Fisheries

Assessment of the South Australian Marine Scalefish Fishery in 2021/22

JJ Smart, R McGarvey, J Feenstra, MJ Drew, J Earl, L Durante, CL Beckmann, D Matthews, JM Matthews, K Mark, J Bussell, J Davey, A Tsolos and C Noell

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SARDI Aquatic & Livestock Sciences
PO Box 120 Henley Beach SA 5022

August 2023

Report to PIRSA Fisheries and Aquaculture

Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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The South Australian Research and Development Institute respects Aboriginal people as the state's first people and nations. We recognise Aboriginal people as traditional owners and occupants of South Australian land and waters. We pay our respects to Aboriginal cultures and to Elders past, present and emerging.

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EXECUTIVE SUMMARY

This report is the sixth in the annual reporting series for South Australia's Commercial Marine Scalefish Fishery (MSF) and the first to occur following the reform of the fishery in 2021. Data considered in this report extend for 39 years from 1 July 1983 to 30 June 2022. The report provides a description of the dynamics of the multi-species, multi-gear fleet and assigns stock status to 31 stocks of 20 species or taxa that are harvested in the fishery, using the National Fishery Status Reporting Framework (Piddocke et al. 2021). It builds on previous assessment reports by Smart et al. (2022b) Drew et al. (2021) and Steer et al. (2018a, 2018b, 2020), and includes a summary of the taxon-specific information relating to: (1) population biology; (2) fishing access; (3) management arrangements; (4) recreational catches from four surveys; (5) trends in commercial fishery statistics at the State-wide, biological stock or zone management unit scales; and (6) an assessment of fishery performance using performance indicators prescribed in the fishery's management plan (PIRSA 2013).

Since the last assessment (Smart et al. 2022b), the MSF has undergone a structural reform that included the formation of four new management zones, implementation of total allowable commercial catches (TACCs) for eleven stocks and a switch from calendar to financial year reporting for fishing season. These updates have been applied throughout this assessment.

<u>Fleet Dynamics</u>

Many of the changes in the operation of the MSF fleet over the past four decades have occurred in response to changes to fisheries management arrangements. These included reductions in fishing effort resulting from the rationalisation of the fleet through the licence amalgamation scheme implemented in 1994, reductions in the number of restricted marine Scalefish ('B-class') licences, and two voluntary net buy-back initiatives in 2005 and 2014. In 2021, 100 MSF licences were surrendered through the MSF reform, with 205 licences remaining. Many of the licences surrendered were either latent or belonged to fishers who owned multiple licences. No B-class licences remain following the MSF reform.

Degrading stock statuses or management restrictions implemented for several primary target species have contributed to the diversification of the fishing fleet over time, with many fishers switching their effort from Snapper, King George Whiting and Garfish to Southern Calamari. As a consequence, Calamari is now the most economically valuable species in the commercial MSF, with a GVP ($5.8 million AUD) that is 57% greater than that of the next most valuable species; King George Whiting ($3.7 million AUD).

Many of the species considered in this report are caught by the haul net sector of the fishery, and some are incidentally caught when more valuable species are targeted. Of these, Yellowfin Whiting, Australian Herring, Snook, Leatherjackets and Yelloweye Mullet are of medium wholesale value. These species share similar commercial catch and effort trends, where effort and catch within the haul net sector has been sequentially reduced over recent decades. Despite the long-term declining trend in effort across the fishery, Snook and Leatherjackets have been increasingly targeted by haul net fishers over recent years. There has also been an increase in catches of Ocean Jackets using fish traps.

Western Australian Salmon had the largest commercial catch in the MSF in 2021/22 at 325 t. Meanwhile catches of Tier 1 stocks (i.e., species with TACCs) were substantially lower than 2020/21. This was anticipated following the fishery's reform, given the new operating conditions for the fishery, as well as the need for autonomous quota trading to occur in this inaugural season.

Stock Status

This report assessed the fishery performance of 20 species (or species groups) comprising 31 stocks. Of these, 23 (~74%) stocks were classified as sustainable, two (~6%) were classified as depleted, two (~6%) were classified as recovering, one was classified as negligible (~3%) and the remaining three (~10%) were classified as undefined as there was insufficient information to assign a stock status (Table E-1). Catch statistics were also presented for Gummy and School Sharks but no status was assigned by these species as they are managed by the Australian Fisheries Management Authority (AFMA).

The focus of this report is the King George Whiting stock assessment. State-wide levels of catch and effort were the lowest recorded in 2021/22 with 176 t and 9,511 fisher-days, respectively. However, the dominant gear type of handlines has maintained high levels of CPUE and was the highest on record in 2021/22 at 22.2 kg.fisher-day^{-1}. Biomass remained high for both the West Coast (WC) and Gulf St Vincent/ Kangaroo Island (GSV/KI) fishing zones, indicating strong stock health. Biomass has been declining for the past six years for the Spencer Gulf (SG) fishing zone due to lower-than-average recruitment over the past ten years. Reduced commercial catches over the past ten years appear to have prevented substantial biomass declines from occurring during this period of poor recruitment. As a result, all three Tier 1 stocks of King George Whiting were classified as sustainable. The reduced recruitment evident in the SG fishing zone, along with declining biomass, should be closely monitored in future assessments.

Future Directions

The most important research needs for the fishery and its management include: (1) delivery of the science projects identified in the 2022 Snapper stock assessment (Drew et al. 2022) to support the monitoring of the Spencer Gulf–West Coast (SG/WC) and GSV Snapper stocks; (2) development of harvest strategies for key species that are tailored to the tiered management of the fishery and provide the decision-making frameworks to support TACC setting; (3) development of an innovative Southern

Calamari stock assessment to enable provision of more reliable scientific advice to support TACC setting; (4) evaluation of the density-dependence hypothesis for Southern Garfish, potentially through the development of a fishery-independent survey; and (5) regular surveys to estimate recreational harvests.

Keywords: Marine Scalefish Fishery, fleet dynamics, stock status.

Table E-1. Status of South Australia's Marine Scalefish Fishery stocks and fishery performanace indicators assessed between 2019–2020 and 2021/22. Note that stock statuses were assigned based on calendar years prior to the current assessment. '+' denotes status was assigned to the biological stock. Stocks abbreviations are: West Coast (WC), Northern Spencer Gulf (NSG), Southern Spencer Gulf (SSG), Northern Gulf St Vincent (NGSV), Southern Gulf St Vincent (SGSV), South East (SE), Spencer Gulf/West Coast (SG/WC), Gulf St Vincent/Kangaroo Island (GSV/KI), Western Victoria (WV), and Marine Scalefish Fishery (MSF).

SPECIES	STOCK	STATUS 2019	2020	2021/22	INDICATORS
KING GEORGE WHITING	WC	Sustainable+	Sustainable+	Sustainable	Catch, CPUE, age structure, biomass
	SG	Sustainable+	Sustainable+	Sustainable	Catch, CPUE, age structure, biomass
	GSV/KI	Sustainable	Sustainable	Sustainable	Catch, CPUE, age structure, biomass
SNAPPER	SG/WC	Depleted+	Depleted+	Depleted+	Catch & Effort
	GSV	Depleting+	Depleted+	Depleted+	Catch & Effort
	WV	Sustainable+	Sustainable+	Sustainable+	Catch & Effort
SOUTHERN GARFISH	WC	Sustainable	Sustainable	Sustainable	Catch & Effort
	SG	Recovering+ (NSG)	Recovering+ (NSG)	Recovering	Catch & Effort
		Sustainable+ (SSG)	Sustainable+ (SSG)		Catch & Effort
	GSV/KI	Depleted+ (NGSV)	Recovering+ (NGSV)	Recovering	Catch & Effort
		Sustainable+ (SGSV)	Sustainable+ (SGSV)		Catch & Effort
	SE	Sustainable	Sustainable	Sustainable	Total Catch
SOUTHERN CALAMARI	WC	Sustainable+ (STATE)	Sustainable+ (STATE)	Sustainable	Catch & Effort
	SG			Sustainable	Catch & Effort
	GSV/KI			Sustainable	Catch & Effort
	SE			Negligible	Total Catch
YELLOWFIN WHITING	SG	Sustainable	Sustainable	Sustainable	Catch & Effort
	GSV/KI	Sustainable	Sustainable	Sustainable	Catch & Effort
BLUE CRABS	WC	Sustainable (MSF)	Sustainable (MSF)	Sustainable	Catch & Effort
WA SALMON	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
AUST. HERRING	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
WHALER SHARKS	STATE	Undefined	Undefined	Undefined	Limited data
SNOOK	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
SAND CRABS	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
YELLOWEYE MULLET	MSF	Sustainable	Sustainable	Sustainable	Catch & Effort
MULLOWAY	MSF	Sustainable	Sustainable	Sustainable	Catch & Effort
OCEAN JACKETS	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
BLUE-THROAT WRASSSE	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
SILVER TREVALLY	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
LEATHERJACKETS	STATE	Undefined	Undefined	Undefined	Limited data
RAYS & SKATES	STATE	Undefined	Undefined	Undefined	Limited data
CUTTLEFISH	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
BLACK BREAM	MSF	Sustainable	Sustainable	Sustainable	Total Catch

1. INTRODUCTION

1.1. Overview

This is the sixth report in this series for the South Australian Marine Scalefish Fishery (MSF) that provides a taxon-specific summary of information on: 1) fisheries biology; 2) fishing access; 3) management arrangements; 4) trends in commercial fishery statistics at the scales of the biological stock or regional management units, and 5) assessment of fishery performance. Data included in this report were sourced from commercial logbook returns provided to SARDI by MSF licence holders over 39 years between the 1983/84 and 2021/22 fishing seasons. This is the first assessment report to be undertaken with fishing seasons as financial (1 July to 30 June each year) rather than calendar years. This is also the first report to assess the fishery since the MSF reform that occurred on 1 July 2021.

This report is partitioned into five sections. Section one (this section) provides an overall description of the MSF, its management arrangements, performance indicators, and details the indicators used to assess the status of the stocks within the fishery. Section two describes the dynamics of the commercial fleet, catch composition, and temporal trends in fishing effort, while section three contains the stock assessment for King George Whiting.

Section four consists of a series of species/taxon-based sub-sections arranged in order of their descending priority. These are structured as 'stand-alone' updates for taxa caught in the fishery, for each of which a summary of the relevant biological information is presented, along with a description of the fishery, associated management regulations, the State-wide and/or zonal fishery statistics, assessment of the fishery against the general performance indicators, and the classification of the stock status for 2021/22. These sub-sections have been reformatted in the current report, such that priority species (i.e., the four primary species and Yellowfin Whiting) are presented as full chapters. The remaining sub-sections are presented as more concise summaries designed to allow readers to quickly access important facts and information.

The fifth and final section synthesises the overall performance of the fishery, details emerging trends within the fishing fleet, and identifies key research priorities that will enhance the assessment and management of South Australia's MSF.

1.2. Description of the Marine Scalefish Fishery

The MSF is a multi-species, multi-gear, multi-sector fishery with > 200 active licence holders in 2021/22 and access to species in the fishery is also available to other commercial, recreational and Aboriginal traditional sectors. Due to the number of licences, gear types used, the species caught, fishers' ability to switch target species and the geographical range, it is considered to be the most complex fishery in South Australian waters.

Commercial fishers in the MSF are permitted to take in excess of 60 marine species, including bony fishes, molluscs, crustaceans, annelid worms, sharks, rays and skates. Fishery production by weight of catch has predominantly consisted of Southern Calamari (*Sepioteuthis australis*), Snapper (*Chrysophrys auratus*), King George Whiting (*Sillaginodes punctatus*), Southern Garfish (*Hyporhamphus melanochir*) and Yellowfin Whiting (*Sillago schomburgkii*). Other species such as Western Australian Salmon (*Arripis truttaceus*), Australian Herring (*Arripis georgianus*), Ocean Jackets (*Nelusetta ayraudi*) and Sand Crabs (*Ovalipes australiensis*) also contribute significantly to the overall catch.

There are 30 types of fishing gear (or devices) endorsed in the MSF. Their uses differ depending on the location of fishing and the species being targeted. With the exception of fishing rods and handlines, all devices must be registered on a licence before they can be used to take fish for trade or business. For the commercial sector there were two types of licences, i.e., Marine Scalefish (A-class) and Restricted Marine Scalefish (B-class). However, no Restricted Marine Scalefish licences remain in the fishery following the recent voluntary licence surrender program (VLSP) implemented through the MSF reform in 2021. A proportion of the Marine Scalefish licence holders have specific net endorsements and are permitted to use haul nets and set/gillnets to target certain species. Restricted Marine Scalefish licence holders had fewer gear endorsements and were prohibited from using nets. In addition, licence holders from the Miscellaneous Fishery, the Northern (NZRLF) and Southern Zone Rock Lobster (SZRLF) fisheries, the Lakes and Coorong Fishery (LCF), three Western King Prawn fisheries and the Blue Crab Fishery (BCF) have all had varying levels of access to the key MSF resources. For example, the three Western King Prawn fisheries can only take certain MSF species as by-products.

The broad mixture of participants, gear types, licence conditions and regulations associated with the MSF make the task of assessing the status of the stocks challenging. This is further compounded by the highly dynamic nature of fisher behavioural responses to resource availability and seafood markets, as they can switch their target effort between species and regions throughout State waters. This complexity means there is considerable capacity for the fishery to expand through the activation of latent effort.

The recreational fishing sector also has access to many of the MSF species through sector allocations, some of which are close to 50% (PIRSA 2013). Most recreational fishing effort occurs in marine waters, including estuaries, with fishers permitted to use several gear types to target a variety of MSF species (Beckmann et al. 2023).

1.3. Management Arrangements

The MSF is managed by the South Australian State Government's Department of Primary Industries and Regions (PIRSA) Fisheries and Aquaculture Division in accordance with the legislative framework provided within the *Fisheries Management Act 2007*, and subordinate *Fisheries Management (General) Regulations 2017*, *Fisheries Management (Marine Scalefish Fisheries) Regulations 2017,* Ministerial determinations, licence conditions and *Management Plan for the South Australian Commercial Marine Scalefish Fishery.*

The commercial MSF underwent considerable management changes prior to 2020/21, including a settlement with the Commonwealth Government Australian Fisheries Management Authority (AFMA) for offshore waters resources management in 1992 (Offshore Constitutional Settlement), limitation through gear restrictions and configuration, licencing, spatial and temporal closures related to protection of spawning areas and size limits. Prior to the reform of the MSF in 2021, there had been three notable management changes implemented to limit, and then reduce, the number of participants in the commercial MSF. The first occurred in 1977, when a freeze was imposed on the issue of new licences, which converted the commercial MSF into a limited-entry fishery. This also involved a 'show-cause provision' that prevented the re-issue of licences to fishers if a minimum level of commercial fishing had not been met. Non-transferable Restricted MSF licences were also created at this time to recognise part-time fishers. The second change was the licence amalgamation scheme which was introduced in 1994. This scheme is essentially a fractional licencing initiative which requires prospective fishers to purchase a certain number of points when buying a licence (Steer and Besley 2016). The third change, implemented in 2005, was a voluntary buy-back of net fishing endorsements and subsequent spatial closures to net fishing. A similar, smaller licence buy-back scheme was also implemented in 2014 in association with the establishment of the network of South Australian Marine Parks. A structural reform of the commercial MSF occurred in 2021 creating the most substantial management changes that have occurred for the MSF.

With the exception of recreational Southern Rock Lobster pot licences, the recreational fishery is not licenced but subjected to a range of regulations, such as size, boat, bag and possession limits, restrictions on the types of gear that may be used, temporal and spatial closures, and the complete or partial protection (e.g. Western Blue Groper) of some species.

1.3.1. Recent Commercial MSF Reform

In July 2021 the commercial MSF underwent a major fishery reform that included 'three pillars': regionalisation, rationalisation, and unitisation. Four regional zones of management were created that included Spencer Gulf (SG), Gulf St Vincent / Kangaroo Island (GSV/KI), the West Coast (WC) and the South East (SE) (Figure 1.3-1). Fish stocks are now managed according to these zones through a tiered management framework (TMF) that assigns each stock to a Tier based on its importance according to several biological, social and economic indicators. Stocks in Tier 1 are managed using a total allowable commercial catch (TACC) with some stocks further managed via individual transferable quotas (ITQs). Tier 2 and Tier 3 stocks are managed without TACCs via input controls. Tier 2 stocks should have sufficient assessments to estimate a recommended biological catch which can be used to assess stock performance, while Tier 3 stocks are assessed using commercial catch and effort statistics. From 1 July 2021 the fish stocks assigned a Tier 1 status include King George Whiting (GSV/KI, SG, WC), Southern Garfish (GSV/KI, SG), Southern Calamari (GSV/KI, SG) and Snapper (GSV/KI, SG, WC, SE). All these stocks are now managed via TACCs and every stock accept King George Whiting in the WC fishing zone has been unitised via ITQs.

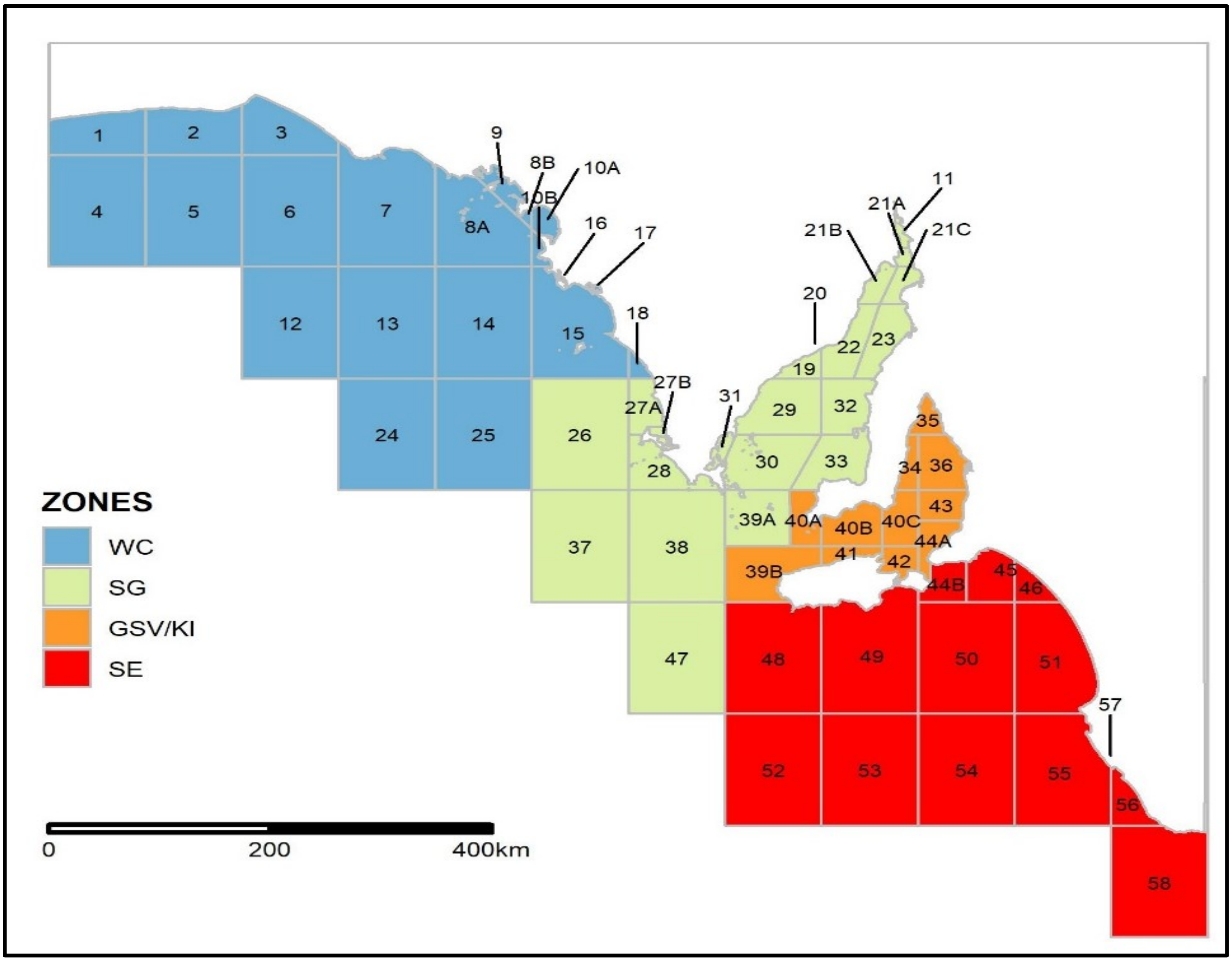


Figure 1.3-1. The fishing zones implemented through the commercial MSF reform in July 2021. These zones are the Spencer Gulf zone (SG), Gulf St Vincent/Kangaroo Island zone (GSV/KI), West Coast zone (WC) and South East zone (SE). The boundaries of each zone are delineated by existing MFA blocks or sub-blocks.

Fleet rationalisation also occurred, where 100 licences were voluntarily surrendered (Smart et al. 2022a). The purpose of the reform was to improve the economic performance of the commercial MSF and increase stock sustainability. Management efforts to achieve this are ongoing. and guided by the recently established Marine Scalefish Fishery Management Advisory Committee (MSFMAC). Full details of the reform and its implications for ongoing future assessments are available in Smart et al. (2022a).

1.3.2. Snapper Management Arrangements

As a result of a management review following the 2019 Snapper Stock Assessment (Fowler et al. 2019), fishing for Snapper was prohibited in all State waters from 1 November 2019 except for the region that now constitutes the SE fishing zone This fishery closure was originally implemented to remain in effect until 1 February 2023 but following an updated assessment of Snapper (Drew et al., 2022), the closure has been extended to 30 June 2026. As such, no updated catch and effort information on Snapper are available for the SG, GSV/KI and WC fishing zones in this assessment.

In 2020, the Snapper fishery in the SE fishing zone was managed using a total allowable catch (TAC) that was divided into a TACC and a total allowable recreational catch (TARC). The TAC in 2020 was set at 75 t and divided among sectors according to their allocations in the Management Plan (PIRSA 2013).

The TACs in the SE fishing zone for the 2021 and 2021/22 fishing seasons were set based on the estimated fishable biomass for the SE Region from the SnapEst model. For the 2021 fishing season, the TAC was set at 26.6 t (48 t pro-rata for five of the possible nine-month season) and divided among sectors following the State-wide allocations. For the 2021/22 fishing season, the TAC was set at 48 t and divided among sectors following the regional distribution of the state-wide sector allocations (Smart et al. 2022)

1.4. Spatial Scale of Assessments

The spatial assessment scale varies among species presented in this report and was determined by differing stock boundaries. Species such as Southern Garfish and Southern Calamari have assessments undertaken at the zone level, but a regional level is also presented to provide a finer spatial scale for examining catch and effort statistics (Figure 1.4-1). Conversely, Snapper are assessed at the biological stock level which includes an amalgamation of the SG and WC fishing zones, as per the spatial boundaries of the SG/WCS. King George Whiting, Blue Crab and Yellowfin Whiting are presented at the zone scale, for zones where commercial MSF catches are not negligible. Lastly, all remaining stocks are assessed at the State-wide scale, as per previous reports. This tailored approach for each species/taxon allows scientific assessments to be conducted at the appropriate biological scale, while management advice can be easily provided at the fishing zone scale.

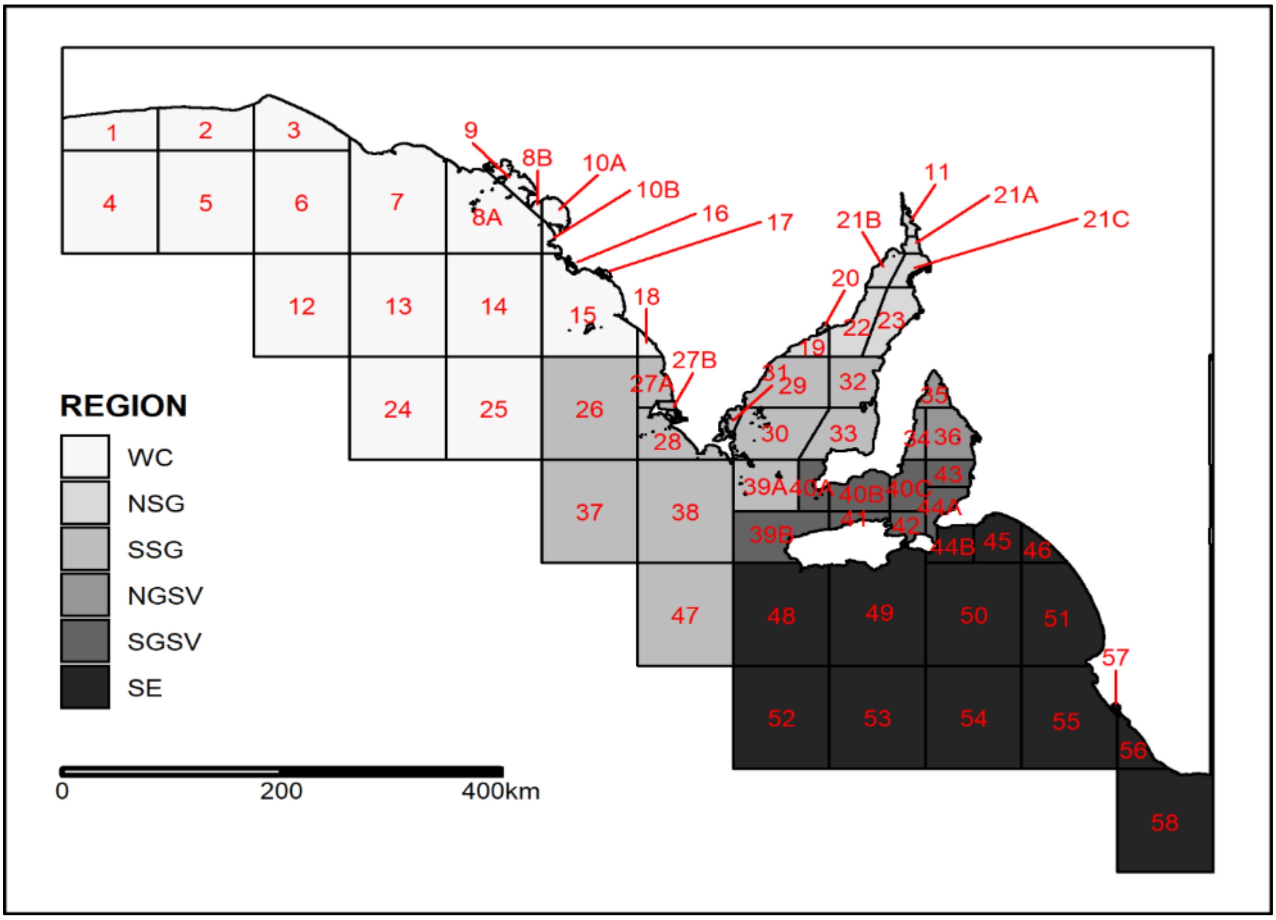


Figure 1.4-1. Marine Fishing Areas of South Australia's Marine Scalefish Fishery showing regional boundaries used in this assessment: West Coast fishing zone (WC), Northern Spencer Gulf (NSG), Southern Spencer Gulf (SSG), Northern Gulf St Vincent (NGSV), Southern Gulf St Vincent (SGSV, and South East fishing zone (SE).

1.5. Fishery Performance Indicators

For each taxon, general performance indicators (PIs) are used to benchmark the performance of the fishery. These are derived from commercial catch, target effort and catch per unit effort CPUE, and vary amongst the taxa. Annual time-series of these PIs were derived from commercial fishery statistics from 1983/84 to 2021/22 (i.e., the reference period). Each performance indicator was benchmarked against the following trigger points:

1. the third highest and third lowest values of the reference period;
2. the greatest (%) inter-annual variation (+ and -) over the reference period;
3. the greatest rate of change (+ and -) over a five-year period; and
4. whether the PI has decreased over the most recent five consecutive years.

Biological performance indicators (BPIs) are also assessed for King George Whiting as part of the current stock assessment.

1.6. Stock Status Classification

A national stock status classification system is used for the assessment of key Australian fish stocks (Piddocke et al. 2021). It considers whether the current level of fishing pressure is adequately controlled to ensure that the stock abundance is not reduced to a point where the production of juveniles and subsequent growth is significantly compromised (i.e., recruitment is impaired). The system combines information on both the current stock size and level of exploitation into a single classification for each stock against defined biological reference points. Each stock is then classified as: sustainable, depleting, recovering, depleted, undefined, or negligible (Table 1.6-1). PIRSA has adopted this classification system to determine the status of all South Australian fish stocks.

Table 1.6-1. Classification scheme used to assign fishery stock status. The description of each stock status and its potential implications for fishery management are also shown (Piddocke et al. 2021).

Stock status	Description	Potential implications for management of the stock
Sustainable	Biomass (or proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (recruitment is not impaired) and for which fishing mortality (or proxy) is adequately controlled to avoid the stock becoming recruitment impaired (overfishing is not occurring).	Appropriate management is in place.
Depleting	Biomass (or proxy) is not yet depleted and recruitment is not yet impaired, but fishing mortality (or proxy) is too high (overfishing is occurring) and moving the stock in the direction of becoming recruitment impaired.	Management is needed to reduce fishing mortality and ensure that the biomass does not become depleted.
Recovering	Biomass (or proxy) is depleted and recruitment is impaired, but management measures are in place to promote stock recovery, and recovery is occurring.	Appropriate management is in place, and there is evidence that the biomass is recovering.
Depleted	Biomass (or proxy) has been reduced through catch and/or non-fishing effects, such that recruitment is impaired. Current management is not adequate to recover the stock, or adequate management measures have been put in place but have not yet resulted in measurable improvements.	Management is needed to recover this stock; if adequate management measures are already in place, more time may be required for them to take effect.
Undefined	Not enough information exists to determine stock status.	Data required to assess stock status are needed.
Negligible	Catches are so low as to be considered negligible and inadequate information exists to determine stock status.	Assessment will not be conducted unless catches and information increase.

2. COMMERCIAL FISHING FLEET DYNAMICS

2.1. Introduction

Fishing fleet dynamics reflect the decisions made by fishers that relate to when and where to fish, the most appropriate gear to use for the target species, and the economics of seafood production. These decisions are influenced by a range of factors, such as the seasonal availability, movement and migration of target stocks, seasonal changes in weather conditions, management arrangements, running costs, market access, wholesale price fluctuations and socio-economics.

A comprehensive evaluation of the spatial and temporal characteristics of fishing activities is required before stock assessment models can be reliably developed to inform management decisions (Hilborn and Walters 1992, Mahévas et al. 2008). In most cases, this includes a detailed break-down of fishery catch patterns, fishing effort, CPUE, the spatial distribution of catches, fishing gear, location and season for each species (Hilborn and Walters 1992).

Whilst most of this report is devoted to the assessment of commercial fishery statistics for specific taxa taken in the MSF in order to determine stock status, this section provides a holistic view of the fishery by examining and comparing trends in commercial catches, fishing effort, gear use, regions and seasonality. This summary illustrates the dynamic nature of the MSF at different spatial and temporal scales, the changes in licence participation rates, and the relationships and trends between target species.

2.2. Methods

The MSF is divided into 58 Marine Fishing Areas (MFAs) for the purpose of statistical reporting and monitoring of commercial fishing activity (Figure 1.4-1). Licenced fishers are required to log their fishing activities by reporting specific details such as MFA fished, number of fishers on board, gear used, species targeted, species caught, weight of catch (whole weight of fish, and trunk/wing weight for shark and rays), catch in numbers of specific species, and method of capture. Prior to 2003, these details were recorded on a monthly basis but since then the fishers have been required to provide a daily log of fishing activity. These records are submitted monthly to PIRSA Fisheries and Aquaculture where they are entered into the Marine Scalefish Fisheries Information System. This database is routinely reviewed and cross-checked as per quality assurance protocols (Vainickis 2010). The current database is a compilation of catch (whole fish weight) and effort data collected from 1 July 1983 to the present and provides the primary source of data used for the assessments of stock status presented in this report. As such, they are based on a 39-year time-series up to and including 2021/22.

The complexity of the MSF database was reduced to a smaller, more manageable dataset that allowed analysis of the major trends in fleet dynamics. Two main approaches were adopted to achieve this. One approach involved aggregating the data into monthly categories. This level of temporal resolution was considered appropriate as monthly data were provided by many fishers prior to 2003. The other approach involved aggregating certain gear types into broader categories. Haul nets, sinking and floating garfish nets, sinking mesh nets, and sinking mixed mesh nets were collectively categorised as haul nets, but were differentiated from large mesh nets (>15 cm mesh size) and set gillnets (5 cm mesh size) which were categorised as set nets. Similarly, handlines, troll lines and fishing rods/poles in the line sector were categorised as handlines. Longlines, drop lines and trot lines were grouped as longlines where appropriate.

2.3. Results

2.3.1. Trends in Number of Active Licences

There was a 75% (from 854 to 217) reduction in the number of licence holders actively operating in the MSF between 1983/84 and 2021/22 (Figure 2.3-1). The largest proportional reduction occurred for the Rock Lobster fisheries, as the number of active licence holders that accessed MSF species declined from 212 in 1987/88 to 22 in 2021/22, representing a 90% reduction. The rate of decline was accelerated from 1994 following the implementation of the licence amalgamation scheme. Two net buy-back schemes also contributed to removing active licences in 2005 and 2014. Of the 217 active licences in 2021/22, 191 were MSF, 22 were from Rock Lobster fisheries and four were from the Miscellaneous Fishery. There were 240 active MSF licences in 2020/21 demonstrating a 23 % reduction constituting 49 licence within a single season. A total of 100 licences were voluntarily surrendered during the reform, indicating that 51 of these licences were latent given that they did not report any fishing activity in 2020/21.

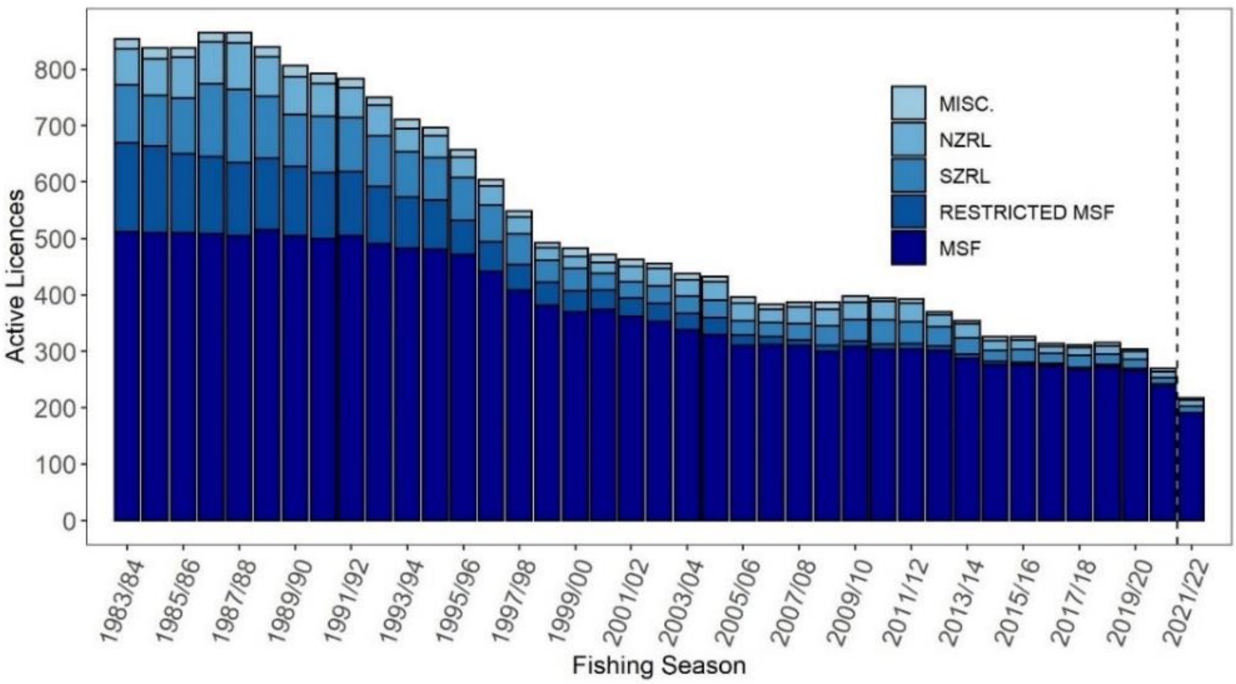


Figure 2.3-1. Long-term trend in the number of active licence holders that have access to the Marine Scalefish Fishery (MSF), including those from the Southern and Northern Zone Rock Lobster (SZRL, NZRL) and Miscellaneous (MISC.) Fisheries. The black dashed line indicates the reform of the MSF in July 2021.

2.3.2. Trends in Commercial Catch

Since 1983/84, there have been considerable shifts in the composition of the commercial MSF catches which have contributed to a long-term declining trend in fishery production (Figure 2.3-2). Catches of the primary species were relatively consistent until 2011/12, when gradual annual decreases started to occur (Figure 2.3-2). Meanwhile, catches of secondary, tertiary and other species have been declining since the 1980s. The 2021/22 annual catch in the MSF fishery was dominated by the secondary species (~40%), followed by the primary (~32%), tertiary (~15%), and the remaining permitted species (~12%) (Figure 2.3-2). This is the first year in the history of the fishery where secondary species constituted a greater percentage of the catch than primary species (Figure 2.3-2). Appendices 7.1 and 7.2 provide summaries of non-confidential annual commercial catches of permitted species taken in the MSF between 1983/84 and 2021/22.

Total annual catches of the primary species declined from a peak of 2,051 t in 2000/01 to a low of 636 t in 2021/22 (Figure 2.3-2). Prior to the 1999/00 fishing season, the composition of the primary species catch was relatively stable, where annual King George Whiting catch accounted for around 36%, followed by Southern Garfish (26%), Snapper (22%), and Southern Calamari (16%). Since then, the relative proportions of the King George Whiting and Southern Garfish catches have declined to 27% and 25% in 2021/22, respectively, whereas annual catches of Southern Calamari (43%) have increased, particularly since 2007/08 (Figure 2.3-2). The proportion of Snapper in the catches of primary species decreased considerably from 51% to 27% between 2010/11 and 2018/19, and then further to 23% in 2021/22 due to the ongoing closure to fishing for the SG/WC and GSV Stocks.

The total annual catch of secondary species averaged 1,626 t between 1983/84–2000/01, and peaked at 2,140 t in 1994/95 (Figure 2.3-2). The total catch of secondary species was stable at around 600–750 $t.yr^{-1}$ during the late 2000s and 2010s, and subsequently declined to a low level of 529 t in 2020/21. Western Australian Salmon and Australian Herring have consistently accounted for most (up to 68% collectively) of the catch of secondary species, while Blue Crabs accounted for most of the remaining catch during the 1990s prior to the formation of the Blue Crab Fishery (Figure 2.3-2). The relative contributions of the other secondary species to the total catch have remained stable since 2008/09, with the exception of Western Australian Salmon whose catches have fluctuated across years.

Annual catches of tertiary species peaked in 1991/92 at 1,147 t, when they were dominated by Ocean Jackets (88%). Ocean Jackets continued to contribute most of the tertiary species catch up to 2005, before targeting of this species all but ceased during 2006/07–2015/16 (Figure 2.3-2). Fishing for Ocean Jackets recommenced in 2016/17 and the highest catch since 2003/04 occurred in 2019/20 (Figure 2.3-2).

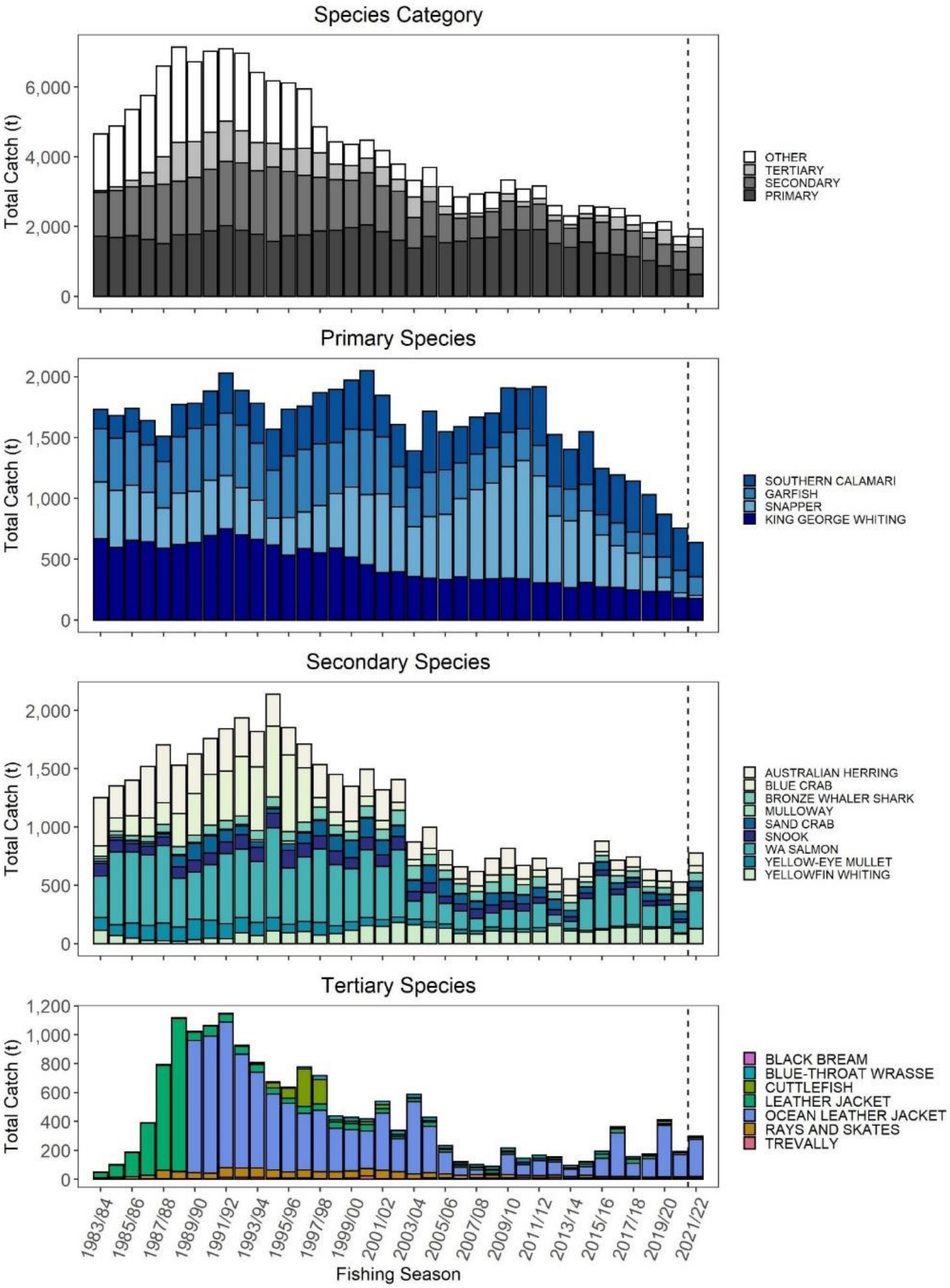


Figure 2.3-2. Long-term trends in total catch (t) in the commercial Marine Scalefish Fishery for primary, secondary and tertiary species between 1983/84 and 2021/22. The black dashed line indicates the reform of the MSF in July 2021.

In 2021/22, the species with the largest catch was Western Australian Salmon at 323 t, followed by Southern Calamari at 278 t (Figure 2.3-3). The remaining primary species, King George Whiting (176 t), Southern Garfish (156 t) and Snapper (25 t), where ranked as the fourth, fifth and eleventh highest catches in 2021/22, respectively (Figure 2.3-3). Southern Calamari had the highest commercial GVP in 2021/22 of $5.8 million AUD. Despite being the fourth and fifth ranked species by catch, King George Whiting and Southern Garfish remained the second and third most economically valuable MSF species with GVPs of $3.7 million and $2.1 million AUD, respectively (Figure 2.3-3). Therefore, while catches of secondary species, increased notably in 2021/22, overtaking those of primary species, they remain far less economically valuable than the traditional primary species of the fishery (Figure 2.3-3).

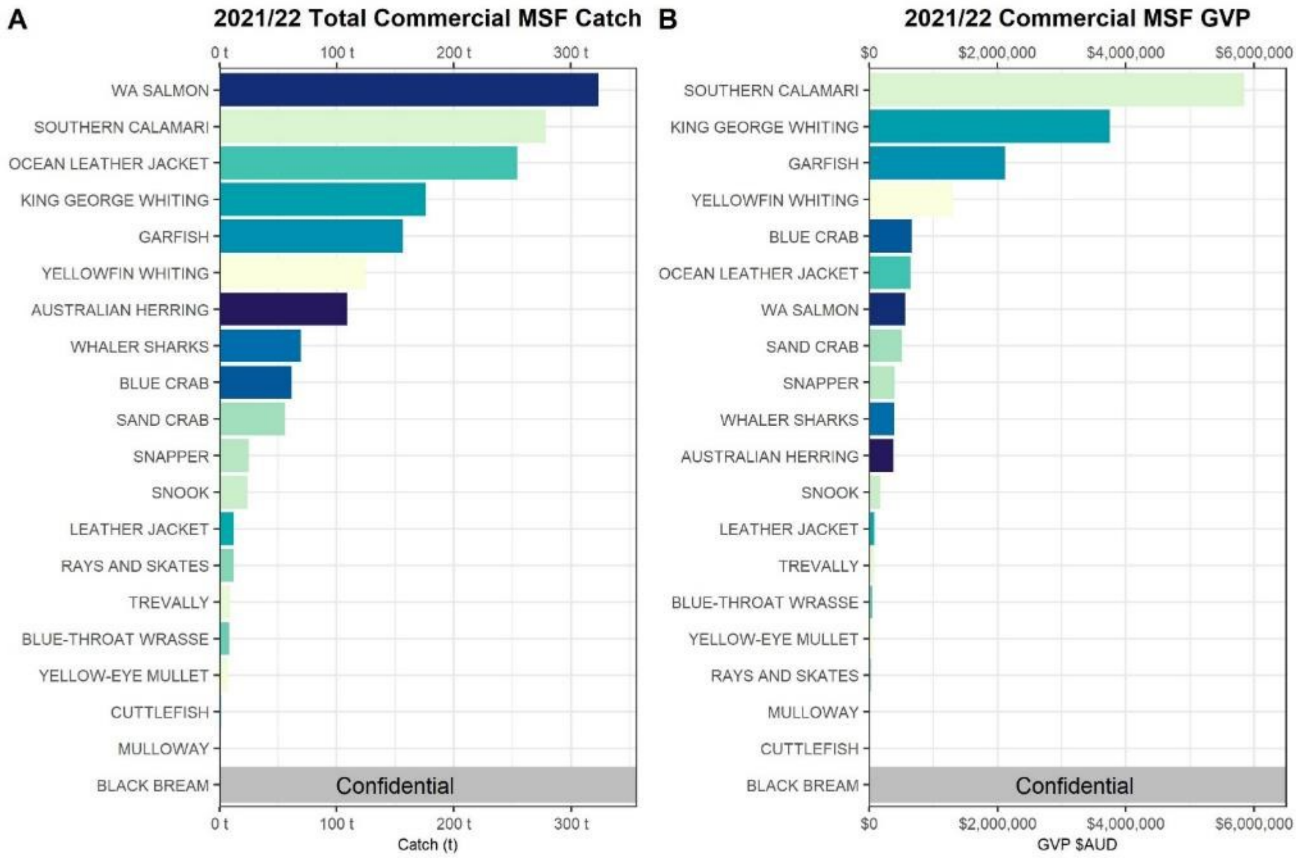


Figure 2.3-3. Species rankings in 2021/22 according to (A) total MSF catch and (B) gross value production (GVP; panel B). Data are not shown for Black Bream due to confidentiality (< 5 licences in 2021/22). Only primary, secondary and tertiary species are included.

2.3.3. Trends in Fishing Effort

2.3.3.1. Species

Annual estimates of total fishing effort peaked at 136,463 fisher-days in 1991/92 (Figure 2.3-4). This represented an 16% increase in annual effort since 1983/84, after which there was an 81% reduction to 26,266 fisher-days in 2021/22.

Since 1983/84, the majority (~80%) of the fishing effort reported in fishery logbooks in most years has been 'targeted effort', whereby fishers nominated a species/taxon as their target. For the remaining (~20%) of effort reported each year, fishers record 'any target' in their catch returns. This increased in 2021/22, with 89% of the total effort dedicated to targeting a species/taxon. Of the reported targeted effort, the four primary species have consistently accounted for the greatest proportion, of which King George Whiting has historically dominated. Since 2011, there has been a subtle shift in targeted fishing activity, as fishers have directed some targeted effort away from Snapper, King George Whiting and Southern Garfish towards Southern Calamari. The relative proportion of effort targeted towards Southern Calamari has increased from 27% in 2010/11 to 48% in 2021/22 (Figure 2.3-4). Southern Calamari is now the most targeted species and has been since 2016/17 (Figure 2.3-4). Over the same period, the relative proportion of effort targeted towards Snapper declined from 27% to < 2% in 2021/22.

The secondary species accounted for approximately 13% of the total targeted fishing effort in 2021/22, which is considerably lower than during the 1990s when they typically accounted for ~15% of all targeted effort (Figure 2.3-4). The distribution of targeted effort amongst the secondary species has also changed considerably over the past 37 years. Historically, Blue Crabs, Western Australian Salmon, Snook and Yelloweye Mullet attracted the most effort, accounting for >95% of targeted effort directed at secondary species in some years during the mid-1980s. Since 2000/01, the relative proportions of effort targeted towards Yelloweye Mullet, Western Australian Salmon and Blue Crab have declined, while those for Yellowfin Whiting and Whaler Sharks have increased.

During 2021/22, > 4% of the State-wide fishing effort was spent targeting the six tertiary species considered in this report (Figure 2.3-4). There were a few periods of notable expansion for some 'niche' tertiary species across the time period, such as Leatherjackets, Ocean Jackets and Cuttlefish. Targeted effort for each of these species doubled over short (<5 years) periods but did not persist. Targeted effort for Ocean Jackets has followed an increasing trend over the last four years, peaking at 605 fisher-days in 2019/20, which is the highest since 2005/06. In 2021/22, 361 fisher days were spent targeting Ocean Jackets (Figure 2.3-4).

