Stock Status Summary – 2021-22

NSW Stock Status Summary – Eastern School Prawn (*Metapenaeus macleayi*)

Assessment Authors and Year

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Stock Status

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

Stock structure and distribution

Eastern School Prawn are distributed throughout south-eastern Australia, being most abundant in New South Wales (NSW) waters, but also abundant in Queensland at latitudes south of Moreton Bay, and infrequently abundant in eastern Victorian waters (Racek 1959). The species resides in estuaries for most of its life (Taylor *et al.* 2017), but generally moves to inshore waters adjacent to the mouths of estuaries to spawn and has been shown to undertake modest northward migrations of up to 70 km (Ruello 1977). The distribution between estuarine and inshore habitats, and associated reproductive processes, are influenced by estuary inflow (Glaister 1978; Taylor and Johnson 2022), and while this is generally a positive influence recent work has shown that flooding can result in poor water quality that impacts species condition (Taylor and Loneragan 2019).

Allozyme variation has been examined (albeit with very few loci) for Eastern School Prawn. While the patterns indicated only minor variation along eastern Australia, the Queensland estuary that was sampled (Noosa River) was distinct from NSW south of the Tweed River (Mulley and Latter 1981, note that Victoria was not included in this study).

Given the information above, stock status is considered at the jurisdictional level for the purposes of this assessment, and thus assumes that all Eastern School Prawn caught within NSW constitute a single 'stock' for status reporting purposes.

Biology

The reproductive biology of Eastern School Prawn and spatial variation therein has not been extensively studied. Following the seminal work of Racek (1959) the most recent exploration of reproduction in the species is found in the thesis of Ruello (1971), which focussed exclusively on the Hunter River estuary. Samples that are reported on within this work showed quiescence through winter, with reproduction occurring through spring and summer (and even into early autumn). Although size-at-maturity was not explicitly reported in terms of L_{50} by Ruello (1971), qualitative analysis of the patterns presented suggested this value is likely to approximate 23 mm carapace length (CL) for males, and 27 mm CL for females, which roughly concurs with the earlier work of Racek (1959).

The most recent fishery independent survey for Eastern School Prawn (Taylor *et al.* 2021, covering survey years 2017-2020) indicated maximum Eastern School Prawn sizes of 30 mm CL for males, and 35 mm CL for females.

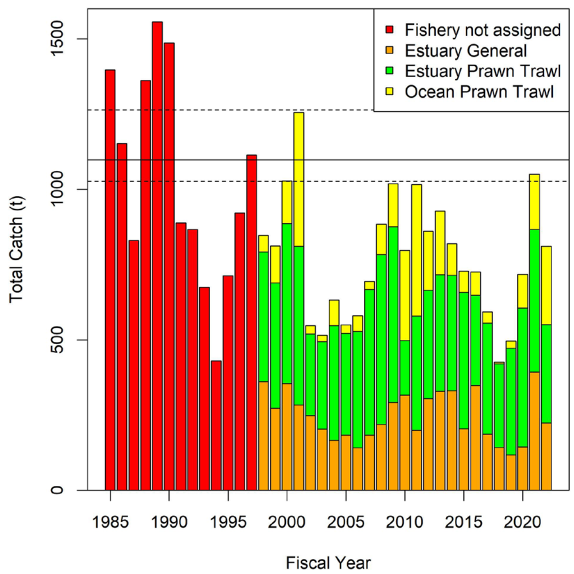
FISHERY STATISTICS

Catch information

Commercial

Eastern School Prawn harvest in NSW has been highly variable over the past 3.5 decades (Fig. 1), which is consistent with general observations of recruitment and catch and reflect the substantial influence of environmental conditions (especially rainfall) on abundance and fisher behaviour (Ruello 1973; Pinto and Maheshwari 2012; Taylor and Loneragan 2019). Simulation modelling has also established that environmental factors can have a strong influence on Eastern School Prawn catches (Ives *et al.* 2009). These traits mean this species displays large inter-annual variations in recruitment, and this is evident in the catch history presented in Fig. 1. The FY2022 total NSW Eastern School Prawn harvest was 810.7 t, with a roughly equal split between Ocean Prawn Trawl (32 %), Estuary Prawn Trawl (40 %), and Estuary General fisheries (28 %).

