Department of Primary Industries
Department of Regional NSW

NSW Stock Status Summary – 2023/24

Eastern King Prawn (*Melicertus plebejus*)

Assessment Authors and Year

Helidoniotis, F. and Taylor, M.D. 2023. NSW Stock Status Summary 2022/23 – Eastern King Prawn (*Melicertus plebejus*). NSW Department of Primary Industries, Fisheries. 21 pp.

Stock Status

Current stock status	On the basis of the evidence contained within this assessment, Eastern King Prawn are currently assessed as **sustainable**

Scope of this report

Eastern King Prawn (*Melicertus plebejus*) is taken within two areas in New South Wales waters: the Ocean Trawl Fishery and the Estuarine Fishery. This report is focused on the Ocean Trawl Fishery.

The most recent stock assessment for Eastern King Prawn was in 2020 (Helidoniotis *et al* 2020). A multi-jurisdictional assessment was conducted to inform the population status of EKP across the Queensland and New South Wales fisheries.

The scope of the current report is to conduct a stock status summary informed by updated standardised catch rates and the previous assessment, to provide a weight-of-evidence determination of EKP status for FY2023 in the Ocean Trawl Fishery with data up to 2022.

Stock structure & distribution

Eastern King Prawn (EKP) is endemic to Australia and distributed along the eastern Australian coast between Hayman Island in Queensland (20°S) and north-eastern Tasmania (42°S) (Montgomery 1990, O'Neill *et al* 2014). In New South Wales, postlarvae recruit to estuarine nursery grounds along the entire coast where they reside until adolescence, after which they emigrate to inshore waters and commence northward spawning migrations shortly thereafter (Taylor and Johnson 2021). These northward migrations are extensive, at times exceeding 1,000 km (Montgomery 1990), and continue as the species grow, often coinciding with a move into deeper water. Spawning usually occurs in offshore areas and the East Australian Current disperses larvae southward (Everett *et al.* 2017). Recent evidence indicates that EKP along eastern Australia can be considered a panmictic stock (Premachandra *et al.* 2022).

Biology

Eastern King Prawn are short-lived (<3 years of age) relative to other marine taxa, but are a fast-growing species, growing up to 73 mm and 52 mm carapace length (CL) for females and males respectively (Lloyd-Jones *et al.* 2012). Growth, condition and survival of EKP within estuarine nursery habitats are negatively impacted by low salinities (Tyler *et al.* 2017), and consequently, postlarvae and juvenile prawns are most common in the lower reaches of estuarine nurseries (Taylor *et al.* 2017; Taylor *et al.* 2018). Growth rates for EKP are faster at more southern latitudes and during summer (Lloyd-Jones et al. 2012). Maturation occurs in coastal waters usually when prawns reach 38–42 mm CL (~4 months of age, Courtney *et al.* 1995; Courtney *et al.* 1996). Most spawning occurs in waters off the northern New South Wales and south-eastern Queensland coast, and may take place at any time during the year (Montgomery *et al.* 2007), however in the northern part of the range it is primarily winter egg production that supports recruitment (Courtney 1997; Montgomery *et al.* 2007).

FISHERY STATISTICS

Catch information

Commercial

Eastern King Prawn are caught in two commercial fisheries within New South Wales: the Ocean Trawl Fishery (OTF) and the Estuary General Fishery (EGF).

Historical records indicate that commercial fishing for Eastern King Prawn in New South Wales dates as far back as colonial times (1800-1820, Ruello 1975), and for much of the very early history of the fishery, harvest was dominated by estuarine catches. Like many penaeid species, catches have been highly variable but have generally declined since the early 1980s. Large removals of smaller estuarine prawns, particularly in southern New South Wales, meant that the stock remained growth overfished for several decades (Montgomery 2000; Taylor 2016). The closure of many estuarine fisheries and the establishment of Recreational Fishing Havens in many estuarine nurseries where commercial harvest was concentrated (Taylor *et al.* 2005) indirectly reduced estuarine catches.

The OTF has higher catches (93-99% of the total catch) across all fisheries ranging between 445 - 637 tonnes over the last 5 years (2018 - 2022). This report is focussed on the OTF.

Catches in the OTF declined from a from a peak of ~1,000 tonnes in the early 1980s, to <500 tonnes in recent years (Figure 1). Catches recently peaked between 2016 and 2018 and were proportionally higher in zone 3-5 and zone 2 (Figure 1). Historically, prior to 1988 zone 2 and zone 1 were proportionally higher than zone 3-5. Since 2018, catches have remained stable in zone 3-5 and zone 2, at approximately 200 tonnes in each zone. In zone 1 catches declined from 200t in 2020 to 100 in 2022. Catches remained stable in zone 3-5 and 2 having a higher proportion of catches since 1989 compared to zone 1.

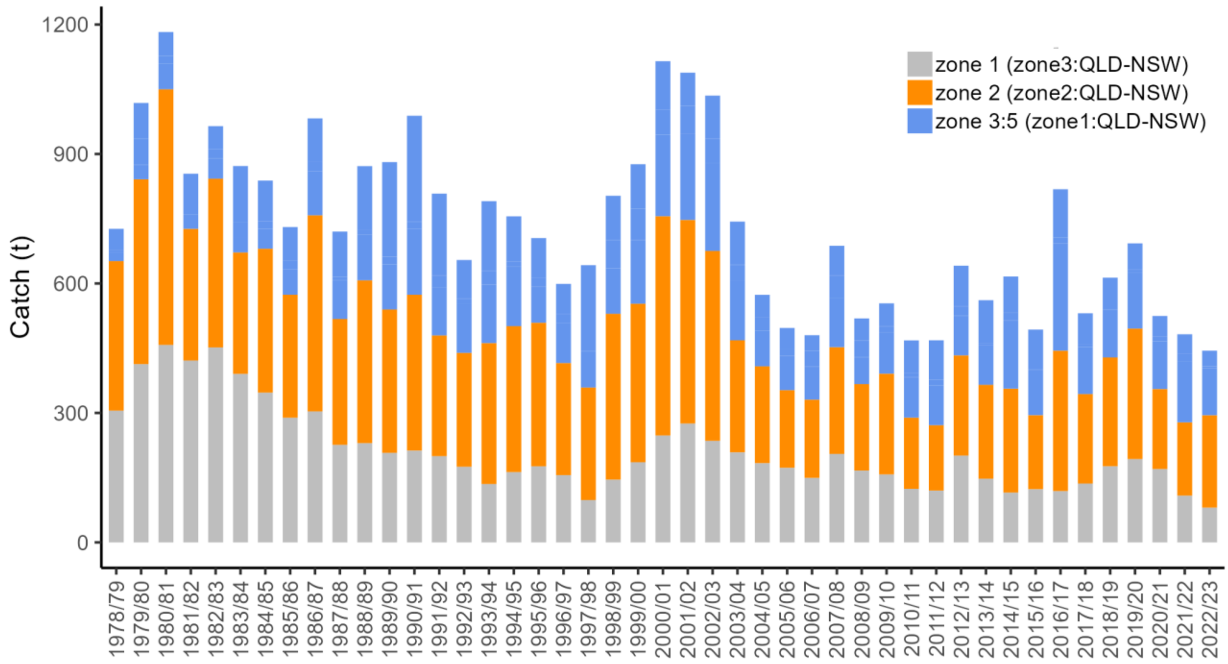

Figure 1 Annual reported landings (t) of Eastern King Prawn from New South Wales Ocean Trawl Fishery, from 1978 to 2023.

