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Fishery Assessment Report for the Small Pelagic Fishery: Fishing Seasons 2021–22, 2022–23 and 2023–24

Report to the Australian Fisheries Management Authority

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Executive Summary

Background and Need

The Small Pelagic Fishery (SPF) has grown rapidly over the last decade. It is now Australia's second largest fishery and produces around ten percent Australia's total annual wild fisheries production. Fish meal and fish oil produced from the SPF are used to replace imported products that were previously used to produce feed for the Australian finfish aquaculture industry. The rapid growth and large size of the SPF have increased the need to ensure that approaches taken to monitoring and assessment are as robust as possible.

The Harvest Strategy (HS) for the SPF uses a tiered approach to balance the different risks to stocks associated with higher and lower exploitation rates against the levels of information collected to monitor and assess stock status. Recommended Biological Catches (RBCs) are calculated by applying species-specific exploitation rates to estimates of spawning biomass obtained using the Daily Egg Production Method (DEPM). Total Allowable Catches (TACs) are calculated by subtracting known sources of mortality from the RBCs.

The SPF HS Framework has three tiers. Each tier is defined by the number of years since the last DEPM survey was conducted. The SPF HS Framework is designed to allow the level of investment in research and assessment to be varied to match commercial interest in exploiting the resource. Assessment costs and the level of information available to manage each stock are highest at Tier 1 and lowest at Tier 3.

The SPF HS was revised in 2024 to incorporate the results of a new updated MSE that incorporated new biological data collected since the previous MSE was done. The main revisions were refining the maximum exploitation rates for Blue Mackerel, Jack and Redbait and adding new Harvest Control Rules that reduce the exploitation rates as the spawning biomass declines towards a point where recruitment is likely to be impaired.

Spatial management arrangements are also in place to reduce the potential for localised depletion of target species. A catch limit of 2,000 tonnes over a 30-day period within designated catch grids is applied to the combined catch of target species, regardless of fishing method. A "Gentlemen's Agreement" has also been established to reduce conflicts with game-fishing tournaments.

An Annual Fishery Assessment is required for stocks at Tier 1 and Tier 2. It is used by the SPF Resource Assessment Group RAG to evaluate if there are reasons to recommend exploitation rates that are lower than the maximum rates identified in the HS Framework.

Objectives

This report summarises Annual Fishery Assessments presented to SPF RAG for the 2021–22, 2022–23 and 2023–24 fishing seasons. Consistent with the SPF HS, the objectives of the report are to:

1. Summarise catch and effort data for the four target species (i.e., Blue Mackerel, Jack Mackerel, Redbait and Sardine)
2. Collate length frequency and age structure data for Blue Mackerel, Jack Mackerel and Redbait in the East Sub-area of the SPF
3. Evaluate spatial and temporal patterns in catch, effort, catch-per-unit effort (CPUE), length frequency and age structure data for evidence of potential localised depletion of target species
4. Synthesize results of Daily Egg Production (DEPM) surveys for each target species
5. Provide information to guide refinement of the monitoring and assessment program for the SPF and, if necessary, identify potential options for refining the SPF HS.

Methods

These five objectives were addressed using fishery-dependent catch/effort and size/age structure data from the SPF and by summarising and critically evaluating information obtained from recent DEPM surveys. Fishery-dependent information was evaluated for evidence of stock depletion, localised depletion or changes in the size and age structure of the catch that cannot be adequately explained by reasons other than a decline in abundance. Recommendations are provided for improving the current monitoring and assessment program for the SPF, including research that is needed to improve estimates of spawning biomass obtained from fishery-independent surveys.

Results and Discussion

Overview

The total catch in the SPF increased from 20 t in 2013–14 to 23,055 t in 2023–24. In 2023–24, 22,991 t was taken by trawlers and 64 t by purse-seine vessels.

Most of the SPF catch is currently taken by trawlers operating off southern NSW. Annual patterns of catch, effort and CPUE do not provide evidence of stock or localised depletion. Spatial catch data and monthly and weekly patterns of catch and CPUE do not suggest that the local availability or abundance of target species have declined.

Recent DEPM studies do not provide evidence of declines in the status of any of the target species. However, there a critical knowledge gaps in current understanding of the reproductive biology of all target species, especially Jack Mackerel and Redbait.

Eastern Sub-area

Blue Mackerel

Total catches of Blue Mackerel in the Eastern Sub-area of the SPF in last three fishing seasons were the highest on record. The total catch by SPF trawlers in 2023–24 was 11,049 t, which was ~95% of the available TAC. Annual CPUE of Blue Mackerel by trawlers off southern NSW since 2015–16 ranged from 3.5 to 8.1 t.trawl hr^{-1}, and do not suggest that availability or abundance have declined over the last decade, including the last three fishing seasons.

The expansion in the number of catch grids from which Blue Mackerel catches have been taken over the last decade is likely to reflect the combined effects of increases in total catch and monthly spatial catch limits that have been established to reduce the potential for localised depletion. Monthly and weekly patterns of catch and CPUE do not provide evidence of localised depletion. Length and age frequencies have been stable over the last decade and do not suggest that local availability or abundance have declined.

The last two DEPM surveys of Blue Mackerel in the Eastern Sub-area of the SPF provided estimates of spawning biomass between 80,000 and 90,000 t. The similarity of these results reflects both the similarity of the estimates of spawning area and egg production obtained from the two plankton surveys, and the use of the same adult reproductive data from South Australia to estimate spawning biomass. All three previous applications of the DEPM to Blue Mackerel in the Eastern Sub-area have highlighted the need to obtain local estimates of adult parameters, especially spawning fraction.

A targeted research project was conducted during the last three spawning seasons to obtain estimates of key adult parameters, especially spawning fraction, from the spawning grounds off southern Queensland and northern NSW. The results from that study will be used in the application of the DEPM to Blue Mackerel conducted in September 2024. The final report for that project will evaluate if there is a need to further improve understanding of the reproductive biology of Blue Mackerel in the Eastern Sub-area of the SPF.

Jack Mackerel

Total catches of Jack Mackerel in the last two fishing seasons were the highest on record. The total catch by SPF trawlers in 2023–24 was 10,084 t, which was approximately 54% of the available TAC. Annual CPUE of Jack Mackerel by trawlers operating off southern NSW since 2015–16 has ranged from 4.2 to 11.6 t.trawl hr^{-1}, and do not suggest that local availability or abundance have declined over the last decade, including the last three years.

The expansion in the number of catch grids from which catches of Jack Mackerel have been taken since 2014–15 is likely to reflect the combined effects of increases in total annual catches and monthly spatial catch limits established to reduce the potential for localised depletion. Monthly and weekly patterns of catch and CPUE do not provide evidence of localised depletion. Length and age frequencies have been stable over the last decade and do not provide evidence that the local availability or abundance over the last decade, including the last three fishing seasons.

DEPM surveys conducted in January 2014 and 2019 suggested that the spawning biomass of Jack Mackerel in the Eastern Sub-area of the SPF was between 150,000 and 160,000 t. Both studies highlighted the need for better understanding of the relationship between size and fecundity and spatiotemporal variations in spawning fraction. The failure of the DEPM survey in the Eastern Sub-area of the SPF in January 2024 to provide a robust estimate of spawning biomass highlighted serious limitations in current knowledge of the reproductive biology of Jack Mackerel. It also highlighted the critical importance of developing industry-based approaches to monitor levels of spawning activity to ensure that future DEPM surveys are conducted during the peak spawning season. A research project is needed to improve estimates of relative fecundity and to understand spatial and temporal variability in the spawning fraction of Jack Mackerel off south-eastern Australia. This project should also develop protocols for monitoring levels of spawning activity to ensure that future DEPM surveys are conducted during the peak spawning season. This project is needed to inform the timing and design of future DEPM surveys and ensure that they provide robust estimates of spawning biomass. The research project should be done before the next DEPM survey.

The results of the plankton survey conducted in the Western Sub-area of the SPF in December 2023 highlighted the unsuitability of the spatial management framework for the SPF for assessing the stock status of Jack Mackerel off south-eastern Australia. This issue needs to be considered when the results of future DEPM surveys are being interpreted. Consideration should be given to ensuring that future applications of the DEPM to Jack Mackerel off south-eastern Australia cover the entire biological stock, which likely extends from the from the Victorian-South Australian border through Bass Strait to the east coast as far south as Tasman Island and north to Port Stephens.

Redbait

Annual catches of Redbait by trawlers operating in the Eastern Sub-area of the SPF since 2019–20 have been relatively stable, ranging between 1,788 t and 2,412 t. The total catch in 2023–24 was 1,788 t, which was approximately 33% of the available TAC. Annual CPUE of Redbait by SPF trawlers operating off southern NSW since 2019–20 ranged from 1.3 and 2.4 t.trawl hr^{-1}, with the highest CPUE occurring in 2023–24. Patterns of annual CPUE do not suggest that the local availability or abundance have declined over the last decade, including the last three fishing seasons.

The expansion in the number of catch grids off southern NSW from which annual catches of Redbait have been taken since 2014-15 is likely to reflect increases in the combined catches of Blue Mackerel and Jack Mackerel over this period and the monthly spatial catch limits that have been established to reduce the potential for localised depletion. Length and age frequencies of Redbait off southern NSW have been relatively stable, but older Redbait have been caught in some years. Age and length frequency data do not provide evidence that the local availability or abundance of Redbait have declined over the last decade, including the last three fishing seasons.

The most recent application of the DEPM to Redbait in the Eastern Sub-area of the SPF suggested that the spawning biomass was approximately 52,000 t. The authors considered that the estimate of spawning biomass was likely to be conservative because a conservative approach was taken to estimating mean daily egg production. However, estimates of spawning fraction and relative fecundity used in calculations were lower than those used in previous studies, which, if incorrect, would have caused the spawning biomass to be over-estimated. These findings highlight the need for further investigation of the reproductive biology of Redbait off south-eastern Australia. However, because recent catches of Redbait have been relatively low compared to the current TAC, the need for this research is not as pressing as the need to address current limitations in the understanding of the reproductive biology of Jack Mackerel.

Discussion, Implications and Recommendations

In the short-term, two projects are needed to improve the monitoring and assessment framework for the SPF. Most importantly, a project is needed to improve current understanding of the reproductive biology of Jack Mackerel off south-eastern Australia and develop methods for monitoring levels of spawning activity to ensure that future DEPM surveys are conducted during the peak spawning season and provide robust estimates of spawning biomass. Because the results are needed to inform the design of future DEPM surveys, this project should be done prior to the next survey. A smaller project is also needed to collate historical fishery-dependent and fishery-independent data for the SPF and establish an integrated database that is available for scientists undertaking future monitoring and research on the fishery.

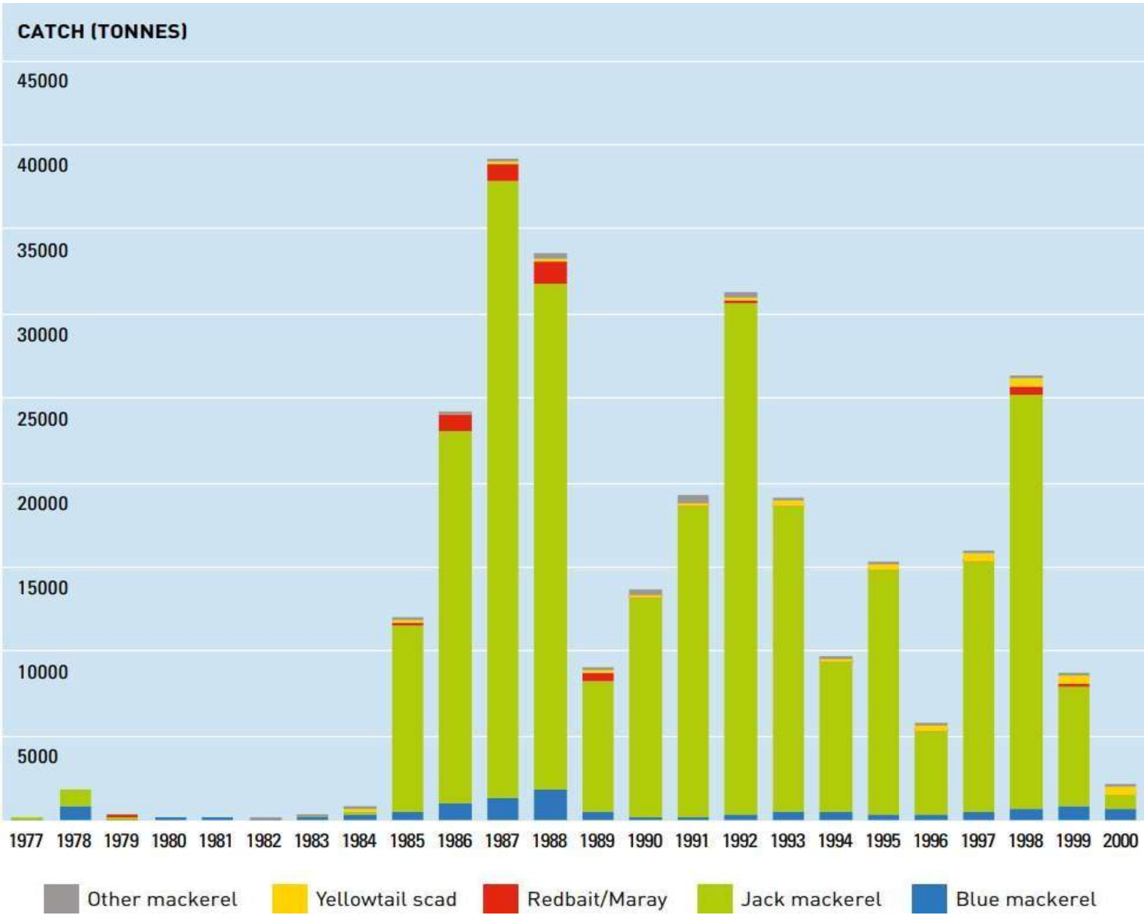
Keywords: Small Pelagic Fishery, Daily Egg Production Method, Spawning Biomass, Blue Mackerel, Jack Mackerel, Redbait, Sardine, Eastern sub-area, Western Sub-area

1. Introduction

1.1 Background

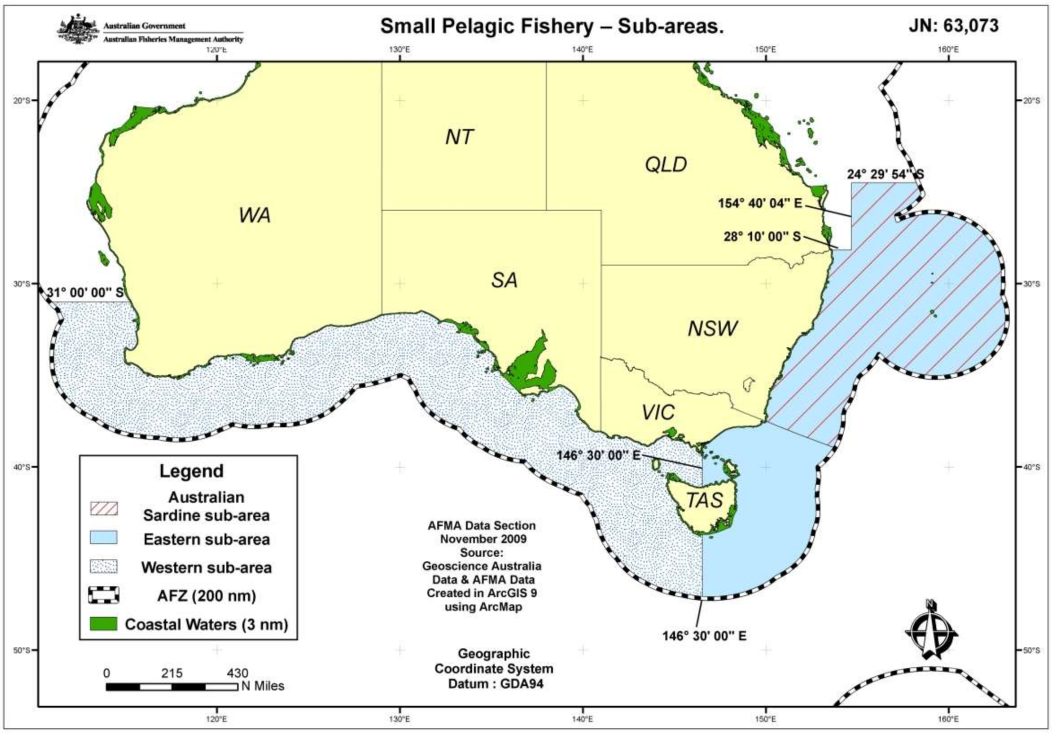
The Commonwealth Small Pelagic Fishery (SPF) was established in 2000 and is managed by the Australian Fisheries Management Authority (AFMA 2008 last revised 2024). The SPF evolved from the Jack Mackerel Fishery (JMF) that operated off Tasmania from 1977 to 2000 and was jointly managed by the Tasmanian and Commonwealth Governments (Bulman et al. 2008; Expert Panel Report 2014; Commonwealth of Australia 2016; Butler et al. 2024). The JMF was a purse-seine fishery, and Jack Mackerel (*Trachurus declivis*) was the target species and dominated catches (Figure 1–1). The highest annual catch in the JMF of approximately 39,700 t was taken in 1987 (Figure 1–1). The SPF retained many of the rules established for the JMF (e.g. four zones) until the SPF Harvest Strategy (SPF HS, AFMA 2008 last revised 2024) and Management Plan (AFMA 2009) were established in 2008 and 2009, respectively (see Bulman et al. 2008).

Figure 1–1. Total annual catch in the Jack Mackerel Fishery from 1977 to 2000. Figure modified from the Expert Panel Report (2014) after Bulman et al. (2008).



The SPF includes both purse-seine vessels and mid–water trawlers that can operate in Commonwealth waters (3 to 200 nm) between southern Queensland and south-western Western Australia, including waters around Tasmania (Figure 1–2). The quota (target) species are Jack Mackerel, Blue Mackerel (*Scomber australasicus*) and Redbait (*Emmelichthys nitidus*) in the Eastern and Western Sub-areas of the SPF (Figure 1–2), and Australian Sardine (*Sardinops sagax*) in the Sardine Sub-area (Figure 1–2). The SPF fishing season extends from 1 May to 30 April.

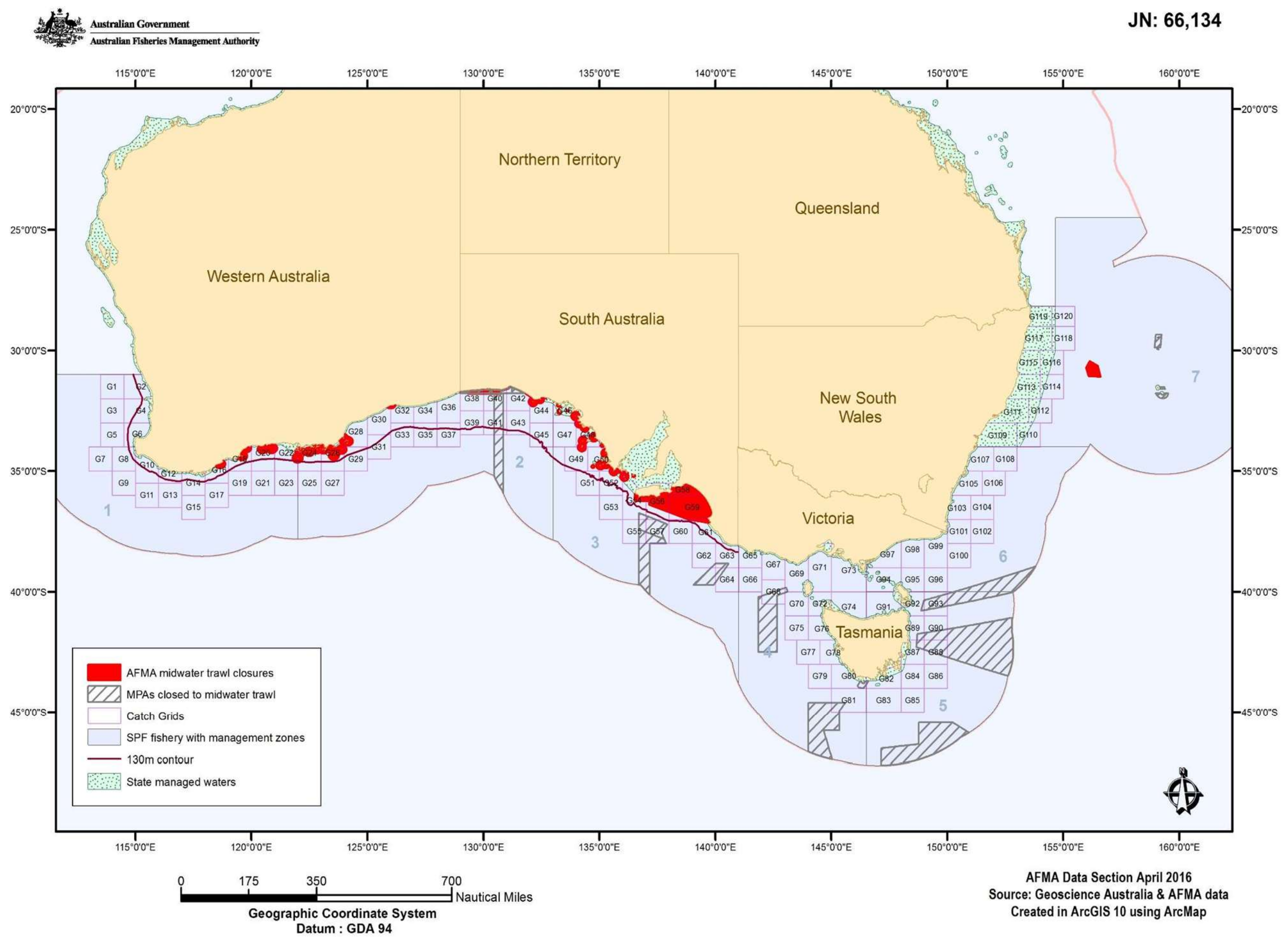
Figure 1–2 Management sub–areas of the Small Pelagic Fishery. (Source: AFMA 2009)



Additional spatial management arrangements have also been established in the SPF to reduce the potential for localised depletion of target species (AFMA 2023). A catch limit of 2,000 tonnes over a 30-day period is applied to the combined catch of target species within the catch grids shown in Figure 1–3. This spatial catch limit applies to all boats operating in the SPF regardless of fishing method.

The company that undertakes the fishing operation off southern NSW has also established a “Gentlemen’s Agreement” to reduce conflicts with game-fishing tournaments held out of local towns (e.g., Merimbula Open Marlin Competition, 8–10 June 2024). This agreement involves trawlers staying at least 30 km away from the tournament area for the week prior to the competition and 50 km away from the area during the competition (Tony Muollo, personal communication).

Figure 1–3. Areas closed to mid-water trawling, management zones and catch the SPF of the Small Pelagic Fishery. (Source: AFMA 2009)



1.2 SPF Harvest Strategy

The SPF HS uses a tiered approach to balance the different risks to stocks associated with higher and lower exploitation rates against the levels of information collected to monitor and assess stock status. The SPF HS was reviewed in 2024 in response to the rapid growth of the fishery and the need to establish decision rules that reduce the exploitation rate as the biomass approaches the point at which recruitment may be impaired. The Management Strategy Evaluations (Smith et al. 2015; Ward et al. 2024a) that underpin the exploitation rates established for individual SPF species in the SPF HS were designed to:

- maintain the spawning biomass of each species, on average, at 50% of the unfished level (B_{50})

- achieve a less than 10% chance over a 50–year period of the spawning biomass falling below the 20% of the unfished level (B_{20}).

Under the SPF HS, Recommended Biological Catches (RBCs) are calculated by applying species–specific exploitation rates (Table 1–1) to estimates of spawning biomass obtained using the Daily Egg Production Method (DEPM). Total Allowable Catches (TACs) are calculated by subtracting known sources of mortality from the RBCs.

The SPF HS Framework has three tiers (Table 1–1). Each tier is defined by the number of years since the last DEPM survey was conducted. The SPF HS Framework is designed to allow the level of investment in research and assessment to be varied to match commercial interest in exploiting the resource. Assessment costs and the level of information available to manage each stock are highest at Tier 1 and lowest at Tier 3.

