Queensland **the Smart State**

Towards Ecologically Sustainable Management of the Torres Strait Prawn Fishery

CRC Torres Strait Task Number 1.5

CRC TORRES STRAIT

Queensland Government
Department of Primary Industries and Fisheries

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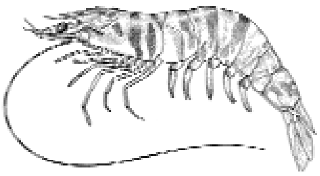
Towards Ecologically Sustainable Management of the Torres Strait Prawn Fishery

CRC Torres Strait Task T1.5 – Final Report



Tiger prawn

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Fisheries Policy and Sustainability

CRC TORRES STRAIT

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Table of contents

Figures

Tables

1 Non-Technical Summary

CRC Torres Strait Task T1.5: Towards Ecologically Sustainable Management of the Torres Strait Prawn Fishery

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Objectives:

1. Develop cost-effective protocols to monitor and quantify the by-catch and environmental impacts of commercial prawn trawling.

2. Monitor the status of target species using both fishery dependent and fishery independent data.

3. Develop biological reference points for target species and undertake Management Strategy Evaluation, in particular a risk assessment of fishing at various levels of fishing mortality.

Non-Technical Summary:

A strong need for research that would assist with the implementation of ecologically sustainable management of the Torres Strait Prawn Fishery (TSPF) was identified at the Torres Strait Fisheries Assessment Group (TSFAG) Prawn Workshop (May 2001) and subsequent meetings of the Torres Strait Prawn Working Group (PWG). It was noted that research directed towards these needs would also assist with the accreditation of the TSPF under the Department of Heritage (DEH) Guidelines for Ecologically Sustainable Management of Fisheries and help address the concerns of Islander Fishers that the trawl fishery may be impacting on catches in the Torres Strait Tropical Rock Lobster Fishery. Addressing these research needs was incorporated into the Torres Strait CRC Task 1.5 (*Towards ecologically sustainable management of the Torres Strait Prawn Fishery*) which operated from late 2003 to December 2006. This Task utilised and built on the earlier research and monitoring conducted by Department of Primary Industries and Fisheries (DPI&F).

OBJECTIVE 1 - BYCATCH

DPI&F liaised with AFMA on the development of an industry funded observer program that monitors and quantifies the bycatch and environmental impacts of prawn trawling. This observer program commenced in the TSPF during 2005 and the Task had input into sampling protocols and the type of data collected.

Bycatch collected on three DPI&F annual research surveys (2004-2006) allowed detailed fishery independent investigation of the composition, distribution and catch rates of bycatch in the TSPF and an assessment of the impact of prawn trawling on the bycatch communities. The surveys were conducted within the main prawn trawling grounds and also in the adjacent areas seasonally closed to trawling and fully closed to trawling (East and West of Warrior Reefs Closures).

The Torres Strait bycatch was typical of tropical prawn trawl bycatch as it was highly diverse and predominantly fish and invertebrates most of which occurred rarely. The dominant fish species and families have changed little since the mid 1980s and the catch rates of bycatch have not markedly altered in two decades. Nearly all of the species occurred throughout all areas surveyed and most of the species had a distribution that ranged across the Indo-Western Pacific Oceans, with nine percent of the species endemic. The bycatch species list was provided to the Torres CRC project: Mapping and characterization of key biotic and physical attributes of the Torres Strait ecosystem and was used in the Level 1 Ecological Risk Assessment (ERA) of the Torres Strait Prawn Fishery undertaken by CSIRO in collaboration with the Principal Investigator for this Task.

Prawn trawling does not appear to have any marked effect on the bycatch of the TSPF. There were no major differences in the bycatch community structure between the areas open, partially closed and entirely closed to trawling however some of the dominant bycatch species were much more prevalent in either the open or closed area. These differences in distribution were due more to the environmental variables of depth, current stress and sediment type than prawn trawling, which is the case for other studies of prawn trawl bycatch in the Torres Strait, the Gulf of Carpentaria and Queensland.

Trawling in the TSPF is restricted to areas that have been trawled since the mid 1970s and these areas represent only about twenty percent of the entire Torres Strait Protected Zone. There are spatial refuges for bycatch species in areas that are not trawled at all or only trawled lightly which may have afforded some degree of protection to these species. These closure management strategies are likely to assist in the long term ecological sustainability of the bycatch species. There is also ongoing research into bycatch reduction devices and the use of onboard processing systems such as hoppers which together can reduce the amount of bycatch caught in the trawl net and increase the survivability of those species caught.

OBJECTIVE 2 – STATUS OF TARGET SPECIES

The status of the target species was monitored using the commercial harvest data collected through the AFMA logbook program. The trends in the data have been regularly reported back to stakeholders at PWG and TSPEHA meetings and via the annual editions of the Torres Prawn Handbook (Taylor et al. 2006) and the tiger prawn stock assessment reports (O'Neill et al. 2005, O’Neill and Turnbull 2006). The recruitment surveys conducted each February in Torres Strait, which are a component of the DPI&F Long Term Monitoring Program for prawns, provided fishery independent data that has been compared with the fishery data and used to support the stock assessment results.

One of the recommendations from the Dr Die review of the 2003 tiger prawn assessment was to compare a sample of individual vessel unload records with the corresponding logbook records to validate the logbook catch weights and address comments from some fishers that they had found consistent differences between their own logbook and unload records. A sample of 171 unload records were voluntarily obtained from fishers and processors and compared with logbook records. This was a difficult and time consuming activity. Differences were found between the logbook data at the level of individual unloads, mainly due to difficulties in matching the unload data with the corresponding daily fishing records in the logbook data.

A comparison of all of the available unload data with the corresponding logbook record however, found only small differences for tiger and endeavour prawns. The catches recorded in the logbooks were 0.4%, 4.6% and 0.1% less than the unload records for total prawn catch, tiger prawn and endeavour prawn respectively. In contrast the logbook king prawn catch, which is only a small percentage of the total catch, was 24% less than the unload records.

In summary, there was a good overall match between the tiger prawn and endeavour prawn catch weights recorded by fishers in their logbooks and the total weights product recorded when vessels unload to mother ships and processors. This indicates that the logbook records provide an accurate estimate of the catch of the fishery and that there is no need to adjust the catches and catch rates obtained from the logbook records using the unload records.

OBJECTIVE 3 - BIOLOGICAL REFERENCE POINTS

The 2004 update of the tiger prawn stock assessment and Alternative Management Workshop were completed, peer reviewed and published (O'Neill and Turnbull 2006). This report addressed most of the recommendations of the Dr David Die review of the 2003 tiger prawn assessment. The analysis presented in that report is based on both fishery dependent data (fisher logbook and unload data) and the fishery independent recruitment surveys. Outputs of the tiger prawn assessment models are biological reference points such as MSY, E_{msy} and B_{msy} and the risk associated with fishing at various levels of fishing mortality. These reference points are being utilised in the process of developing new management arrangements for the fishery.

An Alternative Management Workshop was held in July 2005. The intent of the workshop was to allow fishers, scientists and managers to collaborate on the development of management arrangements that would result in sustainable harvesting of tiger prawns stock while allowing some additional effort directed towards the endeavour prawn stock. During the workshop the need for a further update of the tiger prawn stock assessment to include the 2004-06 harvest data and any additional vessel and gear information was identified.

The updated tiger prawn stock assessment and analysis of trends in commercial catch and effort data indicate that the biomass of tiger prawns has steadily increased since 2000 as fishing effort has decreased. Since 2002 the biomass has been higher than during the 1990's and the stock level required for maximum stock productivity (B_{msy}). As the biomass has increased catch rates of tiger prawns has increased maintaining the annual tiger prawn catch at close to the average for the last 10 years. The 2006 tiger prawn catch was down slightly but this is to be expected in light of the very low fishing effort in 2006. The average annual tiger prawn catch for 2006 is the highest recorded since full logbook records commenced in 1989. The 2006 fishing effort (4,654 days, based on VMS data) was approximately half of the Emsy limit reference point of 9,200 days. Analysis of VMS data indicates that while 40 percent of the fleet utilised all of their available days many vessels used less than 50 percent of their available days.

In conclusion the Task results are assisting with the development of management strategies aimed at ensuring that stocks are harvested in an environmentally sustainable manner and the continued accreditation of the fishery under the Guidelines for the Ecologically Sustainable Management of Fisheries. The results also provide a foundation for the current DAFF funded DPI&F research contract to assess and further develop the outcomes of the Alternative Management Workshop.

2 Task Overview

2.1 Background and Need

A strong need for research that would assist with the implementation of ecologically sustainable management of the Torres Strait Prawn Fishery (TSPF) was identified at the Torres Strait Fisheries Assessment Group (TSFAG) Prawn Workshop (May 2001) and subsequent meetings of the Torres Strait Prawn Working Group (PWG). It was noted that research directed towards these needs would also assist with the accreditation of the TSPF under the Department of Heritage (DEH) Guidelines for Ecologically Sustainable Management of Fisheries and help address the concerns of Islander Fishers that the trawl fishery may be impacting on catches in the Torres Strait Tropical Rock Lobster Fishery.

The Torres Strait Prawn Fishery harvests straddling prawn stocks that are subject to catch sharing arrangements between Australia and Papua New Guinea (PNG) under the Torres Strait Treaty. The March 2003 Australian / PNG bilateral meeting highlighted a need for inclusion of catch and effort data from PNG endorsed vessels into the monitoring and assessment of Australian managed prawn stocks in the Torres Straits. In addition it was suggested that cross-border catch sharing arrangements should be based on an assessment of the sustainable catch from both sides of the Fisheries Jurisdiction Line.

In October 2003 the results of the Torres Strait component of the Fisheries Research and Development Corporation project ‘Reference point management and the role of catch-per-unit effort in prawn and scallop fisheries’ was presented to industry, managers and other stakeholders in the Torres Strait prawn fishery (O’Neill *et al.* 2005). At the request of industry, this research was peer reviewed by Dr David Die, an internationally recognised stock assessment expert from the Miami University (Florida, USA). Dr Die provided a number of recommendations aimed at improving the stock assessment and addressing the concerns of fishers about the model and the data used (Die 2003). He also stated that the scientific advice provided by the assessment was of high quality and utilised state of the art statistical analysis and simulation model.

Addressing these research needs was incorporated into the Torres Strait CRC Task 1.5 (*Towards ecologically sustainable management of the Torres Strait Prawn Fishery*) which operated from late 2003 to December 2006. The Task utilised and built on past research and monitoring that was conducted by the Department of Primary Industries and Fisheries (DPI&F) between 1985 and 2003. There was a close collaboration between fishery managers and the project staff which ensured that the research was directed towards and inputting into the management of the fishery.

An updated tiger prawn assessment that included the 2003 catch and effort data and addressed most of Dr Die’s recommendations was presented to industry, managers and other stakeholders in June / July 2004. As a flow on from the assessment and the Dr Die recommendations an *Alternative Management Workshop* was held in July 2005. The intent of the workshop was to allow fishers, scientists and managers to collaborate on the development of management arrangements that would results in sustainable harvesting of tiger prawns stock while allowing some additional effort directed towards the endeavour prawn stock. One of the outcomes of the Alternative Management Workshop was the need for a further update of the tiger prawn stock assessment to include the 2004-06 harvest data and any additional vessel and gear information that had become available since the previous assessment. The updated assessment was presented to the February 2007 TSPFMAC meeting and is detailed in section 4 of this publication.

The research outputs directly addressed objectives 1, 2 and 4 of the CRC TS Program for Harvested Marine Resources. Analysis of commercial catch and effort data provide information on the status and trends of the prawn resource, exploitation rates, and formed the basis of stock assessment and the development of reference points for management. The stock models were used to evaluate alternative management strategies. The bycatch / observer component of the project addressed objective 3 of the CRC TS Program by providing information relevant to the impact of trawling on bycatch in the TSPF and assisting with the development of an observer program.

2.2 Objectives

The objectives of Torres Strait CRC Task 1.5:

1. Develop cost-effective protocols to monitor and quantify the by-catch and environmental impacts of commercial prawn trawling.

2. Monitor the status of target species using both fishery dependent and fishery independent data.

3. Develop biological reference points for target species and undertake Management Strategy Evaluation, in particular a risk assessment of fishing at various levels of fishing mortality.

2.3 Research Summary

The main research achievements of the Task were:

1. A revised tiger prawn stock assessment (O'Neill and Turnbull 2006) that addressed most of the recommendations of the Dr David Die review. This assessment also included the 2003 catch and effort data and revised fishing power estimates based on additional vessel and gear data. The assessment also included analysis of fishery independent recruitment data collected by the Fisheries Long Term Monitoring Program (LTMP) for the years 1998-2002. This assessment was published as a peer reviewed DPI&F Information Series Report (O'Neill and Turnbull 2006).

2. A key role in the Alternative Management Workshop (July 2005). The intent of the workshop was to allow fishers, scientists and managers to collaborate on the development of management arrangements that would result in sustainable harvesting of tiger prawns stock while allowing some additional effort directed towards the endeavour prawn stock. A summary of the Alternative Management Workshop is detailed in O'Neill and Turnbull (2006).

3. Input into the development of the industry funded AFMA observer program that is aimed at monitoring and quantifying the bycatch and environmental impacts of prawn trawling in the TSPF.

4. An analysis of composition, distribution and catch rates of bycatch in the TSPF from samples collected on three DPI&F annual research surveys (*section 5 of this report*). The author of this section, Ms Cassandra Rose presented her analysis at the July 2006 AMSA conference. The bycatch species list was provided to the Torres CRC project: Mapping and characterization of key biotic and physical attributes of the Torres Strait ecosystem, The species list were also used in the Level 1 Ecological Risk Assessment (ERA) of the Torres Strait Prawn Fishery undertaken by CSIRO in collaboration with the Principal Investigator for this Task.

5. An update of the tiger prawn stock assessment to include the 2004-06 harvest data and additional vessel and gear information. The need for this updated assessment was flagged at the July 2005 Alternative Management Workshop by industry representatives and managers. The Task was granted an extension to 31st December 2006 to facilitate production of the revised assessment. The updated assessment was presented to the February 2007 TSPFMAC meeting, distributed to the industry members via the 2007 edition of the Torres Prawn Handbook and is also presented in section 4 of this publication.

2.4 Assessment Recommendations

In October 2003 by Dr David Die, an internationally recognised stock assessment expert from the Miami University (Florida, USA), reviewed the existing stock assessment work for the TSPF. This review was requested by industry amid concerns about the potential economic impact on fishers of the assessment results. The reviewed focused in particular on the results of the Torres Strait component of the Fisheries Research and Development Corporation project (FRDC 1999/120) 'Reference point management and the role of catch-per-unit effort in prawn and scallop fisheries'. This project (O'Neill *et al.* 2005) was successfully completed between 1999 and 2003 by researchers in DPI&F. The research investigated ways of standardising catch rates provided from logbook catch records, developed stock assessment models for the eastern king prawn, saucer scallop and Torres Strait tiger prawn fisheries, and examined a range of model-based and data based reference points.

Dr Die provided a number of recommendations (Table 2.4.1) aimed at improving the stock assessment for the TSPF and addressing the concerns of fishers about the model and the data used (Die 2003). In his review Dr. Die states…

"*The new assessment presented by O'Neill and Turnbull (2003) are a considerable improvement from the previous assessments. Major improvements were obtained by:*

- *Extending the estimation of relative abundance to a larger time period (1980-2002) and updating the effort creep analysis for the same period*
- *Using a seasonal delay-difference model that captures more of the information contained in the data and allows for the explicit incorporation of stock recruitment functions in the assessment.*
- *Conducting extensive estimation of the uncertainty in the assessment results through bootstrap analyses*
- *Developing a framework for quantitative evaluation of management strategies*

The scientific advice produced by such assessments is therefore of high quality and is sustained by the use of state of the art statistical analysis and simulation modelling.

As for any assessment there are improvements that can be made in the analyses and presentation of results. Although some of the improvements suggested may change the details of the advice on stock status it is unlikely that the general conclusions reached by the recent assessment will change."

An updated tiger prawn assessment that addressed most of Dr Die's recommendations was presented to industry, managers and other stakeholders in July 2004. This updated assessment was jointly funded by the Fisheries Resource Research Fund (FRRF), the Torres Strait CRC and DPI&F. The estimate of sustainable fishing effort (E_{msy}) for tiger prawns has been central to the process of developing new management arrangements for the fishery that will limit effort to a level considered sustainable while minimising the impact on the industry. The risk associated with fishing at various levels of fishing mortality have also been simulated and detailed in the stock assessment reports. The assessment and a summary of the Alternative Management Workshop are detailed in O'Neill and Turnbull (2006); *Stock Assessment of the Torres Strait Tiger Prawn Fishery (Penaeus esculentus).*

Table 2.4.1 The David Die stock assessment recommendations. High priority was given to those *recommendations* that, when followed, may significantly change the scientific advice provided and that can be followed up in a short space of time (weeks). Medium priority was given to those recommendations that can lead to significant change in the advice but that require months of work. Low priority was given to those that are unlikely to change the advice.

Assessment Component and Priority	Recommendation
Catch Data	
1. Medium	That unloading data are obtained, even if it is only samples for some vessels, and that a GLM model is run to determine the significance of correction factors for estimates of landings obtained from logbook data. Factors to be considered in the GLM model could be month, year, area (may not be possible if vessels fish in more than one area during a single unloading period), and possibly type package used to pack prawns. The dependent variable should be the logbook catch for a vessel and the independent the unloading catch for the same vessel in the same period of time. If enough size-grade data is present in logbooks size grade could be also used as a factor. If yearly factors are significant this may put into question the catch rate estimates from logbooks.
2. Low	Data from the PNG side of the fishery should be collated to estimate the annual catch harvested by PNG boats so that this catch can be included in the assessments made by the Torres Strait Prawn Working Group. Also cpue data should be collected so as to start developing indices of abundance from the PNG side of the fishery.
3. Low	That possible biases (time shifts and smoothing) in the procedure to allocate unloading data to particular time periods is investigated by using data for vessels/years when both unloading and logbook data is available.
4. Low	Analyse commercial grading data from logbooks and unloading data to determine the size composition of the catches to initially estimate annual indices of the timing of recruitment. Use these data on recruitment timing in the delay difference model. If the grading data is of high quality and abundant, develop catch at size matrices to develop a fully size/age structured model.
Fishing Power and Standardised Catch Rates	
5. High	That the current database on chain size is used to calculate the expected reduction in fishing power resulting from chain size reductions that occurred in 2001.
6. High	That a 4% decrease in fishing power as a result of the decrease in net size that occurred in 2002 is adopted as the best available estimate for this effect and used in the stock assessment.
7. High	That the effort creep schedule is re-estimated for the last two years and that the delay difference models be run with the new estimates of relative abundance for 2001 and 2002.
8. High	Use a unit of fishing effort in the past (e.g. 1980 effort unit) as the reference for effort creep calculation and reporting. Include a table with the annual nominal effort and the effort corrected for effort creep (in appropriate reference-year units) in the all the reports of the assessment.
9. Medium	That a standardized catch per unit of effort be estimated for endeavour prawns to estimate relative abundance for this species. Use GLM method as for tiger prawns.
10. Medium	That a new GLM is carried out to estimate standardized catch per unit of effort by creating two new area strata as follows: a) Split northern strata in two by choosing grids that are inside the Warrior reef closure and outside of it, and b) split southern strata in two by choosing grids that are in the areas where the highest king prawn catches exist (closer to the reef). To examine if the resulting standardized catch per unit of effort is significantly different to the one obtained in the current assessment.
11. Medium	That the results from the GLM used to estimate effort creep factors are used to estimate an alternative standardised cpue series. This series should be compared to the one used in the current assessment (corrected for effort creep) and used as a sensitivity analysis.
12. Medium	That a new GLM is run by using only data from vessels that were providing data in the early part of the season. This series should be compared to the one used in the current assessment and used as a sensitivity analysis.
13. Medium	That the vessel characteristics database is updated every year.
14. Medium	That old data on landings and catch rates are sought from industry for the period prior to 1980 and these data are used to develop priors for the stock biomass ratio in 1980.
Stock Models and Management Strategy Evaluation (MSE)	
15. High	Further testing of the production model implementation in MATLAB and EXCEL should be made and comparisons to other implementations of the production model implementations such as ASPIC, BIODYN (Punt and Hilborn 1996) or FISHLAB (Kell and Smith 2000) should be conducted to confirm that the production model results are repeatable.
16. High	That only production models with all data be considered to estimate reference points. Also, that the best fits to the data, those of the Fox model, be considered as offering optimistic views of the productivity of the stock.
17. High	Use delay difference model as base case for assessments. Use B_{MSY} and E_{MSY} as limits reference points. The prawn biomass should always be maintained above B_{MSY} and the standardised effort below E_{MSY}.
18. High	Use a target reference point of either 75% or 80% E_{MSY}.
19. High	Working group should develop alternative management strategies to reach target reference points. These strategies should be evaluated by the MSE method.
20. Medium	Management strategies to be tested need to be develop by working group MSE should then be repeated for those strategies
21. Medium	The status quo strategy should be estimated with the 2001 and 2002 data, not the 1999-2002.

The report by O'Neill and Turnbull (2006) addressed and incorporated into the assessment, 16 of the 21 of high, medium and low priority recommendations from Dr Die's (Table 2.4.2). After incorporating the recommendations the results from the updated assessment were similar to (O'Neill et al. 2005) in terms of biomass ratios between 1980 and 2001 and estimates of MSY. Of the five recommendations not completed in the report by O'Neill and Turnbull (2006), three are addressed in this report. The collection of landings data for the years prior to 1980 was not feasible as we were unable to locate any operators from that period who had retained their catch records and the recommendation to use a target reference point of either 75% or 80% EMSY is a management recommendation that needs to be addressed by the TSPFMAC.

Table 2.4.2 Summary on the accomplishment of review recommendations by O'Neill and Turnbull (2006).

Recommendation number, priority and abbreviation from the independent review (detailed in Table 1.1.1)	Recommendations addressed?	Report section where completed or otherwise
1. Medium – correction factors for logbook landings.	No	This report – section 4
2. Low – harvest taken by Papua New Guinea vessels.	Yes	2.1
3. Low – allocating unloading data to time periods.	No	This report – section 4
4. Low – commercial size grading data.	No	This report – section 4
5. High – chain size reductions since 2001.	Yes	2.2 and 2.3
6. High – net size reductions since 2002.	Yes	2.2 and 2.3
7. High – update fishing power estimates.	Yes	2.3
8. High – select a unit of fishing effort.	Yes	2.4
9. Medium – standardise endeavour prawn catch rates.	Yes	2.3
10. Medium – area strata for catch rate standardisations.	Yes	2.3
11. Medium – use GLM for calculating catch rates.	Yes	2.3
12. Medium – data only from vessels prior to 1988.	Yes	2.3
13. Medium – vessel characteristics database.	Yes	2.2
14. Medium – collect harvest data prior to 1980.	No	No operators retained catch records.
15. High – test production model.	Yes	2.4
16. High – all data used in production models.	Yes	2.4
17. High – use delay difference model.	Yes	2.4
18. High – set target reference points.	No	Management recommendation for the TSPFMAC
19. High – working group to develop fishing strategies.	Yes	3
20. Medium – MSE to assess strategies.	Yes	3
21. Medium – status quo from last two years.	Yes	2.3 and 2.4

2.5 Outcomes / Achievements against each objective

Objective 1: Develop cost-effective protocols to monitor and quantify the by-catch and environmental impacts of commercial prawn trawling.

The first part of this objective has been achieved by liaising with AFMA on the development of the industry funded observer program that commenced in the TSPF during 2005. The Task has had input into sampling protocols and the type of data collected. The second component of this object has been achieved in terms of bycatch, through analysis of bycatch samples collected from within the fishery and adjacent fully closed and semi-closed (East of Warrior Closure) areas. The data collected has also been compared with base-line data on bycatch collected by CSIRO during 1985-6.

Objective 2: Monitor the status of target species using both fishery dependent and fishery independent data.

The status of the target species has been monitored using the commercial harvest data collected through the AFMA logbook program. The trends in the data have been regularly reported back to stakeholders at PWG and TSHEHA meetings and via the annual editions of the Torres Prawn Handbook and the tiger prawn stock assessment reports. The Torres Strait component of the DPI&F Long Term Monitoring Program for prawns provided fishery independent data that has been compared with the fishery data and used to support the stock assessment results.

Objective 3: Develop biological reference points for target species and undertake Management Strategy Evaluation, in particular a risk assessment of fishing at various levels of fishing mortality.

Outputs of the tiger prawn assessment models are biological reference points such as MSY, Emsy and Bmsy and the risk associated with fishing at various levels of fishing mortality. These reference points, which are detailed in O'Neill and Turnbull (2006) are being utilised in the process of developing new management arrangements for the fishery.

2.6 Utilisation and Application of the Research

The strategy used to maximise uptake of research findings was regular reporting at Prawn Working Group and Entitlement Holder meetings and the provision of "Research" and "Logbook Statistics" chapters for the annual editions of the Torres Prawn Handbook. This ensured that all stakeholders were informed of the most recent research results.

The results of the research, in particular the tiger prawn stock assessment, have been central to the process of developing new management arrangements for the fishery. At the Alternative Management Workshop industry and managers utilised the research results to discuss and propose new management arrangements for the fishery. The results of the stock assessment models were used by the PZJA, in November 2005, to reduce the allowable effort in the fishery to a level that is considered to be sustainable for tiger prawns. The bycatch species list generated from the bycatch sampling was utilised in the Ecological Risk Assessment developed for the TSPF in June 2006.