Figure 1 Total annual Eastern School Prawn catch by reported fishery (commercial only) within New South Wales from FY1985 – FY2022. Maximum Sustainable Yield (MSY) as estimated from Surplus Production Modelling is indicated by a solid horizontal line, and upper and lower 95% MSY confidence intervals shown as horizontal dashed lines.



Recreational and charter boat

The most recent published estimate of recreational catch in NSW 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 reflected in the high RSE value, recreational catch is somewhat uncertain, as fishing for the species is a niche and sporadic 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 four of the most important recreationally fished estuaries in NSW (Reid and Montgomery 2005).

Aboriginal cultural fishery

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

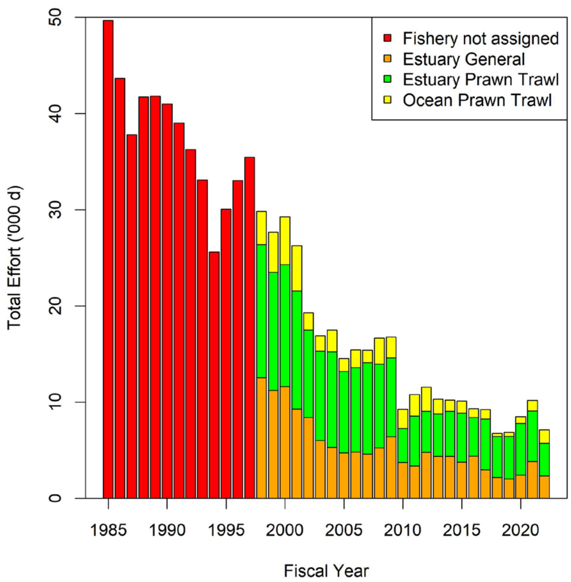
Illegal, unregulated and unreported

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

Fishing effort information

Total fishing effort across all methods and fisheries that reported School Prawn catch was 7,115 days in FY2022 (Fig. 2). Total effort has consistently declined from a maximum of ~50,000 days at the commencement of the reported time series, over the past 3.5 decades (Fig. 2). Changes in reporting mean 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. Also, effort abruptly dropped across all fisheries following the change to daily catch reporting in FY2009 (Fig. 2), which may have been influenced by aggregative effort reporting behaviour (this is discussed further in *Qualifying Comments* below).

Figure 2 Total annual days effort associated with Eastern School Prawn catch by reported fishery (commercial only) within New South Wales from FY1985 – FY2022.



Catch rate information

Eastern School Prawn standardised catch per unit effort (CPUE) was predicted using generalised linear models (GLMs), which provided an estimate of mean catch rates that were corrected for a number of variables that may have biased nominal CPUE. Generalised linear models were fitted in R (R Development Core Team 2017) using the `dosingle` function in the rforcpue package (https://github.com/haddonm/rforcpue). Models included explanatory variables *Year* (fiscal year), *Month*, *Area* (estuary *or* ocean zone), *Rainfall Index* and *Fishing License #* (Licensed Fishing Boat [LFB] number are not used for the NSW Estuary Prawn Trawl, so Fishing License # was assumed to represent vessel/fisher throughout the time series).

Rainfall Index is a variable calculated as part of the NSW Department of Primary Industries Enhanced Drought Information System (EDIS https://edis.dpi.nsw.gov.au/about), a model which integrates meteorological, hydrological and agronomic data to estimate a 'Combined Drought Indicator' for NSW. For the purposes of inclusion in CPUE standardisation for Eastern School Prawn, Rainfall Index is mapped and recalculated for catchments (EDIS generally works at a parish level), and is a percentile rank of rainfall aggregated over 12 months created using a 30 year baseline which captures recent big shifts in climate variability, and factors in climate change. This index is expressed as a value between 0 and 100, where values approaching 0 are close to driest, and values approaching 100 are close to the wettest. Rainfall index is included as a proxy to reflect estuary inflow and its influence on fishing in the standardisation algorithm.

There was no data available to support incorporation of potential changes in fishing power throughout the time series.