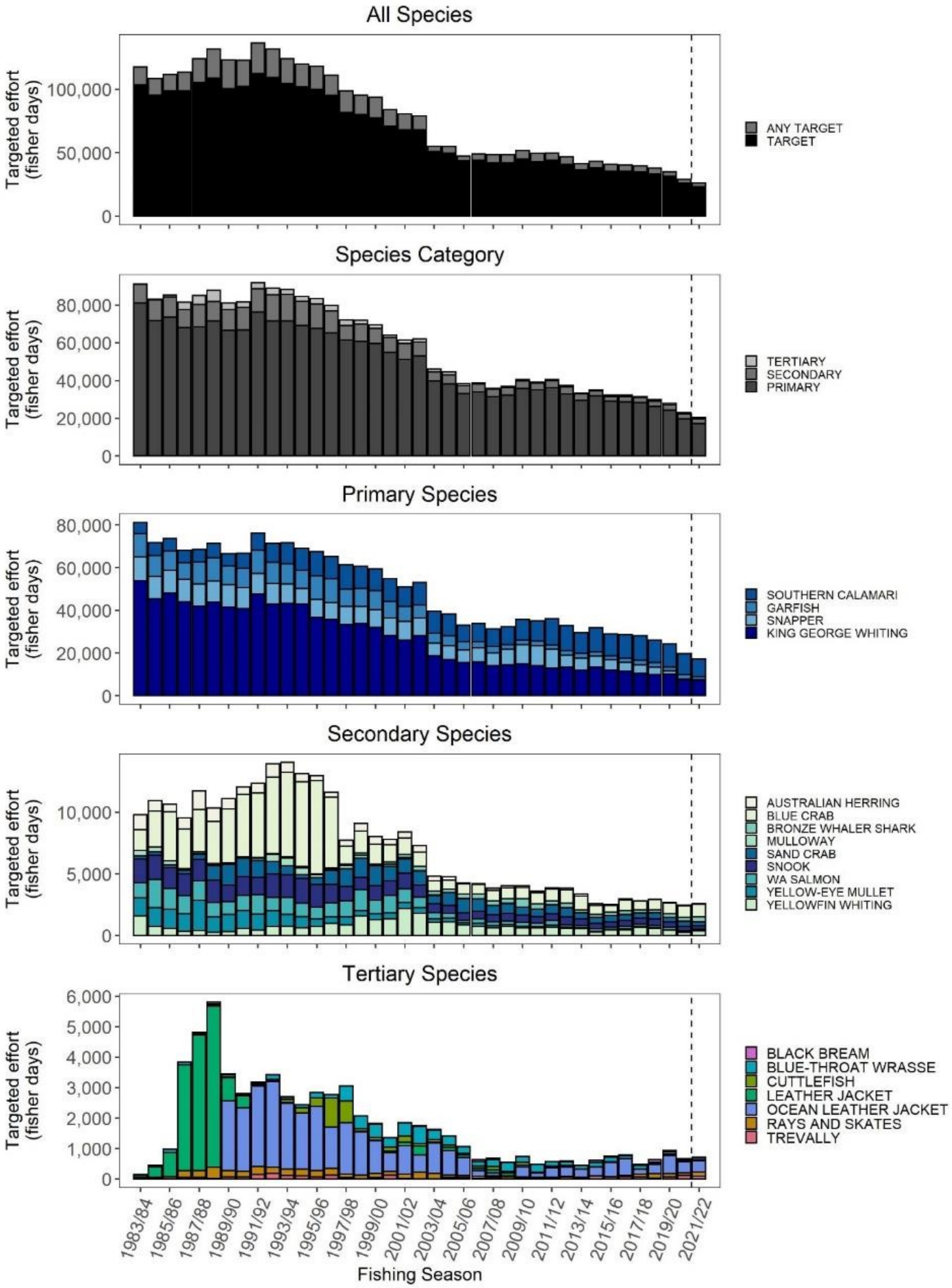


Figure 2.3-4. Total effort (fisher-days) in the commercial Marine Scalefish Fishery between 1983/84 – 2021/22, partitioned into targeting categories in each panel. This includes targeted and non-targeted ('any target') effort (top graph), species category (primary, secondary or tertiary) and species-specific targeted effort (remaining panels). The black dashed line indicates the reform of the MSF in July 2021.

2.3.3.2. Gear

Haul nets and handlines have consistently been the dominant gear types used in the fishery, collectively accounting for >60% of the total fishing effort in most years since 1983/84 (Figure 2.3-5). The proportional use of set nets has declined from 16% in 1987/88 to <1% since 2019/20, with the greatest reduction occurring throughout the late 1990s and early 2000s in response to the State-wide netting review and associated restrictions. The use of squid jigs has steadily increased from 1993/94 as the Southern Calamari fishery evolved from a bait resource to a priority target species and has further increased from 2010/11 onwards. Squid jigs accounted for 27% of the total State-wide fishing effort in 2021/22. The proportional use of longlines doubled from 2008/09 through to 2015/16 and but has since declined and accounted for 7% of the total fishing effort in 2021/22.

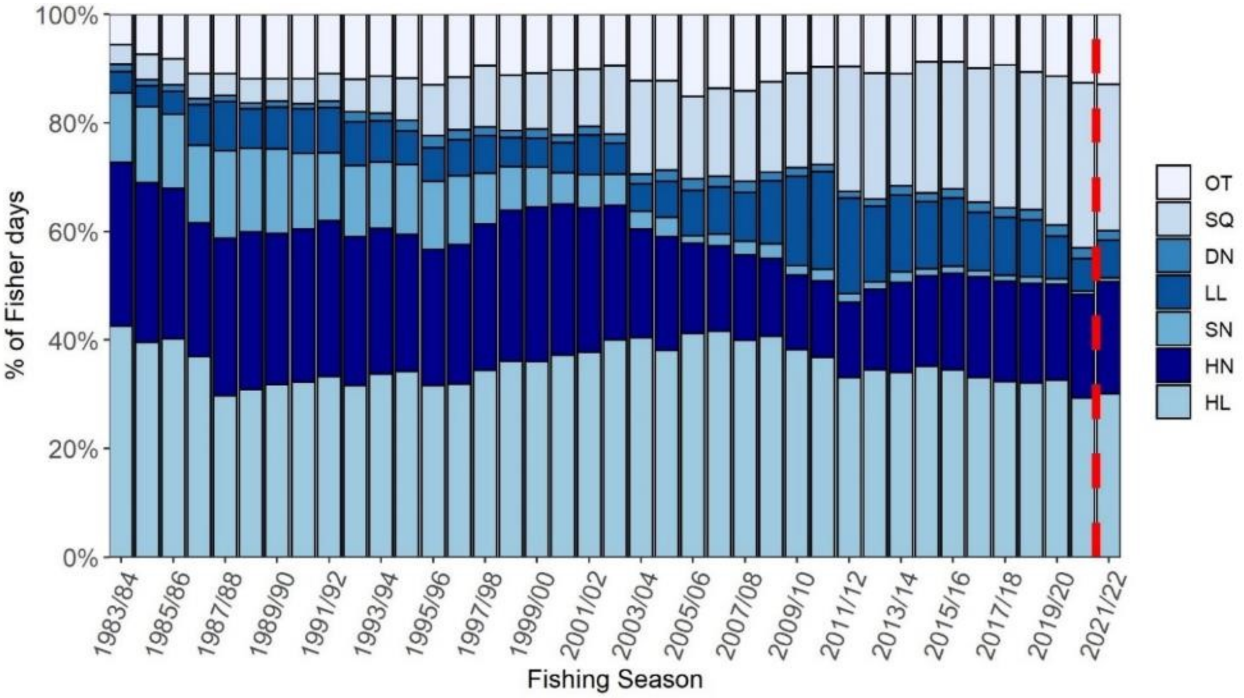


Figure 2.3-5. Gear usage (% of total fishing effort) within the Marine Scalefish Fishery. The red dashed line indicates the reform of the MSF in July 2021.

2.3.3.3. Zone

The percentage of fishing effort across fishing zones has been consistent through time, with the SE fishing zone being the most variable. The percentage of fishing effort occurring in the SE fishing zone peaked at 11% in 1986/87 but has now been below 4% over the past ten fishing seasons (Figure 2.3-6). The GSV/KI and SG fishing zones have been the dominant zones in regard to fishing effort. The proportion of effort occurring within these zones has been relatively stable through time with ~30% of annual effort occurring within the GSV/KI fishing zone and ~40 % of annual effort occurring within the SG fishing zone (Figure 2.3-6). The WC fishing zone has accounted for ~20% of the annual effort across fishing seasons, although this has peaked at 24% in the 2021/22 fishing season (Figure 2.3-6).

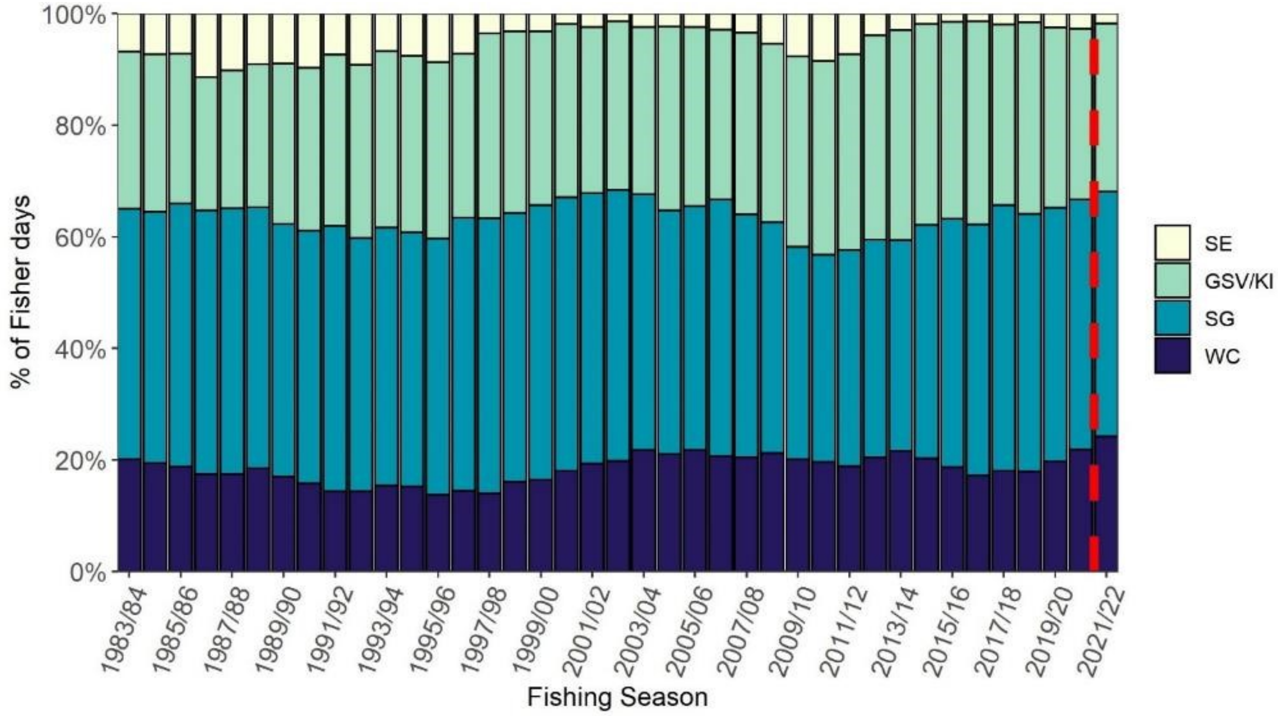


Figure 2.3-6. Effort distribution (% of total fishing effort) across the four MSF fishing zones from 1983/84 – 2021/22. The red dashed line indicates the reform of the MSF in July 2021.

2.3.3.4. Season

The high diversity of target species within the MSF provides fishers with considerable flexibility across seasons (Figure 2.3-7). Among the four primary species, monthly targeted fishing effort for KGW peaked at around 1,300 fisher-days in June and July, and although this species was targeted throughout the year its fishing activity was lowest in summer. Conversely, targeted effort for Southern Garfish was highest during late summer, peaking at just over 320 fisher-days in February. Fishing effort for Southern Garfish was affected by the seasonal closures of the fishery in late winter and early spring since 2016. The seasonal pattern of fishing activity for Southern Calamari and Snapper was similar, with both maintaining relatively high levels of fishing effort throughout the year, peaking in autumn and again in late spring (Figure 2.3-7). Negligible effort for Snapper in November reflects the seasonal closure during this month between 2003 and 2018.

Targeted effort for most of the remaining species peaked during the spring and summer months although some level of fishing activity was maintained throughout the year. Yellowfin Whiting, Bluethroat Wrasse, Silver Trevally, Rays and Skates and, to a lesser extent, Black Bream were the only species that displayed distinct increases in fishing activity during winter and early spring (Figure 2.3-7).

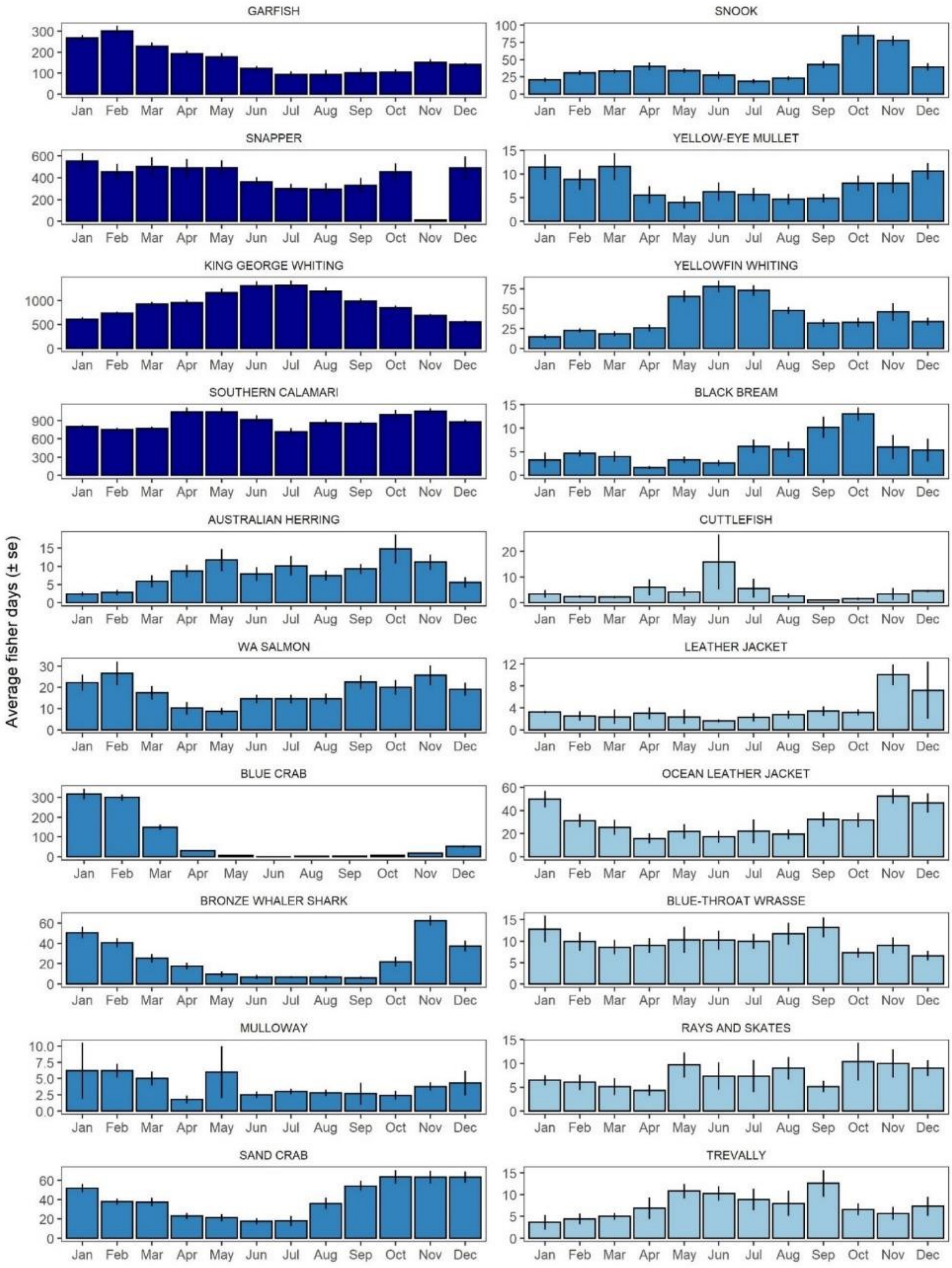


Figure 2.3-7. Monthly pattern of targeted fishing effort (fisher-days averaged (± se)) from 2011/12 to 2021/22 for each primary, secondary and tertiary species/taxon. The different shades denote species category; primary (dark blue), secondary (blue), tertiary (light blue).

2.4. Summary

The 2021/22 fishing season was the first occurrence where the catch of secondary species was greater than that of primary species. There are several reasons for this, with two clear observations being the increased Western Australian Salmon catch and closure of the Snapper fishery across three out of four fishing zones. There have also been ephemeral periods of increased fishing activity for other secondary and tertiary species, such as Western Australian Salmon, Snook and Ocean Jackets that highlights the dynamic capacity of the MSF fishing fleet. Given the declining fishing activity observed for some of the primary species, current fishers may have greater incentive to target an increased diversity of ‘under-utilised’ or ‘lesser-known’ species and to synchronise their fishing activity to the species’ patterns of seasonal abundance. However, 2021/22 also saw reduced catches of most Tier 1 stocks (i.e., the primary species), which could be due to the changing management regime of the fishery and the need for fishers to adjust their fishing operations accordingly. Therefore, while the catch of secondary species was greater than the catch of primary species in 2021/22, it remains to be seen whether this trend will continue.

In 2021/22, catches of King George Whiting and Southern Garfish were overtaken by Western Australian Salmon and Ocean Jackets, which are a secondary and tertiary species, respectively. Despite this, high beach prices maintained their rankings as the second and third most economically valuable species in the fishery according to GVP. This indicates that while catches of secondary and tertiary species may increase and reduce the pressure on primary species to support the fishery, they are currently not as economically viable as the primary species. Southern Calamari remained the most valuable species in the fishery with a GVP of $5.8 million AUD. This was 57% higher than King George Whiting and further highlights the importance of Southern Calamari to the fishery. Not only does Southern Calamari have the highest GVP in the fishery, but also the highest gross margins, indicating that they are the most profitable species to fish for due to high beach prices and low fishing costs (Smart et al. 2022a).

The dynamics of the MSF fleet have shifted in recent years primarily due to changes in management arrangements. The most obvious changes have been the decline in fishing effort driven by the licence amalgamation scheme in 1994, two voluntary net buy-back initiatives (2005 and 2014), and reduction in the number of B-class and Rock Lobster licences active in the fishery. Since their implementation, the major management arrangements have successfully reduced the number of active licence holders by 66%, which has led to a 68% reduction in fishing effort. This has contributed to a gradual spatial contraction of effort across the State, with the fishery becoming almost exclusively confined to gulf waters, around the major regional centres of Port Lincoln and Ceduna, and a few protected bays on the west coast of the Eyre Peninsula. A further 100 licences were voluntarily surrendered from the fishery through the MSF reform. As a result, no B-class licences remain in the fishery as of 2021/22.

While this is the single greatest reduction in licences during the history of the fishery, the full effects on catch and effort will not be completely apparent for several more fishing seasons. This is due to a high number of latent licences being surrendered during the reform. As a result, the general trends in catch and effort (typically declining trends) continued in 2021/22 as most active fishers remained in the fishery. Most fishing effort within the MSF has been targeted, with the remaining activities being non-specific in their target species indicating that fishers were more general in their fishing activity during that period or were not specifically recording a target species in their catch returns.

Other key drivers of recent changes in fleet dynamics include the expansion and subsequent reduction in Snapper catches, particularly following the spatial closures from 1 November 2019, a steady reduction in King George Whiting and Southern Garfish catches, and the shift in effort towards targeting Southern Calamari. Collectively, these four primary species have typically accounted for the almost two thirds of all targeted effort each year, of which King George Whiting has historically dominated. Since 2010/11, there have been substantial declines in targeted effort for Snapper, King George Whiting and Southern Garfish as a consequence of a range of management arrangements (i.e., spatial closures, closed seasons, netting restrictions and catch limits). Simultaneously, targeted effort for Southern Calamari has steadily increased. This species has effectively become a year-round target for many fishers, possibly to offset the loss of access to the other primary species. The increasing trend in the relative use of squid jigs also reflects this shift in behaviour in the fishing fleet.

3. KING GEORGE WHITING STOCK ASSESSMENT

Species summary

King George Whiting

Sillaginodes punctatus

Stock status (Fishing Zone)	Gulf St Vincent/ Kangaroo Island Fishing Zone	Spencer Gulf Fishing Zone	West Coast Fishing Zone
	Sustainable	Sustainable	Sustainable

Species Tier	**Tier 1 in GSV/KI, SG and WC Fishing Zones. Tier 3 in SE Fishing Zone**
Species description	King George Whiting is the largest species of the family Sillaginidae and occur across southern Australia. This species is readily distinguishable from other Australian Whiting by its unique pattern of spots, as well as its highly elongate shape. They have a complex life history that varies across life stages and habitats. Adult fish reside on offshore reefs where spawning occurs in winter. Their eggs are advected and settle into inshore nursery areas within protected bays. Juvenile fish grow and remain in these nursery areas until age three when they move to offshore spawning areas to join the adult stock. King George Whiting can live as old as 22 years old but have moderate growth rates despite their reasonably old longevity.
Fishery description	King George Whiting are caught using several different gear types, with handlines being the most dominant. Large fisheries exist in each of the WC, SG and GSV/KI fishing zones where they are targeted by recreational and commercial fishers. They are the second most economically valuable species to the commercial MSF.
Current assessment program	• Weekly length and age structures collected through market sampling in Adelaide. • Annual examination of commercial fishery statistics. • Recreational data collected every five to seven years through State-wide recreational survey. • Application of a length-and-age-structured population model (WhitEst). • No information is available for Aboriginal/Traditional fishing.

Commercial fishery statistics (State-wide)			Recreational Catch			
Fishing season	**Total MSF catch** *t*	**Total commercial effort** *Fisher-days*	Survey	**Estimated catch** *t (± SE)*	**Retained** *%*	**Released** *%*
2017/18	243	13,333				
2018/19	234	12,754	2000/01	561 (74)	73%	27%
2019/20	234	12,568	2007/08	324 (34)	70%	30%
2020/21	181	9,511	2013/14	367 (63)	73%	27%
2021/22	176	9,610	2021/22	305 (37)	62%	38%

3.1. Biology

King George Whiting (*Sillaginodes punctatus*) is one of the most valuable, coastal marine finfish species of southern Australia. It occurs in coastal and shelf waters, distributed around the southern coastline from Sydney, NSW, to Perth, WA (Kailola et al. 1993). The species is particularly significant in SA, the geographic centre of its distribution, where abundances and fishery productivity are highest.

King George Whiting has a complex life history that involves ontogenetic changes in habitats that are linked by movement at different life history stages (Fowler and Jones 2008). In SA, spawning occurs during autumn and early winter on offshore reefs, shoals and mounds in relatively deep water in exposed localities that experience medium/high wave energy (Fowler et al. 2000a, 2000b, 2002). The eggs and larvae are advected throughout a prolonged pre-settlement duration to nursery areas in shallow, protected bays located in the northern gulfs or those on the west coast and Kangaroo Island (Fowler and Short 1996, Fowler et al. 2000b). Juvenile fish grow and develop in the vicinity of these nursery areas. When they reach approximately three years of age, those in the northern gulfs undertake significant movement southwards, whilst those in coastal bays move off-shore. Such movement ultimately replenishes the populations of older fish on the spawning grounds (Fowler et al. 2000b, 2002). This movement results in a significant ontogenetic shift from relatively protected shallow waters that support extensive meadows of seagrass to more exposed, deeper water and reef habitat. As a consequence, population size and age structures of King George Whiting vary geographically (Fowler et al. 2000a). The northern gulfs and inshore bays support populations with only a few age classes, whereas the off-shore or deeper water populations involve multiple age classes with fish up to 22 years of age. The spawning grounds and nursery areas for King George Whiting can be separated by up to several hundred kilometres. As such, the processes of larval advection and adult movement are significant obligate steps that link the different life history stages and the habitats they occupy (Fowler et al. 2002).

The stock structure for King George Whiting throughout its range in southern Australia remains unresolved due to uncertainty about the connectivity amongst regional populations and the lack of clear phylogeographic genetic structure (Haigh and Donnellan 2000). A recent genetic study indicated that the SA and Victorian populations were genetically similar, but were distinct from those in Western Australia and also in Tasmania (Jenkins et al. 2016). The similar genotypes between the SA and Victorian populations are consistent with the results from hydrodynamic modelling and otolith chemistry analyses which indicate that the Victorian populations may be replenished from spawning grounds located in SA, through the eastward advection of eggs and larvae (Jenkins et al. 2000, 2016). The genetic homogeneity of the SA regional populations indicates that there must be at least a small degree of mixing between them. This was supported through recent research that demonstrated that spawning in some areas can contribute to recruit to areas beyond the adjacent regions based on a biophysical model (Drew et al. 2020, Rogers et al. 2020). There is therefore evidence of a single, panmictic stock existing where spawning from one region can contribute to the recruitment in another (Rogers et al. 2020). For stock assessment and management purposes three stocks are recognised based largely on the locations of and connectivity between nursery areas and spawning grounds (Fowler et al. 2000b, Drew et al. 2021). These stocks are: the west coast of Eyre Peninsula (WC), Spencer Gulf (SG), and Gulf St Vincent/Kangaroo Island (GSV/KI).

3.2. Fishery

King George Whiting is heavily targeted by both the commercial and recreational sectors (Drew et al. 2021). Several life history stages are targeted: young, immature adults in the northern gulfs; the immature fish as they travel southwards; and mature adults on the spawning grounds. As such, during their ontogenetic development, the fish run the gauntlet of fishing lines and nets that are used to target them in different habitats.

Three different commercial fisheries have access to SA's King George Whiting stocks - the MSF, NZRLF and SZRLF (PIRSA 2013). Historically, this species was the most valuable for the commercial sector, but since 2007/08 its total value fell below that of Snapper and more recently below that of Southern Calamari. Nevertheless, King George Whiting often have the highest market price of any species, although this depends on supply and other market conditions. The main gear types used in the commercial fishery to target King George Whiting are handlines, haul nets and set nets. For the recreational sector, this is an iconic species that is heavily targeted with hook and line, principally from boats.

3.3. Harvest Strategy

When the commercial Management Plan was developed (PIRSA 2013), the three King George Whiting stocks were classified as 'sustainably fished' (Fowler et al. 2011). As such, the primary objective of the harvest strategy at that time was to maintain this positive status and fishery performance. However, in the subsequent stock assessment (Fowler et al. 2014), the statuses of the two gulf stocks, i.e. SG and GSV/KI were changed to 'transitional-depleting'. The response was to recover the status of both stocks, whilst maintaining the sustainable status of the West Coast Stock. To this end, significant management changes were implemented in December 2016 which resulted to both stocks recovering and being reclassified as sustainable in 2016 for SG (Steer et al. 2018a), and 2017 for GSV (Steer et al. 2018b). The WC stock has only ever been classified as sustainable.

3.4. Management Regulations

Regulations for managing SA's King George Whiting fishery involve a complex suite of input and output controls (PIRSA 2013). For the commercial sector, the principal means of effort control is 'limited entry', and the number of licence holders operating in the MSF has declined considerably over time. Furthermore, there is a complexity of regulations that apply to the gears that are used to take King George Whiting. These restrict the numbers of handlines and hooks that can be used, and for haul nets and set nets involve gear specifications and spatial and temporal restrictions. The recreational take is managed through size, bag, boat, possession limits and spatial restrictions.

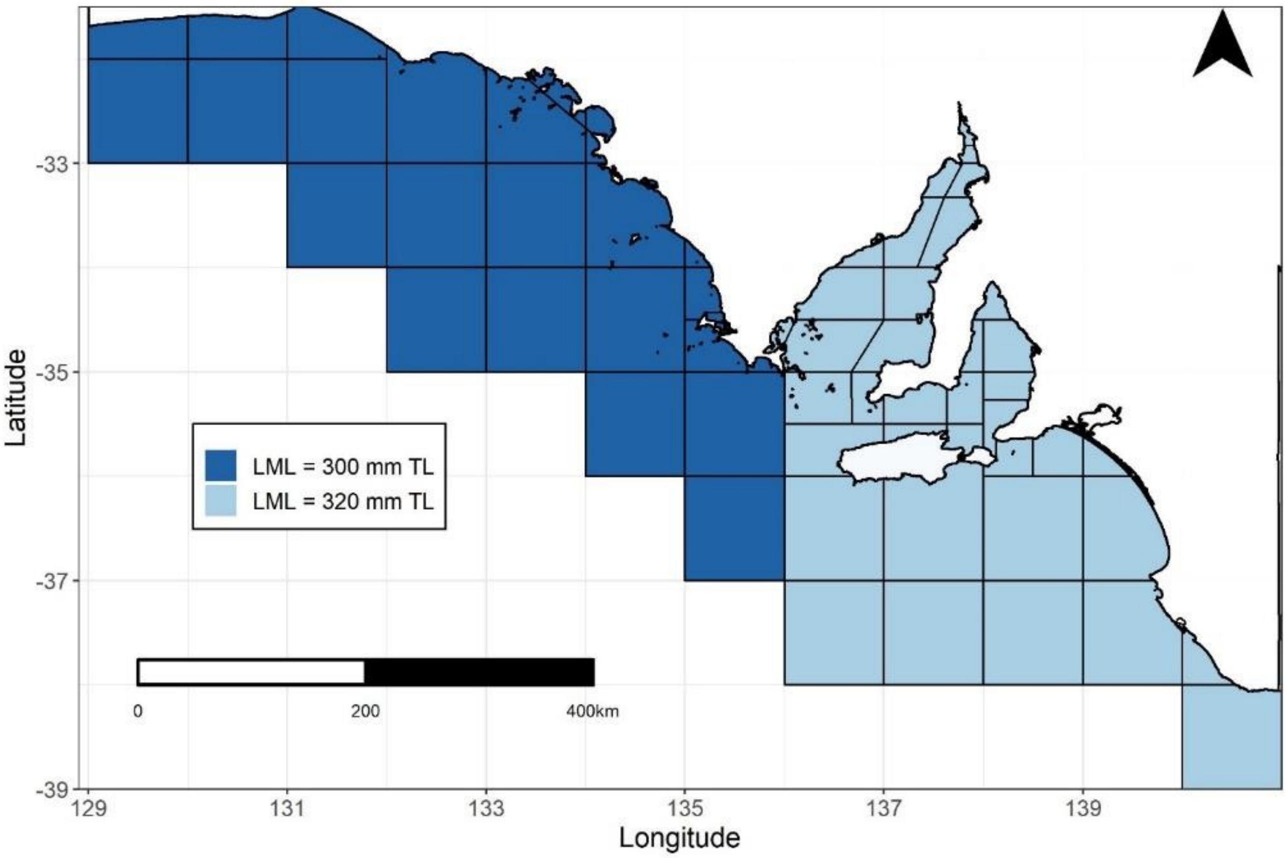


Figure 3.4-1. A map of South Australia indicating the regional legal minimum length (LML) restrictions for King George Whiting since 2016.

The management regulations for King George Whiting were enhanced following the status of "transitional depleting" that was assigned to the two stocks in the South Australian gulfs (Fowler et al. 2014), and the ensuing extensive review of management arrangements that took place throughout 2016. The changes that were implemented in December 2016 were: (1) an increase in legal minimum length (LML) from 310 to 320 mm total length (TL) for all waters east of longitude 136°E, whilst the LML of 300 mm TL was retained in the waters of the west of longitude 136°E (Figure 3.4-1); (2) a State-wide reduction in the recreational bag limit from 12 to 10 legal-sized fish per person, with the boat limit reduced from 36 to 30 fish per boat; (3) a possession limit of either 72 fish or 10 kg of fillets or, if both fish and fillets are possessed, up to 36 fish and up to 5 kg of fillets; and (4) an introduction of a spatial spawning closure in Investigator Strait and southern Spencer Gulf from 1 to 31 May that was first implemented in 2017. This spatial closure was removed in 2020 as all three stocks were classified as sustainable (Table 3.4-1). Following the MSF reform in 2021, King George Whiting stocks in the WC , SG and GSV/KI fishing zones are managed using TACCs, with the SG and GSV/KI fishing zones further managed using ITQs.

Table 3.4-1. Key historical management measures introduced for the King George Whiting commercial fishery. Annotations of these measures are provided in Figure 4.3-1. Reference labels are provided for cross referencing with that figure.

YEAR	MANAGEMENT MEASURE	REGION	DETAILS	PLOT REFERENCE
1995	LML change	State-wide	LML increased from 280 mm TL to 300 mm TL	a
2004	LML change	SG, GSV & SE	LML increased from 300 mm TL to 310 mm TL in all state waters East of longitude 136 degrees East	b
2016	LML change	SG, GSV & SE	LML increased from 310 mm TL to 320 mm TL in all state waters East of longitude 136 degrees East	c
2017	Spatial closure	SG & GSV	One-month closures over spawning grounds in investigator strait and SSG in May each year.	d
2020	Spatial closure removed	SG & GSV	Spatial closures no longer implemented	e
2021/22	TACCs introduced	WC, SG & GSV/KI zones	TACCs introduced following fishery reform. These were unitised as ITQs for the SG and GSV/KI fishing zones.	f

3.5. Methods

3.5.1. Catch Statistics

The fishery dependent data sources considered in this stock assessment were commercial fishery statistics; charter boat fishery catches and recreational fishery catches estimated from four surveys (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015, Beckmann et al. 2023). These data were considered at the State-wide scale and at the scale of the three major fishing zones. Details on the handling of recreational estimates in catch statistics are provided in Section 4.2.2. The stock assessment model for King George Whiting, 'WhitEst', uses interpolated recreational catches to account for recreational harvest between surveys. Details for this analysis are presented in Appendix 7.3. Interpolated recreational catches at the State-wide scale are presented in Section 3.6.1.

The commercial fishery data for King George Whiting were extracted from the commercial Marine Scalefish Fisheries Information System for the 39-year period of 1983/84 to 2021/22. These data were aggregated to provide annual catch statistics at the State-wide and zone levels. For total catch, the three main gear types (handlines, haul nets and set nets) were differentiated. With respect to effort and CPUE, only the data for handlines are considered as the recent low levels of effort in the net sector have reduced the value of the data from this sector as fishery performance indicators (PIRSA 2013).

3.5.2. CPUE Standardisation

A standardised CPUE index was developed for King George Whiting in each of the three main fishing zones through a generalised linear model (GLM) approach (Maunder and Punt 2004). This involved fitting a GLM to commercial logbook data with handline CPUE by fisher day as the dependent variable while including relevant factors as independent variables, including fishing season. This approach determined the effect size of each independent variable and allowed the effect of fishing season on CPUE to be extracted. This provided an index of abundance from logbook data by accounting for the variability of fishery dynamics over time and how this may have influenced CPUE regardless of species abundance.

The GLMs included the following variables: fishing season, fishing month, level of targeting (i.e., if King George Whiting were targeted, not targeted or whether 'Any Target' was recorded in logbooks), MFA sub-block and licence holder. The appropriate model error structure for each stock was determined through a stepwise process where several forms were applied to the full model (i.e., all independent variables included) and the most appropriate candidate was determined based on Akaike's Information Criterion (AIC). A gamma distribution with a log-link function was most appropriate for these data and was applied to all three fishing zones. Lastly, the significant independent variables were determined through a model selection process based on AIC that was performed using the 'dredge' function from the 'MuMIn' R package (Barton 2020). This model selection process demonstrated that the full model provided the best fit to the data for all three stocks. A histogram of fitted values, visual analysis of residuals and a Q-Q plot were used to confirm that the models provided a good fit to the data and that conclusions on stock abundance could be drawn from these models. Lastly, the model coefficients for fishing season were extracted and normalised with a mean of one. These form the standardised CPUE index along with their estimated standard errors.

Standardised CPUE estimates are presented in this assessment for the first time and are not currently implemented in the WhitEst stock assessment model.

3.5.3. Age and Length Compositions

To provide information on population structure, King George Whiting from regional commercial catches were sampled at the SAFCOL fish market in Adelaide as well as by occasional sampling trips to Kangaroo Island and the West Coast. This market sampling involves a two-stage sampling protocol (Fowler et al. 2014). Fishery catches were accessed at the market from which numerous fish were measured to obtain size information. From these, a random sub-sample was taken for further biological analysis. The sampled fish were measured for TL and weighed individually, sexed and the stage of reproductive development was determined. The fish were then dissected for removal of the otoliths that were later used to determine fish age using an established ageing protocol (Fowler and Short 1998, Fowler et al. 2014). Subsequently, regional estimates of annual length and age structures were generated and examined for each of the northern gulfs, the WC fishing zone and the newly created region of Western Eyre Peninsula (WEP) that is now included in the SG fishing zone following the regionalisation of the MSF (Smart et al. 2022a).

Age structures were examined using an age-length key to include data collected from fish that were measured but not aged. This was undertaken by calculating monthly age for each fish based on the month of growth band deposition (August) and month of capture. Monthly ages were transformed to integer ages by converting them to decimal ages and rounding down to the nearest whole age. The age-length key was applied by using the 'FSA' stock assessment package in R (Ogle et al. 2022, R core R-Core-Team 2022) to determine the age distribution for each length class of aged fish. These age distributions were then applied across the length distributions for all fish (i.e., aged and unaged) independently for each region and sampling year. The age structures used as input data for the WhitEst model only included aged fish as WhitEst is an age-and-length-structured model.

3.5.4. 'WhitEst' Fishery Model

The SA King George Whiting fishery stock assessment model, WhitEst, was developed under an FRDC project (Fowler and McGarvey 2000) as a dynamic, spatial, age- and length-structured model. WhitEst integrates multiple data sources, biological and fishery-derived, to estimate model-based fishery biological indicators specified for King George Whiting in the MSF management plan (PIRSA 2013; Table 3.5-1). The model runs over the financial years of available State catch logbook data, from 1983/84 to 2021/22, at a monthly time step.

The WhitEst model accounts for natural and fishing mortality, yearly recruitment, seasonal growth, yearly migration to spawning grounds, differences in catchability by month, spatial cell, sex, and age, and the gradual recruitment of each yearly cohort to legal size as the fish of varying lengths in each year class grow above the LML (McGarvey et al. 2007). Legal minimum length, which had been the principal method of management regulation for controlling exploitation rate in SA King George Whiting, was increased in the two gulfs several times over the model time frame (Table 3.4-1).

WhitEst is a fully spatial model, which accounts for movement. It estimates population numbers for South Australian King George Whiting broken down into seven movement cells (MC) (Figure 3.5-1), two cells for the northern and southern regions of Gulf St. Vincent and Kangaroo Island, three cells for Spencer Gulf (inclusive of the Western Eyre Peninsula), and one for the inshore MFAs of the West Coast. Movement cell 6 (MC6) contains all outlying areas (such as the South East) is currently not modelled by WhitEst as catches are very small. A seventh movement cell of unknown location (not indicated in Figure 3.5-1) is modelled by WhitEst to account for the region where spawning occurs for the WC and WEP regions. This region is outside the footprint of the fishery and therefore no information on catch, effort nor population structure is available for the model. This movement model structure accounts for the annual summer migrations from inshore nursery areas in the northern gulfs to the spawning areas in the southern gulfs, and similarly from inshore to MC 7 off the West Coast and WEP.

Following the reform of the MSF that occurred on 1 July 2021 the spatial structure of WhitEst was updated to accommodate the new fishing zones. The current assessment includes a new movement cell (MC8) covering the Western Eyre Peninsula, MFA blocks 27-28, which had previously been part of the larger inshore West Coast movement cell. Accordingly, the Western Eyre Peninsula is now included as a third movement cell in the Spencer Gulf fishing zone. Other minor redrawing of movement cells was undertaken to align the WhitEst model movement structure with the MSF management zones (Figure 3.5-1). The only remaining spatial discrepancy between the WhitEst zones and the MSF zones of management is MFA sub-block 40A (Figure 1.4-1) which remains in the SSG movement cell in WhitEst but is part of the GSV/KI management zone (Figure 3.5-1). This discrepancy remains as the spatial scale of historical tag recapture data cannot be re-estimated to align with the new zones of management, with this being the only occasion where a discrepancy occurs. This is not consequential for interpretation of BPI's for management decisions as very low levels of fishing effort, catch and biological sampling occurs in MFA 40A.

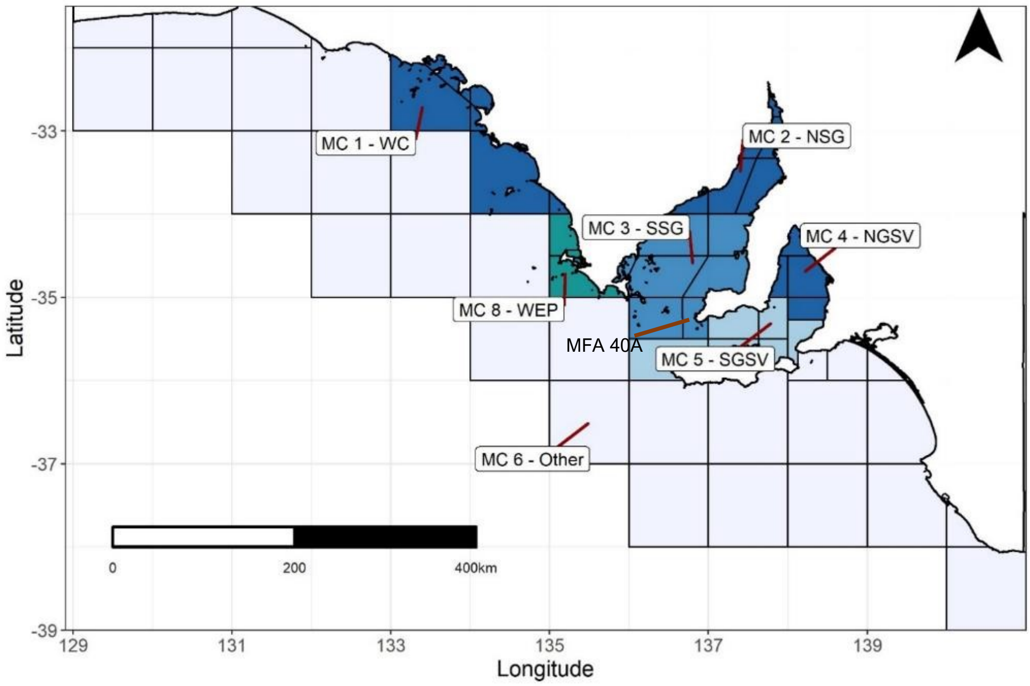


Figure 3.5-1. A map of South Australia indicating the movement cells (MC 1:8) of the WhitEst stock assessment model. Black lines indicate MFA sub-blocks and the coloured shading represents the movement cell that each MFA is assigned to.

The data sources used as input to the WhitEst model, by month and movement cell, included: (1) monthly totals for commercial catch (kg) and effort (fisher days), (2) market samples of the commercial catch from Adelaide and regional SA, giving proportions by length, age and sex for most months through the sampling periods of September 1994 to June 1997, and July 2004 onwards, (3) monthly estimates of recreational catch (retained fish by number) that were interpolated between surveys, and (4) tag-recapture data from studies undertaken in the 1960s, 1970s, and 1980s (Jones et al. 1990, Fowler et al. 2002) used to estimate movement rates in the two gulfs using the recapture-conditioned movement estimation method (McGarvey and Feenstra 2002) that is integrated into WhitEst. The availability of each data source from 1983/84 to 2021/22 are presented in Figure 3.5-2.

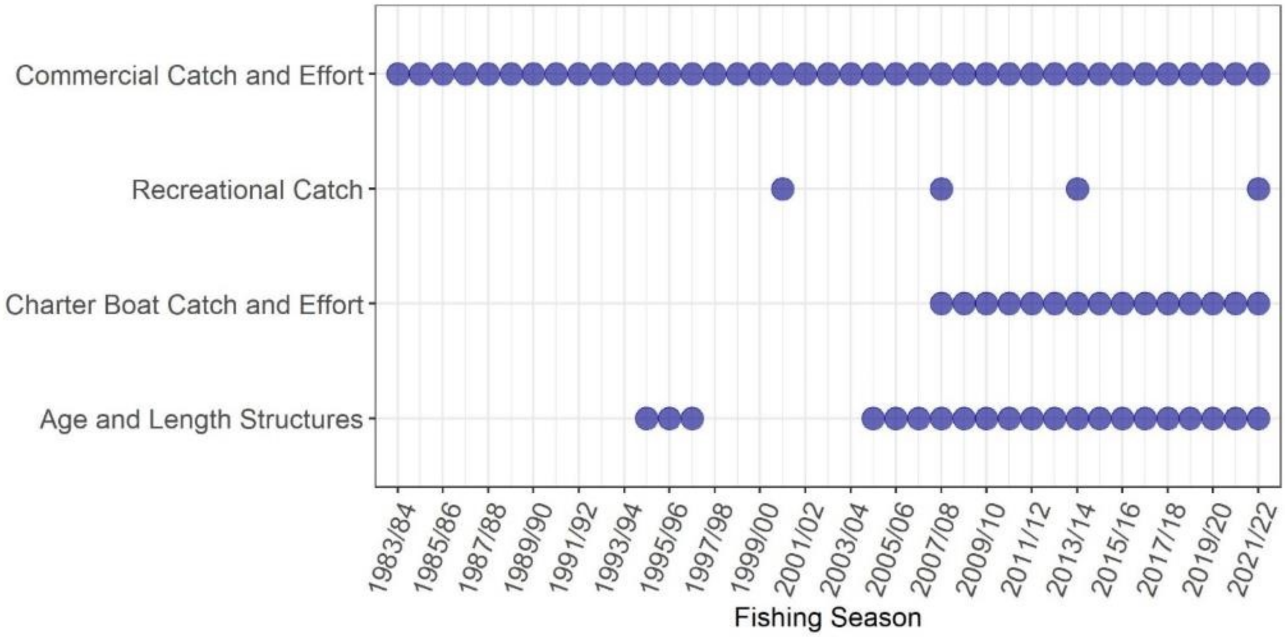


Figure 3.5-2. Availability of the main data sources that inform the WhitEst stock assessment model from 1983/84 to 2021/22. Historical tag-recapture data from the 1960’s, 1970’s and 1980’s are not shown.

WhitEst runs on a monthly time step to account for the seasonality of King George Whiting migration over three months of summer and the seasonal variation in growth and exploitation levels. The model employs the slice-partition method used also for South Australian Snapper and Southern Garfish, to quantify population numbers by both age and by length bin (slices) within each age group (McGarvey et al. 2007). Details of the WhitEst slice partition algorithm were given in a previous assessment report (Appendix 5 in Drew et al. 2021). Commercial catch and effort data are broken down by the four gear types (handline, haul net, set net and all other gears combined) and three target types (targeting King George Whiting, targeting other species, and not targeting a specific species), as reported in commercial catch returns. WhitEst is fitted to these monthly catches assuming Baranov dynamics (Hilborn and Walters 1992). The model is effort-conditioned, and the commercial fishing mortality rate is assumed to vary directly with reported monthly effort in fisher days separately for each of the twelve commercial effort types and for charter boats. The recapture-conditioned approach used to estimate movement rates has the important advantage of being unbiased by tag-non-reporting, tag shedding, and tag-release mortality rates.

Estimates of recreational catch are taken from the King George whiting number totals from four telephone/diary surveys undertaken in 2000/01, 2007/08 and 2013/14, and 2021/22 (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015, Beckmann et al. 2023). Because of high survey sample variability and because monthly breakdowns were not obtained in the recreational survey of 2013/14, a seasonal variation in monthly recreational catches was modelled based on the first, second and fourth recreational surveys, and applied to all years. Details of the GLM developed to estimate this seasonal variation in recreational catch (separately by movement cell) and the method of interpolation between survey years are presented in Appendix 7.3. WhitEst input for recreational effort data does not vary over time being equal to 1.0, and thus recreational fishing mortality rate cannot vary with monthly effort and is instead modelled as a single quantity shared among all years (1983/84–2021/22), for each of the six movement cells and twelve calendar months.

WhitEst integrates these input data sets and, by maximising a likelihood coded in ADMB, estimates the biological performance indicators of biomass, harvest fraction and recruitment, for each of the three stocks, GSV/KI, SG and WC. These indicators are now presented by financial year rather than calendar year as in previous assessments. Also, the biomass indicator was formerly defined as fishable biomass, fish above the LML. But changes in LML over time make comparison between years inconsistent and confounds the longer-term trend of biomass and associated harvest fraction. In the current assessment, the definition of WhitEst biomass has now been modified to be consistent across all years, as fish greater than the original LML of 280 mm TL. Yearly average biomass (tonnes) is computed as the mean of the 12 monthly model estimates in each financial year. Estimates of fishable biomass are approximated from the model to inform TACC setting and for benchmarking against their BPI as directed by the Management Plan (PIRSA 2013). However, these are less informative for informing stock status classifications than the new definition of biomass presented here. Harvest fraction, the proportion of biomass harvested annually, is calculated as the sum of model monthly catches across all commercial gear and target types and both recreational sub-sectors in each financial year divided by (year-average, 280 mm TL+) biomass. WhitEst estimates yearly recruitment as the number of fish in each cohort at age 13 months in May when these fish are all sublegal in size. Cohorts first become partially subject to fishing (faster growing fish reaching LML) around 2.5 years old depending on growth which varies by region and sex. The levels of King George Whiting abundance are influenced by the initial state array which assigns the numbers of fish to each combination of movement cell, sex, age, and slice. In this assessment, these scalar levels were estimated separately by stock. Detailed model specifications and equations for WhitEst fishery and population dynamics and for the data-fitting likelihood functions are given in Appendix 7.4. Fits of the model to data are plotted and discussed in Appendix 7.5.

Fishery models require an input value for the rate of natural mortality (*M*). WhitEst assumes an instantaneous rate of *M* = 0.45 (Jones et al. 1990). This assumption is analysed further in Appendix 7.8, where a range of published methods for estimating *M* were applied to South Australian King George Whiting. These methods had a mid-range (as the average *M*) of 0.47, very close to the value of 0.45 first published by Jones et al. (1990) for this stock which is used as the baseline value for WhitEst. To further investigate the implications of different assumed values for *M*, sensitivity analysis is presented in Appendix 7.6.

Previous assessments have implied that a major source of model estimate uncertainty, probably the largest source, lies in the input data for recreational catch totals. This source of model uncertainty is particularly high for King George Whiting in the two gulfs because recreational take comprises a large majority of the total catch (Figure 3.6-1). The estimates from the four recreational surveys have varying degrees of wide confidence intervals, not least due to the uncertainty in total State-wide participation. In addition, recreational catches for years between surveys are interpolated, and values by month and movement cell are GLM-estimated, bringing additional uncertainty since no direct information is available between surveys. To investigate the implications of this high uncertainty in catch from the (non-charter) recreational sector, we undertook sensitivity analysis, running different data sets of recreational monthly catch constructed under different approaches. The results of these recreational data sensitivity tests are presented in Appendix 7.7.

