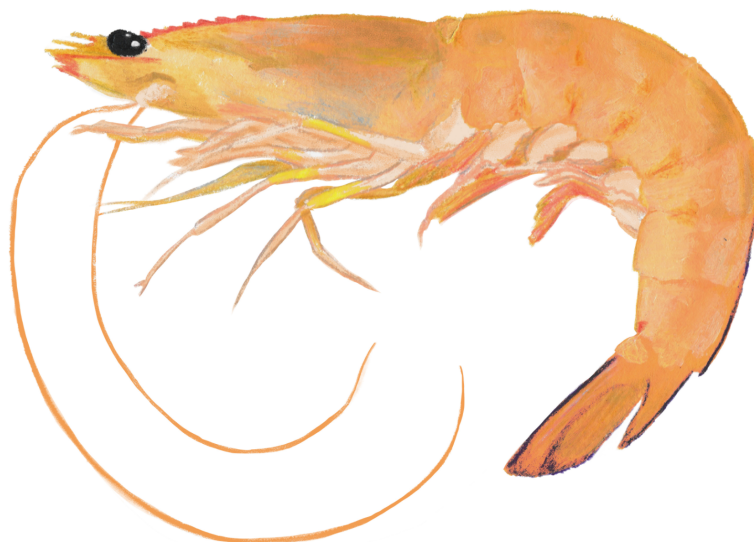




Stock assessment of eastern king prawn (*Melicertus plebejus*) along Australia's east coast, with data to October 2024

July 2026

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Executive summary

Introduction

Eastern king prawn, *Melicertus plebejus* (Hess), is a key species targeted by the Ocean Trawl Fishery in New South Wales and the East Coast Otter Trawl Fishery in Queensland. The fishery is generally considered to have commenced in 1958 and extends from the Swain Reefs in Queensland to Eden in New South Wales, and, to a lesser extent Victoria. Eastern king prawn have a lifespan of up to three years and can grow to a maximum carapace length of 73 millimetres for females and 52 millimetres for males. Females reach maturity from 38–42 millimetres carapace length at approximately four months of age.

This stock assessment was commissioned to establish the status of the New South Wales and Queensland eastern king prawn stock and to meet a condition set by the Marine Stewardship Council.

In this assessment, the stock was assumed to be in an unfished state in 1958. The term ‘biomass’ refers to the total weight of a biological population or stock. ‘Spawning biomass’ refers to female egg production by the stock per year. The ‘spawning biomass ratio’ is the key biomass estimate presented in this stock assessment. This ratio is simply the current spawning biomass as a percentage of the unfished spawning biomass (i.e. the estimated spawning biomass in 1958).

This stock assessment estimated that the biomass in 2024 was between 54% and 88% of unfished levels, with a most likely biomass estimate of 72% of the assumed unfished state in 1958.

This is the fourth stock assessment of east coast eastern king prawn. The previous stock assessment of this stock estimated the spawning biomass ratio in 2019 to be 62% (Helidoniotis et al. 2020) (with a confidence range of 38-81%), similar to the results herein. This assessment contains updates informed by new data and research. These updates included:

- Five additional years of catch, effort and length data.
- Line trawling was incorporated into the calculation of fishing power based on vessel tracking data.
- Fishing power has been updated using gear data now directly accessible from the New South Wales and Queensland logbook gear databases.
- Historical fishing power from 1969–1988 was calculated using methods from Lovett et al. (2023).

This stock assessment was guided by a project team that included a fishery stakeholder as well as an independent fishery scientist.

Methods

The stock assessment used the spatial, length structured two sex model with a monthly time step from the previous assessment, fitted to standardised catch rates, length composition data and commercial size grading data. The model incorporated data from New South Wales and Queensland waters spanning the period 1958-2024, collected from the commercial sectors, port monitoring, fishery independent beam trawl survey, commercial grading data from industry and research. A full listing of all data inputs and sources is given in Table 2.1, with a description of each in Section 2.1.

This assessment modelled the eastern king prawn population as a single genetic stock with spatial stratification across six zones. Growth varied with sex, zone and month and movement varied by month and zone. A full list of model assumptions can be found in Section 2.8.2.

All assessment inputs and outputs were referenced on a fishing year basis, where '2024' means 'November 2023–October 2024'.

In this assessment, the stock was assumed to be in an unfished state in 1958. The term 'biomass' refers to the total weight of a biological population or stock. 'Spawning biomass' refers to female egg production by the stock per year. The 'spawning biomass ratio' is the key biomass estimate presented in this stock assessment. This ratio is simply the current spawning biomass as a percentage of the unfished spawning biomass (i.e. the estimated spawning biomass in 1958).

The stock assessment analysed trawl fishing power and its effect on catch rates. Fishing power captured two main aspects of efficiency: a) differences in catching prawns among vessels due to fleet composition and dynamics, and b) improvements in catching prawns resulting from advances in vessel technology, gear, and line-trawl fishing patterns.

This assessment maintained consistency with the methodology used in the previous eastern king prawn assessment, with updates informed by new data and studies. These updates included:

- Five additional years of catch, effort and length data.
- Line trawling was incorporated into the calculation of fishing power based on vessel tracking data.
- Fishing power has been updated using gear data now directly accessible from the New South Wales and Queensland logbook gear databases.
- Historical fishing power from 1969–1988 was calculated using methods from Lovett et al. (2023).

Two scenarios were considered representing two fishing power calculations for standardised catch rates in New South Wales. Given the model estimates were almost the same for both scenarios, the preferred scenario chosen by the project team was the one that was consistent with the methodology of the previous assessment. The preferred scenario used data from Queensland gear data for fishing power, the second scenario used a combination of New South Wales and Queensland gear data.

The model estimation process consisted of a maximum likelihood step followed by a customized simulated annealing process (optimisation algorithm).

Results

Biomass

The results of this assessment indicated that in the 2024 fishing year, the spawning biomass was between 54% and 88% of unfished levels, with 95% confidence that the value falls within this range (95% confidence interval). The most likely estimate was 72% in 2024 (Figure 1).

The biomass trajectory (Figure 1) showed a decline from an assumed unfished level in 1958, until 1984, after which the biomass value has fluctuated and slowly increased. The eastern king prawn biomass in 2024 was supported by favourable recruitment of new young prawns entering the population in 2023 (Figure 2).

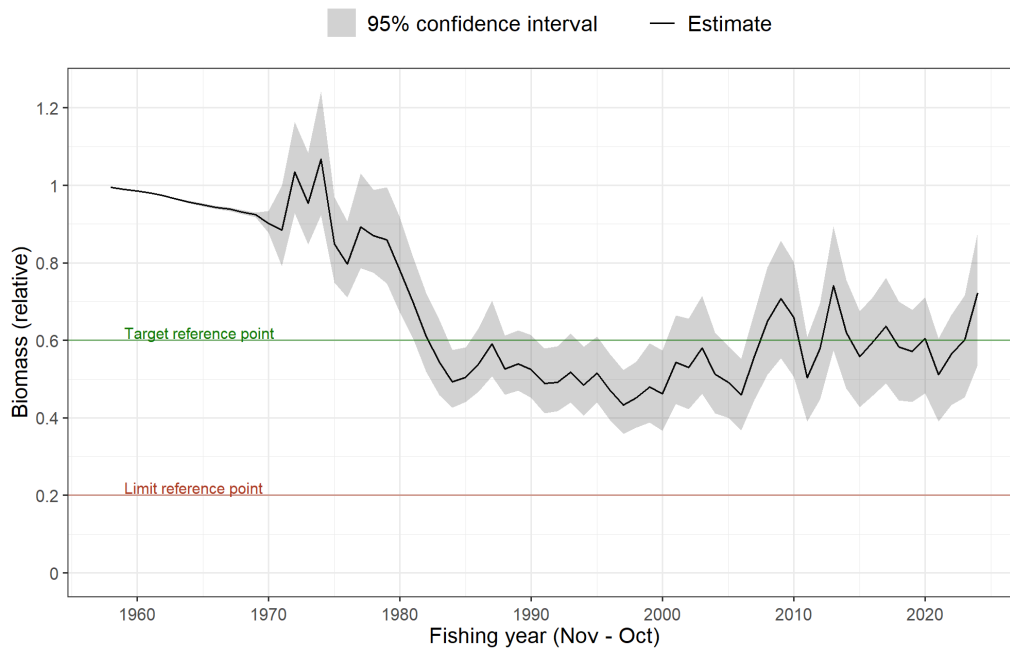


Figure 1: Spawning biomass ratio by fishing year, relative to the unfished level in 1958. The maximum likelihood estimate (MLE) showed the model best prediction and fit to the data.

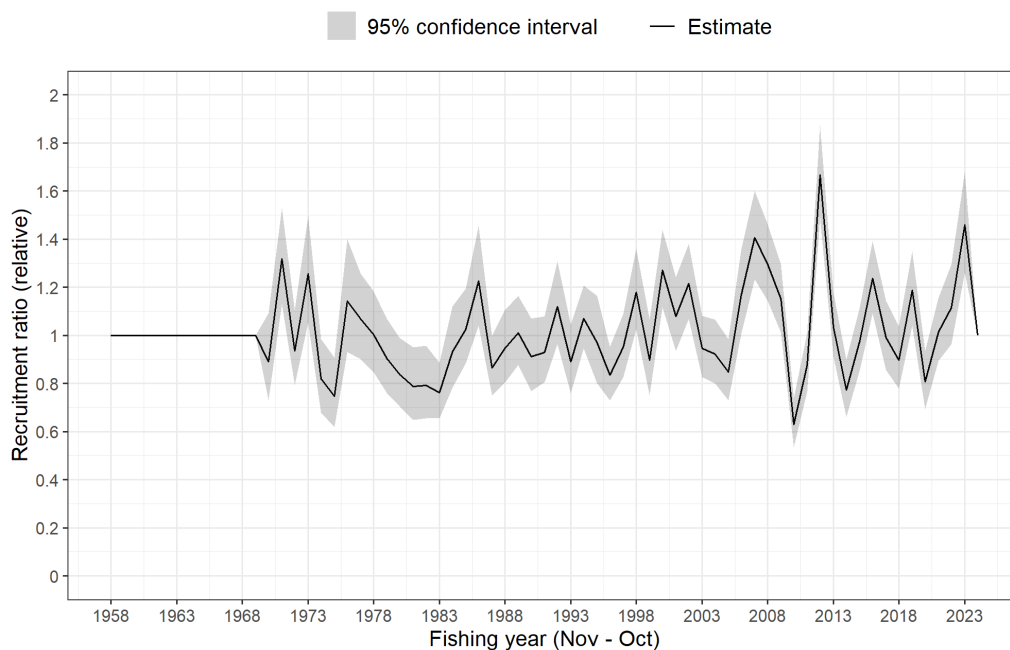


Figure 2: Recruitment ratio (deviations) relative to the mean. 95% confidence intervals are shown.

Catch and effort

Over the last five years 2020 to 2024, total retained catch (New South Wales and Queensland combined) averaged 3,108 tonnes per year. New South Wales harvested 19.5% of the catch of eastern king prawns from 2020 to 2024, and Queensland harvested 80.5% of the catch.

Queensland zones 4–6 dominated annual harvests, with reduced harvests in New South Wales since 2005 (Figure 3).

Fishing effort was higher in Queensland waters relative to New South Wales (Figure 4 and Figure 5).

In the last five years, the average number of boat-nights was 4,646 by 83 vessels in New South Wales. In Queensland, the five year average was 14,669 nights by 165 vessels. Fishing pressure in zone 4 increased post 2015 and declined in 2024.

Fishing effort for 2024 was higher than the effort for maximum economic yield (MEY) in 2019 (Helidoniotis et al. 2020). The 2024 effort was 17,444 boat-nights and above the MEY range estimated in the previous assessment of 9,753 – 12,339 boat-nights per year (median effort of MEY was 11,423). The previous stock assessment estimated the effort for 60% biomass at 16,450 boat-nights.

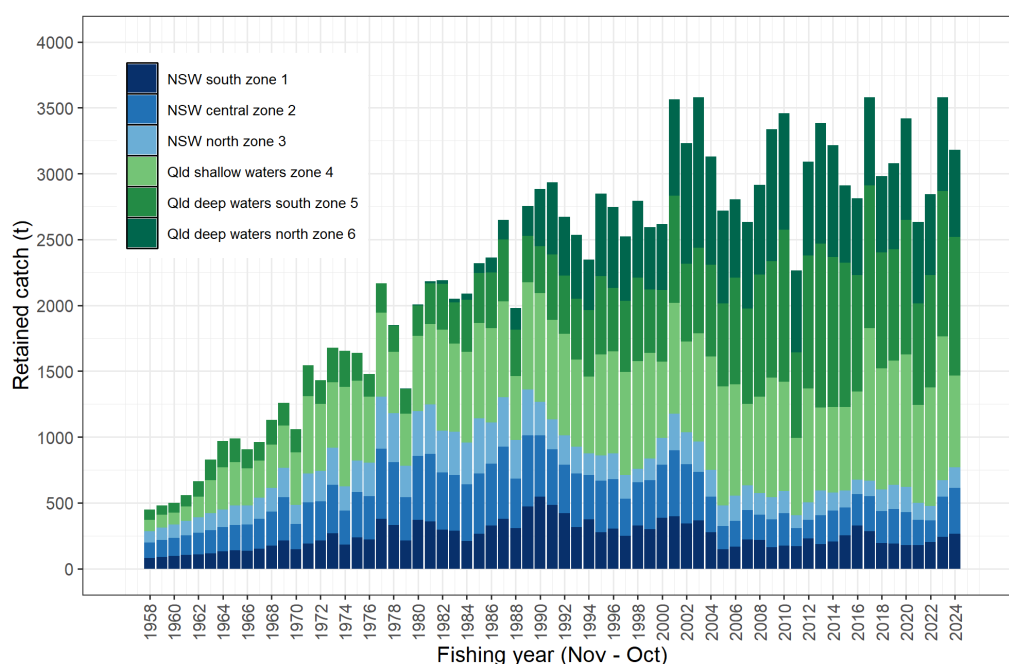


Figure 3: Eastern king prawn harvests from New South Wales (NSW) and Queensland (Qld) waters.

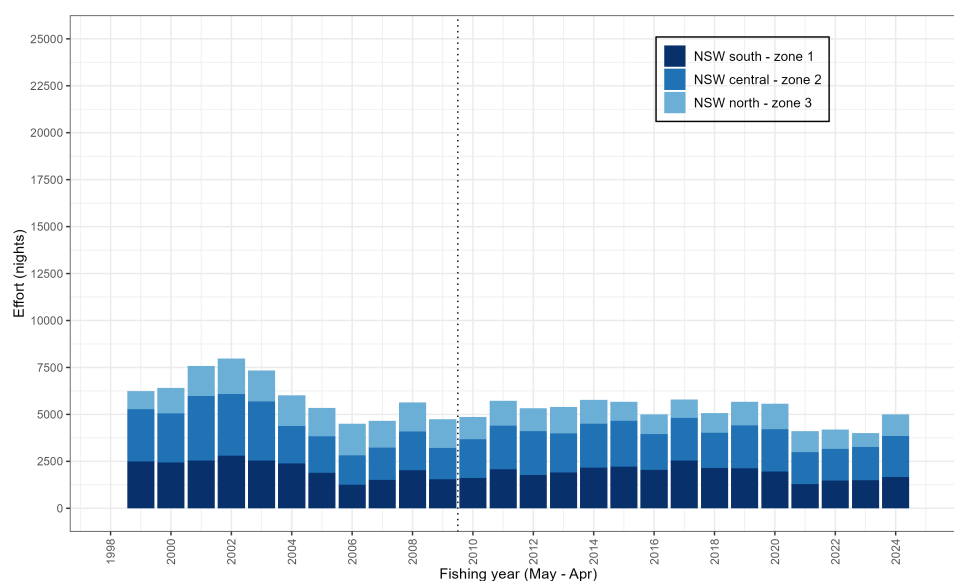


Figure 4: Number of reported fishing nights for eastern king prawn in New South Wales waters. The effort is shown for the New South Wales fishing season which is May to April.

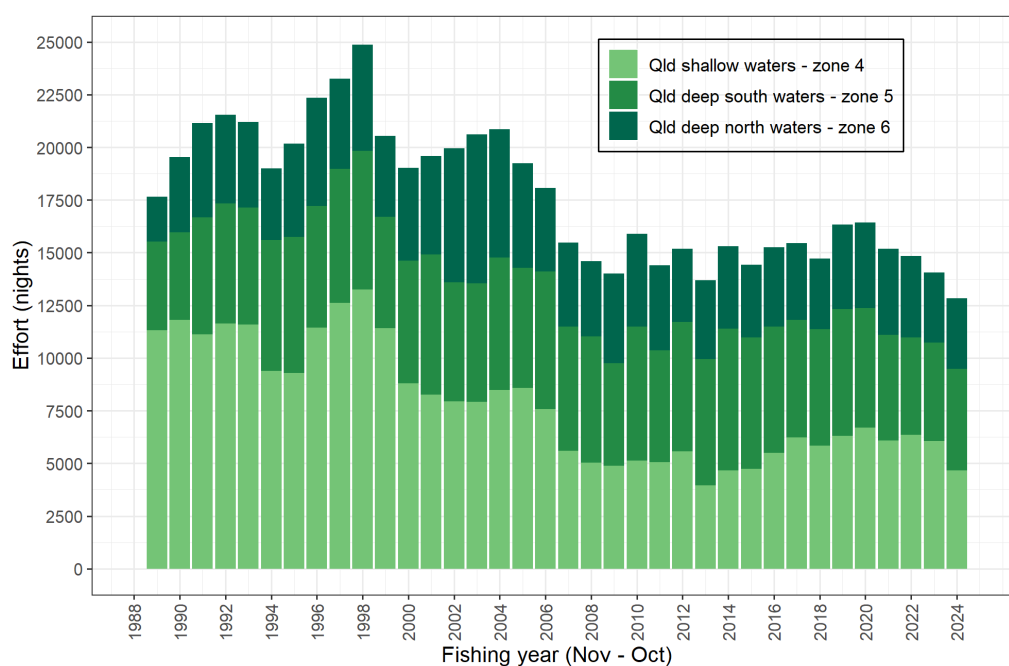


Figure 5: Number of reported fishing nights for eastern king prawn in Queensland waters.

Catch rates

Catch rates from New South Wales and Queensland commercial fleets were standardised separately using linear mixed models. The standardisations accounted for increases in fishing power to estimate indices of abundance (Figure 6).

In general, the time series of catch rates since 2010 showed an increasing trend, particularly in New South Wales waters (zones 1—3).

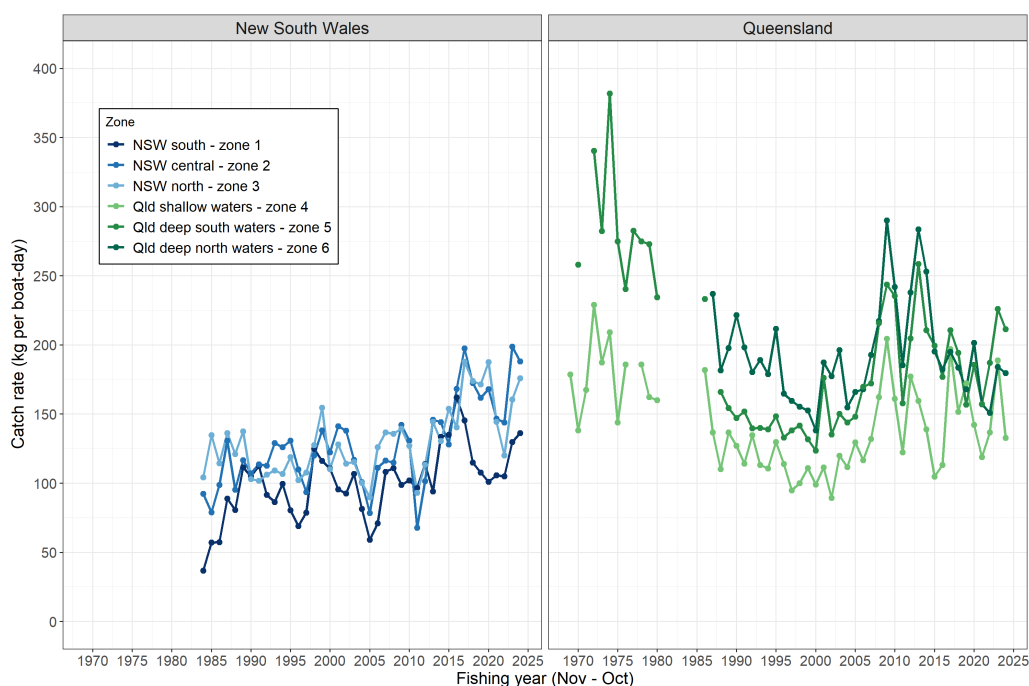


Figure 6: Annual standardised catch rates of eastern king prawns from New South Wales and Queensland waters.

Fishing power

Annual predictions of relative fishing power are in Figure 7. Each result was scaled proportionally to represent the difference from the reference year 1989, which was set to 1. Results were relative and interpreted within each spatial zone only.

The fishing power values in Figure 7 were inclusive of changes in fleet vessel composition, gear efficiency, navigation technology and line trawl fishing patterns by year (the figure predictions combined aspects a) and b) as noted in the methods above).

The values show today's vessels are more effective at fishing than in the past. For example, in a zone, a relative value of 1.8 in 2024 means 80% more catch for the same boat-day of effort compared to a typical 1989 vessel.

The key drivers of fishing power related to bigger and more powerful vessels expending relatively more effort, operating more efficient trawl systems, improved electronics and spatial targeting, fleet restructuring and effort concentration. Reduced fishing and the exit of less efficient vessels has raised average fleet efficiency over time.

Line trawling, (where a vessel trawled back and forth along the same trawl path repeatedly during a night, targeting specific areas where prawns might aggregate), was a new factor analysed in fishing power. Predictions suggested line trawling increased average catches by 11–19%. Line trawling was more common in deeper waters.

Catch rates were standardised to represent an average vessel and fishing power from the last five years 2020–2024 in each zone.

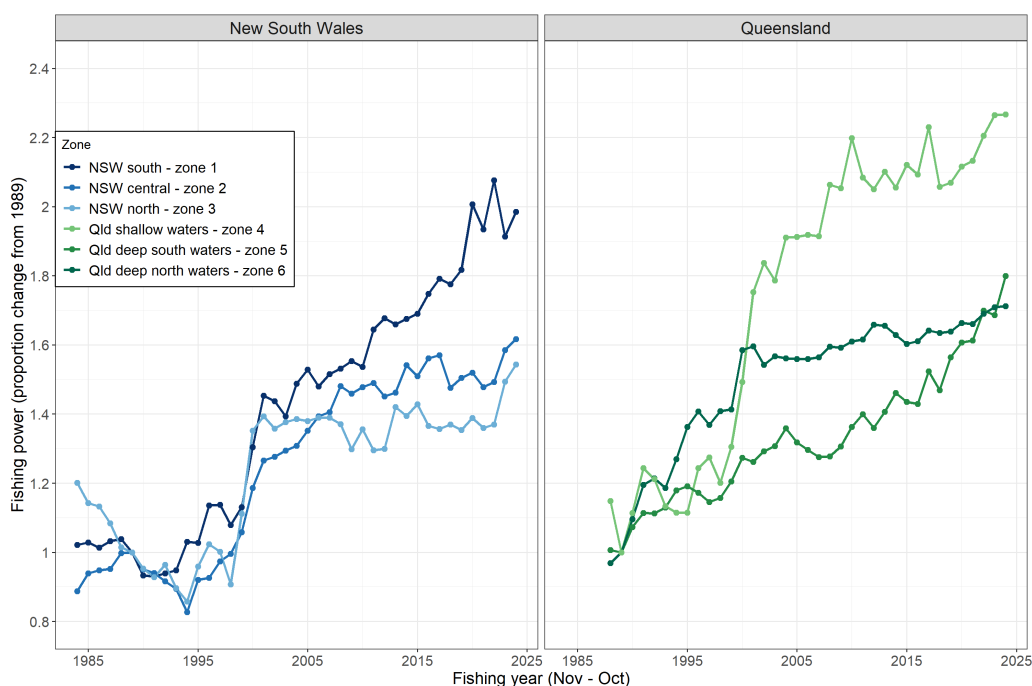


Figure 7: Proportion change in fishing power from 1988 to 2024 for New South Wales and Queensland waters by zone. Each result was scaled relative to the reference year 1989 (set to 1). Results reflect within-zone patterns only and are not comparable across zones.

Key influences

Key influences on biomass results were the annual increases in trawl fishing power (Figure 7) and the large catches from Queensland waters (Figure 3).

Fishing power has increased due to changes in fleet dynamics and vessel capability, gear and trawl efficiency, navigation and electronics, and fisher behaviour.

As a result, fewer boats today can catch as much or more than the many boat-days in the past, so fishing power corrections were essential in the eastern king prawn assessment: without them, nominal catch rates would overestimate stock abundance and reference points.

The model estimated a higher population size to explain the continued high catches from Queensland waters (zones 4–6 in Figure 3). At the same time, catch rates increased since 2010 in New South Wales and generally levelled out in Queensland waters (Figure 6).

Model inferences suggested more prawns travelled from areas along the New South Wales coast, where they grow, and later moved northward into Queensland and deeper waters as adults. Spawning mostly occurs in deeper Queensland waters (source of recruits), with early juveniles (recent spawn / recruits) generally transported south on ocean-currents and settle along the east coast of Australia. Queensland zone 4 recruitment and harvests appeared to be more locally driven.

Recommendations to improve future assessments

Annual data collection on fishing gears used by each vessel is a priority for stock assessment (section 4.3). Fishing power has continued to increase in this trawl fishery and this has influenced trends in standardised catch rates. Real-time catch, effort and gear data integration would support more respon-

sive assessments and indicators for in-season monitoring. Key data gaps include limited and irregular carapace length sampling from Queensland waters.

Collaborative stock assessment between New South Wales and Queensland should continue and investigate alternative population models, such as a delay-difference biomass model to accommodate spatial variance in catch rates. Use of simpler population models, to compare to the spatial-length-sex-month model, requires less data, assumptions and cost to run. Comparative models help improve a weight-of-evidence approach for interpreting results and verifying reference points for managing levels of fishing effort.

Conclusion

This stock assessment benefited from incorporating recommendations from the expanded project team, incorporating line trawling into the calculation of fishing power, and from a new study on New South Wales gear data. These factors all contributed to a more robust model-based assessment.

The estimated spawning biomass of eastern king prawn in fishing year 2024 was approximately 72% of unfished biomass. The 2024 biomass result and confidence intervals were above the 20 percent limit reference point and above the maximum economic yield target biomass of 69% required for profitable fishing (maximum economic yield, MEY). The MEY reference point of 69% was estimated using economic data in Helidoniotis et al. (2020). Biomass results were supported by favourable fluctuations of higher than average recruitment.

Acknowledgements

This stock assessment was capably guided by a project team with extensive knowledge and a diverse range of perspectives on the New South Wales and Queensland east coast stock of eastern king prawn. In addition to departmental staff (including stock assessment scientists, fishery managers, fisheries monitoring staff, and data specialists), the team included an independent scientist and a fishing industry representative.

The project team operated under terms of reference designed to ensure a transparent and evidence-based approach. Project team members were, in alphabetical order:

- Ainslie Denham—Independent Fishery Scientist (Western Australia Department of Primary Industries and Regional Development)
- Warren Egling—Fishery Manager (Fisheries Queensland, DPI)
- Fay Helidoniotis—Stock Assessment (New South Wales, DPIRD)
- Jennifer Larkin—Fisheries Resource Officer (Data) (Fisheries Queensland, DPI)
- Geoffrey Liggins—Stock Assessment (New South Wales, DPIRD)
- Steve Murphy—Fishery Stakeholder, commercial representative
- Michael O'Neill—Stock Assessment (Fisheries Queensland, DPI)
- Andrew Prosser—Biological monitoring representative (Fisheries Queensland, DPI)
- Matt Taylor—Fisheries Scientist (New South Wales, DPIRD)
- Michelle Winning—Chair/Fisheries Assessment Manager (Fisheries Queensland, DPI)
- Joanne Wortmann—Stock Assessment (Fisheries Queensland, DPI)

The entire team is thanked for their time, expertise, and constructive engagement throughout the project.

We thank Jim Craig and John Stewart for extracting and providing the New South Wales commercial catch, catch rate, and length-frequency data. We also acknowledge the contributions of New South Wales monitoring staff for collecting valuable length-frequency data to support the size-based population modelling. We appreciate the management timeline information provided by Fiona McKinnon. Darren Hale and Matt Broadhurst are also thanked for sharing their extensive knowledge of vessel and gear characteristics, which improved understanding of fishing power.

The authors acknowledge the significant time commitment of the fishery stakeholder representative, Steve Murphy. His involvement ensured that all aspects of the assessment were considered not only from a scientific perspective, but also informed by extensive on-water experience. Outside of project team meetings, he consulted with industry networks to provide balanced representation. His contributions set a strong benchmark for ongoing collaboration with industry to enhance future stock assessments.

We also thank independent scientist Dr Ainslie Denham for her continued collaboration and substantial commitment to the project. Her thorough and constructive feedback has strengthened the robustness of the analyses and the comprehensiveness of the final report.

We acknowledge Alise Fox for granting permission to reproduce her artwork on the cover of this report.

Our sincere thanks go to the many DPI Fishery Monitoring staff who contributed to the collection and quality assurance of fishery-independent survey data for Queensland east coast juvenile eastern king prawn, which were integral to this assessment.

We also acknowledge and thank the many fishers, seafood processors, and scientists who have contributed to past and ongoing research on the New South Wales and Queensland east coast stock of eastern king prawn..

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We thank the authors of O'Neill et al. (2005), O'Neill and Leigh (2006), O'Neill and Leigh (2007), Braccini et al. (2012a), O'Neill et al. (2014), Courtney et al. (2014), and Helidoniotis et al. (2020) whose work developed the methods and models underpinning the modelling framework used in this assessment.

This report is an update of Helidoniotis et al. (2020) and hence much of the text is reproduced here.

Glossary

BRD	Bycatch reduction device
CI	Confidence interval or credible interval
CL	Carapace length (mm). Current method of measuring prawn carapace length. Unless otherwise stated it is the length from behind the eye to the back of the head i.e from the post-orbital margin to the posterior edge of the carapace
CPUE	Catch per unit effort
DPI	Department of Primary Industries, Queensland
DPIRD	Department of Primary Industries and Regional Development, New South Wales
EAC	East Australian Current
fm	Fathom, 1 fathom is equal to 1.8288 metres. A fathom is a nautical unit of length primarily used to measure water depth
Fisher–day	A day of fishing by a fishing operator, which corresponds to a single daily logbook record (commercial)
FRDC	Australian Government's Fisheries Research and Development Corporation
GLM	Generalised linear model
MCMC	Markov chain Monte Carlo - a statistical simulation method for approximating the final ('posterior') distribution of a quantity
MEY	Maximum economic yield
QFB	Queensland Fish Board, marketing authority until 1981
Stock	A distinct population that breeds only within itself (rough definition)
TACE	Total allowable commercial effort
TED	Turtle exclusion device

1 Introduction

Eastern king prawn (*Melicertus plebejus*) (Hess, 1865) is endemic to Australia. Eastern king prawn occur on the eastern Australian coast between Hayman Island in Queensland and north-eastern Tasmania (20–42° south), and exhibit strong stock connectivity throughout this range. The species displays a panmictic stock structure across this region (Premachandra et al. 2022).

Eastern king prawn exhibit the typical Penaeidae life cycle, which includes both estuarine and oceanic phases (Young 1978; Young and Carpenter 1977; Masel and Smallwood 2000). Post-larval and juvenile eastern king prawn utilise bare sand and seagrass habitats in estuaries and coastal embayments. Juveniles then leave estuaries and embayments, migrating north to spawn. This migration occurs from New South Wales and inshore Queensland waters to deep waters (depths greater than 50 fathom, fm) off Queensland, where they are targeted by trawl fisheries (Montgomery et al. 2007; Lloyd-Jones et al. 2012; Braccini et al. 2012a; Courtney et al. 2014).

The East Australian Current (EAC) is thought to play a significant role in the distribution of eastern king prawn by transporting planktonic larvae southward to estuaries and embayments, where they develop and grow (Montgomery 1981; Montgomery 1990; Ruello 1975; Everett et al. 2017). Furthermore, tag-recapture studies have demonstrated the species' remarkable capacity for long-distance movement (Taylor and Johnson 2021; Braccini et al. 2012a; Glaister et al. 1990; Lucas 1974), with one individual recorded travelling 1,333 km in just 184 days (Montgomery 1981).

The combined influence of larval transport by the East Australian Current (EAC) and the remarkable movement capabilities of maturing and adult eastern king prawn contribute to the species' extensive geographical distribution, spanning from 20° to 42° south.

Female eastern king prawn mature from 38–42 millimetres carapace length at approximately four months of age (Courtney et al. 1995; Courtney et al. 1996; Lloyd-Jones et al. 2012). Studies on the reproductive biology of females reported that spawning may take place at any time during the year (Montgomery et al. 2007). However, in Queensland the winter egg production produces most larvae that survive into the stock (Montgomery et al. 2007; Courtney 1997a).

Longevity is up to three years, and female eastern king prawn generally grow larger to a maximum size of 73 millimetres carapace length compared to males at 52 millimetres. Eastern king prawn are one of the largest and long-lived of Australia's endemic Penaeid prawns.

Eastern king prawn represent a significant component of the otter trawl fisheries along the eastern coast of Australia. The species is predominantly targeted in New South Wales (28 – 37.5°S, whole of New South Wales coast) and Queensland (22 – 28°S), forming part of two key fisheries: the Ocean Trawl Fishery in New South Wales and the East Coast Otter Trawl Fishery in Queensland.

Fishing operations occur across shallow inshore waters and deeper offshore waters, with vessels employing a range of gear types and vessel sizes specifically adapted to the varying depths and environmental conditions of the fishing grounds. Eastern king prawn have been harvested at depths up to 300 metres, but most harvest occurs between 40 and 200 metres. There has been limited estuary catch in New South Wales since 2000.

New South Wales and Queensland independently manage the eastern king prawn fishing sector within their respective jurisdictions. A range of input controls is implemented in the trawl sectors, including limited vessel entry, boat-day/ effort-unit allocations, vessel and gear size restrictions, and spatial and seasonal closures. Historical events related to the management of the otter-trawl fishery for eastern king prawn in New South Wales and Queensland waters are presented in Appendix E, Table E.1, Table E.2, and Figure E.1.

All assessment inputs and outputs were referenced on a fishing year basis, where '2024' means 'November 2023–October 2024'.

This was the fourth stock assessment of eastern king prawn. Previous biomass ratios were estimated to range (Figure E.1):

- 46% (confidence interval: 25–72%) in 2001 for New South Wales and Queensland, derived using a monthly delay-difference model (O'Neill et al. 2005).
- 75% (confidence interval: 60–85%) in 2010 for New South Wales and Queensland, derived using the monthly-sex-length-spatial model, which was subsequently applied in the following stock assessment (Courtney et al. 2014; O'Neill et al. 2014).
- 62% (confidence interval: 38–81%) in 2019 for New South Wales and Queensland (Helidoniotis et al. 2020).

Following the previous assessment, this assessment used a single preferred scenario approach, rather than an ensemble method to combine the outcomes from multiple scenarios. Two scenarios were considered representing two fishing power calculations assessed for standardised catch rates in New South Wales. Given the model estimates were almost the same for both scenarios, the preferred scenario was the one consistent with the previous assessment. These results are presented in the results section.

The two scenarios related to the calculation of fishing power for New South Wales catch rates. The preferred scenario used data from Queensland gear data for fishing power, the second scenario used a combination of New South Wales and Queensland gear data.

2 Methods

2.1 Data sources

Data sources included in this assessment (Table 2.1) were used to determine catch, catch rates and length compositions by month and zone. The assessment period began in November 1957 (fishing year 1958) up until and including October 2024 (fishing year 2024) based on available information.

Table 2.1: Data inputs for the assessment.

Data	Years	Source	References
NSW Commercial logbooks	1984–2024	Compulsory commercial logbook database (CommCatch monthly)	
NSW Port landings	1967–1979	Port landings data from Clarence River and Evans Head (monthly)	
NSW Landings database	1974–1984	Landings database (annual)	
Qld Commercial logbooks	1988–2024	Compulsory commercial logbook database (CFISH daily)	
Qld Fishboard	1958–1980	Fish Board (annual)	
Qld HTRAWL	1968–1987	QFISH voluntary logbook catch data (daily)	Section 8.3.7 of O'Neill et al. (2005), Section 4.1.2 of O'Neill and Leigh (2006)
NSW gear logbooks	1997–2024	Commercial logbook vessel gear and technology database	(Helidoniotis and Craig 2025)
Qld gear surveys	1988–2004	Two surveys of vessel owner/operators in 2000 and 2004 conducted by FRDC project 1999/120	(O'Neill et al. 2005)
Qld gear logbooks	July 2006–2024	Commercial logbook vessel gear and technology database	
Qld Fishery Independent Beam Trawl Surveys	1999, 2001, 2007–2016, 2018–2022	Pre-recruit abundance indices and length frequencies for eastern king prawn, blue swimmer crab and snapper in south eastern Queensland	(Bessell-Browne et al. 2020)
NSW commercial length frequency	1991, 1992, 2006, 2007, 2015, 2016, 2019–2024	Port monitoring data	
Qld commercial length frequency	1990, 1993, 2001, 2002, 2009	Research data	
Qld commercial grading data	1997, 2006–2019	Industry grading data in the far-northern part of the fishery	

2.2 Zones

Data were stratified by six zones across New South Wales and Queensland State waters (Figure 2.1 and Table 2.2). From south to north the zones were defined and labelled following general movement patterns of eastern king prawn as they grow:

1. New South Wales south (south of 30°south) - zone 1.
2. New South Wales central (between 29 and 30°south) - zone 2.
3. New South Wales north (between 28 and 29°south) - zone 3.
4. Queensland shallow waters (<50 fathom, ($\approx$ 90 m), water depths, between 21 and 28°south) - zone 4.
5. Queensland deep waters south ($\geq$ 50 fathom water depths, between 24.5 and 28°south) - zone 5.
6. Queensland deep waters north ($\geq$ 50 fathom water depths, between 21 and 24.5°south) - zone 6.

The New South Wales commercial logbook definition of zones is shown in Table 2.2.

Table 2.2: Eastern king prawn fishery by analysis zones 1 to 6.

Model zone	Model zone description	New South Wales commercial logbook definition
1	NSW south	Zone 1003-1010
2	NSW central	Zone 1002
3	NSW north	Zone 1001
4	Qld shallow waters <50 fathom	
5	Qld deep waters south $\geq$ 50 fathom	
6	Qld deep waters north $\geq$ 50 fathom	

As the eastern king prawn fishery extends northwards, it occurs further from the coast and in progressively greater depths. The Swain Reefs (22°S) are the approximate northern-most distribution of the fishery and are located about 250 km from the coast. Ruello (1975) reported that the fishery only extended northward to Fraser Island (25°S) in the 1970s, and it was not until Potter and Dredge (1985) undertook a deep water exploratory survey in 1983-1984 that significant catches were reported and the fishery expanded offshore in central Queensland (i.e., 22-24°S).

Juveniles harvested from estuaries and Moreton Bay were excluded. Only catch relating to offshore fishing and fully recruited eastern king prawn were considered. This was consistent with the previous eastern king prawn stock assessments and reflects the marginal and sporadic catches of eastern king prawn in these locations (O'Neill et al. 2005; Courtney et al. 2014; Helidoniotis et al. 2020).

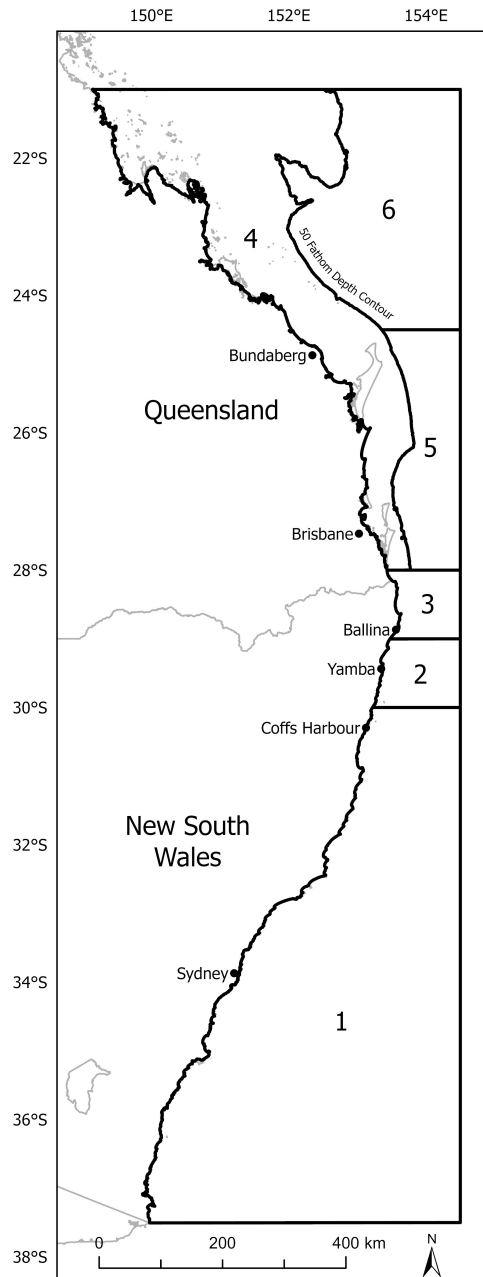


Figure 2.1: Map of the eastern king prawn fishery by analysis zones 1 to 6. Queensland zone 4 covered water depths less than 50 fm and excluded pre-oceanic-recruits from estuaries, Moreton Bay (adjacent to Brisbane) and Fraser Island north. Queensland zones 5 and 6 covered water depths equal to or greater than 50 fm (approximately 90 m). Management and fishing gear were not defined by water depths in New South Wales (zones 1 to 3); zone 1 included minor harvests taken south of Sydney to about 37 degrees south.

