainder of the fishery area. Based on daily catch data (focussed on the key catch areas of Moreton Bay and Hervey Bay), Sumpton et al (2003) found that these limits are likely to affect 33% and 36% of trawl fishing days in Moreton Bay and elsewhere respectively. This information, coupled with low post-release mortality therefore suggests that the trip limits are an effective management tool for reducing and capping the trawl impact on BSC. It is important to note that while the trip limits do contribute to the sustainability of BSC, their primary function is a resource allocation tool. This is necessary for because BSC are extremely important to non-trawl fishers (recreational and commercial pot fishers) as well.

Concerns

In addition to the positive findings presented above, Sumpton et al raised the following points of concern regarding the impact of trawling on BSC:

Trawling was considered to be higher risk to BSC stocks than potting. This was not necessarily due to the number of crabs retained by trawlers (the Report showed that catch and effort for BSC had decreased since management intervention while Catch and Catch per unit effort in the pot fishery had increased significantly) but rather due to post-release mortality and damage to habitats that juvenile BSC are reliant upon.

In this regard, Sumpton et al did note that juveniles are typically associated with shallow bank areas. While some trawling undoubtedly occurs in these areas, it is important to note that the significant inshore closures in the major BSC catch areas (Moreton Bay and Hervey Bay). While not their primary function, these closures would provide significant protection to juvenile BSC. Sumpton also found that in general, BSC caught and retained by trawlers were larger than BSC caught and retained by pot fishers. This is indicative of a fishery that does not operate in areas where catches of small crabs are high.

Data recorded in the CFISH database through commercial fishers logbooks were found to be difficult to interpret, particularly due to the lack of historical information regarding BSC and the spatial resolution of the data.

Management	Comments
Minimum Legal Size (11.5cm)	Provides excellent spawning protection as 100% of BSC are sexually mature by approximately 10cm.
No take of females	Allows for greater egg production.
Trip Limits (100 in Moreton Bay and 500 elsewhere)	Caps total trawl take (and reduces for some individual fishers and specific areas).

The effectiveness of these management arrangements is ensured by the low post-release mortality. This means that a high proportion of regulated crabs[8] survive.

Conclusion – No sustainability concerns.

Red Spot Crabs – Moderate Risk.

From the PSA analysis, red spot crabs have a high capacity to recover from population depletion and a moderate susceptibility to mortality from trawling.

Red spot crabs (*Portunus sanguinolentus*) (RSC) are closely related to BSC and display similar characteristics. They exhibit rapid growth rates, particularly in their first year and mature early. Sexually mature RSC as small as 7.4cm have been recorded in Queensland (Sumpton et al 1989). In addition, RSC can be highly fecund, capable of producing over 1 million eggs per individual in each spawning period (Sukumaran and Neelakantan 1997). Further, RSC are scavengers and opportunistic predators (Haddy 2002), this usually indicates a species that can exploit a broad ecological niche.

Growth and mortality rates have been used to perform a yield per recruit analysis on RSC in Queensland (Courtney and Haddy 2001). This analysis was conducted as part of the review of permitted fish conducted by the DPI&F in late 2001. The yield per recruit concluded that the optimum size of capture for RSC is 10cm.

It is important to note, however, that this modelling assumed that fishing mortality was directed at both males and females of the species. Similar to BSC, a policy of no female take has been implemented for this species. As discussed above, this is likely to provide increased potential for egg production, thereby contributing to the precautionary nature of management arrangements for RSC.

The MLS of 10cm is well above the first size at which maturity is known to occur.

Being a Portunid crab, it is assumed that RSC would show similar survival rates to BSC after being released from trawl nets. In fact RSC mortality rates could be expected to

[8] Regulated crabs are crabs that are either female, undersized male or males caught in excess of the trip limit.

be lower than the BSC given that the RSC generally occurs in shallower waters and are subjected to trawl pressure only in the summer months.

RSC are caught by both recreational and commercial pot fishers, however, in general, the species does not form a significant part of these fisheries with catches reportedly taken incidentally while targeting BSC. Given that the level of conflict between fishing sectors that is evident regarding BSC does not appear to exist for RSC, the imposition of trip limits are not required at this time.

RSC have been classified as moderate risk (rather than low risk like the BSC) because they are caught in a smaller proportion of the active fishery area and because there is no known evidence of them inhabiting non-trawl habitats. Given that this species is exploited world-wide, it is likely that it occurs in a wider proportion of the fishery, but not to a level that supports commercial retention.

Management	**Comments**
Minimum Legal Size (10cm)	Provides excellent spawning protection as RSC are known to be sexually mature at considerably smaller sizes.
No take of females	Allows for greater egg production.

The effectiveness of these management arrangements is ensured by the fact that RSC are likely to exhibit the same low level of post-release mortality that BSC display. This means that a high proportion of regulated crabs survive.

Conclusion – No sustainability concerns.

Octopus – Moderate and Possible High Risk (3 groups).

From the PSA analysis, three groups of octopi have been delineated. Group 1 displays a high capacity to recover from population depletion (i.e. high productivity) and a low to moderate susceptibility to mortality from trawling. Group 2 displays a medium to low productivity and a low to moderate susceptibility to trawl mortality. *Octopus exannulatus* has similar susceptibility characteristics to, and is mid-way between the productivities of both groups. Group 3 has medium to low productivity but a high proportion of attributes where data is deficient. In general, octopus are typified by a low to moderate risk of unsustainable impacts from trawling.

Octopi are a good example of the affect that poor or highly limited information has on the outcomes of the risk assessment model. All of the species that have been identified as ‘possible high risk’ (Appendix 5) have data deficiencies in ALL high-risk attributes.

Haddy (2003) provided an analysis of six octopus species that are likely to comprise the majority of the trawl catch in Queensland. The remaining species of octopus that are found in the state are known to inhabit areas that are unlikely to be trawled to any degree. Even though data regarding likelihood of breeding before capture and preferred habitat for these six species were lacking, all were found to be moderate risk.

This added to the fact that octopuses in general are known to display rapid growth and short life-spans indicates that trawling is unlikely to present a significant sustainability risk to the remaining species of octopus, even though they are known to occur within the active fishery area.

Unlike other cephalopods, octopus display high post trawl survivability, which gives credence to the 66L in possession limit. This prevent fishers from any targeting activity and also means that any octopus incidentally taken in excess of the limit have a high probability of surviving and continuing to contribute to the replenishment of the population.

Management	Comments
66L in possession limit	Reduces targeting of the species. Ensures part of incidental catch is released (survival rate ensures that those individuals would contribute further to the population).

Conclusion – Species that are likely to be most encountered in the fishery are determined as a 'moderate risk', other lesser-known species determined as possible high risk.

Pinkies – Moderate Risk (7 spp), Probable High Risk (3 spp).

Only two attributes separated those species classed as high risk from those classed as moderate risk. These were the likelihood of breeding before first capture and the mortality index. The three species that are in the probable high-risk category have been placed in that category due to the lack of a reliable mortality estimate. Substituting a comparable mortality to *N. furcosis* and *N. Aurifilium* would result in these species being given a moderate risk rating.

Pinkies are the only finfish permitted species. As such they are the only permitted species that can have their risk effectively reduced by the use of bycatch reduction devices (BRDs). With the mandatory use of BRDs throughout the fishery, the risk to nemipterids can effectively be minimised. Devices such as square mesh panels and square mesh codends may be used to reduce the incidental capture of juvenile nemipterid species while still retaining target species and adult nemipterids.

It is important to note that trawl fisheries targeting finfish typically employ very long sweeps (up to more than 10 times the length of prawn trawl sweeps) to "herd" fish from a larger area into the net. Sweeps in the ECTF are prescribed to a maximum of 10m in length, which significantly reduces their efficiency in catching finfish.

As the trawl fishery incorporates a majority of the areas in which nemipterids occur, the identification and protection of key areas is likely to be important to minimising the risk to juvenile nemipterids. The required data to achieve this are not yet available and would probably only be obtainable through fishery independent research or observer programs.

It must be noted that the limited amount of targeting which occurs with nemipterids and their very wide distribution throughout the fishery area, the method used in this assessment may have been over-precautionary with respect to the percentage of the fishery area covered by the species range. As the model has only used the areas where nemipterids where retained, rather than areas where they occur, the range of the species is though to be underestimated.

At present the management directed solely at nemipterids is an in possession limit of 198L (or 0.1989m^3 if frozen), effectively reducing any targeting of the species. Future management to reduce the risks to nemipterids may include options such as the use of certain BRDs in areas known to be important areas for nemipterid juveniles, to reduce the fishing mortality.

Management	Comments

198L in possession limit or $0.1989m^3$ if frozen	Reduces targeting of the species.

Conclusion – Species are deemed 'probable high-risk' due to lack of data. Nemipterids are ubiquitous and abundant particularly in trawl grounds. No serious sustainability concerns.

Cuttlefish – Possible High Risk
From the PSA analysis, cuttlefish have a low to medium capacity to recover from population depletion (i.e. low to medium productivity) and a high susceptibility to mortality from trawling.

There are at least 31 species of cuttlefish (Sepia spp) in Australian waters and 17 of these are known to inhabit Queenslands east coast (Reid 2000; Lu 1998). Some of these species are small and do not contribute to commercial catches while other species can grow up to over 50 cm in mantle length and weigh over 5 kg.

The possible high risk rating for this group of species is a result of the general lack of knowledge surrounding it. Appendix 5 shows that data is lacking on about 75% of the attributes used in the risk assessment.

Fecundity, preferred habitat and likelihood of breeding before capture were all attributes in the risk assessment where a lack of information has resulted in a precautionary high-risk finding.

While quantitative information is not available, it is important to note that some species of cuttlefish use three-dimensional structure such as corals to attach egg masses to after spawning (Haddy 2003). Egg clusters from other species are frequently found on hard substrates in very shallow water (0.5 to 5.0 metres). These show at least some tendency towards the utilisation of habitats and areas that are unlikely to be trawled.

Haddy (2003) also reported that one of the Queensland species for which some information is available (Sepia pharonis) has a maximum fecundity of approximately 1,500 eggs (which is low) but displayed evidence of spawning multiple broods. Cuttlefish in general display rapid growth rates and are known to be reproductive within 8 months, therefore the likelihood of breeding before capture is far greater than a slow growing, late maturing species.

Cuttlefish are known to be an aggregating species, and at these times, their catchability by trawlers is markedly increased. In this regard, the in-possession limit of 66L is likely to be effective in preventing "psuedo-targeting[9]" of these species.

If the trawl fishery incorporates a majority of the areas in which cuttlefish occur, the identification and protection of key areas is likely to be the most appropriate method of minimising the risk of unsustainable impacts. The required data to achieve this are not yet available and would probably only be obtainable through fishery independent research or observer programs. While this is a possibility (see pipefish section), it would be an extremely resource intensive exercise and would need to be assessed in line with the cost to industry that such closures would present.

Management	Comments
66L in possession limit	Reduces targeting of the species.

[9] It is acknowledged that trawlers are unlikely to specifically fish for cuttlefish but the absence of a limit may encourage extra fishing at times or locations where permitted species catch is likely to be increased.

Conclusion – Identified as a 'Possible High Risk' due to lack of knowledge. Some indications that this may be over-precautionary. Methods to identify candidate "cuttlefish areas" should be considered.

Mantis Shrimps – Possible to Probable High Risk.

From the PSA analysis, mantis shrimp have a low capacity to recover from population depletion and a high susceptibility to mortality from trawling. Due to a lack of reliable data on size at maturity, fecundity, fishing mortality and preferred habitats, mantis shrimps have been assessed (except for three 'possible high risk species') as mainly 'probable high risk' species.

Appendix 5 shows that these species have been classed as high risk because of the significant amount of uncertainty about their characteristics (≈ 60% of attributes are unknown/uncertain).

The vast majority of mantis shrimp harvest is sourced from Moreton Bay, where it is subject to a 15L in possession limit. As shown in Table 5.10, mantis shrimp are likely to display a moderate survival rate when released from a trawl net. Moreton Bay is a shallow water trawl area (generally less than 20m). Trawl gear allowed in the Bay is also significantly smaller than the wider trawl fishery, meaning that catch per shot is lower, and therefore "crushing" in the cod end is decreased. These two factors would be a significant benefit in increasing post release survival.

Table 5.8 assigns a high rank (contributing to high susceptibility) to mantis shrimp because they are known to live in burrows on sandy substrates (Haddy 2003). However, these species are also known to inhabit crevices in rocky and coral reefs, meaning that their susceptibility is likely to have been overestimated to a certain degree.

Fecundity and fishing mortality estimates are unknown for these species, which contribute to the 'probable high risk' rating.

Figure 5.1 shows that mantis shrimps are by the far the lowest value permitted species in the fishery. There is potential to protect the species by further regulating its take. The DPI&F has commenced a Review of some of the major issues in the Moreton Bay trawl fishery. While the Review was not initiated in response to species-specific issues, it is possible to address this issue as part of that exercise. The Review will assess the quantities of mantis shrimp being reported to:

- Identify any areas in the Bay that are responsible for particularly high mantis shrimp catches that could be used to protect the species from over-exploitation; and
- Analyse catch information to determine the economic impact and stock benefits that could come by reducing the in-possession limit.

The Moreton Bay Review is considered a more appropriate medium than the General Effort Review as it will involve industry meetings with the licence holders that would be affected by any management intervention.

While the lack of data for mantis shrimps have resulted in their being given a 'probable high-risk' species rating, it is likely that catches of mantis shrimps are sustainable. As the market demand and price for mantis shrimps is low, retention rates are generally low with only a limited number of the smaller vessels in the fleet retaining mantis shrimps.

Management	**Comments**
15L (0.0153m^3) in possession limit	Reduces targeting of the species

Conclusion - Very limited data on mantis shrimps have lead to a 'probable high-risk' species rating. Low prices and few vessels fishing for mantis shrimps means they are likely to be able to sustain current fishing pressure. Further management intervention will be investigated through the Moreton Bay Review.

Barking Crayfish – Probable High Risk.
From the PSA analysis, barking crayfish (*Linuparus trigonus*) have a moderate capacity to recover from population depletion (i.e. low productivity) and a moderate susceptibility to mortality from trawling. It is one species that has benefited significantly from the research being conducted by AFFS. Prior to that project, little was known about the biology of the species (Haddy et al 2003). Factors that have lead to barking crayfish being assessed as a 'possible high-risk' species include limited data on the maximum age of the species and the absence of a reliable estimate of fishing mortality.

At present management arrangements for barking crayfish are limited to a prohibition of the retention of ovigerous (egg bearing) females. However, the prescription in law that barking crayfish are a permitted species only (and can therefore not be targeted) has resulted in a significant reduction in overall catch. Analysis of catch and effort data supplied by fishers shows that in the past the majority of barking crayfish have been taken in a well defined area off Townsville (and to a lesser extent Mackay) (Haddy et al 2003).

Anecdotal information received from fishers is that these deepwater areas do not contain target species at sufficient levels to make trawling viable. The effect of this change in management (in 2001) is therefore that barking crayfish are no longer being taken in their areas of high abundance but continue to be taken at low levels in other areas where they are truly an incidental catch from prawn trawling. Further to this, barking crayfish are known to occur in depths exceeding 300m (Haddy et al 2003). The QECTF only fishes to approximately 220m leaving a considerable proportion of the species range unfished. The importance of these deeper areas to the lifecycle of the species is unknown but presumably results in a level of protection to the standing stock.

Haddy et al (2003) specifically investigated the reproductive biology of barking crayfish using specimens obtained from trawl fishers throughout Queensland with a view to developing further sustainable harvesting strategies. Based upon this work, TrawlMAC recently considered a proposal from AFFS to implement a MLS of 8.0cm carapace length for barking crayfish. TrawlMAC has subsequently forwarded this recommendation to the DPI&F and a proposal is to be progressed at the next opportunity.

As discussed above, prohibition of egg bearing females and MLS can only be effective if the animals that are released have a reasonable chance of survival. In general, crustaceans are robust animals that display low discard mortality. It is expected that a significant proportion of released barking crayfish would survive. This appears to be supported by anecdotal information regarding a small amount of tagging work that was conducted by a commercial fisher in the early 1980's. This project only tagged a small number of individuals in a relatively ad hoc manner, however it is important to note that some tagged individuals were recaptured.

It is expected that the effectiveness of these management arrangements is ensured by the low post-release mortality that barking crayfish probably display. This means that a high proportion of regulated barking crayfish survive after capture and release.

The proposed introduction of a MLS, coupled with the stock protection stemming from unexploited depths outside the fishery at least partially address the low ranking for fishing mortality that has contributed to the ranking as probable high risk.

Management	Comments
No take of egg-bearing females	Allows for greater egg production.
Proposed Minimum Legal Size (80mm)	Provides spawning protection as BC are known to be sexually mature at considerably smaller sizes.

Conclusion – Limited data on fishing mortality and maximum age have lead to probable high-risk classification of barking crayfish. Proposed management changes such as the introduction of MLS will provide significant protection to the spawning stock.

