STATUS OF TIGER PRAWN STOCKS AT THE END OF 2006 IN THE NPF

1 NON-TECHNICAL SUMMARY

Method

Assessment of tiger prawn stocks in the NPF was updated by including the newly available 2006 logbook catch and effort data. As before, the Dichmont *et al.* (2003) model was employed in the assessment. Fishing power in 2006 was estimated using the same method as in Dichmont *et al.* (2003a). In this assessment, three fishing power series were used to define an envelope of fishing power in an attempt to account for the uncertainties involved. The first two series were constructed using one fishing power base model with optimistic or pessimistic parameter values. The third was a sensitivity test and used a different fishing power model that included spatial aspects of the fishery.

Recognizing there is also uncertainty in the estimate of catchability, we compared model outputs with those when catchability was fixed at the values derived by Wang (1999) or doubled.

Grooved tiger prawns

Grooved tiger prawns are not considered over-exploited. In all the four scenarios tested, its stock abundance was 11-48% higher than S_{MSY} at the end of 2006.

Brown tiger prawns

Brown tiger prawn stock is on the way to recovery. Its stock abundance was above S_{MSY} in three of the four scenarios tested, except the Base Case High fishing power series coupled with a catchability value twice that of Wang (1999), in which the stock was estimated 4% below S_{MSY}.

These conclusions are based on the species-specific catch and effort data produced by the species split method (Venables *et al*., 2006). All the results are presented in terms of S_{MSY}, which is now considered as a Limit Reference Point in the NPF. The Target Reference Point of MEY is not included in this report as it will be dealt with separately by other reports. No projections were carried out in this year's assessment as agreed in the February 2007 NPFRAG meeting.

Survey

Since we have undertaken a monitoring survey for the NPF only over the last five years, the abundance indices estimated from the surveys have not been incorporated into the assessment. How best to use the survey data to improve the stock assessment deserves separate consideration as survey data offer spatial perspectives to the fishery distribution that are not contained in the present assessment.

2 TECHNICAL SUMMARY

The status of the Northern Prawn Fishery tiger prawn stocks was investigated by considering a number of management related quantities. These included estimates of the Maximum Sustainable Yield (MSY), the spawning stock (S) that produces the MSY (S_{MSY}), the fishing effort (E) that produces maximum sustainable yields (E_{MSY}), the ratio of the spawning stock biomass in 2006 (S_{2006}) to the S_{MSY} (S_{2006}/S_{MSY}), and the ratio of the present effective effort (E_{2006}) to the E_{MSY} (E_{2006}/E_{MSY}). Using the Dichmont *et al.* (2003) model, estimates of MSY, S_{MSY} and E_{MSY} were calculated using the estimated age-structure of the catch and within-year effort pattern, which is an improvement on the method used by Wang and Die (1996). The within-year effort pattern was an average between 1997 and 2006.

Three fishing power series were used in this assessment. The first two were constructed using one fishing power base model with optimistic (Base Case Low) or pessimistic (Base Case High) parameter values. The third (Spatial High) was a sensitivity test and used a different fishing power model that included spatial aspects of the fishery.

For the **Base Case Low** fishing power series and assuming a **catchability value estimated by Wang (1999)**, then on average, the spawning stock biomass for **grooved** tiger prawns in 2006 (S_{2006}) was in the range of 127% to 169% of S_{MSY}, with the most likely value being 148% (Figure 1). For **brown** tiger prawns the range was 104% to 182% of S_{MSY}, with the most likely value being 139% (Figure 2). The fishing effort in 2006 was 42% of the E_{MSY} for **grooved** tiger prawns (Figure 3) and 36% of the E_{MSY} for **brown** tiger prawns (Figure 4)

For the **Base Case Low** fishing power series and assuming a **catchability value twice that of Wang** (1999), then on average, the spawning stock biomass for **grooved** tiger prawns in 2006 (S_{2006}) was in the range of 119% to 168% of S_{MSY}, with the most likely value being 144% (Figure 1). For **brown** tiger prawns the range was 91% to 173% of S_{MSY}, with the most likely value being 128% (Figure 2). The fishing effort in 2006 was 36% of the E_{MSY} for **grooved** tiger prawns (Figure 3) and 41% of the E_{MSY} for brown tiger prawns (Figure 4).

For the **Base Case High** fishing power series, assuming a **catchability value of Wang** (1999), then on average, the spawning stock biomass for **grooved** tiger prawns in 2006 (S_{2006}) was in the range of 98% to 135% of S_{MSY}, with the most likely value being 116% (Figure 1). For **brown** tiger prawns the range was 81% to 144% of S_{MSY}, with the most likely value being 110% (Figure 2). The fishing effort in 2006 was 63% of the E_{MSY} for **grooved** tiger prawns (Figure 3) and 50% of the E_{MSY} for **brown** tiger prawns (Figure 4).

Finally, for the **Base Case High** fishing power series, using a **catchability value twice that of Wang** (1999), then on average, the spawning stock biomass for **grooved** tiger prawns in 2006 (S_{2006}) was in the range of 92% to 131% of S_{MSY}, with the most likely value being 111% (Figure 1). For **brown** tiger prawns the range was 69% to 128% of S_{MSY}, with the most likely value being 96% (Figure 2). The fishing effort in 2006 was 60% of the E_{MSY} for **grooved** tiger prawns (Figure 3) and 55% of the E_{MSY} for **brown** tiger prawns (Figure 4).

For both tiger prawn species, the 2006 effective fishing effort was below E_{MSY}. For grooved tiger prawns, all the scenarios show the resource in 2006 was above S_{MSY}, and only 0-13% of the simulations in the four scenarios tested produced a spawning stock lower than S_{MSY}. The Limit Reference Point (LRP) of being a greater than 70% that the resource is above S_{MSY} is reached.

For brown tiger prawns, the two Base Case Low senarios show the resource in 2006 was above S_{MSY} in 98% and 90% of the simulations, respectively. The LRP was reached for both cases. In the two pessimistic scenarios, the resource in 2006 fell above S_{MSY} at a probability of 76 and 44% in the cases of "q" and "2q" respectively. Therefore, the LRP was reached only in the former case.

Due to the recent structural change of the fishery, the RAG meeting on 7-8 February 2007, Cleveland decided that no projections would be carried out in this year's assessment. The NPF fishery has been conducting field surveys for the last five years. However, the time series of survey indices is short and has not been incorporated into the assessment. These should be separately considered as they offer a spatial aspect to the fishery distribution not presently contained within the assessment.

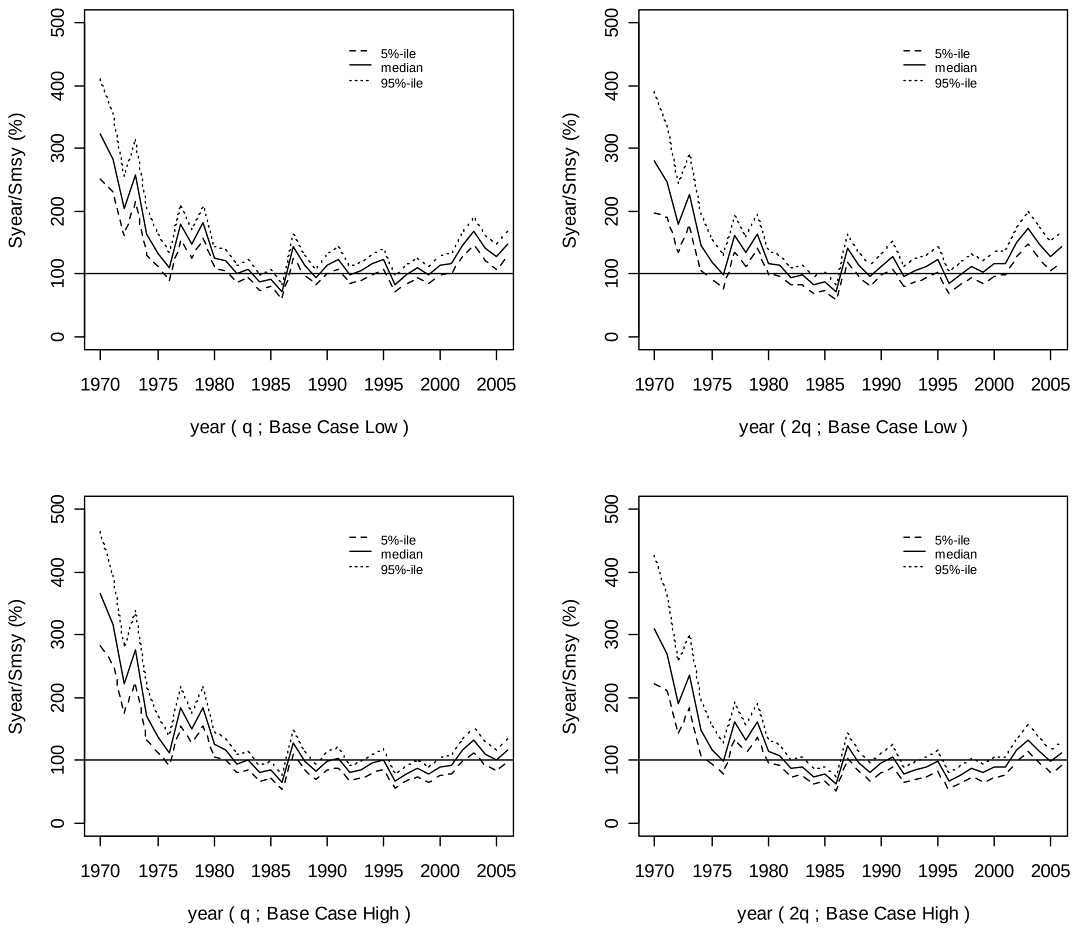

Figure 1: Median (with 5 and 95 percentiles) spawning stock size in a year relative to the Spawner stock size at which the Maximum Sustainable Yield (S_{MSY}) is achieved for ***grooved tiger prawns****; Top row) fishing power set at Base Case Low and catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) fishing power set at Base Case High and catchability at Wang (1999) levels on left and twice those on the right. Points less than 100% are deemed over-exploited as they are below the S_{MSY} Confidence intervals in the estimate of S_{Year} and S_{MSY} are shown.*

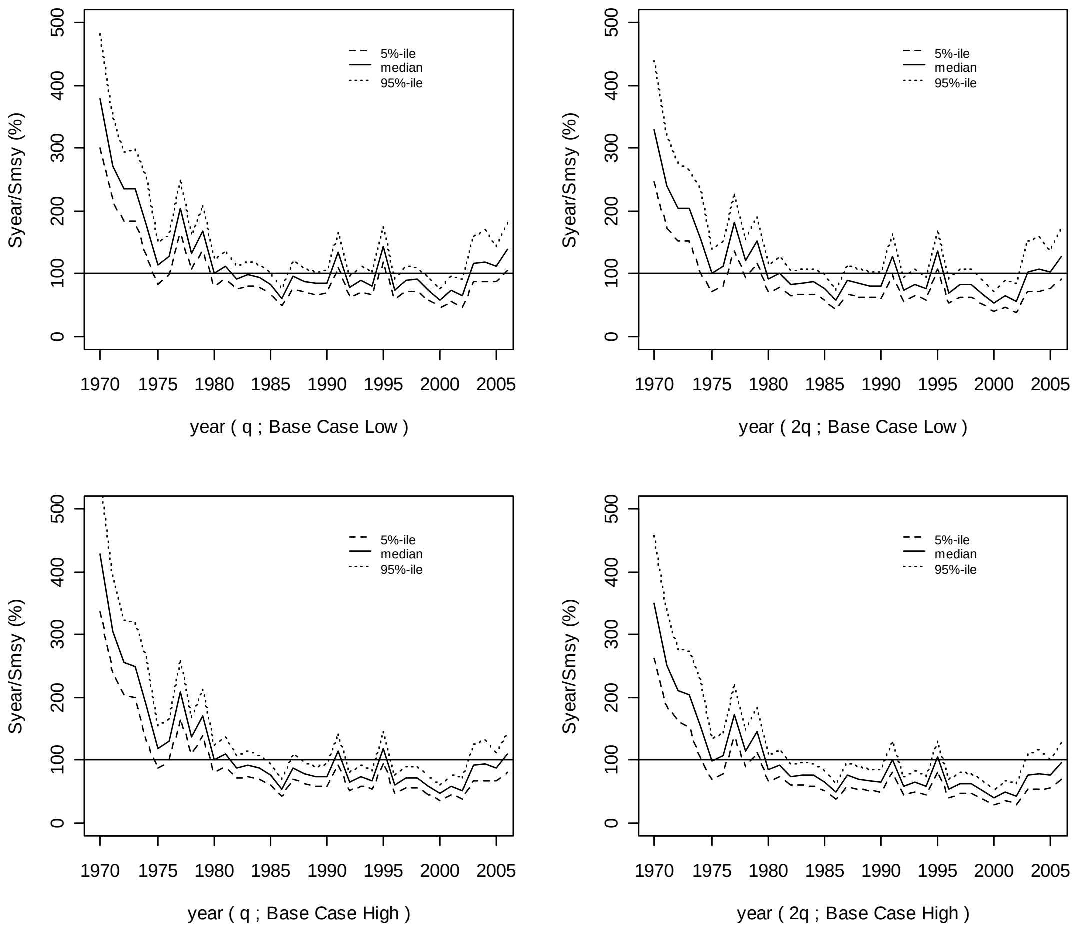

Figure 2: Median (with 5 and 95 percentiles) spawning stock size in a year relative to the Spawner stock size at which the Maximum Sustainable Yield (S_{MSY}) is achieved for ***brown tiger prawns****; Top row)* fishing power set at Base Case Low and *catchability at Wang (1999) levels on left and twice those on the right; and Bottom row)* fishing power set at Base Case High and *catchability at Wang (1999) levels on left and twice those on the right. Points less than 100% are deemed over-exploited as they are below the target reference point. Confidence intervals in the estimate of S_{Year} and S_{MSY} are shown.*