Estuary Prawn Trawl and Ocean Prawn Trawl catch-per-unit-effort (CPUE) data was modelled, and was expressed as $log\left(\frac{Catch\ (kg)}{Effort\ (d)}\right)$ for each non-zero monthly catch and effort record in the time series. The Clarence River estuary, Hunter River estuary, and Hawkesbury River estuary were included in the Estuary Prawn Trawl model, and Ocean Zones 1, 2 and 5 were included in the Ocean Prawn Trawl model. Estuary Prawn Trawl represents the largest component of harvest for Eastern School Prawn, especially in recent years (Fig. 1). For Ocean Prawn Trawl modelling, Rainfall Index for the catchment of the estuary adjacent to the ocean zone (which was also the home port for much of the fleet fishing that zone) was used, as this is where prawns captured in inshore waters are most likely to have emigrated from.

Standardised commercial CPUE are likely to be the most reliable index of relative abundance for Eastern School Prawn. For both the Estuary Prawn Trawl (Fig. 3) and Ocean Prawn Trawl (Fig. 4), CPUE substantially increased during the period post-FY2006. Estuary Prawn Trawl CPUE was lower than that observed for the Ocean Prawn Trawl. This is likely due to differences in gear and fishing power for the Ocean Prawn Trawl fleet, but may also reflect the aggregative behaviour of the species in inshore waters following estuarine flooding (Taylor and Johnson 2022), and comparatively lesser effort (relative to Estuary Prawn Trawl).

Despite some variability, recent Estuary Prawn Trawl CPUE has remained at a level that is well elevated to the geometric mean for the time series (Fig. 3). The sharp dip in FY2018 was likely to be drought-related, whereas the sharp dip in FY2022 was likely due to protracted and catastrophic flooding across the NSW coast during the summer-autumn of this period. The Ocean Prawn Trawl fishery is reliant on the emigration of adolescent and adult Eastern School Prawn from adjacent estuaries. While prawns will emigrate from the estuary every year, economically lucrative catch rates are often associated with the aggregations of prawns which exit the estuary following heavy estuary inflow. The reliance of catch on estuarine conditions and migration contributes to the considerable variability in the CPUE time series (Fig. 4).

Figure 3 Standardised (solid blue line, with 95% confidence intervals indicated) and nominal (dashed black line, representing the geometric mean CPUE for each time increment) catch per unit effort (CPUE) series for New South Wales Estuary Prawn Trawl Eastern School Prawn harvest. Both relative (primary-*y*-axis) and scaled (secondary-*y*-axis) axes are presented to aid interpretation. The solid black line indicates the most recent 10-year average, and the grey shaded area indicated the 95% confidence intervals surrounding this mean. The horizontal grey line represents the geometric mean CPUE through the series. The vertical red lines represent implementation of major changes to reporting which result in breaks in the continuous time series.

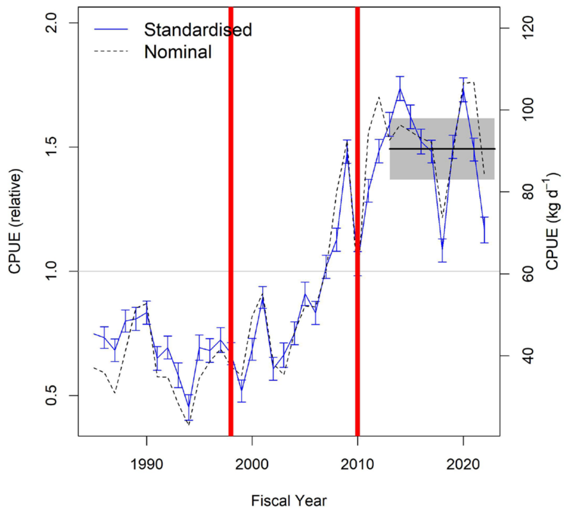
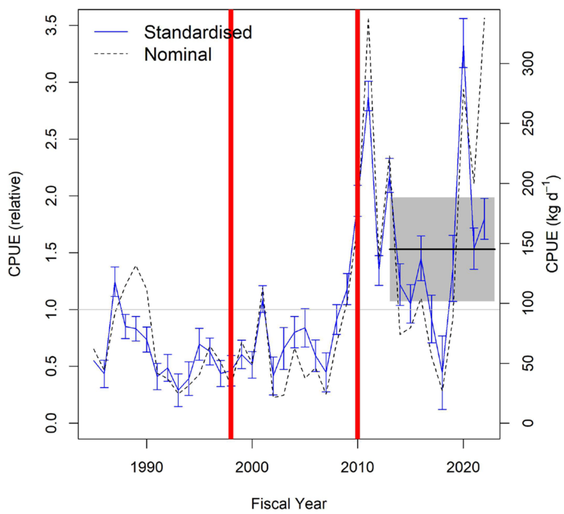