3.5.5. Fishery Performance

Two sets of fishery performance indicators were considered for the King George Whiting fishery at the State-wide and zone scales, i.e., the general performance indicators (PIs) and biological performance indicators (BPIs) (Table 3.5-1). Previously, these indicators were considered at the regional scale (PIRSA 2013) which have been updated in the current assessment to reflect the new zones of management. The PIs considered were; total catch, targeted handline effort, and targeted handline CPUE. The time series of data from 1983/84–2021/22 for the indicators were calculated. The value for 2021/22 was compared against the upper and lower trigger reference points (UTRP and LTRP, respectively) (Table 3.5-1), calculated for the ‘reference period’ designated in the management-plan, from the historical data time series for years prior to 2021/22 back to 1983/84 (PIRSA 2013).

There are four annual BPIs: fishable biomass; harvest fraction; recruitment; and age composition (Table 3.5-1; PIRSA 2013). The first three are estimated by WhitEst, whilst the age composition is obtained directly from market sampling. The new definition of biomass (> 280 mm TL) was included as an additional indicator, corresponding to the TRPs for fishable biomass. This was performed given that a consistent biomass definition is used across years, providing a more appropriate historical reference than fishable biomass, whose definition changes across time with increases to LML.

Performance indicators were produced for King George Whiting at the zone scale with the exception of age compositions which were assessed at the regional scale. The assessment status of each zone was classified based on the national reporting system, considering all general and biological performance indicators, using a weight-of-evidence approach (Table 1.6-1; Piddocke et al. 2021).

Table 3.5-1. Fishery performance indicators and associated trigger reference points used to assess fishery performance as specified in the Management Plan (PIRSA 2013). The type of indicator and whether a primary or secondary one is also indicated. G – general; B – biological.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT
TOTAL CATCH	G	3rd Lowest/3rd Highest
	G	Greatest % interannual change (+/-)
	G	Greatest five-year trend
	G	Decrease over five consecutive years
TARGET HANDLINE EFFORT	G	3rd Lowest/3rd Highest
	G	Greatest % interannual change (+/-)
	G	Greatest five-year trend
	G	Decrease over five consecutive years
TARGET HANDLINE CPUE	G	3rd Lowest/3rd Highest
	G	Greatest % interannual change (+/-)
	G	Greatest five-year trend
	G	Decrease over five consecutive years
BIOMASS > 280 mm TL	B	3-year average is +/- 10% of previous years (1983/84 – 2018/19)
FISHABLE BIOMASS	B	3-year average is +/- 10% of previous years (1983/84 – 2018/19)
HARVEST FRACTION	B	> 28%
RECRUITMENT	B	+/- 10% of average of previous 5 years (2013/14 – 2017/18)
AGE COMPOSITION	B	Change in long term or previous 5 years (2016/17 – 2020/21)

For assessment of catch shares amongst the commercial fisheries, the total catches reported in 2021/22 were compared against their allocations and associated TRPs (Table 3.5-2).

Table 3.5-2. Allocation percentages and trigger limits for SA's King George Whiting commercial fishery. Fishing sectors are; MSF = Marine Scalefish, SZRL = Southern Zone Rock Lobster, NZRL = Northern Zone Rock Lobster.

COMMERCIAL ALLOCATION	MSF	SZRL	NZRL
	98.10%	**n/a**	**1.90%**
TRIGGER 2	n/a	0.50%	2.97%
TRIGGER 3	n/a	0.75%	3.96%

3.6. Results

3.6.1. State-wide Fishery Statistics

The total commercial catch of King George Whiting was 176 t in 2021/22 (*c.f.* 181 t in 2020/21) (Figure 3.6-1). The 2021/22 fishing season had the lowest total catch on record and the seventh consecutive year with total catches below 300 t. The gross value of production (GVP) of King George Whiting in 2021/22 was approximately $3.75 M which is the third lowest since these data became available in 2003/04 (Figure 3.6-1). However, King George Whiting remains the second most valuable species in the fishery after Southern Calamari. The recreational catch of King George Whiting in the 2021/22 survey was 305 t, making it the most retained recreational species by weight (Beckmann et al. 2023). However, it should be noted that the recreational fishing survey occurred between 1 March 2021 and 28 February 2022 and does not align exactly with the 2021/22 fishing season (Beckmann et al. 2023).

The majority of the State-wide harvest since 1983/84 has been taken by the handline sector (Figure 3.6-1). Annual catches in this sector varied between 471 t and 156 t across the history of the fishery, with the lowest handline catch on record occurring in 2021/22. In 2021/22, 89% of the total catch was caught using handlines, while haul net fishing caught 14% and set net fishing caught 5%.

Total fishing effort (i.e., targeted effort and non-targeted effort that produced catches of King George Whiting) for all gears has steadily declined from a peak of 58,716 fisher-days in 1983/84 to a low of 9,511 fisher-days in 2020/21 (Figure 3.6-1). The total effort in 2021/22 was only slightly higher at 9,610 fisher-days. This represents an 83% decrease over 39 years declining at a rate of approximately 1,200 fisher-days per year. Total handline CPUE has steadily increased over time and has risen from 11.2 kg.fisher-day^{-1} in 1983/84 to 22.2 kg.fisher-day^{-1} in 2021/22, which was the highest on record (Figure 3.6-1). The number of licences taking and targeting King George Whiting has declined over-time, corresponding with similar trends in catch and effort. In 2021/22, 165 licences caught King George Whiting while 145 licences targeted it (Figure 3.6-1).

Catches occurred throughout both gulfs in 2021/22 with the highest catches occurring in Southern Spencer Gulf (Figure 3.6-2). The largest catch occurred adjacent to Ceduna (MFA 9), which traditionally has accounted for the majority of the catch on the West Coast of SA. Over the past five years 90% of the King George Whiting catch has been targeted while prior to this 82% of the catch was targeted (Figure 3.6-2). Seasonal catches have always been highest in the winter months (May – August) which corresponds with spawning events, particularly in the southern gulfs and investigator strait. However, catches in May were reduced from 2016/17 – 2020/21 due to spawning closures implemented in Southern Spencer Gulf and the Investigator strait (Table 3.4-1; Figs. 3.6-1; 3.6-2). The SG fishing zone has historically had the highest catches of King George Whiting, followed by the WC fishing zone. Large catches have also occurred in the GSV/KI zone but not to the same degree

(Figure 3.6-2). Negligible amounts of catch occur in the SE fishing zone and therefore this stock is assessed as negligible.

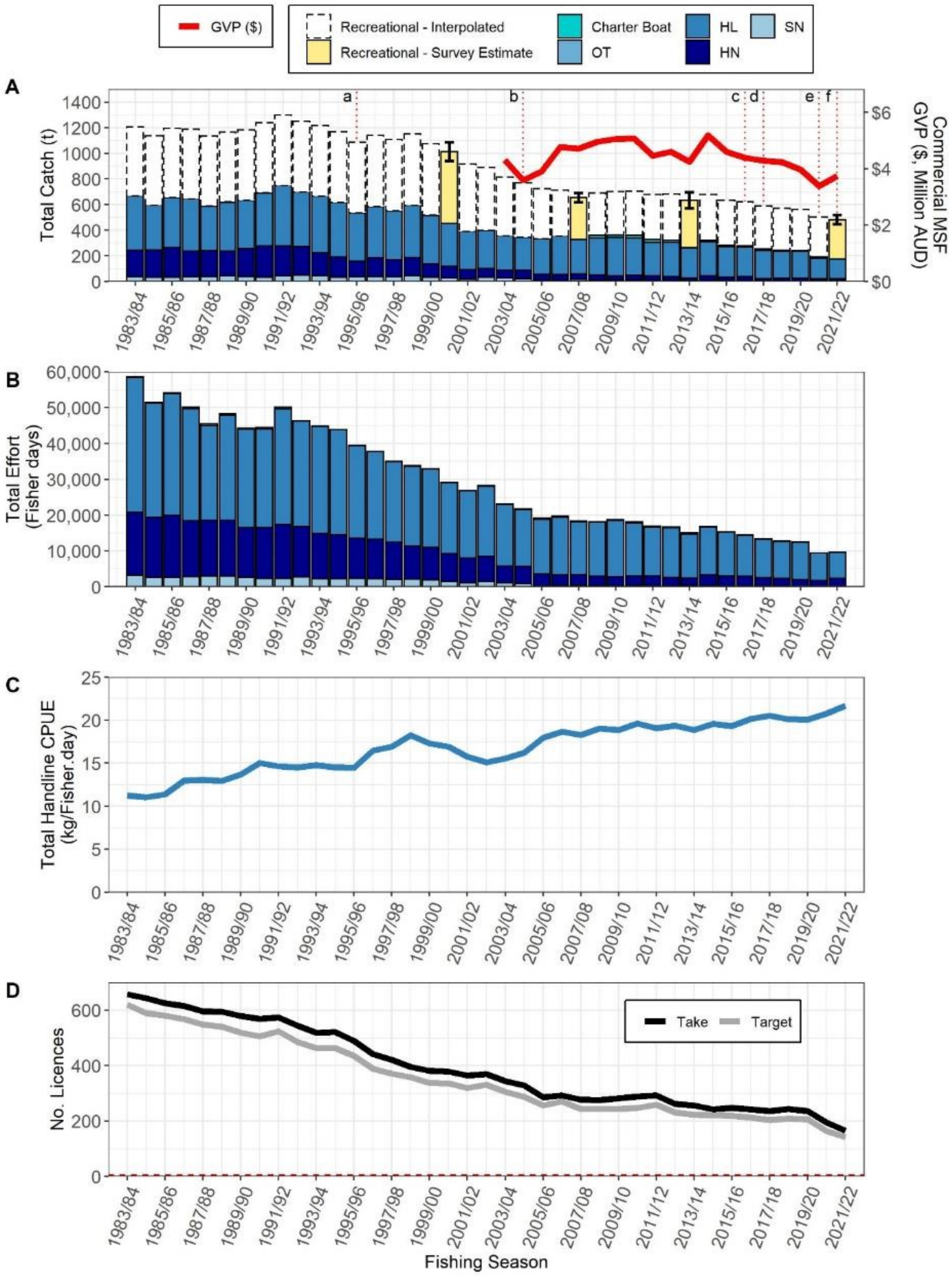


Figure 3.6-1. Long-term trends in State-wide estimates for King George Whiting of (A) total catch for the main gear types (handline, set net, haul net and other), estimated recreational catch, interpolated recreational catch, charter boat catch and gross production value (GVP); (B) Long-term total effort by gear type; (C) total handline CPUE; and (D) the number of active licence holders taking or targeting the species. Red dotted lines on panel A represent significant management interventions which are detailed in Table 3.4-1 using their respective labels. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. The red dashed line on panel D indicates the number of licences where data becomes confidential.

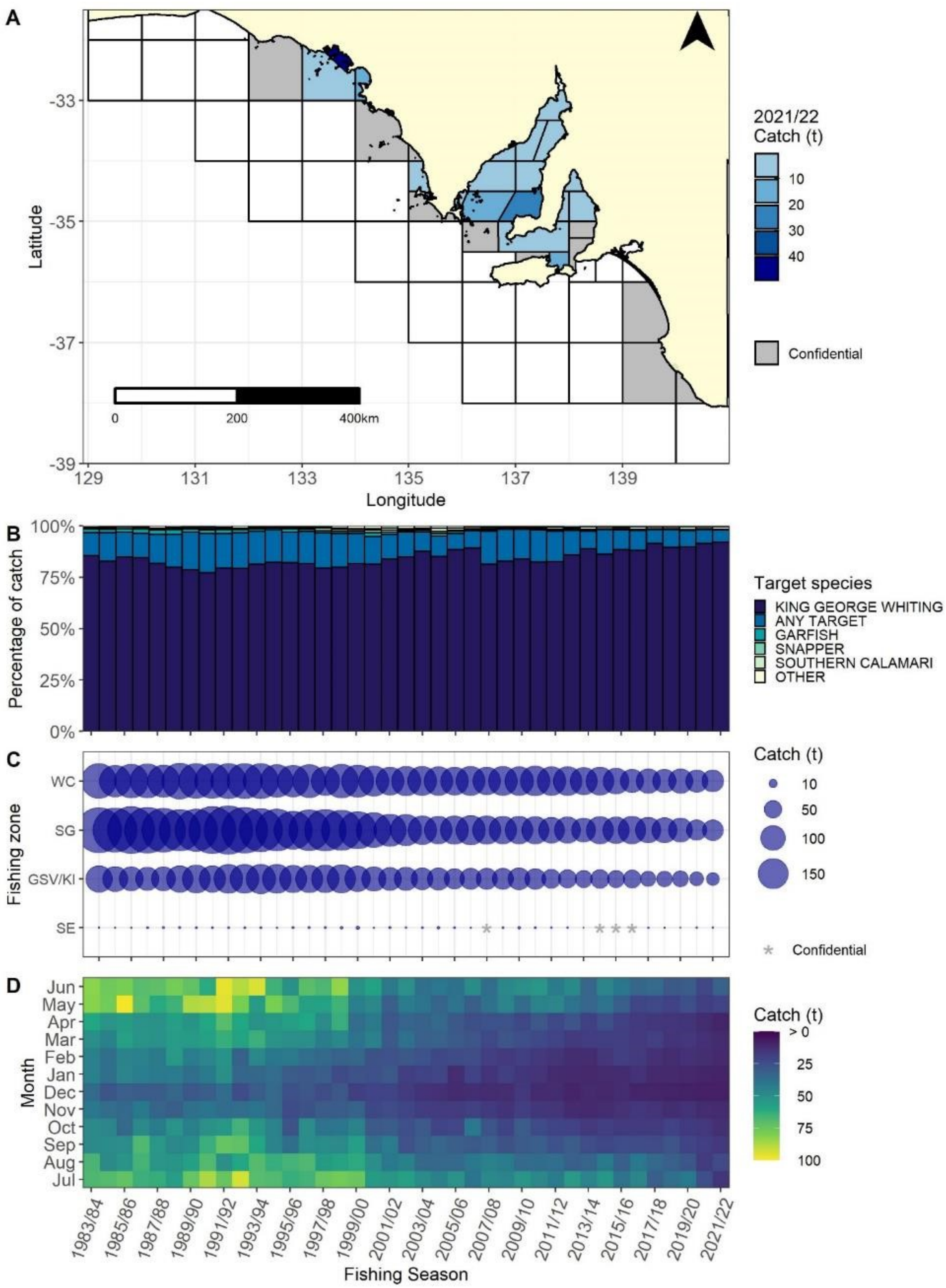


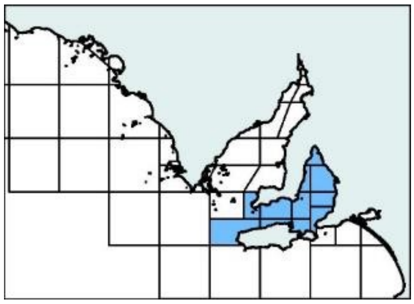
Figure 3.6-2. Regional dynamics of King George Whiting: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of King George Whiting targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

3.6.2. Gulf St Vincent/Kangaroo Island Fishing Zone

Stock summary

King George Whiting

Gulf St Vincent/Kangaroo Island Fishing Zone



Stock status	2019 - Sustainable	2020 - Sustainable	**2021/22 - Sustainable**
Fishery/stock trend	Total MSF catch and effort have been declining since the mid 1990's and were the lowest on record in 2021/22. However, CPUE has been increasing since 2016/17 following several management interventions.		

Commercial catch statistics and TACC

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target HL CPUE *kg/fisher-day*	TACC *t*
2017/18	37	3,036	14.9	-
2018/19	40	3,116	15.5	-
2019/20	42	3,030	15.0	-
2020/21	31	2,302	15.6	-
2021/22	27	2,217	15.9	46

Stock Status Summary	Since the 2016/17 fishing season all available indicators for this fishery have been positive. Commercial catch and effort have been reduced through management measures, both raw and standardised CPUE have been increasing, and no identifiable issues in age and length structures have been detectable. As a result, stable recruitment and low harvest fractions have resulted in relatively high and stable biomass over recent fishing seasons. As such, the GSV/KI stock was classified as **sustainable**.

3.6.2.1. Fishery statistics

The total catch of King George Whiting in the GSV/KI fishing zone was 27 t in 2021/22, constituting 59% of 46 t TACC (Figure 3.6-3). This is the first fishing season where catch has decreased below 30 t. Handlines catches constituted 74% of the catch in 2021/22 at 20 t (Figure 3.6-3). This was the lowest handline catch on record and represented a 34 % reduction over two fishing seasons. The recreational catch in 2021/22 fishing survey was estimated at 76 t at the GSV/KI zone level (Figure 3.6-3).

Targeted effort has had a long-term declining trend and was 1,304 fisher days across all gear types in 2021/22, which as a record low (Figure 3.6-3). Handlines accounted for 94% of the targeted effort in 2021/22, which is consistent with long-term trends in gear use. The 1991/92 fishing season had the largest target effort at 7,841 fisher days, demonstrating a decrease of 83% over time (Figure 3.6-3). Targeted handline CPUE by fisher day has had a long-term increasing trend over the history of the fishery and was the highest on record at 15.9 kg.fisher-day^{-1} in 2021/22 (Figure 3.6-3). Targeted handline CPUE by fisher hour is available from 2003/04 onwards and closely follows the trend of CPUE by fisher day over the same period (Figure 3.6-3). The highest CPUE by fisher hour on record was 4.0 kg.fisher-hour^{-1} in 2020/21, while this decreased slightly to 3.6 kg.fisher-hour^{-1} in 2021/22 (Figure 3.6-3). The number of licences targeting and catching King George Whiting in the GSV/KI fishing zone have declined steadily over time and were the lowest on record in 2021/22 at 29 and 41 licences, respectively (Figure 3.6-3).

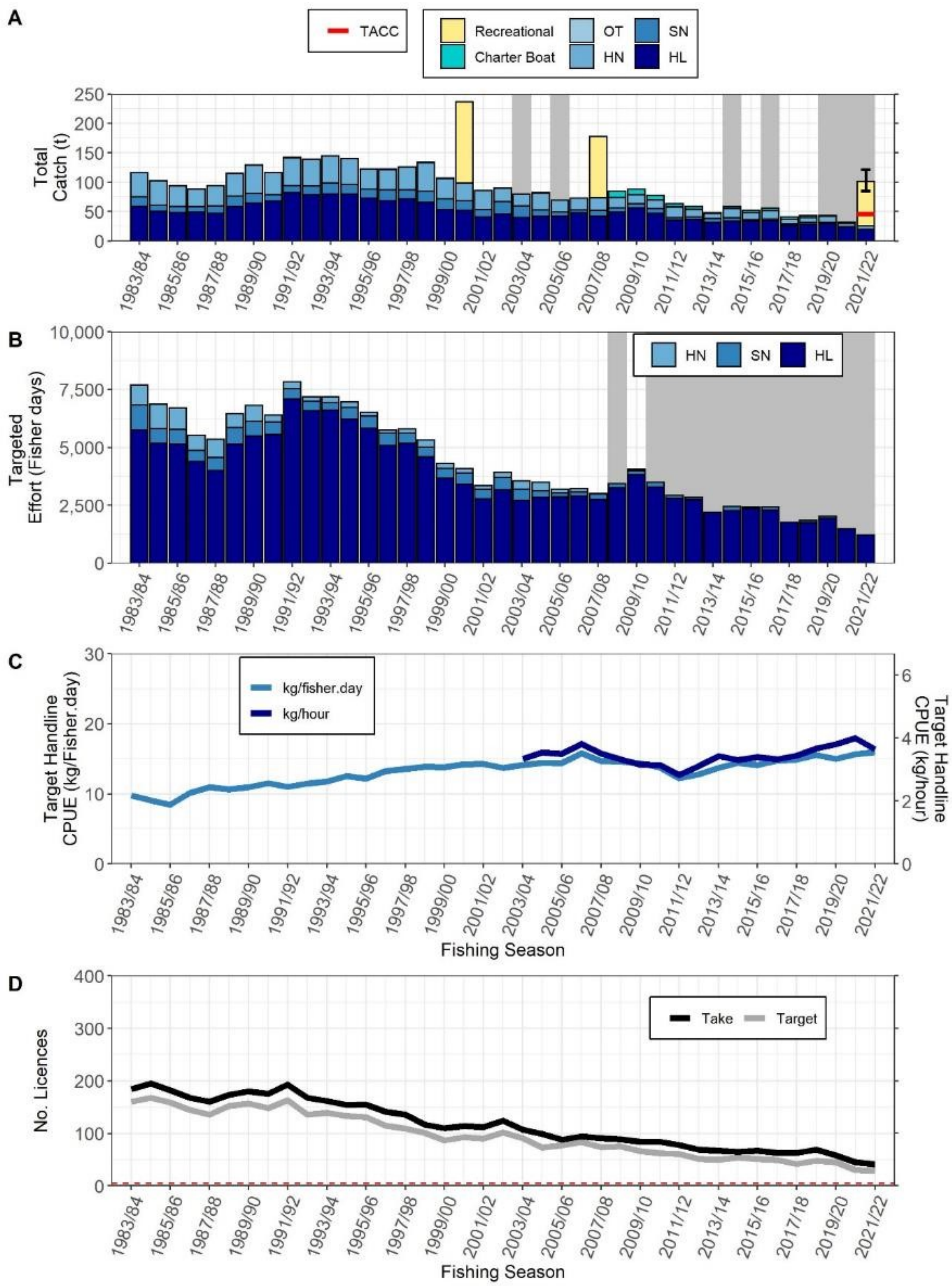


Figure 3.6-3. Long-term trends in catch statistics for King George Whiting in the GSV/KI fishing zone. (A) total catch for the main gear types (handline, set net, haul net and other), estimated recreational catch and charter boat catch; (B) Long-term target effort by gear type; (C) target handline CPUE by fisher day and fisher hour; and (D) the number of active licence holders taking or targeting the species. Error bars on the 2021/22 recreational catch estimate (A) represent the standard error from that survey. The red line indicates the 2021/22 TACC. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on the panel.

3.6.2.2. Age and Length Compositions

Northern Gulf St Vincent (MFAs 34, 35, 36 & 43)

A total of 16,798 fish have been sampled from Northern Gulf St Vincent (NGSV) since 2006/07, of which 1,399 have been aged (Figure 3.6-4; 3.6-5). The resulting annual length distributions were dominated by small to medium sized fish, with most fish < 400 mm TL. The modal sizes varied between 320 and 340 mm TL. Few fish were in the larger (> 400 mm TL) size range, with the largest fish recorded was 530 mm TL in 2009/10. Some degree of length truncation was apparent for 2021/22 where there were fewer fish above 350 mm TL than in previous years (Figure 3.6-4).

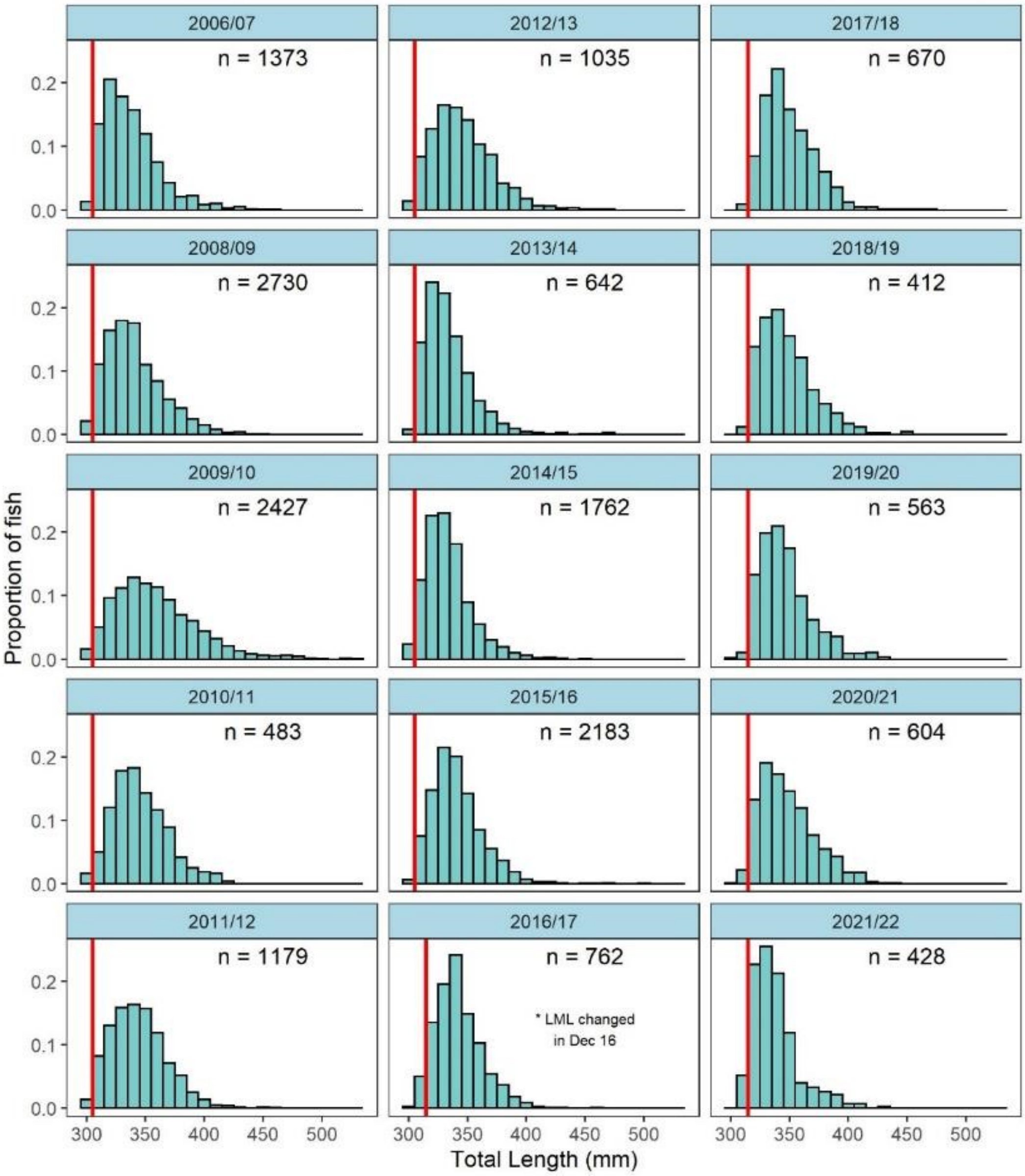


Figure 3.6-4. Total Length distributions of King George Whiting sampled from NGSV from 2006/07 to 2021/22. Red vertical line indicates the LML, which was increased in 2016 from 310 to 320 mm TL.

The age structures were dominated by the 3+ age class for all years besides 2014/15, which was dominated by 2+ year class. There was little representation from older age classes 5+ to 9+ years. No significant changes to age compositions have occurred within the last five years. Therefore, the TRP was not breached in 2021/22 (Figure 3.6-5).

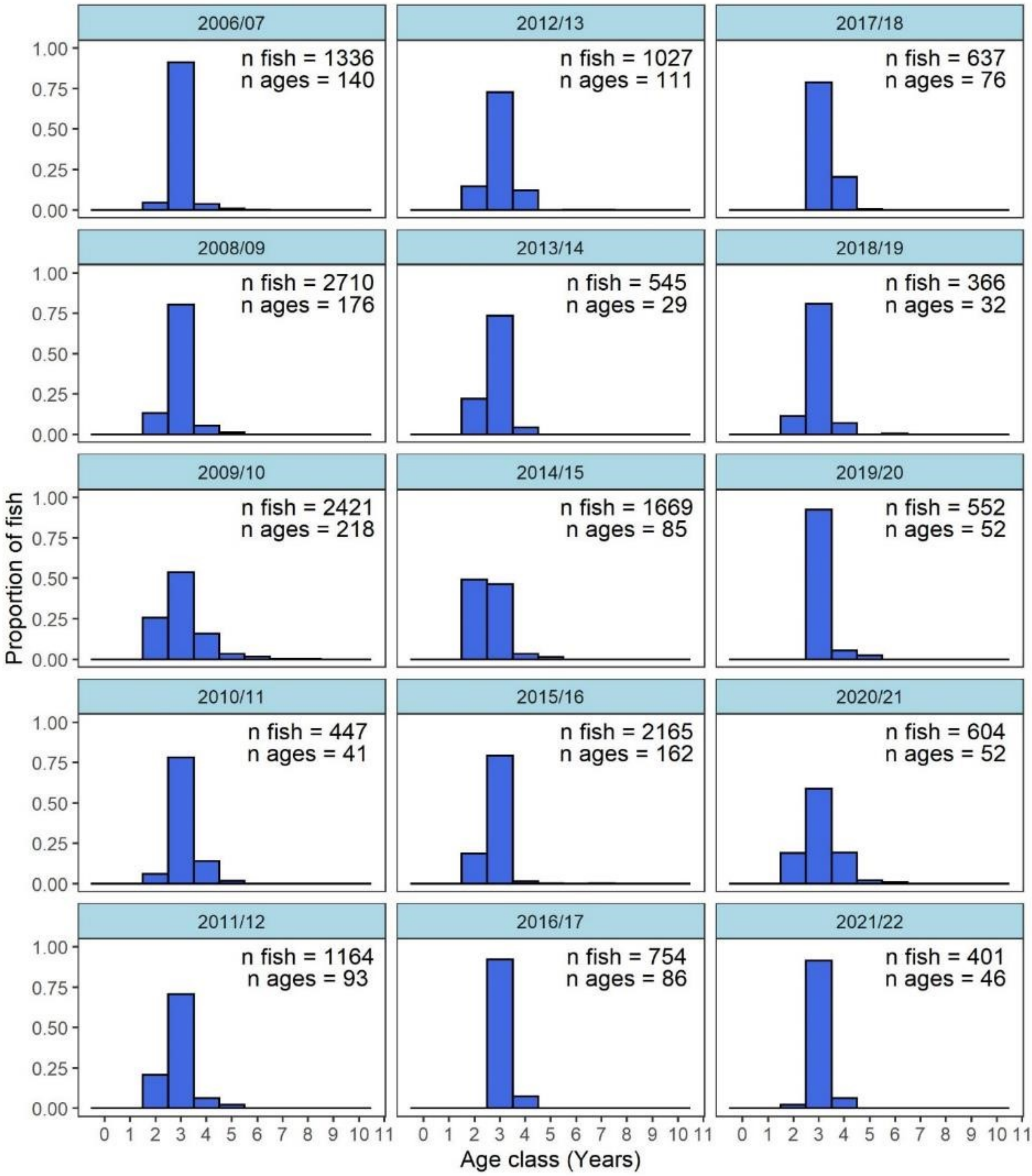


Figure 3.6-5. Age distributions of King George Whiting sampled from NGSV from 2006/07 to 2021/22

Southern Gulf St Vincent (MFAs 39B, 40B, 40C, 41, 42 & 44A)

A total of 17,578 fish have been sampled from Southern Gulf St Vincent (SGSV) since 2006/07, of which 3,291 have been aged (Figure 3.6-6; 3.6-7). This region included a complex range of habitats, from inshore bays which are known for small King George Whiting and deep-water reef habitats where larger spawning fish aggregate. Therefore, the resulting size and age structure information is broader and more variable dependent on the locality of fishing than seen in other regions. The length structures were not consistent between years, with the fish collected in most years were medium sized, ranging from 320 to 30 mm TL. Contrastingly, in 2016/17 the length structure was representative of larger fish, with the majority ranging from 410 to 450 cm TL. This variation in length structure seen in 2016/17 is likely the result of a small sample size and fish sampled were targeted from deeper water locations, where larger fish reside.

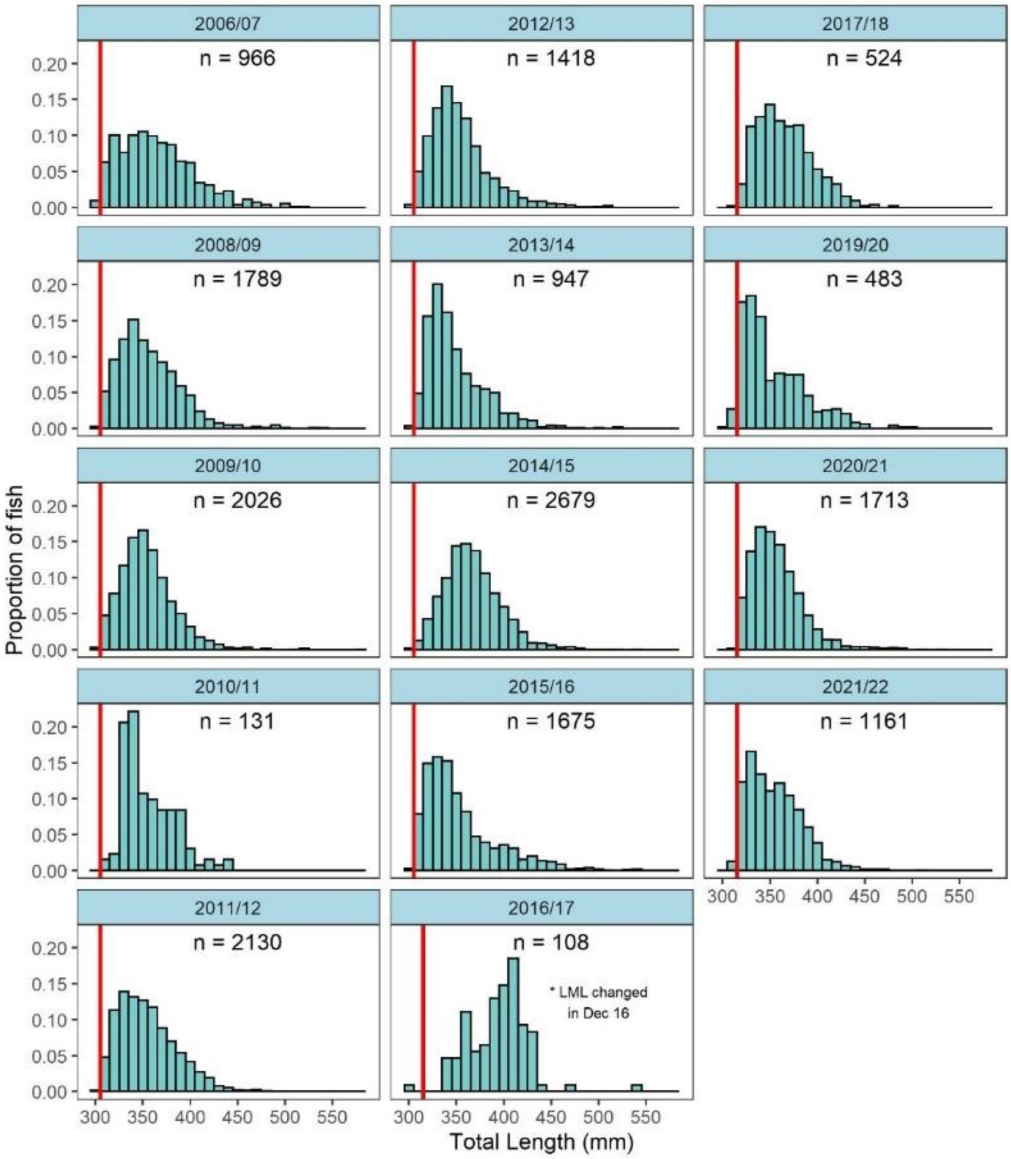


Figure 3.6-6. Total Length distributions of King George Whiting sampled from SGSV from 2006/07 to 2021/22

Similar to other regions, the 3+ and 4+ age classes dominated the age structures with adequate sample sizes attained for interpretation (>100 fish) (Figure 3.6-7). However, the age structures were complex and broader with the highest representation of older year classes >5+ for any region. The oldest fish aged in each year with adequate sample sizes (> 100 fish) were at least 9+ years old, with multiple fish in the 17+ age class captured in 2011/12 and 2014/15. No significant changes to age compositions have occurred within the last five years. Therefore, the TRP was not breached in 2021/22 (Figure 3.6-7).

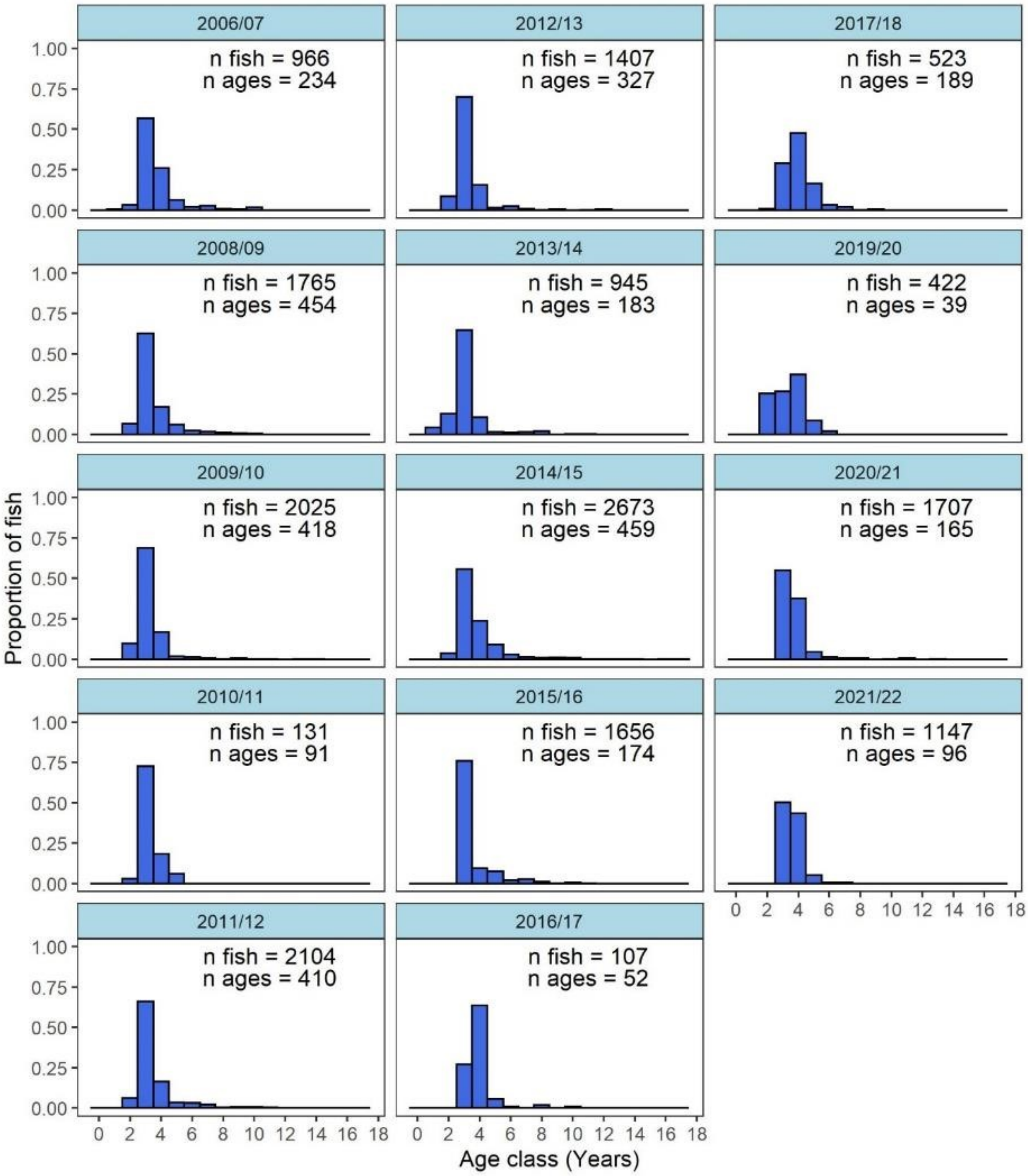


Figure 3.6-7. Age distributions of King George Whiting sampled from SGSV from 2006/07 to 2021/22

3.6.2.3. CPUE standardisation

The standardised CPUE index provided a similar time series to raw target handline CPUE with regards to annual increases and decreases. However, the increasing trend that was visible across years for raw CPUE was dampened by the standardisation, providing a time-series that was flatter across the history of the fishery (Figure 3.6-8).

The standardised CPUE had an increasing trend from 1983/84 to 1997/98, after which a general decline occurred until 2011/12. Since then, standardised CPUE has been increasing steadily (Figure 3.6-8). The GLM revealed that the licence holder variable had the greatest effect size, suggesting that standardising for this variable has had the greatest impact on CPUE trends.

This overall trend of slower rises in abundance and faster declines for standardised CPUE relative to raw (up to the low point of 2011/12) implies that standardisation has captured evidence of rising effective effort for this gear type and removed it to the extent shown.

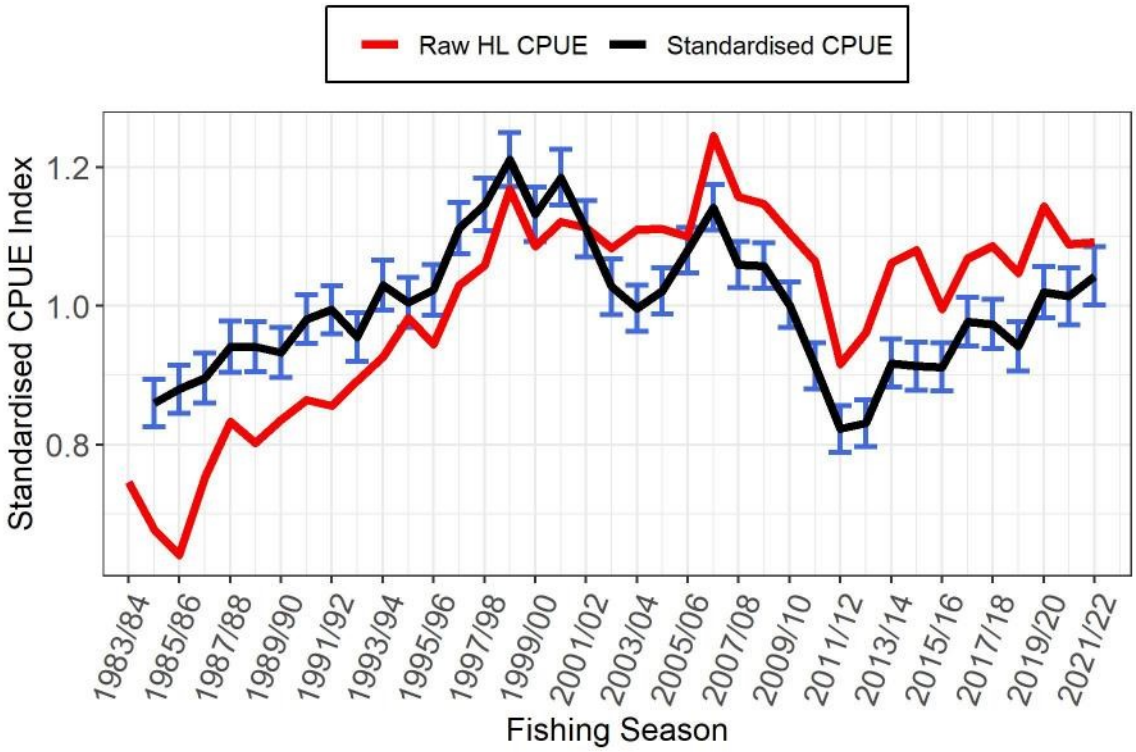


Figure 3.6-8. Standardised CPUE index for King George Whiting from the GSV/KI fishing zone. Black line is the standardised index and blue error bars are the standard error of the standardised (year-effect) coefficients. Solid red line is the raw targeted handline CPUE presented in figure 3.6-3. Both time series have been normalised to a mean of one to enable comparisons.

3.6.2.4. WhitEst model outputs

The biomass of King George Whiting in 2021/22 was 770 t and has been stable since 2018/19 (Figure 3.6-9). This biomass estimate includes all fish above 280 mm TL, accounting for changes to LML which have occurred over the history of the fishery (Table 3.4-1). Biomass has had a generally increasing trend across the history of the fishery with the only decline occurring from 2008/09 to 2015/16. During this time, biomass declined by 12 % over the course of the 2008/09 and 2009/10 fishing seasons from 804 t to 710 t, before stabilising at approximately 700 t. Biomass has increased since this period, demonstrating that the GSV/KI stock is in a healthy state. In 2021/22 the three-year average biomass was 19% above the long-term average, triggering the UTRP (Table 3.4-1). The fishable biomass (whose definition changes through time with changes to LML) was 8% above the long-term average, triggering neither TRP.

The harvest fractions presented in this assessment correspond to a biomass of fish above 280 mm TL, rather than the fishable biomass of a given year. This ensures that a consistent harvest fraction definition is presented across all years that is not influenced by changes in LML through time. The harvest fraction in 2021/22 was the lowest on record at 0.18 yr^{-1} (Figure 3.6-9). Harvest fractions have been below the target harvest fraction listed in the Management Plan of 0.28 yr^{-1} (PIRSA 2013) since 2003/04. Harvest fractions have continuously trended downwards since 1993/94 (Figure 3.6-9). Recruitment has varied over time but has had a generally stable trend (Figure 3.6-9). The number of recruits estimated for the 2018 cohort was 3 million fish. This was 1.8 % below the average of the previous five years but did not trigger the LTRP (Figure 3.6-9; Table 3.4-1).

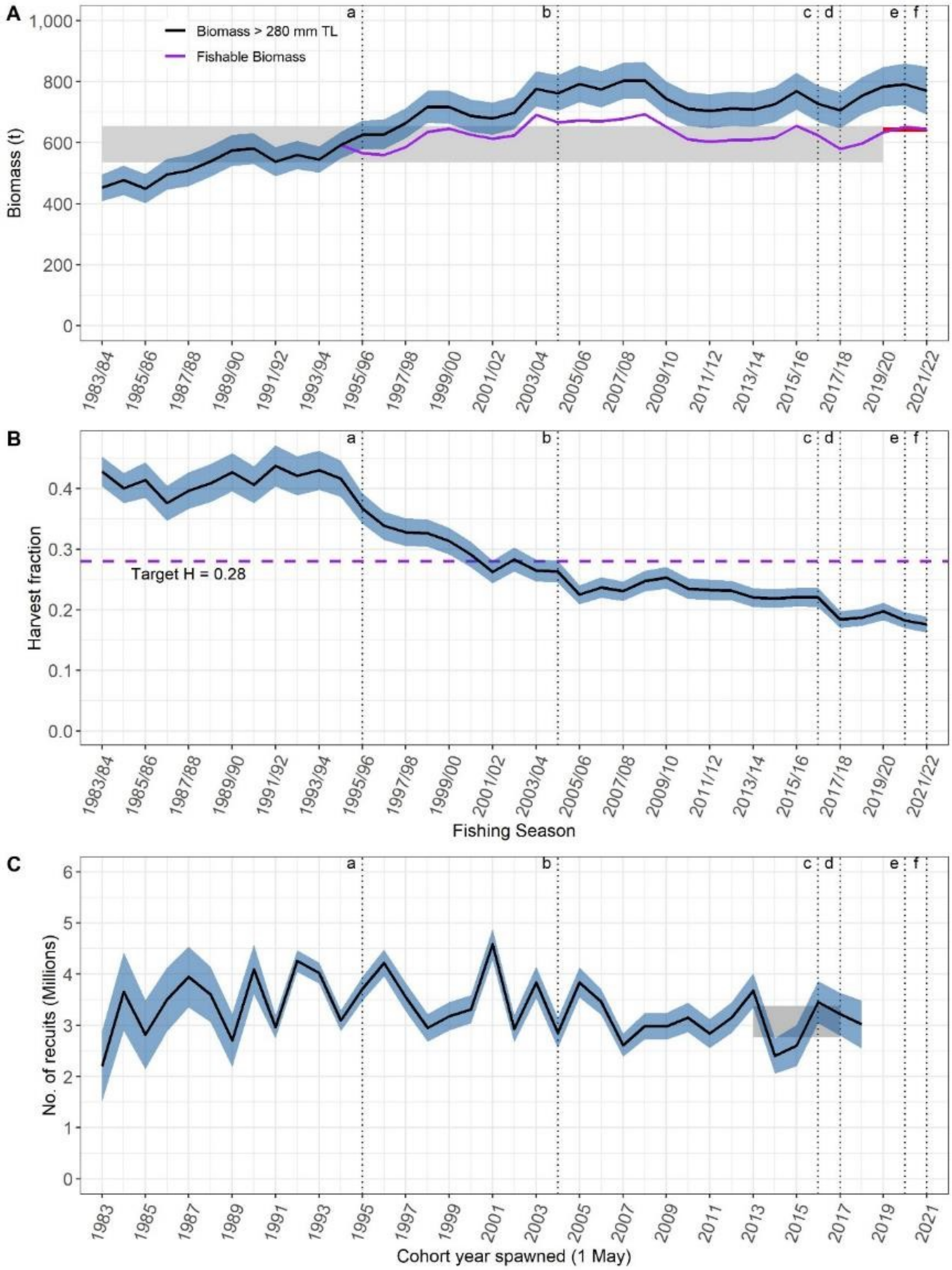


Figure 3.6-9. Biological performance indicators (BPIs) for King George Whiting in the GSV/KI fishing zone: A) biomass (t) which includes the biomass of fish above 280 mm TL (black line and blue shading) and fishable biomass (purple line), B) harvest fraction which corresponds to biomass > 280 mm TL (black line and blue shading), and C) number of recruits the correspond to their cohort year (i.e., year spawned with a birthdate of 1 May; black line and blue shading). The blue shading of each quantity represents the 95% confidence intervals of these estimates. No confidence intervals are available for fishable biomass. The dashed purple line indicates the target harvest fraction of 0.28 yr^{-1} listed in the Management Plan. The grey shading represents the LTRP and UTRP for fishable biomass, harvest fraction and annual recruitment according to their respective BPIs (Table 3.5-1). The red line represents the three year mean fishable biomass. Dotted lines and annotations correspond to key management changes that can be referenced in Table 3.4-1.

3.6.2.5. Stock Status

The 2021/22 fishing season had the lowest catch and effort on record which was to be expected given the reduction in licences from the recent fishery reform (Smart et al. 2022a). However, raw handline CPUE by fisher hour and fisher day have been increasing since 2011/12 with the former breaching the UTRP in 2021/22. The standardised handline CPUE supported the trend of raw CPUE, adding further evidence of strong fishery performance since 2011/12. The declining CPUE between 2006/07 and 2011/12 resulted from a period of declining recruitment for this stock that reduced the biomass during these years. Based on these fishery performance indicators, the GSV/KI stock was classified as 'transitional depleting' (Fowler et al. 2014). This, in association with the stock status assigned to the SG stock, prompted a review of fishery management arrangements that resulted in the changes that were implemented in December 2016.

Since the 2016/17 fishing season all available indicators for this fishery have been positive. Commercial catch and effort have been reduced through management measures, both raw and standardised CPUE have been increasing, and no identifiable issues in age and length structures have been detectable. As a result, the WhitEst model has estimated an increasing biomass over the past several years that was supported by stable recruitment and decreased harvest fractions.

