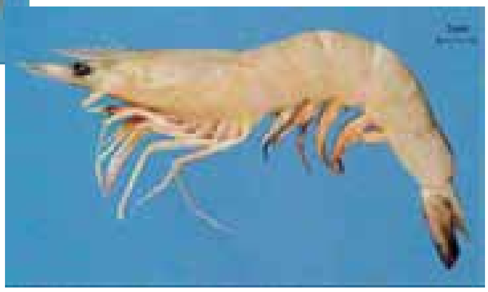
Assessment of the northern Queensland Tiger and Endeavour prawn stocks: 2004 update



C. T. Turnbull and N. A. Gribble

Fisheries and Sustainable Fisheries Programs

Northern Fisheries Centre
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Enquires should be directed to:
Dr Neil Gribble
Northern Fisheries Centre,
PO Box 5396

Cover Photographs: Top panel, Tiger prawn *Penaeus esculentus*; Bottom panel , Endeavour prawn, *Metapenaeus endeavouri*

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Acknowledgements

We wish to acknowledge Mr Lew Williams, Senior Fisheries economist QFS, for logbook database background information from CFISH.

Executive summary

General:

- CFISH Commercial Trawl Logbook database was the source of 1988-2003 Catch and Effort data analysed.
- Extracted data set was for the northern East Coast Trawl grounds, 10° 30’ S to 16° 00’ S.
- Tiger prawn CPUE data were filtered in the following way;
  - Records that were not bulk data (represented more than one days catch) and where the
  - Proportion of tiger prawn > 10% and
  - Proportion of banana prawn <50% and
  - Proportion of king prawn <50%
- Similar filters were used to obtain the endeavour CPUE index but with the proportion of endeavour >10% instead of tiger prawns.
- Biomass dynamic models using the filtered data were constructed following Haddon (2001).

Tiger Prawn assessment:

- Advice has been updated but basically is unchanged from that given in 2003
- Maximum Sustainable Yield (MSY) was estimated at 1,239 t, (ie, between 1,231 – 1,359t, 95% confidence limits), similar to average annual catch for the years 1988 to 2003 of 1,179 t.
- Effort required to achieve MSY (Emsy), was estimated at 19,618 days, (ie, between 16,548 – 23,443 days, 95% confidence limits).
- The analysis indicates that the northern tiger prawn stock is fully exploited but that the data lacks contrast; i.e., catch and effort for the whole time-series was centred on the top of the yield curve.

Endeavour Prawn assessment:

- No change from the 2003 assessment: the analysis then indicated that the northern endeavour prawn stock is fully exploited but again the data lacked contrast; i.e., catch and effort for the whole time-series appeared centred around the top of the yield curve.

1. Northern Otter Trawl Prawn Fishery: Overview.

The Northern otter trawl fishery extends south from Cape York to Broadsound (about 22°S) and includes most of the lagoon areas between the Great Barrier Reef and the Queensland East Coast. This region typically produces slightly more than half of Queensland's otter trawl catch, using about half of the effort in terms of days fished with about 63% of Queensland's trawlers operating in this region. Trawlers may operate in this area as well as in the Southern trawl area. Dual-endorsed boats, with licenses entitling the trawlers to fish in the Torres Strait and the Northern Prawn fishery in the Gulf of Carpentaria, may also operate in this region whilst other areas are closed to fishing.

2. Northern East Coast Tiger/Endeavour Prawn Fishery Stock Assessment

Defining the Fishery

The tiger/endeavour prawn fishery operates within the Great Barrier Reef Marine Park and extends along the Queensland coast between Mackay and Torres Strait (Figure 1). It is a multi-species fishery and two other fisheries, the banana prawn fishery and the red spot king fishery also occur within the range of the tiger/endeavour fishery.

In this assessment the fishery has been regarded as consisting of two main regions or strata based on management arrangements. A seasonal closure between the 15th December and 1st March has applied to the north region or stratum (10.5 to 16 degrees) since the early 1990's whereas the South stratum (16 to 22.5 degrees) been open all year. In 2001 the northern seasonal closure was extended down to Mackay so that it now includes most of the southern stratum of the tiger/endeavour fishery.

Although the strata are based on management arrangements, there are significant differences between the two strata in terms of catches and effort. The northern stratum has the grids with the highest tiger prawn catches, effort and catch rates. Many of the vessels that fish in the south stratum are smaller vessels, which operate close to port. In contrast larger vessels that can stay at sea for many months mainly fish the north stratum.