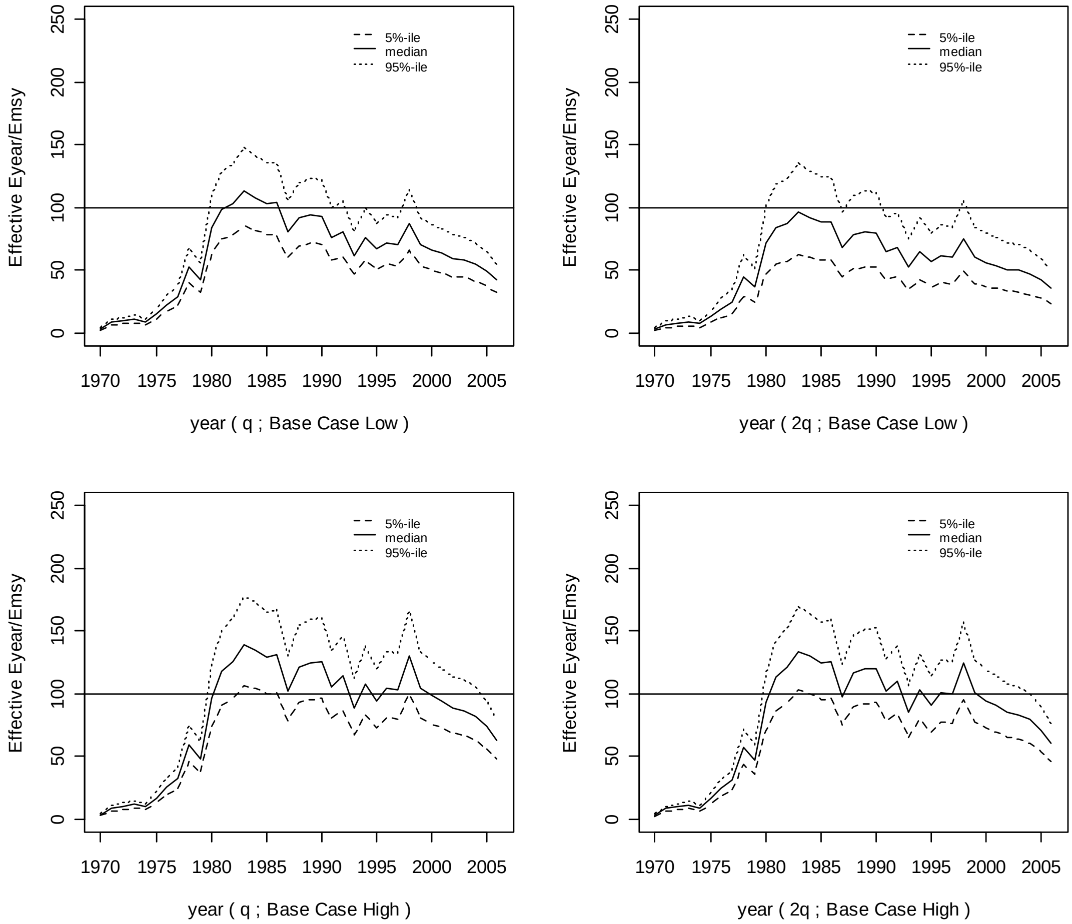

Figure 3: Effective fishing effort relative to the effort that would, on average, produce the Maximum Sustainable Yield (E_{MSY}) for the ***grooved tiger prawns*** *Top row) fishing power at Base Case Low and catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) fishing power at Base Case High with catchability at Wang (1999) levels on left and twice those on the right. Confidence intervals in the estimate of E_{MSY} are shown. Points greater than 100% show years in which the effort levels are higher than the limit reference point, E_{MSY}.*

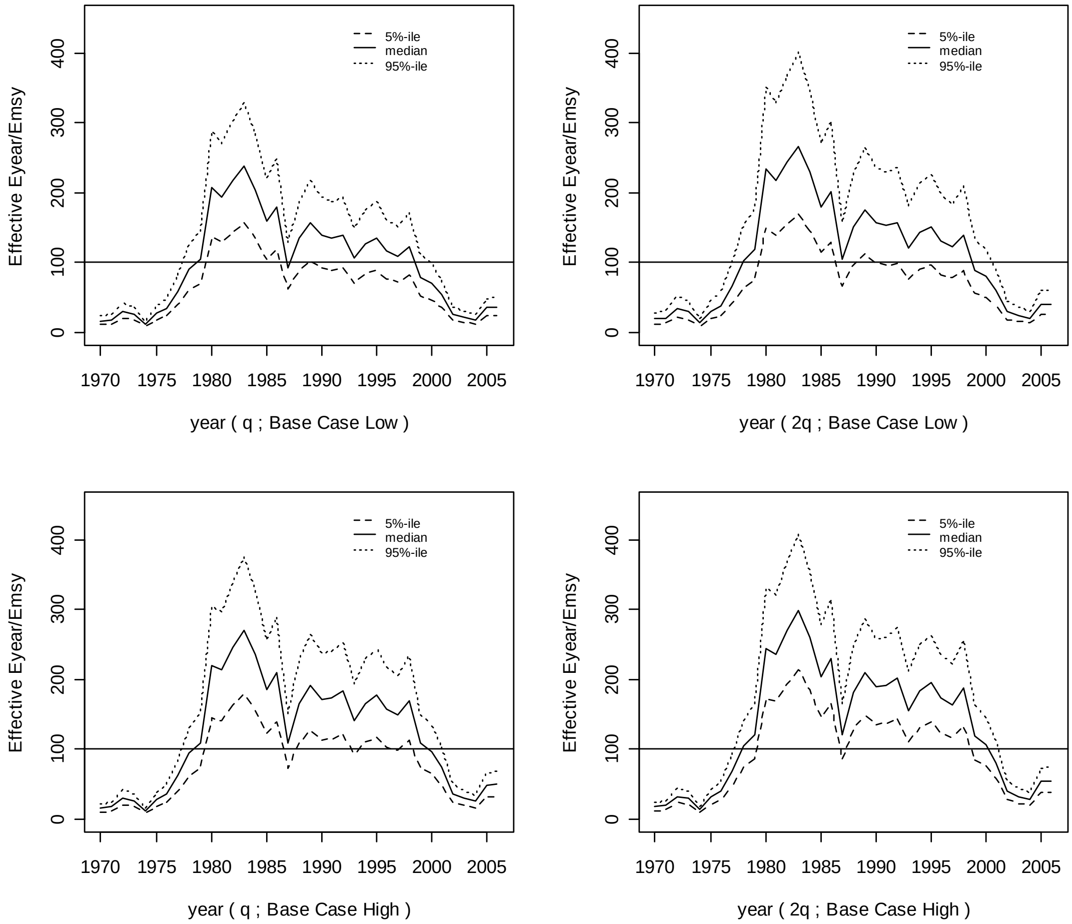

Figure 4:Effective fishing effort relative to the effort that would, on average, produce the Maximum Sustainable Yield (E_{MSY}) for ***brown tiger prawns;*** *Top row) fishing power at Base Case Low and catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) fishing power at Base Case High with catchability at Wang (1999) levels on left and twice those on the right. Confidence intervals in the estimate of E_{MSY} are shown. Points greater than 100% show years in which the effort levels are greater than the limit reference point, E_{MSY}.*

3 REFERENCES

Dichmont, C.M., Punt, A.E., Deng, A., Dell, Q. and Venables, W. 2003. Application of a weekly delay-difference model to commercial catch and effort data for tiger prawns in Australia's Northern Prawn Fishery. *Fisheries Research*. **65**: 335-350.

Dichmont, C, Bishop, J., Venables, W., Sterling, D., Penrose, J., Rawlinson, N. and Eayrs, S. 2003a. A new approach to fishing power analysis and its application in the Northern Prawn Fishery.

Dichmont, C.M., Die, D., Punt, A.E., Venables, W., Bishop, J., Deng, A. and Dell, Q. 2001. Risk analysis and sustainability indicators for prawn stocks in the Northern Prawn Fishery. FRDC 98/109. 187 pp.

Venables, W. N., Kenyon, R. A., Bishop, J. F. B., Dichmont, C. M., Deng, R. A., Burridge, C. Y., Taylor, B. R., Donovan, A G.., Thomas, S. E., Cheers, S. J. (2006) Species Distribution and Catch Allocation: data and methods for the NPF,2002-2004.

Wang, Y.-G. and Die, D. (1996) Stock-recruitment relationships of the tiger prawns (*Penaeus esculentus* and *Penaeus semisulcatus*) in the Australian Northern Prawn Fishery. *Marine and Freshwater Research* **47**, 87-95.

Wang, Y.-G. (1999) A Maximum-likelihood method for estimating natural mortality and catchability coefficient from catch-and-effort data. *Australian Journal of Marine and Freshwater Research* **50**, 307-11.

4 INTRODUCTION

This assessment uses a weekly Deriso-Schnute model (Dichmont *et al.*, 2001 and Dichmont *et al.*, 2003). As agreed by the NPRAG at its meeting on 7-8 February, 2007, the differences from last year's assessment are:

1. The weekly effort pattern was derived using an average of a 10-years window from 1997 to 2006.

2. catch/effort derived by the species splitting model (Venable *et al*. 2006) from logbook data up to the end of 2006

3. no projections were requested due to the restructure of the NPF fleet

As in last year's assessment, four models were displayed in detail (labelled the "Base Case"):

1. with the assumption of Wang's (1999) catchability (hereafter called "q") and twice that number ("2q").

2. with the assumption of a more (labelled "Base Case High") and less precautionary fishing power series (labelled "Base Case Low"), which relate to the "Basic High" and "Basic Low" models presented to the April 2003 NPFAG meeting.

The third fishing power series ("Spatial High") was used to compare the effects of including some spatial changes of the fishery over time in the fishing power analyses. These fishing power series are shown in Figure 5.