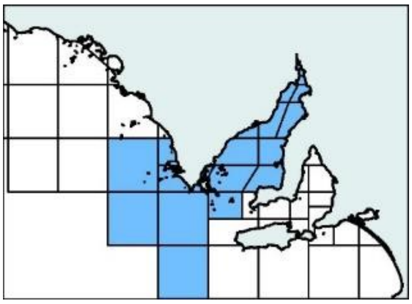
The above evidence indicates that the biomass of King George Whiting within the GSV/KI fishing zone is unlikely to be depleted and that recruitment is unlikely to be impaired. The current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, the GSV/KI stock was classified as **sustainable.**

3.6.3. Spencer Gulf Fishing Zone

Stock summary

King George Whiting

Spencer Gulf Fishing Zone



Stock status	2019 - Sustainable	2020 - Sustainable	**2021/22 - Sustainable**
Fishery/stock trend	Total MSF catch and effort have been declining since the mid 1990's and were the second lowest and lowest on record in 2021/22, respectively. However, CPUE has had a generally increasing trend over the history of the fishery and was the highest on record in 2021/22.		

Commercial catch statistics and TACC

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target HL CPUE *kg/fisher-day*	TACC *t*
2017/18	108	6,174	20.2	-
2018/19	103	5,750	20.0	-
2019/20	96	5,446	19.3	-
2020/21	69	3,764	20.7	-
2021/22	71	4,076	21.9	111.3
Stock Status Summary	Slight declines in biomass have occurred in recent years due to reduced recruitment since 2013. However, declining commercial catches have maintained a low harvest fraction and the LTRP for biomass > 280 mm TL has not been breached. The LTRP for fishable biomass was breached in 2021/22, although this was in part due to the redefinition of fishable biomass that occurred through increases to LML. Raw and standardised CPUE demonstrate strong fishery performance and do not suggest any issues with stock health. As such, the SG stock was classified as **sustainable**.			

3.6.3.1. Fishery statistics

The total catch of King George Whiting in the SG fishing zone was 71 t in 2021/22, constituting 64% of 111 t TACC (Figure 3.6-10). This is the third consecutive fishing season where catch has been below 100 t which has only occurred once prior to this. Handlines catches constituted 82 % of the catch in 2021/22 at 58 t (Figure 3.6-10). This was the second lowest catch on record (*c.f.* 57 t in 2020/21) and the second consecutive year where handline catches were below 60 t. The recreational catch in 2021/22 fishing survey was estimated at 161 t at the SG zone level (Figure 3.6-10).

Targeted effort has had a long-term declining trend and was 2,753 fisher days across all gear types in 2021/22, which as a record low (Figure 3.6-10). Handlines accounted for 96% of the targeted effort in 2021/22, which is consistent with long-term trends in gear use. The 1983/84 fishing season had the largest target effort at 21,532 fisher days, demonstrating a decrease of 87% over time (Figure 3.6-10). Targeted handline CPUE by fisher day has had a long-term increasing trend over the history of the fishery and was the highest on record at 21.9 kg.fisher-day^{-1} in 2021/22 (Figure 3.6-10). Targeted handline CPUE by fisher hour is available from 2003/04 onwards and closely follows the trend of CPUE by fisher day over the same period (Figure 3.6-10). The highest CPUE by fisher hour on record was 4.0 kg.fisher-hour^{-1} in 2021/22 (Figure 3.6-10). The number of licences targeted and catching King George Whiting in the SG fishing zone have declined steadily over time and were the lowest on record in 2021/22 at 80 and 94 licences, respectively (Figure 3.6-10).

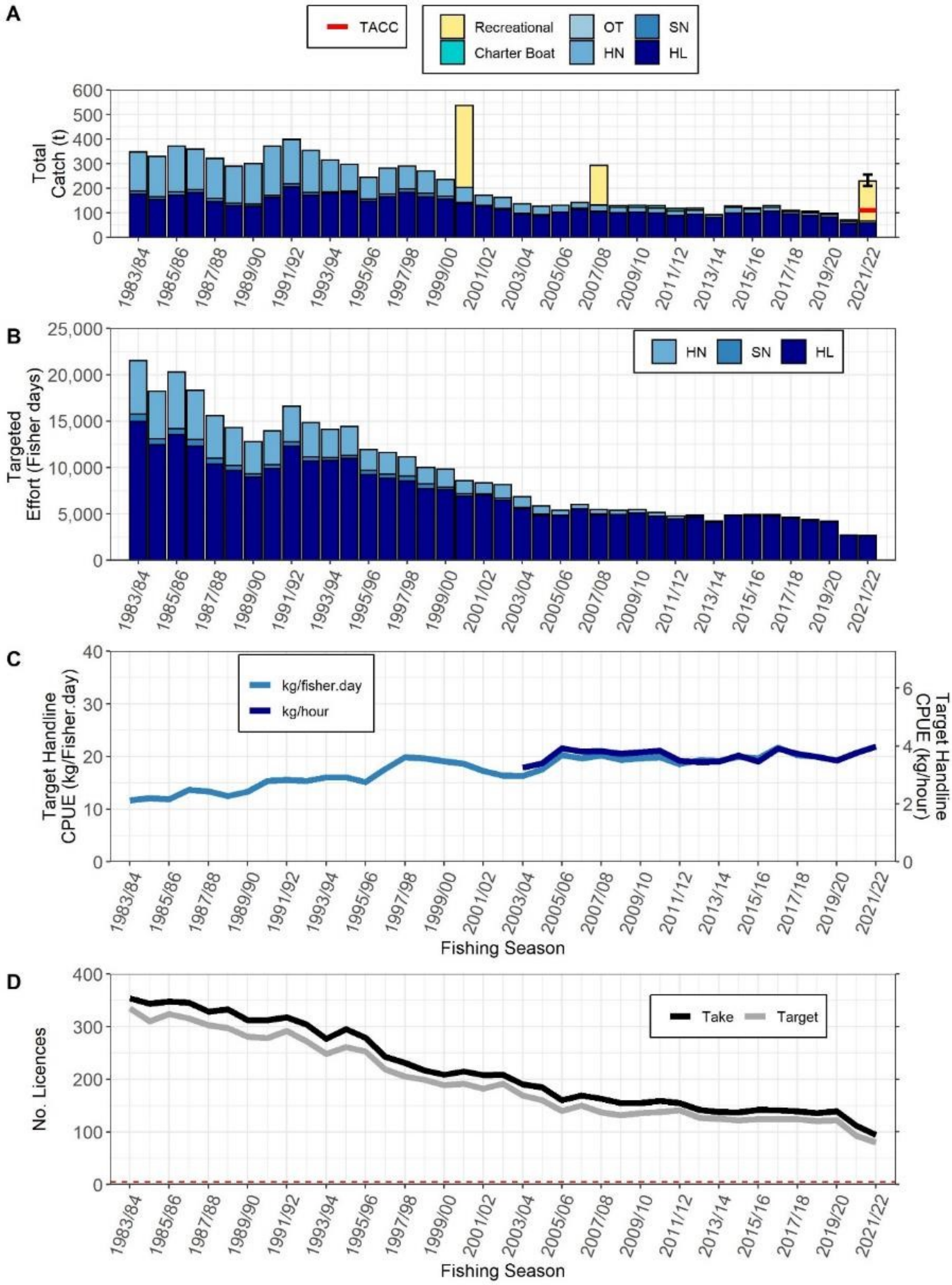


Figure 3.6-10. Long-term trends in catch statistics for King George Whiting in the SG fishing zone. (A) total catch for the main gear types (handline, set net, haul net and other), estimated recreational catch and charter boat catch; (B) Long-term target effort by gear type; (C) target handline CPUE by fisher day and fisher hour; and (D) the number of active licence holders taking or targeting the species. Error bars on the 2021/22 recreational catch estimate (A) represent the standard error from that survey. The red line indicates the 2021/22 TACC. A red dashed line in panel H represents the number of licences where data becomes confidential.

3.6.3.2. Age and Length Compositions

Northern Spencer Gulf (MFAs 11, 19, 20, 21, 22 & 23)

A total of 31,825 fish have been sampled from Northern Spencer Gulf (NSG) since 2006/07, of which 2,2234 have been aged (Figure 3.6-11; 3.6-12). The length structures were relatively consistent between years, with the catches dominated by small to medium fish < 400 mm TL and decreasing numbers of larger fish present. A small variation in modal size classes is evident between 2013/14 and the following years. In 2013/14, most fish ranged in size from 340 – 370 mm TL, whereas the modal size range of the following years was 310 – 340 mm TL. The reduction of fish measured < 320 cm TL after 2016/17 is the result of an increase to the LML. A greater proportion of larger fish occurred in 2021/22 than in recent years (Figure 3.6-11).

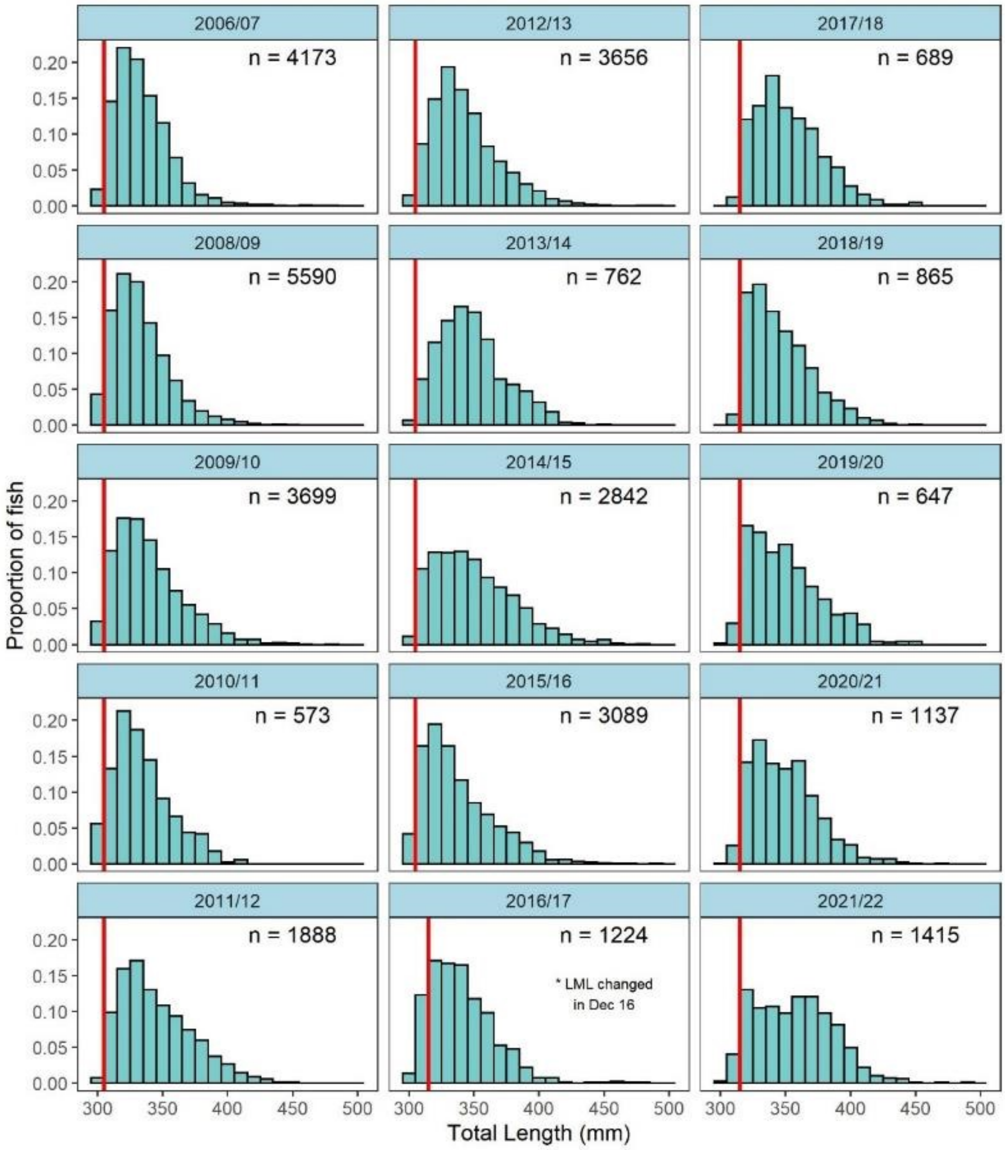


Figure 3.6-11. Total Length distributions of King George Whiting sampled from NSG from 2006/07 to 2021/22. Red vertical line indicates the LML, which was increased in 2016 from 310 to 320 mm TL.

The age structures for all years of sampling were dominated by 3+ and 4+ age classes, which accounted for ~80% of fish sampled annually. An increase in the proportion of age 4+ fish has occurred since 2016/17 which could be the result of decreased mortality, or a lack of age 3+ fish which increases their percentage of the population. An LML change from 310 mm TL to 320 mm TL occurred in 2016/17 but it is unlikely to have caused this change in age structures as the same LML change did not produce any response in age structures for GSV/KI (Figure 3.6 -5). No significant changes to age compositions have occurred within the last five years. Therefore, the TRP was not breached in 2021/22 (Figure 3.6-12).

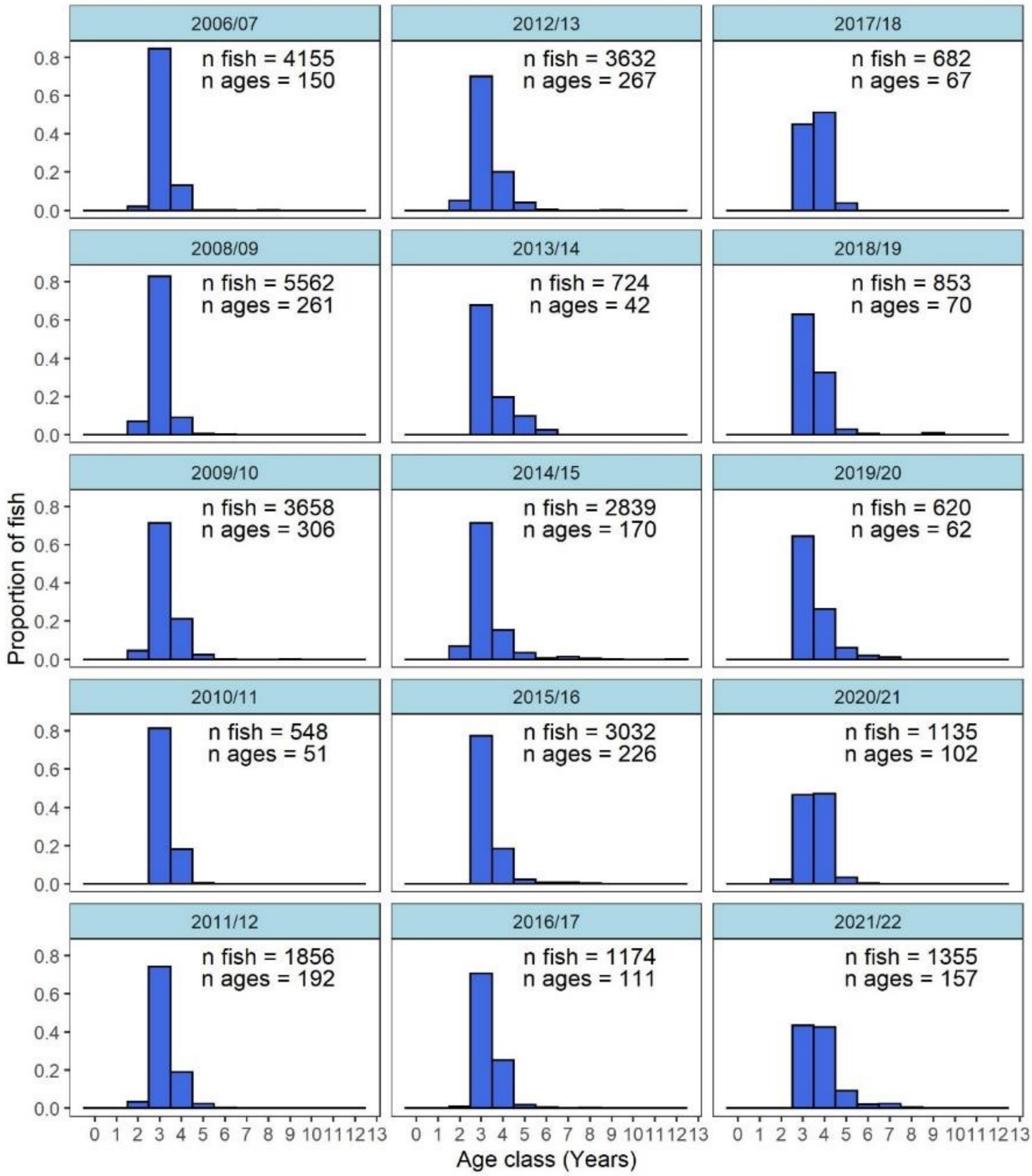


Figure 3.6-12. Age distributions of King George Whiting sampled from NSG from 2006/07 to 2021/22

Southern Spencer Gulf (MFAs 29, 30, 31,32 ,33, 39A & 40A)

A total of 32,096 fish have been sampled from Southern Spencer Gulf (SSG) since 2006/07, of which 3,036 have been aged (Figure 3.6-13; 3.6-14). The size distributions were broader and in general larger than those captured in NSG. The modal lengths were between 340 and 370 mm TL across most years (Figure 3.6-13). Approximately 20% of fish measured were 400 cm TL or larger each year for all years sampled.

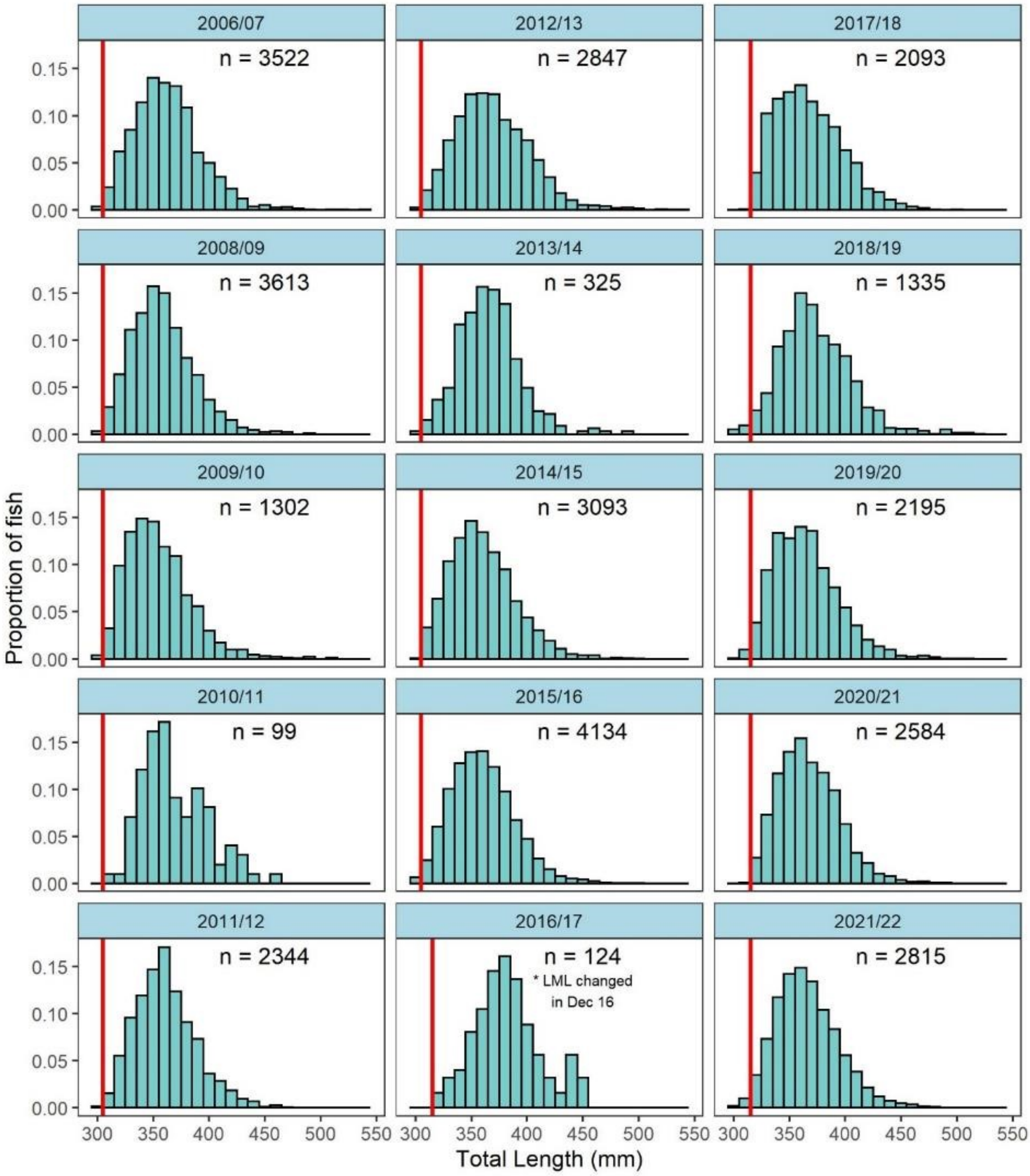


Figure 3.6-13. Total Length distributions of King George Whiting sampled from SSG from 2006/07 to 2021/22. Red vertical line indicates the LML, which was increased in 2016 from 310 to 320 mm TL.

Age distributions were consistent between years and were predominately comprised of 3+, 4+ and 5+ age classes. The presence of older age classes 5+ – 15+ was still relatively low, however they were more numerous than in other regions. The oldest fish in each year was 7+ years or more, with the oldest fish aged 15+ in 2012/13. No significant changes to age compositions have occurred within the last five years. Therefore, the TRP was not breached in 2021/22 (Figure 3.6-14).

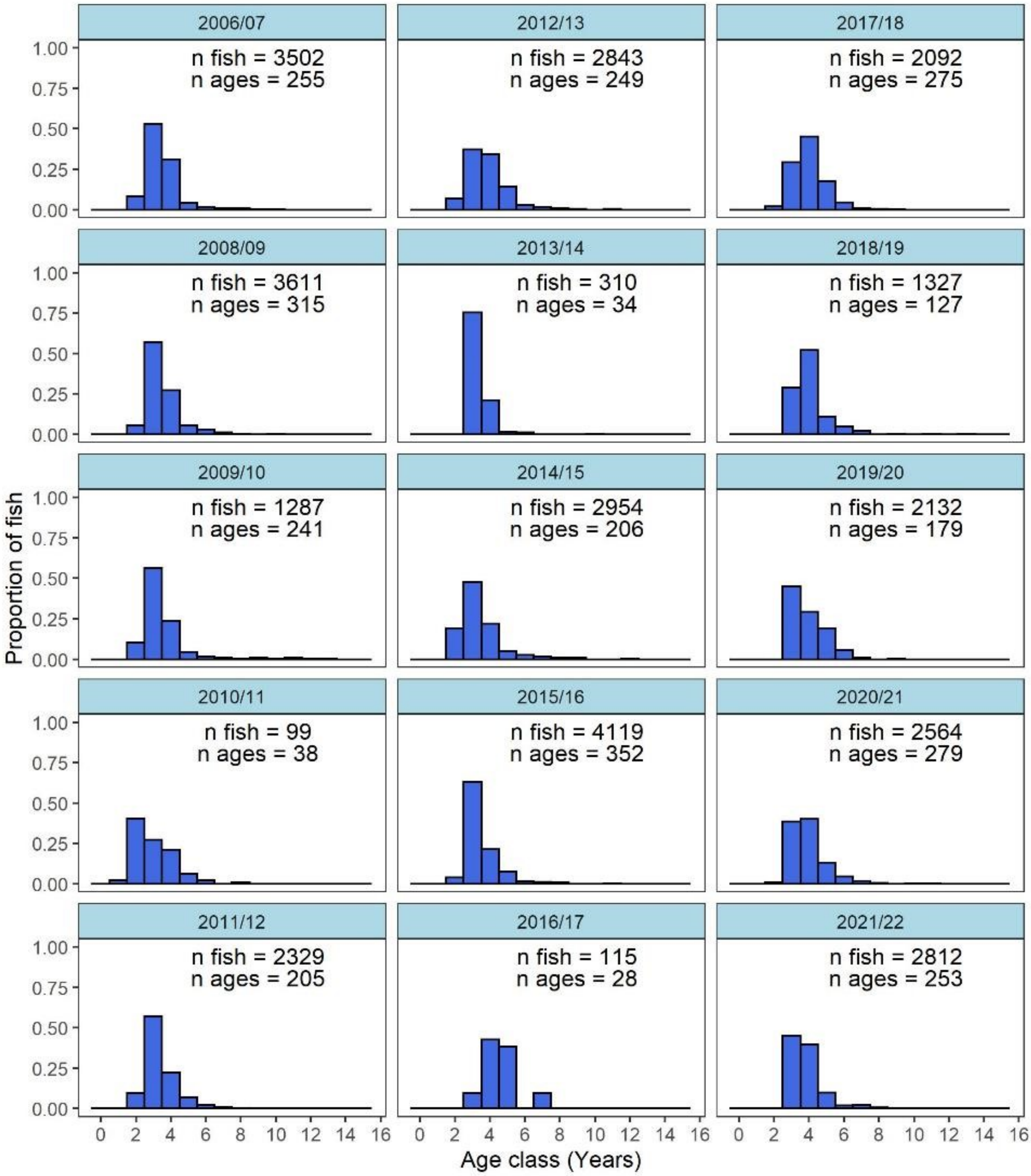


Figure 3.6-14. Age distributions of King George Whiting sampled from SSG from 2006/07 to 2021/22

Western Eyre Peninsula (MFAs 27 & 28)

A total of 9,210 fish have been sampled from the Western Eyre Peninsula since 2006/07, of which 957 have been aged (Figure 3.6-15; 3.6-16). The length distributions were typically smaller than the adjacent SSG region. Instead, they were similar to the NSG and NGSV regions where smaller fish reside in nursery areas prior to the onset of migration at age 3+. The modal lengths were typically between 310 and 320 mm TL which can be partly attributed to the lower LML of this region (300 mm TL; Figure 3.4-1). Differences between years appears to be driven by sample size, when it is likely that fish were taken from fewer samples which may have skewed length distributions. This may have occurred for 2011/12 and 2019/20 (Figure 3.6-15). No fish were sampled from this region in 2021/22.

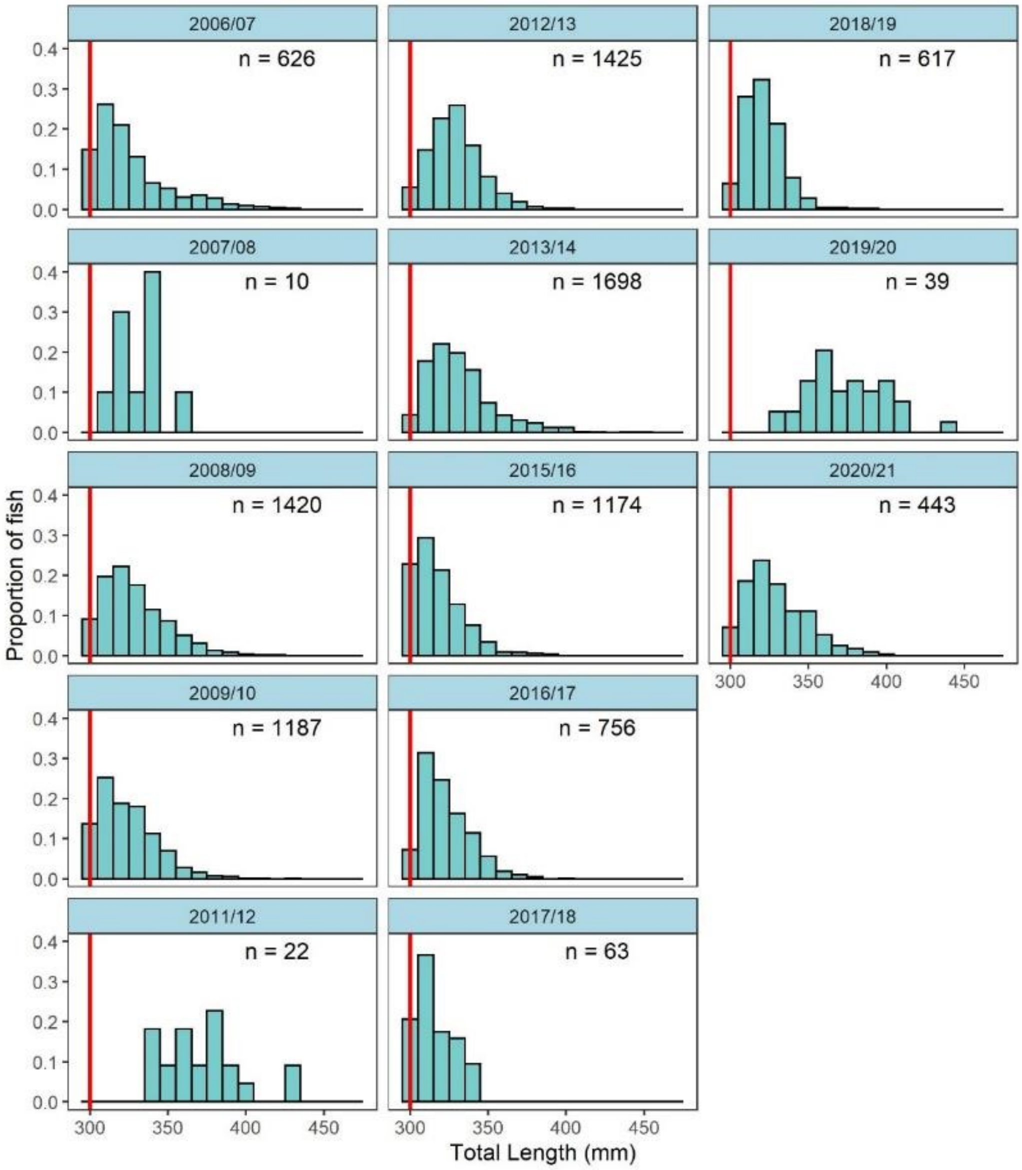


Figure 3.6-15. Total Length distributions of King George Whiting sampled from the Western Eyre Peninsula from 2006/07 to 2020/21. Red vertical line indicates the LML of 300 mm TL.

Age distributions were consistent between years and were predominately comprised of 3+ and 4+ age classes (Figure 3.6-16). The presence of older age classes 7+ was still relatively low, demonstrating that smaller and younger fish reside in this region. This corresponds with our conceptual understanding of population structure where juvenile and immature fish reside in nursery areas within this region before migrating to offshore spawning grounds outside the footprint of the fishery. The TRP of the age composition BPI (PIRSA 2013) cannot assessed as no fish were aged in 2021/22.

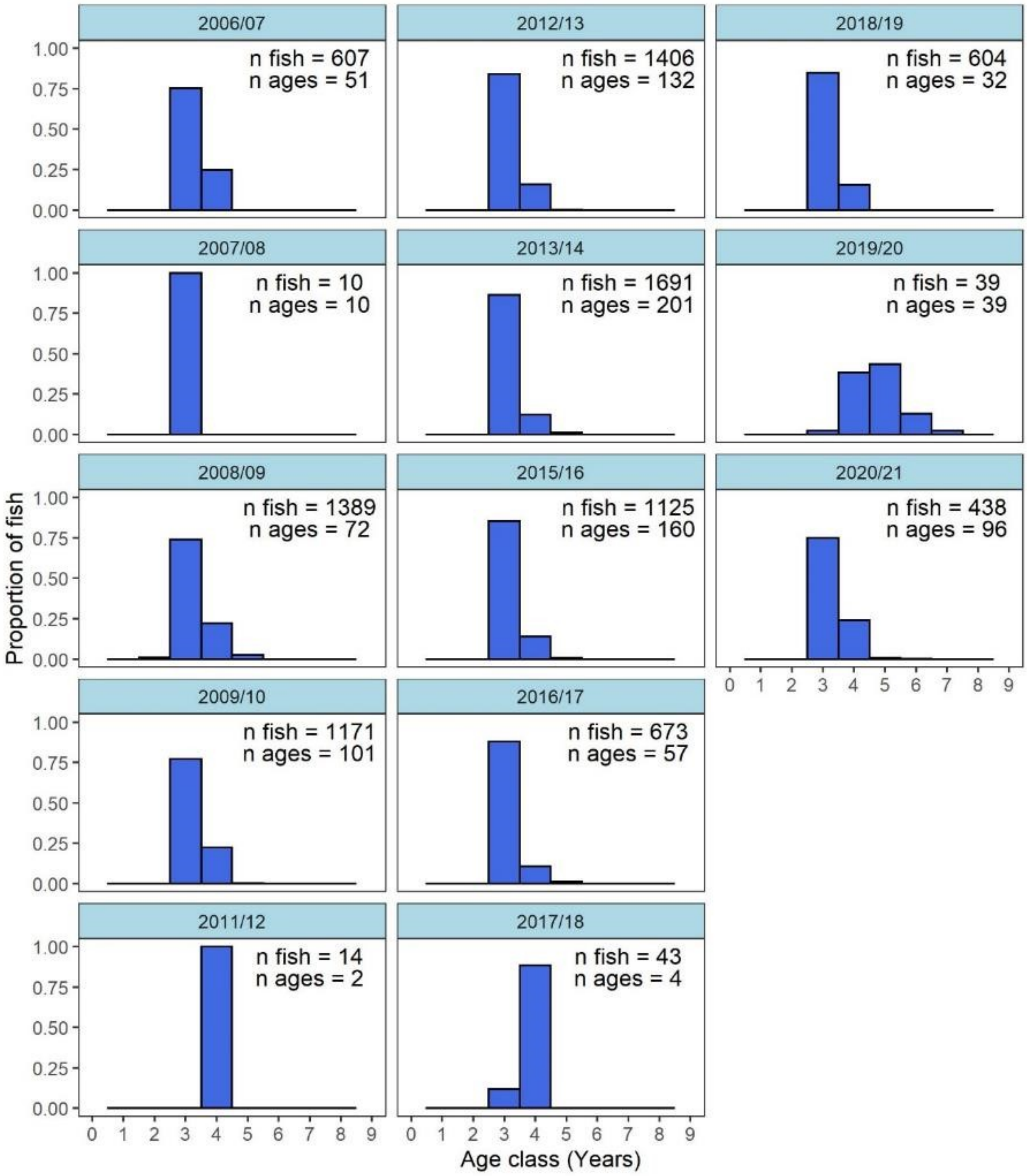


Figure 3.6-16. Age distributions of King George Whiting sampled from the Western Eyre Peninsula from 2006/07 to 2020/21.

3.6.3.3. CPUE standardisation

The standardised CPUE index provided a similar time series to raw target handline CPUE with regards to annual increases and decreases. However, the increasing trend that was visible through time for raw CPUE was less steep for the CPUE standardisation, providing a time-series that was slightly flatter across the history of the fishery (Figure 3.6-17). The standardised CPUE had an increasing trend from 1983/84 to 1997/98, after which a general decline occurred until 2003/04. This then increased over the proceeding five years and has remained stable since then (Figure 3.6-17). Similar to the GSV/KI fishing zone analysis, the GLM revealed that the licence holder variable had the greatest effect size, suggesting that standardising for this variable has had the greatest effect.

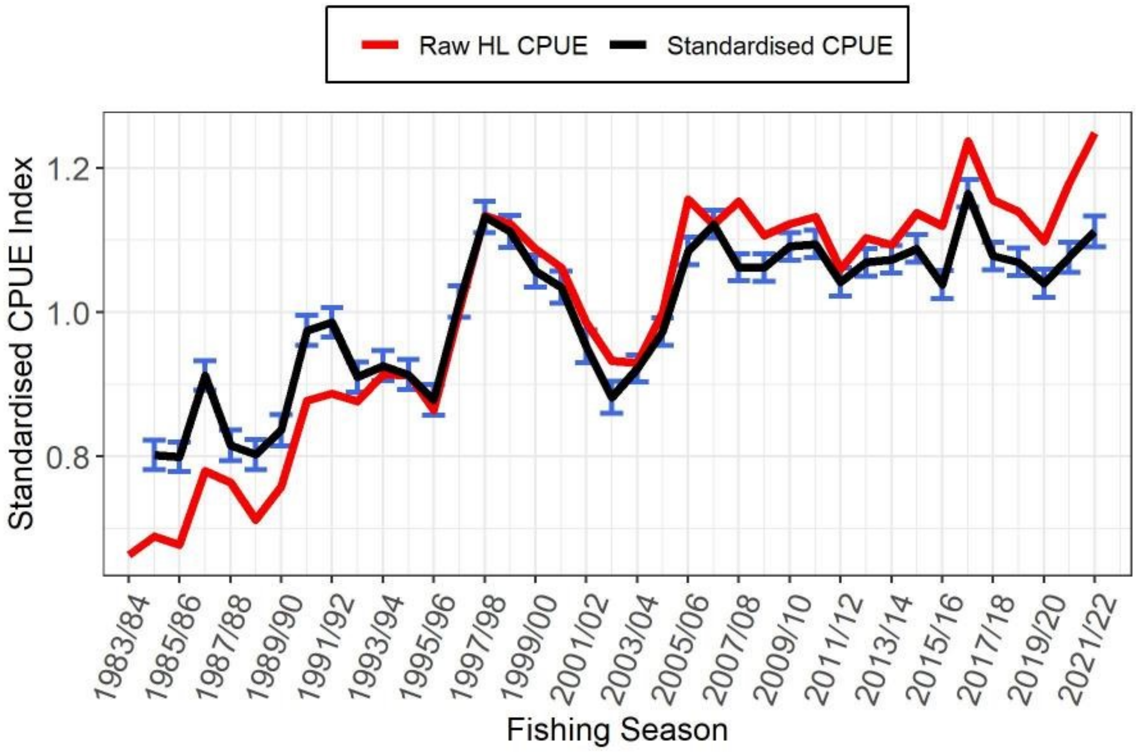


Figure 3.6-17. Standardised CPUE index for King George Whiting from the SG fishing zone. Black line is the standardised index and blue error bars are the standard error of the model coefficients. Solid red line is the raw targeted handline CPUE presented in figure 3.6-10. All results have been normalised to a mean of one to enable comparisons.

3.6.3.4. WhitEst model outputs

The biomass of King George Whiting in 2021/22 was 1,228 t and has been decreasing since an estimate of 1,572 t in 2015/16 (Figure 3.6-18). This biomass estimate includes all fish above 280 mm TL, accounting for changes to LML which have occurred over the history of the fishery (Table 3.4-1). This decline of approximately 22% over a six-year period makes the biomass in 2021/22 the seventh lowest on record and the lowest since 1988 (Figure 3.6-18). Biomass was stable between 2004/05 and 2015/16 prior to this decline commencing. While the biomass in 2021/22 is lowest on record for 33 years, it is only 31% lower than the maximum biomass estimated in the time series of 1,793 t in 1998/99 (Figure 3.6-18). In 2021/22 the three-year average biomass was 6% below the long-term average, triggering neither the UTRP nor LTRP (Table 3.5-1). However, in 2021/22 the three-year average fishable biomass was 11% below the long-term average, triggering the LTRP (Table 3.5-1). It should be noted that the definition of fishable biomass has changed through time due to increases to LML. Therefore, this reduction in biomass is partly due to its redefinition over time, rather than the result of population declines.

The harvest fractions presented in this assessment correspond to a biomass of fish above 280 mm TL, rather than the fishable biomass of a given year. This ensures that a consistent harvest fraction definition is presented across all years that is not influenced by changes in LML through time. The harvest fraction in 2021/22 was the third lowest on record at 0.23 yr^{-1} (Figure 3.6-18). Harvest fractions have been below the target harvest fraction listed in the Management Plan of 0.28 yr^{-1} (PIRSA 2013) since 2003/04. Harvest fractions have generally trended downwards since 1991/92 which has been driven by reduced commercial catches (Figs. 3.6-10; 3.6-18).

Recruitment had a declining trend from 1994 to 2007 but was relatively stable at low levels until 2013. Since then, subsequent recruitment cohorts have been smaller (Figure 3.6-18). The number of recruits estimated for the 2018 cohort was 7 million fish. This was the lowest recruitment on record and was 21.6% below the average of the previous five years and triggered the LTRP (Figure 3.6-18; Table 3.4-1). The 2018 recruitment is the most recent complete cohort estimated by the model given that fish recruit to the fishery at approximately age three.

It should be noted that this assessment was the first to apply the WhitEst model to the Spencer Gulf fishing zone (which includes the western Eyre Peninsula), rather than the biological stock structure defined in previous assessments (Steer et al. 2018a, Drew et al. 2021). Therefore, these model estimates are not comparable to those of previous assessments.

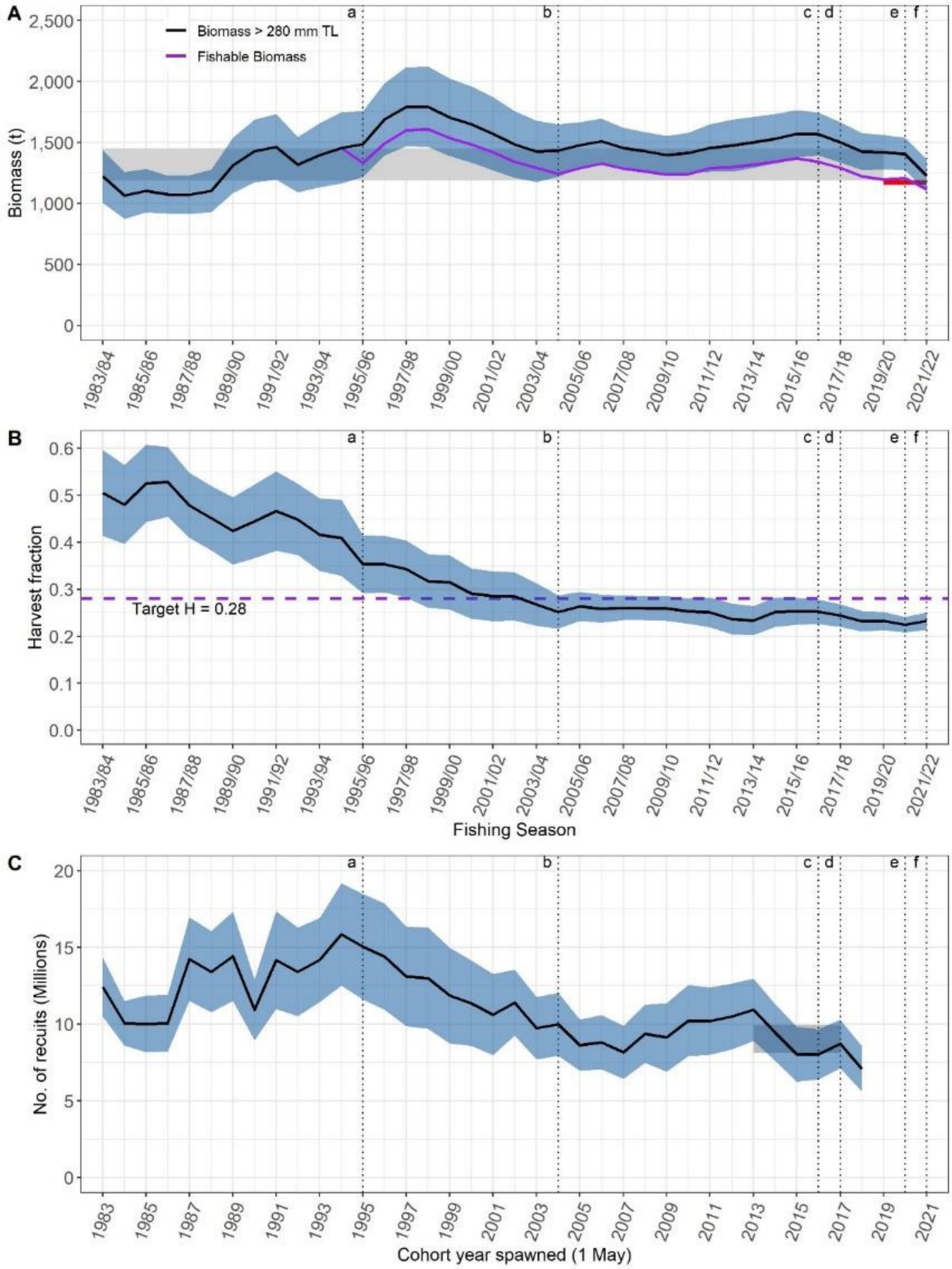


Figure 3.6-18. Biological performance indicators (BPIs) for King George Whiting in the SG fishing zone: A) biomass (t) which includes the biomass of fish above 280 mm TL (black line and blue shading) and fishable biomass (purple line), B) harvest fraction which corresponds to biomass > 280 mm TL (black line and blue shading), and C) number of recruits the correspond to their cohort year (i.e., year spawned with a birthdate of 1 May; black line and blue shading). The blue shading of each quantity represents the 95% confidence intervals of these estimates. No confidence intervals are available for fishable biomass. The dashed purple line indicates the target harvest fraction of 0.28 yr^{-1} listed in the Management Plan. The grey shading represents the LTRP and UTRP for fishable biomass, harvest fraction and annual recruitment according to their respective BPIs (Table 3.5-1). The red line represents the three year mean fishable biomass. Dotted lines and annotations correspond to key management changes that can be referenced in Table 3.4-1.

3.6.3.5. Stock Status

The current assessment included an updated spatial structure for the Spencer Gulf stock which aligns with the new fishing zone boundaries of the MSF reform (Smart et al. 2022a). This stock now includes the Western Eyre Peninsula which was previously included as part of the West Coast stock (Steer et al. 2018a, Drew et al. 2021).

The 2021/22 fishing season had the lowest catch and effort on record which was expected given the reduction in licences from the recent fishery reform (Smart et al. 2022a). However, raw handline CPUE by fisher hour and fisher day has had an increasing trend with the former breaching the UTRP in 2021/22. The standardised handline CPUE supported the trend of raw CPUE, adding further evidence of strong fishery performance.

The NSG age structures revealed a lower percentage of age 3+ fish in the population in recent years which was interpreted by the WhitEst model as reduced recruitment since 2013. A change to LML from 310 mm TL to 320 mm TL occurred in December 2016. However, this 10 mm change in LML is unlikely to have caused this change to the age structures as the same LML change was applied to the GSV/KI fishing zone where no discernible changes in sampled age or length structures have occurred. Therefore, it is likely that recruitment has been low since 2013 and the change in age structures is not the result of changes in LML. As a result, the 2018 cohort was the lowest recruitment on record and breached the LTRP.

Reduced recruitment from 2013 to 2018 has led to a decline in biomass since 2016/17, despite lower commercial catches occurring during these fishing seasons. However, this reduction in biomass has not breached the BPI LTRP for biomass above 280 mm TL. The LTRP was breached for fishable biomass in 2021/22, although this is partly attributable to the changing definition of fishable biomass through time caused by increases to the LML. This indicator is therefore no longer appropriate for assessing population trends. Future assessments should monitor ongoing reductions in recruitment to ensure that they do not cause any long-term consequences for the population.

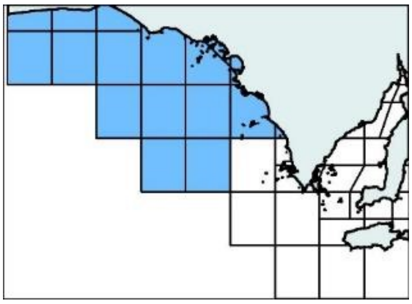
The above evidence indicates that the biomass of King George Whiting within the SG fishing zone is unlikely to be depleted and that recruitment is unlikely to be impaired. The current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, the SG stock was classified as **sustainable.**

3.6.4. West Coast Fishing Zone

Stock summary

King George Whiting

West Coast Fishing Zone



Stock status	2019 - Sustainable	2020 - Sustainable	**2021/22 - Sustainable**
Fishery/stock trend	Total MSF catch and effort have been declining since the mid 1990's and were the lowest on record in 2021/22. However, CPUE has had a generally increasing trend over the history of the fishery and was the fourth highest on record in 2021/22.		

Commercial catch statistics and TACC

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target HL CPUE *kg/fisher-day*	TACC *t*
2017/18	98	4,073	24.2	-
2018/19	91	3,859	23.9	-
2019/20	97	4,061	24.4	-
2020/21	81	3,376	24.4	-
2021/22	78	3,275	24.2	473

Stock Status Summary	All available evidence within this assessment indicates that the King George Whiting stock in the WC fishing zone is healthy and that recent catch and effort have remained at sustainable levels. There have been no discernible differences in annual age structures to indicate overfishing; standardised CPUE indicates a stable index of abundance and the WhitEst model demonstrated that biomass and annual recruitment were high while recent harvest fractions were low. As such, the WC stock was classified as **sustainable**.

3.6.4.1. Fishery Statistics

The total catch of King George Whiting in the WC fishing zone was 78 t in 2021/22, constituting 17% of 473 t TACC (Figure 3.6-19). This is the sixth consecutive fishing season where catch has been below 100 t. Handlines catches constituted more than 99 % of the catch in 2021/22 (Figure 3.6-19). The recreational catch in 2021/22 fishing survey was estimated at 59 t at the WC zone level (Figure 3.6-19).

Targeted handline effort has had a long-term declining trend and was 3,221 fisher days in 2021/22, which was the lowest on record (Figure 3.6-19). The 1983/84 fishing season had the largest target effort at 15,904 fisher days, demonstrating a decrease of 80% over time (Figure 3.6-19). Targeted handline CPUE by fisher day has had a long-term increasing trend over the history of the fishery and was the fourth highest on record at 24.2 $kg.fisher\text{-}day^{-1}$ in 2021/22 (Figure 3.6-19). This was close to the highest CPUE on record which was 24.4 $kg.fisher\text{-}day^{-1}$ in 2019/20 (Figure 3.6-19). Targeted handline CPUE by fisher hour is available from 2003/04 onwards and mostly follows the trend of CPUE by fisher day over the same period, with only difference occurring from 2013/14 – 2019/20 when a slight decline occurred and stabilised. (Figure 3.6-19). The highest CPUE by fisher hour on record was 4.2 $kg.fisher\text{-}hour^{-1}$ in 2011/12, while the CPUE in 2021/22 was 4.1 $kg.fisher\text{-}hour^{-1}$ (Figure 3.6-19). The number of licences targeted and catching King George Whiting in the WC fishing zone have declined steadily over time (Figure 3.6-19). There were 49 licences that targeted and caught King George Whiting in the WC fishing zone in 2021/22 (Figure 3.6-19).

