UPDATED TIGER PRAWN STOCK ASSESSMENT FOR THE TORRES STRAIT PRAWN FISHERY

A Final Report to AFMA for the TSPMAC and TSSAC

Project: 180802

May 2019

Clive Turnbull

Fisheries Consultant

Executive Summary

1. The twenty-one past and present owners of the 30 vessels that have done the majority of the fishing in the TSPF since the 2004 tiger prawn stock assessment were surveyed to collect information on any changes to the vessel and fishing configuration that could have impacted on fishing power. The new data was merged with the data collected on TSPF vessels for the 2004 assessment and used to estimate the trend in fishing power for the years 1980-2018. The new fishing power model was based on the 2004 model but included the additional factors; headline length, vessel size (hull units) and whether or not the vessel was licensed to fish in the Northern Prawn Fishery. These factors were all significant and helped improve the fit of the fishing power model.

2. The updated fishing power analysis resulted in a trend similar to that of the 2004 assessment for the years 1980-2001. The 4% decrease in fishing power suggested by David Die to allow for the 10% reduction in headline length during 2002-03 compares well with the fishing power estimated for those years. The trend in the fleet fishing power since 2004 was relatively flat and the fishing power of the current fleet is similar to that of the vessels fishing during 2000 & 2001.

3. There is only a small difference between the 2004 and 2019 assessments in the parameter estimates for the Beverton-Holt and Ricker Spawner Recruitment Curves. The largest change occurred in the Beverton-Holt curve which is now almost the same as the Ricker curve. This change could be a result of the additional data for high levels of spawners and recruitment that occurred post 2005.

4. The median MSY estimated using the Beverton-Holt Spawner-Recruitment curve decreased from 676 tonnes to 617 tonnes bringing it closer to the Ricker estimate which was 606 tonne for both assessments. The 2019 MSY 95% Confidence Intervals are closer to the median for both Spawner-Recruitment curves than the estimates from the 2004 assessment.

5. The estimates of Emsy for the 2004 assessment were calculated by dividing MSY by the standardised CPUE for 2003 (73.5 kg/d). Using recent CPUE to calculate Emsy as 2018 fishing days is problematic because it does not account for the higher CPUE resulting from the large stock size and the inverse relationship between CPUE and fishing effort. A sensitivity analysis suggests that a 5 year running average of the standardised tiger prawn CPUE may be the best option for smoothing over the annual variability in the Emsy estimates.

6. Post 2008 the annual tiger prawn harvest has been well below the estimates of MSY and the tiger prawn biomass, at 60-88% of Bvirgin, has been well above Bmsy. As a result the post 2008 annual CPUE has been approximately twice that of the years 1991-2003. There are no reasons for concern regarding the stock size and sustainability.

7. The harvest strategy triggers are reviewed and discussed in relation to the updated estimates of MSY, Emsy, Bmsy and the stock biomass. The 680 tonne tiger prawn catch trigger is appropriate but should be separated from the 4,000 day effort trigger as it is consecutive years of harvest levels above MSY that will impact the tiger prawn stock biomass. The purpose of the effort trigger needs to be discussed by the TSPMAC as the estimates of Emsy are highly variable and sensitive to the CPUE that is used to calculate Emsy. The effort trigger could be regarded as an Emey limit reference point as fishing effort above this level is more likely to just reduce the profitability of fishing than be a risk to the stock sustainability.

Introduction

This update of the Torres Strait Prawn Fishery (TSPF) tiger prawn stock assessment was requested by AFMA to determine the current status of the tiger prawn stock and whether the current harvest strategy trigger points are set at levels that should ensure a long term sustainable tiger prawn harvest. Lower tiger prawn catch rates combined with low fishing effort in 2016 and especially 2017 raised concern as to the status of the tiger prawn stock.

In addition, the 2015 tiger prawn catch was 553 tonnes, which is 82% of the Maximum Sustainable Yield (MSY) estimate from the 2004 assessment, while the fishing effort was just under 3,000 days. This raised concerns about the current Emsy cap. The stock assessment on which the current management arrangements and trigger points are based was conducted in 2004 (O'Neill and Turnbull, 2006) and hence an update to re-evaluate the status of this stock was considered timely.

Objectives / performance indicators

1. Update the fishing power for the Torres Strait tiger prawn fishery to account for changes that may have occurred in fishing power of the TSP fleet since the 2004 assessment.

2. Use the updated fishing power to standardise the nominal (unadjusted) monthly tiger prawn Catch Per Unit of Effort (CPUE) from logbook data for the years 1980-2018 to provide a more effective measure or index of tiger prawn abundance.

3. Use the Deriso-Schnute delay-difference model from the 2004 assessment to re-estimate MSY, Bmsy, Emsy and Bt:Bvirgin by fitting the model to the time-series of catch and standardised tiger prawn CPUE data from January 1980 to December 2018.

Outputs

A final report to AFMA for TSPMAC and TSSAC detailing the stock assessment model estimates of MSY, Bmsy, Emsy and the current biomass relative to the estimate of the virgin biomass (Bt:Bvirgin). Based on this information recommend levels of MSY and Emsy for use in the harvest strategy trigger points and the reasoning for the suggested levels.

Methods

The mythology used in this update of the TSPF tiger prawn stock assessment was based on those detailed in (O'Neill and Turnbull, 2006). The tiger prawn stock assessment was updated using the same Deriso-Schnute delay-difference model, coded in the statistical program "MATLAB" that was used for the 2004 assessment. Most of the data processing, fishing power analysis, standardisation of CPUE and the plotting of results were conducted in the statistical programming language "R".

The twenty-one past and present owners of the 30 vessels that have done the majority of the fishing in the TSPF since the 2004 tiger prawn stock assessment were surveyed to collect information on any changes to the vessel and fishing configuration that could have impacted on fishing power. The owners were initially contacted by email to; explain the purpose of the survey, list the information that was being sought and to arrange a suitable time to telephone or meet with them to work through the survey questions. Although a few of the owners were met in person in Cairns, most of the contact was via mobile telephone. The new data was merged with the data collected on TSPF vessels for the 2004 assessment.

The new fishing power model was based on the 2004 model but included the additional factors; headline length, vessel size (hull units) and whether or not the vessel was licensed to fish in the Northern Prawn Fishery. These factors were all significant and helped improve the fit of the fishing power model. The non-vessel factors in the model account for the effects of; year, month, area (north and south 10 degrees latitude, the East of Warrior closure and the Australian Territorial waters north of the fisheries Jurisdiction line), full v's part-night of fishing and lunar phase. The vessel / fishing gear factors that were used in the 2004 assessment and that were also included in this assessment were; engine horsepower, propeller nozzle, gps, computer mapping, BRD and/or TED, net type (double, triple, quad), otter boards (flat, bison, louvre/kilfoil).