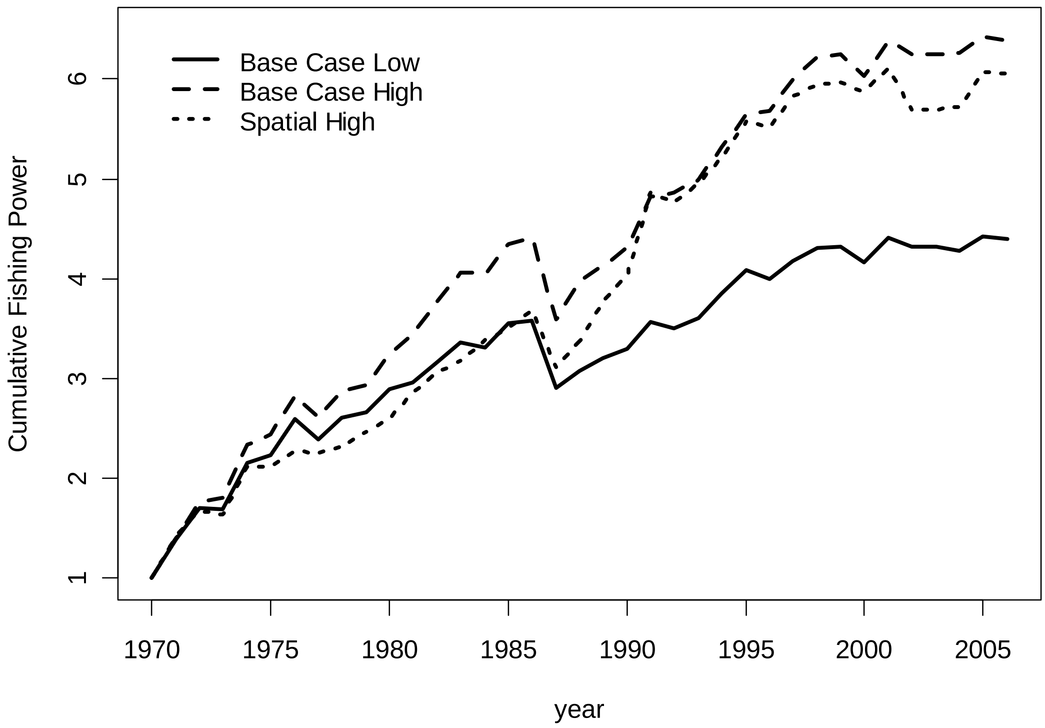

Figure 5: Three cumulative relative fishing power approaches: the Base Case Low fishing power, Base Case High fishing power and the Spatial High fishing power.

The target reference point NORMAC has agreed on is the Maximum Economic Yield (MEY, NORMAC 56) and the potential limit reference point is a 70+% chance that the spawning stock will be above or at the level that produces Maximum Sustainable Yield i.e. S_{MSY} (NORMAC 51). The results of the assessments therefore relate to these and other related management quantities (with their 90% uncertainty intervals). The quantities reported here are:

a) Steepness - the ratio of the recruitment expected at 20% of the virgin spawning stock to the virgin spawning stock size .

b) *MSY* – the (deterministic) Maximum Sustainable Yield.

c) E_{MSY} – the effort level (expressed in terms of 1993 vessel-days) at which *MSY* is achieved.

d) S_{MSY} – the spawning stock biomass index at which the (deterministic) *MSY* is achieved.

e) Depletion or S_{2006}/S_{MSY} – the ratio (expressed as a percentage) of the spawning stock biomass index in 2006 to that at which *MSY* is achieved (in the absence of fluctuations in recruitment), S_{MSY}.

f) Frequency S_{2006} – percentage of bootstrap runs in which S_{2006} fell below 0.98 S_{MSY}.

The steepness of the stock-recruitment relationship is reported as it indicates the relative productivity of the resource (a value close to 0.2 is "low" and close to unity is "high"). Depletion and E_{MSY} are quantities that relate to the current management objectives for the fishery (values for depletion less than 100% indicate over-exploitation).

The catchability coefficient in Wang (1999) was estimated using the data of 1993 and included fishing power. As a result, all the fishing power schedules were calculated relative to 1993, that is, the fishing power value in 1993 was set as 1 in the model. All E_{MSY} and forward projected effort estimates are reported in 1993 fishing days and uses the season length and fishing pattern of 2006.

5 RESULTS AND DISCUSSION

5.1 CATCH AND EFFORT DATA

Catch and effort data from 1970 to 2006 were extracted from AFMA's logbook database for each tiger prawn species. Compared with the data in 2005, the species-combined catch was slightly increased (about 6%) and its corresponding effort was decreased by about 10% in 2006 (Table 1). The nominal effort targeting grooved tiger prawns continued to decrease by about 15%, and that targeting brown tiger prawns increased over 9% from 2005 to 2006.

Table 1. ***Catch (tonnes) and nominal effort (boat-days) for the two species of tiger prawns in the NPF over the last 14 years.***

	Catch		Nominal effort (boat days)		Totals	
	Grooved	**Brown**	**Grooved**	**Brown**	**Catch**	**Effort**
1993	1325	1208	9097	7320	2533	16417
1994	1841	1318	10492	8101	3159	18593
1995	1674	2465	8468	8295	4139	16763
1996	1193	1155	9555	7138	2348	16693
1997	1451	1253	8991	6353	2704	15344
1998	1835	1450	10962	6920	3285	17882
1999	1417	753	8948	4223	2170	13171
2000	1585	634	8756	3873	2219	12629
2001	1478	530	8042	2626	2009	10668
2002	1757	260	7889	975	2017	8864
2003	1950	310	7786	653	2260	8439
2004	1506	259	7369	500	1765	7869
2005	1302	445	6287	1623	1748	7910
2006	1306	550	5350	1775	1856	7125

Using the fishing power series (Figure 5), the 2006 effective effort for grooved tiger prawns has continuously decreased since 2003, but increased significantly since 2004 for brown tiger prawns (Table 2, Table 3 and Table 4).

Figure 6 shows the difference between the CPUEs corrected using the fishing power series and the CPUEs estimated directly from nominal effort.

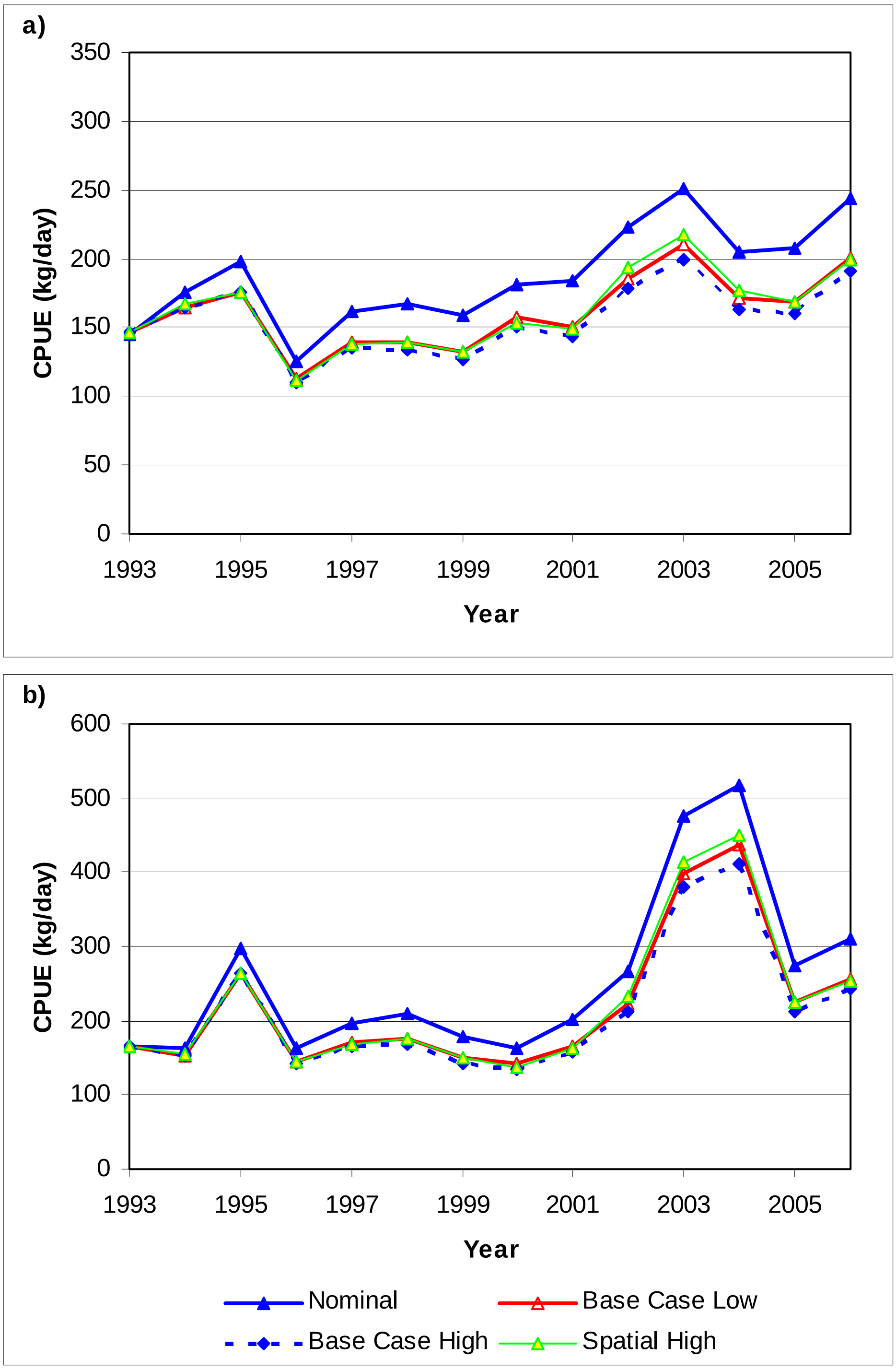

Figure 6: Catch-per-unit effort for a) ***grooved*** *and b)* ***brown tiger*** *prawns from 1993 to 2006 calculated using nominal effort and the new fishing power series.*

Table 2. ***Effective effort (standardised boat-days) and effective catch-per-unit of effort (CPUE in kg per standardised boat-day) for each species of tiger prawns in the NPF during the last 13 years. Fishing power is calculated using the Basic Low schedule of the fishing power project.***

Basic Low fishing power	**Effective effort (standardised boat-days)**		**Effective CPUE (kg per standardised boat days)**		**Totals**	
	Grooved	**Brown**	**Grooved**	**Brown**	**Effective effort**	**Effective CPUE**
1993	9097	7320	146	165	16417	154
1994	11193	8642	164	153	19835	159
1995	9573	9377	175	263	18950	218
1996	10579	7903	113	146	18482	127
1997	10397	7347	140	171	17744	152
1998	13070	8251	140	176	21321	154
1999	10708	5054	132	149	15762	138
2000	10104	4469	157	142	14573	152
2001	9814	3204	151	166	13018	154
2002	9422	1164	186	223	10586	190
2003	9299	780	210	398	10079	224
2004	8740	593	172	436	9333	189
2005	7687	1984	169	224	9671	181
2006	6509	2159	201	255	8668	214

Table 3. ***Effective effort (standardised boat-days) and effective catch-per-unit of effort (CPUE in kg per standardised boat-day) for each species of tiger prawns in the NPF during the last 13 years. Fishing power is calculated using the Basic High schedule of the fishing power project.***

Basic High fishing power	**Effective effort (standardised boat-days)**		**Effective CPUE (kg per standardised boat days)**		**Totals**	
	Grooved	**Brown**	**Grooved**	**Brown**	**Effective effort**	**Effective CPUE**
1993	9097	7320	146	165	16417	154
1994	11178	8630	165	153	19808	160
1995	9571	9376	175	263	18947	218
1996	10871	8121	110	142	18992	124
1997	10780	7617	135	165	18397	147
1998	13660	8623	134	168	22283	147
1999	11198	5285	127	143	16483	132
2000	10586	4683	150	135	15269	145
2001	10290	3360	144	158	13650	147
2002	9879	1221	178	213	11100	182
2003	9750	818	200	379	10568	214
2004	9248	628	163	412	9876	179
2005	8086	2087	161	213	10173	172
2006	6839	2269	191	243	9108	204

Table 4. ***Effective effort (standardised boat-days) and effective catch-per-unit of effort (CPUE in kg per standardised boat-day) for each species of tiger prawns in the NPF during the last 13 years. Fishing power is calculated using the Spatial High schedule of the fishing power project.***

Spatial High fishing power	**Effective effort (standardised boat-days)**		**Effective CPUE (kg per standardised boat days)**		**Totals**	
	Grooved	**Brown**	**Grooved**	**Brown**	**Effective effort**	**Effective CPUE**
1993	9097	7320	146	165	16417	154
1994	11028	8515	167	155	19543	162
1995	9522	9327	176	264	18849	220
1996	10626	7938	112	146	18564	126
1997	10545	7451	138	168	17996	150
1998	13137	8293	140	175	21430	153
1999	10745	5071	132	149	15816	137
2000	10358	4581	153	138	14939	149
2001	9890	3229	149	164	13119	153
2002	9051	1119	194	232	10170	198
2003	8933	749	218	414	9682	233
2004	8489	576	177	449	9065	195
2005	7691	1985	169	224	9676	181
2006	6519	2163	200	254	8682	214

The Dichmont *et al.* (2003) approach was used to assess the status of the resource by estimating recruitment and spawning stock indices. The model uses weekly catch and effort data from 1970 to 2006. In each year's assessment, the model parameters were re-estimated with the addition of new data. Two catchability assumptions were tested: catchability set at Wang's (1999) value and twice that value. Two fishing power series for the Base Case were also tested: "Base Case High" and "Base Case Low". For convenience of reading, the results of the assessment for the two species are presented separately.