In conclusion the Task results are assisting with the development of management strategies aimed at ensuring that stocks are harvested in an environmentally sustainable manner and the continued accreditation of the fishery under the Guidelines for the Ecologically Sustainable Management of Fisheries. The results also provide a foundation for the current DAFF funded DPI&F research contract to assess and further develop the outcomes of the Alternative Management Workshop.

2.7 Publications

'Research' and 'Logbook Statistics' section were written for the 2004, 2005, 2006 and 2007 editions of the Torres Prawn Handbook. This annual publication is one of the main methods by which the results of the stock assessment and monitoring of trends in the status of the stocks has been distributed to stakeholders.

O'Neill, F.M., Turnbull, C.T. (2006) Stock assessment of the Torres Strait Tiger Prawn Fishery (*Penaeus esculentus*). Department of Primary Industries and Fisheries, Queensland. 83pp.

This peer reviewed publication can be viewed and downloaded from the DPI&F web site http://www2.dpi.qld.gov.au/far/18576.html .

3 Description of the fishery

3.1 Main features of the 2006 fishery

The Torres Strait Prawn Fishery (TSPF) is an international, multi-species prawn fishery which operates in the eastern section of the Torres Strait Protected Zone (TSPZ) and the defined 'outside but near' area. The fishery is jointly managed by the Commonwealth and Queensland State Governments of Australia and the Papua New Guinea Government under the Torres Strait Protected Zone Treaty that was ratified in 1985. It is the most valuable commercial fishery in Torres Strait with an annual value to fishers of AUD$18-23 million. A mobile fleet of about 61 Australian vessels operates both in the TSPF and on the Queensland East Coast Otter Trawl Fishery (ECOT). A number of these vessels are also licensed to operate in the Northern Prawn Fishery (NPF). Prawn trawling is largely confined to a relatively narrow strip to the east of the Warrior Reef complex, centred on Yorke Islands, referred to herein as the main trawl grounds (Figure 3.1.1). Only approximately 20% of the total area of the TSPZ is actively trawled.

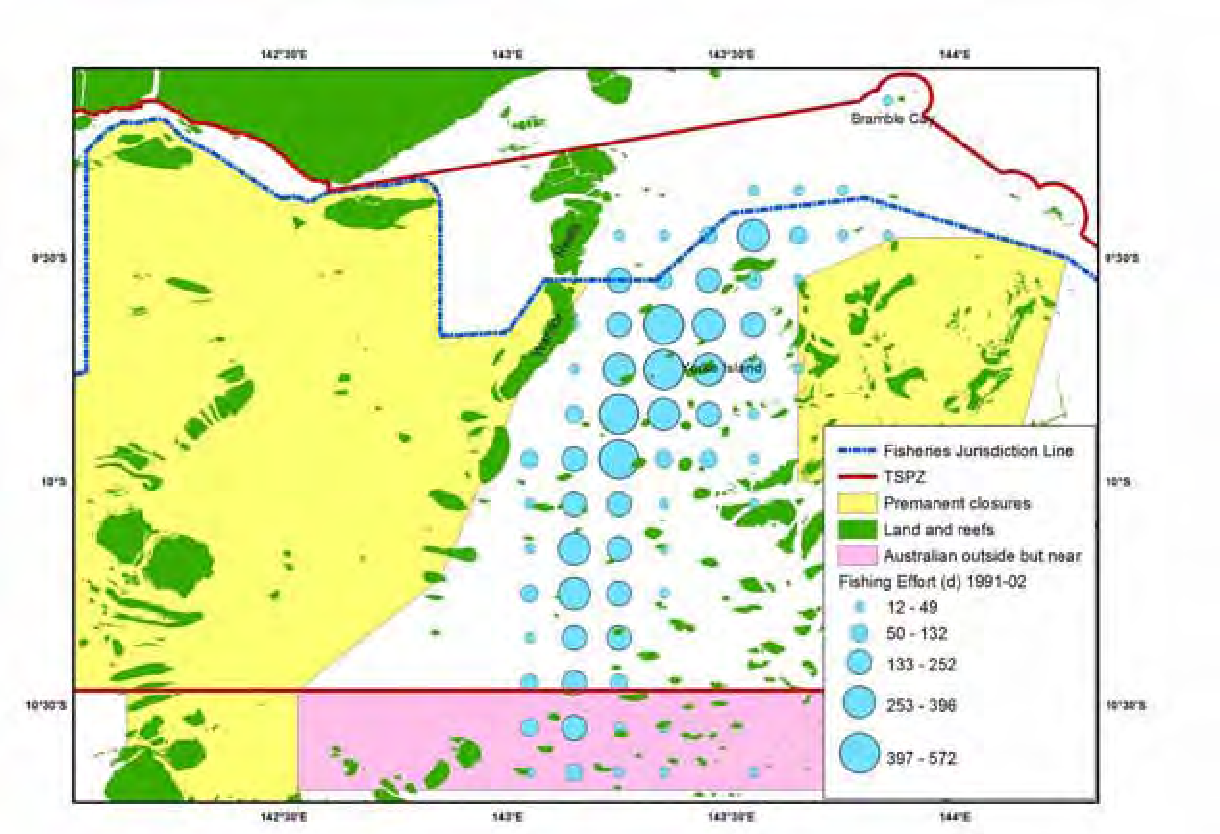

Figure 3.1.1 Location of the Torres Strait Prawn Fishery indicated by the average annual fishing effort summarised by six-minute grids, the Torres Strait Protected Zone, the Fisheries Jurisdiction Lines, and the Australian outside but near area of the prawn fishery.

3.2 History and Management

The prawn trawl fishery in Torres Strait began in the mid 1970s, extending northward from the prawn fishery along the Queensland east coast. When the Torres Strait prawn fishery began, all east coast and Northern Prawn Fishery prawn trawlers were entitled to fish in Torres Strait, effectively allowing access to all of about 1,200 vessels. When the Torres Strait Treaty was ratified in 1985 approximately 500 vessels had obtained a licence to operate in the TSPF.

Since 1985 the Australian and Queensland Governments under the Torres Strait Treaty have jointly managed the TSPF. In 1987 the Protected Zone Joint Authority (PZJA) introduced limited entry and licences were restricted to the 150 vessels that had any history of fishing in Torres

Strait. In 1989 an industry supported freeze on licences was implemented and by June 1992 around 110 vessels were licensed in the fishery.

The Torres Strait Treaty recognises the right of Australia and Papua New Guinea to share the commercial fisheries in the TSPZ. Under Article 23 of the Treaty, Australia and PNG have annually agreed to a specific number of vessels that can fish the other countries waters within the TSPZ. Until recently the Australian fishers have opted to not fish in the PNG area and this has been factored into the calculation of the number of PNG vessels that could be endorsed to fish the Australian area. Although the number of PNG vessels that could have been endorsed to fishing in Australian waters has been eight vessels in most years, there has been little participation in the fishery by PNG operators. This has been attributed to a lack of infrastructure at Daru to support trawl vessels operating in the TSPZ and delays with fishing endorsements for PNG operators.

Seasonal and area closures have played an important role in the management of the fishery. In 1980 the area to the west of the Warrior Reefs was closed at the request of industry, to protect juvenile prawn stocks. Seasonal closures to trawling in the whole of the TSPF commenced in 1985. The current seasonal closure is from the 1st December through to 1st March which coincides with the period when small less valuable prawns recruit into the fishery. In 1991 at industries request, in consultation with Islanders and based on research conducted by DPI&F a further seasonal closure was introduced in the area east of Warrior Reef. This area is open to trawling for only four months; 1st August to 1st December. The combined effect of these closures allows most prawns migrating from west to east through the Warrior Reefs to reach export grade size before they are fished.

Days of fishing access to Australian vessels, based on the maximum number of days fished in the previous four years was introduced at the start of 1993. There was also an additional 10 percent 'downtime' allowance to cover unload periods, bad weather and breakdowns. Trading of licences and fishing access days were implemented in 1994. As at January 2004, there were 77 Australian licensed vessels assigned 13,486 fishing days, compared with 110 licensed vessels in June 1992 with a potential 30,250 fishing days (Kung et al. 2004).

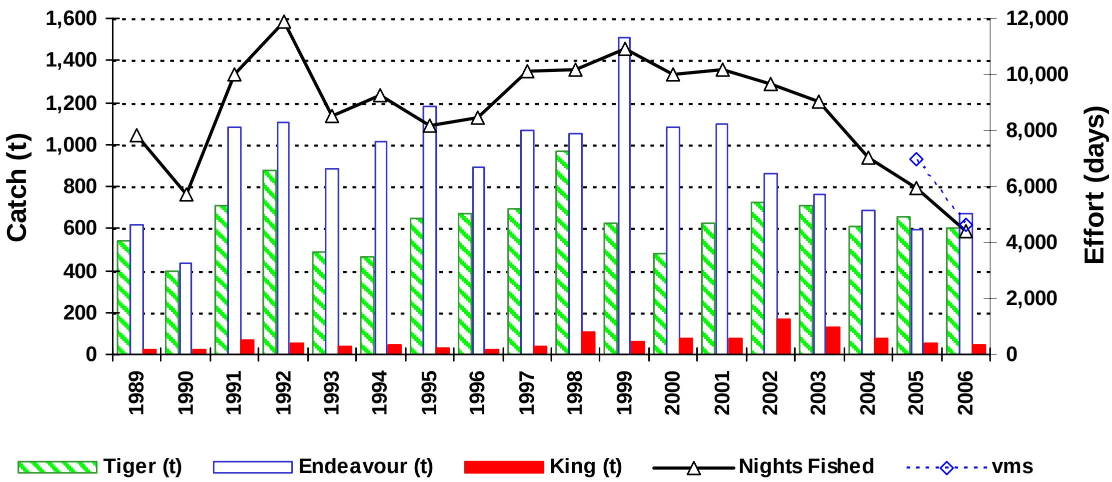

Figure 3.2.1 Annual catch by species group and effort from fisher logbook records. Effort based on Vessel Monitoring System data for 2005 and 2006 is also shown.

Between 2002 and 2005 fishing effort steadily decreased from about 9,600 days, which is close to the average for the 1990's, to around 6,000 days (Figure 3.2.1). Industry representatives attributed the decrease in fishing effort to increasing fuel costs, decreasing prawn prices in overseas markets and uncertainty about the future of the TSPF. As effort decreased tiger prawn catch rates (Figure 3.2.2) steadily increased and the total tiger prawn harvest remained relatively constant at around the ten-year (1993-02) average of 640 tonnes. In contrast the annual harvest of endeavour prawns decreased from the ten-year average of 1,060 tonnes to about 600 tonnes. Although endeavour prawn catch rates during this period were slightly below the long term average, catch rates increased in 2004-05 (Figure 3.2.2) suggesting that endeavour prawn stock biomass had remained relatively stable. In summary it appears that as fuel prices increased and prawn values decreased, fishers focused on catching tiger prawns that have a higher value in the market place and fished less.

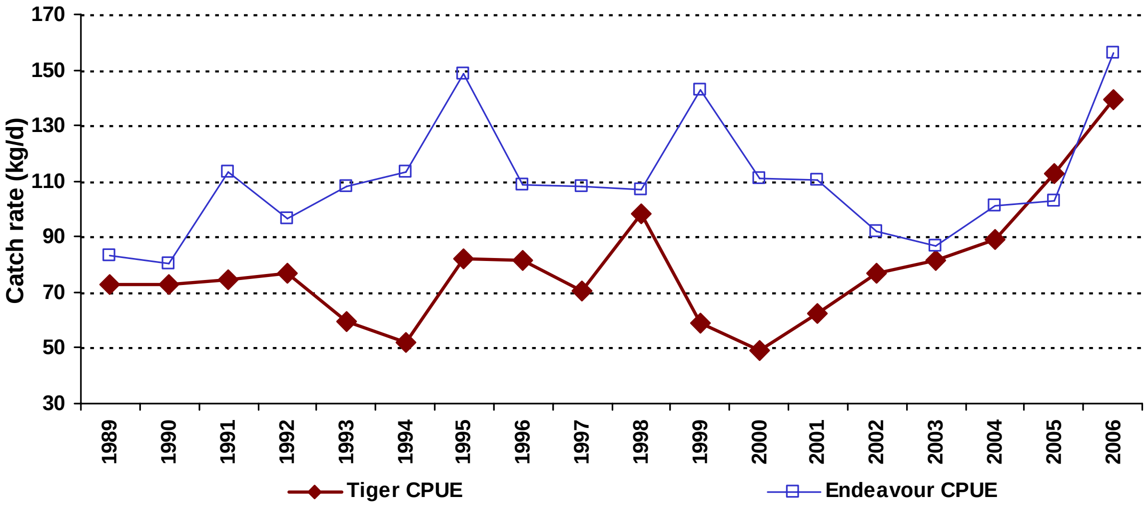

Figure 3.2.2 The average annual catch rates (CPUE) for tiger and endeavour prawns from fisher logbook records.

On the 9th November 2005, the Torres Strait Protected Zone Joint Authority (PZJA) announced that trawl licences would be granted for the 2006 season with pro-rata reductions to an overall cap of 9200 days. This reduction was based on the estimate of Emsy from the 2004 tiger prawn stock assessment. In February 2006 there was Commonwealth Government funded buy-back of licences and allocated fishing days, to give effect to catch sharing arrangements with Papua New Guinea. As a result of the reduction in allocated fishing days and the buy-back the number of Australian licences in the fishery is now 61 and the total number of fishing days allocated to Australian operators stands at approximately 6,867 days (Taylor et al. 2006). The annual catch rates (CPUE) for both tiger and endeavour prawns during 2006 were the highest on record indicating above average stock biomasses.

4 Assessment of the status of prawns stocks in 2006

By Clive Turnbull

4.1 Background

This chapter provides an update of the 2004 Torres Strait tiger prawn stock assessment (O'Neill and Turnbull 2006) to include the 2004-06 harvest data and additional vessel and gear information collected post May 2004. The need for this update was initially flagged at the July 2005 Alternative Management Workshop by industry representatives and managers to provide the most up to date information possible on the status of the tiger prawn stocks. The decision by the PZJA to implement a pro-rata 30 percent reduction in the number of allocated fishing days and the buy-back to provide the fishing access days for PNG vessels to participate in cross boarder fishing increased the need for an updated of the assessment.

4.2 Fishery Independent survey data

The February recruitment surveys that the DPI&F Long Term Fisheries Monitoring Program (LTMP) have conducted in Torres Strait since 1998 provide fishery-independent data that can be used to validate the trends observed in the commercial fisheries data. O'Neill and Turnbull (2006) compared a recruitment index derived from the survey data for the years 1989-2002 with recruitment indices derived from the fishery data and the stock assessment model. All three methods estimated similar recruitment indices between 1999 and 2002. Although the LTMP survey index for 1998 was higher than fishery index the general trend was the same; high recruitment in 1998 following by a decline to a low in 2000 then increasing recruitment through to 2002.

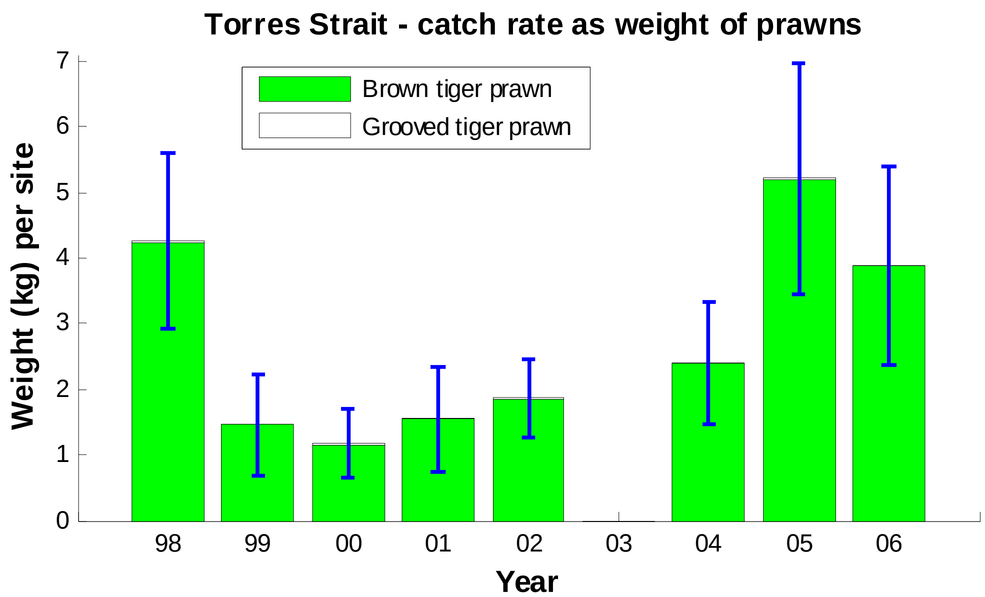

Figure 4.2.1 Tiger prawn catch rates from the February fishery-independent (LTMP) surveys. Note that the Torres Strait tiger prawn catch consists almost entirely of the brown tiger prawn. The error bars indicate the 95 % CI of the tiger prawn catch rate estimates.

The general trend in the survey catch rates of tiger prawns for the years 1998-2006 (Figure 4.2.1) is similar to the trends in the unstandardised commercial catch rates (Figure 3.2.2). Both indicate a period of steadily increasing catch rates between 2000 and 2005. Although the LTMP survey catch rates for 2006 are lower than for 2005, the catch rates from the logbook data for 2006 are the highest on record. The difference between the LTMP survey catch rates and the annual commercial catch rates can be explained by the unusually high tiger prawn catch rates for the months of May to November of the 2006 season (Figure 4.2.2). The commercial tiger prawn catch rates for March 2006 were slightly lower than for March 2005 which matches with the trend observed in the LTMP survey data (Figure 4.2.1).

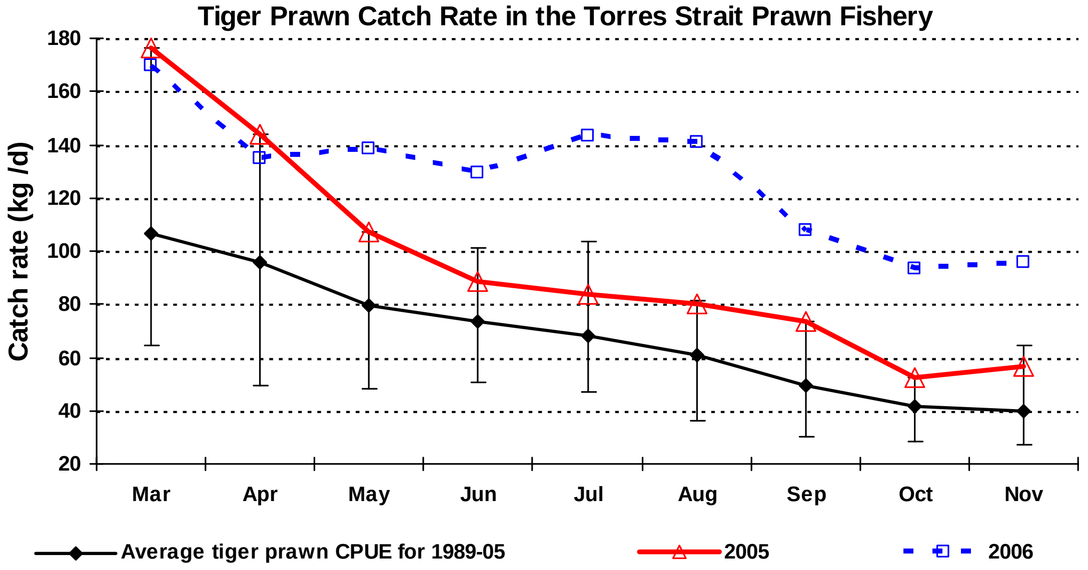

Figure 4.2.2 Monthly tiger prawn catch rates from commercial harvest data. The trends for 2005 and 2006 compared with the average for the years 1989-05. The error bars indicate the maximum and minimum catch rate in each month for the years 1989-05.

Figure 4.2.2 shows that the average monthly tiger prawn catch rate decreases throughout the season. Fishing effort (Figure 4.2.3) also follows this trend due to individual fishers either running out of allocated fishing days or deciding to return to port/ shift to another fishery as the catch rates reach a level that is no longer economically viable.

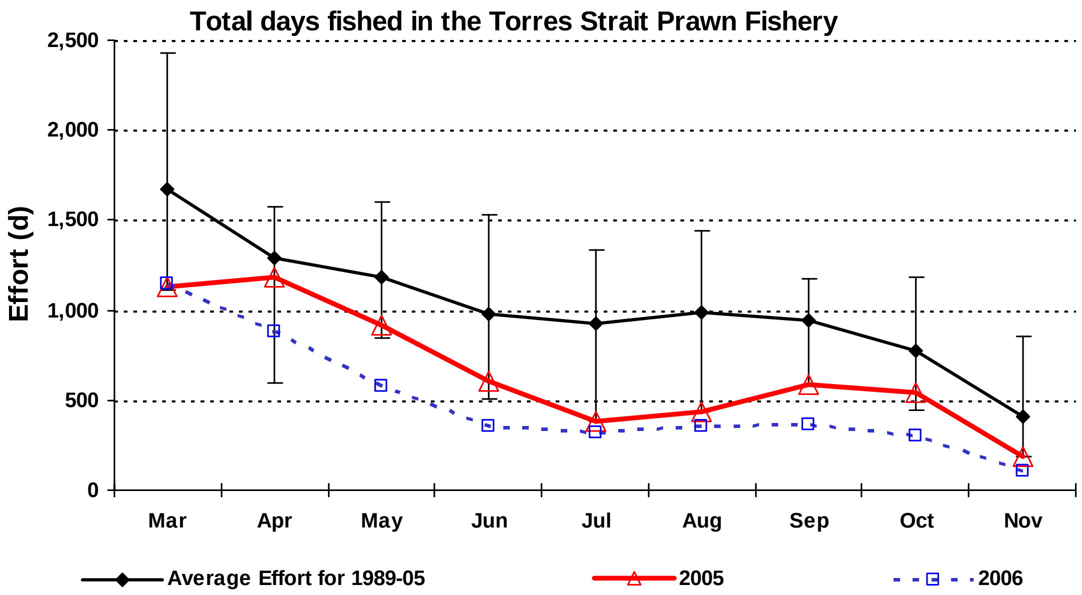

Figure 4.2.3 Monthly fishing effort (days fished) from the logbook records. The trends for 2005 and 2006 compared with the average for the years 1989-05. The error bars indicate the maximum and minimum fishing effort in each month for the years 1989-05.

4.3 Collection of vessel and gear data

The change in fishing power of vessels due to changing management arrangements (introduction of TEDs and BRDs, reduction of net size, changes in the size of the fleet etc) and vessel transfers and upgrades needs to be monitored and incorporated into regular fishery stock assessments. One of the recommendations from the review of the stock assessment was that the vessel characteristics database is updated every year. This was assigned a medium priority (Table 2.4.1). The vessel characteristics database has previously been updated by information collected through gear vessel surveys with each fisher, with the most recent survey undertaken in 2004 (O'Neill and Turnbull 2006). These surveys are highly labour intensive and time consuming.

The NP14 logbook used by the TSPF has a gear sheet that includes much of the data relevant to changes in fishing power and this gear sheet is submitted to AFMA whenever there are any gear changes. The use of data from this sheet to update the vessel characteristics database would be a much simpler and less labour intensive process. Gear sheets from the NP14 logbook were obtained from AFMA logbook section for 34 of the TSPF vessels with information from 2004-2006. This information was used to update the vessel characteristics database to 2006.

A few discrepancies were found for some vessels between the data collected by the 2004 gear vessel survey and the information recorded in the NP14 gear sheets. These discrepancies mostly arose as not all relevant fields on the gear sheet were always completed. In addition the NP14 logbook gear sheet is also used by vessels that operate in the Northern Prawn Fishery (NPF) and not all fields specify whether the information is for the NPF or TSPF (such as those for otter boards and fuel consumption). A possible strategy to address this would be for AFMA observers to validate the NP14 gear sheet data while at sea onboard the commercial vessels. This could be supplemented every few years by observers collecting more detailed information such as that in the gear vessel surveys while onboard the vessel.

4.4 Fishing Power Trends

The trends in fishing power were estimated for the years 1980-2005 using essentially the same procedures as the previous assessment. Since the 2004 analysis was conducted vessel and gear information was obtained for another 20 vessel/owner combinations via surveys of fishers/owners during 2004. In addition information from logbook gear sheets was obtained for 2005. When the fishing power analysis was conducted (November 2006) there was very limited data available in our vessel/gear database for 2006 therefore 2006 was not included in this analysis.

The inclusion of net size in the analysis is the only change that was made to the procedure for estimating the fishing power changes. Although vessels were allowed to increase their nets sizes back up to the 88m after 2003, many vessels have not increased their net sizes resulting in different net sizes being used concurrently in the fishery. Therefore we were able to include net size as a factor in the analysis instead of using the assumed 4 percent suggested by Dr Die.

A different technique was used to try and estimate the effect of the change in the average fishing power of the fleet that may have resulted from the 2006 buy-back. Those vessels that had fished during five out of the six years during 2000-05 were flagged and divided into those vessels that fished in 2006 and those that did not fish in 2006. The average tiger prawn catch rates of those two groups for the years 2000-05 were compared. The group that did fish had a 15 percent higher catch rate. This was then adjusted by the proportional contribution to the total effort during 2000-05 of the group that did not fish. This produced an estimated increase of 3.8 percent due to those vessels not fishing in 2006. This estimate was included in the standardisation of the monthly catch rate data that is one of the main inputs to the assessment model.

Although the updated fishing power trend has a very similar shape to the 2004 assessment the addition of the extra vessel/ gear information has reduced the size of the changes in fishing power (Figure 4.4.1) over the time series. Relative to the reference year of 1989 the highest fishing power was in 1998 and the estimates of the increase in fishing power are about 19% and 11% for the 2004 and 2006 assessments respectively.