2.3 Catch

Historical catch of eastern king prawn date back to the early 1900s. Catch was small (<200 t) until the 1950s, and the fishing year 1958 (from November 1957) was assumed to be the commencement of significant fishing mortality. This was consistent with previous assessments (O'Neill et al. 2005; O'Neill and Leigh 2006; Courtney et al. 2014; O'Neill et al. 2014; Helidoniotis et al. 2020).

The methods employed to reconstruct catch data were consistent with those from the previous eastern king prawn assessments (O'Neill et al. 2005; Courtney et al. 2014; Helidoniotis et al. 2020) and are described in Appendix B.1.

2.4 Fishing power

Fishing power refers to:

- Attributes *within* a vessel, such as engine horsepower, net types and technologies.
- Differences *between* vessels, for instance, an increase in the overall fleet power from the gradual exit of less efficient vessels, leaving the more effective ones to fish.

In the first case, attributes within vessels have evolved over time due to the adoption of advanced technologies such as Global Positioning Systems (GPS), plotters, colour echo sounders, and trawl fishing nets. Additionally, improvements in vessel motors, propellers, communication systems, and even the use of mobile phones can contribute to improvements in fishing efficiencies. It is necessary to account for these gear and technology changes in the catch rate standardisation process to ensure that any differences in catch rates over time due to technological advancements are removed, allowing the catch rate to serve solely as a measure of abundance.

In the second case, changes in vessels fishing efforts over time affect the overall fishing power and time series of catch reports. For example, vessels may exit the fishery or reduce levels of effort for economic decisions such as high fuel costs and competition. It might be expected that these vessels are both less efficient and less powerful than those that remain, contributing to an increase in the fleet's average fishing power (O'Neill and Leigh 2007).

Data for the fishing power estimates from 1988 to 2024 were derived from Queensland trawl logbook records, which included daily catch and effort data for each vessel, along with corresponding gear usage and vessel information. The construction of this dataset was carried out in two distinct periods: 1988–2004 and 2006–2024.

From January 1988 to May 2004, the logbook system contained no vessel data, and this information was obtained from two purposely-designed surveys of vessel owner/ operators (FRDC project 1999/120, O'Neill et al. (2005)). Two face-to-face questionnaire surveys provided information on which fishers adopted new devices and technologies, and when they were adopted. The information was obtained from past and present Queensland east-coast trawl vessel owner/ operators in 2000 and 2004. The vessel owner/ operators selected represented a random set of vessels from each trawl sector that had fished between 1997 and 2004 inclusively (section 6.1 of O'Neill and Leigh (2006)).

Starting in July 2006, the logbook system began recording vessel data. This dataset included comprehensive information on technology and gear, consistent with the details previously documented in the 2000 and 2004 FRDC gear surveys (O'Neill and Leigh 2006). Overall the logbook data on otter-trawl vessel configurations, gears and technologies represented a random set of vessels that had fished between 2007 and 2024 (Table B.2 in Appendix B.3.1)

To develop the dataset for 1988-2024 for the fishing power model, logbook data collected after 2006, which contained gear and technology information, were integrated with the survey datasets from O'Neill et al. (2005). The combined data were subsequently filtered to include only daily records of fishing that had matching gear usage and vessel information, and the fishing power was analysed using logbook records and boat gear data together.

Prior to estimating fishing power, a simple collinearity check was conducted to identify variables correlated among those considered (engine rated power (hp), fuel capacity, length, speed, propeller diameter, pitch, nozzle, GPS, sonar, computer mapping software, net type, net size, ground gear, ground chain mm, board type, the use of try gear, the use of BRDs and TEDs and hours fished). In addition, plots of gear trends were examined to see if gear trends were correlated with other, for example as horsepower increased, vessel speed increased. Any variables that were related cannot all be fitted simultaneously, and therefore only one of those variables was selected to be used in the subsequent linear mixed model.

The data covered fourteen 30 x 30 grids, consistent with the previous assessment (Figure 2.1 in Helidoniotis et al. (2020)) and were consistent with the previous analysis of fishing power in Courtney et al. (2014).

The linear mixed model (LM) with normally distributed errors on the log scale (R Core Team 2025) was used to investigate the impact of technology and vessel fleet efficiency on catch rates in the Queensland eastern king prawn trawl fishery between 1988 and 2024:

$$\begin{aligned} \log wt \sim & \text{zone} * \text{fishyear} * \text{fishmonth} + \text{zone} : \text{lunar} + \text{zone} : \text{lunaradv} + \\ & \text{depth} : \log(\text{hp}) + \text{depth} : \text{gps} + \text{depth} : \text{nettype} + \text{depth} : \text{boards} + \text{depth} : \text{brdted} + \\ & \text{ggear} + \log(\text{hours}) + (1|\text{ACN}) \end{aligned} \quad (2.1)$$

where the LMM type and variables were:

- *logwt*: log transformed daily catch per fishing operation of eastern king prawn ($\log(kg)$)
- *fishyear*: fishing year 1988 to 2024 (factor)
- *fishmonth*: fishing month (factor)
- *zone*: spatial logbook zone fished by the relevant fleet: shallow waters - zone 4, deep waters south - zone 5, deep waters north - zone 6 (factor)
- *lunar*: luminance measure followed a sinusoidal pattern (variate) (Courtney et al. 1996)
- *lunaradv*: lunar adjusted by a quarter cycle (variate) (Courtney et al. 1996)
- *depth*: <50 fathom (≈ 90 m) water depths, or ≥ 50 fathom water depths (factor)
- *log(hp)*: log transformed engine rating in horsepower (variate)
- *gps*: binary variable representing the presence of GPS, (binary variate, 1 = TRUE or 0 = FALSE)
- *nettype*: binary variable representing nettype, (binary variate, 1 = quad or five gear or 0 = single, double or triple gear)
- *boards*: binary variable representing the otter board type, (binary variate, 1 = otter boards other than standard flat otter board or 0 = standard flat otter board)
- *brdted*: binary variable representing the presence of bycatch reduction devices and turtle excluder devices (BRD/ TEDs), (binary variate, 1 = TRUE or 0 = FALSE)
- *ggear*: drop chain, looped chain, drop rope with chain and other less used types (variate), modelled independently because uptake rates were consistent in depths < 50 fathom and depths ≥ 50 fathom
- *log(hours)*: log transformed daily hours fished per fishing operation of eastern king prawn
- *ACN*: anonymous codes for different fishing operations (factor)
- *GLM family and link function*: Normal and identity link

Following O'Neill and Leigh (2006), O'Neill and Leigh (2007), Courtney et al. (2014), O'Neill et al. (2014), and Helidoniotis et al. (2020), the catchability coefficients were calculated from the model in equation 2.1 as:

$$\begin{aligned}\text{Catchability coefficient}_1 &= X\beta \\ \text{Catchability coefficient}_2 &= X\beta + Z\gamma\end{aligned}\tag{2.2}$$

where

- β was a matrix of fixed parameter gear terms, multiplied by
- data X , log engine rated power, GPS, net type, otter board type, BRDs and TEDs $\times$ depth interaction, and ground gear type
- γ was a vector of the random vessel parameter terms, multiplied by
- the vessel matrix Z
- the calculation for the *Catchability coefficient*₁ excluded the random vessel term $Z\gamma$ and showed the fishing power due to gear and technology changes over time
- the calculation for the *Catchability coefficient*₂ included both fixed and random terms, and showed the full change in fishing power and the degree to which the tendency of vessels changing their fishing effort has affected the overall fishing power of the fleet

The catchability coefficients were summed across all gear and vessel terms to obtain a total fishing power estimate. This total fishing power estimate was then averaged for each fishing year and depth (depth <50 fathom ($\approx$ 90 m) water depths, or $\geq$ 50 fathom water depths) to obtain mean annual estimates of fishing power for each depth on the log scale. For the years 2005 and 2006, where data on gear and technology were unavailable, fishing power estimates were derived through linear interpolation using data from the surrounding years, 2004 and 2007.

Following this, the estimates of fishing power were scaled to express relative fishing power in each year as a proportional change relative to the base reference fishing year considered which was 1989; as reported by O'Neill et al. (2003). The 1989 fishing year was selected as the base reference because it was the first fishing year with complete catch records.

Relative fishing power was thus defined as:

$$F_{zy} = \exp(fp_{yz} - fp_{1989z})\tag{2.3}$$

where y is fishing year and z is depth (<50 fathom ($\approx$ 90 m) water depths, or $\geq$ 50 fathom water depths).

Line trawl patterns of fishing was a new factor analysed in fishing power. The fishing method was where a vessel trawled back and forth along the same trawl path repeatedly during a night, targeting specific areas where prawns might aggregate. The effect of line trawling was incorporated into the fishing power analysis using vessel tracking data (Appendix B.3.2). Catchability coefficients for line trawling were calculated for each zone because the uptake of line trawling varied across the three Queensland zones (Figure B.28 in Appendix B.3.2).

The fishing power from line trawling was integrated into the calculation of annual fishing power offsets, as outlined in equation 2.3. These zone-specific fishing power offsets were subsequently utilised as adjustment factors within the standardised catch rate model, ensuring that temporal variations in fishing efficiency were appropriately accounted for.

Confidence intervals on fishing power were calculated from the catchability estimates and covariance matrix for the gear and vessel parameters in each fishing year and region. Calculated 2.5 and 97.5% percentiles on the fishing power distributions represented 95% confidence intervals.

The Queensland standardised catch rates dataset encompasses records dating back to 1969. To address fishing power changes during the earlier period (1969–1988), the fishing power offset was hind-cast for these years (Lovett et al. 2023). This process involved estimating the fishing power offset for 1969 and employing linear interpolation to determine values for the intervening years between 1969 and 1989. The expected fishing power offset for 1969 was derived using the estimated coefficients from Equation 2.1, under the following assumptions in 1969 (Project team communication in Appendix A):

- The average horsepower of the fleet was 170 hp in the deep waters, the average horsepower of the fleet was 165 hp in the shallow waters - zone 4 (this was the average horsepower in 1988 from gear logbook data). Most boats were equipped with either GM 671 or old Gardner diesel engines which were rated at around 170hp.
- Boats towed single gear or twin gear, (*nettype* = 0).
- Flat timberboards were used (*boards* = 0).
- Nets had foot ropes with lead weights attached or foot ropes with chain attached loosely in a Christmas drop (*ggear* = 2 or 4 in equation - very small values no difference in the models).
- There was no computer mapping, GPS, bycatch reduction devices (BRDs) or turtle excluder devices (TEDs).

In the previous assessments O'Neill et al. (2005), O'Neill and Leigh (2006), Courtney et al. (2014), O'Neill et al. (2014), and Helidoniotis et al. (2020) the fishing power applied to New South Wales catch rates was assumed to be the same as that of the Queensland shallow water zone 4, with fishing power for the years 1984-1987 equal to the fishing power in 1988.

A second fishing power scenario for New South Wales was calculated using gear data and modelling from the region. Helidoniotis and Craig (2025) documented changes in fishing technology for the eastern king prawn ocean fishery in New South Wales. Key changes included an increase in horsepower, an increase in freezer capacity, and an increase in the proportion of larger vessels in the fishing fleet. New South Wales logbook catch data were integrated with the gear-vessel information, with data starting from July 1998, as prior to this date, it was not possible to directly associate specific gear types with the species caught.

A linear mixed model with REML using AsReml-R was used to estimate gear parameters (Helidoniotis and Craig 2025). Prior to running the model, a collinearity check was conducted to determine which variables were correlated and only one of the correlated variables was selected for the linear mixed model. As a result, two variables were included in the model, engine rated power and vessel length. A significant change in logbook reporting that affected the effort reported occurred in July 2009 meant that effort was not directly comparable throughout the time series. This led to the division of the dataset for the fishing power model into two distinct periods: pre-2009 and post-2009. The estimates of fishing power were summarised for each year and zone, and scaled to express relative fishing power in each year as a proportional change relative to the base reference fishing year considered which was 1998 or 2010 depending on the dataset used i.e pre-2010 or post 2010. Relative fishing power was defined as:

$$F_{yz} = \exp(fp_{yz} - fp_{1998z}) \quad (2.4)$$

or

$$F_{yz} = \exp(fp_{yz} - fp_{2010z}) \quad (2.5)$$

where *y* is fishing year and *z* is zone.

The results demonstrated a significant increase in fishing power due to increases in engine power prior to 2010, with minimal changes observed in the period post-2010. Consequently, for the engine power component of the second fishing power model, the fishing power associated with the engine power component from equation 2.4 was utilised. Fishing power prior to 1998 was assumed to be equal to the fishing power in 1998, while fishing power after 2009 was assumed to be equal to the fishing power in 2009. Additionally, the effects of otter board gear and line trawl from the Queensland shallow water zone 4 were incorporated.

Confidence intervals on fishing power were calculated from the parameter estimates and covariance matrix for the gear and vessel parameters in each fishing year and zone. Calculated 2.5 and 97.5% percentiles on the fishing power distributions represented 95% confidence intervals.

2.5 Catch rates

Logbook records of commercial retained catch of eastern king prawn (kg whole weight) per boat per day were used as an index of prawn abundance. The index was standardised for the influence of a number of factors. This section outlines the standardisation procedure.

The data filters applied on the logbook data before standardisation are described in Appendix B.2.

2.5.1 Commercial

Three catch rate analyses were conducted on New South Wales and Queensland logbook data (Table 2.3). Analyses 1 and 2 were for Queensland and analysis 3 for New South Wales. Analyses 1 and 3 were based on whole-fleet compulsory logbooks. Analysis 2 was on Queensland pre-1989 eastern king prawn catch rate data from voluntary logbook databases (O'Neill et al. 2005; O'Neill and Leigh 2006) and from Queensland logbook records 1988-2024. This gave a longer time series of catch rates from 1969-2024.

The analyses used to standardise catch rates were linear mixed models (LMM) with normally distributed errors on the log scale (R Core Team 2025). The linear mixed models included both fixed ($X\beta$) and random ($z\gamma$) terms, and followed the methods and terminology of O'Neill and Leigh (2007) and Braccini et al. (2012b). Where data ($X_1, X_2, X_3, X_4, Z_1, Z_2$) were relevant and available, the models were fitted to estimate the following parameter effects:

- scalar model intercept β_0
- abundance β_1 for data X_1 (three-way interaction, fishing year $\times$ month $\times$ zone)
- vessel gear β_2 for data X_2 (log transformed engine rated power, net type, otter boards, gear type, bycatch reduction devices and turtle excluders, GPS, line trawl $\times$ zone interaction)
- lunar phase β_3 for data X_3 (for luminance and luminance shifted one quarter phase)
- fishing effort β_4 for data X_4 (log transformed hours fished for Queensland daily catches, log transformed days fished normalised for New South Wales monthly catches)
- by-catch β_5 for data X_5 (log transformed school whiting catch + 0.001 kg)
- vessel efficiency random effects γ_1 for vessel identifiers Z_1

Table 2.3: Linear mixed models used to standardize catch rates from New South Wales (NSW) and Queensland (Qld).

Analysis 1	Qld: zones 4–6 and fishing years 1989–2024
Response:	$\log \text{ kgs boat}^{-1} \text{ day}^{-1}$
Fixed terms:	$\beta_0 + X_1\beta_1 + X_2\beta_2 + X_3\beta_3 + X_4\beta_4$
Random terms:	$Z_1\gamma_1$
Offset:	Eastern king prawn log fishing power from β_2
Predictions:	β_1
Analysis 2	Qld: zones 4–6 and fishing years 1969–2024
Response:	$\log \text{ kgs boat}^{-1} \text{ day}^{-1}$
Fixed terms:	$\beta_0 + X_1\beta_1 + X_2\beta_2 + X_3\beta_3 + X_4\beta_4$
Random terms:	$Z_1\gamma_1$
Offset:	estimating the fishing power offset for 1969 and employing linear interpolation to determine values for the intervening years between 1969 and 1989 for eastern king prawn log fishing power from β_2 in analysis 1.
Predictions:	β_1
Analysis 3	NSW: zones 1–3 and fishing years 1984–2024
Response:	$\log \text{ kgs boat}^{-1} \text{ day}^{-1}$
Fixed terms:	$\beta_0 + X_1\beta_1 + X_4\beta_4 + X_5\beta_5$
Random terms:	$Z_1\gamma_1$
Offset:	shallow-water eastern king prawn log fishing power from β_2 analysis 1, and 1984–1988 equal to 1989 fishing power, or log fishing power from new fishing power calculation (section 2.4)
Predictions:	β_1

Since New South Wales catches were analysed on a monthly basis, lunar β_3 effects could not be included in analysis 3.

The New South Wales school whiting (*Sillago robusta* and *S. flindersi*) catch effect was estimated to account for logbooks that combined monthly effort data for eastern king prawn and these alternative target species. This targeting/ logbook effect was not observed in Queensland waters (zones 4 to 6).

In 2009 there were changes in New South Wales fisher logbook reporting from monthly to daily reporting, which may have affected the amount of reported effort (Helidoniotis and Taylor 2023). To account for differences in effort reporting before and after 2009, the number of effort days was normalised accordingly (Lovett et al. 2026).

Standardized catch rates were predicted from the 3-way interaction term β_1 , which provided an abundance estimate for each fishing year, month and zone. No predictions were formed for missing month or zone terms. The R procedure "predictInterval" from the merTools package was used to calculate monthly standardized catch rates. Catch rates were standardised to represent an average vessel and fishing power from the last five years 2020–2024 in each zone.

2.5.2 Survey

In southern Queensland, Fisheries Queensland conducted an annual beam trawl survey in Moreton Bay and other key coastal recruitment waters to assess the abundance of pre-recruit eastern king prawn (*Melicertus plebejus*), blue swimmer crab (*Portunus armatus*), and snapper (*Chrysophrys auratus*) (Courtney et al. 2002; Fisheries Queensland 2007; Courtney et al. 2012; Bessell-Browne et al.

2020). The survey was carried out during November and December. The survey began in 2007 (2008 fishing year) and has been conducted every year since, up to and including 2022 (2023 fishing year), with the exception of 2016 (2017 fishing year).

The model developed by Bessell-Browne et al. (2020) was applied to standardise the abundance of pre-recruit eastern king prawn (Appendix B.2.7).

2.6 Biology

Biological information and parameters are from Courtney et al. (2014), O'Neill et al. (2014), and Helidoniotis et al. (2020).

For eastern king prawn length refers to carapace length and is given in mm.

Biological relationships are plotted in Appendix B.4, Figures B.29–B.30.

2.6.1 Growth

Growth was included as a growth transition matrix (Courtney et al. 2014) that allocated a proportion of eastern king prawn in carapace length-class l' at time $t-1$ to grow into new length l over one time-month t (Appendix B.4.1). The transitions varied with eastern king prawn sex, zone and month, and assumed a normal probability density function (Sadovy et al. 2007; O'Neill et al. 2010; Punt et al. 2010).

2.6.2 Maturity and fecundity

Maturity and fecundity values in the model were based on carapace length (mm).

The maturity schedule followed a logistic function (Table 17.6 in Courtney et al. (2014)):

$$\begin{aligned} l_{50} = 38; l_{95} = 45 \text{ for zone} = 3, 5, 6 \\ l_{50} = 40; l_{95} = 45 \text{ for zone} = 1, 2, 4 \end{aligned} \quad (2.6)$$

where

- l_{50} is the length (mm) at which 50% of individuals are mature.
- l_{95} is the length (mm) at which 95% of individuals are mature.
- Zone is defined in Section 2.2.

Fecundity (egg production) at length (mm) per female eastern king prawn was given by Courtney (1997b) and Montgomery et al. (2007):

$$\begin{aligned} f_l &= 10^{(al+b)} \\ a &= 0.0199; b = 4.7528 \end{aligned} \quad (2.7)$$

2.6.3 Spawning

The proportion of eastern king prawn spawning by zone was: (Montgomery et al. 2007):

$$\theta = [0.15, 0.33, 0.6, 0.6, 0.6, 0.75] \quad (2.8)$$

where the vector in equation 2.8 is sequential by zone number.

Montgomery et al. (2007) showed that females capable of spawning were found at all locations but proportions were greater in lower (northern locations) than higher (southern locations) latitudes.

2.6.4 Weight and length

The average eastern king prawn weight (kg) at length l (mm) for sex s was given by: (Courtney 1997b):

$$w_{l,s} = a_s l^{b_s} / 1000$$

$$a_{\text{male}} = 0.0017; b_{\text{male}} = 2.7005$$

$$a_{\text{female}} = 0.0021; b_{\text{female}} = 2.6333 \quad (2.9)$$

2.6.5 Movement

Movement rates of eastern king prawn were estimated from tag-recapture information collected across eastern Australia (Braccini et al. 2012a). Tag-recapture data was too limited to quantify northern eastern king prawn transitions from zone 4 to 6 and this parameter was estimated in the model.

2.6.6 Natural mortality

Ives and Scandol (2007) summarised estimates and variance of natural mortality (M) for eastern king prawns. Estimates were suggested between 0.13 and 0.24 per month, with higher values possibly biased (Courtney et al. 2014; Glaister et al. 1990). One constant average M value of 0.18 per month was used in this stock assessment. This value allowed for 2–3 years longevity (Lloyd-Jones et al. 2012). Natural mortality of 0.18 was used in previous stock modelling (Courtney et al. 2014; Helidoniotis et al. 2020).

2.6.7 Steepness

The assessment estimated steepness and assumed a spawning stock-recruitment relationship in order to spatially model population dynamics and to fit to data.

The stock assessment used a Beverton-Holt function, with recruitment variation, to specify the spawning stock-recruitment relationship (Haddon 2001). The relationship defined the linkage between annual female-spawning stock size over the whole population and the consequent recruitment of new young prawns produced by that spawning.

The Beverton-Holt function contained parameters for: 1) average virgin recruitment for numbers of new prawns (labelled R_0 by zone), and 2) steepness (labelled h).

The steepness parameter defined the behaviour of the stock-recruitment relationship and is sometimes described as the measure of stock productivity when the spawning biomass is declining or depleted.

2.7 Length

Two size-structured data types were used to calibrate eastern king prawn lengths within the population model:

1. Carapace length frequency distributions from New South Wales and Queensland waters.
2. Commercial catch size grade frequency distributions from the deep north zone in Queensland.

Together the frequencies calibrated regional and monthly changes in eastern king prawn size, to estimate prawn length-selectivity.

2.7.1 Commercial length frequency

New South Wales length data was weighted to corresponding catch levels using in house Pieces software (by NSW DPIRD). Summaries of monthly length frequencies were provided for:

- South and central waters zones 1 and 2: March, June, September and December 1991, March, June, September and December 1992, continuous from July 2006 to May 2007, September 2015 to June 2016, July 2019 to October 2019, November 2021 to June 2022, July 2023 to June 2024.
- North waters zone 3: March, June, September and December 1991, March, June, September and December 1992, continuous from July 2006 to May 2007, November 2007, November 2016, continuous from February 2016 to May 2016, continuous from July 2019 to June 2020, November 2021 to January 2022, July and August 2023, November and December 2024, February and March 2024.

Carapace length frequencies from Queensland waters were recorded by scientists on board commercial fishing vessels. Each prawn was sexed and measured to 1 mm length classes:

- Shallow waters zone 4: November and December 1990, October 2001, May 2009.
- Deep south waters zone 5: June and July 1993, and July 2002.
- Deep north zone 6: January 2009.

2.7.2 Commercial size grading

Five vessels operating in Queensland waters provided at-sea eastern king prawn size grading data. The grading data were recorded between September 1997 and November 2019 from the deep northern waters of the fishery. The grading categories classified prawn sizes (number of prawns per pound; heads-on and sexes combined) which were sorted into 5kg boxes. In total, 258 monthly size-grade frequencies were tallied from 1,063,281 boxes and 30,226 boat-days of fishing. Size grade had seven categories, based on prawn catch grades commonly used in the eastern king prawn fishery:

1. $> 30 \text{ lb}^{-1} \approx 1\text{--}27 \text{ mm}$ carapace length
2. $21 - 30 \text{ lb}^{-1} \approx 28\text{--}33 \text{ mm}$
3. $16 - 20 \text{ lb}^{-1} \approx 34\text{--}37 \text{ mm}$
4. $10 - 15 \text{ lb}^{-1} \approx 38\text{--}43 \text{ mm}$
5. $8 - 10 \text{ lb}^{-1} \approx 44\text{--}47 \text{ mm}$
6. $6 - 8 \text{ lb}^{-1} \approx 48\text{--}53 \text{ mm}$
7. $< 6 \text{ lb}^{-1} \approx 54\text{--}75 \text{ mm}$

Soft and broken prawns, classified as an additional category, were infrequent and not analysed. No independent data were available to assess the accuracy of the at-sea commercial eastern king prawn size grading, but the same data were acceptable to processors to determine price paid to fishers. Larger prawns fetched a higher price for the same weight. Similar prawn boxes (3 kg) have been validated as a reasonable measure for tiger prawn lengths in the Northern Prawn Fishery (O'Neill et al. 1999).

2.8 Population model

2.8.1 Description

The eastern king prawn population dynamics tracked monthly numbers (N) and biomass (B) of eastern king prawn by their sex (s), length (l) and spatial zone (r) (O'Neill et al. 2014; Helidoniotis et al. 2020). Every month (t) the biological processes of regional mortality, growth, movement and recruitment were accounted. O'Neill et al. (2014), Courtney et al. (2014) and Helidoniotis et al. (2020) detail the model equations.

The model dynamics were structured to occur throughout a month, year and zone, where:

- Exploitable biomass was computed mid-month in two forms based on the number of prawns, prawn weight-at-length and vulnerability. This was done to calculate:
 - Harvest rates using half of natural mortality M to estimate exploitable biomass before fishing (biomass form B^1), and to calculate
 - Catch rates by applying half of the harvest rate to B^1 to calculate exploitable biomass B^2 . Catch rates estimated from B^2 were used to fit to the standardised catch rates.
- Recruitment was introduced into the model as a single cohort with a normal distribution at length.
- Growth, movement, and recruitment (half for each sex) occurred monthly before fishing.

The key equation for eastern king prawn population dynamics was:

Number of prawns

$$N_{l,r,t,s} = \exp(-M) \sum_{r'} T_{r,r',t-1} \sum_{l'} \Xi_{l,l',r',t-1,s} (1 - v_{l,r'} u_{r',t-1}) N_{l',r',t-1,s} + 0.5R_{l,r,t} \quad (2.10)$$

where $\mathbf{T}$ was the transition probability matrix for moving eastern king prawn between regions $r' \rightarrow r$, Ξ was the growth transition matrix that allocated a proportion of eastern king prawn in length class l' at time t to grow into a new length l over one time-month, M was natural mortality, v was vulnerability / selectivity and u was the harvest rate (fraction of exploitable biomass harvested).

Recruitment R was a Beverton–Holt formulation by fishing year. Annual recruitment was apportioned into length classes l (1...75 mm) by sex, month and zone. Annual recruitment deviations were estimated 1970 – 2023, with other years deterministic. The female spawning index, annual number of eggs, were summed over mature lengths, spawning months and zones.

2.8.2 Assumptions

The main assumptions underlying the model included:

- The stock was in an unfished state in 1958.
- The sex ratio of eastern king prawn at birth was 50% and eastern king prawn did not change sex during their life.
- Spawning by females occurred in all zones with varied fractions.
- Growth was included as a growth transition matrix that was formulated on the von Bertalanffy model framework taking into account the seasonal changes and the effect of latitude (Lloyd-Jones et al. 2012; Courtney et al. 2014).
- The weight, maturity and fecundity of eastern king prawn were parametric functions of their length.

- Eastern king prawn movements varied by fishing month and zone, but were the same between years.
- Prawn movement from shallow waters in Queensland (zone 4) to deep waters in the north (zone 6) was estimated based on movement from shallow waters in Queensland (zone 4) to deep waters in the south (zone 5).
- Fishing vulnerability/ selectivity of eastern king prawn was a function of length. Survey vulnerability was domed, otherwise logistic for the fishery zones.
- Expected (deterministic) annual recruitment was a Beverton-Holt function of spawning stock size. Recruitment occurred in zones 1–4.
- The instantaneous natural mortality rate M was constant and did not depend on size, sex or year.
- Fishing occurred in the middle of the month.
- Catch rates were proportional to abundance, and informed on the monthly change in abundance of eastern king prawn.
- Catchability was seasonal by zone.

Results assumed pre-1989 Queensland catch rates were reliably standardised to post-1988 data (Courtney et al. 2014). Past modelling was not overly sensitive to the uncertainty in historical total catches (Courtney et al. 2014).

2.8.3 Parameters

Model parameters are listed in Table 2.4.

Table 2.4: Definitions and values for the population model parameters.

Parameter	Value (se)	Description
ξ	estimated	Used to determine Beverton-Holt steepness h , one estimated value of steepness was assumed for the stock
γ_r	estimated for zones 1-4	Used to determine $R_{0,r}$ for zones 1 to 4
μ_r	estimated for zones 1-4	Mode of monthly recruitment pattern for zones 1 to 4
κ_r	estimated κ_1 for zones 1 to 3 (NSW) estimated κ_2 for zone 4 (Qld)	Concentration of monthly recruitment pattern for zones 1 to 4
l_r^{50}	estimated for zones 1-6	Length at 50% selection by zone for estimated logistic vulnerability
δ	estimated	Initial steepness of logistic vulnerability for all zones
l_{rising}^{50}	estimated	Length at 50% selection by the survey on the upward slope
l_{diff}	estimated	The difference between the length at 50% and 95% selection by the survey
$l_{falling}^{50}$	estimated	Length at 50% selection by the survey on the downward slope
ρ	estimated	Used to calculate movement from zone 4 to zone 6 in the variable T in (Equation 2.10)
ζ	estimated	The amplitude of catchability across zones
ϕ_r	estimated for zones 1-6	The peak timing of catchability for each zone
η_y	estimated for each year y	Recruitment deviations between 1970 and 2023. Log deviations was solved with sum of zero.
M	0.18 (0.02)	One parameter for instantaneous natural mortality per month (Helidoniotis et al. 2020)
$nllp$	0 (0.005)	Standard deviation std for any negative log-likelihood -LL penalties
$sigRlow$	0.1	Lower penalty bound on annual recruitment log std
$sigRup$	0.3	Upper penalty bound on annual recruitment log std
$sigma1$	0.1	NSW zones 1 to 3 minimum log cpue std for -LL
$sigma2$	0.06	Qld zones 4 to 6 minimum log cpue std for -LL for post-1987 logbook data
$sigma3$	0.12	Qld zones 4 to 6 minimum log cpue std for -LL for pre-1988 htrawl logbook data
$sigma4$	0.08	Survey zone 4 min log cpue std for -LL

2.8.4 Estimation

Model parameters were estimated by calibrating the model to regional standardised catch rates, length composition data and commercial size grading data, like in Helidoniotis et al. (2020). Effective sample sizes for scaling multinomial likelihoods were calculated within the model in order to give realistic weighting to the size composition data. The model was run where the weighting of catch rates and length data was the same (log-likelihoods x 1 and not adjusted).

A penalty function was included to prevent unrealistically large population estimates and low harvest rate estimates. Penalty likelihood functions were also used for stock-recruitment steepness ($h > 0.8$), annual recruitment variation (η) and bounds for the monthly recruitment parameters. The model and data fitting negative log-likelihoods were described by O'Neill et al. (2014) and Courtney et al. (2014).

The estimation process was conducted in Matlab 2025a (MathWorks 2025), and consisted of a maximum likelihood (ML) step followed by a customised simulated annealing (Markov Chain Monte Carlo – MCMC) program (O'Neill et al. 2014; Courtney et al. 2014; O'Neill et al. 2022).

The ML fitting was run in two phases. The model was first run in one phase with the penalty function included to prevent unrealistic large population estimates and low harvest rate estimates. In phase 2 the penalty was switched off. ML fits were rerun in loops to test convergence.

The customised simulated annealing program was then run to check the ML parameter solutions and estimate the parameter covariance matrix. The annealing method first simulated the combined negative log-likelihood (objective) process at large steps, and then slowly decreased the step size, thus, to minimise the negative log-likelihood.

The simulated annealing started from a scaling factor of 100 and then reduced the step size to 10, and then 1. For each scaling factor, the annealing process ran for 2000 iterations of each of the estimated parameters. The covariance matrix measured the differences in the negative log-likelihood with each parameter jump.

From the maximum likelihood estimates and their covariance matrix, five thousand multivariate normal parameter vectors generated the confidence intervals on model predictions (Richards et al. 1998). The maximum likelihood parameter estimates and their covariance matrix were stored for running simulations for confidence intervals. Goodness-of-fit plots were examined to evaluate model fits.

2.8.5 Scenario

Two fishing power scenarios were evaluated in New South Wales standardised catch rates:

- The New South Wales fishing power scenario was built on Queensland data and aligned with the previous assessment. Model results for this preferred scenario are in the results section for consistency with the previous assessment.
- The New South Wales fishing power scenario was built on New South Wales and Queensland data. Model results for this scenario are presented as an alternative scenario in Appendix D.

3 Results

3.1 Model inputs

3.1.1 Data

Model inputs are illustrated for eastern king prawn in Figure 3.1. The time-series of data are shown for each spatial zone by year. Figure circles are proportional to catch size for harvests and indices and to sample size for size compositions. Note that the circle area is relative within a data type.

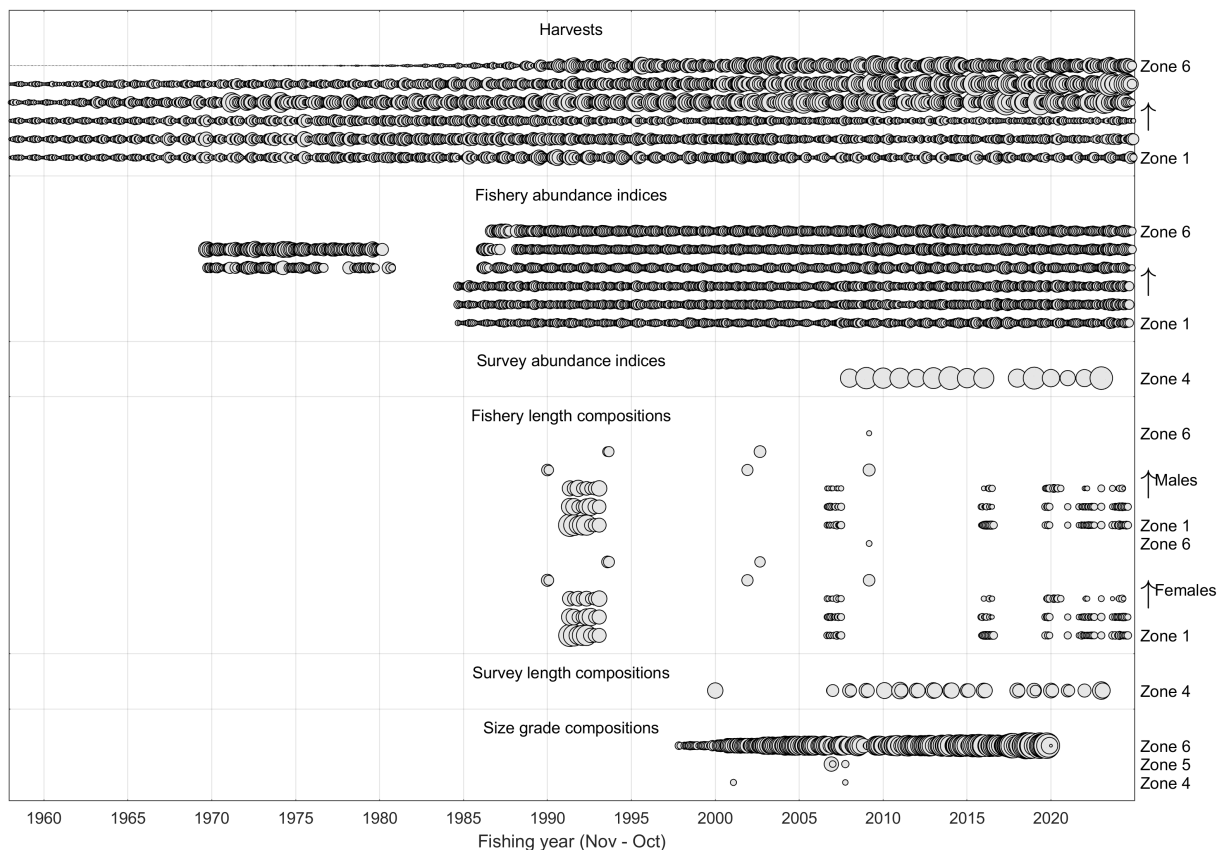


Figure 3.1: Data presence by year and zone for each category of data type from New South Wales and Queensland.

3.1.2 Catch

The annual time series of eastern king prawn retained catches are shown in Figure 3.2. Catches were estimated using methods specific to New South Wales and Queensland (Appendix B.1). It is important to note that the model operates on monthly time step; therefore, the retained catch used as model input is on a monthly scale (Figure B.1). The discussion below focuses on the annual catch figure (Figure 3.2), as it provides a clearer representation of trends and patterns, making it easier to interpret the data than the monthly catch figure (Figure B.1).

The annual catches across all zones combined increased consistently from 1958, reaching an initial peak of 3,580 t in 2003. Following this, catches fluctuated, with notable peaks exceeding 3,500 t in 2017

and 2023. The lowest recorded catch since the commencement of logbooks in 1988 occurred in 2011, with a total of 2,264 t.

The majority of the catch was from Queensland. In the last five years, an average of 2,501 tonnes of eastern king prawn were caught from Queensland waters annually between 2020 and 2024 (excluding Moreton Bay). An additional 607 t average was caught annually in New South Wales over this time period.

Queensland harvested 80.5% of the catch of eastern king prawns, with New South Wales taking 19.5% from 2020 to 2024.

The catch from the deep north zone 6, as shown in Figure 3.2, began in 1981 and gradually increased from that point onward. This aligned with the findings of Ruello (1975), who reported that the eastern king prawn fishery only extended northward to Fraser Island (25°S) in the 1970s. It was not until Potter and Dredge (1985) undertook a deep water exploratory survey in 1983-84 that significant catches were reported and the fishery expanded offshore in central Queensland (22 – 24°S).

In New South Wales on average 35%, 41% and 24% of the catch was taken annually from the south, central and north zones 1–3 from 2020 to 2024. In Queensland, on average 65% of the catch was taken annually from the deep waters from 2020 to 2024.

Figure B.1 shows the seasonal change in eastern king prawn catch by zone.

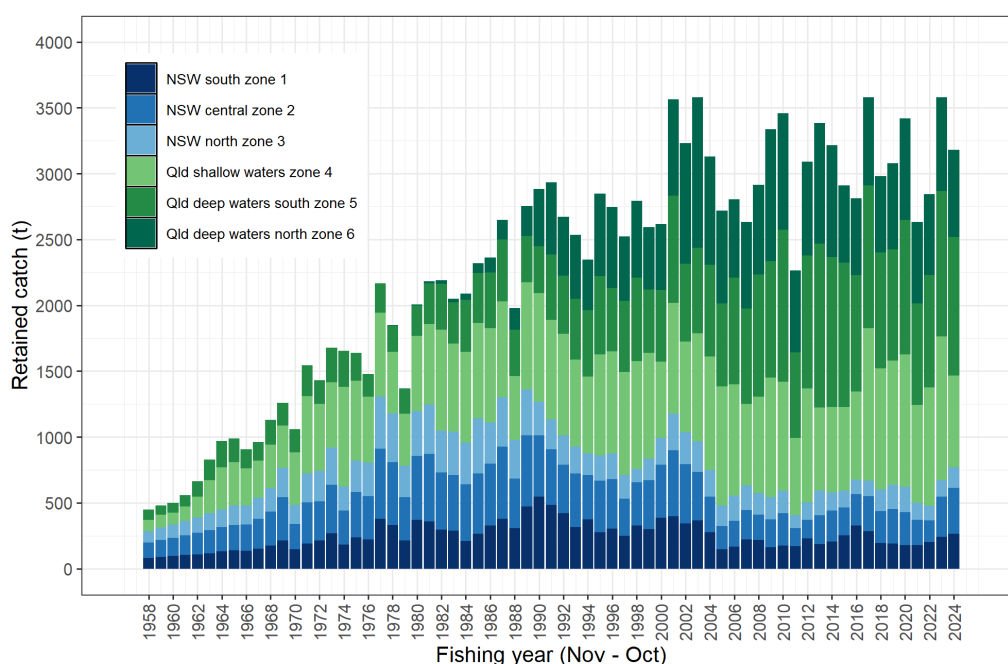


Figure 3.2: Eastern king prawn harvests from New South Wales (NSW) and Queensland (Qld) waters.