Recreational & Charter boat

The most recent published estimate of recreational catch in New South Wales was for FY2020 (Murphy *et al.* 2022), with catch of prawns (all species) estimated at 398,068 individuals and a residual standard error (RSE) of 60%. As indicated in the high RSE value, recreational catch is somewhat uncertain, as fishing for the species is a niche activity and is generally not well represented within the sampling frame for this fishing survey. Other historic estimates of prawn catch include ~105 t (all species) in FY2001 National Recreational and Indigenous Fishing Survey, and an average of ~32 t (all species, averaged across 1992-1994) per 'recreational prawn fishing season' (November to March, but would approximate annual catch as fishing is minimal outside of these periods) in some of the most important recreationally fished estuaries in New South Wales (Reid and Montgomery 2005).

Indigenous

There is no information available on the take of Eastern School Prawn by the New South Wales Aboriginal cultural fishery.

Illegal, Unregulated and Unreported

There is no information available on the Illegal, unregulated and unreported take of Eastern School Prawn in New South Wales.

Fishing effort information

Total fishing effort across all methods and fisheries that reported Eastern King Prawn catch was 3762 days in FY2023 (Figure 2). Total effort has declined from a maximum of 28989 days in FY2003, to 3762 in FY2023, with a notable decline occurring between FY2005 and FY2010 (Figure 2). Changes in logbook reporting means that effort is not directly comparable throughout the time series. In particular, prior to FY1998, effort of different gear types could not be directly mapped to the species harvested, and a further major change in reporting occurred following FY2009.

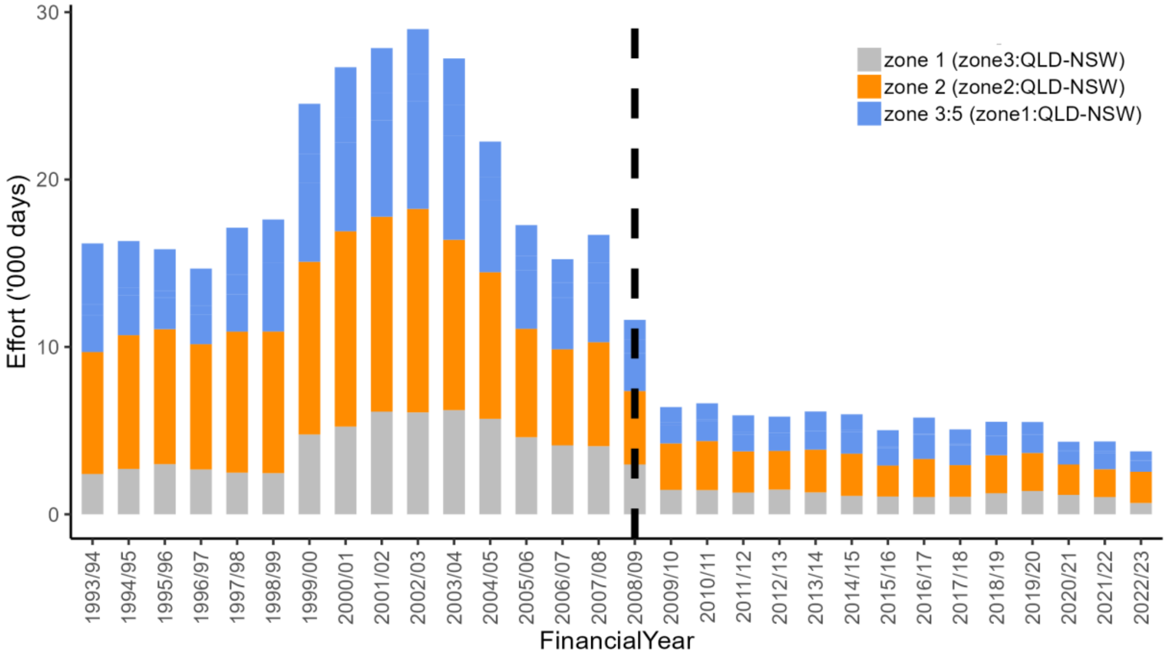

Figure 2. Annual reported effort ('000 days) of Eastern King Prawn from New South Wales, from 1978 to 2023. The vertical dashed line represent change in log book reporting

In 2009 there were changes in fisher logbook reporting from monthly to daily reporting. The ComCatch database consists of monthly reporting (all records pre-FY2010) and a 'mapped ComCatch' dataset (post-FY2010) based on daily reporting. The 'mapped-ComCatch' dataset is derived from daily FishOnline records that were re-aggregated into monthly data to form the 'mapped-ComCatch' dataset. The reason for the mapping was to have a continuous 'ComCatch' dataset up until the present day. The change in logbook reporting might not affect the amount of reported catch however it might affect the amount of reported effort, and for a catch rate standardisation that relies on catch and effort, this is an important consideration. The change in reporting was explored to determine if this led to different effort values. The data used for this analysis was the ComCatch data FY2010 - FY2023 (i.e the native ComCatch data and the mapped Comcatch data). The reason for using this data set is because it was used in the catch rate standardisation in the previous assessment (Helidoniotis *et al*, 2020). The number of days effort reported for each month was presented as a histogram (Figure 3). The histogram indicated a greater frequency of relatively high effort being reported pre-FY2010 compared to the mapped ComCatch (post-FY2010). This may result in artificially high catch rate indices from 2009 onwards relative to pre-FY2010. For the analysis of catch rate standardisation, any variation in effort occuring through the time series can be an issue however a more pertinent issue is when that variation in effort changes quite distinctly as it did in the ComCatch database. In addition, (Figure 3) indicates aggregative reporting behaviour in the period when records were reported monthly (pre-FY2010). In the pre-FY2010 data, there were peaks in records where 10 d month-1 (2 working weeks) and 20 d month-1 (4 working weeks) were reported, suggesting aggregation and rounding. This pattern diminished in the post-FY2009 period, and the frequency of fisher days tailed off. This highlights the difference in effort reporting between the ComCatch and the mapped-ComCatch database, and provides justification for conducting two separate time series for the catch rate standardisations: native ComCatch data for pre-FY2010 and native FishOnline data for post-FY2010 (i.e not use the ComCatch data post-FY2010). The reason for dispensing with the post-FY2010 ComCatch is that FishOnline collects more data than ComCatch e.g grids, latitude, longitude, and hourly reporting. FishOnline has been present now for a good number of years and this warrants the switch to FishOnline. It is recommended that this switch be accounted for in future assessments by applying a different catchability between the two time-series of catch rates.