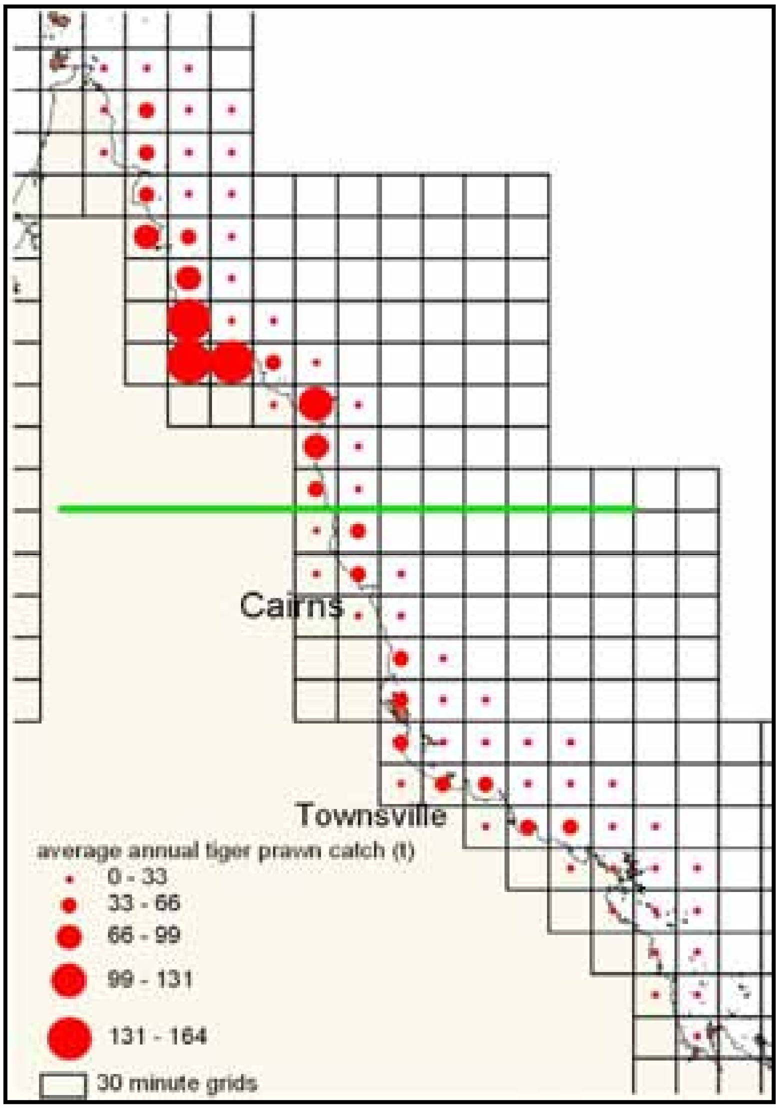

Figure 1 The average tiger prawn catch by 30 minute logbook grid. The green line shows the division between the northern and southern strata.

The multi-species nature of the tiger/endeavour fishery is clearly shown in Figure 2, which shows the species composition of long term fisheries monitoring samples, taken within tiger prawn grounds at the start of the 2000 season (Turnbull et.al., 2004). Species composition changes with latitude along the coast and each species category consists of two main species. Species composition also changes with distance away from the coast. Banana prawns tend to occur close inshore but still overlap spatially with tiger/endeavour grounds. Although red spot king prawns tend to occur in higher densities off shore between the reefs considerable numbers are harvested along with western king prawns, from northern inshore tiger/endeavour grounds (Figure 2).

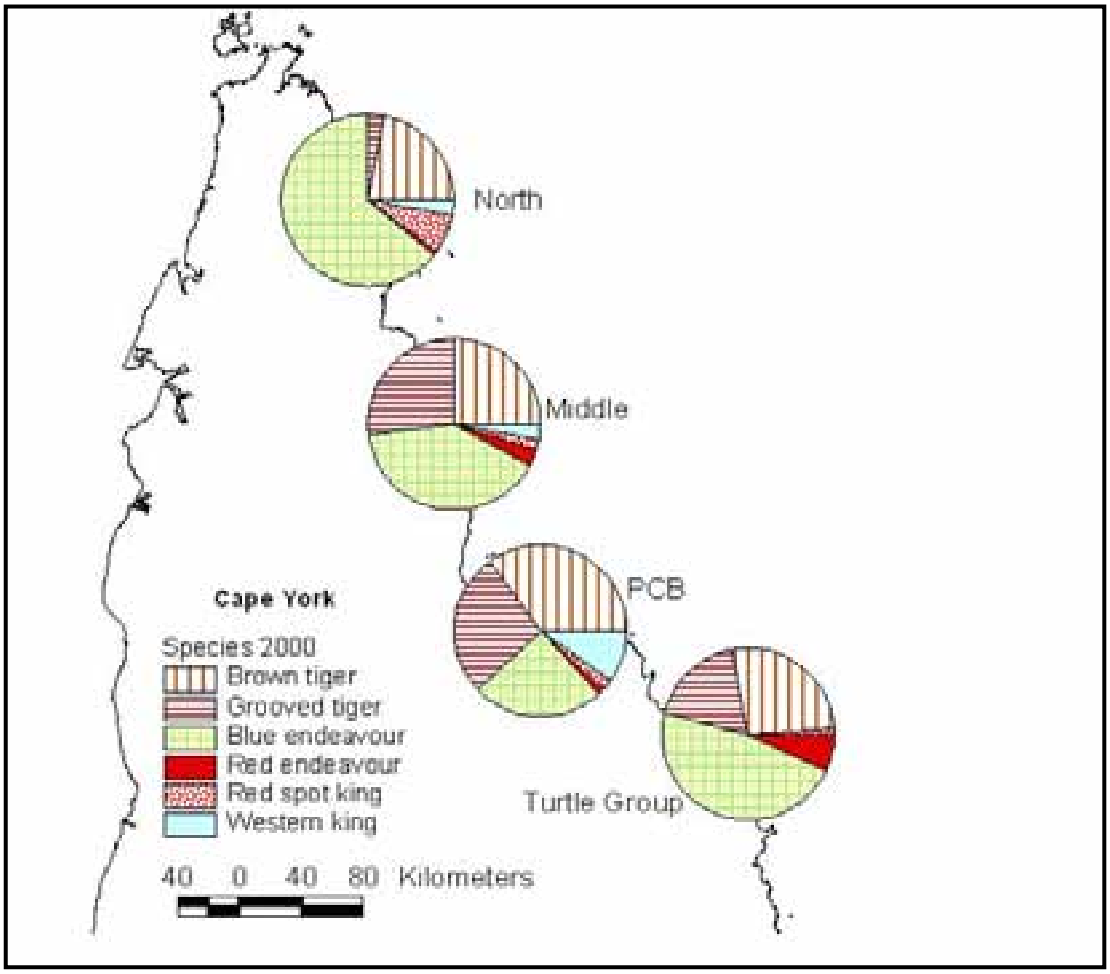

Figure 2 Species composition as numbers, based on Long Term Fisheries Monitoring Samples collected from the Tiger/Endeavour Fishery at the start of the 2000 season (source: Turnbull et.al., 2004)..

Data and data processing

Daily vessel logbook records for the years 1988 to 2001 were extracted from the trawl CFISH database and used as the source of data for the stock models. The records were grouped into north and south strata on the basis of 30-minute logbook grids (Figure 1).