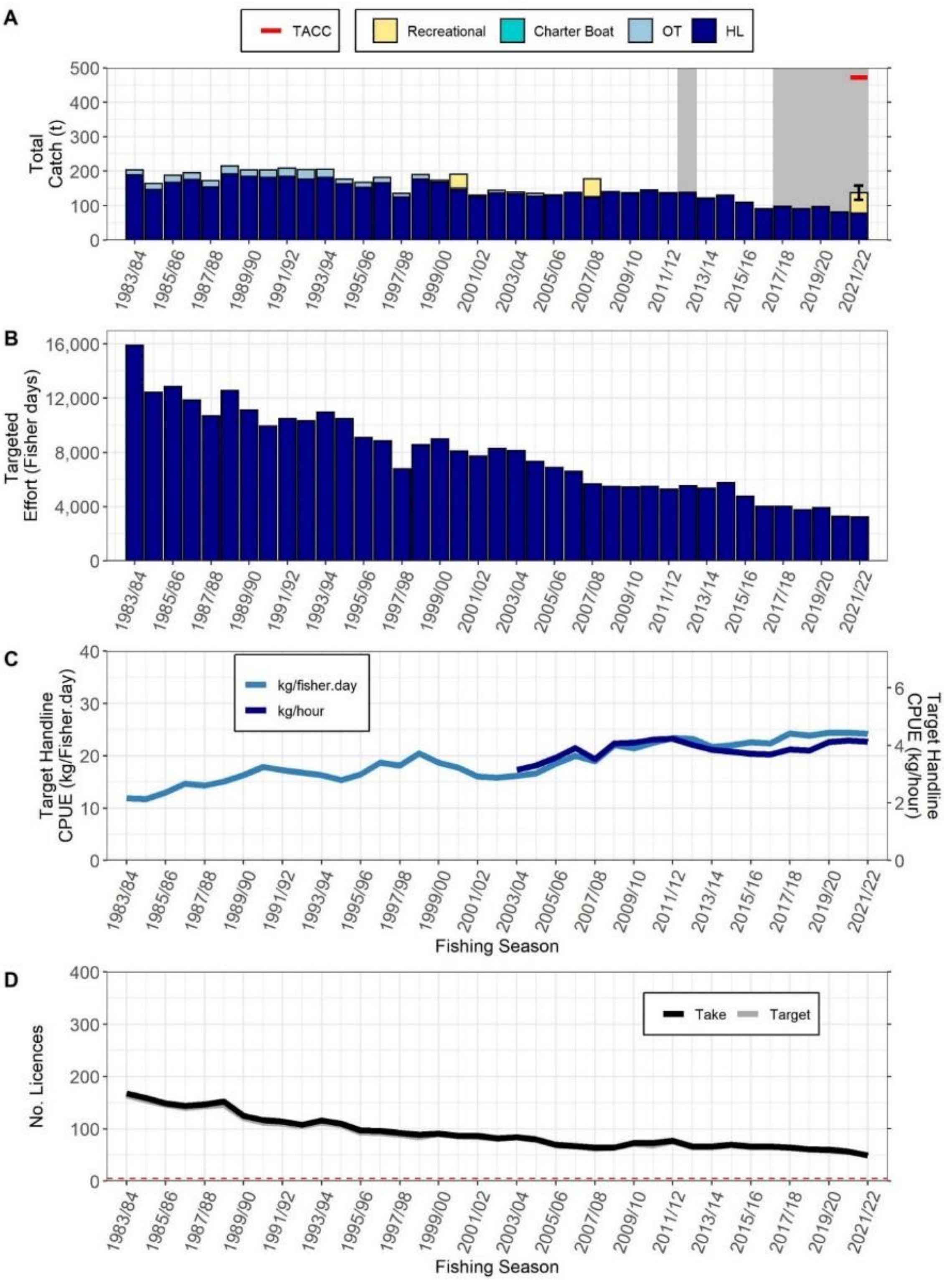


Figure 3.6-19. Long-term trends in catch statistics for King George Whiting in the WC fishing zone. (A) total catch for the main gear types (handline, set net, haul net and other), estimated recreational catch and charter boat catch; (B) Long-term target effort by gear type; (C) target handline CPUE by fisher day and fisher hour; and (D) the number of active licence holders taking or targeting the species. Error bars on the 2021/22 recreational catch estimate (A) represent the standard error from that survey. The red line indicates the 2021/22 TACC. A red dashed line in panel H represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on the panel.

3.6.4.2. Age and Length Compositions

A total of 26,662 fish have been sampled from the WC fishing zone since 2006/07, of which 3,740 have been aged (Figure 3.6-20; 3.6-21). Length distributions were consistently characterised by small to medium-sized fish 300 – 350 mm TL, however a few larger (> 400 mm TL) fish were sampled in relatively low numbers across years. From 2015/16 onwards larger fish have been occurring in catches with modes increasing from ~ 330mm TL to 350 – 360 mm TL in recent years (Figure 3.6-20).

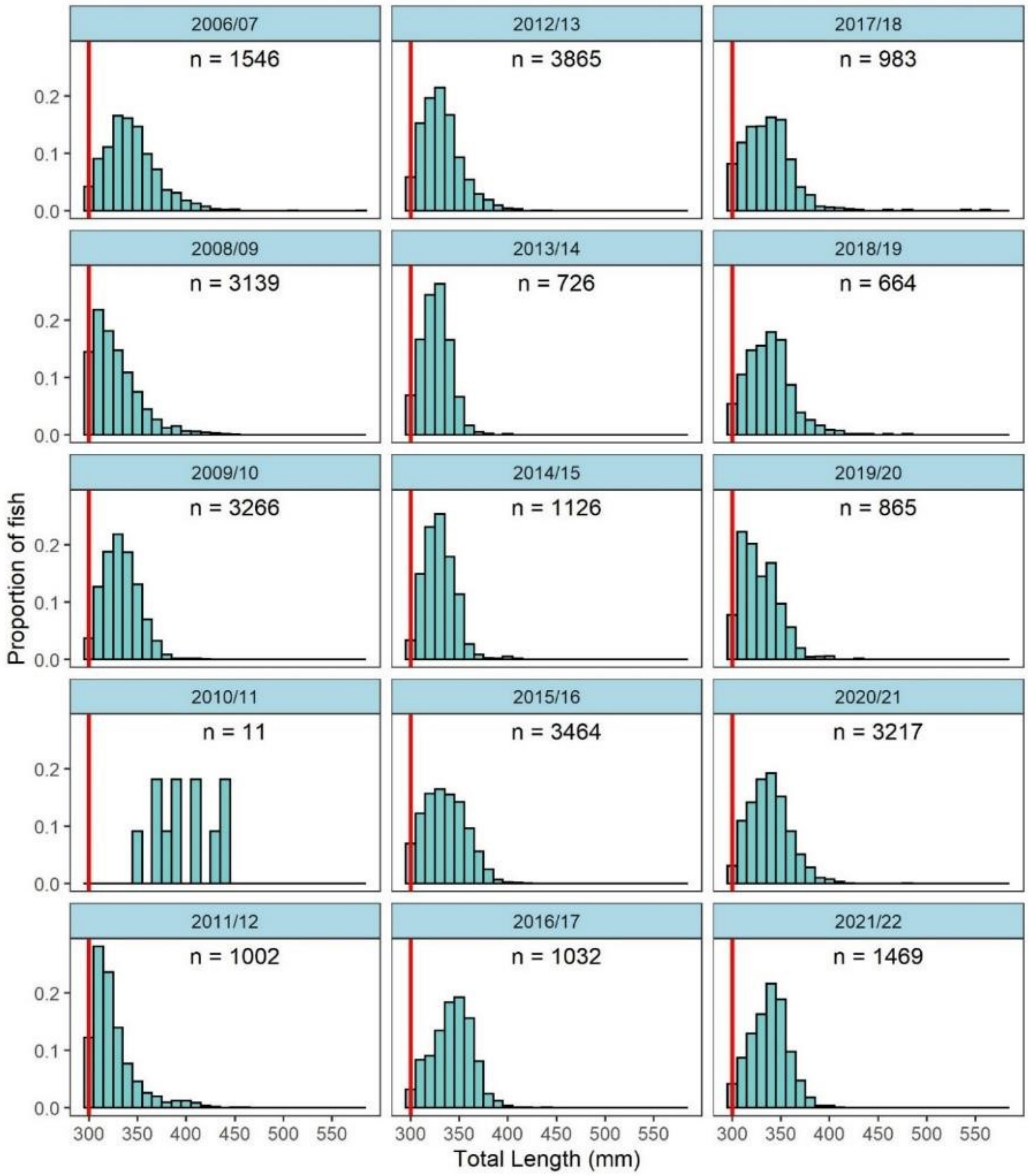


Figure 3.6-20. Total Length distributions of King George Whiting sampled from the WC fishing zone from 2006/07 to 2021/22. Red vertical line indicates the LML of 300 mm TL.

The age structures across all years were dominated by fish 3+ years, whilst the 2+ age class was most prevalent in 2014/15 while older fish were sampled in 2019/20 (Figure 3.6-21). The small variation in age structures between years is most likely a result of reduced sample sizes and the timing of sampling occurring in relation to the nominated birth date of 1st May. No significant changes to age compositions have occurred within the last five years. Therefore, the TRP was not breached in 2021/22 (Figure 3.6-21)

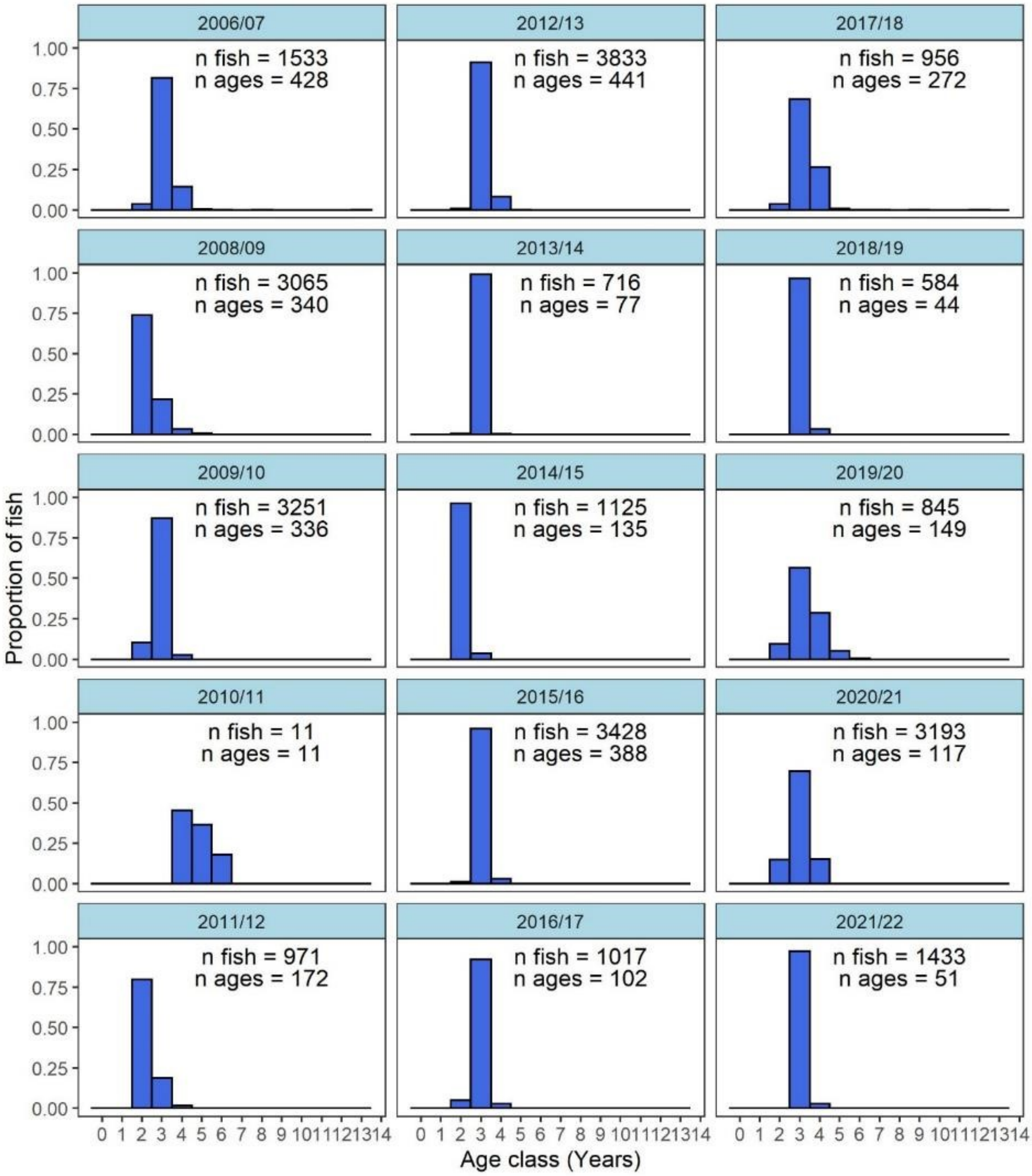


Figure 3.6-21. Age distributions of King George Whiting sampled from WC fishing zone from 2006/07 to 2021/22

3.6.4.3. CPUE Standardisation

The standardised CPUE index estimated increases and decreases in CPUE that were similar to raw target handline CPUE. However, the general increasing trend for raw CPUE by fisher day was dampened by the standardisation, providing a time-series that was flatter across the history of the fishery (Figure 3.6-22). The standardised CPUE had an increasing trend from 1983/84 to 1998/99, after which a general decline occurred until 2002/03. Standardised CPUE then increased until 2011/12 and has remained relatively stable since then (Figure 3.6-22). The GLM revealed that the licence holder variable had the greatest effect size, suggesting that standardising for this variable has had the greatest effect.

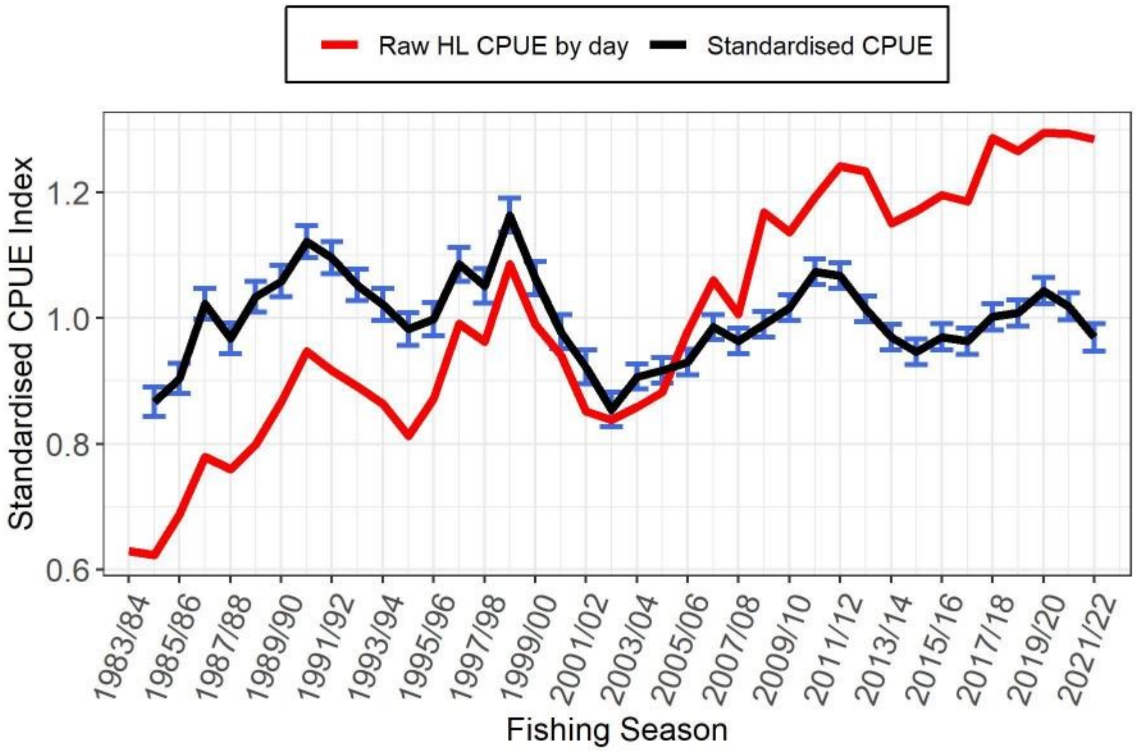


Figure 3.6-22. Standardised CPUE index for King George Whiting from the WC fishing zone. Black line is the standardised index and blue error bars are the standard error of the model coefficients. Solid red line is the raw targeted handline CPUE presented in figure 3.6-19. All results have been normalised to a mean of one to enable comparisons.

3.6.4.4. WhitEst Model Outputs

The biomass of King George Whiting in 2021/22 was 2,718 t and has been increasing since 2016/17 (Figure 3.6-23). This biomass estimate includes all fish above 280 mm TL, accounting for changes to LML which have occurred over the history of the fishery (Table 3.4-1). Biomass has been increasing since 2002/03 although a short decline occurred between 2012/13 and 2014/15, from which the biomass has since recovered. The biomass in 2021/22 was the second highest on record behind 2,791 t in 2012/13 (Figure 3.6-23). In 2021/22 the three-year average biomass was 32% above the long-term average, triggering the UTRP (Table 3.4-1). The fishable biomass (whose definition changes through time with changes to LML) was 27% above the long-term average; triggering UTRP (Figure 3.6-23).

The harvest fractions presented in this assessment correspond to a biomass of fish above 280 mm TL, rather than the fishable biomass of a given year. This ensures that a consistent harvest fraction definition is presented across all years that is not influenced by changes in LML through time. The harvest fraction in 2021/22 was the lowest on record at 0.05 yr^{-1} (Figure 3.6-23). Harvest fractions have been below the target harvest fraction listed in the Management Plan of 0.28 yr^{-1} (PIRSA 2013) across the history of the fishery (Figure 3.6-23). Harvest fractions have trended downwards since the first fishing season when logbooks were introduced in 1983/84 which was 0.19 yr^{-1} (Figure 3.6-23). Recruitment has generally increased over time, although it has stabilised from 2006 onwards (Figure 3.6-23). The number of recruits estimated for the 2018 cohort was 26.3 million fish. This was 6.3% below the average of the previous five years but did not trigger the LTRP (Figure 3.6-23; Table 3.4-1).

It should be noted that this assessment was the first to apply the WhitEst model to the West Coast fishing zone (which does not include the western Eyre Peninsula), rather than the biological stock structure defined in previous assessments (Steer et al. 2018a, Drew et al. 2021). Therefore, these model estimates are not comparable to those of previous assessments.

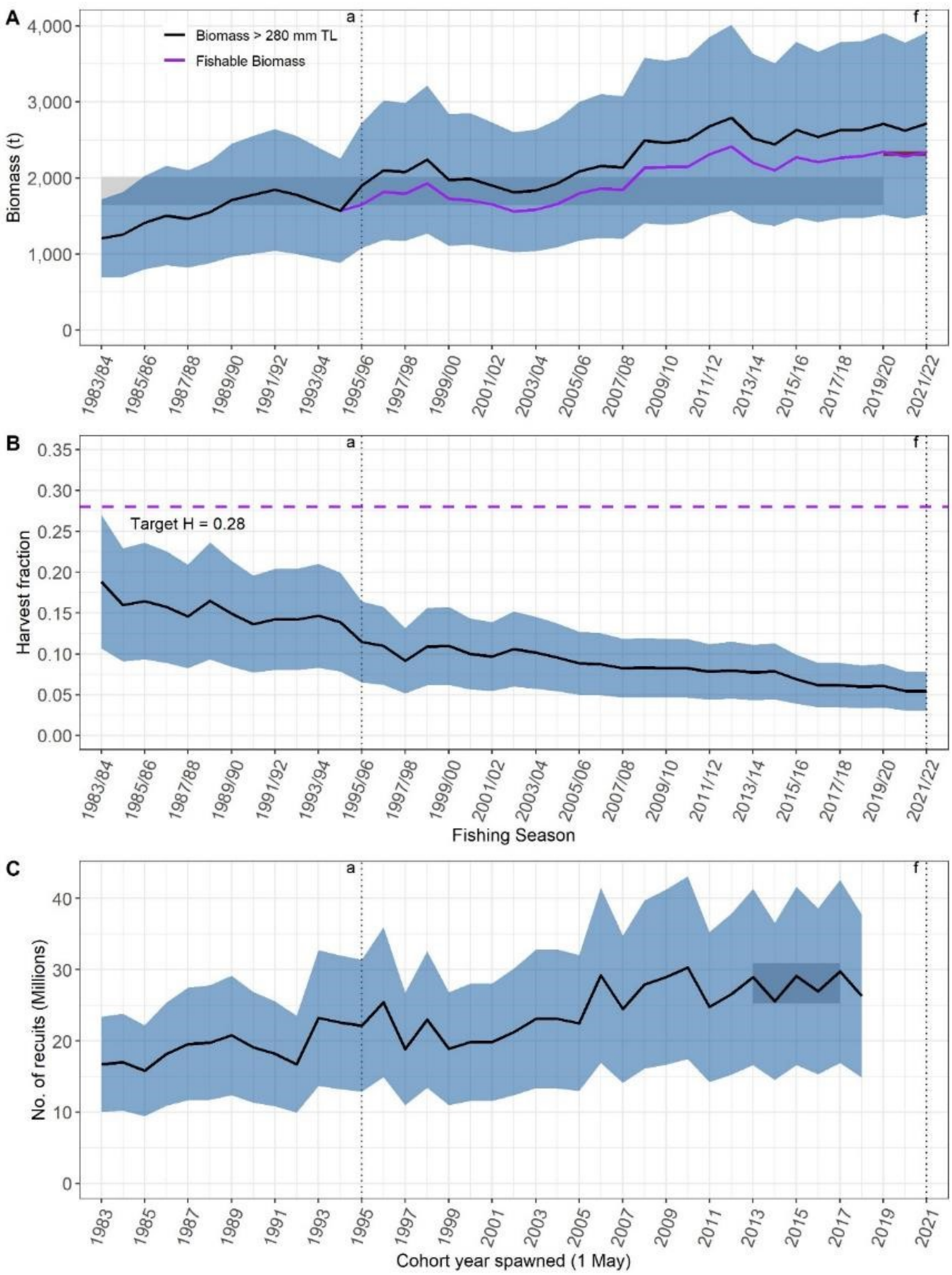


Figure 3.6-23. Biological performance indicators (BPIs) for King George Whiting in the WC fishing zone: A) biomass (t) which includes the biomass of fish above 280 mm TL (black line and blue shading) and fishable biomass (purple line), B) harvest fraction which corresponds to biomass > 280 mm TL (black line and blue shading), and C) number of recruits the correspond to their cohort year (i.e., year spawned with a birthdate of 1 May; black line and blue shading). The blue shading of each quantity represents the 95% confidence intervals of these estimates. No confidence intervals are available for fishable biomass. The dashed purple line indicates the target harvest fraction of 0.28 yr^{-1} listed in the Management Plan. The grey shading represents the LTRP and UTRP for fishable biomass, harvest fraction and annual recruitment according to their respective BPIs (Table 3.5-1). The red line represents the three year mean fishable biomass. Dotted lines and annotations correspond to key management changes that can be referenced in Table 3.4-1. Only the management changes that were applied to the WCFZ are shown.

3.6.4.5. Stock Status

The current assessment included an updated spatial structure for the West Coast stock which aligns with the new fishing zone boundaries of the MSF reform (Smart et al. 2022a). Previously, this stock was considered to be the entirety of the West Coast of South Australia which spanned approximately 400 km of coast line (Steer et al. 2018a, Drew et al. 2021). There were three main fishing locations along this coastline which included the key fishing ports of Ceduna/Streaky Bay, Elliston and Coffin Bay. Tagging studies conducted in the 1960's, 1970's and 1980's were summarised by Fowler and McGarvey (2000) which demonstrated limited adult movement along the coastline between the Western Eyre Peninsula and Ceduna. Instead, most recaptures from the West Coast occurred within the local bays that fish were tagged in, differing to the large-scale southward movements documented for the two gulfs (Fowler and McGarvey 2000). The limited interactions between these areas therefore allowed the Western Eyre Peninsula region (south east from Elliston to the tip of the Eyre Peninsula) to be separated from the West Coast fishing zone for current and future assessments.

In previous assessments, the WC King George Whiting stock has been consistently classified as sustainable (Steer et al. 2018a, Drew et al. 2021). All available evidence within this assessment also indicates that the King George Whiting stock in the WC fishing zone is healthy and that recent catch and effort have remained at sustainable levels. There have been no discernible differences in annual age structures to indicate overfishing; standardised CPUE indicates a stable index of abundance and the WhitEst model demonstrated that biomass and annual recruitment were high while recent harvest fractions were low.

Commercial catch and effort was the lowest on record in 2021/22, in line with recent trends. This reflects the declining number of fishers in the fishery. Recently, 100 fishing licences were removed from the State-wide fishery through a voluntary surrender program, which will further limit fishing effort (Smart et al. 2022a). A TACC of 473 t was set for the West Coast fishing zone in 2021/22, of which only 17% was caught. This TACC was set using recent average biomasses and the target harvest fraction listed in the management plan (Smart et al. 2022a). This tonnage was substantially higher than recent catches given that recent biomass is at a record high and that the fishery has never been fished at this level of exploitation. Therefore, a TACC under-catch of this magnitude should not be interpreted as a stock sustainability issue, but rather a fishery undergoing significant management transition where catch limits may be refined. This will be addressed through upcoming harvest strategy development.

The above evidence indicates that the biomass of King George Whiting within the WC fishing zone is unlikely to be depleted and that recruitment is unlikely to be impaired. The current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, the WC stock was classified as **sustainable**.

3.7. Fishery Performance Indicators

There were nine breaches of general trigger reference points across the three zones (Table 3.7-1). The lower trigger reference point (LTRP) for 3rd lowest or highest total catch was breached for all three zones as catches were the lowest on record (Table 3.7-1). The same breach also occurred for target handline effort which was also the lowest on record for all three zones. A consecutive decrease over five-years also occurred for target handline effort in the SG fishing zone. The upper trigger reference point (UTRP) for 3rd lowest or highest target handline CPUE was breached for the GSV/KI and SG fishing zones which were the highest on record (Table 3.7-1).

For the BPIs, three positive and two negative TRPs were breached (Table 3.7-1). Recruitment was 21.6 % below the previous five-year average for the SG fishing zone, triggering the LTRP. This also occurred in the previous assessment (Drew et al. 2021). The LTRP was also triggered for fishable biomass for the SG fishing zone (11% below the historical average), although no TRPs were triggered for biomass above 280 mm TL. Lastly, the biomass above 280 mm TL were 19% and 32% above the historical average for the GSV/KI and WC fishing zones, respectively; triggering the UTRP for both zones (Table 3.7-1). The UTRP was also triggered for fishable biomass in the WC fishing zone at 27% above the historical average.

The catch data from the three commercial fisheries were compared against their allocations using Triggers 2 and 3 as reference points. No negative trigger reference points were breached (Table 3.7-2).

Table 3.7-1. Fishery performance indicators and associated trigger reference points used to assess fishery performance as specified in the Management Plan (PIRSA 2013). The type of indicator and whether a primary or secondary one is also indicated. G – general; B – biological. Lower trigger reference point (LTRP) breaches are indicated in light blue and upper trigger reference point (UTRP) breaches are indicated in blue. ✖ indicates that no trigger has been breached.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	GSV/KI	SG	WC
TOTAL CATCH	G	3rd Lowest/3rd Highest	LTRP	LTRP	LTRP
	G	Greatest % interannual change (+/-)	✖	✖	✖
	G	Greatest five-year trend	✖	✖	✖
	G	Decrease over five consecutive years	✖	✖	✖
TARGET HANDLINE EFFORT	G	3rd Lowest/3rd Highest	LTRP	LTRP	LTRP
	G	Greatest % interannual change (+/-)	✖	✖	✖
	G	Greatest five-year trend	✖	✖	✖
	G	Decrease over five consecutive years	✖	TRIGGERED	✖
TARGET HANDLINE CPUE	G	3rd Lowest/3rd Highest	UTRP	UTRP	✖
	G	Greatest % interannual change (+/-)	✖	✖	✖
	G	Greatest five-year trend	✖	✖	✖
	G	Decrease over five consecutive years	✖	✖	✖
BIOMASS > 280mm (TL)	B	3-year average is +/- 10% of previous years (1983/84 – 2018/19)	19%	-6%	32%
FISHABLE BIOMASS	B	3-year average is +/- 10% of previous years (1983/84 – 2018/19)	8%	-11%	27%
HARVEST FRACTION	B	> 28%	17.6%	23.3%	5.4 %
RECRUITMENT	B	+/- 10% of average of previous 5 years (2013/14 – 2017/18)	1.8% below	21.6% below	6.3 % below
AGE COMPOSITION	B	Change in long term or previous 5 years (2016/17 – 2020/21)	✖	✖	✖

Table 3.7-2. King George Whiting sector catches and shares against their allocation percentages and trigger reference points. MSF = Marine Scalefish, NZRL = Northern Zone Rock Lobster and SZRL = Southern Zone Rock Lobster. No colour – allocation not exceeded. Trigger 2 (light blue) is breached if the respective sector allocation is breached for three consecutive years or in four of the previous five years. Trigger 3 is breached if the respective sector allocation is breached in any one year. The sector catch in tonnes is displayed with the State-wide catch percentage provided in parentheses.

COMMERCIAL ALLOCATION	MSF	SZRL	NZRLF
	98.1%	n/a	1.9%
TRIGGER 2	-	0.5%	2.97%
TRIGGER 3	-	0.75%	3.96%
2017/18	239.64 (98.76 %)	0.01 (0 %)	3.01 (1.24 %)
2018/19	231.2 (98.82 %)	0.02 (0.01 %)	2.73 (1.17 %)
2019/20	232.66 (99.27 %)	0.04 (0.07 %)	1.67 (0.71 %)
2020/21	180.56 (99.59 %)	0.12 (0.08 %)	0.63 (0.35 %)
2021/22	175.22 (98.49 %)	0.14 (1.14 %)	0.76 (0.43 %)

3.8. Discussion

3.8.1. Stock Status

King George Whiting was classified as sustainable in the GSV/KI, SG and WC fishing zones. Recent estimates of biomass were high for the GSV/KI and WC zones which has been achieved through decreasing harvest fractions. Recent biomass estimates for the SG fishing zone have been decreasing over a six-year period but not at substantial rates. This has been driven by lower-than-average recruitment since 2013. This decline in biomass for the SG fishing zone did not trigger the LTRP for biomass above 280 mm TL and therefore a sustainable status was retained in the current assessment. However, these low levels of recruitment and declines in biomass may warrant a change in status in future assessments should they continue. This should be monitored over the proceeding fishing seasons.

3.8.2. Updates In This Assessment

Several important updates have been made in the current assessment with regards to spatial scale of assessment, analysis of catch and effort statistics, and the WhitEst fishery model. The most significant update is the redefinition of the spatial scale of assessment from biological stocks to management units. This was required following the regionalisation of the MSF through its recent reform, which extended the SG fishing zone westwards such that it now includes the Western Eyre Peninsula. This zone boundary was defined as it acknowledged the natural fleet boundaries that were associated with different fishing ports (Smart et al. 2022a). Fishers operating westward of the Eyre Peninsula were either based in Port Lincoln and accessed both SG and Coffin Bay, or from Streaky Bay and Ceduna and accessed the surrounding areas. This zone boundary did not align with the biological stock boundaries of the WC and SG stocks, requiring a change to the spatial scale of assessment to support TACC setting for the different management zones. This spatial update was incorporated into the WhitEst model by creating a new movement cell (WEP; MC8) which could be included in the SG fishing zone for purposes of reporting BPIs. In particular, WEP recruitment and biomass were included in the SG fishing zone SG. As King George Whiting remain subject to different LML either side of 136^{o} longitude, WhitEst models shared growth for WC and WEP, while WEP recruitment was estimated separately from both WC and SG fishing zones. This was facilitated by WhitEst freely estimating recruitment, and therefore no stock recruitment relationship was confounded by these model mechanics. There is also no evidence of significant movement of fish between the WC fishing zone and the Western Eyre Peninsula based on tag recaptures (Fowler and McGarvey 2000). Therefore, migration in WhitEst occurs from both of these movement cells to MC8, the unfished stock that resides offshore for which no information is available. Therefore, the new model structure sufficiently captures the key biological aspects of King George Whiting while ensuring assessments can be undertaken at the zone scale required for TACC setting.

Analysis of catch and effort statistics have been improved in the current assessment by analysing raw targeted handline CPUE by both fisher day and fisher hour, and by standardising CPUE using GLM methods. Several previous assessments have highlighted the importance of these updates as the consideration of raw targeted CPUE at the fisher day scale was a coarse method for assessing the fishery and did not account for the influences of fleet dynamics (Fowler et al. 2014, Drew et al. 2021). Calculating CPUE by fisher hour was facilitated in this assessment through some minor data cleaning (for example no logbook record could include more than 24 hours in a given day) and by examining the distribution of fisher hours for each zone. There was a strong agreement between the fisher day and fisher hour CPUE trends, indicating that fisher day was a more reliable CPUE index than previously considered. Given that CPUE by fisher hour was only available from 2003/04 onwards, this relationship was important as it allowed the longer timeseries of CPUE by fisher day to be used as the main PI die to its longer timeseries.

A standardised CPUE was produced for the first time in this assessment. The standardised indices for all three stocks aligned with the annual increases and decreases of the raw target handline CPUE by fisher day. However, the standardised CPUE for each stock did not estimate the strong increasing trends evident in the raw CPUE indices. Previous assessments have noted the potential for 'effort creep' to occur as the fishery becomes more efficient over time through advances in technology and fisher experience (Fowler et al. 2014, Drew et al. 2021). These standardised CPUE results indicate some capacity to account for effort creep, given that general CPUE increases over time were far less apparent than raw CPUE. Whilst noting that some CPUE standardisation currently occurs within the WhitEst model, which fits to multiple effort types according to different gears and levels of targeting, incorporation of these standardised CPUE series into future versions of the WhitEst model would be beneficial and appropriate.

Aside from the redefined spatial structure, two further updates were made to the WhitEst model. Firstly, for reporting purposes biomass was redefined from fishable biomass to the biomass of fish above 280 mm TL. This was the original LML in place until 1995 when it was increased to 300 mm TL. Increases to the LML have been one of the major management mechanisms for reducing fishing mortality across all sectors. Therefore, the full effects of these management measures were more apparent when the definition of biomass was not updated with each subsequent LML change. The third model update was the incorporation of region-specific scalars for the initial population array. These scalars multiply the overall population number of the initial state array, at the start of the model time series and influence absolute population size by region. In the WC this parameter has a wide uncertainty, and also a very high correlation with population size. This high correlation and high estimate uncertainty for this scalar parameter (±40% as 95% CI) is not seen for the two gulfs (±5% in GSV/KI and ±9% in SG). Therefore, the 95% confidence intervals for the WC model were wider than those of previous assessments. This wide uncertainty in WC biomass is due to fewer age-length samples, and more importantly, to the complete absence of information about the fish that move offshore from the inshore WC movement cell, from where no data are obtained. Therefore, this level of uncertainty was appropriate, given the level of information available for this zone in comparison to the two gulfs.

3.8.3. Fishery Dynamics

King George Whiting catch and effort were among the lowest on record for all three Tier 1 fishing zones in 2021/22. This was anticipated given that there has been a long term trend of declining catch and effort identified in several previous assessments (Steer et al. 2018a, Drew et al. 2021), which was attributed to the declining number of active licences across the fishery. The recent reform further reduced the fishery by 100 licences in 2021 through a voluntary licence surrender program (VLSP). While this reduced the fleet size by approximately one third, State-wide catches of King George Whiting only declined by 5 t between the 2020/21 and 2021/22 fishing seasons. This occurred as many of the licences surrendered through the VLSP constituted mostly latent effort and had not been fished to a large extent over the past several fishing seasons.

The TACCs were under caught by 41 %, 36 % and 83 % across the GSV/KI, SG and WC fishing zones respectively in 2021/22. The TACCs for the SG and GSV/KI fishing zones for the 2021/22 fishing season were set using average catches over the 2015 – 2019 fishing seasons. The TACC for the WC fishing zone was determined based on recent estimates of population size, the target harvest fraction of 28% in the management plan, and the zonal catch share for the commercial sector (Smart et al. 2022a). As a result, the TACC of 473 t in the 2021/22 was far greater than recent King George Whiting catches in the WC fishing zone. Given the declining catch and effort that has occurred in recent seasons, as well as the further reduction in licences through the VLSP, these TACCs were unlikely to be caught. This has been documented across several other Tier 1 stocks in the current assessment and was predicted by research conducted during the reform on the effects of fleet rationalisation (Smart et al. 2022a). Therefore, these uncaught TACCs are most likely attributable to changes in fishery dynamics, rather than a reflection on stock health.

3.8.4. Population Dynamics

Natural mortality (*M*) for King George Whiting was re-evaluated in the current assessment given the importance of this parameter (Drew et al. 2021). The estimate of *M* developed for the WhitEst model, and included in all its applications to date, was $0.45yr^{-1}$ (Fowler and McGarvey 2000). This was a mid-point taken between two estimates of *M*, based on longevity and on growth rate (Jones et al. 1990). This analysis was repeated in the current assessment (Appendix 7.8) but using several estimation methods based on multiple life history traits that included different estimates of longevity and growth. This range of *M* estimates was tested in a sensitivity analysis to understand the impact of *M* on the new WhitEst model structure (Appendix 7.6). A value of 0.47yr^{-1} was the average across all of the *M* estimates included in this reanalysis, demonstrating that 0.45yr^{-1} was an appropriate value and was therefore maintained in the model. The variation in *M* estimates derived in Appendix 7.8 is the result of disparate life history characteristics that King George Whiting exhibit. While they are a relatively long lived species, reaching ages of up 22 years old (Fowler and Duffy 2021), they are also a fast growing species that may suffer from higher *M* at younger ages. While the level of *M* used in WhitEst has implications for absolute values of biomass, it does not alter the trend in biomass through time as this parameter is time-invariant.

The biomass above 280 mm TL for the GSV/KI and WC fishing zones is currently above the UTRP. For the GSV/KI fishing zone this has been driven by low recent harvest fractions and stable recruitment. For the WC fishing zone this has been driven by low harvest fractions and increasing recruitment. While the SG fishing zone has also had low harvest fractions, recent declines in recruitment produced a decline in biomass above 280 mm TL over the last five fishing seasons. The LTRP for biomass above 280 mm TL has not yet been breached, but this may occur in future assessments should recruitment remain low. The LTRP for fishable biomass was breached in 2021/22 for the SG fishing zone. However, this BPI is no longer an appropriate indicator for assessing changes in population size due to the redefinition of fishable biomass that occurred with each LML increase. Therefore, the biomass above 280 mm TL indicator was included as weight of evidence for the SG fishing zone stock status classification. Decreasing commercial catch and effort in recent fishing seasons has likely protected the SG stock during this period of low recruitment. A continuing decline in recruitment may require future management action to ensure the stock status remains sustainable in future fishing seasons.

A ‘transitional depleting’ status was assigned to the SG stock during the last occasion when biomass similarly declined (Fowler et al. 2014). There were several lines of evidence for this previous status which were different to the current assessment. While the previous reduction in biomass was also attributable to reduced recruitment, there were also demonstrable declines in raw CPUE (Fowler et al. 2014). During this previous assessment, it was identified that some uncertainty existed around CPUE given that raw values calculated using fisher days could have been hyperstable (Fowler et al. 2014). This previous assessment cautiously assigned a transitional depleting status due to this reduced recruitment and biomass, along with uncertainty in the CPUE series whose potential hyperstability could have been masking greater declines (Fowler et al. 2014). The current assessment has addressed some of the uncertainty around CPUE through the inclusion of target handline CPUE by fisher hour and the standardisation of CPUE by fisher day. These analyses demonstrated a low likelihood that hyperstability in raw CPUE would mask stock declines.

3.8.5. Assessment Uncertainties

The main uncertainty in this assessment for King George Whiting relates to the relationships between fishable biomass and the estimates of the various fishery performance indicators. The primary data used as indicators and which underpin the estimation of the biological indicators by WhitEst are the commercial fishery statistics. It is expected that the parameters of catch, effort and CPUE are influenced by the biomass of King George Whiting. Nevertheless, there are other factors relating to fisher behaviour and technological advancements that also influence these relationships. Fishers can change their fishing effort between different target species and also move between regions of the fishery in order to pursue better financial gain. Following the reform of the MSF, it is anticipated that many licence holders will change the way that they fish or market their catch. Fishers will look to maximise the economic returns of their King George Whiting quota over the course of the fishing season. This may lead to ‘high-grading’ where fish of a certain size are targeted as they receive a higher market price. Also, fishers may send larger fish to interstate markets where higher prices may be received, preventing adequate ongoing sampling of these fish. While anticipation of exact changes in fishery dynamics is not possible, it remains important for researchers to engage with industry and understand any changes that occur with how the fishery operates. This will ensure that these changes do not affect assessments or can be accounted for within them.

A further uncertainty relates to the poor understanding of temporal trends in catch and effort by the recreational sector. It is apparent from the four telephone/diary surveys undertaken (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015, Beckmann et al. 2023) that this sector accounts for a significant proportion of the total catch of King George Whiting. The estimates of recreational catch used in the WhitEst model were interpolated from the limited data available from the telephone/diary surveys undertaken in 2000/01, 2007/08, 2013/14 and 2021/22, but it is unlikely that such interpolated values provide a reliable time series of estimates of recreational catch and effort, especially at a monthly and regional scale. In addition, the estimates of catch and effort from the telephone/diary surveys were very imprecise. Yet, the estimated time series of recreational catches are likely to have had considerable impact on the output parameters from WhitEst. This uncertainty is not explicit in the model estimates which uses a method that assumes the recreational catch total inputs are given without error.

3.8.6. Future Research Needs

A new management plan is under development following the reform of the MSF that will include an updated harvest strategy for the fishery. The development and testing of appropriate performance indicators and associated reference points for this harvest strategy is imperative, and the WhitEst model may require further updates to support this. Two potential updates are the integration of standardised rather than raw CPUE, and model projections that can support harvest strategy development and management strategy evaluation. The standardised CPUE estimated in the current assessment has demonstrated that raw CPUE was unlikely to be susceptible to hyperstability and will remain an important indicator for the fishery. However, the standardised CPUE also identified that some effort creep may be present, accounting for the increasing raw CPUE trend witnessed for all of the stocks during the history of the fishery. Incorporating CPUE standardisation into WhitEst will be the next extension of this analysis. Additionally, the ability to project model estimates forward under varying catch levels will support harvest strategy testing, and would therefore be a valuable model development. This would also allow scenarios of varying recruitment strength to be tested for the SG fishing zone, should a period of low recruitment continue and require a management response as a result.

Reconsideration of appropriate BPIs must be considered as part of the next harvest strategy. Currently, fishable biomass is a BPI with a reference period of 1983/84 to 2018/19 in this assessment. However, the LML has been increased on three occasions for SG and GSV within this reference period, creating a discrepant definition of fishable biomass to assess the population against. The current assessment has updated the definition of biomass and a corresponding BPI to complement the existing fishable biomass BPI. These provided different outcomes for the SG fishing zone where the LTRP was triggered for fishable biomass. However, the BPI for biomass > 280 mm TL is more appropriate for determining stock status and was considered with greater weight when assigning a sustainable status to the SG fishing zone. The need for such an update highlights the importance of incorporating appropriate BPIs in the forthcoming King George Whiting harvest strategy.

The greatest uncertainty for the WC fishing zone is the portion of the King George Whiting stock that resides offshore, outside of the footprint of the fishery. The current levels of catch in the WC fishing zone are likely sustainable, given the number of operators in this region and the abundance of age 2- and 3-year-old fish available in inshore areas. However, the recruitment of this stock is dependent on a healthy adult population which is understood to reside offshore in deeper waters, similar to the gulfs (Fowler and McGarvey 2000). Fish from these areas are not caught frequently and as a result there is no catch and effort data to include in the WhitEst model, nor do these fish occur in age and length samples. This portion of the stock is therefore not included in the stock assessment model and uncertainty around this must be cautiously considered in decision making. A better understanding of the offshore King George Whiting stock would further strengthen the stock status for this zone and reduce the uncertainty in its assessment.

One of the most significant requirements to better assess the status of SA's King George Whiting stocks is to improve the estimates of recreational catch and effort. A current project (FRDC 2020/056; Evaluation of a smart-phone application to collect recreational fishing catch estimates, including an assessment against an independent probability-based survey, using South Australia as a case study) could provide a complimentary data collection method that could increase the frequency of recreational data collection available for this assessment. Since more than half of the total catch is estimated to be taken by the recreational sector, these catches dominate exploitation levels, especially for the GSV/KI Stock. Better, and more frequent, recreational catch data would directly improve the comparison of shares and biological performance indicators from the WhitEst model. Recently, a State-wide recreational fisher survey was completed utilising a combination of telephone/diary questionnaires supplemented by on-site sampling at key fishing locations (Beckmann et al. 2023). Regular State-wide surveys, targeted on-site surveys and on-going app-based data collection could lead to an improved understanding of the level of catch and effort within the recreational sector for King George Whiting. The implementation of a phone App has the potential to lead to more frequent and up to date recreational fishing data, which is an integral input and also a source of uncertainty for future stock assessment models. Continuous advancement in the collection of recreational data is the single greatest improvement that could be made to the SA King George Whiting assessment.

4. STOCK STATUS OF REMAINING SPECIES

4.1. Introduction

This section of the report uses a weight-of-evidence approach to determine the stock status of 20 MSF species or taxonomic groups that are distributed across the ‘Primary’, ‘Secondary’ and ‘Tertiary’ species categories, as defined in the Management Plan (PIRSA 2013).

For each species or taxon, the relevant biological information is presented, along with a description of the fishery; associated management regulations; interrogation of the fishery statistics at either the biological stock, State-wide or zone scale; assessment of the fishery against the general performance indicators; and a classification of stock status.

Catch statistics and fishery information for Gummy Shark and School Shark are also presented. However, no statuses are assigned to these species as they are managed through Australian Fisheries Management Authority (AFMA) fisheries.

4.2. Methods

4.2.1. Commercial Catch and Effort

Commercial catch and effort data are the primary data considered in this section. The appropriate data for each taxon were extracted from the SARDI Aquatic Sciences’ commercial Marine Scalefish Fisheries Information System which includes data from the Marine Scalefish, Northern and Southern Zone Rock Lobster fisheries. These data span a 39-year time-series from 1983/84 to 2021/22 and were aggregated at either the biological stock, State-wide or zone scales to provide annual estimates of catch and effort for the main gear types (Table 4.2-1). Gear types were amalgamated according to the descriptions given in section 2.2. Data on by-product of Southern Calamari by SA’s three Western King Prawn fisheries were also included.

The presentation of data was limited by constraints of confidentiality, i.e., data could only be presented for years when summarised from five or more fishers. The general performance indicators for 2021/22 were benchmarked against the trigger reference points calculated from the historical data as per the management plan (PIRSA 2013). The national stock status classification system developed for the Status of Australian Fish Stocks Report 2020 (Piddocke et al. 2021) was used to assign stock status (see Table 1.6-1).

Table 4.2-1. List of MSF categories and species/taxa considered in this report, the scale of their stock boundary, main gear types, and whether the assessment is based on targeted or total catch and effort data.

CATEGORY	SPECIES / TAXON	STOCK	GEAR	TARGETED OR TOTAL
PRIMARY	SNAPPER	Biological	Handline, Longline	Targeted
	KING GEORGE WHITING	Zone	Handline, Haul Net, Set net	Targeted
	SOUTHERN CALAMARI	Zone	Squid Jig, Haul Net	Targeted
	SOUTHERN GARFISH	Zone	Haul Net, Dab Net	Targeted
SECONDARY	YELLOWFIN WHITING	Zone	Haul Net, Set Net	Total (SG); Targeted (GSV/KI)
	WA SALMON	State-wide	Haul Net	Targeted
	AUST. HERRING	State-wide	Haul Net	Targeted
	SNOOK	State-wide	Haul Net	Targeted
	BLUE CRABS	WC Zone	Crab Net	Targeted
	SAND CRABS	State-wide	Crab Net	Targeted
	YELLOWEYE MULLET	State-wide	Haul Net	Total
	MULLOWAY	State-wide	Handline, Set Net	Total
	WHALER SHARKS	State-wide	Longline	Targeted
TERTIARY	OCEAN JACKETS	State-wide	Fish Trap	Total
	BLUETHROAT WRASSE	State-wide	Handline, Longline	Targeted
	SILVER TREVALLY	State-wide	Handline	Total
	LEATHERJACKETS	State-wide	Haul Net	Total
	RAYS AND SKATES	State-wide	Haul Net, Longline	Total
	CUTTLEFISH	State-wide	Squid Jig	Targeted
	BLACK BREAM	State-wide	All	Total

4.2.2. Recreational Catch and Effort

Recreational data are presented at the State-wide and fishing zone scale where applicable. State-wide estimates are available from each of the four recreational fishing surveys (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015, Beckmann et al. 2023). Regional average weights were used to estimate the 2021/22 State-wide recreational harvest, improving estimates where size differed regionally within each species. The standard error for each State-wide recreational harvest was determined using on the coefficient of variation for the retained number of fish in each survey. This was the only error estimate presented in the first three recreational fishing surveys and corresponds to the harvest weight which was calculated as the retained number of fish multiplied by the average fish weight (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015). The 2021/22 recreational fishing survey provided an improved error estimate for recreational harvest which was calculated by accounting for both error in the retained number of fish and the variance in fish weight across regions (Beckmann et al. 2023). However, these error estimates are not presented in the current report as it would be inconsistent with the errors reported for the previous surveys.

Where data were available, recreational catches at the zone level were recalculated to match the spatial scale of the management zones. A standard error at the zone scale is presented for the 2021/22 survey (CV of retained number) as this statistic can be readily calculated for this survey. This will be attempted for 2000/01 and 2007/08 recreational surveys in future reports but was not undertaken for the current assessment due to difficulties with re-estimating standard errors from historical datasets. Charter boat catches are included in the estimated recreational catches of each survey.

It should be noted that each recreational survey did not occur over an exact financial year (i.e., 1 July to 30 June). Therefore, while surveys are referred to by financial year, they do not correspond to the same time periods presented for corresponding commercial catches. Each estimate of recreational catch only includes South Australian residents.

4.2.3. Catch MSY Models

A catch MSY (cMSY) assessment is a model-assisted analysis which uses a Schaefer production model to determine viable estimates of MSY based on prior specification for species' productivity and depletion levels at the beginning and end of the time series (Martell and Froese 2013). These assessments can be very effective when changes in population size are evident in the catch history of a stock. However, they are less successful if changes in catches have been affected by management or changes in fishery dynamics. As these models rely strongly on catch data, they may not be suitable for stocks with large or variable recreational catches or that do not have recreational data regularly available. Therefore, while they are a valuable tool that can be applied to any stock, they must be used judiciously and in a precautionary manner when used to assign stock status or management advice. In the current assessment, cMSY models were applied to both Yellowfin Whiting stocks and Blue Crabs in the WC fishing zone. This was justified as recreational catches are far lower for these stocks than commercial catches. Therefore, these models were run using only commercial catch data under the assumption that changes in the stock size are evident in commercial catch trends. All models were applied using the 'datalowSA' package in the R programming environment (Haddon 2020, R core R-Core-Team 2022).

