Assessment of the seasonal closure of the North Queensland prawn trawl grounds.

Final Report

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EXECUTIVE SUMMARY.

- Catch and CPUE in the northern section of the East Coast Trawl grounds have been relatively stable over the last 5 years, given a high inter-annual variability typical of tropical penaeid fisheries. There are no major detrimental trends evident, although a slight decline in tiger prawn catch may be present.
- The current seasonal closure appears to protect the juvenile recruitment of the brown tiger prawn, most recruits of the king prawn, and the first of two pulses of grooved tiger prawn recruitment. Endeavour prawn recruits are at best only partially protected.
- Modelling suggests that; (1) the fishery is currently fully exploited, and (2) the current seasonal closure provides a small direct benefit to the fishery. The outcome of alternative "no-closure" management would be dependent on the behaviour of the fleet. If there was no significant increase in fishing effort over the Jan-Feb juvenile recruitment period and the pulse of effort that currently occurs at the start of the fishing season was reduced, then catch-rates would improve with a marginal decrease in total catch and value. (In effect a voluntary closure and a rational redistribution of effort). If however there was a major increase in effort over the period of juvenile recruitment then the catch-rates and value to the fishery would significantly decline.
- Prices paid for product vary by species, size class, and by month. Premium prices are paid for large export grade tiger prawns but good prices are also received for export grade Endeavour prawns. A basic supply and demand relationship is evident between the quantity of product and the price paid, but there is also a high degree of interannual variation making it impossible to describe a typical annual price profile for the five years studied.
- Analysis of fleet dynamics shows trawlers are highly mobile along the Queensland east coast with approximately 80% of the boats fishing in the northern section for less than 150 out the possible 275 days. Boats that trawl in the section for less than 50 days made up approximately 50% of the northern fleet and contribute heavily to the pulse of effort immediately after the seasonal closure.
- The results of this assessment and modelling are summarised as potential risks and benefits of five possible options for the management of the northern section of the Queensland east coast prawn trawl fishery (see discussion).

INTRODUCTION.

Seasonal closure of the northern section of the prawn trawl grounds along the eastern coast of Queensland has been in place as a management strategy for 10 years, principally to protect juvenile *Penaeus esculentus* (brown tiger prawn) from growth overfishing (Glaister, 1989; Watson and Mellors, 1990)). A number of studies assessing the ongoing effects of this seasonal closure have been performed (Coles et al, 1985, 1987; Derbyshire et al., 1993). Assessments of seasonal closures have also been carried out both to the north in Torres Straits (Mellors 1990), and to the south in the Bowen-Mackay section (Gribble and Dredge, 1993). Most of these studies have addressed the biological status of the stock and have not considered a cost-benefit of the closure in terms of the fleet. Gribble and Dredge (1994), pointed out that for the central section prawn trawl grounds a "pulse" of effort occurred at the start of the fishing season as non-local boats come into the fishery to take advantage of the perceived build-up of large prawns caused by the closure. As with the gulf coast of Texas (Cobb and Caddy, 1989), a concentration of trawlers occurs after a closure which can actually increase rather than redistribute the annual fishing effort.

The current assessment focuses on the behaviour of the fleet in the northern section of the prawn trawl grounds and on the distribution of the fishing effort, the catch and the catch value in dollar terms. The assessment compares the current seasonal closure to a no closure option and attempts to expand on previous studies by:

- Reviewing the current literature on the effectiveness of seasonal closures, particularly in the context of tropical Northern Australia.
- Reviewing biological research data on the prawn stocks of the northern section of the GBR to establish parameters for stock assessment and modelling.
- Simulating changes in catch rates in addition to total yield and value changes. Simulated catch rates were not analysed in the earlier assessments made for east coast prawn fisheries.
- Analysis of the dollar benefit to the fishery based on the known yearly price profiles for each species and matching this profile to the availability of product.
- Analysis of the effect of the seasonal closure on fleet dynamics in the northern section of the GBR.

METHODS.

Summary data was extracted for the northern section from the catch-effort logbook database, QFISH, maintained by the Queensland Fish Management Authority. Fleet composition and the times-series of prawn catch-effort was estimated from these summaries for 1990-1994. The statistical area defined as the "northern section" and used in subsequent analysis was taken as the block 10°00'S, 142°00'E to 16°30'S, 147°00' E; from the southern edge of Torres Strait down to Cape Tribulation. During 1990-1992 and 1993-1994 research trawls were carried out on a monthly basis in the Princess Charlotte Bay area, 13°00' to 15°00S', (Derbyshire et al., 1993 and 1995). Population structure and biological parameters of the multi-species prawn fishery of the northern section were derived primarily from these research projects.

The profile of the dollar value for commercial prawns over the five years was obtained in two ways. A fish "processor" database is maintained by the QFMA, QFISH program, which gives basic summaries of what weight of product is sold and its value. Secondly, a number of local skippers supplied prices they obtained for graded commercial category prawns during each year. These were combined and composite monthly profiles were generated.

Descriptive statistics and graphical analysis were performed with the appropriate tools in EXCEL, Version 5.0 Microsoft, California, (also Microsoft Analysis ToolPak, GreyMatter International Inc, MA). Simulation of alternative management strategies was implemented using SYMSIS, Watson et al 1993, and checked against the multi-species Y/R simulation model of Gribble and Dredge, 1993.

REVIEW OF LITERATURE AND PAST RESEARCH PROJECTS.

Ian Somers (CSIRO) reviewed the options for manipulation of fishing effort and the benefits of seasonal closures in Australia's prawn fisheries, mainly from the perspective of the Gulf of Carpentaria prawn trawl fishery (Somers, 1990). He stated that, "limited entry in conjunction with restrictions on vessel and gear characteristics has become the standard means of controlling total fishing capacity. Closures are now the most popular, administratively simple, equitable, and socially acceptable means of manipulating fishing effort patterns to optimise catch size composition." He also pointed out that seasonal closures can reduce operating costs without reducing annual revenue and will make seasonal peaks in catch rates more regular. In his analysis Somers used a simplified model for a single species fishery with tiger prawns and banana prawns run separately.

Watson and Restrepo (1995) used a more sophisticated model to explore the effects of multiple recruitment pulses on the yield of prawn fisheries and the effect of an increase in fishing effort that can occur in anticipation of valuable catches immediately following a closure (ie a pulse of effort). They found when a species had a single tight cohort of recruits then an appropriately timed closure could improve the yield-per-recruit to the fishery by 30 to 40%. If however recruitment was spread out in a multi-cohort pattern then the best a closure could improve yield-per-recruit was 7%. A multi-species yield-per-recruit analysis (Gribble and Dredge, 1993) found that the seasonal closure on the Queensland Central Coast only improved the yield by 5%. Similarly a multi-species assessment of the closure in Princes Charlotte Bay showed at best a 5-10% improvement in yield and value (Derbyshire et al., 1993). The direct benefit of seasonal closures in multi-species prawn fisheries, such as on the northern section of Queensland's east coast, would appear to be relatively low but as noted by Somers (1990) there are operational cost savings to fishers by not fishing during the closure. In terms of cost-benefit analysis it may be that the reduction in costs is the primary economic advantage to seasonal closures in such fisheries.

Socio-bioeconomic models describing the interaction of fleet dynamics (the behaviour of fishers), the population dynamics of prawn, and market forces are rare (eg, Krauthamer et al., 1987). Cobb and Caddy (1989) noted a byproduct of seasonal closures protecting juvenile prawns on the Gulf coast of Texas was a strong pulse of fishing effort as fishers congregated in anticipation of large catches at the opening of the season. The economic implication of the pulse was an increase in overall revenue due to the increase in product although the revenue per boat did not necessarily increase because of the larger number of boats fishing. The biological implication was increased pressure on the stock which actually went against the original management aims of the seasonal closure. On a much smaller scale, a similar "pulse" of effort occurred at the start of the fishing season on the Queensland central coast prawn trawl grounds (Gribble and Dredge, 1993). Again there was an increased yield in proportion to the increased effort, but with an unknown long-term effect on the prawn stocks.