As the tiger prawn fishery is a multi-species fishery it was necessary to filter out records that are probably associated with targeting of other species such as banana or red spot king prawns. The distributions of these species largely overlap with the distribution of tiger and endeavour prawns and much of the position information is fairly course (30 minute or 6 minute grid level) therefore they cannot be separated using the spatial information in the CFISH database. Daily boat catch composition was used to establish which species were being targeted for each daily catch record.

An annual catch rate index for tiger prawns was calculated by taking the geometric mean of the daily vessel catches (CPUE) after they had been filtered using the following rules:

- Records that were not bulk data (represented more than one days catch) and where the
- Proportion of tiger prawn in the daily vessel catch > 10% and
- Proportion of banana prawn in the daily vessel catch <50% and
- Proportion of king prawn in the daily vessel catch <50%

A flag (Pday), which is based on the number of hours trawled per day, was also used to eliminate daily vessel records that represented only a part night of fishing or fishing into daylight hours. Similar filters were used to obtain the endeavour CPUE index but with the proportion of endeavour >10% instead of tiger prawns. The distribution of catch rate data from logbook records tends to be skewed upwards. This tends to bias the arithmetic mean upwards away from the central point of the data. The geometric means were used as the catch rate indices to compensate for the bias created by right hand tail of very high catch rate records.

In Figure 3 - Figure 6 the “catch” is the sum of the catch of all records (no filtering). “Targeted catch” is the catch recorded by the filtered records. “Total days” are the sum of all days of effort recorded in the stratum. “Tiger days” and “endeavour days” are the sum of effort records in the filtered data for each species group. The process of filtering the data to obtain the CPUE indices reduces the catch associated with the CPUE index by 1 percent for tiger prawns and 2 percent for endeavour prawns in the north stratum whereas there is a much larger percentage reduction in the days associated with catching tiger and endeavour prawns, 6 percent and 9 percent respectively.

In the south stratum there is a much larger difference between the total effort and targeted effort for both tiger and endeavour prawns. This indicates that many of the records, especially for the south stratum, are associated with targeting of other species categories such as banana and red spot king prawns. This justifies the filtering used and makes the CPUE indices more indicative of the underlying trends in Tiger and Endeavour prawn stock biomass.

Trends in catch and effort

Tiger Prawns

The annual tiger prawn catch of the 2000 season was down on average in both strata due to a season of poor tiger prawn recruitment. Long Term Monitoring Program (LTMP) trawl surveys of the north stratum indicate that the 2000 season had the lowest tiger prawn recruitment and the recruitment has increased in subsequent years. The surveys also indicate that the 1999 season had the highest recruitment during the years 1998-2002 (Turnbull et al. 2004). This is reflected in the commercial catch and effort data. In the north stratum catch has remained stable at around 1,000 tonnes while effort has decreased. Similarly in the south strata catch has increased faster than the effort since 2001. Note that the low catch in 2001 reflects a very low level of fishing effort.

