Australian Government
Australian Fisheries Management Authority

Northern Prawn Fishery Resource Assessment Group (NPRAG)

Meeting minutes

7 December 2022

Microsoft Teams

Meeting participants

Position	Participant
Chair	Ian Knuckey, Fishwell Consulting
NPRAG members	Ian Boot, Industry member Rik Buckworth, Scientific member Tom Kompas, Economic member Éva Plagányi, Scientific member Phil Robson, Industry member Jeremy Smith, AFMA[1] member Bryan van Wyk, Industry member
Invited participant	Annie Jarrett, NPFI[2]
AFMA Employees	Cate Coddington (executive officer) Brodie Macdonald
Observers	Roy Deng, CSIRO[3] Trevor Hutton, CSIRO Brandon Meteyard, NPFI Shijie Zhou, CSIRO
Apologies	
David Brewer, Scientific member Sean Pascoe, CSIRO	

Agenda item 1. Preliminaries

a. Welcome and apologies

Ian Knuckey, the Chair, opened the meeting with an Acknowledgement of Country at 1400 AEDT[4].

The RAG noted that there was a quorum as per *Fisheries Administration Paper 12* (FAP12).

b. Declarations of interest

The RAG discussed potential conflicts of interest, as outlined in FAP12. Participant declarations of interest are at **Attachment A**. Research providers, particularly those associated with CSIRO, were deemed to have a potential conflict of interest with **Agenda Item 3**: *Research proposal consideration*. These participants left the meeting and their participation in the item was discussed by the remaining participants. It was agreed that these participants should be present for the discussion but should leave the meeting for recommendations.

c. Adoption of agenda

The RAG adopted the agenda as final (**Attachment B**).

[1] Australian Fisheries Management Authority
[2] Northern Prawn Fishery Industry
[3] Commonwealth Scientific and Industrial Research Organisation
[4] Australian Eastern Standard Time

d. Minutes from previous meetings

The RAG endorsed the 15 July 2022 NPRAG meeting minutes and noted that they have been published on the AFMA website on the NPRAG past meetings webpage.

Agenda item 2. Red endeavour prawns

The RAG noted that the Northern Prawn Fishery is undergoing Marine Stewardship Council (MSC) recertification and that the MSC assessment team has requested (to inform final scoring) further information relating to:

- updated stock assessment outputs for red endeavour prawn using the current stock assessment model, in particular details as to the uncertainty associated with red endeavour stock status estimates derived from the models (**Agenda Item 2a**).
- progress on improvements to stock assessment modelling for red endeavour prawns (**Agenda Item 2b**).

a. Updated 2022 stock assessment results

The RAG noted the information provided by Roy Deng on the updated 2022 stock assessment results for red endeavour prawns (**Attachment C**), in particular:

- CSIRO have conducted additional sensitivity analyses using the latest version of the bio-economic model (as outlined in the February and May 2022 NPRAG meetings), but also including sensitivities for red endeavour prawns (a summary of the updated assessment, including the sensitivity tests for the four-species model, is at **Attachment C**).
- the key outputs of the updated red endeavour prawn stock assessment include:
    - Red endeavour prawns are primarily a byproduct species and, given the multispecies nature of the fishery, the stock level at MEY (maximum economic yield) for the fishery may be less than that at MSY.
    - Based on the -year moving average, the spawning stock size of red endeavour prawns was estimated to be at 92% of the Maximum Sustainable Yield level (S_{MSY}) at the end of 2021. Different sensitivities of this figure ranged 80-92%.
    - The reference case model estimated the spawning stock size relative to S_{MSY} was 87%, with a range between 74-87% from the sensitivity tests.
    - The stock was estimated not to be overfished relative to the limit reference point of 50% of S_{MSY} (based on the most recent 5-year average); and
    - The stock has been close to, or above, its S_{MEY} level since 2010. The stock is expected to remain sustainable.

The RAG thanked Roy Deng and the team for their work and discussed the impacts of the assessment on MSC certification:

- MSC requires stocks to fluctuate around the target of MSY. While the stock is assessed as slightly below MSY (acceptable under Commonwealth Harvest Strategy Policy) the posterior median distribution for the ratio of the 5-year average biomass is 93% and this indicates that there is a reasonable likelihood that the stock is over MSY and therefore should not be of concern.
- It was noted that the model used for this updated assessment did not include the improvements relating to red endeavour prawn growth rates and CPUE standardisation, which are expected to lead to further improvements to biomass estimation and depletion levels for red endeavour prawns (discussed at **Agenda Item 2b**).

b. Progress of improvements to the stock assessment

The RAG noted the information provided by Shijie Zhou on the progress of improvements to the stock assessment (**Attachment D**):