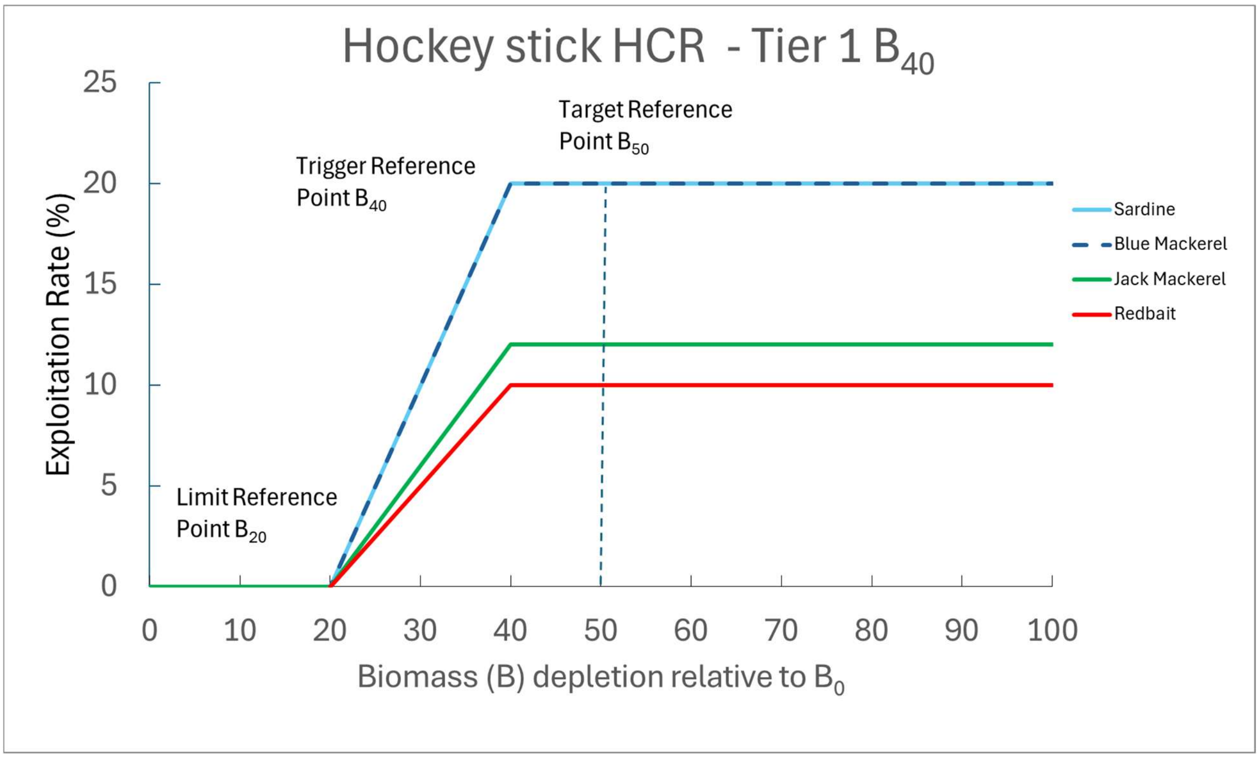
The SPF HS was revised in 2024 to reflect the results of an updated MSE (Ward et al. 2024a) that incorporated biological data collected since the previous MSE was completed (Smith et al 2015). The main changes to the SPF HS were refining the maximum exploitation rates for Blue Mackerel, Jack and Redbait, adding new Harvest Control Rules (HCRs), streamlining the text and consolidating the description of the three tiers into a single table (Table 1–1).

Species Sub–area(s)	**Tier 1**		**Tier 2**		**Tier 3**	
	Max ER	**Max Seasons**	**Max ER**	**Max Seasons**	**Max ER**	**Max Seasons**
Sardine						
Sardine	20%	5 seasons	10%	5 seasons	5%	Indefinite
Blue Mackerel						
Eastern	20%	5 seasons	10%	5 seasons	5%	Indefinite
Western	20%	5 seasons	10%	5 seasons	5%	Indefinite
Jack Mackerels						
Eastern	14%	5 seasons	7%	10 seasons	3.5%	Indefinite
Western	14%	5 seasons	7%	10 seasons	3.5%	Indefinite
Redbait						
Eastern	12%	5 seasons	6%	10 seasons	3%	Indefinite
Western	12%	5 seasons	6%	10 seasons	3%	Indefinite

Table 1–1. The revised SPF HS Framework showing maximum exploitation rates (Max ER) and maximum number of fishing seasons between applications of the DEPM (Max Seasons).

The new HCRs reduce the exploitation rates if the spawning biomass of a stock declines more than 20% below the Target Reference Point of B_{50} and towards the Limit Reference Point of B_{20} where recruitment is likely to be impaired. The HCRs specify that the maximum exploitation rate applied to a stock (Table 1–1) is reduced linearly (i.e., using a hockey stick rule, Figure 2) if the estimate of spawning biomass from the latest DEPM survey is below the Trigger Reference Point of B40 and above the Limit Reference Point of B20. The maximum exploitation rate for a stock is maintained if the spawning biomass is above B_{40} (Figure 1–2). Targeted fishing is ceased if the spawning biomass is below B_{20}. Reductions in the exploitation rate for each species at Tier 1 (i.e., a DEPM survey conducted within the last five years) under these HCRs are shown in Figure 1–2. Maximum exploitation rates at Tiers 2 and 3 are also reduced (i.e., to 50% and 25% of the Tier 1 level, respectively) if the estimate of spawning biomass from the latest DEPM survey was between B_{40} and B_{20}. The maximum exploitation rate at each tier is maintained if the estimate of spawning biomass from the latest DEPM survey was above of B_{40}. Targeted fishing is ceased at all tiers if the spawning biomass is below B_{20}.

Figure 1–4. Harvest Control Rules for linearly reducing (i.e., using a hockey stick rule) the exploitation rates for each species at Tier 1 (Table 1–1) if the estimate of spawning biomass from the latest DEPM survey is below the proxy Trigger Reference Point of B_{40} and above the proxy Limit Reference Point of B_{20}. The maximum exploitation rate is maintained if the spawning biomass is above B_{40}. Targeted fishing is ceased if the spawning biomass is below B_{20}.



1.3 Assessment and Monitoring

The amount of fishery–dependent information collected for a stock varies among tiers as outlined in the HS Framework. An Annual Fishery Assessment is required for stocks at Tier 1 and Tier 2, whereas a review of available catch and effort data is undertaken for stocks at

Tier 3. The Annual Fishery Assessment provides a detailed analysis of the data obtained from the fishery during the previous fishing season and evaluates stock status between applications of the DEPM.

The Annual Fishery Assessment is used by SPF RAG to evaluate if there are reasons to recommend exploitation rates lower than the maximum rates identified in the SPF HS Framework. The Annual Fishery Assessment must include:

- historical catch, effort and CPUE data from 2001 onwards
- detailed analyses of catch, effort and CPUE data from the previous fishing season
- length frequency and age structure information from catches for each stock fished
- analysis of spatial and temporal patterns of effort and catch, and
- evidence suitable for detecting stock depletion, localised depletion or changes in the size and age structure of the catch that cannot be adequately explained by reasons other than a decline in abundance.

1.4 Objectives

The aim of this project was to conduct monitoring and assessment of quota (target) species in the SPF for the 2021–22, 2022–23 and 2023–24 fishing seasons. Consistent with the SPF HS Framework, the objectives of this report are to:

1. Summarise catch and effort data from logbooks, observers and catch and disposal records for each target species in each sub-area of the SPF
2. Collect length and age frequency data for Blue Mackerel, Jack Mackerel and Redbait in the Eastern Sub-area of the SPF
3. Evaluate spatial and temporal patterns in catch, effort, CPUE, length and age frequency data for evidence of potential localised depletion of target species
4. Synthesize and critically evaluate information from historical applications of the Daily Egg Production Method (DEPM) to target species
5. Provide recommendations to inform the ongoing refinement of the monitoring and assessment program for the SPF, including identifying additional research that may be required to ensure that future estimates of spawning biomass of target species obtained using the DEPM are as robust as possible.

The information complied to address these five objectives was evaluated for evidence of stock depletion, localised depletion or changes in the size and age structure of the catch that cannot be adequately explained by reasons other than a decline in abundance.

2. Methods

2.1 Annual catch, effort and CPUE

This report summarises annual catch, effort and catch–per–unit effort (CPUE) data for target species taken by mid–water trawlers and purse-seine vessels in the three sub-areas of the SPF from 2001–02 to 2023–24. The report on the fishing seasons of 2021–22, 2022–23 and 2023–24. SPF data used in this report were provided to IMAS by AFMA. Catch, effort and CPUE data are also presented for NSW purse-seine vessels targeting Blue Mackerel and Sardine in the Sardine Sub-area of the SPF. The NSW data were provided to IMAS in summarised form (i.e., annual total catch and effort) by the NSW Department of Primary Industries (DPI). CPUE was calculated from total catch and effort by year using a simple ratio estimator. Variance (± Standard Error) was estimated from individual CPUE values (Rice 1995) in the software package R (R Core Team 2022). .

2.2 Monthly and weekly CPUE

Monthly and weekly patterns of catch and CPUE were evaluated for evidence of potential localised depletion of each SPF target species.

2.3 Length and age frequencies

Data used to estimate length– and age–frequencies were obtained from samples of Blue Mackerel, Jack Mackerel and Redbait collected from the East Sub-area of the SPF by industry and/or AFMA observers during the 2021–22, 2022–23 and 2023–24 fishing seasons (Table 2–1). Images of historical length– and age–frequencies were sourced from Grammer et al. (2022).

Ages were estimated from five fish randomly selected from each sample as recommended by Ward and Grammer (2019). The age of each fish was estimated by counting the edges of opaque zones in thin sectioned otoliths using methods consistent with those applied in previous studies (see Grammer et al. 2022 for detailed descriptions). The methods used for each species follow the approaches developed by Marriott and Manning (2011) for Blue Mackerel, Lyle et al. (2000) for Jack Mackerel, and Ewing and Lyle (2009) for Redbait. Ageing techniques used for Jack Mackerel and Redbait were calibrated using the otolith reference collection at IMAS. Otoliths from reference collections held by the NSW DPI and the South Australian Research and Development Institute (SARDI) were used to calibrate the ageing techniques used for Blue Mackerel. Each otolith was aged by two readers. Where the counts of the readers differed, the otolith was re–read and aged by consensus. To account for uneven sample sizes, length- and age-frequencies were weighted by the number of fish in each sample and by the total weight of that species in the corresponding trawl.

Fishing Season	Species	Samples (N)	Fish (n)	Otoliths Weighed	Otoliths Read
2021–22	Blue Mackerel	19	183	165	179
2021–22	Jack Mackerel	20	200	196	198
2021–22	Redbait	15	160	124	146
2022–23	Blue Mackerel*	24	244	234	118
2022–23	Blue Mackerel	8	121	115	59
2022–23	Jack Mackerel	25	288	287	120
2022–23	Redbait	20	237	234	95
2023–24	Blue Mackerel	24	471	162	113
2023–24	Jack Mackerel	25	565	137	122
2023–24	Redbait	17	329	79	85

`Table 2–1. Number of samples (N), fish measured (n), otoliths weighed and otoliths read for Blue Mackerel, Jack Mackerel and Redbait in the 2021–22, 2022–23 and 2023–24 fishing seasons.

2.4 Historical applications of the DEPM

Under the SPF HS, estimates of spawning biomass obtained using the DEPM are used to set RBCs and TACs. The concept underpinning the DEPM is that the spawning biomass of fish that spawn pelagic eggs can be estimated by dividing the mean number of eggs produced per day throughout the spawning area (total daily egg production) by the mean number of eggs produced per unit mass of adult fish (mean daily fecundity; Parker, 1980; Ward et al. 2021b). Total daily egg production is calculated from estimates of mean daily egg production (P_0) and spawning area (A) obtained from ichthyoplankton surveys. Mean daily fecundity is estimated from three adult reproductive parameters, i.e. sex ratio by weight (R), spawning fraction (S) and relative fecundity (F‘), that are estimated from samples obtained from either fishery–dependent or fishery–independent sampling.

The DEPM has now been applied to each target species in the three sub-areas of the SPF (Table 2–2). Details of how the method was applied to each target species in each Sub-area of the SPF are described in the publications listed in Table 2–2. The current report summarises the results of these applications of the DEPM to target species and identifies research that is needed to ensure that future estimates of spawning biomass obtained for each stock are as robust as possible.

SPF Sub-area	Species	Years DEPM was applied	Reference
Eastern	Blue Mackerel	2003 2004 2014 2019 2024	Ward et al. (2007, 2009) Ward et al. (2007, 2009) Ward et al. (2015b) Ward et al. (2021) Ward et al. (in prep)
Eastern	Jack Mackerel	2002 2014 2019 2024	Neira (2011) Ward et al. (2015a) Ward et al. (2020) Ward et al. (2025)
Eastern	Redbait	2005 2006 2020	Neira et al. (2008), Neira and Lyle (2011) Neira et al. (2008), Neira and Lyle (2011) Grammer et al.(2022)
Sardine	Sardine	1997 1998 2014 2019 2024	Staunton Smith and Ward (2000) Staunton Smith and Ward (2000) Ward et al. (2015b) Ward et al. (2020) Ward et al. (in prep)
Western	Blue Mackerel	2005	Ward and Rogers (2007), Ward et al, (2009)
Western	Jack Mackerel	2017 2023	Ward et al. (2018) Ward et al. (2025)
Western	Redbait	2017	Ward et al. (2018)

Table 2–2. Years in which the Daily Egg Production Method has been applied to target species in each of the three sub-areas of the SPF.

2.5 Recommendations

Information collated in this project are used to evaluate the suitability of the current monitoring and assessment program for the SPF and, if necessary, identify options for improvement. This report also identifies research that may be needed to ensure that future applications of the DEPM to each target species provide estimates of spawning biomass that are as robust as possible.

3. Results

3.1 Overview

Annual catch, effort and CPUE

Total catches in the 2021–22, 2022–23 and 2023–24 fishing seasons were the three highest in the history of the SPF (Figure 3–1A). The total catch in 2023–24 was 23,055 t.

Mid-water trawlers (henceforth called trawlers) have taken most of the SPF catch since 2001–02 (Figure 3–1B). The total catch by SPF trawlers in the 2021–22, 2022–23 and 2023–24 fishing seasons were the three highest on record. The total catch by SPF trawlers in 2023–24 was 22,991 t.

The trawl sector of the SPF has grown rapidly over the last decade (Figure 3–1B, C). A factory-trawler operated in the SPF from 2014–15 to 2016–17 and a trawl operation was established off southern NSW in 2016–17 (Grammer et al 2022). Since 2014–15, most of the SPF catch has been taken by trawlers operating off southern NSW (Figure 3–2) and annual catches have been dominated by Jack Mackerel and Blue Mackerel (Figure 3–1A, B). In contrast, from 2001–02 to 2010–11, most trawl catches were taken around Tasmania and Redbait was the main species taken (Figure 3–1B, 3–2). Low levels of catch and effort by SPF trawlers from 2011–12 and 2014–2015 are likely to reflect a lack of markets and fish availability near the processing facility off eastern Tasmania rather than low levels of overall abundance (Butler et al. 2024).

The CPUE of trawlers operating off southern NSW since 2015/16 has been relatively stable, ranging from 8.2 in 2017–18 to 13.6 t. trawl.hr^{-1} in 2021–22 (Figure 3–1C). The decline in the CPUE of SPF trawlers from 2003–04 to 2010–11 is likely to reflect the reduced catches of Redbait off eastern Tasmania during this period (Figure 3–1B, 3–2).

SPF purse-seine vessels caught over 500 t per annum from 2003–04 to 2010–11 (Figure 3–1D. Most of the catch was Blue Mackerel and Sardine. The highest total annual catch SPF purse-seine vessels was 3,603 t in 2006–07, which included 2,221 t of Blue Mackerel and 1,166 t of Sardine. The annual catch SPF purse-seine vessels has not exceeded 250 t since 2010–11. The total SPF purse-seine catch in 2023–24 was 64 t.

Localised depletion

The expansion in the number of catch grids (Figure 3–2) off southern NSW from which annual catches in the SPF have been taken since 2014-15 (Figure 3–2) may reflect the combined effects of the increases in total annual catches over this period and the monthly spatial catch limits (i.e., 2000 t over 30 days in each catch grid) that were established to reduce the potential for localised depletion. There is no apparent decline in monthly or weekly patterns of catch and CPUE off southern NSW over the last three fishing seasons that would suggest that localised depletion has occurred (Figure 3–3). In contrast, the reductions in catch and CPUE off southern Tasmania from 2003–04 to 2010–11 are consistent with a reduction in the local availability or abundance of target species.

Figure 3–1. Total annual catch in the SPF (A), annual catch, effort and catch–per–unit–effort (CPUE) by SPF trawlers (B and C) and SPF purse-seine vessels (D and E) from 2000–01 to 2023–24.

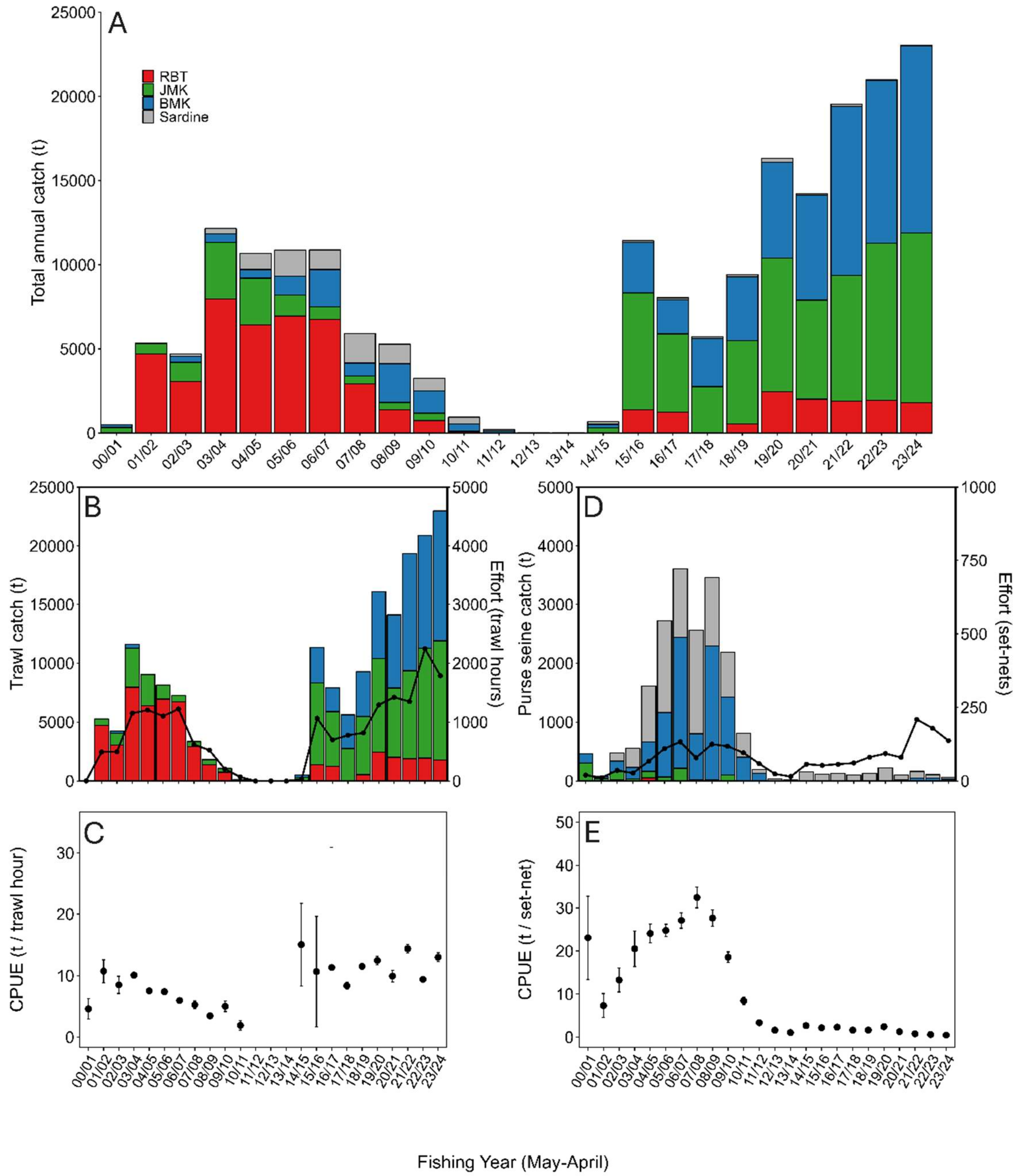


Figure 3–2. Spatial distribution of catches in SPF trawlers and purse-seinevessels (combined) from 2000–01 to 2023–24.

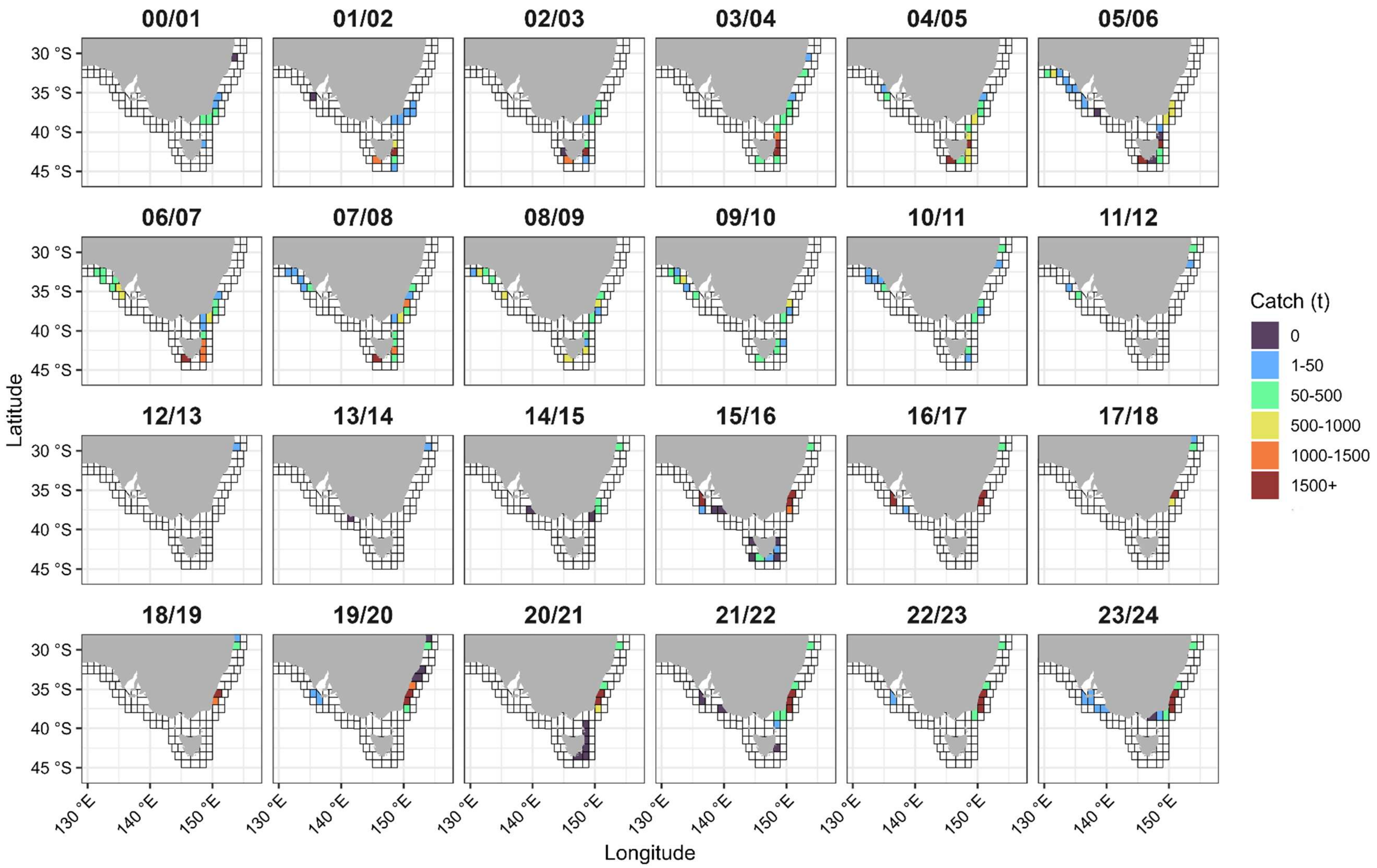
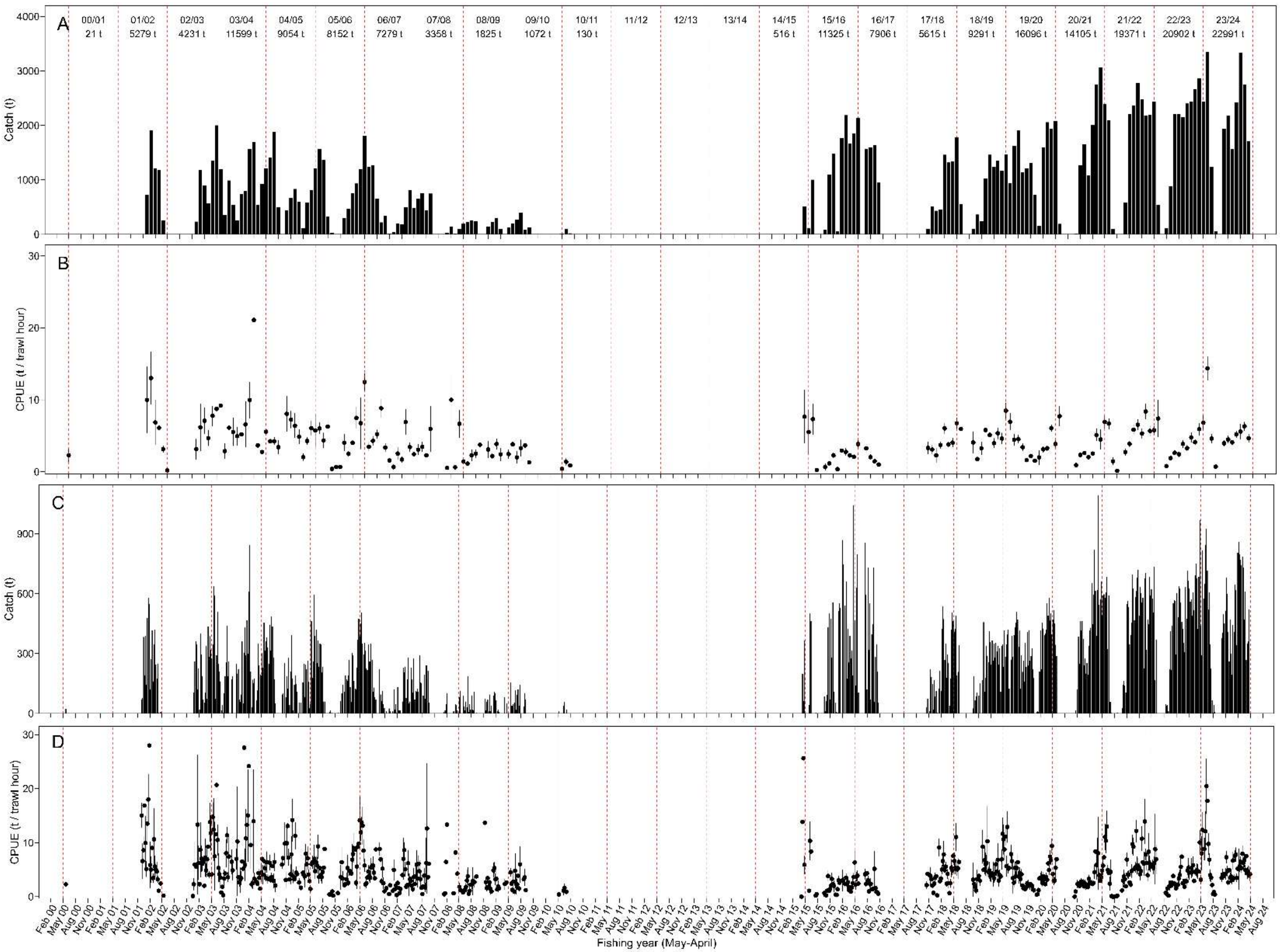


Figure 3–3 Monthly and weekly CPUE of target species by SPF trawlers from 2000–01 to 2023–24.