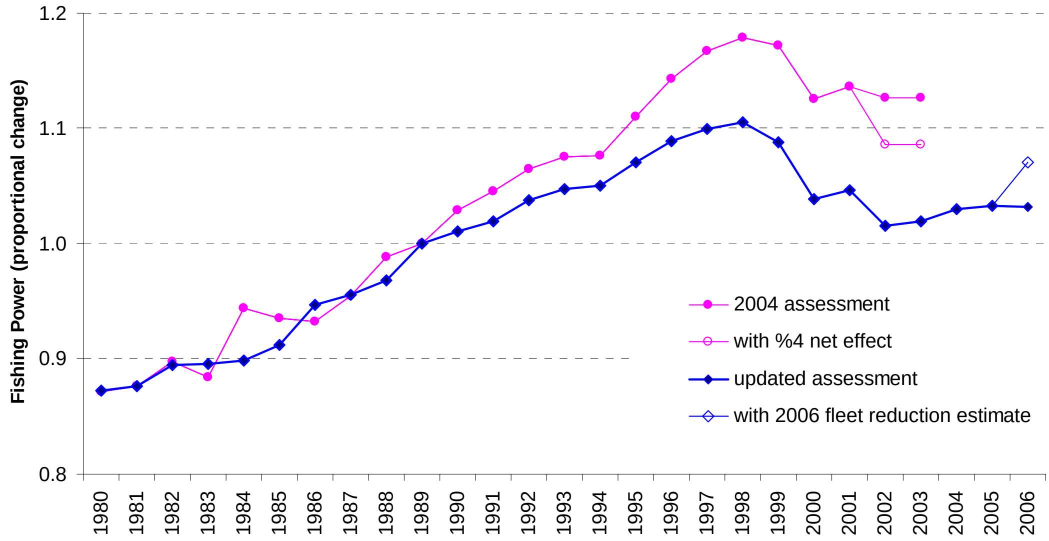

Figure 4.4.1 Comparison of the 2004 and 2006 estimates of the fishing power trends.

The current estimate of fishing power for 2006, including the estimated change due to the fleet reduction is about 7% above the reference year of 1989. As a comparison the estimate for 2003 from the earlier assessment, when the net reduction effect was included, was about 8.6 % above the reference year.

4.5 Update of the tiger prawn assessment

The updated tiger prawn stock assessment indicates that the biomass of tiger prawns has steadily increased since 2000 as fishing effort has declined. The upper plot in Figure 4.5.1 shows the monthly biomass estimates from the fitted stock model. The annual cycle in biomass size which results in a cycle in the catch rates is clearly visible. The lower plot shows annual change in the biomass expressed as a ratio of the virgin or unfished stock size. The two dotted horizontal lines are the estimated minimum biomass size (B_{msy}) that is needed to ensure the stock is at maximum productivity. The upper estimate is based on the best fit of the Ricker stock recruitment model and the lower is based on the best fit of the Beverton-Holt stock recruitment model.

The lower plot in Figure 4.5.1 shows that since 2002 the annual biomass estimate has been higher than during the 1990's and the stock level required for maximum stock productivity (B_{msy}). Since 2000 the stock size has steadily increased as the fishing effort has decreased (Figure 3.2.1). It is worth noting that the 2006 fishing effort (4,654 days, based on VMS data) was approximately half of the E_{msy} limit reference point of 9,200 days currently used in this fishery. Despite the low level of fishing effort in 2006 the tiger prawn catch was just below average due to the unusually high and sustained catch rates for the season (Figure 4.2.2).

Analysis of the VMS data for 2006 indicates that while 41 percent of the fleet (25 vessels) used all of their allocated days, four vessels with large allocation did not fish in Torres Strait. In addition another seven vessels that have greater than 80 allocated fishing days attached to their licence, used 50 percent or less of their allocated days. This observation may be of relevance to any discussions related to leasing of fishing days.

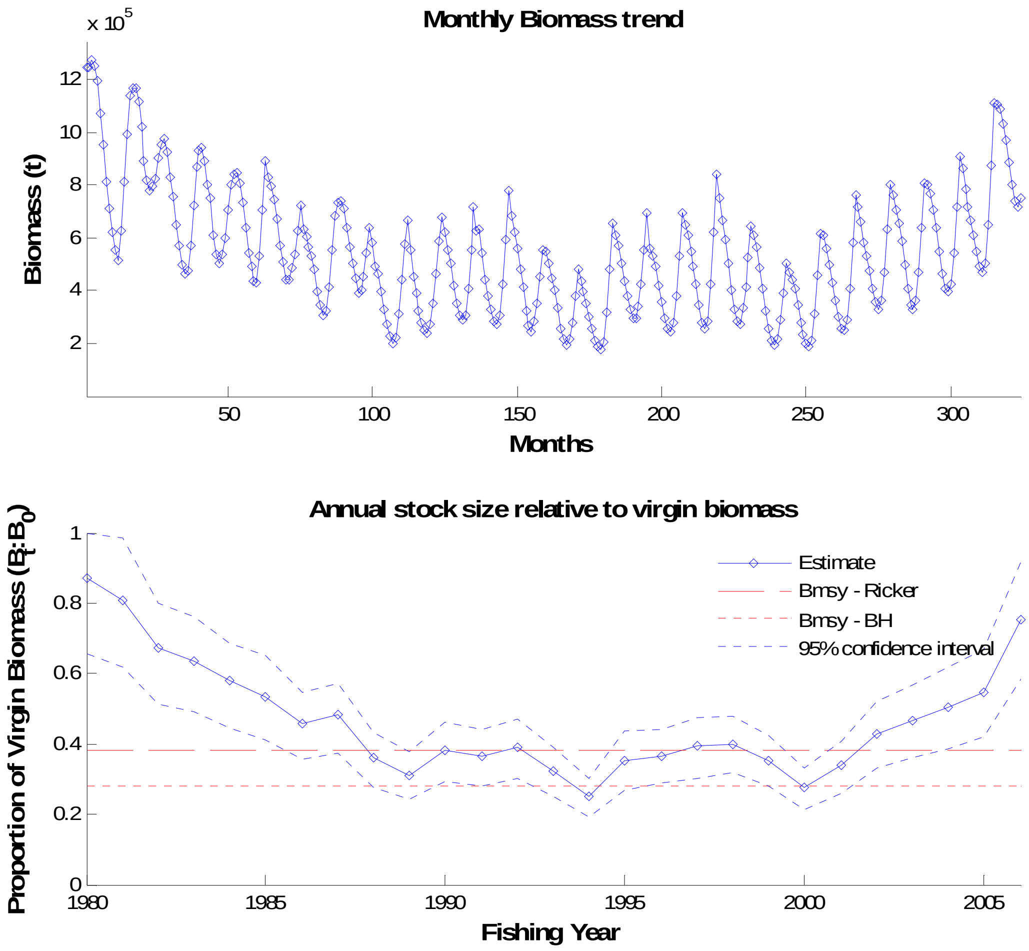

Figure 4.5.1 Trend in tiger prawn stock biomass; estimated from the tiger prawn stock assessment model.

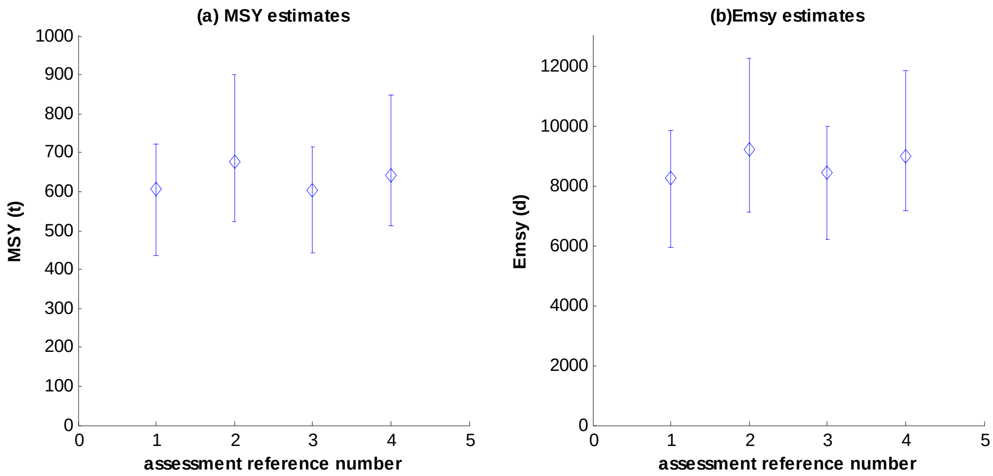

Figure 4.5.2 Comparison of management reference point estimates. Codes 1 and 2 on the horizontal axis identify the 2004 assessment; Ricker and BH respectively. Codes 3 and 4 on the horizontal axis identify the current assessment; Ricker and BH respectively.

The estimates of MSY and E_{msy} from the updated assessment are similar to those of the 2004 assessment (Figure 4.5.2). As additional years of data are added it is to be expected that these estimates will vary as the confidence intervals are quite wide, especially for the estimate of E_{msy}. The main take home message from the updated assessment is that tiger prawn biomass in recent years has been above the B_{msy} reference level and increasing. The assessment model estimates of recruitment have also been increasing in recent years.

4.6 Discussion

The 2004 tiger prawn stock assessment has been updated to include the commercial harvest data (logbook data) for the year 2004, 2005 and 2006. Although there was still some logbook records not available for 2006 when the data was provided by AFMA late in December 2006 the missing information would have a negligible impact on the assessment results.

The updated tiger prawn stock assessment and analysis of trends in commercial catch and effort data indicate that the biomass of tiger prawns has steadily increased since 2000 as fishing effort has decreased. Since 2002 the biomass has been higher than during the 1990's and the stock level required for maximum stock productivity (B_{msy}). As the biomass has increased catch rates of tiger prawns has increased maintaining the annual tiger prawn catch at close to the average for the last 10 years. The 2006 tiger prawn catch was down slightly but this is to be expected in light of the very low fishing effort in 2006. The average annual tiger prawn catch for 2006 is the highest recorded since full logbook records commenced in 1989.

The 2006 fishing effort (4,654 days, based on VMS data) was approximately half of the E_{msy} limit reference point of 9,200 days. Analysis of VMS data indicates that while 40 percent of the fleet utilised all of their available days many vessels used less than 50 percent of their available days.

4.7 References

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O'Neill, M.F., Courtney, A.J., Good, N.M., Turnbull, C.T., Yeomans, K.M., Staunton Smith, J. and Shootingstar, C. (2005) 'Reference point management and the role of catch-per-unit effort in prawn and scallop fisheries. FRDC Project #1999/120 Final Report.' Department of Primary Industries and Fisheries, Queensland QO 05001.

O'Neill, F.M., Turnbull, C.T. (2006) Stock assessment of the Torres Strait Tiger Prawn Fishery (*Penaeus esculentus*). Department of Primary Industries and Fisheries, Queensland. 83pp.

5 Catch data from unload records

By Cassandra Rose and Clive Turnbull

5.1 Introduction

The catches of individual fishing vessels are weighed and recorded on unloading dockets during transfer of the catch to 'mother-ships' (transport vessels) when at sea or 'cold-stores' when in port. These unload records provide a potential method of validating the data recorded by fishers in their logbooks and if necessary making adjustments to make the catch data more accurate and hence improve the accuracy of the stock assessment. Although fishers are generally quite good at estimating their catches weights based on the volume of their catch some concerns about the accuracy of the logbook catch weights being used in the stock assessment were raised by fishers.

During the review of the stock assessment by Dr Die a number of fishers noted that when they compared their logbook and unload records, the logbook catch was 15-20 percent lower. Apparently, not all fishers include the catch of soft and broken prawns or the catch from try shots in the logbook data. Discrepancies between the weight of catch entered into the logbook and the weight of catch recorded on the unload records may arise because most fishers base their logbook catch on the number of cartons of product per night multiplied by an assumed carton weight, whereas during an unload to a mother-ship or buyer the cartons are weighed and accurate weights of product recorded. Although the unload records should be more accurate they are pooled catch for a period of two weeks or possibly longer and at time are comprised of the catch of several fisheries.

The 2003 review by Dr Die of the Torres Strait tiger prawn stock assessment addressed these concerns through four recommendations that could improve the data used in the stock assessment. These recommendations were in summary:

1	Medium – correction factors for logbook landings.
3	Low – allocating unloading data to time periods.
4	Low – commercial size grading data.
14	Medium – collect harvest data prior to 1980.

The full wordings of the recommendations are listed in Table 2.4.1. The collection of individual fishers unload records may address these recommendations and the need to have some form of logbook validation to satisfy the requirements for accreditation of the fishery for export under the Environment Protection Biodiversity Conservation Act 1999.

5.2 Methods

At the commencement of the gear vessel surveys in February 2004 a letter was sent to all Torres Strait Prawn Entitlement Holders (TSPEH) that provided information on the reasons for both the gear vessel surveys and the need to obtain samples of individual fishers unload records from both recent years and from the early period of the fishery (late 1970s and early 1980s). The letter requested their support for the research and provision of this information. While the gear vessel surveys were conducted Task staff asked individual vessel owners about the possibility of obtaining copies of some of their unload records, however the response was not particularly positive. At that time there was a possibility of a reduction in the number of vessels in the TSPF and the recent introduction of the Great Barrier Reef Marine Park Authority Representative Areas Program had rezoned some trawl grounds to a non-trawl zoning category.

To try and obtain unload records through avenues other than directly from the fishers various government agencies were contacted. The:

- Australian Quarantine Inspection Service (AQUIS) used to receive the unload records, but this ceased five years ago and the unload records now go directly to the coldstores where the mother ship sends the product it unloads from the vessels at sea.

- Customs only record data on the quantities of exported prawn in the summary category of ‘frozen prawns’ and do not have the detailed product catch data information.

- Australian Bureau of Agricultural and Resource Economics (ABARE) and Australian Bureau of Statistics (ABS) receive their prawn catch data from Customs.

The cold-stores and agents that buy and sell prawns were contacted and were willing to provide access to the unload records with letters of permission from the vessel owners. All cold-stores and agents retained unload records only for the last five years. Over the next year nearly all TSPEH were contacted individually and asked if they would provide access to a sample of their unload records. It took a long time to get into contact with all of the owners as many were at sea and most waited till they were in port to consider providing access to the records.

There were fifteen TSPEH that either directly provided copies of random unload records from the last five years or signed letters of permission to access a random selection of 3-4 of their unload records per year from the Cold Stores. These were all from the period 1999-2004. A total of 248 unload records from 21 vessels were collected along with their corresponding DPI Transfer Certificate that documents the dates that the product was caught at sea (the catch period).

COMPARISON OF UNLOAD RECORD AND LOGBOOK DATA

The unload record is filled out when the vessel at sea unloads the catch to the mother-ship, roughly every two weeks. The information written on the unload record is: vessel name, date of unload to mother-ship, and for each product (the names varied at times but were mostly tiger, endeavour, king, whites, mix, bug, squid) the grade, number of cartons, gross kilograms and net kilograms (kg). The period over which this was caught is not written on the unload record but on the corresponding DPI Transfer Certificate. The catches of each type of prawn category were summed to give a total catch weight of: prawn (all prawns combined), tiger, endeavour, king and any other category written such as ‘whites’.

The logbook data can be summarised in the form of daily entries of: vessel name, date, prawn (the total prawn weight in kg), tiger, endeavour, king, mix, coral prawn, bug, squid (all in kg). At the time of this work data on grades of each species was not entered into the logbooks. The catch period on the DPI Transfer Certificate was used to extract the dates from the logbook data over which the product on the unload record was caught at sea. The catch from this period was summed to provide a total catch weight of: prawn, tiger, endeavour and king. The by-products were not included in these comparisons.

The weight of catches from each unload record were then compared to the logbook records. For each of total prawn, tiger, endeavour and king the percent difference in weights (Dw) between the unload record and logbook was expressed as:

$$Dw = \frac{(W_L - W_U)}{W_L} \times 100$$

Where W_L was the weight in the logbook, W_U was the weight in the unload record.

We found that in many cases, the total prawn catches (or catches of each of the species) did not match between the unload record and the logbook data with differences of more than 30%. It appeared we were comparing catches from totally different dates. A closer examination of the catch period written on the DPI Transfer Certificate revealed that they were often inaccurately recorded. For example, sometimes the catch dates appeared to match the movement of the mother-ship rather than the dates on which the product was actually caught.

To deal with this sometimes inaccurate catch period we set up a process to compare unload records and logbook data. That is, catch weights of total prawn were compared between the unload record and logbook:

- If the difference was less than 20% the catch dates written on the DPI Transfer Certificate were used.

- If the difference was greater than 20% then we looked at different catch dates in the logbook records that appeared to match more logically with when the product on the unload record was actually caught. We set a limit on how much we varied the dates written on the DPI Transfer Certificate. That is, up to 2 weeks either side of that written catch period.

The name of the product recorded on the unload record varied among vessels and skippers, probably mostly as result of product marketing. For example, king prawns were recorded on the unload record variously as:

- Endeavour + king
- Endeavour + red spot king
- Endeavour + red spot king + tiger

These have been written as different species in the logbooks sometimes under ‘endeavour’ and sometimes under ‘king’ in the logbook. Each unload record was examined in comparison to the corresponding logbook data and a decision made on the best method of matching the unload and logbook species categories. Occasionally king prawns were recorded in the unload records but do not appear at all in the equivalent logbook records. In these cases it appears that king prawns have been included with the endeavour species in the logbook records.

5.3 Results

Of the 248 unload records collected, 171 were able to be compared to the logbook data. These were all from the period 1999-2004 and were from 21 vessels (15 owners).

Seventy seven unload records were excluded as they were:
- Queensland East Coast Prawn Trawl Fishery only (60 records);
- A mixture of NPF and TSPF where the TSPF catches could not be clearly separated (4 records);
- Consecutive unload catch records added together that could not be matched to a catch period (9 records); and
- There were no matching DPI Transfer Certificate for the unload record to provide the catch period (4 records).

Catch periods were adjusted for 78 of the 171 unload records (46% of unload records). The catch period used for the logbook data was not changed by more than 15 days either side of that written on the DPI Transfer Certificate (except in 6 cases where it was clear the written catch period was not logical). In most cases the catch period was only altered by 1-5 days to provide a total catch that was much more similar to the catch reported on the unload record.

Generally the reported logbook catches matched very closely to the catches unloaded by the vessels. Across all 171 unload records, the total prawn logbook catches were 0.4% less than that of the unload records, the tiger prawn logbook catches were 4.6% less than unload records, and endeavour prawn logbook catches were only 0.1% less than unload records (Table 5.3.1).

Table 5.3.1 The mean (+se) difference of the logbook catch data from the unload catch data. Catch data from 171 unload records was used.

Species	Mean (+se) of the logbook catch from the unload record catch
Total Prawn	-0.4 + 0.7
Tiger	-4.6 + 3.5
Endeavour	-0.1 + 1.5
King*	-23.7 + 9.4

* 3 records with a difference of > 1000 % were excluded.

However, for king prawns the logbook and unload records did not match well, with a mean difference of 24% less king prawns reported in the logbooks than were actually unloaded by the vessels. Some of these differences may have been due to the various ways in which the catch of king prawns is recorded in the logbook.

There were sometimes very large differences between the weight of king prawn written on the unload record (where it was recorded solely as ‘king prawn’) and the weight of king prawn reported in the corresponding logbook data. These large differences occurred for at least one unload/logbook record comparisons from most of the vessels. A couple of examples were: 49 kg of king prawn recorded on the unload record whereas 2 kg of king prawn was recorded in the logbook and; 1059 kg king prawn recorded on the unload record whereas 462 kg of king prawn was recorded in the logbook. These large discrepancies were not associated with assigning the product of king prawn on the unload record to a different logbook species category. In all cases the unload record had written ‘king prawn’.

Due to confidentiality requirements, comparisons of the logbook data and the unload records for each vessel cannot be presented. However, for all vessels the total prawn, tiger prawn and endeavour prawn catch weights were very similar between the logbook data and the unload record. The king prawn catches had the greatest differences.

The results of the comparisons between each unload record and the corresponding logbook data were forwarded to each of the fifteen owners that provided access to their unload records.

5.4 Discussion

We were only able to progress the first of the four Dr Die recommendations that relate to the catch data. There were insufficient records to make it viable to peruse recommendations 3 (adjusting for the delay in the recording of the unload data) and 4 (the use of prawn grades as a proxy for size information). In addition none of the current or past Torres Strait Prawn fishes that we were able to contact have any records from the 1980s or earlier (recommendation 14). As such it was not possible to develop priors for the stock biomass ratio in 1980 as recommended in the review of the stock assessment.

A sample of 171 unload records were voluntarily obtained from fishers and processors and compared with logbook records. This was a difficult and time consuming activity for the following reasons:

- Obtaining permission to access individual fishers unload catch records was extremely labour intensive and not very productive. There was a general reluctance on the part of many fishers to provide their confidential catch records due to the uncertainty around the future management arrangements for the fishery.

- The catch period recorded on the DPI Transfer Certificate was often inaccurate making it difficult to compare the unload records with the logbook records. It was a very slow process working through the logbook catches for each unload record and totalling catches for a few days either before, after or both sides of the catch period specified on the DPI Transfer Certificate; and

- There was no consistent pattern in the manner in which product such as 'whites' 'endeavour + king' was assigned to the either 'endeavour' or 'king' prawn species in the logbook.

Differences were found between the logbook data at the level of individual unloads, mainly due to difficulties in matching the unload data with the corresponding daily fishing records in the logbook data.

Less resource intensive logbook validation systems are applied by AFMA in the Commonwealth South Eastern Shark and Scalefish Fishery (SESS) and in the NPF. In the SESS, for each catch landing fishers are required to provide the unload record (catch disposal record) and the corresponding logbook sheets as part of quota monitoring.

In the NPF fishers submit a Season Landing Return (SLR) at the end of each fishing season to AFMA. The banana prawn and tiger prawn seasons are approximately two and four months respectively. This SLR contains the total weight of the catch of each species for the season sourced from the fishers' own records. AFMA compares the SLR catches to the gross logbook catches and in most cases the catches match within five percent (Haine *et al*. 2005). Both of these methods avoid the problem of inaccurate records for the catch period and the labour intensive process of accessing unload records by requesting these records from each fisher.

The logbook validation method used by AFMA in the NPF may be more appropriate for the Torres Strait Prawn Fishery. It is less demanding on the fishers and less labour intensive than the method used in the SESS. The annual total catch by species at the end of the fishing season (March- December) recorded by the vessel owner from their unload records could be submitted to AFMA and compared to the total catch recorded on the logbooks for that season. This may also reduce the problem with the king prawn data as the owner may know how the different product categories of king prawn were reported in the logbooks.

It may be difficult for some vessel owners to provide the annual total catch by species from the TSPF as the catch from some vessels is often a combination of catch from two fisheries, the TSPF and the Qld East Coast Trawl Fishery and at times also includes catch from the NPF. However there is a need for some form of logbook validation system to satisfy requirements for accreditation of the fishery for export under the Environment Protection Biodiversity Conservation Act 1999 and that used for the NPF may be the simplest method for the TSPF.

A comparison of all of the available unload data with the corresponding logbook record however, found only small differences for tiger and endeavour prawns. The catches recorded in the logbooks were 0.4%, 4.6% and 0.1% less than the unload records for total prawn catch, tiger prawn and endeavour prawn respectively. In contrast the logbook king prawn catch, which is only a small percentage of the total catch, was 24% less than the unload records.

In summary, there was a good overall match between the tiger prawn and endeavour prawn catch weights recorded by fishers in their logbooks and the total weights of product recorded when vessels unload to mother ships and processors. This indicates that the logbook records provide an accurate estimate of the catch of the fishery and that there is no need to adjust the catches and catch rates obtained from the logbook records using the unload records.

5.5 References

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Haine, O.S., Garvey, J.R. (2005) Nothern Prawn Fishery Data Summary 2005. Logbook Program, Australian Fisheries Management Authority, Canberra

6 Torres Strait Prawn trawl bycatch

By Cassandra Rose

6.1 Introduction

Objective 1 of the TSCRC Task 1.5 was to 'Develop cost-effective protocols to monitor and quantify the by-catch and environmental impacts of commercial prawn trawling'.

The first part of this objective was achieved by liaising with AFMA on the development of an industry funded observer program that monitors and quantifies the by-catch and environmental impacts of prawn trawling. This observer program commenced in the TSPF during 2005 and the Task had input into sampling protocols and the type of data collected.

The second component of the objective was achieved through analysis of bycatch samples collected on three DPI&F annual research surveys (2004-2006). This allowed detailed fishery independent investigation of the composition, distribution and catch rates of bycatch in the TSPF and an assessment of the impact of prawn trawling on the bycatch communities. The surveys were conducted within the main prawn trawling grounds and also in the adjacent areas seasonally closed to trawling and fully closed to trawling (East and West of Warrior Reefs Closures). The bycatch species list generated by this analysis was provided to the Torres CRC project: Mapping and characterization of key biotic and physical attributes of the Torres Strait ecosystem and was used in the Level 1 Ecological Risk Assessment (ERA) of the Torres Strait Prawn Fishery undertaken by CSIRO in collaboration with the Principal Investigator for this Task.

Prawn trawling is a relatively non-selective fishing method where the bycatch is often a significantly higher proportion of the catch than the target species. In recent years Australian environmental legislation has become more stringent to help ensure that all Australian fisheries operate in an ecologically sustainable manner. The Environment Protection Biodiversity Conservation Act 1999 requires all fisheries that export product to show that they are not impacting in a negative manner on any of the target species, in the TSPF prawns, or any other species that the fishery interacts with, in the TSPF, mainly bycatch.