The fishing power trend was used to standardise the nominal (unadjusted) monthly tiger prawn Catch Per Unit of Effort (CPUE) from logbook data for the years 1980-2018 resulting in a more effective measure or index of tiger prawn abundance. The standardised CPUE and monthly tiger prawn harvest (catch) were inputs to the same delay-difference model that was used for the 2004 assessment. The model parameters that were estimated were the tiger prawn catchability coefficient (the relationship between biomass and fishing mortality), annual recruitment for the years 1980-2018 and the two parameters for the function used to describe the monthly recruitment pattern. This was achieved by minimising the difference between the "predicted" CPUE generated by the model and the standardised "observed" CPUE from logbook data. The Beverton-Holt and Ricker Spawner-Recruitment equations were then fitted to the annual spawner and recruitment stock numbers generated by the tiger prawn model.

Finally the management reference points; Maximum Sustainable Yield (MSY), the tiger prawn Biomass needed for MSY (Bmsy), the current size of the tiger prawn stock in relation to the estimate of the virgin biomass (Bt:Bvirgin) and the fishing Effort in days that would result in a harvest of MSY (Emsy) were estimated using the same MATLAB code as that used for the 2004 assessment.

Results

Survey coverage

Figure 1 is a plot of the proportion of daily vessel fishing records that linked to the combined vessel/gear information obtained from the 2000-02 and 2019 surveys. The coverage was 80-100 percent of the fishing effort post 2003; the highest for the whole time-series.

The 2019 owner survey, a 2001 copy of the Queensland fishing vessel table and the current version of the Queensland fishing vessel table, which is available online, were used to source size data (Hull units, length, breadth and draft) for most vessels that have ever fished in the TSPF. There were only a few vessels that fished the early years for which information could not be obtained.

Note that prior to 1989 logbooks were only compulsory for NPF endorsed vessels therefore the logbook data accounts for only 12-67% of the total fishing effort during 1980-1988.

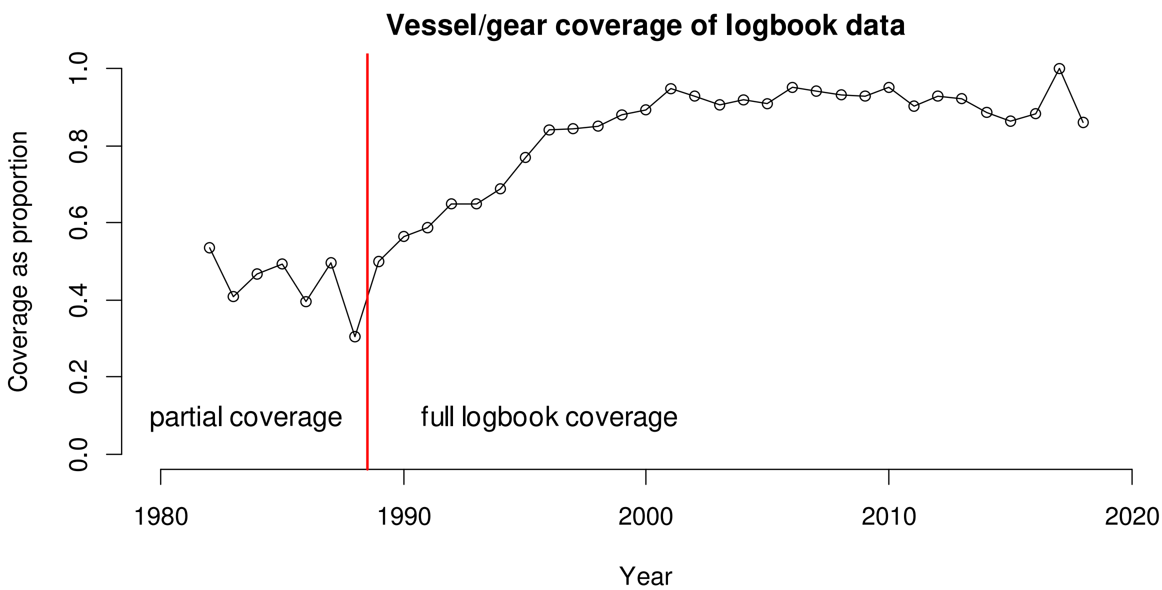

Figure 1 Vessel and fishing gear coverage of all logbook data as a proportion. Note that prior to 1989 logbooks were only compulsory for NPF endorsed vessels therefore the logbook data only accounts for 12-67% of the total fishing effort.

Fishing Power

The annual trend in fishing power from the 2019 analysis was very similar to that from the 2004 assessment for the years 1980-2001 (Figure 2). During 2002-03 there was a mandated 10% reduction in headline length that was implemented at the request of industry as a way to address sustainability. This was reversed at the end of 2003 by as it was a problem for both industry and enforcement when vessels were frequently moving between the Torres Strait and Queensland trawl fisheries and the benefits in terms of sustainability were marginal. Headline length was not a factor in the 2004 fishing power analysis because it was not significant. Most vessels in the initial gear survey had always used the maximum net size so there was insufficient information in the data to estimate the effect of headline length. Dr David Die in his review (Die 2003) suggested applying a 4% reduction in fishing power for 2002-03 to account for the 10% change in headline length.

Although the 10% reduction was reversed at the start of 2004 not all vessels immediately changed back to the larger net size. In addition, since the NPF restructure some vessels are using slightly smaller nets because they are restricted in the NPF on headline length and they use the same nets in both fisheries. This has allowed the fishing power model to now estimate the effect of headline length and the new fishing power trend closely matches the 4% reduction suggested by Dr Die.