- The first two stages of the project, growth and CPUE standardisation, have been reviewed and approved by the RAG (November 2021 and July 2022 NPRAG meetings).
- Stage three of the project, *developing stock assessment methods for red endeavour prawn and improving the blue endeavour assessment model*, is progressing and will be considered by NPRAG when the project is completed in March 2023.
- Various scenarios and options in regard to spatial structure, fishery history, and modelling techniques have been explored, the following scenarios have been used for each species:
    - Two alternative spatial treatments: one across the whole of the NPF and the other assuming four independent regions.
    - Two types of catches: one using the nominal catch from the logbooks in the biomass dynamics model and the other one converting catches in months to body weight (measured in August).
    - Three alternative Bayesian priors: non-informative, weakly-informative, and a new data-driven prior.
    - Two options for including abundance index: one using only fishery CPUE and the other using fishery CPUE and the scientific survey index.
    - Two Bayesian model structures: one applying traditional Bayesian models and the other using hierarchical Bayesian models.
- Preliminary results show that the tailored CPUE for endeavour prawns (from stage 2 of the project) will have a notable impact on stock status. Noting that the results need to be fully reviewed, it is expected that the revised model will estimate that stock status is higher than current estimates – hence is about MSY with no concern for either stock.

The RAG thanked Shijie Zhou for his work on improvements to the assessment.

Recommendation

The RAG recommended that CSIRO provide the following summaries to the MSC assessment team:

- The updated 2022 stock assessment for red endeavour prawns (**Attachment C**)
- The endeavour prawn assessment improvement project that reflects the status of the project; with stages 1 and 2 completed and stage 3 in progress (**Attachment D**).

Agenda item 3. Research proposal consideration

The RAG noted:

- that, in response to the AFMA Research Committee (ARC) call for research proposals for potential funding in 2023-24:
    - CSIRO submitted a proposal against the priority *detailed analysis of environmental contributors that could affect tiger prawn population dynamics*.
    - no proposal was submitted against the estimation of banana prawn price flexibilities priority.
- funding for the third year of the vessel charter for the NPF recruitment/spawning surveys (AFMA project 200803) has been included in the ARC draft 2023-24 budget.

The RAG noted the information provided by Éva Plagányi on the proposal regarding a detailed analysis of environmental contributors that could affect tiger prawn population dynamics:

- As developed at the NPRAG July 2022 meeting, the research structure is pragmatic with the research in three stages: 1) compile the relevant data, 2) test the potential role of environmental variability in driving population dynamics using the ecosystem model[5], and 3) undertake fieldwork to fill any data gap relating to juvenile prawns (optional). The implementation of the fieldwork, the most expensive stage, will depend on the impact of the absence of such data on model outcomes.

- While many commercial fisheries are increasingly impacted by environmental variability, currently there are no established models for considering such variability. As such, this research could be ground-breaking for stock assessments.

The RAG discussed the research proposal:

- Traditional owners will need to be engaged for the third stage of the project as there is overlap between the proposed fieldwork areas and native title determination areas.
- Industry members outlined that it is imperative that the project commences given the uncertainty in the fishery with respect to climate change. However, concern regarding the expense of the project was raised, particularly given the current financial situation in the fishery and the anticipated expenses for the 2023-24 financial year (a full stock assessment year).
- Alternate funding could be sought to offset the expense to industry due to the strategic nature of this research and the potential application to other commercial fisheries:
  - Given the relevance and strategic nature of the research, the ARC is likely to provide recommendations about seeking other funding including directing the project to the Fisheries Research Development Corporation (FRDC) for consideration. The FRDC could be a more appropriate funding source noting that FRDC are providing some funding for the strategic review of the tiger prawn fishery workshop in February 2023, which is also related to this proposal.
  - While other similar projects are being undertaken to consider climate change impacts, these are not tailored to fishery needs. The most synergistic project is being undertaken in the Torres Strait, the climate and oceanographic modelling is not as extensive as what has already been conducted in the Northern Prawn Fishery area in addition to the work included in this proposal.
  - It may be possible to optimise collection of data by combining with existing research programs, for example the juvenile and spawning surveys undertaken by CSIRO prior to each season.

After those deemed to have a conflict of interest left the meeting (researchers), the RAG provided the following advice for the research proposal review form regarding the project:

- Full support was provided across all relevant criteria.
- It aligns well with the call for research and addresses priority 7 of the NPF strategic research plan 2019-2023 *continue research to identify the potential impact of climate change on the fishery and options to adjust to changes* with outcomes of the research likely to be adopted.
- While the project is cost effective, particularly the first and second stages, it is a strategic project that could benefit other fisheries and also aligns with the AFMA Commission request to integrate research on climate change impacts into RAG, MAC and Commission decision-making processes. As such, other funding sources should be investigated.
- Data will be accessible as there is a data agreement in place between CSIRO and AFMA
- CSIRO has proven experience with such research and has demonstrated successful integration of environmental driver considerations into stock assessments and harvest strategies.