5.2 GROOVED TIGER PRAWNS

5.2.1 RECRUITMENT AND SPAWNING STOCK

The estimates of grooved tiger prawn annual recruitment for the "Base Case Low" and that for "Base Case High" are shown in Figure 7. An increase in recruitment could be seen in all the four scenarios from 2005 to 2006, although the extent differed with scenarios

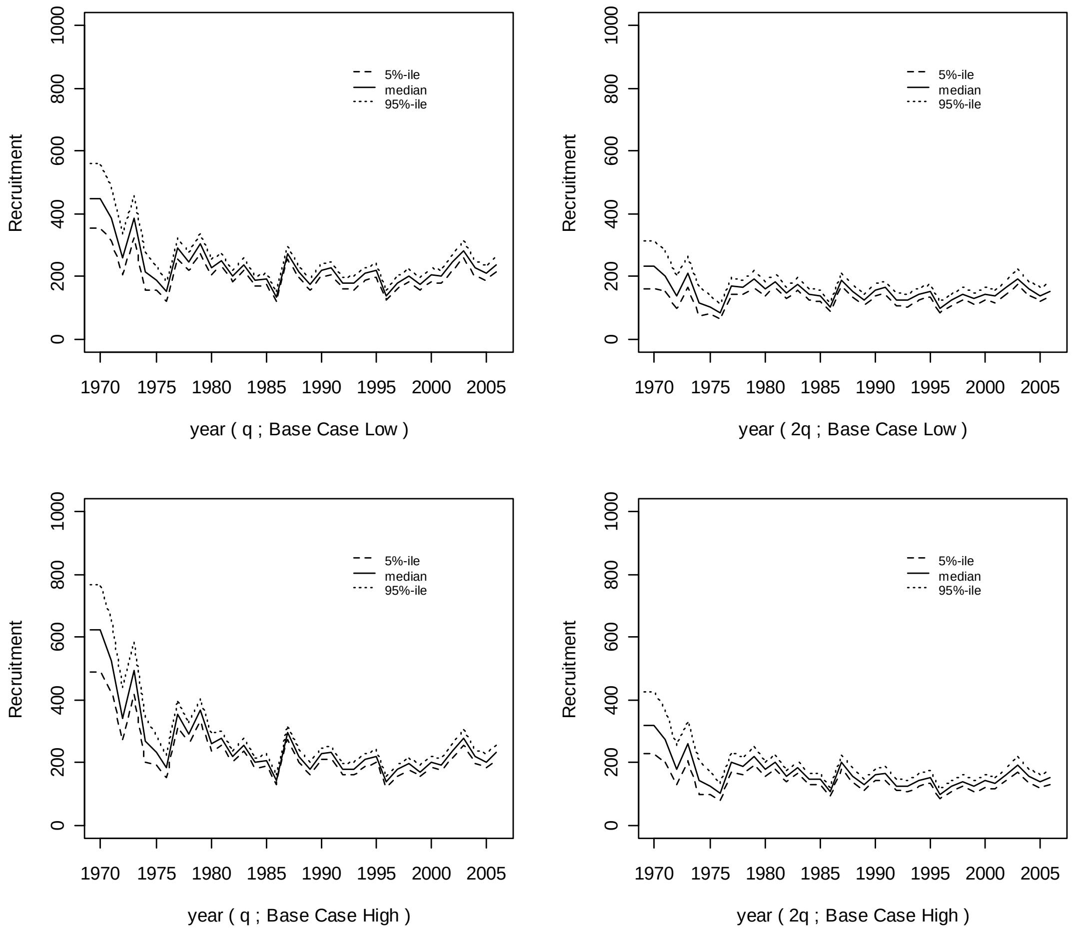

Figure 7: Median recruitment index (with 5 and 95 percentiles) for ***grooved tiger*** *prawns for Top row) Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right. Confidence intervals in the recruitment estimates are reflected.*

Spawning stock index represents the abundance of female prawns in spawning condition during the year. The "Base Case Low" and the "Base Case High" spawning indices under the two assumptions of catchability for grooved tiger prawns with the associated confidence intervals are given in Figure 8. The 2006 spawning stock index of grooved tiger prawns increased from the previous year.

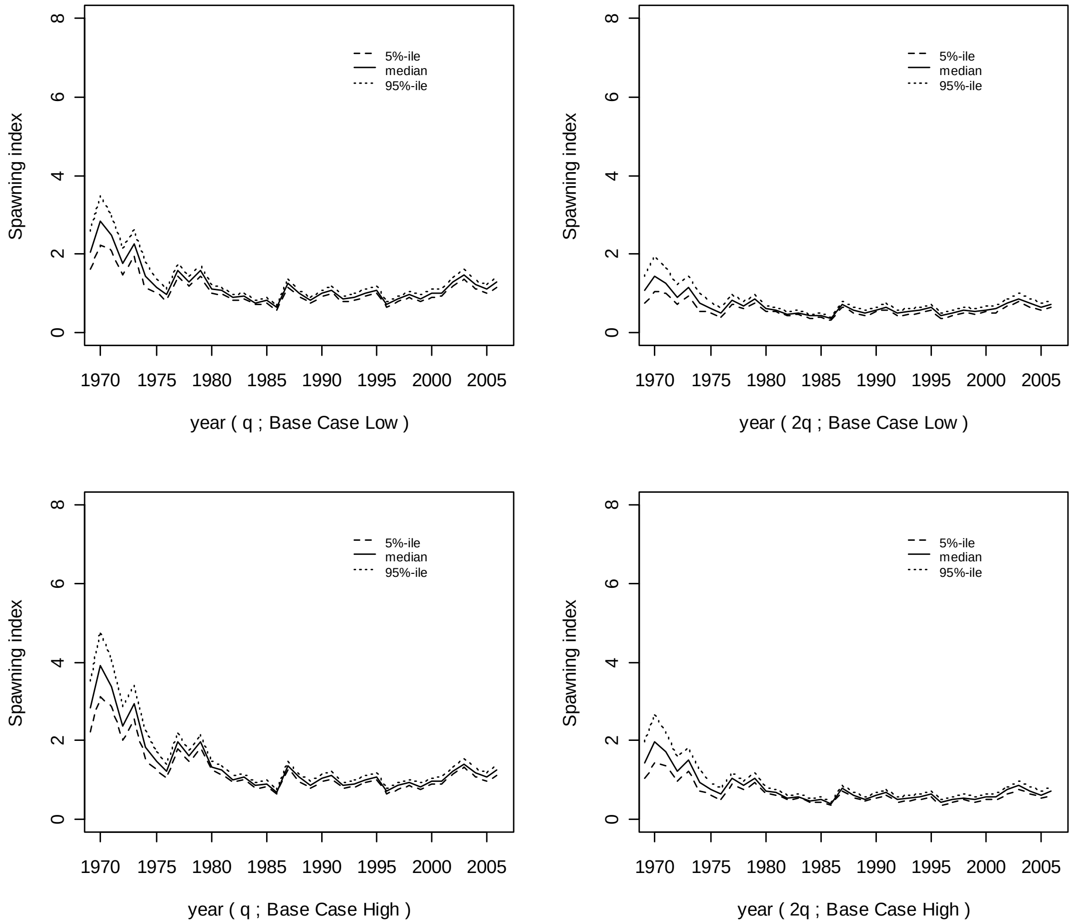

Figure 8: Median spawning stock indices (with 5 and 95 percentiles) for ***grooved tiger*** *prawns for Top row) the Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) the Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right. Confidence intervals in the spawning values are reflected.*

5.2.2 MANAGEMENT AND OTHER OUTPUTS

The grooved tiger prawn management and other quantities reported below are derived from the stock-recruitment function, which relates the recruits that would be produced in the subsequent biological year with the spawners of the previous calendar year (Figure 9). The 2005 stock index that resulted in the 2005/2006 recruitment is highlighted on the graphs.

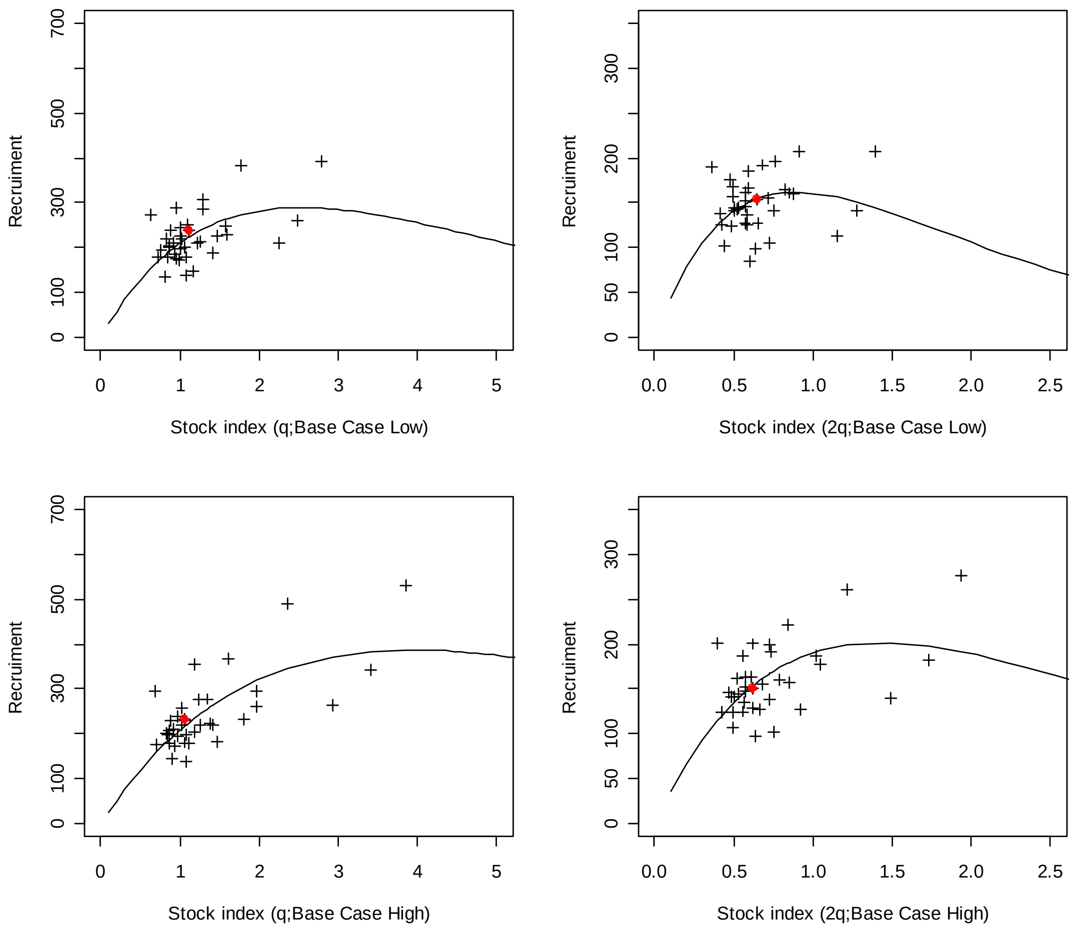

Figure 9: Estimated annual spawners that produce recruits, fitted as a stock recruitment relationship for ***grooved tiger*** *prawn. Top row) the Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) the Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right. The red/solid spot indicates the 2005 spawning index and resultant 2005/2006 recruitment value.*

From the stock-recruitment relationships, the long-term equilibrium (sustainable) yield was estimated for different levels of effective effort. The estimated maximum sustainable yield and its corresponding effective effort are shown in Figure 10. The squares indicate the positions of the 2006 catch and effective effort. For grooved tiger prawn species, standardised effort levels are below the E_{MSY} in all the four scenarios.