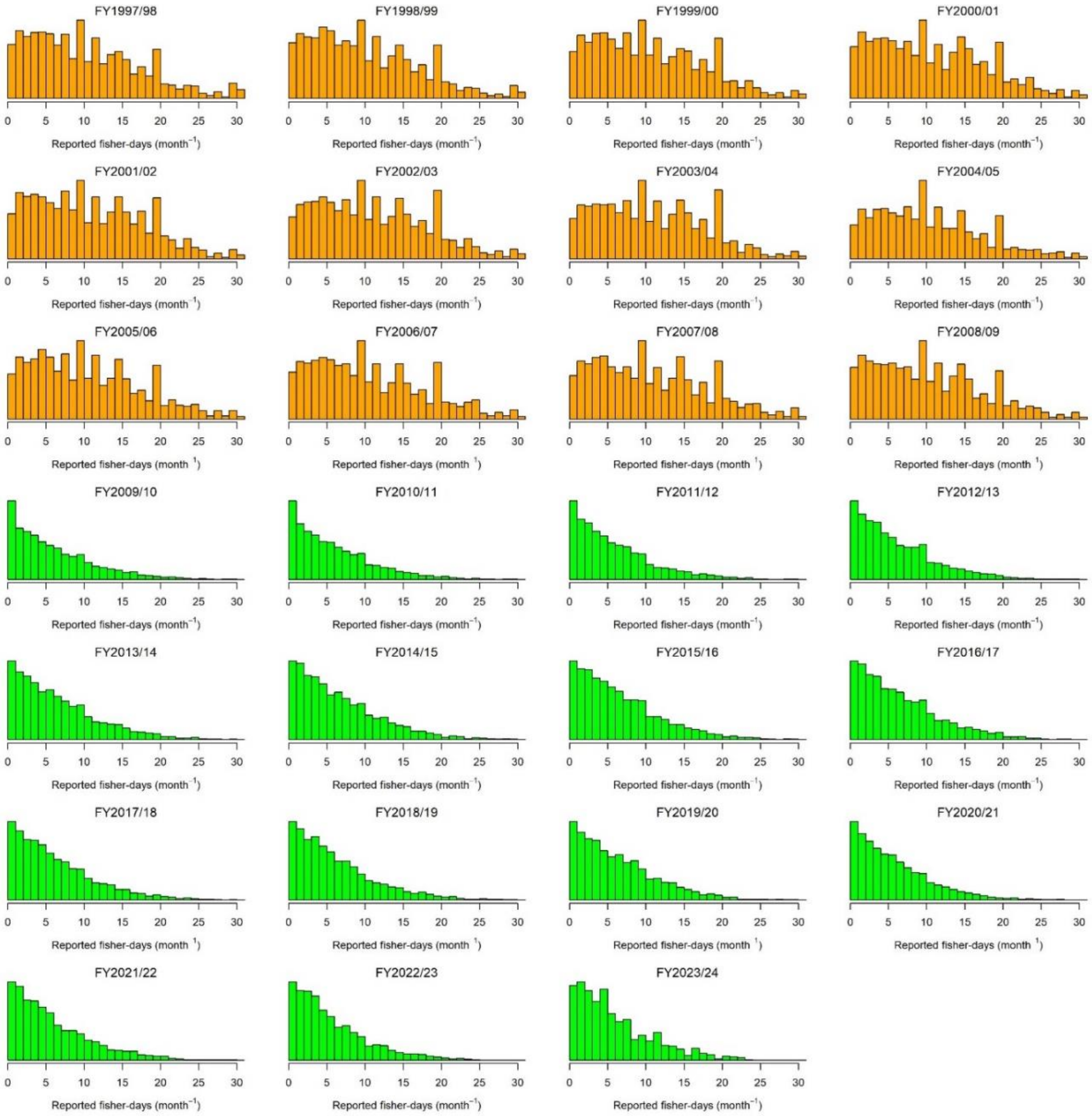

Figure 3 Histogram showing trends in effort reporting for the Eastern King Prawn from New South Wales Ocean Trawl Fishery for the period FY1997 to FY2324. Monthly records from the ComCatch database (pre-FY2010) are shown in orange, whereas the number of daily records (reflecting fisher-days) reported per month from the mapped ComCatch dataset (post-FY2009) are shown in green.

Catch rate information

Following the spatial structure of the 2020 assessment, regional (zonal) standardised catch rates were calculated for EKP in three zones: zone 1 (QLD-NSW zone 3), zone 2 (QLD-NSW zone 2) and zone 3-5 (QLD-NSW zone 1), (Figure 4).

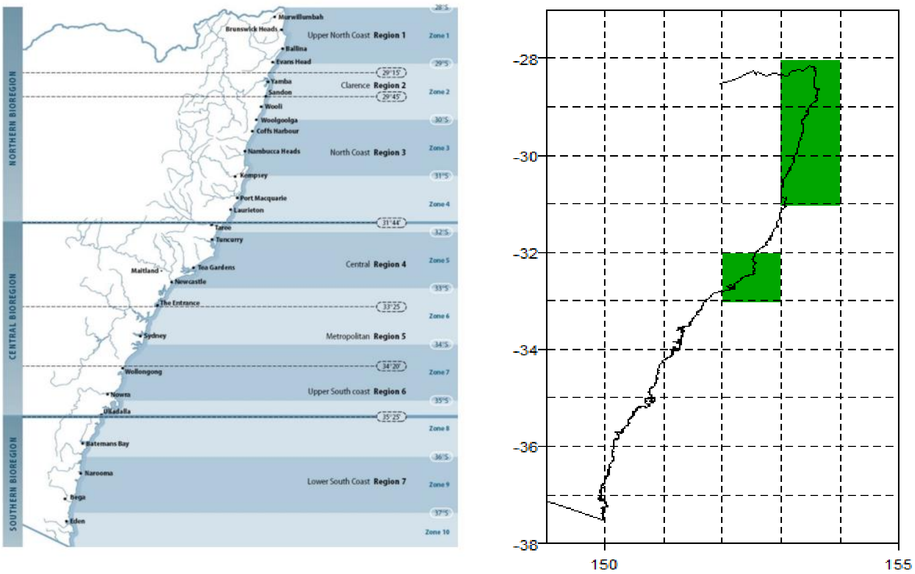

Figure 4 Fishing grids corresponding to the catch rate analysis for Eastern King Prawn in New South Wales. The map on the left presents the NSW ocean zones and the map on the right presents the grids within each zone used in the catch rate analysis.

In zone 3-5 the catch rate in 2022 remained above the 2019 level, zone 2 was approximately the same as 2019, however in zone 1 the catch rate in 2022 decreased below 2019 levels (Figure 5). The catches were higher in zone 3-5 and zone 2 and this coupled with the favourable catch rates there, might indicate that the stock was sustainable. If the favourable outcome of previous assessment is assumed to represent New South Wales, and given there were no marked decreases in catch rates in the current analyses, it is assumed that Eastern King Prawn in New South Wales remained sustainable in 2022.