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[5] The model to be used for the project from "*Ecological modelling of the impacts of water development in the Gulf of Carpentaria with particular reference to impacts on the Northern Prawn Fishery*" (FRDC2018-079)

Recommendation

The RAG:

- provided full support for the project *detailed analysis of environmental contributors that could affect tiger prawn population dynamics* given the importance of the research for the fishery.
- recommended that alternative funding sources be investigated as it aligns with the Commission priorities across fisheries and the potential application to other fisheries.

Action Item 1: CSIRO

CSIRO to update the *detailed analysis of environmental contributors that could affect tiger prawn population dynamics* research proposal to have more of a strategic focus; the research is ground-breaking and could have broader implications with benefit flowing to other fisheries.

Action Item 2: AFMA

AFMA to distribute the completed research proposal assessment form to NPRAG for comment.

Agenda item 4. Other Business

The RAG noted that factsheets are being developed for the Northern Prawn Fishery tiger prawn strategic planning workshop being held in February 2023. While CSIRO has carriage for developing most of these, Tom Kompas has been given responsibility for developing a factsheet relating to minimum effort threshold.

Action Item 3: Tom Kompas / CSIRO

Tom Kompas to work with Sean Pascoe to develop a factsheet relating to the low effort threshold for the tiger prawn assessment. Éva Plagányi to provide further information about the needs of the factsheet to Tom Kompas.

Close of meeting: 1550 AEDT

Attachment A – Register of interest

Name	Declared interests
Chair	
Ian Knuckey	**Positions:** Director –Fishwell Consulting Pty Ltd Director –Olrac Australia (Electronic logbooks) Chair –Northern Prawn Fishery Resource Assessment Group Chair –Tropical Rock Lobster Resource Assessment Group Chair –Victorian Rock Lobster and Giant Crab Assessment Group Chair –Victorian Central Zone Abalone Fisheries Resource Advisory Group Chair –Gulf of St Vincent's Prawn Fishery MAC Research Scientific Committee Scientific Member –Northern Prawn Management Advisory Committee Scientific Member –Gulf of St Vincent's Prawn Fishery Management Advisory Committee Scientific Member –Tropical Tuna Resource Assessment Group Scientific Member – SESSF Resource Assessment Group Councillor –Victorian Marine and Coastal Council Member –The Geelong Agri Collective **Fishwell current/recent projects:** DAWE Project: Multi-sector fisheries capacity building AFMA 2022: Annual monitoring, reporting and assessment of SPF marine mammal interactions, including effectiveness of mitigation measures AFMA 2020-0807: Bass Strait Scallop Fishery Survey – 2020-22 AFMA project: Design sea cucumber fishery-independent survey for Coral Sea FRDC 2019-027: Improving and promoting fish-trawl selectivity in the SESSF and GABTS FRDC 2018-021: Development and evaluation of SESSF multi-species harvest strategies Traffic Project: Shark Product Traceability Sea Cucumber Assn: Design and implementation of various sea cucumber dive surveys. Australia Bay: Queensland Gulf of Carpentaria Developmental Fin Fish Trawl Fishery Beach Energy: BACI study of Prion Marine Seismic Survey impacts relative biomass of scallops on beds in the immediate vicinity. Expert Witness: Gladstone Harbour development impacts
Members	
Ian Boot	Industry member – NPRAG & NORMAC Managing Director of Austfish, a company that operates NPF vessels. Has a commercial interest in the fishery. NPF broodstock permit holder. Participates in scampi fishing.
Rik Buckworth	Scientific Member – NPRAG Director -Sea Sense Australia Pty Ltd Adjunct Professor – Charles Darwin University CSIRO Honorary Fellow Chair of the NT Aquarium Fishery Management Advisory Committee Consultancy contract with NPFI to review Red Endeavour Prawns Current and pending projects with government agencies, CDU and fishing industry for projects in the NT, Torres Strait and Qld Researcher involved particularly in stock assessment research in NPF. Has in the past and may in future seek and receive funding for research in the fishery. Member – Data Working Group for the GABTF
Tom Kompas	Economic member – NPRAG Employed by University of Melbourne. Research provider. Has in the past and may in future seek and receive funding for research in the fishery.
Éva Plagányi	Scientific member – NPRAG Employee of CSIRO. Research provider involved particularly in stock assessment research in NPF.