It is important to note that the new Dichmont *et al.* (2003) model calculates the indicators taking into consideration the age at which the animals are caught. Effort is assumed to be distributed using the average effort pattern from 1997 to 2006.

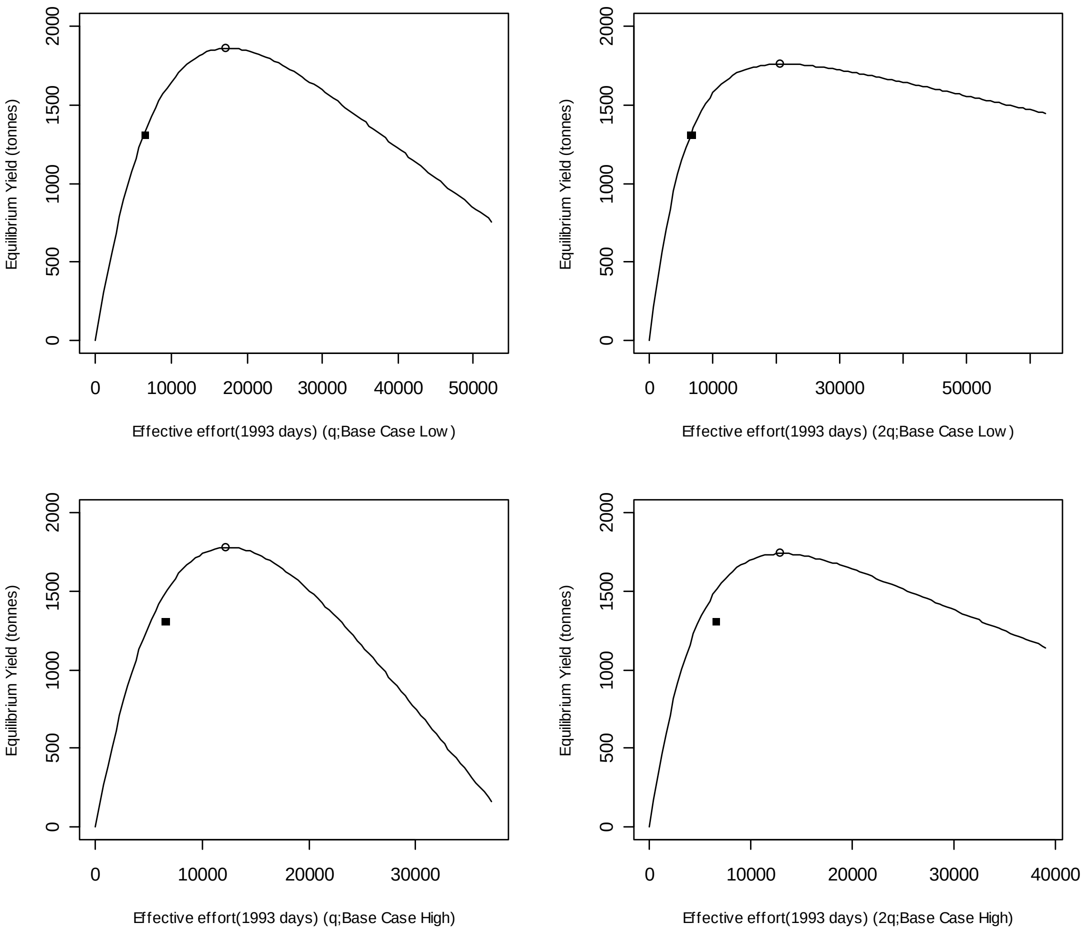

Figure 10: Equilibrium yield and effective effort for ***grooved tiger*** *prawn. Top row) the Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) the Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right.*

Steepness is an indicator of resource productivity. Its estimated value suggests that grooved tiger pawn stock has a low or medium productivity, depending on the catchability assumption and the fishing power series used (Table 5 and Table 7 in Appendix A). Equilibrium yield levels for a particular effort are shown in Figure 10.

For both Base Case Low and Base Case High fishing power series and both catchability assumptions, the median effective fishing effort in 2006 was only 36-63% of E_{MSY} (Figure 11).

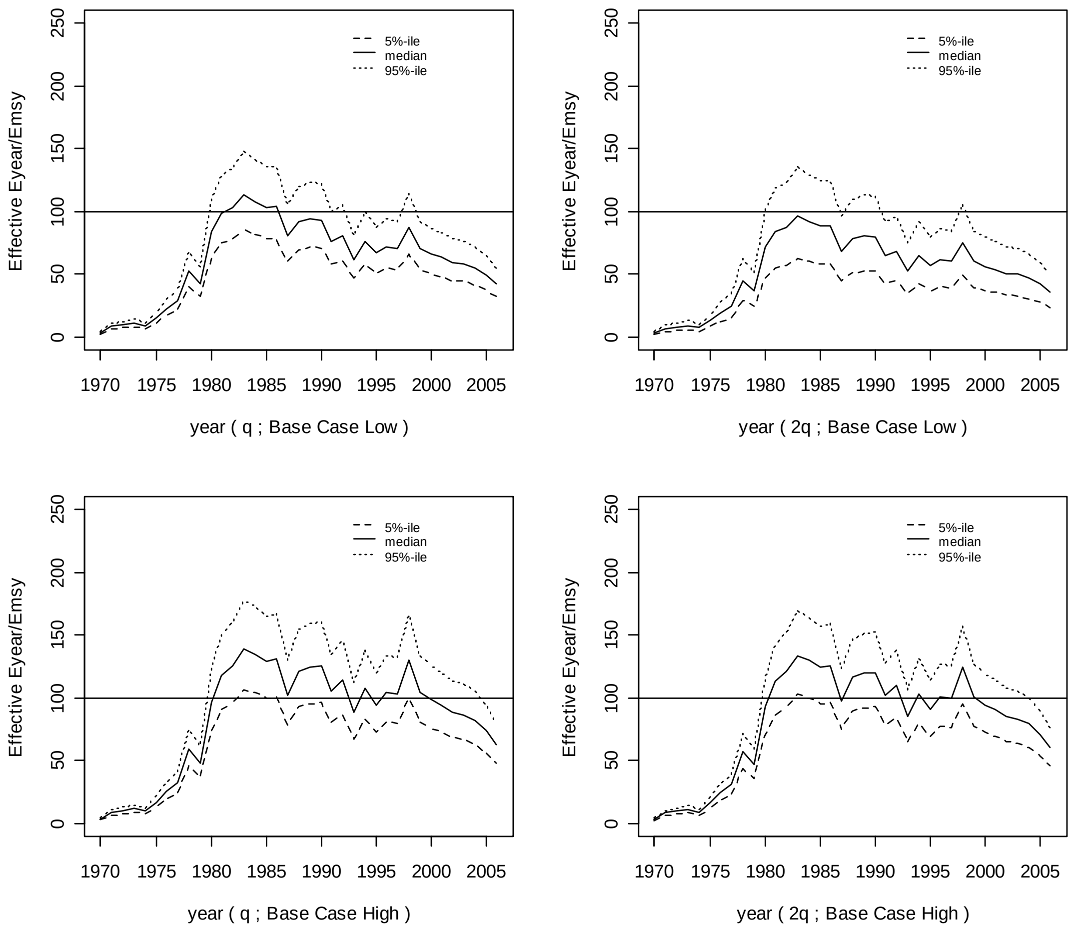

Figure 11: Effective fishing effort for ***grooved tiger*** *prawn. Top row) the Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) the Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right relative to the effort that would, on average, produce the Maximum Sustainable Yield (E_{MSY}). Confidence intervals in the estimate of E_{MSY} are reflected. Points greater than 100% show years in which the effort levels are greater than the limit reference point, E_{MSY}.*

For both Base Case low/high and both catchability assumptions the spawning stock biomass for grooved tiger prawns in 2006 (S_{2006}) was always above S_{MSY} (Figure 12), with differences from 11-48%.

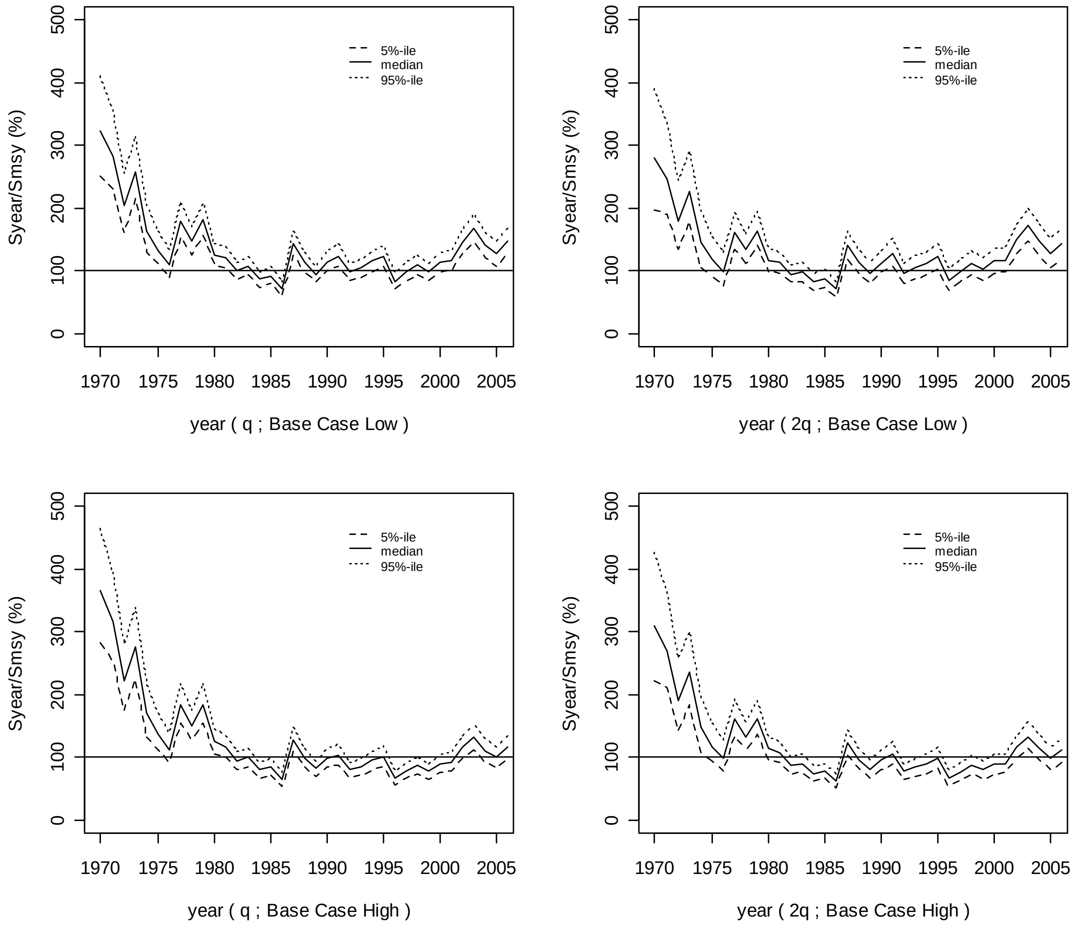

*Figure 12: Median spawning stock biomass ratio (with 5 and 95 percentiles) for **grooved tiger** prawns. Top row) the Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) the Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right showing spawning stock size in a year relative to the Spawner stock size at which the Maximum Sustainable Yield (S_{MSY}) is achieved. Points less than 100% are deemed over-exploited as they are below the target reference point.*

5.3 BROWN TIGER PRAWNS

5.3.1 RECRUITMENT AND SPAWNING STOCK

The estimated brown tiger prawn annual recruitment for the "Base Case Low" and that for "Base Case High" are shown in Figure 13. Recruitment increased in 2006 in all the four scenarios.