An on-going series of research projects on the reproductive biology, population dynamics, and spatial distribution of prawn stocks of the Great Barrier Reef region have been carried out by QDPI Fisheries from the early 1980's till the present. Sites for these studies stretched from the southern GBR to the border of Torres Strait and have included Bowen/Mackay (21° S), Townsville (19° S), Cairns (17° S), Princess Charlotte Bay (14° S), and the Cross-shelf Closure ("Green Zone") from Shelburne Bay to Raine Island (11° S).

Based on this research 22 species of penaeid prawns have been identified from the GBR region, with 6 of these being commercially exploited by the Queensland East Coast Trawl fleet. The stocks of the commercial prawns are genetically continuous although tagging studies suggest that there are local populations with a low level of cross-migration which maintains the genetic homogeneity. The movement by a small percentage of the population also provides "pioneers" for new areas of suitable habitat or areas that have been depopulated due to storms or heavy trawling. Commercial species tend to inhabit the inshore reefal lagoon with the exception of *Penaeus longistylus* (the red spot king prawn) which is associated with the reef and inter-reef habitats. Strong spatial trends have been found in the distribution of the penaeid prawns in the GBR region with each species occupying a preferred zone or habitat type as part of a complex cross-shelf mosaic. Spatially auto-correlated phenomena are also apparent due to "schooling" or contagious distribution of adults. Juvenile prawns are associated with inshore seagrass and algal beds, or with the reef-top seagrass beds in the case of the red spot king prawn. Recently discovered deep water seagrass beds appear to have a suite of non-commercial "coral prawn" species associated with them (Derbyshire et al., 1995; Coles, QDPI NFC, pers comm).

The most recent comprehensive research project into the effects of the seasonal closure in the northern section of the Queensland east coast prawn trawl grounds was centred on Princess Charlotte Bay (Derbyshire et al., 1993). The general conclusions from this work were that a seasonal closure over the December to March period was effective in protecting juvenile recruitment of a number of commercially important prawn species and that there was a gain of 5% to 9% in dollar value to the fishery.

ANALYSIS AND RESULTS.

(1) Description of the fishery.

Fishing effort.

Over the five years of the study an average of 274 boats per year fished within the northern section although not necessarily over the full year nor in every year. Boats that fished in the section every year made up only 25% of the fleet (see table 2). The maximum number of days spent in the fishery by a single boat in any year ranged from 216 to 266 days, the minimum was one day (see table 1). To put this in perspective, given the annual seasonal closure of approximately 90 days then the absolute maximum that could be fished would be around 275 days in any one year. Total fishing effort over the five years was 95,884 boat-days at an average of 19,177 boat-days per year.

Table 1. Fishing effort in the northern section of the Queensland east coast prawn trawl grounds (southern edge of Torres Strait to Cape Tribulation).

	1990	1991	1992	1993	1994
Total days	20652	16661	18145	21756	18670
no boats	312	281	252	266	260
avg boat day	66.2	59.3	72.0	81.8	71.8
min boat day	1	1	1	1	1
max boat day	231	216	253	266	247
Boats spending >150 boat days in section	27	31	51	58	47
Boats spending < 50 boat days in section	149	158	143	126	129

Table 2. Number of boats that fished the northern section of the Queensland east coast prawn trawl grounds in one or more years over the five years analysed.

Years Fished	Number of boats
5 out of 5yrs	117
4 out of 5yrs	74
3 out of 5yrs	67
2 out of 5yrs	83
1 out of 5yrs	123
TOTAL	464

Profile of fishing effort over 1990-94.

A monthly breakdown of fishing effort in the northern section of the Queensland east coast prawn trawl grounds is summarised and presented as a time-series in figure 1. The annual seasonal closure extended from early December till early April during 1990-

91 and till early March in 1992-93-94 (see Appendix Table AX 4). A pulse of effort at the beginning of the fishing season was pronounced in each year, the effort then diminished throughout the rest of the year.

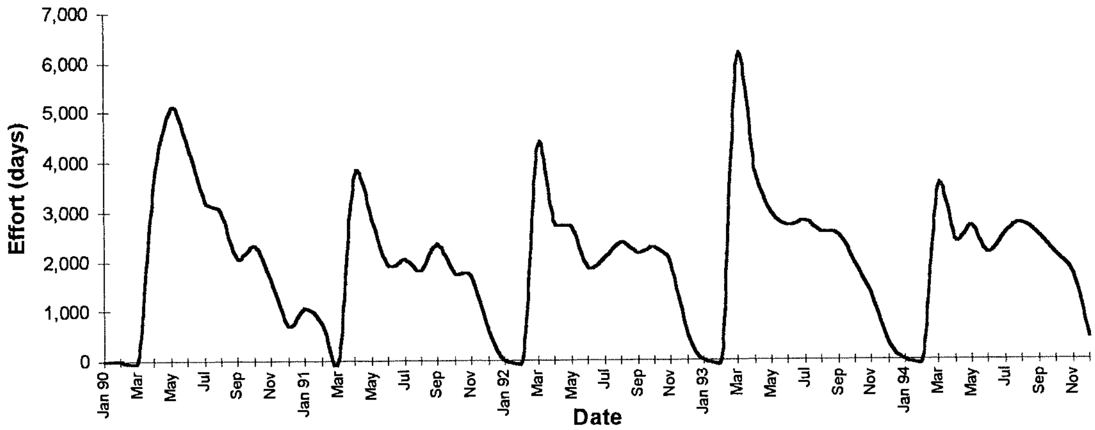

Figure 1. Time plot of monthly fishing effort in the Northern Section of the Queensland East Coast prawn trawl grounds for each year from 1990 to 1994.

Profile of catch and CPUE over 1990-94.

During the five years between 90-94 the annual prawn catch from the northern section of the Queensland east coast prawn trawl grounds remained reasonably stable at around the 2,266 tonnes but ranged from 2,005 to 2,627 tonnes (Table 4). The yearly catch profile mimicked the effort with a pulse of at the beginning of each fishing season then a diminishing return throughout the rest of the year (fig 2a).

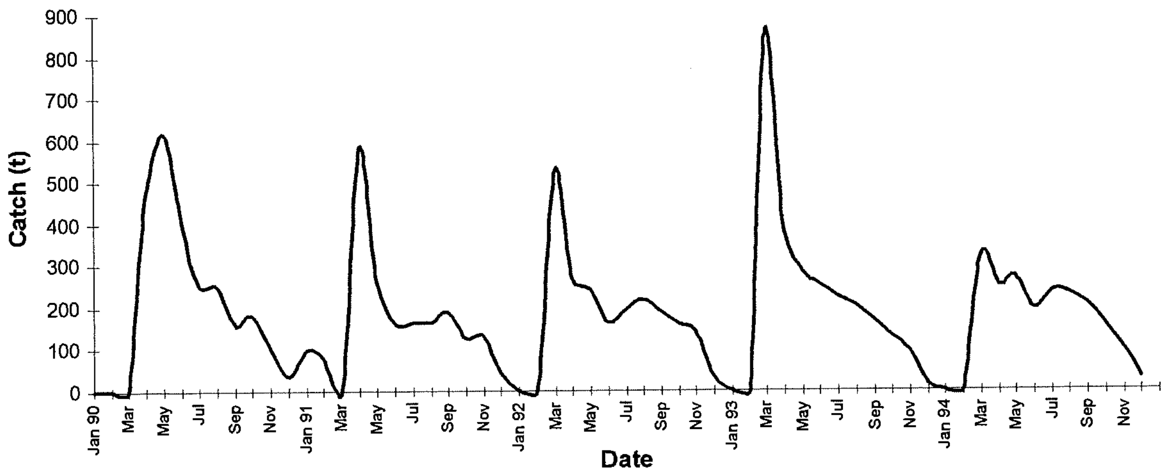

Figure 2a. Time plot of monthly total prawn catch in tonnes from the Northern Section of the Queensland East Coast prawn trawl grounds for each year from 1990 to 1994 .

Table 4. Prawn catch in tonnes from the northern section of the Queensland east coast prawn trawl grounds (taken from the southern edge of Torres Strait to Cape Tribulation).