Name	Declared interests
	Also currently receiving FRDC funding related to development of a GoC ecosystem model. Has in the past and may in future seek and receive funding for research in the fishery. Scientific member of TRLRAG and TS HCRAG.
Phil Robson	Industry member – NPRAG Employee of A Raptis and Sons, responsible for managing NPF vessels & an NT demersal fish trawler. Has provided charter for scientific surveys in NPF in the past and may in future.
Jeremy Smith	AFMA member – NPRAG Employed by AFMA, A/g Manager of Northern Prawn Fishery. No interest, pecuniary or otherwise.
Bryan van Wyk	Industry member – NPRAG Employed by Austral Fisheries, a company with SFR holdings in the fishery.
Invited participant	
Annie Jarrett	CEO – NPFI Commonwealth Fisheries Association Director Chair – Australian Council of Prawn Fisheries (ACPF) Member of the FRDC selection panel. Invited participant - NORMAC No pecuniary interests Represents the interests of industry.
AFMA employees	
Cate Coddington (EO)	AFMA employee No interest, pecuniary or otherwise.
Brodie Macdonald	Employed by AFMA, Senior Manager – Northern Fisheries. No interest, pecuniary or otherwise
Observers	
Roy Deng	Employed by CSIRO. Research provider. Member of a research body providing scientific advisory services to the fishery management. May in future seek and receive funding for research in the fishery.
Trevor Hutton	Employed by CSIRO. Research provider. Has in the past and may in future seek and receive funding for research in the fishery.
Brandon Meteyard	Employed by NPFI. No pecuniary interests. Represents the interests of industry

Attachment B – Final meeting agenda

Item	Purpose	Presenter
1. Preliminaries a. Welcome and apologies b. Declarations of interest c. Adoption of Agenda d. Minutes from previous meeting	For action	Chair
2. Red endeavour prawns a. Updated 2022 stock assessment results b. Progress of improvements to the stock assessment	a. For advice b. For information	CSIRO
3. NPF Research	For advice	AFMA
4. Other business		
End of Meeting		

Attachment C – Updated results and sensitivity analyses for red endeavour prawns from the 2022 NPF stock assessment models

The updated results and sensitivity analyses for red endeavour prawns from the 2022 NPF stock assessment models

Roy A. Deng, André E. Punt, Sean Pascoe and Éva E. Plagányi

CSIRO

Background

The 2022 NPF stock assessment report (Deng et al., 2022) was provided to the MSC assessment team during the NPF's MSC re-certification process. The MSC assessment team held a site visit meeting during November 2022 to explain the preliminary assessment results to the NPF industry, managers, and scientists.

During the discussion of the target species stock status assessment, it was clarified that the main reason for the lower score for red endeavour prawns was due to insufficient information being provided on the uncertainty associated with estimates of stock status owing to the NPF stock assessment report only including red endeavour prawns in one sensitivity analysis. However, the production model on which the 2022 stock assessment for red endeavour prawns is based also produced Bayesian posteriors for the biomass time-trajectory from which an uncertainty range for stock status can be computed. Also, as another measure of uncertainty, it is possible to conduct similar sensitivity tests to those for the three-species model but including red endeavour prawns. This document therefore provides additional results for red endeavour prawns: the results of additional sensitivity analyses based on the four-species model and summary statistics of the Bayesian posteriors for biomass relative to the limit reference point.

Sensitivity tests for the four-species model

The following two types of stock assessment method are applied to form the basis for the assessment: a) the reference case, comprised of size-structured models for the two tiger prawn species, and a Bayesian hierarchical biomass dynamic model for blue and red endeavour prawns; and b) a Deriso model for each of the two tiger prawn species and blue endeavour prawns (Dichmont et al., 2003). Punt et al. (2011) provides a summary of the specifications of the model used as the base case for the bio-economic analyses.

Various improvements have been made to the approach of Punt et al. (2011) (e.g., Deng et al., 2021; Hutton et al., 2018) and the bio-economic model was refined (Buckworth et al., 2015) based on a retrospective study of model performance (Deng et al., 2015). The analyses in this document are based on the latest version of the bio-economic model.

The sensitivity tests for the four-species model consider the following key factors (Table 1):

- reference case (four species equivalent to the base case, which includes three species);
- mid-high fishing power series;
- fixed (specified by NPRAG in 2013) fishing effort pattern;
- estimated fishing pattern;
- effort changes constrained;
- lower minimum effort threshold; and
- no minimum effort threshold

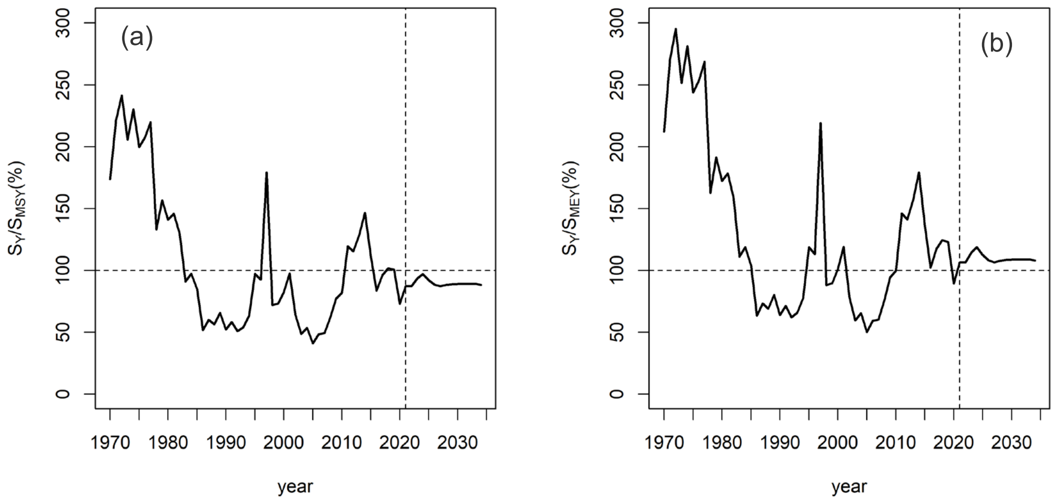
Table 1. Description of settings for the Reference Case and sensitivity tests. All analyses involve size-structured models for grooved and brown tiger prawns, and a Bayesian hierarchical model for the two endeavour prawns.