3.1.3 Fishing power

Gear and technology trends are shown in Appendix B.3.1.

The estimated gear and technology catchability coefficients are shown in Tables B.3 - B.5 in Appendix B.3.3. Their interpretation provides insights into some of the notable associations with larger catches (i.e. higher fishing power/ catchability).

Changes in fishing power due to vessel and gear upgrades were measured by the β fixed effects (black lines in Figures 3.3, 3.5 and 3.6). Changes due to evolution of the fleet profile were measured through the random vessel terms γ . The random term effect was illustrated by the difference between the overall fishing power estimate (grey line) and the fishing power estimate from the β fixed effects only (black line) in Figures 3.3, 3.5 and 3.6. Results were relative and interpreted within each spatial zone only.

Increase in fishing power in Queensland shallow water zone 4 was mostly driven by the changing fleet profile (measured by the random term), with the lesser catching vessels fishing less or exiting and the more effective vessels remaining in the fishery. Between 1989 and 2024, overall fishing power increased by 126% in Queensland shallow waters, 71% in Queensland deep north waters and 80% in Queensland deep south waters (grey lines in Figure 3.3).

The rate of increase in fishing power was greater in the shallower, inshore fishery, likely due to the lower initial levels of technological capital investment in these vessels, which provided greater potential for technology transfer and improvements in fishing power (O'Neill et al. 2005). Uncertainty in fishing power estimates was higher in shallow waters due to higher variability in vessel characteristics in this depth sector.

In Queensland deep north zone 6, fishing power from both fixed and random terms remained relatively constant from 2004 onwards. This reflected the low potential for the larger, more powerful deep-water vessels to increase their fishing power.

In the Queensland offshore south zone 5, overall fishing power continued to improve after 2004, largely being driven by the trend of the less efficient vessels leaving the fishery or fishing less effort.

In shallow waters zone 5, vessels saw significant upgrades in the early 2000s, including the adoption of quad gear, bycatch reduction devices (BRDs), and turtle excluder devices (TEDs), which led to an increase in fishing power during this time.

In deep waters zones 5 and 6, fishing power increased due to advancements in engine capacity, the adoption of line trawling techniques, and the use of GPS and drop chains.

Between 1989 and 2024, fishing power from gear and technology changes increased by 33% in shallow waters, 35% in northern deep waters, and 43% in southern deep waters (black lines in Figure 3.3). These fixed-term fishing power estimates were used as offsets in catch rate standardisations.

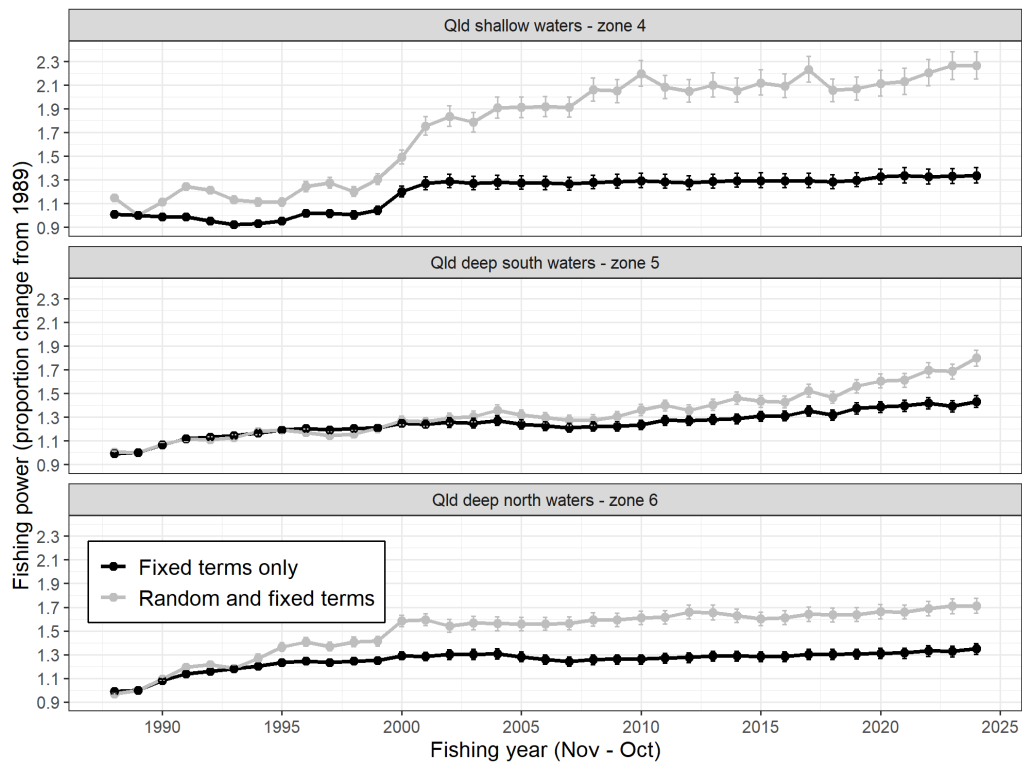


Figure 3.3: Fixed and random effects (95% confidence intervals) on the proportion change in fishing power from 1988 to 2024 for Queensland waters. Combined terms (i.e. fixed and random) are shown in grey and fixed terms only are shown in black. The proportional change represents the difference from the reference year 1989, which was set to 1. Results reflect within-zone patterns only and are not comparable across zones.

Figure 3.4 depicts the proportional changes in fishing power attributed to fixed gear terms over the time series from 1969 to 2024. In 1969, the fishing power was 99% of the 1989 level for the shallow inshore zone and 85% for the deep waters.

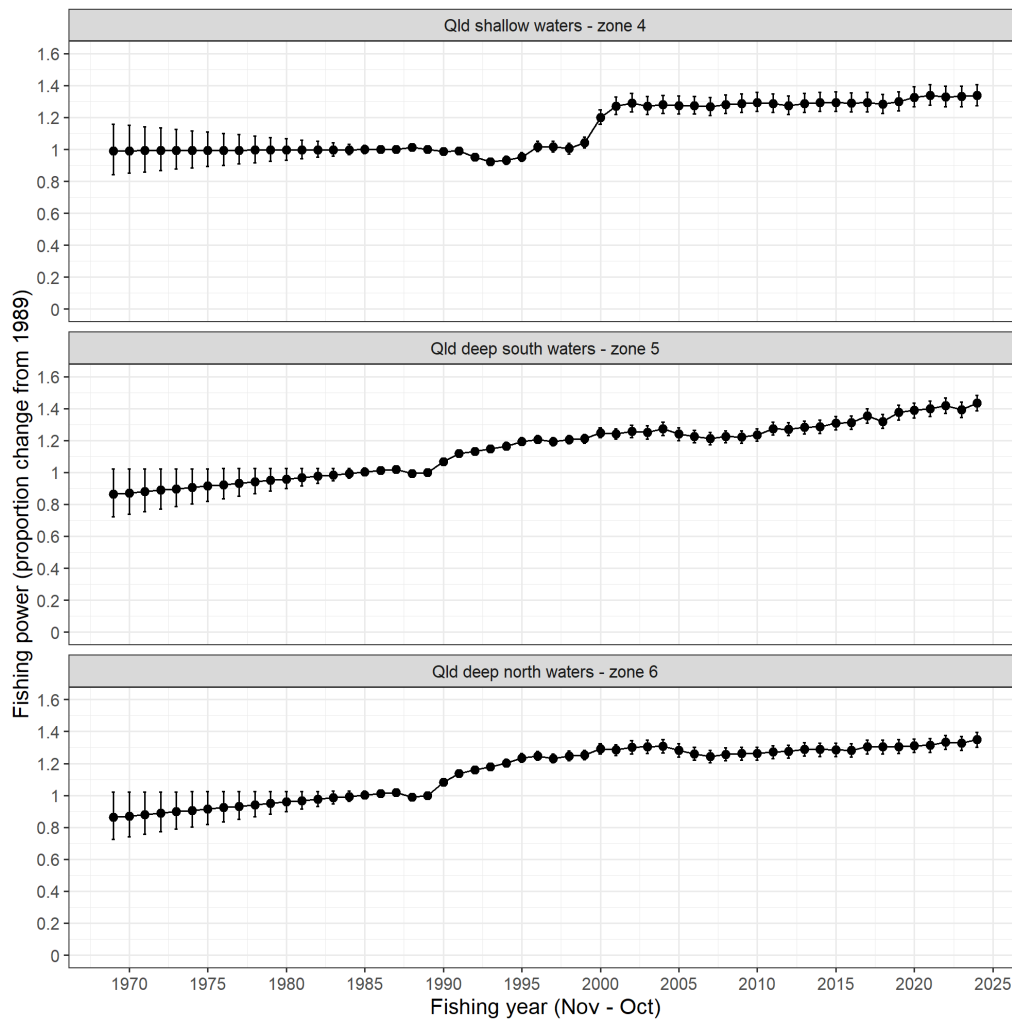


Figure 3.4: Proportional change in Queensland fishing power from fixed gear terms from 1969 to 2024 for Queensland waters. The proportional change represents the differences from the reference year 1989 set to 1. 95% confidence intervals are shown. Results reflect within-zone patterns only and are not comparable across zones.

For the preferred scenario the fishing power offset applied to New South Wales catch rates was from the Queensland shallow waters zone 4 fishing power calculations (black line in Figure 3.3 for zone 4). These fixed gear terms and the fixed and random terms (i.e. including New South Wales vessel effect) are shown in Figure 3.5. Between 1989 and 2024, overall fishing power increased by an estimated 98% in south zone 1, 61% in central zone 2, and 54% in north zone 3 (grey lines in Figure 3.5).

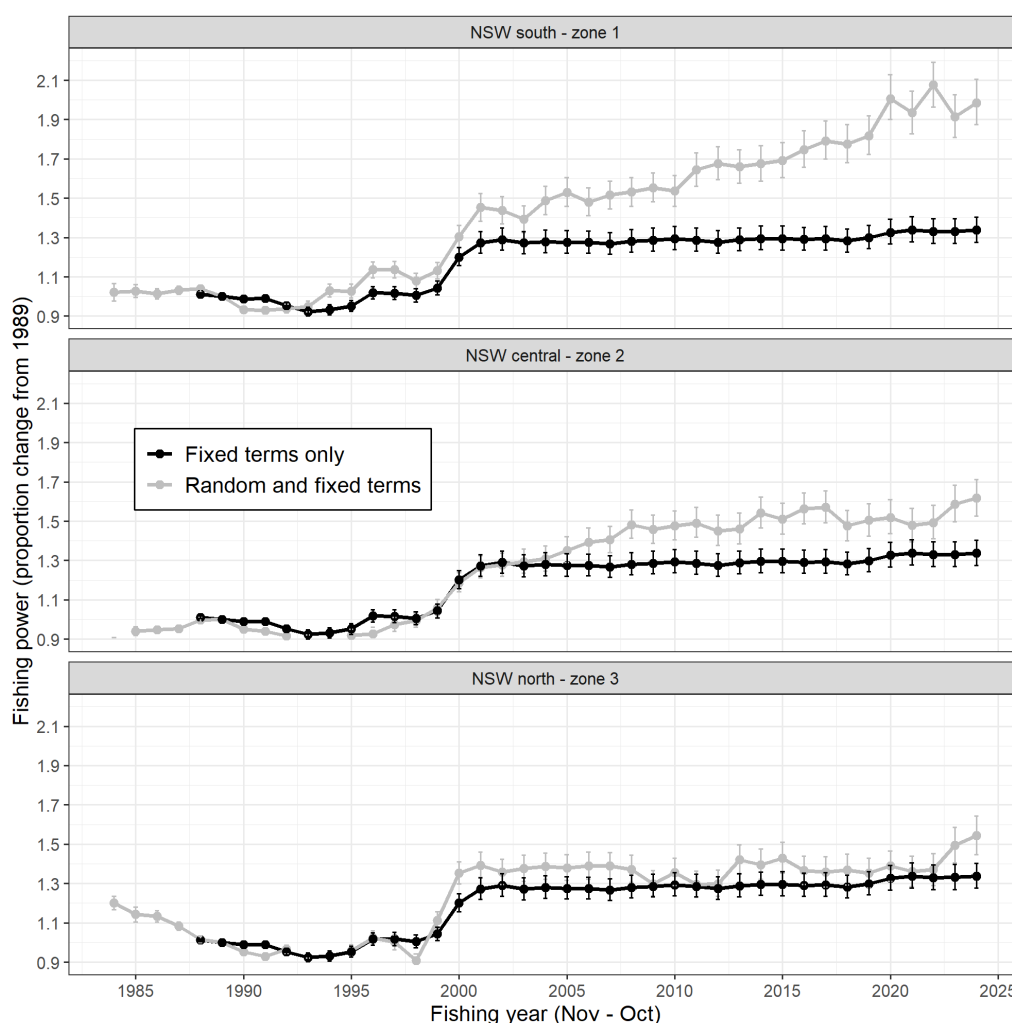


Figure 3.5: Fixed and random effects (95% confidence intervals) on the proportion change in fishing power from 1984 to 2024 for New South Wales waters. Combined terms (i.e. fixed and random) are shown in grey and fixed terms only are shown in black. Fixed terms were from Queensland shallow waters zone 4 fishing power in Figure 3.4. The proportional change represents the difference from the reference year 1989, which was set to 1. Results reflect within-zone patterns only and are not comparable across zones.

The second fishing power scenario is shown in Figure 3.6.

The increase in fishing power in New South Wales was primarily driven by the departure of smaller, less efficient vessels from the fleet or a reduction in fishing activity by these vessels (grey lines in Figures 3.5 and 3.6). The rate of increase in fishing power was more pronounced in the southern waters of the New South Wales fishery (zone 1). This was due to a higher number of vessels leaving the southern fishery or operating with reduced effort compared to the central and north zones.

For the second fishing power scenario, engine power within vessels (remained consistent over time in New South Wales, Helidoniotis and Craig (2025)), combined with Queensland fishing gear, (otter boards and line trawl patterns of fishing), estimated that the trend in fishing power attributable to gear modifications showed small increases of less than 15% relative to 1989 (black lines in Figure 3.6). These fixed-term fishing power estimates were applied in New South Wales catch rate standardisations.

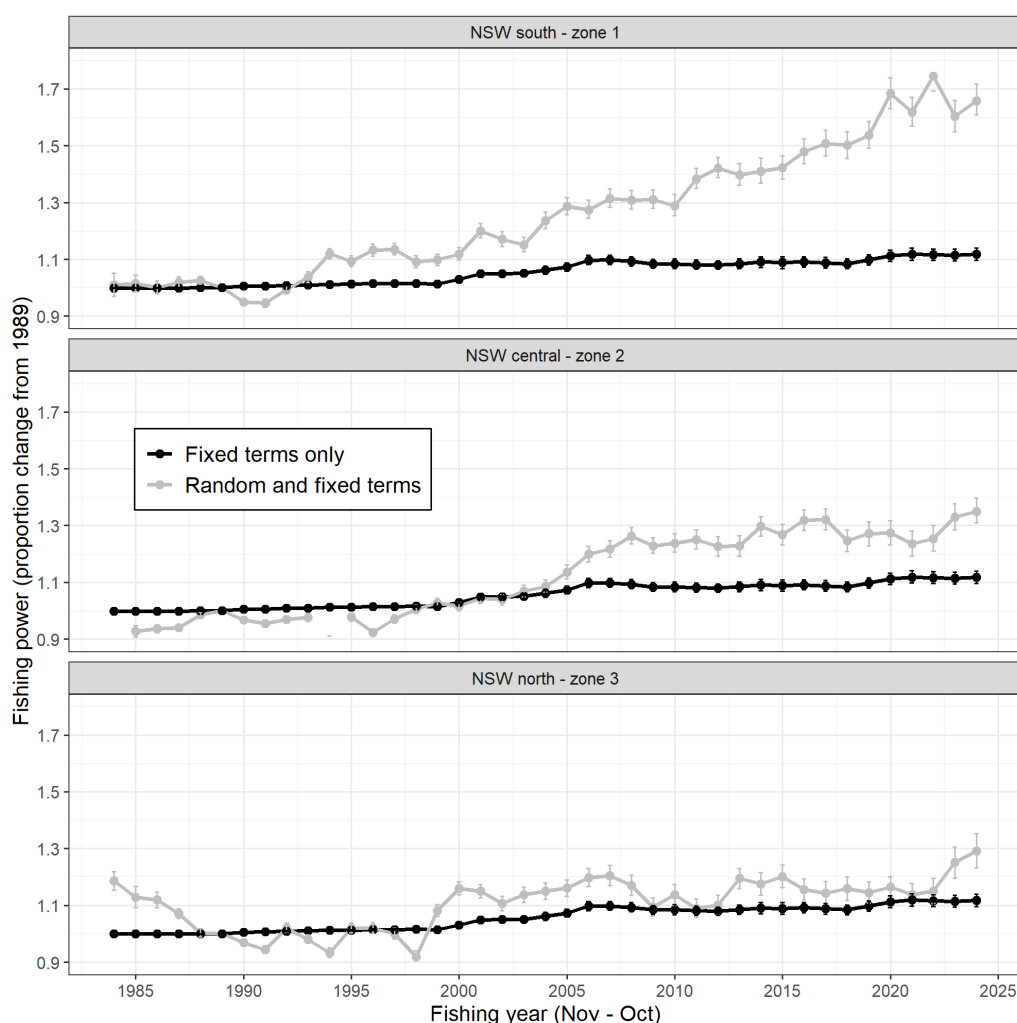


Figure 3.6: Fixed and random effects (95% confidence intervals) on the proportion change in fishing power from 1988 to 2024 for New South Wales waters. Combined terms (i.e. fixed and random) are shown in grey and fixed terms only are shown in black. Fixed terms were from New South Wales and Queensland gear data (alternative scenario). The proportional change represents the difference from the reference year 1989, which was set to 1. Results reflect within-zone patterns only and are not comparable across zones.

3.1.4 Catch rates

3.1.4.1 Commercial

Standardised monthly catch rates are shown in Figure 3.7 and Figure 3.8.

There was a sharp increase in the standardised catch rates in all zones between 2007 and 2010, followed by regular fluctuations since 2010. Queensland catch rates were higher than New South Wales catch rates.

Within Queensland, the annual catch rate was lower for shallow waters zone 4 than deep waters zones 5 and 6.

Within New South Wales the annual catch rate increased over the last 14 years narrowing the difference between New South Wales and Queensland.

Annual catch rates with standard error bars are shown in Figures B.11 - B.16 in Appendix B.2.

Standardisation diagnostics are provided in Appendix B.2.

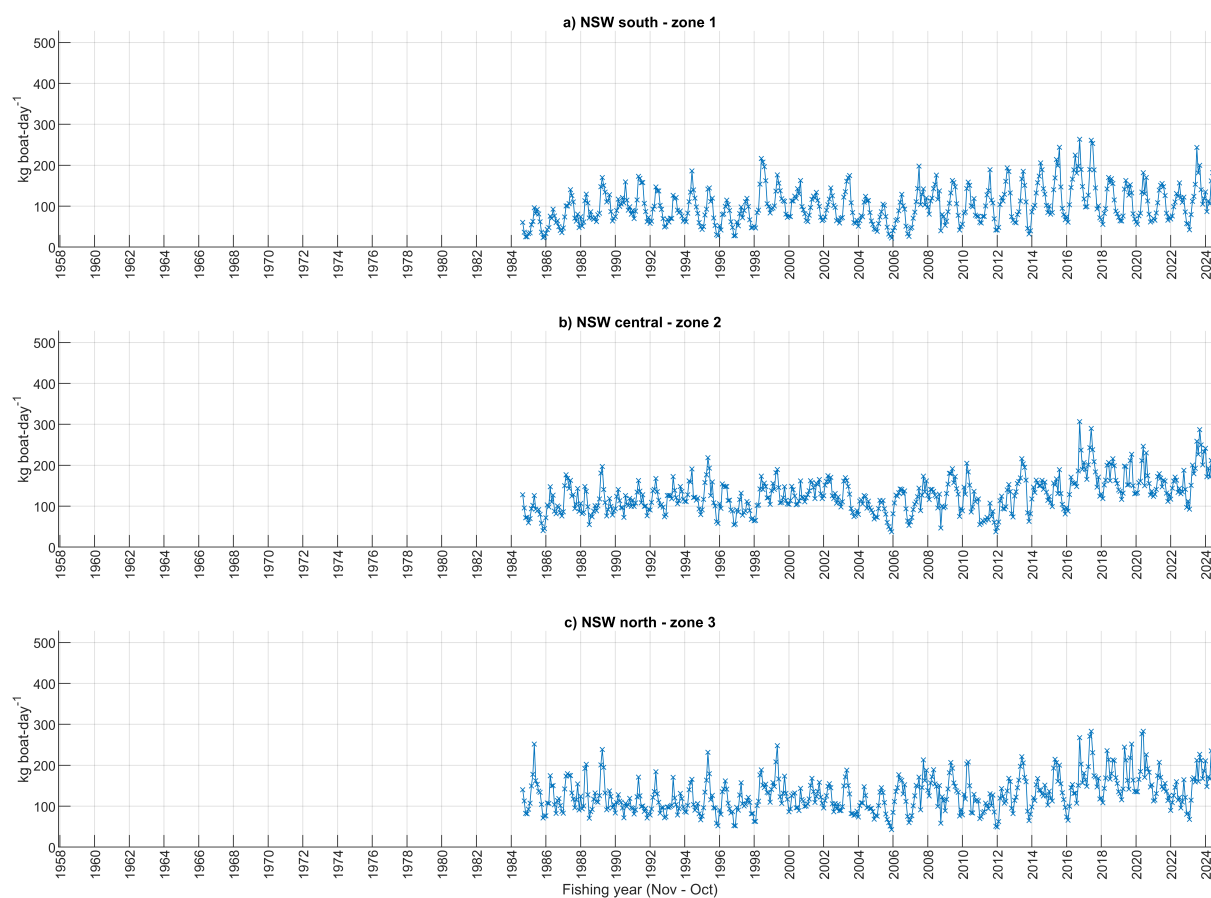


Figure 3.7: Monthly standardised catch rates for New South Wales eastern king prawn. Relative standard errors were $\pm 12\%$.

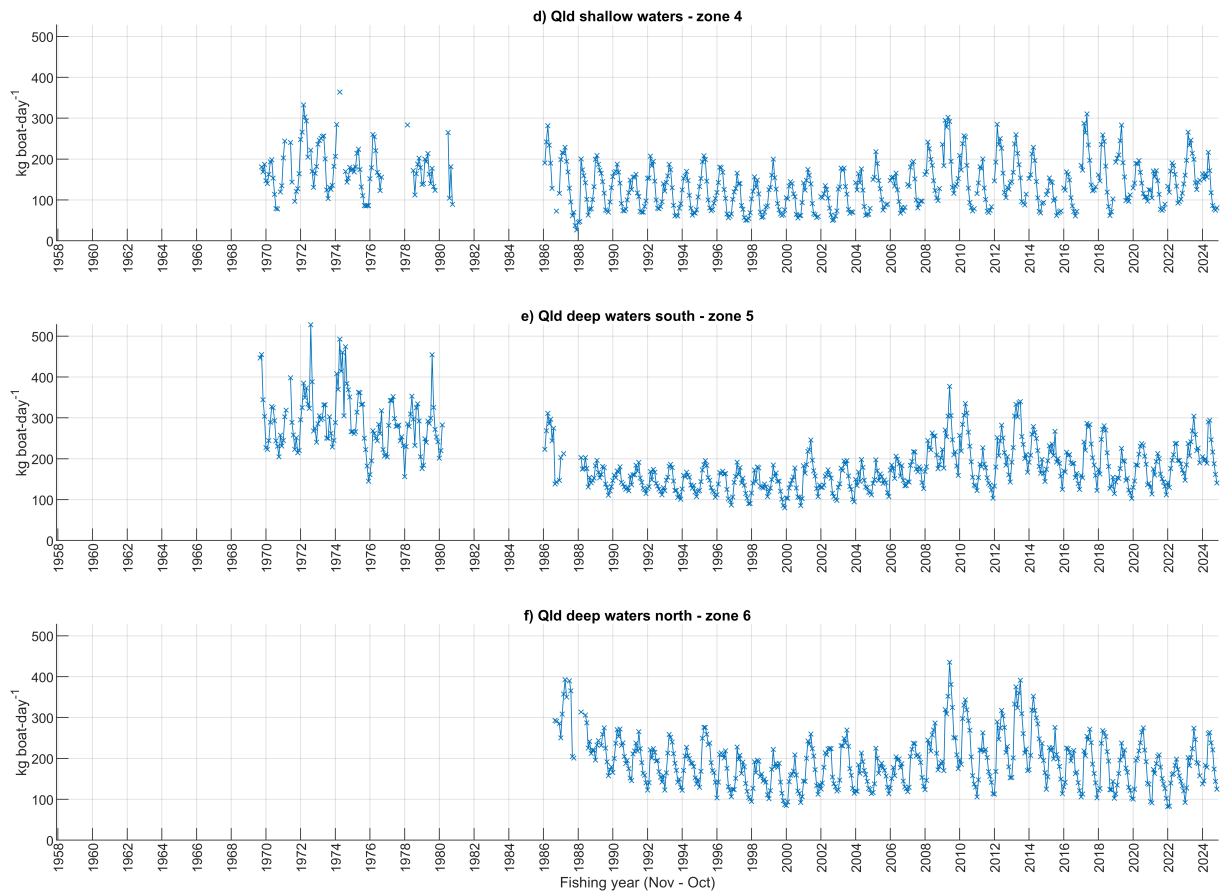


Figure 3.8: Monthly standardised catch rates for Queensland eastern king prawn. Relative standard errors were $\pm 15\%$ pre-1988 and $\pm 3\%$ post 1988.

3.1.4.2 Survey

The annual standardised index showed a subtle long-term increase in abundance from the 2008 to 2023 fishing years (Figure 3.9). Strong recruitment was observed in the 2023 fishing year. Standardisation diagnostics are provided in Appendix B.2.7.

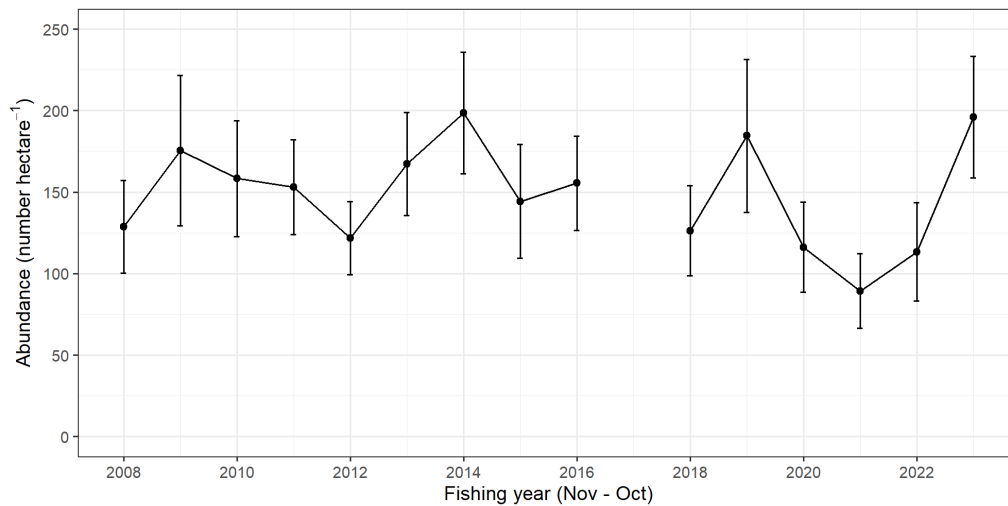


Figure 3.9: Standardised catch rate densities of eastern king prawn from the fishery independent beam trawl survey. Error bars represent 95% confidence intervals. Note the survey was not conducted in November and December of 2016 and 2023 (fishing years 2017 and 2024).

3.1.5 Length

Commercial length compositions of eastern king prawn are shown by zone and sex, aggregated across time (Figure 3.10).

In general the length-frequency data revealed that smaller prawns were more common in the southernmost zone of New South Wales (zone 1) and the size increased in the more northern zones (zones 5 to 6, Figure 3.10).

For the shallow waters zone 4 (southern Queensland), prawn sizes were smaller and the zone was an area for recruitment into the fishery and for continued growth of eastern king prawns.

The fishery independent length frequency data had a smaller size range of prawns 5–40 mm CL (Figure 3.11).

Females dominated the larger 40–60 mm CL size classes, whereas there were more males in the 20–40 mm CL size classes.

The maximum sizes sampled for males and females were consistent with the maximum attainable size for each sex (Glaister et al. 1987; Lloyd-Jones et al. 2012). There was an overlap in sizes between males and females in the Queensland shallow waters and the New South Wales southernmost zone.

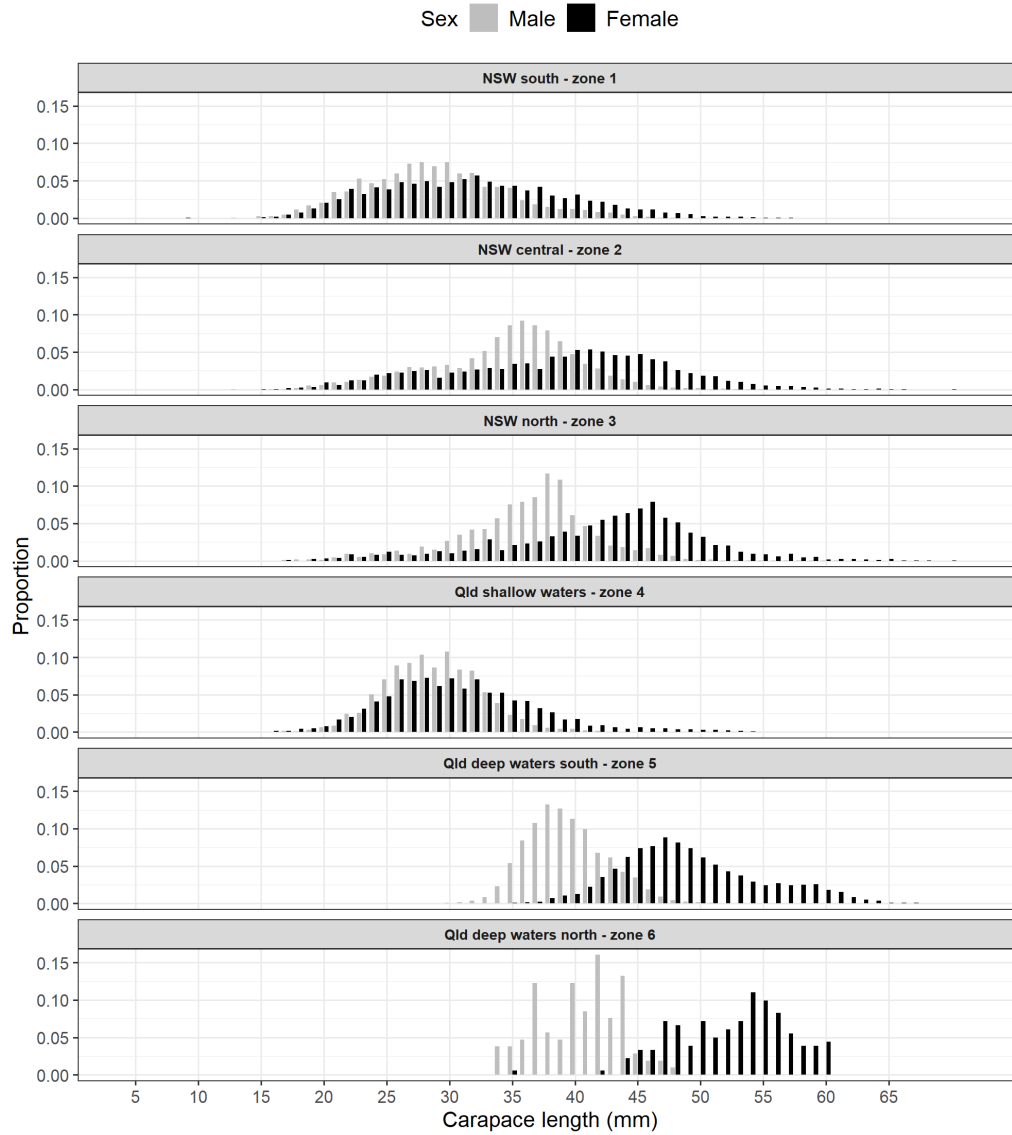


Figure 3.10: Length compositions of eastern king prawn aggregated across time by zone and sex.

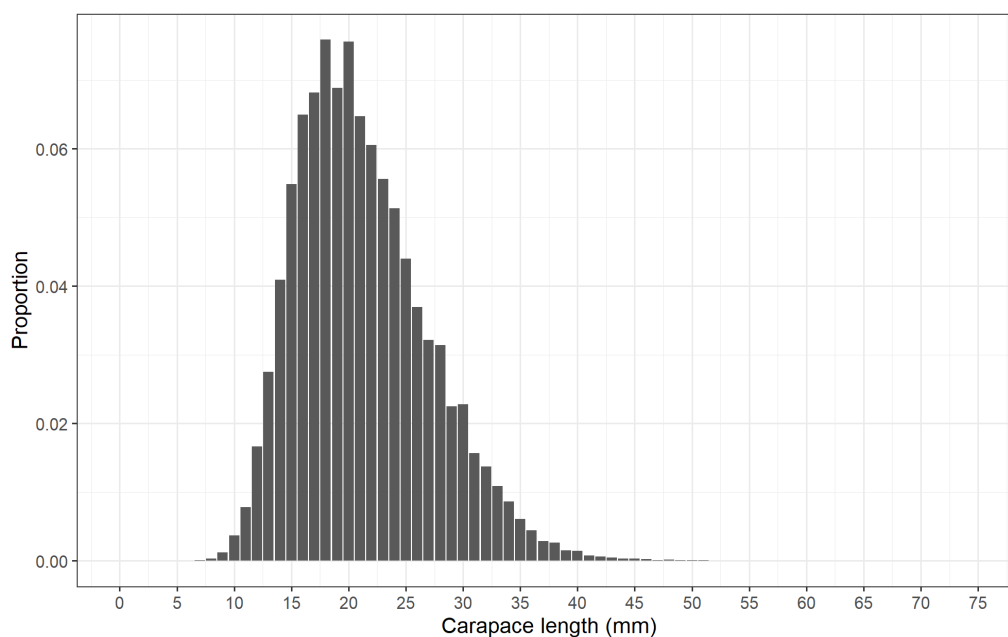


Figure 3.11: Length compositions of eastern king prawn aggregated across time for the Queensland fishery independent beam trawl survey in Moreton Bay.

A summary of the grading data used in the analysis is provided in Figure 3.12. Note that males don't grow large enough to contribute to the larger grades. As such, the large size grades (fewer than 6 prawns per pound and 6-8 prawns per pound) were comprised entirely of females. When the number of boxes was summed for January (vessels and years pooled), the composition of the catch was dominated by smaller grades (i.e., 16-20 and 10-15 prawns per pound). In contrast, when boxes were summed for July (vessels and years pooled), the catch was mainly comprised of large grades (i.e., fewer than 6 prawns per pound and 6-8 prawns per pound).

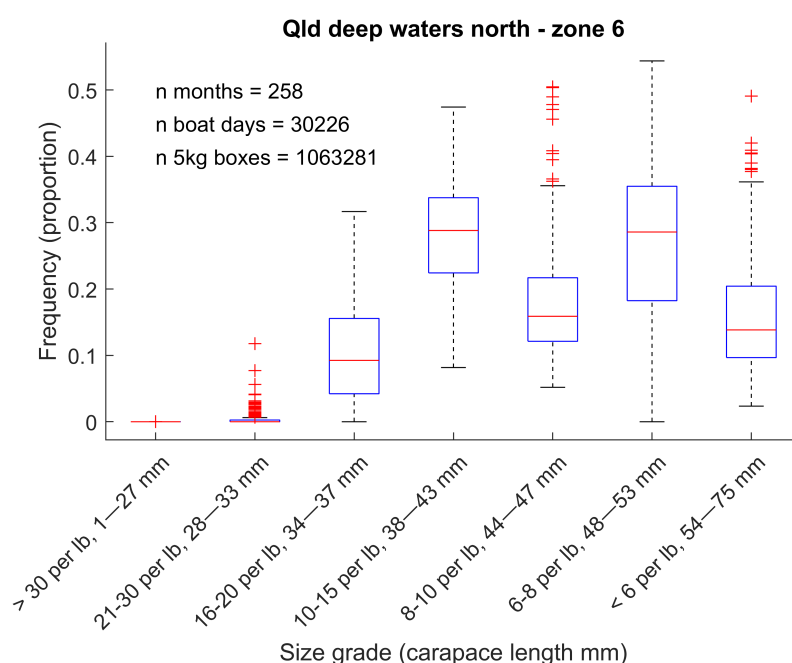


Figure 3.12: Boxplot summary of the gradings data – numbers of 5 kg boxes in each size grade from zone 6, provided by vessels between 1997 and 2019.

3.2 Model outputs

3.2.1 Parameters

In total there were 82 parameters estimated by the monthly length-spatial model.

The parameters included 53 for calculating the annual recruitment deviations, 4 for initial recruitments in zones 1–4, 7 for allowing seasonal catchability, 10 for selectivity, 6 for seasonal recruitments, 1 for a movement multiplier between zones 4 and 6, and 1 for transformed steepness of the Beverton-Holt equation.

All parameter estimates converged. Multiple optimisations and simulated annealing produced consistent estimates and convergence to the same solution.

The parameters and standard errors are listed in Table 3.1 except for the recruitment deviations. There were two fixed parameters: natural mortality at $M = 0.18$ per month, and the zone 4 survey domed vulnerability right asymptote = 0.

Growth parameters were predetermined and built into the size transition matrix which was used for monthly growth by zone.

Results produced higher $\log R_0$ estimates and population size than the previous assessment (Helidoniotis et al. 2020). This was for the model to explain the continued high catches from zones 4–6 (Figure 3.2).

For the data inputs on the northward movements of prawns, the model seeded more recruitment south into New South Wales zone 3 to uphold the expanded harvests in Queensland, particularly in zones 4 and 5. Queensland zone 4 harvest continued to remain strong and model recruitment into this area supported most of the productivity.

Table 3.1: Estimated model parameters, excluding parameters for the recruitment deviations.

Parameter	Zone	Description	Value	Standard error
ξ	All	Used to determine Beverton-Holt steepness h	-1.0494	0.0962
γ	Zone 1	Used to determine R_0	1.8593	0.0962
	Zone 2		1.9891	0.0861
	Zone 3		3.1203	0.061
	Zone 4		1.7482	0.0692
μ	Zone 1	Mode of the monthly recruitment pattern	4.3386	0.0918
	Zone 2		4.2544	0.0898
	Zone 3		8.5872	0.0883
	Zone 4		13	0.06
κ	Zone 1:3	Concentration of the monthly recruitment pattern	1.5398	0.0854
	Zone 4		2.2619	0.0846
l^{50}	Zone 1	Length at 50% selection	35.4746	0.1
	Zone 2		34.0563	0.1024
	Zone 3		37.7986	0.0829
	Zone 4		24.8082	0.1043
	Zone 5		37.8154	0.0867
	Zone 6		37.7973	0.0792
δ	All	Initial steepness of the vulnerability curve	0.4281	0.0532
l^{50}_{rising}	All	Length at 50% selection by the survey on the upward slope	24.3832	0.1154
l_{diff}	All	Difference between the length at 50% selection by the survey and 95% selection	17.0316	0.0937
$l^{50}_{falling}$	All	Length at 50% selection by the survey on the downward slope	31.5284	0.0835
ρ	All	Movement from zone 4 to zone 6	-1.6909	0.0888
ζ	All	Catchability amplitude	-0.2777	0.0369
ϕ	Zone 1	Catchability seasonal modes	0.7914	0.0839
	Zone 2		-0.2932	0.0909
	Zone 3		-7.929	0.0877
	Zone 4		-0.5552	0.084
	Zone 5		-0.7449	0.0837
	Zone 6		-0.0246	0.0704

3.2.2 Goodness-of-fit

The model was calibrated to zone specific standardised catch rates and length frequency data. Each model fit to data is discussed in turn:

- Commercial catch rate data for each commercial fishery zone (zone 1 to 6), diagnostics are in Appendix C.1.
- Survey abundance index from zone 4, diagnostics are in Appendix C.1.2.
- Length frequency data (female and male) from each commercial fishery zone (zone 1 to 6).
- Survey length frequency data from zone 4.
- Commercial size grade frequencies from zone 6.

In general, the model tracked commercial catch rate trends and seasonal patterns well. However, fits in some years were varied when zones exhibited their own individuality.

For New South Wales zones 1 to 3, the predicted catch rates in some years were generally lower than the observed data after 2014 (Figure 3.13). This related to differing patterns in Queensland zones 4–6 catch rates. Statistical down-weighting of zones 4–6 would improve fits to zones 1–3.

Interestingly in zones 1–3, some years signalled two possible spikes in seasonal recruitment (Figure 3.13), (example fishing years 2016, 2019, 2020, 2022, 2023). This irregularity, sometimes occurring in different months, was unlike the typical single recruitment pulse seen in Queensland waters; only single recruitment pulses per year were allowed for in the model design.

In contrast, for Queensland zones 4 to 6, the predictions of catch rates aligned well with the observed data and fell within the observed range (Figure 3.14).