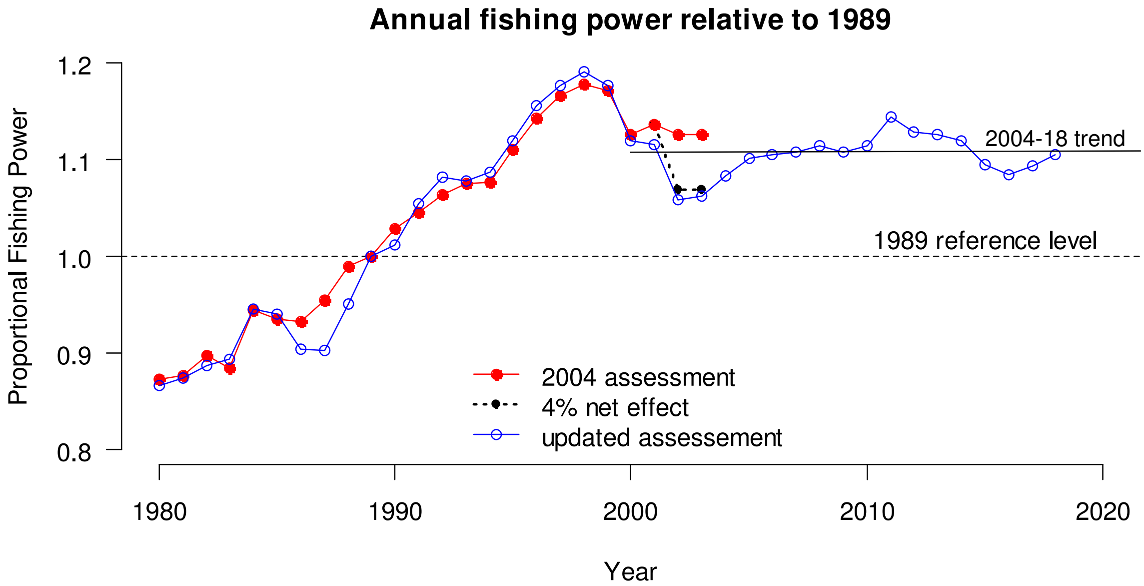

Figure 2 Annual fishing power estimates relative to 1989.

Although fishing power post 2003 has been variable due to which vessels and net configurations have done the majority of the fishing each year; the overall trend is horizontal (Figure 2). This indicates the average fleet fishing power has not increased therefore factors other than fishing power are responsible for the elevated tiger prawn CPUE post 2005.

Standardised CPUE

Figure 3 compares the nominal (unadjusted) tiger prawn CPUE obtained from the daily vessel logbook records with the standardised CPUE. The effect of fishing power can be seen as an elevation of the pre 1989 CPUEs and a down rating of the post 1989 CPUEs.

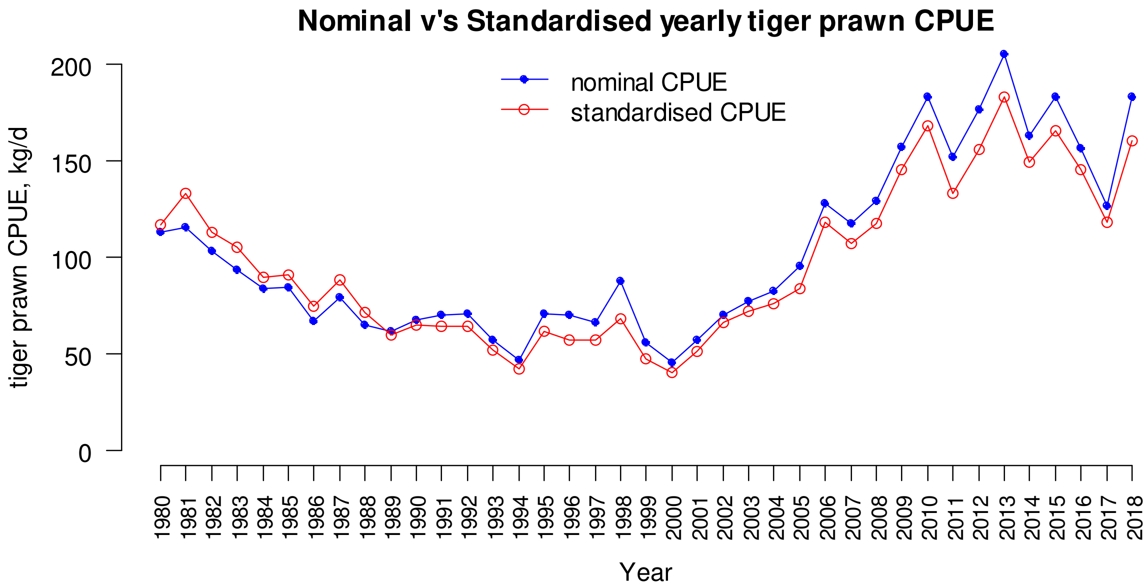

Figure 3 Comparison of annual nominal and standardised tiger prawn CPUE.

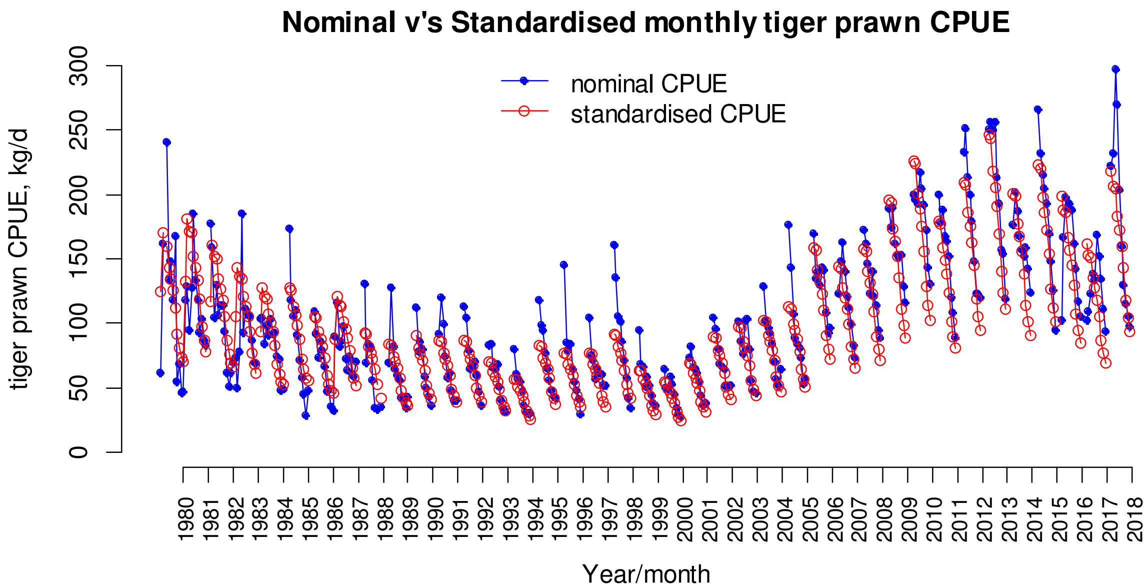

Figure 4 Comparison of the monthly nominal and standardised tiger prawn CPUE

In the monthly CPUE comparison (Figure 4) the drop in CPUE during the fishing season is clearly visible. This is a result of recruitment occurring in the early months of the season followed by a decrease in the tiger prawn biomass due to the combined effects of fishing and natural mortality. The annual CPUE trend in Figure 3 is also visible as the overall pattern of the monthly CPUE plotted in Figure 4.