Figure 4 Standardised (solid blue line, with 95% confidence intervals indicated) and nominal (dashed black line, representing the geometric mean CPUE for each time increment) catch per unit effort (CPUE) series for New South Wales Ocean Prawn Trawl Eastern School Prawn harvest. Both relative (primary-*y*-axis) and scaled (secondary-*y*-axis) axes are presented to aid interpretation. The solid black line indicates the most recent 10-year average, and the grey shaded area indicated the 95% confidence intervals surrounding this mean. The horizontal grey line represents the geometric mean CPUE through the series. The vertical red lines represent implementation of major changes to reporting which result in breaks in the continuous time series.



For both Estuary Prawn Trawl and Ocean Prawn Trawl, average CPUE over the past 10 years remain well above the geometric mean of the time series considered (with the exception of the Ocean Prawn Trawl during the drought from FY2017-2018), and there was no evidence of a consistent downward trajectory in standardised catch rates for the species.

STOCK ASSESSMENT

Stock assessment methodology

Year of most recent assessment

2023 (incorporating data to the end of FY2022)

Assessment method

Two assessment methods were employed:

1. Standardised catch rates: Modelling of standardised CPUE time series, specifically the trajectory of standardised CPUE, and comparison against recent mean standardised CPUE

2. Surplus Production Modelling (SPM): Surplus Production Modelling was undertaken using the datalowSA package in R v. 4.3.1. The SPM uses population productivity (r), carrying capacity (K), and initial biomass (B_{init}) parameters of an underlying Schaefer production model, to describe the dynamics of the stock in terms of its exploitable biomass.

Main data inputs

Main data sources employed in the analyses included:

a) Commercial catch of Eastern School Prawn landed across all fisheries within NSW, from FY1985 – FY2022, derived from the New South Wales ComCatch database for FY1985 – FY2009, and FishOnline database from FY2010 – FY2022. Commercial catches were expressed as the total catch per fiscal year for the period above

b) Standardised CPUE for Estuary Prawn Trawl and Ocean Prawn Trawl harvest within New South Wales, from 1985 – 2022, derived from records in the New South Wales ComCatch database for FY1985 – FY2009, and FishOnline database from FY2010 – FY2022. Daily FishOnline reporting was mapped to the monthly ComCatch reporting format, meaning all input data were monthly aggregates of catch and effort per fisher, but records were excluded when average aggregate monthly catch rates exceeded 1,000 kg d^{-1} (as excessive catch rates are potentially the result of aggregative effort reporting, as outlined in *Qualifying Comments* below). Standardised CPUE were expressed as the predicted mean per fiscal year for the period above. Standardised CPUE for Estuary Prawn Trawl only was used in Surplus Production Modelling

c) Rainfall Index data, obtained from the NSW Department of Primary Industries Enhanced Drought Information System (EDIS https://edis.dpi.nsw.gov.au/about)

Key model structure and assumptions

1. Standardised catch rates: Model structure is as described in *Catch rate trends*, above. The analysis assumes that annual CPUE represent a relative index of abundance, and are not unduly influenced by error in reporting or other factors that are not explicitly or indirectly accounted for through the standardisation model.

2. Surplus Production Model: The SPM uses the Schaefer production model with maximum surplus production assumed to equal $0.5 \cdot K$. Initial estimates for *r* and *K* parameters for the SPM were obtained from preliminary simulations using a Catch-MSY model (Martell and Froese 2013) within the datalowSA package, using the above data sources (and assuming medium resilience). The stock was assumed to have been depleted prior to the time series of data that was included (this assumption was supported by Catch-MSY modelling which suggested initial depletion of ~0.6), so initial values for the model included B_{init}. Starting estimates of B_{init} were optimised by minimisation of negative log-likelihood.

Sources of uncertainty evaluated

SPM outcomes were explored within a simulation framework testing a range of initial parameters. Outlying estimates were rare, and the median starting values from these simulations were used for model predictions.

Bootstrapping was used to derive confidence intervals for all parameters, estimates and indicators.