4.3. Snapper

	Species summary

Snapper

Chrysophrys auratus

Stock status (biological stock)	Gulf St Vincent Stock	Spencer Gulf/West Coast	Western Victoria Stock
	Depleted – fishery closed	Depleted – fishery closed	Sustainable

Species Tier	**Tier 1 in all zones** – last stock assessment was conducted in 2022 and included data up until 2021/22 (Drew et al. 2022)
Species description	Snapper are a large-bodied, demersal teleost of the Sparidae family. They have a broad distribution through temperate and sub-tropical waters of the Indo-Pacific region. In Australia, and are distributed from the north coast of WA extending around the southern coastline, across to Tas and up to northern QLD (Kailola et al. 1993). They inhabit a diverse range of habitats extending from shallow bays and estuaries to the continental shelf edge (1–200 m depth). South Australia has three stocks: SG/WC, GSV/KI, and SE (WVS). Snapper is a long-lived species (up to 36 years old) and matures at 3–4 years of age at a FL of 25–35 cm.
Fishery description	Snapper are a major target species for recreational and commercial fishers. Commercial catches were historically highest in SG where handlines were the dominant gear. In the early 2000's declining catches occurred in the SG fishing zone as catches increased in the GSV/KI zone. During this time, longlines became the dominant gear. Snapper fishing was closed to all sectors in every zone except for the SE in 2019 due to declining stock statuses.
Current assessment program	• Weekly length and age structures collected through market sampling in Adelaide. • Fishery-dependent sampling of length and age structures during fishery closures. • Annual examination of commercial fishery statistics. • Recreational data collected every five to seven years through State-wide recreational survey. • Fishery independent estimates of biomass estimated using the DEPM. • Application of a length-and-age-structured population model (SnapEst). • No information is available for Aboriginal/Traditional fishing.

Commercial fishery statistics (State-wide)			Recreational Catch				
Fishing Season	**Total MSF catch** *t*	**Total commercial effort** *Fisher-days*	Survey	**Estimated catch** *t (± SE)*	**Reported SE catch** *t*	**Retained** *%*	**Released** *%*
2017/18	304	4,911					
2018/19	281	4,547	2000/01	275 (65)	-	26%	74%
2019/20	115	1,882	2007/08	175 (27)	-	25%	75%
2020/21	43	430	2013/14	332 (128)	-	48%	52%
2021/22	25	263	2021/22	11 (8)	3	9%	91%

4.3.1. Biology

Snapper (*Chrysophrys auratus*) is a species of teleost fish in the family Sparidae. It is a large, long-lived, demersal, finfish species that is broadly distributed throughout the Indo-Pacific region, where its extensive distribution includes the coastal waters of the southern two-thirds of the Australian continental mainland as well as northern Tasmania (Kailola et al. 1993). Throughout this distribution, Snapper occupy a diversity of habitats from shallow bays and estuaries to the edge of the continental shelf across a depth range to at least 200 m. The stock structure for Snapper in Australian waters is complex, as there are considerable differences in the spatial scales over which populations are divisible into separate stocks (Fowler 2016, Fowler et al. 2017). A recent study indicated that there are three stocks that occur in South Australian coastal waters (Fowler 2016, Fowler et al. 2017). The Western Victorian Stock (WVS) is a cross-jurisdictional stock that extends westward from Wilsons Promontory, Victoria into the south eastern waters of South Australia (SA) as far west as Cape Jervis. There are also two wholly South Australian stocks, i.e. the Spencer Gulf/West Coast Stock (SG/WCS) and Gulf St. Vincent Stock (GSVS) (Fowler 2016, Fowler et al. 2017).

The recent study on the stock structure of Snapper was also informative about the demographic processes responsible for the replenishment of the three stocks. It indicated that each stock depends on recruitment into a primary nursery area: Port Phillip Bay (PPB), Victoria for the WVS; Northern Spencer Gulf (NSG) for the SG/WCS; and Northern Gulf St. Vincent (NGSV) for the GSVS (Fowler 2016). For the South East Region (SE), Snapper abundance varies episodically, as fish of a few years of age migrate westwards to this region over hundreds of km from PPB (Fowler et al. 2017). This occurs several years after strong year classes recruit to PPB, and as such is likely to be a density dependent process related to inter-annual variation in recruitment. The populations of Snapper that occupy the two northern gulfs in SA are independent and self-recruiting. They also experience inter-annual variation in recruitment of 0+ fish (Fowler and Jennings 2003, Fowler and McGlennon 2011), most likely as a consequence of variable larval survivorship. Each is an important nursery area that acts as a source of emigration of sub-adult and adult fish that replenish regional populations in adjacent coastal waters (Fowler 2016). NSG is the source region for immigrants to Southern Spencer Gulf (SSG) and most likely also for the West Coast of Eyre Peninsula (WC), whilst NGSV is the source for Southern Gulf St. Vincent (SGSV). As such, the dynamics in the regional populations of SA are primarily driven by temporally variable recruitment and subsequent emigration of fish from the source regions that support the nursery areas to adjacent regional populations (Fowler 2016).

4.3.2. Fishery

Snapper is an iconic fishery resource in each mainland State of Australia (Kailola et al. 1993). Throughout the mid-2000s, SA was the dominant State-based contributor to the national total catches of both the commercial and recreational sectors (Fowler 2016). SA's Snapper fishery is geographically extensive and encompasses most of the State's coastal marine waters from the far west coast of Eyre Peninsula to the SE region, although the highest abundances have generally been in Spencer Gulf (SG) or Gulf St. Vincent (GSV), which have consequently produced the highest fishery catches (Fowler et al. 2020b).

Snapper is a primary target species of the commercial and recreational sectors of SA (PIRSA 2013). Licence holders from four different commercial fisheries have access to the fishery, i.e., the Marine Scalefish Fishery (MSF), the Northern Zone and Southern Zone Rock Lobster Fisheries (NZRLF, SZRLF) and the Lakes and Coorong Fishery (LCF) (PIRSA 2013). The main gear types used to target Snapper by commercial fishers are handlines and longlines, since using haul nets to take Snapper was prohibited in 1993. For local recreational fishers and others from inter-state, Snapper has been an important species in SA's waters because of their desire to catch the large trophy fish. Such recreational fishers target Snapper using rods and lines, primarily from boats, although jetty and land-based catches do occur. Based on the recreational fishing survey in 2013/14, the contributions to total catch by the commercial and recreational sectors were 62% and 38%, respectively (Giri and Hall 2015).

The spatial structure of SA's Snapper fishery underwent considerable change between 2008 and 2012 (Fowler 2016). Historically, SG supported the highest catches and CPUE. However, these declined considerably, whilst contemporaneously those in NGSV and the SE increased to unprecedented levels (Steer et al. 2018a, Steer et al. 2018b). For the three different stocks these changes reflected different, independent demographic processes that related to recruitment and adult migration (Fowler 2016, Fowler et al. 2017). From 2011 onwards, the changes in the spatial structure of the fishery and stock status have caused considerable issues for managing the fishery. This resulted in numerous management changes that were implemented to limit commercial catches and to maximise the opportunities for spawning and recruitment success. Furthermore, several FRDC-funded research projects were undertaken to firstly identify the demographic processes responsible for the observed spatial changes (FRDC 2012/020; Fowler 2016). and also to develop a fishery independent index of fishable biomass (FRDC 2014/019; Steer et al. 2017).

4.3.3. Management Regulations

The timeseries below describes the broad approach and historical changes to the management protocols for the commercial, recreational and charter boat sectors of the Snapper fishery (Table 4.3-1). Nevertheless, since 1st November 2019, these protocols have been superseded by significant spatial closures and management changes. For greater detail of the historical management regulations for the commercial Snapper fishery of South Australia, refer to Drew et al. 2022.

Table 4.3-1. Key historical management measures introduced for the Snapper commercial fishery. Annotations of these measures are provided in Figure 4.3-1. Reference labels are provided for cross referencing with that figure.

YEAR	MANAGEMENT MEASURE	REGION	DETAILS	PLOT REFERENCE
1993	Gear restriction	State-wide	Prohibition of catching Snapper with fish traps or any net	a
2003	Seasonal closure	State-wide	Month long closure implemented in November of each year	b
2012	Trip limit (kg)	SG & GSV	800 kg daily trip limit applied	c
2012	Seasonal closure	State-wide	Seasonal closures extended to mid-December	c
2013	Spatial closures	SG & GSV	Spatial closures implemented for key spawning areas from November to January inclusive.	d
2013	Trip limit (kg)	SG & GSV	500 kg daily trip limit applied	d
2013	LL Hook limit	SG & GSV	Hook limits reduced to 200 from 400	d
2016	Trip limit (kg)	SG	200 kg daily trip limit applied	e
2016	Trip limit (kg)	GSV/SE	350 kg daily trip limit applied	e
2018	Spatial closure	SG and GSV	Locations of spawning closures revised	f
2019	Fishery closures	SG, GSV/KI & WC zones	Snapper fishery closed to all sectors	g
2020	TAC introduced	SE	TAC introduced from 2019 onwards	h
2021	ITQ introduced	State-wide	ITQ and fishing zones introduced and removal of seasonal closure in the SE	i

4.3.4. State-wide Fishery Statistics

Estimates of total State-wide commercial catch have fluctuated over varying time scales. Since 2003/04, State-wide catch increased to a record level of 970.9 t in 2010/11, before declining to 280.7 t in 2018/2019 (pre-gulfs closures) (Figure 4.3-1). In 2020/21 and 2021/22, catch declined to record low levels with all landings coming from the SE Region, due to the fishery closures for SG/WCS and GSVS. Furthermore, catches in the SE Region for 2020/21 and 2021/22 were constrained by TACCs (Table 4.3-1).

Historically, HL was the most significant gear type used to target Snapper, with HL catches accounting for the variation in total catch until 2008/09. The contribution of LL to total catch increased between 2004/05 and 2011/12, when it became the dominant gear type. Both HL and LL catches have declined since 2010/11. In 2021/22, 99.3% of the total catch was caught by LL in the SE fishing zone.

From the mid-1980s to 2007/08 there was a gradual long-term declining trend in total commercial fishing effort for Snapper (Figure 4.3-1). This was followed by a period of increased effort between 2008/09 and 2011/12 that corresponded to the increase in LL effort. Longline effort declined from 2012/13, complementing the declining trend in HL effort since 2003/04. As such, the total fishing effort of 4,547 fisher-days in 2018/19, which was the last full year of fishing prior to the gulf closures was the lowest recorded since 1983/84. In 2021/22, the total fishing effort was 263 fisher-days.

State-wide HL CPUE fluctuated between 1983/84 and 2007/08 but demonstrated a long-term increasing trend (Figure 4.3-1). From 2008/09 it decreased considerably, concomitant with the emerging increase in LL effort. In contrast, LL CPUE increased substantially between 2002/03 and 2014/15, before declining each year between 2016/17 and 2019/20. From 2020/21 to 2021/22 LL CPUE has increased to close to record levels. The LL CPUE for 2021/22, estimated for the SE Region only, was fourth highest on record at 100.0 $kg.fisher\text{-}day^{-1}$. The total number of licences who reported taking Snapper declined consistently from 422 in 1986/87 to 248 in 1999/00 (Figure 4.3-1). Licence numbers then stabilised for a decade before declining from 262 in 2009/10 to 175 Licences in 2018/19. The number of Licences that targeted Snapper varied similarly and fell from 202 in 2009/10 to 138 in 2018/19. In 2021/22, a total of nine licences reported taking Snapper, of which 8 licences reported targeting Snapper. In 2021/22, 97.65% of the total commercial catch of Snapper was taken by the MSF, with SZRLF accounting for the remaining 2.35%.

The relative contributions of the three stocks to total State-wide catches have changed considerably over time, in response to the change in spatial structure of the fishery between 2007/08 and 2011/12, and the fishery closures implemented in late 2019. The SG/WCS provided the highest proportions of annual catches up to 2009/10, after which they declined to their lowest levels from 2012 and 2019 (Figure 4.3-2). Catches from the GSVS were generally low until 2005/06, they then increased gradually until 2007/08, before increasing further between 2007 and 2010, when catches from this stock became (and subsequently remained) the main contributor to the State-wide catch, up to 2019. The catches from the SE Region also increased rapidly between 2007 and 2010, before declining back to a low level in 2013 where they have remained at a relatively low level up until 2021

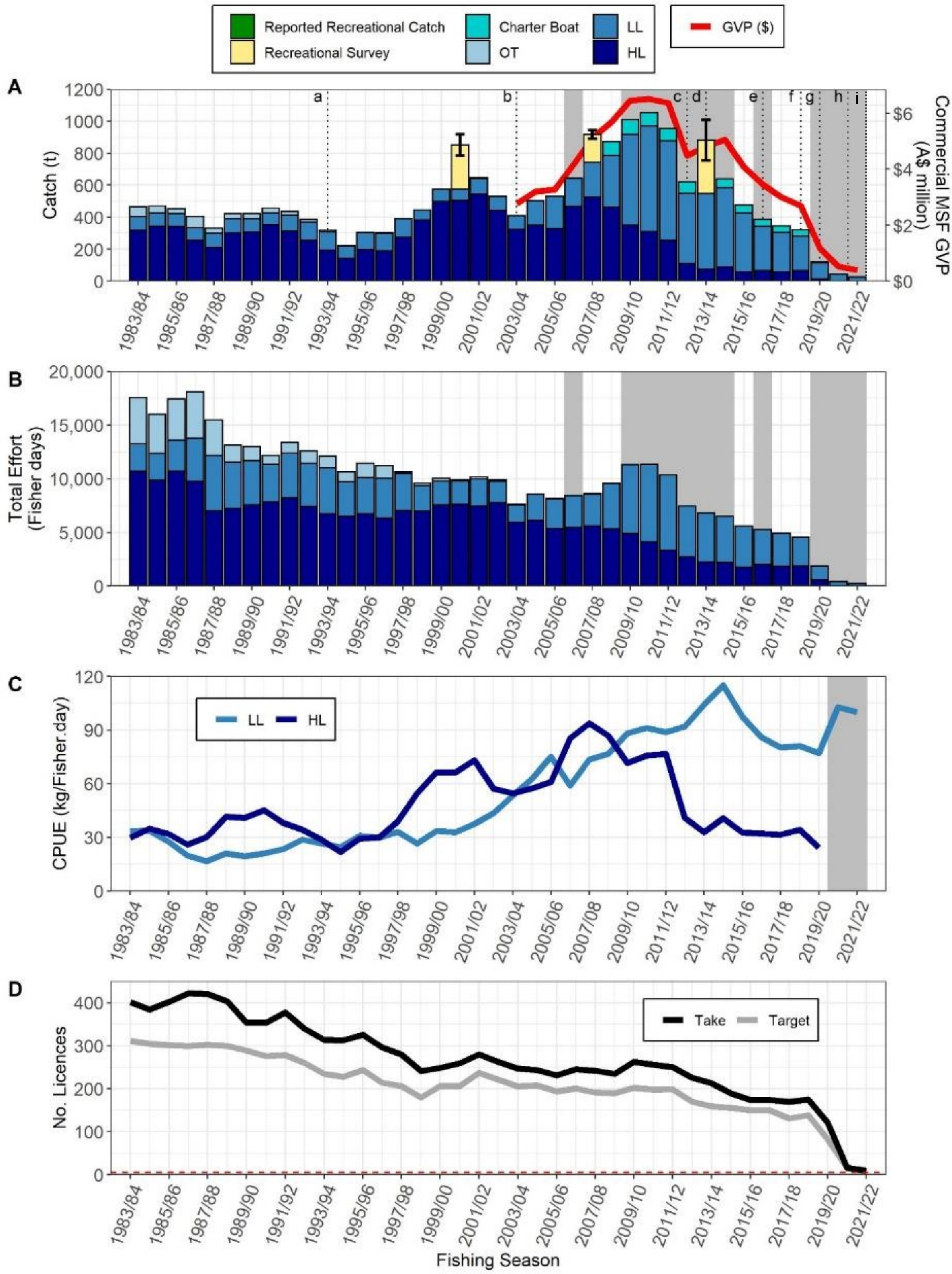


Figure 4.3-1. State-wide Snapper catch and effort. Long-term trends in: (A) total catch of the main gear types (longline (LL) and handline (HL)), estimates of recreational and charter boat catch, and gross production value, alphabetical annotations refer to Table 4.3-1; (B) targeted effort of main gear types; (C) targeted LL and HL catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Red dashed line indicated the level of five licences. Grey shading represents a fishing season where less than 5 fishers were operating with a gear type and was confidential and are not included on the panel.

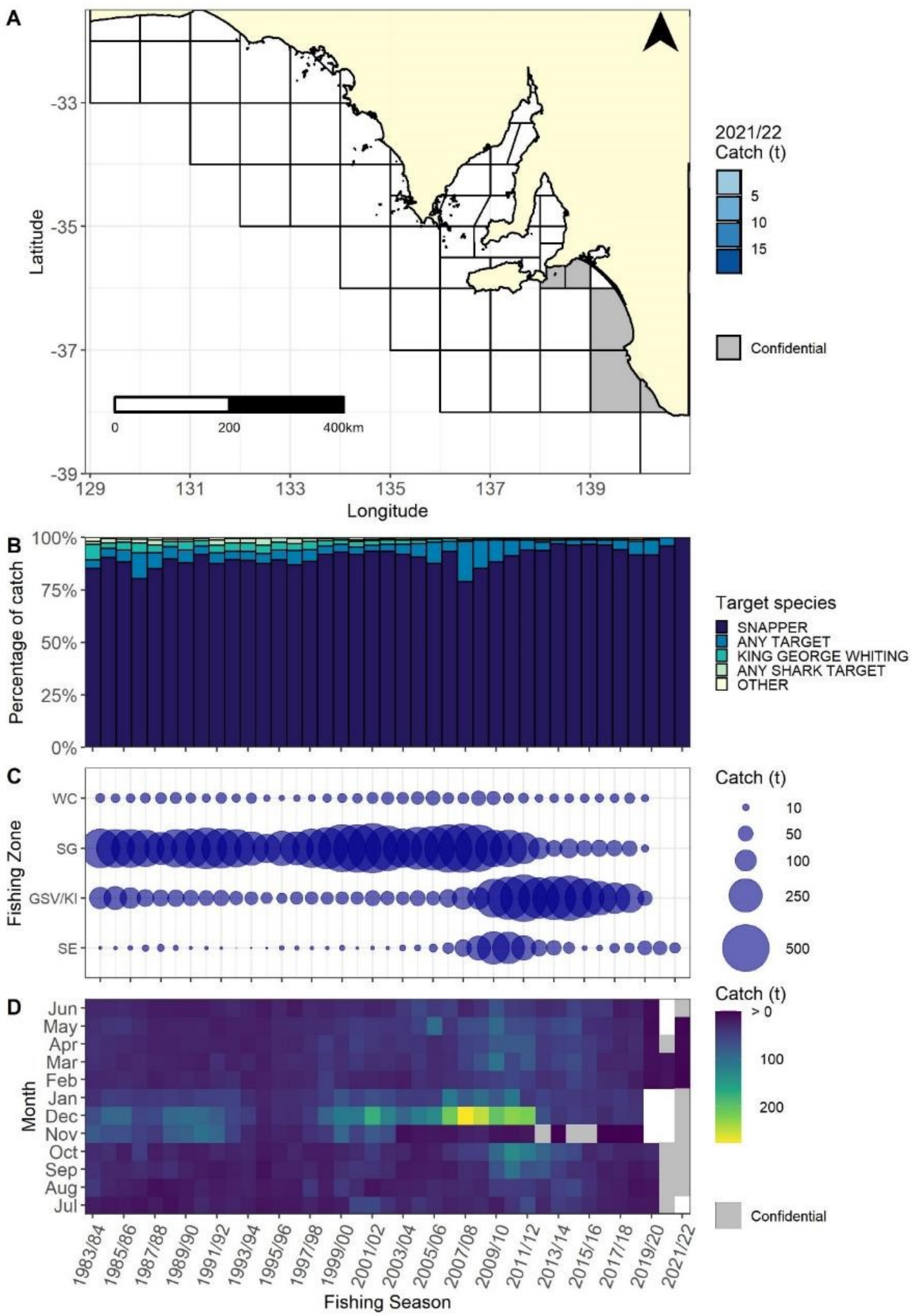


Figure 4.3-2. Regional dynamics of Snapper: (A) The spatial distribution of catch in MFAs by the commercial sector in 2021/22. (B) Percentage of targeted Snapper catch across fishing seasons. Long-term trends in: (C) the annual distribution of catch among regions, (D) months of the year. Grey shading represents a fishing season where less than 5 fishers were operating and therefore are confidential and are not included on the panel.

4.3.5. Fishery Performance Indicators

The general fishery performance indicators were assessed for only the SE fishing zone, as the SG/WC and GSV zones remain closed to fishing for the 2021/22 period (Table 4.3-2). In the SE for 2021/22 there was only one breach of the trigger reference point for the second highest targeted longline CPUE (kg.fisher-day^{-1}) on record (Table 4.3-2). Some of the trigger reference points for effort and CPUE for handlines were confidential in the 2021/22 period as there were less than 5 fishers using this gear type during this reporting period.

Table 4.3-2. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the regional spatial scales for Snapper in 2021/22. Lower trigger reference point (LTRP) breaches are indicated in light blue and upper trigger reference point (UTRP) breaches are indicated in blue. û indicates that no trigger has been breached. ✓ indicates that the trigger for five consecutive decreases has been triggered. Conf. identifies confidential data which prevents a PI from being assessed.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	SG/WC	GSV	SE
TOTAL CATCH	G	3rd Lowest/3rd Highest	-	-	×
	G	Greatest % interannual change (+/-)	-	-	×
	G	Greatest five-year trend	-	-	×
	G	Decrease over five consecutive years	-	-	×
TARGET HANDLINE EFFORT	G	3rd Lowest/3rd Highest	-	-	Conf.
	G	Greatest % interannual change (+/-)	-	-	Conf.
	G	Greatest five-year trend	-	-	Conf.
	G	Decrease over five consecutive years	-	-	×
TARGET HANDLINE CPUE	G	3rd Lowest/3rd Highest	-	-	Conf.
	G	Greatest % interannual change (+/-)	-	-	Conf.
	G	Greatest five-year trend	-	-	Conf.
	G	Decrease over five consecutive years	-	-	×
PROPORTION OF TARGET HL CATCHES EXCEEDING 200KG (PROP200KGTARHL)	G	3rd Lowest/3rd Highest	-	-	×
	G	Greatest % interannual change (+/-)	-	-	×
	G	Greatest five-year trend	-	-	×
	G	Decrease over five consecutive years	-	-	×
TARGET LONGLINE EFFORT	G	3rd Lowest/3rd Highest	-	-	×
	G	Greatest % interannual change (+/-)	-	-	×
	G	Greatest five-year trend	-	-	×
	G	Decrease over five consecutive years	-	-	×
TARGET LONGLINE CPUE	G	3rd Lowest/3rd Highest	-	-	UTRP
	G	Greatest % interannual change (+/-)	-	-	×
	G	Greatest five-year trend	-	-	×
	G	Decrease over five consecutive years	-	-	×
PROPORTION OF TARGET LL CATCHES EXCEEDING 200KG (PROP200KGTARLL)	G	3rd Lowest/3rd Highest	-	-	×
	G	Greatest % interannual change (+/-)	-	-	×
	G	Greatest five-year trend	-	-	×
	G	Decrease over five consecutive years	-	-	×

The proportions of the total commercial catches taken by the different commercial fisheries are presented for each year from 2017/18 to 2021/22 in Table 4.3-3. The relative catches from the four commercial fisheries in 202/22 were compared against their allocations using Triggers 2 & 3 s prescribed in the PIRSA management plan (2013) as reference points. No trigger reference points were exceeded for the 2021/22 period.

Commercial allocations were not breached by any sector in in 2021/22 (Table 4.3-3).

Table 4.3-3. Results from consideration of commercial catches of Snapper by fishery against their allocation percentages and trigger reference points. MSF = Marine Scalefish, NZRL = Northern Zone Rock Lobster and SZRL = Southern Zone Rock Lobster, LCF = Lakes and Coorong Fishery. No colour – allocation not exceeded. Trigger 2 (light blue) is breached if the respective sector allocation is breached for three consecutive years or in four of the previous five years. Trigger 3 is breached if the respective sector allocation is breached in any one year. The sector catch in tonnes is displayed with the State-wide catch percentage provided in parentheses.

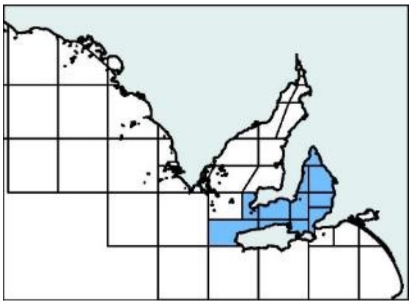
COMMERCIAL ALLOCATION	MSF	SZRL	NZRLF	LCF
	97.50%	**1.78%**	**0.68%**	**0.04%**
TRIGGER 2	-	2.68%	1.30%	0.75%
TRIGGER 3	-	3.58%	2.00%	1.00%
2017/18	294.87 (96.87%)	8.93 (2.94 %)	0.58 (0.19 %)	0.00 (0.00 %)
2018/19	273.04 (97.19 %)	7.35 (2.62 %)	0.27 (0.10 %)	0.27 (0.10 %)
2019/20	105.13 (91.41 %)	9.74 (8.47 %)	0.14 (0.12 %)	0.00 (0.00 %)
2020/21	36.16 (84.34 %)	6.72 (15.66 %)	0.00 (0.00 %)	0.00 (0.00 %)
2021/22	24.58 (97.65 %)	0.59 (2.35 %)	0.00 (0.00 %)	0.02 (0.01 %)

4.3.6. Gulf St Vincent Stock

Stock summary

Snapper

Gulf St Vincent stock



Stock status	2019 - Depleting	2020 - Depleted; fishery closed	**2021/22 – Depleted; fishery closed**
Fishery/stock trend	Traditionally, a small-scale fishery with annual catches of ~50 t for two decades from 1986/87 to 2006/07. Exponential increase in longline catch and effort from 2009/10, peaking at a total commercial catch of 500.1 t in 2011/12. Declining catch, effort, and CPUE from 2015/16 led to concerns about the sustainability of this fishery. Management intervention culminated in a total fishery closure for this stock from November 2019, followed by a continuation of the closure from February 2023 through to June 2026.		

Commercial catch and TACC

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target LL CPUE *kg/fisher-day*	TACC *t*
2017/18	212.0	2536	107.6	-
2018/19	184.0	2342	107.1	-
2019/20	46.3	662	98.4	-
2020/21	0	0	0	-
2021/22	0	0	0	0

Stock Status Summary	A total fishing closure was initially implemented for this stock from November 2019 through to February 2023. In 2020, the status of the GSVS was changed from 'depleting' to 'depleted' (Fowler et al. 2020). This reflected the declines in estimates of spawning biomass, model estimated fishable biomass, poor recruitment since 2009 and persistent high targeted catch and effort. No evidence of improvements in biomass or recruitment were identified in the 2022 stock assessment and as a result this stock retained its depleted status and the total fishing closure was extended from February 2023 through to June 2026.

4.3.6.1. Catch Statistics

As a result of the closure for this stock in November 2019, there are no fishing statistics available. Catch and effort statistics for the GSVS are reported and analysed for the period of 1983/84 to 2019/20. Between 1983/84 and 2005/06, the GSVS produced relatively low catches (Figure 4.3-3). However, from 2006/07, total catch increased exponentially, culminating in the record catch of 500.1 t in 2011/12. Total catch then decreased between 2011/12 and 2015/16, after which the rate of decline increased until the fishery closure. In 2018/19, the last year full year of fishing pre-closure, total commercial catch was 184.0 t.

Targeted HL catch has generally been low for this stock despite the high effort levels during the early 1980s (Figure 4.3-3). Targeted effort declined to a low level in 1994/95 and has since remained low but has varied cyclically. Estimates of annual targeted HL CPUE were low until 2001/02, before they increased to the highest levels between 2006/07 and 2013/14 (Figure 4.3-3). Handline CPUE has subsequently decreased to a moderate level, with 41.6 kg.fisher-day^{-1} recorded in 2018/19.

The number of licences using handline declined considerably through the 1980s and 1990s. The number that reported taking Snapper declined from 77 in 1983/84 to 51 in 2018/19 (Figure 4.3-3). Similarly, the number that targeted Snapper reduced from 67 to 44. The number of reported daily handline catches have generally been <300.yr^{-1} since 2007/08 (Figure 4.3-3). The estimates of Prop200kgTarHL peaked at 0.23 in 2007/08, but since 2014/15 have been low at <0.1.

The LL fishery for the GSVS largely accounted for the rapid increase in total catches from 2008/09 – 2010/11 (Figure 4.3-3). Between 2008/09 and 2015/16, targeted LL catch increased from 64.5 t to 334.8 t (Figure 4.3-3). This increase was associated with a 297.4% increase in targeted longline fishing effort from 705 to 2,802 fisher-days. Targeted LL fishing effort then declined between 2016/17 and 2018/19 from 2,124 to 1,439 fisher-days (Figure 4.3-3). Between 2007/08 and 2014/15, LL CPUE increased considerably, peaking at 146.5 kg.fisher-day^{-1} (Figure 4.3-3). From 2015/16, LL CPUE declined reaching 107.1 kg.fisher-day^{-1} in 2018/19. Catch per unit of effort of kilogram per hook varied annually since 2003/04 and diverged away from the period of highest recorded values of LL CPUE between 2010/11 to 2013/14.

The number of LL licences that took and targeted Snapper peaked in 2011/12 at 68 and 66, respectively, but since declined to 30 and 29 in 2018/19 (Figure 2-5J). The number of daily longline catches increased from 2008/09, peaked in 2011/12 at 1,478 catches and then declined between 2015/16 and 2018/19 to 620 catches (Figure 4.3-3). The Prop200kgTarLL was low from 2003/04 to 2007/08 (<0.2) but then increased up to 0.59 in 2014/15. Since then, there has been a general decline to 0.40 in 2018/19.

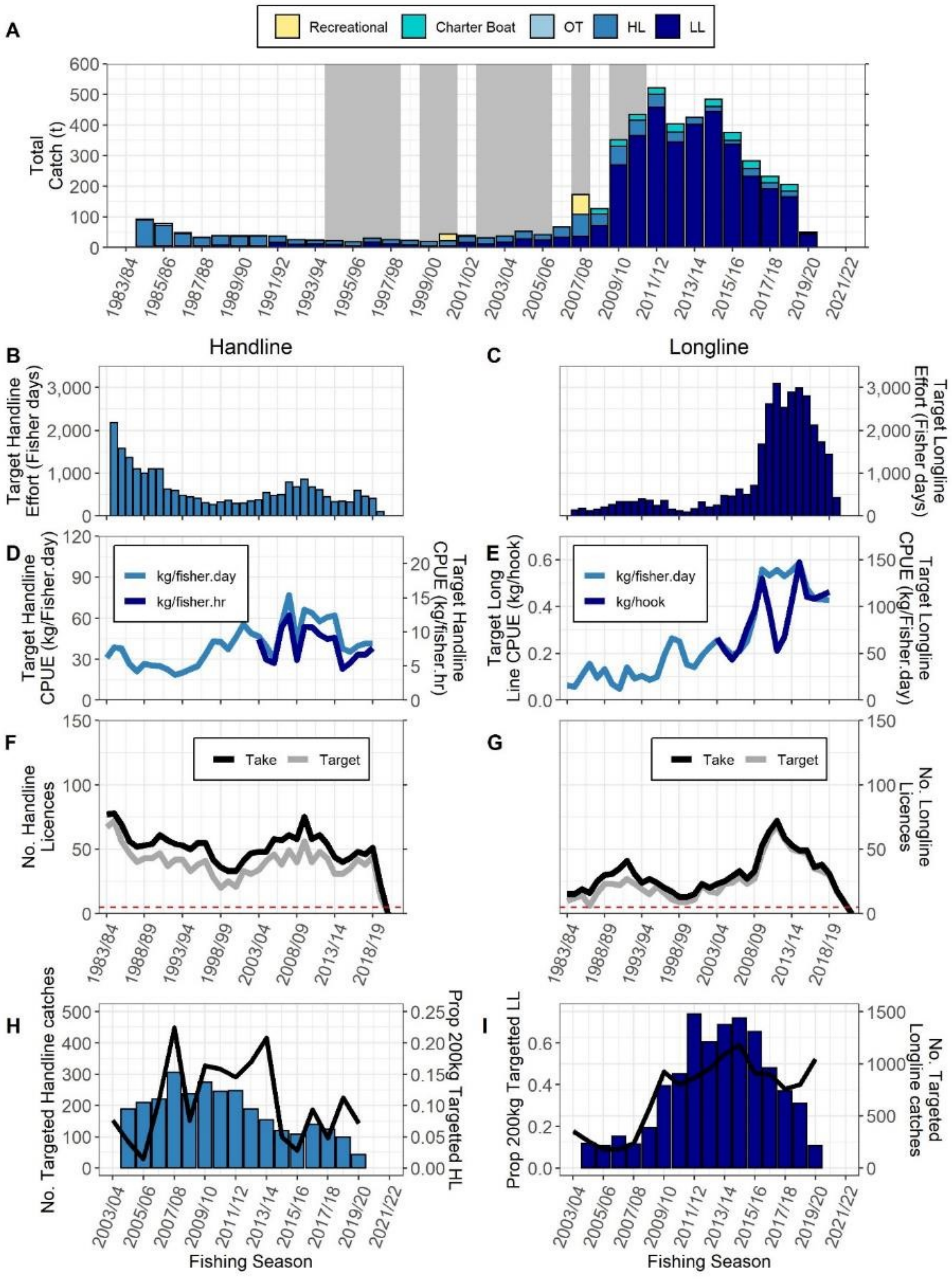


Figure 4.3-3. Key fishery statistics used to inform the status of Snapper in the SE fishing zones. Long-term trends in (A) total catch by gear and sector; targeted effort, handline (B) and longline (C); targeted CPUE metrics handline (D) and longline (E); number of licence holders taking and targeting Snapper for handlines (F) and longlines (G); number of daily catches and Proportion of targeted catches > 200kg for handlines (H) and longlines (I); A red dashed line in panel F ang G represents the number of licences below which data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on the panel.

4.3.6.2. Stock Status

Fishery statistics were not available for the GSVS for 2020–2022 following the closure of the fishery from November 2019. Trends in commercial fishery statistics for the GSVS, particularly for the LL sector, increased between 2007 and 2010 to its highest levels, which were maintained until 2015. Thereafter, declines were observed in total catch, targeted LL catch, effort, CPUE, the number of LL fishers targeting and taking Snapper, the number of their reported daily catches, and Prop200kgTarLL.

Age structures developed for 2020, 2021 and 2022 were broad for both the NGSV and SGSV. A small number of fish from the previous strong year classes of 2007 and 2009 remained in the recent age structures in NGSV. A 2014-year class emerged and persisted, and this age class dominated the recent age structures for SGSV. Nevertheless, recruitment over recent years has been low.

Fishery-independent estimates of spawning biomass from the DEPM show declines in spawning biomass, from 2,780 (± SE; 1,444) in 2014 to 404 t (± SE; 124) in 2021. There was a 50% decline in estimated spawning biomass between the 2019 and 2021 surveys, which was directly related to a 57% reduction in spawning area.

Modelled fishable biomass from SnapEst peaked at 4,300 t (± SE; 104) in 2011, before declining by 92% to 343 t (± SE; 67) in 2020, which was the lowest on record. Fishable biomass has since remained largely unchanged. The increase in biomass through the 2000s reflected the recruitment of numerous strong year classes to the population during the 1990s and 2000s. The subsequent reduction in biomass related to relatively poor recruitment from 2009 to 2019, coupled with unprecedented catches. Egg production in 2022 was estimated at 2% of that expected for an unfished stock. Average recruitment over the last three years was estimated at 78% lower than for the previous six years and 90% lower than the historical level. Consistent with low recent biomass, poor recent recruitment, and low egg production, the four reference points for the biological performance indicators were negatively triggered.

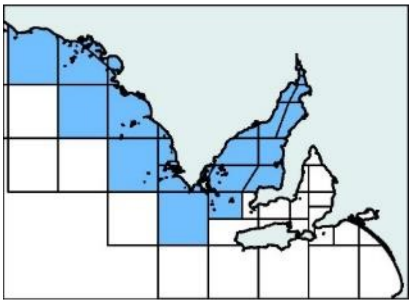
In 2020, the status of the GSVS was changed from ‘depleting’ to ‘depleted’ (Fowler et al. 2020). This reflected the decline in estimated spawning biomass from DEPM since 2014, poor recruitment since 2009, persistent high targeted catch and effort until 2018/19, and decreasing fishable biomass from SnapEst. Multiple lines of evidence demonstrate that management has not yet resulted in measurable improvements, and that the stock has continued to persist at low levels. These are: (i) poor recruitment between 2010 and 2019, despite the appearance of the 2014-year class; (ii) continued low estimates of spawning biomass; and (iii) continued low SnapEst estimated fishable biomass and egg production. Biomass is depleted, recruitment is impaired and the GSVS remains classified as ‘**depleted**.’

4.3.7. Spencer Gulf/West Coast Stock

Stock summary

Snapper

Spencer Gulf/West Coast stock



Stock status	2019 - Depleted	2020 - Depleted; fishery closed	**2021/22 – Depleted; fishery closed**
Fishery/stock trend	Historically, South Australia's most productive Snapper stock. Predominately a handline fishery until 2004/05 when the use of longlines began to increase. Total catch averaged 321 t between 1983/84 and 1997/98, catches then increased and averaged 458.4 t until 2011/12. Total catch then declined from 2012/13 and averaged 70.3 t until the closure of the fishery in November 2019.		

Commercial catch and TACC

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target HL CPUE *kg/fisher-day*	TACC *t*
2017/18	71.8	1945	48.8	-
2018/19	75.3	1830	59.8	-
2019/20	23.2	671	42.5	-
2020/21	0	0	0	-
2021/22	0	0	0	-

Stock Status Summary	A total fishing closure was implemented for this stock from November 2019 through to February 2023, which was then further extended to June 2026 after the continued depleted stock status from the 2022 stock assessment. During 2012 to 2013, the status of the SG/WCS was transitional depleting (Fowler et al. 2020). This status reflected the significant and continued declines in commercial catches and CPUE for both NSG and SSG. From 2012 a raft of management interventions was implemented to curtail the declining trends. In the assessment in 2018, the status of this stock was further downgraded to 'depleted', reflecting that commercial fishery statistics to 2017 remained at historically low levels (Steer et al. 2018b). The declines in fishery productivity and stock status primarily reflected poor recruitment throughout the 2000s, which indicated that recruitment had become impaired. A total fishery closure was implemented for this stock in November 2019, no evidence of improvements in biomass or recruitment were identified in the 2022 stock assessment, as a result this stock retained its depleted status and the total fishing closure was extended from February 2023 through to June 2026.

4.3.7.1. Catch Statistics

Prior to the fishery closure in November 2019, annual catches from the SG/WCS varied cyclically (linked to strong recruitment events) for most of the period from 1983/84 to 2018/19, with peaks in 2001/02 (591.0 t) and 2007/08 (572.9 t) (Figure 4.3-4). From 2007/08 to 2013/14, annual catches decreased, and subsequently remained relatively stable at a low level. In 2017/18, the lowest catch (pre-closure) of 71.8 t was taken.

The highest targeted HL catch of 493.2 t was taken in 2001/02, which since decreased and in 2017/18 was the lowest on record at 28.1 t (Figure 4.3-4). Targeted HL effort increased from 1997/98 to 2001/02 when it was at its highest level of 5,212 fisher-days (Figure 4.3-4). Since then, HL effort declined to the lowest level recorded at 569 fisher-days in 2018/19. Targeted HL CPUE has fluctuated, but showed a long-term increasing trend to 2011/12, with a peak at 132.6 kg.fisher-day^{-1} in 2007/08, before declining to 59.8 kg.fisher-day^{-1} in 2018/19. Handline CPUE by hour reflects the trend of the CPUE by fisher day, peaking at 22.2 kg.fisher-hour^{-1} in 2011/12.

The numbers of licence holders who targeted and caught Snapper using HL have declined slowly since 1983/84 until the temporary closure of the fishery in November 2019. Those taking Snapper using HL fell from 214 in 1983/84 to 99 in 2018/19, while those targeting Snapper fell from 174 to 63 over the same period. Between 2003/04 and 2011/12, the number of reported daily HL catches (between February and October) declined and from 2012/13 to 2018/19 were relatively stable but low (i.e., generally <400 catches.yr^{-1}). Estimates of Prop200kgHLTar ranged from 0.1 to 0.33 but showed no long-term trend.

From 1983/84 to 2003/04, targeted LL catch for the SG/WCS was relatively stable before it increased and peaked at 167.4 t in 2005/06 (Figure 4.3-4). Catch declined thereafter and, by 2018/19 had fallen to 30.9 t. Targeted LL effort peaked at 2,441 fisher-days in 1996/97, but then declined to 609 fisher-days in 2018/19. Highest targeted LL CPUE occurred between 2005/06 and 2008/09, peaking at 97.3 kg.fisher-day^{-1} in 2005/06 (Figure 4.3-4). After 2008/09, it decreased and then stablised and was 50.7 kg.fisher-day^{-1} in 2018/19. The LL CPUE of kg.hook^{-1} reflected similar trends as kg.fisher-day^{-1} from 2003/04 to 2011/12, it then subsequently increased to its peak of 0.29 kg.hook^{-1} in 2016/17.

Since 1988/89, the number of licence holders taking Snapper with LL fell from 121 to 55 while those targeting Snapper fell from 109 to 45 (Figure 4.3-4). The numbers of reported daily LL catches fell between 2008/09 and 2012/13 and have subsequently remained at the relatively low level of <500 catches.yr^{-1}(Figure 4.3-4). The annual estimates of Prop200kgLLTar peaked at 0.30 in 2007/08, prior to daily catches being constrained by trip limits. They then declined to approximately 0.1 in 2010/11 and have since remained around this low level.

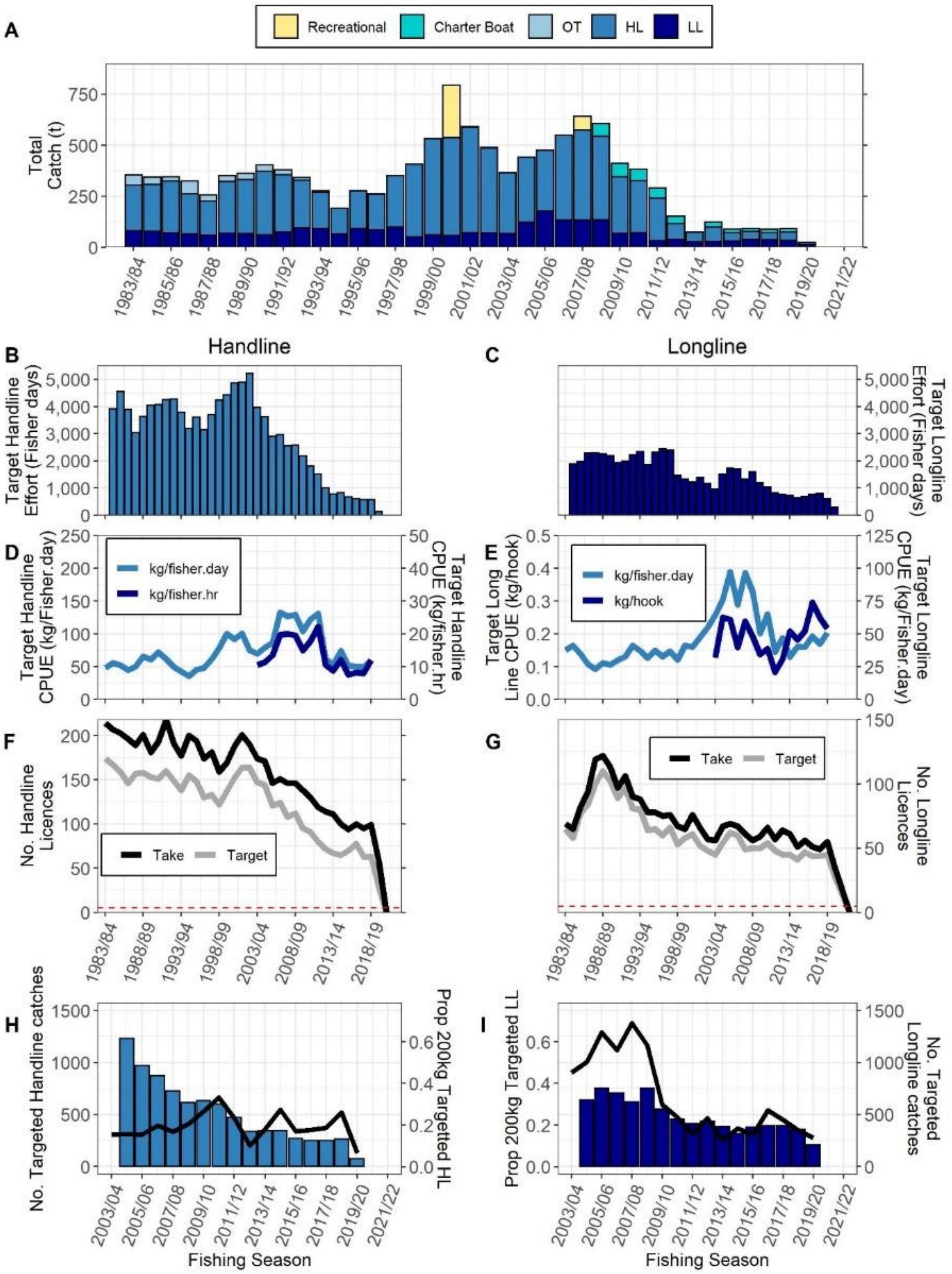


Figure 4.3-4. Key fishery statistics used to inform the status of Snapper in the SG/WC fishing zones. Long-term trends in (A) total catch by gear and sector; targeted effort, handline (B) and longline (C); targeted CPUE metrics handline (D) and longline (E); number of licence holders taking and targeting Snapper for handlines (F) and longlines (G); number of daily catches and Proportion of targeted catches > 200kg for handlines (H) and longlines (I); A red dashed line in panel F ang G represents the number of licences where data becomes confidential.

4.3.7.2. Stock Status

Fishery statistics were not available for the SG/WC for 2020–2022 following the closure of the fishery from November 2019. Historic trends have shown substantial declines in most fishery statistics from the mid-2000s. These declines were apparent for total catch, targeted HL effort and CPUE, targeted LL effort and CPUE, Prop200kgTarLL, targeted catches by gear type and the numbers of fishers who took and targeted Snapper. These patterns indicated a rapid decline and persistent low biomass levels (Drew et al. 2022).

Age structures sampled in 2019, 2020 and 2021 and presented in the recent 2022 stock assessment show that the population in NSG is dominated by small, young fish up to seven years of age, and a low proportion of older fish (Drew et al. 2022). These contemporary age structures contrast with those from the 1990s and 2000s that included many fish of >20 years of age and some >30 years old (McGlennon et al. 2000, Fowler et al. 2010, 2016a). Recent age structures indicate the presence of 2014 and 2016-year classes. The age structures for SSG contained a broader range of year classes but were still predominantly composed of fish up to seven years of age. These data demonstrate that the age composition of the SG/WCS remains truncated and that recent recruitment has been comparatively low.

Applications of the DEPM in NSG in 2013, 2018, 2019 and 2021 indicated a continued decline in spawning biomass over this period (Drew et al. 2022). The estimate of spawning biomass in 2021 was 108 t (± SE; 65); which was a 39% reduction from the estimate in 2019 (177 t ± SE; 34). The reduction in spawning biomass between surveys largely resulted from a 49.5% reduction in spawning area and an 18% increase in spawning fraction. The results from four applications of the DEPM since 2013 support the continued low level of spawning biomass in NSG (Drew et al. 2022).

The SnapEst model estimates of fishable biomass declined by 90% from a peak of 5,244 t (± SE; 104) in 2005 to 543 t (± SE; 65) in 2022, which is the third lowest estimated biomass. Fishable biomass from SnapEst has remained largely unchanged since the lowest estimate of 469 t (± SE; 53) in 2020 (Drew et al. 2022). Model outputs indicate that the decline in fishable biomass relates to a prolonged period of poor recruitment throughout the 2000s and from 2010, and increasing harvest fractions, caused by the continued fishing of a depleting stock prior to the closure. The model outputs show that egg production in 2022 was estimated at 2% of that expected for an unfished stock and that average recruitment over the last three years was estimated at 28% lower than the previous six years, and 81% lower than the historical mean. Consistent with low recent biomass, extended trends in poor recruitment and low levels of egg production, the four reference points for the biological performance indicators were negatively triggered.

Several independent datasets demonstrate that the fishable biomass and recruitment for the SG/WCS indicate no signs of measurable improvements and have continued to persist at historically low levels.

These include: (i) truncated age structures – the very low proportion of large, old fish in the population; (ii) continued lack of recruitment of any new strong year classes; and (iii) continuing declines in spawning biomass. Integration of all data in SnapEst confirms this. The model-estimated decline in biomass of the SG/WCS has occurred since the mid-2000s and has been apparent at the regional and biological stock levels since 2013 (Fowler et al. 2013, 2016a, 2019, 2020). The primary causes of the decline are 23 consecutive years of poor recruitment since 1999, evident in the lack of strong year classes in annual age structures throughout the 2000s and into the 2010s (Fowler et al. 2016a, 2019), coupled with ongoing exploitation of a depleting stock prior to the fishery closure.

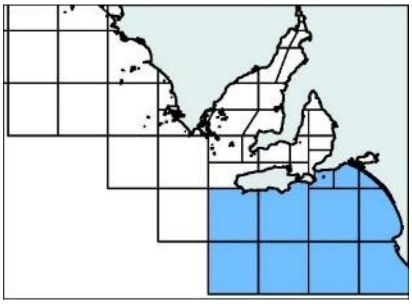
The SG/WCS has been classified as 'depleted' since 2018. It is evident that the biomass and recruitment of the SG/WCS remains at low levels with no evidence of measurable stock recovery following the closure of the fishery. Biomass is depleted, recruitment is impaired and the SG/WCS remains classified as '**depleted**.'