The aim of this work was to investigate that composition and distribution of bycatch of the Torres Strait Prawn Trawl Fishery (TSPF) and to assess the impact of prawn trawling on the bycatch communities. This is additional and very detailed bycatch information that complements the AFMA industry funded observer program that commenced in 2005. The observer program monitors the level and condition of lobster bycatch, validates logbook data on target and byproduct species and describes and quantifies the by-catch and capture of protected species. It may also incorporate other work at times such as testing alternative bycatch reduction devices.

Although fishery independent prawn recruitment surveys have been conducted during February-March of each year since 1998 by DPI&F, they have focussed on the commercial prawn species. The only bycatch information collected was total weight of bycatch. These annual surveys were conducted in areas of the TSPF with differing intensities of trawling, that is, in the main trawl ground area open to prawn trawling the entire season; in the east of Warrior Reefs area closed to trawling for the first 5 months of the season; and in the west of Warrior Reefs entirely closed to trawling (Figure 6.2.1). The survey vessel used nets similar to those in the commercial prawn trawl fishery that have Turtle Excluder Devices (TEDs) and Bycatch Reduction Devices (BRDs) installed. These annual fishery independent surveys provided the opportunity to compare the community composition and distribution of small bycatch (fish and invertebrates) across these three areas of varying trawl intensity. This comparison allowed an assessment of the impact of prawn trawling on the bycatch communities of the TSPF. The collection of bycatch on these annual surveys will also provide fishery independent information on the interactions of prawn trawlers with protected species.

Published information on the composition of prawn trawl bycatch in the Torres Straits is limited to two studies. One was conducted in 1985-1986 and chartered a commercial trawler to sample every three months within the main trawl grounds and also within the west of Warrior Reef closure (Harris and Poiner 1990). The other was undertaken in 1997 and used a CSIRO research trawler to survey the southern area of the main Torres Strait trawl grounds (Stobutzki 2000). The bycatch data from these two studies was combined to provide an assessment of the relative sustainability of the fish bycatch (Turnbull *et al.* 2001). This examined the susceptibility of species to capture and mortality due to trawling and their ability to recover once their population has been decreased. Five species were identified as least likely to be sustainable as they were benthic or demersal species and prefer trawl grounds. The species most likely to be sustainable were pelagic species. The assessment concluded there was a need for up to date estimates of bycatch composition and catch rates, including improved identification of invertebrates and elasmobranches.

A study of the seabed in Torres Strait (Pitcher *et al.* 2004) stated that "species identification is essential because Torres Strait is a biogeographic boundary due to past periodic separation of east and west fauna, an important concern for regional marine planning". Since the seabed study a large project is underway to map the seabed habitat biodiversity of the Torres Strait (Mapping and characterization of key biotic and physical attributes of the Torres Strait ecosystem funded by the Torres Strait CRC and with contributions from CSIRO, Geoscience Australia, DPI&F and the Queensland Museum).

While species identification of bycatch is essential, detection of changes in the bycatch communities through monitoring programs or observer work would be much more cost effective if those changes could be detected at higher taxonomic levels. Some disturbance studies on marine communities have indicated that the aggregation of species data to higher taxonomic levels of family or phyla has resulted in no loss of information and in some cases has increased the ability to detect differences in the marine communities (Warwick 1993).

6.2 Methods

6.2.1 Bycatch Sampling

Yearly fishery independent prawn recruitment surveys are conducted by DPI&F to assess the state of prawn stocks in the Torres Strait. These are done in February as close as possible to the new moon just before the opening of prawn trawling season. The survey sites were fixed and chosen to represent both the area open to fishing and the closure areas around Warrior Reef that harbour juvenile prawns (Figure 6.2.1).

Samples of bycatch were collected on these surveys in 2004, 2005 and 2006 at the 16 fixed sites that were surveyed for prawns: 5 in the area open to trawling; 5 in the east of Warrior Reef area seasonally closed to trawling; and 6 in the west of Warrior Reef area entirely closed to trawling. These three areas are referred to as open, semi closed and closed. Bycatch was also collected from additional sites that were surveyed for the prawn stock assessment in the open area in 2005 (2 sites) and 2006 (the 2 extra sites from 2005 and 2 more sites) (Figure 6.2.1).

The DPI&F 18 metre research trawler, the RV Gwendoline May was used for all surveys. It has four 4 fathom commercial mesh nets, each with a headrope length of 7.62 m, 51mm mesh in the body of the net and 44mm mesh in the codend. At night each site was surveyed by a one nautical mile trawl at an average trawl speed of 3.0 knots. The depth and time taken to trawl (generally around 20 minutes) were recorded.

The catch from each net was emptied onto a sorting tray divided into four quarters and the prawns collected (Figure 6.2.2). In 2004 at each of the 16 sites one subsample of the bycatch was retained from the port inner net (16 bycatch subsamples). In 2005 and 2006 two subsamples were retained, one from each of the port inner and starboard inner nets. In 2005, 18 sites were sampled resulting in a total of 36 subsamples and in 2006 there were 20 sites with 40 subsamples. Subsamples were retained from 2 nets per trawl to determine how many more bycatch species were recorded by processing a larger subsample from each trawl. Over the 3 years, 92 subsamples of bycatch were collected from 54 trawls at a total of 20 sites.

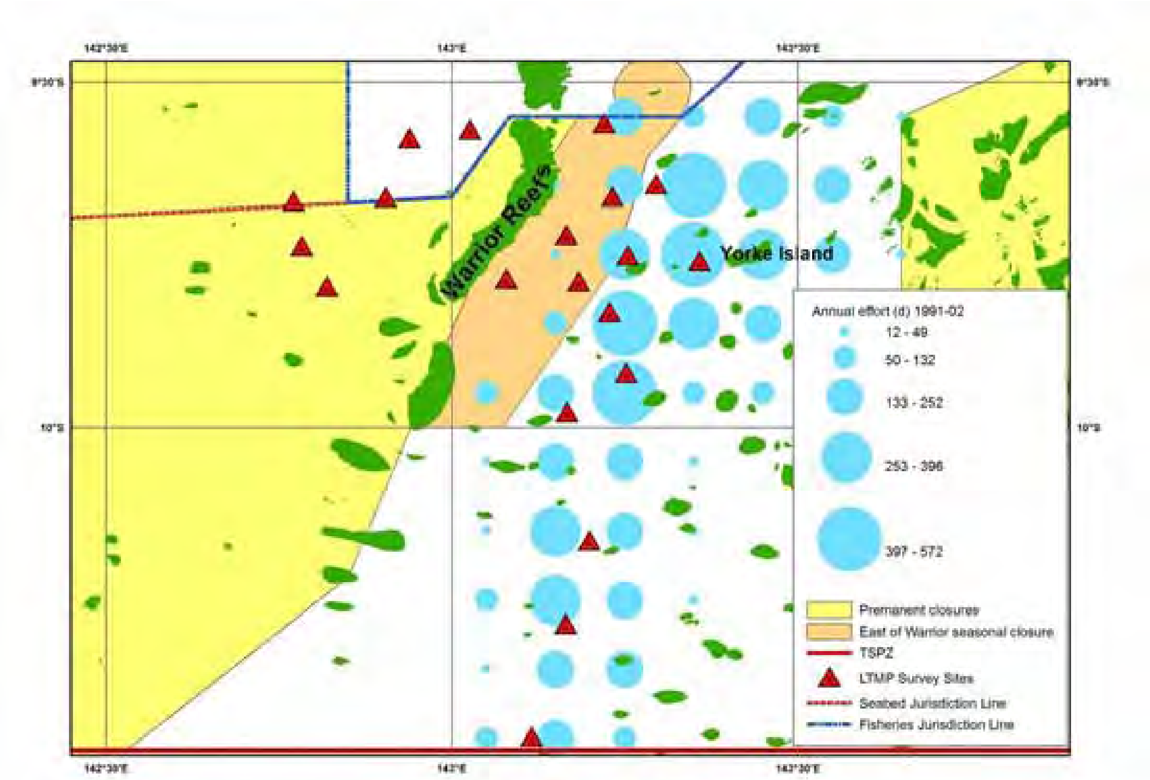


Figure 6.2.1 Locations of the fishery independent surveys sites. Two of the survey sites to the west of Warrior Reefs are within Torres Strait waters that are under Papua New Guinea jurisdiction.

The bycatch subsample was generally 5 to 8 kg, a quantity that could be processed in a cost and time effective manner given the allocated resources. The total bycatch from the net and the subsample were weighed. The subsamples were then frozen and taken back to the DPI&F laboratory at Northern Fisheries Centre, Cairns. Any large bycatch such as sharks, turtles and sea snakes were photographed and discarded alive.

Figure 6.2.2 Sorting the catch on the RV Gwendoline May sorting tray. One net was emptied into each quarter of the tray.

6.2.2 Species identification

All individuals in the bycatch were identified to the lowest possible taxonomic level. For each species or taxa, twenty individuals were measured to the nearest millimetre and the weight of all individuals of that species recorded to the nearest 0.1 gram.

Specialist taxonomic references and the DPI&F Species Register (SR) were used to identify the bycatch species. The DPI&F have developed a web based Species Register of bycatch species to provide a single source of taxonomic information to assist accurate identification. Each species identified is entered into the SR with a photograph and all relevant taxonomic information and is assigned an SR number. A specimen of the species is sent to a Museum for validation of the identification.

All the original bycatch data is stored on the DPI&F Long Term Monitoring Program database with SR numbers and also a CAAB code for those fauna identified to species. The Codes for Australian Aquatic Biota (CAAB) is an 8-digit coding system for aquatic organisms in the Australian region maintained by CSIRO Division of Marine and Atmospheric Research (Rees *et al.* 1999). Species data were aggregated to the higher taxonomic levels of family and phyla. Some invertebrate taxa were unable to be identified to the family level and were excluded from the family analyses.

The distributional range of each species was investigated to examine the possible occurrence of endemic species in the bycatch. Information was sourced from the Australian Faunal Directory (2006), Oceanographic Biogeographic Information System (2006), Froese and Pauly (2006) and some specialist taxonomic references.

6.2.3 Sediment type and current stress

The depth at each site was recorded to the nearest metre (m) from the depth sounder onboard the RV Gwendoline May. Sediment type (% gravel, % sand and % mud) and seabed current stress (Pascals N/m^2) data for each site location were extracted from the data collected for the Torres Strait Seabed study (Pitcher *et al.* 2004).

6.3 Analyses

6.3.1 Data analyses

For all subsamples, the estimated catch of each species (in number of individuals and weight) was standardised to represent the total catch from the net by using a grossing factor (the ratio of the total bycatch weight to the weight of the subsample). For the remainder of this report these are still referred to as subsamples, although they have all been standardised. As all trawls were one nautical mile all catch data refer to number of individuals/swept area (referred to herein as abundance) or g/swept area (weight). The area swept *S* was estimated by:

$$S = \frac{H \times F \times D}{10\,000}$$

Where *H* was the headrope length of one net (7.62 m), *F* was the net spread factor (0.70) from Courtney *et al*. (2005) and *D* was the distance trawled (1 nautical mile or 1 852 m). Division by 10 000 converts the area in metres to hectares. Each net swept 0.99 hectare (ha).

6.3.2 Catch rates

To allow comparisons of catch rates among years, areas and species and to other studies the catch weights were converted to a weight (g or kg) per 1 hectare. The study of 1985-1986 in Torres Strait reported catch rates in kg/30 minutes for some of the major taxonomic groups (Harris and Poiner 1990). To allow comparison of catch rates to that study the catch weights of the same major taxonomic groups were converted to kg/30 minutes, using the mean trawl time of 20 minutes. The trawler used by Harris and Poiner (1990) was of the same configuration and net type as the RV Gwendoline May though the nets were each 5 fathoms with a headrope length of 9.16 m, one fathom larger than those of the RV Gwendoline May. Our catch rates were adjusted to match the swept area of the trawler used in Harris and Poiner (1990). It was not possible to compare the catch rates from this 2004-2006 survey with the other trawl bycatch study in the Torres Strait, Stobutzki *et al.* (2000) as those bycatch samples were collected by a very large stern trawler, that is different net size and configuration and catch rates were presented in terms of number or kg per hour, rather than swept area.

The DPI&F research surveys in the Torres Strait were also conducted on the northern Queensland coast on the same survey trips. This provided an opportunity to assess the catch rates of bycatch between the two regions by comparison of the total bycatch weight recorded at sea from the two inner nets.

6.3.3 Univariate analyses

One way analyses of variance (ANOVAs) were used to test for differences between the three areas, open, semi closed and closed for each of 3 years 2004-2006 (with sites as replicates). The variables used were number of species, number of families, abundance and weight.

Two way repeated measures ANOVAs were used to examine the differences between the three areas for each of the variables and the number and catch rate (kg/ha) of fish species across the 3 years. Data was used from the port inner net only for the 3 years and only those sites that were sampled every year were included (16 sites): 5 in the open area; 5 in the semi closed area; and 6 in the closed area.

One way ANOVAs were used for the 36 bycatch species that occurred in all three areas every year to test for differences in the abundance of each of the species among the three areas. Data from port inner nets only was used and only the 16 sites sampled every year.

Homogeneity of variances was tested using Bartlett's test. For all data these tests were not significant ($P>0.05$). A diagnostic on the residuals from the analyses of variance indicated normal distributions. Hence there was no need to transform any of the data prior to analysis.

When an ANOVA showed significant effects, *a posteriori* multiple comparison tests were done using the Least Significant Difference procedure.

In cases of non-significant effects, post-hoc power analyses were used to determine the minimum detectable difference that the analyses could have detected at 5% significance level with an adequate power of 0.8 (Fairweather 1991). Power analyses was also used to determine the number of sites needed to detect a change of 50% of the mean number of species, families, abundance and weight among the 3 areas at a 5% significance level and with a power of 0.8.

6.3.4 Multivariate analysis

Multidimensional (MDS) scaling was used to examine the bycatch community composition, that is, species, their abundances and weights, among the three areas over the 3 years and also to examine this variation in relation to the environmental variables, depth, current stress and sediment type. All 92 subsamples were used in these analyses (all sites and nets from each year). The statistical software package PRIMER (Clarke and Warwick 2001) was used for these analyses. A Bray-Curtis similarity matrix was applied to classify the similarity between pairs of samples based on the square root transformed species abundance and weight, family and phyla abundance data and the untransformed environmental data.

A non-metric MDS ordination based on the rank order information in the similarity matrix was used to display the similarity relationships between sites in multidimensional space. The ordination can have as many dimensions as there are variables, but most meaningful patterns are recovered in the early ordination axes and a stress coefficient indicates how well a two dimensional display represents the relationship among sites (stress values <0.2 are considered to provide adequate representation) (Clarke and Warwick 2001).

The ordinations were carried out on species and families that were present in at least 5% of samples across the 3 years (159 species and 66 families). This ensured that very rare species or families were not included in the analyses.

A useful comparative measure of the degree of separation of areas (predefined as a factor in the analyses) in the MDS is an analysis of similarities (ANOSIM procedure in PRIMER) that is based on the similarity matrix and computes an 'R' statistic. This tests the null hypothesis that there are no differences in community composition among the areas. If the Global R statistic = 1 the null hypothesis is false and there are differences among areas. If Global R=0 the null hypothesis is true and there are no differences among areas. Pairwise R statistics reveal between which pair of areas the differences lie and gives an absolute measure of how separated the areas are. On a scale of 0 (indistinguishable) to 1 (highly separate): R>0.75 well separated; R>0.5 overlapping but different; and R<0.25 barely separable (Clarke and Gorley 2001, Clarke and Warwick 2001).

The relationship between each of the biotic variables (species and family abundance and weight) and the abiotic or environmental variables (depth, current stress and sediment type) was examined by a process in PRIMER that tests all abiotic variables singly and in all combinations to find the combination (or single variable) that attains best match to each of the biotic similarity matrices. That is, it calculates a measure of agreement between the abiotic and biotic similarity matrices. If the environmental variables are responsible for structuring the biological community composition then the two matrices will be in complete agreement. A standard spearman rank correlation is used. Spearman 'p' lies in the range -1 to 1 where -1 represents complete opposition and 1 represents complete agreement (Clarke and Gorley 2001).

6.4 Results

6.4.1 Description of bycatch

BYCATCH COMPOSITION BY MAJOR GROUPS

The prawn trawl bycatch from 2004-2006 and all 92 subsamples was dominated by fish (teleosts) that accounted for 77% of the total bycatch weight, followed by crustaceans at 17% (Table 6.4.1). All of the invertebrates combined represented 22.4% of the total bycatch weight and were dominated by crabs and non-commercial prawns (commonly referred to as coral prawns). Other invertebrates refer to ascidians, anemones and soft corals.

Elasmobranchs were a very small percent of the bycatch. Over the 3 years, three small sharks and two small rays were caught and returned to the sea alive: *Carcharhinus dussumieri* (whitecheek shark); *Stegostoma fasciatum* (zebra shark); *Rhynchobatus australiae* (white-spotted guitarfish); *Dasyatis leylandi* (painted maskray); and *Gymnura australis* (butterfly ray).

Table 6.4.1 Major groups of bycatch from all sites sampled over the 3 years ranked in descending order of percent weight of total bycatch weight.

Group	% total
Teleost	77.4
Crustacean	17.1
Mollusc	3.2
Echinoderm	1.8
Other invertebrate	0.3
Algae	0.1
Elasmobranch	0.1

To allow a comparison of the bycatch composition by the major groups with the study in the Torres Strait in 1985-1986, the bycatch was grouped into the same categories as presented in that work (Harris and Poiner 1990) (Table 6.4.2). In 2004-2006 fish and crabs were more dominant and scallops less dominant than in the mid 1980s.

Table 6.4.2 Bycatch groups from all sites sampled over 2004-2006 compared with the bycatch from 1985-1986 (Harris and Poiner 1990). Percent total is percent weight of the total bycatch weight.

Group	2004-2006 % total	1985-1986 % total
Teleosts	77.4	52-69
Crabs	11.8	8
Scallops	1.7	3
Cephalopods	1.4	1
Sharks and rays	0.1	1-3

BYCATCH SPECIES

Over the 3 years and all 92 bycatch subsamples a total of 374 taxa were recorded from 112 families and a total weight of 778 kg. More than half the taxa were fish species (196 species). Most species occurred rarely in the catch, as 94% of the species contributed < 1% to the total bycatch weight and 70% of the species occurred in <10% of all subsamples. Only 8% of the species were recorded in more than 50% of the subsamples (Appendix 3). All bycatch were identified to species except 55 taxa that consisted of mostly echinoderms, some ascidians, anemones and soft corals.

Only 23 species exceeded 1% of the species bycatch by weight and these species accounted for 65% of the total bycatch weight (Table 6.4.3). These 23 species were dominated by fish, accounting for 78% of the weight of these 23 species, followed by portunid crabs at 16%, then scallops and coral prawns at 3% each.

Table 6.4.3 Dominant species by weight from all sites sampled over the 3 years ranked in descending order of % of total bycatch weight.

Species	Family	% total	Group
Scolopsis taenioptera	Nemipteridae	8.2	fish
Lethrinus genivittatus	Lethrinidae	6.2	fish
Paramonacanthus spp	Monacanthidae	5.1	fish
Apogon fasciatus	Apogonidae	4.0	fish
Portunus (Xiphonectes) tenuipes	Portunidae	3.7	crab
Nemipterus furcosus	Nemipteridae	3.4	fish
Nemipterus hexodon	Nemipteridae	3.1	fish
Portunus (Monomia) rubromarginatus	Portunidae	3.1	crab
Priancanthus tayenus	Priancanthidae	3.0	fish
Nemipterus peronii	Nemipteridae	2.9	fish
Apogon truncatus	Apogonidae	2.3	fish
Portunus (Lupocycloporus) gracilimanus	Portunidae	2.1	crab
Metapenaeopsis rosea	Penaeidae	2.1	coral prawn
Choerodon cephalotes	Labridae	2.0	fish
Saurida argentea/tumbil complex	Synodontidae	2.0	fish
Saurida undosquamis/grandisquamis complex	Synodontidae	2.0	fish
Inegocia japonica	Platycephalidae	2.0	fish
Pseudorhombus spinosus	Paralichthyidae	1.7	fish
Amusium pleuronectes	Pectinidae	1.7	scallop
Thalamita sima	Portunidae	1.6	crab
Upeneus asymmetricus	Mullidae	1.3	fish
Lagocephalus sceleratus	Tetraodontidae	1.2	fish
Terapon theraps	Terapontidae	1.0	fish

Paramonacanthus spp, the third most dominant species in terms of weight was also the most commonly occurring fish as it was present in all but one of the 92 subsamples with a 98.9% frequency of capture (Appendix 3). Two species, *Paramonacanthus choirocephalus* and *Paramonacanthus otisensis* hybridise in the region north of Princess Charlotte Bay, on the north Queensland coast (Hutchins 1997). As it was not possible to distinguish between these species and hybrids in the Torres Strait bycatch they were recorded as *Paramonacanthus spp*. Some other species that are under review due to taxonomic problems with the species and/or group were referred to as a species complex (pers. comm. Dan Gledhill CSIRO 2006).

FISH BYCATCH

Of the 196 fish species recorded over the 3 years and all subsamples, 24 species from 14 families accounted for >1% of the total fish bycatch weight (Table 6.4.4).

Table 6.4.4 Dominant fish species and families from all sites and years ranked in descending order of % of total fish bycatch weight.

Species	Family	% comp
Scolopsis taenioptera	Nemipteridae	10.5
Lethrinus genivittatus	Lethrinidae	8.0
Paramonacanthus spp	Monacanthidae	6.6
Apogon fasciatus	Apogonidae	5.2
Nemipterus furcosus	Nemipteridae	4.4
Nemipterus hexodon	Nemipteridae	4.0
Priancanthus tayenus	Priancanthidae	3.8
Nemipterus peronii	Nemipteridae	3.8
Apogon truncatus	Apogonidae	3.0
Choerodon cephalotes	Labridae	2.6
Saurida argentea/tumbil complex	Synodontidae	2.6
Saurida undosquamis/grandisquamis complex	Synodontidae	2.6
Inegocia japonica	Platycephalidae	2.5
Pseudorhombus spinosus	Paralichthyidae	2.2
Upeneus asymmetricus	Mullidae	1.7
Lagocephalus sceleratus	Tetraodontidae	1.6
Terapon theraps	Terapontidae	1.2
Upeneus luzonius	Mullidae	1.2
Apogon poecilopterus	Apogonidae	1.2
Siganus canaliculatus	Siganidae	1.1
Sorsogona tuberculata	Platycephalidae	1.1
Torquigener whitleyi	Tetraodontidae	1.0
Diagramma pictum labiosum	Haemulidae	1.0
Pseudorhombus argus	Paralichthyidae	1.0

The ten most dominant bycatch fish species caught were: *Scolopsis taenioptera* (monocle bream); *Lethrinus genivittatus* (emperor); *Paramonacanthus spp* (leatherjacket); *Apogon fasciatus* and *Apogon truncatus* (cardinal fish); *Nemipterus furcosus*, *Nemipterus hexodon* and *Nemipterus peronii* (threadfin breams); and *Priancanthus tayenus* (bigeye).

For each of the 3 years, 2004 -2006 the same ten fish families were the dominant fish families by weight, with the first fish family, Nemipteridae the most dominant family every year. These families were: Nemipteridae (threadfin bream); Lethrinidae (emperor); Monacanthidae (leatherjacket); Apogonidae (cardinal fish); Priancanthidae (bigeye); Labridae (wrasse); Synodontidae (lizardfish); Paralichthyidae (flounder); Mullidae (goatfish); and Tetraodontidae (pufferfish).

BYCATCH EACH YEAR

The bycatch composition did not vary greatly among the three years 2004-2006. Each year most species occurred rarely with almost the same 24 to 28 species each accounting for >1% of the total bycatch weight. These species were nearly all fish (78-79% of total bycatch weight), followed by portunid crabs, non-commercial prawns and scallops.

There were slightly more species recorded in 2006 than 2005, however there were also more sites sampled in the latter year (Table 6.4.5). The numbers of individuals recorded were similar in 2005 and 2006 however the weight of the bycatch was greater in 2005. The bycatch characteristics from 2004 were not comparable to the other two years as only one subsample from each trawl was retained from fewer sites in 2004.

Table 6.4.5 Summary of bycatch characteristics for each year from all sites and nets sampled each year.

Year	No. sites	Subsample	No. species	No. families	No. individuals	Weight (kg)
2004	16	1	192	81	7 011	99. 66
2005	18	2	245	78	28 885	378.49
2006	20	2	268	101	29 066	300.33

CATCH RATES

The mean catch rates of bycatch across the same sites sampled each year (port inner net only) varied among years with the highest catch rates in 2005 (Table 6.4.6).

Table 6.4.6 Mean catch rates (+ se) of bycatch for each of the years for same sites sampled each year and port inner net. Mean catch rates are in kg/ha.

Year	Mean catch rate (kg/ha)
2004	6.31 $\pm$ 0.74
2005	8.85 $\pm$ 0.97
2006	6.96 $\pm$ 0.51

There was no clear trend in catch rates among the three areas over 2004-2006. In 2004 there was a decline in catch rates from the open to the closed area. In 2005 the catch rate in the open area was higher than the other two areas that had very similar catch rates, and in 2006 the closed area had the highest catch rate, followed by the open and then the semi closed area (Table 6.4.7).

Table 6.4.7 Mean catch rates (+se) of bycatch in each of the areas (open, semi closed and closed) for each year. Mean catch rates are in kg/ha and are for the same sites sampled each year and port inner nets only.