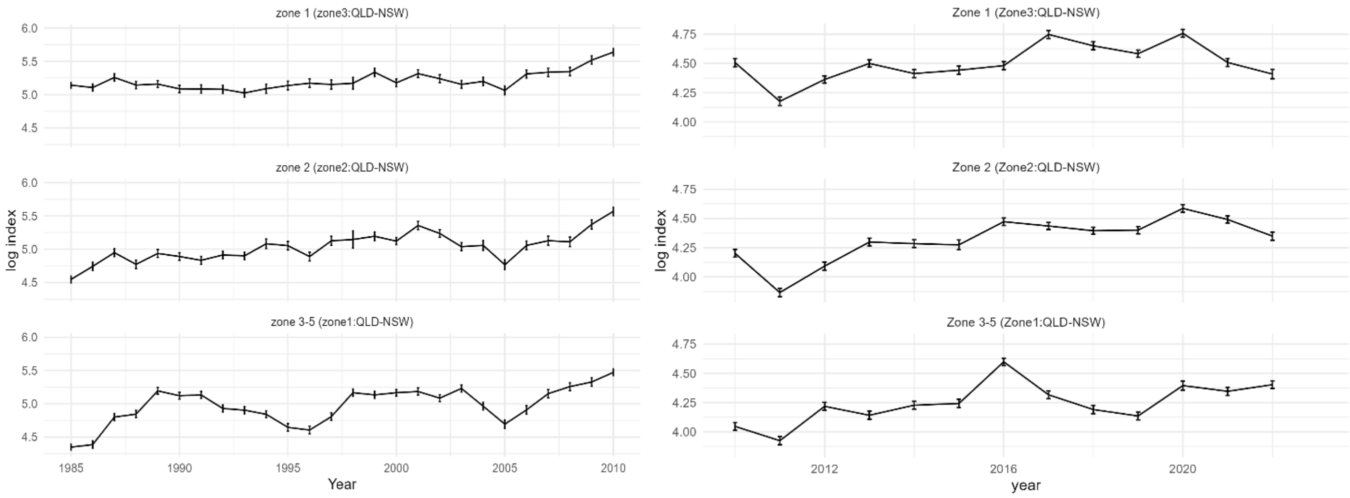

Figure 5 Annual indices of catch rate standardisation of Eastern King Prawn from New South Wales Ocean Trawl Fishery, from 1985 to 2022. The left plots are based on ComCatch data and the right plots are based on FishOnline.

Stock Assessment

Stock Assessment Methodology

Year of most recent assessment:

2023 (using data to 2021/22)

Data inputs

The data sources included in this report (Table 1) were used to determine catch rates, and to create total annual harvests. The time series of data varied between different data sources. Harvest data had the longest time series of 44 years from 1979 to current year and the catch and effort data spanned 37 years.

The data sources used in the catch rate analysis included records in the ComCatch database for FY1985 – FY2009, and FishOnline database from FY2010 – FY2022. Standardised catch rate was calculated for two time periods 1985 – 2010 based on ComCatch database and 2010 – 2022 based on FishOnline database. The ComCatch database were monthly aggregates of catch and effort per fisher. The FishOnline database were daily records consisting of hourly catch and effort data.

Table 1. Summary of the main data sources of commercial fishery records and changes to fisher reporting requirements through time

Time period	Data source	Reporting requirements
Pre-1984	HCatch	Catch unit – kg per month No fisher, vessel or effort information available Spatial scale – 3 broad ocean zones
July 1984 – June 1997	ComCatch	Catch unit – kg per month Effort unit – days fished per month, total number of shots and total hours trawled per month Catch data not linked to individual methods, therefore, effort only assigned to catches when a single method was used in a given month Spatial scale – 3 broad ocean zones
July 1997 – June 2009	ComCatch	Catch unit – kg per month Effort unit – days fished per month, total number of shots and total hours trawled per month Catch data provided for each method used Spatial scale – 3 broad ocean zones
July 2009 – present	FishOnline	Catch unit – kg per fishing event (daily records) Effort unit – various, one per method; hours fished, net length or number of shots, hooks, lures or traps; hours trawled per day Catch data provided for each method used Spatial scale – individual estuaries, 7 broad regions; 0.1° x 0.1° C-square grid Voluntary E-reporting of catch records since 2011 Compulsory E-reporting for quota reconciliation since 2019

Assessment method

A weight-of-evidence approach has been used to classify the biological status of the New South Wales Eastern King Prawn stock based on:

1) standardised catch rates: Modelling of a standardised catch rate time series for three assessment zones within the OTF, and

2) comparison against standardised catch rate in the previous formal assessment.

There are three zones within the Ocean Trawl Fishery, numbered sequentially from south to north as follows: zone 3-5 is New South Wales south, zone 2 is New South Wales central, zone 1 is New South Wales north (left map, Figure 4).

The catch rate standardisation was spatially stratified into three commercial fishing zones across New South Wales to take into account spatially explicit size distribution of EKP owing to their movement patterns. The zones were numbered sequentially from south to north as follows: zone 3-5 - New South Wales south, zone 2 - New South Wales central, zone 1 - New South Wales north. Each zone was further subdivided into smaller grids and the data from these specific grids (highlighted on the right map in Figure 4) were used toward the analysis of the updated catch rate standardisations.

For the catch rate standardisation, 4 grids were selected (Figure 4). Grids were based on where most of the harvest occurred. Daily harvest (kg) and vessel identification for 30' logbook grids were obtained for trawl fishing between 2009 and 2022 calendar years (FishOnline logbook catch data), collected by New South Wales Fisheries. Lunar data was based on Courtney et al. (1996) and O'Neill and Leigh (2007). The data consisted of a continuous daily luminous scale of 0 (new moon) to 1 (full moon).

The OTP fishery is a multi-species fishery, consisting also of School Whiting, octopus, bugs and squid. Given the multi-species complexity of fishery exploratory analyses were used to help define the proportion of other species that are targeted (Courtney et al 2014). A consistent 20-60% of the catch consisted of School Whiting. Therefore, based on New South Wales business rules, a higher 60% catch rule was used to infer EKP targeting for the analysis of standardised catch rates.

The following criteria were applied to the logbook data to filter catch and effort data specific to Eastern King Prawn.

- each logbook event ID that had EKP anywhere in the record
- only Fishing method 11 was used

The data set was further filtered to include a core set of grids and vessels. Catches were aggregated over all years and the grids with 95% of the total catch were selected. Following from that, a set of core vessels were selected that had fished for at least 2 years or more. The data were subdivided into three zones: (1) New South Wales south, (2) New South Wales central, (3) New South Wales north.

Standardised catch rates were analysed for each dataset using a linear mixed effect model (lmer) in R (R Core Team, 2019). The model form was

log(catch/fpoffset) ~ year + month + zone + year:month + year:zone + month:zone + year:month:zone + zone:logwh + zone:logeffort + lunar + (1|acn), REML = TRUE, data = EKP)

where *log(catch/fpoffset)* was the catch adjusted for fishing power, *year* was the fishing year, *month* was the fishing month, *zone* was the three spatial zone, *fpoffset* was the fishing power offset, *logwh* was the effect of whiting catch (*Sillago robusta* and *S. flindersi*)

Fishing power has been reported to affect catch rates (O'Neill and Leigh 2007) and this was included in the current standardisation. Additional analyses (reported in the Appendix) were conducted to compare different methods including REML (Genstat, VSN International), AsReml (in R, R Core Team) and lmer (in R, R Core Team). All three methods used linear mixed effect models with vessel ID as the random effect. More details are provided in the Appendix. Furthermore an additional standardization using a glm model was conducted for comparison with the linear mixed effect models and presented in the Appendix.

Status Indicators - Limit & Target Reference Levels

Biomass indicator or proxyg	B/B_0
Biomass Limit Reference Point	B_{20} (20% of pre-exploitation spawning biomass), through adoption of the Australian standard in national SAFS reporting
Biomass Target Reference Point	NA
Fishing mortality indicator or proxy	F/F_{msy}
Fishing mortality Limit Reference Point	NA
Fishing Mortality Target Reference Point	NA

Results and Discussion

After filtering on fishing method and zonal area of fishing grounds for Eastern King Prawn, 4 grids remained of the initial 11 grids and these were used for estimating annual catches (Figure 1).