Spawner-Recruitment Curves

There is only a small difference between the 2004 and 2019 assessments in the parameter estimates for the Beverton-Holt and Ricker Spawner Recruitment Curves (Table 1). The largest change occurred in the Beverton-Holt curve which is now almost the same as the Ricker curve within the range of the spawner index data (Figure 5). This change could be a result of the additional data for higher levels of spawners that occurred post 2005.

Table 1 Spawner-Recruitment relationship parameter estimates for the Beverton-Holt and Ricker curves.

Parameters	2004	2019	2004	2019
Spawner Recruit parameter	Beverton-Holt	Beverton-Holt	Ricker	Ricker
alpha	0.03296	0.0542	13.76	12.71
beta	1.32E-08	1.03E-08	7.89E-08	6.80E-08

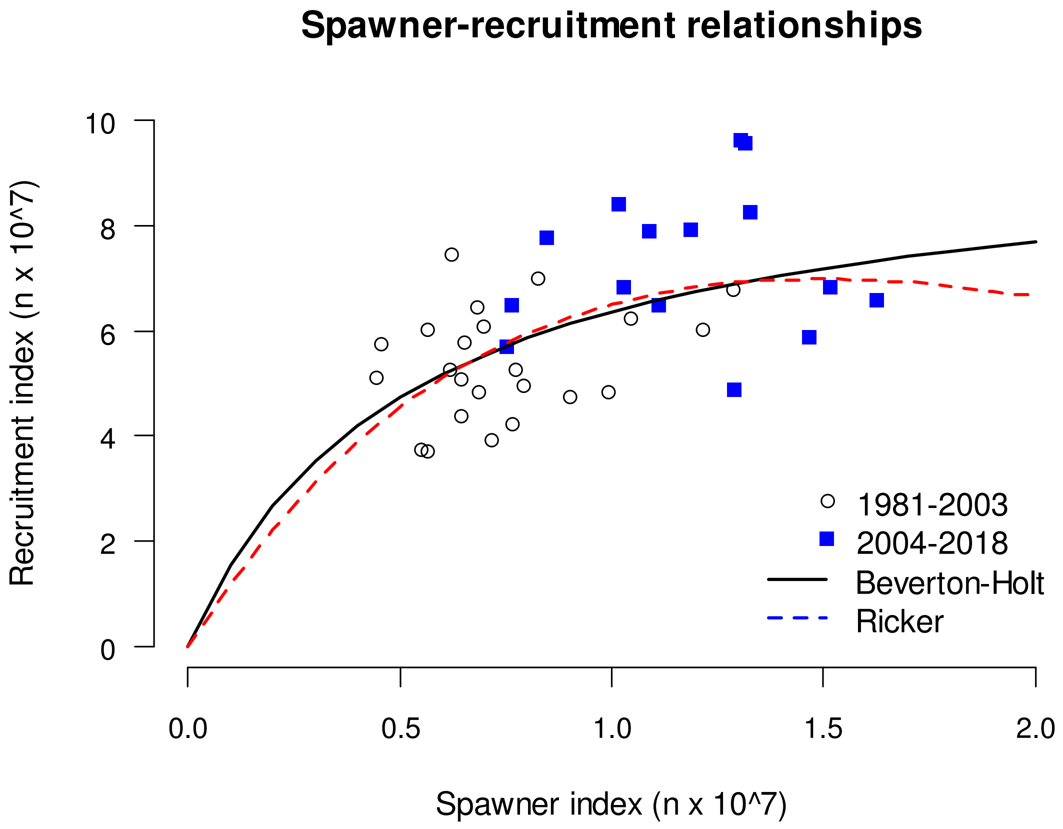

Figure 5 The Beverton-Holt and Ricker Spawner-Recruitment curves fitted to the annual spawner and recruitment stock numbers generated by the tiger prawn model for the years 1981-2003 (black open circles) and 2004-2018 (blue squares).

Biomass trajectory

The model estimates of the virgin biomass (Bvirgin), the Biomass at MSY (Bmsy) and Bmsy as a proportion of Bvirgin are listed in Table 2 for the Beverton-Holt and Ricker Spawner-Recruitment Curves (SRC). These were used to plots the biomass trajectories in Figure 6.

Table 2 The model estimates of B_{MSY}, B_0 in tonnes and B_{MSY} as proportion of B_0.

Spawner-Recruit Curve	Beverton-Holt	Ricker
B_0	1073	1044
B_{MSY}	346	415
$B_{MSY} : B_0$	0.323	0.397