	1990	1991	1992	1993	1994
Total	2,516	2,032	2,147	2,627	2,005

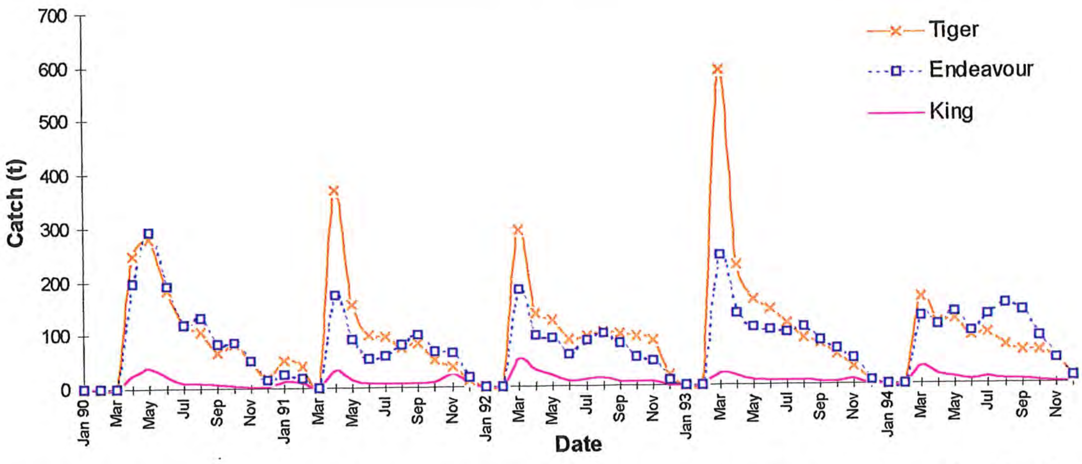

Figure 2b. Time plot of monthly prawn catch for the major species groups, from the Northern Section of the Queensland East Coast prawn trawl grounds for each year from 1990 to 1994.

Catches of endeavour prawns tend to mirror the catches of tiger prawns at the start of the season (Fig. 2b). Although tiger prawns are the primary target species the two species groups generally occur in similar areas and this is reflected in the catch. In the later half of the year however, for catches of endeavour prawn catches often increase while tiger catches continue to drop. A similar pattern of catches has been observed in the catches of the Torres Strait Prawn Fishery.

The resultant CPUE (fig 2c) has an initial sharp decline then remains reasonably constant dropping again late in the season, as seen in similar studies within the section in the past (Derbyshire et al 1993). Catch and CPUE in the northern section of the East Coast Trawl grounds have been relatively stable over the last 5 years, given a high inter-annual variability typical of tropical penaeid fisheries. There are no major detrimental trends evident, although a slight decline in tiger prawn catch may be present.

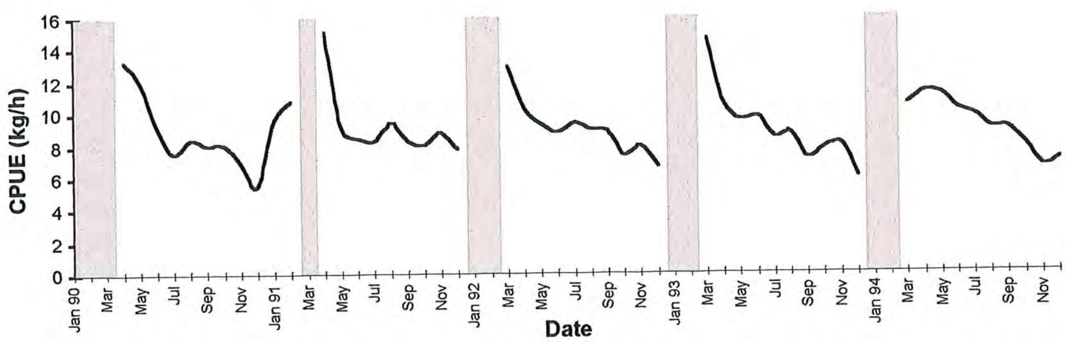

Figure 2c. Time plot of monthly prawn CPUE in kg/boathour from the Northern Section of the Queensland East Coast prawn trawl grounds for each year from 1990 to 1994. Note shaded bars represent seasonal closure.

A breakdown by commercial species category is shown in fig 2d and 2e. Minor species made up less than 2% of the catch, the major components were tiger prawns, endeavour prawns, and king prawns (both Red spot and Blue leg kings). In terms of export earnings the tiger prawn catch is the most important, however the catch of endeavour prawns represents substantial proportion of the value on both the local market and as a relatively low value export.

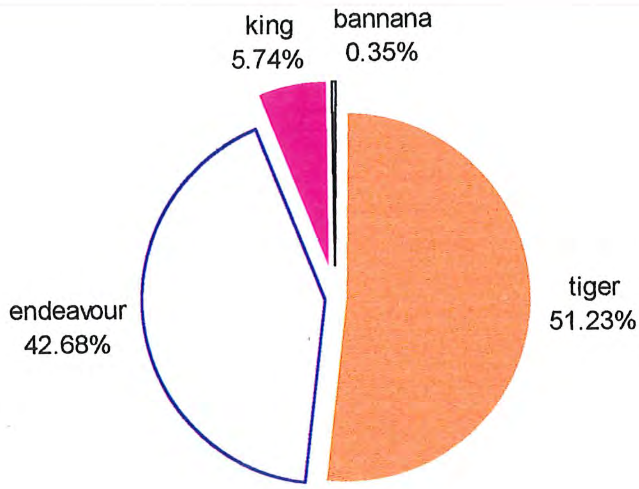

Figure 2d. Catch composition by weight of the prawn trawl catch from the Northern Section of the Queensland East Coast prawn trawl grounds from 1990 to 1994.

The percentage of tiger prawns in the monthly catch appears to have two peaks, one at the beginning of the fishing season and a second smaller peak in the second half of the year. These peaks may simply reflect the mix of brown tiger and grooved tiger prawns that are caught in the northern section. The brown tiger has a single spawning and pulse of recruits in the summer while the grooved tiger has two spawnings one in summer and a second in autumn.

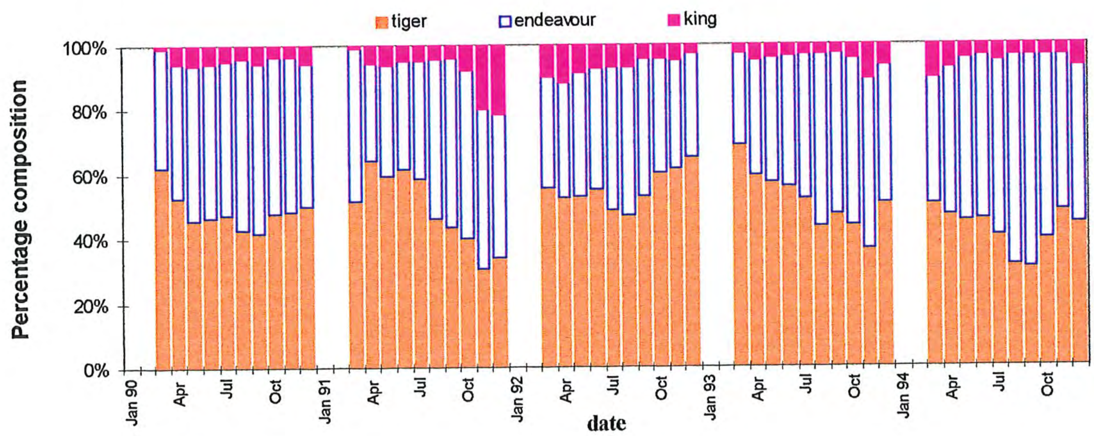

Figure 2e. Percentage species composition by weight of the prawn trawl catch from the Northern Section of the Queensland East Coast prawn trawl grounds for each year from 1990 to 1994.

(2). Profile of price per species over 1990-94.

Gribble and Dredge (1993) showed that the export price structure is as important as population dynamics of prawn species when considering dollar value per recruit. The price structure per commercial category (count per pound) for tiger prawns and endeavour prawns is presented as a monthly time-series in fig 3a. This profile was derived from a number of sources and as such represents a generalisation only. Local variations of price within the northern section could and did occur.