Upon filtering on the highest 95% of landings, the highest landings occurred in 4 logbook grids (30' x 30' grids), for the period 2009–2022. The remaining 11 grids accounted for about 5% of the catch. The 4 grids were used to represent catch rates for the fishery as a whole.

Overall, the updated standardization indicated that catch rates increase in 2020 in all three zones in New South Wales. However, since 2020 the trends have varied between zones. In zone 3-5 the catch rate remained above the 2019 level, in zone 2 it was approximately at the 2019 level, however in zone 1 the catch rate decreased to below 2019 levels (Figure 6). The catches were higher in zone 3-5 and 2 and this coupled with the favourable trend in catch rates in those zones, might indicate that the condition of the New South Wales is sustainable. If the catch rate results from the previous assessment are accepted as a proxy for biomass, it is assumed that overall, the spawning biomass was sustainable in 2022 in New South Wales given that no marked decreases in catch rate were apparent in the current analyses.

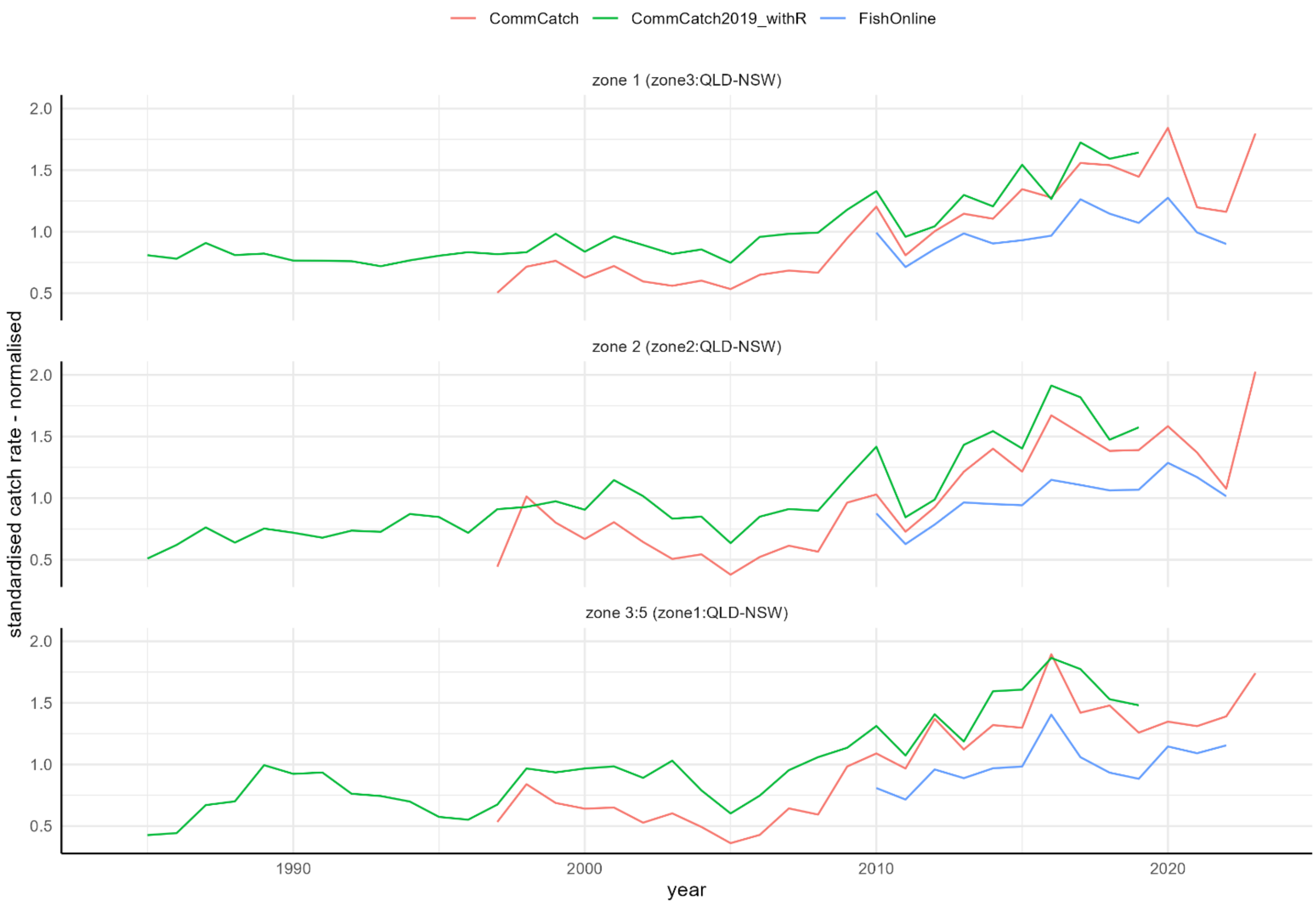

Figure 6 Annual standardised catch rate for Eastern King Prawn in New South Wales. Also shown are comparisons between the two databases ComCatch and FishOnline. The two ComCatch series are catch rate analyses using GENSTAT (REML) and R (REML in R software). The FishOnline series used R (REML in R software).

The most recent stock assessment for Eastern King Prawn was in 2020 (Helidoniotis *et al* 2020) and previously in 2014 (Courtney *et al* 2014). The assessment was conducted on the biological stock spanning Queensland and New South Wales. The most recent assessment estimated that the 2019 spawning biomass across both jurisdictions combined was 62% of the unfished 1958 level, suggesting that the stock was sustainable. The model fitted the Queensland and New South Wales catch rate data equally well and therefore it is assumed that the spawning biomass in New South Wales was sustainable in 2019. The catch rate standardization for New South Wales indicated that the trend increased since the commencement of records in 1984. There was a marked increase between 2012 and 2016 for all three zones, before decreasing slightly until 2019 which was the end of the time series.

The purpose of the current report and the analyses herein was to determine the current status of the New South Wales stock in 2022 based on the previous assessment and updated catch rate standardizations. Results indicated that catch rates increase in 2020 in all three zones in New South Wales. However, since 2020 the trends have varied between zones. In zone 3-5 the catch rate remained above the 2019 level, in zone 2 it was approximately the same as 2019, however in zone 1 the catch rate decreased to below 2019 levels. The catches were higher in zone 3-5 and 2 and this coupled with the favourable trends in catch rates there, indicate that the New South Wales stock is sustainable. The previous assessment indicated that the stock for EKP was sustainable, however this applied to both Queensland and NSW combined and was not differentiated into jurisdictions. If the sustainable outcome of previous assessment is assumed to also apply to all of New South Wales and given that no marked decreases in catch rate were apparent in the current analyses, it is likely that Eastern King Prawn in New South Wales remained sustainable in 2022.