4.3.8. South East fishing zone

Stock summary

Snapper

South East Fishing Zone



Stock status	2019 - Sustainable	2020 - Sustainable	**2021/22 - Sustainable**

Fishery/stock trend

The South East Snapper stock is the western extremity of the cross-jurisdictional Western Victorian Snapper Stock (WVS), which is dependent on emigration from strong year classes of recruitment to Port Philip Bay (VIC). Snapper in the South East fishing zone is managed under a TAC divided among commercial, charter, recreational and Aboriginal / Traditional sectors. Modelled estimates of fishable biomass have continued to increase driven by recent years of strong recruitment. The most recent estimate of biomass which included all data up to 2019 was 349 t (± SE; 70) which was the largest modelled biomass since 2011. Biomass is expected to continue increasing over the next several years.

Commercial catch and TACC

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target LL CPUE *kg/fisher-day*	TACC/TARC *t*
2017/18	21	429	57.7	-
2018/19	21	375	64.5	-
2019/20	46	549	85.5	60.75 (for 2020 calendar year)
2020/21	43	430	101.8	21.6 (1 Feb 2021–30 Jun 2021)
2021/22	25	263	100.7	36/12

Stock Status Summary

Substantial increases in annual fishery catches, effort, and CPUE occurred between 2008/09 and 201/12, which then declined through to 2015/16 and remained at low levels to 2019. Catches then increased as a small amount of effort was transferred from the two closed Snapper stocks (SG/WCS and GSVS) from November 2019. Catches from 2019/20 in the South East fishing zone have been constrained by TACs. However, CPUE in kg.fisher-day^{-1} have been the highest on record from 2020/21–2021/22.

In 2016 (Hamer and Conron 2016), 2018 (Stewardson et al. 2018) and 2021 (Piddocke et al. 2021), the WVS was classified as 'sustainable'. The annual 0+ recruitment survey showed that over the 30 years to 2022, there had been eight years for which recruitment was above the long-term average. Furthermore, the 2018-year class was the largest yet recorded and the 2022- year class the third highest on record (Table 5-4). These lines of evidence suggest that the adult biomass is at a level sufficient to ensure that future levels of recruitment are adequate, i.e., recruitment is not impaired, and fishing mortality is adequately controlled to avoid the stock from becoming impaired.

4.3.8.1. Catch Statistics

The SE Region has generally produced low catches of Snapper compared to the other stocks. However, from 2006/07 to 2010/11 there was an exponential increase in catch that peaked in 2009/10 at 239.1 t (Figure 4.3-5). Catch then declined sharply to 8.1 t in 2016/17 before moderately increasing to 45.5 t in 2019/20. In 2021/22 the TACC was 36 t with whilst the total commercial catch declined to 25.2 t.

Targeted HL catch in the SE Region has always been low, with a mean annual catch of 2.7 t (Figure 4.3-5). Catch increased between 2005/06 and 2009/10 and peaked in 2007/08 at 16.3 t (Figure 4.3-5). These catches reflect low but variable fishing effort, which peaked at 444 fisher-days in 2006/07 (Figure 4.3-5). Until 2002/03, targeted HL CPUE was generally <20 kg.fisher-day^{-1} (Figure 4.3-5). It increased to its highest levels from 2007/08 to 2008/09, peaking at 54.4 kg.fisher-day^{-1} in 2007/08. Since then, HL CPUE declined and was at its lowest level in 20 years at 14.8 for 2021/22.

The numbers of HL licences that took and targeted Snapper peaked in 1986/87, at 19 and 14, respectively (Figure 4.3-5) before declining to <5 fishers targeting Snapper between 2016/17 and 2021/22 (except for 2018/19 (n=11). Prop200kgTarHL was highest from 2005/06 to 2008/09, but in most years has either been close to or zero.

Up to 2007/08, annual targeted LL catches were generally <5 t. There was then a rapid increase to the highest recorded catch of 221.3 t in 2009/10 (Figure 4.3-5). Longline catches then declined to 4.9 t in 2016/17, recently target LL catches have increased back up to 40.8 t in both 2018/19 and 2020/21. In 2021/22, it then reduced back to 25.0 t, which was constrained by TACC. There was a considerable increase in targeted LL effort from 64 fisher-days in 2002/03 to its peak at 2,853 fisher-days in 2010/11 (Figure 4.3-5). Effort subsequently declined to 131 fisher-days in 2015/16 but increased to 248 fisher-days in 2021/22. Targeted LL CPUE in fisher days increased between 2007 and 2010, reaching 84.8 kg.fisher-day^{-1} in 2009/10 (Figure 4.3-5). Since 2010/11 it has been variable, however recently it has peaked at 101.8 kg.fisher-day^{-1} in 2020/21 and 100.7 kg.fisher-day^{-1} in 2021/22. Targeted LL CPUE of kg.hook^{-1} peaked in 2004/05 at 0.39 kg.hook^{-1} hook as effort was the lowest recorded (8875 hooks set) since 2003/04. It then went through a period of decline between 2011/12 and 2015/16, which reflected the decrease in targeted LL catch. Since 2017/18, it has plateaued at ~0.17 kg.hook^{-1}, and diverged from the CPUE values for kg.fisher-day^{-1}. The numbers of LL fishers who took Snapper peaked in 2010/11 at 45 and the number of fishers that targeted Snapper peaked in 2009/10. Subsequently both have declined to 9 and 8, respectively, in 2021/22 as the harvesting of Snapper is now controlled by ITQs (Figure 4.3-5). Prop200kgTarLL also peaked in 2009/10 at 0.53 and then declined to 0.1 in 2016/17. From 2017, it increased reaching its third highest level of 0.52 in 2020/21, then declined to 0.40 in 2021/22.

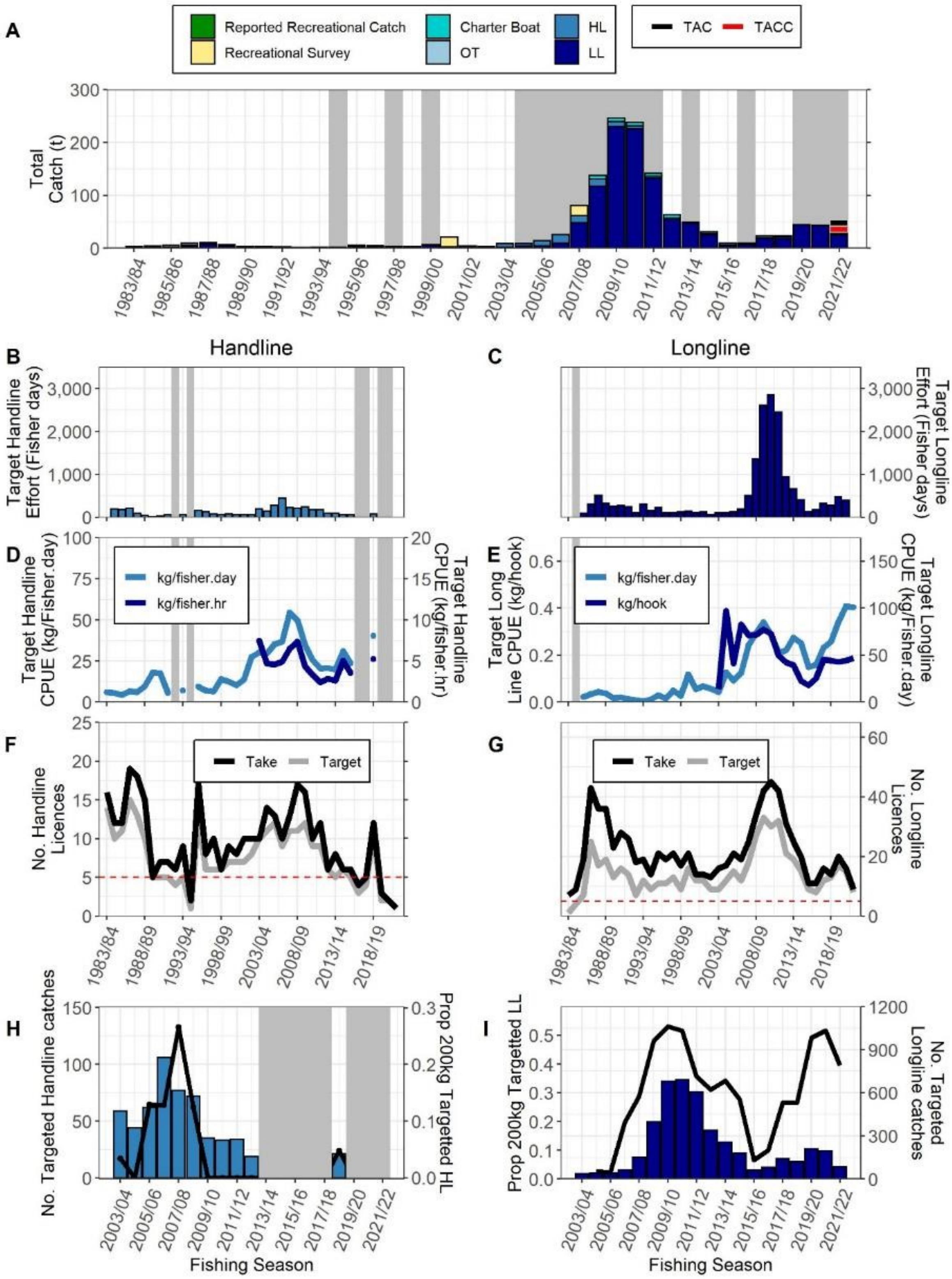


Figure 4.3-5. Key fishery statistics used to inform the status of Snapper in the SE fishing zones. Long-term trends in (A) total catch by gear and sector; targeted effort, handline (B) and longline (C); targeted CPUE metrics handline (D) and longline (E); number of licence holders taking and targeting Snapper for handlines (F) and longlines (G); number of daily catches and Proportion of targeted catches > 200kg for handlines (H) and longlines (I); A red dashed line in panel F ang G represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on the panel.

4.3.8.2. Stock Status

The Snapper population in the SE Region of SA is the western extremity of the cross-jurisdictional Western Victorian Stock (WVS). This population is primarily sustained through the emigration of fish from the main nursery area, which is located in Port Phillip Bay (PPB), Victoria (Fowler 2016, Fowler et al. 2017a).

Substantial increases in annual fishery catches, effort, and CPUE occurred between 2007/08 and 2012/13, which then declined through to 2015/16 and remained at low levels to 2019. Longline catch and effort moderately increased in 2020/21 and then moderated in 2021/22, consistent with changes in total allowable catches between fishing seasons. As a result of recent increases in catch and effort, targeted LL CPUE (kg.fisher-day^{-1}) reached its second highest level in 2021/22, triggering the general performance indicator.

Age structures in the most recent assessment (Drew et al. 2022) for 2020, 2021 and 2022 were dominated by the 2013- and 2014-year classes and there were comparatively few fish remaining from the above average 2009- and 2010-year classes. The age structures for the SE Region continue to demonstrate strong correlation with the timeseries of 0+ recruitment in PPB. As such, it is expected that the strong 2018-year class from PPB will recruit to the fishable biomass of the SE Region in the near future (Drew et al. 2022).

Outputs from the SnapEst model in the 2022 assessment (Drew et al. 2022) indicate a substantial increase in fishable biomass between 2005 and 2008 following recruitment of two strong year classes to PPB in 2001 and 2004, and the subsequent emigration of Snapper from PPB to the SE Region. Fishable biomass then decreased until 2015 as a result of exploitation and low recruitment since 2004. Transitioning from HL to LL CPUE (kg/hooks) in SnapEst has resulted in a doubling of model-estimated fishable biomass compared to the previous assessment. Model-estimated fishable biomass has steadily increased from 176 t (± SE; 45) in 2016 to 349 t (± SE; 70) in 2022, which reflects recruitment of the 2013- and 2014-year classes to the fishery. All six biological performance indicators were triggered, four negative (trends in recruitment, egg production, age composition) and two positive (harvest fraction and trends in fishable biomass) (Drew et al. 2022).

While the TACs for the 2021 and 2021/22 fishing seasons were set based on the estimated fishable biomass for the SE Region (which is largely influenced by CPUE), there are other considerations when setting the target harvest fraction and TAC for the SE Region. Firstly, this region is a sink population of the WVS with adult abundance is dependent on recruitment success within PPB. Fish from this area move to the SE Region of SA, but relatively few return (Fowler et al. 2017). Secondly, recent strong recruitment to PPB in 2013, 2014, 2018 and 2022 suggests future replenishment of the SE Region population.

In 2016 (Hamer and Conron 2016), 2018 (Stewardson et al. 2018) and 2021 (Piddocke et al. 2021), the WVS was classified as '**sustainable**'. The annual 0+ recruitment survey showed that over the 30 years to 2022, there had been eight years for which recruitment was above the long-term average. Furthermore, the 2018-year class was the largest yet recorded and the 2022- year class the third highest on record (Table 5-4). These lines of evidence suggest that the adult biomass is at a level sufficient to ensure that future levels of recruitment are adequate, i.e., recruitment is not impaired, and fishing mortality is adequately controlled to avoid the stock from becoming impaired.

4.4. Southern Garfish

Species summary

Southern Garfish

Hyporhamphus melanochir

Stock status (Fishing Zone)	Gulf St Vincent/ Kangaroo Island Fishing Zone	Spencer Gulf Fishing Zone	West Coast Fishing Zone	South East Fishing Zone
	Recovering	**Recovering**	**Sustainable**	**Negligible**

Species Tier	**Tier 1 in GSV/KI & SG fishing zones. Tier 3 in WC and SE fishing zones –** last stock assessment was conducted in 2022 and included data to 2020 (Smart et al. 2022b)
Species description	Southern Garfish are a productive, fast-growing species of 'halfbeak' that are endemic to southern Australia. They form large schools in shallow, inshore marine waters and their abundance are associated with sea grass beds. They are particularly abundant in South Australia's northern gulfs.
Fishery description	Southern Garfish fishing predominantly occurs in the two gulf zones with biomass being highest in the northern region of each gulf. Haul nets are the dominant commercial gear type. However, due to extensive netting restrictions, dab nets are the dominant gear types in the southern gulfs and WC fishing zone where smaller catches occur.
Current assessment program	• Weekly length and age structures collected through market sampling in Adelaide. • Annual examination of commercial fishery statistics. • Recreational data collected every five to seven years through State-wide recreational survey. • Application of a length-and-age-structured population model (GarEst). • No information is available for Aboriginal/Traditional fishing.

Commercial fishery statistics (State-wide)			**Recreational Catch**			
Fishing Season	**Total MSF catch** *t*	**Total commercial effort** *Fisher-days*	Survey	**Estimated catch** *t (± SE)*	**Retained** *%*	**Released** *%*
2017/18	174	4,939				
2018/19	192	4,873	2000/01	115 (20)	87%	13%
2019/20	168	4,193	2007/08	75 (14)	81%	19%
2020/21	182	4,128	2013/14	79 (22)	89%	11%
2021/22	156	4,288	2021/22	24 (5)	81%	19%

4.4.1. Biology

Southern Garfish (*Hyporhamphus melanochir*) is a surface-associated marine teleost species of the Hemiramphidae family. They are elongate in body shape and have a distinctive lower jaw that forms an extended beak which is much longer than the upper jaw. Southern Garfish is endemic to coastal waters of southern Australia. It is distributed from Shark Bay in Western Australia, along the southern coast of Australia including Tasmanian waters, and as far east as Eden in New South Wales (Kailola et al. 1993, Noell and Ye 2008). The species forms schools in sheltered bays and shallow, inshore, marine waters to depths of ~20 m, and are often associated with seagrass beds (Earl et al. 2011). They are particularly abundant throughout the gulf regions of South Australia.

Southern Garfish has a bipartite life history that is characteristic of most marine fish species. It is a multiple batch spawning species that has a protracted spawning period of six months from October to March (Fowler 2019). During the spawning period, only a small proportion (10–20%) of the population are in spawning condition at any given time (Giannoni 2013). This indicates that reproductive activity is asynchronous with small pulses of spawning activity, which is most likely a consequence of the large size of the developing oocytes (approximately 3 mm in diameter) and the time required for them to mature (Noell 2005, Fowler 2019). The estimated length-at-50%-maturity (L_{50}) for female Southern Garfish in South Australia is 215 mm total length (TL), which is equivalent to the mean age of 17.5 months (Ye et al. 2002).

The eggs of Southern Garfish are negatively buoyant and are adapted for attachment to substrate such as seagrass blades and macroalgae (Jordan et al. 1998, Noell 2005). Although it is possible that the eggs are moved through attachment to drifting substrate, there is assumed to be greater potential for large-scale transport during the pelagic larval stage. The developing larvae remain near the surface and their movement is likely to be heavily influenced by the physical environment (i.e., tides and wind-driven currents) until the completion of fin formation at ~20 days post-hatch (Noell 2005, Fowler 2019). Thereafter, the late-stage larvae and juveniles can actively influence their dispersal. The juvenile fish develop quickly and, like the adults, are considered largely sedentary in their movement. It is possible that the limited movement of adult fish is a consequence of an obligate relationship between Southern Garfish and the intertidal seagrass *Zostera muelleri* which constitutes a significant component of the adult diet (Robertson and Klumpp 1983, Earl et al. 2011).

In 1999 and 2000, a total of 2,079 Southern Garfish from commercial catches in South Australia were aged for a study on age and growth (Ye et al. 2002). There were seven age classes (0+ to 6+ years) that contributed to the commercial catches; however, the catches were dominated (89%) by fish from 1+ and 2+ age classes. Less than 2% were from 4+ to 6+ age classes. A more recent study, which compared the size and age structures of the fishery with those of the 1950s, indicated that historically the fishery was once dominated by fish from 4+ and 5+ age classes, but over numerous years of exploitation, the age structure has become considerably truncated to consist primarily of fish from 1+ and 2+ age classes (Fowler and Ling 2010).

The population dynamics and stock structure of Southern Garfish in South Australia has been investigated using a variety of different approaches. Movement has not been investigated directly through a tagging study because of their fragile nature and susceptibility to injury and mortality as a result of capture and handling. Consequently, movement was inferred through a multi-disciplinary otolith study that involved the analysis of otolith microchemistry (trace elements and stable isotopes) (Steer et al. 2009b) and otolith morphometrics (Steer et al. 2009a, 2010, Steer and Fowler 2015), and a concurrent study that considered parasite assemblages (Hutson et al. 2011). The results of these studies suggested that the movement of adult fish was limited and that they remained associated with a particular area or bay during the first few years of their lives. This evidence of restricted movement and site-fidelity underpinned the conceptual model of stock structure for Southern Garfish in South Australia, i.e., that the State-wide distribution was divided into numerous populations that were largely discrete. These populations were: the bays along the West Coast of Eyre Peninsula (WC), Northern Spencer Gulf (NSG), Southern Spencer Gulf (SSG), Northern Gulf St Vincent (NGSV), Southern Gulf St Vincent (SGSV), and the South East (SE) (Steer et al. 2018b).

More recently, Fowler (2019) examined the demographics and population connectivity of Southern Garfish in Gulf St Vincent. The study provided fishery-independent evidence that the highest abundances of adult fish were in the northern part of the gulf and that abundance decreased moving southward. This spatial distribution of adults aligned with the distribution and abundance of the seagrass *Zostera muelleri* and is consistent with the limited movement of adult fish inferred from the previous otolith-based studies. Furthermore, Fowler (2019) also investigated the spatial distribution of Southern Garfish larvae to provide insight into the processes that replenish the two regional populations (i.e., NGSV and SGSV). The results indicated that there was local retention of larvae in each region. However, the study also identified that a large proportion of larvae produced in SGSV were transported northward and contributed to the replenishment of the population in NGSV (Fowler 2019). Consequently, the conceptual model of spatial scale of assessment was updated to recognise the importance of larval supply from SGSV to the NGSV population, and the two populations were classified as a single biological stock (i.e., the Gulf St Vincent stock). Although the demographic processes of Southern Garfish in Spencer Gulf were not investigated, it is likely that the processes responsible for population replenishment are similar.

4.4.2. Fishery

Southern Garfish is a significant inshore fishery species of southern Australia, with fisheries also existing in Victoria, Tasmania, and Western Australia. Historically, the national commercial catch for this species has been dominated by South Australia where the catch has often exceeded 400 t per annum, with an approximate value of $1.8 M (EconSearch 2021). This species is also a popular target amongst South Australian recreational anglers (Jones 2009, Giri and Hall 2015).

In South Australia, licence holders from three different commercial fisheries have access to Southern Garfish. These are the MSF, NZRLF and SZRLF. The Southern Garfish fishery is principally located in Spencer Gulf and Gulf St Vincent and managed through a series of input and output controls. Commercial fishers typically target Southern Garfish using haul nets and dab nets. Haul net fishers account for the majority (~90%) of the commercial catch even though their fishing activities are restricted by regulation to waters <5 m deep. The fishery in the northern gulfs is dominated by haul net fishing while large areas in the southern gulfs are closed to haul netting. Subsequently, the dab net fisheries in the southern gulfs provide the best indicators of stock status in these regions (Fowler 2019).

Recreational fishers are permitted to use dab nets but predominantly use traditional hook and line as they fish from boats and shore-based platforms throughout the State. In 2013/14, this sector took an estimated 870,147 Southern Garfish, equating to an estimated state-wide catch of 79.2 t (Giri and Hall 2015). In 2021/22, recreational fishers caught an estimated 264,506 Southern Garfish, equating to an estimated state-wide catch of 24 t (Beckmann et al. 2023).

4.4.3. Management Regulations

The commercial MSF has undergone considerable management changes over the past 39 years that has seen the fishery restructured and limited through gear restrictions and configuration, licencing, spatial and temporal closures, size limits and most recently, total allowable commercial catches (TACCs). Although most of these management changes have been generic in nature, there have been a few that have largely impacted the Southern Garfish fishery. The most notable of these has been a series of net fishing spatial closures. Areas closed to netting were first implemented on the West Coast in 1958 and were subsequently followed by a depth-delimited ban in the early 1970s when net fishers were restricted to operate in coastal waters <5 m deep. Further netting closures were implemented in 1983, 1994, 1995, 1997 and 2005. In addition, deep water netting exemptions for a few commercial operators were revoked in 2006. These closures have significantly restricted the commercial Southern Garfish haul net fishers to relatively small areas within the northern gulfs. Following the implementation of several marine parks in 2014, it was estimated that net fishers in Northern Gulf St Vincent have access to 465 km^2 of fishable area, which is approximately 55% less than the 1,028 km^2 available in Northern Spencer Gulf (Steer et al. 2016).

In 2001, the legal minimum length (LML) for Southern Garfish was increased from 210 mm to 230 mm TL. This increase was made to ensure that at least 50% of Southern Garfish at that size would be reproductively mature and therefore had the opportunity to spawn at least once prior to capture (Ye et al. 2002). Despite this increase, no corresponding changes to the mesh size regulations for haul nets were implemented. Reductions in the recreational bag and boat limits were also implemented in 2001.

Biological performance indicators (BPIs) for Southern Garfish were outlined as part of the Management Plan for the South Australian commercial MSF, which was released in October 2013 (PIRSA 2013). Although no specific management arrangements were prescribed in the Management Plan to achieve these BPI reference points (RPs), a range of tools were identified, and an adaptive management approach outlined to consider the management arrangements needed to meet the RPs over time. These included gear modifications, spatial and temporal closures, and effort/catch management (PIRSA 2013). Through collaborative research and consultation amongst PIRSA, SARDI and the commercial fishing industry, it was agreed that a combination of effort and gear-based management strategies should be adopted to reach the operational targets. Furthermore, it was agreed that these strategies should be dynamic and altered in response to the status of the fishery. Initially, two 20-day seasonal closures that alternated between the gulfs were implemented in 2012. The duration of these closures was subsequently increased to 38 days in 2013, 40 days in 2014, 60 days in 2016, 80 days in 2018, and 80 days in 2019 for Gulf St Vincent. Similarly, the minimum regulated mesh size of the pocket component of the haul nets was sequentially increased from 30 mm to 32 mm in 2013, from 32 to 35 mm in 2017 and from 35 to 36 mm in 2019. Furthermore, the LML of Southern Garfish for commercial fishers was increased from 230 mm to 250 mm TL in 2015. In 2016, the recreational bag and boat limit of Southern Garfish was halved from 60 and 180 fish, respectively, to 30 and 90 fish. Following the implementation of TACCs in the GSV/KI and SG fishing zones, several management measures were reconsidered in 2021. The haul net pocket mesh size was maintained at 36 mm for the GSV/KI and SG fishing zones but reduced to 32 mm in all other areas. Additionally, the seasonal closures were removed and the LML was reversed to 230 mm TL to reduce discarding from the larger mesh size in the gulf zones.

Table 4.4-1. Key historical management measures introduced for the Southern Garfish commercial fishery. Annotations of these measures are provided in Figure 4.4-1. Reference labels are provided for cross referencing with that figure.

YEAR	MANAGEMENT MEASURE	REGION	DETAILS	PLOT REFERENCE
2001	LML Change	State-wide	LML increased from 210 mm TL to 230 mm TL	a
2005	Fleet reduction	State-wide	Voluntary buyback of net fishing licences in June 2005 that results in 44.7% reduction of net fishing effort.	b
2005	Spatial closure	SG & GSV/KI zones	Netting closures implemented in the southern gulfs in August 2005, restricting net fishing to the northern gulfs.	b
2012-2020	Seasonal closure	SG & GSV/KI zones	A spring closure in each gulf of 20 – 80 days depending on the year	c (commencement of closures annotated only)
2015	LML change	State-wide	LML increased from 230 mm TL to 250 mm TL for the commercial sector. The LML remained at 230 mm TL for the recreational sector	d
2015	Gear restriction	State-wide	Minimum mesh size of haul net pockets increased from 32 mm to 34 mm for standard knot meshes and from 34mm to 35 mm for knotless meshes	d
2016	Gear restriction	State-wide	Minimum mesh size of haul net pockets increased from 34 mm to 35 mm for standard knot meshes.	e
2016	Bag and bota limit	State-wide	Recreational bag and boat limit reduced from 60 and 180 fish, respectively, to 30 and 90 fish.	e
2017	Gear restriction	State-wide	Only knotted meshes were permitted for haul nets	f
2019	Gear restriction	State-wide	Minimum mesh size of haul net pockets increased from 35 mm to 36 mm.	g
2021/22	Fleet reduction	State-wide	Voluntary licence surrender program	h
2021/22	TACC	SG & GSV/KI zones	TACC management commenced	h
2021/22	Seasonal closure	SG & GSV/KI zones	Seasonal closures ceased following implementation of TACC	h
2021/22	LML change	State-wide	LML reduced to 230 mm TL for all sectors following implementation of TACC	h
2021/22	Gear restriction	WC & SE zones	Minimum mesh size of haul net pockets reduced from 36 mm to 32 mm. No change in gear restrictions for the GSV/KI and SG zones.	h

4.4.4. State-wide Fishery Statistics

The total commercial catch of Southern Garfish was 156 t in 2021/22 (*cf.* 182 t in 2020/21) (Figure 4.4-1). The 2021/22 season was lowest total catch on record and the seventh consecutive year with total catches below 200 t. Despite this record low catch, the gross value of production (GVP) of Southern Garfish in 2021/22 was approximately $2.1 M having increased by $455,000 over the past three years (Figure 4.4-1).

The haul net sector has accounted for ~90% of the State-wide harvest since 1983/84 (Figure 4.4-1). Annual catches in this sector varied between 482 t and 280 t from 1983/84 to 2002/03. However, catches have steadily declined since 2002/03, averaging 219 t since then. The haul net sector caught 141 t in 2021/22 which accounted for 90% of the state-wide commercial catch. The dab net sector accounts for most of the remaining commercial catch (~10%). This sector yielded higher than average catches throughout the 1990s (~64 t) compared to the last decade when catches rarely exceeded 30 t, and was 15 t in 2021/22 (Figure 4.4-1).

Total fishing effort (includes targeted effort and non-targeted effort that produced catches of Southern Garfish) for the haul net and dab net sectors has steadily declined from a peak of 18,227 fisher-days in 1983/84 to a low of 4,128 fisher-days in 2020/21 (Figure 4.4-1). This represents a 78% decrease over 39 years declining at a rate of 390 fisher-days.yr^{-1}. This decline can largely be attributed to a consistent reduction in haul net effort. Fishing effort has recently stabilised and maintained consistent levels of targeting. This trend was consistent for haul net and dab net gear sectors.

Total haul net CPUE remained relatively high from 2005/06 to 2013/14, averaging 50.5 kg.fisher-day^{-1} (Figure 4.4-1). Since 2013/14, the CPUE for total haul net effort has declined to 27.9 kg.fisher-day^{-1} in 2015/16 before increasing to 45.4 kg.fisher-day^{-1} in 2020/21. The CPUE was 36.5 kg.fisher-day^{-1} in 2021/22 (Figure 4.4-1). Dab net CPUE historically displayed a long-term increasing trend from 1983/84 to 2001/02, rising from 28.0 kg.fisher-day^{-1} in 1983/84 to a peak of 61.0 kg.fisher-day^{-1} in 2001/02 (Figure 4.4-1). This increase was not sustained as it dropped to 28.6 kg.fisher-day^{-1} in 2006/07. CPUE in the dab net sector since 2013/14 has ranged between 37 and 46 kg.fisher-day^{-1}. In 2021/22, dab net CPUE was 40.9 kg.fisher-day^{-1}.

Two management strategies have reduced the number of licence holders in South Australia's MSF. The first was the licence amalgamation scheme implemented in 1994, which has contributed significantly to the long-term decline in the number of commercial fishers who land Southern Garfish. The second was the 2005 net buy-back. These two strategies contributed to the 59% reduction in the number of commercial fishers landing Southern Garfish from 1995/96 to 2011/12 (Figure 4.4-1).

Most of the State-wide catch of Southern Garfish has historically been landed in the GSV/KI and SG fishing zones, predominantly in the northern gulfs (Figure 4.4-2). Catches from the WC, SSG and SGSV were considerably reduced from 2005 onwards as a result of the net buyback and subsequent netting closures in those regions. The relative proportion of commercial catches where Southern Garfish were nominated the target species was 61%. This has remained constant between the last five fishing seasons and in the seasons prior (Figure 4.4-2).

From 1983/84 to 1999/00, most Southern Garfish were landed during autumn (Figure 4.4-2). This was followed by two years during which high catches uncharacteristically peaked in mid-winter (July/August). Since then, overall monthly catches have declined considerably with most of the landings taken from January to August (Figure 4.4-2). These recent changes reflect the implementation of seasonal fishing closures in Spencer Gulf and Gulf St Vincent.

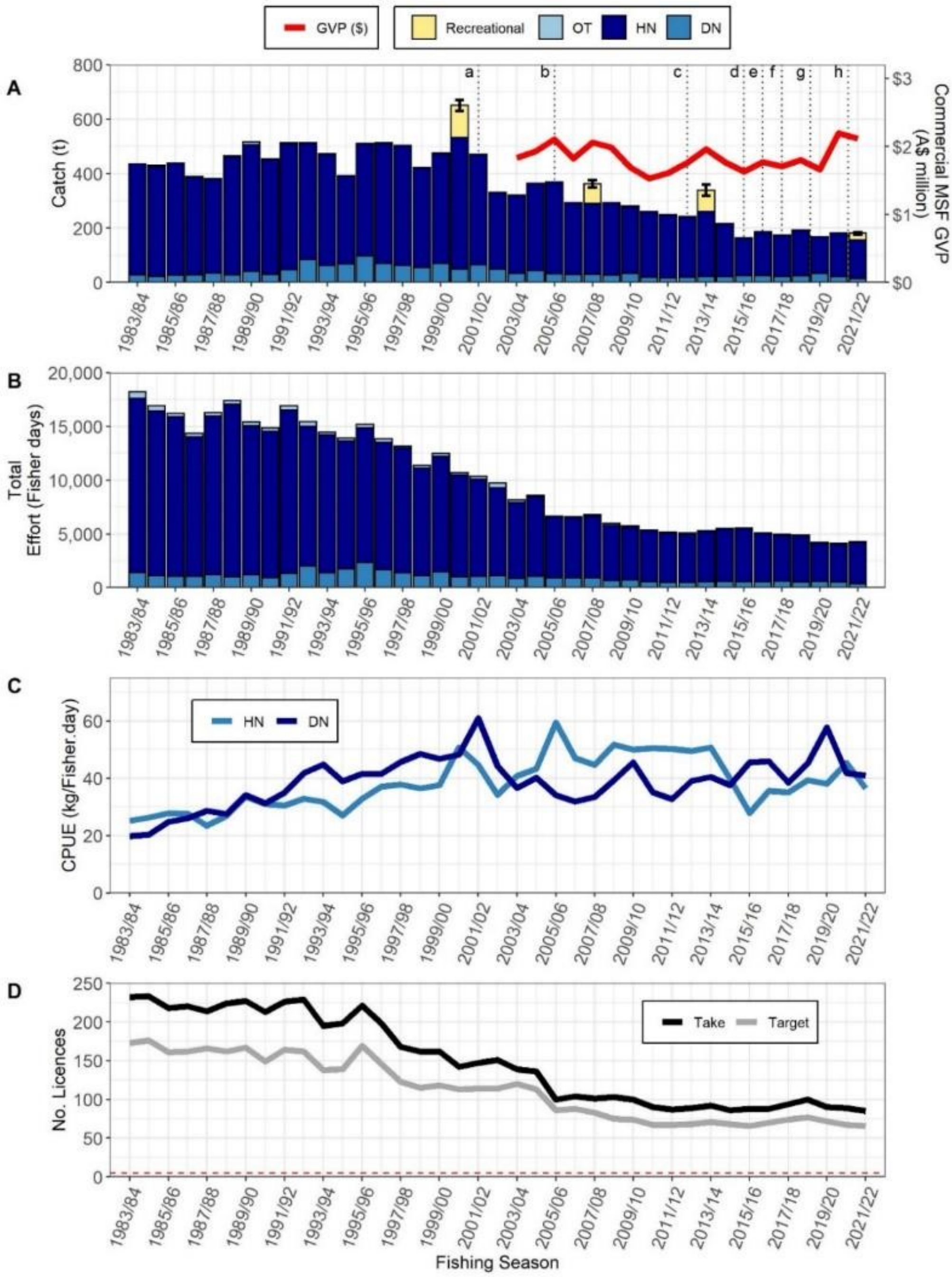


Figure 4.4-1. Long-term trends in State-wide estimates for Southern Garfish of (A) total catch for the main gear types (haul net, dab net), estimated recreational catch and gross production value; (B) Long-term total effort for haul nets and dab nets; (C) total CPUE for haul nets and dab nets; and (D) the number of active licence holders taking or targeting the species. Dotted lines on panel A represent significant management interventions which are detailed in Table 4.4-1 using their respective labels. Error bars on the recreational catch estimates (A) represent the standard error of those surveys.

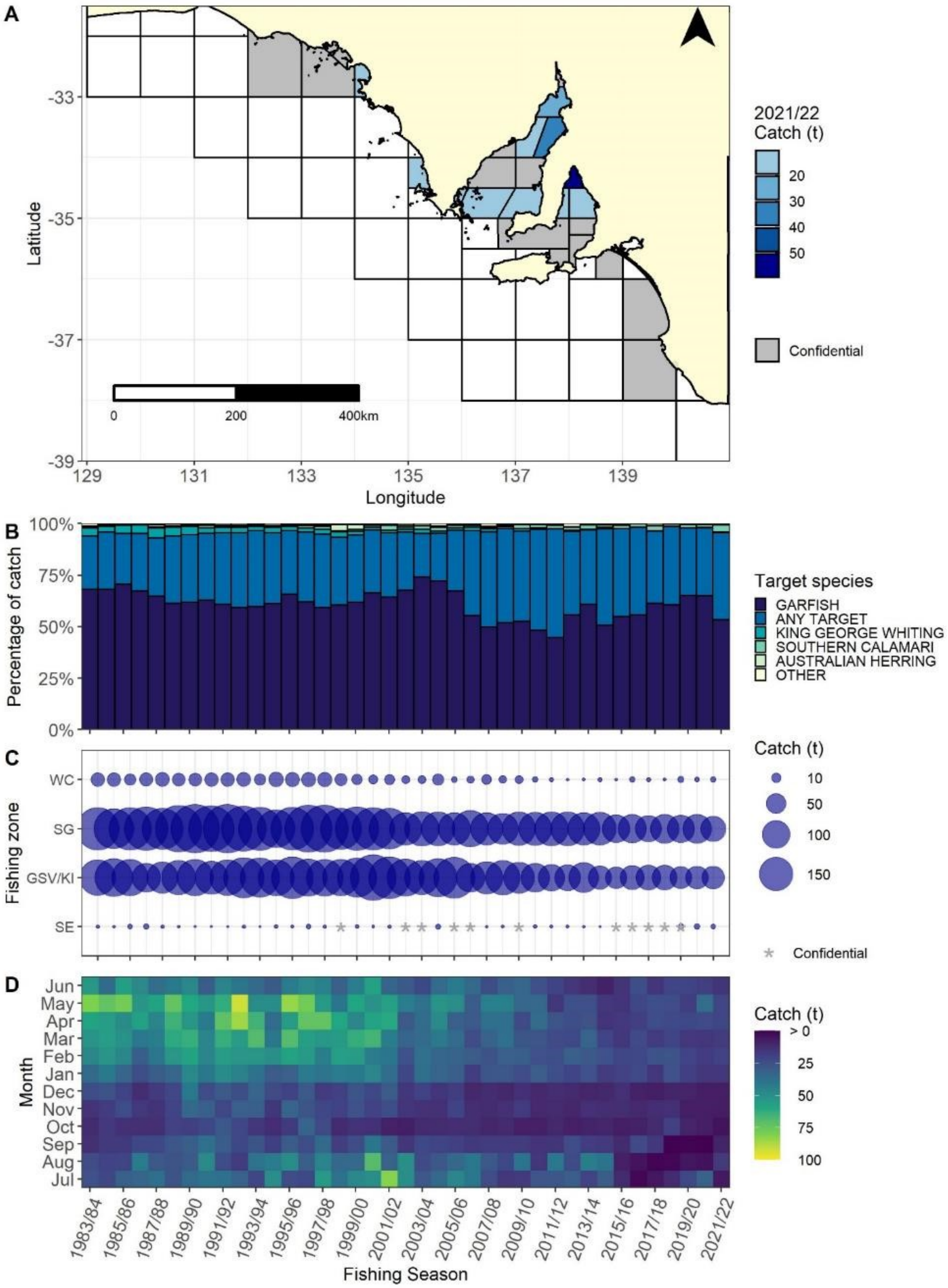


Figure 4.4-2. Regional dynamics of Southern Garfish: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among regions, (D) months of the year.

4.4.5. Fishery Performance Indicators and Sector Allocations

Commercial allocation trigger 3 was breached by the Southern Zone Rock Lobster Fishery (SZRL) in 2021/22 (Table 4.4-2). The catch percentage for the SZRL was 1.79% which exceeds the single year trigger of 1.00%. No other sectors breached their allocations.

Table 4.4-2. Results from consideration of commercial catches of Southern Garfish by fishery against their allocation percentages and trigger reference points. MSF = Marine Scalefish, NZRL = Northern Zone Rock Lobster and SZRL = Southern Zone Rock Lobster. No colour – allocation not exceeded. Trigger 2 (light blue) is breached if the respective sector allocation is breached for three consecutive years or in four of the previous five years. Trigger 3 is breached if the respective sector allocation is breached in any one year. The sector catch in tonnes is displayed with the State-wide catch percentage provided in parentheses.

COMMERCIAL ALLOCATION	MSF	SZRL	NZRLF
	99.79%	0.16%	0.05%
TRIGGER 2	-	0.75%	0.75%
TRIGGER 3	-	1.00%	1.00%
2017/18	174.01 (99.75 %)	0.44 (0.25 %)	0.00 (0 %)
2018/19	192.08 (99.97 %)	0.04 (0.02 %)	0.01 (0.01 %)
2019/20	167.45 (99.53 %)	0.80 (0.47 %)	0.00 (0 %)
2020/21	181.06 (99.62 %)	0.70 (0.38 %)	0.00 (0 %)
2021/22	154.62 (98.84 %)	1.79 (1.14 %)	0.02 (0.01 %)

Performance indicators for Southern Garfish include total catch, and targeted haul net effort and CPUE, and targeted dab net effort and CPUE. Performance indicators are applied at a sub-region level in order to better describe regional fishery dynamics, as per the management plan (PIRSA 2013). Eleven lower trigger reference points (LTRP) and one upper trigger reference points (UTRP) were triggered across the five spatial regions in 2021/22, in addition to one trigger for a five-year consecutive decrease for target dab net effort in SSG (Table 4.4-3).

Table 4.4-3. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the regional spatial scales for Southern Garfish in 2021/22. Lower trigger reference point (LTRP) breaches are indicated in light blue and upper trigger reference point (UTRP) breaches are indicated in blue. × indicates that no trigger has been breached. ✓ indicates that the trigger for five consecutive decreases has been triggered. Conf. identifies confidential data which prevents a PI from being assessed.

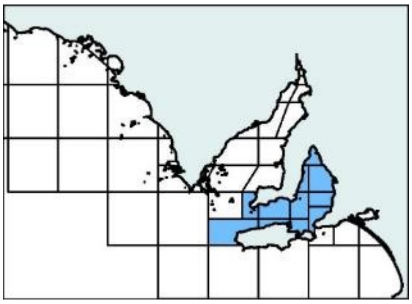
PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	WC	NSG	SSG	NSGV	SGSV
TOTAL CATCH	G	3rd Lowest/3rd Highest	×	LTRP	LTRP	×	LTRP
	G	Greatest % interannual change (+/-)	×	×	×	×	×
	G	Greatest five-year trend	×	×	×	×	×
	G	Decrease over five consecutive years	×	×	×	×	×
TARGET HAUL NET EFFORT	G	3rd Lowest/3rd Highest	Conf.	LTRP	Conf.	LTRP	Conf.
	G	Greatest % interannual change (+/-)	Conf.	×	Conf.	×	×
	G	Greatest five-year trend	Conf.	×	Conf.	×	Conf.
	G	Decrease over five consecutive years	×	×	×	×	Conf.
TARGET HAUL NET CPUE	G	3rd Lowest/3rd Highest	Conf.	×	Conf.	×	×
	G	Greatest % interannual change (+/-)	Conf.	×	Conf.	×	×
	G	Greatest five-year trend	Conf.	×	Conf.	×	Conf.
	G	Decrease over five consecutive years	×	×	×	×	Conf.
TARGET DAB NET EFFORT	G	3rd Lowest/3rd Highest	×	LTRP	LTRP	×	LTRP
	G	Greatest % interannual change (+/-)	×	×	×	×	×
	G	Greatest five-year trend	×	×	×	×	×
	G	Decrease over five consecutive years	×	×	✓	×	×
TARGET DAB NET CPUE	G	3rd Lowest/3rd Highest	×	LTRP	×	×	×
	G	Greatest % interannual change (+/-)	×	×	×	×	UTRP
	G	Greatest five-year trend	×	×	×	×	×
	G	Decrease over five consecutive years	×	×	×	×	×

4.4.6. Gulf St Vincent/Kangaroo Island Fishing Zone

Stock summary

Southern Garfish

Gulf St Vincent Fishing Zone



Stock status	2019 - Depleted	2020 - Recovering	**2021/22 - Recovering**
Fishery/stock trend	Southern Garfish catches in the GSV/KI zone are dominated by the haul net sector which accounts for ~90% of the annual catch. Management measures aimed to reduce effort has resulted in the recovery of the fishery demonstrable increases to biomass in recent assessments.		

Commercial catch statistics and TACC

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target HN CPUE *kg/fisher-day*	TACC *t*
2017/18	81	2,068	53.5	-
2018/19	81	2,077	49.9	-
2019/20	62	1,682	44.0	-
2020/21	67	1,593	60.6	-
2021/22	68	1,721	65.5	71

Stock Status Summary	A recovering status was assigned in the 2020 stock assessment as biomass had increased to above the LTRP and harvest fractions had been reduced through on-going management. However, there remained signs of recruitment impairment which prevented a sustainable stock status from being considered. The fishery statistics for the 2021/22 do not indicate any issues with the stock that may have arisen since the last full stock assessment. Therefore, a recovering status has been maintained. This will be re-evaluated during the next full stock assessment which is scheduled for the 2022/23 assessment report.

4.4.6.1. Catch Statistics

The total catch of Southern Garfish in the GSV/KI fishing zone was 68 t in 2021/22, constituting 96% of the TACC (Figure 4.4-3). This level of catch was comparable to the previous two fishing seasons which had relatively stable catch and effort. The total effort was 1,721 fisher days in 2021/22 which was an increase from 1,593 in 2020/21. The haul net sector accounted for 63 t of Southern Garfish catch (93% of the total catch) with the dab net sector catching 5 t in 2021/22. This dab net catch was the lowest on record, matching a record low total effort of 108 fisher days in 2021/22. This was likely driven by haul net licence holders holding most of the GSV/KI Southern Garfish quota and a likely reduction in dab net fishing through the fleet rationalisation that occurred through the fishery reform (Smart et al. 2022a). Twenty-six licences caught and targeted Southern Garfish in the GSV/KI fishing zone during 2021/22 which was the lowest on record (Figure 4.4-3). The recreational catch in 2021/22 was 9 t (Beckmann et al. 2023).

Northern Gulf St Vincent (NGSV) is the second-most productive commercial fishing region in South Australia for Southern Garfish and catches are dominated by the haul net sector. Annual catches peaked a 241 t in 2000/01 and have been above 150 t in seven out of 39 years, before declining to a record low of 46 t in 2019/20. The total catch in 2021/22 was 61 t which was the fifth lowest on record (Figure 4.4-3). There was a strong relationship between haul net CPUE based on kg.fisher-day^{-1} and haul net CPUE based on kg.haul^{-1} since 2003/04 when units of effort have been reported in logbooks (Figure 4.4-3). In 2021/22, the CPUE was 109.7 kg.haul^{-1} which was third highest on record. Similarly, the CPUE based on fisher day was 65.5 kg.fisher-day^{-1} which was the third highest since 2003/04.

Southern Gulf St Vincent (SGSV) is dominated by the dab net sector due to spatial restrictions around haul net fishing. Since 2005, negligible catches have occurred from the haul net sector and these records are now confidential in most years (Figure 4.4-3). Total catches in SGSV are far lower than NGSV and have averaged 4 t over the previous ten fishing seasons. This matches the low levels of effort in this region (Figure 4.4-3). In the 2021/22 season the total dab net catch of Southern Garfish from SGSV was 1 t while targeted effort and CPUE were both confidential.

4.4.6.2. Stock Status

These fishery statistics do not indicate any stock declines in the fishery in 2021/22. Despite the fleet rationalisation and unitisation that occurred through the 2021 fishery reform, catch and effort has been stable and the TACC was almost caught, which did not occur for many other Tier 1 MSF stocks. In the 2020 stock assessment, Southern Garfish was treated as two separate stocks for NGSV and SGSV (Smart et al. 2022b). With the implementation of the new zones of management following the MSF reform, these stocks have been combined in this assessment while describing fishery dynamics at a sub-region scale. The stock status of NGSV has been applied at the zone level, given its dominance both in terms of biomass and fishery production (Smart et al. 2022b). The previous Southern Garfish assessment assigned a recovering status to NGSV based on model-based outputs that also considered fishery and biological data from the SGSV stock. This status was assigned as harvest fractions had been reduced through effective fisheries management and biomass had increased to above the LTRP for the first time since 2009 (Smart et al. 2022b). Despite these positive signs, recruitment remained low and possibly impaired; leading to a stock status of ‘recovering’ being assigned. Given that the current assessment has only considered updated catch and effort statistics, this status has been maintained for 2021/22. The next opportunity to reconsider the stock status of

Southern Garfish for GSV/KI will be the next full stock assessment that is scheduled for 2022/23. As such, the GSV/KI stock remains classified as **recovering.**

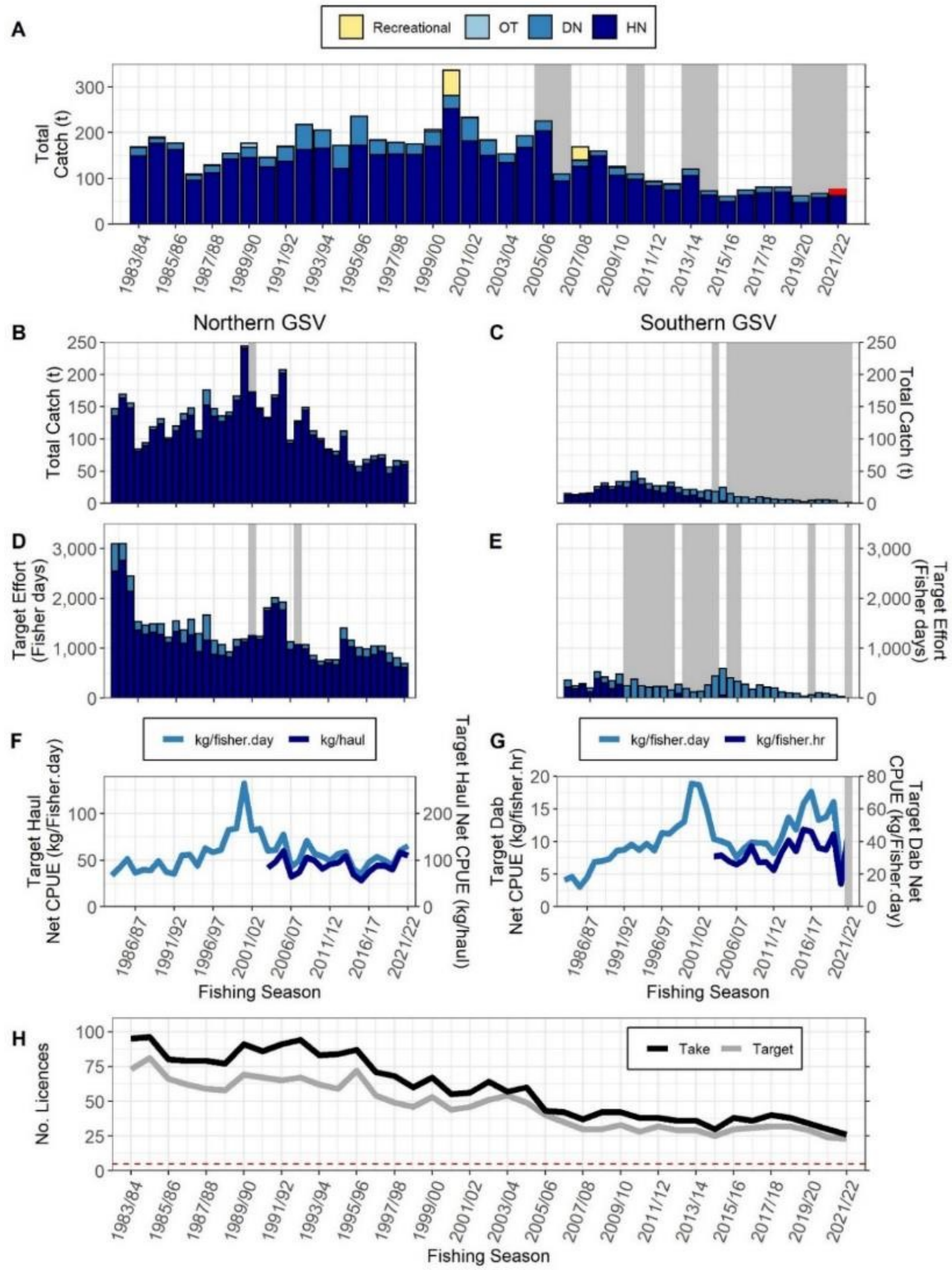


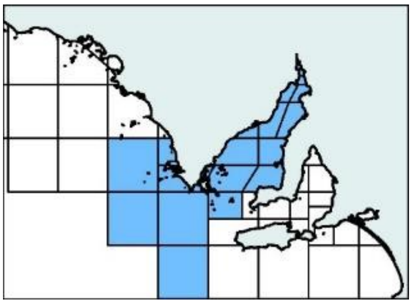
Figure 4.4-3. Key fishery statistics used to inform the status of Southern Garfish in the GSV/KI fishing zone. Long-term trends in (A) total catch by gear and sector; targeted haul net catch in NGSV (B) and targeted dab net catch in SGSV (C); targeted haul net effort in NGSV (D) and targeted dab net effort in SGSV (E); targeted haul net CPUE by fisher day and number of hauls in NGSV (F) targeted dab net CPUE by fisher day and fisher hours in SGSV(G); and (H) the number of active licences taking and targeting the species. Error bars on the 2021/22 recreational catch estimate (A) represent the standard error from that survey. The red line indicates the 2021/22 TACC. A red dashed line in panel H represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on the panel.