Balmain Bugs – True High Risk.

From the PSA analysis, the Balmain bug (*Ibacus chacei, I. Brucei* and *I. alticranatus*) has a relatively moderate capacity to recover from population depletion (i.e. moderate productivity) but are moderately to highly susceptibility to capture from trawling. There is adequate data on which to base Ibacus chacei (garlic bug) and I. brucei (honey bug) as a "true high-risk species". *I. alticrenatus* (velvet bug) has insufficient data available on maximum age and fishing mortality, resulting in classification as "probable high-risk species."

Balmain bugs are managed according to a MLS of 10cm carapace width and a prohibition on the retention of ovigerous females. Haddy et al. (in prep.) reported that ovigerous female Balmain bugs carry approximately 1,700 to 61,300 eggs per brood. Compared to some other species such as blue swimmer crabs, which can carry in the order of 1,000,000 eggs, this suggests a fairly low fecundity. It has also been reported (DPI&F 2001) that bugs in general display low population densities. These trends can indicate a predisposition to overfishing if not well managed and highlights the need for MLS to be based on accurate information.

The MLS was introduced as a result of the review of permitted fish in late 2001 and is consistent with that implemented by New South Wales. Recent investigation (as part of the AFFS project) into the reproductive biology of the three most common species of Balmain bugs caught in Queensland shows that the current MLS is appropriate in managing the Ibacus genus.

Of the three species, two are relatively small and of the 2,411 individuals analysed, none were immature below the current MLS. This indicates that there is considerable scope to decrease the MLS for these species (see below).

In general, individuals of the larger species (*I. chacei*, garlic bug) were found to mature at slightly below the current MLS. This indicates that there is not necessarily a sustainability concern for the species but that it may be appropriate to consider a marginal increase in the MLS to ensure that management is precautionary (see below).

As discussed with blue swimmer crabs, red spot crabs and barking crayfish, these management arrangements are only effective if Balmain bugs have low discard mortality. While there has been little work to quantify the mortality rate of Balmain bugs in Queensland, it is arguable that discard mortality would be low. This is based on the general trend in crustaceans for high survival. Hill et al. (1998) investigated the discard mortality of Moreton Bay bugs (*Thenus spp*.), finding that approximately 98% of these animals survived after being released. Given the similarities between these two genera, it can be assumed that a significant proportion of Balmain bugs survive capture and release.

The role of the MLS is important as it addresses the productivity criteria "likelihood of breeding before capture". These species were assigned a high risk ranking of 3 for that criterion based on the fact that the majority of bugs are caught at below the size at first maturity. The PSA model does not account for the fact that bugs below 10 cm are released, therefore 100% of the bugs that are retained are greater than the size at first maturity. The enforced discard of the majority of bugs captured also has relevance to the criteria about overall fishing mortality as this also assumes that all bugs caught are killed; this is not the case.

These two criteria alone have been significant in the overall rating of high risk for these species.

In addition to the MLS, there is strong evidence (derived from research and presented by fishers) that TEDs and BRDs play a role in excluding a significant proportion of the Balmain bug catch (T Courtney AFFS, pers. comm. 2004).

Future Action
As stated above, the differences in size and growth rates among Ibacus species allows for the investigation of separate minimum legal sizes for some Balmain bug species.

Fishers have for some time been claiming that *I. brucei* (honey bug) and *I. alticranatus* (velvet bug) rarely exceed the MLS for 'Balmain bugs', effectively limiting commercial access to a significant portion of the 'Balmain bug' stock. The AFFS research project has confirmed that *I. brucei* and *I. alticranatus* mature at significantly smaller sizes than the major species of Balmain bugs and could therefore be managed via a sperate MLS. This is assisted by the fact that these two species are easily distinguished from the larger, more common Balmain bug.

Available information suggests that the MLS for the velvet and honey bugs could be set at 80mm carapace width. This would effectively allow fishers to retain a larger proportion of these species than are currently landed while still affording adequate protection to stocks to ensure continued egg production.

Results from the current research project also suggest that in order to ensure continued precautionary management, the MLS of the garlic bug (*I. chacei* – assessed as true high-risk) should be marginally increased to 10.5cm. This slight increase would ensure that the majority of individuals are protected until they have had opportunity to reproduce.

These proposals have been discussed and endorsed by TrawlMAC (in 2003). The DPI&F has committed to seeking stakeholder opinions about the proposals at the next opportunity.

Management	**Comments**
Minimum Legal Size (10cm)	Provides spawning protection as most Balmain bugs are known to be sexually mature at smaller sizes.
No take of egg-bearing females	Allows for greater egg production.
Proposed Specific Minimum Legal Sizes (8.0cm and 10.5cm)	Provides far greater spawning protection because sizes are set according to biological characteristics of individual species.

Conclusion – *Ibacus chacei* and *I. brucei* have been identified as true high-risk species, and *I. alticranatus* as ' probable high risk' species. Proposed actions to ensure appropriate management per species could be used to address the relative risk ratings among species.

Pipefish – True High Risk.

From the PSA analysis, *Solegnathus hardwickii* and *S. dunckeri* have relatively low capacities to recover from population depletion and a high susceptibility to mortality from trawling.

Pipefish are members of the family Syngnathidae. Under the Plan only two species of pipefish can be retained, *Solegnathus hardwickii* (Hardwick's pipehorse) and *S. dunckeri* (Duncker's pipehorse). In addition, a "trip" limit of 50 individuals[10] has been placed on pipefish.

Commercial catch data (from fisher's logbooks) is only available from 2000 onwards, however, since the management arrangements were introduced, reported catches of pipefish have decreased significantly from 7,877 in 2001 to 5,214 in 2002. Connolly et al (2001) raised concerns that the catch and catch rate of syngnathids reported in the logbooks in 2000 was significantly less than that calculated from processor records of pipefish purchases from the ECTF and export data from Queensland.

Connolly et al (2001) reported that as many as 25,900 pipefish were purchased from the ECTF in 2000 and this figure matched the available data on exports to major markets in Hong Kong and Taiwan. Under reporting of species like pipefish is of concern to the DPI&F. However, it is important to note that 2000 was the first year in which pipefish were included in commercial logbooks as a separate column. The level of reporting has been addressed through the latest trawl logbook (discussed below). It is anticipated that the continual improvement of the reporting system will result in an overall improvement of the data collected, especially in terms of permitted species.

Over exploitation of some syngnathids species has resulted in the family being red listed as vulnerable under the International Union for Conservation of Nature (Haddy 2002).

Pipefish are a listed marine species under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). As such, any activity that results in the death or injury of pipefish in or on a Commonwealth are is illegal under the EPBC Act unless undertaken with the approval of the Commonwealth Environment Minister. The EPBC Act is administered by the Federal Department of Environment and Heritage (DEH).

Between November 2001 and April 2002, the DPI&F negotiated with DEH to obtain approval from the Minister to continue trawl operations. This approval was given on 10 July 2002 when the Minister accredited the Plan of Management for syngnathid harvest submitted by the DPI&F.

The accreditation and subsequent negotiations with DEH regarding export accreditation have included, in detail, mechanisms to ensure that adequate protection is afforded to pipefish.

In early 2002, the DPI&F introduced the OT08 logbook, which contains a much greater level of detail to allow fishers to report pipefish catch at a species level. The DPI&F is also working towards the development of a pilot observer program that will assist in the monitoring of bycatch such as pipefish.

Given that it is extremely difficult (if not impossible) to design a net configuration that will reduce the capture of pipefish without also allowing target species to escape, a major step towards the conservation of pipefish may be the identification of specific areas of high pipefish abundance. If such areas can be identified, then potential exists to implement permanent or seasonal closures to reduce the trawl impact upon pipefish.

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[10] Trip limit refers to 50 individuals in total, not 50 individuals from each species.

Identifying habitat preferences for pipefish is extremely difficult given their relative rarity in trawl catches. Courtney et al 2003 conducted an exploratory analysis of fishery independent catch data obtained through the DPI&F long term monitoring scallop surveys and specific charters undertaken as part of the major bycatch project. The purpose of this exercise was to identify faunal community associations between pipefish (focussing on *S. hardwickii*) and other bycatch species.

In time, such associations could be used in conjunction with data from observer programs and fishery dependant data (logbooks) to aid in the identification of key pipefish areas that could be investigated for closure.

Connolly et al (2001) found that pipefish are likely to be associated soft sediments and three-dimensional structures such as reefs. This was supported by anecdotal evidence from commercial fishers that catch rates were highest when trawling amongst reef areas. Connolly et al suggested that the uptake of accurate navigational equipment such as GPS and depth sounders could result in greater impacts on syngnathids because trawlers have the ability to explore new fishing grounds around and between reefs. The DPI&F believes that this is unlikely to occur for two reasons.

Firstly, when the Plan was implemented, a large area of untrawled and lightly trawled water was closed to prevent the expansion of trawling. The majority of these closed areas are offshore[11], around reefs etc. These closures limit the ability of trawl fishers to seek new fishing grounds in and around habitats that are likely to support large numbers of pipefish. The total area of these habitat types that are closed to trawling will be significantly increased shortly upon introduction of the Commonwealth Government's Representative Areas Program.

Secondly, the introduction of the Effort Management System in 2001 has effectively placed an intrinsic value on each night/day that trawlers fish. Anecdotal information from industry members is that this deters fishers from "exploring" new grounds as they need to guarantee a certain level of prawn/scallop catch to justify the use of a fishing day. As a result, effort is typically concentrated on main trawl grounds where given catches can be expected. This information is supported by the fact that the total area trawled by the fleet has reduced since the inception of the Plan (see Section 3.2 – spatial distribution of effort).

Management	Comments
"Trip Limit" (50 individuals)	Caps total trawl-take of pipefish to prevent further expansion
Restricted to two species	Prevents further expansion (such as trawling in new areas where different pipefish species occur)
Proposed/ongoing Research and monitoring to identify key areas for pipefish populations	Intended to identify alternative arrangements such as spatial management of risks to pipefish.

Conclusion – Pipefish have been identified as a true high-risk species. Detailed spatial data may be required to help minimise the risk of overfishing.

[11] This is an important consideration as pipefish captures have only been reported in depths greater than 25m (Connolly et al 2001).

Appendix 1. Preliminary Framework for Risk Assessment : Productivity Susceptibility Analysis

[Adapted from the Ecological Risk Assessment for the Effects of Fishing Framework of Hobday *et al.*,CSIRO (in prep.)]

Attribute	**Rank**	**(most sustainable to least sustainable)**	
PRODUCTIVITY (Intrinsic Recovery Capacity)	**1**	**2**	**3**
Likelihood of breeding before capture	The mean length at capture is >10% greater than the length at first maturity	The mean length at capture is within ± 10% of the length at first maturity	The mean length at capture >10% less than the minimum length at first maturity
Maximum age	Species reaches its maximum age in <2.5 years	Species reaches its maximum age in ≥ 2.5 years and ≤ 5 years	Species reaches its maximum age in >5 years
Annual Fecundity	> 100,000 eggs produced	≤ 100,000 and ≥ 10, 000 eggs produced	< 10, 000 eggs produced
Reproductive strategy	Broadcast spawners or little parental care of eggs and/or young	Guard eggs or incubate eggs and/or young or are demersal spawners	Bear live young or brood young
Mortality index	0.5 - 5.00	5.01 - 50.00	>50
SUSCEPTIBILITY (to trawl related capture or mortality)	Rank	(most sustainable to least sustainable)	
	1	2	3
Preferred Habitat	Species mostly occur in habitats outside trawl grounds, such as reef associated species	Species known to occur over sandy or muddy sediments or on prawn/ scallop grounds but also use other habitats such as reefs and estuaries	Species occur over sandy or muddy sediments or on prawn/ scallop trawl grounds
Percentage of the active fishery area within the permitted species range	Species range > 66% of the active fishery area	Species range ≤ 66% and ≥ 33% of the active fishery area	Species range <33% of the active fishery area
Post-capture survival (of discards)	Likelihood of survival >66%	Likelihood of survival ≤ 66% and ≥ 33%	Likelihood of survival <33%
Note: In the PSA, Permitted species assessed to be at moderate to high risk in terms of their rate of productive capacity to recover from potential depletion or damage by the fishery and their susceptibility to capture or mortality by trawling, are subject to further assessment for risk of overfishing based on their relative rates of removal. Species assessed to be at low risk in the PSA are given a rationale explaining their low risk status, and are not assessed further against the relative removal rates of other Permitted Species, unless a species regarded as being at high risk from the fishery before the PSA, is assessed to be low risk in the PSA. This would require investigation for a plausible explanation. If this cannot be readily found, the re-consideration of attributes and ranking definitions in the PSA framework may be necessary.			

Appendix 2. Results of Risk Assessment for QECTF Permitted Species

	Productivity							Susceptibility				Total Risk	
Species	**Species Code**	**Bred before capture**	**Max_ Age**	**Fecund_**	**Reprod_ Strat**	**Mort Index**	**Productivity Score**	Habitat	**Range**	**Discard Survival**	**Average Susceptibility Score**	**Risk Score**	**Risk Rating**
Portunus pelagicus	*Pp*	1	2	1	2	1	1.40	2	2	1	1.67	2.18	Low
Octopus kagoshimensis	*Ok*	3	1	2	1	2	1.80	3	2	1	2.00	2.69	Moderate
Octopus marginatus	*Om*	3	1	2	1	2	1.80	3	2	1	2.00	2.69	Moderate
Portunus sanguinolentus	*Ps*	1	2	1	2	1	1.40	3	3	1	2.33	2.72	Moderate
Octopus exannulatus	*Oe*	3	1	3	1	2	2.00	3	2	1	2.00	2.83	Moderate
Nemipterus furcosus	*Nf*	1	2	1	1	1	1.20	3	2	3	2.67	2.92	Moderate
Nemipterus nematopus	*Nn*	1	2	1	1	1	1.20	3	2	3	2.67	2.92	Moderate
Nemipterus theodorei	*Nt*	1	2	1	1	1	1.20	3	2	3	2.67	2.92	Moderate
Octopus australis	*Oa*	3	1	3	2	2	2.20	3	2	1	2.00	2.97	Moderate
Octopus graptus	*Og*	3	1	3	2	2	2.20	3	2	1	2.00	2.97	Moderate
Nemipterus hexodon	*Nh*	2	2	1	1	1	1.40	3	2	3	2.67	3.01	Moderate
Nemipterus peronii	*Np*	2	2	1	1	1	1.40	3	2	3	2.67	3.01	Moderate
Nemipterus celebicus	*Nc*	1	2	1	1	3	1.60	3	2	3	2.67	3.11	Moderate
Nemipterus metopias	*Nme*	1	2	1	1	3	1.60	3	2	3	2.67	3.11	Moderate

Species	Species Code	Bred before capture	Max_ Age	Fecund_	Reprod_ Strat	Mort Index	Productivity Score	Habitat	Range	Discard Survival	Average Susceptibility Score	Risk Score	Risk Rating
Ibacus brucei	*Ib*	3	3	2	2	1	2.20	3	3	1	2.33	3.21	High
Ibacus chacei	*Ic*	3	3	2	2	1	2.20	3	3	1	2.33	3.21	High
Linuparus trigonus	*Lt*	1	3	2	2	3	2.20	3	3	1	2.33	3.21	High
Solegnathus dunckeri	*Sd*	1	2	3	3	2	2.20	1	3	3	2.33	3.21	High
Nemipterus aurifilum	*Na*	2	2	1	1	3	1.80	3	2	3	2.67	3.22	High
Nemipterus mesoprion	*Nm*	2	2	1	1	3	1.80	3	2	3	2.67	3.22	High
Nemipterus sp	*Nsp*	2	2	1	1	3	1.80	3	2	3	2.67	3.22	High
Octopus sp	*Osp*	3	1	3	3	3	2.60	3	2	1	2.00	3.28	High
Octopus sp B	*OspB*	3	1	3	3	3	2.60	3	2	1	2.00	3.28	High
Octopus sp D	*OspD*	3	1	3	3	3	2.60	3	2	1	2.00	3.28	High
Octopus sp G	*OspG*	3	1	3	3	3	2.60	3	2	1	2.00	3.28	High
Octopus sp I	*OspI*	3	1	3	3	3	2.60	3	2	1	2.00	3.28	High
Octopus sp J	*OspJ*	3	1	3	3	3	2.60	3	2	1	2.00	3.28	High
Sepia elliptica	*Se*	3	1	3	2	1	2.00	3	2	3	2.67	3.33	High