Result Summary

Biomass status in relation to Limit	B/B0 > 20% based on weight of evidence approach
Biomass status in relation to Target	NA
Fishing mortality in relation to Limit	NA
Fishing mortality in relation to Target	NA
Current SAFS stock status	Sustainable (New South Wales)
Current Commonwealth stock status	Not overfished Not subject to overfishing

Assumptions

The assumption in the standardised catch rate is that there is a linear relationship between catch rate and exploitable biomass. However, this might not be valid. For example, hyperstability may be occurring (catch rate remain stable while the stock size changes) or hyper-depletion (catch rates decline much faster than stock size changes) may occur. The purpose of standardization is to account for variation in the data that is not attributable to changes in abundance (Maunder and Punt 2004). However, the standardisation might not successfully account for all of this variation. The availability of the fish to the gear is another source of uncertainty that may influence the catch rate. Availability can be the result of aggregating behaviour; increasing catchability or efficiency of a fishing method through time (O'Neill *et al* 2005, O'Neill *et al* 2014). Another source of uncertainty is the model structure used in the linear regression. Some jurisdictions use effort as an offset (where the response variable is catch /effort) while other jurisdiction use effort as a term (where catch is the response term). Future work is recommended to the explore the difference in trends due to the model structure and different linear regression models (i.e between REML and glm). The difference between linear regression models has been partially explored the Appendix of this report. Preliminary results indicate a clear difference in trend between two types of linear regression models; the widely use GLM model and a REML model

Uncertainty

In addition to the assumptions inherent in catch rate standardisation, changes in commercial logbook reporting may also affect catch rates, (as presented in the Section on Fishing effort in this report). The change in logbook distorted the effort reported, which may result in artificially high catch rate indices from FY2009 onwards relative to pre-FY2010 as suggested by the result in (Figure 6). It is likely that this would have influenced the previous assessment model by Helidoniotis *et al* (2020) given that it was fitted to catch rated standardisations. If that is the case, the favourable model outcome of 62% biomass ratio in 2020 assessment might be overoptimistic. It is recommended that this be taken into consideration when evaluating the current status of the New South Wales stock. Fishing power is also known to affect the catch rate of Eastern King Prawn (O'Neill and Leigh 2007, O'Neill et al, 2003) and it is recommended to conduct analyses on fishing power using New South Wales data.

Fishery interactions

The majority of Eastern King Prawn catch is taken via prawn trawl gear within ocean waters. Bycatch and impacts on non-target species are common in prawn trawling operations (Kennelly 1995), and diverse assemblages are often captured (Taylor et al. 2020). Recent OTF observer surveys showed average discarded catch of up to ~0.5 t per trip, but interactions with threatened and protected species were generally low (Johnson and Barnes 2023).

Stakeholder engagement

Ocean Trawl Fishery shareholders, fishers and/or their representatives were invited to participate in online presentations of OTF-related assessments for Eastern King Prawn and Eastern School Prawn on 14 December 2023, to provide any relevant commentary on the assessment and raise any other relevant information. No major issues or points of discussion were raised.

Qualifying Comments

New South Wales catch and effort logbook data vary spatially and temporally across different eras, delineated by changes in fisher reporting requirements and other management changes. The change in the method of effort reporting during 2009/10 limits the certainty with which conclusions can be made regarding shifts in effort and catch rates around that time. The multi-jurisdictional nature of the biological may also have affected trends in fishery metrics.

Results from catch rate standardisation methods must be interpreted with caution, given the limited information used to derive population parameters and stock status.

Factors other than fishing, including climate change and other environmental processes, may affect changes in the abundance and biological functioning of the Eastern King Prawn stock through time.

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Appendices

Management changes

Table A 1.Management changes applied to Eastern King Prawn fishery in New South Wales

Year	Management Change
1997	Commercial logbook reporting requirements change
2006	Introduction of Ocean Trawl Share Management Plan
2009	Commercial logbook reporting change from monthly to daily reporting
2019	Finalised New South Wales Business Adjustment Program interim unitised Ocean Trawl Fishery effort quota, and Whiting quota (which will have affected targeting behaviour in the OTF)
2024	Effort quota set

Linear regression analyses

Ancillary analyses were conducted to explore the following two questions:

1) Does a linear regression model using REML differ between two software packages used in stock assessments. The two regression model are AsREML-R and GENSTAT REML, found in R software and GENSTAT, respectively.

2) What is the difference in outputs between the following linear regression models lmer (R software), glm (R software) and GENSTAT REML

Summary of results

Results indicate that AsREML-R produces identical results to GENSTAT REML. Results from comparing lmer, glm and GENSTAT REML indicate that lmer and GENSTAT REML are identical, and given that GENSTAT REML is identical to AsREML-R it follows that lmer is identical to AsREML-R when the same model formula is used. However glm differed markedly. It is recommended that future work is required to validate models and to confidently select a linear regression model for catch rate standardization. It is also suggested that the model formula be explore and whether the catch is the response variable and effort as a covariate or whether catch/effort should the response variable.

Conversion of EKP catch rate standardisation from Genstat to R

Author team: Steve Morris and Fay Helidoniotis

Acknowledgements. The Queensland Department of Agriculture is acknowledged for formulating the code for the catch rate standardisation that was written in GENSTAT

Backround

The previous assessment by Helidoniotis (et al 2020) included a catch rate standardization generated by GENSTAT using REML. Although GENSTAT is purpose built for linear regression it required expertise and was unable to be streamlined within the R software package. The benefit of using GENSTAT REML however is that it applied a linear mixed effects model that included both fixed and random effects in the catch rate standardization. Fortunately the company that produces GENSTAT, VSNI, also produces an R equivalent of REML called AsREML-R. This opened up the possibility to explore AsREML-R and compare it to GENSTAT REML to determine if AsREML-R can replace GENSTAT.

Comparison between GENSTAT REML and AsREML-R

To explore AsREML-R and compare it to GENSTAT, a catch rate standardisation was conducted using the same data that was used with GENSAT in Helidoniotis (et al 2020). The results for the catch rate standardisation from AsREML-R were then compared to that generate by GENSTAT (Figure A 1). Both AsREML-R and GENSTAT used REML and a random effect in the model formula. The catch rate standardization was conducted for each zone within the New South Wales fishery for Eastern King Prawn. The results show that the catch rate standardisation in AsREML is almost identical to GENSTAR REML in both trends and scale (Figure A 1s) and therefore AsREML can replace GENSTAT REML. In addition, AsREML-R includes smoothing functions which offer a greater selection of different linear regression models.