3.2 Eastern Sub-area

3.2.1 Blue Mackerel

Annual catch, effort and CPUE

Annual catches, effort and CPUE of Blue Mackerel by trawlers operating in the Eastern Sub-area of the SPF are shown in Figure 3–4A, B. Annual catches of Blue Mackerel by SPF trawlers did not exceed 350 t until 2015–16. Since 2015–16, the lowest annual catch was 1,247 t in 2016–17.

Total catches of Blue Mackerel by trawlers in the Eastern Sub-area of the SPF in the 2021–22, 2022–23 and 2023–24 fishing seasons were the three highest on record (Figure 3–4A). The total catch of Blue Mackerel in 2023–24 was 11,049 t, which was 95.2% of the available TAC of 11,610 t (AFMA 2023).

Since 2014–15, most of the SPF catch of Blue Mackerel has been taken off southern NSW (Figure 3–5). In contrast, annual catches of Blue Mackerel from 2000–01 to 2010–11 of less than 310 t were taken by trawlers that operated in the Eastern Sub-area of the SPF (Figure 3–4, 3–5). CPUE of Blue Mackerel by trawlers operating off southern NSW since 2015–16 have ranged between 3.5 and 8.1 t.trawl hr^{-1}. Annual CPUE does not show a pattern of decline that suggests the local abundance or availability of Blue Mackerel have declined over this period.

Since 2015-16, annual catches of Blue Mackerel taken by purse-seine vessels operating in the SPF and the NSW Ocean Haul Fishery have been much lower than those taken by SPF trawlers (Figure 3–4C, 3–4D). The highest catch of SPF and NSW purse-seine vessels were 280 t in 2005-06 and 583 t in 2004-05, respectively. In 2023–24, the annual catches of SPF and NSW purse-seine vessels were 30 t and 237 t, respectively.

Localised depletion

The expansion in the number of catch grids (Figure 1–3) off southern NSW from which annual catches of Blue Mackerel have been taken since 2014-15 (Figure 3–5) may reflect the combined effects of the increases in total annual catches over this period and the monthly spatial catch limits (i.e., 2000 t over 30 days in each catch grid) that were established to reduce the potential for localised depletion. Monthly and weekly patterns of catch and CPUE (Figure 3–6) do not suggest that there has been localised depletion of Blue Mackerel off southern NSW .

Figure 3–4. Total annual catch, effort and catch–per–unit–effort (CPUE) of Blue Mackerel by SPF trawlers (A and B), SPF purse-seine vessels (C and D) and NSW purse-seinevessels (E–F) from 2000–01 to 2023–2024.

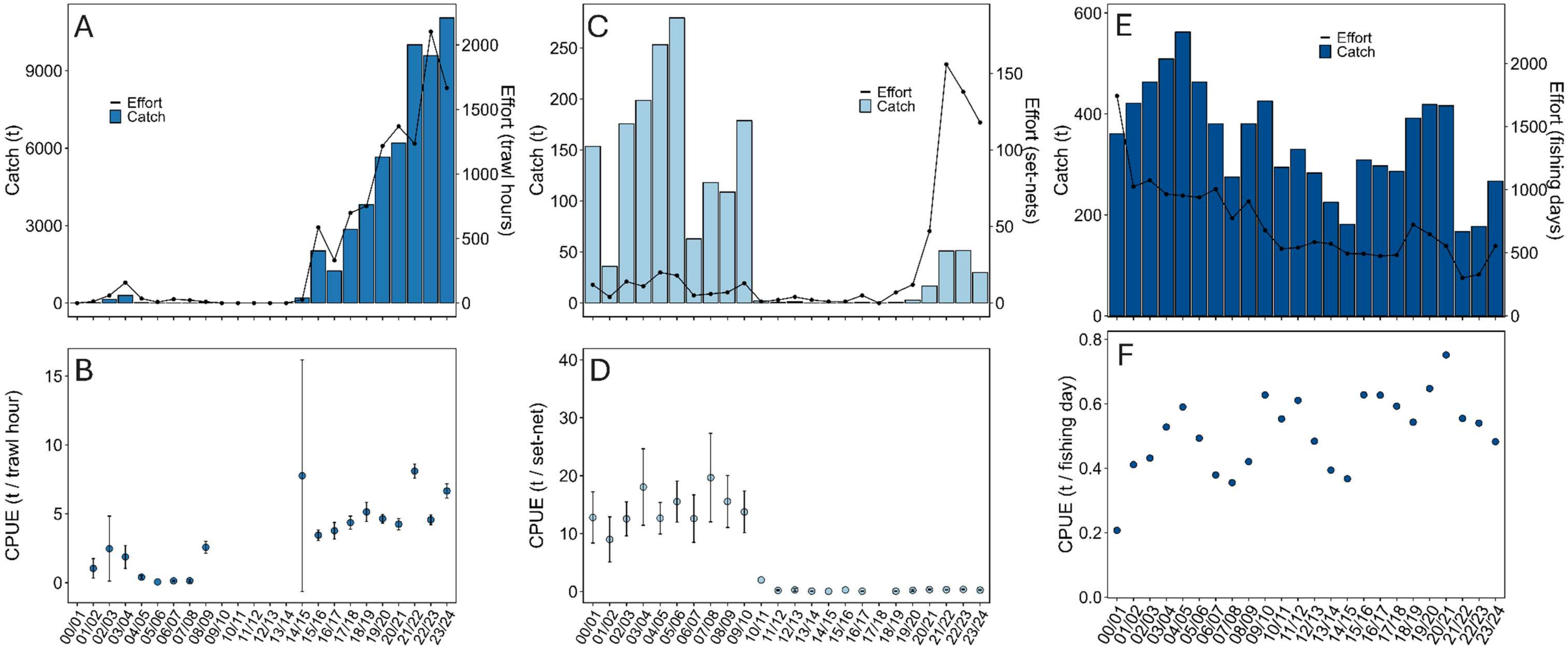


Figure 3–5. Spatial distribution of catches of Blue Mackerel in the SPF trawlers and purse-seine vessels (combined) from 2000–01 to 2023–24.

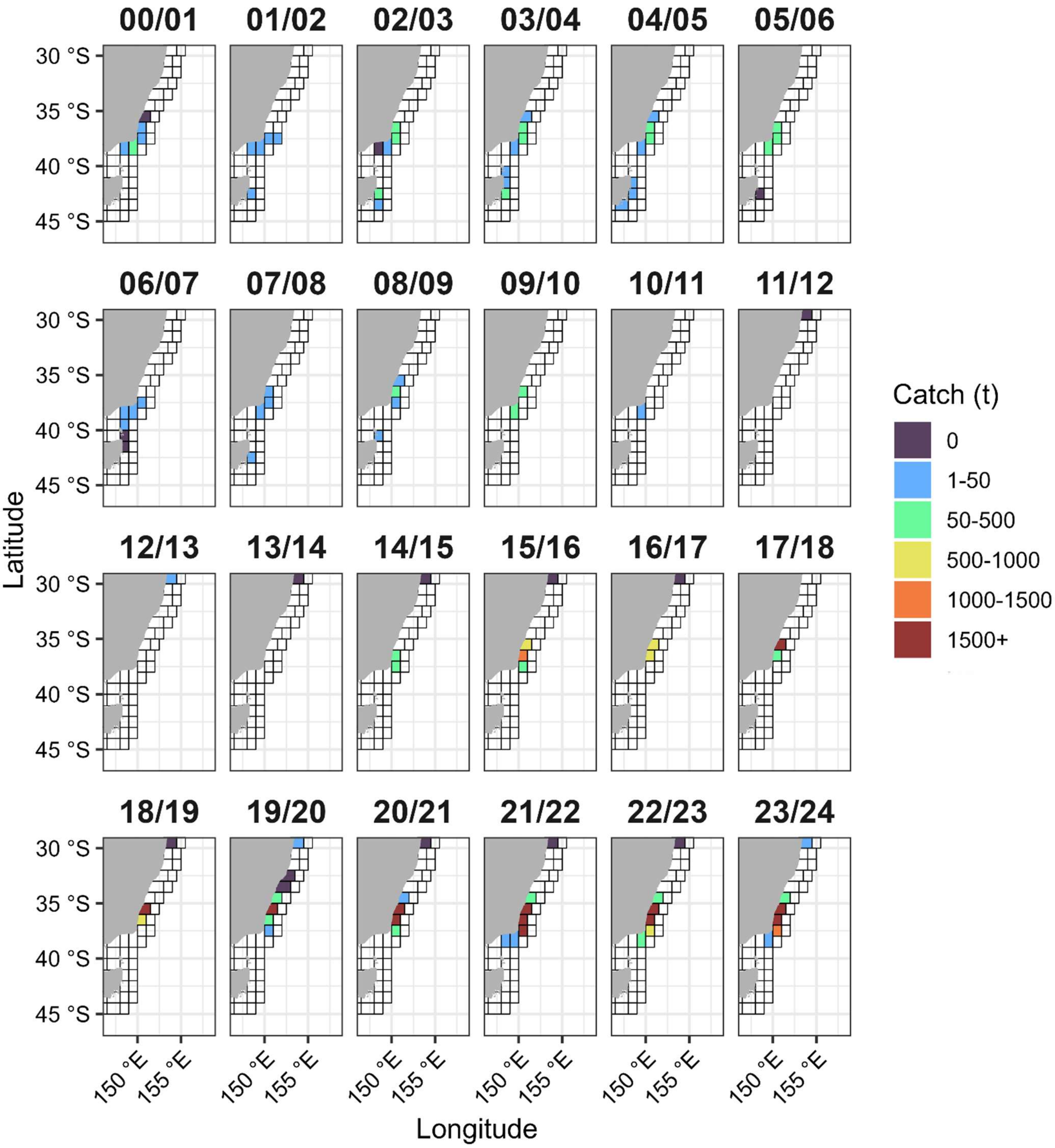
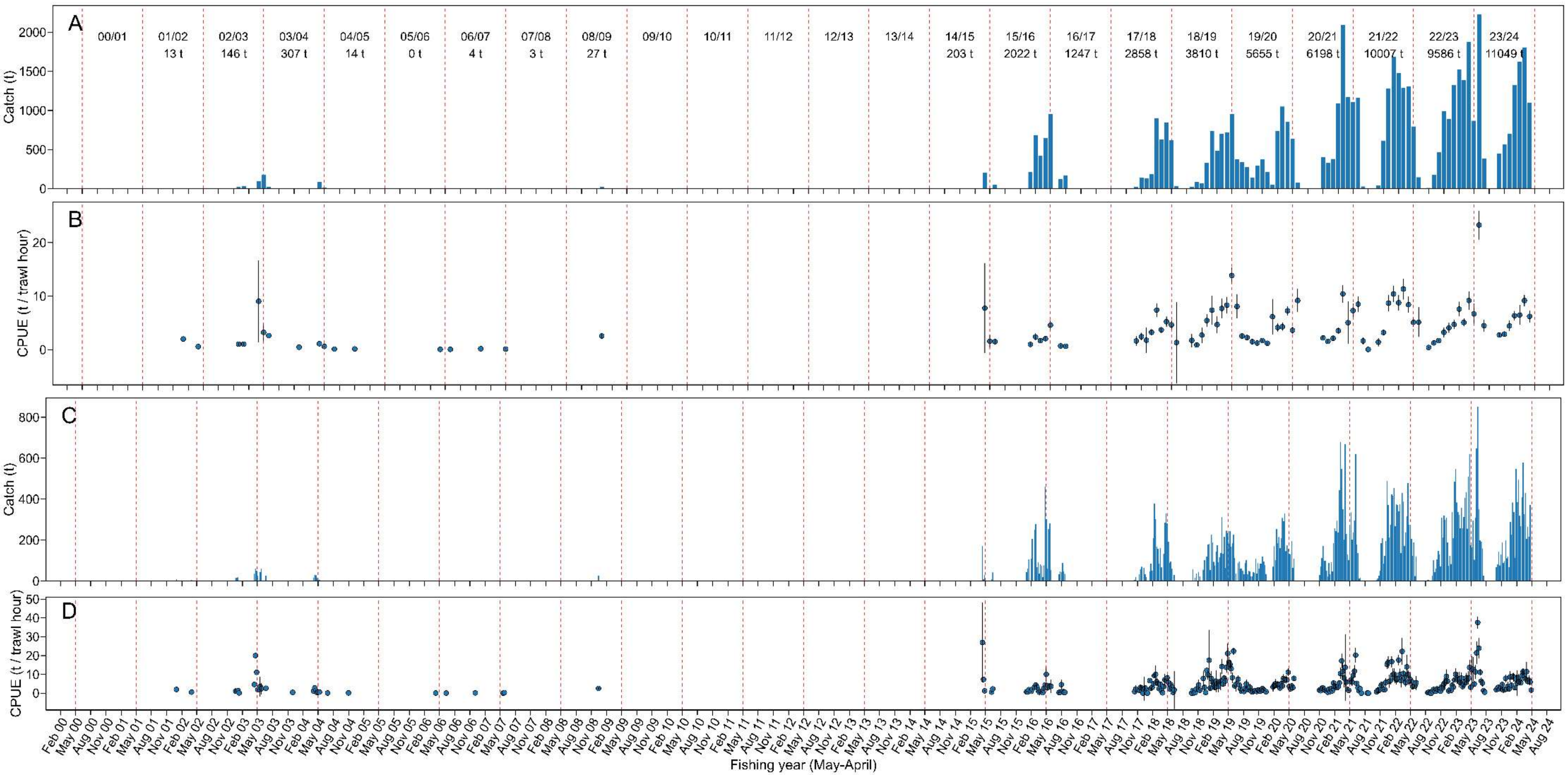


Figure 3–6. Monthly and weekly catch and CPUE of Blue Mackerel by SPF trawlers from 2000–01 to 2023–24.



Length and age frequencies

The modal lengths and ages of Blue Mackerel off southern NSW have typically been between 240 and 300 mm and 2-3 years, respectively (Figures 3–7, 3–8). There have been no changes in the modal length or age frequencies (Figures 3–7, 3–8) that suggest the local availability or abundance of Blue Mackerel off southern NSW have been declined over the last decade, including over the last three fishing seasons.

Daily Egg Production Method

The DEPM was first applied to Blue Mackerel in the Eastern Sub-area of the SPF by Ward and Rogers (2007) and Ward et al. (2009) based on plankton surveys conducted in October 2003 and July 2004. The results of those studies were preliminary but demonstrated the potential suitability of the DEPM for ongoing assessment of Blue Mackerel. Reproductive data published by Rogers et al. (2009) showed that the peak spawning season of Blue Mackerel off eastern Australia occurred in September. The best estimate of spawning biomass provided by Ward et al. (2009) for Blue Mackerel off eastern Australia of approximately 30,000 t was considered conservative, partly because it was conducted outside the peak spawning season. The other key uncertainty in this application of the DEPM was that adult parameters were estimated using data from South Australia. Ward et al. (2009) identified that the highest immediate priorities for additional research to improve the application of the DEPM in the Eastern Sub-area of the SPF were: (1) to develop cost-effective and reliable genetic techniques for identifying early stage eggs; (2) to establish a temperature-egg development key; (3) to identify locations and methods for collecting samples to estimate adult reproductive parameters; and (4) to measure the degeneration rates of POFs to ensure that estimates of spawning fraction are reliable.

The DEPM was re-applied to Blue Mackerel in the Eastern Sub-area of the SPF in 2014 and 2019. The distribution and abundance of Blue Mackerel eggs collected in the plankton surveys conducted during 2014 and 2019 were similar (Figure 3–9). Trawl surveys conducted in both years failed to collect adult samples suitable for estimating adult DEPM parameters, especially spawning fraction. Estimates of adult parameters from samples collected from South Australia (Rogers et al. 2009; Ward et al. 2009) were again used to estimate spawning biomass. Ward et al. (2015) indicated that because the estimate of spawning biomass for 2014 of 83,304 t was based on estimates of adult parameters from South Australia it should be treated with caution. The estimate of spawning biomass for 2019 of 88,265 t came with similar caveats. The similarity of the estimates of spawning biomass for 2024 and 2019 reflect both the similarity of the estimates of mean daily egg production and spawning area obtained in the two surveys, and the use of same adult reproductive data from South Australia. A targeted study to designed obtain samples suitable for estimating spawning fraction of Blue Mackerel off eastern Australia was conducted from 2022 to 2024 (Ward et al. 2023). The results of that study will be used in the application of the DEPM to Blue Mackerel in the Eastern Sub-area of the SPF in September 2024.

Figure 3–7. Annual length frequencies of Blue Mackerel in catches by SPF trawlers from 2000–01 to 2023–24.

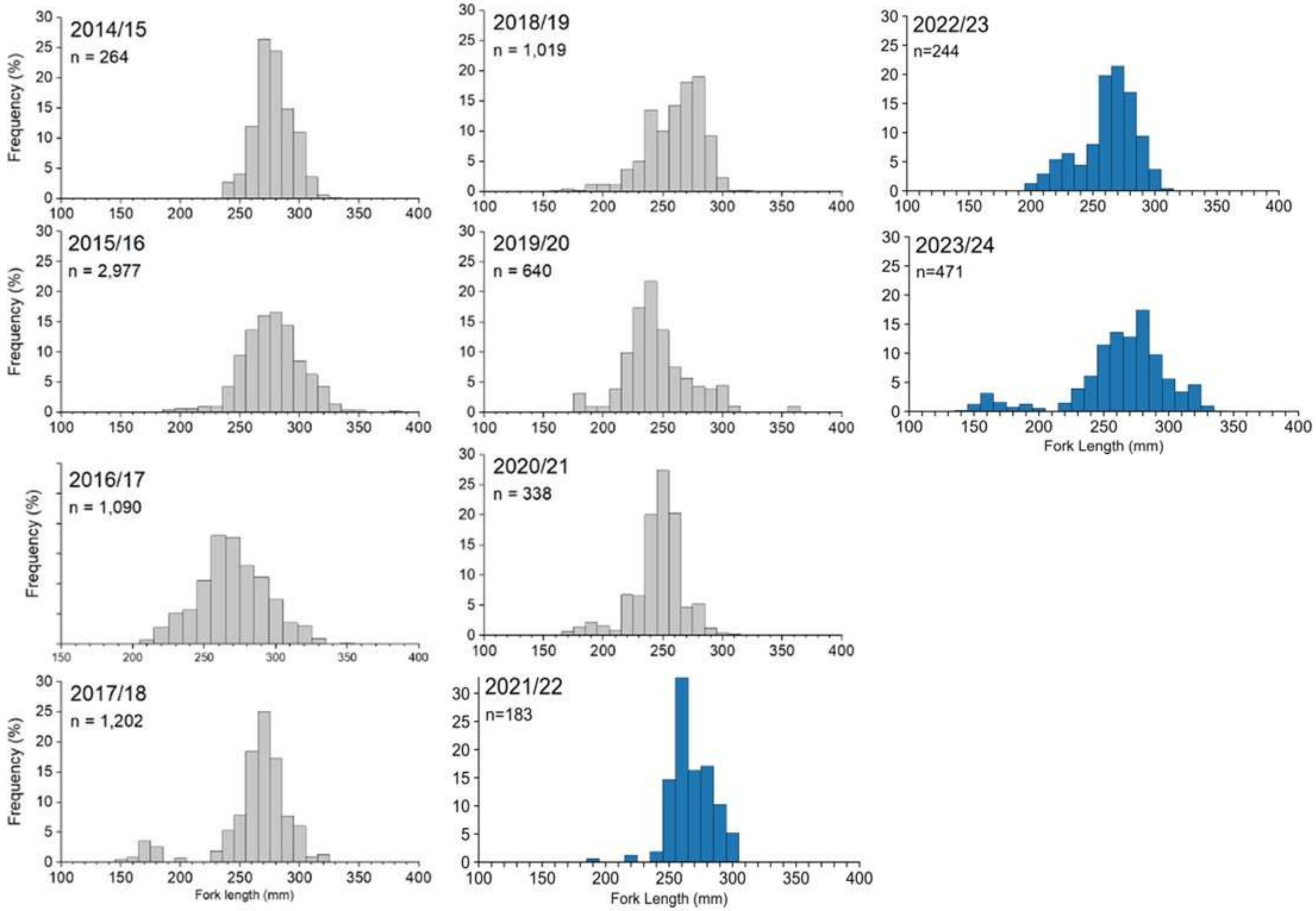


Figure 3–8. Annual age frequencies of Blue Mackerel in catches by SPF trawlers from 2000–01 to 2023–24.

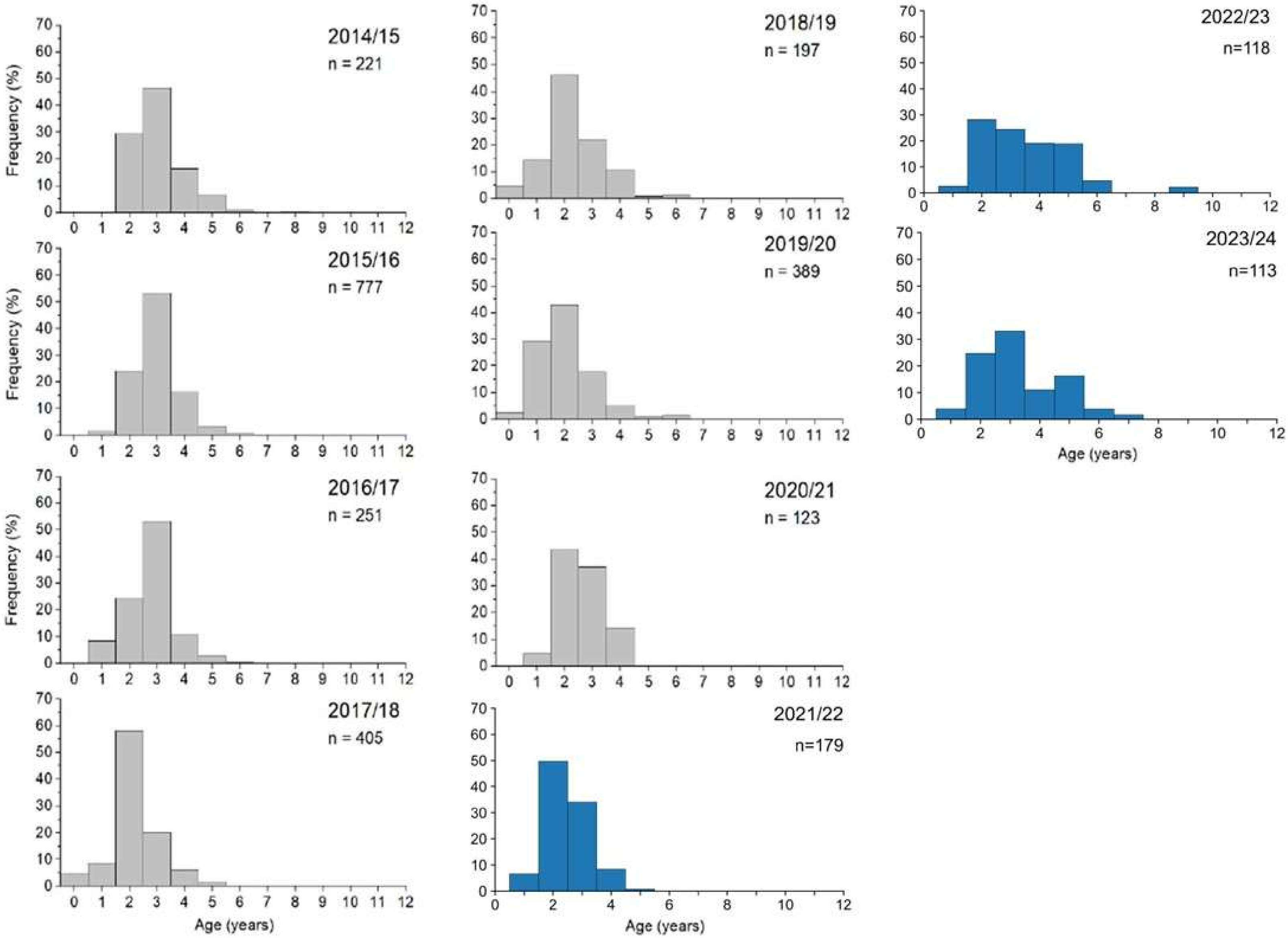
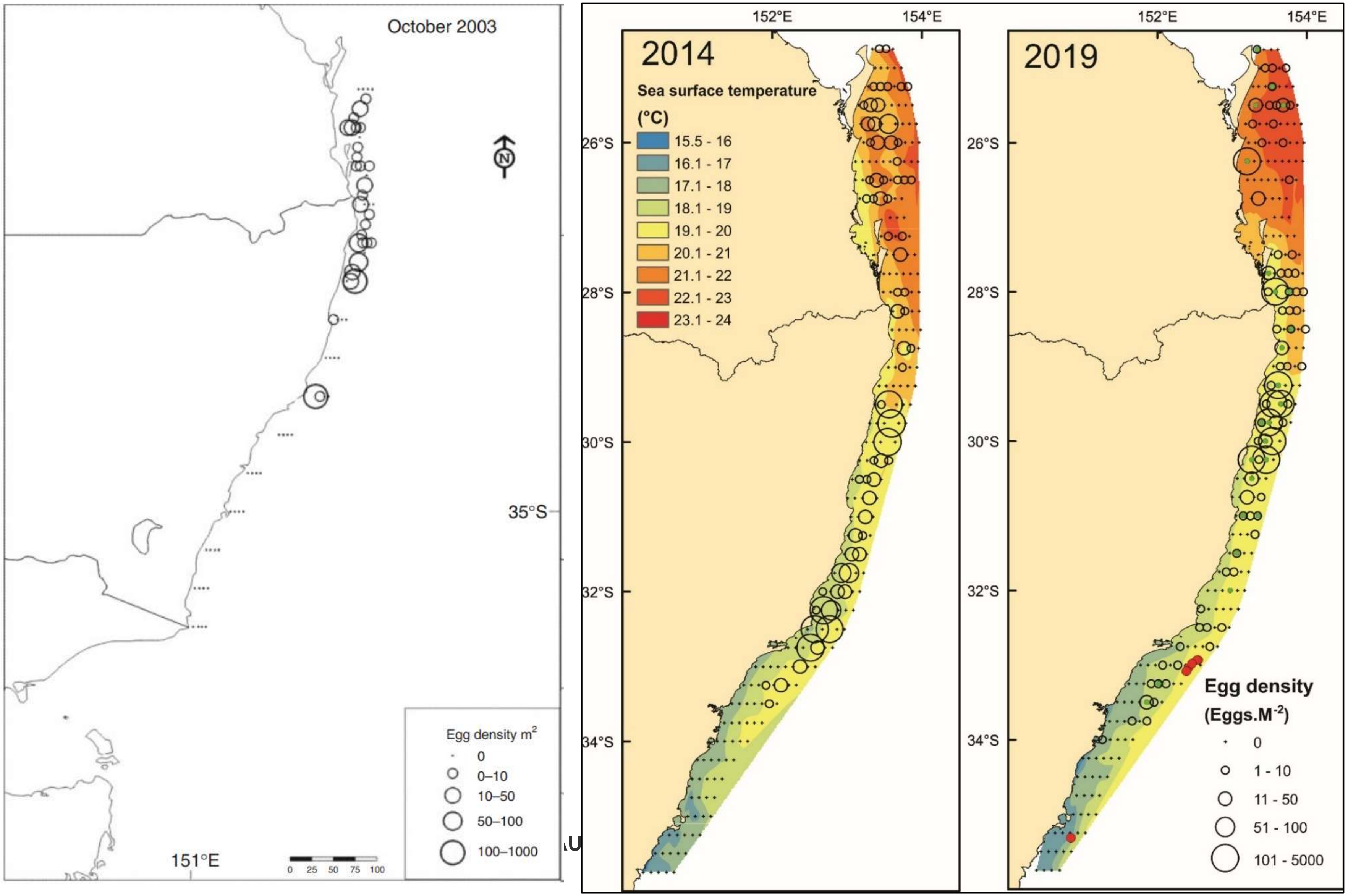


Figure 3–9. Maps showing densities of Blue Mackerel eggs and Sea Surface Temperatures (SSTs) in plankton surveys conducted in the Eastern Sub-area in October 2013, August-September 2014 and September 2019.