Year	Area mean catch rate (kg/ha)		
	Open	Semi closed	Closed
2004	7.9 $\pm$ 0.9	6.0 $\pm$ 16	5.3 $\pm$ 1.2
2005	12.0 $\pm$ 1.7	7.5 $\pm$ 1.2	7.4 $\pm$ 1.5
2006	7.3 $\pm$ 0.4	6.0 $\pm$ 0.9	7.5 $\pm$ 1.1

The comparison of the RV Gwendoline May bycatch weights recorded at sea between the Torres Strait and the northeast Queensland coast indicated that consistently more bycatch was caught in the Torres Strait. Mean catches over 3 years show that there was 1.2 times more bycatch caught in the Torres Strait than on the Queensland northeast coast. When each individual year was examined the same result was evident, that is between 1.1 and 1.4 times more bycatch was caught in the Torres Strait.

Comparison of the taxonomic groups defined in the earlier Torres Strait bycatch study of 1985-1986 (Harris and Poiner 1990) with the bycatch of 2004-2006 indicated that the bycatch catch rates have not markedly altered in two decades. The 2004-2006 catch rates are within the ranges reported for the earlier study, except for crabs and squid which have marginally higher catch rates in 2004-2006 than 1985-1986. The current catch rates of fish and total bycatch are around the mid point of the ranges reported for the 1980s study while non-commercial prawns are slightly higher and scallops slightly lower than the 1985-1986 mid points of catch ranges (Table 6.4.8).

Table 6.4.8 Comparison of catch rates (kg/30 minutes) between 2004-2006 and 1985-1986. The 2004-2006 mean catch rate (+se) is compared to that range of catch rates reported in Harris and Poiner (1990) and the midpoint of that range.

Taxonomic Group	2004-2006 Mean catch rate (+se) (kg/30min)	1985-1986 Catch rate mid point (kg/30min)	1985-1986 Catch rate Range (kg/30min)
Fish	49.13 + 2.53	49.9	23.9-75.8
Crabs	7.48 + 0.93	5.3	4.09-6.5
Non-commercial prawns	2.52 + 0.43	2.0	0.88-3.09
Scallops	1.55 + 0.37	2.0	0.8-3.17
Squid	0.30 + 0.18	0.1	0.01-0.22
Total bycatch	63.46 + 2.99	61.5	35.0-87.9

A more recent study of trawl bycatch was conducted on the Queensland northeast coast in the tiger/endeavour prawn trawl fishery between February 2001 and November 2002 (Courtney *et al.* 2005).The catch rates in grams/hectare from the 2004-2006 ten dominant species by weight (Table 6.4.3) were compared to the catch rates reported for those same bycatch species in northeast Queensland.

For each year and across all three years the Torres Strait species catch rates were considerably higher than those of northeast Queensland. Two exceptions to this were *Scolopsis taenioptera* and *Apogon fasciatus* in 2004 that had a similar catch rates in Torres Strait to those in northeast Queensland. It was also apparent that there was considerable variation in catch rates of these bycatch species from year to year in the Torres Strait (Table 6.4.9).

Table 6.4.9 Comparison of mean catch rates in g/ha between Torres Strait (for each year and across all years) and North Queensland. The 2004-2006 mean catch rate is compared to mean catch rates reported in Courtney et al. (2005).

Species	Torres Strait mean catch rate (g/ha)				North Queensland mean catch rate (g/ha)
	2004	2005	2006	2004-2006	
Scolopsis taenioptera	484.6	989.3	872.7	857.8	498.6
Lethrinus genivittatus	1746.1	2389.5	488.4	1386.2	45.6
Paramonacanthus spp	152.9	769.6	194.7	445.2	
Apogon fasciatus	151.2	317.6	465.8	372.1	104.2
Portunus (Xiphonectes) tenuipes	272.8	494.8	208.5	337.9	71.1
Nemipterus furcosus	252.5	675.4	383.3	474.9	43.1
Nemipterus hexodon	341.6	537.0	232.1	386.6	101.5
Portunus (Monomia) rubromarginatus	169.2	384.6	203.9	283.7	19.3
Priancanthus tayenus	538.4	359.0	255.2	350.5	86.6
Nemipterus peronii	183.6	404.4	276.9	317.4	25.3

A comparison of catch rates of other less dominant bycatch species caught in 2004-2006 with the northeast Queensland species catch rates (Courtney *et al.* 2005) found that although many of the Torres Strait species did have higher catch rates, there were some species that had very similar catch rates between the two regions.

6.4.2 Distribution of bycatch species

DISTRIBUTION RANGES

Of the 374 species of bycatch, 32 species (9%) were endemic (Appendix 4a). Twenty five of these species were reported to occur only in northern Australian waters, though none occurred solely in the Torres Strait. There was one protected seahorse species that is discussed in more detail below (Section 6.4.3). The other endemic species were 21 fish, 7 crustaceans, 2 gastropods and 1 cuttlefish.

All endemic species occurred rarely in the bycatch. More than half the species had very low occurrences at <0.1% of the total bycatch weight. The resilience, considered to be the capacity of the species to withstand exploitation (Froese and Pauly 2006) was reported for half of these endemics. It was in all cases either high, with a minimum population doubling time of less than 15 months or medium, with a minimum population doubling time of 1.4 - 4.4 years (Appendix 4a).

There were 23 species with distributions restricted to Australian and Papua New Guinea waters (Appendix 4b). Of these, all except one species occurred rarely in the bycatch with half of the species with very low occurrences at <0.1% of bycatch weight, similar to the endemic species. The resilience for those species with information was also high to medium. One species, a coral prawn *Metapenaeopsis rosea* accounted for 2.3% of the total bycatch weight.

An additional 16 species had a slightly wider distributional range of Australia, Papua New Guinea and Indonesia. There was one species in this group that is protected under Australian legislation, a pipehorse that is discussed in more detail below (Section 6.4.3).

Of the other 374 bycatch species, 196 species were widely distributed, mostly throughout the Indo-Western Pacific Oceans. The 107 remaining species were identified only to genus or higher taxonomic levels and as such it was not possible to identify their distributional range.

SPECIES UNIQUE TO THE AREAS SURVEYED WITHIN THE TORRES STRAIT

Of the 374 taxa collected over 2004-2005 from the three areas in the Torres Strait (open, semi closed and closed) hardly any were consistently unique to each area. There were just two species that only occurred in the closed area for all 3 years: *Halimeda sp* (a calcareous algae); and *Leiognathus decorus* (a ponyfish). There were no species that only occurred in the semi closed area all 3 years and there was just one species, *Sepia pharaonis* (a cuttlefish) that only occurred in the open area for all 3 years.

6.4.3 Protected Species

Queensland and Commonwealth legislation protects a number of marine species in Australian waters. Under the EPBC Act among others, turtles, seahorse and pipefish (Sygnathidae) and sea snakes are protected (Torres Strait Prawn Fishery Working Group 2005).

In the 2004-2006 fishery independent annual surveys of the TSPF there were very low catches of protected species.

One sea turtle *Natator depressus* (flatback) was captured in the semi closed area of the fishery and returned to the sea alive. Two sea snakes were caught and returned to the sea alive. One *Astrotia stokesii* (Stokes sea snake) was caught in the area closed to trawling and one unidentified sea snake was caught in the semi closed area.

Three Sygnathidae were caught and retained as they were not alive. Two *Hippocampus hendriki* (eastern spiny seahorse) and one *Haliichthys taeniophorus* (ribboned pipehorse), all of which were caught in the area of the fishery closed to trawling.

A species that is indirectly related to the Sygnathidae, *Pegasus volitans* (slender seamoth) was recorded from 41% of bycatch subsamples collected over the three years. It occurred in all areas of the fishery, those open and closed to trawling. It is commonly taken in trawls, but not considered a vulnerable species (Harris and Ward 1999) and is widely distributed throughout the Indo-Western Pacific Oceans (Froese and Pauly 2006).

6.4.4 Bycatch species previously identified as at risk from trawling

In an assessment conducted to identify those species at risk to trawling in the Torres Strait, 5 fish species were identified as least likely to be sustainable (Turnbull *et al.* 2001) (Table 6.4.10).

In the surveys from 2004-2006 none of these species were caught. However for 4 of the 5 species, species were recorded that were taxonomically very closely related (Table 6.4.10).

Table 6.4.10 Species previously identified as least sustainable and the taxonomically similar species with their frequency of capture which is the percentage occurrence in the 92 subsamples. Common names are those used in Turnbull (et al. 2001).

Species least sustainable	Common name	Similar species in 2004-2006	% freq. of capture
Paracentropogan vespa	Spot fin waspfish	*Paracentropogon longispinis**	40
Dactyloptena orientalis	Oriental searobin	*Dactlyoptena paplio*	35
Apistops caloundra	Short finned waspfish	*Apistus carinatus*	28
Paraploactis trachyderma	Velvet fish	*Paraploactis intonsa*	1
Polydactlyus sheridani	Threadfin	*No Polydactlyus sp. recorded*	

* This species may be a synonym of *Paracentropogan vespa* (Carpenter and Niem 1998)

All the 4 taxonomically similar species occurred only in the areas open to prawn trawling, except for *Paracentropogon longispinis* that also occurred in the area completely closed to trawling. Three of the species were also recorded quite frequently, occurring in 28-40% of the subsamples (Table 6.4.10).

In the same risk assessment 7 fish species were identified as the most likely to be sustainable: *Megalaspis cordyla* (finny scad); *Echeneis naucrates* (slender suckerfish); *Drepane punctata* (spotted batfish); *Platax tiera* (round faced batfish); *Zabidus novaemaculatus* (nine-spined batfish); *Pellona ditchela* (ditchelee); and *Pelates quadrilineatus* (four-lined grunter perch) (Turnbull *et al.* 2001).

The first 5 of these species were not recorded in the 2004-2006 surveys, nor were any taxonomically closely related species. *Pellona ditchela* occurred in one site only within the area closed to trawling in very low abundance and *Pelates quadrilineatus* occurred in two sites both also within the area closed to trawling and also in very low abundance.

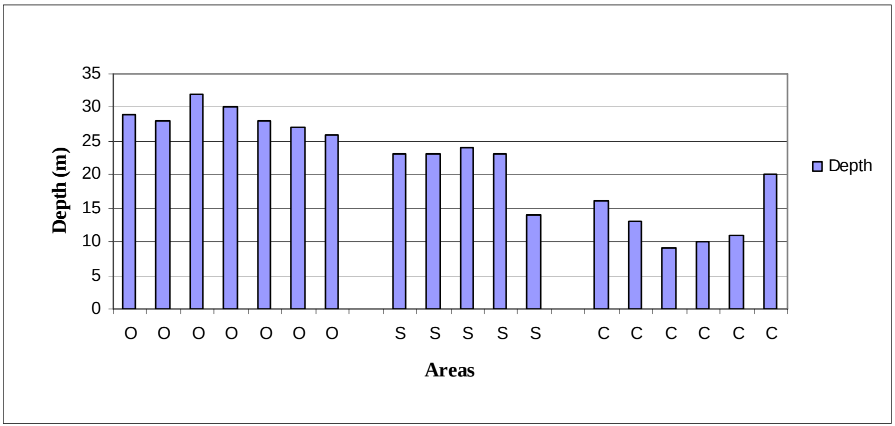
6.4.5 Environmental variables

The depth range of all sites surveyed in the Torres Strait was 9-32 metres (m) (Figure 6.4.1a). The two sites within the closed area in Papua New Guinea (PNG) waters (Figure 6.2.1) were the shallowest at 9-10m. All other sites in the closed area were within 11-20m, with one of the sites in the semi closed area (14m) within this depth range. This site was the northern most of all sites in the semi closed areas (Figure 6.2.1). The rest of the semi closed sites were all slightly deeper at 23-24m and all sites within the open area, the main trawl grounds, were the deepest at 26-32m.

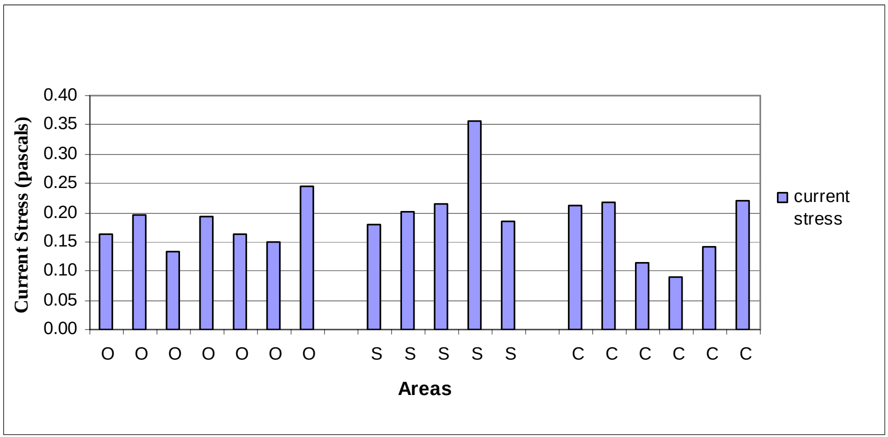
The seabed current stress was the lowest for the two sites in the closed area within PNG waters at 0.09-0.115 (pascals N/m^2) (Figure 6.4.1b and Figure 6.2.1). There was no trend in seabed current stress among the remainder of the sites within the closed area and the other two areas. The sites all had varying current stress within the range 0.132-0.244 pascals. One site in the semi closed area was an exception with a higher current stress of 0.358 pascals. This site was the most inshore and closest to the southern corridor between the Warrior Reefs (Figure 6.2.1).

The sediment type varied across the sites with no obvious trend in % mud, % sand and % gravel among the three areas (Figure 6.4.1c). The precent range for each sediment type was: mud 1.3-66.5%; sand 22.0-88.4%; and gravel 0.2-53.5%. There were two sites with more gravel than elsewhere at 40-50%. These were the most northerly sites in the semi closed and closed areas (Figure 6.2.1).

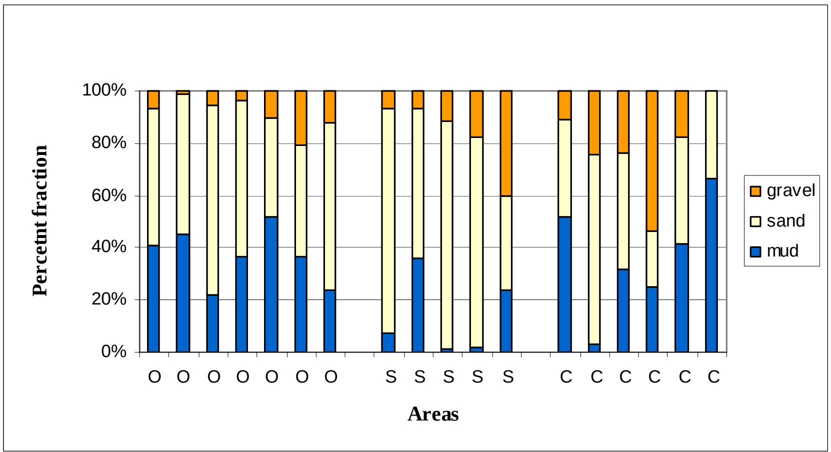
In summary, the two sites in PNG waters were the shallowest with the least current stress. There was a depth gradient evident across the three areas; with the closed area the shallowest through the semi closed area of moderate depth to the open area with the deepest waters. There was no such clear distinction in current stress and sediment type among the three areas. Except for the two low current sites in PNG, and one higher current site in the semi closed area, all other sites had a similar current stress. The sediment type was mostly a mixture of mud and sand in varying proportions. The two most northerly sites surveyed had the highest percent of gravel.



A. Depth



B. Seabed Current Stress



C. Sediment type

Figure 6.4.1 Environmental variables at each site within each of the three areas, O-open, S-semi closed and C-closed. A. Depth (m). B. Seabed current stress (Pascals N/m2). C. Sediment type (% grain size fraction).

6.4.6 Bycatch community structure

AREAS AND YEARS

For each of the three years there was no significant difference in number of species, number of families, abundance or weight among the three areas, except in two cases, that is for weight in 2005 and abundance in 2006 (Figure 6.4.2). In 2005 the weight of bycatch was significantly (P<0.05) greater in the open area than the other two areas and in 2006 the abundance was significantly (P<0.01) greater in the closed area than the other two areas.

For the three years and all sites sampled every year (only port inner net samples) there was no significant difference in any of the variable among years and areas except for the same cases detected in the individual year analysis. That is, in 2005 the weight of bycatch was significantly greater (P<0.05) in the open area than at all other areas and years and in 2006 the abundance was significantly greater (P<0.05) in the closed area than at all other areas and years.

The minimum difference in the number of species, number of families, abundance or weight among the 3 areas that these analyses could detect at a 5% significance level and with adequate power of 0.8 increased from 2004 to 2006, which most likely reflects the increase in number of sites surveyed each year. The analyses were able to detect smaller differences among areas in the numbers of species and families than for abundance and weight. The smallest minimum detectable difference was for species and families when all three years data were combined, that is, 2004-2006 (Table 6.4.11).

Table 6.4.11 Minimum detectable difference among the three areas (open, semi closed and closed) for numbers of species, families, abundance and weight at 5% significance level and power of 0.8 for each of the years. Values are percent of the overall mean. Port inner net data only. For each separate year all sites sampled each year were included and for 2004-2006 only those sites sampled every year were included.

Variable	**Minimum detectable difference (%)**			
	2004	**2005**	**2006**	**2004-2006**
No. species	57	35	19	18
No. families	51	29	24	20
Abundance	99	69	54	57
Weight	95	75	55	72

To detect a change among areas of 50% of the mean numbers of species and families at 5% significance level and with adequate power of 0.8, an average of 8 sites within each area would be required. For mean abundance and weight more sites are required with an average of 16 needed within each area. Note that this is for a bycatch subsample of 5-8 kg from one net per 20 minute trawl that is caught using quad trawl gear of 4 x 4 fathom nets.

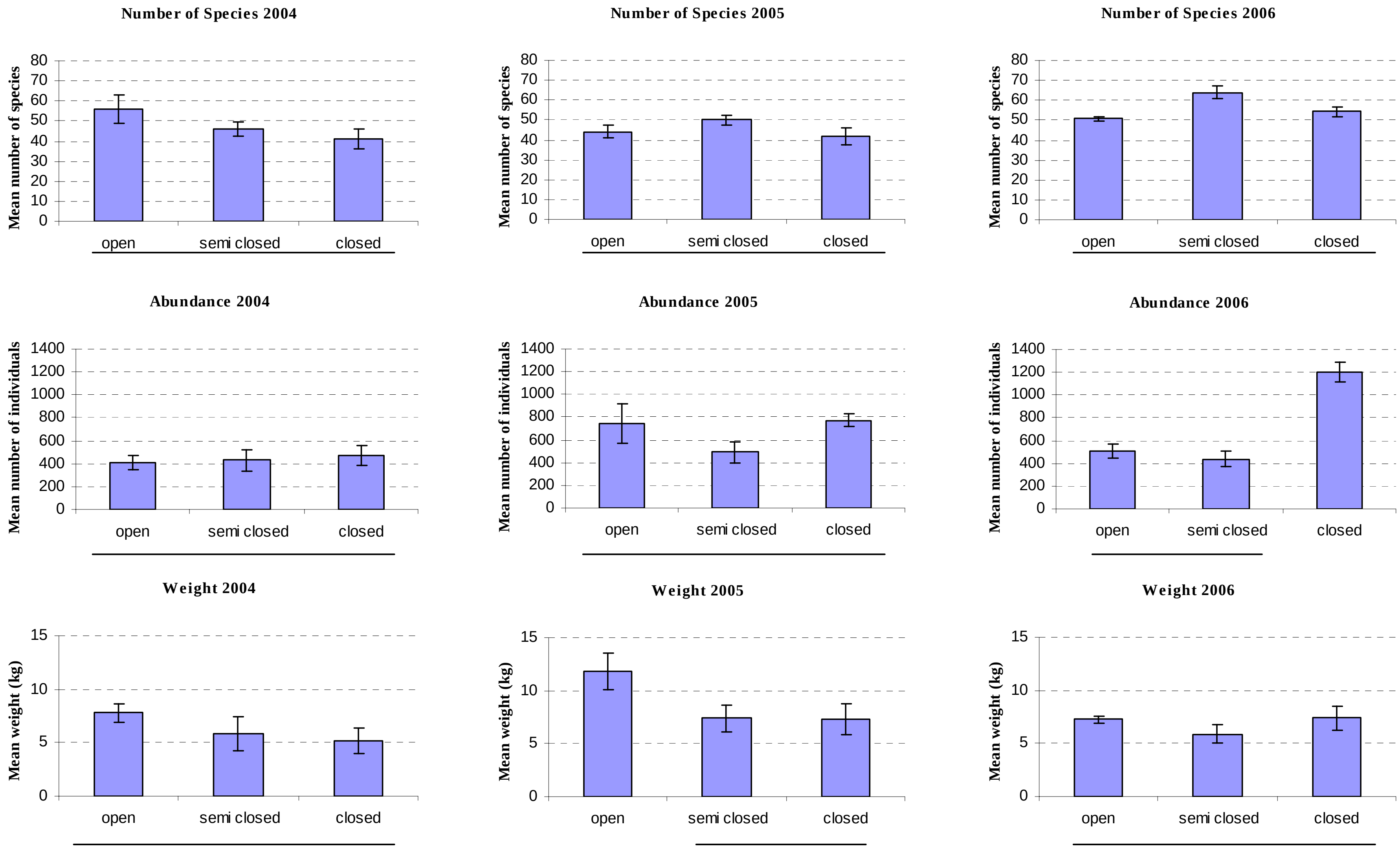


Figure 6.4.2 Mean (+se) numbers of species, abundance (number/1.06 ha) and weight (kg/1.06ha) at each of the areas, open, semi closed and closed for each of the years 2004-2006. Only data from sites sampled every year and from port inner net. Those areas joined by a line are not significantly different.

FISH SPECIES AMONG AREAS

The mean number of fish species and the mean catch rate of fish species in kg/ha in each area across all 3 years was not significantly different among areas (Table 6.4.12).

Table 6.4.12 Mean number (+se) of fish species and mean catch rate (+se) (kg/ha) caught per site in each area over the three years 2004-2006. Only data from sites sampled every year and from port inner net.

Area	**Mean no. fish species**	**Mean catch rate fish species (kg/ha)**
Open	35.3 $\pm$ 1.4	7.17 $\pm$ 0.71
Semi closed	37.6 $\pm$ 2.0	5.53 $\pm$ 0.73
Closed	32.0 $\pm$ 1.6	4.91 $\pm$ 0.65

INDIVIDUAL SPECIES ANALYSES

With respect to the analyses of the 36 individual species that occurred in all 3 areas for all 3 years, the findings were similar for each of the three years. In 2004, 2005 and 2006 there were 8, 9 and 11 species respectively that showed a significant difference among areas (P<0.05 to P<0.001) with 6 of these species common to each year. Each year, all but one species had significantly higher abundance in the open area compared to the closed area. The abundance in the semi closed area was between that of the open and closed areas, varying in whether it was more closely aligned with the open or closed area. The six species that were consistently more abundant in the open area were: *Nemipterus peronii*; *Priacanthus tayenus; Scolopsis taenioptera; Pseudorhombus spinosus; Amusium pleuronectes;* and *Portunus gracilimanus* (4 fish, 1 scallop and 1 portunid crab respectively). Three species, *Selaroiodes leptolepis* in 2004 (P<0.05), *Parachaetodon ocellatus* in 2005 (P<0.05) and *Portunus (Xiphonectes) hastatoides* in 2006 (P<0.01) were significantly more abundant in the closed area.

PORT VERSUS STARBOARD NET

There was a sampling bias between the port inner and starboard inner net, with this bias inconsistent between years. There is no clear explanation for this bias. In 2005 the starboard inner net was significantly greater than the port inner net for all bycatch variables, that is, numbers of species, numbers of families, abundance and weight (all P<0.05). By taking two samples from each trawl (one from port inner net and one from starboard inner net) rather than just one sample from each trawl (one of the inner nets), 19% more species and 11% more families were retained (the percent difference in the number of species between the combination of the two nets and the highest catching net) (Table 6.4.13). That is if the size of the bycatch sample retained from a trawl is doubled from 5-8kg to 10-16kg, 19% more species and 11% more families were retained.

In 2006 there was also a significant difference between nets although it was opposite to the previous year, that is, the port inner net was significantly greater than starboard inner and only for numbers of species and families (P<0.05). Two subsamples from each trawl retained 20% more species and 12% more families than retaining only one sample per trawl (Table 6.4.13).

Table 6.4.13 Numbers of species and families caught in each of the port inner and starboard inner nets and in the combination of both inner nets for 2005 and 2006.

Net	**2005**		**2006**	
	No. species	No. families	No. species	No. families
Port Inner (PI)	183	62	224	90
Starboard Inner (SI)	206	70	209	81
PI and SI	245	78	268	101

6.4.7 Bycatch community composition

ABUNDANCE

The multivariate analysis of species abundance across all years and 92 samples indicated that the species and their abundances were different in the closed area than from the semi closed and open areas which were more similar to one another (Figure 6.4.3). The species abundances of the samples from the open area were most similar to one another, indicated by the fairly tight grouping of all samples taken in this area.

The closed areas had sites that were quite different from one another with the two sites within the closed area in PNG waters (Figure 6.2.1) forming a distinct group (top group in Figure 6.4.3- it consisted of all ten samples-2 from 2004 where one sample from port inner net was taken at each site, 4 each from 2005 and 2006 where two samples, port inner and starboard inner, were taken at each site). Another group of samples from the closed areas consisted of just over half of the samples from the two sites on the Seabed Jurisdiction Line (Figure 6.4.3 and Figure 6.2.1). The other samples from these two sites were more similar to the rest of the closed sites. The stress of the MDS was adequate but quite high at 0.19 so this grouping of sites was checked against a clustering of the sites into a dendogram (an alternative grouping process) and the same groups were evident.