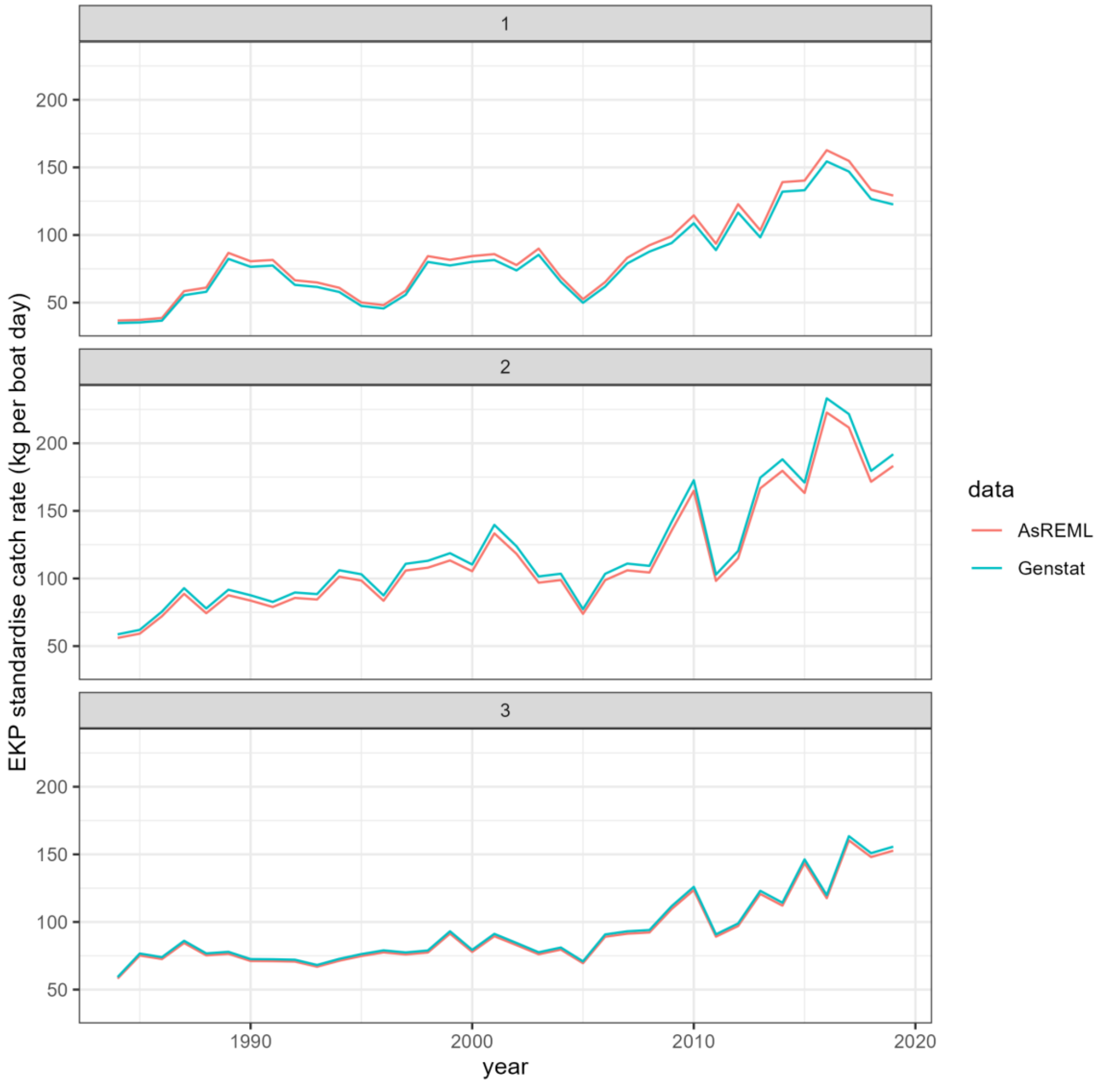

Figure A 1. Comparison of annual standardised catch rates between GENSTAT REML and AsREML for New South Wales Eastern King Prawn

Model validation

Whiting catch

Whiting was used as a covariate in the linear regression model because it is co-caught with Eastern King Prawn. Shallower waters might result in more whiting in the catch, than deeper waters. Seasonality may also be a factor with more whiting in the summer and more prawns in winter. Vessel may be another key factor with larger vessels capable of catching more whiting than small vessels due to the herding nature of the fishing operation in circumstances where the tow is travelling at relatively higher velocity.

In the data there were 10473 reports of 0kg whiting out of the 16888 reports. The transformation to log(whiting+0.001) created a bimodal distribution with a high leverage point at log(0.001)=-6.9 (Figure A 2) and this is not recommended as a covariate.

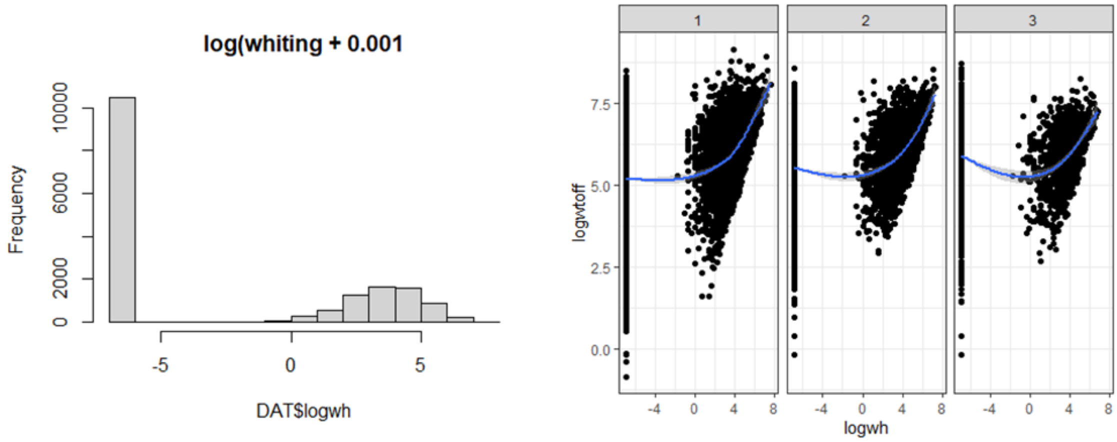

Figure A 2. Diagnostics of the catch rate standardisation of Eastern King Prawn in New South Wales

Results of the model validation suggest that the whiting covariate needs to be addressed to improve the model. One possible solution is to convert whiting into a factor with different levels.

Log transform of days fished

The days fished per report is log-transformed and enters the CPUE standardisation model as a covariate in interaction with fishing zone. With consideration for the following figure (Figure A 3), the reason is not obvious - it does not linearise the relationship between the adjusted catch and days fished. It does not "normalise" the distribution of days fished; which is not a requirement for the model. It does increase the frequency of observations as days fished increases which would give higher leverage on the slope towards longer trips. Perhaps this idea could be revisited.

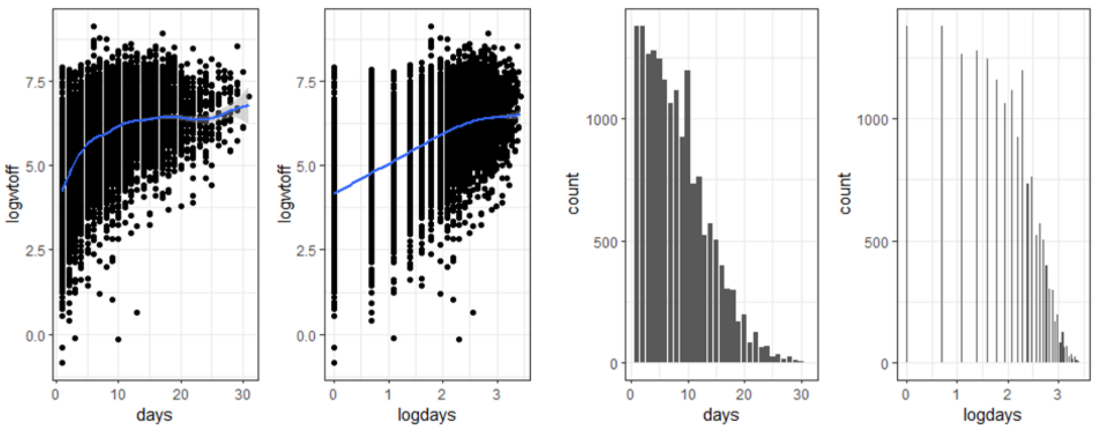

Figure A 3. Diagnostics of the data transformation using in the catch rate standardisation of Eastern King Prawn in New South Wales