3.2 Eastern Sub-area

3.2.2 Jack Mackerel

Annual catch, effort and CPUE

Annual catches, effort and CPUE of Jack Mackerel by trawlers operating in the Eastern Sub-area of the SPF are shown in Figure 3–10A, B. Total catches in the 2022–23 and 2023–24 fishing seasons were the highest on record (Figure 3–10A). The total catch in 2023–24 was 10,084 t, which was 53.9% of the available TAC of 18,720 t (AFMA 2023).

Since 2014–15, most of the catch of Jack Mackerel in the SPF has been taken off southern NSW (Figure 3–11). In contrast, from 2000–01 to 2010–11 most of the catch of Jack Mackerel was taken by trawlers operating off Tasmania and the highest annual catch was 3,300 t in 2003–04 (Figure 3–10, 3–11). Since 2015–16, CPUE of Jack Mackerel by SPF trawlers operating off southern NSW has ranged from 4.2 to 11.6 t.trawl hr^{-1}. Annual CPUE does not show a pattern of decline that suggests the local abundance or availability of Blue Mackerel have declined over this period

Annual catches of Jack Mackerel taken by SPF purse-seine vessels have been much lower than those taken by trawlers (Figure 3–10C, 3–10D). The highest annual catch of Jack Mackerel by SPF purse-seine vessels was 307 t, which was taken off eastern Tasmania in 2000–01. The annual catch of Jack Mackerel by SPF purse-seine vessels has not exceeded 100 t since 2004–05.

Localised depletion

The expansion in the number of catch grids (Figure 1–3) off southern NSW from which annual catches of Jack Mackerel have been taken since 2014-15 (Figure 3–11) likely reflects the combined effects of increases in total annual catches over this period and the monthly spatial catch limits (2,000 t over 30 days in each grid square) that were established to reduce the potential for localised depletion. Monthly and weekly patterns of catch and CPUE of Jack Mackerel shown in Figure 3–12 do not provide evidence of localised depletion.

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Figure 3–10. Total annual catch, effort and CPUE of Jack Mackerel by SPF trawlers (A and B) and SPF purse-seine vessels (C and D) from 2000–01 to 2023–2024

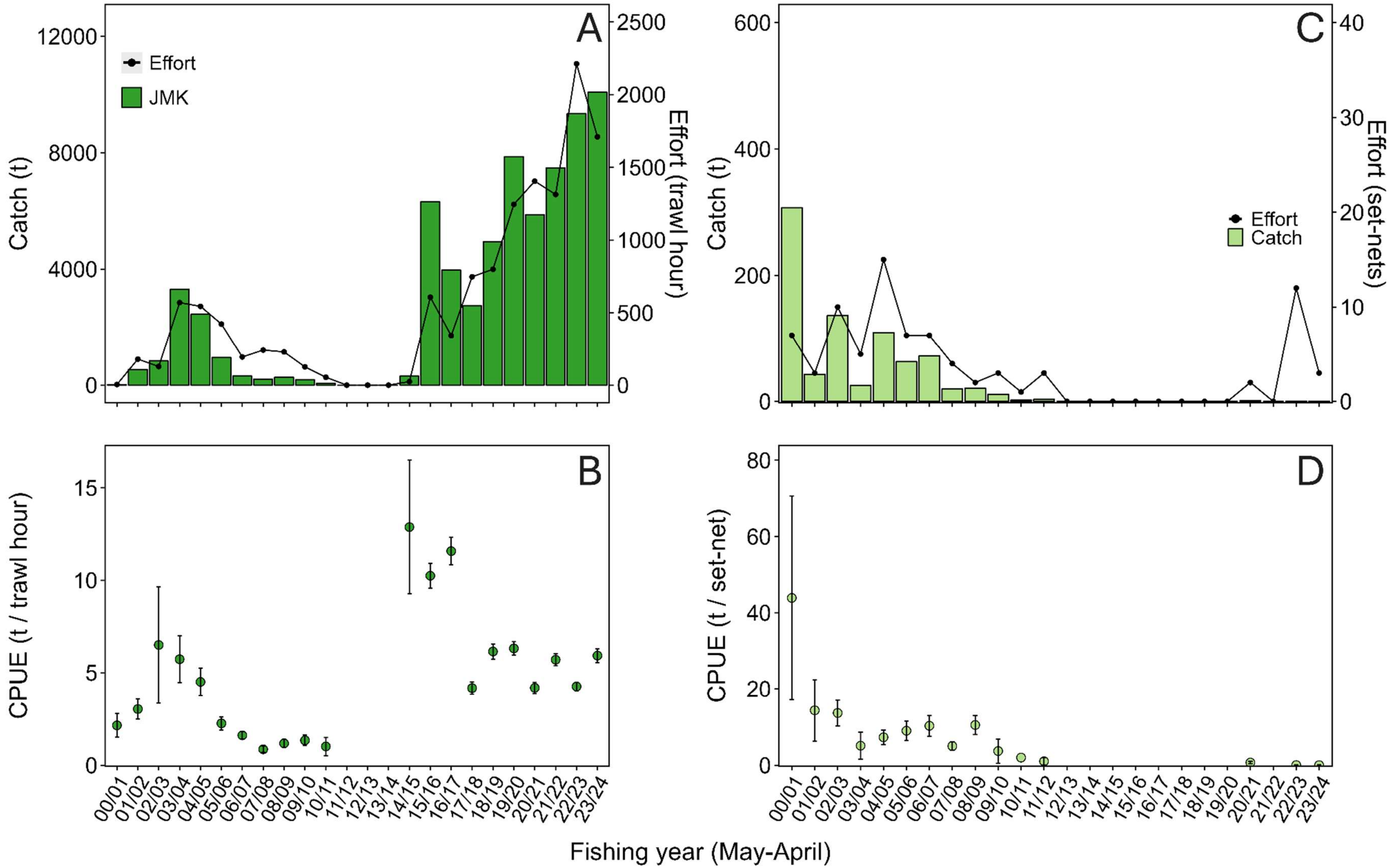


Figure 3–11. Spatial distribution of catches of Jack Mackerel in the SPF from 2000–01 to 2023–24.

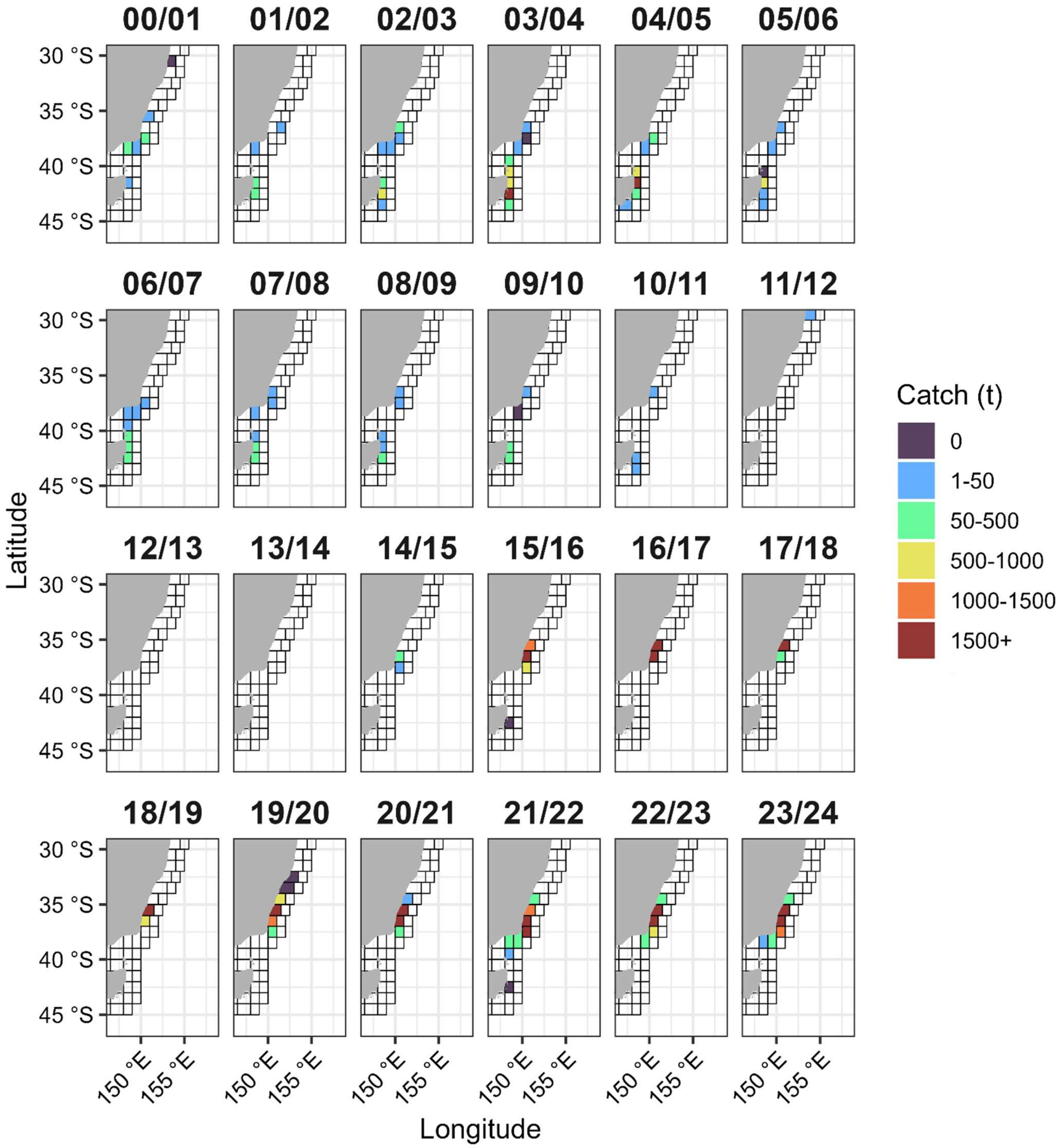
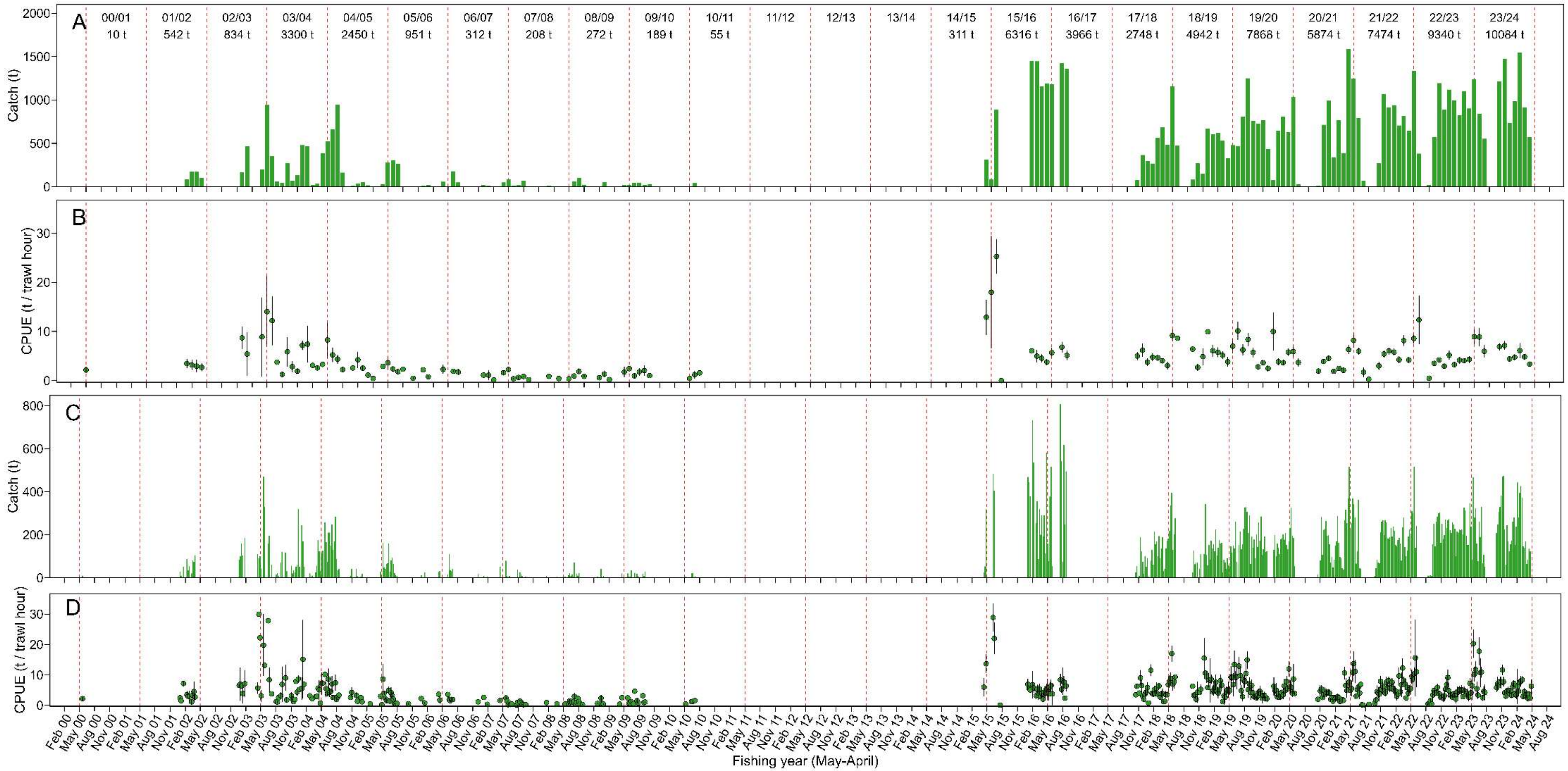


Figure 3–12. Monthly and weekly CPUE of Jack Mackerel by SPF trawlers from 2000–01 to 2023–24.



Length and age frequencies

The modal lengths and ages of Jack Mackerel off southern NSW have typically been between 240 and 280 mm (Figures 3–13) and 2-5 years (Figures 3–14), respectively. There have no changes in the modal length or age frequencies (Figures 3–13, 3–14) that suggest the local availability or abundance of Jack Mackerel off southern NSW have declined over the last decade, including over the last three fishing seasons

Daily Egg Production Method

The DEPM was first applied to Jack Mackerel in the Eastern Sub-area of the SPF by Neira (2011) using plankton samples collected from the Blue Mackerel DEPM survey conducted in October 2022 (Ward and Rogers 2007). The study by Neira (2011) indicated that the DEPM is an appropriate technique for assessing Jack Mackerel, but did not provide robust estimates of spawning biomass because the plankton survey did not cover the entire spawning area or coincide with the peak (summer) spawning season (see Jordan 1994; Jordan et al. 1995). The other key limitation of the study was that estimates of adult DEPM reproductive parameters, especially spawning fraction, were based on data obtained from other species (i.e., *Trachurus trachurus* and *T. symmetricus*) in other ecosystems. The most important contribution from the study was the introduction of a molecular technique for discriminating the eggs of Jack Mackerel from the co–occurring Yellowtail Scad (*Trachurus novaezelandiae*) that has been used in subsequent applications of the DEPM to Jack Mackerel in south-eastern Australia (also see Perry 2011; Neira et al. 2015).

The first dedicated plankton survey of Jack Mackerel in the Eastern Sub-area of the SPF was conducted by Ward et al. (2015, 2016) during 8–22 January 2014 (Figure 3–15). It was conducted during January because plankton surveys conducted in 1988–89, 1989–90 and 1990–91 by Jordan et al. (1995) indicated that the peak spawning season off eastern Tasmania occurred during January. Ward et al. (2015) provided an estimate of spawning biomass of 157,805 t (95% CI = 59,570–358,731) that the authors considered robust. The study included a trawl survey conducted during 12–18 January 2014 that provided the first estimates of the adult DEPM parameters, especially spawning fraction, of Jack Mackerel off eastern Australia. However, Ward et al. (2015, 2016) also identified the need to further investigate the size-fecundity relationship of Jack Mackerel as well as spatial, temporal and size–related variations in spawning fraction. The main weakness of the survey conducted in 2014 was that it did not include Bass Strait, which later studies revealed was an important spawning area for Jack Mackerel off south-eastern Australia (Ward et al. 2020).

Figure 3–13. Annual length frequencies of Jack Mackerel in catches by SPF trawlers from 2000–01 to 2023–24.

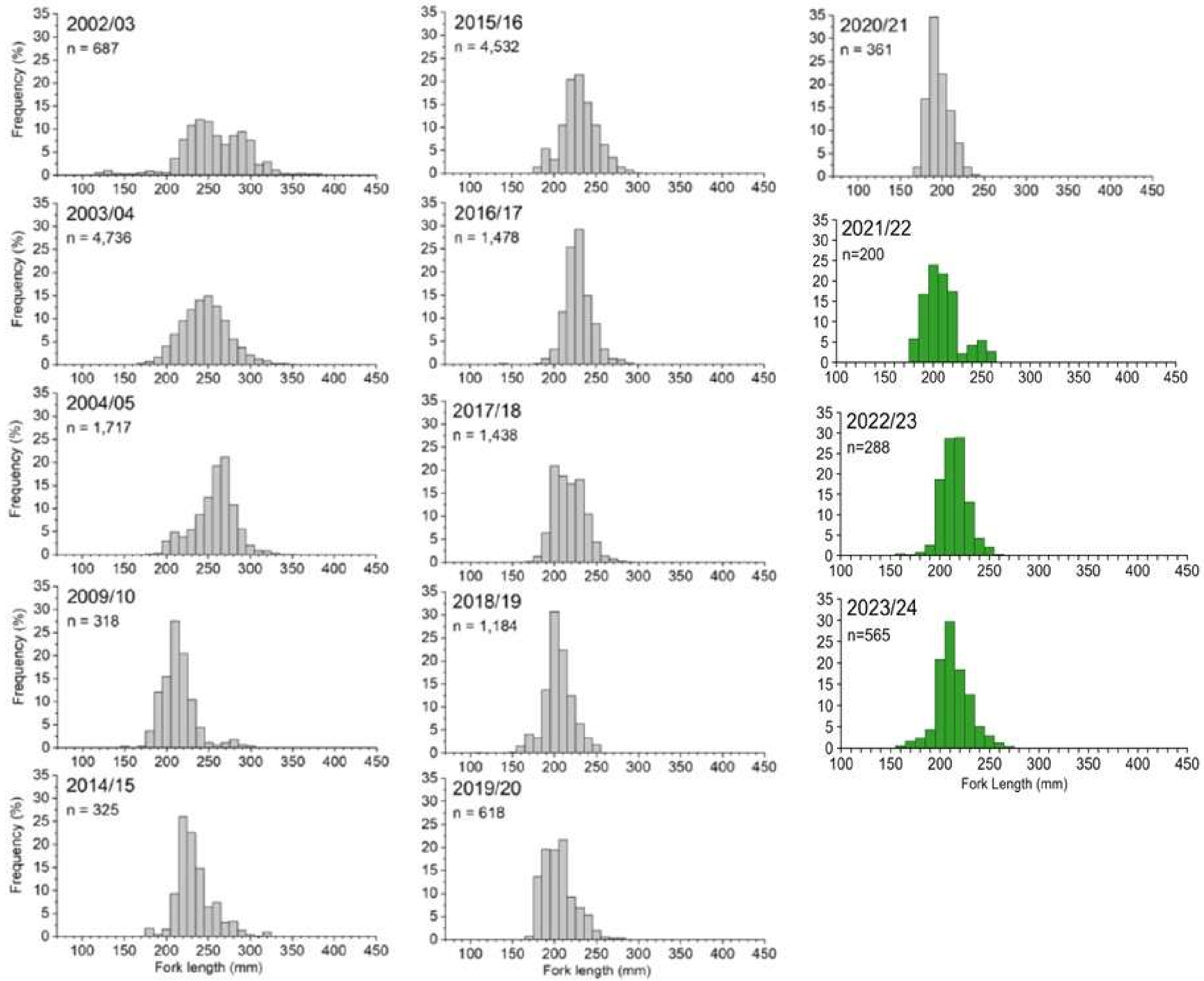


Figure 3–14. Annual age frequencies of Jack Mackerel in catches by SPF trawlers from 2000–01 to 2023–24.