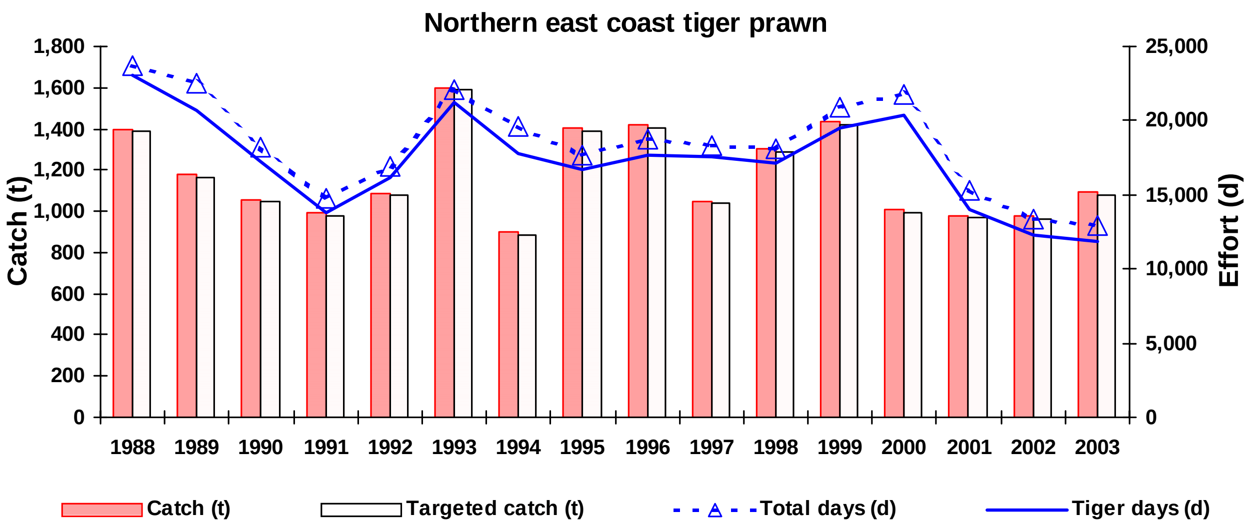

Figure 3 Tiger prawn catch and associated effort in the north stratum

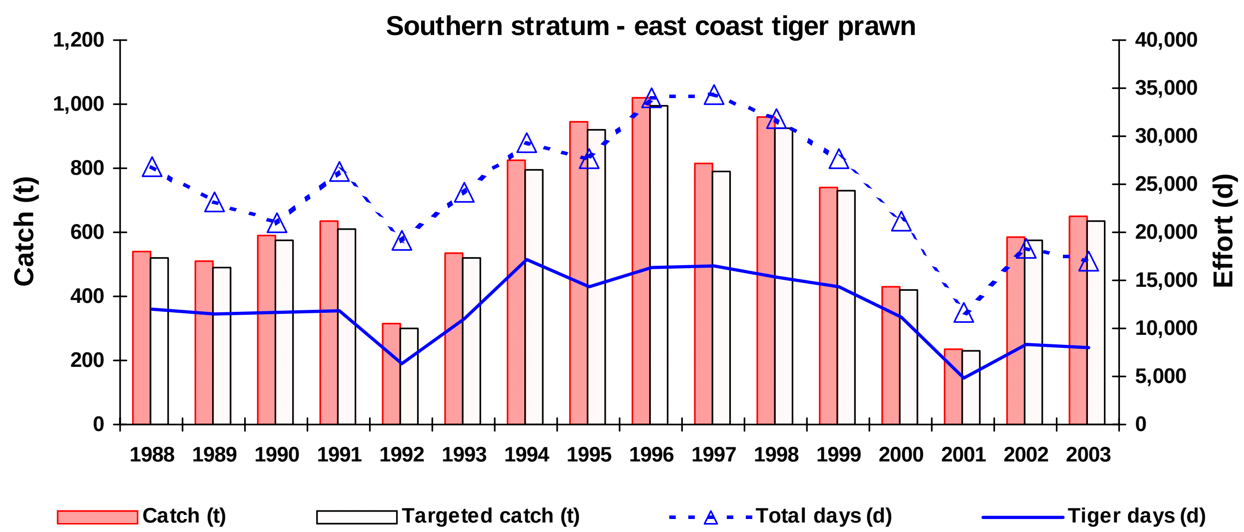

Figure 4 Tiger prawn catch and associated effort in the south stratum

The average annual catch of tiger prawns in the north stratum (1,179t) was almost twice the average annual catch of the south (645t). The tiger prawn catch since 1999 is below average due to a large decrease in effort since the implementation of the new East Coast Trawl Management Plan.

Endeavour Prawns

In both strata changes in endeavour prawn catch largely reflects the level of fishing effort. Although the annual catch in both strata in recent years has been below average so has both total fishing effort and the effort associated with catching endeavour prawns.

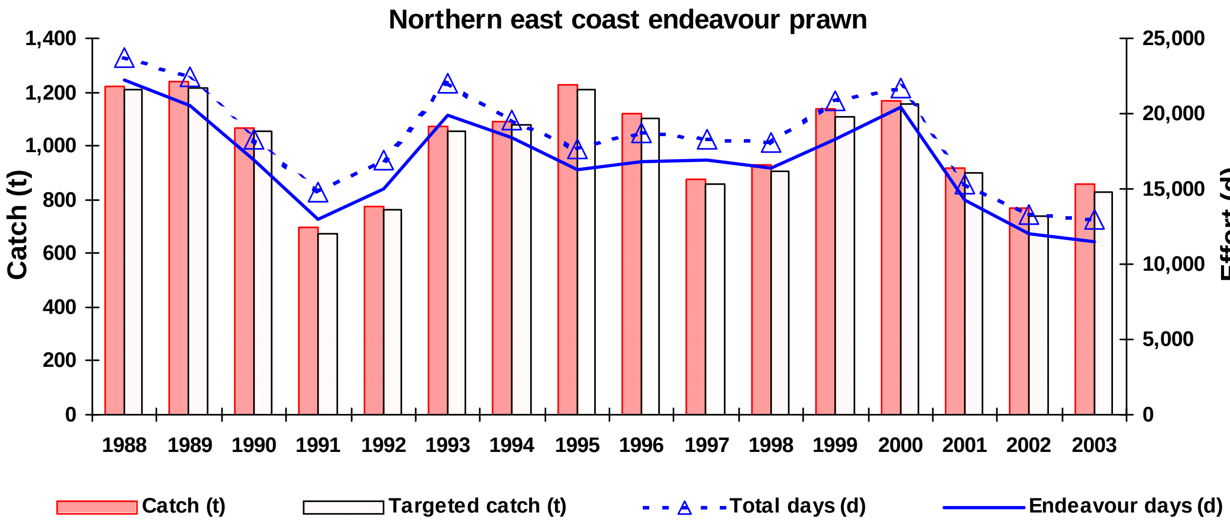

Figure 5 Endeavour prawn catch and associated effort in the north stratum

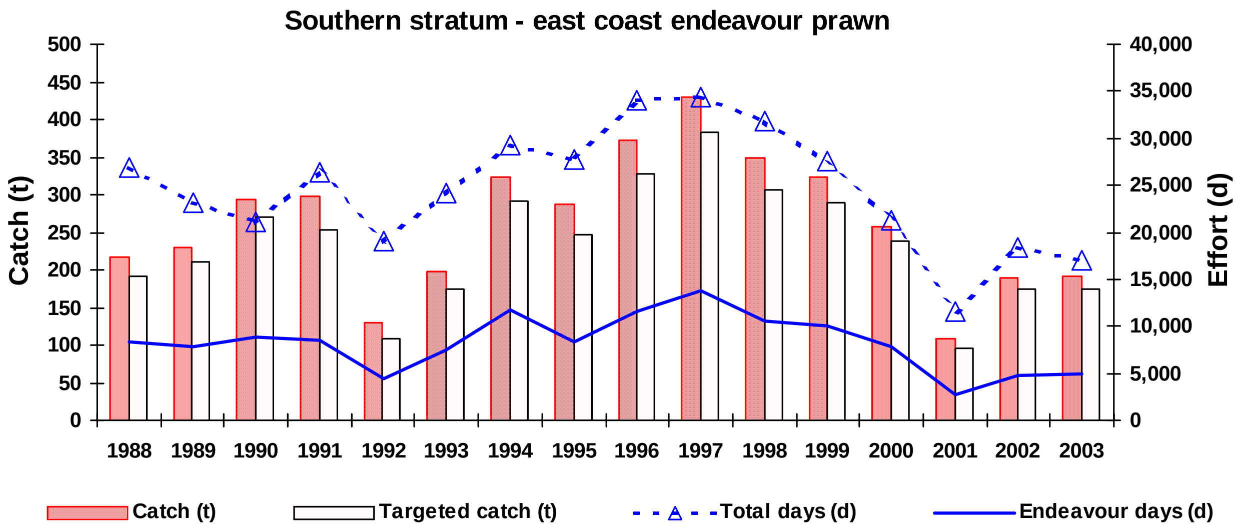

Figure 6 Endeavour prawn catch and associated effort in the south stratum

The average annual catch of endeavour prawns in the north stratum (1,010t) is nearly four times as high as the average annual catch of the south (262t). The 2001 north stratum catch of 918 tonne is below average due to the large reduction in fishing effort. The 2001 endeavour prawn catch in the south stratum (108t) was about one third of the long-term average (262t) again due to a significant decrease in both total fishing effort and effort targeted at endeavour prawns.