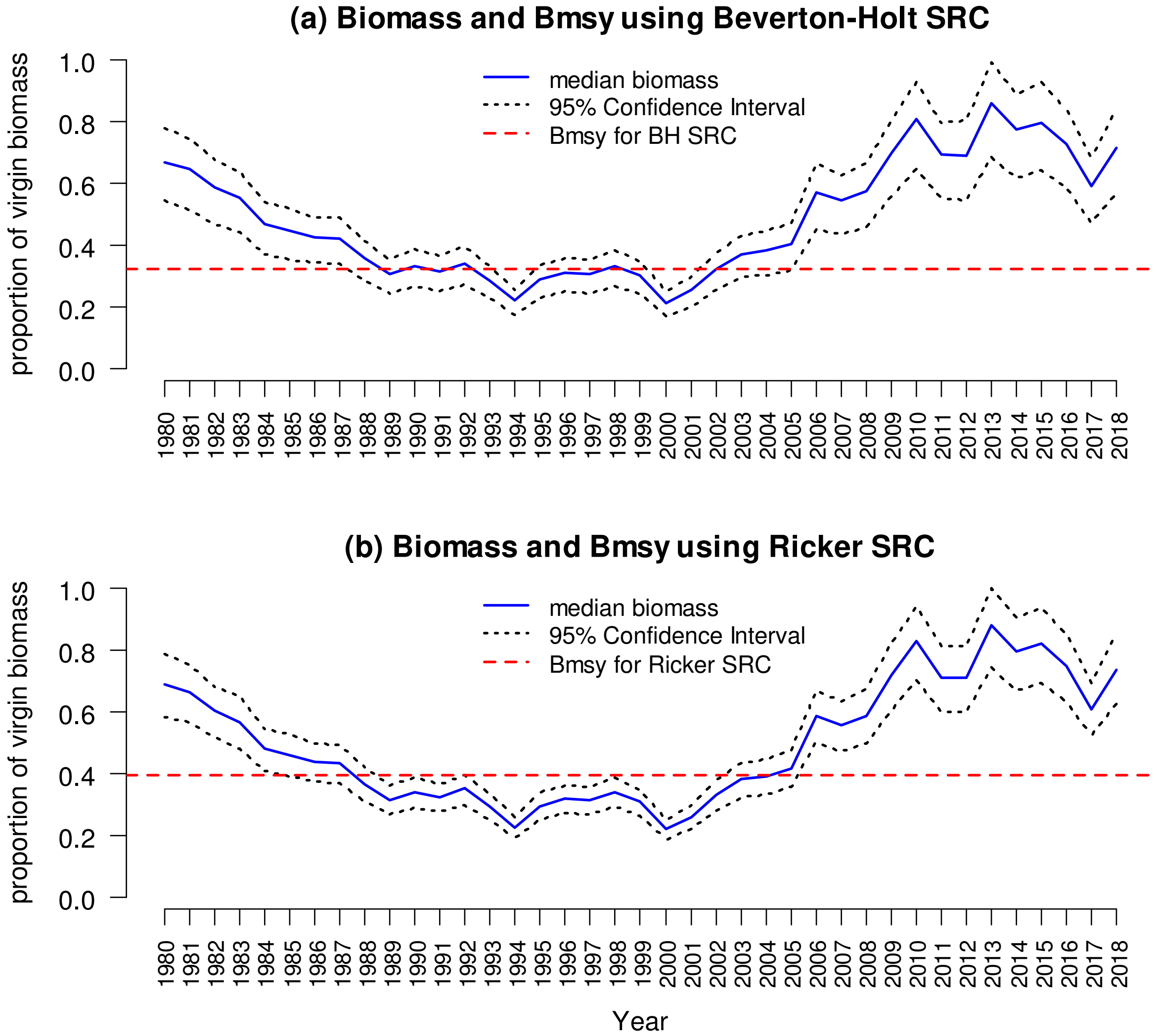

Figure 6 Yearly tiger prawn biomass and B_{MSY} as a proportion of the virgin biomass based on (a) the Beverton-Holt and (b) the Ricker spawner-recruitment curves.

The "Period of highest fishing effort", 1991-2003 (Turnbull and Cocking 2018) matches the years when the biomass was varying from slightly above to below the "red dashed" B_{MSY} reference lines in Figure 6. During the years 1991-2003 the mean annual tiger prawn catches were 668 (465:965) tonnes and three times the catch was above MSY (676 tonnes Beverten-Holt) for two consecutive years; 1991-2, 1997-98 and 2002-3.

Post 2005 the model estimates of annual tiger prawn biomass varied between 60-88% of the estimated virgin biomass and was well above the estimates of the Biomass required for Maximum Sustainable (Bmsy) using both the Beverton-Holt (Figure 6(a)) and Ricker (Figure 6(b) spawner-recruitment curves. Based on these results there are no reasons for concern with regard to the health of the tiger prawn stock in recent years.

Maximum Sustainable Yield

The median (middle value) of the estimates of Maximum Sustainable Yield (MSY) from the 2004 and 2019 assessments (Table 3 and Figure 7) ranged from 606 to 676 tonnes. The median MSY estimated using the Beverton-Holt Spawner-Recruitment has dropped from 676 tonnes to 617 tonnes bringing it closer to the Ricker estimate which was 606 tonne for both assessments. The 2019 MSY 95% Confidence Intervals are closer to the median for both Spawner-Recruitment curves than for the 2004 assessment. The catch trigger of 680 tonnes is within the 95% Confidence Intervals of all estimates.

Table 3 Maximum Sustainable Yield estimates from the 2004 and 2019 tiger prawn stock assessments.

Spawner-Recruit Curve	Assessment Year	MSY	lower 95% CI	upper 95% CI
Beverton-Holt	2004	676	523	899
Beverton-Holt	2019	617	507	763
Ricker	2004	606	436	722
Ricker	2019	606	483	697

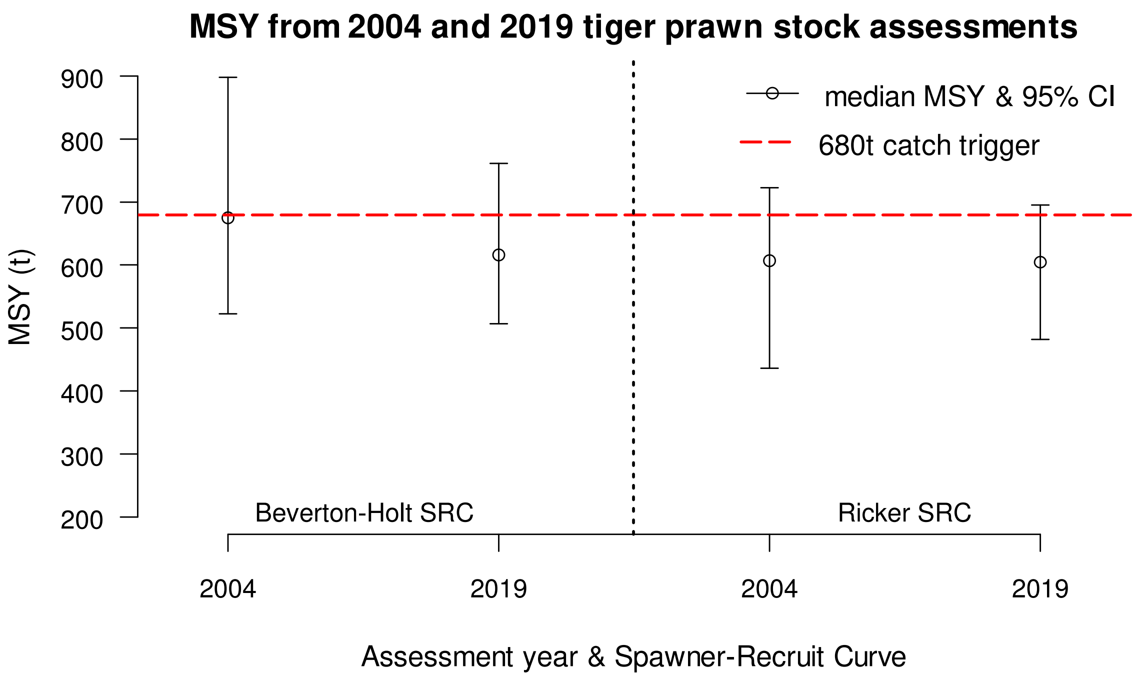

Figure 7 Maximum Sustainable Yield (MSY) estimates for the 2004 and 2019 tiger prawn stock assessments.