Status indicators - Limit and target reference levels

Biomass indicator or proxy	There is no biomass indicator or proxy specified in a formal harvest strategy for Eastern School Prawn. For the purposes of this assessment, the mean estimated biomass depletion (expressed as a proportion of *K*) from SPM analyses was selected as a proxy.
Biomass Limit Reference Point	There is no Biomass Limit Reference Point specified in a formal harvest strategy for Eastern School Prawn. For the purposes of this assessment, the value of 20% of estimated *K* was selected for the Limit Reference Point (B_{lim}).
Biomass Target Reference Point	There is no Biomass Target Reference Point specified in a formal harvest strategy for Eastern School Prawn. For the purposes of this assessment, the value of 48% of estimated *K* was selected for the target reference point (B_{targ}).

Fishing mortality indicator or proxy	There is no fishing mortality indicator or proxy specified in a formal harvest strategy for Eastern School Prawn. For the purposes of this assessment, the mean estimated harvest rate from SPM analyses was selected as a proxy.
Fishing mortality Limit Reference Point	There is no Fishing Mortality Limit Reference Point specified in a formal harvest strategy for Eastern School Prawn. For the purposes of this assessment, F_{lim} is specified as the estimated harvest rate which corresponds with B_{lim}.
Fishing mortality Target Reference Point	There is no Fishing Mortality Target Reference Point specified in a formal harvest strategy for Eastern School Prawn. For the purposes of this assessment, F_{targ} is specified as the estimated harvest rate which corresponds with B_{targ}.

Stock assessment results

1. Standardised catch rates

The assessment of standardised CPUE for Eastern School Prawn harvest in the NSW Estuary Prawn Trawl and Ocean Prawn Trawl is outlined under *Catch rate trends* above. For both Estuary Prawn Trawl and Ocean Prawn Trawl, while variable, the average CPUE over the past 10 years remained well above the geometric mean of the time series considered (with the exception of the Ocean Prawn Trawl during the drought from FY2017-2018), and there was no evidence of a consistent downward trajectory in standardised catch rates for the species.

2. Surplus Production Modelling

The stock status trajectory for NSW Eastern School Prawn from FY1985 – FY2022 is presented in Fig. 5, with the catch history and corresponding harvest rates are also illustrated to aid interpretation of the status trajectory. A summary of the main variables of interest, and the uncertainty surrounding them, is found in Table 1. The recent trajectory showed that the estimated harvest rates increased slightly during FY2020 and FY2021, but remained well below F_{targ} during both of these periods. For FY2022, the estimated biomass was well above the Target Reference Point with a depletion estimate of 0.76, and the harvest rate is well below the Target Reference Point. While there is substantial uncertainty in some of the SPM parameters (Table 1), the confidence interval for *Depletion* (2.5 % CI) and *Harvest rate* (97.5% CI) remains well above and below (respectively) the corresponding target reference points. Total catch in FY2022 (811 t, Fig. 1) is also well below the 2.5 % CI for *MSY* (1,003 t).

Figure 5 Phase plot showing the modelled stock status trajectory for NSW Eastern School Prawn from FY1985 – FY2022 (left panel), and catch history and corresponding harvest rates (right panel). Limit and target reference levels are shown for biomass (B_{lim} = 0.20·B_0; B_{targ} = 0.48·B_0 respectively) and corresponding references for fishing mortality (F_{lim} and F_{targ} respectively) are indicated (note that F_{targ} is also indicated on the right panel). The beginning and final fiscal years of the time series are also indicated.