The exception in zone 4, was that the predictions did not capture the full seasonal variability, as they were neither as high nor as low as the observed catch rates. Catch rates in zone 6 were fit marginally higher in some later years.

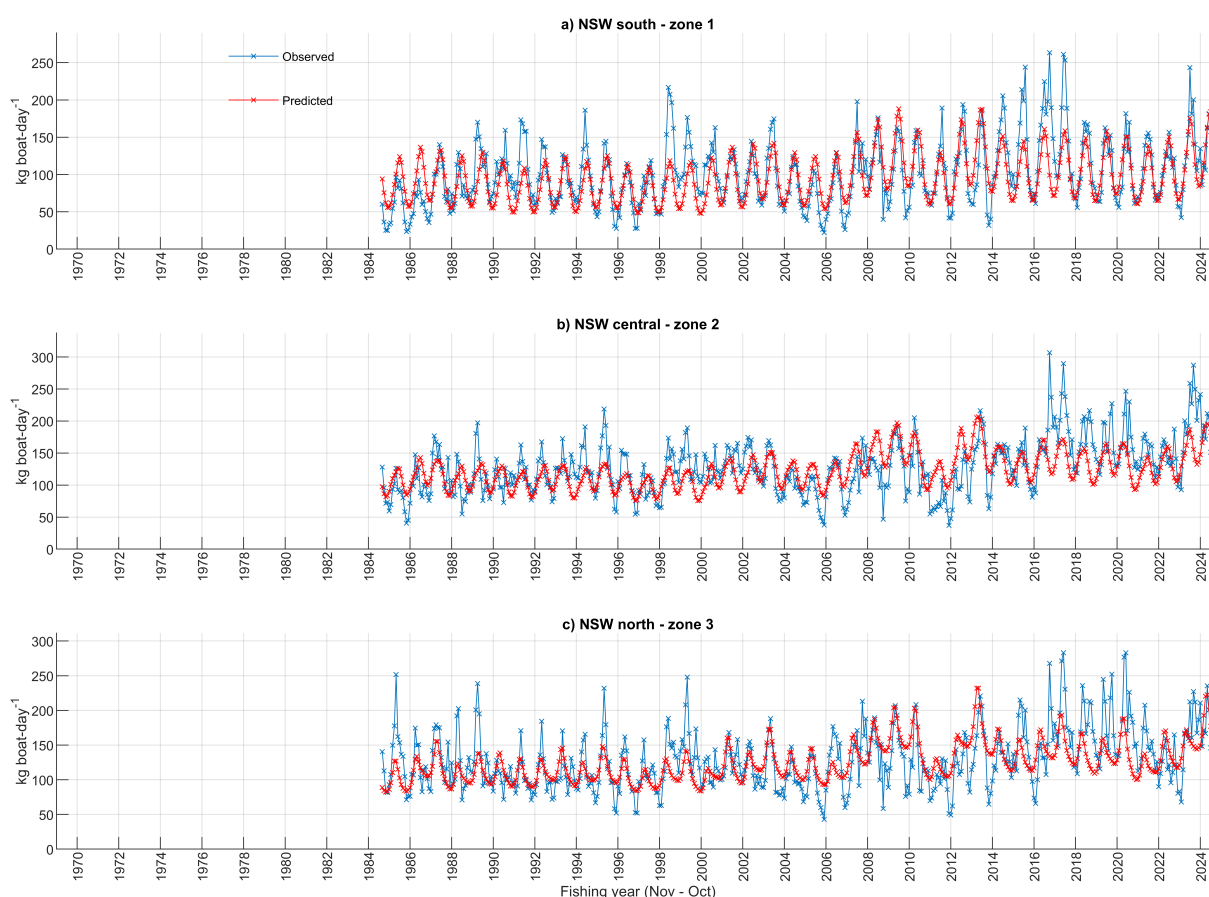


Figure 3.13: Eastern king prawn observed (standardised) and model predicted catch rates for each spatial zone and month in New South Wales.

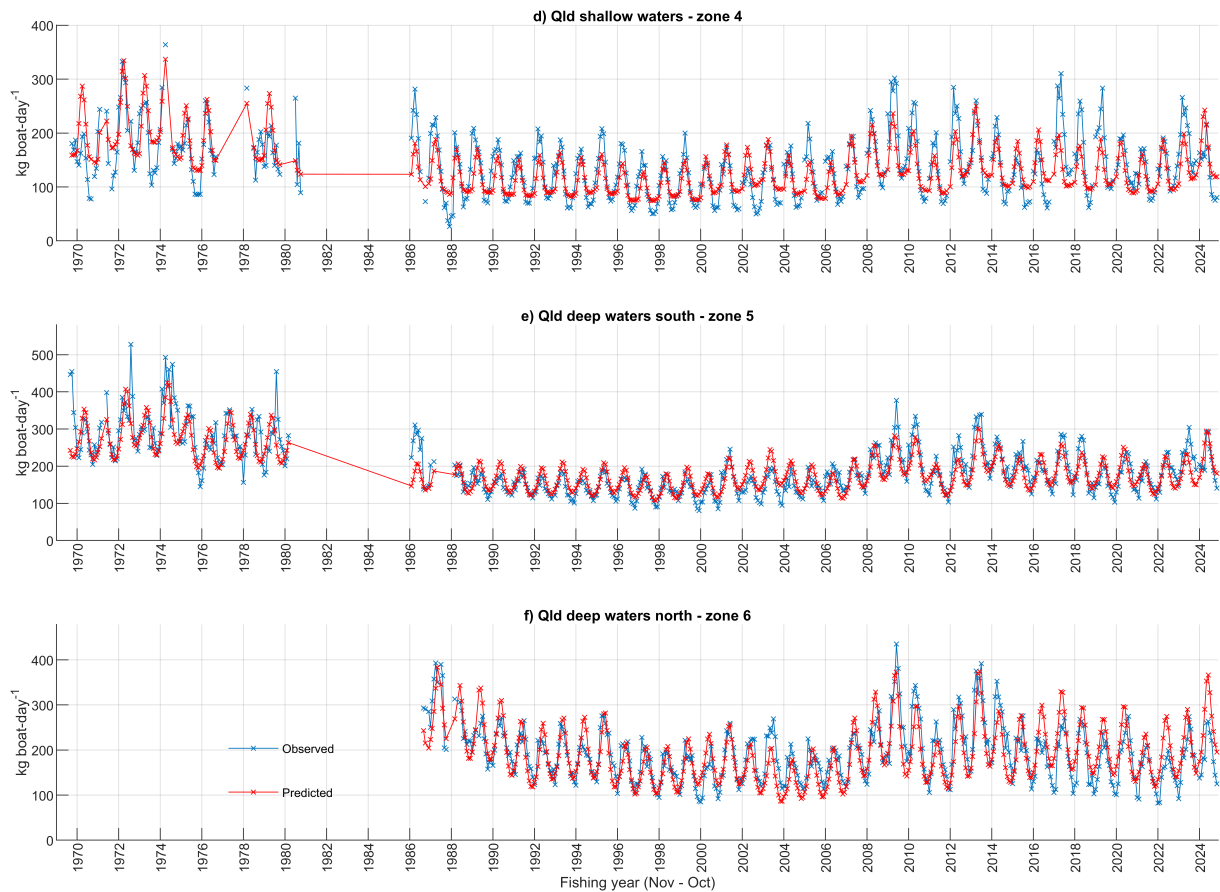


Figure 3.14: Eastern king prawn observed (standardised) and model predicted catch rates for each spatial zone and month in Queensland.

The fits to the survey recruitment index varied across the data (Figure 3.15).

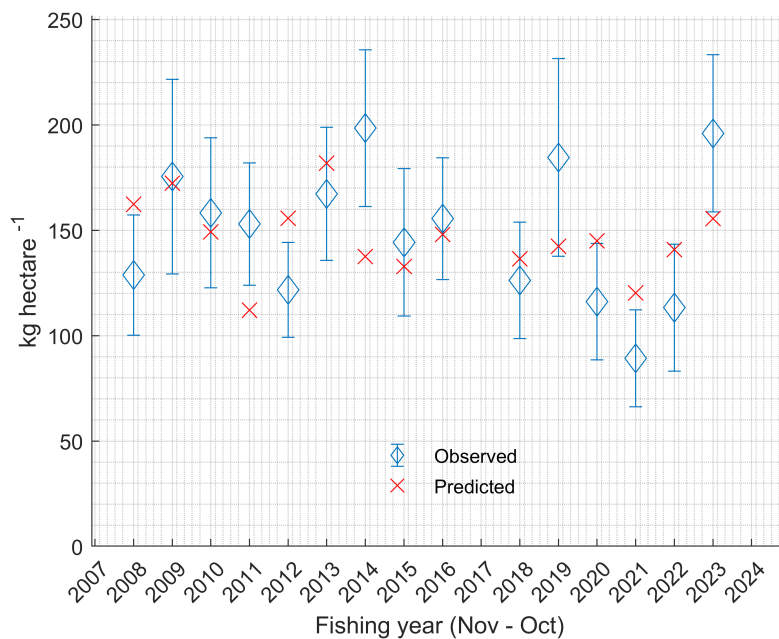


Figure 3.15: Observed and predicted standardised survey index from fishery independent beam trawl surveys for Queensland shallow waters - zone 4.

The fits to the length frequencies for zones 1 to zone 5 were reasonable with zone 6 having little data to improve the fit (Figure 3.16). The number of months of data from Queensland waters were also limited. In general, there was some variance between sampled months and the peaked length distributions with some off-centred fits suggested a degree of sample correlation (Francis 2011).

Fits to the survey length data were sound, as this aspect was more structurally designed in model recruitment (Figure 3.17).

Commercial size grade frequencies were used as an additional length data for zone 6. There was reasonable agreement between the predicted estimates from the model and observed data, apart from the largest grade size. The predicted largest grade was higher than the observed proportion (Figure 3.18). Grading sizes do exhibit higher variance than carapace length data (O'Neill et al. 1999).

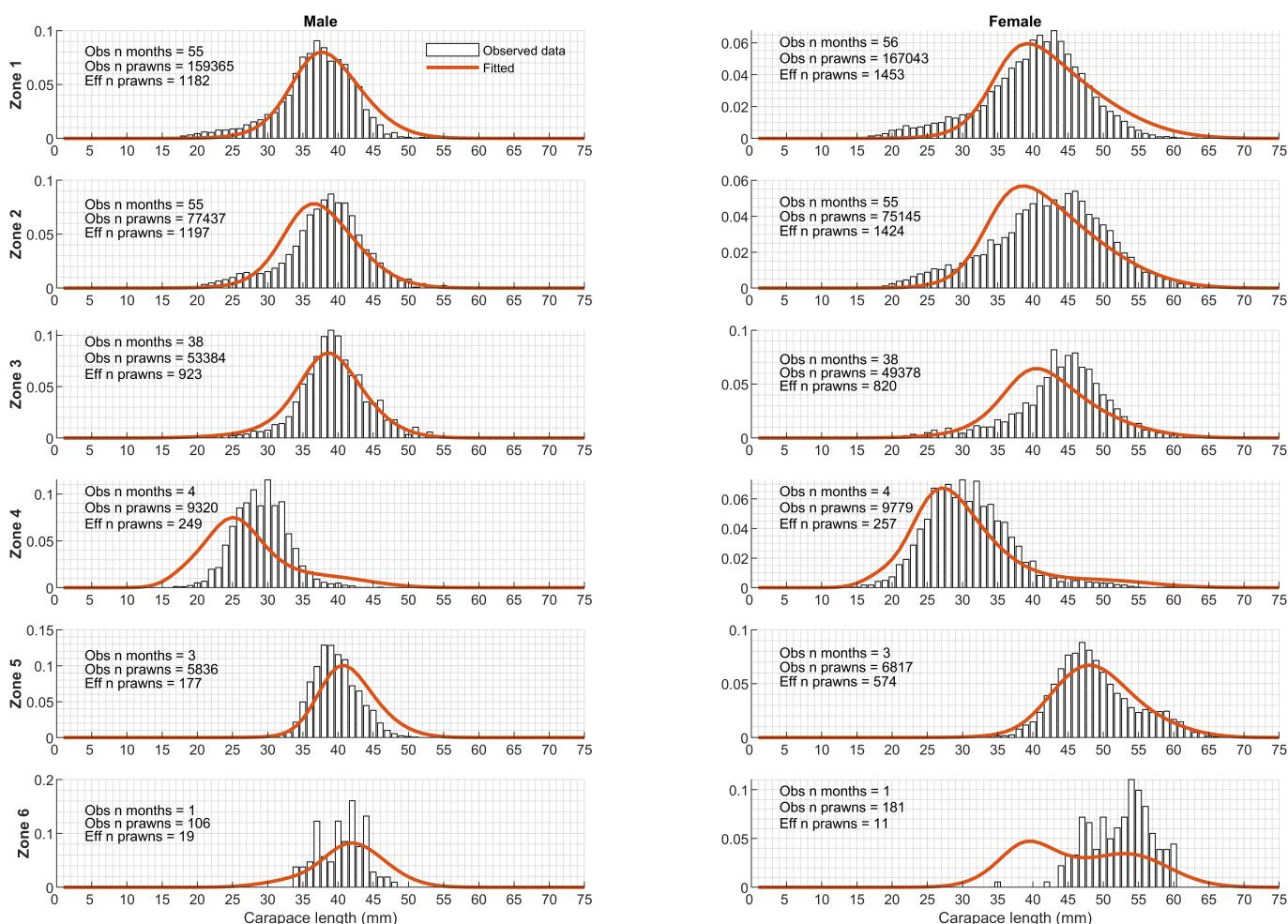


Figure 3.16: Observed and predicted overall length frequencies by sex and zone.

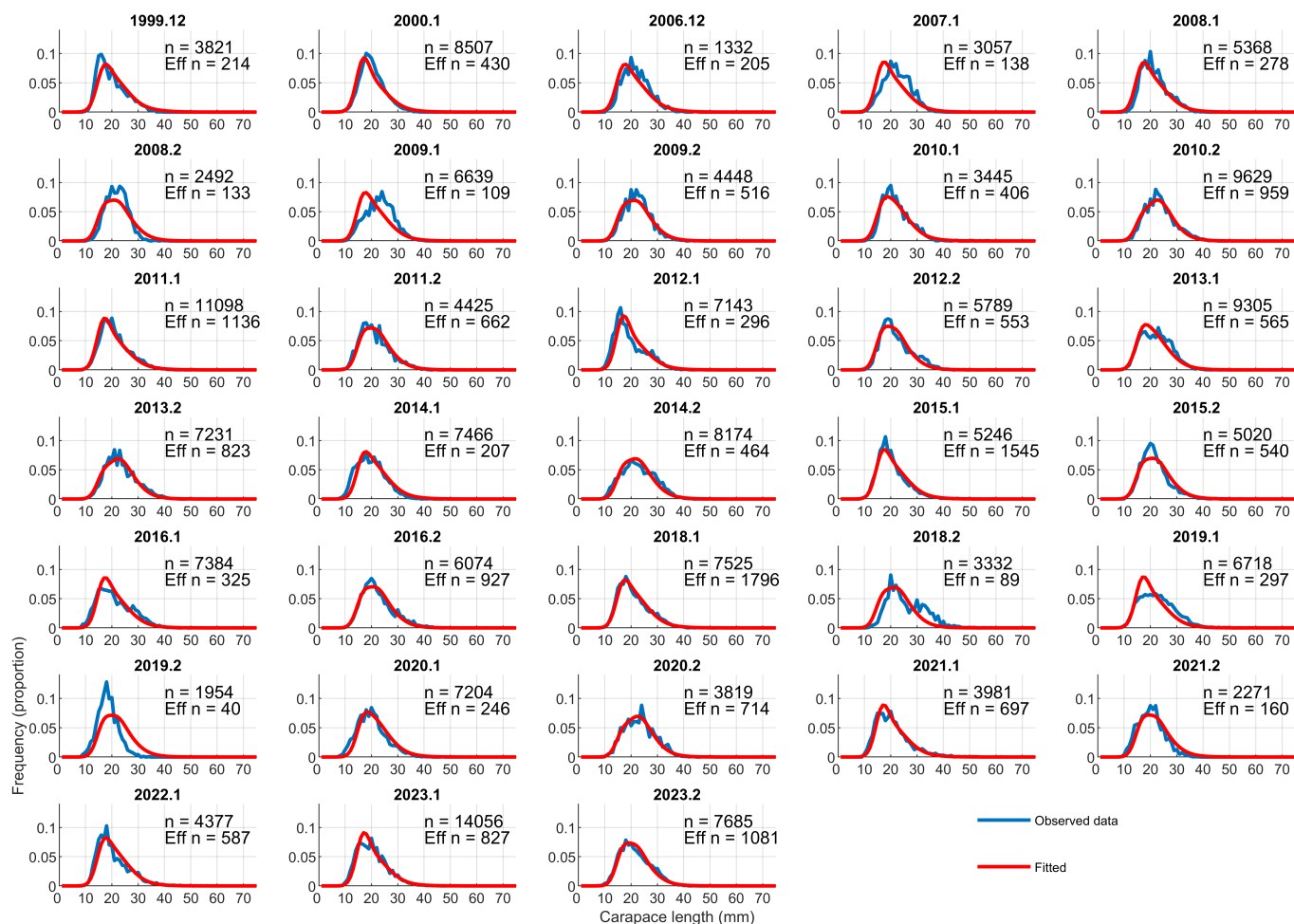


Figure 3.17: Monthly observed and predicted length frequency distribution from fishery independent beam trawl survey for females and males.

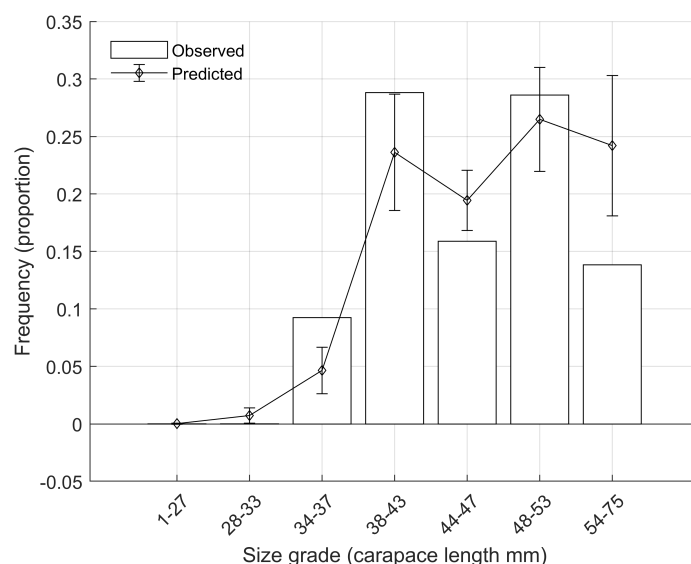


Figure 3.18: Eastern king prawn observed and model predicted frequencies of size grading data from Queensland deep north waters (zone 6). The plot frequencies were summed by effective sample numbers over 258 monthly prawn-size-box frequencies.

3.2.3 Catchability and selectivity

Parameters for catchability and length-based selectivity to fishing were estimated within the model (Table 3.1).

The estimated monthly catchability showed seasonal variation (peak and amplitude) across zones (Figure 3.19).

Catchability was estimated with similar monthly patterns in zones 2 and 4–6. Specifically, catchability in these zones tended to peak December to March and wane late winter. The peak catchability was October to December with a low in May for New South Wales north waters – zone 3, and zone 1 peak catchability was later during autumn and waned during winter and spring.

New South Wales central and south waters (zones 2 and 1), and Queensland deep south waters (zone 5) were less seasonal. The amplitude in catchability was highest in Queensland deep north (zone 6) and New South Wales north (zone 3).

The logistic selectivity function (Figure 3.20) illustrates the relative proportion of eastern king prawns of a given length that are vulnerable to captured in each zone, ranging from 0 to 100%.

Eastern king prawn mean carapace length at 50% vulnerability was 35 mm in zone 1, 34 mm in zone 2, 38 mm in zone 3, 25 mm in zone 4, 38 mm in zone 5 and 38 mm in zone 6.

Eastern king prawns in shallower waters were selected at smaller sizes compared to those in deeper waters. This pattern aligns with their life cycle, as sub-adults migrate into inshore waters, where they grow rapidly to reach maturity at a carapace length (CL) of approximately 38–42 mm. Once mature, prawns of this size typically move to deeper waters.

The survey selectivity, represented by the black line in Figure 3.20, used a dome-shaped pattern with selectivity peaking at carapace length (CL) of 26 mm.

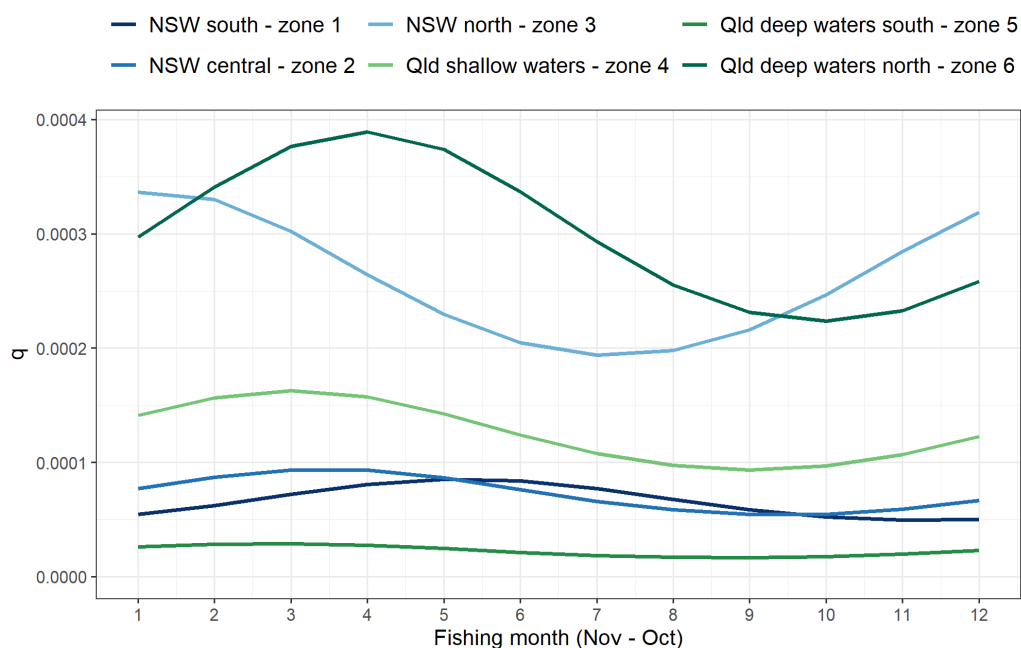


Figure 3.19: Model estimated catchability by month and zone.

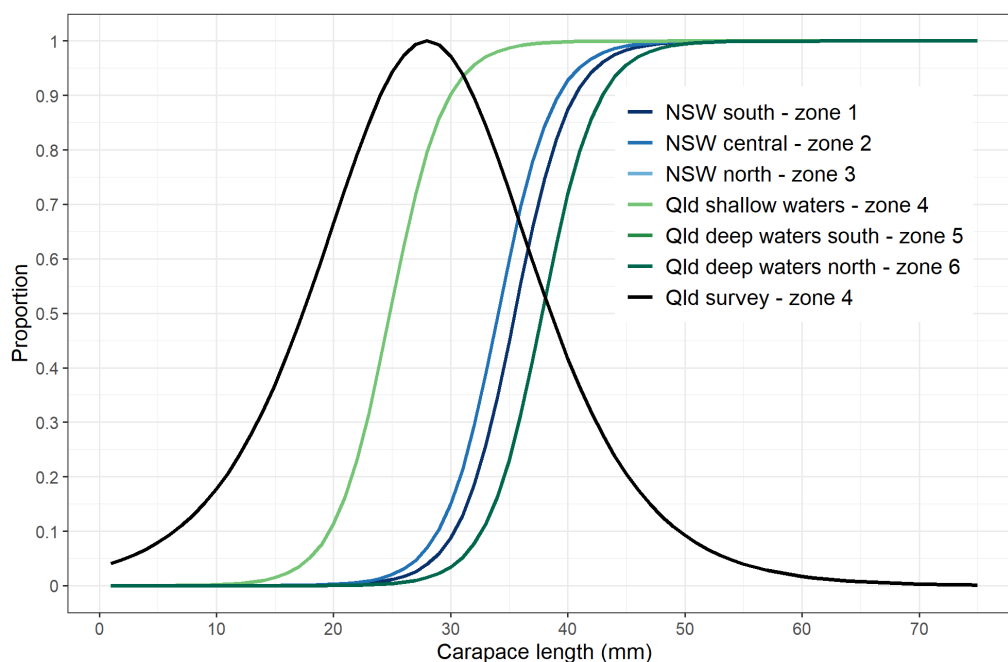


Figure 3.20: Model estimated length-based selectivity by zone for eastern king prawn. The selectivity results also include the beam trawl survey.

3.2.4 Biomass

The estimated time series of spawning biomass relative to the unfished state is shown in Figure 3.21. The model predicted that historical eastern king prawn spawning biomass, expressed as a ratio of egg production relative to 1958, declined to roughly 49% (43–57%) in 1984, steadily increased to 57% (44–68%) in 2019, and increased to 72% in 2024 (54–88% confidence interval). The biomass ratios have shown greater fluctuations since 2000.

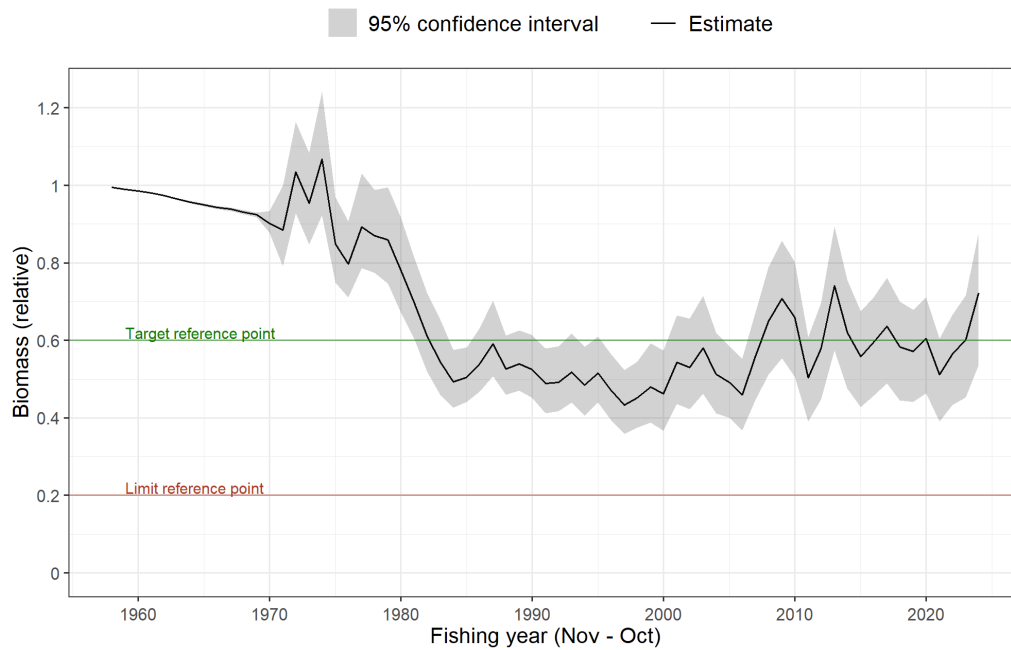


Figure 3.21: Spawning biomass ratio by fishing year, relative to the unfished level in 1958. The maximum likelihood estimate (MLE) showed the model best prediction and fit to the data.

4 Discussion

4.1 Fishing power

The discussion will focus on two types of fishing power:

- Attributes *within* a vessel.
- Differences *between* vessels.

Attributes within a vessel, such as engine horsepower, net types and technologies: The analysis indicated that annual changes in average fishing power differed between the zones. Fishing power in the shallow waters had the highest rate of increase, possibly because vessels in these sectors originally had less technological capital investment, and therefore, the greatest potential for technology transfer and improvement in fishing power. Fishing power in the shallow waters had the highest rate of increase around the year 2000, when BRDs and TEDs were adopted and the number of vessels using quad and five netgear type increased. In the deep water zones, average fishing power increases were more gradual than in the shallow waters, with the vessels adopting upgrades to engine power and the adoption of GPS and line trawl patterns of fishing. O'Neill et al. (2005) suggested that management controls such as restrictions on vessel and engine size, may have indirectly limited the size of nets that fishers tow, thereby constraining fishing power.

A further point to discuss in relation to fishing power was that some technological adoptions did not relate to expected higher or lower catches. This was difficult to explain other than to state that estimating fishing power is a complex multivariate function and dependent on the range of different vessels fishing. The negative effect of GPS on catches in the eastern king prawn shallow waters may be due to some unique features of eastern king prawns and the trawl fishery. Eastern king prawn have a strong northerly migratory pattern in much greater depths than other prawn species and are generally fished along narrow depth contours (O'Neill and Leigh 2007). These features may have lowered the significance of GPS in shallow waters. The effects of BRDs (Bycatch Reduction Devices) and TEDs (Turtle Excluder Devices) on target species catches can be highly variable. It is not uncommon in the scientific literature to find instances where BRDs have a positive effect on target species catch rates. Examples where BRDs have had a positive effect on catch rates of target species include Rogers et al. (1997), Broadhurst and Kennelly (1997), and Steele et al. (2002). This was observed in shallow waters, whereas in deeper waters, the impact of these devices was negligible.

Standardising average catch rates to account for changes in average annual fishing power was essential to ensure that catch rates reflected only changes in abundance. When standardised to 1989 fishing power, the adjusted catch rates were higher than the observed nominal catch rates prior to 1989 and lower than the observed nominal catch rates after 1989.

Differences between vessels, for instance, an increase in the overall fleet power from the gradual exit of less efficient vessels, leaving the more effective ones to fish: Since 1989, the shallow water fleet profile has shown continuous improvement, primarily due to the departure of less efficient vessels and the retention of more effective ones in the region. In the deep northern waters, the fleet profile has remained relatively stable since 2004, reflecting the limited potential for larger, more powerful vessels to

further increase their fishing power in the deep northern zone. In contrast, the fleet profile in the deep southern zone has continued to improve gradually.

4.2 Population model

Parameter estimation occurred using two methodologies: maximum likelihood estimation (ML) and a customised simulated annealing (Markov chain Monte Carlo - MCMC) program. Final biomass estimates produced by the ML and simulated annealing program were comparable, indicating good model performance and optimisation consistency. This suggests that the methodologies used were robust and provided reliable estimates for the biomass.

The fits to input data were reasonable (Section 3.2.2). The model fit well to the commercial length data, the fishery independent length data and the size gradings data. Model fits to recruitment survey catch rates were good. There is room for improvement to the fits to the New South Wales catch rates. This was achieved by reducing the weighting for the length data ($\log\text{-likelihoods} \times 0.1$), but then the model fits to the commercial length data in the Queensland inshore zone 4 were worse, as were the model fits to the length frequencies from the fishery independent beam trawl survey. This data weighting exercise resulted in slightly higher biomass estimates compared to those reported in the original report, which is to be expected due to the model fitting better to the increased New South Wales catch rates.

The recruitment steepness was estimated at 0.25 and was in line with other Penaeid prawn analyses reported by Ye (2000). (Prawn stocks analysed by Ye (2000) had steepness less than 0.5). Steepness is an important parameter describing the relationship between annual spawning (egg production) and the following year's recruitment (number of new prawns entering the ocean fishery). In Australia, estimates of steepness in the Northern Prawn Fishery have ranged from 0.26 to 0.36 for the two species of tiger prawns (Dichmont et al. 2001). Previous values of eastern king prawn steepness were 0.25 (Helidoniotis et al. 2020) and 0.28 (Courtney et al. 2014; O'Neill et al. 2014).

A second scenario was conducted in which a new fishing power offset was applied to New South Wales catch rates. This offset was derived using data from both New South Wales and Queensland. By applying this fishing power offset, the catch rates in the later years were higher compared to those calculated with the preferred fishing power offset. Consequently, the slightly higher trend in New South Wales catch rates resulted in an estimated spawning biomass for 2024 that was marginally higher, at 73%.

Stock assessment methodology continues to evolve, and Fisheries Queensland is progressively adopting ensemble approaches — where outputs from multiple plausible model scenarios are combined — as a way of more fully characterising uncertainty in biomass estimates. For eastern king prawn, the stock assessment used a well-established single preferred scenario approach, consistent with all previous eastern king prawn assessments. This choice was considered carefully by the project team, which included an independent scientist from Western Australia DPIRD, New South Wales stock assessment scientists, and a commercial fishing representative, and reflects several features of this particular stock and model:

- The biology of eastern king prawn is well understood and extensively researched. Key parameters such as growth rates, natural mortality, and recruitment variability are well-defined for eastern king prawn, leaving little room for significant variation that would necessitate multiple scenarios.

- The data available for eastern king prawn, including catch, effort, and biological information, is robust, reliable, and stable. This consistency in data quality supports a single preferred scenario without requiring alternative scenarios to address data uncertainties.
- Different values of steepness were tested, but for the model to fit to the available data the steepness was estimated at 0.25, in line with previous assessment estimates and estimates of steepness from other prawn species assessments.

4.3 Recommendations

The stock assessment relied on trends in standardised catch rates and fishing power. A critical requirement for future analyses is the availability of up-to-date and comprehensive fishing power data for each vessel operating in New South Wales and Queensland. Since the previous assessment (Helidoniotis et al. 2020), significant improvements have been made in the recording, maintenance, and verification of these data through fishery logbooks in both New South Wales and Queensland. Enhanced logbook compliance has facilitated the direct utilisation of gear data from the logbooks, eliminating the need to impute gear information from the gear surveys conducted in 2000 and 2004 (FRDC project 1999/120, O'Neill et al. (2005)). Given that technological improvements are likely to continue occurring in most fisheries (O'Neill and Leigh 2007; Robins et al. 1998), reinforcement of logbook compliance should remain a priority.

Even with ongoing monitoring of logbook gear data, it is often challenging to identify effective changes in the fishery until after they have occurred. However, the recent implementation of satellite vessel monitoring systems (VMS) and electronic catch and effort reporting systems now allows for real-time analysis of catches, combined with detailed information on vessel and trawl gear specifications. This advancement enables the provision of up-to-date stock assessments to fisheries managers. Such real-time data is particularly critical for the harvest strategy in the southern offshore trawl region, where decision rules permit adjustments to the total allowable commercial effort for eastern king prawn if a new fishing power estimate becomes available (page 11, Fisheries Queensland (2021)).

It is also important to build upon the amount of historical gear and technology information prior to 1988, to allow estimates of annual fishing power changes and to standardise catch rates across all years (e.g. 1970–2024; historical pre 1988 data + compulsory logbook data $\geq$ 1988).

Helidoniotis and Taylor (2023) proposed that changes in fishing power could be accounted for by including vessel as a main term in the model. Future research should focus on analysing fishing power trends both with and without the inclusion of vessel as a fixed factor in the linear model.

One component of fishing power that could not be directly assessed in this study was skipper skill. As noted by O'Neill and Leigh (2006), improved skipper knowledge and experience over time can enhance a vessel's fishing power, even without any changes to equipment. Accurately quantifying the impact of fisher skill would require consideration of factors such as the number of years a skipper has been active or the cumulative number of nights they have fished. Additionally, O'Neill and Leigh (2006) highlighted that the adoption of new equipment by some operators can indirectly benefit others. For instance, advancements in technology may enable all vessels to improve their ability to locate eastern king prawn grounds. These factors—enhanced skipper skill and modified fishing behaviours influenced by other vessels—may lead to underestimations of fishing power. However, the extent of this underestimation remains uncertain. Bishop et al. (2004) demonstrated in their study of Australia's Northern Prawn Fishery that when sufficient capture-system variables (e.g., engine size, net size, etc.) are included in the analysis, the influence of skipper skill becomes statistically nonsignificant or minimal. This does not imply that

factors such as skipper skill, organisational capacity, fishing intuition, or experience are unimportant. Rather, it suggests that incorporating a comprehensive set of capture-system variables into the analysis can yield robust estimates of fishing power and standardised catch rates.

Further work on the structure of the catch rate model could be explored. In this analysis effort is used as a term in the model (where catch is the response term). Helidoniotis and Taylor (2023) suggested that models using effort as an offset (where the response variable is catch /effort) could also be explored.

A deterministic monthly migration pattern was used to model the movements of prawns between the six zones. Courtney et al. (2014) suggested that modelling of eastern king prawn could be improved by incorporating uncertainty in the movement matrix between years.

The primary assumption in the modelling was that the Queensland voluntarily-recorded pre-1989 eastern king prawn catch rates were standardised suitably against post-1988 catch rates. The pre-1989 catch rates provided crucial contrast to model change in abundance between 1958 and 2024. Without this contrast, model outputs would be less certain. Further work could be conducted to improve the uncertainty in the historic catch and effort data used in the standardised catch rate model. Comparisons of the nominal catch rates of fishers present in both HTRAWL and CFISH data sets showed that reporting was relatively consistent between the two data sets (Section B.2.2), which helped to justify the use of the HTRAWL data. Additional research in this space could further validate the use of these data.

The model used in this assessment has been well-established, thoroughly reviewed, and successfully applied to support management decisions over many years. As a potential future research project, collaborative efforts between New South Wales and Queensland should continue and investigate alternative population models, such as a delay-difference biomass model to accommodate spatial variance in catch rates. Use of simpler population models, to compare to the spatial-length-sex-month model, requires less data, assumptions and cost to run. Comparative models help improve a weight-of-evidence approach for interpreting results and verifying reference points for managing levels of fishing effort.

Updating the length grading frequency data will provide a more accurate representation of the length frequency for the Queensland deep north waters - zone 6.

Length frequencies from Queensland waters have been measured sporadically. While there is length frequency data from the fishery independent beam trawl survey for the shallow waters - zone 4, updated collection of size composition monitoring data will improve the robustness of the model and provide a more fully-updated assessment.

Fisheries Queensland is committed to continuing to improve its stock assessment practice. Future eastern king prawn assessments will consider whether ensemble approaches are appropriate as methodology develops and as the assessment model is reviewed and updated.

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A Project Team

Project teams form an important part of the stock assessment process by providing guidance from experts from various disciplines relevant to the stock assessment. This approach ensures scientific validation and increases transparency. The following sections of this appendix briefly describe decisions and recommendations made by the project team for this assessment, both in and out of session of project team meetings.

The sections highlighted below indicate instances where recommendations for alternative methods or components differed from those used in previous assessments. Methods or components not explicitly mentioned indicate that the approaches remained consistent with those applied in past assessments.

A.1 Fishing power

The fishing power model indicated a significant catchability effect of BRDs and TEDs in shallow water depths. Consequently, an investigation was conducted focusing on the parameters GPS and BRDs and TEDs using data up to 1999. This approach was taken because, by 2002, the majority of vessels had adopted GPS, BRDs, and TEDs, potentially reducing the contrast in the dataset when using the full time series. After careful consideration, the project team opted to retain the methodology from previous assessments and chose not to incorporate the new catchability estimates for GPS and BRD TEDs.

The latest core methodology developed in the prawns assessments (Lovett et al. 2023) was adopted for estimating historical fishing power, replacing the previous approach of linear interpolation backwards from 1988. As part of this process, the project team needed to determine the gear settings used in 1969. Input from the industry representative, who consulted fishers, was invaluable in accurately defining these values.

It was recommended that line trawling be included as a factor in the estimation of fishing power.

The uptake of line trawling before 2002 was modelled on GPS uptake. This meant that between 1995 and the introduction of VMS in 2002, the uptake of line trawling remained constant, aligning with the VMS uptake observed in 2002. This suggested that line trawling became truly effective from 1995 onwards. Prior to 1995, while fishers may have attempted line trawling, its effectiveness was likely limited due to the constraints of early GPS systems, which provided only three positional fixes per night. The graph, which shows a decline to zero before 1995, effectively reflected this reduced efficiency during the earlier period (Figure B.28 in Appendix B.3.2).

A.2 Catch rates

The project team noted that a quota for whiting catch was introduced in New South Wales in 2019 (New South Wales Department of Primary Industries and Regional Development, New South Wales 2022). School whiting (*Sillago robusta* and *S. flindersi*) are commonly caught as bycatch in the New South Wales eastern king prawn fishery. In the previous assessments, to account for this, school whiting catch was incorporated into the catch rate model as a variate, represented as (log transformed school whiting catch + 0.001 kg).

Several models were tested to evaluate whether the introduction of the whiting quota had an impact on catch rates and to determine if adjustments to the catch rate model were necessary. The models tested included:

$$\text{logwt} = \text{zone} * \text{fishyear} * \text{fishmonth} + \text{zone} : \text{logdays} + \log(\text{whiting} + 0.001) + 1|\text{ACN} \quad (\text{A.1})$$

$$\text{logwt} = \text{zone} * \text{fishyear} * \text{fishmonth} + \text{zone} : \text{logdays} + \text{zone} : \text{logp} + 1|\text{ACN} \quad (\text{A.2})$$

$$\text{logwt} = \text{zone} * \text{fishyear} * \text{fishmonth} + \text{zone} : \text{logdays} + \text{zone} : \text{quotayear} : \text{logp} + 1|\text{ACN} \quad (\text{A.3})$$

where the LMM type and variables were:

- *logwt*: log transformed monthly catch per fishing operation of eastern king prawn (log kg)
- *fishyear*: fishing year 1988 to 2024 (factor)
- *fishmonth*: fishing month (factor)
- *zone*: spatial logbook zone fished by the relevant fleet, (north, central or south) (factor)
- *logdays*: log transformed days fished (variate)
- *log(whiting + 0.001)*: log transformed whiting catch in kgs (variate)
- *logp*: log transformed p where $p = \frac{\text{whiting kgs}}{\text{eastern king prawn kgs} + \text{whiting kgs}}$ (variate)
- *quotayear*: binary variable representing quota year, (binary variate, 1 = quota year on or after May 2019 or 0 = non quota year before May 2019)

The parameter values associated with the whiting component in equations A.1 to A.3 were compared to assess their differences.