Trends in catch rates of tiger and endeavour prawns

Although the annual catch rate of tiger prawns in the north stratum is higher than in the south, the trends over time are the similar (Figure 7 and Figure 8). The decline in catch rates during 1999 and 2000 was followed by improved catch rates in subsequent years. The 2001 northern stratum tiger prawn catch rate of 60 kg/d was slightly above the long term average of 56 kg/d and considerably higher than the 2000 catch rate of 41 kg/d. Tiger prawn catch rates for both strata have continued to increase since the low in 2000. Although these higher catch rates reflect the higher recruitment levels of tiger prawns in recent years in the northern stratum (Turnbull et al. 2004) they could also reflect changes in the average fishing power of the fleet. The licence buy-back that was implemented along with the new Trawl Management Plan would have selectively removed the less efficient vessels in the fleet. The extension of the season closure down to Mackay may have also helped to increase the average annual catch rate for the south stratum.

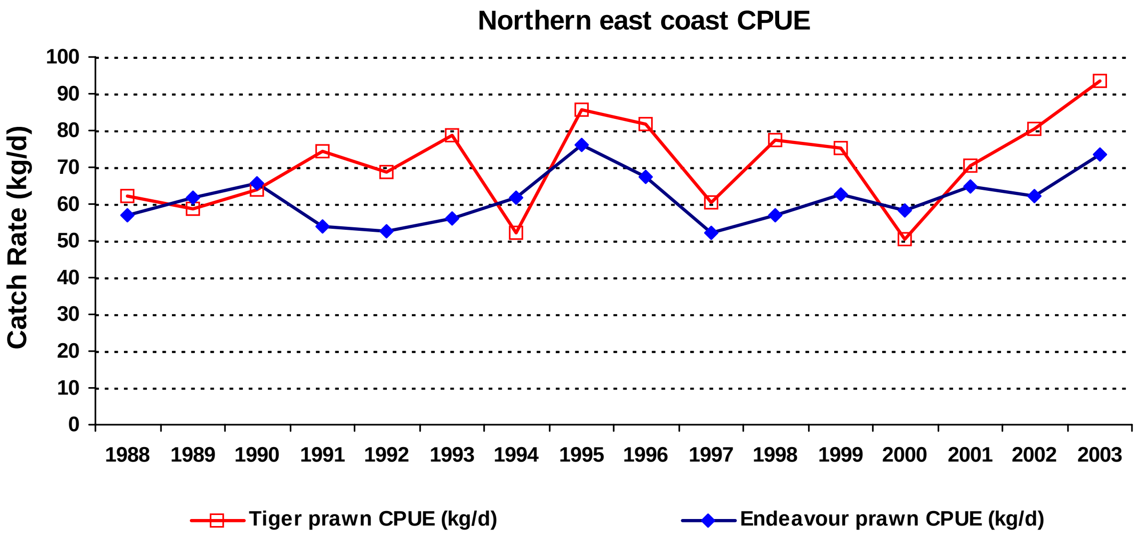

Figure 7 Annual tiger prawn catch rates associated with harvesting tiger prawns in the north stratum.

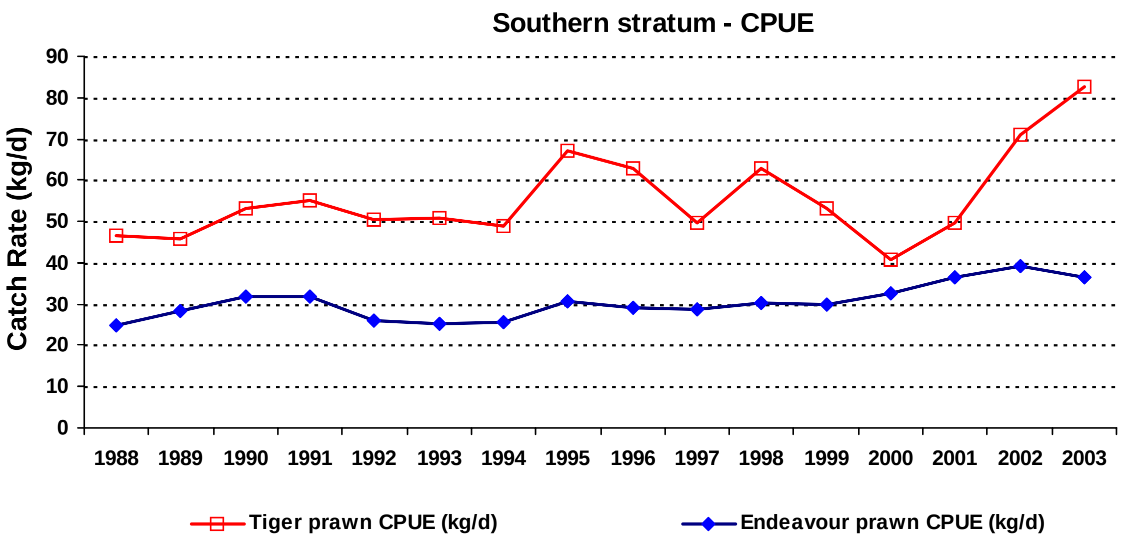

Figure 8 Annual endeavour prawn catch rates associated with harvesting endeavour prawns in the south stratum.