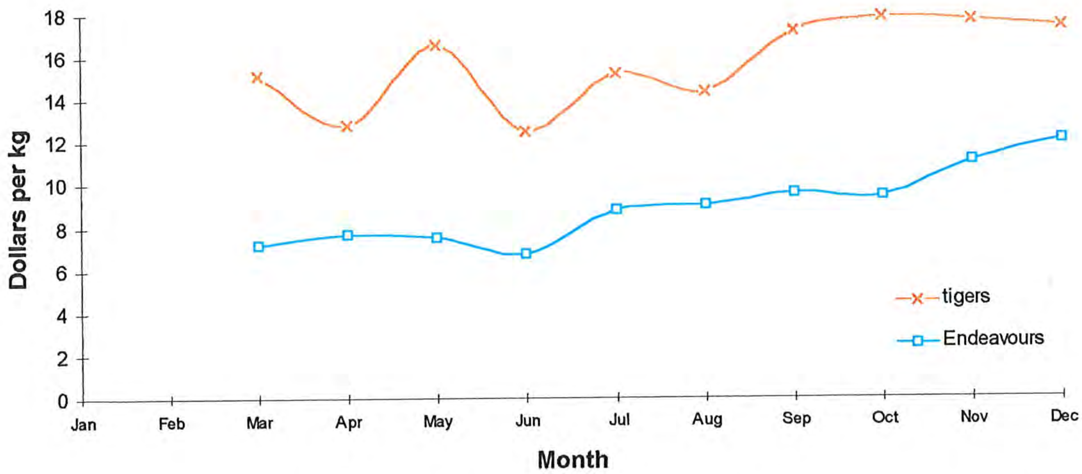

Figure 3a. Monthly price structure from the Northern Section of the Queensland East Coast prawn trawl grounds, averaged over the period from 1990 to 1995.

The elastic "supply-demand curve" describes the normal situation where if large quantities of prawns are available to the market then the price drops and if the supply of prawns is limited then the price rises. This normal situation can be distorted by factors outside the market effecting the demand for prawns. Two such events, the death of the Japanese Emperor and wide scale failure in Asia of aquaculture prawn crops due to disease, caused the price of prawns exported to Japan to fall in the first case, and in the second example caused the price of Australian prawns to rise due a lack of low-cost competition. These events have shown that the export prawn price structure can be "demand driven" and is not determined simply by the quantity of prawn caught.

In normal circumstances the pulse of effort at the start of the season would supply large quantities of prawn to the market hence the price should be relatively low (see fig 3a). In the northern section boats only fishing during the first few weeks of the season would tend to exploit the large quantities of relatively low value prawn. Boats fishing over the full year would exploit the lower quantities of higher value prawns on a more sustained basis. Reinforcing this pattern is the occurrence of brown tiger prawn recruits (small prawn) early in the season, with the high-value export grades not normally caught till later in the year. As seen above however, a volatile export price structure can modify this simple scenario.

The yearly variation in price for commercial categories of tiger prawns (fig 3b) shows this volatility clearly. In 1992 and 1993 the price of all size categories started low then increased as the season progressed, following the normal supply-demand relationship. Comparing the catch in kg in 1993 (fig 2a) with the price structure in that year (fig 3b) is a good example of the law of supply and demand; when catches were good the price was low. In 1994 and 1995 however the prices began on a high then dropped which is the reverse of what could have been expected based on the previous two years. In 1994 the catch was not high in the early part of the season (fig 2a) which partially explains the high prices early in that year. The price differential between U/10, 10/20, and 21/30's appears to have widened in each year from 1992, with an increasing premium being paid for U/10. The price paid for 21/30's was the same in 1995 as in 1992 although it had increased then decreased in the two intervening years.

These changes in price structure have a number of implications:

- prior to 1994 the low prices at the start of the season would have counter-acted the increased quantities of tiger prawns caught, considerably diminishing the financial gain from a pulse of effort.
- since 1994 the high prices at the start of the season would mean that a pulse of effort (resulting in an increase of product) would tend to maximise the financial gain.
- large quantities of smaller prawn (21/30's) are usually caught at the start of the season hence the differential in price between small and large prawn would mean relatively lower prices during the pulse of effort, again diminishing the financial gain.

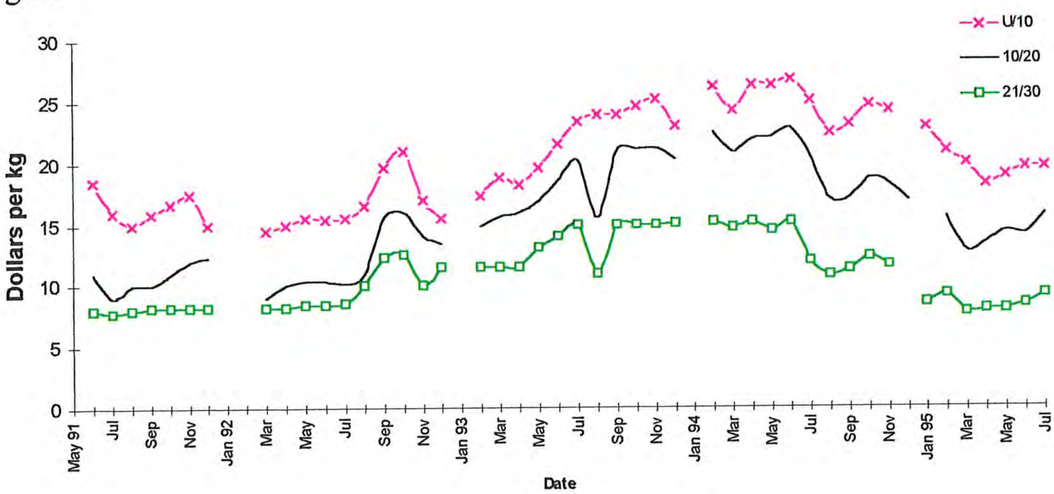

Figure 3b. Yearly price structure for tiger prawn from the Northern Section of the Queensland East Coast prawn trawl grounds, over the period from 1991 to 1995.

The prawn price information reflects the complex system of commodity economics where a large number of domestic and overseas influences can effect the price gained by the producer. The dollar value or financial benefit of the seasonal closure will depend largely on the price paid in a particular month rather than on the generalised price profile of a typical or "normal" year. In the best case where high prices are paid at the start of the season, the benefit of the closure will be high by maximising the number of export-size prawn in the catch. In the case where prices are initially low, the benefit of the closure will be reduced because of an over supply of low-value product too early in the season.

We have used the yearly mid-point or average prices in our simulations of the fishery (see Appendix Table X3) rather than the price profile of any one year because of the inter-annual price volatility. Although this generalisation does not utilise the finer resolution provided in the monthly data it does allow a comparison between years and between management options.

(3) Population structure.

Within the Cape Tribulation to Torres Strait section there have been two recent studies into prawn species composition and population structure, the Princess Charlotte Bay study (Derbyshire et al 1993) and the "Green Zone" study (Gribble unpublished data) in the Cairncross Island region. Both studies showed that the brown tiger prawn was the major component of the commercial tiger prawn catch. Industry does not distinguish between the brown and grooved tiger prawns but these are distinct species with different spawning times. The ratio between brown tiger prawns and grooved tiger prawns varies geographically and was largely dependent on the distribution of high mud content sediments. Similarly the ratio of the two endeavour prawns was variable but in the two studies cited the blue endeavour prawn dominated the commercial catch in the northern section.

The population structure changes from predominantly small prawn early in the year, due mainly to the influx of tiger prawn juveniles, to larger export-grade prawn mid-year as the recruits grow and move into deeper water. Recruitment from minor species and a second pulse of grooved tiger prawn recruits in April to June make the picture more complex. Endeavour prawns tend to recruit throughout the year but with a summer maxima, hence there will be small prawn from a number of species on the trawl grounds all year. For all species, spawning and recruitment make take place over a number of months and can be affected by climatic variables such as rainfall and cyclones. The current timing of the closure protects the majority of juvenile brown tiger prawns up to 21/30 size category.

(4) Simulation of possible management scenarios.

Modelling protocol.

SIMSYS (Watson *et al.* 1993) is an age-based trawl fishery simulation program developed to help with the assessment of both seasonal and spatial closures to multi-species prawn trawl (or similar) fisheries. The model can be used to compare different seasonal and spatial closure scenarios in terms of changes in weight and numbers of prawns caught for each species, the value of the catch, the size of the population, and fishing effort.