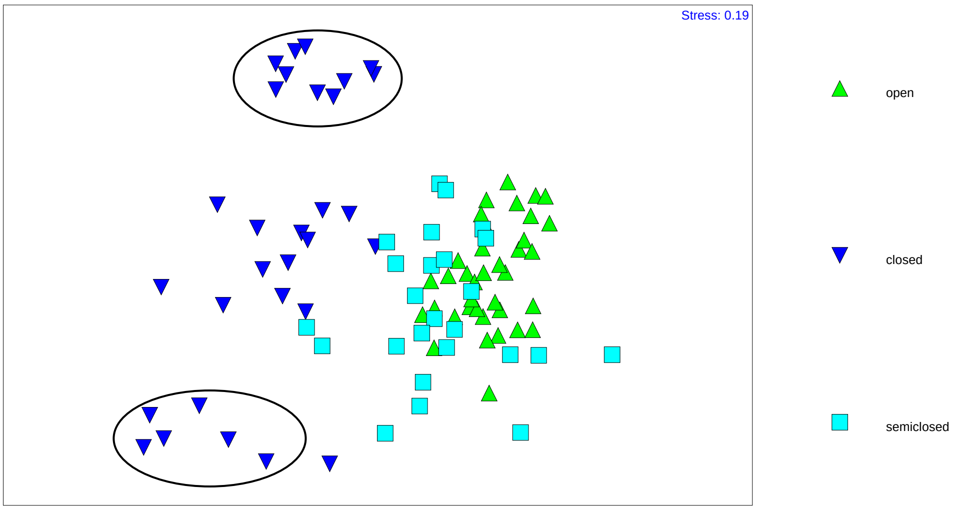


Figure 6.4.3 Two dimensional multidimensional scaling ordination (MDS) of species abundance across all 3 years and all subsamples. The sites are each represented by a symbol that indicates the area it is from (open, semi closed, closed).

The analysis of similarities (ANOSIM) in species abundance among the three areas confirmed the MDS two dimensional display of the relationships among sites (Figure 6.4.3). It indicated the areas overlap but there were some differences (Global R=0.538) and the Pairwise R revealed that the greatest differences were between the open and closed areas which were very well separated (R=0.753). The open and semi closed areas were not markedly different (R=0.354), nor were the closed and semi closed areas (R=0.429).

When the species and their abundances were grouped by samples within each year it was apparent that there was no yearly trend as no distinct yearly groups of samples were evident (Figure 6.4.4). The ANOSIM confirmed that there were no differences between the years (Global R=0.306).

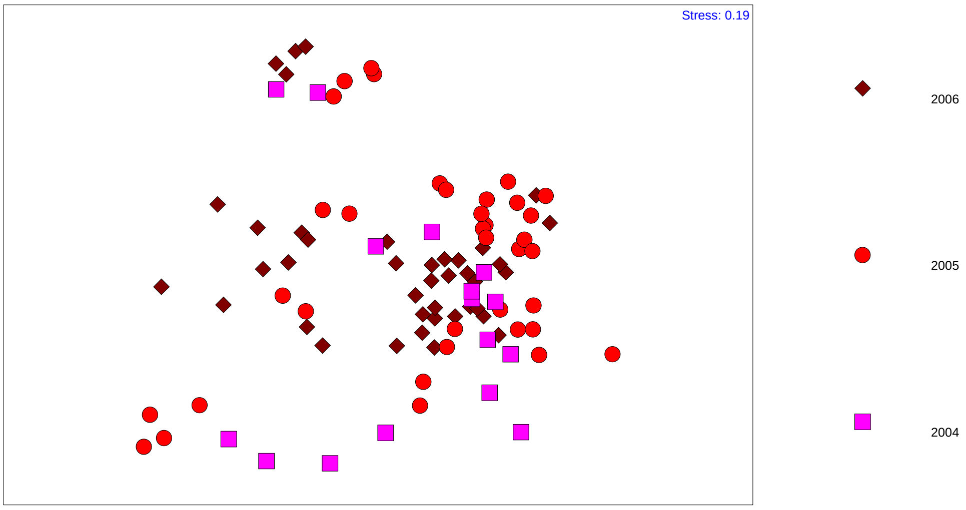
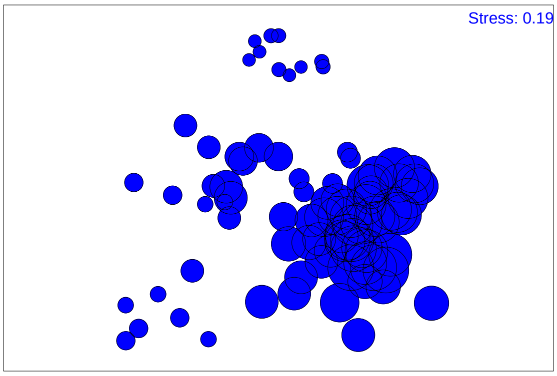
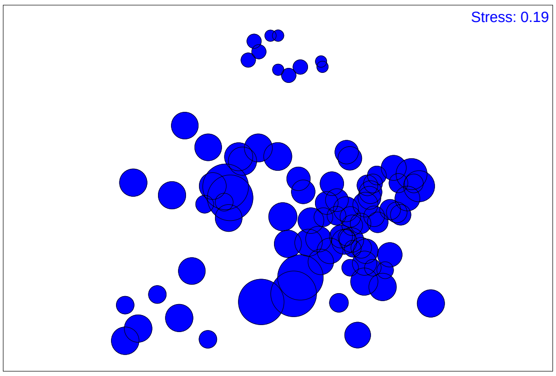


Figure 6.4.4 Two dimensional MDS of species abundance across all 3 years and all subsamples. The sites are each represented by a symbol that indicates the year it was collected (2004, 2005 and 2006).

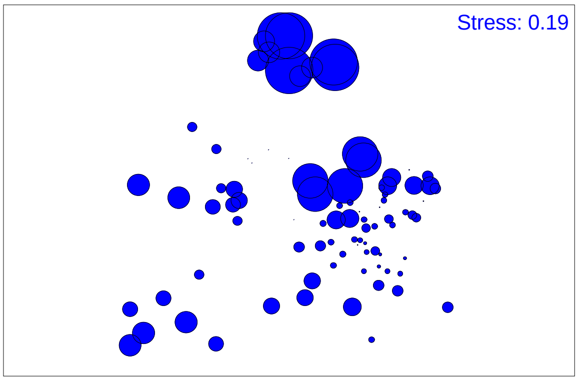
The pattern of sites based on species and their abundances was correlated to the environmental variable of depth (p=0.554), followed by the combination of depth and seabed current stress (p=0.550) and then the combination of percent gravel and depth at R=0.524. This correlation is obvious in the plots of depth and current stress and percent gravel as circles of differing diameters that represent the value of these variables in each sample (termed bubble plots in PRIMER) superimposed on the species abundance MDS Figure 6.4.3 (Figure 6.4.5a-c). The strongest correlation of depth is apparent as the two separate PNG sites are the shallowest, and the other group of separate closed sites are also all shallow, while the gradation of the remainder of the closed sites through the semi closed to open sites matches extremely well to the changing depth profile across these areas. The separation of the two PNG sites is also very well matched to current stress as these sites clearly have the least currents. One of them also has a high percent of gravel.



A. Depth



B. Seabed current stress



C. Percent gravel

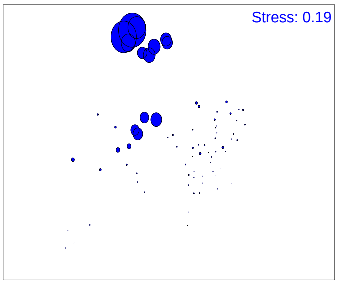
Figure 6.4.5 Depth (m), seabed current stress (Pascals) and percent gravel values in each sample superimposed on the species abundance MDS.

Based on the species abundance MDS, there were 10 species that accounted for almost 30% of the dissimilarities in species and their abundances between the open and closed areas (Table 6.4.14). The 3 species most responsible for the differences (two fish and a coral prawn) were all much more abundant in the closed area with the 2nd species almost completely absent from the open area. The following 6 species were all much more abundant in the open area, with two of these, a portunid crab and scallop almost completely absent from the closed area.

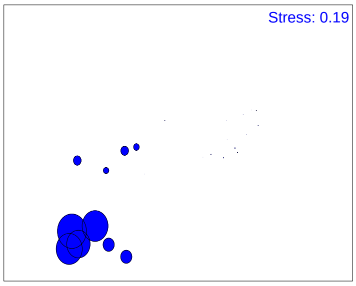
Table 6.4.14 Species that accounted for high proportions of the dissimilarity (as a percent of the total dissimilarity) between the open and closed area over all 3 years and all subsamples. The average abundance in each area is numbers of individuals/1.06ha with the highest abundance for each species marked with *.

Species		Open area abundance	Closed area abundance	% dissimilarity
Apogon fasciatus	Cardinal fish	14.88	140.14*	3.68
Lethrinus genivittatus	Emperor	2.15	115.55*	3.49
Metapenaeopsis rosea	Coral prawn	16.15	108.90*	3.36
Paramonacanthus spp	Leather jacket	105.97*	22.03	2.95
Scolopsis taenioptera	Bream	48.96*	6.84	2.71
Portunus (Xiphonectes) tenuipes	Portunid crab	65.85*	10.30	2.58
Portunus (Lupocycloporus) gracilimanus	Portunid crab	42.57*	1.28	2.50
Trachypenaeus (Megokris) granulosus	Coral prawn	37.03*	24.65	2.26
Amusium pleuronectes	Scallop	35.67*	1.14	2.07
Trachypenaeus((Trachypenaeus) anchoralis	Coral prawn	2.18	48.37*	2.01

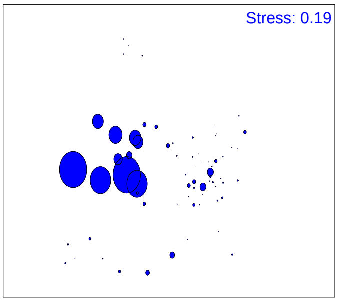
The abundances of the first 4 species most influential in causing the species MDS separation of open from closed areas were superimposed on that MDS (Figure 6.4.3) as circles that represent the species' average abundance values (over 3 years) in each sample (Figure 6.4.6a-d). These provide a clear visual display of the degree to which these species were responsible for the separation of the open and closed areas.



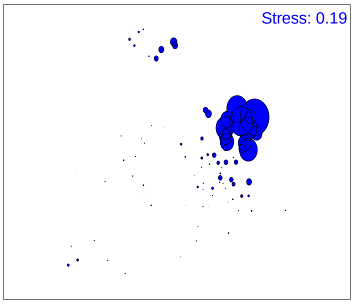
A. *Apogon fasciatus*



B. Lethrinus *genevittatus*



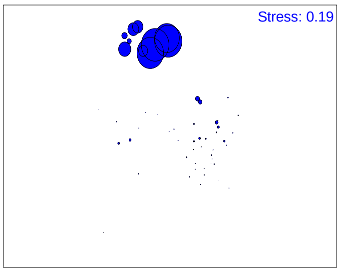
C. *Metapenaeopsis rosea*



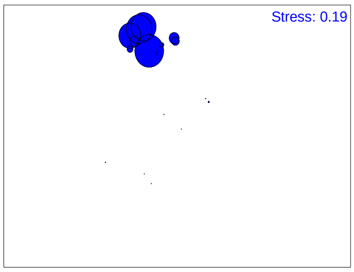
D. *Paramonacanthus spp.*

Figure 6.4.6 Plots of the abundance of the four species most responsible for the separation of areas superimposed on the species abundance MDS. Abundance is the average abundance in each sample over the 3 years and is number/1.06 ha.

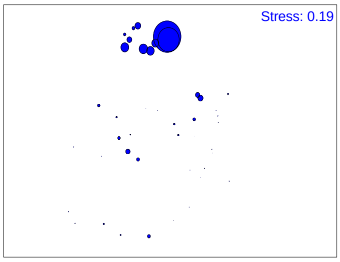
There were six species that accounted for 25% of the strong separation of the two sites within the closed area in PNG waters (top group in Figure 6.4.3) from all other sites and 50% of the similarity of these sites to one another: *Apogon fasciatus*; *Apogon poecilopterus*; *Upeneus sulphureus; Torquigener whitleyi*; *Acentrogobius caninus*; and *Trachypenaeus (Trachysalambria) fulvus* (five fish and one coral prawn). These species were all most abundant at the two PNG sites and occurred rarely elsewhere for all 3 years as indicated by the bubble plots of the abundance of the five fish (Figure 6.4.6a and Figure 6.4.7a-d). Species that also drove this separation of these two PNG sites due to their almost complete absence from these sites were: *Scolopsis taenioptera; Trachypenaeus (Megokris) granulosus; Metapenaeopsis rosea; Portunus (Monomia) rubromarginatus; Portunus (Lupocycloporus) gracilimanus;* and *Nemipterus peronii*.



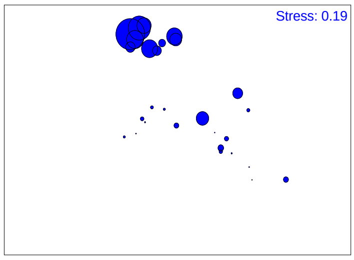
A. *Apogon poecilopterus*



B. Upeneus sulphureus



C. *Torquigener whitleyi*



D. Acentrogobius caninus

Figure 6.4.7 The abundance of four species most responsible for the separation of the two sites in PNG from all other sites, superimposed on the species abundance MDS. Abundance is the average abundance in each sample over the 3 years and is number/1.06 ha.

WEIGHT

The multivariate analysis of the weight of species across all years and 92 subsamples produced almost an identical pattern of sites in the MDS as for species abundance. The degree of separation of areas was also the same as indicated by the same Global R and the same Pairwise R for the separation of the open and closed areas and there was also no difference in the weight of species among years.

These patterns in the sites based on weights of species were also well matched to depth and current stress with similar correlation values as for abundance.

Similar to species abundance there were 10 species that accounted for almost 30% of the dissimilarities in species weights between the open and closed areas and 7 of these 10 species were the same (Table 6.4.14) (the two *Trachypeneaus* coral prawn species and the scallop were not among the species influential with regard to weight). The other three species influential in terms of weight were *Nemipterus furcosus*, *Nemipterus hexodon* (bream) and *Priacanthus tayenus* (bigeye). They all had much higher weights in the open area than the closed area.

Of the combined 13 species influential in separating the open and closed areas based on abundance and weight, all were among the 23 species that exceeded 1% of the species bycatch by weight (Table 6.4.3) except the two *Trachypeneaus* coral prawn species.

One of these coral prawns, *Trachypenaeus (Trachypenaeus) anchoralis*, is endemic to northern Australia (Appendix 4a) and although it occurred in the open area it was 22 times more abundant and had 15 times higher weight in the closed area than the open area. It was collected only in 2005 and 2006, predominantly from the three most westerly sites within the closed area (Figure 6.2.1).

Another coral prawn species *Metapenaeopsis rosea* has a distribution that is restricted to the waters of northern Australia and PNG (Appendix 4b). It was collected each of the three years and across all years it had 7 times higher abundance and biomass in the closed area than the open area. It predominantly occurred in the same three most westerly sites within the closed area as *T. anchoralis.*

In summary, the bycatch species and their abundance and weight were different in the closed area to the semi closed and open areas, with the bycatch from the two PNG sites in the closed area the most different from the rest. This pattern of sites based on the biological communities was well matched to the pattern of sites based on depth and current stress (and to a lesser degree percent gravel), which indicates these environmental variables are to an extent responsible for structuring the bycatch community composition. There were a total of 13 species that occurred in much higher abundances and weights in either the open or closed areas, driving the separation of the two areas and there were 6 species that occurred almost solely in the two PNG sites within the closed area.

FAMILY AND PHYLA ANALYSES

The multivariate analysis of the abundance of families across all years and 92 subsamples produced almost an identical pattern of sites in the MDS as for species abundance. The MDS had the same level as stress as the species abundance MDS and the degree of separation of the open and closed areas (Global and Pairwise R) was also the same as the species abundance.

Similar to the species abundance MDS, the correlation of the family abundance MDS was greatest with depth (p=0.486), followed by the combination of depth and seabed current stress (p=0.466). The strength of the correlations were less than those for species abundance.

There were 10 families that accounted for 50% of the dissimilarities between the open and closed areas (Table 6.4.15). These families were nearly all those of the most influential species with regard to species abundance (Table 6.4.14).

Seven of these families were among the families of the 23 dominant species by weight (Table 6.4.3), the exceptions were Penaeidae (non-commercial prawns), Portunidae (crabs) and Leiognathidae (small ponyfish).

Table 6.4.15 Families that accounted for high proportions of the dissimilarity (as a % of the total dissimilarity) between the open and closed area over all 3 years and subsamples. The average abundance in each area is numbers of individuals/1.06ha with the highest abundance for each family marked with *.

Species	Open area abundance	Closed area abundance	% dissimilarity
Penaeidae	70.57	258.24*	7.77
Apogonidae	43.47	182.37*	6.02
Portunidae	168.26*	34.86	6.01
Lethrinidae	2.56	115.65*	5.89
Monacanthidae	118.07*	27.12	5.35
Nemipteridae	95.18*	21.40	5.29
Leiognathidae	2.60	51.12*	4.43
Mullidae	5.45	34.50*	3.73
Pectinidae	38.58*	1.54	3.68
Terapontidae	5.96	17.57*	2.88

The multivariate analyses of phyla abundance did not reveal any patterns in the sites among areas or years. The Global R indicated no separation of areas based on phyla abundance and the correlation of the phyla MDS with the environmental variables was very poor, with a p= 0.218 for the combination of depth, current stress and % mud.

In summary it is clear that little information is lost when the higher taxonomic level of family is used to detect differences in the bycatch communities among areas. However the taxonomic level of phyla is too gross as it did not detect the same differences among areas as the species and family analyses.

ANALYSES OF EACH YEAR

The stress of the MDS analyses for all 3 years and sites (0.19) was adequate, but quite high. Each of the years were analysed separately to determine if any more detail in the separation of sites was apparent and to examine more closely the finding from the univariate analyses of the greater weights in the open area in 2005 and higher abundances in the closed area in 2006 (Figure 6.4.2).

The biological MDS ordinations of species abundance and biomass each year all showed fairly similar patterns to that of all 3 years with the separation of the closed and open areas becoming more distinct from 2004 to 2006. The stress levels of the ordinations were lower at 0.13-0.14 which indicated two dimensions were a good representation of the relationship among sites.

In 2004 the two groups of closed sites (those in PNG and those on the Seabed Jurisdiction Line Figure 6.2.1) appeared separate from the others for both abundance and weight, but the Global R of 0.265 indicated no real separation of any of the three areas. Depth and current stress had the greatest correlation with the biological MDS at p=0.426, followed by depth and percent gravel at p=0.418

In 2005, similar to 2004, the two groups of closed sites (those in PNG and those on the Seabed Jurisdiction Line) appeared separate for both species abundance and weight. The Global R of 0.48 for both variables indicated a stronger separation of areas than in 2004 with a pairwise R of 0.646 for abundance and R of 0.674 for weight that indicated a strong separation of the open and closed areas, with a slightly greater separation for weight. This complemented the finding of the univariate analyses for weight, however it also separated the open areas from the closed based on abundance whereas the univariate analyses did not detect a significant difference in abundance. There were two species with very high weight in the open area: *Scolopsis taenioptera* and *Paramonocanthus spp* with the latter of these also with very high abundance in the open area.

In 2005 depth was the most correlated environmental variable with the biological MDS at p=0.523 and p=0.528 for abundance and weight respectively, almost as high as the correlation for species abundance over 3 years. The combination of currents, depth and percent mud was the next highest correlation at p=0.488 for both variables.

In 2006 as for the previous years, the group of two sites in PNG was separate from all other sites for both species abundance and weight; however the other distinct group consisted of the remainder of the closed sites and the site in the semi closed area closest to the corridor between the Warrior Reefs (Figure 6.2.1). The Global R of 0.624 for both abundance and weight indicated a clearer separation among areas than for other 2 years (and the combined 3 yr species analyses). The pairwise R of 0.879 for abundance showed this separation to be very strong between the open and closed areas and even stronger for weight at R=0.902. This complemented the finding of the univariate analyses for abundance in 2006, however it also separated the open areas from the closed based on weight whereas the univariate analyses did not detect a significant difference in weight. There were two species of very high weight and abundance in the closed area compared to the open area: *Apogon fasciatus* and *Metapenaeopsis rosea*. A very high weight of *Lethrinus genevittatus* and a very high abundance of *Trachypenaeus (Trachypenaeus) anchoralis* in the closed area were also evident.

In 2006 the combination of depth and current stress was the strongest correlation with the biological MDS ordinations of all the years (and the combined 3 yr species analyses) at p=0.697 for both abundance and weight. This was followed by depth at p= 0.687 and then the combination of depth, current stress and % gravel at p=0.642.

The species with the most influence in separating the open and closed areas each year were consistently similar to 7 of the 13 species most influential for the analyses of all year species abundance and weight (Table 6.4.14 and Section 6.4.7 Weight), that is: *Lethrinus genivittatus*; *Scolopsis taenioptera*; *Apogon fasciatus; Portunus (Lupocycloporus) gracilimanus; Portunus (Xiphonectes) tenuipes*; *Nemipterus furcosus;* and *Priacanthus tayenus*.

For each of the years the results of the multivariate analyses of family abundance and weight were very similar to those of the corresponding species analyses.

In summary, the areas open to trawling and those closed to trawling were most different from each other with these differences slightly stronger each year from 2004 to 2006 and with similar species that drove those differences each year. The one consistent and clearly separated group each year was that of the two sites in the closed area in PNG which were the two shallowest sites with the least current stress. As the degree of separation between the open and closed areas increased so too did the correlation of the biological MDS with depth and current stress and to a lesser extent sediment type. This reinforces the finding for the analyses of all 3 years data that these variables, in particular depth and current stress have a strong role in structuring the bycatch community composition. This was most clearly evident in 2006 where more than two-thirds of the pattern of sites matched between the community composition and the combination of depth and current stress.

6.5 Discussion

6.5.1 Bycatch description

The bycatch composition was typical of north-eastern Australian prawn trawl fisheries. It was consistent over the three years 2004-2006 and was very similar to that reported in previous bycatch studies conducted in the Torres Strait in the mid 1980s and in 1997. The dominance of fish at 77% of the total weight was almost identical to the 78% fish by weight reported in the summary of both previous studies (Turnbull *et al*. 2001). In this study the invertebrates contributed slightly more by weight at 22% than the 16% of previous years, and were dominated by crabs, coral prawns and scallops similar to the earlier years. A comparison to the bycatch data from 1985-1986 only (Harris and Poiner 1990) indicated that in this study fish and crabs were slightly more dominant and scallops slightly less dominant in the bycatch than two decades earlier. This dominance of fish, crabs and coral prawns was also found in prawn trawl bycatch off the north Queensland coast in the 1980s (Watson *et al*. 1990) and in 2001-2002 (Courtney *et al*. 2005).

More sharks and rays were retained in the earlier Torres Strait studies; however they were prior to the use of TEDs in the nets which now exclude many of the larger sharks and rays.

We found that typical of tropical prawn trawl bycatch it was highly diverse with 374 species, most of which occurred rarely. There were relatively few dominant species with only twenty three that each accounted for >1% of the total weight. These species were a mixture of benthic and demersal finfish and crabs, mainly breams, emperors, leatherjackets, cardinal fish, bigeyes, wrasse, lizardfish, goatfish, pufferfish and portunid crabs.

The dominant bycatch species of the Torres Strait prawn fishery have changed little in two decades. Six of the top ten dominant species occurred within the top twelve dominant species from the combined earlier studies in the Torres Strait (Turnbull *et al*. 2001), that is: *Scolopsis taenioptera; Nemipterus furcosus*; *Nemipterus hexodon*; *Nemipterus peronii* (all bream); *Paramonacanthus spp* (leatherjackets); and *Priancanthus tayenus* (bigeye).

Also six of our top ten fish families were in the top ten dominant families in the mid 1980s and four of our highly dominant fish species were the main dominant fish two decades earlier (Harris and Poiner 1990). These six families were Nemipteridae (threadfin bream), Priancanthidae (bigeye), Synodontidae (lizardfish), Mullidae (goatfish), Tetraodontidae (pufferfish) and Monacanthidae (leatherjacket). The fish were the four bream species. In addition, of the thirty one other main fish species from 1985-1986 we recorded twenty nine of these, with more than half in the top thirty species by weight.

The catch rates of the bycatch were within the large range of catch rates reported for the mid 1980s, and the current catch rates of total bycatch and fish around the mid point of the ranges reported for the 1980s study (Harris and Poiner 1990). The 2004-2006 mean catch rate of all the bycatch was 28% less than the highest catch rate of 1985-1986. A recent study of the effectiveness of TEDs and BRDs showed a 24% reduction of catch rates in the Queensland eastern king prawn fishery with the use of these devices (Courtney *et al*. 2005). Our bycatch catch rates were similar to those reported in that study although they varied from year to year with the highest catch rates of 8.85 kg/ha in 2005. This concurs with anecdotal comments from prawn trawl fishers from the Torres Strait that the first few months of the fishing season in 2005, which was a time of higher prawn catches, was a period when greater than normal amounts of bycatch were caught.