Scenario name	Fishing power	Weekly pattern	Max. effort change	Low effort threshold	Base-case effort pattern
Four-species reference	Low	Most-recent two-year average	NA	2,777	Yes
Mid-high fishing power	Mid-High	Most-recent two-year average	NA	2,777	Yes
Fixed effort pattern	Low	NPRAG 2013 specified season	NA	2,777	No
Estimate season	Low	Estimated	NA	2,777	No
Constraining effort change (year-on-year)	Low	Most-recent two-year average	15%	2,777	Yes
Low minimum effort threshold	Low	Most-recent two-year average	NA	1,000	Yes
No minimum effort threshold	Low	Most-recent two-year average	NA	1	Yes

Results

The spawning stock size of red endeavour prawns was estimated to be less than S_{MSY} at the end of 2021, its reference case relative depletion rate at 87%, with a range between 74-87% from the sensitivity tests (Table 2; Figure 1), but the stock was estimated not to be over-fished relative to the limit reference point of 50% of S_{MSY} (based on the most recent 5-year average). The most-recent five-year average spawning stock size is estimated to be 92% of S_{MSY} and ranges between 80%-92% among the sensitivity tests (Table 2). The posterior median for the ratio of the 5-year average biomass to S_{MSY} is 0.93 (90% credibility interval 0.67-1.36) (Figure 2).

Figure 1. Status of the stock relative to reference points for red endeavour prawns for the reference four-species sensitivity test. (a) spawning stock size (S) relative to spawning stock size corresponding to Maximum Sustainable Yield (S_{MSY}), and (b) spawning stock size relative to the spawning stock size corresponding to Maximum Economic Yield (S_{MEY}).



While below S_{MSY}, the stock has been close to, or above, its S_{MEY} level since 2010. The objective of the management of the fishery is to maximise net economic returns for the fishery as a whole. As red endeavour prawns are primarily a byproduct species, the stock level at MEY (maximum economic yield) given the multispecies nature of the fishery is less than that at MSY. The stock, however, is expected to remain sustainable at this level.

Figure 2. Most-recent five-year average spawning stock size relative to S_{MSY}

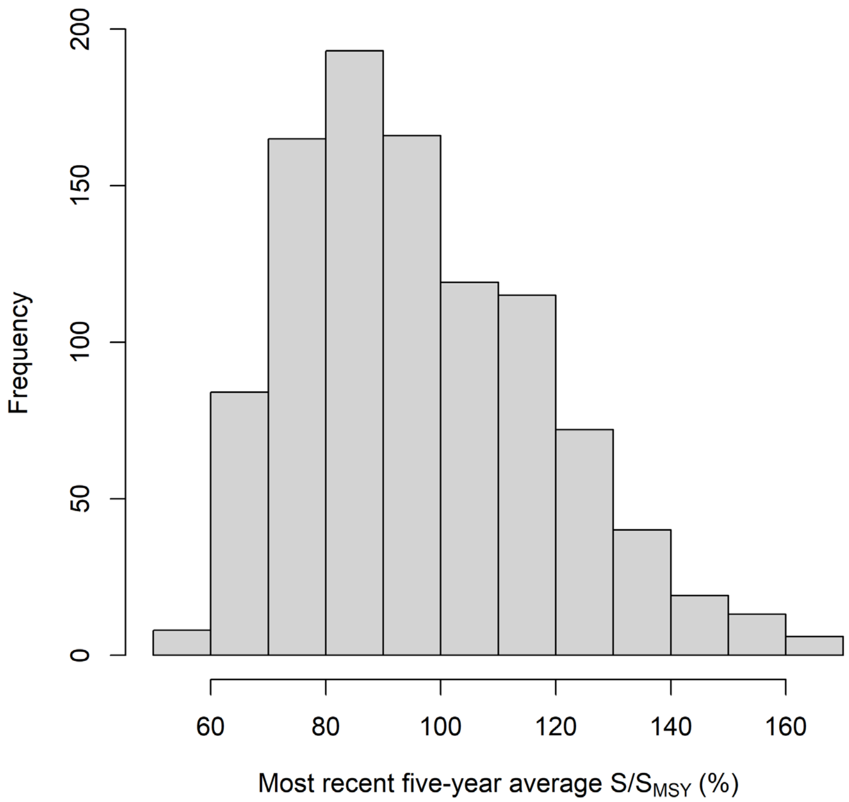


Table 2. Sensitivity tests results for red endeavour prawns**.** E_{MSY} is the effort level (expressed in terms of 2021 boat days) at which MSY is achieved and S_{MSY} is the spawner stock index at which (deterministic) MSY is achieved. A dash indicates that the value is the same as that for the Base Case.