Effort at Maximum Sustainable Yield (E_{MSY})

The estimates of Emsy for the 2004 assessment were calculated by dividing MSY by the standardised CPUE for 2003 (73.5 kg/d). Using the same CPUE for the 2019 assessment results in similar, although slightly lower Emsy estimates (Table 4 and Figure 8(a)). In contrast, if the 2018 annual standardised CPUE of 160.3 kg/day is applied, Emsy changes to 3846 and 3778 days for the BH and Ricker SRCs respectively (Table 4 and Figure 8(b)).

Table 4 Fishing Effort for Maximum Sustainable Yield (E_{MSY}) calculated using the 2003 and 2018 annual standardised CPUE.

Spawner-Recruit Curve	Assessment Year	Emsy (2003 days)	lower 95% CI	upper 95% CI
Beverton-Holt	2004	9197	7116	12231
Beverton-Holt	2019	8389	6903	10374
Ricker	2004	8245	5932	9823
Ricker	2019	8240	6568	9480
		Emsy (2018 days)		
Beverton-Holt	2004	4217	3263	5608
Beverton-Holt	2019	3846	3165	4757
Ricker	2004	3780	2720	4504
Ricker	2019	3778	3011	4347

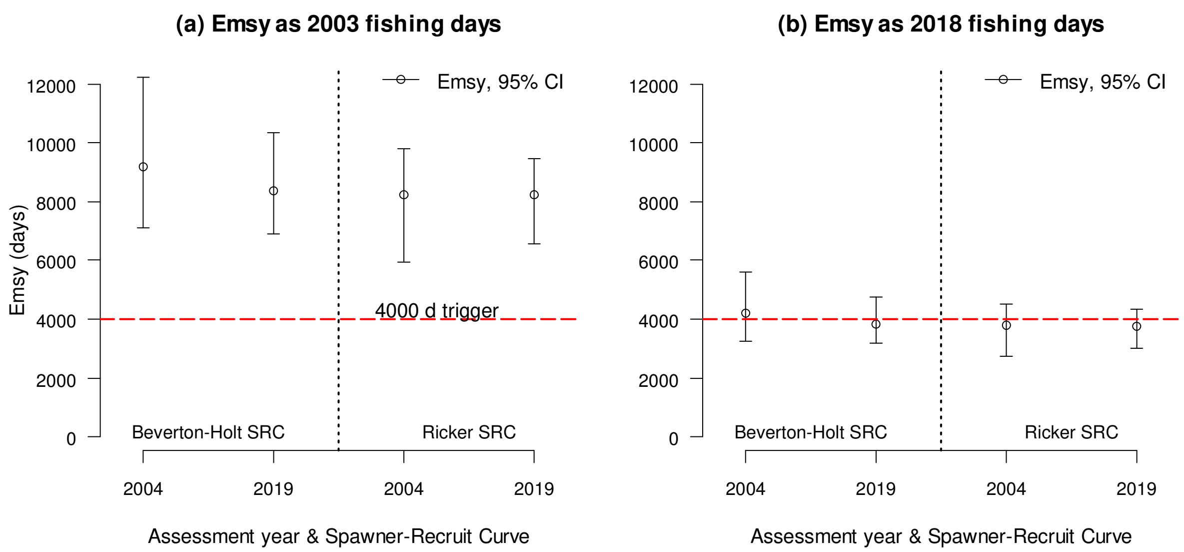

Figure 8 Emsy estimates as 2003 and 2018 fishing days.

Sensitivity Analysis of Emsy to Standardised tiger prawn CPUE

The above results demonstrate that by just using the most recent CPUE to update Emsy to "2018 days of fishing effort" may be inappropriate because this method does not account for all of the reasons behind the elevated CPUE post 2005. The fishing efficiency or fishing power has not significantly increased since 2003 therefore the increased CPUE is mainly a result of the higher tiger prawn biomass and the lower number of active vessels and annual fishing effort.

This raises the question "What CPUE should be used when updating the Emsy estimate? The following sensitivity analysis (Figure 9 and Table 5) based on the 2019 Beverton-Holt MSY estimate, compares Emsy estimated using the yearly standardised CPUE with a 3 year running average and a 5 year running average. The results show that Emsy in highly variable when using the yearly standardised CPUE for the years1985 to 2018. The 3 year running average of CPUE helps to stabilise the variation in Emsy between years and the 5 year running average of CPUE provides the most stable Emsy estimates. The plot also illustrates the inverse relationship between CPUE and Emsy.

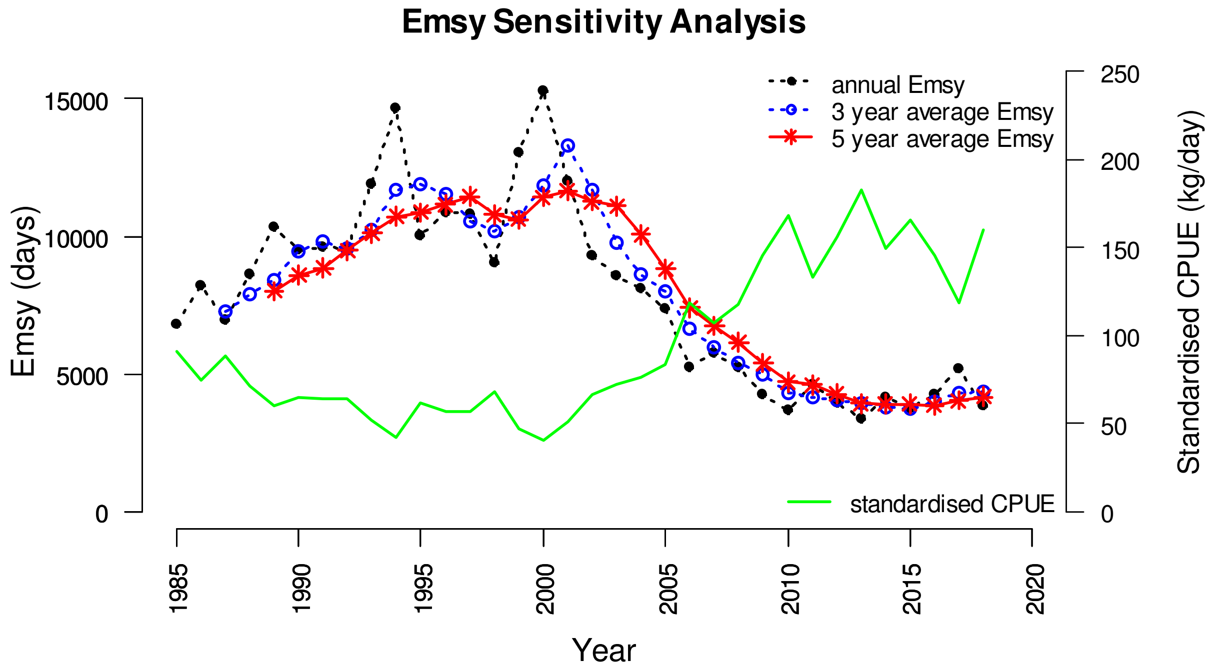

Figure 9 A comparison of Emsy calculated using; the annual standardised CPUE, a 3 year running average CPUE and a 5 year running average CPUE. The annual standardised CPUE is shown as a green line and is scaled to the right x-axis.