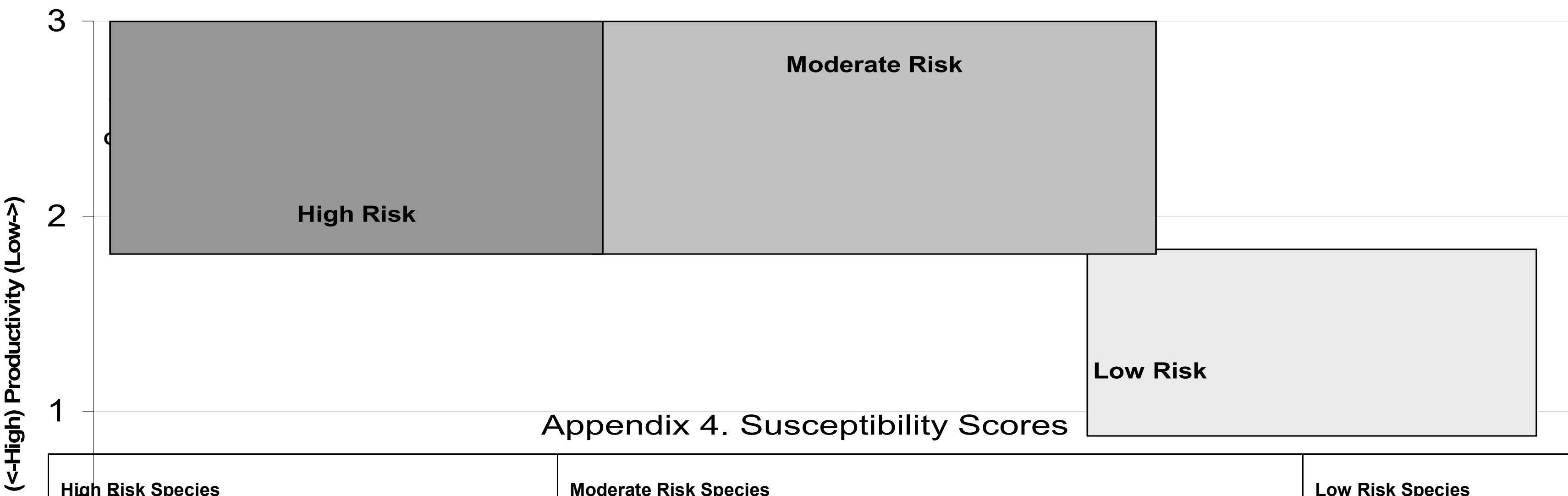
Species	Species Code	Bred before capture	Max_ Age	Fecund_	Reprod_ Strat	Mort Index	Productivity Score	Habitat	Range	Discard Survival	Average Susceptibility Score	Risk Score	Risk Rating
Sepia limata	*Sl*	3	1	3	2	1	2.00	3	2	3	2.67	3.33	High
Sepia opipara	*So*	3	1	3	2	1	2.00	3	2	3	2.67	3.33	High
Sepia papuensis	*Spa*	3	1	3	2	1	2.00	3	2	3	2.67	3.33	High
Sepia pharaonis	*Sph*	3	1	3	2	1	2.00	3	2	3	2.67	3.33	High
Sepia plangon	*Spl*	3	1	3	2	1	2.00	3	2	3	2.67	3.33	High
Sepia rex	*Sre*	3	1	3	2	1	2.00	3	2	3	2.67	3.33	High
Sepia rozella	*Sro*	3	1	3	2	1	2.00	3	2	3	2.67	3.33	High
Sepia smithi	*Ss*	3	1	3	2	1	2.00	3	2	3	2.67	3.33	High
Sepia whitleyana	*Sw*	3	1	3	2	1	2.00	3	2	3	2.67	3.33	High
Solegnathus hardwickii	*Sh*	3	2	3	3	1	2.40	1	3	3	2.33	3.35	High
Odontodactylus cultrifer	*Oc*	3	2	3	2	1	2.20	3	3	2	2.67	3.46	High
Ibacus sp	*Isp*	3	3	2	2	3	2.60	3	3	1	2.33	3.49	High
Bellosquilla laevis	*Bl*	3	2	3	2	2	2.40	3	3	2	2.67	3.59	High
Erugosquilla woodmasoni	*Ew*	3	2	3	2	2	2.40	3	3	2	2.67	3.59	High
Metasepia pfefferi	*Mp*	3	1	3	2	3	2.40	3	2	3	2.67	3.59	High
Species	Species	Bred	Max_	Fecund_	Reprod	Mort Index	Productivity	Habitat	Range	Discard	Average	Risk	Risk

	Code	before capture	Age		_ Strat		Score			Survival	Susceptibility Score	Score	Rating
Quollastria gonypetes	*Qg*	3	2	3	2	2	2.40	3	3	2	2.67	3.59	High
Sepia mestus	*Sme*	3	1	3	2	3	2.40	3	2	3	2.67	3.59	High
Sepia mira	*Smi*	3	1	3	2	3	2.40	3	2	3	2.67	3.59	High
Sepia sp	*Ssp*	3	1	3	2	3	2.40	3	2	3	2.67	3.59	High
Carinosquilla australensis	*Ca*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Carinosquilla carinata	*Cc*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Carinosquilla multicarinata	*Cm*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Dictyosquilla foveolata	*Df*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Harpiosquilla harpax	*Hh*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Harpiosquilla melanoura	*Hm*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Harpiosquilla sinensis	*Hs*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Kempina mikado	*Km*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Miyakea nepa	*Mn*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Odontodactylus japonicus	*Oj*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Oratosquilla anomola	*Oan*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Species	**Species Code**	**Bred before**	**Max_ Age**	**Fecund_**	**Reprod_ Strat**	**Mort Index**	**Productivity Score**	Habitat	**Range**	**Discard Survival**	**Average Susceptibility**	**Risk Score**	**Risk Rating**

		capture									Score		
Oratosquilla nepa	*On*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Oratosquilla sp	*Orsp*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Oratosquillina interrupta	*Oi*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Oratosquillina quinquedentata	*Oq*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High
Oratosquillina stephensoni	*Os*	3	2	3	2	3	2.60	3	3	2	2.67	3.72	High

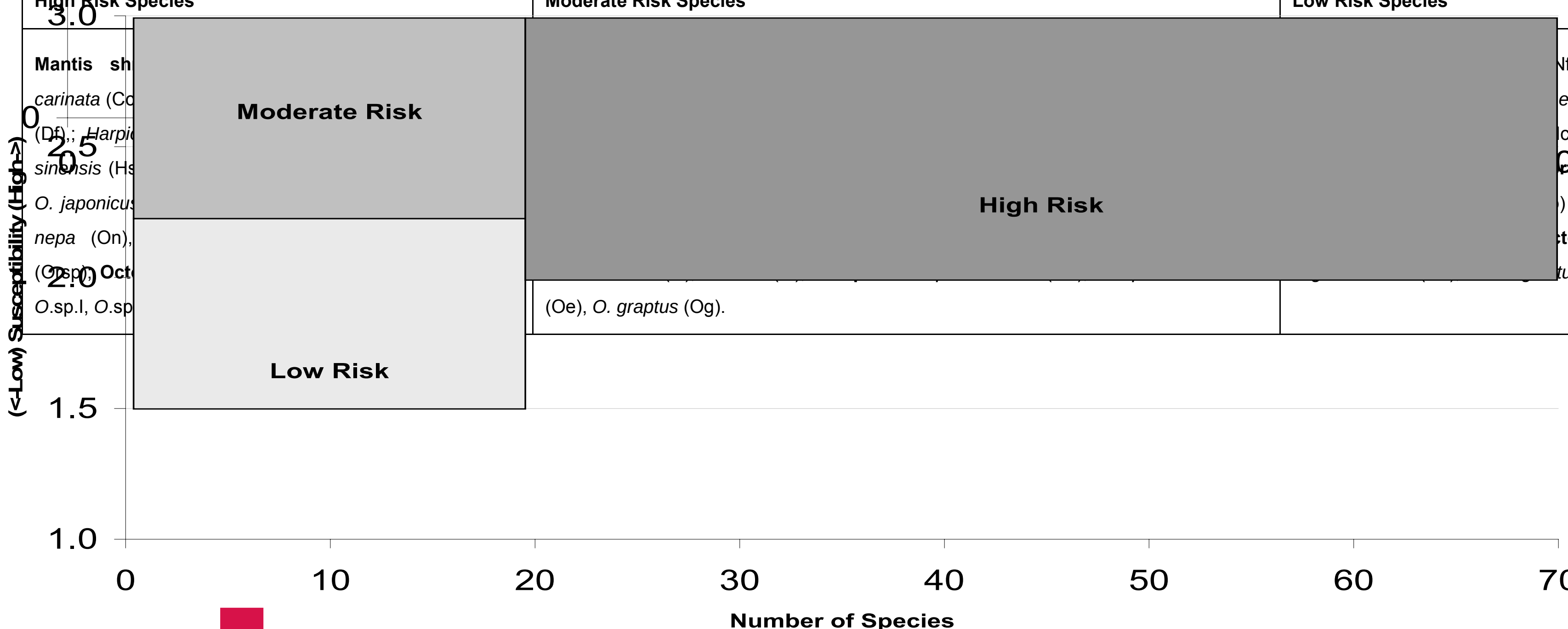
Total Risk Score	**Risk Rating**
<2.64	**Low**
≥ 2.64 and ≤ 3.18	**Moderate**
>3.18	**High**

Appendix 3. Productivity Scores



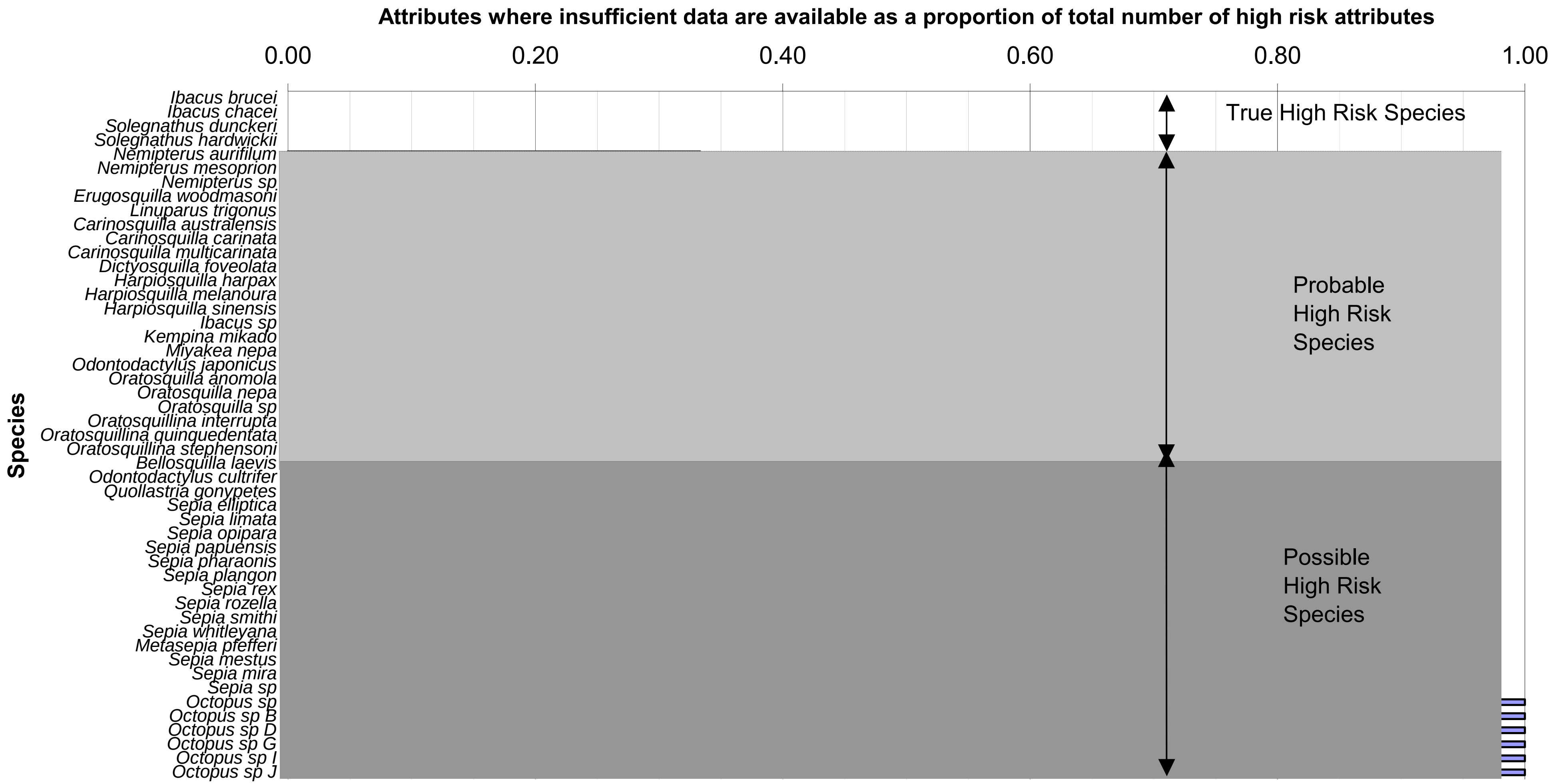
Appendix 4. Susceptibility Scores

High Risk Species	Moderate Risk Species	Low Risk Species
Mantis sh *carinata* (Co (Df),; *Harpi* *sinensis* (Hs *O. japonicus* *nepa* (On), (O.sp), **Octo** *O*.sp.I, *O*.sp	(Oe), *O. graptus* (Og).	Nf), *N. aurifilum* *etopias* (Nme), lc), *N. hexodon* **tunid crabs:**) *Portunus* **ctopus:**, *O.* *tus* (Om).

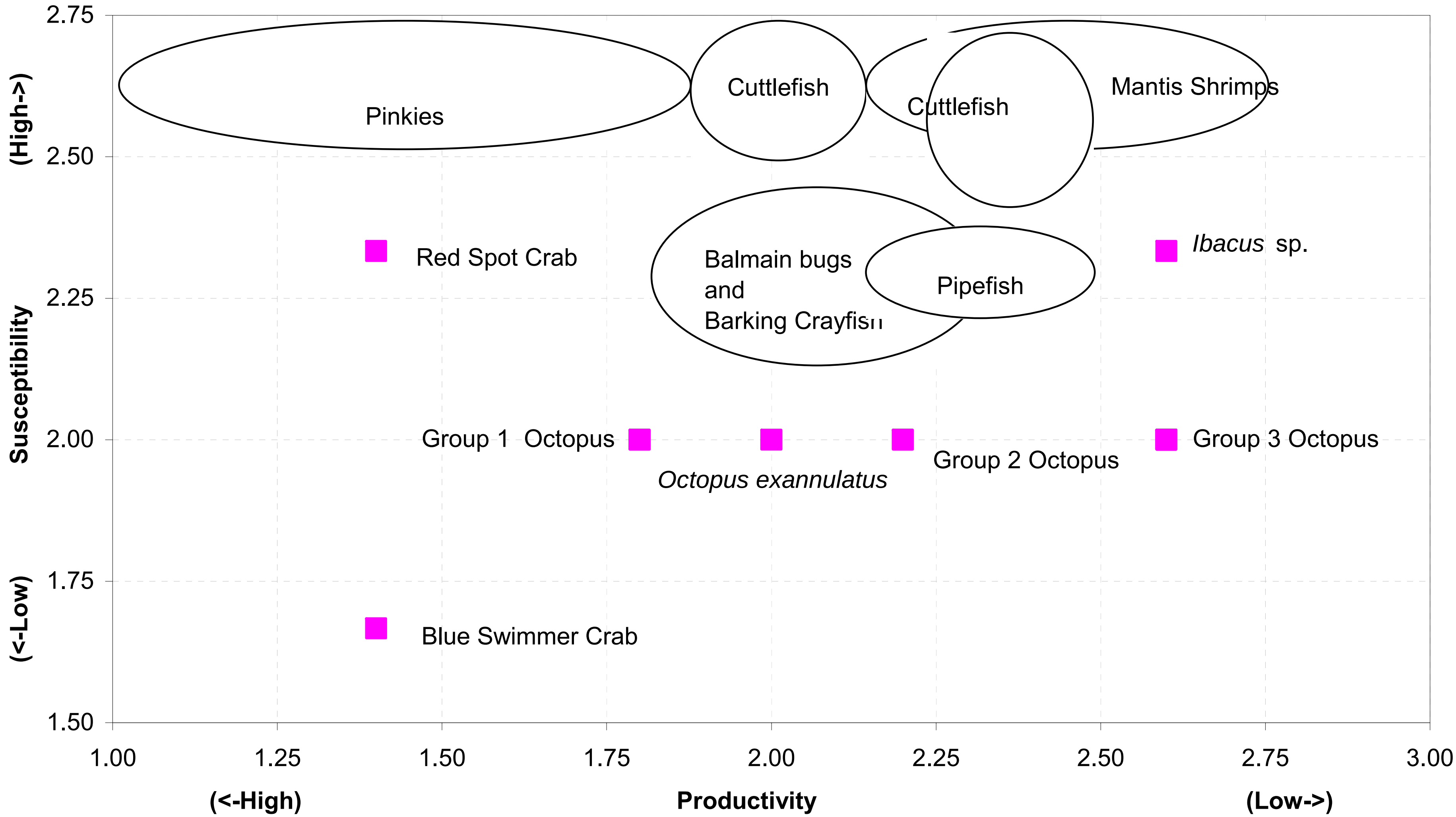


Low Risk Species	Moderate Risk Species	High Risk Species
Blue Swimmer crab: *Portunus pelagicus* (Pp); **Octopus groups 1, 2 and 3:** *Octopus australis* (Oa), *O.exannulatus* (Oe), *O. kagoshimensis* (Ok), *O. graptus* (Og), *O. marginatus* (Om), *Octopus sp., O. sp.B, O. sp. D, O. sp. G, O. sp. I, and O. sp. J.*.	**Balmain bugs:** *Ibacus chacei* (Ic), *I. brucei* (Ib); and *I.* sp.); **Barking crayfish:** *Linuparus trigonus* (Lt); **Red spot crab:** *Portunus sanguiolentus* (Ps); **Pipefish:** *Solegnathus hardwickii* (Sh) and *Solegnathus dunckeri* (Sd).	**Cuttlefish:** *Sepia limata* (Sl), *S. mestus* (Sm), *S. opipara* (So), *S. papuensis* (Spa), *S. pharoanis* (Sph), *Sepia plangon* (Spl) ,*S. rex* (Sre), *S. rozella* (Sro), *S. smithi* (Ss), *S. whitleyana* (Sw) and *Metasepia pfefferi* (Mp); and **Mantis shrimps:** *Bellosquilla laevis* (Bl), *Carinosquilla australensis* (Ca), *C. carinata* (Cc), *C. multicarinata* (Cm), *Dictyosquilla foveolata* (Df), *Erugosquilla woodmasoni* (Ew); *Harpiosquilla harpax* (Hh), *H. melanoura* (Hm), *H. sinensis* (Hs), *Kempina mikado* (Km), *Miyakea nepa* (Mn), *Odontodactylus cultrifer* (Oc), *O. japonicus* (Oj), *O. anomola* (Oa), *O. interupta* (Oi), *O. nepa* (On), *O. quinquedentata* (Oq), *Oratosquilla sp.* (Orsp), *O. stephensoni* (Os), *Quollastria gonypetes* (Qg).