A comparison of Figure 7 and Figure 8 shows that endeavour prawn catch rate indices for the two strata are quite different. The northern catch rates are much higher than the southern catch rates and there is little similarity in the trends

3. Stock Assessment Model

Total yearly catches and annual Catch Per Unit of Effort (CPUE) indices by species category and strata were fitted to a Schaefer non–equilibrium Surplus Production Model (Haddon, 2001, Example Box 10.4). The catch used is the total catch for each species category for each stratum based on all records. The CPUE indices are the geometric mean catch rates based on records that were indicative of targeting of each species category. This type of model requires a long time-series of catch and CPUE data that covers periods of low and high fishing effort and preferably includes the developmental period of the fishery.

In the model, annual biomass is estimated using the following equation.

$$\text{Biomass}_{[\text{this year}]} = \text{Biomass}_{[\text{start of last year}]} + \text{growth} - \text{catch}$$

$$B_{t+1} = B_{t+1} + (r/p)B_t\{1-(B_t/K)^p\} - C_t$$

r = biomass growth rate

K = maximum biomass or carrying capacity of the environment

p= skew of production curve. In this analysis p was set to 1 which constraints the model to the Schaefer form of the equation.

Model CPUE is calculated using the following equation.

$$\text{CPUE}_{[\text{model}]}=\text{Biomass x Fishing Effort x catchability}$$

$$\text{CPUE}_t = B_t \text{ x } E_t \text{ x } q_t$$

B_t = biomass in year t

E_t = fishing effort in year t

qt = catchability in year t

A log likelihood objective function and the solver function in Excel were used to fit the model CPUE to the observed CPUE indices and estimate the model parameters of r, K, B_0 (the biomass at the start of the time-series) and q (the catchability at the start of the time-series). Adjustments for changes in fishing power of the fleet (effort standardisation) were inputted to the model by adjusting the annual catchability (q_t) using our best estimates of the proportional change in fishing power over the time-series. The annual change in fishing power of the north Queensland east coast tiger prawn fleet for the years 1989 to 1999 (Figure 9) was estimated by O'Neill et al. (2003). In this stock assessment it was assumed the fishing power has continued to increase at an average of 0.613 percent per annum since 1999. This percent annual change is the linear increase in fishing power for the years 1989 to 1999. It was also assumed that 1988 had the same fishing power as 1989.

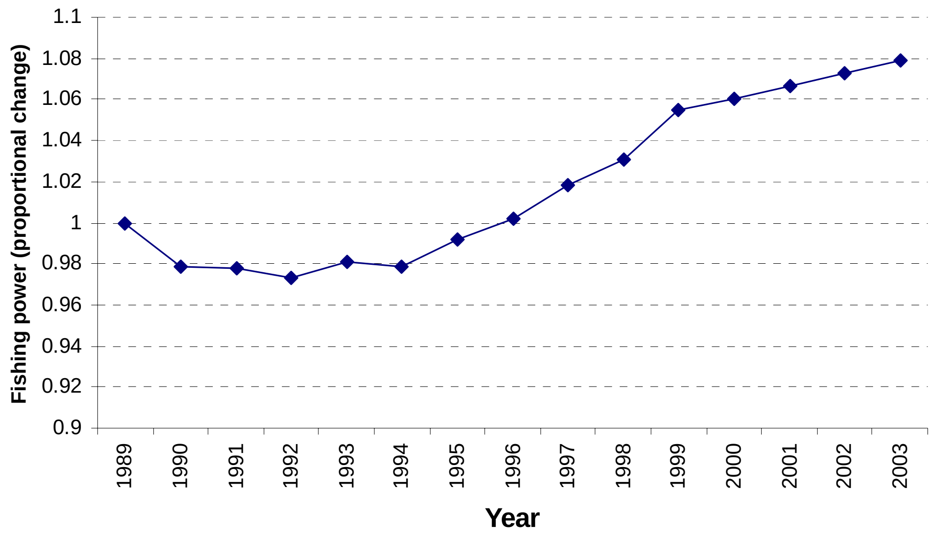

Figure 9 The proportional change in the fishing power of the north Queensland east coast tiger prawn fleet relative to 1989.

The best fit of the model CPUE to the observed CPUE, the one with the highest log-likelihood, is obtained by repeatedly fitting the model using various initial estimates of the model parameters. This iterative process is needed to bypass local maxima on the response surface of the objective function. Once the best or optimal fit has been obtained the model can be bootstrapped to determine the standard errors of the parameter estimates.

Model Results

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

Tiger Prawns North

A stable and biologically realistic fit of the Schaefer Surplus production model was obtained using the total catch annual catch and the annual geometric mean of the daily vessel records for the northern stratum. The records used to calculate the annual catch rates were filtered as described in the “Data and data processing” section to eliminate records obviously associated fishing for non-tiger prawn species. The optimal fit was bootstrapped 1,000 times to obtain the 95 percent confidence intervals of the model and management parameter estimates.