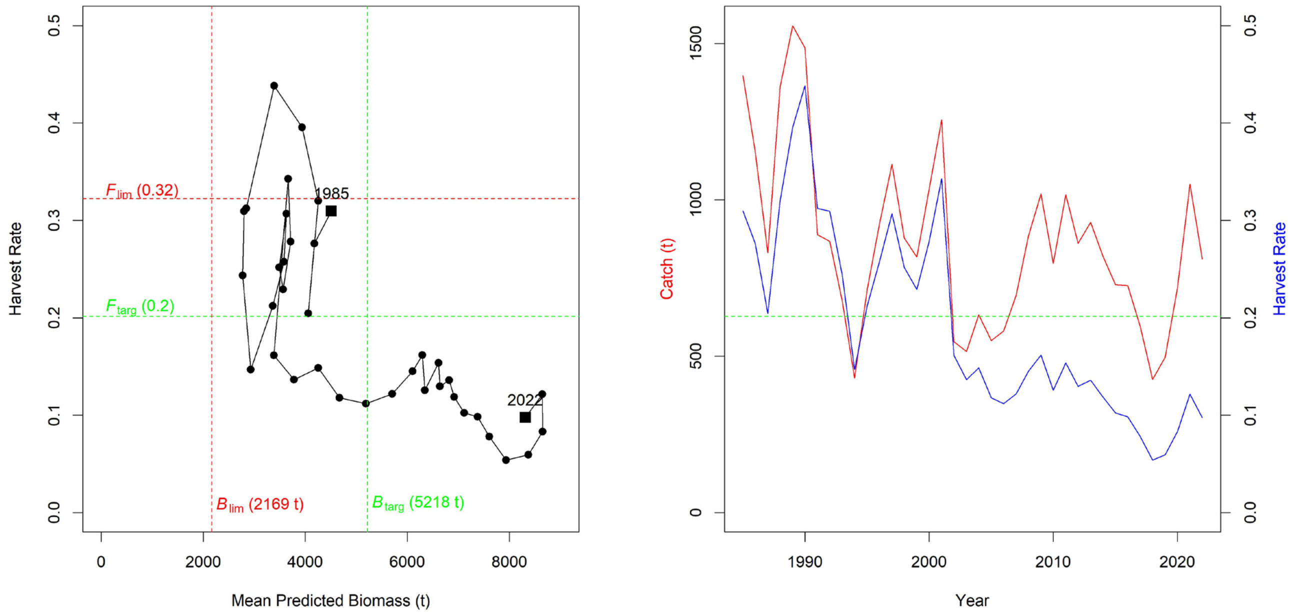
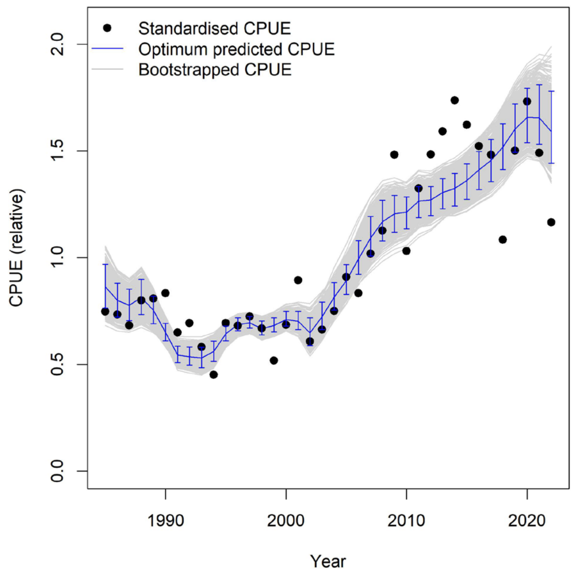


Table 1 Summary outputs from the SPM assessment for NSW Eastern School Prawn, showing mean and 95 % confidence intervals (CIs) for key parameters.

Parameter	2.5 %	Mean	97.5 %
r	0.25	0.41	0.58
K ('000 t)	7.41	11.6	20.3
B_{init} ('000 t)	3.53	4.62	6.41
MSY ('000 t)	1.03	1.10	1.26
$Depletion_{FY2022}$	0.71	0.76	0.78
$Harvest\text{-}rate_{FY2022}$	0.06	0.10	0.15

Predicted CPUE trajectories are presented in Fig. 6. While the SPM estimated standardised CPUE reasonably well, there are some deviations in the series, particularly for the latter 15 years. This may arise as environmental variability becomes more influential on the stock during the latter time series, perhaps due to lower harvest rates and decreased influence of fishing on overall stock dynamics. Notwithstanding the minor decline in FY2022 (due to catastrophic flooding), and similarly to the standardised CPUE analysis presented earlier, there was no evidence for a sustained decline in standardised CPUE for Eastern School Prawn in NSW

Figure 6 Catch rate trajectories (predicted from bootstrapping) from Surplus Production Modelling. The optimum predicted CPUE trajectory is indicated (blue line), along with 90 % CIs. The original standardised CPUE series for Estuary Prawn Trawl is indicated as filled black circles.