Indicator	4 species (including red endeavour prawn)	Mid-High	Fixed effort pattern	Estimate Pattern	Constrained effort change	No effort threshold	Lower effort threshold
$Catch_{2022}$ (t)	241	278	259	239	55	91	251
Observed C_{2021} (t)	170	-	-	-	-	-	-
MSY (t)	324	-	330	335	-	-	372
MEY (t)	177	167	140	181	162	162	226
S_{MEY}/S_{MSY} (%)	82	85	77	76	86	84	83
S_{2021}/S_0 (%)	41	-	-	-	-	-	-
S_{2021}/S_{MSY} (%)	**87**	**-**	**76**	**80**	**-**	**-**	**74**
S_{2021}/S_{MEY} (%)	106	102	99	106	102	104	90
5-year mav($S_{2017-2021}/S_{MSY}$) (%)	**92**	**92**	**80**	**84**	**92**	**92**	**80**
S_{2028}/S_{MEY} (%)	106	102	105	103	104	106	89

Conclusion

The uncertainty associated with model estimates of red endeavour stock status was evaluated by computing the uncertainty range based on the Bayesian posteriors, as well as by running a number of sensitivity tests incorporating a range of alternative assumptions, in an analogous fashion to those presented using the three-species model, but shown here using the four-species model instead.

The results suggested that the stock is estimated to have been slightly less than S_{MSY} at the end of 2021, but that there is high confidence that the stock is well above the limit reference level as the most-recent five-year average spawning stock size ranged between 80%-92% of S_{MSY} across all sensitivity tests. Moreover, the posterior median for the ratio of the 5-year average biomass to S_{MSY} is 0.93 (90% credibility interval 0.67-1.36).

The main reason that the stocks have been below S_{MSY} is that the species is primarily a byproduct within a multispecies fishery that has an objective of maximising sustainable profits over the fishery as a whole. To this end, the stocks have generally been higher than their MEY stock level for the last decade. As S_{MEY} is also a sustainable reference point, the sustainability of the stock is not considered of concern.

Future red endeavour modelling and sensitivity tests will account for updates to the CPUE and models as are currently underway.

Acknowledgements

This project benefitted from consultation with, and extensive feedback from, members of the Northern Prawn Fisheries Resource Assessment Group (NPRAG). Australian Fisheries Management Authority (AFMA) and the Northern Prawn Fishery Industry (NPFI, Ltd.) are acknowledged for providing the data required for this project. Shijie Zhou is acknowledged for providing advice on Bayesian production models. This work was funded by the AFMA Research Fund, CSIRO and NPFI, AFMA Project No. 2020/0833: Northern Prawn Fishery Assessments 2022-2024.

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Attachment D – Summary of the endeavour prawn project

Summary of endeavour prawn project

Shijie Zhou, Yeming Lei, Roy Deng, Trevor Hutton, Margaret Miller, Tonya van Der Velde

CSIRO Environment

The project "Red endeavour prawn assessment – further potential improvements" was co-funded by AFMA and CSIRO. The project started in August 2021 and will be completed by March 2023. This is a staged project, including three major components: 1. Modelling growth of red endeavour prawns using data from historical surveys in the NPF; 2. Conducting CPUE standardization for both blue and red endeavour prawns; and 3. developing stock assessment methods for red endeavour prawn and improving the blue endeavour assessment model. Stages 1 and 2 have been successfully accomplished and most work has been completed for Stage 3 which is under internal review. This summary briefly describes major outcomes from the project.

1. Modelling growth of red endeavour prawns

Growth has been studied for several major prawn species in the Northern Prawn Fishery (NPF). However, red endeavour prawn (*M. ensis*) is a relatively data-poor species and its growth has been studied only once (by Park, 1999). The study was a very useful contribution to our knowledge of endeavour prawns in the NPF, but the estimated parameters in Park (1999) were considered "dubious" due to a lack of rigor in data handling and the modelling method applied.

The requests to update the preliminary assessment of red endeavour prawns led to an investigation of previously unused data from historical prawn surveys in the North-Western Gulf of Carpentaria between 1983 and 1985. Extensive length frequency distribution data (LFD) were collected for all commercial prawn species, including red endeavour prawns. A commercial fishing vessel, "Maxim", was chartered for these surveys. Consequently, the dataset was often referred to as the "Maxim surveys". Data collected during the surveys have been previously used for tiger prawn assessments, as these two species are the mainstay of the revenue of the fishery. This historical dataset had not been utilized for modelling growth of endeavour prawns. In the current project, this overlooked dataset was used to estimate growth of red endeavour prawns.