Parameter estimates in equation A.1: $\text{logwh} = -0.003170576$

Parameter estimates in equation A.2: $\text{zone1.logp} = -0.05881728$, $\text{zone2.logp} = -0.02497820$, $\text{zone3.logp} = -0.04160454$

Parameter estimates in equation A.3: $\text{zone1.quotayear0.logp} = -0.05734511$, $\text{zone2.quotayear0.logp} = -0.02515589$, $\text{zone3.quotayear0.logp} = -0.04306244$, $\text{zone1.quotayear1.logp} = -0.07584978$, $\text{zone2.quotayear1.logp} = -0.02289478$, $\text{zone3.quotayear1.logp} = -0.02662735$

The parameter estimates were minimal, suggesting a negligible impact on the model. Consequently, no modifications to the standardised catch rate model were considered necessary.

A.3 Modelling

The project team recommended to use the well established and reviewed model from the previous assessment. As a potential future research project, collaborative efforts between New South Wales and Queensland could investigate alternative modelling approaches.

B Model inputs

B.1 Catch

Monthly catch from 1958–2024 were reconstructed from: (Table 2.1):

- New South Wales monthly port landings data from 1967–1979.
- New South Wales annual landings research data from 1974–1984.
- New South Wales monthly commercial logbooks from 1984–2024.
- Queensland Fish Board annual records from 1958–1981.
- Queensland daily commercial logbooks 1988–2024.

New South Wales commercial catch from 1985–2024 were from monthly commercial Ocean Prawn Trawl logbook records for eastern king prawn (species ID 701915). Each data record represented a monthly catch return for each endorsement holder (FL number) and vessel (LFB number). If an endorsement holder managed more than one vessel, then separate monthly catch returns were reported for each vessel. Only catch relating to offshore fishing were analysed.

New South Wales missing records on total annual eastern king prawn catch between 1958–1974 were estimated from log-linear regression using the annual landings research data from 1974–1984. The prawn catch records from 1958–1978 aggregated species and zones. The proportion comprising eastern king prawn was separated based on information presented in Annual New South Wales Fisheries Reports with a base value of 20% given for the years from 1900–1957, and 42% observed in 1979. Hence, eastern king prawn was separated assuming a 1% annual increase starting from 21% in 1958 through to 41% in 1978. All New South Wales regional eastern king prawn harvests were identifiable from 1979. Regional harvests from 1958–1984 were disaggregated assuming an historical split of 28% for south zone, 41% for central zone and 31% for north zone based on the average for these zones between 1985 and 1989 from logbooks. Monthly catch patterns from 1958–1984 were modelled using a quasi-Poisson generalised linear model (GLM) with a log link function, based on monthly port landings data collected from Evans Head and Clarence River. Model terms for the GLM were financial year by financial month and port.

Queensland commercial catch from 1989–2024 were from daily trawl logbook records south of 22° south and east of 152.5° east and inclusive between 21° and 22° south to include the Swain Reefs. In the logbooks eastern king prawn was defined by the CAAB species codes from Table 4.1 of O'Neill and Leigh (2006): 28711908, 28711047, 28711052, 28711910, 99280006, 28711048, 28711000 (Prawn - red spot and blue leg king, Prawn - blue leg king, Prawn - eastern king, Prawn-king, Prawn - mixed bait, Prawn - red spot king, Prawn-unspecified). Moreton Bay grids W37 and W38 were excluded. Only catch relating to offshore fishing and fully recruited eastern king prawns were considered. This was due to the multi-species nature of prawn trawling in Moreton Bay and the non-specific recording of prawn catches. Also, eastern king prawns in Moreton Bay are usually all pre-recruits to the offshore fishery (i.e. mostly less than 25 mm carapace length). The analysis here only related to eastern king prawns first recruiting to the offshore fishery (i.e. prawns greater than about 26 mm carapace length); this was consistent with the eastern-king prawn stock assessments of O'Neill et al. (2005), O'Neill and Leigh (2006), O'Neill et al. (2014), Courtney et al. (2014), and Helidoniotis et al. (2020).

Queensland Fish Board prawn catch from 1958–1981 provided an annual spatial breakdown by fishing port from the port of Bundaberg south to the Queensland/ New South Wales state border. Missing records on total annual eastern king prawn harvest between 1981 and 1988 were estimated from log-linear regression using 1958–1981 Fish Board data and 1989–2010 (logbook) annual estimates (adjusted R^2 equal 0.86). Because the Fish Board data included the Moreton Bay area, Moreton Bay prawn catch for 1958–1988 was estimated from logbook 1989–1994 data for grids W37 and W38 for all prawn species using a poisson model from the GitHub RROCK package. This was then subtracted from the Fishboard data.

In the shallow waters, it was assumed that eastern king prawn comprised 11% of the catch for the years from 1900–1957, and 80% observed in 1975. Hence, eastern king prawn was separated assuming a linear increase starting from 11% in 1958 through to 80% in 1975. The estimated catch 1958–1988 was then adjusted down by a multiplier of 0.8 (Braccini et al. 2012a; Courtney et al. 2014). Queensland eastern king prawn landings from 1958–1988 were expanded monthly based on Poisson generalized linear modelling of harvest patterns using 1989–1994 data. A log link model was used on catch weight, and dispersion was estimated; the model terms were zone by month and zone by fishing year (adjusted R^2 equals 0.64). Normal random uncertainty error of 0.26 (standard deviation implied from GLM analysis) was propagated monthly from 1958–1988.

Figure B.1 shows the seasonal change in eastern king prawn catch by zone.

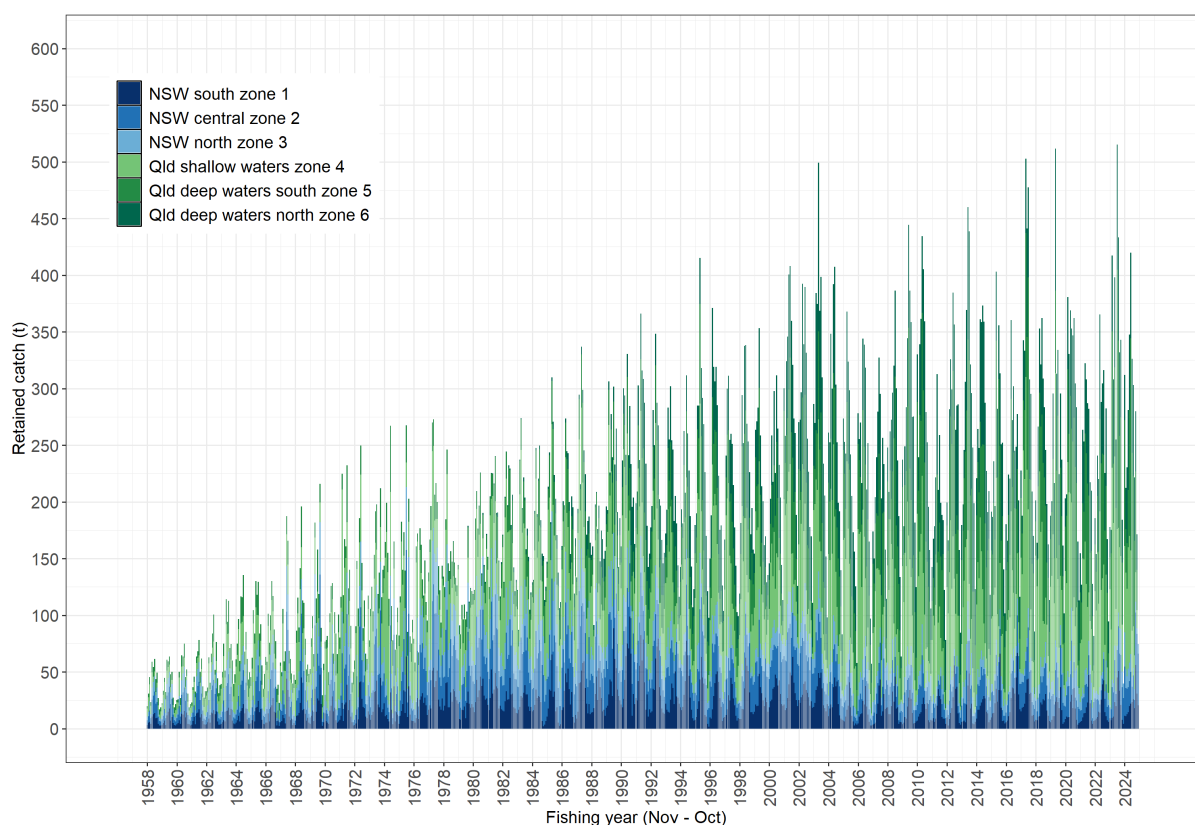


Figure B.1: Monthly eastern king prawn harvests from New South Wales (NSW) and Queensland (Qld) waters.

B.2 Catch rates

B.2.1 Data New South Wales

The following was applied to the monthly logbook data:

- Only data from ocean zones 1 through 5 were included, with zones 4 and 5 assigned to zone 3.
- Records were aggregated to Fishing Licence (FL), Licenced Fishing Boat identity (LFB, i.e. vessel), Period (YYYYMM), and NSW ocean zone, and matched against total whiting catch that was also recorded by that FL x LFB x Period x NewAreaID combination.
- For the entire time series, only records with Ocean Prawn Trawl effort were included.
- For the period July 1984- June 1997, only logbook entries where a single LFB was used in a month were included. Catch was not directly mapped to effort of different methods, only records with a single method of fishing in a month were included.
- For the period July 1997 - June 2009 days of effort within a fishery was explicitly recorded/reported against catch, on a monthly basis.
- For the period July 2009 onwards daily reporting was mapped as monthly reports to align with monthly 1997-2009 logbooks.
- The data were reduced to vessels who fished in more than one year.
- The data were reduced to vessels who fished in more than twenty days.

Note on effort (days): In 2009 there were changes in New South Wales fisher logbook reporting from monthly to daily reporting and this might affect the amount of reported effort (Helidoniotis and Taylor 2023). The monthly logbook ComCatch database consisted of monthly reporting (all records pre-financial year (FY) 2010) and a 'mapped ComCatch' dataset (post FY2010) based on daily reporting. The 'mapped-ComCatch' dataset was derived from daily FishOnline records that were re-aggregated into monthly data to form the 'mapped-ComCatch' dataset. Figure 3 of Helidoniotis and Taylor (2023) showed that the number of days of effort per month plotted as a histogram indicated a greater frequency of relatively high effort being reported pre-FY2010 compared to the mapped ComCatch (post-FY2010). Thus for the model the number of effort days were normalised for pre and post 2009 and the normalised days were used in the standardisation model (Lovett et al. 2026).

B.2.2 Data Queensland

To proceed with catch rate analyses, the logbook data required filtering to produce one record per boat-day, with each boat-day including just one location (the 6' reporting grid in which most of the catch by volume was caught). To produce reliable indices of abundance that avoid confounding influences on catch rates (e.g., fisher experience, vessel specific fishing power, or shifts in fishing behaviour like targeting), the fishers and grid cells that did not substantially contribute to the fishery, or that were not representative of the fishery, were removed prior to catch rate analysis per the following filters (O'Neill et al. 2005; O'Neill and Leigh 2006; Courtney et al. 2014; O'Neill et al. 2014; Helidoniotis et al. 2020):

- The data were reduced to only fishing records that used the otter trawl fishing method.
- Eastern king prawn was defined by the CAAB species codes from Table 4.1 of O'Neill and Leigh (2006): 28711908, 28711047, 28711052, 28711910, 99280006, 28711048, 28711000 (Prawn - red spot and blue leg king, Prawn - blue leg king, Prawn - eastern king, Prawn-king, Prawn - mixed bait, Prawn - red spot king, Prawn-unspecified).

- Saucer scallop caught on the same boat day with eastern king prawn was defined by the CAAB species codes 23270000, 23270001, 23270003, 23270005 (Scallop-mud, Scallop-queen, Scallop-saucer, Scallop-unspecified).
- Only daily records which were identified by the same operation date and end date of fishing.
 - All catch for the day was assigned to the grid with the greatest catch.
 - ‘Hours fished’ for the day was calculated as the maximum hours of each record for logbook data (Lovett et al. 2023).
- The catch rate data were reduced to the grids.
 - Eastern king prawns deep: u28, u29, v28, v30, v31, w26, w27, w28, x35, x36, x32, x33, x34, x37.
 - Eastern king prawns shallow: w33, w34, w35, w36.

More than 90% of the Queensland eastern king prawn fishery logbook data records, the targeted catch was clearly eastern king prawns as no other prawn species were reported in the catch. In this respect, the Queensland eastern king prawn fishery could almost be described as monospecific, which contrasts strongly with the multispecies nature of the New South Wales eastern king prawn fishery. Only a very minor component of Queensland eastern king prawn logbook records were associated with uncertainty in regard to whether the target species was eastern king prawn or scallop.

The definition from Courtney et al. (2014) was applied to the daily logbook data: The daily catch of each species group was converted to dollars by multiplying the catch weight by the price (i.e., \$16 per kg for eastern king prawn and \$20 per kg meat weight for scallops). Targeted effort for a given boat-day was then determined based on the species with the highest catch value. The logbooks were filtered to include only records targeting eastern king prawn, which accounted for 95.7% of the total logbook entries.

HTRAWL data from 1969-1987 was the historic catch and effort information from voluntary logbook catch data collected between 1968 and 1987 prior to implementation of the compulsory logbook system in 1988. HTRAWL data were of varying quality and quantity and initially described in Section 8.3.7 of O'Neill et al. (2005). The HTRAWL data required filtering to produce one record per boat-day, with each boat-day including just one location (the 6' reporting grid in which most of the catch by volume was caught). The following filters were applied to the HTRAWL data (O'Neill et al. 2005; O'Neill and Leigh 2006; Courtney et al. 2014; O'Neill et al. 2014; Helidoniotis et al. 2020):

- Only daily records which were identified by the same operation date and end date of fishing.
 - All catch for the day was assigned to the grid with the greatest catch.
 - ‘Hours fished’ for the day was calculated as the sum of hours of each record for HTRAWL data (Lovett et al. 2023) .

The filtered HTRAWL catch rate data were appended onto the filtered eastern king prawn logbook data. The following filters were then applied:

- The data were reduced to boats who fished in more than one year.
- The data were reduced to boats who fished in more than thirty days (in the HTRAWL data lower numbers of fishing records exhibited too much variability, (Courtney et al. 2014)).

Limited data resulted in a time gap between 1981 and 1983.

Comparisons of the nominal catch rates of fishers present in both HTRAWL and compulsory logbook data sets showed that reporting was relatively consistent between the two data sets. After applying data filters, 240 unique ACNs reported catch of eastern king prawns in the HTRAWL data set, 485 in the compulsory logbook data set, and 107 were common to both data sets. This implied a degree of continuity between the two data sets, which helped to justify the use of the HTRAWL data.

B.2.3 Diagnostics

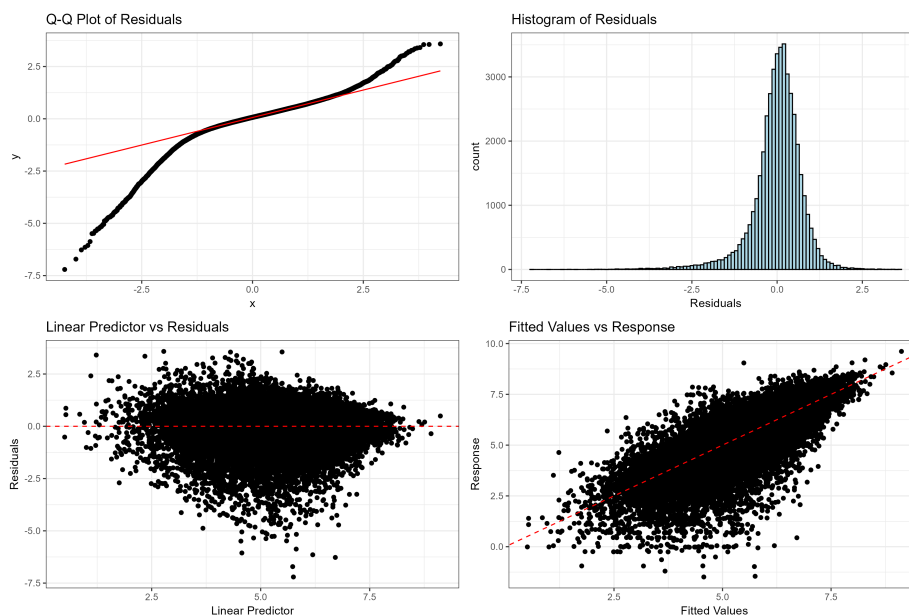


Figure B.2: Analysis of residuals for the New South Wales commercial catch rate model.

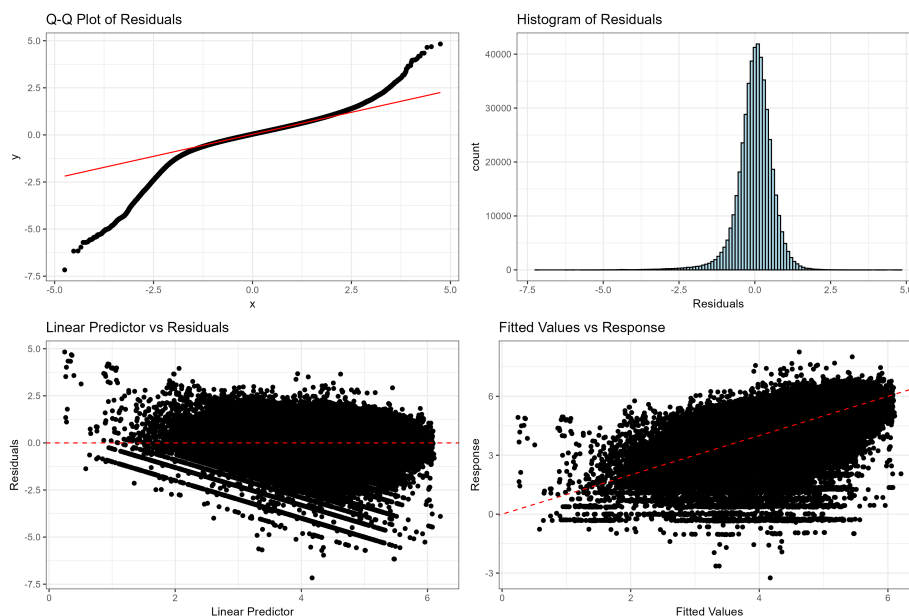


Figure B.3: Analysis of residuals for the Queensland commercial catch rate model.

B.2.4 Lunar

In Figure B.4 lunar value of < 0.15 represents the "New moon", lunar value of > 0.85 represents the "Full moon".

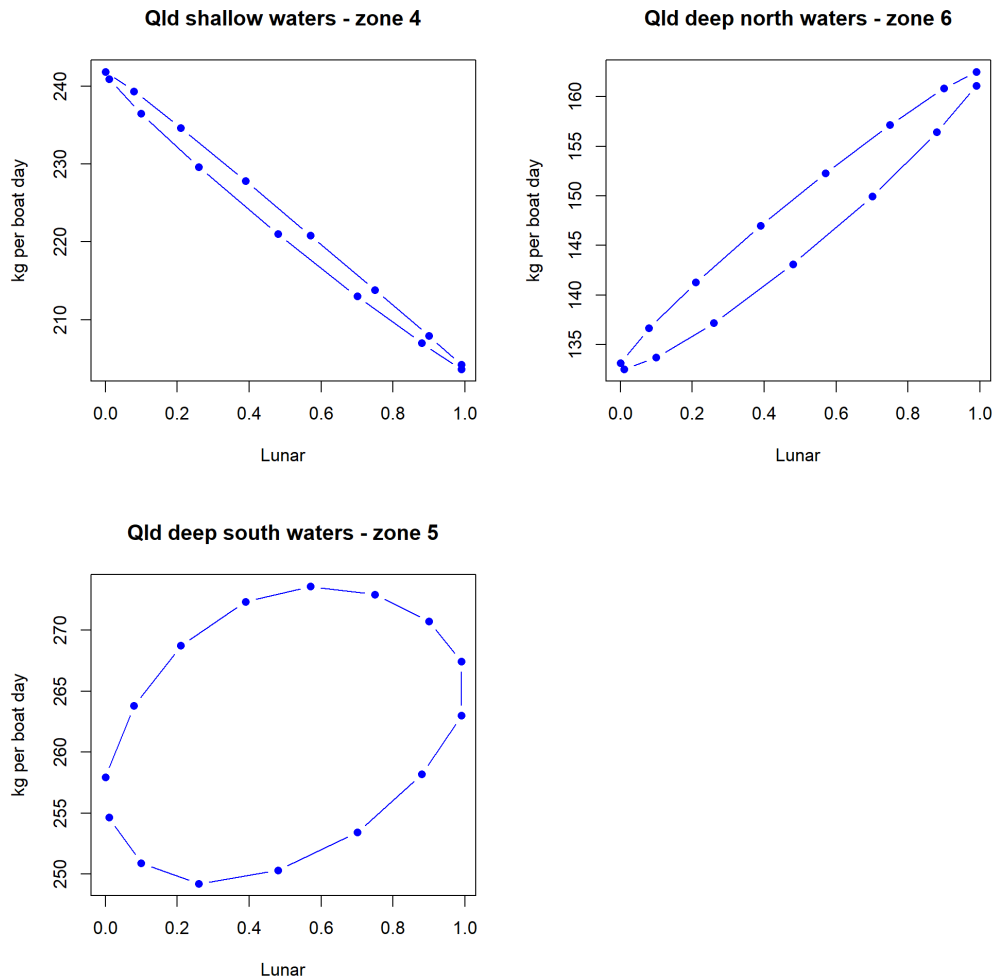


Figure B.4: Queensland catch rate model effect plot - lunar.

B.2.5 Influence

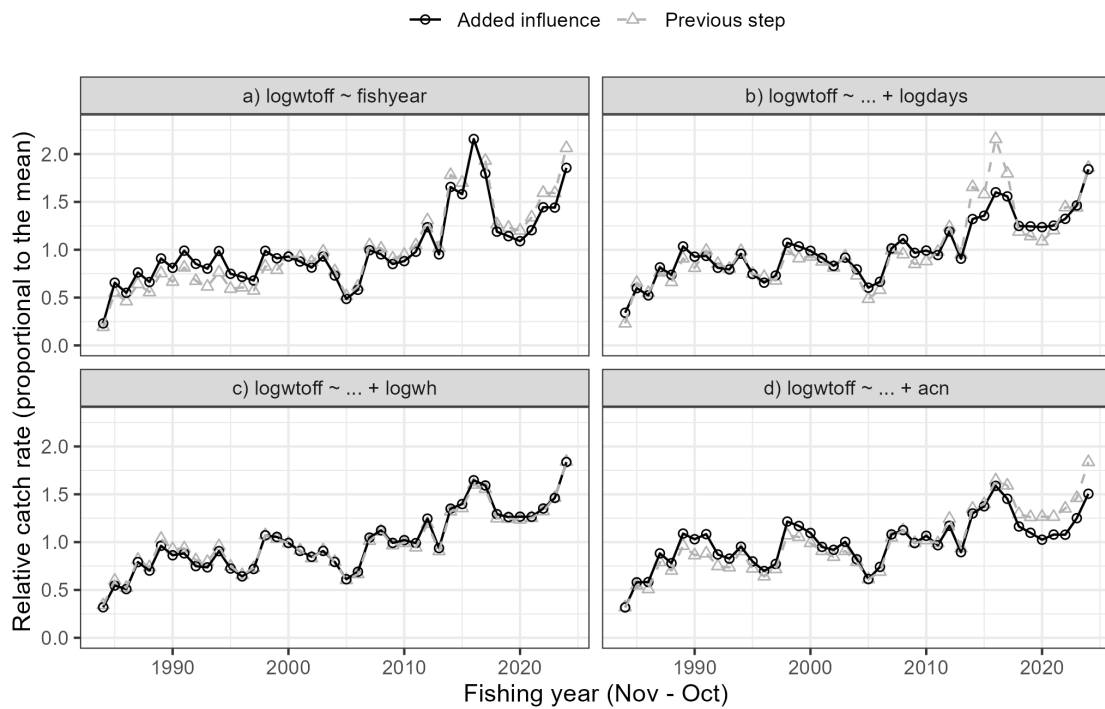


Figure B.5: Influence plots for New South Wales south waters - zone 1.

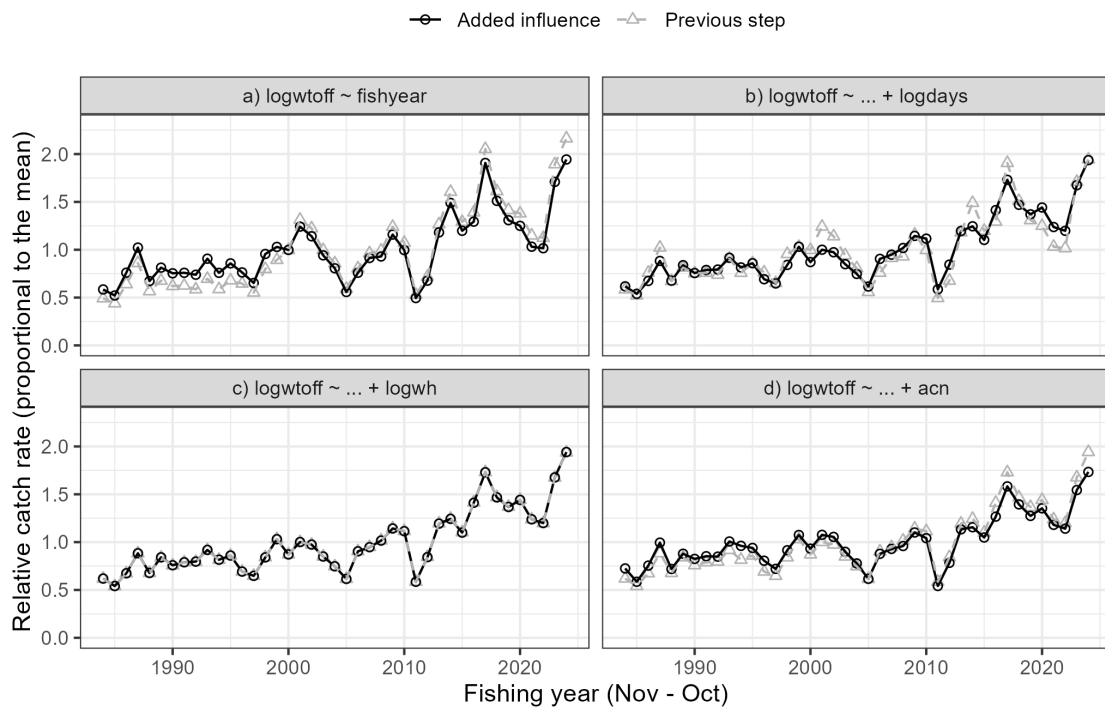


Figure B.6: Influence plots for New South Wales central waters - zone 2.

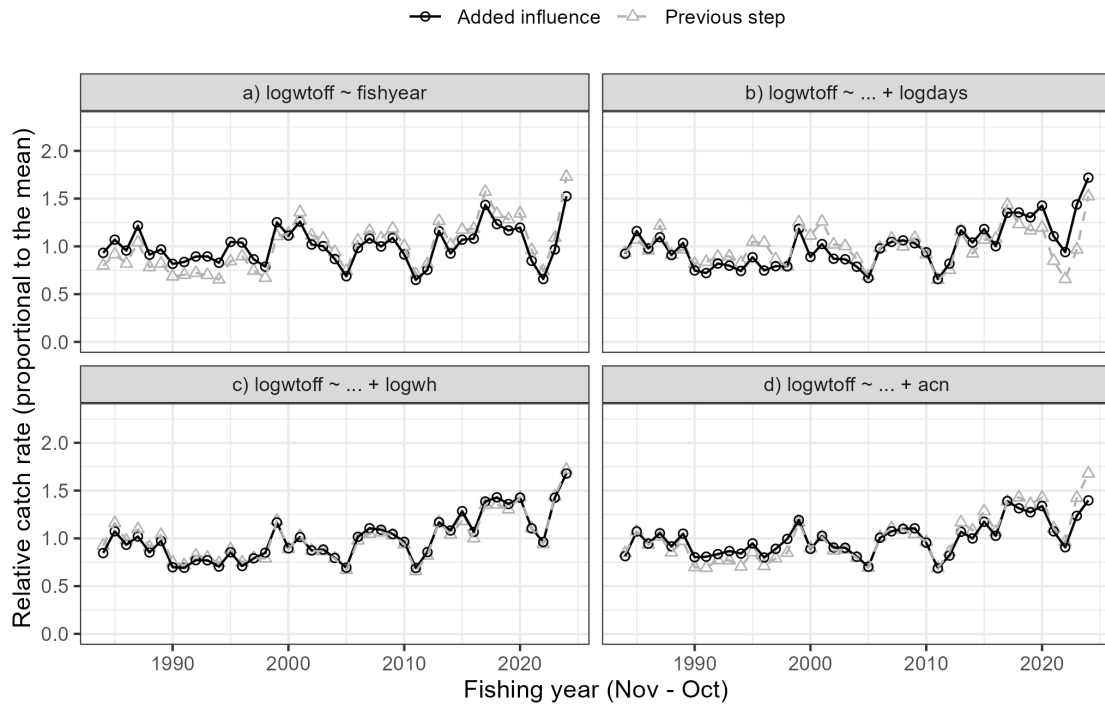


Figure B.7: Influence plots for New South Wales north waters - zone 3.

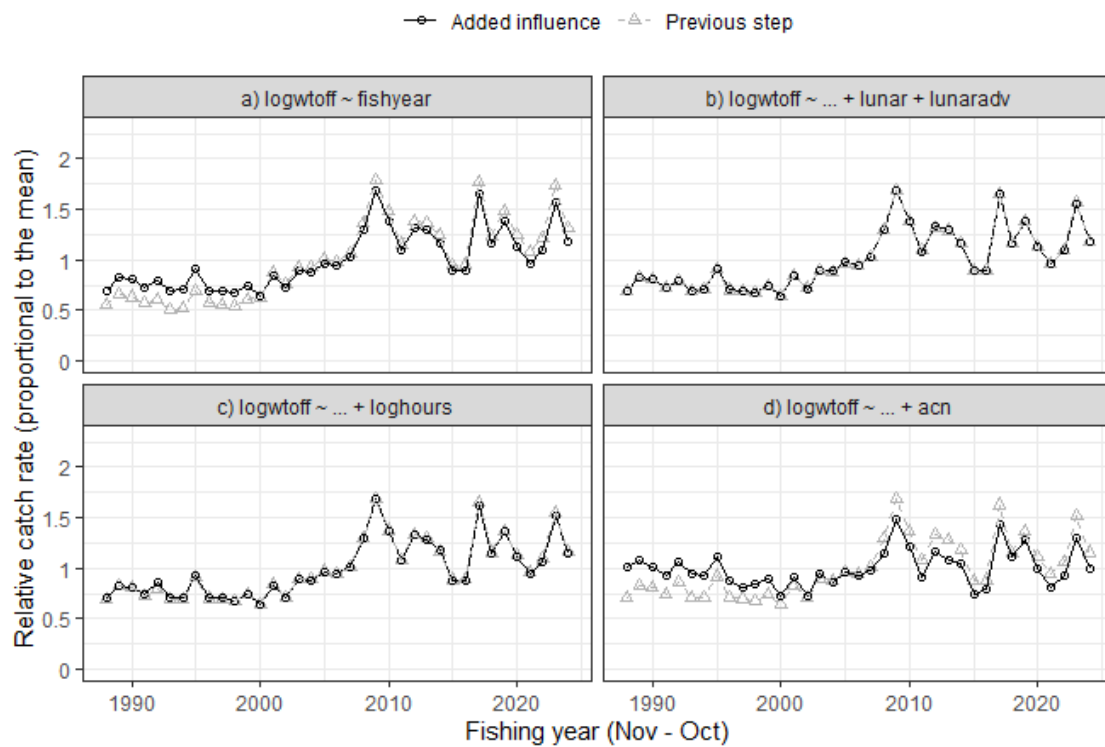


Figure B.8: Influence plots for Queensland shallow waters - zone 4.

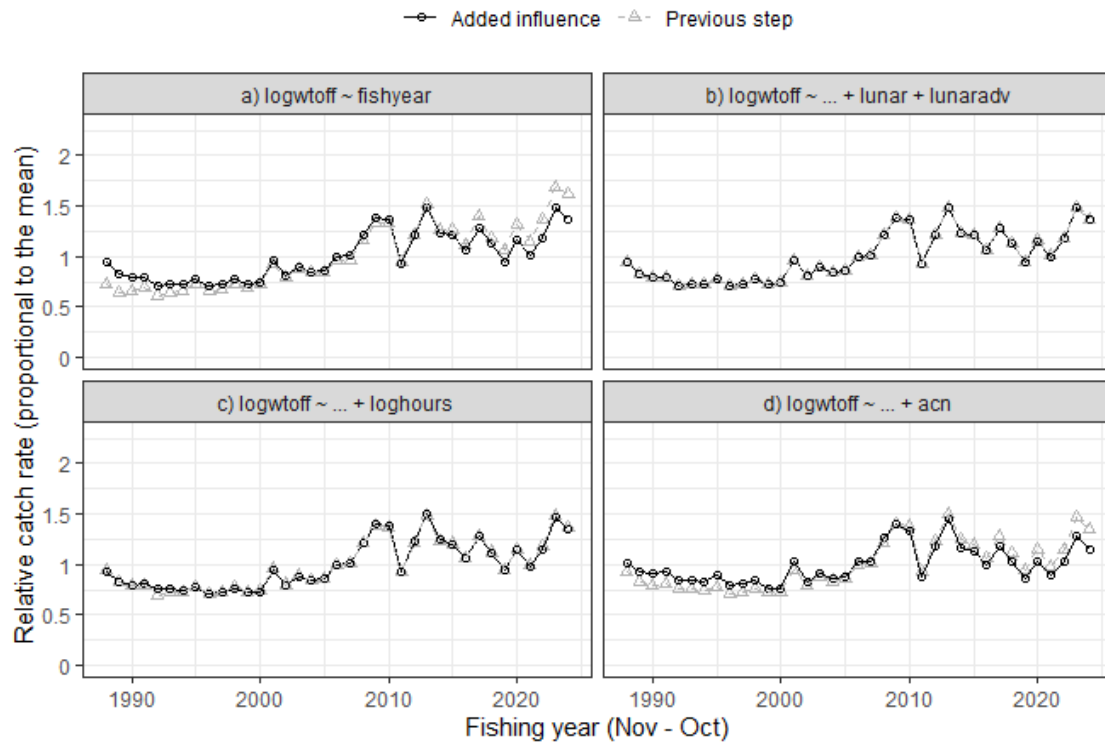


Figure B.9: Influence plots for Queensland deep south waters - zone 5.

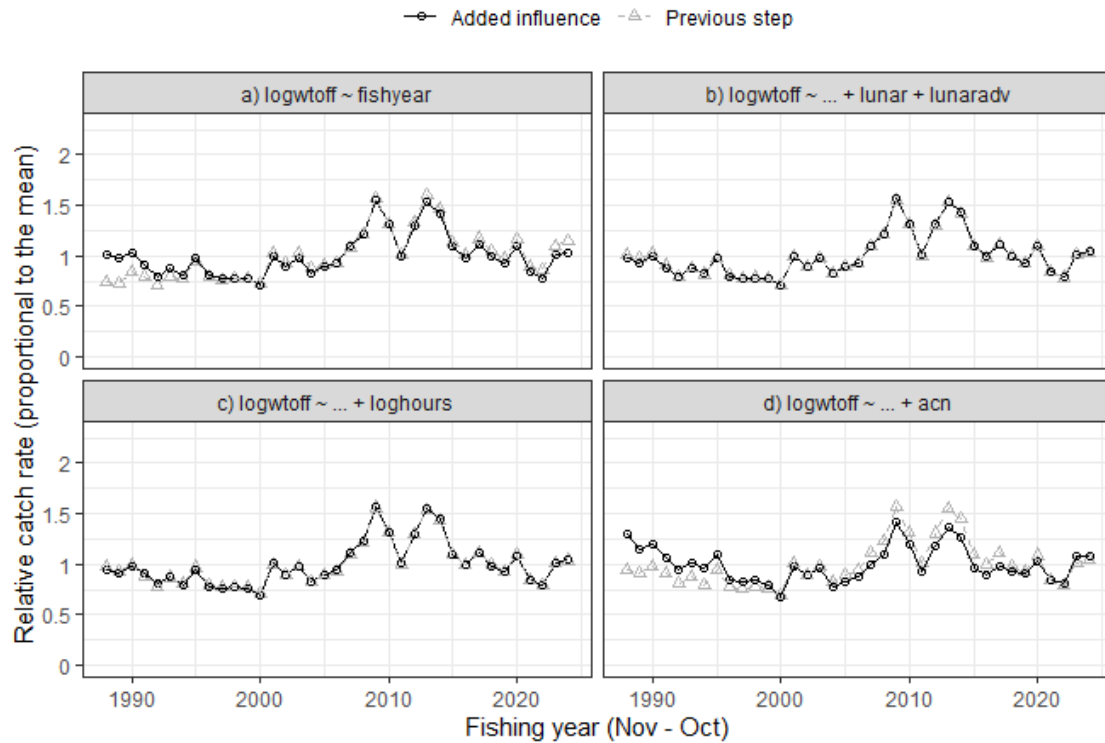


Figure B.10: Influence plots for Queensland deep north waters - zone 6.

B.2.6 Annual

The annual catch rates are presented in Figures B.11 - B.16. To ensure clarity and accurate interpretation, the catch rates are displayed separately for each zone, allowing the error bars to be appropriately represented and ensuring that each zone is visualised on its own scale.

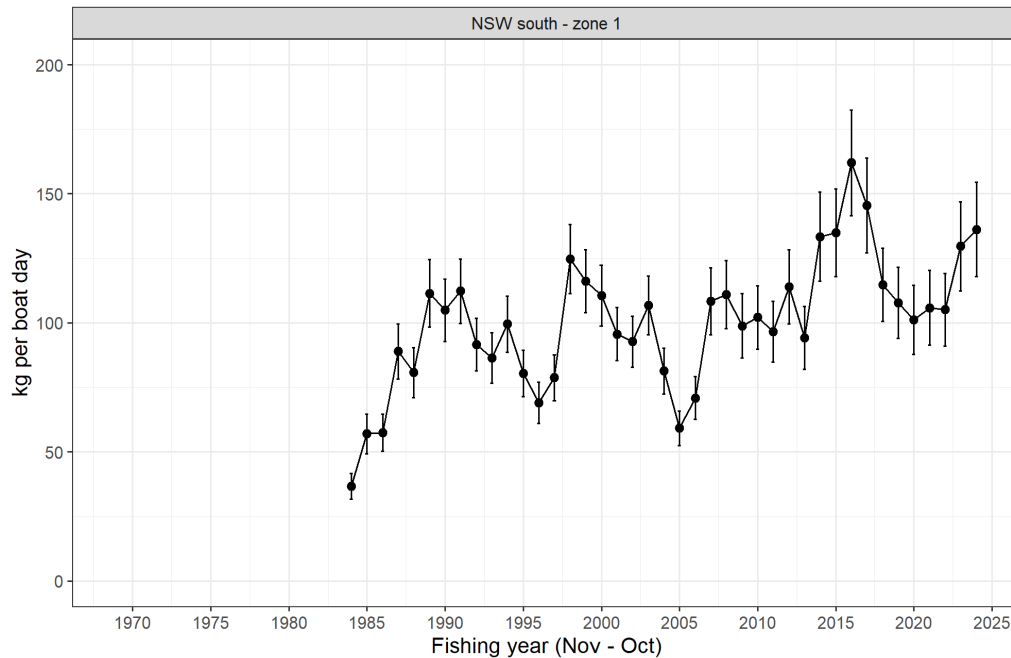


Figure B.11: Annual standardised catch rates for eastern king prawn for New South Wales south - zone 1. Error bars represent 95% confidence intervals.