Appendix 5. Assignment of Species to the Precautionary High Risk Category



Appendix 6. Risk Plot



6 Bycatch

6.1 Addressing Bycatch in the QECTF

6.1.1 *Purpose*

The incidental capture of non-target (and undersized target) species is a significant issue in all trawl fisheries. The Plan has a review event, to be assessed by 1 January 2005, of a reduction of the amount of fish taken other than principal fish by 40%. In order to meet this objective, a range of measures to reduce the level of bycatch in the fishery have been introduced. These include bycatch reduction devices (BRDs), turtle excluder devices (TEDs), permanent and temporal fisheries closures, effort reduction and effort concentration. In addition to these the Great Barrier Reef Marine Park (GBRMP) existing closures and the additional closures that came into effect on 1 July 2004 resulting from the Representative Areas Program (RAP) will afford significant protection to 'trawl bycatch' species populations. The RAP will result in a 43.3% reduction in the 'General Use A' zone, i.e. that which is open to trawling. Only 33.7% of the GBRMP is open to trawling as of 1 July 2004.

6.1.2 *Achievements under the plan*

Effort Reduction
As bycatch is caught in varying quantities throughout the fishery, reductions in fishing effort would have the largest single effect on the level of bycatch taken in the QECTF. The Plan has effectively reduced effort by 40% since 1996 (See section 8.1). This reduction in effort, results in a comparative reduction in the area swept by the fishery and therefore also a comparable reduction in the amount of bycatch captured.

BRDS
Bycatch reduction devices (BRDs) are devices placed in the trawl net to facilitate the escape of incidentally caught non-target and undersized target species, while minimising the loss of target species. BRDs were incrementally introduced into the fishery commencing May 1999 and compulsory in all nets by September 2002. There are currently 5 recognized BRDs listed in the Plan:

- Square mesh cod end (SMC);
- Square mesh panel;
- Fisheye;
- Bigeye; and
- Radial escape section.

The dimensions of each device, including their positioning in the net are all defined in the Plan to ensure, as far as possible, that each device is used to maximum affect. Several of these devices were tested during the FRDC PROJECT 2000/170: Bycatch weight, composition and preliminary estimates of the impact of bycatch reduction devices in Queensland's trawl fishery. The results of these tests are presented in Table 6.1.

Table 6.1. Bycatch reductions by device and sector from FRDC PROJECT 2000/170. Results are based on total bycatch, including monsters, from the 4 controlled charters.

Sector	BRD Type	Bycatch Reductions by device		
		BRD	TED	TED + BRD
Eastern king prawn (Shallow)	Radial Escape Section	19%	10%	24%
Eastern king prawn (Deep)	Square mesh codend	18%	3% increase	29%
Tiger/endeavour prawn	Radial Escape Section	11%	14%	20%
Saucer Scallop	Square mesh codend	40%	47%	77%

The DPI&F has also developed protocols to test new and modified devices that can be added to the list of recognized BRDs. These protocols include two phases:

- Fishers submit an application to trial a new BRD. Applications, which are approved by the technical working group, are given general Fisheries Permits to trial the device on board vessels during normal fishing activities.
- Subject to the results from the initial trials, a statistically robust trial may be conducted by the DPI&F to determine the effectiveness of the device. Final approval of the device is dependant upon effective bycatch reduction during this trial.

Funding and staff time has been allocated to test 2 devices for listing in the Plan by the end of 2004. This will include testing devices suitable for both the tiger/endeavour prawn fishery in north Queensland and the eastern king prawn fishery in south Queensland.

In May 2004, the DPI&F tested the first of these devices ("V-Cut in a bell codend") in the shallow water EKP fishery with encouraging results, particularly in the exclusion of finfish bycatch (average reduction in total bycatch of 16%).

TEDS

To reduce the capture and subsequent mortality of sea turtles in trawl nets, turtle excluder devices (TEDs) were implemented in certain sectors of the fishery in 1999 before being made mandatory in the entire QECTF in 2001. Dimensions of TEDs legislated in the QECTF are sufficient to allow at least 98% of all turtles encountered in the fishery area to escape from the net upon capture (Gaddes et al 2004). Even in areas where turtles are not generally encountered (such as the deepwater net area), TEDs are effective at excluding large bycatch such as sharks and rays.

Further development is to be undertaken during 2004 to improve the efficiency of TEDs in the fishery and to ensure that maximum protection is given to the largest Green turtles (Chelonia mydas) inhabiting the fishery area. This development will include 10 workshops to allow industry, DPI&F, AFFS and U.S. gear specialists to develop proposals for the use of TEDs that represent a balance between maximum turtle protection and optimum product retention.

Closed Waters

Bycatch species in Queensland are afforded a significant level of refuge by the large areas of the fishery that are temporally or permanently closed to trawling. The QECTF currently has:

- Seasonal closures – from 15 December until 1 March in the northern region and from 20 December until 1 November in the southern region;
- Daylight closures In the scallop fishery and parts of the tiger/endeavour prawn fishery;
- Weekend closures – In Moreton Bay; and
- Permanent and seasonal area closures - that were introduced for a range of reasons such as nursery and juvenile protection and avoidance of bycatch.

Table 6.2. Spatial analysis of the East Coast Trawl Fishery Area in 2002.

	Total Fishery		GBRWHA[12]	
	Area (km^2)	%	Area (km^2)	%
Total Area of Fishery	546,267	100%	345,848	100%
Total Area of Permanent Closures	172,089	32%	169,510	49%
Total Area available to be fished	374,177	68%	176,338	51%
Area Fished	140,852	26%	105,226	30%

[12] Closures based on current zoning as of 1 April 2003

Area Not Fished	233,326	43%	71,112	21%
Area of Major Seasonal Closures	312,654	57%	255,798	74%
Area with some restriction on trawling	318,954	58%	292,608	85%

The proportion of the fishery closed to trawling is shown in Table 6.2. In addition to the large areas of the fishery (32%) that are permanently closed to trawling, 43% of the area is not fished and 58% has some restriction on trawling. The introduction of the GBRMPA RAP increases these non-trawl areas, significantly increasing the refuge areas available to bycatch species. The RAP has resulted in a 43.3% reduction in the 'General Use A' zone, i.e. that which is open to trawling. Only 33.7% of the GBRMP is now open to trawling as of 1 July 2004.

Other Factors

Spatial changes in effort after the implementation of the plan can also change the amount of bycatch taken by the fishery. Figure 6.1 shows the relative bycatch catch rates for the 3 major sectors examined by the FRDC PROJECT 2000/170: Bycatch weight, composition and preliminary estimates of the impact of bycatch reduction devices in Queensland's trawl fishery. Clearly the deepwater eastern king prawn sector has the lowest levels of bycatch in the QECTF. Based on the data presented in section 3.2, there has been an overall shift in effort away from the tiger/endeavour prawn and saucer scallop sectors. The eastern king prawn sector also had an obvious shift in effort with a reduction in the shallower inshore areas and an increase in the deeper offshore areas. These shifts in effort may have resulted in a reduction in bycatch given the very low bycatch catch rates in the deep-water eastern king prawn sector.

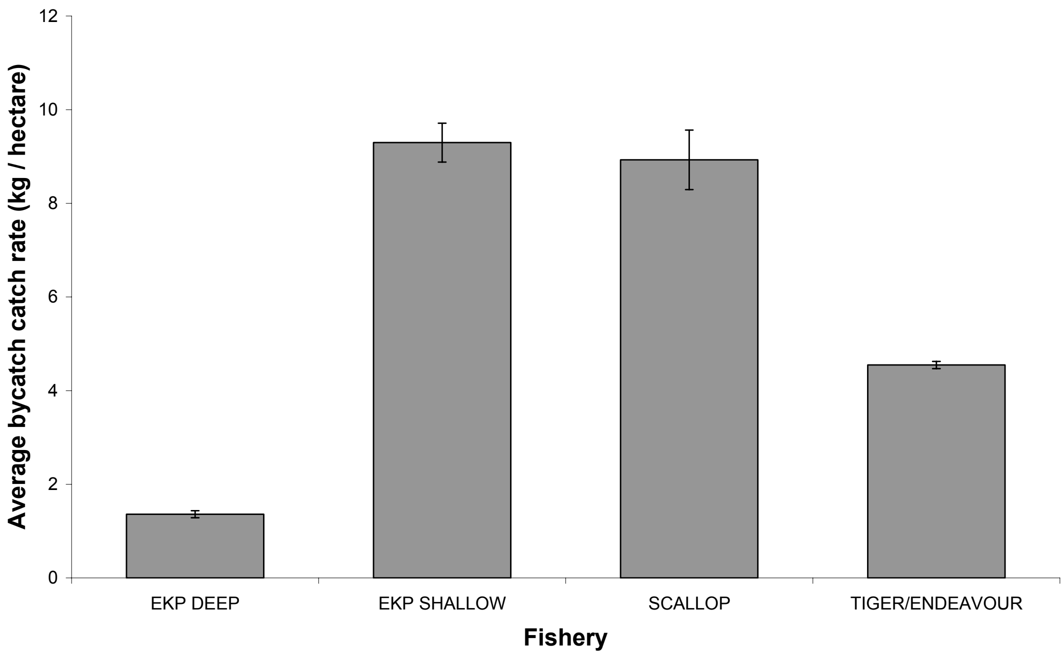


Figure 6.1. Bycatch catch rates by sector (based on a standard net with no BRDs).

6.1.3 *Research to assess the sustainability of bycatch*

The DPI&F has encouraged and contributed to several major research projects aimed at assessing and reducing the levels of bycatch in the QECTF, two of those projects are discussed below:

FRDC Project 2000/170: Bycatch weight, composition and preliminary estimates of the impact bycatch reduction devices in Queensland's trawl fishery.

The outcomes of this research project will enhance knowledge of the species composition of bycatch by major fishery sector in the QECTF. The project also tested recognised BRDs in the tiger/endeavour prawn, scallop, deep and shallow water eastern king prawn fisheries. The results of these tests will reveal the amount of bycatch reduction achieved by each device and the species each device excludes. The results of this project will be used to determine if the fishery has met the 40% reduction in bycatch as required under the plan. It is anticipated that a final report on this project will be released in late 2004.

FRDC Project 2003/021: Mapping Bycatch & Seabed Benthos Assemblages in the GBR Region for Environmental Risk Assessment & Sustainable Management of the Queensland East Coast Trawl Fishery.

From 2003 to 2006, this project will map sea floor habitats and their associated life across the length and breadth of the GBR marine park to support conservation and fisheries objectives. The project will assist in determining whether current harvests and impacts on non-target species and wider ecosystem values are consistent with ESD principles.
It is anticipated that a final report on this project will be released in 2007.

6.1.4 *Summary*

The qualitative analysis presented here indicates that the precautionary management measures in place are adequate to ensure that the impacts on the bycatch species in the fishery area are sustainable. A more comprehensive quantitative analysis may be available when the results of current research projects are published.

7 Economic sustainability

7.1 Economic Analysis of Changes in the Fishery

7.1.1 *Purpose*

Ensuring the economic viability of the fishery is a priority of the DPI&F. This section of the Review presents the first detailed assessment of the economic performance of the East Coast Trawl fishery (T1 and T2 endorsed vessels) from 1996 to 2003. The study period includes the introduction of the Trawl Plan, which involved reducing the number of vessels operating in the fishery as well as capping the fishing days at the 1996 level.

Note, the assessment is restricted to the catching sector and does not include downstream industries such as the processing sector due to the lack of adequate economic data.

7.1.2 *Economic studies of otter trawl fleets*

There are three studies that provide background data in relation to the financial and economic operation of otter trawl fleets in Australia: Torres Strait Prawn Fishery (Galeano *et al* 2003); Northern Prawn Fishery (Galeano *et al* 2003); and Queensland - Economic study of commercial fishing (QFS 1997/98).

7.1.3 *Which data to use?*

There are several consistencies between the three sets of information, notably the relative similarity between the percent of operating costs of crew (40%), fuel (20%) and repairs and maintenance (20%).

The differences between the East coast trawl fishery costs and the other two studies are essentially the crew costs. Crew costs on the east coat vessels will probably be higher as a proportion of total costs and of yearly boat income. The crew is usually paid a percent of trip turnover. In the case of Torres Strait and Gulf, ABARE used 8% for the skipper and 4% for the crew per person. This indicates that crew costs are about 32% of annual turnover. On the east coast the skipper may receive up to 18% of the turnover and the crew between 7% and 11% of the turnover. This translates around 40% of turnover.

Overall, cash costs account for about 75% of gross boat income. The three studies suggest that an average rate of economic return to capital investment to a fishing business is around 7%. It is predicted that the rate of return on the East coast T1/T2 fleet is around 4%.

7.1.4 *Prawn price trends*

Historical trends

Prawn prices in Queensland are established by a number of factors. These include the price received for export product; this price is influenced by:

- The value of the Australian dollar (AUD) compared to key currencies such as the $US;
- The demand in importing countries and the level of export (about 50% wild caught prawn production is exported);
- Supply of competing product both wild caught and aquaculture; and
- Species, prawn size (grade), form and quality.

In addition, the import of prawn in its various forms into Australia and the price for which it is sold, influences the price offered to fishers.

Figure 7.1 uses the domestic prawn prices complied by ABARE plotted against the movement of CPI over the same period. The domestic prawn prices are indicative only and are based on an amalgamation of sources such as the Sydney auction prices, Queensland fish board auction prices and information provided by prawn buyers operating in the domestic and export markets.

The CPI trend indicates that inflation increased over the period by about 4% each year. At the same time the nominal price of prawn increased by about 50 cents per kilogram each year from 1980 onwards.

The real price of prawns adjusted to the year 2002, increased by about 5 cents each year from 1979 to 2002 although there was much inter year variability over the period. The $US may have an effect on the variability of prawn prices.

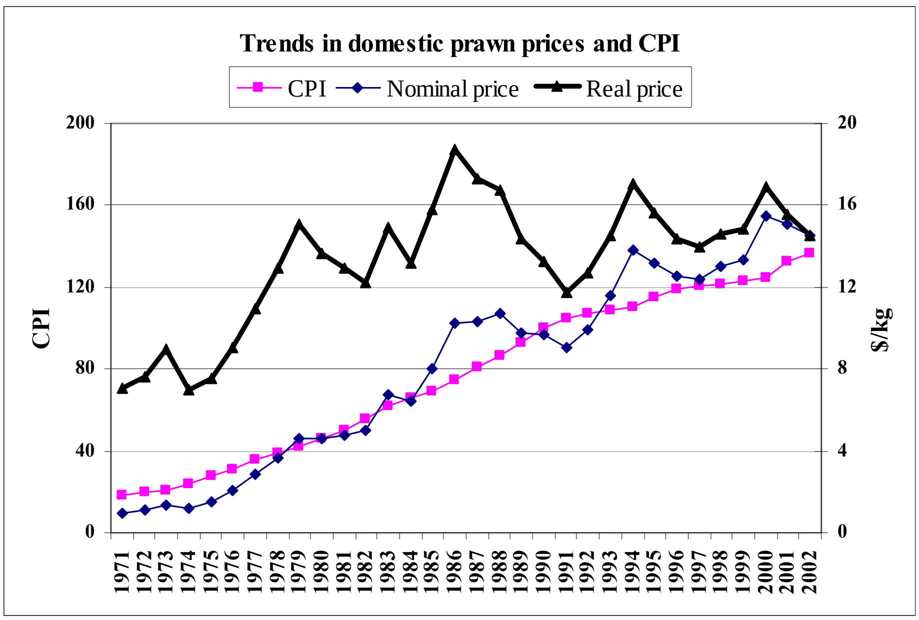


Figure 7.1. Trends in domestic prawn prices and CPI from 1971 to 2002.