Table 5 Data for figure 9.

year	Standardised tiger prawn CPUE			Emsy estimates		
	annual	3 year average	5 year average	annual	3 year average	5 year average
1985	90.8			6795		
1986	74.9			8234		
1987	88.4	84.7		6983	7285	
1988	71.6	78.3		8613	7879	
1989	59.7	73.2	77.1	10338	8426	8004
1990	64.9	65.4	71.9	9502	9432	8580
1991	64.2	62.9	69.8	9608	9802	8844
1992	64.4	64.5	65.0	9582	9564	9496
1993	51.9	60.2	61.0	11878	10252	10109
1994	42.1	52.8	57.5	14673	11687	10729
1995	61.4	51.8	56.8	10044	11910	10861
1996	56.8	53.4	55.3	10860	11548	11152
1997	57.1	58.5	53.9	10804	10556	11454
1998	68.3	60.7	57.1	9038	10160	10799
1999	47.3	57.6	58.2	13035	10717	10603
2000	40.4	52.0	54.0	15275	11866	11429
2001	51.3	46.3	52.9	12023	13312	11667
2002	66.4	52.7	54.7	9289	11705	11270
2003	72.2	63.3	55.5	8551	9748	11112
2004	76.1	71.6	61.3	8107	8622	10069
2005	83.8	77.4	70.0	7363	7977	8819
2006	118.2	92.7	83.3	5218	6655	7403
2007	106.9	103.0	91.4	5771	5991	6748
2008	117.5	114.2	100.5	5251	5402	6139
2009	145.6	123.3	114.4	4239	5003	5393
2010	168.3	143.8	131.3	3666	4291	4699
2011	133.2	149.0	134.3	4631	4140	4594
2012	156.1	152.6	144.1	3952	4044	4280
2013	183.1	157.5	157.3	3370	3918	3923
2014	149.3	162.9	158.0	4131	3789	3905
2015	165.9	166.1	157.5	3719	3714	3916
2016	145.6	153.6	160.0	4237	4016	3856
2017	118.4	143.3	152.5	5212	4305	4046
2018	160.3	141.4	147.9	3850	4363	4171

Relationship between Catch Rate and Fishing Effort

There is a curved inverse relationship between the standardised CPUE and the prior months fishing effort (Figure 10(a)). As fishing effort in the previous month increases CPUE appears to drop rapidly at first then more slowly. Because the CPUE and effort data are both skewed upwards they need to be transformed to perform a linear regression. A logarithmic transformation normalised the distribution of the CPUE data and a square root transformation normalised the fishing effort data.

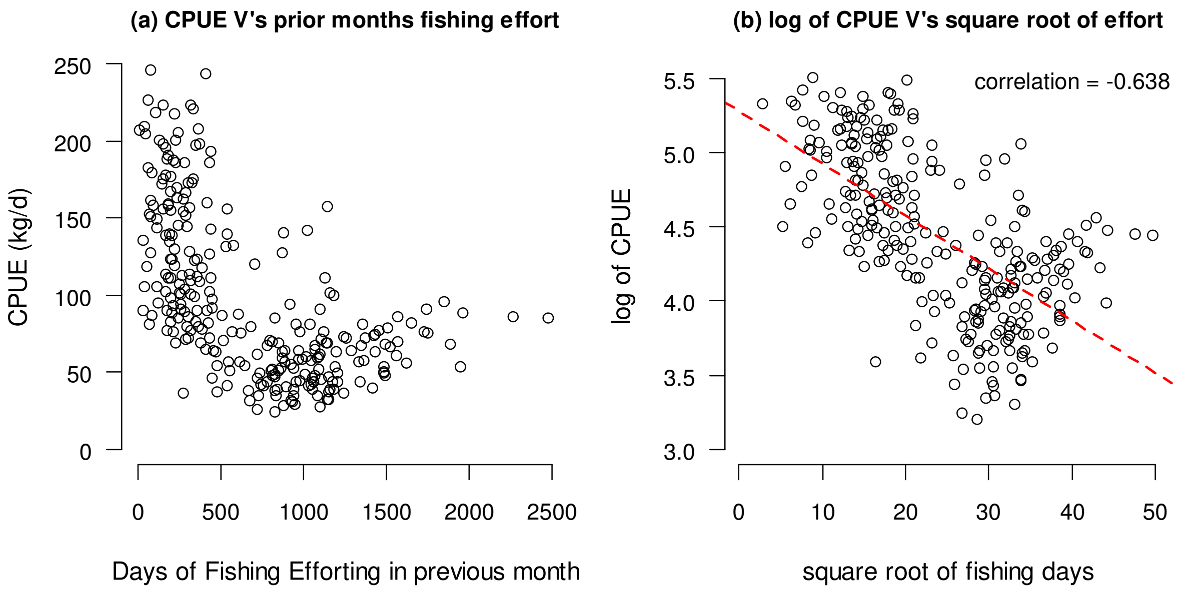

Figure 10 Correlation between CPUE and the prior month of fishing effort.

There is a negative linear correlation between the transformed data sets (Figure 10(b)). The explanation of this relationship is that high fishing effort at the start of a season fishes the stock down quicker resulting in a lower CPUE in subsequent months. Conversely, if fishing effort is low during the early months CPUE remains high until recruitment reduces and the combination of fishing and natural mortality start to reduce the stock size. Therefore if fishing effort increases as a result of improvements in the economics of prawn trawling, the average CPUE is likely to decrease, resulting in an increased Emsy estimate.

Discussion

The updated estimates of MSY, Emsy, Bmsy and the current stock biomass in relation to the virgin biomass, provide the data needed to review the harvest strategy triggers. The current trigger points in the harvest strategy (AFMA 2011, See Appendix) are an annual catch of more than 680 tonne of tiger prawn and/or 4000 days of annual fishing effort over two consecutive years.