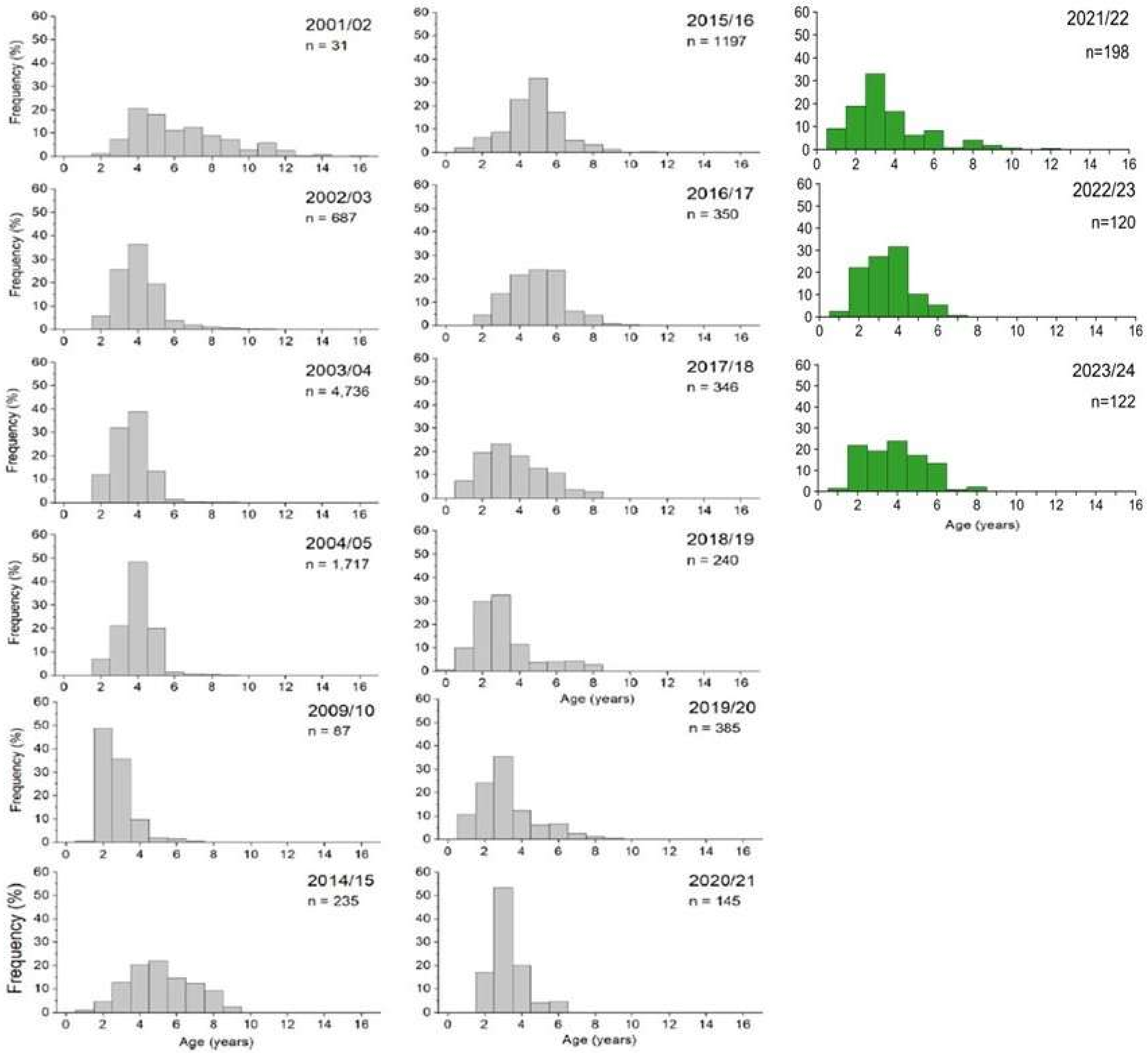
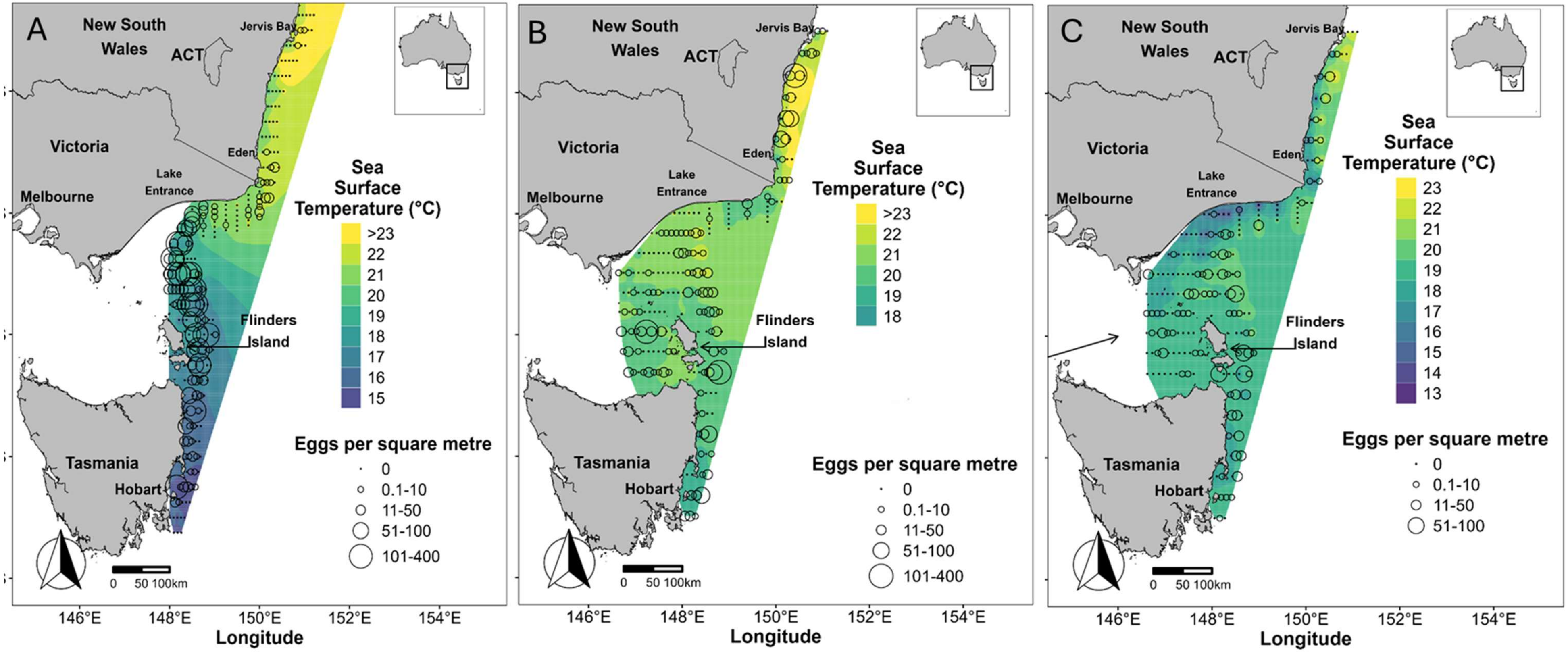


Figure 3–15. Maps showing densities of Jack Mackerel eggs and Sea Surface Temperatures (SSTs) in the plankton surveys conducted the Eastern Sub-area in 2014 (A), 2019 (B) and 2024 (C) (Souce: Ward et al. 2025).



The second application of the DEPM to Jack Mackerel East was conducted in January 2019 (Ward et al. 2020). The plankton and trawl surveys were conducted concurrently from a single vessel during 15 January to 7 February 2019 (Figure 3–15). That study showed that eastern Bass Strait is an important spawning area for Jack Mackerel. However, low values of mean daily egg production and spawning fraction combined with high rates of atresia observed in ovaries suggested that the study may not have been conducted during the peak spawning season. This problem was attributed to the relatively late start date of the survey (mid-January rather than early January) and the extended time taken to complete the survey that resulted from conducting both plankton and adult sampling from a single vessel. The study identified that the precision of estimates of spawning biomass could be improved by combining two parameters, i.e., batch fecundity and female weight, into a single parameter called relative fecundity. The estimate of spawning biomass of 156,292 t (95% CI = 49,120–263,496 t) for 2019 was considered suitable for setting TACs because it was based on robust and/or conservative estimates of key parameters.

The third application of the DEPM to Jack Mackerel East was conducted in January 2019 (Ward et al. 2025). Plankton samples were collected during 6–22 January 2024 (Figure 3–15) and adult sampling was undertaken from a separate vessel during 11–17 January 2024. Fewer eggs were collected during the 2024 plankton survey (385 eggs) than in the two previous applications of the DEPM to this stock (i.e., 3,530 eggs in 2014 and 921 eggs in 2019). A robust estimate of spawning biomass for 2024 could not be calculated because samples collected during the trawl survey did not including the actively spawning fish needed to estimate adult DEPM parameters, especially spawning fraction. Ward et al. (2025) presented evidence to suggest that the reason that spawning adults were not collected was that the peak spawning season in 2024 occurred during December rather than January. The study also suggested that shelf waters off eastern Tasmania, where Ward et al. (2015) and Jordan et al (1995) had collected many eggs, may no longer be the main spawning ground of Jack Mackerel in this region. Ward et al (2025) also presented results of a plankton survey conducted in December 2023 (Figure 3–19) that, combined with results from the surveys conducted and January in 2019 and 2024, suggest that the distribution of Jack Mackerel is continuous throughout Bass Strait. Ward et al (2025) emphasised that the potential for movement of Jack Mackerel between these two sub-areas would need to be considered when interpreting the results of future DEPM surveys. Ward et al (2025) also suggested that the failure of the survey conducted in January 2024 to provide a robust estimate of spawning biomass demonstrated the paucity of current knowledge of the reproductive biology of Jack Mackerel off south-eastern Australia. Ward et al. (2025) reiterated the recommendations of Ward et al. (2015, 2016) and identified that there is an urgent need to investigate the size-fecundity relationship and spatial, temporal and size-related variations in spawning fraction of Jack Mackerel off eastern Australia. Ward et al. (2025) also emphasised the urgent need to develop industry-based methods for monitoring spawning activity of Jack Mackerel off eastern Australian that can be used to ensure that future DEPM surveys are conducted during the peak spawning season. Ward et al. (2025) recommended that this research project should be done before the next DEPM survey.

3.2 Eastern Sub-area

3.2.3 Redbait

Annual catch, effort and CPUE

Annual catches, effort and CPUE of Redbait by trawlers operating in the Eastern Sub-area of the SPF are shown in Figure 3–16. Annual catches since 2019–20 have ranged between 2,412 t and 1,788 t (Figure 3–8A). The total catch in 2023–24 was 1,788 t, which was approximately 33% of the available TAC of 5,380 t.

Since 2014–15, most of the catch of Redbait by SPF trawlers has been taken off southern NSW (Figure 3–16, 3–17). However, the highest annual catch of Redbait by SPF trawlers in the Eastern Sub-area of 7,721 t was taken off eastern Tasmania in 2003–04 (Figure 3–16, 3–17).

Annual CPUE of Redbait by SPF trawlers operating off southern NSW since 2019–20 ranged from 1.3 and 2.4 t.trawl hr^{-1}, with the highest CPUE occurring in 2023–24. Patterns of annual CPUE do not provide evidence that the local availability or abundance of Redbait has declined over the last decade. In contrast, the decline in annual CPUE of SPF trawlers operating off eastern Tasmania from 2001–02 to 2010–11 is consistent with a decline in the local availability or abundance of Redbait over that period.

Catches of Redbait taken by SPF purse-seine vessels have been much lower than those taken by SPF trawlers (Figure 3–16C). The highest annual catch of Redbait by SPF purse-seine vessels of 54 t was taken off eastern Tasmania in 2004–05.

Localised depletion

The expansion in the number of catch grids (Figure 1–3) off southern NSW from which annual catches of Redbait have been taken since 2014-15 (Figure 3–17) likely reflects the combined effects of increases in total annual catches of Blue Mackerel and Jack Mackerel over this period and the monthly spatial catch limits (2000 t over 30 days in each grid square) that were established to reduce the potential for localised depletion. Monthly and weekly patterns of catch and CPUE of Redbait shown in Figure 3–18 do not provide evidence of localised depletion resulting from the fishing operation off southern NSW. However, the decline in CPUE off Tasmania from 2001–02 to 2009–10 is consistent with a decline in the local abundance or availability of Redbait that could have been caused by either fishing pressure and/or an environmental driven change in distribution.

Figure 3–16. Total annual catch, effort and CPUE of Redbait by SPF trawlers (A and B) and SPF purse-seine vessels (C and D) operating in the Eastern Sub-area of the SPF from 2000–01 to 2023–2024.

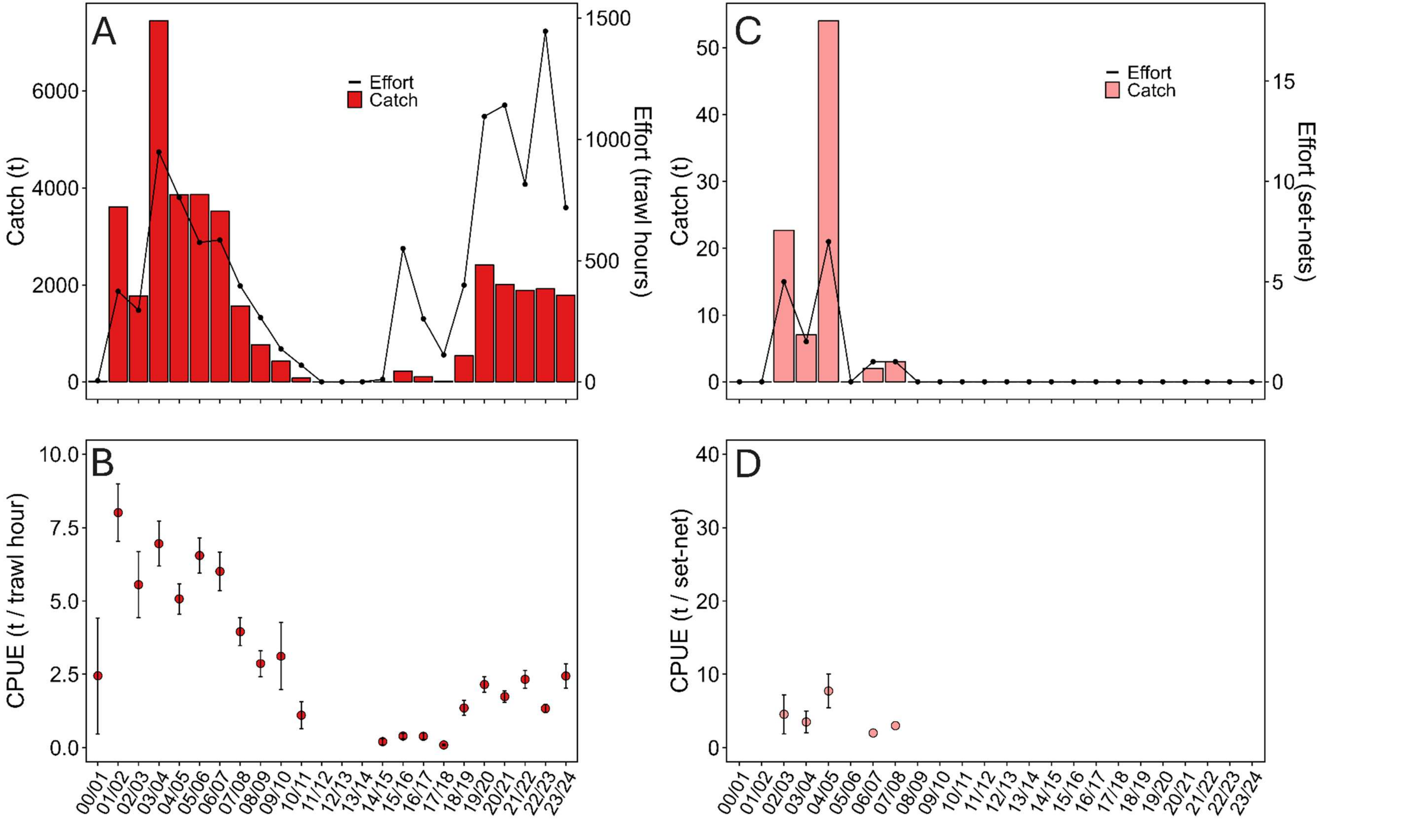
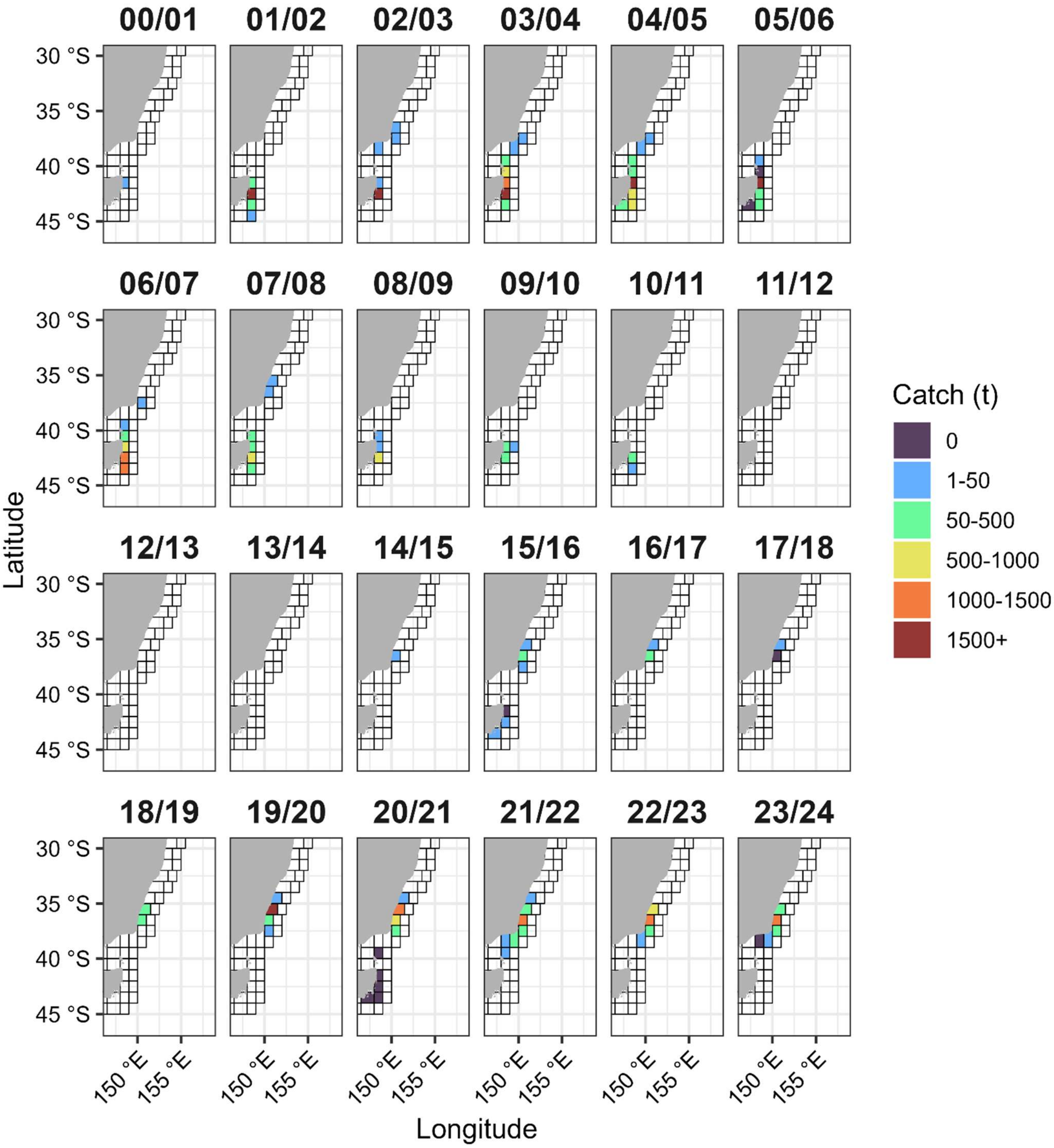


Figure 3–17. Spatial distribution of catches of Redbait in trawlers and purse-seine vessels (combined) in the SPF from 2000–01 to 2023–24.



Length and age frequencies

The modal lengths and ages of Redbait off southern NSW have typically been between 140 and 240 mm (Figures 3–19) and 2-3 years (Figures 3–20), respectively. However, older Redbait were caught in 2014–15 to 2017–18. For example, in 2015–16 and 2017–18, the modal ages were 7 and 10 years, respectively. There have been no changes in the modal length or age frequencies (Figures 3–19, 3–20) that suggest the local availability or abundance of Redbait off southern NSW have been declined over the last decade.

Daily Egg Production Method

The first application of the DEPM to Redbait in the Eastern Sub-area of the SPF (Figure 3–21) provided estimates of spawning biomass of 86,990 t (CV 0.37) for 2005 and 50,782 t (CV 0.19) for 2006 (Neira et al 2008; Neira and Lyle 2011). The authors considered that estimates of spawning biomass were likely to be negatively biased because the surveys did not extend north into southern NSW where Redbait also spawns. However, estimates of sex ratio used to calculate spawning biomass in 2005 (0.30) and 2006 (0.44) were lower than the likely value of around 0.5, which would cause the spawning biomass to be over-estimated. The estimates of spawning fraction for 2005 (0.315) and 2006 (0.321) used to estimate spawning biomass were similar to the highest value obtained by Ewing and Lyle (2009) using three different methods (0.2, 0.25 and 0.3). Ewing and Lyle (2009) concluded that Redbait spawn every three days, which equates to a spawning fraction of 0.33, and supports the suitability of the estimates of spawning fraction used by Neira and Lyle (2011).

The most recent application of the DEPM to Redbait in the Eastern Sub-area of the SPF (Figure 3–21) suggested that the spawning biomass was 52,629 t (95% CI = 13,937–91,321) (Grammer et al. 2022). The estimate of egg production of 22.7 eggs.day^{-1}.m^{-2} used by Grammer et al. (2022) was less than one third of the comparable value of approximately 80 eggs.day^{-1}.m^{-2} (converted from ~4 eggs/0.05m^{2}/day) used by Neira and Lyle (2011), which had a proportional downward effect on the estimate of spawning biomass. The log-linear method used by Grammer et al. (2022) is known to be negatively biased (e.g. Ward et al. 2022), so Grammer et al. (2022) considered that the estimate of mean daily egg production was likely to provide a conservative estimate of spawning biomass. However, the estimate of spawning fraction used by Grammer et al. (2022) of 0.195 is lower than the values of 0.315 and 0.321 used by Neira and Lyle (2011), which if incorrect would cause the spawning biomass to be over-estimated. The estimate of relative fecundity of 82.6 eggs·g^{-1} used Grammer et al. (2022) is also lower than the equivalent value of ~169.6 eggs·g^{-1} (calculated by dividing mean batch fecundity of 27,162 eggs by mean female weight of 160.12 g) estimated by Ewing and Lyle (2009) which, if incorrect, would also cause spawning biomass to be over-estimated. The findings highlight the need for further investigation of the reproductive biology of Redbait off south–eastern Australia, especially spawning fraction and relative fecundity.

Figure 3–18. Monthly and weekly CPUE of Redbait by trawlers in the SPF from 2000–01 to 2023–24.

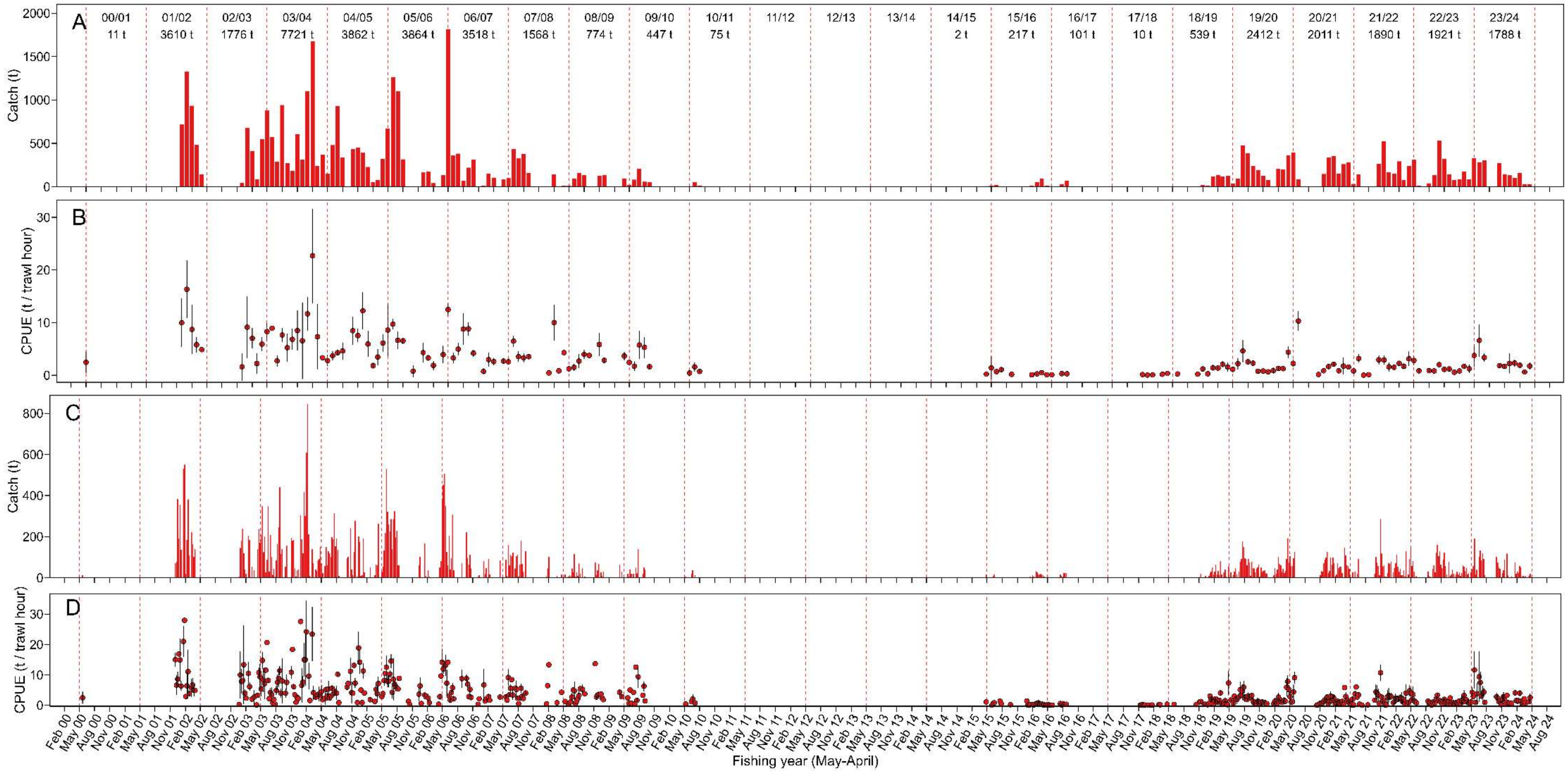


Figure 3–19. Annual length frequencies of Redbait in catches by SPF trawlers from 2000–01 to 2023–24.