The model uses estimates of growth and movement obtained from prawn tagging, recruitment patterns estimated from monthly research trawl samples and patterns of monthly fishing effort obtained from logbook data. Monthly logbook catches and species composition are used to help tune and verify the simulation model. Monthly age classes of prawns of each species and sex are simulated to the age of 18 months. The simulation consists of recruiting prawns into the fishery at the appropriate month and age, then growing the prawns and applying natural and fishing mortality to produce estimates of yield.

Changes in the monthly pattern of fishing effort as a result of closures is one of the main parameters that affects that output from the model. We can only guess at the response of the fleet to a new closure using logbook data for years with and without closures as a guide. How the simulated fleet reacts to a closure can have a large effect on the catch and effort output from the model. The result of a simulation where all of the effort lost during the closure is all transferred to the open part of the season, can be quite different to a simulation where the total effort is decreased as a result of the closure. Theoretically an appropriately timed closure that results in less effort can produce greater catch and hence more dollars per hour trawled for individual vessels.

Although the model is a simplification of the real world and estimates of some parameters like natural mortality are uncertain, it is an attempt to simulate what happens in the real fishery and hence serves as a guide to the possible impact of a new closure regime or pattern and level of effort. A simulation gives a "reasonable projection" only and should not be used as an accurate prediction.

Parameter estimates.

Estimates of the growth, length-weight, net selectivity and natural mortality parameters required to simulate the fishery were obtained from tagging and research sampling studies conducted in Princess Charlotte Bay, the Turtle Group Islands, Torres Strait and the Bowen-Mackay area. (Derbyshire et al 1993, 1995; Gribble and Dredge 1992; Mellors, 1990) The estimates used are listed in the tables X1 and X2 in the appendix.

Recruitment pattern.

The recruitment pattern is the relative numbers of prawns of each species, sex and age moving into the fishery during each month of the year. This pattern was determined from analysis of monthly research samples collected from closed shallow water areas adjacent to the fishery. Research samples collected for the Queensland Department of Primary Industries studies near the Turtle Group Islands and in Princess Charlotte Bay were used to represent the recruitment pattern for the northern Queensland east coast. A limitation to this data is that it is not possible to extrapolate from the research sampling to a fishery wide index of recruitment strength .

Simulation scenarios.

SYMSIS was used to compare the current northern seasonal closure to the alternative management option of removing the seasonal closure. The current seasonal closure scenario was used to tune and verify the simulation model. Recruitment strength, for which we have no independent yearly estimates, was adjusted until the model catches reflected those observed in the logbook records for the years 1992-94.

The only changes made between the closure and non closure simulations, was in the pattern and level of fishing effort applied to the model of the fishery.

The main unknown in attempting to simulate the "no closure" option is the way in which the fleet will react to the removal of the closure. As we cannot predict this reaction we simulated three possible patterns of fishing effort (Figure 4 and Appendix Table X4) that could result from the removal of the closure;

- The fleet maintains the current level of fishing effort with a redistribution of effort into the months that were previously closed. This scenario assumes that vessels will not work longer and the pulse of effort that occurs at the start of the current season will be spread into the months that were closed. Most vessels do not work every day of the current season and some time each year is required for refits. It has always been a general practise for vessels to take time off during the Christmas and New Year celebrations and to refit in January and February. This pseudo closure behaviour is reflected in the effort pattern assumed in this scenario with December having the lowest effort level for the year and an increase in January-February to a maximum around March-April.

- An increase in total effort, particularly during January-February. This scenario is based on the assumption that vessels will work longer as there would be more time to fish. In addition some vessels have endorsements to operate in other fisheries that are closed during the early months of the year. This could further concentrate effort in this fishery particularly in February. The predicted drop in effort in March would be due to vessels moving to the Torres Strait and Northern Prawn Fisheries which open in March and April respectively.

- A reduction in effort, particularly in the early months of the year. The assumption used here is the converse of the one often applied to the introduction of a closure. It has been claimed that a seasonal closure can increase effort as there is an expectation that catches will be good at the opening of the closure. This expectation results in a large "pulse" of effort at the start of the season. This expectation may also attract vessels to an area that they may not otherwise fish, hence increasing the initial pulse of effort still further. The converse of this assumption, suggests that removal of a closure will reduce effort back to the level that existed prior to the introduction of the closure.

The monthly pattern of effort was the only parameter altered between the four simulations of the northern east coast prawn fishery. Monthly fishing effort is a key parameter that directly influences the yield (weight of catch) and value of catch that the model predicts.

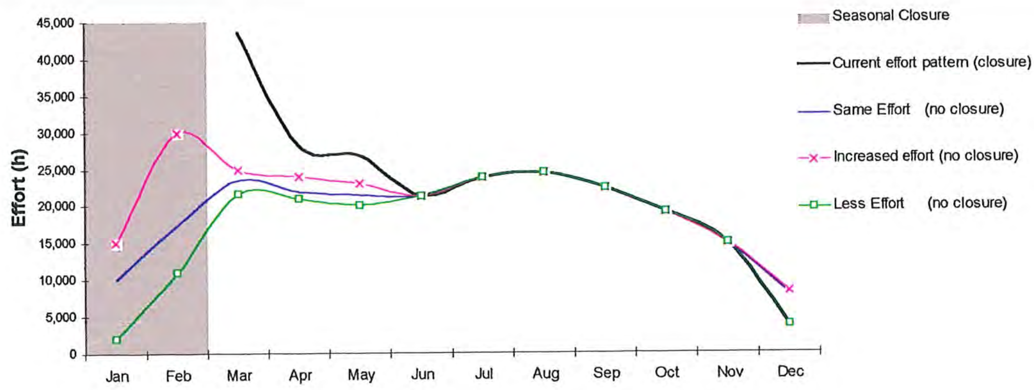

Figure 4. Patterns of fishing effort used to compare the current closure with a non closure option.

Results of the simulations.

The simulation results suggest that retention of the current closure may be the best management option as only one non closure scenario (reduced effort) improved simulated catches. Comparing the simulation of the current closure with the three simulated non closures produced the following results (see table 4);

- [Same effort with no closure] : In this simulation the catch was reduced by about 1%, value of the catch reduced by $0.5 million (2%), and catch rates were slightly lower. This indicates that the fishers would be worse off if the closure was removed.

- [Effort increased by 10% with no closure] : In this simulation the total catch remained the same while the value of the catch decreased by $0.9 million (3.5%), and catch rates dropped from 9.24 to 8.39 kg per h^{-1}. Although the total catch of tiger prawns increased there was a shift towards the smaller and less valuable grades. Under this scenario fishers would be working harder for a smaller return.

- [Effort down by 10% with no closure] : In this simulation the total catch decreased by 2%, while the value of the catch dropped by only $0.3 million (0.9%) and catch rates increased from 9.24 to 10.07 kg per h^{-1}. Under this scenario fishers would be working less for a better return.

Table 4. Output of Seasonal Closure Simulations.

		No closure scenarios		
	Current closure	**Same Effort**	**Increased effort**	**Less Effort**
Brown tiger prawn catch (t)	733	727	748	704
Grooved tiger prawn catch (t)	423	422	424	419
Blue endeavour prawn catch (t)	959	946	940	950
Total prawn catch (t)	**2,115**	**2,096**	**2,112**	**2,073**
% change		-0.90	-0.14	-1.99
Effort (h)	**228,800**	**228,800**	**251,700**	**205,900**
% change		0.00	10.01	-10.01
Catch rates -CPUE (kg per h)	**9.24**	**9.16**	**8.39**	**10.07**
Value of catch (millions $)	**26.57**	**26.05**	**25.65**	**26.34**

(5) Fleet Dynamics.

Definitions.

An analysis of the fleet effort dynamics based on days spent in the fishery (similar to the system used for the Torres Strait fishery), defined "*long-term* boats" as spending more than 150 days in the fishery, with "*short-term* boats" defined as spending less than 50 days in the fishery (see table 1). In any year *long-term* boats made up approximately 9-20% of the fleet while *short-term* boats made up 47-57%. The remaining 30-40% of the fleet could be classed as "*medium-term* boats" which in any one year would have fished consistently, but not exclusively, within the northern section.

Catch and effort distribution.