Figure 7.2 shows the movement in real prices for the three main species harvested from 1992/93 to 2002/03. There has been significant inter-annual variability in the value of all species, with a consistent decline in since 2000.

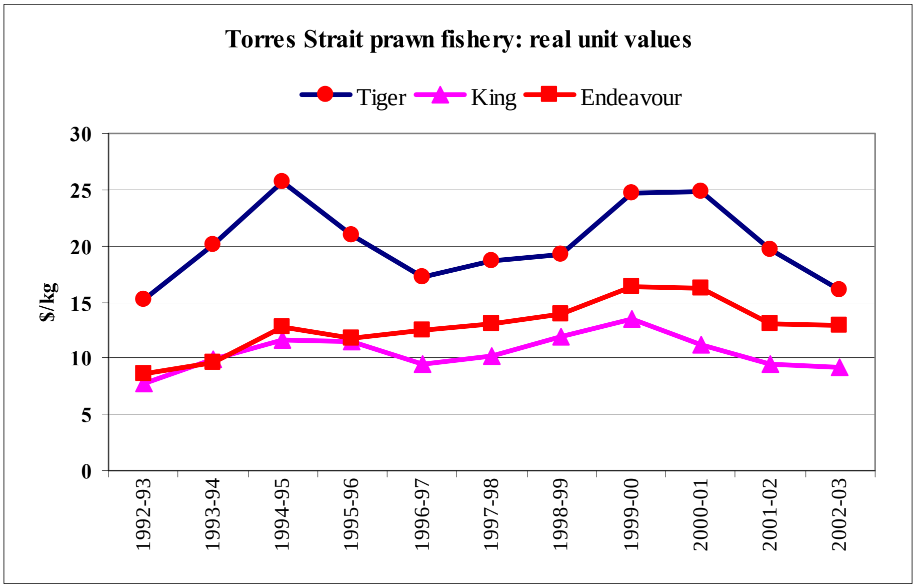


Figure 7.2. Torres Strait prawn fishery - real prices for the main species harvested. Graph is extracted from the ABARE "Australian fisheries surveys report 2003" for the Torres Strait prawn fishery (figure D pp21).

7.1.5 *Possible future trends in prawn prices*

A presentation to the Rural Press Club in April 2002 by C. Delgardo of a joint International Food Policy Institute/FAO study that analysed trends in livestock (including "fisheries" products) to the year 2020, suggested that the price offered for high value crustaceans would increase by approximately 16% from 1997 to 2020, and increase by less than 1% in real price each year. The study also suggested that "low value" food fish, which would include small aquaculture prawns, would only increase by 7% over the period, less than 0.5% each year.

As stated above, the relative value of the AUD compared to the $US plays an important role in determining economic viability, particularly via the export process. At present the AUD is about 75cents compared to the $US, which is considerably higher than it has been in previous years. The recent ABARE Outlook conference suggested that the AUD would remain at about this level for the remainder of the year then gradually decline to about 60 cents over the next five years. These values suggest that prawn export prices will be down compared to recent previous years when the AUD was at a lower level of around 0.55 $US.

The supply of aquaculture prawns worldwide has increased substantially over the last few years. This has lead to a glut in the small to medium prawns sizes especially of "vannamei" aquaculture prawns.

Some importing countries have strict conditions regarding quality of prawns being sold in their country. Negative influence on domestic production in both the wild caught and aquaculture sectors is also a key factor to some countries. Concerns over the levels of especially antibiotics in aquaculture prawns have been used as to exclude them from particular markets such as the USA. As a result of this embargo the producers then seek to unload the prawns into any available market that will accept them.

Australia currently accepts the import of "vannamei" prawns and this is of concern to both the aquaculture and wild harvest sectors in Australia. The stocks of "vannamei" prawn in Australia appear to be holding down the price being offered to trawler operators for small to medium prawns on the domestic markets.

Consequently, as a result of the relative strength of the AUD and the influence of imported aquaculture prawns is unlikely that prawn prices in real terms will return to what is regarded as normal prices in the near future and price will probably be at the lower level.

7.1.6 *Performance of the T1/T2 fleet – 1996 to 2003*

Background
Data used in this analysis was extracted from CEFISH in mid February 2004. It is anticipated that more than 93% of the 2003 data had been entered into the database and is included in this analysis. Catch data has been converted to income using standard "beach prices" that have been collated from a number of sources. It is acknowledged that these are estimates and the income data will not be 100% accurate. However, the methodology is sound for the analysis of industry wide trends.

East coast performances – summary results
The trawl Plan has resulted in significant changes to the number and size of vessels and their fishing behaviour. Table 7.1 shows the economic impact of these changes on the fleet. Despite a 7% reduction in the number of days fished per boat, all other rates of performance experienced significant increases of 22 to 29%.

Table 7.1. Temporal changes in number of boats, number of days fished, total catch, GVP, catch rates and effort per boat from 1996 to 2003.

Year	1996	1997	1998	1999	2000	2001	2002	2003
	Level of Performance							
Boats	759	767	747	734	706	582	483	466
Days	102176	106812	103998	98000	89695	67729	62432	58739
Catch (t)	10966	9914	11115	9976	8248	7995	8124	8108
GVP ($m)	136	123	139	125	103	101	101	102
	Rates of performance							
Kg/day	107	93	107	102	92	118	130	138
Days/boat/yr	135	139	139	134	127	116	129	126
T/boat/yr	14.4	12.9	14.9	13.6	11.7	13.7	16.8	17.4
GVP/boat/yr	178000	160000	185000	170000	146000	173000	208000	218000
GVP/day	1327	1153	1332	1274	1151	1493	1614	1737

Table 7.2 uses fleet averages (means) for 1996/97 and 2002/03 to show further trends in the operating performance of the trawl fleet. The number of boats in the fleet and the number of days fished in the fishery reduced significantly, resulting in deceases to both total GVP and total catch. Despite this, the rates of performance, notably kg per day and GVP per day increased over the period (Figures 7.3 and 7.4).

Other key findings:

- Average catch per boat per annum has increased from 14 tonnes to 17 tonnes; and
- Boats with a high annual catch displayed higher daily catch rates than low annual catch boats, meaning overall catch is not simply a function of number of days fished.

Table 7.2. Summary of trends for all T1 & T2 boats.

Item	Mean 9697	Mean 0203	Trend per year	Goodness Fit[1]	Percent change
Level of performance (total for fleet)					
Boats	763	475	-48	0.85	-38
Days	104494	60586	-7656	0.88	-42
Catch (t)	10440	8116	-477	0.76	-22
GVP ($m)	129	101	-6	0.75	-22

Rates of performance (means for fleet)					
Kg/day	100	134	5.1	0.55	34
Days/boat/yr	137	128	-2.2	0.50	-7
t/boat/yr	13.7	17.1	0.41	0.28	25
GVP/boat/yr	169000	213000	5476	0.32	26
GVP/day	1240	1676	66	0.58	35

[1]Goodness Fit (R^2) – the closer to 1 the better – if less than 0.55 not a good descriptor of the trend.

Figure 7.3 shows the significant reduction in the number of vessels and levelling out of catch since the introduction of the Plan. Figure 7.4 compares the decline in days fished per boat each year with the increase in GVP per boat for each year.

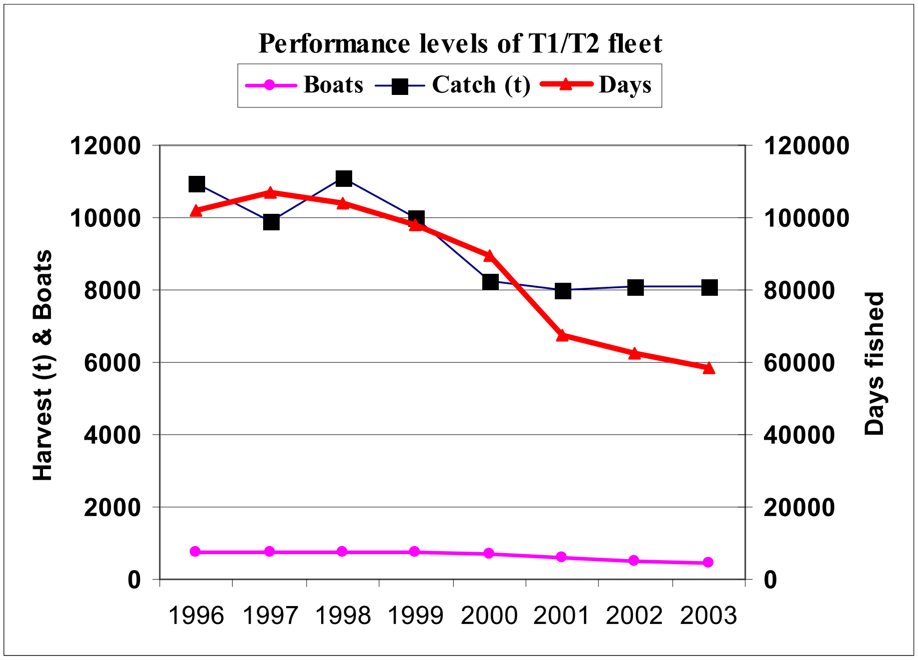


Figure 7.3. Trends in annual level of performance of T1/T2 fleet.

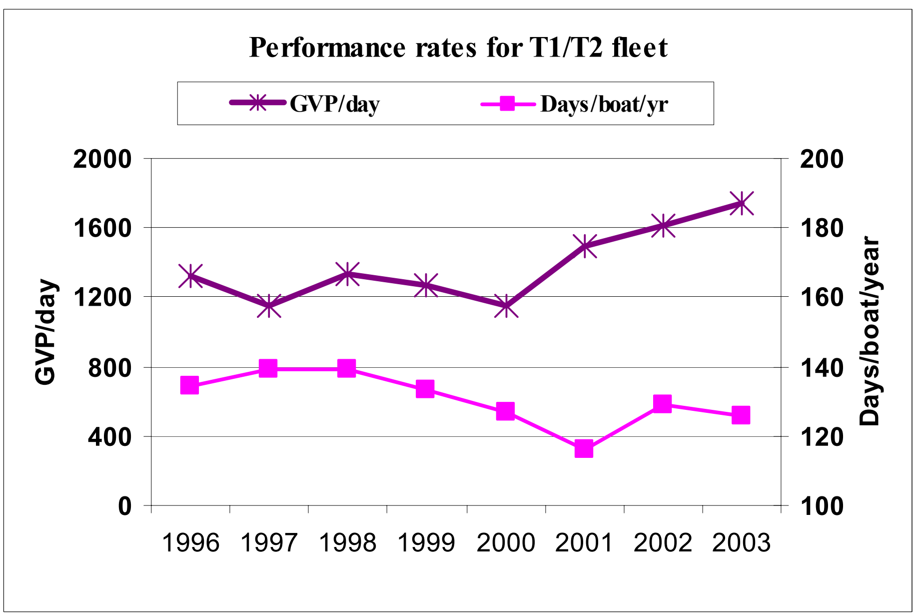


Figure 7.4. Trends in performance - indicators of rates (mean for T1/T2 fleet).

7.1.7 *State wide performance - Distribution analysis*

The summary information above provides a useful overview of what has occurred in the fishery. Distributional analysis provides a more detailed overview of the behaviour of the boats in the fleet and the resulting trends. Assessing the trends in the distributions is of particular value when there is considerable range in data values.

Table 7.3 shows the number of boats within arbitrarily defined annual catch categories (tonnes), for the years 1996 to 2003. The maximum number of boats in each year has been highlighted in grey.

The highlighted values indicate that the modal number of boats harvest between 15 to 20 tonnes of fish each year (Table 7.3). There has been little change between categories over the study period. The annual harvest per boat has increased from about 14t to 17t. This is primarily due to a larger proportion of boats harvesting at higher levels (Figure 7.5).

Table 7.3. Number of boats in each annual weight harvest category.

Catch category (t/year)	1996	1997	1998	1999	2000	2001	2002	2003
Less 0.2	8	6	9	8	7	10	7	
0.2 - 0.5	10	9	12	6	9	17	3	5
0.5 - 1	15	15	15	21	16	14	6	5
1 - 2	27	29	22	21	33	19	11	8
2 - 3	30	37	20	23	28	22	13	13
3 - 5	38	72	51	46	70	43	21	31
5 - 7	54	67	57	68	86	53	34	37
7 - 9	77	67	70	74	86	42	33	40
9 - 11	64	66	56	75	64	43	39	27
11 - 15	113	127	118	127	122	93	74	64
15 - 20	151	125	127	127	77	102	87	78
20 - 25	74	66	69	52	54	55	62	63
25 - 35	61	62	83	55	30	45	54	57
35 - 45	25	12	27	23	17	14	26	19
45 - 55	11	6	7	7	5	5	10	13
55 - 65	1		3	1	2	4	3	2
65 Plus		1	1			1		4
	759	767	747	734	706	582	483	466

Table 7.4 shows the number of days fished for the boats in each harvest weight category.

Table 7.4. Days fished per boat by annual weight harvested category.

Catch category (t/year)	1996	1997	1998	1999	2000	2001	2002	2003	Mean days
Less 0.2	3	7	4	3	2	9	6		5
0.2 - 0.5	8	8	10	9	7	8	10	15	9
0.5 - 1	10	21	15	19	20	14	13	8	16
1 - 2	23	32	25	22	38	24	25	26	28
2 - 3	43	51	32	40	43	33	37	29	40
3 - 5	57	65	62	66	77	59	50	51	64
5 - 7	90	104	83	93	96	70	70	82	88
7 - 9	107	122	112	105	124	100	96	80	109
9 - 11	123	133	130	127	126	105	104	98	121
11 - 15	142	160	153	147	150	131	121	116	143
15 - 20	166	184	169	169	173	150	144	138	164
20 - 25	196	193	187	196	194	168	163	152	181
25 - 35	207	229	210	210	224	187	185	186	205
35 - 45	225	246	237	244	233	232	229	228	234

45 - 55	249	255	275	241	256	259	242	236	249
55 - 65	275		271	284	193	278	293	234	264
65 Plus		276	278			333		319	309
Mean days per boat	135	139	139	134	127	116	129	126	131

In the modal weight class (15 – 20 t/year) the mean number of days fished has declined from about 170 days at the start of the period to about 140 days at the end (Table 7.5 and Figure 7.5). This suggests that the mean daily harvest has increased over the time. Similar patterns emerge for the 2-3 to 25-35 weight categories. The limited number of boats in the weight categories greater than the 35-45 makes it difficult to make any substantial conclusions.

Figure 7.5 shows the percent of boats in 1996-1997 and 2002-2003 (means of the two calendar years) for each of the harvest weight categories. It is apparent that there has been little change in the modal value from pre-plan to post-plan. However, a greater proportion of boats in the fleet in 2002-03 were harvesting at higher levels (20-25 tonnes and 45-55 tonnes) than in the pre-plan years.

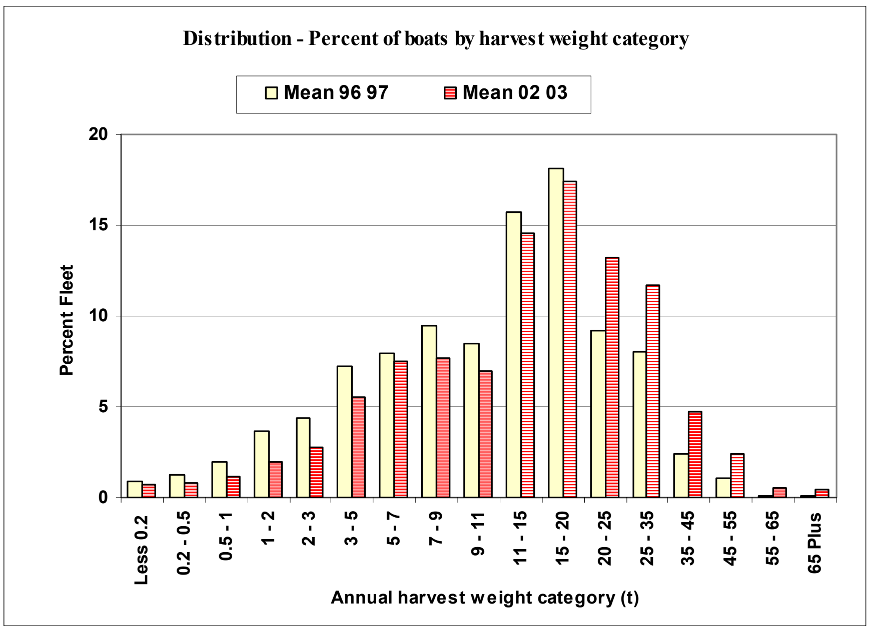


Figure 7.5. Distribution of the percentage of boats by harvest category.