We applied two major methods: (1) the classic ELEFAN (Electronical LEngth Frequency ANalysis) implemented in recently developed R packages TropFishR and fishboot, and (2) Bayesian growth models (BGM) developed in this study. We used the new algorithms, ELEFAN_GA (genetic algorithms) and ELEFAN_SA (simulated annealing) included in the two R packages. Since the von Bertalanffy growth function (VBGF) has been widely adopted for modelling prawn species, we also used this form of growth function. Furthermore, we employed two versions of VBGF, the standard 3-parameter model and a seasonal oscillation model that involves two additional parameters. Since male and female red endeavour prawns have different body sizes, all models in this study treat the two sexes separately.

The Maxim surveys provide a time series of LFD, enabling length mode progression analyses. It has been widely recognized that modelling growth from LFD cannot obtain age-related information, including the theoretical age at length zero, t_0. This is because the time series of LFD includes survey timing but no actual age information. Our Bayesian growth model attempts to overcome this obstacle so that the model can estimate actual ages, including t_0. The main idea behind the BGM is to use LFD from multiple year-classes. We examined the performance of this new BGM using computer simulation. The results from the simulated synthetic LFD show that the BGM can produce reliable posteriors for VBGF parameters (including ages) when three cohorts are available. When only two cohorts are available (as is the case for red endeavour prawns), informative priors are needed for age-related parameters. However, it would be difficult to estimate ages when there is only one cohort. In all cases, the key growth parameters, the asymptotic length L_{inf} and the growth coefficient K, can be easily derived.

Our analysis involves a combination of 12 models: 3 methods (GA, SA, and BGM), two forms of VBGF (standard and seasonal), and two sexes. Interestingly, all models lead to comparable results for each sex. While there is some variation in results amongst the methods and growth functions, the estimates of the growth parameters are more consistent than studies for other prawn species. The seasonal oscillation models fit the LFD data better than the standard VBGF, but the differences in fit are not statistically significant. Recommendations regarding the use of growth parameters are made in the report and in the published paper.

In the discussion, the results were compared with existing studies on modelling growth of red endeavour prawns outside Australia and in the NPF. The current analysis is the most rigorous and reliable to date. Nevertheless, there are several weaknesses related to data quality and the amount of data. It would be useful for future studies to simultaneously model LFD data from multiple sources usinga hierarchical modelling framework.

Stage 1 resulted in one research report and one journal paper published in ICES Journal of Marine Science.

2. CPUE standardization for blue and red endeavour prawns

An abundance index is one of the most important types of data used in fisheries stock assessments and CPUE standardisation is an essential procedure to obtain a reliable abundance index. However, there has been no CPUE standardisation, nor fishing power analysis specifically for endeavour prawns in the NPF. The current stock assessment of endeavour prawns applies a fishing power time-series derived largely from tiger prawns to adjust nominal CPUE. This practice may lead to incorrect abundance indices because endeavour prawns differing spatially from tiger prawns and fishing efficiency improvement may differ between target and nontarget species.

In Stage 2, we applied eight alternative statistical models for CPUE standardisation. These models were composed of four generalized linear models (GLM)s and four generalized additive models (GAMs). These techniques assume two alternative statistical distributions: a delta-lognormal distribution and a Tweedie distribution. Moreover, two model structures are investigated: with or without including interaction terms for some predictor variables. A range of fishery and technology variables were explored for their potential inclusion as predictors and about 17 of those were finally adopted in these GLMs and GAMs.

The eight models were applied to the two species separately and to the two species combined as a group of endeavour prawns. Furthermore, the analyses were carried out at two spatial levels: treating the population in the whole NPF area as a single stock and modelling them at four sub-stock regions. Thirty-two models were investigated, resulting from the combination of different statistical models (eight), species/group (three), and regions (5). The statistical models were fitted to catch and effort data from the NPF logbooks between 1970 and 2020. These fitted models were then used for CPUE standardisation based on 1,645 grids of 0.1 by 0.1 degrees that have been fished by the tiger prawn fleet during the 51 years. The models utilize both positive and zero catch records, include the daily number of vessels as a predictor, and the predicted catch rates are based on the same grids every year. Hence, it is hoped that the analyses account for historical management changes that result in spatial and temporal closures and reduction in fleet size, eliminating the effect of changes in the spatial and temporal distribution of fishing effort and intensity.

Several statistics were employed for model evaluation and comparison, including the Akaike Information Criterion (AIC), deviance explained, mean squared error (MSE), and adjusted R^2. Comparing R^2 (between 0.39 and 0.44 from the GAMs) with those from tiger prawn analyses indicated that these models performed reasonably well (describe similar levels of variation within the data), given that endeavour prawns are non-target species. The results suggest that the estimated abundance index can be obtained from modelling the logbook data together with vessel information and can be used for stock assessments of endeavour prawns.