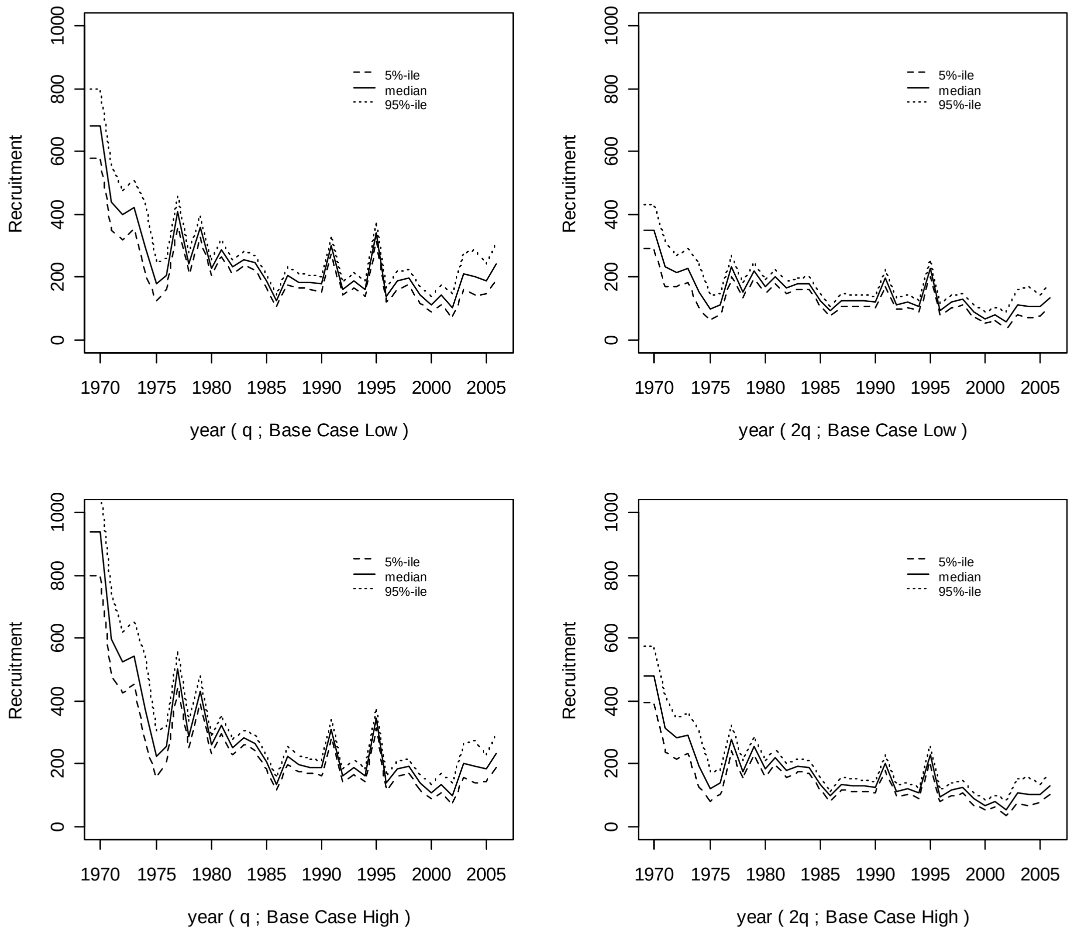

*Figure 13: Median recruitment index (with 5 and 95 percentiles) for **brown tiger** prawns Top row) Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right. Confidence intervals in the recruitment estimates are reflected.*

Spawning stock biomass indices for the year represent the relative number of female prawns in spawning condition during the calendar year. The "Base Case Low" spawning indices and the "Base Case High" spawning indices for the two catchability assumptions for brown tiger prawns with the associated confidence intervals are given in Figure 14. The spawning stock index of brown tiger prawns also increased from the 2005 level.

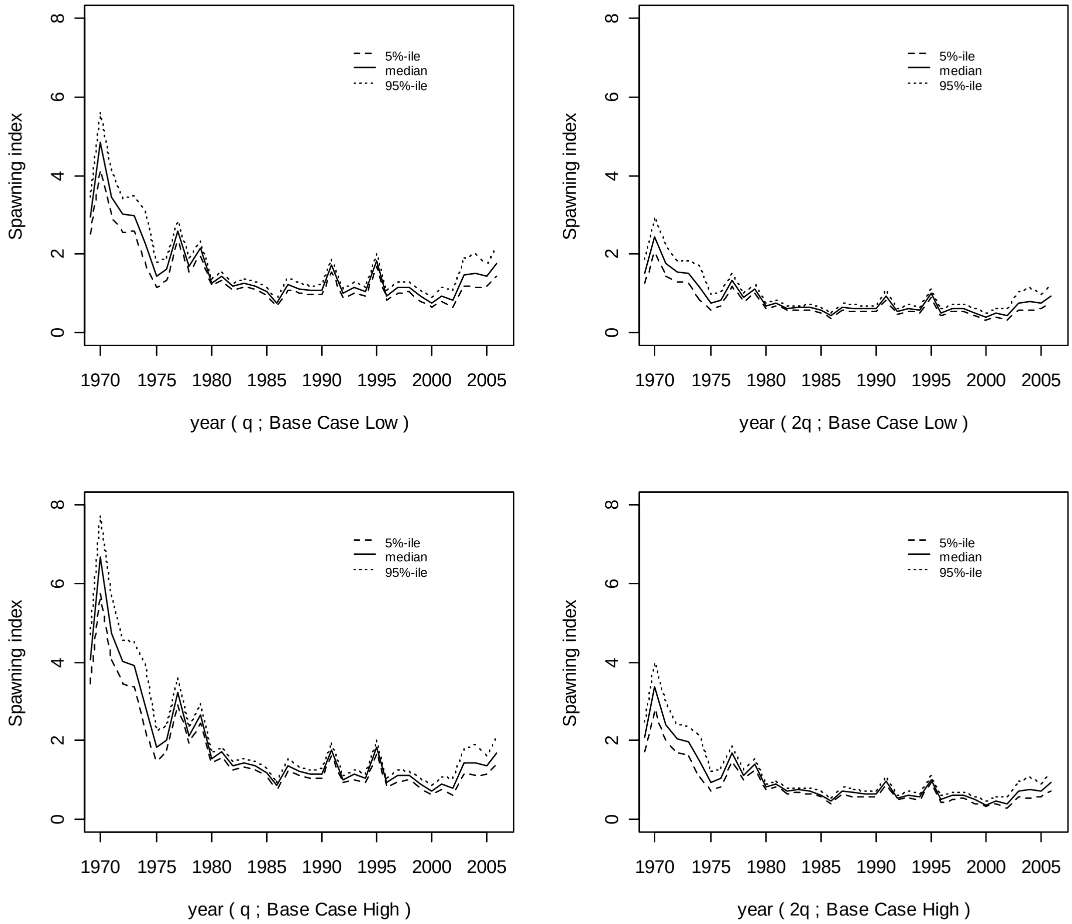

Figure 14: Median spawning stock biomass indices (with 5 and 95 percentiles) for ***brown tiger*** *prawns Top row) the Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) the Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right. Confidence intervals in the spawning values are reflected.*

5.3.2 MANAGEMENT AND OTHER OUTPUTS

The management and other quantities reported below are derived from the stock-recruitment function, which relates the recruits that would be produced in the subsequent biological year with the spawners of the previous calendar year (Figure 15). The 2005 stock index that resulted in the 2005/2006 recruitment is highlighted on the graphs.

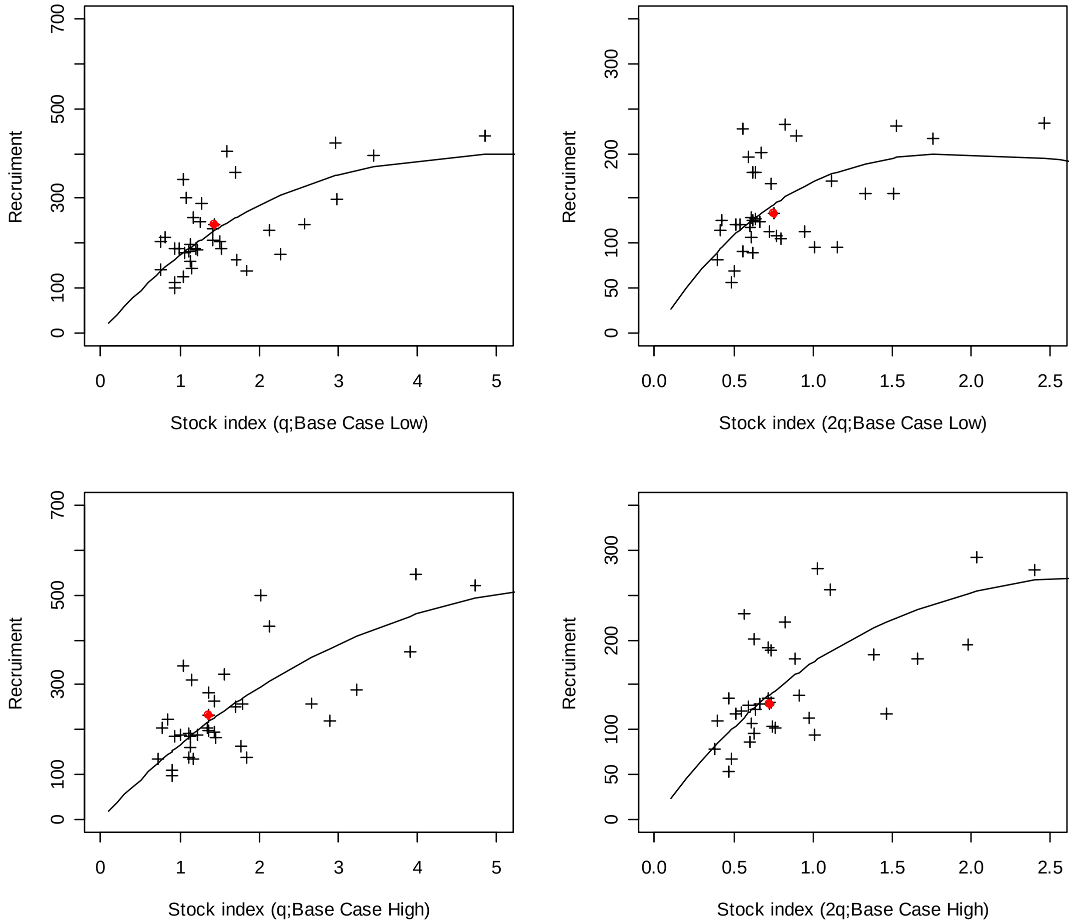

Figure 15: Estimated annual spawning stock biomass index that produce recruits, fitted as a stock recruitment relationship for ***brown tiger*** *prawn. Top row) the Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) the Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right. The red/solid spot indicates the 2005 spawning index and resultant 2005/2006 recruitment value.*

From the stock-recruitment relationships, the long-term equilibrium (sustainable) yield was estimated for different levels of effective effort. The estimated maximum sustainable yield and effective effort at the maximum sustainable yield are shown in Figure 16. The position of the 2006 catch and effective effort is also shown. For brown tiger prawn species, standardised effort levels are lower than the E_{MSY} equilibrium levels.

It is important to note that the Dichmont *et al.* (2003) model calculates the indicators taking into consideration the age at which the animals are caught. Effort is assumed to be distributed using the average effort pattern from 1997 to 2006.

The steepness values estimated suggest the resource has a low or medium productivity depending on the catchability assumption or fishing power series used (Table 6 and Table 8 in Appendix A).

In all the four scenarios tested, Base Case runs, the effective fishing effort in 2006 was very low, only 16-55% of E_{MSY} (Figure 17). For Base Case Low and both catchability assumptions the spawning stock biomass for brown tiger prawns in 2006 (S_{2006}) was above $S_{MSY.}$ For Base Case High, the spawning stock was slightly above S_{MSY} if one catchability was used, but slightly lower than S_{MSY} when catchability assumed a value twice that of Wang (1999, Figure 18).