Using the categories defined, *short-term* boats were present in the fishery predominantly during the first two months of the season (fig 5), while *long-term* boats tended to be present in the fishery evenly throughout the year. *Medium-term* boats shared the characteristics of both the other groups showing a significant pulse of effort in the first month of the season but a more sustained effort throughout the year. The catch (fig 6) follows a similar pattern with a peak in the first two months of the season followed by a plateau.

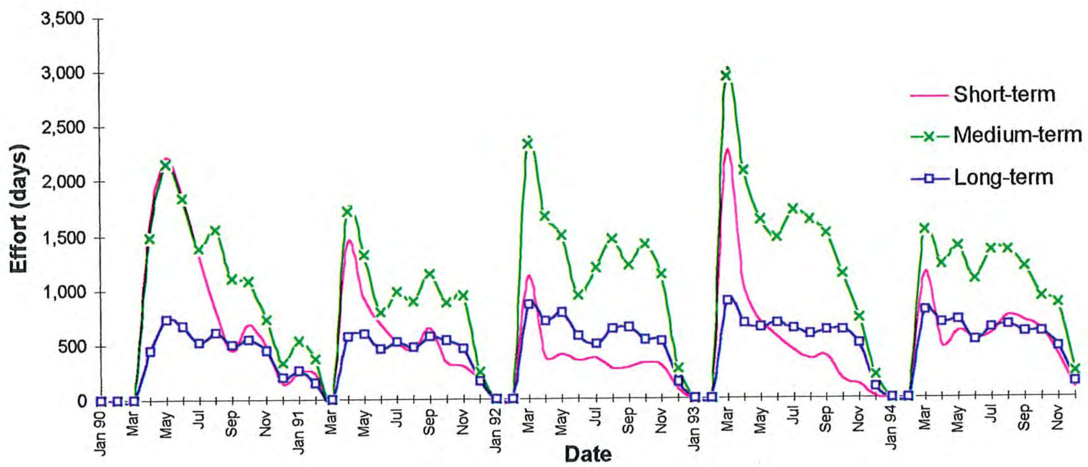

Figure 5. Effort distribution among sections of the prawn fleet in the Northern Section of the Queensland East Coast prawn trawl grounds for each year from 1990 to 1994.

Although individual *short-term* boats spend less than 50 days in the fishery, in aggregate they contributed a significant proportion of the annual catch. The catch was mainly concentrated in the period immediately after the season opened but even during the later part of the year the *short-term* contribution mirrored that of the *long-term* boats in three of the five years analysed. Fleet movements are therefore not simply in response to the seasonal closure but show an underlying mobility with boats moving into and out of the northern section throughout the year.

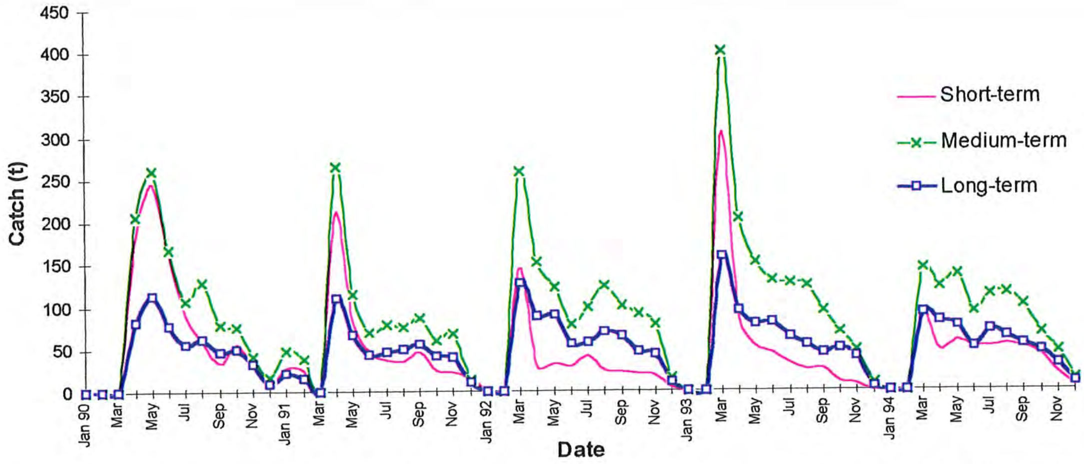

Figure 6. Catch distribution among sections of the prawn fleet in the Northern Section of the Queensland East Coast prawn trawl grounds for each year from 1990 to 1994.

Simulated effect of fleet dynamics on catch.

To answer a question raised by the northern branch of the Queensland Commercial Fishermen's Organisation, four patterns of fishing effort were simulated using SIMSYS to investigate the impact of fleet dynamics, in particular of *short-term* effort, on the fishery. Effort profile was the only parameter changed between each of the simulation scenarios which used the same biological parameters as the previous simulations.

The four patterns of fishing effort simulated were:

1. the average effort pattern observed during the years 1992-94.
   (ie current state of the fishery).
2. a no closure option with the observed effort redistributed.
   (ie no reduction in the total effort)
3. the current closure and the observed effort pattern for *temporary* and *long-term* only.
   (ie *short-term* boat effort, which is 21% of the annual total, removed)
4. a no closure option using a redistribution of the observed effort for *temporary* and *long-term* only (ie a redistribution of the effort pattern for scenario 3)

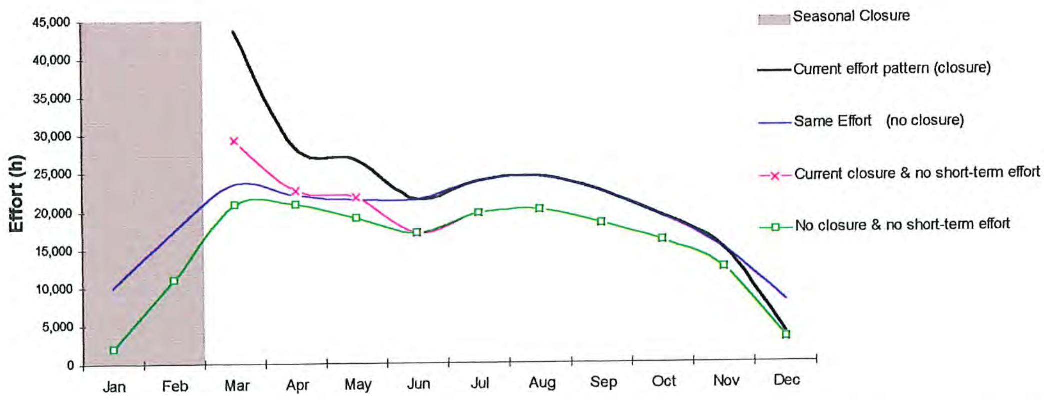

Figure 7. Fishing effort patterns used to investigate the effect of fleet dynamics on the fishery

It is assumed that the "no closure" effort patterns would show a reduced effort level during December to February (ie essentially a voluntary seasonal closure). This is based on the tradition that most operators stop working during the summer period for social reasons and to refit their vessels. The assumption also made is that the "no closure" effort pattern would follow the precedent of the Central Coast fishery where after removal of the seasonal closure the pulse of effort at the start of the season redistributed to later in the year and there was little increase in effort over December to February (Gribble and Dredge 1992). **As noted in the previous simulations, however, if there was an increase in effort over this critical period of juvenile recruitment then the catch-rates and value will decrease significantly irrespective of the fleet dynamics.**

Table 5. Output of Fleet effort Simulations.

	Scenario 1 Current closure & effort pattern	**Scenario 2** No closure & current effort redistributed	**Scenario 3** Current closure & no short-term effort	**Scenario 4** No closure & no short-term effort
Brown tiger prawn catch (t)	733	727	683	682
Grooved tiger prawn catch (t)	423	422	407	406
Blue endeavour prawn catch (t)	959	946	945	938
Total prawn catch (t)	**2,115**	**2,096**	**2,035**	**2025**
% change		-0.90	-3.78	-4.26
Effort (h)	**228,800**	**228,800**	**180,200**	**180,200**
% change		0.00	-21.24	-21.24
Catch rates -CPUE (kg per h)	**9.24**	**9.16**	**11.29**	**11.24**
Value of catch (millions $)	**26.57**	**26.05**	**26**	**25.96**
% change		-1.96	-1.20	-2.30
biomass (t)	2,732	2,706	3,143	3121

A comparison of scenarios 1 with 3 and 2 with 4, examines the effect of reducing effort, particularly at the start of the season. We simulated this reduction by removing from scenarios 3 and 4 an amount of effort equivalent to the *short-term* boat effort (21% of the total effort). The effort patterns for scenario 2 and 4 was calculated by redistributing the effort for March-May in scenario 1 and 3 respectively, into the closed months (January-February).