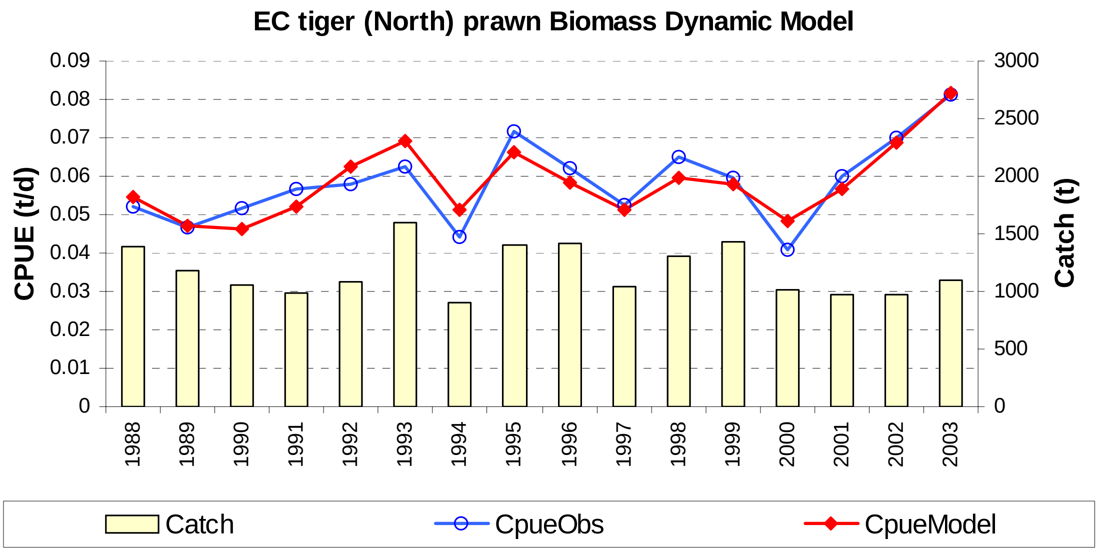

Figure 10 Results of the tiger prawn model fit for the north stratum. Catch rates (CPUE) are scaled to the right axis and catch is scaled to the left axis.

The trend in the model catch rates closely matches the observed catch rates (Figure 10) reflecting the good fit of the model to the data. Although total tiger prawn catch has been blow average in recent years due to declining effort, catch rates have been steadily increasing. The new model parameters estimates of growth (r), carrying capacity (K), initial biomass (B0) and catchability (q) are all very close to the previous estimates (

Table 1). The only difference between the previous assessments and this assessment is the addition of catch and catch rate data for the years 2002-03. The new model fit is slightly better (higher log-likelihood) and the confidence intervals for the model estimates are slightly tighter than for the previous assessment. Since 2000 fishing effort has declined to the lowest level recorded in the time-series. This is starting to provide both greater contrast in the data and information on the response of the stock to lower levels of fishing effort.

The new estimates of the management parameters Maximum Sustainable Yield (MSY), the effort required to harvest MSY (E_{msy}) and the stock biomass that will produce MSY (B_{msy}) were also similar to estimates from the previous assessment. In the case of the Schaefer model which assumes a symmetrical product curve B_{msy} is at 50 percent of the carrying capacity (K/2). The average annual catch for the years 1988 to 2003 (1,179 t) is close to the estimate of MSY (1,239 t) indicating that the fishery is fully exploited. Consistently fishing at or above MSY is likely to result in stocks declining below B_{msy} which would result in unsustainable harvest levels and lower catches and catch rates for the fleet. It is generally considered that fishing should be conducted at about 10% below MSY to ensure that stocks are not overfished and to maximise the economic efficiency of the fleet.

Table 1 Model parameter estimates, fit of model and management parameters. The numbers in brackets are the 95% confidence intervals of the estimates. Note that Emsy is standardised to 2001 days of fishing effort for comparison with the previous assessment.

Parameter	New assessment	Previous assessment
Growth (r)	1.91 (1.43 – 2.52)	1.88 (1.30 – 2.82)
Carrying capacity (K)	2,595 (2,057 – 3,845)	2,635 (1,895 – 4,223)
Initial biomass (B_0)	1,197 (905 – 1,670)	1,196 (830 – 1,948)
Catchability (q)	0.000046 (0.000033 – 0.000063)	0.000045 (0.000031 –0.00007)
LogLikehood	17.22	14.28
MSY	1,238 (1,231 – 1,359)	1,239 (1,277 – 1,400)
E_{msy} (2001)	19,618 (16,548 – 23,443)	19,150 (15,800 – 23,637)
B_{msy}	1,298 (1,019 – 1,838)	1,318 (948 – 1,318)

The estimated stock size for the north stratum (Figure 11) has been varying around the estimate of B_{msy}. This indicates that the stock is currently at maximum productivity and that any further decline in the stock size, due increased fishing effort would result in an over exploited stock. Ideally the stock size should be maintained just above B_{msy} to ensure sustainable harvest levels. As effort has declined in recent years the estimate of stock size has risen above the estimate of B_{msy} for the tiger prawn stock in the north stratum.

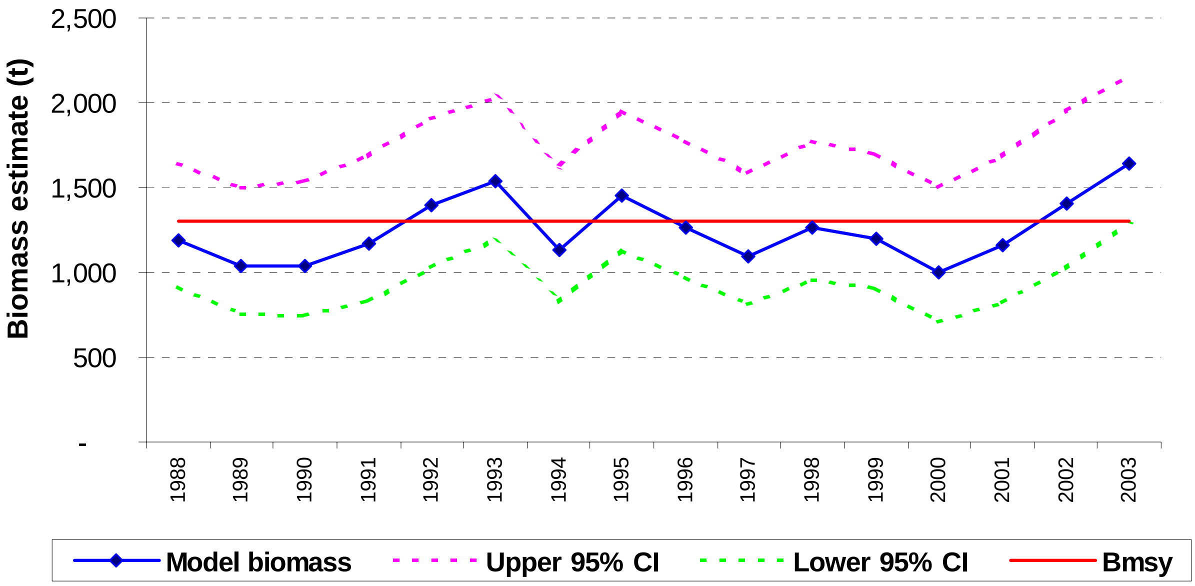

Figure 11 Model estimates of tiger prawn stock biomass and B_{msy} for the north stratum

The plot of catch and effort against the model yield curve (Figure 12) also indicates that the tiger prawn stock in the north stratum is fully exploited as catch and effort for the whole time-series is centred on the top of the curve, which is MSY. The curve is based on the median parameter estimates from the bootstrap results. The model would be improved if we had data from periods of low fishing effort i.e. the left hand side of the curve.