Among the eight statistical models, the generalized additive models that assumed a Tweedie distribution and included interaction terms generally performed best. When this GAM model was applied to the two species combined, and across the whole NPF area, the model described 45.8% of the total deviance and resulted in a MSE (in log-scale) of 0.423. However, the standardized CPUE trends were quite similar among alternative models. The trends of the standardized abundance index over time (SI_y) from alternative models are difficult to distinguish visually and the difference in the abundance index values is small (mean CV 0.046 for four GAMs over the 51 years). Therefore, it is not critical to determine the best model and using time series of abundance index estimated by any of the four GAMs would be appropriate. The time series of SI_y indicates that endeavour prawns were more abundant in the early years but less abundant in recent years based on the raw or nominal CPUE estimates. SI_y declined significantly before 1986 but slowly increased during the 1990s and since early 2000s has tended to be less variable. When the change in standardized CPUE is expressed as a change in relative fishing power FP_y, fishing efficiency on endeavour prawns has increased from $FP_{1970} = 1$ to $FP_{2020} = 2.96$ during the 51 years. The average annual creeping factor is $C\% = (2.96 – 1)/51 = 3.8\%$.

In addition to analysing the two species of endeavour prawns combined as a group, CPUE standardisation was also carried out for blue and red endeavour prawns separately. Interestingly, the temporal trends of SI_y were very similar among the two species and the group. Specifically, blue endeavour prawn and the combined group exhibited a nearly identical pattern. We hypothesised that the similar results were due to the fact that endeavour prawns were recorded as a group in the logbooks but split into two species using a statistical model afterwards. The proportion of one species in the group was fairly stable over time with blue endeavour prawn dominating. Hence, it was unnecessary to model two species independently. It was recommended that the results from the combined two species as a group be used in future stock assessments. It should be noted that this is inconsistent with the current application of CPUE standardization to tiger prawns where fishing power is estimated from the combined catches of two species of tiger prawns plus one half of endeavour prawn catches.

Standardizing CPUE at the sub-stock level was more challenging. When the catch data were divided into four endeavour prawn Stock Regions, low fishing effort in some regions and years reduced model stability and made model comparison difficult. The standardized CPUE trends were distinguishable among the four GAMs, particularly for Stock 1 and Stock 4. When stock assessment was conducted at multi-stock level (as in the current Bayesian hierarchical biomass production model used to assess blue endeavour prawns), stock-specific SI_y can be adopted; otherwise, the region-wide SI_y should be used.

The results from this study were indirectly validated through comparison with estimates for other species or from other fisheries. The changes in relative fishing efficiency gauged by the mean creeping factor could be compared across studies. A preliminary study using a Bayesian state-space depletion model estimated that relative fishing efficiency of the brown tiger prawn fleet on blue endeavour prawn in the NPF only increased 0.22 times between 1970 and 2005, equivalent to less than 1% per year increase during the 35 years. In the Queensland East Coast Trawl Fishery, fishing power for northern endeavour prawns increased by an average of 0.93% per year (13% increase from 1989 to 2003). For other species, mean annual creeping factors are 0.57%, 1.21%, 2.86%, and 0.35% for tiger prawn, red spot king prawn, east king prawn, and saucer scallop, respectively. Our estimated creeping factor of 3.8% for endeavour prawns was larger than the estimates in the Queensland East Coast Trawl Fishery, but close to the creeping factor for the white banana prawns in the NPF (3.88% per year from 1987 to 2011). Globally, most estimated creep factors were around 2–4%/yr, and our estimates was within this range. Independent estimates of changes to the fishing power for endeavour prawns would be complicated by reason of their being a bycatch species rather than a target. Estimating changes to the catching efficiency (or fishing power) of tiger prawn effort that succeeds in taking a bycatch species may be biased for reasons related more to the target tiger prawn fishery than the incidental catch of endeavour prawns in the areas where the distributions of the two types of prawn overlap.

3. Developing stock assessment methods for red endeavour prawn and improving blue endeavour assessment model

Endeavour prawns in the NPF are relatively data-poor compared to targeted grooved and brown tiger prawns. A lack of biological and fisheries data, for example, maturity at size, natural mortality, spawning patterns, availability, and catchability, prevented application of data-rich, shorter time step models to be applied to the endeavour prawns. Consequently, the existing blue endeavour prawn assessment adopts a biomass dynamics model (BDM, aka surplus production model) with an annual time step. Biomass dynamics models require less information and make fewer but stronger assumptions and avoid the need to estimate difficult parameters such as stock-recruitment relationship parameter such as steepness, annual and weekly recruitments, gear selectivity, spawning biomass, etc. We continued to apply the approach to assessing the blue endeavour prawns and adopted Bayesian BDM for both red and blue endeavour prawns. This stage work has been mostly completed and currently is under internal review.