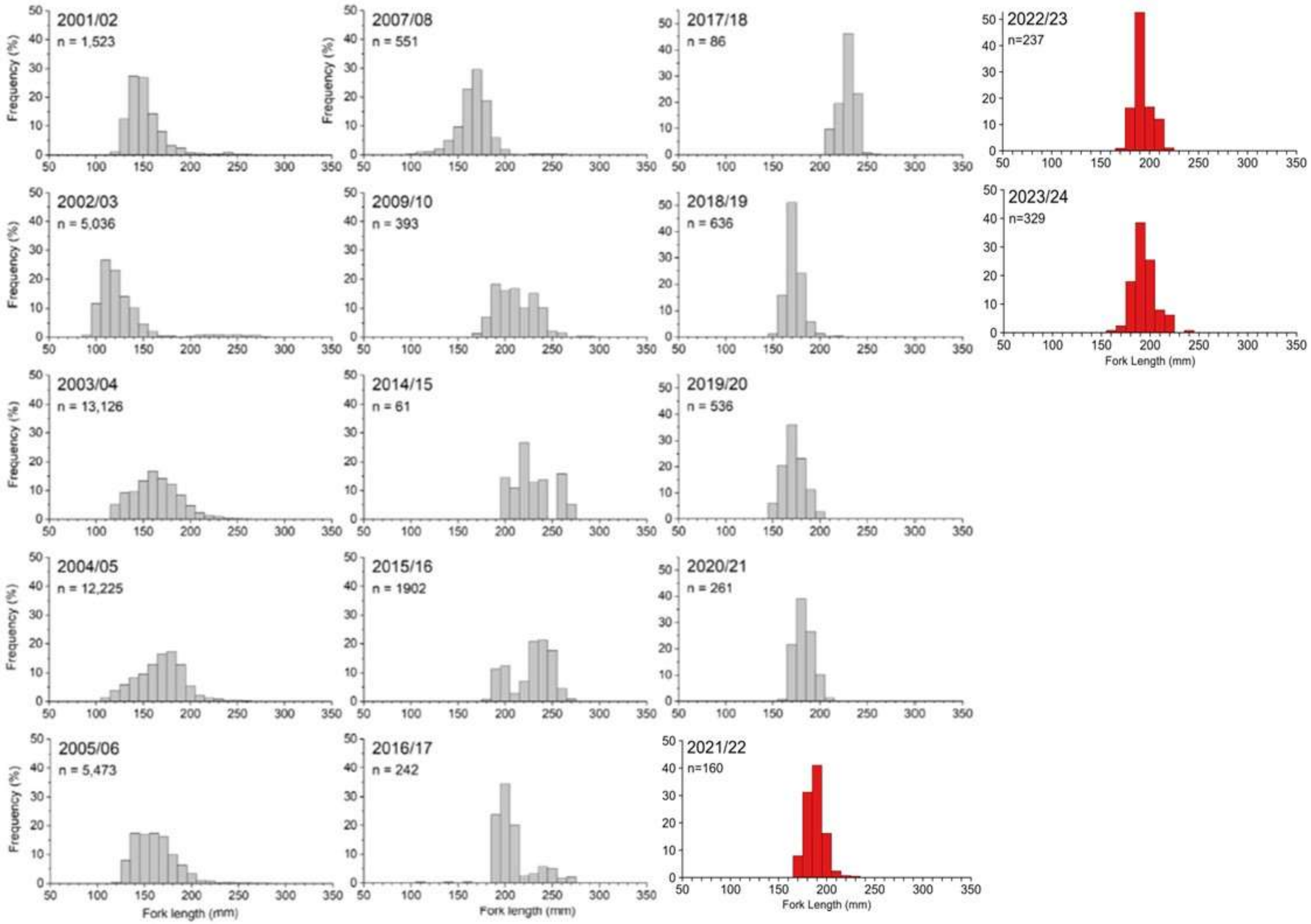


Figure 3–20. Annual age frequencies of Redbait in catches by SPF trawlers from 2000–01 to 2023–24.

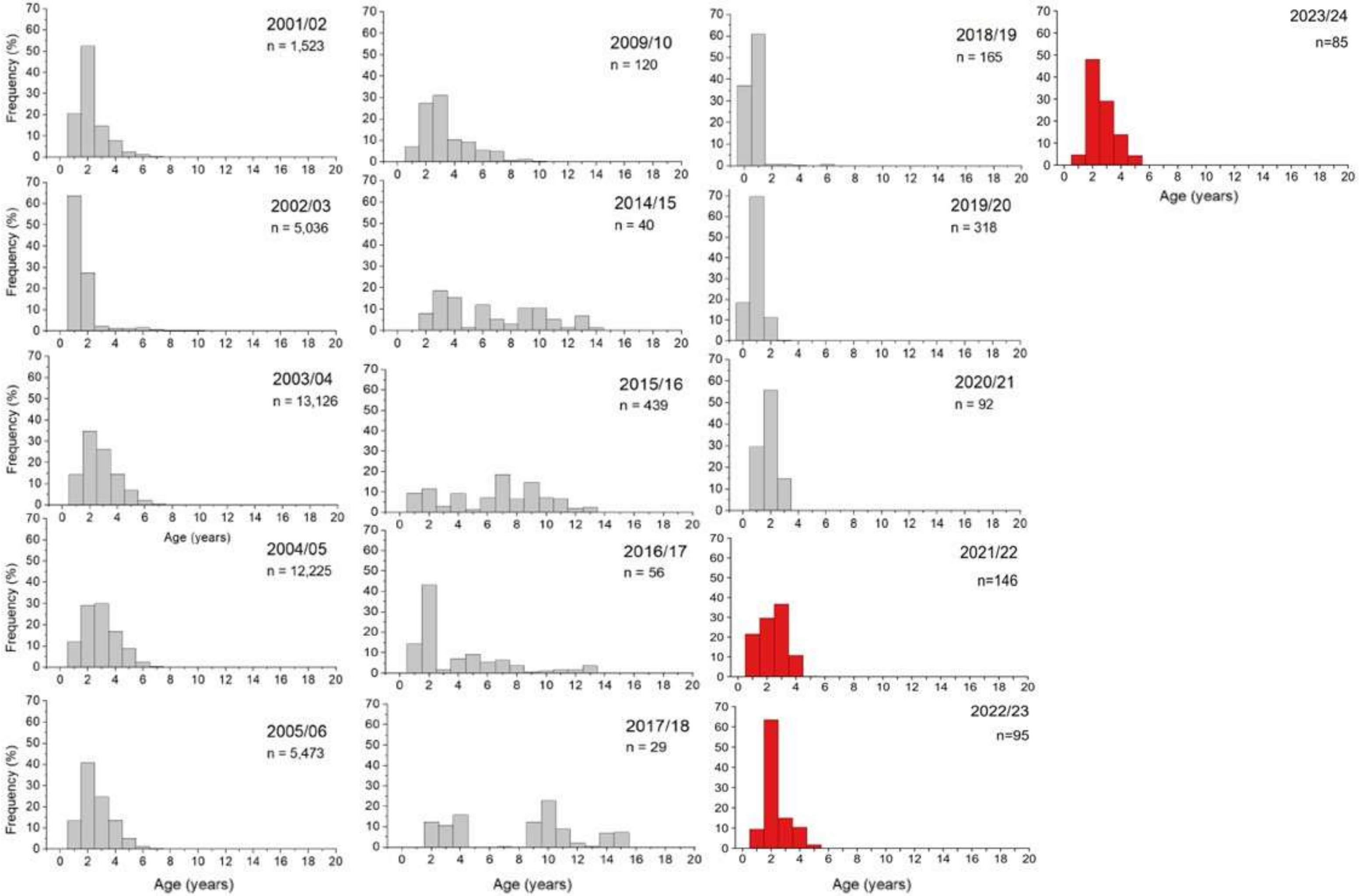
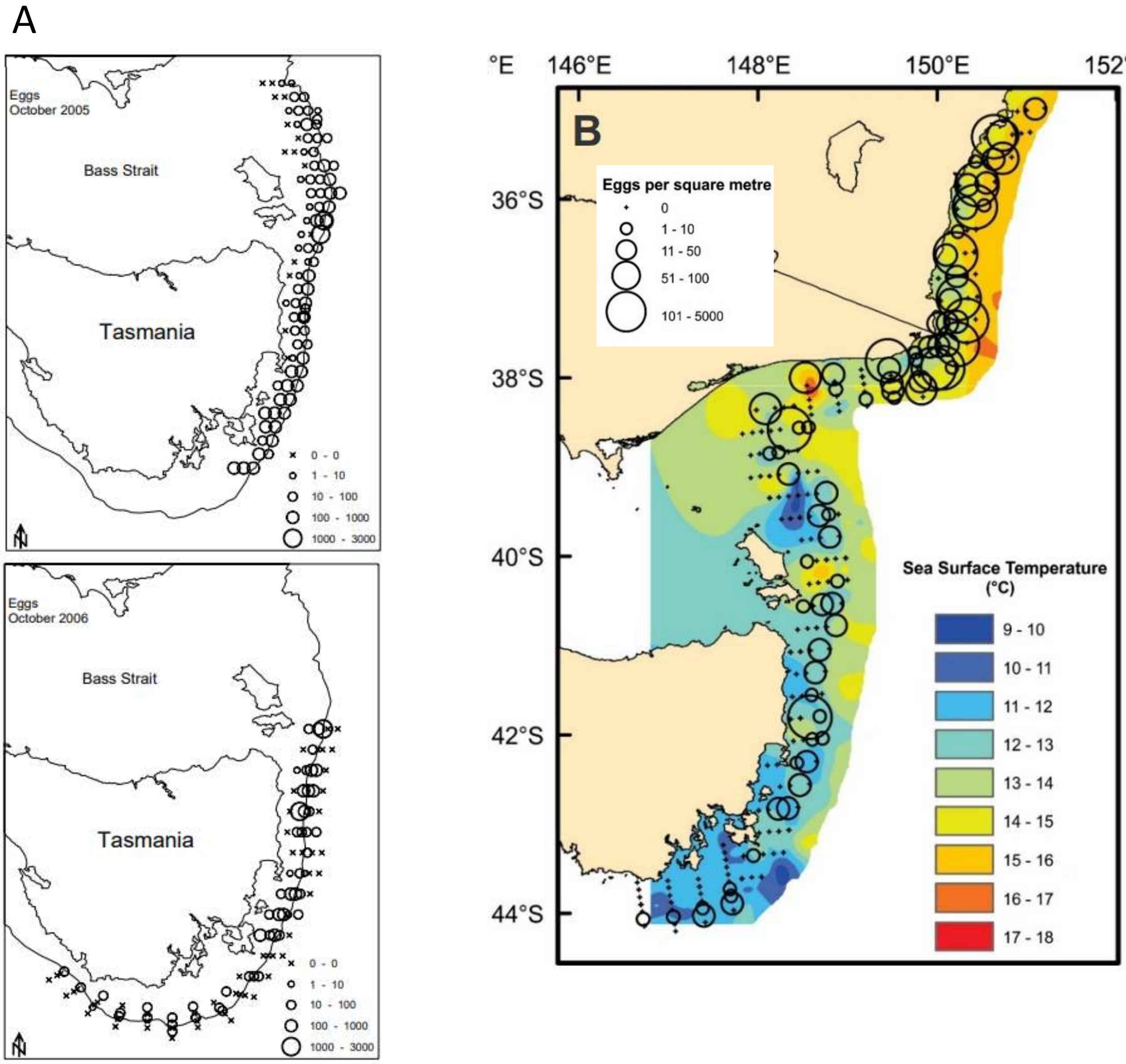


Figure 3–21. Maps showing densities of Redbait eggs in plankton surveys conducted in the Eastern Sub-areain A) October 2005 and 2006 (Source: Neira et al. 2008) and October 2020 (Source: Grammer et al. 2022).



3.3 Sardine Sub-area

3.3.1 Sardine

Annual catch, effort and CPUE

Most of the Sardine catch in the Sardine Sub-area of the SPF has been taken by purse-seine vessels operating in the SPF and the NSW Ocean Haul Fishery (Figure 3–22). The two main fishing areas are located off northern and southern NSW (Figure 3–23). The highest annual catches by SPF and NSW purse-seine vessels were 1,759 t in 2007–08 and 2,063 t in 2008–09, respectively. The total catch of SPF and NSW purse-seine vessels in 2023–24 were 34 t and 473 t, respectively. In 2023–24 SPF trawlers also landed 16 t of Sardine. The total catch of Sardine Sub-area of the SPF in 2023–24 was much lower than the RBC of 8,060 t (AFMA 2023).

Daily Egg Production Method

Preliminary applications of the DEPM to Sardine off eastern Australia in 1997 and 1998 suggested that spawning biomass was at least 25,000 t (Staunton Smith and Ward 2000). Recent applications of the DEPM suggested that the spawning biomass of Sardine in the Eastern Sub-area of the SPF declined from 49,575 t (95% CI = 24,179–213,323) in 2014 and 42,724 (95% CI = 15,487–69,962) t in 2019 (Ward et al. 2015a, 2020). This decline was largely driven by a marked reduction on the number of eggs collected between 30ºS and 33ºS in 2019 compared to 2014 (Figure 3–24). Future applications of the DEPM to this stock should use the methods established for applying the DEPM to Sardine off South Australia (Ward et al. 2021b). The approach that is taken should include estimating mean daily egg production using all historical data available rather than only data collected annually. As recommended by Ward et al. (2020), it would also be beneficial to undertake additional adult sampling off eastern Australia to obtain reliable local estimates of adult parameters, especially spawning fraction. However, given the current low catches the need for this work is not urgent. The results of the DEPM survey conducted in 2024 will provide an update on the current size of the spawning biomass in the Sardine Sub-area.

Figure 3–22. Total annual catch and effort and CPUE of Sardine by SPF purse-seine (A and B) and NSW purse-seine(B and C) vessels from 2000–01 to 2023–2024

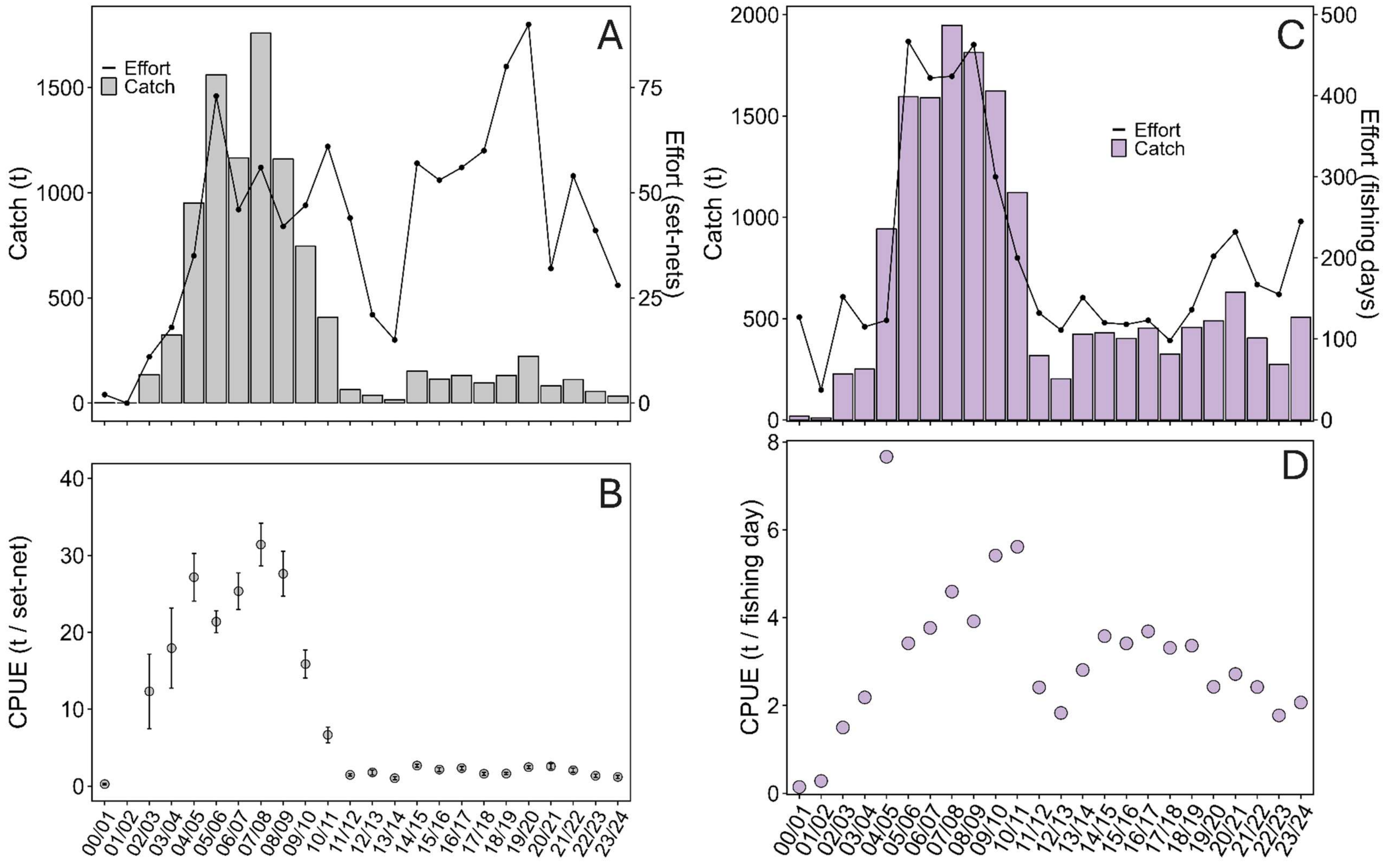


Figure 3–23. Spatial distribution of catches of Sardine in the SPF from 2000–01 to 2023–24.

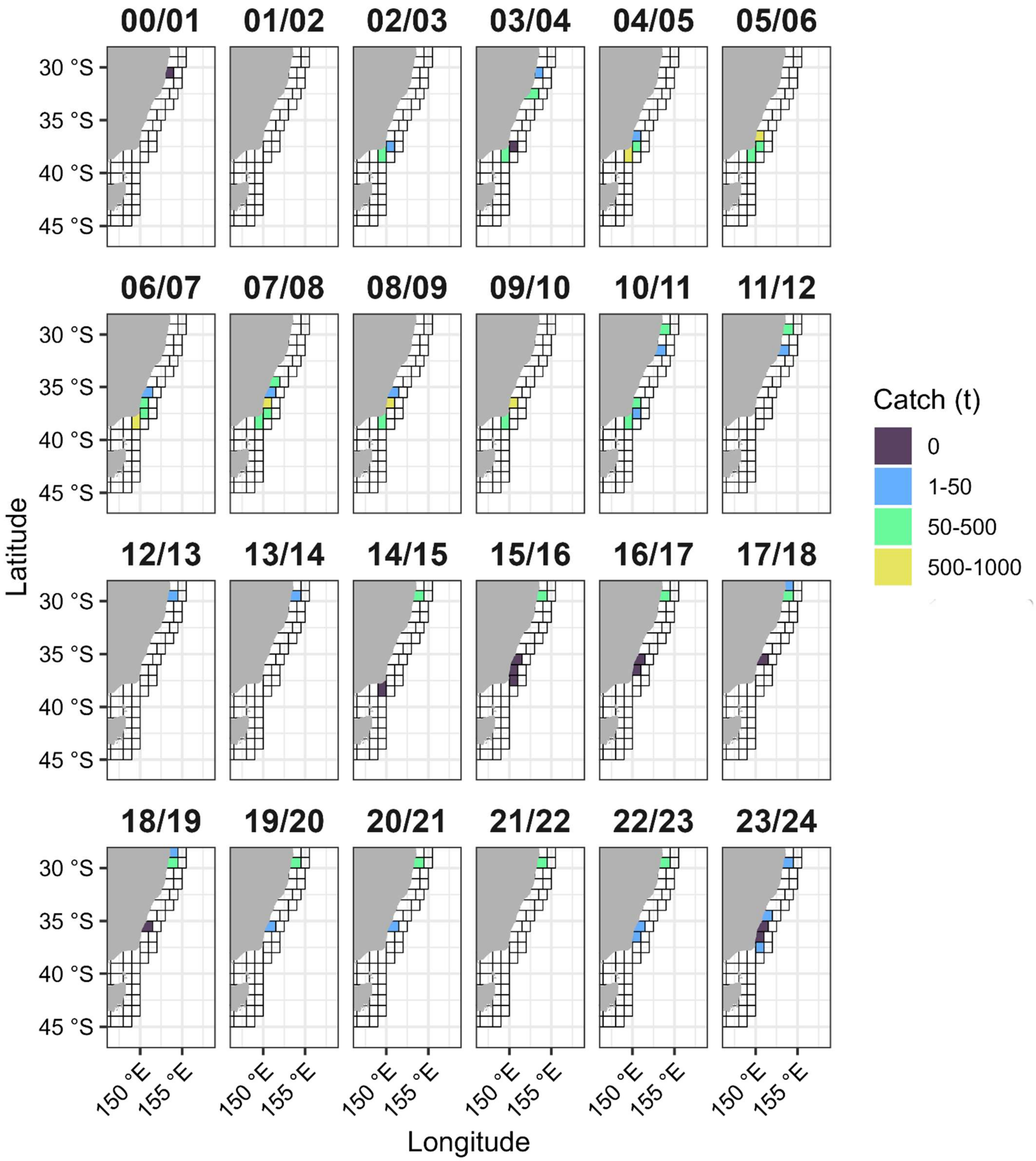
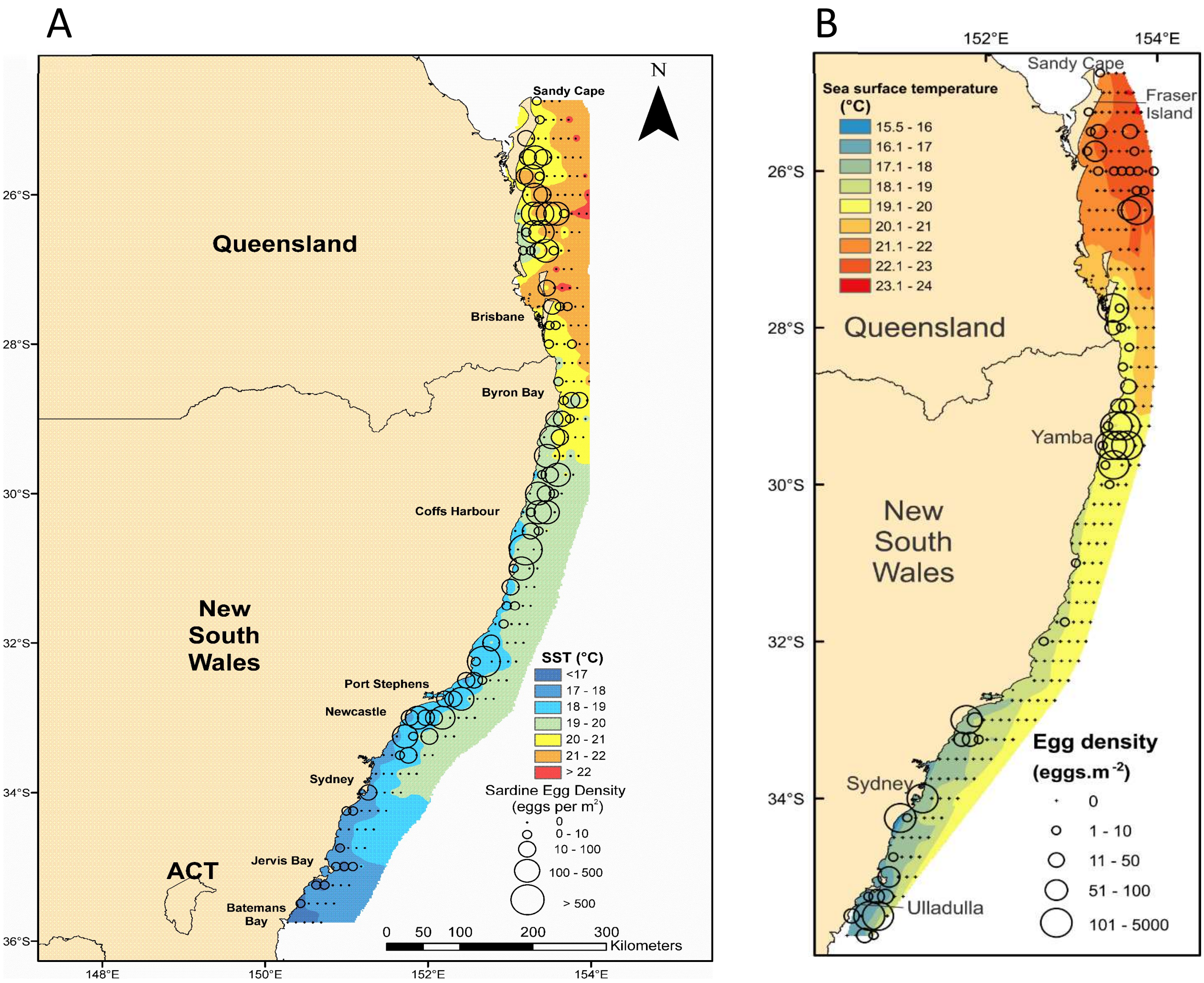


Figure 3–24. Maps showing densities of Sardine eggs and Sea Surface Temperatures (SSTs) in the plankton surveys conducted in the Eastern Sub-areaof the SPF during (A) 19 August to 14 September 2014 (Source Ward et al. 2015b) and (B) 4–24 September 2019 (Source Ward et al. 2021).



3.4 Western Sub-area

3.4.1 Blue Mackerel

Annual catch, effort and CPUE

Catches of Blue Mackerel in the Western Sub-area of the SPF have been sporadic. A factory trawler caught 979 t and 766 t of Blue Mackerel south of Kangaroos Island in 2025–16 and 2016–17, respectively (Figure 3–25, 26). Purse-seine vessels that operated out of Port Lincoln caught Blue Mackerel in the Western Sub-area of the SPF from 2001–02 to 2011–12, including annual catches of 2,158 t and 2,164 t in 2006–07 and 2008–09, respectively.

Daily Egg Production Method

A preliminary application of the DEPM to Blue Mackerel in the Western Sub-area of the SPF was conducted by Ward and Rogers (2007) and Ward et al. (2009). Those studies used plankton samples collected during a DEPM survey of Sardine conducted off South Australia in 2005 to provide estimates of minimum spawning biomass of around 45,000 to 68,000 t. The plankton survey only covered a small proportion of the total area of the Western Sub-area of the SPF (Figure 3–27) and Ward and Rogers (2007) demonstrated the presence of Blue Mackerel eggs in the western Great Australian Bight outside the area covered by the 2005 survey. The estimates of spawning biomass provided by Ward et al. (2009) are therefore likely to be conservative. Ward et al. (2009) concluded that the DEPM is a suitable tool for assessment of Australia’s Blue Mackerel populations but identified the need to 1) develop cost–effective and reliable techniques for genetic identification of early-stage eggs; 2) develop species-specific egg development-temperature keys for calculating egg production; and 3) calculate degeneration rates of post–ovulatory follicles needed to obtain provide reliable estimates of spawning fraction.