Table 7.5, Figure 7.6 and Table 7.6 summarise the distribution of annual income by category over the period. Modal income is between $200 000 to $400 000 range. In 1996 to 2001, about 18% of boats were in this income range, compared to about 25% in 2002/03. When this information is converted to percent of boats in each income class the movement of boats toward higher income categories is clearly evident (Figure 7.6).

Figure 7.6 indicates that those boats in the higher annual harvest weight categories also had higher daily catch rates than those in lower annual categories. This means that those boats catching more 'product' per year are catching more 'product' per day and not necessarily just fishing more days per year.

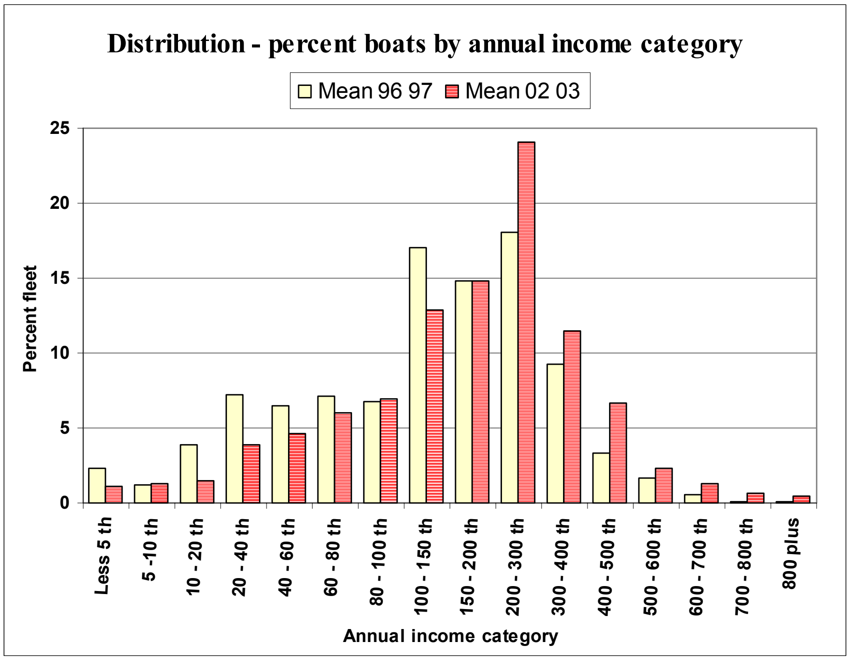


Figure 7.6. Distribution of the percent of boats by annual income category.

Table 7.5. Number of boats by Annual income category.

Income category	1996	1997	1998	1999	2000	2001	2002	2003
Less 5 th	20	16	17	16	19	24	8	3
5 -10 th	8	10	16	18	17	13	6	6
10 - 20 th	31	28	20	14	22	17	8	6
20 - 40 th	47	64	43	44	62	33	18	19
40 - 60 th	37	62	48	55	62	34	21	23
60 - 80 th	48	61	54	48	63	45	26	31
80 - 100 th	53	50	43	52	55	36	29	37
100 - 150 th	134	126	112	141	133	93	69	53
150 - 200 th	117	109	118	116	96	82	72	69
200 - 300 th	142	133	132	127	102	112	120	109
300 - 400 th	65	77	76	51	44	52	56	53
400 - 500 th	30	21	39	33	13	27	32	31
500 - 600 th	18	7	23	13	13	7	10	12
600 - 700 th	7	2	3	4	3	5	6	6
700 - 800 th	1		3	2	2	1	2	4
800 plus	1	1				1		4
Total boats	759	767	747	734	706	582	483	466

th = Thousands of dollars

About 60% of the boats were in the income range from $100 000 to $400 000 from 1996 to 2001. This has increased to just over two thirds of the fleet in 2002/03. In 2002 and 2003 the modal value of about 25% of the boats were in the $200 000 to $300 000 range, an increase from about 18% of the fleet for 1996 to 2001 period.

Table 7.6. Mean daily gross income ($) (called GVP) by annual income categories.

Income category	1996	1997	1998	1999	2000	2001	2002	2003	Mean Daily $

Less 5 th	375	224	311	301	374	272	303	154	292
5 -10 th	615	271	688	397	307	696	646	722	448
10 - 20 th	491	375	544	750	396	591	574	690	489
20 - 40 th	715	536	624	627	471	734	919	865	607
40 - 60 th	680	630	589	587	558	883	903	1006	652
60 - 80 th	700	643	779	731	642	906	1089	892	745
80 - 100 th	943	768	845	871	821	975	1035	1092	893
100 - 150 th	986	911	945	983	983	1082	1153	1291	1003
150 - 200 th	1111	1037	1128	1147	1153	1367	1351	1445	1180
200 - 300 th	1422	1325	1406	1401	1352	1634	1623	1692	1464
300 - 400 th	1675	1591	1718	1717	1604	1851	1979	2025	1749
400 - 500 th	2020	1727	1886	1917	1857	2083	2012	2173	1965
500 - 600 th	2379	2115	2233	2206	2155	2435	2226	2171	2240
600 - 700 th	2314	2541	2556	2473	2880	2359	2505	2936	2536
700 - 800 th	2590!		2652	2610	3487	2319	2260	3143	2758
800 plus	4387	3865				2478		2870	3079
Mean Daily $	1327	1153	1332	1274	1151	1493	1614	1737	1348

The mean number of days fished by the fleet has declined from about 140 days to 130 days per vessels per year (Table 7.1). This reduction in fishing effort is reflected in Table 7.7 where modal value declined from the 150 to 200 days fished category to the 100 to 150 days fished category.

Table 7.7. Number of boats in days fished category.

Days fished category	1996	1997	1998	1999	2000	2001	2002	2003
1 - 10	24	19	24	28	19	27	13	6
10 - 30	53	52	57	36	45	48	21	25
30 - 60	51	62	55	64	55	61	44	46
60 - 100	88	88	69	83	113	81	64	77
100 - 150	201	174	161	205	198	177	153	148
150 - 200	209	213	236	194	180	145	135	114
200 - 250	110	127	116	94	82	30	39	34
250 plus	23	32	29	30	14	13	14	16
Boats	759	767	747	734	706	582	483	466

There has not been any major change in the distributions of fishing effort between the start and the end of the study period (Figure 7.7), apart from the small modal shift noted in Table 7.7.

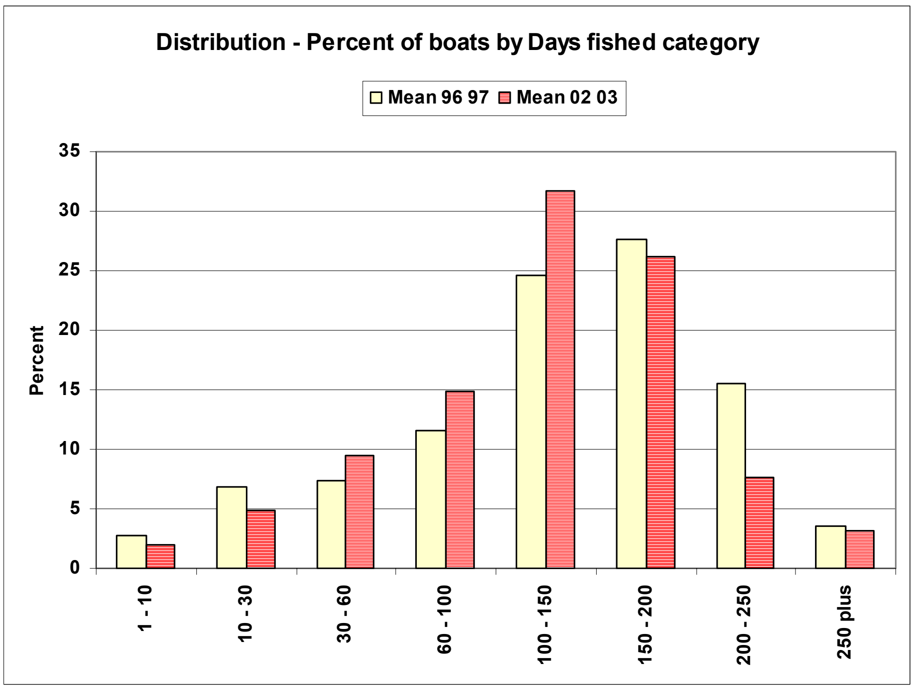


Figure 7.7. Percent of Fleet - distribution percent by annual days fished category.

Tables 7.8 and 7.9 summarise the number of boats in days fished and boat hull units (vessel size). The largest proportion of vessels in the fleet (24%) are between 36 to 45 Hull Units, these vessels typically fish between 120 to 180 days per year.

Table 7.8. All T1/T2 - Number and percent boats - categorised by days fished and hull unit categories – mean 2002 and 2003.

Days fished category	Hull unit category							No. Boats	% Boats
	less 15	16 - 25	26 - 35	36 - 45	46 - 55	56 - 65	65 plus		
1 - 10	6	0	1	1	3	2	0	7	1
10 - 30	9	3	1	3	3	6	8	18	4
30 - 60	18	10	6	7	8	10	19	43	9
60 - 90	31	17	11	5	8	14	11	54	12
90 - 120	17	24	17	11	19	4	12	70	15

120 - 150	14	23	25	21	22	12	14	93	20
150 - 180	5	19	25	23	24	19	12	91	20
180 - 210	0	5	11	14	5	13	8	41	9
210 - 250	0	0	4	13	5	7	6	27	6
250 plus	0	0	0	3	3	13	8	15	3
Total	100	100	100	100	100	100	100	457	100
Boats – (number)	33	77	89	111	59	47	42	457	0
Boats (% total)	7	17	19	24	13	10	9	100	

It is worth noting that some of the lager vessels in the fleet are dual endorsed (i.e. they have licences to trawl in other fisheries such as the Torres Strait). This means that the number of days they fish per year has decreased due to fishing in other fisheries.

Hull unit size appears to have a positive effect on mean daily harvest per boat. This is supported by industry information. Excluding the "less than 15" hull unit boats because of the small number of boats in the group, it appears that mean daily harvest increases from about 100 kg/day for the 16 - 25 hull units up to 152 kg for the 46 – 55 hull unit vessels (Table 7.9). The daily harvest rate remains relatively consistent for boats with more than 56 hull units at approximately 160 kg per day (Table 7.8). There are about 89 boats in these two categories.

Secondly, overall, the mean daily harvest rate increased with days fished, meaning that boats that fished for more days also caught more product each day. Mean daily catch rates declined from about 130 kg/day for the 10 to 60 days fishing activity to a low of about 117 kg/day for the 120 – 150 days fished category and then increased to about 170 kg/day for the highest days fished category.

Table 7.9. All T1/T2 - Mean daily harvest per day - categorized by days fished and hull unit categories – mean 2002 and 2003.

Hull unit category								
Days fished category	less 15	16 - 25	26 - 35	36 - 45	46 - 55	56 - 65	65 plus	Mean Kg/day
1 - 10	110			197	134	116		118
10 - 30	72	106	87	128	109	135	206	131
30 - 60	65	118	110	131	125	154	203	130
60 - 90	83	81	101	129	155	182	149	115
90 - 120	64	103	110	128	153	174	184	121
120 - 150	69	97	105	129	141	137	150	117
150 - 180	75	104	127	131	155	152	150	132
180 - 210		112	128	158	151	154	170	147
210 - 250			139	166	199	160	140	163
250 plus				173	151	176	171	171
Mean Kg/day by Hull	73	101	118	144	152	160	163	134

Note there are several large vessels register to fish on the East Coast that probably fish significantly in other jurisdictions such as the Torres Strait and the Northern Prawn Fishery. These vessels fish only 10 – 60 days on the east coast however have some of the highest catch rates (Table 7.9).

7.1.8 *Performance of boats operating in 2003 – trends since 1996*

In 2003, 466 T1/T2 boats reported actual fishing in the East Coast Trawl fishery. This section assesses the performance of the 466 boats since 1996. The data presented below are based solely on the 466 boats that reported fishing activity in 2003. It is worth noting that the actual number of boats that reported fishing varied from year to year. This, and the fact that there were approximately 20 licensed boats in the fishery that did not fish in 2003 supports the assumption that there will always be a certain proportion of un-fished effort in any given year. This also supports the appropriateness of analysing actual effort as well as potential effort in section 8 below.
Tables 7.10 to 7.12 present the same information as tables 7.1 to 7.9, but only for the 466 boats that reported fishing in 2003. Data in Tables 7.10 to 7.12 show similar trends to the overall fleet.

Table 7.10. Annual performance since 1996 of T1/T2 boats active in the fishery in 2003.

Year	1996	1997	1998	1999	2000	2001	2002	2003
Level of performance								
Boats	446	454	446	454	449	457	453	466
Days	64408	66097	65685	63478	61589	57785	60553	58739
Catch (t)	7455	6664	7657	7069	6286	7110	7887	8108
GVP ($m)	94	85	97	90	80	91	98	102
Rate of Performance								
Kg/day	116	101	117	111	102	123	130	138
Days/boat/yr	144	146	147	140	137	126	134	126
T/boat/yr	16.7	14.7	17.2	15.6	14.0	15.6	17.4	17.4
GVP/boat/yr	211000	187000	218000	198000	179000	199369	216000	219000
GVP/day	1463	1285	1480	1418	1302	1577	1616	1737

Table 7.11. Summary performance since 1996 of T1/T2 boats active in the fishery in 2003.

Item	Mean 9697	Mean 0203	Trend per year	Goodness Fit[1]	Percent change
Level of performance (total for fleet)					
Boats	450	460	0.27	0.53	2
Days	65253	59646	0.00	0.75	-9
Catch (t)	7060	7997	0.00	0.15	13
GVP ($m)	90	100	0.13	0.14	12
Rates of performance (means for fleet)					
Kg/day	108	134	0.13	0.50	24
Days/boat/yr	145	130	-0.26	0.79	-10
t/boat/yr	16	17	0.50	0.07	11
GVP/boat/yr	199163	217496	0.00	0.06	9
GVP/day	1374	1677	0.01	0.50	22

[1]Goodness Fit (R^2): the closer to 1 the better, and if less than 0.55 not a good descriptor of the trend. R^2 is only a simplistic method for demonstrating the "spread" of data around a trendline. However, it is worth noting that the goodness of fit estimates in the trends from the remaining fleet are very poor compared to the goodness of fit in the trends from the overall fishery (Tables 7.2 and 7.11). This could be interpreted as meaning that the trends shown in Table 7.2 are being driven, to some extent, by the reductions in fishing effort and number of boats.

Distribution analysis

Table 7.12. Number of boats by days fished categories.

Days fished category	1996	1997	1998	1999	2000	2001	2002	2003
1 - 10	12	13	11	12	9	7	7	6
10 - 30	29	34	36	24	25	30	13	25
30 - 60	24	31	31	43	36	41	40	46

60 - 90	24	33	25	31	45	45	47	61
90 - 120	55	38	33	47	55	71	65	74
120 - 150	71	63	58	80	71	96	96	90
150 - 180	84	81	85	83	84	83	97	86
180 - 210	69	71	83	63	62	50	49	33
210 - 250	60	66	61	47	48	21	25	29
250 plus	18	24	23	24	14	13	14	16
Total boats	446	454	446	454	449	457	453	466

The Table 7.12 and Figure 7.8 show a concentration of boats to the 30 – 180 days fished categories. The boats that have moved into these categories have mainly come from the 180 – 250 days fished categories. This assumption is supported by Table 7.13, which shows that only 30% of boats in the remaining fleet increased the number of days they fished between 1996 and 2003.