The 2004-2006 catch rates of Torres Strait bycatch species tended to be higher than those in the tiger/endeavour prawn trawl fishery on the northeast Queensland coast (Courtney *et al*. 2005), however there was considerable variation in catch rates of these Torres Strait species from year to year. All but two of the ten dominant species in the Torres Strait bycatch had considerably higher catch rates than those from northeast Queensland, although these species did not all appear to have the same degree of dominance amongst the northeast Queensland bycatch. Catch rates of other less dominant species caught in the Torres Strait were also generally higher than in northeast Queensland although there were some species that had very similar catch rates. On our surveys, which were also conducted on the northeast Queensland coast we found a similar trend of consistently higher catch rates of bycatch in the Torres Strait compared to northeast Queensland.

In general the bycatch species were of tropical Indo-western Pacific distribution with nine percent of the species endemic. Most of these were reported to occur only in northern Australian waters, although none occurred solely in the Torres Strait and they mostly occurred very rarely in the bycatch. For the species with available information their capacity to withstand exploitation was considered to be medium to high. These species and those with distributions restricted to Australian and PNG waters have been listed (Appendix 4) for TSPF managers and scientists as these may be species that need to be highlighted in Ecological Risk Assessment processes of the TSPF.

All but three of the 374 bycatch species were distributed throughout the areas of the TSPF surveyed. Over the three years of bycatch collection: only two species were unique to the closed area to the west of Warrior Reefs, a calcareous algae and a ponyfish; no species were unique to the semi closed area east of Warrior Reefs; and only a cuttlefish species was recorded solely from the main prawn trawl grounds.

The catches of protected species were very low in these surveys with the capture of one flatback turtle, two sea snakes (all returned to the sea alive) and three Sygnathidae. The turtle and one of the seasnakes were recorded from the area that is only open to trawling for part of the year while the other seasnake and the sygnathids were captured in the area of the fishery entirely closed to trawling.

One of the sygnathids, the eastern spiny seahorse, is endemic to Australia with a restricted distribution from the inner Great Barrier Reef of the Capricornia region to the north-eastern Gulf of Carpentaria, Queensland (Kuiter 2001). Its resilience or capacity to withstand exploitation is reported to be high with a minimum population doubling time of less than 15 months. International trade of this species is monitored through a licensing system (CITES II, since 5.15.04) and a minimum size of 10 cm applies (Froese and Pauly 2006). The other sygnathid, a ribboned pipehorse is distributed in Indonesian waters around Irian Jaya and in Australian waters from Shark Bay, Western Australia to the Torres Straits. Its resilience to exploitation is high with a minimum population doubling time of less than 15 months (Froese and Pauly 2006).

One of the sea snakes, the Stokes sea snake was a species identified as potentially at risk from prawn trawling in an assessment of sea snakes caught in the Northern Prawn Fishery (NPF) (Milton 2001). This large, bulky sea snake was shown to have life history traits that indicated it had a poor capacity to sustain fishing mortality. It was considered to probably be long lived, have poor survival from trawling, be caught before it can breed and have a large proportion of the fished population caught by the NPF. This study was undertaken before the introduction of TEDs and BRDs which have been shown to enable the escapement of some sea snakes from the trawl (Brewer *et al.* 1998). It is not possible to say whether this assessment would be the same in the TSPF which is a fishery much smaller in area and with different habitats to the NPF and with the current use of TEDs and BRDs. This species was captured only once in the 2004-2006 surveys and from within the area entirely closed to trawling at a site furtherest from the main trawl grounds, that is, the most westerly site located on the Seabed Jurisdiction Line (Figure 6.2.1). However it does raise this as a species that should be addressed in Ecological Risk Assessment processes of the TSPF. Catches of all sea snakes are currently being monitored by AFMA observers onboard commercial trawl vessels in the TSPF and there is a DPI&F project underway in Queensland waters testing the effectiveness of different types of BRDs to reduce sea snake capture (pers. comm. Tony Courtney DPI&F 2006).

Other bycatch species previously identified at risk from trawling in the Torres Strait were five species of fish that were benthic or demersal species and prefer soft muddy sediments (Turnbull *et al.* 2001) (Table 6.4.10). In the surveys from 2004-2006 none of these species were caught, which may indicate that the assessment was correct and they were at risk and are no longer present. For four of the five species, there were species recorded that were taxonomically very closely related. All four of these species occurred only in the areas open to prawn trawling, except for *Paracentropogon longispinis* (a waspfish) that also occurred in the area completely closed to trawling, and three of the species occurred frequently.

The risk assessment used to identify the five fish species provided a first step in the process for assessing ecological sustainability. However the high risk ranking of these five species was described by Turnbull *et al*. (2001) as a reflection of the application of the precautionary approach rather than a certainty that they are the least sustainable. There was a lack of information available concerning the survival of these species after capture, their relative catchability during the day/night, the probability of breeding before capture or the mortality index. In the same risk assessment seven pelagic fish species were identified as the most likely to be sustainable, though five of these were not recorded in these surveys, nor were any closely related species, and the two that were present were caught in low abundance in the area closed to trawling. These findings tend to indicate that this risk assessment may not have been accurate for these species.

This approach has limitations due to the lack of species-specific biological and ecological data available for many of the bycatch species captured in these fishery independent surveys and has in some cases been shown to be inadequate for reflecting changes in fishing impacts on the ecological sustainability of species (Griffiths *et al*. 2006). Other models and processes by which to determine ecological sustainability are continually being developed and improved. One new approach considers the spatial distribution of each species with respect to trawl grounds and uses this as a measure of the potential impacts from fishing. If the species is distributed within trawl grounds but also occurs in unfished regions, these regions may provide a significant spatial refuge and the species may be at far less risk than one whose entire natural distribution is largely within trawl grounds, particularly if it is within high trawl effort areas. For widely distributed species, depending on their mobility, individuals in unfished refuge areas may even replenish the proportion of the population taken by the fishery (Griffiths *et al.* 2006).

The bycatch species list from this study was provided to the Torres CRC project: Mapping and characterization of key biotic and physical attributes of the Torres Strait ecosystem and was used in the Level 1 Ecological Risk Assessment (ERA) of the Torres Strait Prawn Fishery undertaken by CSIRO in collaboration with the Principal Investigator for this Task. This ERA aims to identify risks of prawn trawl fishing to the Torres Strait environment with respect to target, bycatch and protected species and habitats. It will lead to the implementation of actions to manage high risk activities and species.

6.5.2 Potential impacts of trawling on bycatch

The gross measures of bycatch community structure (number of species, number of families, abundance or weight) showed no difference in the bycatch over the three years among the three areas, that is, those open to trawling, partially closed to trawling and entirely closed to trawling, except for two cases. In 2005 the weight of bycatch was significantly greater in the open area than the other two areas and in 2006 the bycatch abundance was significantly greater in the closed area than the other two areas.

A closer examination of the distribution and composition of bycatch species through multivariate analyses did reveal that some of the species and their abundances and weights were different in the closed area from those in the partially closed and entirely open areas. These two areas where trawling occurs had bycatch communities that were somewhat similar to one another.

The differences in the bycatch communities between the area entirely closed to trawling and the area entirely open to trawling were the greatest and were strongly related to the depth gradient and current stress and to a lesser degree sediment type. Sites in the closed area were all in 9-20 metres while those in the open area were all in 26-32 metres of water. There were two sites in the closed area that are within PNG waters where the composition of the bycatch was most different from that at all other sites across the three areas and these sites were the shallowest (9-10 metres) with the lowest seabed current stress.

These findings are similar to others studies of prawn trawl bycatch. In Queensland, Courtney (*et al.* 2005) found that bycatch assemblages differed with depth with the largest differences apparent between the shallow and deepest depths and Watson (*et al.* 1990) reported that demersal bycatch assemblages were correlated with depth and sediment type. In the Torres Strait current stress was found to be the most important physical factor in structuring patterns in the major biological communities of epibenthos, seagrass, algae, lobsters and prawn trawl fish bycatch (Pitcher *et al.* 2004). The Torres Strait is a shallow area of continental shelf with complex topography comprising numerous reefs and islands where tides and currents dominate the physical oceanography with extremely strong tidal currents in channels between reefs. These tidal currents cause seabed current shear stress that redistributes sediments and appears to influence the biological assemblages (Pitcher *et al.* 2004).

The prawn trawl fish bycatch referred to by Pitcher (*et al.* 2004) was that from Harris and Poiner (1990). Pitcher (*et al.* 2004) summarised some of the data not presented by Harris and Poiner (1990) and found that fish bycatch assemblages differed between areas open and closed to trawling in terms of numbers of species, with more species in the closed areas, but not in terms of catch rates. The difference in numbers of species was stated as most likely due to environmental differences rather than effects of prawn trawl effort.

We found no significant differences between areas in either the numbers of species or catch rates. The number of fish species was higher in 2004-2006 at 35 and 32 in the open and closed areas respectively compared to the numbers in 1985-1986 of 15 and 21 in the open and closed areas. The bycatch fish catch rates were slightly higher in 2004-2006 in the open area and lower in the closed area compared to the catch rates of the mid 1980s. We recorded 7.2 and 4.9 kg/ha in the open and closed areas respectively and in the 1980s the catch rates were 6.3 and 7.1 kg/ha in the open and closed areas. Despite no significant differences in numbers of fish species or catch rates between areas, we did find there were differences in the bycatch communities with respect to species between the open and closed areas that were strongly influenced by the environmental variables, similar to Pitcher (*et al.* 2004).

There were relatively few species that were different between the open and closed areas, though there were some species that tended to be more prevalent in one of the two areas, driving the separation of areas in the multivariate analyses of differences in community composition. Of these thirteen species, nine were much prevalent in the area open to trawling. They were a leatherjacket, three bream, a bigeye, two portunid crabs, a coral prawn and a scallop. The four species that were much more prevalent in the closed area were a cardinal fish, an emperor and two coral prawns (Table 6.4.14 and Section 6.4.7 Weight).

These influential species were among the twenty three most dominant species by weight in the bycatch (Table 6.4.3), which indicates that the distribution of the most dominant species appeared to drive the separation of open and closed areas in the multivariate analyses. The majority of the bycatch species occurred in areas both open and closed to trawling, as shown by the lack of species consistently unique to an area. This tends to indicate that there was no marked effect of trawling on the bycatch species and differences detected in the bycatch community composition were due more to the environmental variables of depth, current stress and sediment type than trawling. The analyses of family level data produced the same results as the species data, except that the strength of the correlation between the biological and environmental variables was weaker than that of the species analyses. As such, little information was lost when the higher taxonomic level of family was used to detect differences in the bycatch structure and communities among areas.

Stobutzki (*et al.* 2003) could not detect a difference attributable to prawn trawling in populations of fish bycatch between a large area closed to trawling and the adjacent open area in the western Gulf of Carpentaria within the Northern Prawn Fishery. This lack of difference was partly attributed to the low trawling intensity in the areas open to trawling.

There was no consistent difference in the bycatch from areas open and closed to prawn trawling in a north Queensland study (Burridge *et al.* 2006) and it was found, similar to other northern Australian prawn trawl studies, that for many of the common bycatch species depth and sediment type were influential on their distribution.At times, though not always, there was a difference of fifty percent or more in the biomass of a small proportion of species between zones. That is, the biomass of *Lethrinus genvittatus, Pentapodus paradiseus*, *Upeneus tragula* and *Leiognathus sp.* was considerably higher in the closed zone than the open zone. We also found that these four species were more prevalent in the area closed to trawling than the open area, though only the first of these, *Lethrinus genvittatus* occurred almost exclusively in the closed areaFigure 6.4.6b). The north Queensland study reported one species, *Apogon poecilopterus* that had twice the biomass in the open zone than the closed zone which is contrary to this study where this species occurred almost entirely in the closed area at the two PNG sites that were the shallowest with the least current stress. It appears there are at times differences in the bycatch communities in comparisons of areas open and closed to trawling, however these are far from consistent and not directly attributable to prawn trawling.

(Burridge *et al.* 2006) attributed this lack of consistent, measurable differences partly to the unevenly distributed and relatively low intensity of trawl effort in the open zone that left extensive areas unfished and partly to the complex seabed habitat and high biodiversity of the bycatch. They found changes in bycatch composition over relatively small distances and concluded that given this high degree of variation it could be expected that differences between open and closed zones were simply a result of inherent variability and not related to the effect of trawling. It was stated that it is difficult to obtain accurate quantitative measures of trawl impacts in such a complex environment with high biodiversity and low level of trawling. Impacts of repeated prawn trawling have clearly been shown on epibenthic communities that consist of sessile organisms attached to the seabed (Pitcher *et al.* 2000, Turnbull *et al.* 2001, Burridge *et al*. 2006). Trawling an area repeatedly can alter seabed complexity, remove, damage or kill these attached fauna and can result in substantial impacts to these communities. With regard to trawl bycatch it appears the impact of trawling is far less marked. Lesser impacts are more difficult to detect particularly with tropical prawn trawling where the bycatch is a highly diverse community of mobile demersal and benthic fauna and where the trawling is often aggregated leaving large areas of grounds relatively untrawled. The Torres Strait is no exception as the bycatch communities are highly diverse and although the trawl effort is mostly within a relatively narrow corridor it is aggregated within this corridor so that for the majority of the main trawl grounds trawl effort is relatively low (Figure 6.2.1).

This study of the Torres Strait prawn trawl bycatch was able to detect relatively small differences in the numbers of species among areas (eighteen percent, Table 6.4.11) and as none were evident it is apparent that trawling does not have a marked impact on the numbers of bycatch species. It was not possible to detect such small differences in the abundances and weights among areas due to their higher variability, except for the two cases where the abundances were markedly higher in the closed area in 2006 and weights much greater in the open area in 2005. However, the multivariate analyses of species composition provided a complement to these univariate analyses and were able to reveal differences among species which showed that among the dominant species there were some that were much more prevalent in either the areas open or closed to trawling (particularly in 2005 and 2006) and the distribution of these species was strongly related to the environmental variables. The majority of bycatch species occurred throughout the areas open and closed to trawling in variable numbers and weights with no consistent trend among areas or years. This tends to confirm that trawling does not have a marked impact on the distribution, abundance and weight of the bycatch species.

6.6 Conclusion

The Torres Strait bycatch was typical of tropical prawn trawl bycatch. It was highly diverse and predominantly fish and invertebrates, most of which occurred rarely. The dominant fish species and families have changed little since the mid 1980s and the catch rates of bycatch have not markedly altered in two decades. Nearly all of the species occurred throughout all areas of the fishery surveyed and most of the species had a distribution that ranged across the Indo-Western Pacific Oceans, with nine percent of the species endemic.

Prawn trawling does not appear to have any marked effect on the bycatch of the Torres Strait Prawn Fishery. There were no major differences in the benthic community structure between the areas open, partially closed and closed to trawling; however some of the dominant species were more prevalent in either the open or closed area. These differences in distribution were due more to the environmental variables of depth, current stress and sediment type than prawn trawling, which has been found to be the case for other studies of prawn trawl bycatch in the Torres Strait, the Gulf of Carpentaria and Queensland.

Trawling in the Torres Strait Prawn Fishery is restricted to areas that have been trawled since the mid 1970s and that represent only about twenty percent of the entire TSPF. There are spatial refuges for bycatch species in areas that are not trawled at all or only trawled lightly which may have afforded some degree of protection to these species. These management strategies are likely to assist in the long term ecological sustainability of the bycatch species. There is also ongoing research into bycatch reduction devices and the use of onboard processing systems such as hoppers which together can reduce the amount of bycatch caught in the trawl net and increase the survivability of those species caught.

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7 Appendix 1 Bycatch species lists

List of the 374 taxa sampled across all sites (92 subsamples) and over the years 2004 to 2006 with the catch rate (mean catch in grams per hectare), percent of total bycatch weight and frequency of capture which is the percentage occurrence in the 92 subsamples. For all taxa there is DPI&F Species Register number and for those fauna identified to species also a CAAB code. The 23 dominant species, those accounting for >1% of the total bycatch weight, are marked with *.

Species	Mean catch rate g/ha	% total	% Freq. of capture	CAAB code	DPI&F SR no.
Acaudina sp A	11.951	<0.1	2.2		749
Acentrogobius caninus	182.494	0.6	30.4	37 428019	614
Actinaria sp A	1.822	<0.1	1.1		1003
Adventor elongates	14.628	<0.1	3.3	37 290004	93
Alcyonacea sp A	55.159	<0.1	5.4		644
Alcyonacea sp B	43.632	<0.1	1.1		750
Alectis indicus	30.944	<0.1	3.3	37 337038	667
Alepes apercna	178.520	<0.1	2.2	37 337010	122
Alepes vari	94.028	<0.1	4.3	37 337067	
Alpheidae sp A	2.025	<0.1	1.1		775
Amblygaster sirm	9.611	<0.1	1.1	37 085006	
Amniataba caudavittata	110.194	<0.1	1.1	37 321007	1311
Amusium pleuronectes*	213.561	1.7	66.3	23 270003	556
Anacanthus barbatus	12.891	<0.1	7.6	37 465010	113
Annachlamys flabellata	30.361	0.1	19.6	23 270004	555
Apistus carinatus	45.102	0.1	28.3	37 287011	202
Apogon albimarculosus	4.555	<0.1	1.1	37 327014	816
Apogon brevicaudatus	70.808	0.4	53.3	37 327005	131
Apogon cavitiensis	6.127	<0.1	12.0	37 327028	121
Apogon fasciatus*	372.146	4.0	92.4	37 327158	145
Apogon fuscomaculatus	8.892	<0.1	15.2	37 327140	634
Apogon melanopus	66.131	0.1	7.6	37 327016	697
Apogon nigripinnis	9.915	<0.1	5.4	37 327009	146
Apogon poecilopterus	134.861	0.9	57.6	37 327026	147
Apogon semilineatus	3.313	<0.1	1.1	37 327004	148
Apogon septemstriatus	14.668	<0.1	16.3	37 327012	149
Apogon timorensis	7.078	<0.1	2.2	37 327077	619
Apogon truncatus*	206.432	2.3	95.7	37 327013	144
Arius thalassinus	35.624	<0.1	8.7	37 188001	678
Arnoglossus waitei	7.275	<0.1	12.0	37 460045	133
Arothron manilensis	38.929	<0.1	1.1	37 467020	269
Ascidiacea sp A	104.143	<0.1	3.3		598
Ascidiacea sp B	40.686	<0.1	8.7		610
Ascidiacea sp C	12.219	<0.1	2.2		629
Ascidiacea sp E	19.169	<0.1	2.2		790
Ascidiacea sp H	37.620	<0.1	1.1		956
Ascidiacea sp K	15.087	<0.1	1.1		1321
Ascidiacea sp L	121.726	<0.1	2.2		1322
Ascidiacea sp M	246.773	0.1	2.2		1323
Aseraggodes melanostictus	21.041	<0.1	4.3	37 462016	664
Ashtoret granulosa	31.988	<0.1	1.1	28 877001	439
Asteroidae sp B	4.568	<0.1	1.1		625

Species	Mean catch rate g/ha	% total	% Freq. of capture	CAAB code	DPI&F SR no.
Asteroidae sp C	48.143	<0.1	2.2		628
Asteroidae sp D	3.543	<0.1	1.1		726
Asteroidae sp E	29.407	<0.1	2.2		728
Asteroidae sp K	39.316	<0.1	4.3		1329
Asteroidae sp L	157.289	<0.1	1.1		1330
Astropecten sp A	9.551	<0.1	3.3		597
Astropecten sp B	4.414	<0.1	2.2		727
Atys naucum	11.739	<0.1	1.1		1319
Axiidae sp A	3.847	<0.1	1.1		1332
Axiidae sp B	2.733	<0.1	2.2		1333
Brachirus muelleri	69.161	<0.1	4.3	37 462007	180
Bregmaceros spp	0.607	<0.1	1.1	37 225004	142
Bufonaria rana	15.589	<0.1	1.1	24 170002	525
Calappa sp A	20.043	<0.1	2.2		772
Calliurichthys grossi	83.195	0.6	65.2	37 427007	134
Carangoides caeruleopinnatus	17.753	<0.1	3.3	37 337021	114
Carangoides gymnostethus	122.753	<0.1	1.1	37 337022	691
Carangoides hedlandensis	26.559	<0.1	4.3	37 337042	116
Carangoides humerosus	38.962	<0.1	8.7	37 337031	117
Carangoides talamparoides	18.727	<0.1	1.1	37 337043	17
Caranx bucculentus	104.745	0.3	20.7	37 337016	18
Caridean sp A	1.312	<0.1	1.1		613
Carinosquilla spinosus	10.022	<0.1	1.1		584
Carinosquilla thailandensis	21.635	<0.1	5.4	28 051015	1000
Caulastrea sp A	15.451	<0.1	1.1		1339
Centriscus scutatus	3.841	<0.1	31.5	37 280001	32
Centrogyns vaigiensis	28.194	<0.1	12.0	37 311030	33
Ceriantharia sp B	1.923	<0.1	1.1		720
Chaetodermis penicilligera	284.690	<0.1	1.1	37 465013	111
Chaetodontoplus duboulayi	74.262	<0.1	1.1	37 365009	348
Charybdis (Charybdis) callianassa	6.175	<0.1	2.2	28 911037	669
Charybdis (Charybdis) jaubertensis	21.477	<0.1	17.4	28 911075	407
Charybdis (Charybdis) natator	114.440	<0.1	2.2	28 911002	405
Charybdis (Charybdis) orientalis	37.318	<0.1	4.3	28 911078	1338
Charybdis (Charybdis) yaldwyni	25.255	<0.1	6.5	28 911081	896
Charybdis (Goniohellenus) truncata	60.834	0.4	57.6	28 911015	404
Chelmon marginalis	6.124	<0.1	2.2	37 365007	
Chicoreus (Triplex) cervicornis	9.061	<0.1	1.1	24 200020	738
Choerodon cephalotes*	307.904	2.0	56.5	37 384004	42
Choerodon cyanodus	216.226	<0.1	52.2	37 384072	1162
Choerodon monostigma	84.236	0.5	1.1	37 384008	70
Choerodon sugillatum	105.569	0.4	33.7	37 384009	49
Clibanarius sp A	6.389	<0.1	5.4		886
Clibanarius sp B	7.179	<0.1	6.5		711
Clibanarius sp C	1.569	<0.1	2.2		1336
Clypeasteridae sp A	226.608	0.3	9.8		617
Clypeasteridae sp B	77.029	<0.1	2.2		646
Clypeasteridae sp C	0.456	<0.1	2.2		1327
Coradion chrysozonus	10.711	<0.1	1.1	37 365004	28
Corbulidae sp A	4.049	<0.1	1.1		1318
Cottapistus cottoides	4.777	<0.1	1.1	37 287014	205

Species	Mean catch rate g/ha	% total	% Freq. of capture	CAAB code	DPI&F SR no.
Crinoid sp A	294.992	0.2	5.4		599
Crinoid sp B	3.328	<0.1	2.2		600
Crinoid sp C	6.999	<0.1	1.1		609
Crinoid sp D	62.687	0.1	9.8		612
Crinoid sp E	6.152	<0.1	4.3		608
Crinoid sp F	8.720	<0.1	1.1		622
Crinoid sp G	4.568	<0.1	12.0		630
Crinoid sp H	10.796	<0.1	1.1		633
Crinoid sp I	11.212	<0.1	1.1		635
Crinoid sp J	5.061	<0.1	1.1		718
Crinoid sp K	13.008	<0.1	2.2		719
Crinoid sp L	0.911	<0.1	1.1		722
Crinoid sp N	55.305	<0.1	1.1		760
Crinoid sp P	2.141	<0.1	1.1		887
Crinoid sp Q	82.223	0.1	10.9		892
Cryptopodia sp A	8.503	<0.1	1.1		1337
Cyclichthys orbicularis	16.480	<0.1	1.1	37 469007	68
Cynoglossus maculipinnis	40.164	<0.1	6.5	37 463003	714
Cynoglossus sp A	59.507	<0.1	2.2		594
Cypraea subviridis	4.049	<0.1	1.1	24 155003	549
Dactyloptena papilio	100.628	0.4	34.8	37 308001	64
Dactylopus dactylopus	39.439	0.1	18.5	37 427005	139
Dardanus hessii	1.378	<0.1	2.2	28 827011	467
Diagramma pictum labiosum	172.675	0.8	38.0	37 350003	106
Distorsio reticulata	24.538	<0.1	1.1	24 174001	523
Dorippe quadridens	9.448	<0.1	3.3	28 870001	469
Dosinia altenai	16.610	<0.1	1.1	23 380033	636
Dromidiopsis australiensis	10.443	<0.1	2.2	28 852005	471
Dussumieria elopsoides	62.357	<0.1	1.1	37 085010	882
Echinoid sp B	224.914	0.1	2.2		675
Echinoid sp F	5.936	<0.1	2.2		898
Echinoid sp G	21.584	<0.1	1.1		911
Echinoid sp N	106.024	<0.1	1.1		
Elates ransonneti	10.057	<0.1	5.4	37 296013	375
Encrasicholina sp A	3.598	<0.1	1.1		1004
Engyprosopon grandisquama	73.166	0.6	67.4	37 460012	124
Epinephelus quoyanus	209.443	<0.1	1.1	37 311040	876
Epinephelus sexfasciatus	126.083	0.6	39.1	37 311017	169
Erugosquilla grahami	40.644	<0.1	1.1	28 051032	1335
Erugosquilla woodmasoni	29.846	<0.1	3.3	28 051033	420
Euristhmus nudiceps	179.145	0.7	33.7	37 192003	332
Euryale asperum	52.287	<0.1	1.1	25 170004	632
Feroxodon multistriatus	534.748	0.4	6.5	37 467010	1254
Fistularia commersonii	2.139	<0.1	3.3	37 278001	53
Fistularia petimba	21.330	0.1	29.3	37 278002	52
Gazza minuta	146.150	0.1	4.3	37 341007	744
Gerres filamentosus	197.439	0.1	2.2	37 349003	947
Gerres oblongus	110.229	0.1	4.3	37 349022	50
Gerres subfasciatus	111.996	0.4	32.6	37 349005	60
Glaucosoma magnificum	214.772	0.4	16.3	37 320002	823
Gnathanodon speciosus	318.210	0.2	4.3	37 337012	22