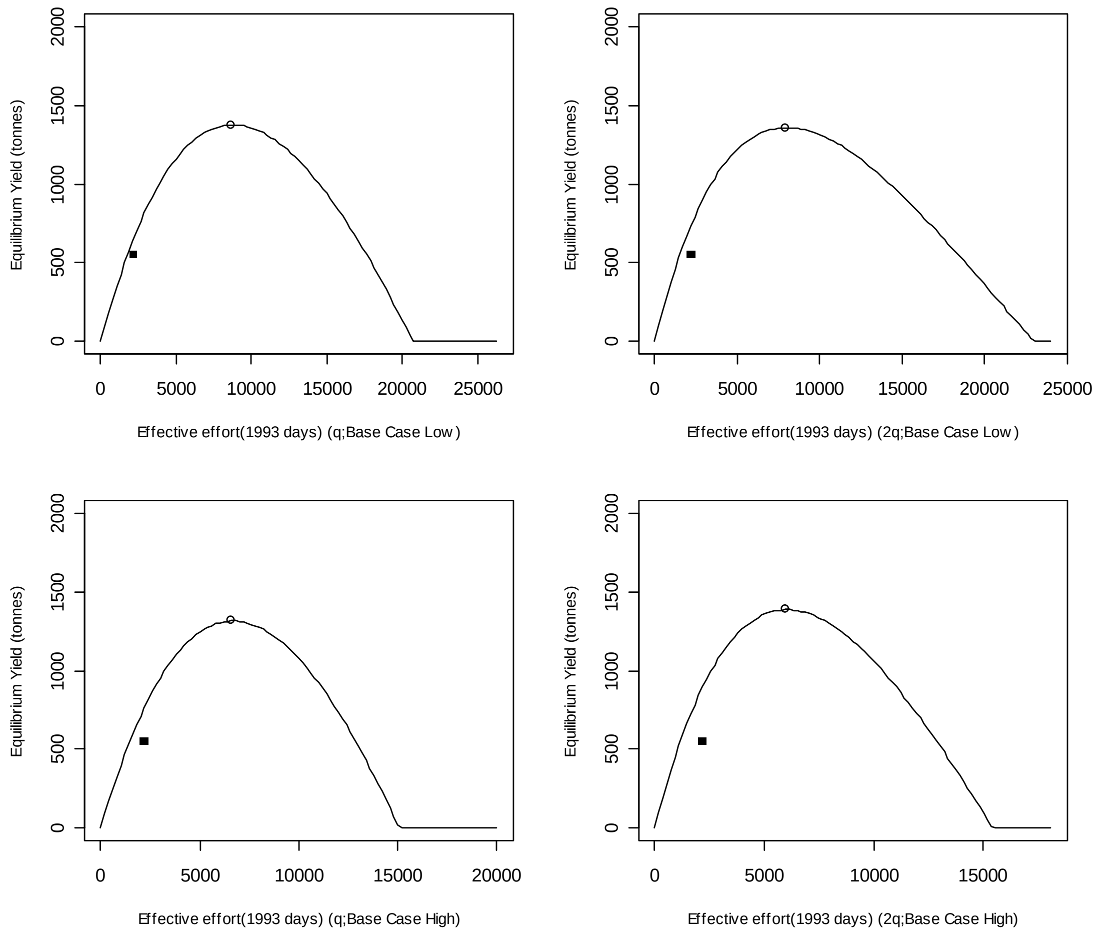

*Figure 16: Equilibrium yield and effective effort for **brown tiger** prawn. Top row) the Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) the Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right.*

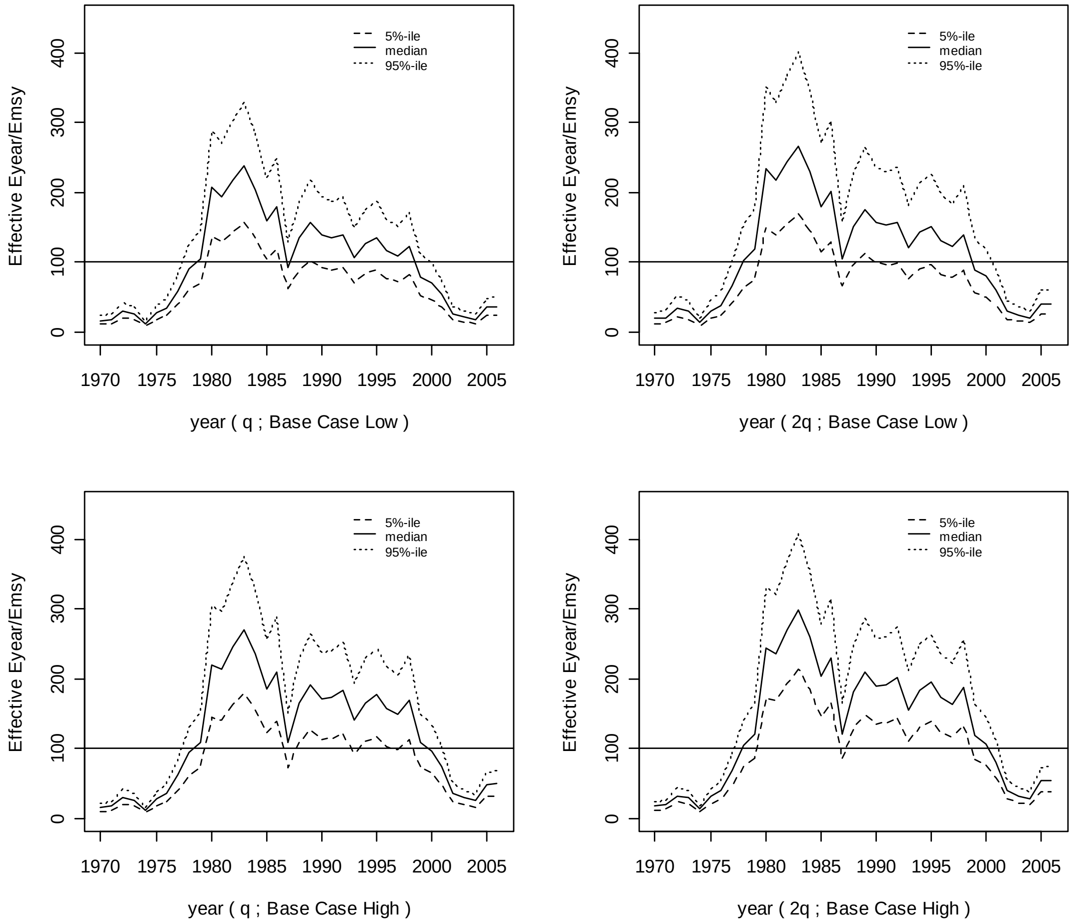

*Figure 17: Effective fishing effort for **brown tiger** prawn. Top row) the Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) the Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right relative to the effort that would, on average, produce the Maximum Sustainable Yield (E_{MSY}). Confidence intervals in the estimate of E_{MSY} are reflected. Points greater than 100% show years in which the effort levels are greater than the limit reference point, E_{MSY}.*

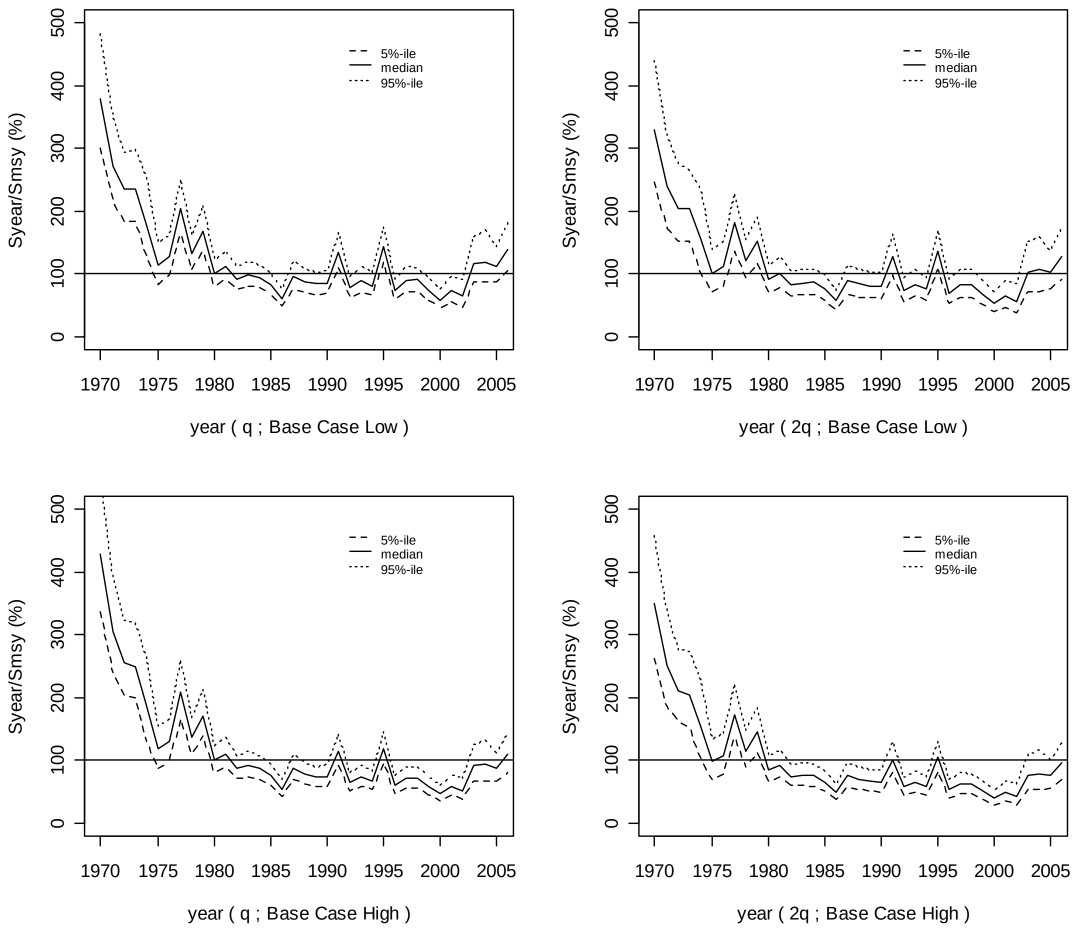

Figure 18: Median spawning stock biomass ratio (with 5 and 95 percentiles) for ***brown tiger*** *prawns. Top row) the Base Case Low fishing power series with catchability at Wang (1999) levels on left and twice those on the right; and Bottom row) the Base Case High fishing power series with catchability at Wang (1999) levels on left and twice those on the right showing spawning stock size in a year relative to the Spawning stock size at which the Maximum Sustainable Yield (S_{MSY}) is achieved. Points less than 100% are deemed over-exploited as they are below the target reference point.*

5.4 SENSITIVITY TESTS FOR BOTH TIGER PRAWN SPECIES

Management indicators and their confidence intervals estimated based on the four scenarios are presented in Table 7 and Table 8 in Appendix A and summarised in Figure 19. However, a further run was undertaken as a sensitivity test which includes some spatial changes within the fishing power series. The sensitivity test is using a fishing power series (“Spatial High”) with both catchability assumptions.