Figure 3–25. Total annual catch of Blue Mackerel by SPF trawlers (A and B) and purse-seine vessels (C and D) in the Western Sub-area of the SPF from 2000–01 to 2023–2024

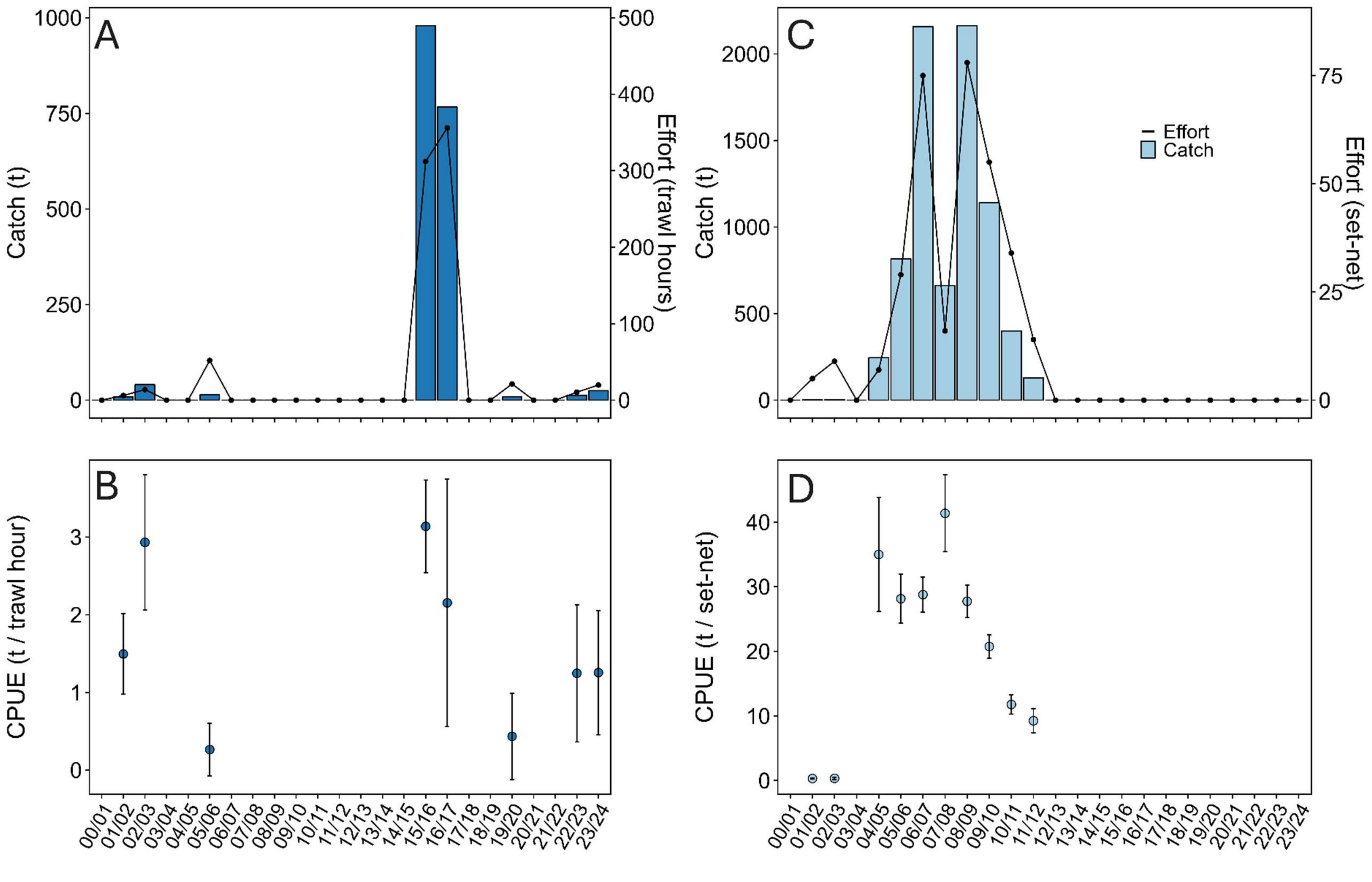


Figure 3–26. Spatial distribution of catches of Blue Mackerel in the Western Sub-areain the SPF from 2000–01 to 2023–24.

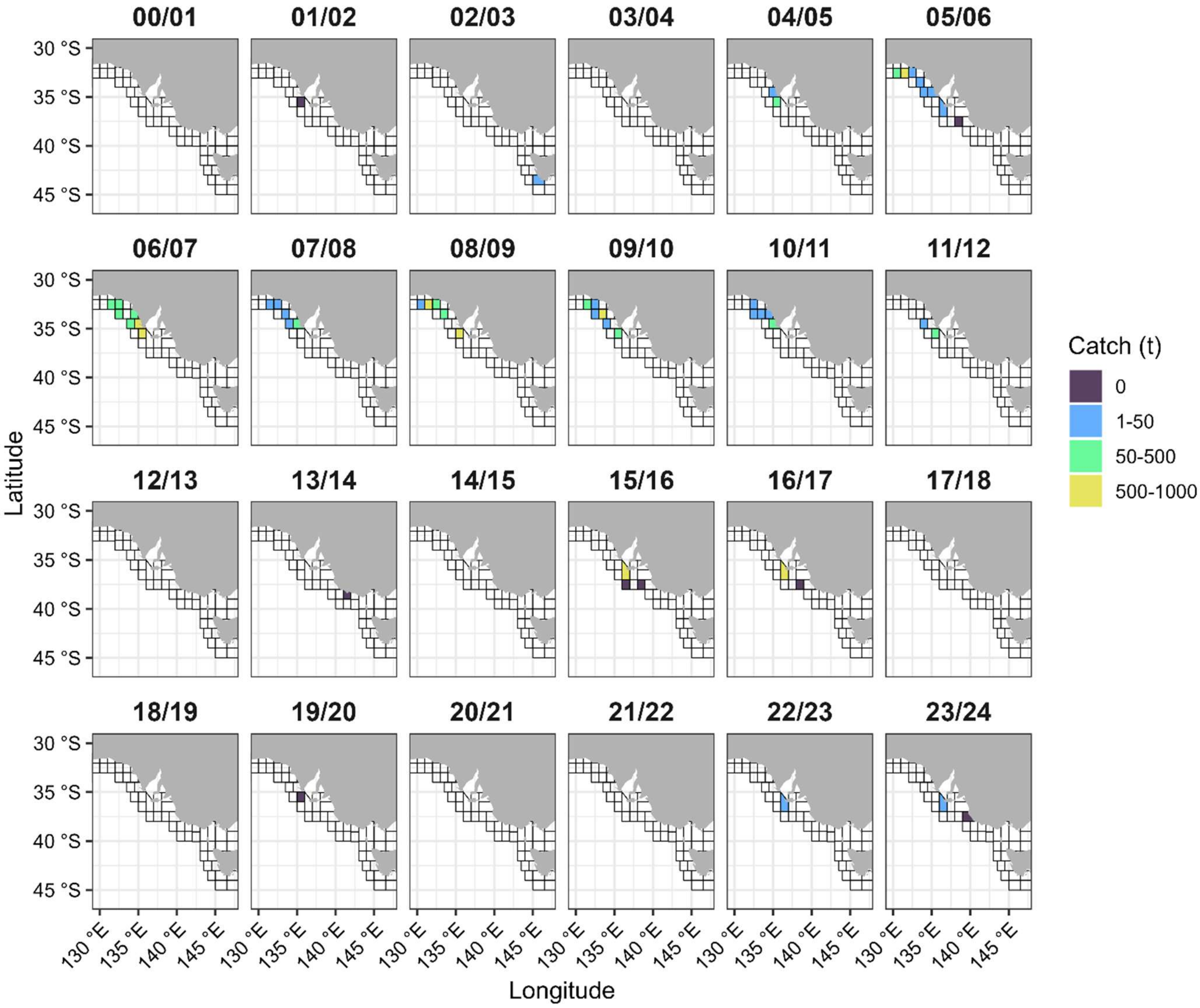
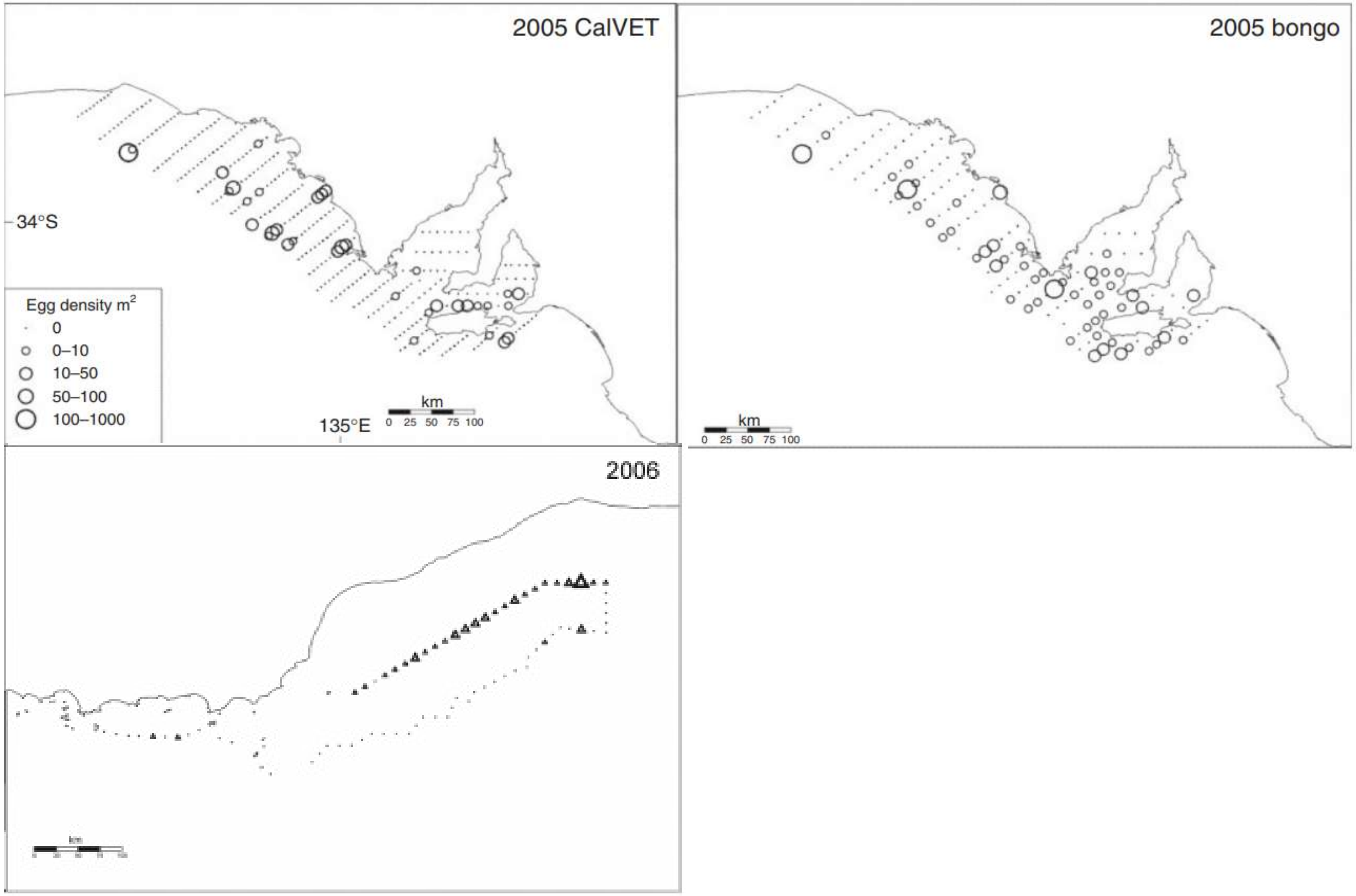


Figure 3–27. Maps showing densities of Blue Mackerel eggs in the plankton survey conducted in the Western Sub-area of the SPF during 2005 (Source: Ward et al. 2009) and an exporatory plankton survey in the western Great Australian Bight during 2006 (Souce: Ward and Rogers 2007).



3.4 Western Sub-area

3.4.2 Jack Mackerel

Annual catch, effort and CPUE

Small catches (>250 t) of Jack Mackerel were taken by SPF trawlers operating off western Tasmania in 2001–02 to 2009–10 (Figure 3–28, 3–29). The highest annual catches of Jack Mackerel from the Western Sub-area of the SPF of 634 t and 686 t were taken by a factory trawler in 2015–16 and 2016–17, respectively (Figure 3–28, 29).

Daily Egg Production Method

The DEPM was first applied to Jack Mackerel in the Western Sub-area of the SPF in 2016–17 by Ward et al. (2019). Plankton sampling was conducted west of Portland during 2–12 December 2016 and east of Portland during 15 January to 6 February 2017 (Figure 3–30). Opportunistic plankton sampling was also done in western Bass Strait during 30 January to 3 February 2017 to assess the potential importance of Bass Strait as spawning area for Jack Mackerel (and Sardine). Demersal trawling was undertaken to collect adult Jack Mackerel in the area where plankton sampling was conducted in January and February 2017, but most fish collected were small and immature and, therefore, not suitable for estimating adult parameters. Instead, adult parameters were estimated from samples collected from the Eastern Sub-area by Ward et al. (2020). The estimate of spawning biomass provided for the area between western Kangaroo Island and south–western Tasmania was ~31,000 t which is likely an under-estimate of the total abundance of Jack Mackerel in the Western Sub-area of the SPF.

A plankton survey of the area between the Victorian-South Australian border and the line at 146°30’E that divides the Western and Eastern Sub-areas of the SPF was conducted in December 2023 (Figure 3–30). The results of that study confirmed the importance of Bass Strait as a spawning area for Jack Mackerel and suggested that the separation of the SPF into Eastern and Western Sub-areas may not reflect the stock structure off south–eastern Australia. Rather, the results suggest that there may be only one stock that extends from the Victorian-South Australian border to central NSW.

Figure 3–28. Total annual catch and catch–per–unit–effort (CPUE, below) of Jack Mackerel by trawlers (A and B) and purse-seine vessels (C and D) in the Western Sub-area of the SPF 2000–01 to 2023–2024

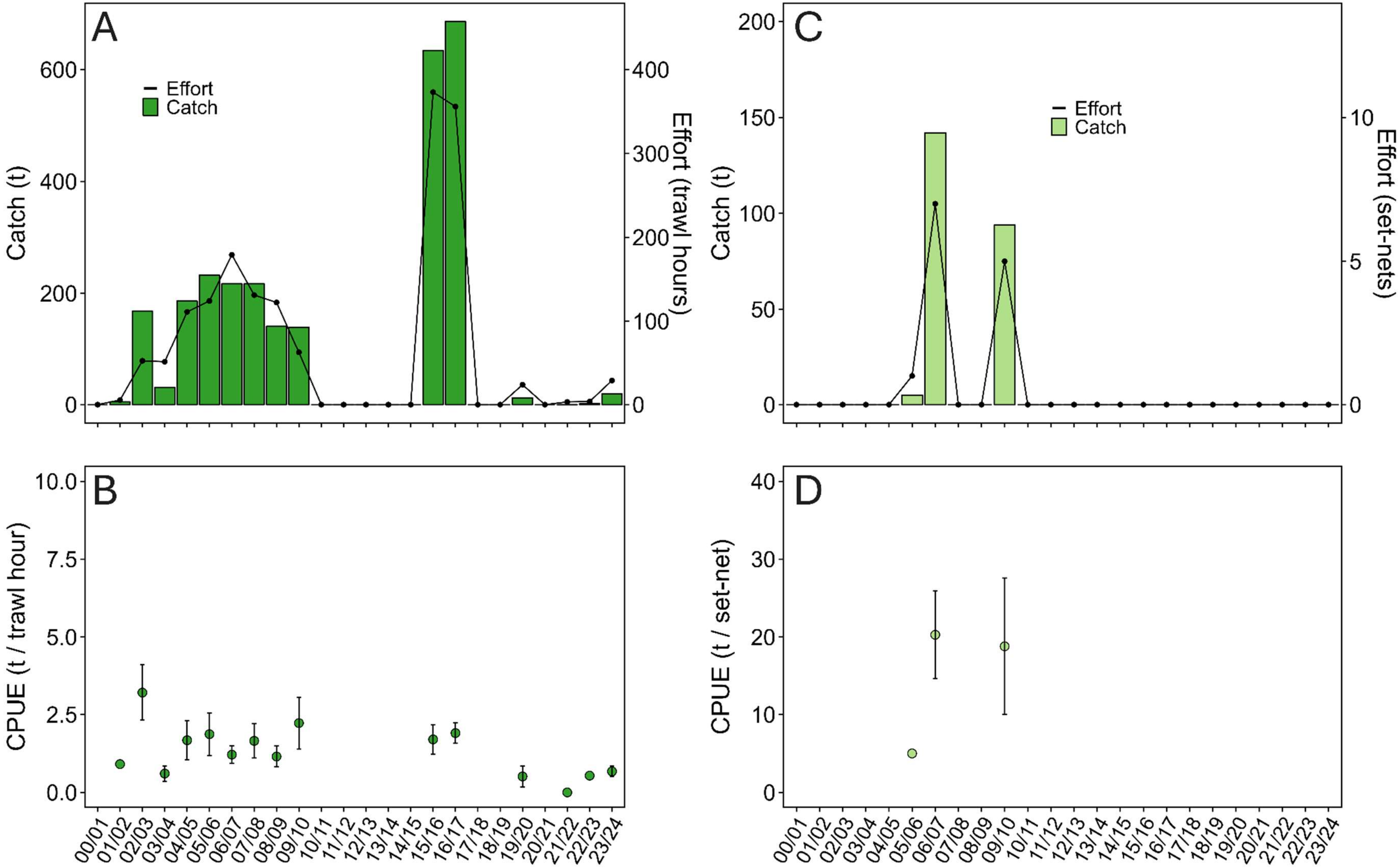


Figure 3–29. Spatial distribution of catches of Jack Mackerel in the Western Sub-areain the SPF from 2000–01 to 2023–24.

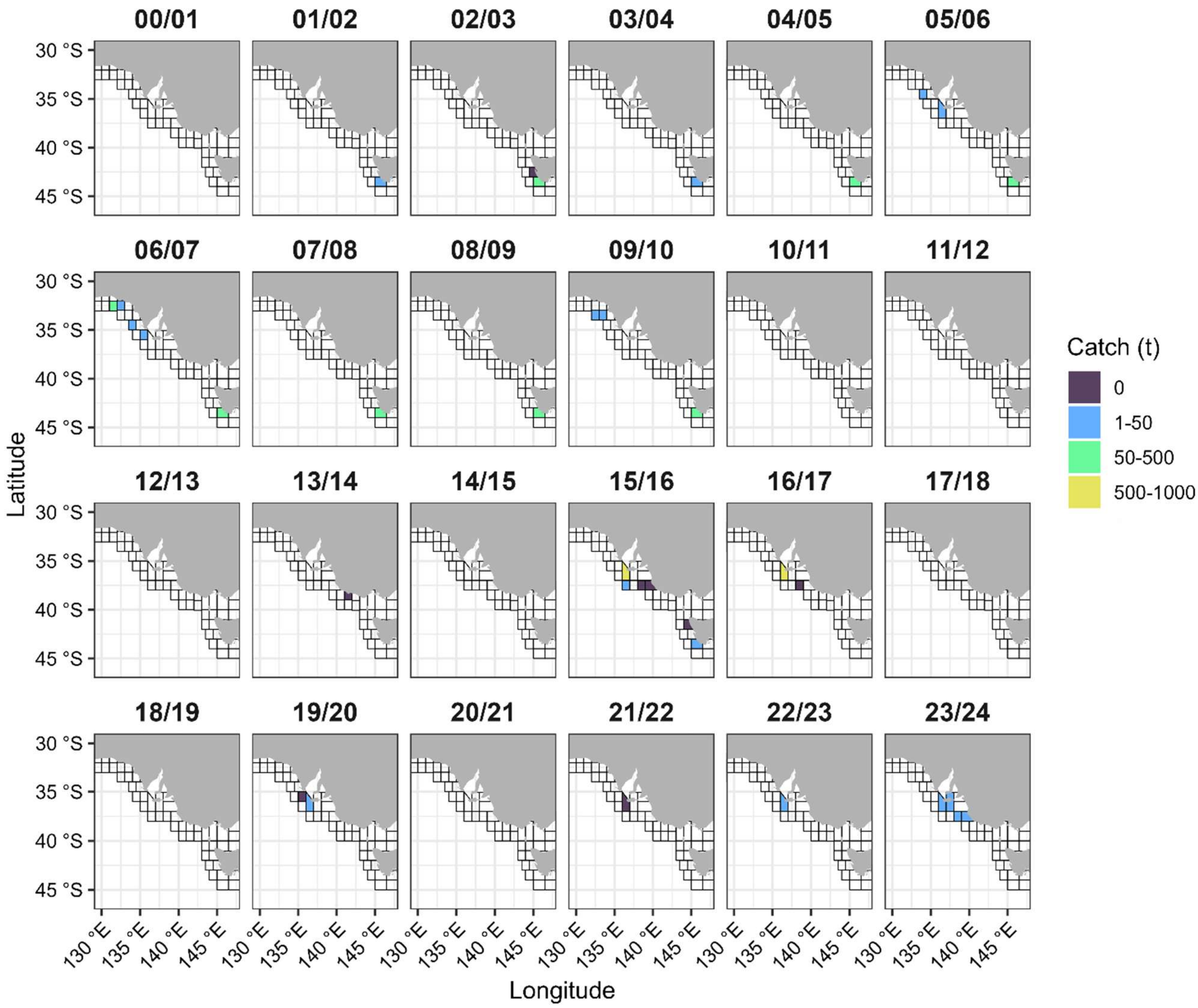
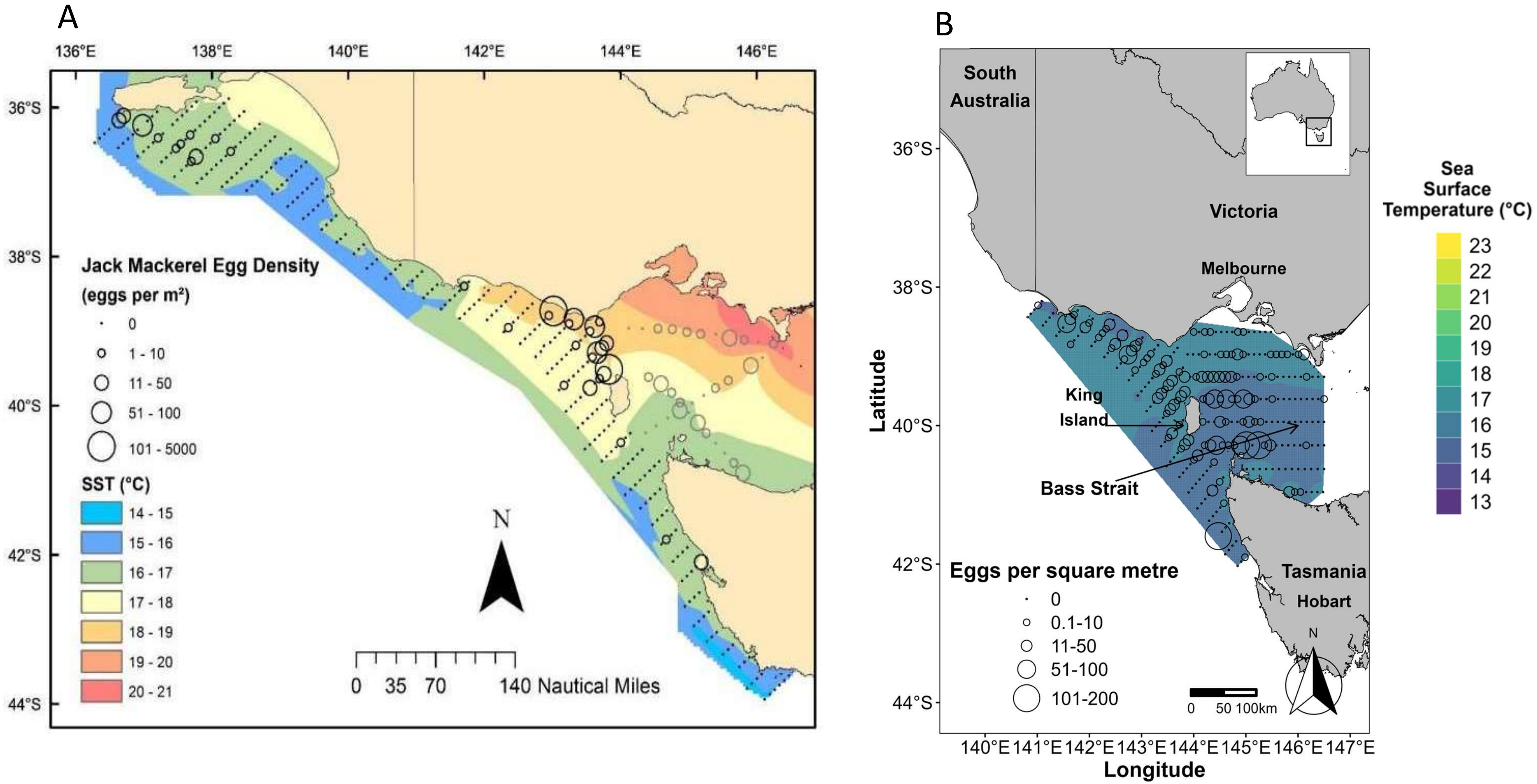


Figure 3–30. Maps showing densities of Jack Mackerel eggs in the plankton survey conducted in the Western Sub-areaof the SPF during A) 2–12 December 2016 and 15 January to 6 February 2017 and B) December 2016/17 (Source: Ward et al. 2018) and December 2023 (Souce: Ward et al. 2025).