Species	Mean catch rate g/ha	% total	% Freq. of capture	CAAB code	DPI&F SR no.
Gobiidae sp A	7.329	<0.1	2.2		1313
Grammatobothus polyopthalmus	106.432	0.6	52.2	37 460010	126
Haliichthys taeniophorus	6.782	<0.1	1.1	37 282007	819
Halimeda sp A	29.675	<0.1	5.4		573
Halophila spinulosa	131.602	0.1	8.7	63 605003	572
Haustellum multiplicatus	3.239	<0.1	1.1	24 200018	1314
Hemiramphus robustus	31.968	<0.1	3.3	37 234013	706
Herklotsichthys lippa	10.663	<0.1	3.3	37 085008	8
Herpetopoma atrata	2.025	<0.1	1.1	24 046004	1316
Hippocampus hendriki	1.743	<0.1	1.1	37 282125	637
Holothuria (Metriatyla) ocellata	67.713	0.1	15.2	25 416030	682
Holothuria sp M	6.819	<0.1	1.1		787
Hyastenus campbelli	6.472	<0.1	2.2	28 880030	450
Hyastenus sp A	0.607	<0.1	1.1		773
Hydroid sp B	26.191	<0.1	16.3		694
Hydroid sp A	7.890	<0.1	1.1		621
Hydroid sp C	3.745	<0.1	1.1		724
Inegocia japonica*	182.079	2.0	92.4	37 296029	363
Inimicus caledonicus	21.905	<0.1	2.2	37 287055	208
Inimicus sinensis	12.107	<0.1	1.1	37 287020	
Ixa sp A	1.012	<0.1	1.1		776
Izanami inermis	75.816	0.1	7.6	28 877004	482
Johnius borneensis	36.773	<0.1	2.2	37 354007	822
Jonas leuteanus	94.718	<0.1	2.2	28 900002	13
Kanekonia queenslandica	2.187	<0.1	5.4	37 290007	96
Lactoria cornuta	151.034	<0.1	1.1	37 466004	377
Lagocephalus lunaris	1052.144	0.3	2.2	37 467012	
Lagocephalus sceleratus*	130.823	1.2	81.5	37 467007	274
Lagocephalus spadiceus	134.509	0.1	6.5	37 467017	234
Leiognathus bindus	25.671	0.1	21.7	37 341002	86
Leiognathus decorus	37.272	<0.1	8.7	37 341016	305
Leiognathus elongatus	1.700	<0.1	2.2	37 341011	306
Leiognathus fasciatus	11.592	<0.1	1.1	37 341009	
Leiognathus leuciscus	66.730	0.1	15.2	37 341005	308
Leiognathus moretoniensis	124.301	0.4	28.3	37 341012	309
Leiognathus sp	102.118	0.4	35.9	37 341003	658
Leiognathus splendens	32.045	<0.1	3.3	37 341010	312
Lethrinus genivittatus*	1386.215	6.2	38.0	37 351002	331
Lethrinus lentjan	208.223	0.4	15.2	37 351007	677
Lupocyclus rotundatus	28.647	<0.1	2.2	28 911034	398
Lutjanus carponotatus	10.022	<0.1	1.1	37 346011	827
Lutjanus malabaricus	145.218	0.5	28.3	37 346007	321
Lutjanus russelli	15.488	<0.1	1.1	37 346065	322
Lutjanus vitta	90.132	0.1	13.0	37 346003	119
Metapenaeopsis hilarula	3.127	<0.1	3.3	28 711060	
Metapenaeopsis mogiensis complanata	5.399	<0.1	3.3	28 711015	485
Metapenaeopsis novaeguineae	47.422	0.1	17.4	28 711016	641
Metapenaeopsis palmensis	41.077	0.3	65.2	28 711017	476
Metapenaeopsis rosea*	226.353	2.1	78.3	28 711019	481
Metapenaeopsis sinica	15.622	0.1	38.0	28 711070	
Metapenaeopsis toloensis	61.624	<0.1	5.4	28 711072	763

Species	Mean catch rate g/ha	% total	% Freq. of capture	CAAB code	DPI&F SR no.
Metasepia pfefferi	59.214	<0.1	4.3	23 607015	498
Minous trachycephalus	16.811	<0.1	2.2	37 287024	210
Minous versicolor	32.447	<0.1	2.2	37 287021	211
Monacanthus chinensis	29.076	0.1	26.1	37 465009	83
Murex acanthostephes	1.701	<0.1	1.1	24 200016	618
Nassarius (nassarius) coronatus	3.725	<0.1	1.1	24 202133	1320
Nemipterus furcosus*	474.810	3.4	60.9	37 347005	293
Nemipterus hexodon*	386.527	3.1	68.5	37 347014	294
Nemipterus nematopus	82.311	0.1	5.4	37 347002	756
Nemipterus peronii*	317.360	2.9	79.3	37 347003	295
Nuculidae sp A	2.803	<0.1	1.1		1317
Octopus exannulatus	59.379	<0.1	3.3	23 659024	505
Octopus sp J	53.422	<0.1	7.6		663
Octopus sp K	32.406	<0.1	4.3		680
Ophiochasma stellata	0.686	<0.1	2.2	25 180018	
Ophiocomidae sp A	1.012	<0.1	1.1		721
Ophiomaza cacaotica	1.822	<0.1	1.1	25 192028	
Ophuroid sp A	8.090	<0.1	12.0		631
Ophuroid sp B	2.362	<0.1	4.3		626
Ophuroid sp C	1.721	<0.1	1.1		715
Ophuroid sp D	2.092	<0.1	3.3		716
Ophuroid sp H	3.624	<0.1	1.1		888
Ophuroid sp I	0.486	<0.1	1.1		894
Oratosqillina inornata	38.110	0.1	12.0	28 051051	585
Oratosquillina quinquedentata	67.401	0.1	18.5	28 051054	417
Orbonymus rameus	20.449	<0.1	2.2	37 427009	162
Palaemonidae sp A	2.442	<0.1	4.3		1334
Palaemonidae sp B	0.911	<0.1	1.1		
Pandalidae sp A	1.118	<0.1	1.1		1331
Pantolabus radiatus	46.768	<0.1	2.2	37 337047	24
Papilloculiceps nematophthalmus	134.255	0.2	10.9	37 296023	376
Paracaudina sp A	81.443	<0.1	2.2		748
Paracentropogon longispinis	25.062	0.1	40.2	37 287016	649
Parachaetodon ocellatus	34.097	0.1	32.6	37 365003	4
Paramonacanthus filicauda complex	1.215	<0.1	1.1		85
Paramonacanthus spp*	445.121	5.1	98.9		325
Parapenaeopsis cornuta	6.377	<0.1	1.1	28 711031	
Parapercis diplospilus	4.111	<0.1	10.9	37 390014	378
Parapercis nebulosa	87.353	0.1	7.6	37 390005	387
Paraplagusia sinerama	57.882	<0.1	1.1	37 463022	72
Paraploactis intonsa	64.691	<0.1	1.1	37 290010	593
Paraploactis trachyderma	4.657	<0.1	1.1	37 290011	1312
Parastromateus niger	9.516	<0.1	1.1	37 337072	206
Parexocoetus mento	13.343	<0.1	4.3	37 233003	752
Parthenope longimanus	6.782	<0.1	1.1	28 895002	801
Parupeneus heptacanthus	16.500	<0.1	1.1	37 355004	288
Pegasus volitans	19.601	0.1	41.3	37 309002	383
Pelates quadrilineatus	255.998	0.6	18.5	37 321001	263
Pelates sexlineatus	93.677	<0.1	2.2	37 321005	264
Pellona ditchela	52.061	<0.1	1.1	37 085009	642
Pennatulacea sp A	31.497	<0.1	1.1		647

Species	Mean catch rate g/ha	% total	% Freq. of capture	CAAB code	DPI&F SR no.
Pennatulacea sp B	12.504	<0.1	1.1		696
Pennatulacea sp C	36.597	<0.1	2.2		725
Pentapodus paradiseus	205.242	0.5	22.8	37 347028	298
Pentaprion longimanus	33.010	0.1	37.0	37 349002	48
Peristrominous dolosus	7.187	<0.1	1.1	37 290012	98
Phalangipus australiensis	2.733	<0.1	1.1	28 880038	454
Phalangipus sp A	6.055	<0.1	6.5		768
Philine angasi	3.410	<0.1	4.3	24 322002	695
Photololigo chinensis complex	26.469	<0.1	5.4	23 617901	
Photololigo sp A	7.761	<0.1	7.6		733
Pinnidae sp A	4.044	<0.1	2.2		681
Placamen calophyllum	7.289	<0.1	1.1	23 380023	673
Platax teira	7.390	<0.1	1.1	37 362004	56
Platycephalus indicus	76.529	<0.1	1.1	37 296033	336
Platylambrus sp A	1.518	<0.1	1.1		1009
Plotosus lineatus	35.265	<0.1	8.7	37 192002	362
Pomadasys maculatus	161.925	0.1	5.4	37 350002	108
Porcellana triloba	0.328	<0.1	2.2	28 843047	713
Portunus (Cycloachelous) granulatus	30.369	<0.1	1.1	28 911028	388
Portunus (Lupocycloporus) gracilimanus*	220.705	2.1	80.4	28 911027	391
Portunus (Monomia) argentatus	3.054	<0.1	2.2	28 911032	390
Portunus (Monomia) rubromarginatus*	283.711	3.1	92.4	28 911026	396
Portunus (Portunus) pelagicus	174.308	0.7	33.7	28 911005	395
Portunus (Xiphonectes) hastatoides	7.355	<0.1	32.6	28 911030	389
Portunus (Xiphonectes) rugosus	9.087	<0.1	3.3	28 911070	399
Portunus (Xiphonectes) tenuipes*	337.915	3.7	93.5	28 911042	408
Priancanthus tayenus*	350.488	3.0	72.8	37 326003	355
Prionocidaris sp A	16.378	<0.1	1.1		1328
Pristotis obtusirostris	32.566	0.1	34.8	37 372001	352
Psammoperca waigiensis	108.782	<0.1	2.2	37 310001	826
Psettodes erumei	318.139	0.2	6.5	37 457001	329
Pseudochromis quinquedentatus	2.049	<0.1	1.1	37 313001	190
Pseudocolochirus violaceus	557.535	0.5	7.6	25 408031	685
Pseudomonacanthus elongatus	18.760	0.1	43.5	37 465029	326
Pseudomonacanthus peroni	21.637	<0.1	19.6	37 465020	358
Pseudorhombus argus	154.952	0.7	41.3	37 460038	368
Pseudorhombus arsius	225.083	0.6	23.9	37 460009	360
Pseudorhombus diplospilus	175.309	0.6	28.3	37 460015	370
Pseudorhombus elevatus	69.981	0.3	35.9	37 460008	372
Pseudorhombus jenynsii	49.815	<0.1	1.1	37 460002	373
Pseudorhombus spinosus*	217.783	1.7	67.4	37 460011	386
Pterois spp	29.566	<0.1	7.6		214
Repomucenus belcheri	32.505	0.2	53.3	37 427011	123
Repomucenus limiceps	99.105	0.6	50.0	37 427012	136
Repomucenus sublaevis	128.561	<0.1	1.1	37 427010	138
Rhynchostracion nasus	61.269	0.1	20.7	37 466005	688
Samaris cristatus	16.103	<0.1	2.2	37 461006	197
Sardinella albella	12.552	<0.1	1.1	37 085014	1
Sardinella gibbosa	31.161	<0.1	3.3	37 085013	10
Saurida argentea/tumbil complex*	378.763	2.0	45.7		250
Saurida nebulosa	57.907	<0.1	1.1	37 118027	254

Species	Mean catch rate g/ha	% total	% Freq. of capture	CAAB code	DPI&F SR no.
Saurida undosquamis/grandisquamis complex*	191.763	2.0	89.1	t	757
Scarus ghobban	63.572	<0.1	1.1	37 386001	1158
Scolopsis taenioptera*	857.766	8.2	81.5	37 347008	301
Scorpaenopsis cotticeps	33.406	<0.1	1.1	37 287106	217
Scorpaenopsis furneauxi	21.927	<0.1	1.1	37 287038	693
Scorpaenopsis neglecta	7.330	<0.1	4.3	37 287030	1310
Scorpaenopsis venosa	22.847	<0.1	2.2	37 287086	218
Scyllarus sp A	0.875	<0.1	1.1		783
Scyllarus sp B	32.615	0.1	32.6		596
Secutor insidiator	11.197	<0.1	5.4	37 341006	313
Selar boops	75.492	<0.1	2.2	37 337008	25
Selaroides leptolepis	78.828	0.4	41.3	37 337015	39
Sepia elliptica	105.533	0.6	51.1	23 607003	497
Sepia papuensis	35.872	<0.1	7.6	23 607007	496
Sepia pharaonis	34.743	<0.1	6.5	23 607008	495
Sepia plangon	39.540	0.1	16.3	23 607012	490
Sepia smithi	139.989	0.5	30.4	23 607013	493
Sepiadariidae sp A	5.118	<0.1	5.4		668
Sepiadariidae sp B	5.561	<0.1	4.3		735
Sepiolidae sp A	5.568	<0.1	1.1		743
Sepioteuthis lessoniana	332.437	<0.1	1.1	23 617006	1324
Sicyonia lancifera	4.283	<0.1	1.1	28 715001	410
Siganus canaliculatus	157.298	0.9	46.7	37 438004	170
Sillago maculata	190.574	0.2	7.6	37 330015	175
Sillago robusta	109.690	0.4	33.7	37 330005	191
Sillago sihama	263.565	0.2	5.4	37 330006	177
Siphamia roseigaster	2.382	<0.1	2.2	37 327017	163
Sorsogona tuberculata	127.283	0.9	57.6	37 296030	341
Spatangoida sp B	486.407	0.1	1.1		1326
Sphenopus marsupialis	30.168	<0.1	5.4	11 287001	1063
Sphyraena flavicauda	134.476	<0.1	1.1	37 382007	189
Stellaster equestris	55.293	0.1	17.4	25 122026	1044
Stichopus sp A	6.186	<0.1	1.1		1325
Stolephorus sp A	3.554	<0.1	4.3		755
Stolephorus sp B	11.694	<0.1	10.9		961
Strombus (Doxander) vittatus	9.204	<0.1	3.3	24 125001	513
Strongylura leiura	22.574	<0.1	1.1	37 235003	707
Suggrundus macracanthus	36.495	0.1	17.4	37 296012	590
Synodus hoshinonis	30.904	<0.1	6.5	37 118010	
Synodus sageneus	93.816	0.2	21.7	37 118004	275
Tamaria megaloplax	20.373	<0.1	4.3	25 125047	1285
Tathicarpus butleri	8.225	<0.1	4.3	37 210003	82
Tellina (Tellinella) pulcherrima	8.503	<0.1	1.1	23 355013	1315
Temnotrema sp A	145.276	0.1	5.4		640
Temnotrema sp B	63.774	<0.1	1.1		959
Terapon theraps*	204.651	1.0	40.2	37 321003	266
Tetrabrachium ocellatum	17.918	<0.1	1.1	37 210010	267
Thalamita sima*	352.430	1.6	39.1	28 911022	434
Thalamita sp A	1.620	<0.1	1.1		771
Thenus indicus	188.269	0.7	31.5	28 821007	740
Thenus orientalis	173.372	0.2	12.0	28 821008	427

Species	Mean catch rate g/ha	% total	% Freq. of capture	CAAB code	DPI&F SR no.
Thenus sp A	176.459	<0.1	1.1		732
Torquigener pallimaculatus	52.439	0.3	48.9	37 467009	260
Torquigener whitleyi	139.454	0.8	47.8	37 467028	223
Trachinocephalus myops	136.006	0.1	3.3	37 118002	248
Trachypenaeus (Megokris) granulosus	72.920	0.7	81.5	28 711058	411
Trachypenaeus (Trachypenaeus) anchoralis	89.132	0.4	40.2	28 711054	459
Trachypenaeus (Trachysalambria) curvirostris	12.969	<0.1	5.4	28 711055	428
Trachypenaeus (Trachysalambria) fulvus	93.445	0.3	23.9	28 711056	
Tragulichthys jaculiferus	296.322	0.2	4.3	37 469004	71
Trichiurus lepturus	4.825	<0.1	4.3	37 440004	765
Tripodichthys angustifrons	1.263	<0.1	10.9	37 464007	228
Trixiphichthys weberi	75.921	0.1	9.8	37 464001	229
Upeneus asymmetricus*	280.466	1.3	39.1	37 355010	279
Upeneus luzonius	264.897	0.9	29.3	37 355009	280
Upeneus moluccensis	13.868	<0.1	2.2	37 355003	281
Upeneus sp 1	78.632	<0.1	2.2	37 355008	1010
Upeneus sulphureus	213.743	0.5	18.5	37 355007	282
Upeneus sundaicus	126.531	0.3	19.6	37 355013	283
Upeneus tragula complex	159.101	0.4	22.8		284
Xenophora (Xenophora) solaroides	4.283	<0.1	4.3	24 145001	739
Xenophora indica	5.466	<0.1	1.1	24 145002	530
Yongeichthys nebulosus	117.533	0.7	53.3	37 428001	690
Zebrias cancellatus	22.372	<0.1	1.1	37 462006	181
Zebrias quagga	53.854	<0.1	1.1	37 462004	183

a. Endemic Species, percent of total bycatch weight, distribution within Australia and Resilience (where available). Source of distributional information: Australian Faunal Directory (2006), Oceanographic Biogeographic Information System (2006) and Froese and Pauly (2006). The latter authors were also the source of the Resilience data.

Endemic Species	% total	Distribution	Resilience
Hippocampus hendriki	<0.1	Torres Strait, Central Queensland (Qld)	High, minimum population doubling time < 15 months
Trachypenaeus (Trachypenaeus) anchoralis	0.5	Northern Australia from Keppel Bay(Qld) north to Shark Bay (Western Australia WA)	
Trachypenaeus (Trachysalambria) fulvus	0.3	Known only from limited area, from Shark Bay (WA) to Moreton Bay (Qld)	
Thenus indicus	0.8	Gulf of Carpentaria, Qld north coast	
Charybdis (Charybdis) yaldwyni	<0.1	Northern Australia only	
Charybdis (Charybdis) jaubertensis	<0.1	Northern Australia only	
Jonas leuteanus	<0.1	Qld	
Sepia plangon	0.1	Eastern Australia:Cape York to Brisbane(Qld)	
Murex acanthostephes	<0.1	Northern Australian from North West Cape (WA) to Torres Strait	
Haustellum multiplicatus	<0.1	Shark Bay north to Brisbane	
Scorpaenopsis furneauxi	<0.1	Northeastern Qld to eastern Arafura Sea	Medium, min population doubling time 1.4 - 4.4 years
Kanekonia queenslandica	<0.1	WA	
Peristrominous dolosus	<0.1	Shark Bay (WA) and Gulf of Carpentaria (Qld/ Northern Territory NT)	
Arnoglossus waitei	<0.1	Arafura Sea and southern Qld	High, min population doubling time< 15 months
Upeneus sp 1	<0.1	Northern Australia	
Paraploactis intonsa	<0.1	Known only from Shark Bay (WA). Qld Museum confirmed id	
Calliurichthys grossi	0.7	Northern half of Australia from Moreton Bay to Shark Bay	High, min population doubling time < 15 months
Repomucenus limiceps	0.6	Northern Australia- southern Qld north to Shark Bay (WA)	Medium, min population doubling time 1.4 - 4.4 years
Leiognathus sp	0.5	From Cairns (Qld) north to Exmouth (WA).	
Repomucenus sublaevis	<0.1	Northern half of Australia from Moreton Bay(Qld) north to Shark Bay(WA).	High, min population doubling time <15 months
Choerodon sugillatum	0.4	Northern Australia:from northwestern Australia to Qld	Medium, min population doubling time 1.4 - 4.4 years
Apogon fuscomaculatus	<0.1	Northwestern Australia.	High, min population doubling time < 15 months
Apogon melanopus	0.1	Arafura Sea and northwestern Australia	High, min population doubling time < 15 months
Alepes apercna	0.1	Northern Australia, from Exmouth Gulf(WA) to Wide Bay (Qld)	High, min population doubling time < 15 months
Zebrias cancellatus	<0.1	Northwestern Australia.	Medium, min population doubling time 1.4 - 4.4 years
Siphamia roseigaster	<0.1	Sydney (NSW) north to Pilbara (WA)	High, min population doubling time < 15 months
Pseudorhombus jenynsii	<0.1	Most coasts of Australia	Medium, min population doubling time 1.4 - 4.4 years
Paraploactis trachyderma	<0.1	Australia.	
Sillago robusta	0.5	Fremantle north to Shark Bay (western population) & southern Qld to	High, min population doubling time < 15 months

Endemic Species	% total	Distribution	Resilience
		NSW (eastern popn).	
Parapercis nebulosa	0.1	WA to NSW	Medium, min population doubling time 1.4 - 4.4 years
Sillago maculate	0.2	Australia	High, min population doubling time < 15 months
Dromidiopsis australiensis	<0.1	Australia	

b. Species with restricted distribution to Papua New Guinea and Australia, percent of total bycatch weight, detailed Australian distribution and Resilience (where available). Source of distributional information: Australian Faunal Study (2006), Oceanographic Biogeographic Information System (2006) and Froese and Pauly (2006). The latter authors were also the source of the Resilience data.

Species	% total	Distribution - All Papua New Guinea and Australia	Resilience
Metapenaeopsis rosea	2.3	Brisbane north to Shark Bay (WA).	
Metapenaeopsis novaeguineae	0.1	Brisbane north to South Aust.	
Sepia smithi	0.6	Timor, Arafura and Coral Seas, Brisbane north to Shark Bay (WA).	
Pseudorhombus spinosus	1.9	Southern Qld to WA	Medium, minimum population doubling time 1.4 - 4.4 years
Cynoglossus maculipinnis	<0.1	Southern Qld to WA	High, min population doubling time < 15 months
Paraplagusia sinerama	<0.1	Joseph Bonaparte Gulf (NT)	Medium, min population doubling time 1.4 - 4.4 years
Adventor elongatus	<0.1	No details on Aust distribution	
Hemiramphus robustus	<0.1	Sydney (NSW) north to Perth (WA)	High, min population doubling time < 15 months
Leiognathus moretoniensis	0.5	Sydney north to Shark Bay (WA)	High, min population doubling time < 15 months
Tragulichthys jaculiferus	0.2	northern Australia and Arafura Sea	
Minous versicolor	<0.1	Qld north to WA	
Herklotsichthys lippa	<0.1	Cape York (Qld) north to Exmouth Gulf (WA).	High, min population doubling time < 15 months
Gerres subfasciatus	0.5	Northern Aust.	
Pantolabus radiatus	<0.1	Brisbane north to Pilbara (WA)	
Torquigener whitleyi	0.9	Darwin (NT) to North West Cape (WA)	
Choerodon monostigma	0.6	Darwin (NT) to North West Cape (WA)	
Apogon albimaculosus	<0.1	Northwestern Aust.	
Glaucosoma magnificum	0.5	Cape York (Qld) north to Exmouth Gulf (WA).	
Repomucenus belcheri	0.2	Brisbane north to Broome (WA)	
Feroxodon multistriatus	0.5	Darwin (NT) to North West Cape (WA)	
Dactyloptena papilio	0.5	Northwestern Australia and Arafura Sea	
Amniataba caudavittata	<0.1	No details on Aust distribution	
Chelmon marginalis	<0.1	Qld to WA	High, min population doubling time < 15 months

8 Appendix 2 Intellectual Property

BACKGROUND INTELLECTUAL PROPERTY

The background intellectual property that the Principal Investigator brought to the Task was:

- All the data collected by DPI&F during research surveys and prawn tagging operations conducted during 1985-1991;

- Annual research surveys conducted since 1985. The first three surveys were funded by Fisheries Research Development Corporation Project 97/146 and those of 2001-2002 and 2004-2006 were funded by DPI&F Long Term Monitoring Program; and

- Gear survey data relevant to the Torres Strait prawn fleet that was collected by the FRDC Project 1999/120.

This data was made available to complement the data collected by this Task.

INTELLECTUAL PROPERTY FROM THIS TASK

No patentable or marketable products or processes have arisen from this research. The main IP from this Task were the datasets for target and bycatch species. These are stored on the DPI&F Long Term Monitoring Program database. These datasets were shared with the Torres CRC project: Mapping and characterization of key biotic and physical attributes of the Torres Strait ecosystem (CSIRO). Intellectual property accruing from the analysis and interpretation of raw data vests jointly with the Cooperative Research Centre for the Torres Strait and the Principal Investigator.

The Gear vessel data collected from the TSPF fleet in 2004 remains the intellectual property of the fishers and is stored with the Principal Investigator. The unload records provided by individual fishers to Task staff remains the intellectual property of the fishers. Compulsory fishing logbook data remains the intellectual property of the Australian Fisheries Management Authority. All results of this Task are published in scientific and non-technical literature.

CONFIDENTIALITY CONSIDERATIONS

As the logbook, buyers unload records and VMS data is confidential only summarised data was presented in handouts, publications and presentations. The agreed rule with the logbook sections of both AFMA and DPI&F is that each data point presented by based on information from five or more vessels.