The results of a comparison of scenarios 3 and 4 with the current closure and effort pattern (scenario 1) are as follows;

- [Current closure and no *short-term* effort]: In this simulation the 21% drop in effort resulted in a 4% drop in total catch and a drop of only $0.6 million (1.2%) in the value of the catch while catch rates increased from 9.24 to 11.29 kg per h^{-1}. According to this simulation individual fishers would be working less for a better return.

- [No closure and no *short-term* effort]: The results of this simulation were very similar to those of scenario 3. The improvement in catches however, was slightly less than for scenario 3 and catches and value dropped slightly more. This reflects the finding that appropriately timed closures can improve catches as long as they do not increase total effort.

The simulated catch rates during the first few months after the opening of the season also appeared to be more sustained for scenarios 3 and 4. The simulated stock size or population numbers also increased by approximately 15%. If a Stock-Recruitment Relationship exists (ie., the number of recruits depends on the number of spawning adults as suggested for the Gulf (Somers, 1990)) then increasing stock size would increase the number of recruits to the fishery. These results suggests that the fishery is fully exploited and that a reduction in effort, particularly in the early months of the season, may significantly improve catches for individual fishers at the expense of a slight drop in total production.

Coarse sensitivity analysis on the estimate of natural Mortality.

Although natural mortality is a critical parameter in determining the number of individuals that survive from one month to the next, it is difficult if not impossible to measure for most fisheries. For this reason it was important to determine the sensitivity of the model output to natural mortality (Gribble and Dredge, 1993). A coarse sensitivity analysis was performed using very high (approx. 0.5 per month) and very low (approx. 0.1 per month) estimates of natural mortality. We found that for both of these extreme estimates, simulated catch rates increased when fishing effort, particularly at the start of the season, was removed from the simulation. This pattern was observed for all of the species simulated even though the timing and age of recruitment of each species to the fishery was different; suggesting that fishing effort is a major parameter effecting prawn abundance and, as noted from previous simulations, that the fishery is fully exploited.

DISCUSSION.

Analysis of the prawn catch and effort data, combined with the simulation studies, show no dramatic declines in stocks over the period covered by the QFISH logbook program although the fishery currently appears to be fully exploited. In considering management strategies appropriate for the northern section of the Queensland east coast prawn trawl fishery the following options are put forward.

Option 1. **Status quo, no change to existing seasonal closure.**

Risks.

- Loss of potential income to fishers through inappropriate timing of the closure of the trawl grounds.
- Loss of potential income as large adult prawns from the previous year are not fishable during the closure.
- A pulse of effort at the start of the season as trawlers concentrate in order to exploit the perceived increase in prawns after the closure.
- A drop in price due to the temporary over supply of product, caused by the pulse of effort, and/or overseas buyer's anticipating an over supply at the start of the season.
- Protect the juveniles of only one species (brown tigers) at the expense of other species.

Benefits.

- Maximise income to fishers while protecting juveniles from growth-overfishing.
- Provide a fishery-wide closure at a time when traditionally most fishers choose to refit and spend time with family (ie provide a level playing field).
- Synchronise the seasonal closures in Torres Strait and Northern Queensland.

Comment.

Because of the variability in the spawning and recruitment of tropical prawn stocks the timing of seasonal closures needs to addressed as risk management; ie. if the timing is appropriate in four out of five years then this may be the best that can be achieved. Studies in PCB and Bowen/Mackay have shown that spawning/recruitment pulses can vary both in strength and in timing, by up to a month in some years. The current timing appears to protect the juveniles of the brown tiger prawns and king prawns, and the first spawning of the grooved tiger prawns. The juveniles of the endeavour prawns, which recruit year round with a peak over the summer, are not well protected nor are recruits from the second spawning of the grooved tiger prawns.

The simulations suggest that there is a small but real benefit from the existing closure. Definitely no value is lost through the current 2.5 month closure and there would be a saving in operating costs to the fishers. Similar conclusions were reached by the assessments made for PCB (Derbyshire et al 1993) and Bowen/Mackay (Gribble and Dredge 1993). The pulse of effort at the start of the season appears to be an inherent drawback to seasonal closures (eg. Cobb and Caddy, 1989) and probably reflects a basic element of human nature.

Option 2. **Removal of seasonal closure .. assuming no increase in effort over Jan-Feb** (Central Coast precedent).

Risks.

- Break down in the synchronisation of the seasonal closure in Northern Queensland with those in Torres Strait.
- Increase effort by bringing into the fishery boats that cannot fish in Torres Strait and/or the Gulf of Carpentaria due to the seasonal closures there.
- Increased pressure on juvenile/small prawn.

Benefits.

- Remove pulse of effort at the start of the season.
- Allow access to remaining adult stock (eg red spot king prawn) during Jan-Feb.
- Spread supply of product more evenly throughout the year
- Spread refit times over the whole year.

Comment.

The simulations show that if there was no significant increase in the effort during the critical juvenile recruitment in Jan-Feb and the pulse of effort at the start of the season was reduced, then all indicators would be marginally worse than the current situation. If a decease in overall effort occurred then there would be an increase in catch-rates over the current situation. This scenario represents a defacto seasonal closure but without the usual pulse of effort at the beginning of the season. The crucial consideration is whether the precedent of the Central Coast fishery, where the above scenario was observed after removal of the seasonal closure in 1990, is a reasonable expectation in the northern section.

Option 3. **Removal of seasonal closure .. assuming an increase in effort over Jan-Feb.**

Risks.

- Increased pressure on the critical juvenile recruitment leading to a drop in adult catch.
- Loss of income due to a reduction in number of export size prawn (and possible oversupply of smaller size prawn on the domestic market).
- Overall increase of effort on stocks that are already fully exploited.

Benefits (as in option 2).

- Remove pulse of effort at the start of the season.
- Allow access to remaining adult stock (eg red spot king prawn) during Jan-Feb.
- Spread refit times over the whole year
- Spread supply of product more evenly throughout the year.

Comment.

Simulations suggest that this is a worst case scenario where the value to the fishery actually decreases compared to the current situation although the fishing effort increases. Biologically there would be a high risk of an increase in pressure on the already fully exploited stocks, in particular on the juvenile recruits.

Option 4. **Increase duration of seasonal closure or second "spawner" closure.**

Risk.

- Loss of income to fishers with no real gain to stocks.
- Increased pulse of effort at end of closure (or closures) increasing pressure on stocks.

Benefits.

- Decrease overall effort on stocks giving long-term gain to fishery (eg Ian Somers, 1990).
- Protect both juveniles and spawning females of the prawn stocks.

Comment.

The simulations show that a relatively large drop in effort results in only a small drop in total catch and, depending on the timing, only a small drop in value returned to the fishers. This result is typical of a fully exploited fishery and a reduction in the overall fishing effort would be prudent (which is acknowledged in the current QFMA two-for-one boat upgrade rule). One problem is that the fishery exploits a multispecies assemblage which means that there are many spawning and recruitment pulses throughout the year hence determining the optimum timing for a seasonal closure to protect recruits is difficult. Currently the high export value brown tiger prawns receives the best protection against growth-overfishing, with the other species receiving partial protection.

While protection of spawning females is biologically a good idea, the Workshop on Spawning Stock-Recruitment in Australian Crustacean Fisheries (Courtney and Cosgrove 1994) presented no evidence of a stock-recruitment problem for any Queensland prawn stock. This does not mean that such a problem might not appear in the future, simply that currently there is no evidence of the problem.

Option 5. **Replacement of seasonal closure with area closures to protect juveniles** (enforcement using INMARSAT transponders).

Risks.
- Inadequate identification of the juvenile nursery/recruitment areas for each species may give inadequate protection of juveniles.
- Inadequate enforcement of the area closures may give inadequate protection of juveniles.
- Increase effort on adult spawning stock.