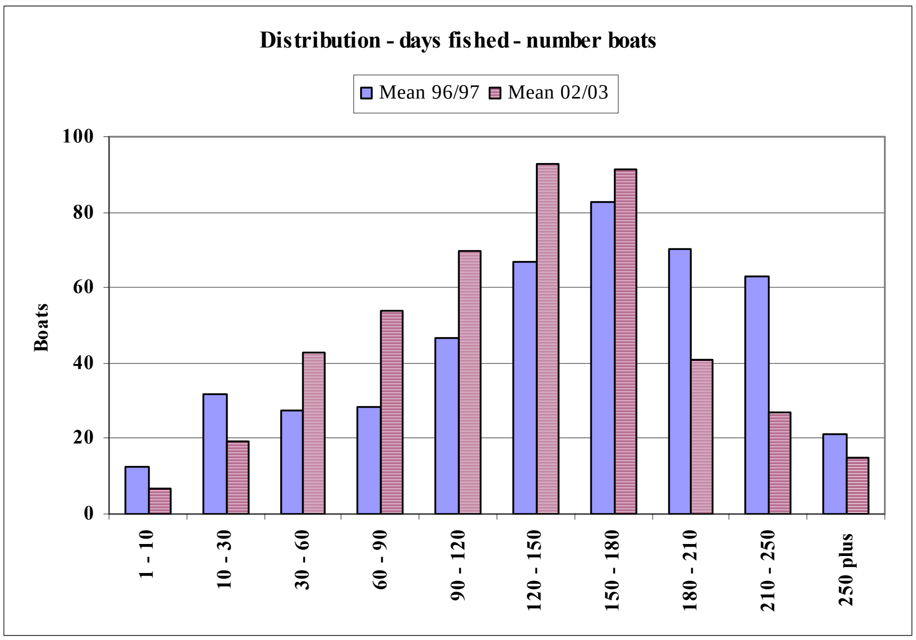


Figure 7.8. Distribution of the number of boats by days fished categories.

Table 7.13. Boats changing days fished from 1996 to 2003.

Indicator	Boats	Percent
Decreased days	324	70
Increased days	142	30
Total boats	466	100

The Figure 7.9 indicates that the number of boats in the $150 000 to $400 000 categories has not changed between the start and end of the study period. However, mean daily harvest per boat in each of the groupings has increased. Furthermore there is an increase in the number of boats in the $400,000 to $500,000 income category.

Overall, 70% of the boats decreased the number of days they fished over the period from 1996 to 2003. The data infers that the overall economic efficiency of the fleet has improved, this is reflected in the increase in daily catch rates, that have been achieved through fishing for a fewer number of days (70% less days) (Figure 7.9).

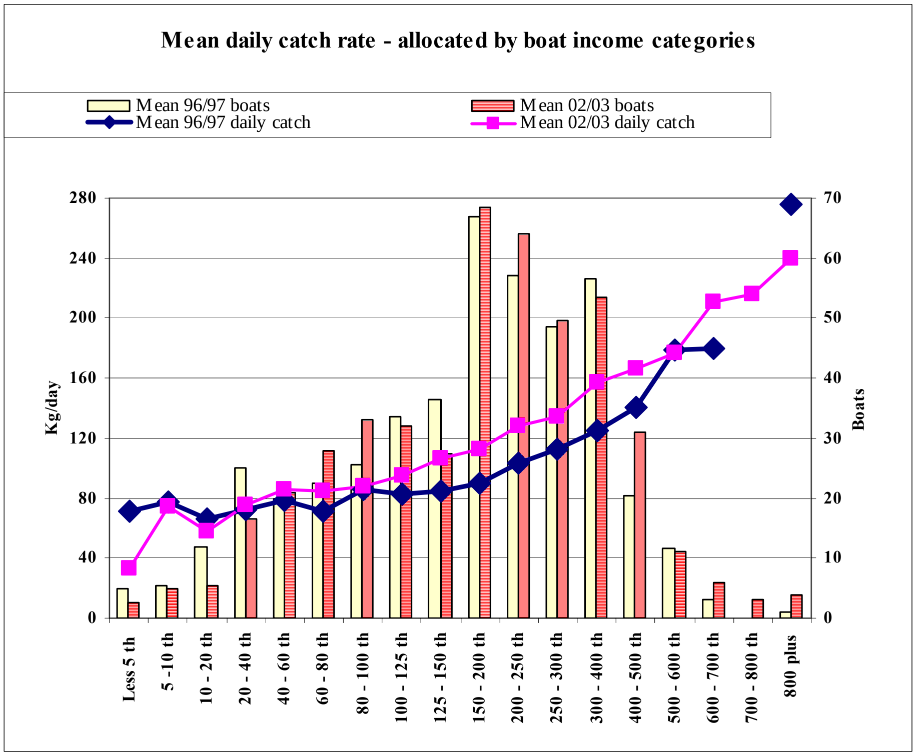


Figure 7.9. Mean daily catch rate and number of boats classified by income categories.

Table 7.14 summarises the number of years that each boat in the remaining fleet reported fishing activity in the eight years from 1996 to 2003. Eighty-seven percent of the boats fished in all eight years, i.e. every year from 1996 to 2003.

Table 7.14. The number of years during the 1996 to 2003 period that boats reported catch.

Years	Boats	Percent
3	2	0
4	5	1
5	3	1
6	15	3
7	34	7
8	407	87
Total	466	100

7.1.9 *Regional Analysis – ALL T1/T2 vessels*

For the purposes of a regional analysis, two provinces were delineated; the northern trawl province (north of 22 degrees the Cape York and within the GBR lagoon) and the southern trawl province south from 22 degrees to the NSW border, outside the GBR lagoon, but excluding Moreton Bay.

Boats that worked in both areas have been included in both sets of analyses. Possible future analyses will differentiate between those boats that worked only in a single province and those that worked in both and will investigate the changes through time.

Table 7.15. Northern Province - summary data.

Item	Trend	Goodness of fit	Percent change	Mean 96/97	Mean 02/03
Level of Performance (total)					
Boats	-33	0.84	-37	494	310
Catch (t)	-343	0.66	-26	6014	4478

Days	-4238	0.84	-42	54469	31605
GVP ($m)	-5	0.66	-27	78	57
Rate of Performance (means)					
Mean					
Kg/day	4	0.43	28	110	142
Days/boat	-2	0.54	-8	110	102
T/boat	0.21	0.10	18	12	14
GVP/boat	2268	0.07	17	157496	183971
GVP/day	53	0.37	27	1424	1804

Table 7.16. Southern Province - summary data.

Item	Trend	Goodness of fit	Percent change	Mean 96/97	Mean 0203
Level of performance (total)					
Boats	-35	0.89	-42	524	302
Catch (t)	-133	0.49	-18	4419	3638
Days	-3418	0.80	-42	50025	28981
GVP ($m)	-1	0.26	-14	52	44
Rate of performance (means)					
Mean					
Kg/day	6	0.69	42	89	126
Days/boat	0	0.01	1	95	96
T/boat	0.55	0.73	43	8	12
GVP/boat	7676	0.81	49	98762	147527
GVP/day	82	0.78	48	1036	1536

The “Percent change” columns in Table 7.15 and 7.16 provide the clearest summary of the temporal changes that have occurred in the fleet over the period of the introduction of the Plan. The number of boats working in the Northern province declined by approximately 37% while in the Southern Province numbers declined by approximately 42%. Catch declined by 25% and 18% in the Northern and Southern provinces respectively.

The mean daily harvest increased by 28% in the Northern Province and by 42% in the Southern area. Days per boat declined in both areas while mean annual GVP per boat and mean income per day also increased.

The data summarised in this ‘economic performance section’ of the General Effort Review indicates positive trends regarding the economic viability of the trawl fleet. However, caution should be used in extrapolating beyond that reported, as additional analysis needs be undertaken to identify the actual causes of the apparent changes. For example, there are many factors other than management arrangements that can influence fishing activity, catch rates and profitability of fishing businesses.

8 Effort Management

8.1 Review of Effort Management Tools under the Fisheries (East Coast Trawl) Management Plan 1999

8.1.1 *Purpose*

This section of the Effort Review reports on the mechanisms currently in place to manage effort in the East Coast Trawl Fishery, and outlines the performance of the fishery in achieving the effort reductions outlined in various agreements made between the Queensland Government, Industry and the Commonwealth Government. Effort management forms the basis of the Plan and probably constitutes the largest single reform that the trawl fishery has undergone. Fishing effort is measured and discussed in several contexts as described below.

8.1.2 *Measures of Effort*

Fishing Days
Fishing days have historically been used to measure and record fishing effort in the QECTF (and most fisheries). In the past, a fishing day has simply been a day in which a particular vessel or vessels fished. However, this is not the case anymore.

During the effort allocation process, days fished were counted from individual logbooks in the QECTF. These days formed the basis of the decisions regarding the allocation of effort. As a result of this process, each licence was allocated a certain number of "fishing days". Fishing days are the simplest measure of effort, however, other measures have been chosen for specific circumstances because they allow greater accuracy.

Steaming Days
Four steaming days are allocated to operators on an annual basis. These days are issued to compensate for circumstances where the Vessel Monitoring System records an individual as having fished (and therefore deducts a fishing day from the licence) and the fisher disputes the use of the day however is not able to provide sufficient evidence to convince the decision-maker that fishing did not occur.

Note: It is legal for operators to fish on a steaming day.

Over Quota Days
As discussed above, each operator is allocated a certain number of fishing days and is allowed to supplement these days with steaming days. If an individual continues to fish once all of their fishing and steaming days are used, each subsequent day is recorded as an over quota day. There are very few over quota days recorded each year.

Active Days
An active day is any day on which trawling occurs. Active days are therefore a summation of fishing days, steaming days and over quota days. Active days are usually used when discussing effort in conjunction with catch (such as CPUE), as active days are in effect what the logbook system records. Active days used to be referred to as "fishing days" or "days fished" prior to the implementation of the Plan.

Hull Units
Hull Units are a measure of the size of each vessel. In short, Hull Units are a measure of the underdeck volume of the boat.

Effort Units
Effort Units (EUs) form the basis of the Effort Management System (EMS) under the Plan. Once the number of fishing days that each operator was entitled to had been calculated, these days were converted to EUs based upon the size of each individual vessel (measured in Hull Units). Therefore a EU is a standardised measure of fishing effort; hence a large vessel requires more EUs than a smaller vessel to make one fishing day.

EUs were introduced into the QECTF to account for the fact that a small vessel is not likely to exert the same amount of “fishing power” in one active day as a larger boat. The EMS is based upon an inter-tradeable system, it was important that some commensurate measure of effort was introduced that could be traded between licences. An EU is a standardised measure of fishing effort, regardless of the vessel it is used by a large vessel requires more EUs to make one fishing day than a small vessel. In this way effort creep, whereby whole fishing days are transferred from small vessels to large ones, is countered.

EUs only pertain to fishing days. That is, the EUs were converted from fishing days to allow trading. The steaming days are issued to each individual on a yearly basis and are not tradable. There is therefore no general need to discuss steaming days in terms of EUs (with the following exception).

Notional Effort Units
As part of the agreement between the State and Commonwealth Governments regarding the Plan, a specific cap on the use of effort in the GBRWHA was agreed upon. This cap was to be measured in EUs (as they are the most appropriate measure of absolute fishing effort). The Great Barrier Reef Marine Park Authority raised concerns that fishing could occur on steaming days without contributing to the cap. This was particularly a concern at the time as each operator was issued 14 steaming days per year (as opposed to the current 4).

Notional effort units therefore include fishing days, steaming days and over quota days and were introduced specifically, and only for measuring effort in the GBRWHA in terms of the effort cap. In this regard, the Clients Licensing System (a DPI&F data base linked to VMS) converts all active days to notional EUs.

8.1.3 *Relationship between Boat Length and Fishing Power*

While there is general agreement that there is a relationship between the size of a boat and its fishing ability, researchers, managers and industry have struggled to reach agreement on the nature of the relationship. In April 2000, the Department contracted the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to develop a model that quantified the relationship. CSIRO completed this task by comparing the catch rates of given vessels with their attributes. The CSIRO model formed the basis of the “Effort Unit Conversion Factors” (EUCFs) that are now included in the Plan.

As stated above, a single EU constitutes the same amount of fishing power regardless of which licence uses it. As a large boat requires more EUs to make a fishing day than a small boat the EUCF is used to define the number of EUs required by a given sized boat to make each fishing day. Table 8.1 summarises the EUCF (or number of effort units per fishing day) for each size-class of boat.

Table 8.1. Effort Unit Conversion Factors (Schedule 5 of the *Fisheries (East Coast Trawl) Management Plan 1999*).

Hull Units	EUCF
1	3
2	5
3	6
4	7
5	9
6	10
7	11
8	12
9	13
10	14
11	15
12	16
13	17
14	18
15	19
16	20
17	21
18	22
19	23
20	24
21	25
22	26
23	27
24	28
25	28

Hull Units	EUCF
26	29
27	30
28	31
29	32
30	33
31	33
32	34
33	35
34	36
35	37
36	37
37	38
38	39
39	40
40	40
41	41
42	42
43	43
44	43
45	44
46	45
47	46
48	46
49	47
50	48

Hull Units	EUCF
51	49
52	49
53	50
54	51
55	51
56	52
57	53
58	54
59	54
60	55
61	56
62	56
63	57
64	58
65	58
66	59
67	60
68	60
69	61
70	62

The application of EUCFs accounts for the majority of effort creep that occurs through size increase when a small boat is replaced with a large one. It does not, however account for effort creep as a result of technological improvement, engine size change etc.

8.1.4 *Effort Unit Reduction Targets*

During the development of the Fisheries (East Coast Trawl) Management Plan 1999 (Plan) in general and the effort management component specifically, there were considerable negotiations about the need to reduce fishing effort in the fishery. The magnitude of the required reductions and the mechanisms needed to achieve them were particular points of discussion.

Between 1999 and 2000, this topic was discussed in many forums, including a task force of the Great Barrier Reef Ministerial Council (GBRMC), the GBRMC itself, and a stakeholder working group set up by the Premier of Queensland. The outcomes from such forums were used in negotiations between the parties.

The final agreements reached between industry representatives, the Queensland and Commonwealth Governments are based upon the outcomes of the Premiers Stakeholder Working Group (PSWG) and are largely reflected in the Plan.

In short, the agreement that was reached as far as effort management in the wider trawl fishery was as follows:

- Use the 1996 levels of fishing effort as a starting point (108,356 days);
- Immediate reduction of 5% of fishing days as the industry contribution to a structural adjustment scheme (reduced to 1996 level to 102,929 days);

- Government funded "buy-back" to target removal of a further 10% of effort units;
- Inclusion of surrender provisions to annually reduce the number of effort units in the fishery to compensate for increases in fishing effort due to boat replacement, technology uptake and other factors (effort creep); and
- A mandatory review of fishing effort in the fishery after three effort years (the GER).

This agreement differed from early deliberations by the GBRMC and its task force, which advocated an effort cap based on 1996 levels, followed by a reduction of 15% over the first three effort years, followed by a review. If that review demonstrated that effort was not yet sustainable, a further 10% reduction (5% per year) in effort would be required in 2004 and 2005. It was determined that this regime would have a significant negative impact the economic viability of individuals in the fishery and was not accepted by the Queensland Government.

Effort Reduction Targets in the Plan

According to Schedule 2 of the Plan, in order to meet the objective of "ensuring fisheries resources are taken in an ecologically sustainable way", the number of EUs must decrease by:

13% or more in the first effort year; and
1% or more in each subsequent effort year; and
2% or more during every 2-effort years for any licence.

Schedule 2 also states that to meet the objective of "providing an economically viable, but ecologically sustainable, trawl fishery", the number of EUs must not decrease by:

4% or more in each of 3 consecutive effort years; or
5% or more in each of 2 consecutive effort years; or
6% or more in an effort year after the second effort year.

Therefore, the minimum effort unit reduction under the Plan is 1% per year and the maximum is 6%. If this range is not adhered to, a "review" is to be initiated. Obviously, the GER is far more significant than a review based on these targets would be, but seeks to achieve the same goal: ensuring the ecological sustainability of fishing effort.

Effort Reductions to account for Effort Creep

The current effort management system requires surrenders on transfer of licences, transfers of effort units and vessel replacements. The PSWG stated in it's report: "Concern was expressed about the potential for trawl fishing effort to continue to increase through the adoption of technology and by boat replacement…To compensate for this eventuality, it has been agreed vessel replacement and trading in effort units will incur a penalty."

The surrender provisions that have been included in the Plan (discussed below) were expected to meet an annual reduction of 3%. This reflects the best estimate of effort creep that was available at the time (in 2000). This was primarily based on extrapolation of data from the Northern Prawn Fishery (Gulf of Carpentaria). As discussed in Section 3.1.5, the Department of Primary Industries and Fisheries has now conducted an in-depth analysis of the factors that contribute to effort creep in the trawl fishery. This analysis indicated that for the period 1989 to 1999 effort creep varied from 0.226 and 1.591 per year depending on fishing sector. On a whole of fishery basis, this equates to an annual increase of approximately 1% per year.

It is recommended by the Review that the figure of 1% annual increase in fishing power be used in assessing effort reductions in the Fishery.

Effort Reductions Required by 31 December 2003
Table 8.2 outlines the required effort unit reductions according to the agreement reached prior to the introduction of the Effort Management System.

Table 8.2. Required effort unit reductions.