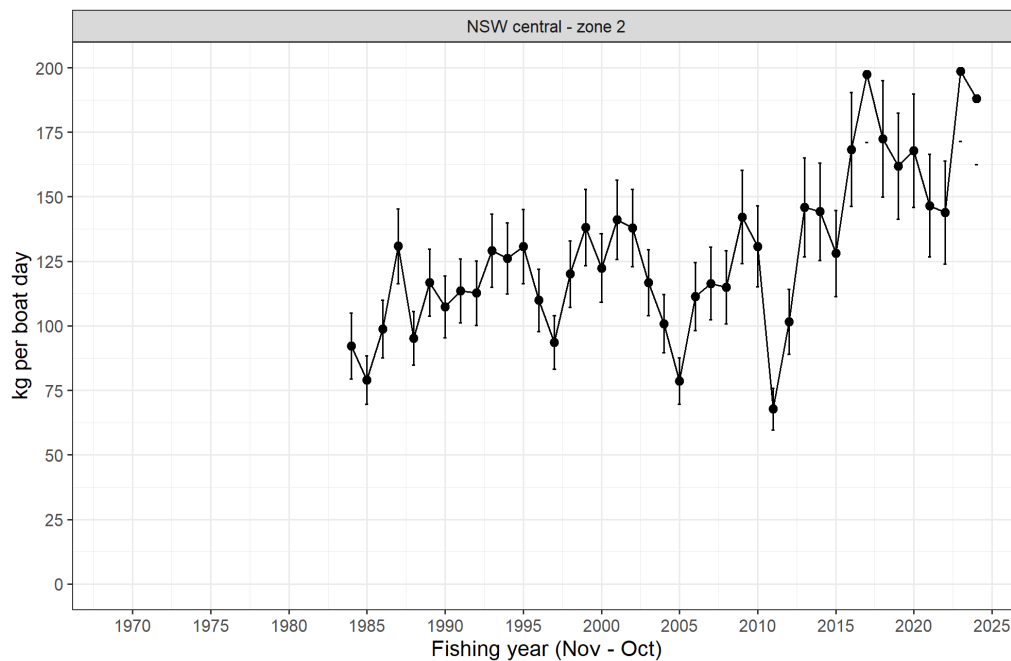


Figure B.12: Annual standardised catch rates for eastern king prawn for New South Wales central - zone 2. Error bars represent 95% confidence intervals.

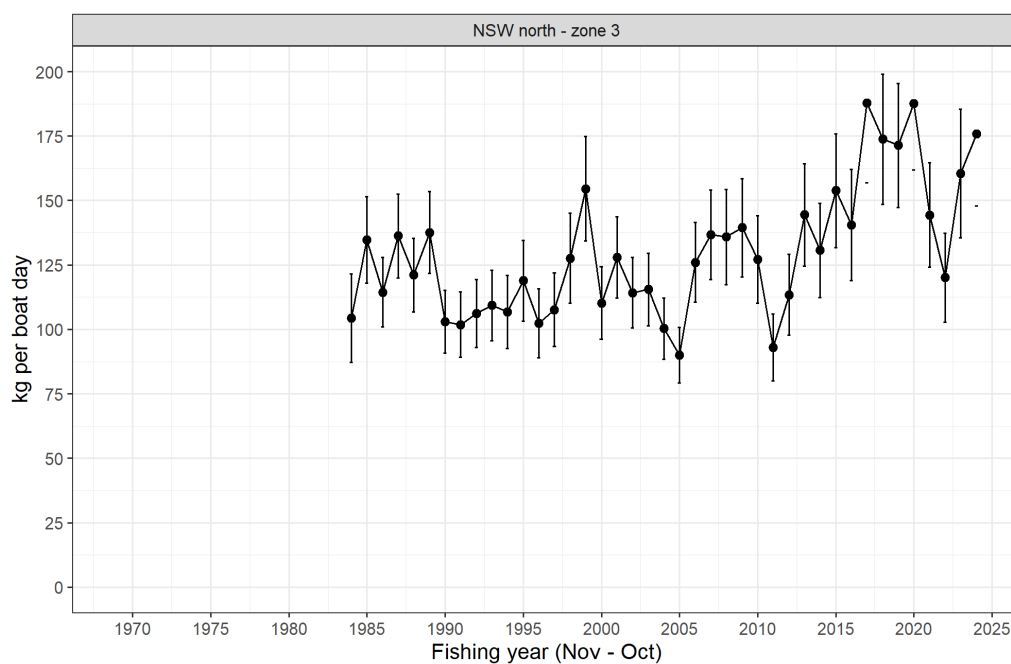


Figure B.13: Annual standardised catch rates for eastern king prawn for New South Wales north - zone 3. Error bars represent 95% confidence intervals.

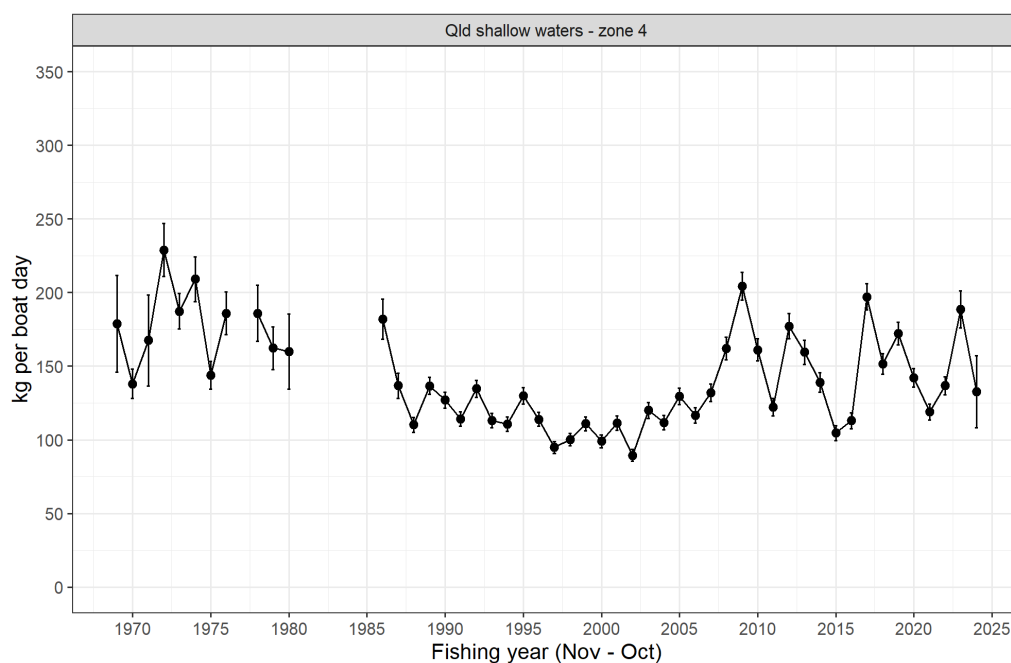


Figure B.14: Annual standardised catch rates for eastern king prawn for Queensland shallow waters - zone 4. Error bars represent 95% confidence intervals.

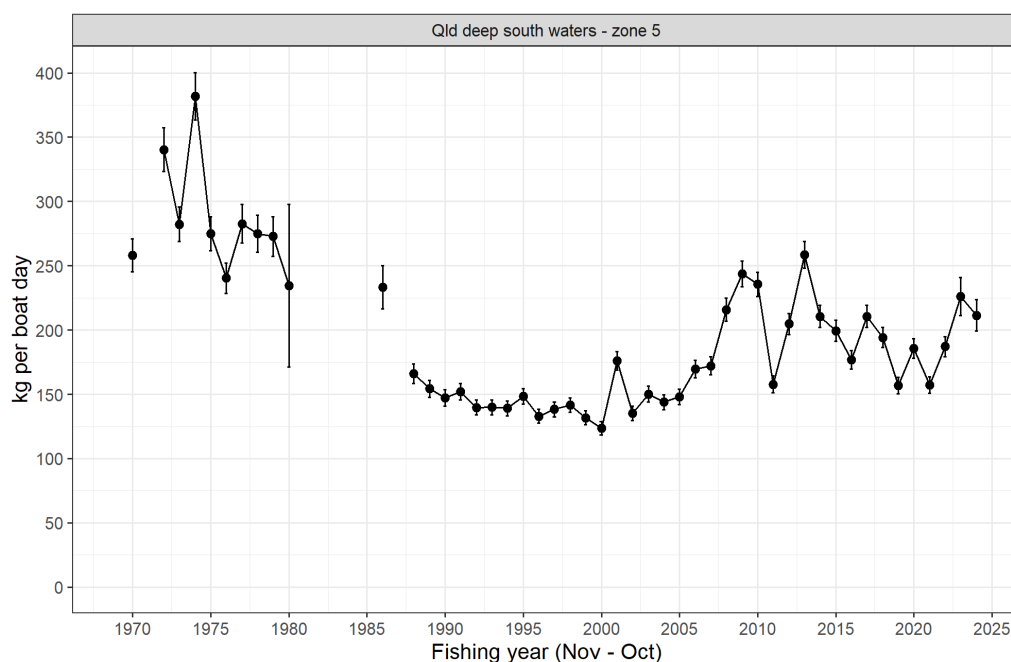


Figure B.15: Annual standardised catch rates for eastern king prawn for Queensland deep south waters - zone 5. Error bars represent 95% confidence intervals.

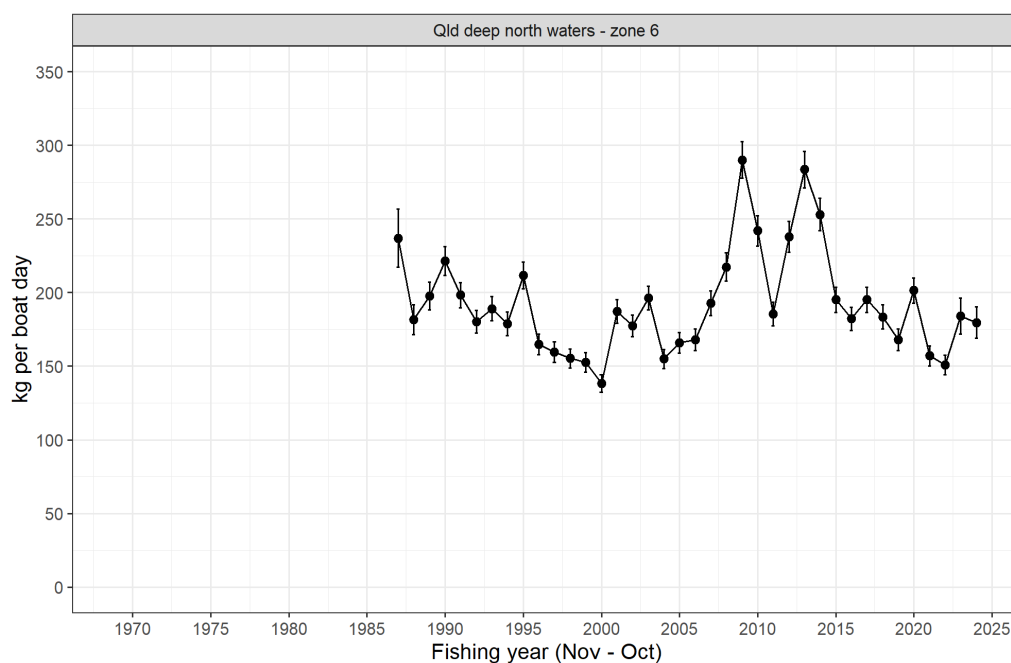


Figure B.16: Annual standardised catch rates for eastern king prawn for Queensland deep north waters - zone 6. Error bars represent 95% confidence intervals.

B.2.7 Survey

The model from Bessell-Browne et al. (2020) was used to standardise the abundance of pre-recruit eastern king prawn. The model included an interaction between year and area, with additive effects of start time group, depth category and lunar phase (Table 1 of Bessell-Browne et al. (2020)), where:

- Start time group was the start time of each sample grouped into four time blocks, including the three hour blocks following 17:00, 21:00, 00:00 and 03:00.
- Lunar phase was used as a categorical variable of either full, waxing, waning or new moon split equally between the 29 days of the lunar cycle.
- Depth was grouped into six categories of 10 m blocks, with each label representing the 10 m up to and including that depth.

The best fitting model for eastern king prawn was a generalised linear model with a negative binomial distribution (McCullagh and Nelder 1989).

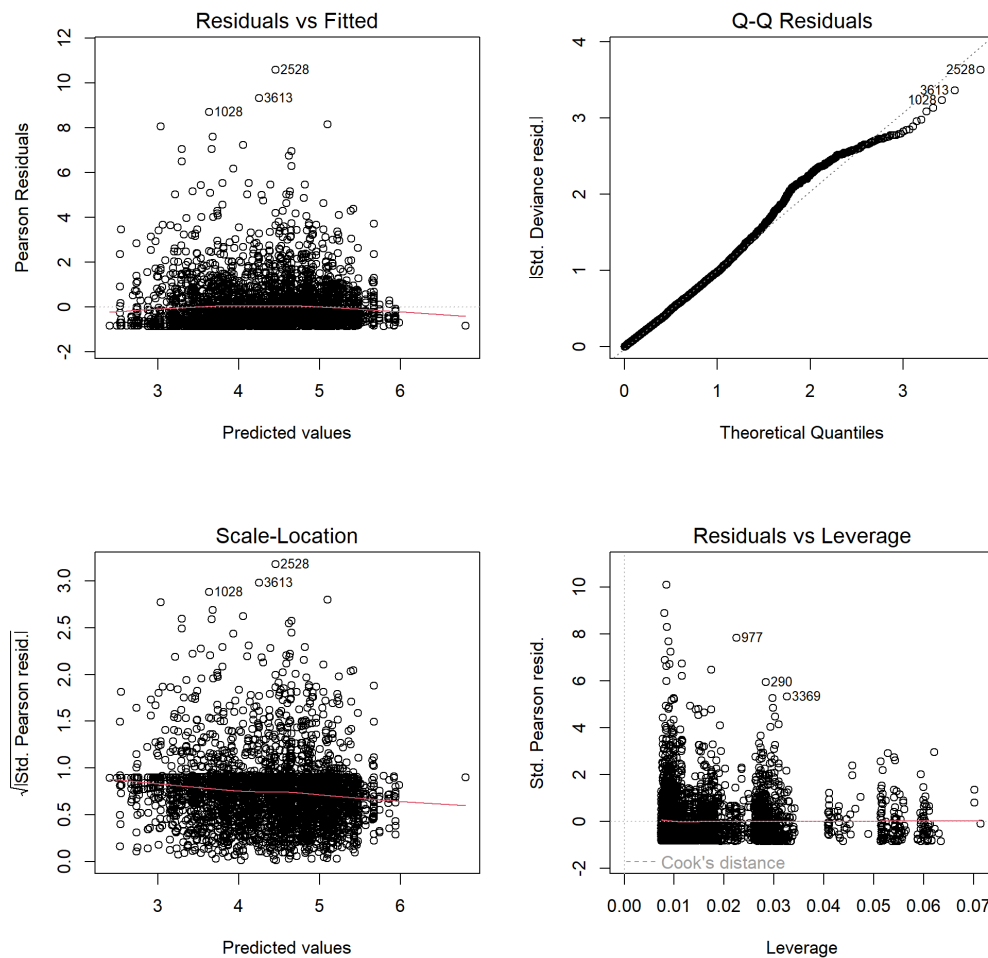


Figure B.17: Diagnostics for the survey standardisation.

Following the methods of Bessell-Browne et al. (2020), Model 1 in Table B.1 was used to standardise the survey data. The AIC of the model including the Month term (model 2 in Table B.1) is slightly lower than the AIC of the model excluding Month (model 1 in Table B.1). This suggests that Month has a relatively small impact on the model compared to other predictors like Year:Area or Depth category. Adding Month to the model increases complexity (adds 1 degree of freedom) for only a very small improvement in AIC.

Table B.1: Top model fits for eastern king prawn, including the model terms, number of parameters (n), Akaike Information Criteria (AIC) and delta AIC.

Number	Model	n	AIC	δ AIC
1	Year $\times$ Area + Depth + Lunar phase + Start time group	49	26 231	0
2	Year $\times$ Area + Depth + Lunar phase + Start time group + Month	50	26 228	-3
3	Year $\times$ Area + Depth + Lunar phase	46	26 250	19
4	Year $\times$ Area + Depth + Start time group	46	26 307	76
5	Year $\times$ Area + Lunar phase + Start time group	44	26 351	120
6	Year + Area + Depth + Lunar phase + Start time group	28	26 414	183

B.3 Fishing Power

B.3.1 Gear trends

Overall the logbook data 2007-2024 on otter-trawl vessel configurations, gears and technologies covered 237 vessel owner/ operators from July 2006-October 2024, which represented a rate of 72.6% of the total 326 operators. The logbook gear dataset included vessels that collectively accounted for 98.5% of the total catch of eastern king prawn between July 2006 and October 2024. A breakdown of the number of vessel owners in each year with recorded gear and technology logbook information is provided in Table B.2.

Table B.2: Breakdown of the number of vessel owners or skippers in each year with recorded gear and technology logbook information.

Fishing year (Nov - Oct)	Number of vessel owners
2006	92
2007	138
2008	136
2009	129
2010	142
2011	125
2012	124
2013	122
2014	117
2015	119
2016	122
2017	129
2018	135
2019	138
2020	140
2021	135
2022	128
2023	125
2024	117

The gear and technology trends are shown in Figures B.18 - B.26. Data for these trends were from Queensland gear surveys 1988-2004 and Queensland logbook gear data 2007-2024. (Note that the graphs have missing data for the years 2005 and 2006). The data for Figure B.27 were from New South Wales gear logbook data.

Engine power The average engine rated horsepower increased between 1988 and 2024 in both shallow and deep water (Figure B.18). Vessels fishing for eastern king prawns in deep waters (> 50 fm) had the most powerful rated engines of about 390 HP (290 Kw) by 2024.

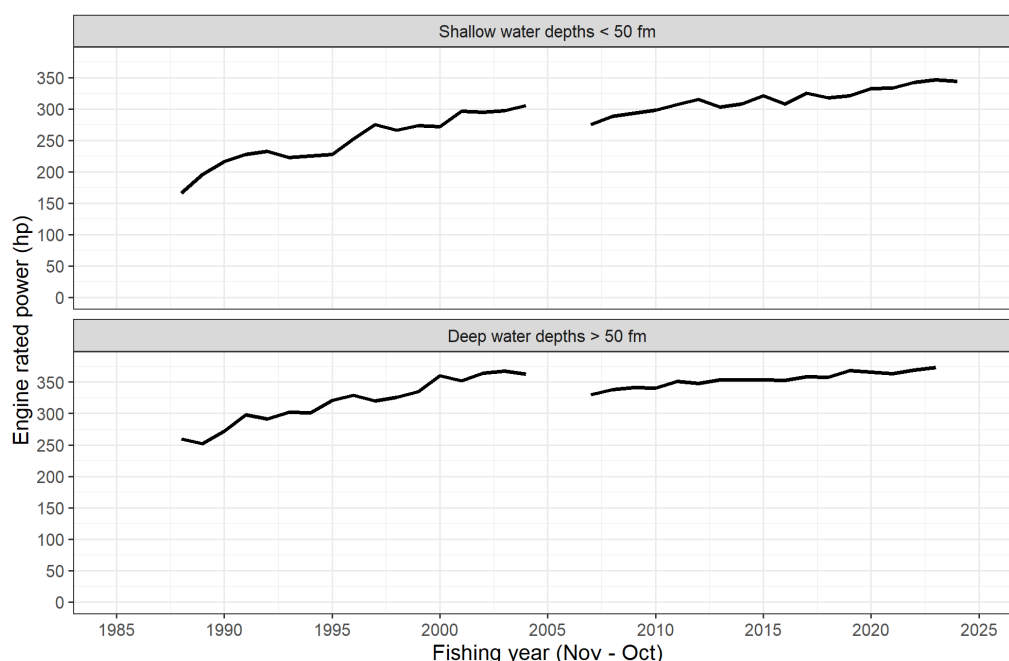


Figure B.18: The average engine rated power by fishing year and depth sector. The plots are weighted averages according to the number of days fished by each vessel in each fishing year and depth sector.

Net configurations: Ground gear types Since 2000, drop chains have become more popular when fishing for eastern king prawns in both shallow and deep water depths (Figure B.19 and Figure B.20).

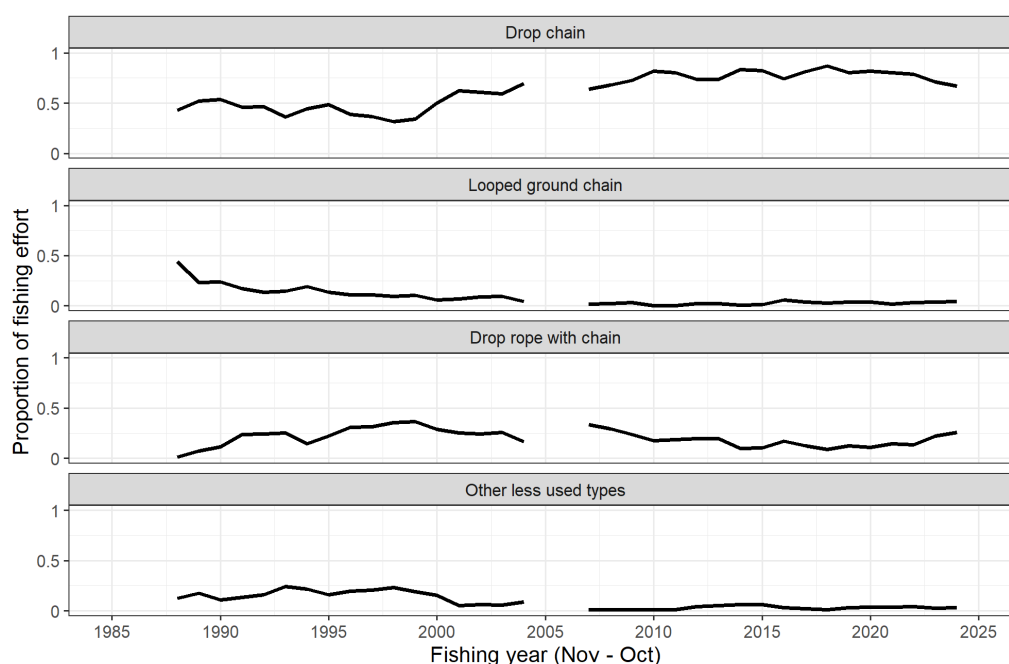


Figure B.19: The proportion of total annual fishing effort by vessels in each fishing year for shallow water depths using different ground gear.

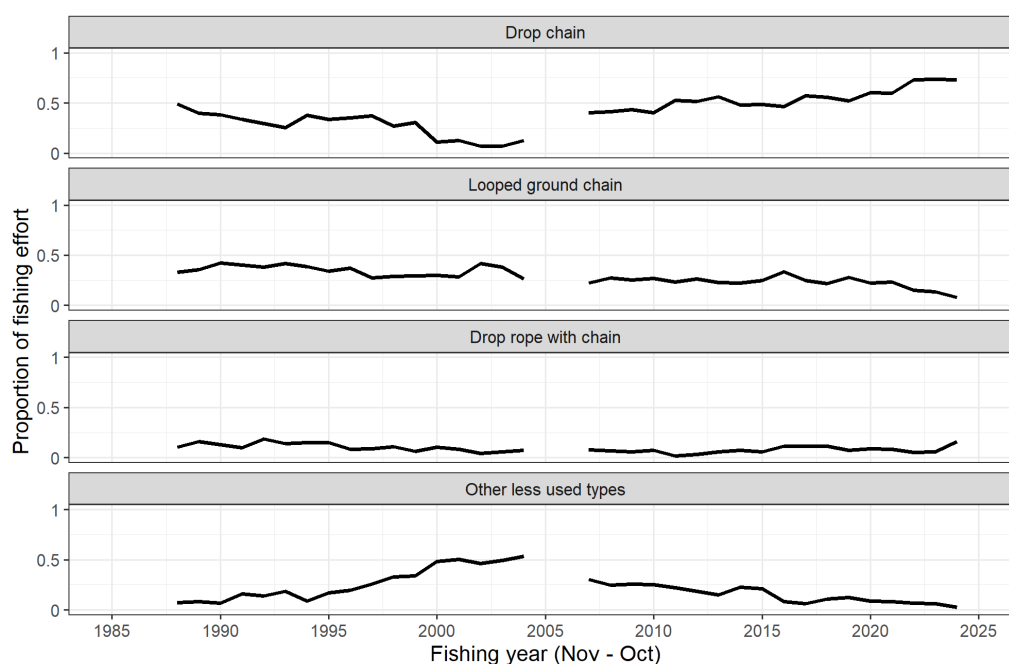


Figure B.20: The proportion of total annual fishing effort by vessels in each fishing year for deep water depths using different ground gear.

Net configurations: Otter boards In shallow water depths the decline in the use of flat boards has been replaced by the adoption of louvre boards (Figure B.21). Flat otter boards have been the most common board type used in deep water depth over the last 37 years (Figure B.22).

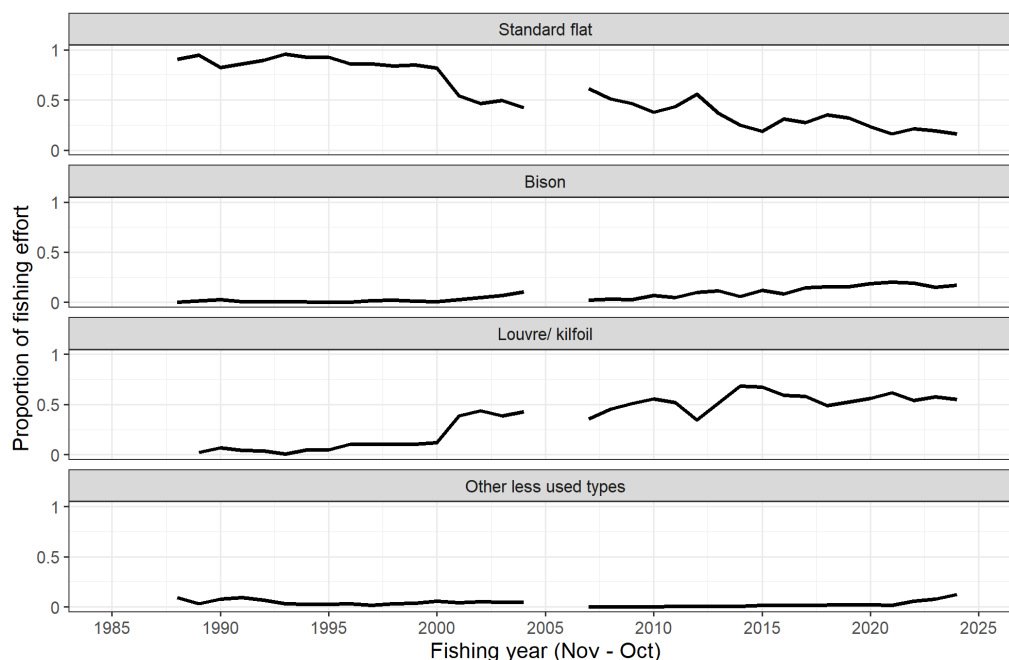


Figure B.21: The proportion of total annual fishing effort by vessels in each fishing year for shallow water depths using different otter boards.

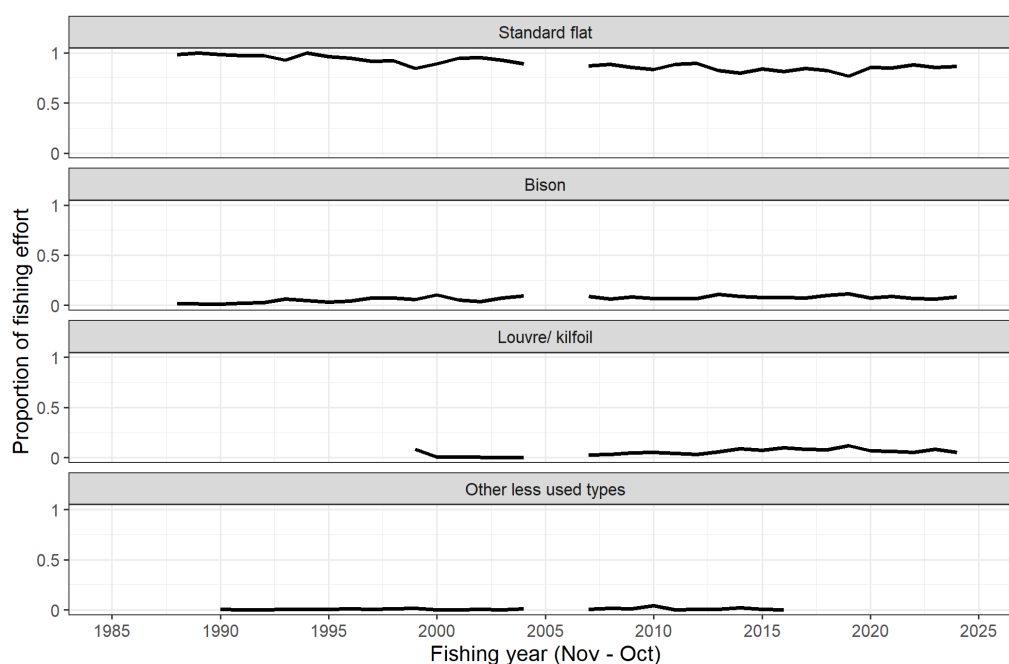


Figure B.22: The proportion of total annual fishing effort by vessels in each fishing year for deep water depths using different otter boards.

Net configurations: Nettype The configuration of trawl nets changed in 2000 for shallow water gear. From 2000 there was a trend for more vessels to fish with quad gear in the shallow water eastern king prawn sector (Figure B.23). In deep water fishing for eastern king prawns essentially all fishing effort remained with triple gear (Figure B.24).

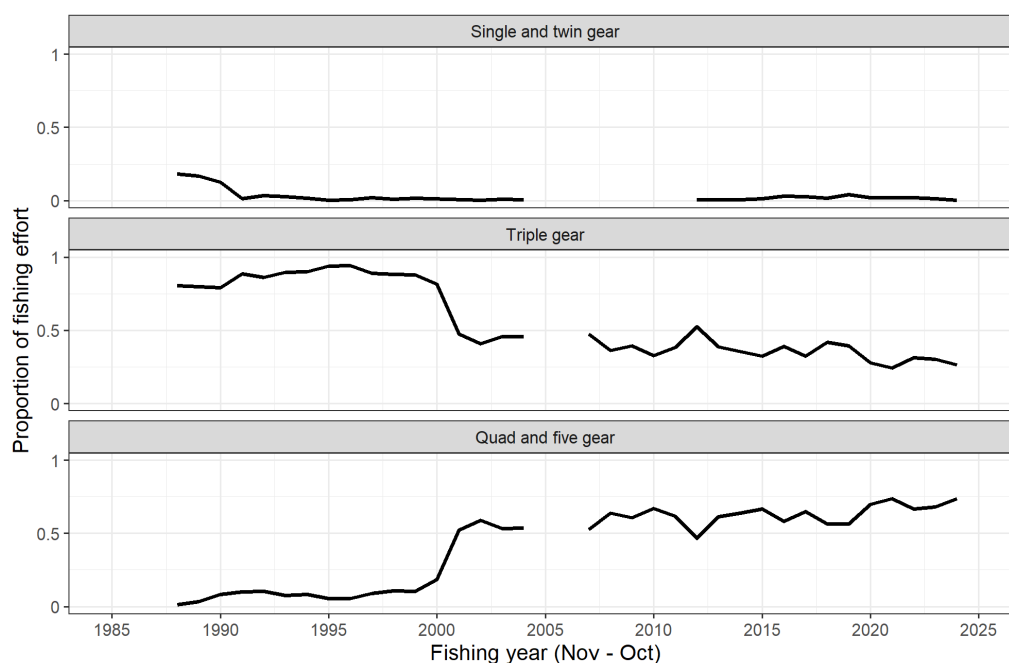


Figure B.23: The proportion of total annual fishing effort by vessels in each fishing year for shallow water depths using different net types.

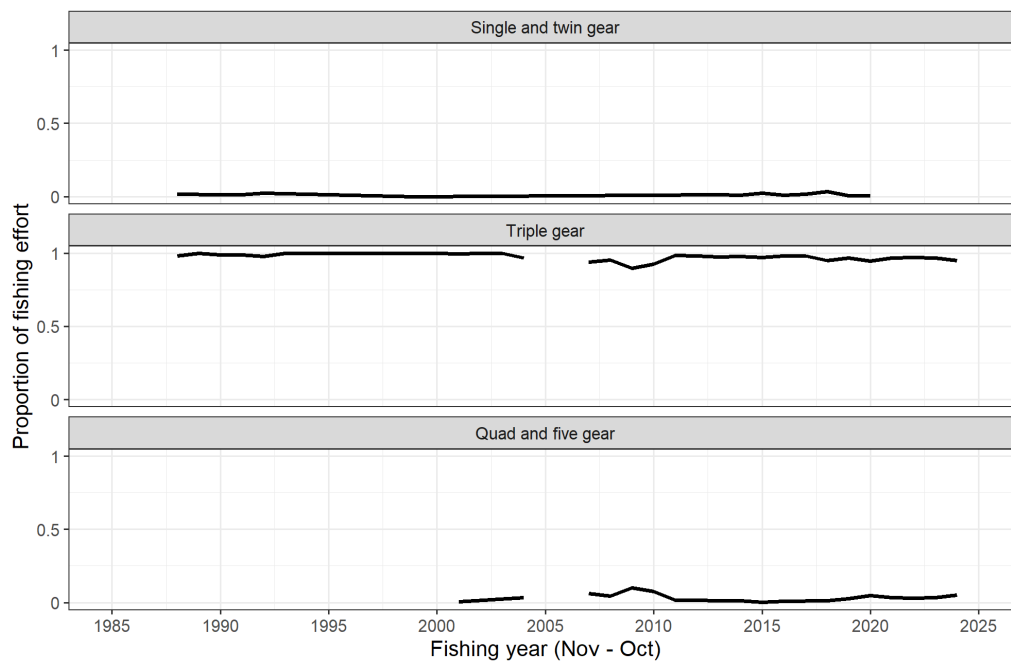


Figure B.24: The proportion of total annual fishing effort by vessels in each fishing year for deep water depths using different net types.

Bycatch reduction devices and turtle excluders BRDs and TEDs were used voluntarily in the Queensland east coast otter trawl fishery in the 1990's. By January 2002 the use of BRDs and TEDs was compulsory in all trawl sectors. The following describes their compulsory introduction:

- BRDs March 2000 — All otter trawl nets except for deep-water (> 50 fm), scallop and try-gear.
- BRDs January 2001 — All waters of the Great Barrier Reef Marine Park.
- BRDs July 2001 — For scallop and deep waters.
- TEDs January 2001 — All nets except when taking scallop or in the deep water.
- TEDs July 2001 — Extended to cover scallop nets.
- TEDs January 2002 — Extended to cover the deep water.

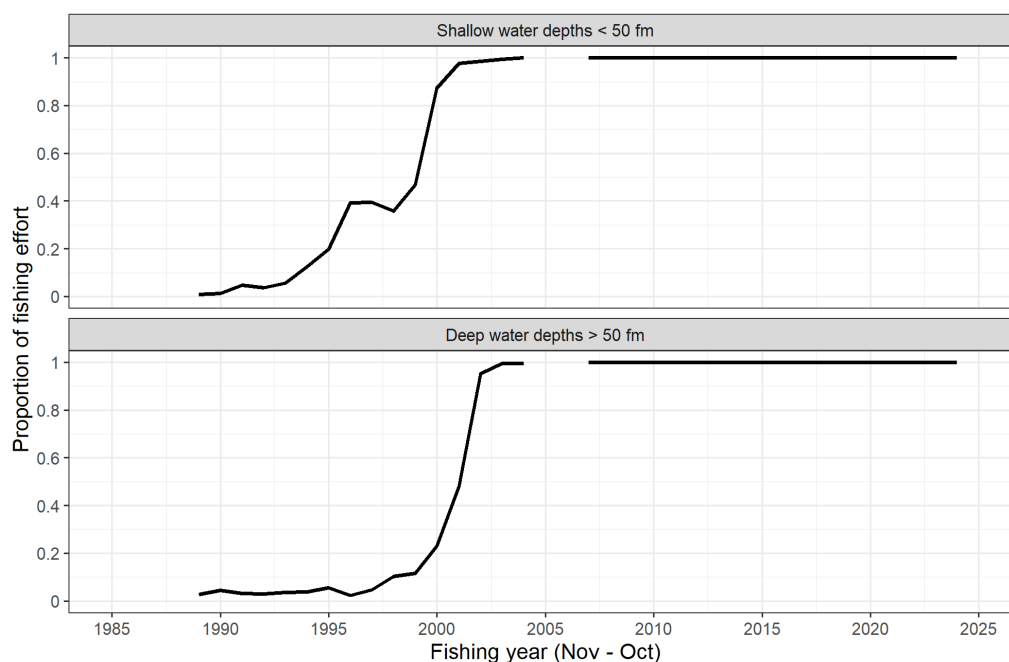


Figure B.25: The proportion of total annual fishing effort by vessels in each fishing year and depth sector using a try-gear net and bycatch reduction and/or turtle excluders.

Navigation: *Global positioning systems* GPS began to be adopted in 1988, and by 1996 was installed on nearly every vessel in all depths (Figure B.26).

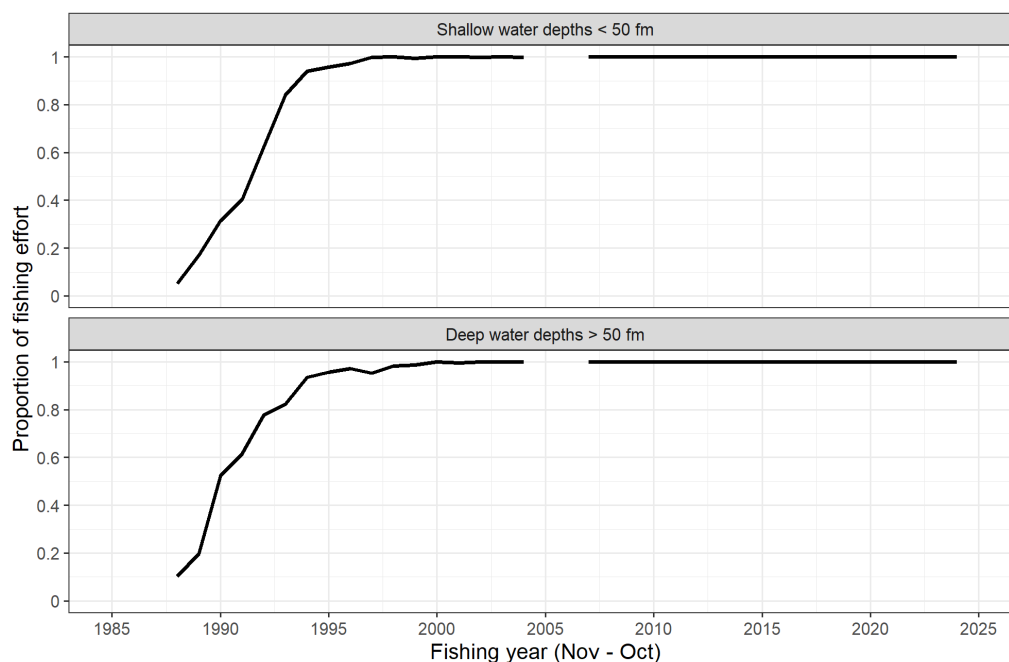


Figure B.26: The proportion of total annual fishing effort by vessels in each fishing year and depth sector using global positioning systems.

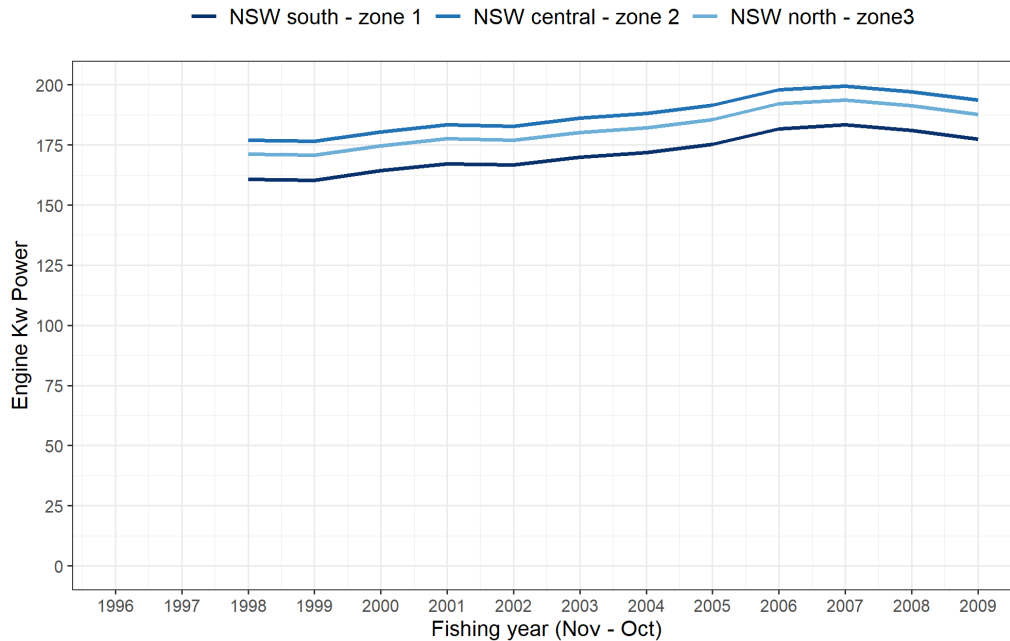


Figure B.27: The average engine rated power by fishing year and zone in New South Wales. Engine power did not increase after 2009.

B.3.2 Line trawl

This analysis aimed to determine whether a day of trawl vessel tracking data met the criteria for line trawling, defined as follows:

Line trawling occurs when a sequence of linear or non-linear points is repeated at least once, either forwards or in reverse. These sequences can include subsets of the original sequence, provided the subset represents at least 2 hours of activity. Additionally, the trawling must occur at a speed between 1 and 5.4 knots.