3.4 Western Sub-area

3.4.1 Redbait

Annual catch, effort and CPUE

Significant quantities of Redbait were taken off south-western Tasmania from 2001–02 to 2009–10 (Figure 3–31, 3–32). The annual catch peaked of Redbait from the Western Sub-area of the SPF peaked at 3,228 t in 2006–07 (Figure 3–31, 3–32). A factory caught 1,156 t and 1,139 t of Redbait from the Western Sub-area in 2015–16 and 2016–17, respectively.

Daily Egg Production Method

The DEPM was applied to Redbait in the Western Sub-area of the SPF in 2017 (Ward et al. 2019). Ichthyoplankton samples were collected during October from sites between western Kangaroo Island and south-western Tasmania (Figure 3.33). Adult samples were collected by a demersal trawler between Portland, Victoria and western Tasmania. The estimate of spawning biomass of 66,767 t (CI = 28,797–190,392) was considered suitable for setting RBCs because it is based on robust and/or conservative estimate of key parameters. For example, the estimate of spawning fraction was considered robust because similar estimates of this parameter were obtained using females with hydrated oocytes and three POF stages separately, which the authors suggested meant that samples were not biased towards females spawning on a particular night. However, the estimate of mean spawning fraction of 0.21 was lower than the estimate of 0.3 obtained by Ewing and Lyle (2009), which if incorrect would have caused spawning biomass to be over-estimated. Similarly, the relative fecundity that can be calculated from estimates of batch fecundity and female weight provided by Ward et al. (2019) of 92.6 eggs.g^{-1} was lower than the comparable value from Ewing and Lyle (2009) of 169.6 eggs.g^{-1}, which if incorrect would also cause the spawning biomass to be over-estimated. Ward et al. (2019) correctly noted that one of the main uncertainties in estimating the spawning biomass for Redbait relates to estimation of mean daily egg production. This uncertainty is caused by the extended developmental time of Redbait eggs (4 days) and the apparent under-sampling of early-stage (Day 1) eggs. Ward et al. (2019) addressed this challenge by removing Day 1 eggs from dataset and estimating mean daily egg production from the mean of values obtained using models that are likely to provide conservative estimates of mean daily egg production. Future studies should consider using a GLM with a negative bionomial error structure and variance increasing linearly with the mean to estimate mean daily egg production (Ward et al. 2021). The findings of Ward et al. (2019) highlight the need for further investigation of the reproductive biology of Redbait off south-eastern Australia, especially relative fecundity and spawning fraction.

Figure 3–31. Total annual catch, effort (A) and CPUE (B) of Redbait by SPF trawlers in the Western Sub-area of the SPF 2000–01 to 2023–2024.

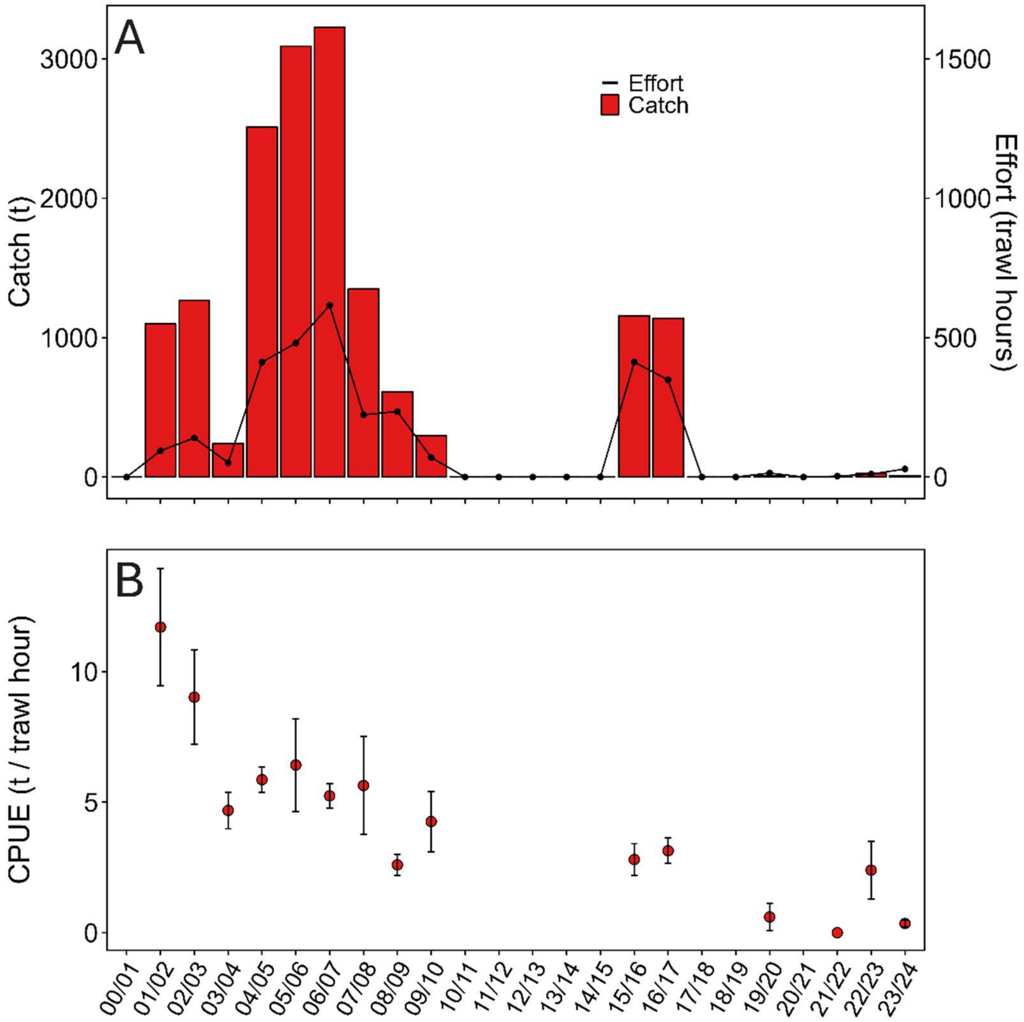


Figure 3–32. Spatial distribution of catches of Redbait in the Western Sub-area in the SPF from 2000–01 to 2023–24

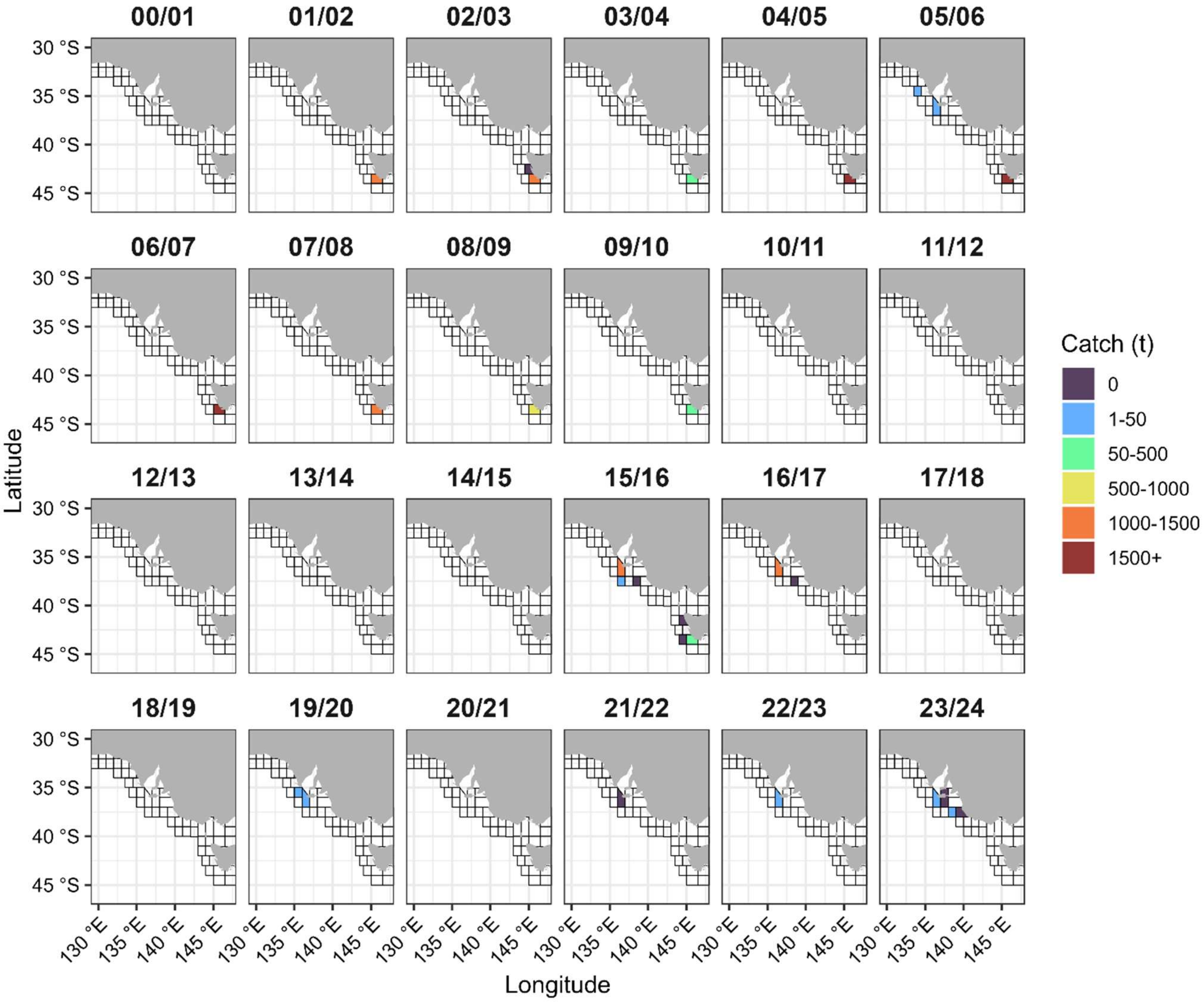
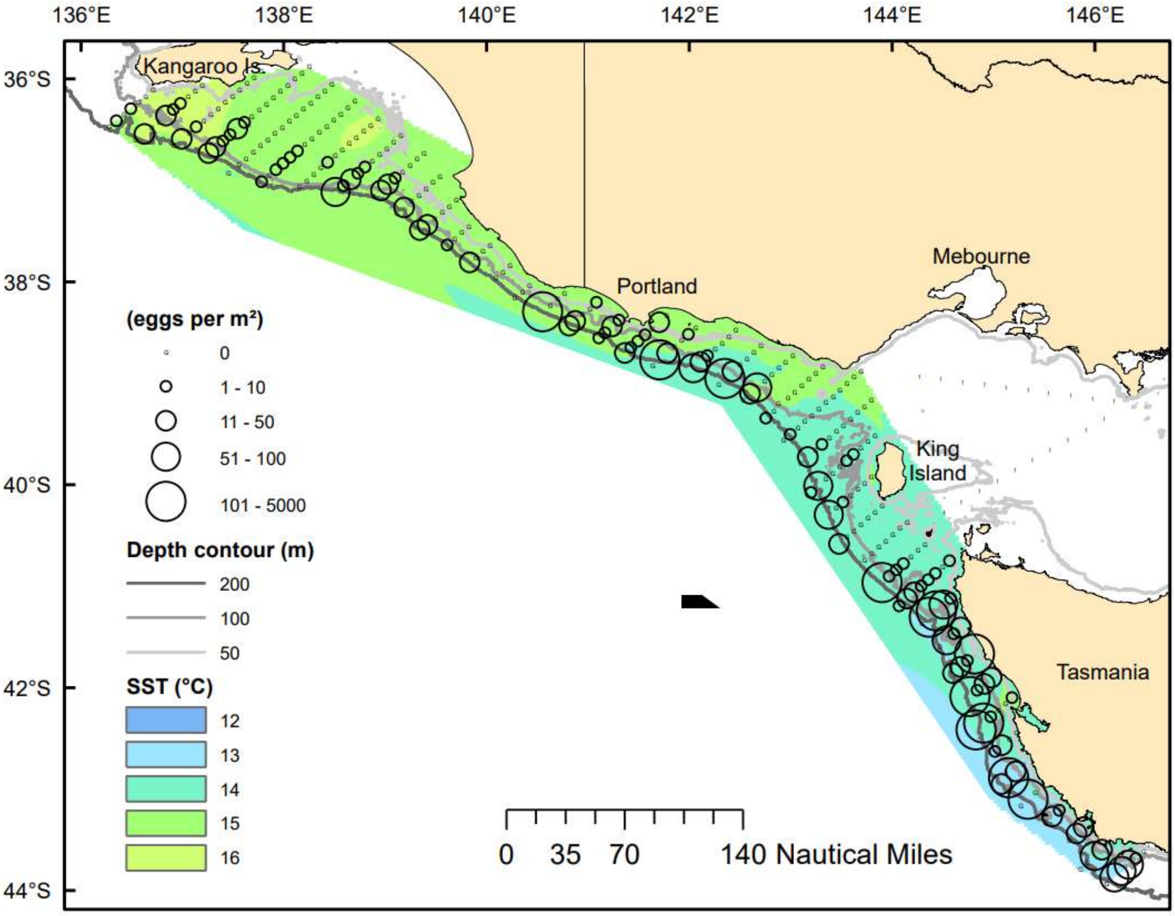


Figure 3–33. Map showing distribution and densities of Redbait eggs collected in the plankton survey conducted in the Western Sub-area of the SPF during October 2017 (Source: Ward et al. 2018).



4. Discussion

4.1 Overview

The SPF has grown rapidly over the last decade. In 2013–14, the total annual catch was less than 20 t. In contrast, the annual catch in 2022–23 and 2023–24 exceeded 20,000 t, making the SPF Australia's second largest fishery after the South Australian Sardine Fishery, which currently catches over 45,000 t annually (Grammer at al. 2024). Collectively, the SASF and SPF currently take approximately one third of Australia's total annual wild fisheries production (Tuynman et al. 2023). The annual catch of the SPF in 2023-24 of 23,055 t equates to approximately ten percent Australia's total annual wild fisheries catch. The rapid growth and large size of the SPF have increased the need to ensure that monitoring and assessment is as robust as possible.

This report shows that the growth of the SPF over the last decade has been driven by the development of the trawling operation off southern NSW. Most of the catch has been used to produce fish meal and fish oil which is then used to produce feed for finfish aquaculture, replacing products previously imported from overseas. The main species taken in the trawl operation are Blue Mackerel and Jack Mackerel, with smaller quantities of Redbait. The following discussion focuses on evaluating and refining current approaches for monitoring and assessment of these three species in the Eastern Sub-area of the SPF.

There are a multitude of reasons why monitoring and assessment of the SPF is inherently challenging. For example, the SPF covers a vast geographical area, and the target species are widely distributed and highly mobile with complex species-specific patterns of movement and stock structure. The distribution, abundance and productivity of small pelagic fishes are also highly sensitive to changes in environmental conditions. There is also growing evidence that the spatial structure of the SPF does not match the stock structure of at least some of the target species (e.g., Grammer et al. 2021). It is well known that fishery-dependent data like those presented in this report provide relatively limited insights into the stock status of small pelagic fishes such as those taken in the SPF. That is why the SPF HS specifies the need for a fishery-independent approach to stock assessment using the DEPM. However, because the SPF HS was only established in 2008, and because the DEPM surveys which underpin the management of fishery are only done every five years, there are critical gaps in current understanding of the reproductive biology and ecology of the three main target species that impact the reliability of estimates of spawning biomass obtained from each application of DEPM. Furthermore, because research and monitoring of the SPF has been done as discrete projects by multiple research institutions, historical data from both fishery-dependent and fishery-independent studies have not been complied into a single integrated database. One of the biggest challenges to writing the current report, and to producing other publications on the fishery, has been collating the historical data. We strongly recommend that a project is established to collate all existing data on the SPF and develop an integrated database that is accessible to researchers that undertake future studies of the fishery.

4.2 Blue Mackerel

The separation of the SPF into Eastern and Western Sub-areas is reasonably good match for the stock structure of Blue Mackerel. Evidence currently available suggests that there are separate stocks of Blue Mackerel off the eastern and southern Australia (e.g., Ward et al. 2001; Bulman et al. 2008; Schmarr et al. 2011), and that the line dividing the SPF into sub-areas is a reasonable proxy for their delineation. Certainly, the spawning grounds off the east coast, i.e. from southern Queensland to central NSW, and in the Great Australian Bight, are spatially discrete and should continue to be surveyed separately. Assessing Blue Mackerel in the Eastern and Western Sub-areas as separate stocks is consistent with the stock structure of this species.

Up until 2014/15, when a factory trawler entered the SPF, Blue Mackerel was a minor component catches in the Eastern Sub-area, as it had been in the Jack Mackerel Fishery. However, in 2023–24 Blue Mackerel was the dominant species taken by trawlers off southern NSW. The total annual catch in 2023–24 was 11,049 t, which was ~95% of the available TAC (AFMA 2023). Fishery-dependent data presented in this report do not provide evidence to suggest that the SPF is impacting the local or broader stock of Blue Mackerel. In this respect, it is worth noting that the current fishing operation is located a long way south of the main spawning grounds off southern Queensland and northern NSW (Ward et al. 2015b, 2020).

The last two DEPM surveys of Blue Mackerel in the Eastern Sub-area of the SPF both provided estimates of spawning biomass between 80,000 and 90,000 t (Ward et al 2015, 2020). The similarity of these results reflects both the similarity of the estimates of spawning area and egg production obtained from the two plankton surveys, and the use of the same adult reproductive data from South Australia to estimate spawning biomass. Applications of the DEPM by Ward et al. (2009; 2015a, 2020) identified the critical need to obtain estimates of adult reproductive parameters, especially spawning fraction, of Blue Mackerel in the Eastern Sub-area of the SPF.

A targeted project was conducted during the peak spawning seasons (mainly September) in 2022, 2023 and 2024 to obtain estimates of adult parameters, especially spawning fraction, from the spawning grounds off southern Queensland and northern NSW (e.g. Ward et al. 2023). The results from that study will be used in the application of the DEPM to Blue Mackerel that was conducted off southern Queensland and northern NSW in September 2024. The final report for that project will evaluate if there is a need to further improve understanding of the reproductive biology of Blue Mackerel in the Eastern Sub-area of the SPF.

4.3 Jack Mackerel

There is growing evidence that the stock structure of Jack Mackerel does not match the division of the SPF into Eastern and Western Sub-areas. Rather the presence of eggs throughout Bass Strait (e.g., Ward et al. 2025) suggests that Jack Mackerel is distributed continuously from the Victorian-South Australian border through Bass Strait to the east coast as far south as Tasman Island and north to Port Stephens. Applying the DEPM to either half of this apparent biological stock raises the potential for a significant portion of the likely adult population to lie outside the survey area and not be accounted for in the estimate of spawning biomass. Furthermore, the potential for the movement of spawning biomass between the two components of the stock cannot be discounted. As a result, the relative and absolute biomass of Jack Mackerel in the two sub-areas may vary over time. Assessing Jack Mackerel separately in the Eastern and Western Sub-areas does not match the likely stock structure of this species.

Jack Mackerel was the target species in the purse-seine fishery that operated off eastern Tasmania from 1977 to 2000. The decline in annual catch of Jack Mackerel from the peak of almost 40,000 t that was taken in 1987 to the sporadic catches that were taken from the late 1980s up until the Jack Mackerel Fishery ended in 2000, has been variously attributed to over-fishing and/or changes in fish behaviour and distribution associated with oceanographic variability and ecosystem change (Young et al. 1993; McLeod et al. 2012; Commonwealth of Australia 2016). The decline and volatility of the Jack Mackerel Fishery highlights the dynamic complexity of the patterns of distribution and abundance of Jack Mackerel off south-eastern Australia.

The total catch of Jack Mackerel by trawlers operating off southern NSW in 2023–24 was 10,084 t, which is the highest in the history of the SPF and approximately 54% of the available TAC (AFMA 2023). The fishery-dependent data presented in this report do not provide evidence to suggest that the SPF is impacting the local or broader stock of Jack Mackerel. The area where most of this catch was taken is located in the northern part of the spawning area of Jack Mackerel off south-eastern Australia.

DEPM surveys conducted in January 2014 and 2019 suggested that the spawning biomass of Jack Mackerel in the Eastern Sub-area of the SPF was between 150,000 and 160,000 t (Ward et al. 2015a, 2016, 2020). These studies highlighted limitations in understanding of the relationship between size and fecundity and spatial and temporal variations in spawning fraction. The failure of the DEPM survey conducted in the Eastern Sub-area of the SPF in January 2024 to provide a robust estimate of spawning biomass further highlighted limitations in current knowledge of the reproductive biology of Jack Mackerel off south-eastern Australia (see Ward et al. 2015a, 2016, 2020, 2025). It also highlighted the critical importance of developing approaches to monitor levels of spawning activity to ensure that future DEPM surveys are conducted during the peak spawning season. A research project is needed to improve estimates of relative fecundity and better understand spatial and temporal variability in spawning fraction of Jack Mackerel off south-eastern Australia. This project should develop protocols for monitoring levels of spawning activity to ensure that future DEPM surveys are conducted during the peak spawning season. This project is needed to inform the design of future DEPM surveys and ensure that they provide robust estimates of spawning biomass. Therefore, the project should be done before the next DEPM survey.

The results of the plankton survey conducted in the Western Sub-area of the SPF in December 2023 (Ward et al. 2025) highlighted the unsuitability of the spatial management framework for the SPF for assessing the stock status of Jack Mackerel off south-eastern Australia. This issue needs to be considered when the results of future DEPM surveys are being interpreted. Consideration should be given to ensuring that future applications of the DEPM to Jack Mackerel off south-eastern Australia cover the entire likely biological stock. It would be prudent to investigate if there are opportunities to coordinate future applications of the DEPM to Jack Mackerel with surveys conducted to assess the South-eastern Australian Sardine Stock that is under the jurisdiction of the Tasmanian Government (see Ward et al. 2024a).

4.4 Redbait

There is growing evidence that the stock structure of Redbait off south-eastern Australia may not match the division of the SPF into Eastern and Western Sub-areas. Rather, the presence of Redbait eggs off southern Tasmania suggest that there may be no clear impediment to mixing of Redbait from the eastern and western coasts of Tasmania (Neira 2008, Neira and Lyle 2011, Ward et al. 2018, Grammer et al. 2021, 2022). However, the narrow band of spawning habitat off southern Tasmania (Ward in prep.), compared to the large area of Bass Strait through which Jack Mackerel from the western Victoria and the east coast can mix, suggests that the potential for movement between the two sub-areas of the SPF may be less significant for Redbait than for Jack Mackerel. Therefore, continuing to conduct separate DEPM surveys for Redbait in the Eastern and Western Sub-areas is likely to be appropriate.

Redbait was the target species in the trawl operation that was conducted off Tasmania in 2001–02 to 2010–11. The highest annual catch taken in that operation of 6,514 t in 2003–04 was much larger than the highest annual catch that has been taken in the current fishing operation off southern NSW of 2,349 t in 2019–20. The current fishing operation off southern NSW is located on the north-eastern part of the likely distribution of this stock, which Bulman et al. (2008) suggested extends from the South Australian/Victorian border to southern NSW, but which more recent studies suggest may extend further west (Ward et al. 2018).

The total catch of Redbait from the Eastern Sub-area in 2023–24 was 1,788 t, which was approximately 33% of the available TAC. The fishery-dependent data presented in this report do not provide any evidence to suggest that trawlers operating off southern NSW are impacting the local or broader stock of Redbait. However, the decline in CPUE off Tasmania from 2001–02 to 2009–10, which could have been caused by either fishing pressure and/or environmental changes, highlights the need for ongoing monitoring for evidence of localised depletion.

Several aspects of the application of the DEPM to Redbait need to be refined. The most important issue that needs to be resolved are differences between estimates of relative fecundity and spawning fraction obtained in recent studies (Ward et al. 2018, Grammer et al. 2022) and those obtained by Ewing and Lyle (2008). However, because recent catches of Redbait have been relatively low, the need for this research is not as urgent as the need to address current limitations in the understanding of the reproductive biology of Jack Mackerel. It is, however, an issue that would ideally be addressed before the next DEPM survey for Redbait is done.

4.5 Conclusions and recommendations

In the short-term, two projects are needed to improve the monitoring and assessment framework for the SPF. Most importantly, a project is needed to improve current understanding of the reproductive biology of Jack Mackerel off south-eastern Australia and develop methods for monitoring levels of spawning activity to ensure that future DEPM surveys are conducted during the peak spawning season and provide robust estimates of spawning biomass. Because the results are needed to inform the design of future DEPM surveys, this project should be done prior to the next survey. A smaller project is also needed to collate historical fishery-dependent and fishery-independent data for the SPF and establish an integrated database that is available for scientists undertaking future monitoring and research on the fishery.

In the medium term, there is also a need to resolve uncertainties surrounding estimates of spawning fraction and relative fecundity for Redbait. This work should be done before the next DEPM survey for Redbait, but the need is not as pressing as the need for research on the reproductive biology of Jack Mackerel. It would also be beneficial to update the genetic methods currently used to validate the morphological identification of the early-stage eggs of Jack Mackerel, Blue Mackerel and Redbait. This would ideally involve the *in situ* hybridisation approach that was developed for Snapper by Oxley et al. (2017) that preserves the integrity of eggs and ensures 100% accuracy of egg identifications by colouring the eggs of target species. This approach could potentially be developed as student projects for each species.

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