	Based on 1% Effort Creep per year		Based on 3% Effort Creep per year	
	Annual Reduction	Cumulative Reduction	Annual Reduction	Cumulative Reduction
Starting amount	100.00%		100.00%	
SAS	15.00%		15.00%	
Remaining	85.00%	15.00%	85.00%	15.00%
2001 Surrenders	1.00%		3.00%	
Remaining	84.15%	15.85%	82.45%	17.55%
2002 Surrenders	1.00%		3.00%	
Remaining	83.31%	16.69%	79.98%	20.02%
2003 Surrenders	1.00%		3.00%	
Remaining	82.48%	**17.52%**	77.58%	**22.42%**

On the basis that effort creep occurs at a rate of 1% per year, the 1996 level of effort should have been reduced by a total of 17.52% during the first three effort years via the Structural Adjustment Scheme and the surrender provisions in the Plan (Table 8.2). If an effort creep rate of 3% per year were applied, the cumulative reduction target would be 22.42%.

8.1.5 *Effort Reduction Strategies*

There are three effort reduction strategies contained in the Plan that reflect the outcomes of the PSWG. These are primarily market based and seek to remove EUs from individuals in the fishery when they engage in certain activities. These are often referred to as “penalties”, which is not an accurate description. The concept of a penalty is to discourage certain activities, whereas these activities are vital in order for the fishery to meet the desired EU reduction.

The three EU surrender requirements are:

- Licence Transfers: When a licence changes ownership, a total of 5% of the total number of EUs held on the licence must be surrendered to the chief executive. This surrender provision is detailed in section 117 of the Plan;
- Effort Unit Trading: As described above, EUs are a tradeable quota unit. However, when packages of EUs are transferred from one trawl licence to another, a total of 10% of the number being transferred must be surrendered to the chief executive. This surrender provision is detailed in section 118 of the Plan; and
- Boat Replacement: When a licence holder wishes to place their trawl licence on a new boat (or make significant modifications to the existing boat), they are required to surrender a certain number of EUs. The magnitude of the surrender is dependant on the size of the new boat that is to be attached to the licence and varies from as little as 67 EUs to as high as 2,931. The requirement for this surrender is detailed in section 132 of the Plan and the number of EUs to be surrendered (for each size-class of boat) is in Schedule 5.

There are a number of exemptions to these surrender conditions: Section 65C of the Fisheries Act 1994 places an onus on the chief executive to waive any fee or surrender requirement when a licence holder transfers or amends a licence to give effect to the following:

To give effect to—
A settlement between spouses or former spouses; or
Bankruptcy; or
Winding up or administration under the Corporations Act; or
Section 70C(3); or
To administer a deceased estate; or
Because of the loss, at sea, of the boat being used in relation to the authority, through storm, capsize, collision or fire.

The Plan also contains a provision that allows for reduced effort unit surrender in the event that a person replaces a trawl vessel due to a sinking or similar event. This provision would only be used in the event that 'the event' did meet section 65C described above.

A "top-up" provision that allows a person who has replaced their boat to transfer a certain number of EUs onto the licence without the usual surrender of 10% has also been included in the Plan.

8.1.6 *Effort Reductions to Date*

Assessing the achievement of effort reductions is complicated for several reasons. Firstly, as discussed above, the 5% industry contribution to the SAS was removed as fishing days. Secondly, although the effort agreed upon for the allocation of EUs was the equivalent to 102,929 fishing days, only 96,000 fishing days were initially allocated. The remaining 6,929 fishing days were set aside for use as supplementary and appeal days. It has therefore been necessary to use aggregate factors to determine the number of EUs that would have been in the fishery if all 108,346 fishing days were allocated, as this is the agreed "bench mark".

There were 758 licences in the fishery when the EMS was introduced in 2001. The original allocation formula (which resulted in the allocation of 96,000 days) was manipulated and applied to each licence to result in an allocation of the 108,346 days to the fleet (agreed "bench mark").

A total number of 3,859,155 EUs for the 758 licences that were in force at the commencement of the allocation process has therefore been used as a starting point for the assessment of effort reductions to date.

Table 8.3. Effort Reductions in the East Coast Trawl Fishery.

	Days	**EU**
Benchmark		
1996	108,346	3,859,155
Total Allocation	102,929	3,666,186
Initial Allocation	96,000	3,419,802
Buyback	11,431	369,847
Usable Effort for Allocation	91,498	3,296,339
Dec 2003 Allocated	77,097	3,108,893
2003 Used	64,738	2,616,605
Reductions		
1996 to Total	5,417	192,969

	5%	5%
1996 to 2003 Allocated	31,249	750,262
	28.8%	**19.4%**
1996 to 2003 Used	43,608	1,242,550
	40.2%	32.2%
Usable to 2003 Allocated	14,401	187,446
	15.7%	5.7%
Targets		**Achieved**
3% Effort Creep	22.42%	NO
1% Effort Creep	**17.52%**	**YES**
Review Events (3% first year, 1% after)	19.19%	YES
GBRMC (days)	15%	YES

The Plan has achieved a total reduction of 19.4% of EUs when the end of 2003 is compared to the 1996 benchmark (Table 8.3).

In applying an annual reduction of 1% to account for effort creep, the required cumulative reduction from 1996 to 2003 as recommended by the PSWG would be 17.52% of EUs. Table 8.3 clearly shows that the agreed effort reduction target has been achieved.

The review events in the Plan require a minimum cumulative reduction of 19.2% (i.e. 15% from the SAS, 3% in 2001 and 1% in each of 2002 and 2003). This cumulative requirement has been exceeded, but only because the SAS removed slightly more than 15% and surrenders in 2001 were slightly higher than the required 3%. In both 2002 and 2003, the minimum of 1% was not reached.

It is important to review effort reductions in light of the actual amount of effort that is being used in the fishery. Table 8.3 shows a reduction of 32.2% in the number of EUs used from 1996 to December 2003. This is a significant achievement. The analysis of actual effort as well as potential effort is appropriate given that there will always be numerous factors that will prevent 100% utilisation of effort. These include weather, refits, market dynamics and the fact that most licence holders are multi-endorsed.

The review events in the Plan require a minimum cumulative reduction of 19.2% (i.e. 15% from the SAS, 3% in 2001 and 1% in each of 2002 and 2003). This cumulative requirement has been exceeded, but only because the SAS removed slightly more than 15% and surrenders in 2001 were slightly higher than the required 3%. In both 2002 and 2003, the minimum of 1% was not reached. This must be a consideration when future management arrangements are being developed.

8.1.7 *Specific Effort Reduction Mechanisms*

As discussed above, while the agreed and legislated cumulative effort reduction targets have been exceeded to date, the surrender provisions in the Plan did not achieve a level of 1% per annum in 2002 or 2003.

Transfer of Effort Units
In 2001, there were 200 individual transactions where effort units were transferred, resulting in a total surrender of almost 35,000 effort units. In contrast, there were only 95 transactions in 2002, and 73 in 2003 resulting in the surrender of approximately 10,500 units and 9,700 units respectively. This is a reduction in the number of effort units surrendered of approximately 72% over the three seasons.

Transfer of Licences

License transfers are the only type of surrender that remained relatively constant over the three effort years. In 2001, there were 35 transfers, resulting in approximately 7,000 units, and in 2002 there were 36 transfers with a surrender of approximately 9,000 units. A further 33 transfers with a surrender of approximately 8,000 occurred in 2003.

Boat Replacement

Surrenders due to boat replacement varied significantly between the three years. Surrenders through boat replacement fell from 17,000 to 2,500 between the 2001 and 2002 but increased to approximately 9,000 units in 2003. Despite the variation, the boat replacement surrenders in all years were less than expected.

8.1.8 *Issues with the Current EU Surrender Strategies*

While it is recognised that the current surrender provisions were developed through extensive consultation, based on information available at the time, they may no longer be appropriate because:

- There is general uncertainty regarding their ability to effectively manage effort;
- They seek to obtain EU surrenders from a small proportion of the fleet to account for the effort creep of the fleet as a whole; and
- There is suggestion that they are counter-productive in that they discourage fishers from replacing boats or transferring licences and EUs.

Uncertainty

There is a high level of uncertainty in the management of effort using the current surrender provisions. That is, there is no conclusive method available to predict the number of EUs that will be surrendered in a given period, or the mechanisms that will contribute to these surrenders. As described above, the current provisions have not achieved the desired target of 3% per annum, or even the minimum legislative target of 1% per annum.

Models predicting the level of surrenders prior to the introduction of the EU system were based heavily on boat replacements contributing to the majority of surrenders. This modelling was conducted prior to the adjustment scheme of late 2000, which removed 99 licences from the fishery. It now seems apparent that a large proportion of the boats attached to those licences would have been due for replacement in the next few years. Surrenders of effort units due to boat replacement have therefore not been as high as originally predicted.

A further factor contributing to the uncertainty in overall surrenders is the restrictive nature of the surrender provisions themselves. This is particularly the case with EU transfers and boat replacements. Anecdotal advice from industry representatives is that these surrender provisions actively discourage licence holders from engaging in these activities, thereby compromising the ability of the fishery to meet it's legislated and intended targets.

Lastly, the reductions that have been evident in the number of surrenders due to EU trading could be expected to continue. The data indicates that in the first effort year, there was a "flurry" of trading as fishers who wished to stay in the fishery increased their allocation and those who decided to leave sold their allocation. It is highly probable that from now on those fishers remaining in the fishery will identify and purchase the level of effort (number of effort units) they need to produce specific economic returns in the future. As a result it is likely that future EU trading (and subsequent surrenders) will be substantially reduced.

Appropriateness of targeted surrenders
As discussed above, the purpose of EU reductions is to account for effort creep throughout the fleet. Questions have been raised as to the appropriateness of obtaining those EUs from only a small proportion of the fleet.

If it could be definitely shown that those fishers who transfer EUs or whole licences are contributing to effort creep over and above those fishers who do not, such surrenders would be more justifiable. However, under the current management, a licence holder can purchase new nets and navigation equipment, thereby increasing their fishing power, without any surrender. Another fisher may sell some EUs and be required to surrender a potentially large number of EUs, without actually increasing the fishing power of their operation or the fleet in general.

In this regard, the surrenders for boat replacement are slightly more appropriate as they recognise that in most instances where EU surrenders apply, the fisher is replacing with a boat that has some quality making it more effective or desirable as a fishing boat. However, even in this case, the EUCF accounts for the difference in fishing power between boats of different sizes, so the boat replacement surrenders only account for non-size related changes in fishing power. Given the magnitude of the surrenders for boat replacement, it is highly likely that those fishers who replace boats are over-contributing to overall EU surrenders.

Temporary Transfers
The current situation effectively discourages any form of temporary transfer (such as quota leasing) because such transactions would incur EU surrenders. This removes flexibility from the system as it prevents the movement of EUs between licences on an informal basis to account for fishery and market dynamics.

8.1.9 *Future Effort Reduction Targets and Strategies*

As discussed above, the figure of 1% annual increase in fishing power should be used in assessing effort reductions in the Fishery. **This figure should be updated to reflect recent changes in the Fishery and the impact that those changes have had on fishing power.**

There is an urgent need to identify more appropriate effort reduction mechanisms. In particular, a system is required that provides certainty and flexibility to fishers while achieving a reduction appropriate for estimated effort creep.

8.1.10 *Great Barrier Reef World Heritage Area Effort Cap*

Another issue that that is directly relevant to the management of effort in the fishery is the total allowable effort in the Great Barrier Reef World Heritage Area. As a condition of its contribution to the East Coast Trawl Adjustment Scheme in 2000, the Commonwealth Government insisted that mechanisms should be introduced to ensure that effort directed at the WHA was specifically managed.

Historically, approximately 70% of fishing effort in the trawl fishery was directed at stocks within the Marine Park. Concerns were raised by the Commonwealth that in the absence of specific management, effort traditionally directed elsewhere could migrate into the Park to account for that removed by the adjustment scheme.

To address these concerns, a cap on the total amount of notional effort units that could be used in the WHA was introduced. This cap was based on approximately 70% of the total number of effort units in the fishery. The Plan states that once this cap has been reached, the WHA becomes closed.

A need was also identified for the cap to be annually reduced to account for effort creep. As discussed above, the best available estimate of effort creep at that time was 3% per annum, and as such, the WHA cap reduced by 3% in 2002 and 2003. Written agreements between the State and Queensland only focussed on the first three effort years, and as such, only 2002 and 2003 were catered for under the Plan. In late 2003, the Plan was amended to carry the 2003 cap into 2004 (i.e.: no reduction) while the GER is being completed.

At this time, stock-based effort management is not available. Therefore the continuation of a WHA effort cap is deemed appropriate until a more effective management system can be developed and agreed upon that utilises the outputs of stock assessments. The cap was not reached during the first three effort years, but has been in the vicinity of 90% in each of the last two years. Ensuring that a disproportionate amount of total trawl effort is not used in the WHA remains a valid consideration.

Given that the overall effort in the fishery reduces by an annual percentage, it is reasonable to reduce the WHA Cap by the same proportion. As discussed above, an annual reduction of 1% per annum is proposed as appropriate to counter effort creep in the fishery, if this becomes the agreed level then it follows that **the WHA cap should also decrease by 1% per year.**

9 Future Directions

The long-term sustainability of demersal trawl fisheries is highly dependent on minimising negative impacts on discards, benthos and the overall ecosystem that the fisheries operate within. Queensland's ECTF has and continues to operate under significant scrutiny, which is amplified by the existence of approximately 70% of the fishery within the Great Barrier Reef World Heritage Area (GBRWHA).

The ECTF has undergone significant structural adjustment over the last five years following the introduction of the Plan. The significant reductions in fishing effort that have resulted from this adjustment have been a major contributor to the sustainability of the fishery. Input controls, in the form of limits on net size, Bycatch Reduction Devices (BRDs), turtle excluder devices and permanent closures have significantly reduced the negative impacts of trawling on principal and permitted species and bycatch in the fishery.

The fishery now operates under a framework of continuous improvement and refining of management arrangements put in place by the trawl Plan to ensure that the sustainability of the fishery is maintained. The DPI&F is committed to delivering a profitable industry that is ecologically sustainable. This General Effort Review represents an assessment of the performance of the Plan in delivering an ecologically sustainable fishery. The review process and outcomes have identified a number of areas that need to be addressed in the near future in order to ensure the fishery remains economically viable and ecologically sustainable.

Current Effort Management System

The effort management system has been a key element of the trawl Plan. The surrender of effort units on transfers and boat replacements has hindered the continued self-restructuring of the fleet and the capacity of individual licence holders to refine business operations and optimise economic returns. The Effort Management System will be reviewed in 2005 and a new process developed that will provide for management of effort in relation to effort creep whilst allowing for vessel replacements and trading/leasing of effort units amongst licence holders.

The periodic reassessment of effort creep in the fishery will be essential for effective management. A process will be developed that will identify when future reviews are required. A 'checks and balances' process may be advocated that tracks annual changes in effort creep allowing for annual reductions or increases in effort units.

Great Barrier Reef World Heritage Area (GBRWHA) Cap in Effort

Total effort (number of effort units) in the ECTF is capped across the fleet (T1, T1/M1, T2 endorsed vessels). Noting the area restrictions relevant to each fishery symbol, vessels have the capacity to fish in any part of the fishery area outside of permanent and seasonal closures. Approximately 70% of the effort is applied to the fishery area within the GBRWHA. In line with Great Barrier Reef Marine Park Authority management objectives for the GBRWHA it would be inappropriate for the entire East Coast trawl fishery effort to be applied to the world heritage area. The GBRWHA cap was put in place to prevent any increase in the proportion of effort applied to the GBRWHA, i.e. prevent effort from exceeding ≈70% of the entire effort of the East Coast trawl fishery. The annual reductions in the cap, until 2003, were based on extrapolated estimates of effort creep from another trawl fishery that were agreed by Queensland Government, Commonwealth Government and Industry at the time of the revision of the Plan in 2000. Effort creep was estimated to be 3% per year. A comprehensive analysis of effort creep in the fishery (from 1989 to 1999) has recently been completed that indicates that effort creep was actually in the order of 0.2 to 1.7% per year during that time. The DPI&F has recently completed a further revision of effort creep for the period 2000 to 2003 and results will be available in early 2005.

The on-going refinement and development of stock assessments for key principal species may provide a means or framework for refining the spatial scale at which effort is managed in the fishery. That is, the application of effort management to each stock or fishing region in such a way as to implement the results of stock assessment modelling is a definite possibility for the ECTF. Under such a regime, effort management would be based on a measure of sustainability (such as x% of the estimated effort that would result in Maximum Sustainable Yield) and may therefore make the GBRWHA cap a redundant provision.

The continued development of BRDs and gear technologies that increase the survival of bycatch (discards) and minimise the negative impacts of trawling on the ecosystem is a priority. The use of effective BRDs is critical to minimising the bycatch landed and will contribute significantly to the sustainability of the fishery.

Industry and management need to commit to progressing changes that improve the management and economic viability of the fishery. More effective and productive linkages between management and industry may be achieved in the future by developing partnerships that lead to the overall goal of co-management.

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