Based on the results of this assessment it appears that during 1991-2003 the tiger prawn stock was varying around the stock size that is most productive (Bmsy). If the Harvest Strategy had existed during 1991-2003 when the number of vessels fishing and effort were highest, the catch trigger would have been activated on three occasions; 1991-2, 1997-98 and 2002-3. The effort trigger of 4,000 days would have been activated every year. Although the fishery was harvesting tiger prawn at MSY (mean 668, range 465:965 tonnes) and appeared to be sustainable; economically a lower number of vessels and fishing effort would have been more profitable.

As biomass increases the slope of the Spawner-Recruitment curves become smaller and the Ricker curve becomes slightly negative (Figure 5). The implication of this is that maintaining the biomass too close to Bvirgin is not desirable as there is little or no increase in recruitment. Economically and from a management perspective it is better to aim to operate a fishery slightly above Bmsy as this reduces the possibility of a stock collapse and improves the economics of fishing through higher CPUE whilst still allowing a harvest that is on average close to but below MSY.

Recruitment in prawn fisheries is highly variable (Figure 5) therefore occasional harvests above MSY in years when the biomass is high are to be expected and are not a concern. Post 2008 the annual tiger prawn harvest has been well below the estimates of MSY and the tiger prawn biomass, at 60-88% of Bvirgin, has been well above Bmsy (33% Beverton-Holt, 40% Ricker). These are the main reasons for the mean annual CPUE post 2008 being roughly twice that of the years 1991-2003. Hence there are no reasons for concern regarding the stock size and sustainability.

The current tiger harvest rate is sustainable and could be increased if the economics of trawling improved allowing a slightly higher level of fishing effort. Although higher than the updated median value of the Beverton-Holt MSY estimate the 680 tonne tiger prawn catch trigger is within the 95% Confidence Intervals of all the MSY estimates. Occasional catches above MSY when the biomass is high are sustainable. Consideration should be given to separating the catch triggers from the effort trigger because it is years of consecutive fishing above MSY that will impact the prawn stock biomass (i.e. remove the “and/or” that is currently between the harvest strategy triggers 1a, 1b and 1c).

The 2015 season was the only year that catch was above the lower 95% Confidence Intervals of the updated MSY estimates. The 2015 the biomass was 80% of Bvirgin which is well above Bmsy and hence quite sustainable. The fact that the 2015 harvest was taken by only 2,969 days of fishing is a result of the high biomass and hence a high CPUE that allowed the harvest to be taken by a relatively small amount of fishing effort (compared to 1991-2003). This is an example of fishing at the Effort for maximum economic yield (Emey).

The estimates of Emsy for the 2004 assessment were calculated by dividing MSY by the standardised CPUE for 2003 (73.5 kg/d). Using recent CPUE to calculate Emsy as 2018 fishing days is problematic because it does not account for the higher CPUE resulting from the large stock size and the inverse relationship between CPUE and fishing effort. A sensitivity analysis was conducted to help address the question “What CPUE should be used when updating the Emsy estimate?” This analysis shows that using a single year standardised CPUE results in highly variable estimates of Emsy. A 5 year running average appears to be the best option for smoothing over the variability.

The purpose of the effort trigger needs to be discussed by TSPMAC as the estimates of Emsy are highly variable and sensitive to the CPUE that is used to calculate Emsy. The effort trigger is a good concept that fits with the use of a TAE as the primary management control of the fishery harvest. The use of a Total Allowable Effort (TAE) as opposed to a Total Allowable Catch (TAC) suits the variable nature of recruitment in prawn fisheries by allowing additional harvest in years when biomass is high whilst restricting harvest in years when it is low because of a lower CPUE. The 4,000 day trigger is close to the median values of all of the Emsy estimates using the 2018 CPUE (Table 4 and Figure 8). Biomass in 2018 was 80% (Beverton-Holt) or 82% (Ricker) of virgin biomass which is the main reason that CPUE is so much higher than in 2003 when the biomass was 37% (Beverton-Holt) or 38% (Ricker). The lower number of active vessels and annual fishing effort are the other reasons that annual CPUE is higher because the fishing mortality is lower and spread over the fishing season instead of high and concentrated in the early months. Perhaps the effort trigger could be viewed as an Emey limit reference point as fishing effort above this level is more likely to just reduce the profitability of fishing (because of reduced CPUE) than be a risk to the stock sustainability.

References

AFMA, (2011) Harvest Strategy for the Torres Strait Prawn Fishery 2011, Australian Fisheries Management Authority (AFMA).

Die, D.J. (2003) Review of the stock assessment of the Torres Strait prawn fishery. Australian Fisheries Management Authority (AFMA).

O'Neill, M. F. and C. T. Turnbull (2006). Stock assessment of the Torres Strait tiger prawn fishery (Penaeus esculentus). Queensland, Department of Primary Industries and Fisheries.

Turnbull, C., Cocking, Lisa (2019), *Torres Strait Prawn Fishery Data Summary 2018*, Australian Fisheries Management Authority. Canberra, Australia.

Turnbull, C.T., Tanimoto, M., O'Neill, M.F., Campbell, A. and Fairweather, C.L. (2009) Torres Strait Spatial Management Research Project 2007-09. Final Report for DAFF Consultancy DAFF83/06. Department of Employment, Economic Development and Innovation, Brisbane, Australia

Appendix

Extract from: Harvest Strategy for the Torres Strait Prawn Fishery, 2011

6.2 Decision rules and trigger points

Decision Rule: TAE for the fishery to be set based on the MSY for Tiger prawn up to 9,200 days (maximum) for the maximum period allowable under the Plan (currently 3 years) unless triggers are reached.

Trigger 1: *If any one of the trigger points below is reached within the Australian area of jurisdiction each year over two (2) consecutive years:*

Trigger 1a – *If ≥ 4000*[1] *days of TAE has been utilised in a season; and/or*

Trigger 1b – *If ≥ 680*[2] *tonnes of Tiger prawns has been caught in a season; and/or*

Trigger 1c – *If ≥ 620*[4] *tonnes of Endeavour prawns has been caught in a season;*
then

Decision Rule 1:

a) PZJA agencies to commence indentifying research requirements including updating of the stock assessment and bio-economic modelling;
b) reconvene Harvest Strategy Working Group to oversee research and further development of the TSPF Harvest Strategy;
c) estimate B_{MEY} using results obtained from both updated and historical research data; and
d) revisit target reference points and trigger points to develop decision rules for setting the TAE based on B_{MEY} and taking into consideration the revised and updated research outputs, the current status of the fishery and social environment in which the fishery operates (including decisions rules detailing what is done when stock assessments are undertaken and when they aren't undertaken).

[1] Effort triggers are monitored using VMS data.
[2] Catch triggers are monitored through the logbook data.