Stock assessment result summary

Biomass status in relation to limit	There is no Biomass Limit Reference Point specified in a formal harvest strategy for Eastern School Prawn. Modelled (estimated) biomass for FY2022 (8,311 t) was well above the B_{lim} estimate of 2,169 t
Biomass status in relation to Target	There is no Biomass Target Reference Point specified in a formal harvest strategy for Eastern School Prawn. Modelled (estimated) biomass for FY2022 (8,311 t) was well above the B_{targ} estimate of 5,218 t
Fishing mortality in relation to Limit	There is no Fishing Mortality Limit Reference Point specified in a formal harvest strategy for Eastern School Prawn. Modelled (estimated) harvest rate for FY2022 (0.10) was well below the F_{lim} estimate of 0.32
Fishing mortality in relation to Target	There is no Fishing Mortality Target Reference Point specified in a formal harvest strategy for Eastern School Prawn. Modelled (estimated) harvest rate for

	FY2022 (0.10) was well below the F_{targ} estimate of 0.20
Current SAFS stock status	Sustainable

Fishery interactions

The majority of Eastern School Prawn catch is taken via prawn trawl gear within estuarine and inshore 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 Ocean Prawn Trawl 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). An observer program on the Estuary Prawn Trawl fishery has not yet been undertaken, however several gear modifications are available to reduce interaction or capture of non-target species (Broadhurst *et al.* 2012), that are used by fishers to varying degrees.

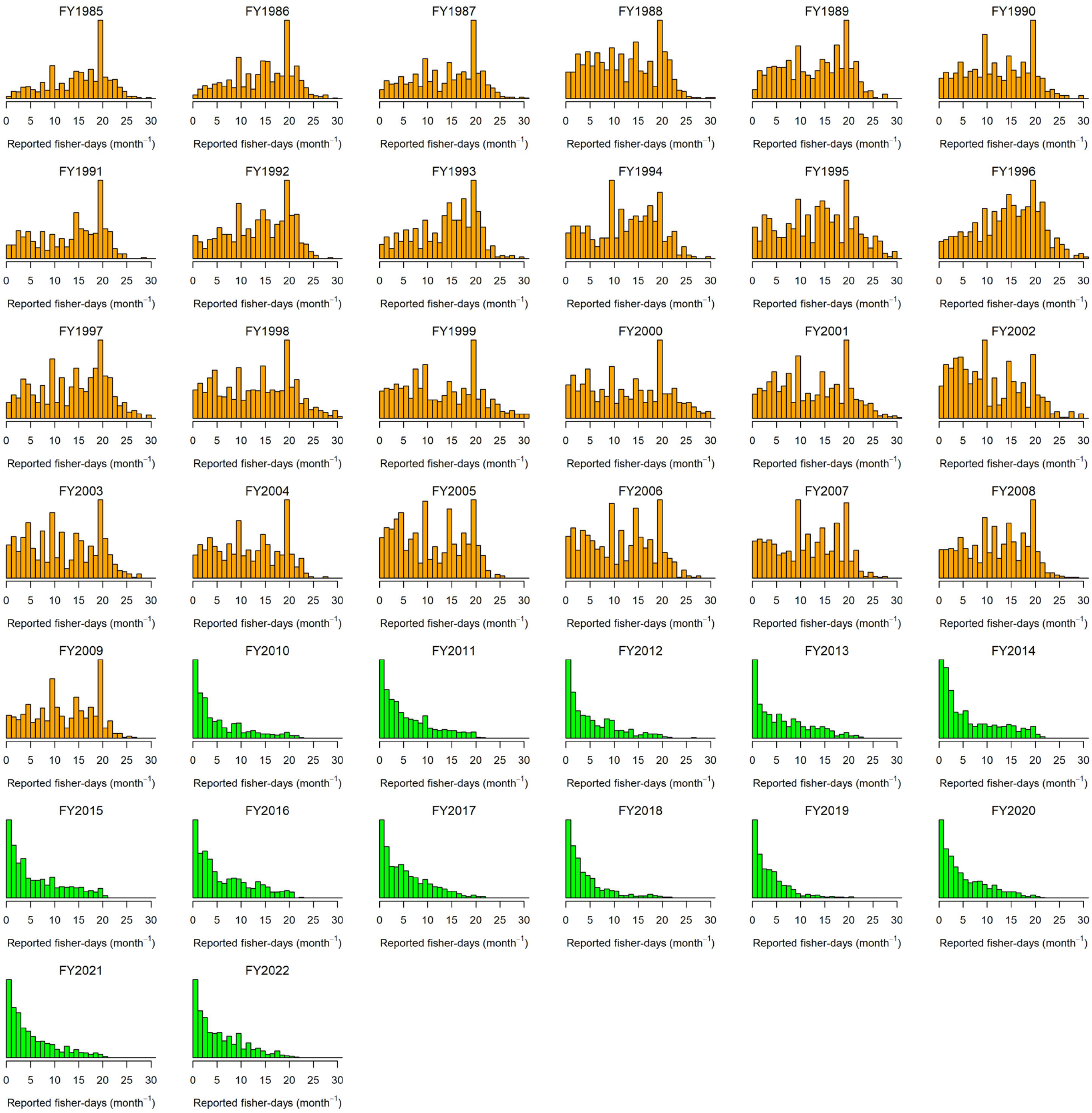
The methods commonly used to capture Eastern School Prawn in the Estuary General fishery (e.g., prawn seine/haul, set pocket [stow] net, prawn running net) are reasonably selective, and often exploit aggregations and predictable migratory behaviours to target prawn species explicitly. Consequently, interactions with non-target species for Eastern School Prawn captured within this fishery are low (e.g., Andrew *et al.* 1995; Gray *et al.* 2003), and bycatch is often in good condition upon release.