Benefits.
- No requirement for seasonal closure of the adult prawn trawling grounds.
- Remove pulse of effort at the start of the season.
- Allow access to remaining adult stock (eg red spot king prawn) during Jan-Feb.
- Highly targeted protection of juveniles of each species with few side-effects.
- Spread refit times over the whole year
- Spread supply of product more evenly throughout the year.

Comment.

Given that the seasonal closure was originally enacted to protect juvenile prawns then a similar level of protection could be given if all the juvenile nursery/recruitment areas were identified and set aside as area closures. Adequate enforcement of those area closures is the crucial consideration for this option to be effective.

Derbyshire et al (1995) showed that the inshore nursery closure in the Turtle Island Group was necessary for recruitment further down the coast but they also observed a fairly systematic non-compliance under the current enforcement regime (Derbyshire, QDPI, pers comm). Die et al (1992 a & b) have shown through modelling spatial closures that the effects of "cheating" (illegal trawling) are substantial and quickly erode the benefit of such closures. The QFMA has recently done a feasibility trial of an INMARSAT Vessel Monitoring System (VMS) using satellite transponders to continuously locate fishing boats (Neil Trainor, QFMA, pers comm). If the VMS was generally adopted then it would provide an effective method of enforcement of area closures which is essential if juvenile recruitment were to be protected under this scenario.

Cost benefit analysis.

In the current assessment, detail of the yearly prawn price structure was investigated to establish the actual return to the trawler operator of the current seasonal closure. The prawn price information however, reflects the complex system of commodity economics where a large number of domestic and overseas influences can effect the price gained by the producer. There can be variation within and between years in both the price for a species and in the price per size category. The dollar value or financial benefit of the seasonal closure will depend largely on the price paid in a particular month rather than on the generalised price profile of a typical or "normal" year. In the best case scenario, where high prices are paid at the start of the season, the current closure will increase revenue by maximising the number of export-size prawn in the catch. In the case where prices are initially low, the benefit of the closure will be reduced because of an over supply of low-value product too early in the season.

Somers (1990) points out that to be effective, management models need to take the "average year" for environmental variables (which may effect prawn abundance), accepting that some years will be better and some worse than expectation. Our study suggests that the same approach needs to be applied to price variables. We have used the yearly mid-point or average prices in our simulations of the fishery rather than the price profile of any one year because of the inter-annual price volatility. Although this generalisation does not utilise the finer resolution provided in the month by month data it does allow a comparison between years and between management options.

No attempt was made to document costs of trawling or the cost savings made by not trawling during the seasonal closure. It was assumed that savings would be significant because refit time could be scheduled during the closure therefore incurring no loss of fishing time, and there would be a saving in fuel, wages, and wear on boats and fishing gear. A future study would need to document these costs but this area of analysis needs to be handled with diplomacy as the data can be both complex and highly sensitive, and can only be gathered with the trawler operators full understanding and prior consent.

Fleet dynamics.

Analysis of the summary logbook data highlights the highly mobile character of the Queensland East Coast Prawn fleet, particularly in the north. Only 41% of the fleet fished in the northern section for more than four out of the five years analysed. The remainder of the fleet either fished elsewhere on the coast (or in the Gulf of Carpentaria or Torres Straits) or were out of the fishery for other reasons for at least one full year. Within any year less than 20% of the fleet fished in the northern section for more than 150 out of a possible 275 days. The remaining 80% of the fleet fished in other fisheries as well as the northern section for a large proportion of the year. This mobility makes defining a "local boat" very difficult. Boats that are registered at ports within the section may not fish there consistently, as is the case with dual endorsed boats that work a large proportion of the season in the Torres Straits. Less than 6% of the boats fishing the northern section were registered locally (QFMA data) and spent more than 150 days in the fishery for more than four out of the five years studied.

A practical method of describing the fleet dynamics was to categorise boats on the basis of "commitment" to the fishery as demonstrated by the number of days spent fishing within the section. This principle is currently used in the management of the Torres Strait prawn fishery. While it is an arbitrary measure it has the benefit of simplicity yet allows the overall structure and movements of the fleet to be described and modelled. Simulations suggest that removal of short-term effort would be beneficial for the fishery but this is simply a subset of the need to reduce effort overall, and to reduce the pulse of effort at the start of the season in particular. It is difficult to formulate a management option based on fleet dynamics due the high mobility of the fishing fleet in the northern section.

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APPENDIX.

Table X1. Growth and Length-Weight parameters used in the model

Species	Sex	Growth		Length Weight	
		K	L_∞	A	B
Brown Tiger	F	.2	42.5	.001722	2.8
	M	.24	34.9	.001528	2.85
Grooved Tiger	F	.19	51.9	.001243	2.89
	M	.31	37.4	.001207	2.91
Blue Endeavour	F	.25	38	.000995	2.95
	M	.25	32	.000606	3.13

Table X2. Natural Mortality and Net Selectivity parameters used in the model

Species	Natural Mortality		Net Selectivity	
	A	B	δ	L_{50}
Brown Tiger	5.513	.01	.3	21.57
Grooved Tiger	5.513	.01	.3	21.57
Blue Endeavour	5.513	.02773	.4	19.79

Table X3. Price structure used in the model to calculate the value of the catch.

Commercial Grade (count per pound)	Price ($/lb)	
	Tiger Prawns	Endeavour Prawns
30 +	$6	$6
20 - 30	$16	$8
10 - 20	$22	$10
U 10	$26	$10

Table X4. The Fishing effort (h) profiles used in the simulations of the fishery.

Month	Current effort pattern (closure)	Same Effort (no closure)	Increased effort (no closure)	Less Effort (no closure)	Current closure & no short-term effort	No closure & no short-term effort
Jan		10,000	15,000	2,000		2000
Feb		17,400	30,000	11,000		11000
Mar	43,600	23,500	25,000	21,700	29,300	20,800
Apr	28,200	22,000	24,000	21,000	22,600	20,800
May	26,800	21,500	23,000	20,000	21,700	19,000
Jun	21,400	21,400	21,400	21,400	17,000	17,000
Jul	23,900	23,900	23,900	23,900	19,600	19,600
Aug	24,500	24,500	24,500	24,500	20,100	20,100
Sep	22,500	22,500	22,500	22,500	18,300	18,300
Oct	19,200	19,200	19,200	19,200	16,000	16,000
Nov	14,900	14,900	14,900	14,900	12,400	12,400
Dec	3,800	8,000	8,300	3,800	3,200	3,200
Totals	228,800	228,800	251,700	205,900	180,200	180,200
% change		0	10.01	-10.01	-21.24	-21.24
change		0	22,900	-22,900	-48,600	-48,600

Table X5. Details of seasonal closures in Northern Australia during 1990-94

Year	Closure type and dates.
1990	• Torres Strait & Northern East Coast Closure 15 December 1989 to 15 April 1990 note: daylight trawling ban recinded • NPF Closure 1 December 1989 to 15 April 1990, Mid Year Closure 22 June to 1 August 1990
1991	• Torres Strait Closure 1 December 1990 to 1 March 1991, Area closure (East of Warrior Reef) 1 December 1990 to 31 May 1991, Permanent Darnley Island Closure introduced • Northern East Coast Closures, (a) PCB 1 Jan 91 to 8 April 91, (b) north of Cape Tribulation 15 Feb to 8 April 91 • NPF Closure 1 December 1990 to 1 April 1991, Mid Year Closure 8 June to 1 August 1990
1992	• Torres Strait Closure 1 December 1991 to 1 March 1992, Area closure (East of Warrior Reef) 1 December 1991 to 31 July 1992 . • Northern East Coast Closure (North of Cape Tribulation) 15 December 1991 to 1 March 1992 • NPF Closure 30 November 1991 to 31 March 1992, Mid Year Closure 8 June to 1 August 1992
1993	• Torres Strait Seasonal closure 1 December 1991 to 1 March 1992, Area closure (East of Warrior Reef) 1 December 1991 to 31 July 1992 . • Northern East Coast Closure (North of Cape Tribulation) 15 December 1992 to 1 March 1993
1994	• Torres Strait Seasonal closure 1 December 1991 to 1 March 1992, Area closure (East of Warrior Reef) 1 December 1991 to 31 July 1992 . • Northern East Coast (North of Cape Tribulation), 20 December 1993 to 1 March 1994