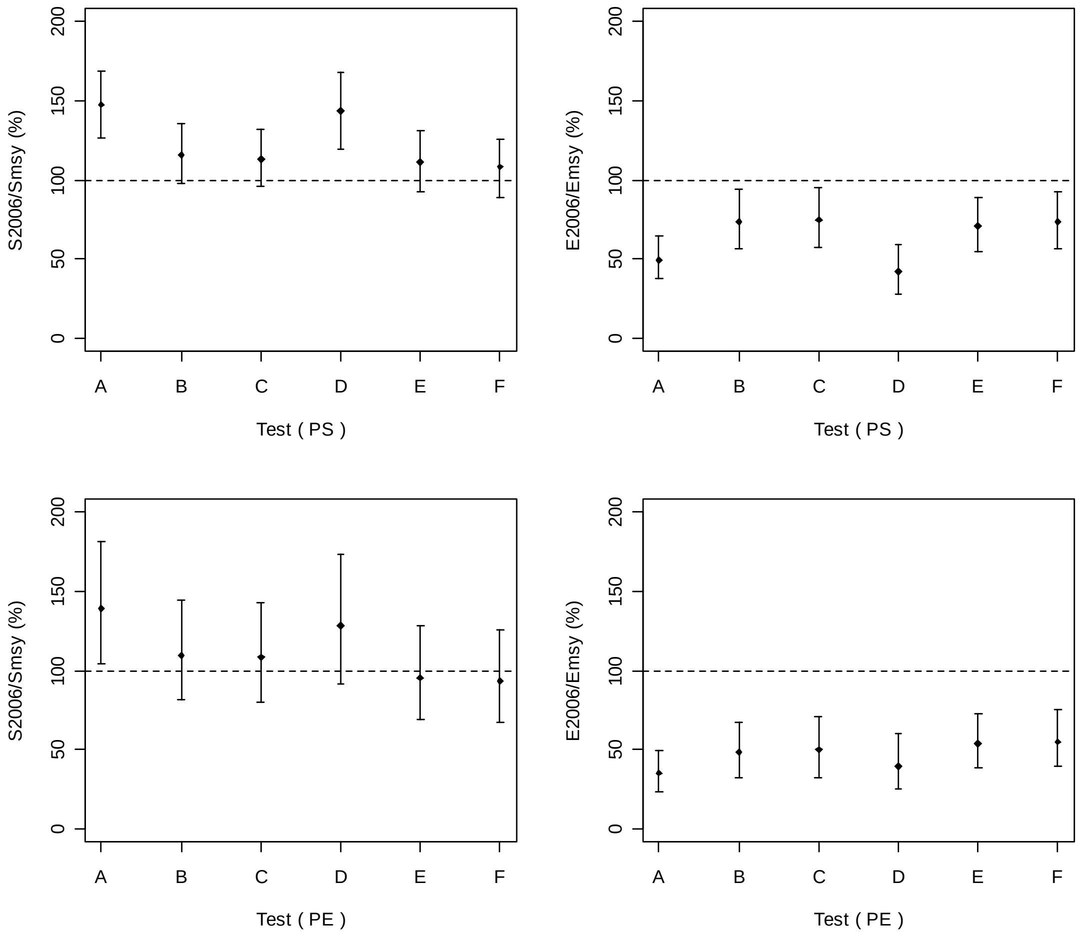

Figure 19: Sensitivity tests of the spawning stock size in year 2006 relative to the Spawning stock size at the Maximum Sustainable Yield and effort in year 2006 relative to E_{MSY} for top row) ***grooved (PS)*** *and bottom row)* ***brown tiger (PE)*** *prawns (median values with 5 and 95 percentiles).*

Test A: *Base Case Low fishing power, q;*
Test B: *Base Case High fishing power, q*
Test C: *Spatial High fishing power, q*
Test D: *Base Case Low fishing power, 2q*
Test E: *Base Case High fishing power, 2q*
Test F: *Spatial High fishing power, 2q*

The main difference between the “q” and “2q” runs lies in the estimate of steepness – much higher when “2q” is used (Table 7 and Table 8). This means that the resource with the “2q” assumption is more productive. The most optimistic estimates of spawning stock size occurred when fishing power was set at Basic Low.

Not included in the tests, but equally important, are incorporation of a stock structure, the possibility of hyperstability in the biomass index, and changes in fishing power from 2005 and 2006. Discussions of some of these are given in Dichmont *et al.* (2001) and Dichmont *et al.* (2006). It is important to note that the tests shown here therefore do not provide all possible combinations of the management values, but rather highlights the model’s sensitivity to certain assumptions.

It should be noted that the assessment lacks fishery independent data sources. The whole assessment relies on logbook data to determine fishing mortality, catchability and fishing power. This process results in serious modelling confounding. An independent data source such as the survey data is being undertaken and, if continued, would greatly benefit the assessment in the medium or long-term.

6 CONCLUSION

The Dichmont *et al.* (2003) model was applied to logbook data from 1970 to 2006. Three fishing power series were used in the assessment with different degrees of precaution and spatial complexity. Furthermore, following the recommendation of Deriso’s (2001) review of the tiger prawn assessment, the catchability value reported in Wang (1999) and twice that value were used in the assessment. Selecting between these fishing power and catchability assumptions could only be resolved by long-term fishery independent data, which at present is not available. From different runs we conclude:

1. The model parameter estimates are sensitive to both the fishing power and the catchability assumption, but the management objectives are mostly only affected by fishing power. Recruitment in 2006 for both tiger species was estimated as being higher than that in 2005.

2. In most tests, for both tiger prawns, the conclusions are sensitive to the fishing power series used. The most conservative estimates of spawning stock size occurred when fishing power was set at “Basic High” and “Spatial High”. However, the spawning stock in 2006 for grooved tiger pawns was estimated as being higher than S_{MSY} in all the four scenarios and that for brown tiger prawns above S_{MSY} in three out of the four scenarios.

3. These conclusions are based on the species-specific catch and effort data produced by the species split model in Venables et al (2006).

7 REFERENCES

AFMA (1995). Future management of the northern tiger prawn fishery. Possible management strategies and needs. Proceedings and conclusions of the Workshop held in Cairns on the 7 of February 1994. AFMA, Canberra.

CSIRO (1993). Responses to biological uncertainties in the Northern Prawn Fishery. CSIRO Division of Fisheries, Cleveland Australia, unpublished manuscript.

Deriso, R. 2001. A Review of the 2001 Assessment of Tiger Prawns in the Northern Prawn Fishery. Report to NORMAC 51.

Dichmont, C.M., Deng, A.R., Venables, W., Punt, A.E., Haddon, M. and Tattersall, K. 2005. A new approach to assessment in the NPF: spatial models in a management strategy environment that includes uncertainty. FRDC 2001/002. 165 pp.

Dichmont, C.M, Punt, A.E, Deng, A, Dell, Q and Venables, W. 2003. Application of a weekly delay-difference model to commercial catch and effort data for tiger prawns in Australia's Northern Prawn Fishery. *Fisheries Research*. 65: 335-350.

Dichmont, C.M., Die, D., Punt, A.E., Venables, W., Bishop, J., Deng, A. and Dell, Q. 2001. Risk analysis and sustainability indicators for prawn stocks in the Northern Prawn Fishery. FRDC 96/109. 187 pp.

Venables, W. N., Kenyon, R. A., Bishop, J. F. B., Dichmont, C. M., Deng, R. A., Burridge, C. Y., Taylor, B. R., Donovan, A G.., Thomas, S. E., Cheers, S. J. (2006) Species Distribution and Catch Allocation: data and methods for the NPF,2002-2004.

Wang, Y. and Die, D.J. (1996). Stock-recruitment relationships for the tiger prawns (*Penaeus esculentus* and *Penaeus semisulcatus*) in the Australian Northern Prawn Fishery. Marine and Freshwater research. 47, 87-95.

Wang, Y.-G. (1999) A Maximum-likelihood method for estimating natural mortality and catchability coefficient from catch-and-effort data. *Australian Journal of Marine and Freshwater Research* **50**, 307-11.

8 ACKNOWLEDGEMENTS

Thanks to Janet Bishop for providing fishing power data and the logbook data in the required format. The NPRAG established the Base Case and sensitivity test criteria. The updated fishing power series was provided by the fishing power project team of Janet Bishop and Dave Sterling. Work could not have been possible without the industry providing their data and AFMA managing and providing it to CSIRO. The assessment was funded from the NPRAG funds by the AFMA Research Fund and industry.

9 APPENDIX A: SUMMARY TABLES

Table 5: ***Results of relevant management measures and parameter estimates for grooved tiger prawns for the "Base Case Low" and the "Base Case High". E_{MSY} is the effort level (expressed in terms of 1993 days) at which MSY is achieved and S_{MSY} is the spawner stock index at which the (deterministic) MSY is achieved. Figures in brackets are the 5 and 95 percentiles.***

Fishing power	**Base Case Low**		**Base Case High**	
Catchability value	**q**	**2q**	**q**	**2q**
Steepness	0.356 0.326 - 0.393	0.509 0.449 - 0.58	0.315 0.294 - 0.341	0.418 0.383 - 0.459
S_{2006}/S_{MSY} (%)	148 127 - 169	144 119 - 168	116 98 - 135	111 92 - 131
MSY (tonnes)	1840 1620 - 2104	1765 1602 - 1919	1768 1517 - 2043	1730 1564 - 1910
E_{MSY} (1993 days)	16053 12284 - 21169	18833 13383 - 28743	11334 8878 - 14756	11787 9337 - 15338
Effective E_{2006}/E_{MSY} (%)	42 32 - 55	36 24 - 51	63 48 - 80	60 46 - 76
S_{MSY}	0.872 0.779 - 0.981	0.509 0.456 - 0.566	1.068 0.936 - 1.231	0.637 0.566 - 0.721
Frequency S_{2006} fell below S_{MSY} (%)	0	0	5.2	13.4

Table 6: ***Results of relevant management measures and parameter estimates for brown tiger prawns for the "Base Case Low" and the "Base Case High". E_{MSY} is the effort level (expressed in terms of 1993 days) at which MSY is achieved and S_{MSY} is the spawner stock index at which the (deterministic) MSY is achieved. Figures in brackets are the 5 and 95 percentiles.***

Fishing power	**Base Case Low**		**Base Case High**	
Catchability value	**q**	**2q**	**q**	**2q**
Steepness	0.297 0.274 - 0.339	0.374 0.331 - 0.45	0.273 0.255 - 0.306	0.333 0.304 - 0.378
S_{2006}/S_{MSY} (%)	139 104 - 182	128 91 - 173	110 81 - 144	96 69 - 128
MSY (tonnes)	1407 1140 - 1814	1393 1148 - 1687	1344 1046 - 1796	1417 1157 - 1742
E_{MSY} (1993 days)	7605 5470 - 11475	6752 4490 - 10636	5789 4188 - 8760	5251 3855 - 7363
Effective E_{2006}/E_{MSY} (%)	36 24 - 50	41 26 - 61	50 33 - 69	55 39 - 75
S_{MSY}	1.274 1.047 - 1.53	0.738 0.598 - 0.939	1.555 1.259 - 1.909	0.964 0.765 - 1.21
Frequency S_{2006} fell below S_{MSY} (%)	2.2	10.4	24.4	55.8

Table 7: ***Sensitivity tests of median management quantities and other outputs for grooved tiger prawns. Values in brackets are 5 and 95 percentiles). E_{MSY} is the effort level (expressed in terms of 1993 days) at which MSY is achieved and S_{MSY} is the spawner stock index at which the (deterministic) MSY is achieved. Figures in brackets are the 5 and 95 percentiles.***

Model	**Basic Low fishing power**	**Basic High fishing power**	**Spatial High fishing power**	**Basic Low fishing power**	**Basic High fishing power**	**Spatial High fishing power**
Catchability	q	q	q	2q	2q	2q
Steepness	0.356	0.315	0.308	0.509	0.418	0.403
	148	116	113	144	111	108
S_{2006}/Smsy(%)	1840	1768	1773	1765	1730	1738
	16053	11334	10598	18833	11787	10827
MSY(tonnes)	0.356	0.315	0.308	0.509	0.418	0.403
	148	116	113	144	111	108
Emsy(1993 days)	1840	1768	1773	1765	1730	1738
Effective E_{2006}/Emsy(%)	42	63	64	36	60	63
Smsy	0.872	1.068	1.127	0.509	0.637	0.673

Table 8: ***Sensitivity tests of median management quantities and other outputs for brown tiger prawns. Values in brackets are 5 and 95 percentiles). E_{MSY} is the effort level (expressed in terms of 1993 days) at which MSY is achieved and S_{MSY} is the spawner stock index at which the (deterministic) MSY is achieved. Figures in brackets are the 5 and 95 percentiles.***

Model	Basic Low fishing power	Basic High fishing power	Spatial High fishing power	Basic Low fishing power	Basic High fishing power	Spatial High fishing power
Catchability	q	q	q	2q	2q	2q
steepness	0.297	0.273	0.268	0.374	0.333	0.324
	139	110	108	128	96	93
S_{2006}/Smsy(%)	1407	1344	1316	1393	1417	1405
	7605	5789	5384	6752	5251	4867
MSY(tonnes)	0.297	0.273	0.268	0.374	0.333	0.324
	139	110	108	128	96	93
Emsy(1993 days)	1407	1344	1316	1393	1417	1405
Effective E_{2006}/Emsy(%)	36	50	51	41	55	57
Smsy	1.274	1.555	1.628	0.738	0.964	1.021