Method overview

- 1. Removing non-trawl points based on speed** Points with speeds outside the range of 1–5.4 knots were excluded, as these speeds indicated either stationary activity or movement too fast for trawling.
- 2. Defining sequences based on change in angle** Sequences were identified as continuous points where the change in bearing between adjacent polls was less than 30 degrees. For data before 28 August 2024, bearing was calculated using the direction between polls, while post-2024 data included bearing directly from tracking units. Sequences could vary in length, including single-point sequences.
- 3. Matching sequences based on rectangular distance** Each point in one sequence was compared to points in another sequence. A rectangular range was defined around each point: 0.05 degrees forward/backward (direction of travel) and 0.001 degrees left/right (perpendicular). Points from both sequences were considered matched if they fell within each other's ranges.
- 4. Filtering matched sequences to meet the threshold** For each pair of sequences, the distinct number of matched points in both sequences was counted. If both counts exceeded 2, the pair

was considered adequately matched. If at least one pair of matched sequences met this threshold, the day was classified as having line trawling.

Note on Data: The dataset initially recorded polls hourly. After 1 June 2019, polling frequency increased to every 15 minutes. To maintain consistency, only the first poll of each hour was retained for data collected after this date.

The line trawl uptake for the period 2002 to 2024 was retrospectively estimated (hindcast) to the year 1988 using the trend in GPS adoption (Figure B.26) and scaling the GPS uptake to align with the 2002 line trawl uptake (Figure B.28). This analysis was performed independently for three distinct Queensland zones (inshore, offshore north, and offshore south) to account for regional variability in line trawl uptake trends.

Between 1995 and the introduction of VMS in 2002, the uptake of line trawling remained constant, aligning with the VMS uptake observed in 2002. This suggests that line trawling became truly effective from 1995 onwards. Prior to 1995, while fishers may have attempted line trawling, its effectiveness was likely limited due to the constraints of early GPS systems, which provided only three positional fixes per night. The graph, which shows a decline to zero before 1995, effectively reflects this reduced efficiency during the earlier period.

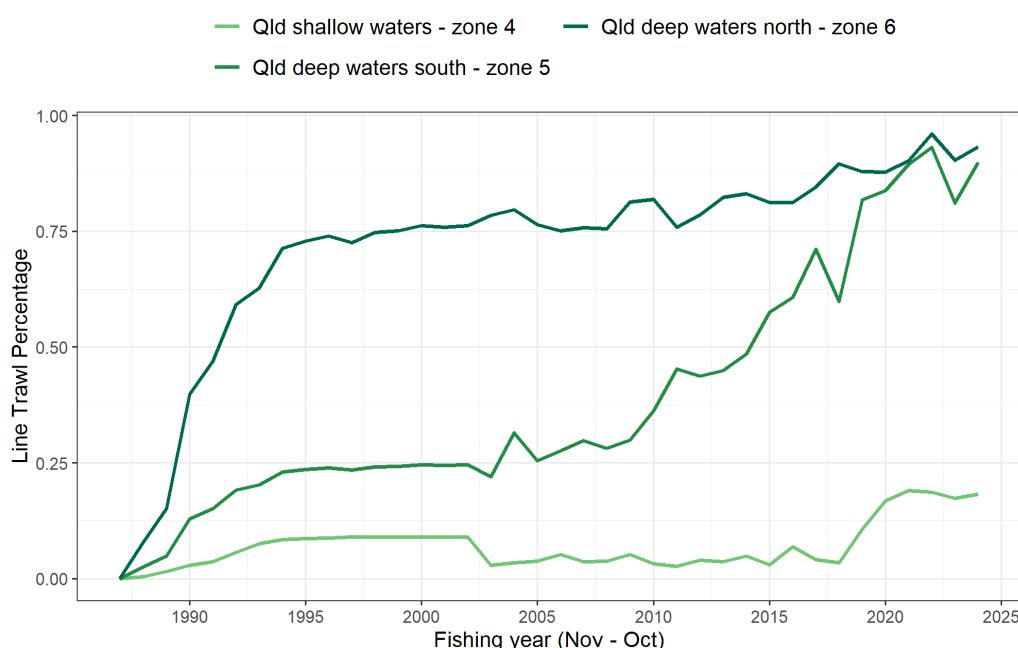


Figure B.28: Line trawl uptake for eastern king prawn vessels.

B.3.3 Gear catchability

The estimated gear and technology parameters are shown in Table B.3. Their interpretation provides insights into some of the notable associations with larger catches (i.e. higher fishing power/ catchability). It should be noted that the following descriptions were relative and specific to each gear and technology. In function, fishing-power is a diverse interaction of multiplicative combination of gears and technologies, as outlined in Section 2.4.

The coefficient for engine rated power from Table B.3 indicated that higher engine power was associated with higher eastern king prawn catches. Vessels increasing their engine power by 100 HP or more were generally associated with 11% larger average catches in deep waters and 0.6% larger average catches in shallow waters. These percentages were calculated as follows: example deep water for horse power of 350 hp and 250 hp:

$$\text{catchability} = \exp(\log(350) \times 0.339 - \log(250) \times 0.339) \quad (\text{B.1})$$

where 0.339 was the coefficient for horse power for deep water from Table B.3.

Vessels equipped with GPS were associated with about 10% larger average catches in deep waters ($\exp(0.093)$).

Vessels using quad gear were associated with smaller catches compared to those using triple gear in deep waters. In shallow waters, vessels using quad gear achieved about 6% larger average catches than vessels with triple gear ($\exp(0.057)$).

There were minimal differences between ground gears.

Vessels using Louvre and Kilfoil otter boards achieved 3% larger average catches ($\exp(0.031)$) than vessels fishing with Standard otter boards in shallow water.

Vessels equipped with a turtle excluder device (TED) and/or a bycatch reduction device (BRD) were associated with approximately 38% higher catches of eastern king prawns in shallow waters ($\exp(0.323)$). This parameter estimate was also similarly large in the previous assessment (Helidoniotis et al. 2020). It was not uncommon to find examples of positive effects of BRD in the literature (O'Neill and Leigh 2006). Examples where BRDs have had a positive effect on catch rates of target species include Rogers et al. (1997), Broadhurst and Kennelly (1997), and Steele et al. (2002).

BRDs and TEDs were used voluntarily in the Queensland east coast otter trawl fishery in the 1990's. By March 2000 the use of BRDs was compulsory and by January 2001 the use of TEDs was compulsory in trawl sectors less than 50 fathoms. By January 2002 the use of BRDs and TEDs was compulsory in all trawl sectors.

The negative model term for GPS in shallow waters seems counterintuitive. However, analyses based on fishery-dependent (observational) data can sometimes produce unexpected parameter estimates for the vessel gear terms due to low contrast in the data for these parameters with respect to the full model. Alternatively, this may represent the range/change of vessels fishing and the practical combination of certain gears and specific fishery behaviour. Courtney et al. (2014) noted that negative estimates for the parameter GPS in shallow waters may be due to some unique features of eastern king prawns and the fishery. Eastern king prawns have a strong northerly migratory pattern in much greater depths than other prawn species and are generally fished along narrow depth contours (O'Neill and Leigh 2007). These features may have lowered the significance of GPS in shallow waters. The influence of BRDs and TEDs in the deep water was close to zero.

The line trawl parameters were estimated by zone and are shown in Table B.4. The adoption of line trawling was between 12 to 19% higher than average catch.

Table B.3: Summary of parameter estimates for catchability (fishing power β) terms from the LMER model (natural log transformed). Standard errors are shown in brackets, - indicates the gear type was not estimated for that water depth.

Parameter estimates (log scale) for β_2 (catchability coefficients)	Deep waters	Shallow waters	All waters
Engine rated power	0.339 (0.017)	0.019 (0.016)	-
GPS	0.093 (0.014)	-0.166 (0.017)	-
Trawl gear - number of nets			-
Single, double and triple	0	0	-
Quad and Five	-0.086 (0.017)	0.057 (0.011)	-
Ground gear			
Drop chain	-	-	0
Looped chain	-	-	-0.009 (0.006)
Drop rope with chain	-	-	0.004 (0.006)
Other less used types	-	-	-0.01 (0.006)
Otter boards			
Standard flat	0	0	-
Bison, Louvre/ Kilfoil	-0.069 (0.01)	0.031 (0.011)	-
BRD and TED	-0.002 (0.012)	0.323 (0.013)	-

Table B.4: Summary of line trawl parameter estimates for catchability (fishing power β) terms from the LMER model (natural log transformed). Standard errors are shown in brackets.

Parameter estimates (log scale) for β_2 (catchability coefficients)	Shallow waters	Deep waters south	Deep waters north
Line trawl	0.163 (0.011)	0.112 (0.005)	0.175 (0.006)

The coefficient for engine rated power from Table B.5 from NewSouth Wales data pre 2009 indicated that higher engine power was associated with higher eastern king prawn catches. Vessels increasing their engine power by 100 Kw or more were generally associated with 20% larger average catches. These percentages were calculated as follows: example horse power of 260 kw (350 hp) and 186 kw (250 hp):

$$\text{catchability} = \exp(\log(260) \times 0.6371 - \log(186) \times 0.6371) \quad (\text{B.2})$$

where 0.6371 was the coefficient for engine power from Table B.5.

Table B.5: Summary of parameter estimate for catchability (fishing power β) term for engine kw power from New South Wales data pre 2009 (natural log transformed). Standard errors are shown in brackets

Parameter	Estimate (log scale) for β_2 (catchability coefficient)
logkw	0.6371 (0.0507)

B.4 Biology

B.4.1 Growth

The growth model was based on the latitudinal and seasonal estimates of eastern king prawn (Lloyd-Jones et al. 2012). Their κ and θ_1 parameters were rescaled per degree of latitude and month. The

parameter “lat” specified the degree latitude for each zone and σ were the standard deviations of the monthly growth increment, in millimetres (Table 17.6 in Courtney et al. (2014)):

$$\begin{aligned} \text{lat} &= [-32.0, -29.5, -28.5, -26.5, -23] \\ \sigma_{\text{male}} &= 2.069; \sigma_{\text{female}} = 2.277 \end{aligned} \quad (\text{B.3})$$

B.4.2 Weight and length

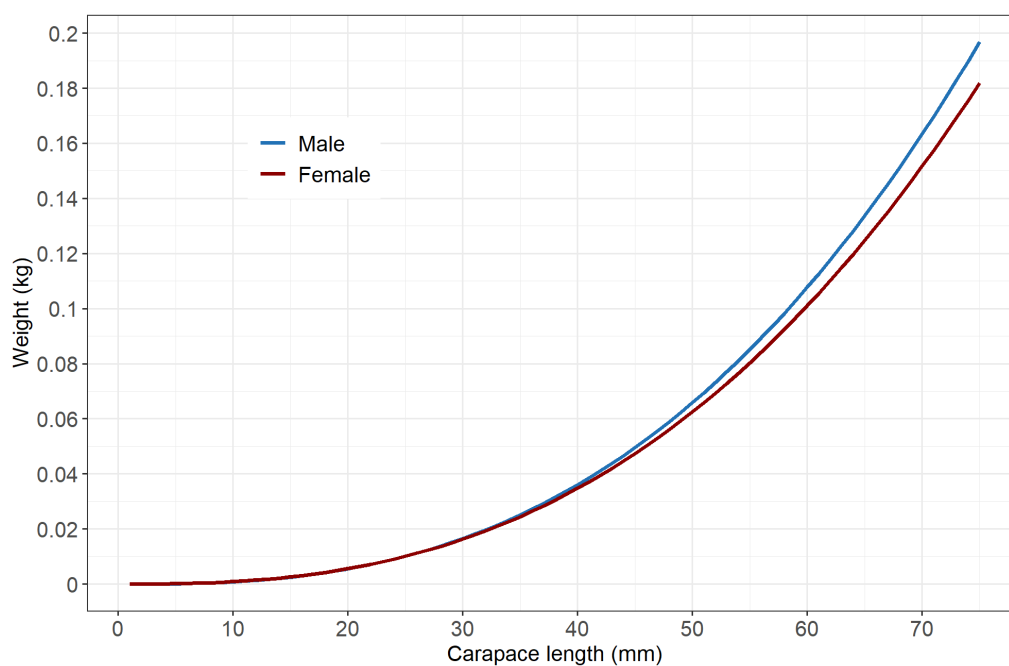


Figure B.29: Weight-length relationship for Queensland and New South Wales eastern king prawn.

B.4.3 Fecundity and maturity

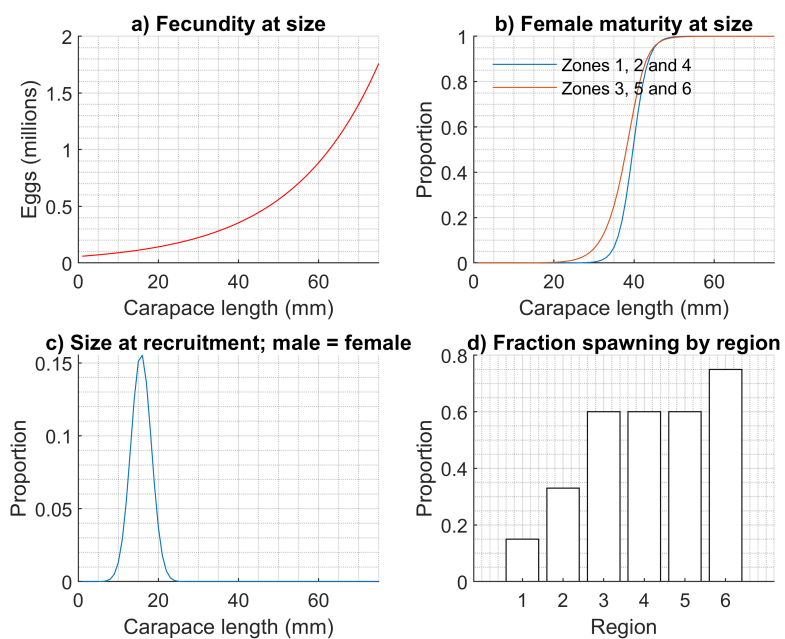


Figure B.30: a) Fecundity-length relationship, b) Maturity-length relationship, c) Size at recruitment and d) Fraction spawning by zone for Queensland and New South Wales eastern king prawn.

C Model goodness-of-fit

C.1 Catch rates

C.1.1 Commercial

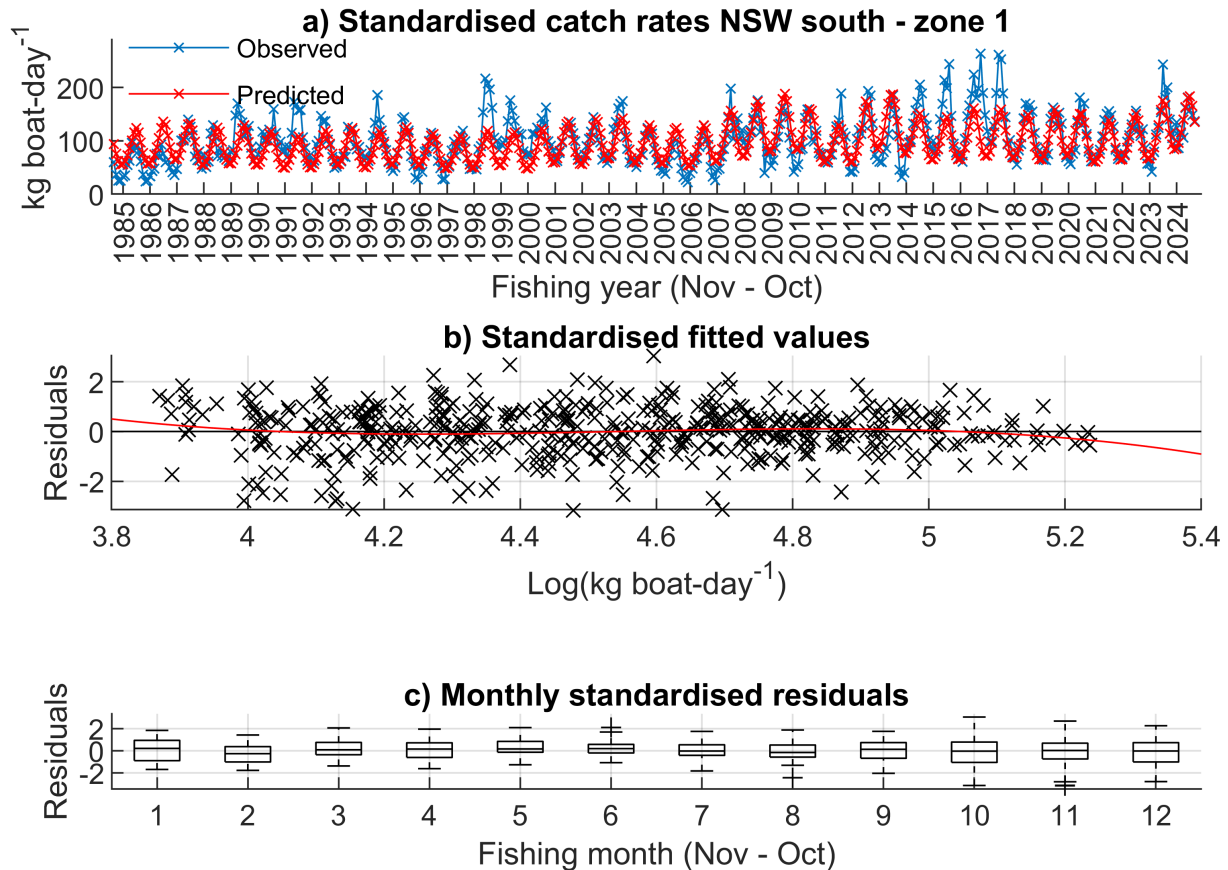


Figure C.1: Diagnostics for observed and predicted standardised catch rates for New South Wales south waters - zone 1.

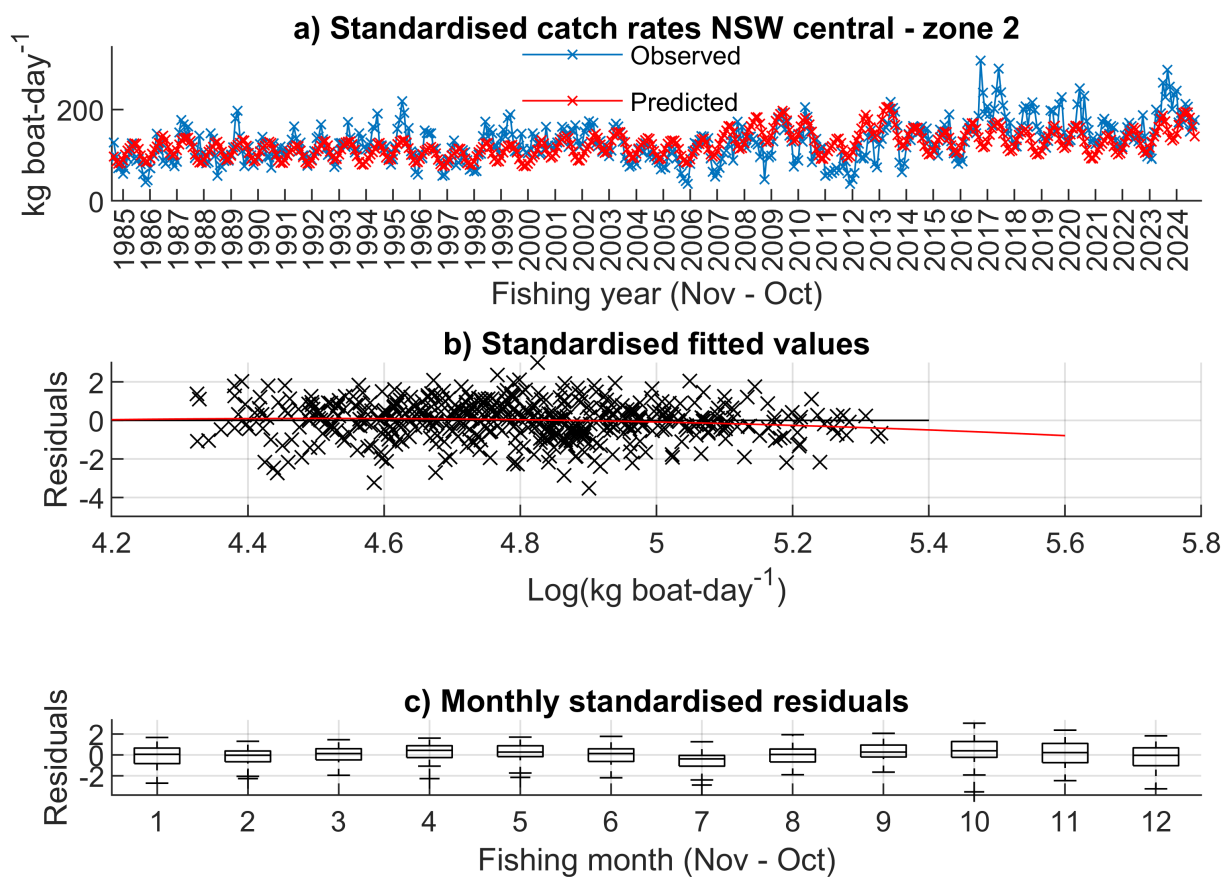


Figure C.2: Diagnostics for observed and predicted standardised catch rates for New South Wales central waters - zone 2.

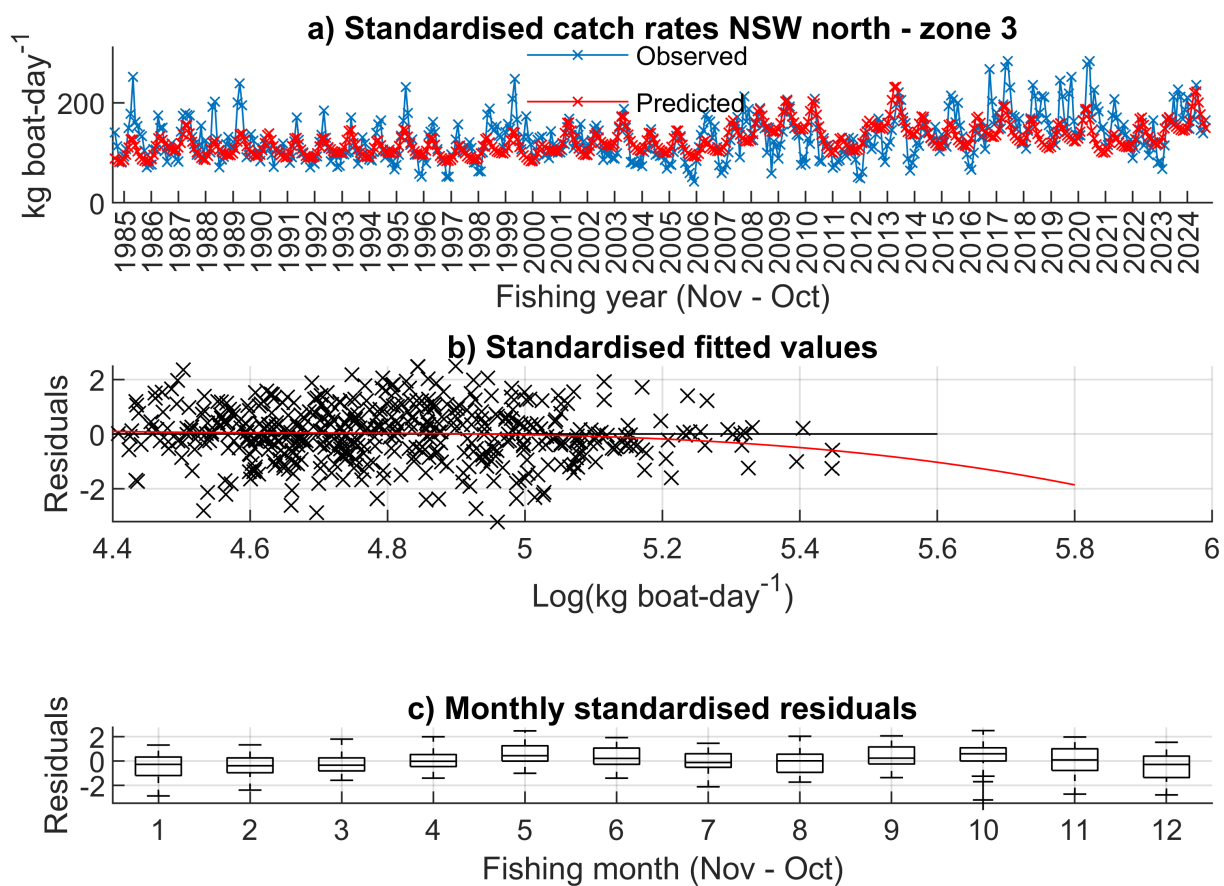


Figure C.3: Diagnostics for observed and predicted standardised catch rates for New South Wales north waters - zone 3.

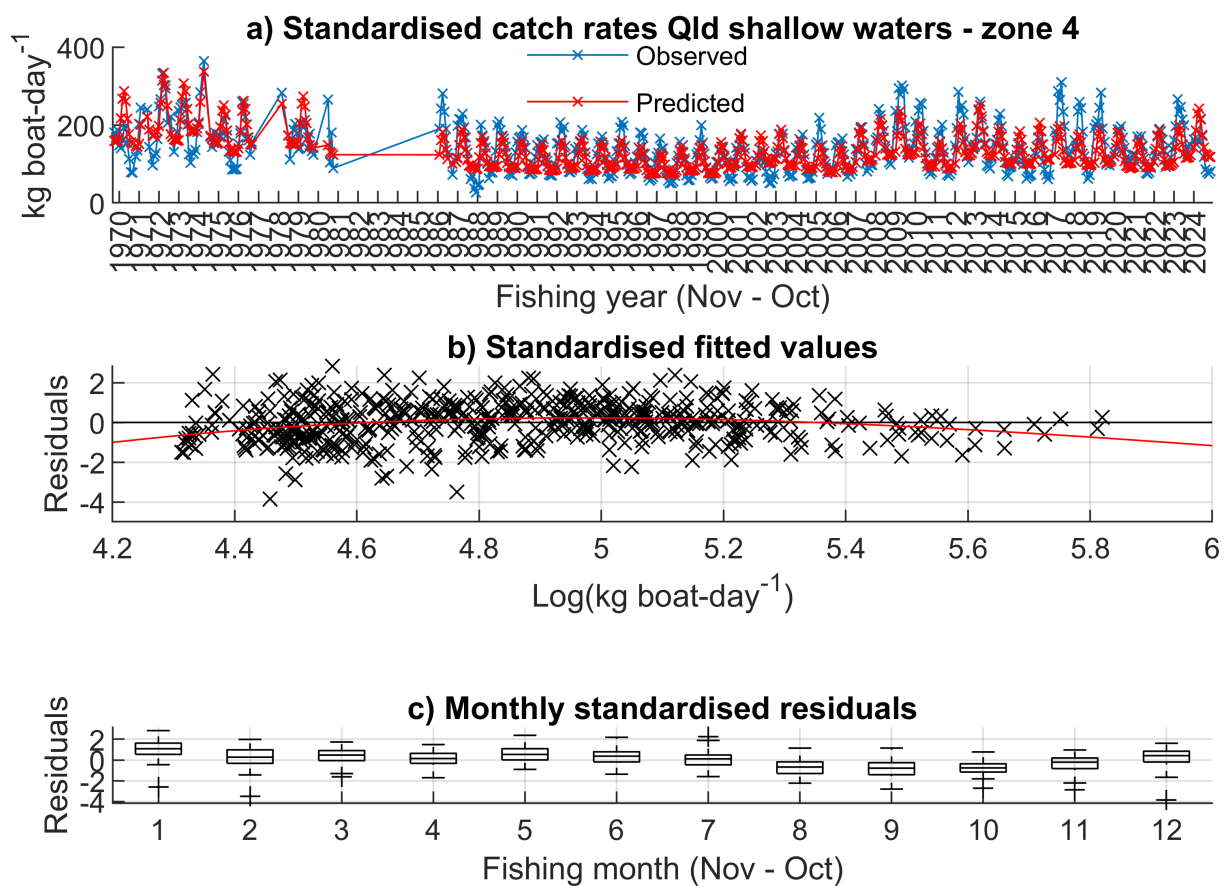


Figure C.4: Diagnostics for observed and predicted standardised catch rates for Queensland shallow waters - zone 4.

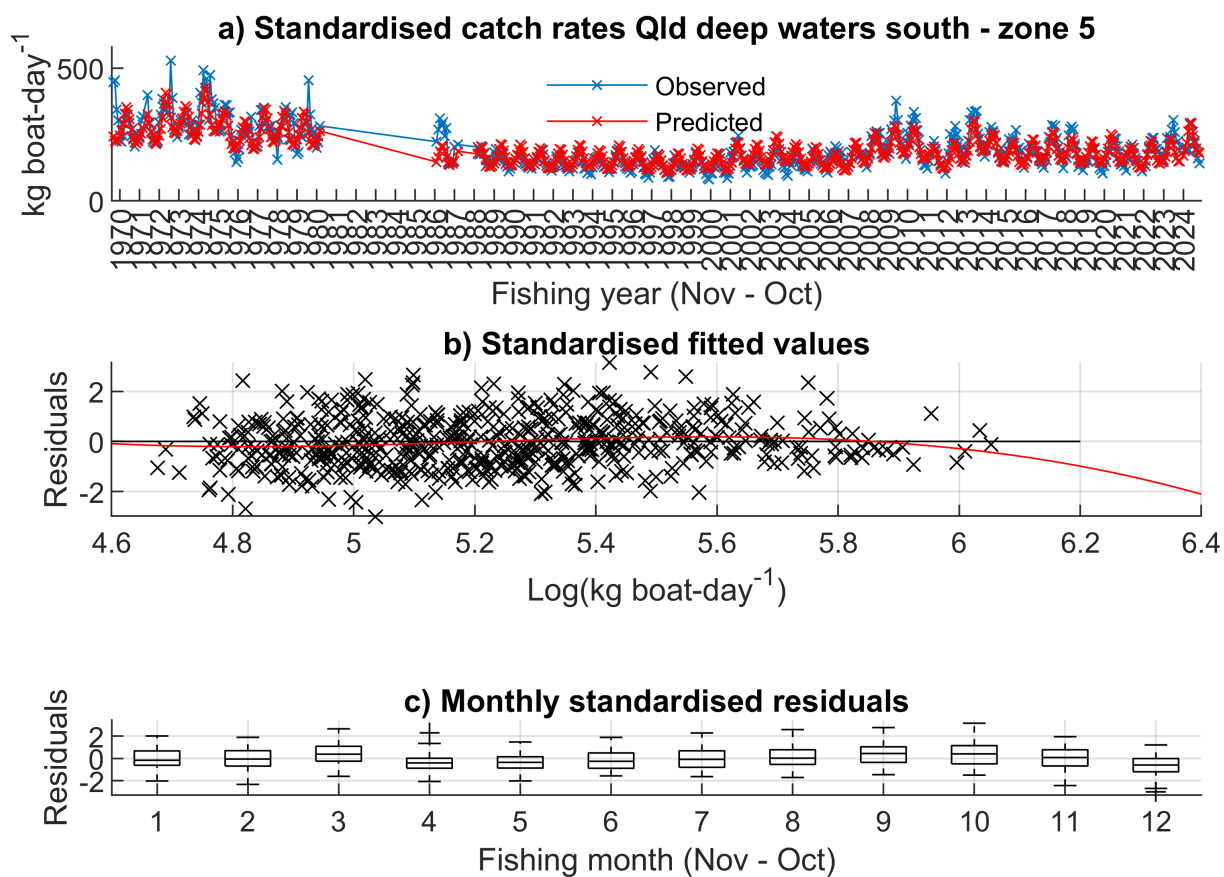


Figure C.5: Diagnostics for observed and predicted standardised catch rates for Queensland deep waters south - zone 5.

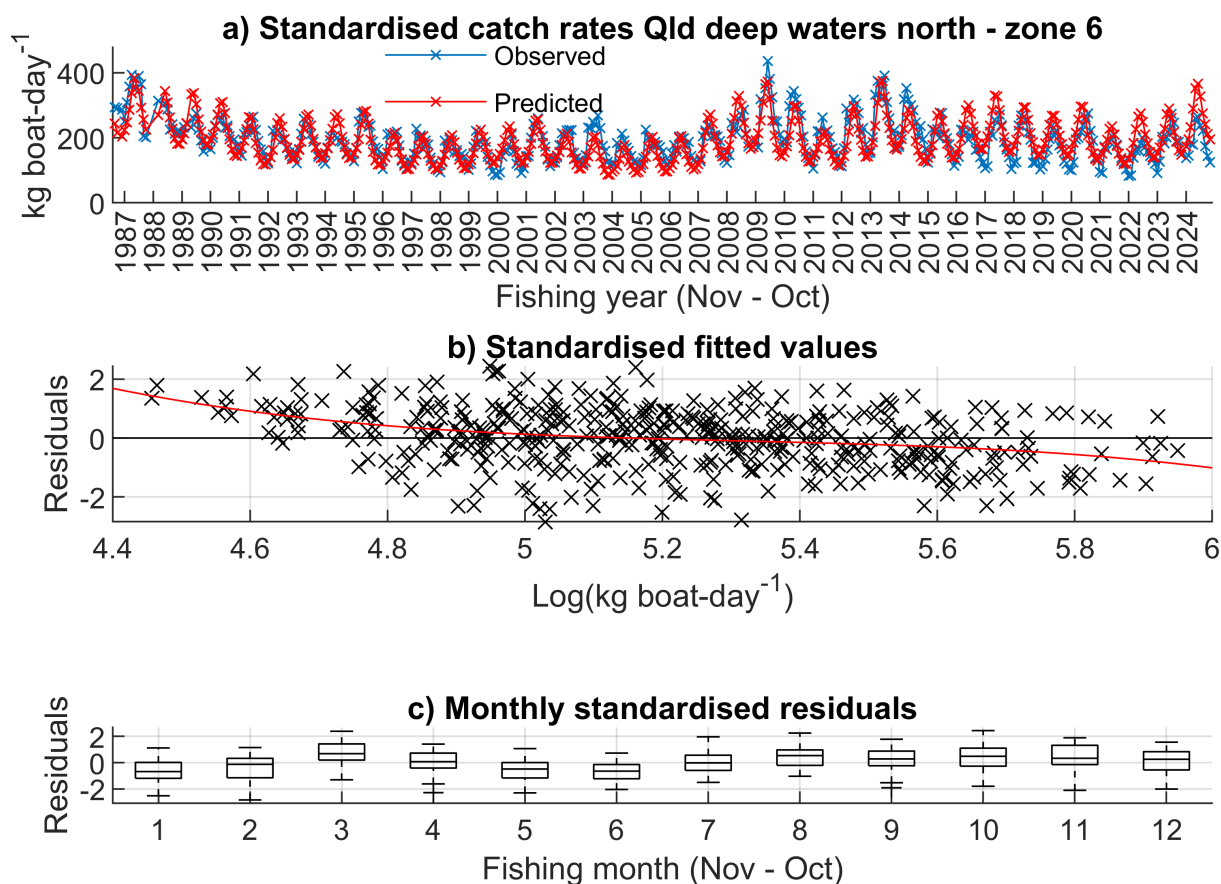


Figure C.6: Diagnostics for observed and predicted standardised catch rates for Queensland deep waters north - zone 6.

C.1.2 Survey

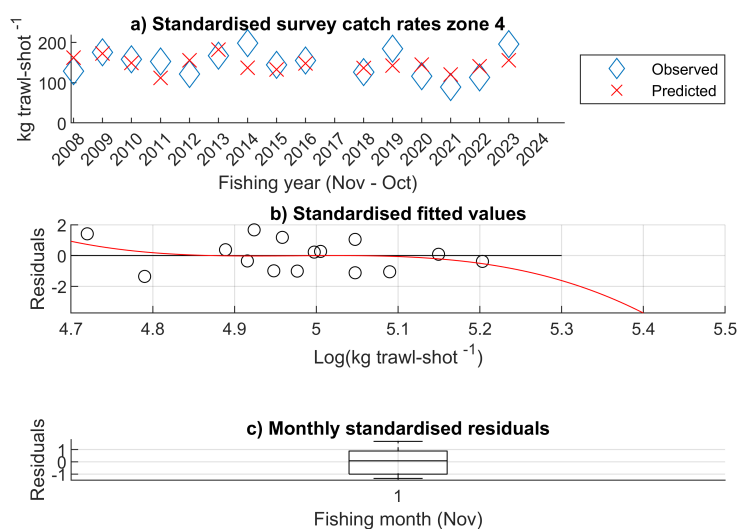


Figure C.7: Diagnostics for observed and predicted standardised survey index from fishery independent beam trawl surveys for Queensland shallow waters - zone 4.

C.2 Recruitment

The model predicted a stable recruitment pattern prior to the year 2000 and thereafter strong fluctuations were evident with years of higher than average recruitment in 2007, 2012 and 2023 (Figure C.8).

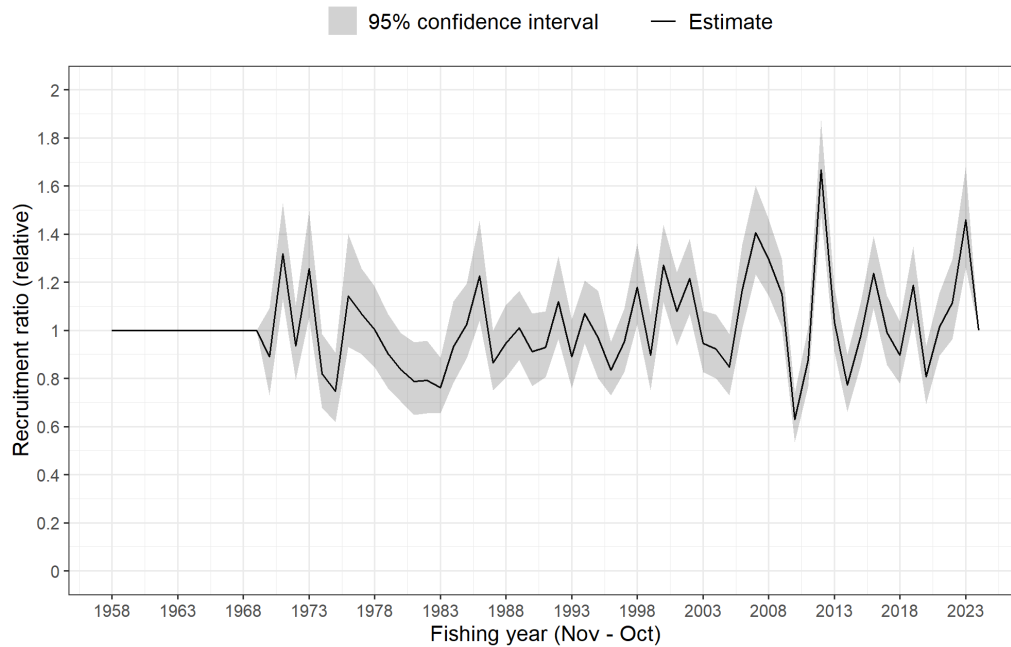


Figure C.8: Recruitment ratio (deviations) relative to the mean. 95% confidence intervals are shown.

D Scenario

This section reports on the model estimates when the second scenario for fishing power calculated from New South Wales and Queensland gear data was applied in the standardisation of New South Wales catch rates.

The model estimated that the historical eastern king prawn spawning biomass, expressed as the ratio of egg production relative to 1958, was 73% in 2024 (confidence interval: 49–90%) (figure D.1).

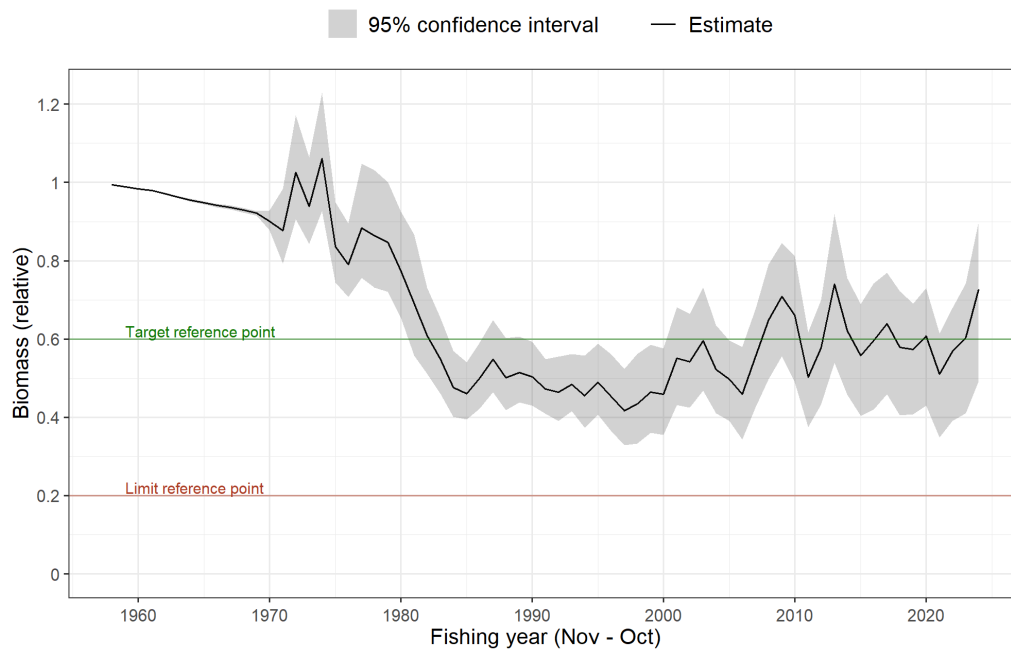


Figure D.1: Spawning biomass ratio by fishing year, relative to the unfished level in 1958. The maximum likelihood estimate (MLE) showed the model best prediction and fit to the data.