Comparison of different linear regression models

Backround

The previous assessment by Helidoniotis (*et al* 2020) included a catch rate standardization generated by GENSTAT using REML. Although GENSTAT is purpose built for linear regression it required expertise and was unable to be streamlined within the R software package. AsREML-R can be used instead but both GENSTAT and AsREML-R require the purchase of a licence which can be costly. The benefit of using GENSTAT REML and AsREML-R however is that they apply a linear mixed effects model that included both fixed and random effects in the catch rate standardization. A similar mixed effect model in R is lmer (with REML) however lmer was quite slow and it is not known if the standardisation is comparable to GENSTAT REML. In additon the glm model is often used in fisheries stock assessment and therefore a glm was also included. An analysis was conducted to compare lmer, glm and GENSTAT REML.

Method

To explore and compare lmer, glm and GENSTAT, a catch rate standardisation was conducted using the same data that was used with GENSAT in Helidoniotis (et al 2020). The results for the catch rate standardisation from lmer and glm were then compared to that generate by GENSTAT. Both lmer and GENSTAT used REML and a random effect in the model formula,whereas glm was only a fixed effect model with no random effects. The catch rate standardization was conducted for each zone within the New South Wales fishery for Eastern King Prawn. Three model were explored

1. the glm model

glm(logwtoff ~ fyear + fmonth + zone + fyear:fmonth + fyear:zone + fmonth:zone + fyear:fmonth:zone + zone:logwh + zone:logdays + acn, data=EKP2019_CC)

2. the lmer model

lmer(log(catch/fpoffset1) ~ fyear + fmonth + zone + fyear:fmonth + fyear:zone + fmonth:zone + fyear:fmonth:zone + zone:logwh + zone:logdays + (1|acn), REML = TRUE, data = EKP2019_CC)

3. the GENSTAT REML model

VCOMPONENTS [FIXED=fyearfmonthzone+zone.logwh+zone.logdays; FACTORIAL=3] RANDOM=acn;
INITIAL=1,1; CONSTRAINTS=none,none REML
[PRINT=model,COMPONENTS,effects,vcovariance,covariancemodel,means,deviance,waldTests,monitoring;
PSE=estimates;
FMETHOD=automatic; MVINCLUDE=*; METHOD=AI; MAXCYCLE=20] logwtoff; SAVE=_remlsave

The results show that the catch rate standardization in lmer is almost identical to GENSTAT REML and hence AsREML-R in terms of trends. Tne scale may have differed but that is due to the different levels used in the prediction which can be adjusted. The more important result is that the trends are identical. The glm was notably different and flatter with not as much contrast in the data (Figure A 4). The result indicate that lmer can be used to replace GENSTAT REML and can also be used instead of AsREML-R where cost is an issue. It is not known whether lmer can include a smoothing function whereas AsREML_R can include a smoother which increases the the utility of ASREMLR. Nevertheless lmer is a viable alternative to GENSTAT

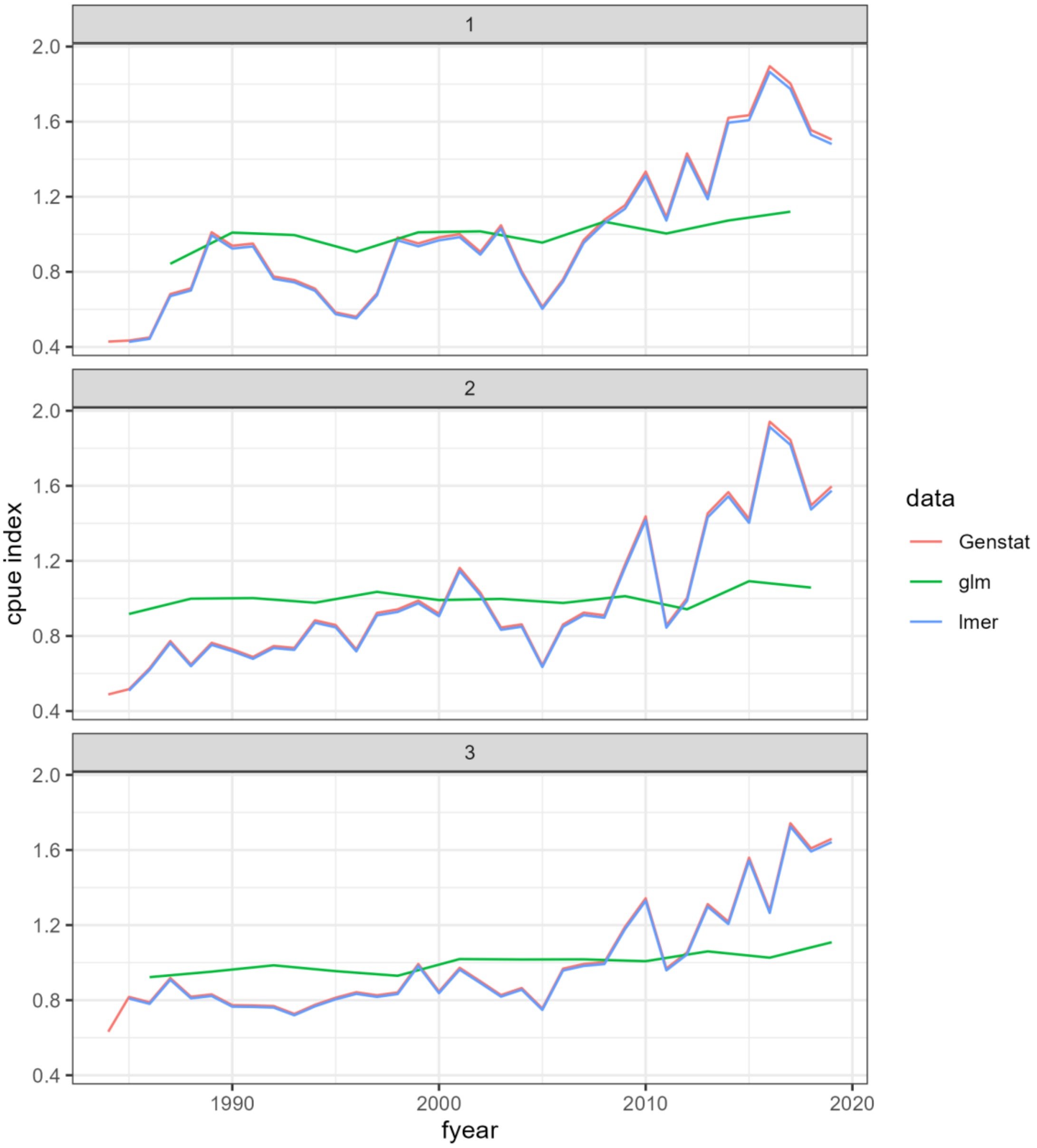

Figure A 4.Comparison of annual standardised catch rates between GENSTAT REML and lmer (R software) for New South Wales Eastern King Prawn