Qualifying comments

Effort reporting

Some uncertainties regarding effort reporting are present throughout the time series. First, effort was not directly reported against catch of Eastern School Prawn for records collected pre-FY1998, and the analysis here relied on mapping effort to catch data 'after the fact'. Secondly, for Estuary Prawn Trawl, data exploration revealed potential aggregative reporting behaviour for effort, both for the period when records were reported monthly (pre-FY2010), and when daily records were required (post-FY2009, in this data set daily records were aggregated [summed] by fisher-month to align with pre-FY2010 records). This was evident in the data in two ways. There were distinct peaks in records where 10 d month^{-1} (2 working weeks), 15 d month^{-1} (3 working weeks), and 20 d month^{-1} (4 working weeks) were reported (Fig. 7), suggesting aggregation and rounding into finite weekly units (5 days in a working week) may have been occurring. This pattern diminished in the post-FY2009 period, however, the distribution of recorded effort changed radically (Fig. 7)—in particular, records of 1-3 fisher-days per month were heavily over-represented within the data. For the period post-FY2009, fishers are required to submit a separate record for each day on which fishing occurs, but these relationships suggest potential aggregative reporting behaviour whereby fishers are submitting a single record once per month (resulting in 1 d month^{-1} effort), once per fortnight (resulting in 2 d month^{-1} effort), or once per week. This would have the effect of inflating CPUE for these records, as an entire week or month of catch would be divided by an aggregated unit of effort. The effect of different approaches to deal with this was explored (Morris 2022), and the best approach involved excluding records where monthly catch/effort was excessive or unrealistic. For this reason, it was decided, based on expert opinion, to remove records for which monthly aggregate catch/effort exceeded 1000 kg d^{-1} (for Estuary Prawn Trawl) and 5,000 kg d^{-1} (for Ocean Prawn Trawl) from the data used in the catch rate standardisation process, which resulted in the loss of <1 % of data. Despite this action, however, some bias associated with aggregative reporting behaviour is likely to remain in the analysis and outputs presented in this assessment.

Figure 7 Histogram showing the distribution of reported Estuary Prawn Trawl effort records across the time series investigated. Monthly records from the ComCatch database (pre-FY2010) are shown in orange, whereas daily records from the FishOnline database aggregated to fisher-month (post-FY2009) are shown in green.



Standardised CPUE series

Correlation analysis for standardised CPUE and catch data was undertaken across the entire available time series. Outcomes of this analysis suggested strong negative correlation between catch and CPUE for both forward and backward lags for Eastern School Prawn, with an estimated optimal lag around -9 years. This is counter-intuitive for a short-lived species; however, the analyses may have been detecting long-run cyclicity in the dataset, and may have been heavily influenced by the substantial increases in CPUE between 2006 and 2010.

Modelling

The modelling approaches used in the current assessment are simplistic and generic by nature; therefore, results should be interpreted with caution. The data presented above suggests a moderate level of uncertainty in all estimates. The modelling approach employed may perform poorly for short-lived species, particularly where stocks may be characterised by episodic recruitment arising through environmental variation. The uncertainty created by aggregative effort reporting behaviour (discussed above), and the erroneous nature of fisher log-book reporting in NSW more generally, should be considered when interpreting the results of SPM.

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