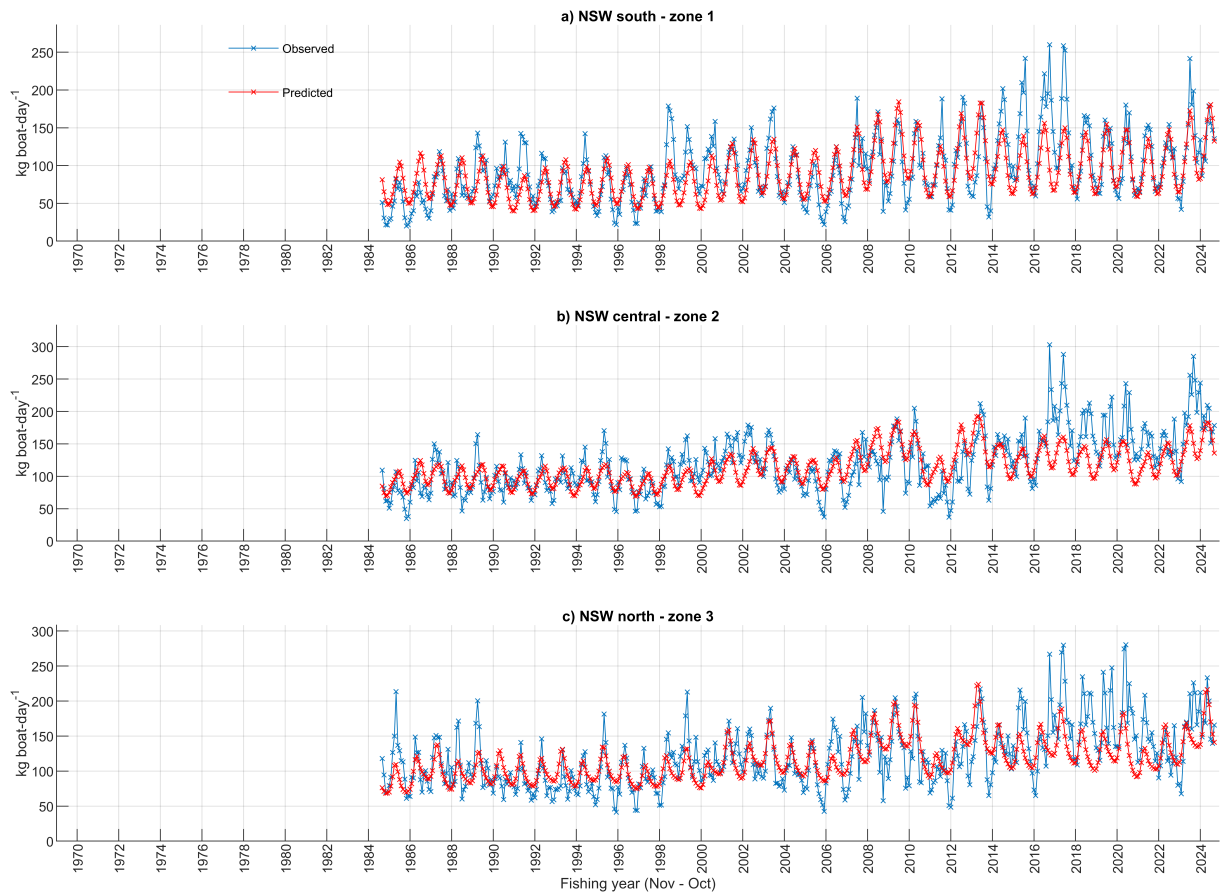


Figure D.2: Observed and predicted monthly standardised catch rates for New South Wales zones.

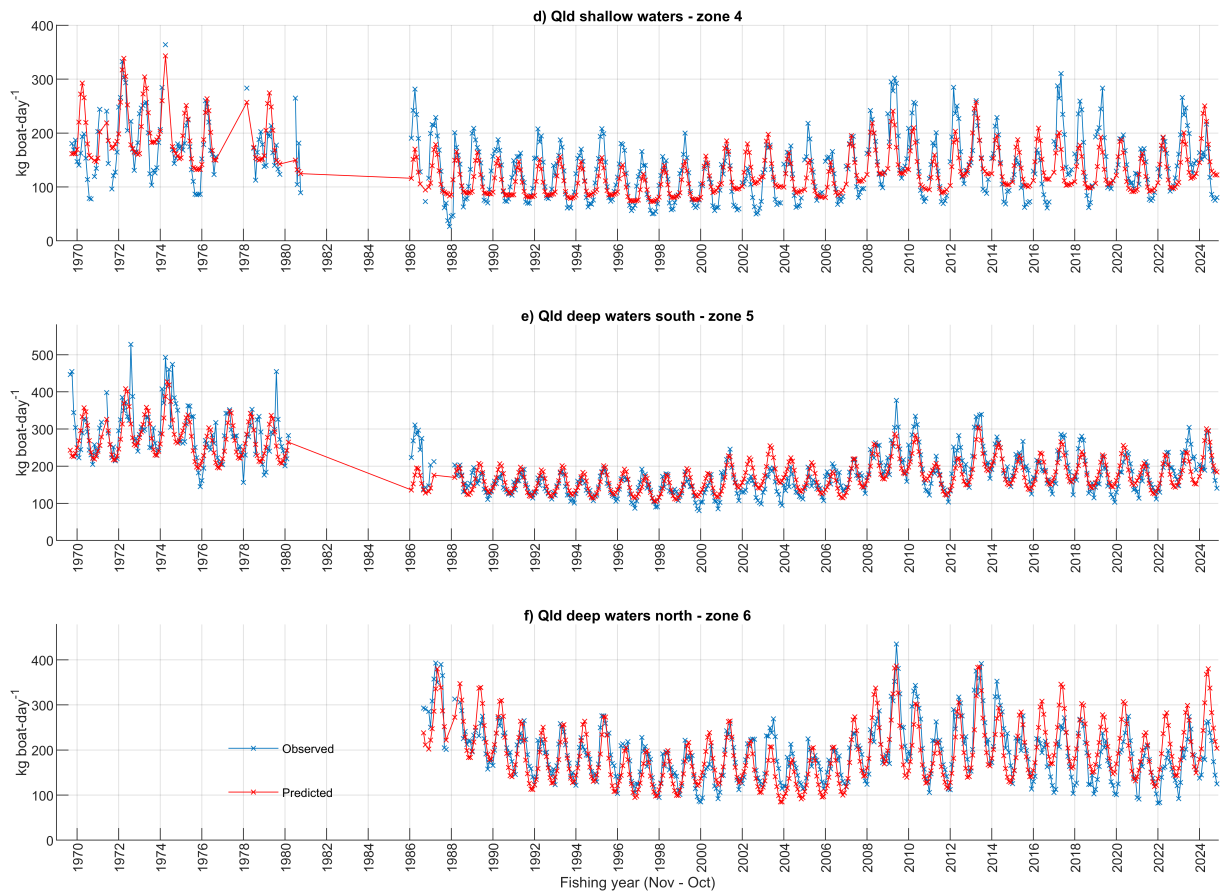


Figure D.3: Observed and predicted monthly standardised catch rates for Queensland zones.

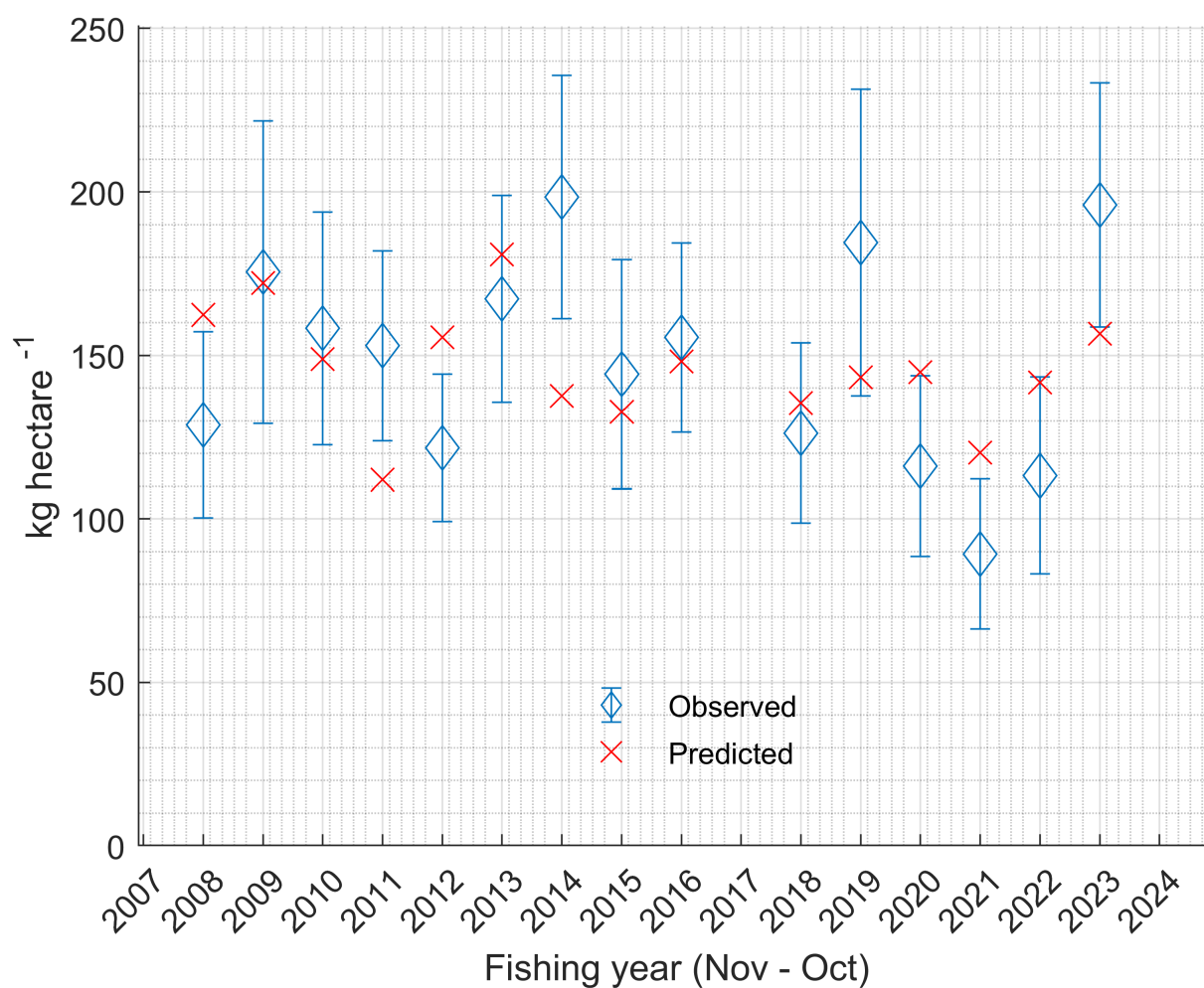


Figure D.4: Observed and predicted standardised survey index from fishery independent beam trawl surveys for Queensland shallow waters - zone 4.

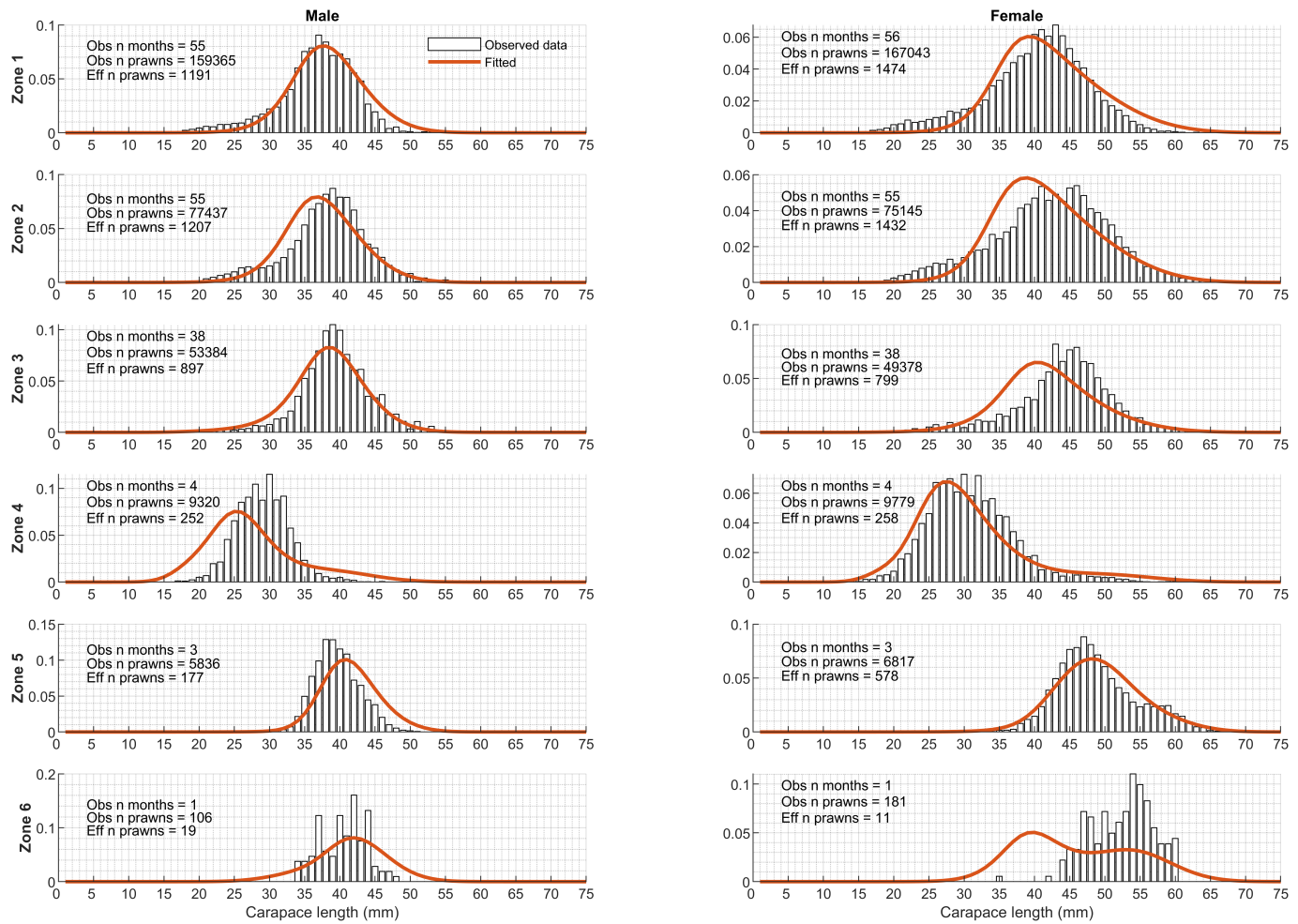


Figure D.5: Observed and predicted overall length frequency by sex.

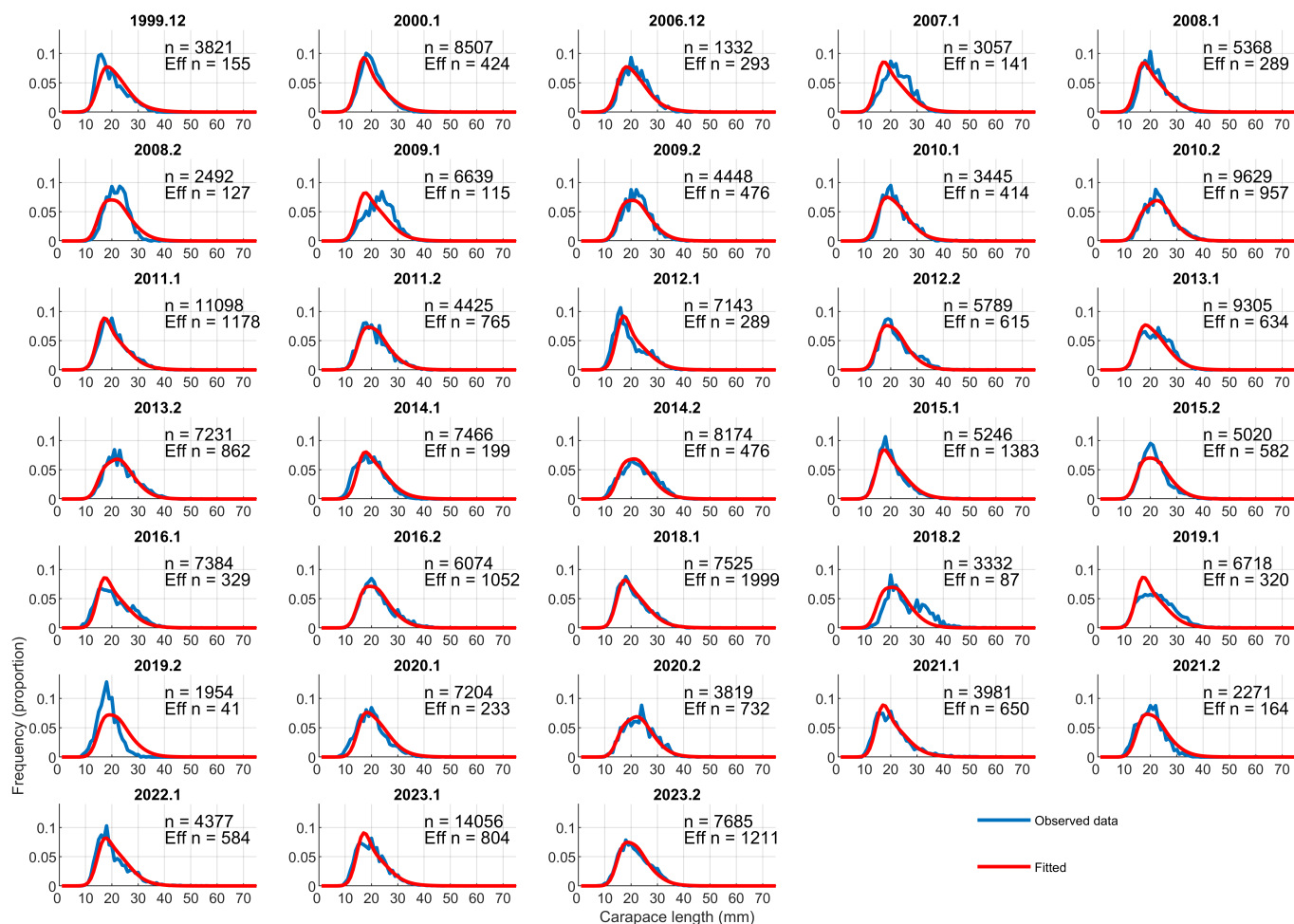


Figure D.6: Monthly observed and predicted length frequency distribution from fishery independent beam trawl survey for females and males.

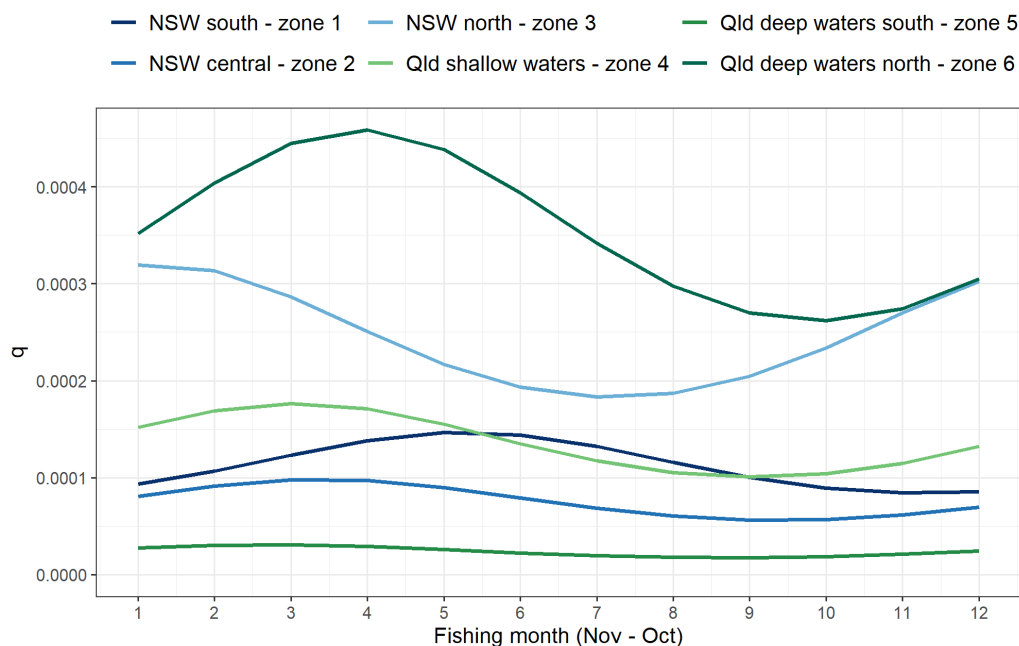


Figure D.7: Model estimated catchability by month and zone.

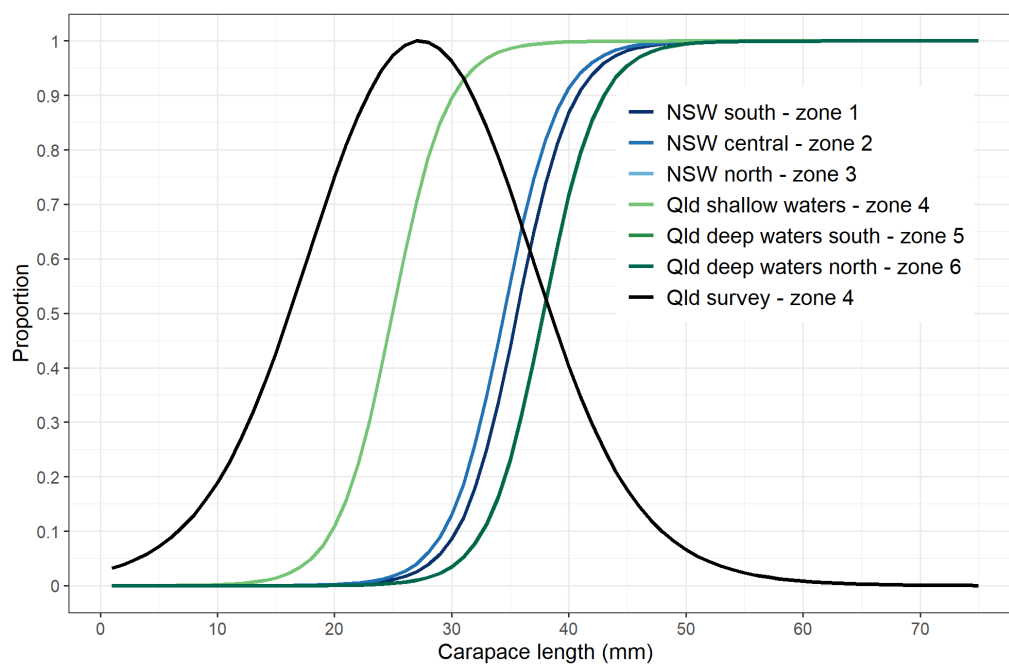


Figure D.8: Model estimated length-based selectivity by zone for eastern king prawn. The selectivity results also include the beam trawl survey.

Table D.1: Estimated model parameters, excluding the 53 recruitment coordinates.

Parameter	Zone	Description	Value	Standard error
ξ	All	Used to determine Beverton-Holt steepness h	-0.9679	0.0976
γ	Zone 1	Used to determine R_0	1.2974	0.0976
	Zone 2		2.0225	0.0826
	Zone 3		3.1615	0.0529
	Zone 4		1.3157	0.0818
μ	Zone 1	Mode of the monthly recruitment pattern	4.3322	0.1027
	Zone 2		4.3486	0.0749
	Zone 3		8.7082	0.0924
	Zone 4		1.2224	0.0812
κ	Zone 1:3	Concentration of the monthly recruitment pattern	1.5272	0.0819
	Zone 4		3.5513	0.1148
l^{50}	Zone 1	Length at 50% selection	35.57	0.1122
	Zone 2		34.4629	0.1188
	Zone 3		37.8025	0.0836
	Zone 4		24.9452	0.1047
	Zone 5		37.8489	0.0823
	Zone 6		37.8014	0.099
δ	All	Initial steepness of the vulnerability curve	0.4256	0.0368
l^{50}_{rising}	All	Length at 50% selection by the survey on the upward slope	18.3872	0.1091
l_{diff}	All	Difference between the length at 50% selection by the survey and 95% selection	13.8208	0.1007
$l^{50}_{falling}$	All	Length at 50% selection by the survey on the downward slope	36.1976	0.0969
ρ	All	Movement from region 4 to region 6	-1.6553	0.0925
ζ	All	Catchability amplitude	-0.2803	0.0323
ϕ	Zone 1	Catchability seasonal modes	0.7948	0.0955
	Zone 2		-0.3075	0.0974
	Zone 3		-8	0.1017
	Zone 4		-0.5269	0.083
	Zone 5		-0.7752	0.0962
	Zone 6		-0.0519	0.0987

E Fishery management

New South Wales and Queensland currently manage the eastern king prawn sector independently within each state. A range of management input controls on the trawl sectors are used, including limited vessel entry, boat-day/effort-unit allocations, vessel and gear size restrictions, and spatial and seasonal closures. Historical events of otter-trawl fishery management in New South Wales and east coast Queensland waters, relating to eastern king prawn are shown in Table E.1 and Table E.2. Events were collated from New South Wales Government (1994), New South Wales Department of Primary Industries and Regional Development, New South Wales (2004), Montgomery (2000), Camp et al. (2023), and New South Wales Department of Primary Industries and Regional Development, New South Wales (2026) and from the Fisheries Queensland dashboard of fishery timelines, FISHNET, and the DME all seasons summary, (Helidoniotis et al. 2020; O'Neill et al. 2004; O'Neill and Leigh 2006; Lovett et al. 2023; Hand 2003; Great Barrier Reef Marine Park Authority 2004).

Table E.1: Management measures applied to eastern king prawn in New South Wales waters.

Year	Management
1940's	Compulsory commercial catch logbook reporting commenced. Reporting was yearly summaries by fiscal year, from 1941 to 1983/84. Data consists of undifferentiated prawns prior to 1997.
1982	Seasonal area closures were first introduced in the Fishery to protect juvenile king prawns (OPT Inshore: Brunswick, Richmond, Clarence, Evans and Macleay Rivers)
1984	Licensing freeze on boats and Commercial Fishing Licenses
	Compulsory commercial catch logbook reporting changed. Reporting was monthly. Prawns species were undifferentiated. Catch could not be linked to effort if more than one fishing method was used in a month. The effort quantity used was days fished
1985	(OPT offshore) Management Plan for prawn trawling introduced restricting entry of new fishing vessels to the fishery, regulations based on hull size and engine power that aimed to control increases in fishing effort (fishery under Cth jurisdiction)
	July (OPT offshore) - Access to trawling for eastern king prawns outside 3 nautical miles was restricted to vessels with a demonstrated history of participation or financial commitment to the fishery
	(OPT offshore) Boat replacement policy- restricts boat length/ engine power for ocean prawn trawlers
1987	(OPT Inshore) Freeze on the issue of new NSW commercial fishing licences introduced (applies only to fisheries inside 3nm, under NSW jurisdiction prior to OCS)
1990's	Juvenile King Prawn closures
early 1990's	Management Rules were implemented including hull, engine and net restrictions and unit adjustment program
1990	(OPT offshore) Net length restrictions introduced for offshore ocean prawn trawlers. The controls reduced by about 40% the total amount of net that could be used in the offshore sector of the fishery (outside 3 nautical miles)

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Table E.1 – *Continued from previous page*

Year	Management
	(OPT offshore and deepwater) Access / transfer rules introduced and rules for amalgamating boat licences for purpose of increasing hull size / engine power and net length
1990	Offshore Constitutional Settlement (OCS) established. An agreement between the Commonwealth and the States (including NSW) that establishes jurisdictional boundaries for marine resource management, including fisheries (December)
1994	Fisheries Management Act 1994 was implemented
	NSW Commercial Fisheries Licensing Policy introduced in June 1994 (to support implementation of the Fisheries Management Act 1994 and the Fisheries Management (General) Regulation 1995) replaced licence freezes with new way for controlled entry in the fishery (one in one out, catch validation)
1995	Fisheries Management (General) Regulation 1995 commenced
1997	Marine Parks Act provided a declaration of marine parks in New South Wales (Marine Parks Authority website 2026)
	Declared a restricted fishery with adjustment via business amalgamations
1998	Compulsory commercial catch logbook reporting changed. Prawn species are now differentiated. Commercial catches are still reported monthly. Catch now linked to days of effort within a fishery, but this was an indirect link.
	Solitary Islands Marine Park declared. The MP covers 70,000 hectares, trawling is prohibited in sanctuary zones (12%) and habitat protection zones (54%).
May 1999	Mandatory use of BRDs for ocean prawn trawl nets (May 1999)
2000 to 2010's	Progressive introduction of MPs including commercial business buyouts
2001	Additional seasonal/spatial area closures (juvenile king prawn closures) implemented off Tweed Heads, Brunswick Heads, Ballina, Evans Head, South West Rocks, Angourie Point, Newcastle, Forster and Port Stephens
2002	Jervis Bay Marine Park zones and management rules commenced (October). The MP covers 215 km ² , trawling is prohibited in sanctuary zones and habitat protection zones.
	Fisheries Management (General) regulation 2002 (1 Sept)
2004	First Point of Sale Prawn Counts implemented
	New addition of Juvenile King Prawn closure off Crowdy Head.
	Additional BRDs introduced with improved effectiveness
	OP1 - Offshore Prawn Trawling closure (June)
	General Ocean Prawn Trawling Closure prohibiting the take of fish (including prawns) by means of an otter trawl net, Coffs Harbour Trawling closure
2005	Port Stephens - Great Lakes Marine Park established (December).
2006	Cape Byron Marine Park zones and management rules commenced (May). The MP covers 22,000 hectares.
	Use of 'bobbin gear' is restricted to a size not greater than 100mm in diameter

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Table E.1 – Continued from previous page

Year	Management
2007	Introduction of Ocean Trawl Share Management Plan with adjustment via minimum shareholding requirements (New South Wales Department of Primary Industries 2007)
	This provided a fishery management strategy for the Ocean Trawl Fishery that outlined fishing rules, vision and goals for the fishery
	Port Stephens - Great Lakes Marine Park zones and management rules commenced. The MP covers 980 km ² , trawling is prohibited in sanctuary zones and habitat protection zones.
	Batemans Marine Park zones and management rules commenced. The MP covers 850 km ² , trawling is prohibited in all zones
	Adoption of Ocean Trawl Share Management Plan with adjustment via minimum shareholding requirements.
2008	Implemented prohibitions on trawling in ocean waters that are east of the 1,100 metre depth contour, waters immediately above any part of the seabed that is comprised of hard rock or reef and prohibition of mid-water trawling
2009	Compulsory commercial catch logbook reporting changed. Commercial daily logbook reporting commenced. Total trawl time (hours) is required for each day. The effort quantity used was effort specific (eg number of hooks, trawl time)
	Implemented mandatory use of 'droppers' for ocean prawn trawl nets (1 January 2009)
	Restricted trawl nets to a single ground chain of no greater than 12 mm gauge (1 January 2009)
2010	Minimum shareholding requirements implemented via Share Management Plan. Access to the fishery is limited to shareholders, or their nominated fishers
2012	Further increase to minimum shareholding requirements
2017 - 2019	Commercial Business Adjustment Program (BAP) significantly reducing endorsement numbers, introducing quotas, new boat replacement rules
2017	Subsidized share trading market opens, Buyouts under BAP (May)
2019	Effort quota commenced for ocean trawl prawning (eastern king prawn and eastern school prawn). TAE determination of 542, 000 standardised hull units (SHU) was made for the fishing period 1 May 2019 to 30 April 2020 and maintained at the same level for each fishing period to 2023/24 fishing period
	Catches of Eastern School Whiting and Stout Whiting combined (Trawl Whiting), taken in the Ocean Trawl Share Management Fishery subject to quota management (New South Wales Department of Primary Industries 2022).
	Total Allowable Catch (TAC) for trawl Whiting was set at 1,189.1 tonnes (t) for 2019/20 fishing period
	The current maximum headline lengths replaced with a standard maximum headline length of 55m
May 2020	TAC for trawl Whiting set at 898 t (1 May 2020 - 30 April 2021)
May 2021	TAC for trawl Whiting set at 1,066 t (1 May 2021 - 30 April 2022)

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Table E.1 – *Continued from previous page*

Year	Management
May 2024	Ocean trawl prawn TACE reduced by 10% to 487,800 standardised hull unit days (1 May 2024 - 30 April 2025)
May 2025	TAC for trawl Whiting set at 1,980 t

Table E.2: Management measures applied to eastern king prawn in Queensland waters.

Year	Management
1968	Just over 400 licenced trawlers (symbols) state-wide. No effort caps. Voluntary catch logbook reporting operated between 1968 and 1987.
1976	Introduction of the Fisheries Act (1976). Just under 700 symbols state-wide. No effort caps.
1980	Just over 1,400 symbols state-wide. No effort caps.
1983	Declaration of the first area (or section) of the Great Barrier Reef Marine Park (GBRMP). More sections were progressively declared to be parts of the Marine Park between 1983 and 1989. No major effects for eastern king prawn in waters south of the GBRMP.
1988	Compulsory commercial catch logbook reporting commenced.
1990	Daylight trawling banned. 2:1 vessel replacement policy.
1994	Introduction of the Fisheries Act (1994).
1999	Introduction of the trawl plan with no effort caps and TED and BRD use listed. Reduction in symbols to 800 state-wide.
2000	Introduction of the southern trawl closure from 20 September to 31 October inclusive. Vessel Monitoring System introduced for trawlers, except Moreton Bay, to tally effort use. In March the use of BRDs and TEDs was compulsory in all trawl sectors except for deep-water (>50 fm) scallop and try-gear.
	Queensland East Coast Otter Trawl Fishery buyback. Approximately 145 symbols removed state-wide. Revised trawl plan with effort unit trading system. Allocated effort units were based on historical participation in the fishery and the standardised hull units of the vessel.
2001	The state-wide allocated effort units were 2,983,319. In January the use of BRDs was compulsory in all waters of the Great Barrier Reef Marine Park, the use of TEDs was compulsory for all nets except when taking scallop or in the deep water. In July the use of BRDs was compulsory for scallop and deep waters, the compulsory use of TEDs was extended to cover scallop nets.
2002	In January the compulsory use of TEDs was extended to cover deep water.

Continued on next page

Table E.2 – *Continued from previous page*

Year	Management
2003	The state-wide allocated effort units were 2,925,321. 527 symbols state-wide at the end of 2003, after the revised plan, effort trading and vessels exiting.
2004	In July of 2004 the GBRMP was rezoned reducing the trawl fishable area by 6%. No major effects for EKP south of the GBRMP.
2005	As a result of the GBRMP zoning, 136,462 trawl effort units (approximately 21 licences) were purchased by the Australian Government. Stock assessment 1 on eastern king prawn. No MEY, but 2/3 of MSY effort was 17,109 boat-nights.
2006	Trawl gear description sheets were introduced in the OT09 catch logbook.
2010	Introduction of the Fisheries (East Coast Trawl) Management Plan (2010). The definition of TEDs was made effective.
2013	More frequent reporting of trawl gears encouraged in logbooks per species. Reminder letters and contacting fishers by phone resulted in improved gear sheet submissions. The reporting of trawl gear data was 10–40% of licences per year prior to 2013 but improved dramatically since 2013 (> 80% of licences).
2014	Stock assessment 2 on eastern king prawn. MEY effort was between 7,000 and 14,000 boat-nights.
2015	The type of BRDs were restricted to Fisheye, Bigeye, Square Mesh Cod End, Square mesh panel, V-cut, and bell codend. Radial escape section and Popeye fish excluder were prohibited. Public release of the MRAG report – review of fisheries management.
2016	The use or possession of trawl spikes, ploughs, rippers, and other similar devices that attach to trawl sleds, boards or beams were prohibited.
2017	Sustainable Fisheries Strategy 2017-2027 released, considering the public feedback on the Green Paper, and setting target reference points and harvest strategies for key fish stocks.
2019	The eastern king prawn fishery area was defined by the introduction of the Fisheries (Commercial Fisheries) Regulation and Declaration 2019.
2020	Maximum vessel size increased to 20 m length (120 hull units). The state-wide allocated effort units were 2,764,017, with 58.4% being used. Stock assessment 3 on eastern king prawn. MEY effort was 11,423 boat-nights.
2021	The five regional trawl harvest strategies commenced, for 2021–2026. Each trawl region had an annual effort unit cap (TACE per region). EKP is the primary target species in the southern offshore trawl region. The southern offshore effort cap was set at 845,266 effort units. The cap included a catch share of 80% to Queensland and 20% to New South Wales. The cap used an average 2015–2019 vessel standardised hull unit of 64.23. The cap was set for a target biomass of 60%. The MEY cap result of 586,959 effort units was not used, for a target biomass of 69%. Catch disposal records (CDR) introduced. Reporting retained species by grade, number of containers and kg. The commercial fishing app (Qld eFisher) introduced for digital catch reporting.

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Table E.2 – Continued from previous page

Year	Management
2023	Announced commercial structural adjustment, including optional buyout of T1 symbols.
2024	The southern offshore effort cap was unchanged at 845,266 effort units. This cap represented 62% of the 1,353,115 total effort units owned by the 185 holders in the southern offshore trawl region.

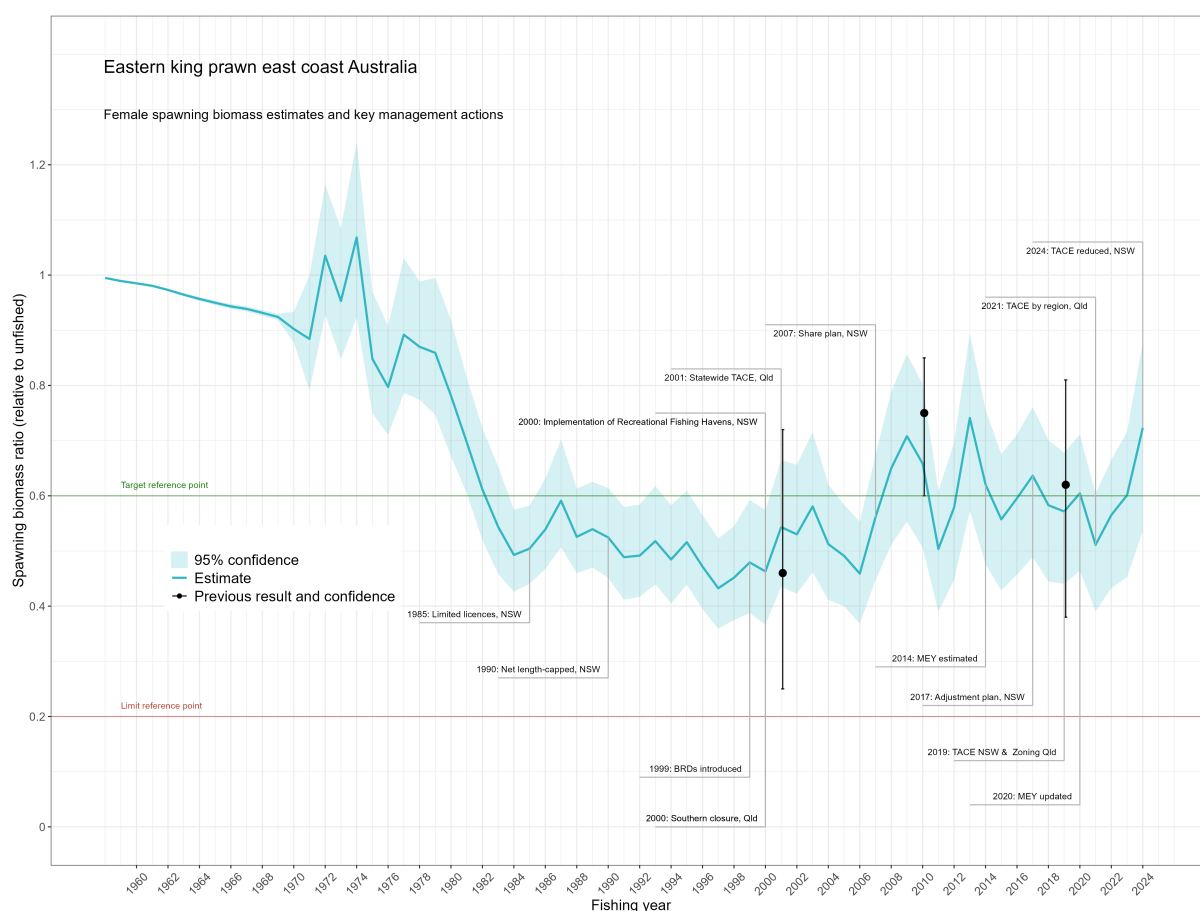


Figure E.1: Eastern king prawn biomass estimates by fishing year, from the new stock assessment compared with key fishery dates and past assessment results in 2001, 2010 and 2019.