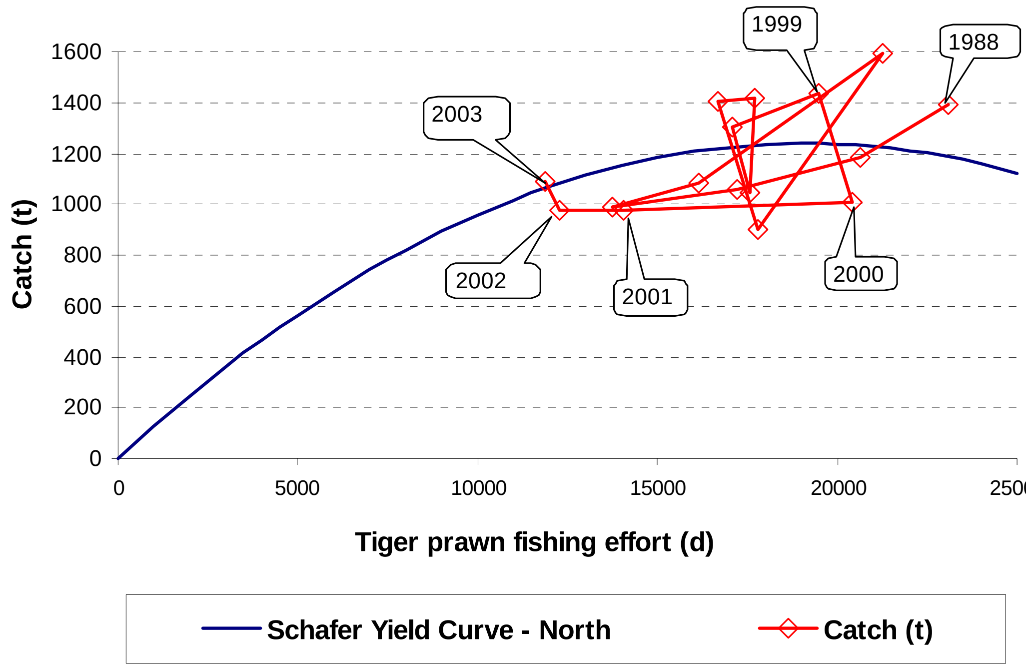

Figure 12 Annual catch versus fishing effort and the Schaefer Yield Curve for tiger prawns in the north stratum

Future Stock Assessments

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

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

The importing of low price aquaculture "Vannamei" (P. vannamei) prawns in 2003-2004 has had a dramatic effect on the behaviour of trawler operators, now more heavily targeting the larger sizes of Tiger prawn. Small size categories of endeavour prawns, in particular, represent a poor cost/benefit to fishers at current prices given the intense competition with aquaculture imports. This change in targeting (and possible discarding) if sustained will affect CPUE estimates and will need to be incorporated in future assessments.

A delay difference model that utilizes available biological information on stock structure and growth rates could also be used as an alternate model of the fishery. This model however requires detailed information on the species split by area and time so that the commercial catch categories can be accurately partitioned into species. Information on the species split at the start of the season is being provided at a coarse level (30 minute grids) by the Prawn Long Term Monitoring Surveys (Turnbull et al., 2004).

4. Summary

The northern Queensland East Coast stocks of tiger and endeavour prawns are currently fully exploited, with both catch and effort at the top of the yield curve. There has been some pullback along the respective yield curves due to a reduction in effort since the introduction of the 2000 trawl plan (as predicted in Gribble and Turnbull, 1996). No detrimental trends are apparent in the logbook catch and effort data of either prawn category at this time.

A number of caveats need to be applied to the assessment however:

1. The data time-series is relatively short and does not contain the developmental stage of the fishery, hence the current level of the stock is uncertain beyond that it is stable and currently fully-exploited. The authors suspect that the stocks have been fished down heavily in the past and the current productivity may be relatively low.
2. The logbook categories of “Tiger” and “Endeavour” are actually suites of up to three species that are morphologically similar. Tigers can be mixtures of *Peneaus semisulcatus*, *P. esculentus*, and *P. monodon*, while Endeavours include *Metapenaeus endeavouri* and *M. ensis*. The assessment was made on the grouped “category” data, which might mask stock changes in individual species.
3. Both species groups are known to aggregate to a greater or lesser degree which may make CPUE a poor indicator of underlying abundance, hence may lower the power of current assessment models based on CPUE time-series.

5. References

Gribble, N.A. and Turnbull, C. (1996) “Assessment of the seasonal closure of the North Queensland prawn trawl grounds” DPIQ Information Series QI96021 [26 pages]

Haddon, M. (2001) “Modelling and Quantitative Methods in Fisheries.” (Chapman and Hall: New York).

O'Neill, M.F., Courtney, A.J., Turnbull, C.T., Good, N.M., Yeomans, K.M., Smith, J.S., Shootingstar, C. (2003) Comparison of relative fishing power between different sectors of the Queensland trawl fishery, Australia. *Fisheries Research* **65**, 309-321.

Turnbull, C., Mellors, J., Atfield, J. (2004) *Fisheries Long-Term Monitoring Program, A summary of tiger and endeavour prawn survey results: 1998-2002*. Department of Primary Industries and Fisheries, Queensland.