4.4.7. Spencer Gulf Fishing Zone

Stock summary

Southern Garfish

Spencer Gulf Fishing Zone



Stock status	2019 - Recovering	2020 - Recovering	**2021/22 - Recovering**
Fishery/stock trend	Southern Garfish catches in the SG fishing zone are dominated by the haul net sector which accounts for ~95% of the annual catch. Management measures aimed to reduce effort have resulted in the recovery of the fishery with biomass within the TRPs for the fishery. There was a TACC under catch of 16 t in 2021/22 which is interpreted as a consequence of the recent fishery reform.		

Commercial catch statistics and TACC

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target HN CPUE *kg/fisher-day*	TACC *t*
2017/18	91	2,804	51.6	-
2018/19	110	2,727	66.3	-
2019/20	99	2,317	84.9	-
2020/21	109	2,379	82.7	-
2021/22	84	2,413	65.7	100
Stock Status Summary	A recovering status was assigned in the 2020 stock assessment as harvest fractions had been reduced through effective fisheries management and biomass was stable and within the limit reference points. However, their remained signs of recruitment impairment which prevented a sustainable stock status from being considered. The fishery statistics for the 2021/22 do not indicate any issues with the stock that may have arisen since the last full stock assessment. Therefore, a recovering status has been maintained. This will be re-evaluated during the next full stock assessment which is scheduled for the 2022/23 assessment report.			

4.4.7.1. Catch Statistics

The total catch of Southern Garfish in the SG fishing zone was 84 t in 2021/22, representing an under catch of 16 t of the TACC (Figure 4.4-4). This was the lowest catch on record for this zone while total effort and number of licences were the third and fourth lowest, respectively (Figure 4.4-4). The total effort was 2,413 fisher days in 2021/22 which was a small increase from 2,379 in 2020/21. The haul net sector accounted for 78 t of Southern Garfish catch (94% of the total catch) with the dab net sector catching 5 t in 2021/22. This dab net catch was the lowest on record, matching a record low total effort of 130 fisher days in 2021/22. Fifty licences caught and targeted Southern Garfish in the SG fishing zone during 2021/22 which was the fourth lowest on record (Figure 4.4-4). The recreational catch in 2021/22 was 12 t (Beckmann et al. 2023).

Northern Spencer Gulf (NSG) has been the most productive region for Southern Garfish in South Australia since 1983/84. The highest recorded catch was 252 t in 1989/90 although catches in excess of 200 t have not occurred since 1997/98. Catch declined rapidly (by 61%) from 215 t in 1997/98 to 109 t in 2002/03. Annual catches have exceeded 140 t three times since 2002/03 and remained relatively stable between 145 and 128 t from 2011/12 to 2014/15, before decreasing to and stabilising at ~90 t over the past eight years.

There has been a long-term trend of decreasing fishing effort in NSG, from a peak of 3,477 targeted fisher-days in 1991/92 to 412 fisher-days in 2014/15. This trend has been driven by the haul net sector, which has consistently contributed > 95% of the fishing effort (Figure 4.4-4). Targeted CPUE for haul net fishers trended upwards from 51.5 kg.fisher-day^{-1} in 2003/04 to 123.9 kg.fisher-day^{-1} in 2012/13, representing a 240% increase over nine years (Figure 4.4-4). CPUE subsequently fell from 118.9 kg.fisher-day^{-1} in 2014/15 to 51.6 kg.fisher-day^{-1} in 2017/18 (Figure 4.4-4). However, CPUE has since increased and has been oscillating between ~65 - 85 kg.fisher-day^{-1} since then. Since 2003/04, when units of effort have been reported in logbooks, CPUE in kg.fisher-day^{-1} and kg.haul^{-1} have followed the same trend and CPUE was 84.2 kg.haul^{-1} in 2021/22. Few dab net fishers (< 13) have historically targeted Southern Garfish in this region each year and in 2021/22 the catch and effort was confidential.

Large areas of Southern Spencer Gulf have been closed to commercial haul net fishing since 2005, and as a result, the relative contribution of this region to the State-wide catch has been < 18% since 2005/06. Approximately half of the haul net fishers who operated in this region specifically targeted Southern Garfish and the peak total catch was 58 t in 1997/98. However, haul net effort has been reduced through spatial restrictions imposed in 2005, and now this region is almost exclusively fished by the dab net sector. Total catch of Southern Garfish in this region ranged between 9 and 12 t in the past 5 years and was 6 t in 2021/22 (*c.f.* 9 t in 2020/21) (Figure 4.4-4). Targeted dab net effort was the lowest on record in 2021/22 at 115 fisher days while targeted dab net CPUE was 40.7 kg kg.fisher-day^{-1} (Figure 4.4-4). CPUE by number of fisher hours has had a similar trend to CPUE by fisher day, but has been more stable in recent years. In 2021/22 the CPUE was 9.4 kg.fisher-hr^{1} which was the fourth highest on record.

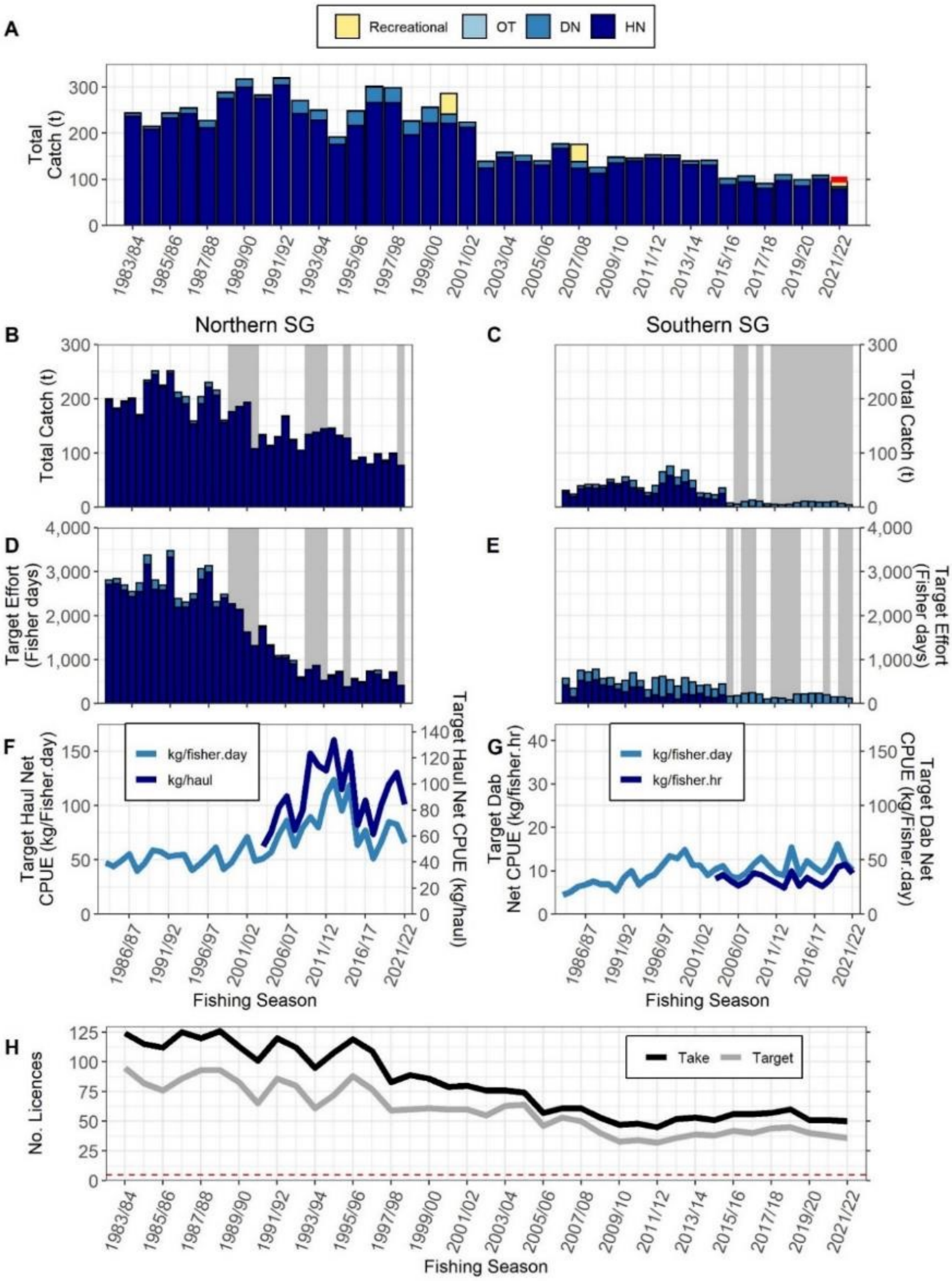


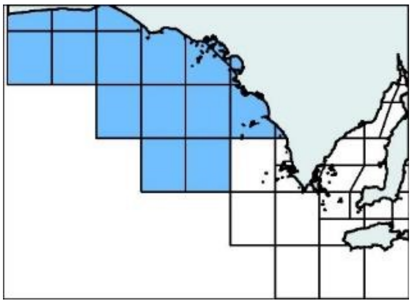
Figure 4.4-4. Key fishery statistics used to inform the status of Southern Garfish in the SG fishing zone. Long-term trends in (A) total catch by gear and sector; targeted haul net catch in NSG (B) and targeted dab net catch in SSG (C); targeted haul net effort in NSG (D) and targeted dab net effort in SSG (E); targeted haul net CPUE by fisher day and number of hauls in NSG (F) targeted dab net CPUE by fisher day and fisher hours in SSG(G); and (H) the number of active licences taking and targeting the species. Error bars on the 2021/22 recreational catch estimate (A) represent the standard error from that survey. The red line indicates the 2021/22 TACC. A ed dashed line in panel H represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on the panel.

4.4.7.2. Stock Status

These fishery statistics do not indicate any stock declines in the fishery in 2021/22. Reduced catches and effort are the result of fleet rationalisation and the unitisation that occurred through recent fishery reform. Catches that are lower than the TACC are common in newly unitised fisheries as fishers become familiar with trading ITQs and the additional reporting requirements that occur with unitisation. In the 2020 stock assessment, Southern Garfish was treated as two separate stocks for NSG and SSG (Smart et al. 2022b). With the implementation of the new zones of management following the MSF reform, these stocks have been combined in this assessment while describing fishery dynamics at a sub-region scale. The stock status of NSG has been applied at the zone level, given its dominance both in terms of biomass and fishery production (Smart et al. 2022b). The previous Southern Garfish assessment assigned a recovering status to NSG based on model-based outputs that also considered fishery and biological data from the SSG stock. This status was assigned as harvest fractions had been reduced through effective fisheries management and biomass was stable and within the limit reference points (Smart et al. 2022b). Despite these positive signs, recruitment remained low and possibly impaired; leading to a status of ‘recovering’ being retained. Given that the current assessment has only considered updated catch and effort statistics, this status has been maintained for 2021/22. The next opportunity to reconsider the stock status of Southern Garfish for SG will be the next full stock assessment that is scheduled for 2022/23. As such, the SG stock remains classified as **recovering.**

4.4.8. West Coast Fishing Zone

Stock summary			
Southern Garfish *West Coast Fishing Zone*			
Stock status	2019 - Sustainable	2020 - Sustainable	**2021/22 - Sustainable**
Fishery/stock trend	Southern Garfish fishing is limited in the WC fishing zone due to broad spatial netting closures which limits the haul net sector. Annual catches of Southern Garfish in the WC fishing zone have typically been less than 5 t since the 2005 net licence buy back scheme.		



Commercial catch statistics			
Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target DN CPUE *kg/fisher-day*
2017/18	2	42	*Confidential*
2018/19	1	42	*Confidential*
2019/20	4	116	67.6
2020/21	2	76	33.4
2021/22	3	95	37.9
Stock Status Summary	Southern Garfish catches in the WC fishing zone have been decreasing with time and have become negligible. Catches have not been above 5 t since 2009/10 which has been driven by changes in the fishery through netting restrictions and fleet rationalisation since 2005. However, reduced catches are the result of changing fishery dynamics rather than stock declines and targeted fishing for Southern Garfish still occurs despite low levels of catch. Therefore, the stock status classification of sustainable was retained.		

4.4.8.1. Catch Statistics

The total catch of Southern Garfish from the WC fishing zone was 3 t for 2021/22 which corresponds to 2% of the State-wide catch. Catches for the WC fishing zone have always been substantially lower than that of the gulfs. However, catches have declined over time due to a continuous reduction in haul net effort through the implementation of commercial netting restrictions (Figure 4.4-5). Annual Southern Garfish catch peaked at 27 t in 1994/95, of which the haul net sector landed 94% (Figure4.4-5). Catches have been below 5 t since 2009/10 and fell to the lowest recorded level of 0.7 t in 2012/13.

Targeted fishing effort across all gears has declined by 90% since 1983/84, with fishers spending 95 days targeting Southern Garfish in 2021/22. Dab nets emerged as the dominant gear type in 2007/08, although targeted catch has declined substantially since then to < 1 t in most years. In 2021/22, the targeted dab net catch increased to 2.6 (Figure 4.4-5). The recreational catch in 2021/22 was 1 t (Beckmann et al. 2023). Targeted CPUE for 2021/22 was 37.9 $kg.fisher\text{-}day^{-1}$ and 5.8 kg.fisher.hr\` (Figure 4.4-5) which are difficult to put into context due to several preceeding years of confidential data.

4.4.8.2. Stock Status

These fishery statistics demonstrate that Southern Garfish fishing in the WC fishing zone is decreasing with time and catches are negligible. Catches have not been above 5 t since 2009/10 which has been driven by changes in the fishery through netting restrictions and fleet rationalisation since 2005. There are no sustainability concerns for this stock and catches have remained low and stable. Such evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current catch level is unlikely to cause the stock to become recruitment impaired. On this basis, Southern Garfish in the WC fishing zone is classified as a **sustainable** stock.

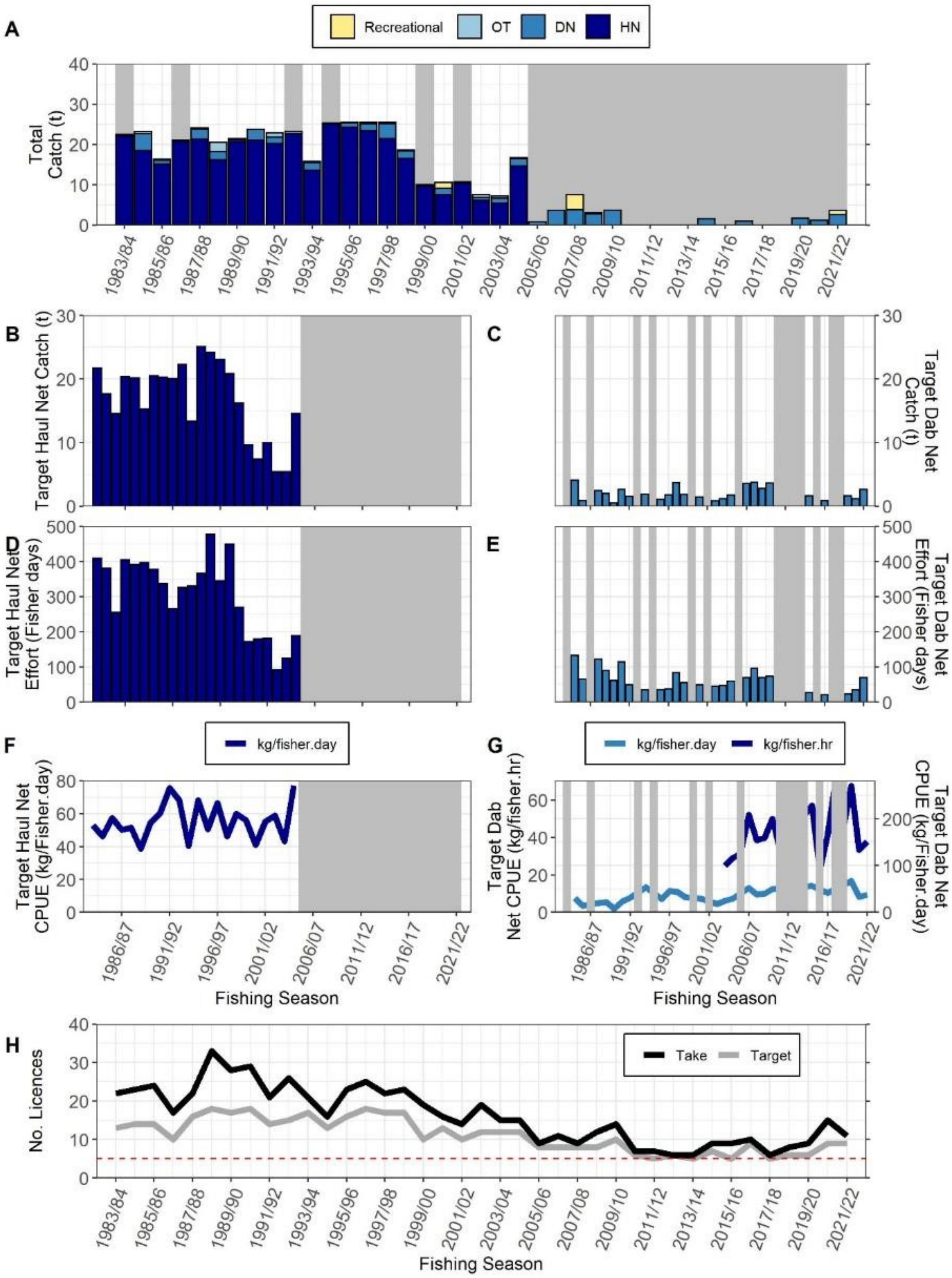


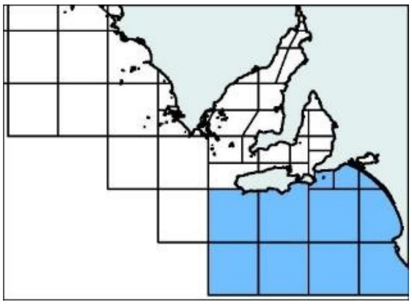
Figure 4.4-5. Key fishery statistics used to inform the status of Southern Garfish in the WC fishing zone. Long-term trends in (A) total catch by gear and sector; targeted haul net catch (B) and targeted dab net catch (C); targeted haul net effort (D) and targeted dab net effort (E); targeted haul net CPUE by fisher day (F) targeted dab net CPUE by fisher day and fisher hours (G); and (H) the number of active licences taking and targeting the species. Error bars on the 2021/22 recreational catch estimate (A) represent the standard error from that survey. A red dashed line in panel H represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on the panel.

4.4.9. South East Fishing Zone

Stock summary

Southern Garfish

South East Fishing Zone



Stock status	2019 - Sustainable	2020 – Sustainable	**2021/22 - Sustainable**
Fishery/stock trend	The highest commercial catch on record was 3t in 2020/21 with commercial statistics being confidential in many fishing seasons. Dab nets account for most of the effort in the South East fishing zone.		

Commercial catch

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target DN CPUE *kg/fisher-day*
2017/18	*Confidential*	*Confidential*	*Confidential*
2018/19	*Confidential*	*Confidential*	*Confidential*
2019/20	*Confidential*	*Confidential*	*Confidential*
2020/21	3	80	41.0
2021/22	2	59	37.2
Stock Status Summary	Negligible amounts of catch occur in the SE fishing zone and the limited amount of fishing effort prevents data from being presented in most fishing seasons due to confidentiality. There have never been any indications of overfishing that could have caused the stock decline or recruitment impairment to occur. Therefore, the stock status classification of sustainable was retained.		

4.4.9.1. Catch Statistics

The total catch of Southern Garfish from the SE fishing zone was 2 t for 2021/22 which corresponds to 1% of the State-wide catch (Figure 4.4-6). Catches for the SE fishing zone have always been substantially lower than that of the gulfs. The dominant gear type is dab nets which accounts for > 99% of the catch across years. Recreational catch estimates for all surveys are uncertain given the low number of households that reported catching Southern Garfish in the SE fishing zone. Therefore, these results are not presented.

4.4.9.2. Stock Status

There are no sustainability concerns for this stock and catches have remained low and stable. Such evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current catch level is unlikely to cause the stock to become recruitment impaired. On this basis, Southern Garfish in the SE fishing zone is classified as a **sustainable** stock.

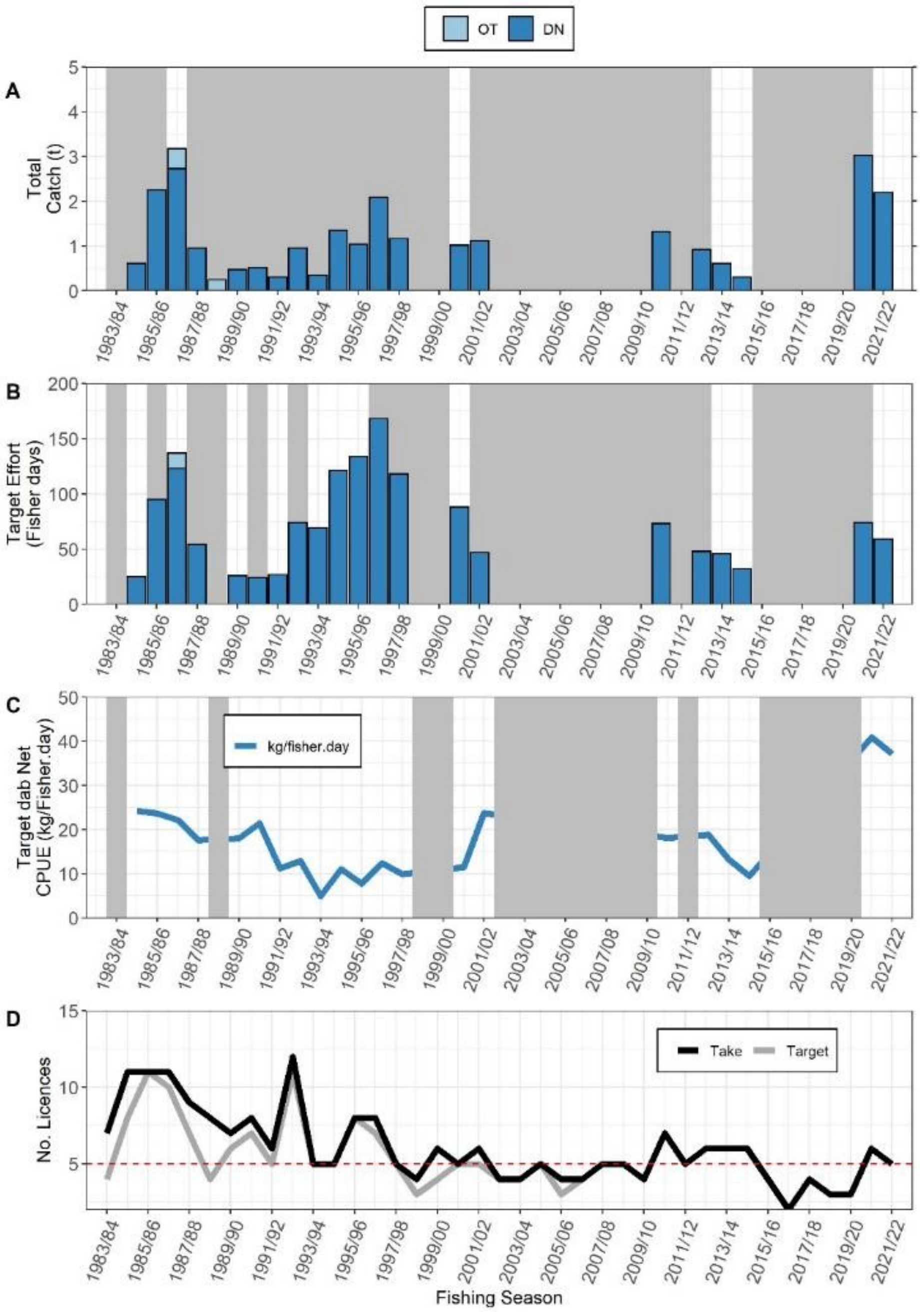


Figure 4.4-6. Key fishery statistics used to inform the status of Southern Garfish in the SE fishing zone. Long-term trends in (A) total catch by gear and sector; targeted dab net effort (B) and targeted dab net CPUE (C); and (D) the number of active licences taking and targeting the species. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on the panel.

4.5. Southern Calamari

Species summary

Southern Calamari

Sepioteuthis australis

Stock status (Fishing Zone)	Gulf St Vincent/ Kangaroo Island Fishing Zone	Spencer Gulf Fishing Zone	West Coast Fishing Zone	South East Fishing Zone
	Sustainable	**Sustainable**	**Sustainable**	**Negligible**

Species Tier	**Tier 1 species in GSV/KI and SG fishing zones. Tier 3 in WC and SE fishing zones.**
Species description	Southern Calamari are endemic to southern Australia and New Zealand waters. It has rapid growth and a sub-annual life-span. Adults and juveniles are found in shallow inshore waters while sub-adults are found in offshore areas to depths of <70 m. A single biological stock exists across southern Australia although population dynamics can occur at finer, regional scales.
Fishery description	Southern Calamari are caught predominantly in the gulf zones, as well as the WC fishing zone where catches have been lower. Squid Jigs are the dominant gear types in all zones. State-wide catch and CPUE have been increasing through time as Southern Calamari have achieved higher market prices and therefore fishers have transitioned away from catching Southern Calamari for bait. All three prawn fisheries have specified allocations with Southern Calamari being caught as by-product.
Current assessment program	• No formal stock assessment. • Annual commercial fishery statistics provided through a stock status summary. • Recreational data collected every five to seven years through State-wide recreational survey. • No information is available for Aboriginal/Traditional fishing.

Commercial fishery statistics (State-wide)			Recreational Catch			
Fishing Season	**Total MSF catch** *t*	**Total commercial effort** *Fisher-days*	Survey	**Estimated catch** *t (± SE)*	**Retained** %	**Released** %
2017/18	422	14,894				
2018/19	322	13,639	2000/01	386 (88)	99%	1%
2019/20	349	13,647	2007/08	206 (28)	98%	2%
2020/21	350	12,663	2013/14	155 (36)	99%	1%
2021/22	278	10,882	2021/22	220 (28)	96%	4%

4.5.1. Biology

Southern Calamari (*Sepioteuthis australis*) is endemic to southern Australian and northern New Zealand waters. In southern Australia, it ranges from Dampier in Western Australia to Moreton Bay in Queensland, including Tasmania.

The life-history of Southern Calamari is characterised by rapid growth and a sub-annual life-span (Jackson 2004). In South Australia, adults and juveniles are predominantly found in shallow, inshore waters. Offshore waters to depths <70 m tend to be occupied by sub-adults (Winstanley et al. 1983). The patterns of distribution and abundance of adult Southern Calamari in South Australia's gulfs tends to be seasonal and consistent amongst years (Triantafillos 2001). Adult abundance typically increases for six months to a peak and declines for the remainder of the year. Timing of these peaks varies among regions and follows an anti-clockwise progression around the gulfs. This cycle starts in the south-east during late spring and concludes along the western coasts during late winter. Seasonal patterns in water clarity, associated with the prevailing cross-offshore winds, appear to drive this progression as Southern Calamari spawn in shallow seagrass habitats found along protected leeward shores (Triantafillos 2001, Steer et al. 2007). Spawning occurs throughout the year and recruitment to the fishery is continuous.

The biological stock structure across the distribution of Southern Calamari is complex and potentially dynamic. One study used allozyme markers to identify three genetic types with overlapping distributions and possible stocks off Western Australia, South Australia, New South Wales and Tasmania (data are not available for Victoria) (Triantafillos 2004). In contrast, another study using microsatellite markers found little genetic differentiation between seven study sites in Western Australia, South Australia, Victoria and Tasmania (Smith et al. 2015). It also identified Tasmania as a possible important site for gene-flow. Life history dynamics, and studies of movement and statolith microchemistry in Tasmania also suggest some localised biological stock structuring (Pecl et al. 2011).

For the purpose of this assessment South Australia's Southern Calamari is considered to be a component of the southern Australian biological stock but with regional dynamics occurring within each MSF fishing zone. Zonal stocks therefore represent management units rather than distinct biological stocks.

4.5.2. Fishery

In South Australia, the Southern Calamari resource is shared by multiple sectors. Adult Southern Calamari are targeted by commercial MSF fishers, charter fishery clients, and recreational fishers on the inshore spawning grounds, while juveniles and sub-adults are incidentally caught by commercial prawn trawlers operating in the deeper (>10 m), offshore, gulf waters. The commercial prawn trawling fleet are permitted to retain and sell Southern Calamari as by-product.

Recreational fishers target Southern Calamari from jetties, breakwaters and rocky shorelines. Most of the catch is landed by handlines and rods and reels using squid jigs. Commercial fishers also mostly use these jigs, but are also licenced to use haul nets, set nets and dab nets.

Daily boat and bag limits apply to the recreational sector. In 2021/22, this sector took an estimated 550,179 Southern Calamari, equating to an estimated catch of 220 t (Beckmann et al. 2023).

4.5.3. Management Regulations

As far back as 1992, there were fishery management concerns about the increasing popularity of Southern Calamari fishing by both recreational and commercial fishers and the potential vulnerability of the spawning stocks (Australia 1992). These concerns resulted in the implementation of recreational bag and boat limits in 1995 (i.e., 15 per bag and a maximum of 45 per boat per day with 3 people onboard) and have remained unchanged. Currently, input controls such as spatial and temporal closures and gear restrictions (minimum mesh size 30 mm and lengths 600 m) apply to the net sector; however, these are generic measures rather than being specific to Southern Calamari. Restrictions currently prevent netting in all metropolitan waters and in waters >5m deep, as well as in numerous bays and marine protected areas. The jigging sector dominates the Southern Calamari fishery and is permitted in most State waters, with the exception of several aquatic reserves. In 2004, a full-time cephalopod fishing closure was implemented in False Bay, northern Spencer Gulf, to protect the annual spawning aggregation of the Giant Australian Cuttlefish (*Sepia apama*). It is not known whether this spatial closure also provides some regional protection for spawning Southern Calamari. A TACC has been implemented in the SG and GSV/KI fishing zones since 2021/22.

4.5.4. State-wide Fishery Statistics

Total State-wide commercial catch of Southern Calamari inclusive of the prawn fisheries by-product was 322 t in 2021/22 while the recreational catch was 220 t (Beckmann et al. 2023). The total MSF catch of Southern Calamari catch was 278 t ranking it the second highest among MSF species in 2021/22. However, this also represented the lowest State-wide catch since the 1989/90 fishing season (Figure 4.5-1). This decline in catch was matched by an overall decline in effort and the number of fishers in 2021/22 which were both the lowest on record. The number of licences targeting Southern Calamari was 149 and the number of fisher days were 10,882 in 2021/22 (Figure 4.5-1). Long term trends in CPUE have been stable, increasing slightly through time, for both squid jig and haul net gears and were 30.9 kg.fisher-day^{-1} and 16.0 kg.fisher-day^{-1} in 2021/22, respectively (Figure 4.5-1). Increasing beach prices over the past 20 years has led to a fishery GVP of $5.8 M in 2021/22, making Southern Calamari the most economically important species in the fishery.

Southern Calamari is taken as by-product in all three South Australian commercial prawn fisheries and has consistently accounted for <10% of total State-wide catches since it was first reported in 2003/04 until 2019/20. It has increased over time and peaked at 13.6% in 2021/22. Though, it is important to note that prawn fishery catches have remained constant at ~45 t over the past two fishing seasons while the commensurate MSF catch has decreased by 20% in that same period.

Prior to 1991/92, the jig and haul net sectors of the MSF contributed equally to annual catches. Since then, jigs have become the preferred gear type and have generally accounted for 70–80% of the annual catch. In 2021/22 79% of the catch was taken by squid jigs and 21% was caught using haul nets.

Although, Southern Calamari are caught throughout the year, catches tend to peak during late spring and late autumn (Figure 4.5-2). Southern Calamari is caught throughout the State with the majority landed within the gulfs, particularly around Yorke Peninsula (Figure 4.5-2). Catches in the WC fishing zone have averaged ~15t over the history of the fishery. Negligible amounts of catch occur in the SE fishing zone and therefore this stock is not assessed given that much of the data is confidential. A negligible status is therefore assigned for Southern Calamari in the SE fishing zone.

Over the past five fishing seasons, 88% of the State-wide Southern Calamari catch was targeted with the majority of remaining catches reported as ‘Any target species’ (Figure 4.5-2). The percentage of Southern Calamari targeted in the MSF was 74% prior to the 2017/18 fishing season, indicating that increased targeting has been occurring in recent years.

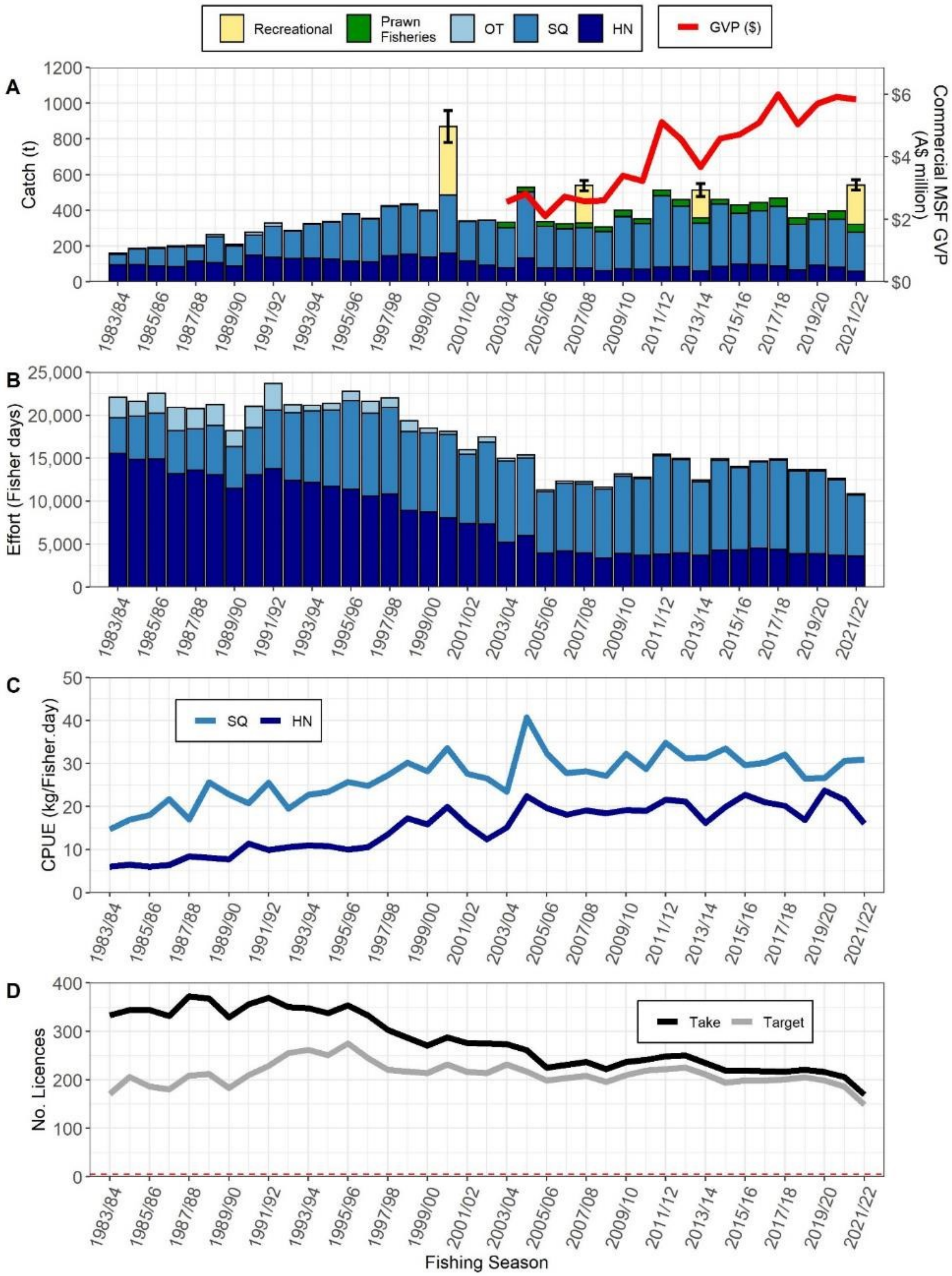


Figure 4.5-1. Long-term trends in State-wide estimates for Southern Calamari of (A) total catch for the main gear types (squid jig, haul net, prawn by-product), estimated recreational catch and gross production value; (B) Long-term total effort for squid jigs and haul nets; (C) total CPUE for squid jigs and haul nets; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys.

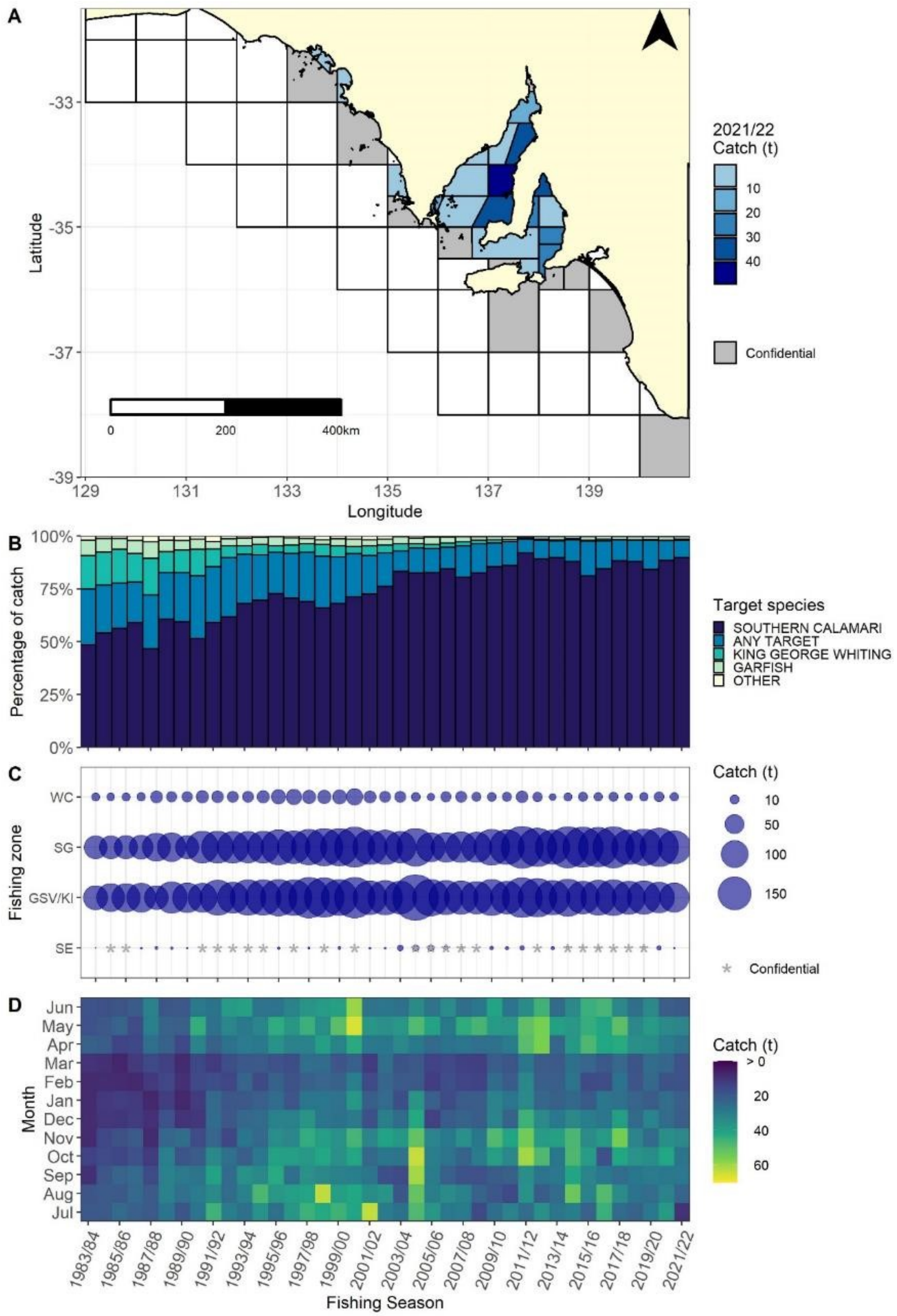


Figure 4.5-2. Regional dynamics of Southern Calamari: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among regions, (D) months of the year.

4.5.5. Fishery Performance Indicators

Commercial allocation triggers 2 and 3 were breached by the Spencer Gulf Prawn Fishery (SGPF) in 2021/22 (Table 4.5-1). The catch percentage for the SGPF was 12.21% which exceeds the single year trigger 3 of 11.2%. Additionally, the multi-year trigger 2 of 8.2% was triggered in four of the previous five years. No other sectors breached their allocations.

Table 4.5-1. Commercial catches of Southern Calamari by fishery against their allocation percentages and trigger reference points. MSF = Marine Scalefish, NZRL = Northern Zone Rock Lobster, SZRL = Southern Zone Rock Lobster, GSVPF = Gulf St Vincent Prawn Fishery; SGPF = Spencer Gulf Prawn Fishery; WCPF = West Coast Prawn Fishery. No colour – allocation not exceeded. Trigger 2 (light blue) is breached if the respective sector allocation is breached for three consecutive years or in four of the previous five years. Trigger 3 is breached if the respective sector allocation is breached in any one year. The higher of the two triggers is highlighted. The sector catch in tonnes is displayed with the State-wide catch percentage provided in parentheses.

COMMERCIAL ALLOCATION	MSF	SZRL	NZRLF	GSVPF	SGPF	WCPF
	90.91%	n/a	0.73%	0.73%	7.47%	0.16%
TRIGGER 2	92.70%	-	1.46%	1.46%	8.20%	0.75%
TRIGGER 3	95.40%	-	2.19%	2.19%	11.20%	1.00%
2017/18	421.9 t (90.23 %)	-	0.5 t (0.11 %)	4.2 t (0.90 %)	40.2 t (8.60 %)	Conf.
2018/19	321.7 t (90.01 %)	-	0.2 t (0.06 %)	2.6 t (0.72 %)	32.4 t (9.05 %)	Conf.
2019/20	348.7 t (91.43 %)	-	0.1 t (0.02 %)	2.2 t (0.58 %)	29.7 t (7.79 %)	Conf.
2020/21	349.5 t (88.45 %)	-	0.3 t (0.08 %)	1.6 t (0.41 %)	42.9 t (10.85 %)	Conf.
2021/22	277.4 t (86.12 %)	-	0.5 t (0.16 %)	4.3 t (1.33 %)	39.3 t (12.21 %)	Conf.

Performance indicators for Southern Calamari include total catch, targeted squid jig effort and CPUE, and targeted haul net effort and CPUE. Performance indicators are applied at a sub-region level in order to better identify potential localised depletion, as per the management plan (PIRSA 2013). Four lower trigger reference points (LTRP) and two upper trigger reference points (UTRP) were triggered across the five spatial regions in 2021/22 (Table 4.5-2).

Table 4.5-2. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the regional spatial scales for Southern Calamari in 2021/22. Lower trigger reference point (LTRP) breaches are indicated in light blue and upper trigger reference point (UTRP) breaches are indicated in blue. × indicates that no trigger has been breached.

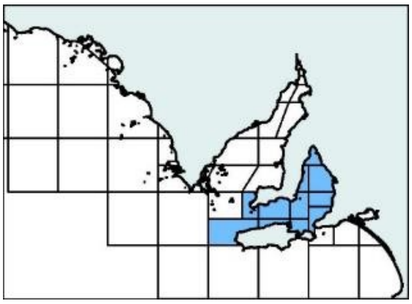
PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	WC	NSG	SSG	NSGV	SGSV
TOTAL CATCH	G	3rd Lowest/3rd Highest	×	×	×	×	×
	G	Greatest % interannual change (+/-)	×	×	×	×	×
	G	Greatest five-year trend	×	×	×	×	×
	G	Decrease over five consecutive years	×	LTRP	×	×	×
TARGET JIG EFFORT	G	3rd Lowest/3rd Highest	×	×	×	×	LTRP
	G	Greatest % interannual change (+/-)	×	×	×	×	×
	G	Greatest five-year trend	×	LTRP	LTRP	×	×
	G	Decrease over five consecutive years	×	×	×	×	×
TARGET JIG CPUE	G	3rd Lowest/3rd Highest	×	×	UTRP	×	×
	G	Greatest % interannual change (+/-)	×	×	×	×	×
	G	Greatest five-year trend	×	×	×	×	×
	G	Decrease over five consecutive years	×	×	×	×	×
TARGET HAUL NET EFFORT	G	3rd Lowest/3rd Highest	×	UTRP	×	×	×
	G	Greatest % interannual change (+/-)	×	×	×	×	×
	G	Greatest five-year trend	×	×	×	×	×
	G	Decrease over five consecutive years	×	×	×	×	×
TARGET HAUL NET CPUE	G	3rd Lowest/3rd Highest	×	×	×	×	×
	G	Greatest % interannual change (+/-)	×	×	×	×	×
	G	Greatest five-year trend	×	×	×	×	×
	G	Decrease over five consecutive years	×	×	×	×	×

4.5.6. Gulf St Vincent/Kangaroo Island Fishing Zone

Stock summary

Southern Calamari

Gulf St Vincent/Kangaroo Island Fishing Zone



Stock status	2019 - Sustainable	2020 - Sustainable	**2021/22 - Sustainable**
Fishery/stock trend	Total MSF catch and effort have been declining over the past five fishing seasons and were the lowest on record in 2021/22. However, CPUE has remained stable and increased in 2021/22. This trend remained consistent across northern and southern GSV.		

Commercial catch statistics and TACC

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target SQ CPUE *kg/fisher-day*	TACC *t*
2017/18	176 t	5,980	34.0	-
2018/19	150 t	5,972	29.1	-
2019/20	154 t	6,076	28.9	-
2020/21	129 t	5,270	28.5	
2021/22	118 t	4,740	29.8	162 t
Stock Status Summary	The TACC in 2021/22 was under caught by 44 t (27%) in 2021/22 which is linked to a record low level of fishing effort. However, declines in catch and effort were determined to be responses to the recent reform of the fishery and the new operating conditions for licence holders. Stable CPUE with modest increases in 2021/22 across both northern and southern GSV indicate that there are no sustainability concerns that can be detected from the data available.			

4.5.6.1. Catch Statistics

The TACC for the 2021/22 fishing season was 162 t for the GSV/KI fishing zone. However, this was not caught as the total MSF catch was the lowest since the 1986/87 fishing season at 118 t (Figure 4.5-3). This corresponds with decreases in total effort and the number of active licences in 2021/22 which were the lowest on record at 4,740 fisher days and 60 licences (take and target), respectively (Figure 4.5-3). Targeted squid jig CPUE in fisher days remained stable with recent fishing seasons for both the NGSV and SGSV regions in 2021/22 at 31.5 kg.fisher-day^{-1} and 28.5 kg.fisher-day^{-1}, respectively. However, targeted squid jig CPUE in fisher hours increased in both regions to 4.6 kg.fisher.hr^{-1} and 4.7 kg.fisher.hr^{-1}, respectively (Figure 4.5-3). These are the highest CPUEs in ~ 5 years for both regions. The Gulf St Vincent Prawn Fishery (GSVPF) caught 4.3 t of Southern Calamari in the GSV/KI fishing zone in 2021/22 while recreational fishers caught 90 t (Beckmann et al. 2023).

Historically, SGSV has accounted for the greatest proportion of catch and effort for the GSV/KI fishing zone (Figure 4.5-3). This remained the case in 2021/22 where 50 t of Southern Calamari was caught by the MSF in SGSV versus 40 t in NGSV. Total effort was also higher in SGSV at 1,779 fisher days versus 1,259 fisher days in NGSV. Squid jigs account for the majority of the zone catch at 77% in 2021/22. The remaining 23% was taken using haul nets, predominantly in NGSV due to netting restrictions in SGSV.

4.5.6.2. Stock Status

These fishery statistics do not indicate any stock declines in the fishery in 2021/22. Reduced catches and effort are the result of fleet rationalisation and the unitisation that occurred through recent fishery reform. Catches that are lower than the TACC are common in newly unitised fisheries as fishers become familiar with trading ITQs and the additional reporting requirements that occur with unitisation. Increasing CPUE from a period of relative stability for both NSGV and SGSV demonstrates that population declines are unlikely. However, it should be noted that the fishery statistics for the GSV/KI fishing zone were examined at the finest spatial scale possible given current logbook reporting conditions. There is the possibility for localised population declines to occur for Southern Calamari which may go undetected through this analysis. Additionally, cephalopod populations are susceptible to environmental change and often fluctuate with environmental conditions (Arkhipkin et al. 2021). Given the economic importance of Southern Calamari to the MSF, there would be great benefit in enhancing the assessment program to ensure that stock declines do not unknowingly occur through examining fishery statistics alone.

The above evidence indicates that the biomass of Southern Calamari within the GSV/KI fishing zone is unlikely to be depleted and that recruitment is unlikely to be impaired. The current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, the GSV/KI stock was classified as **sustainable.**

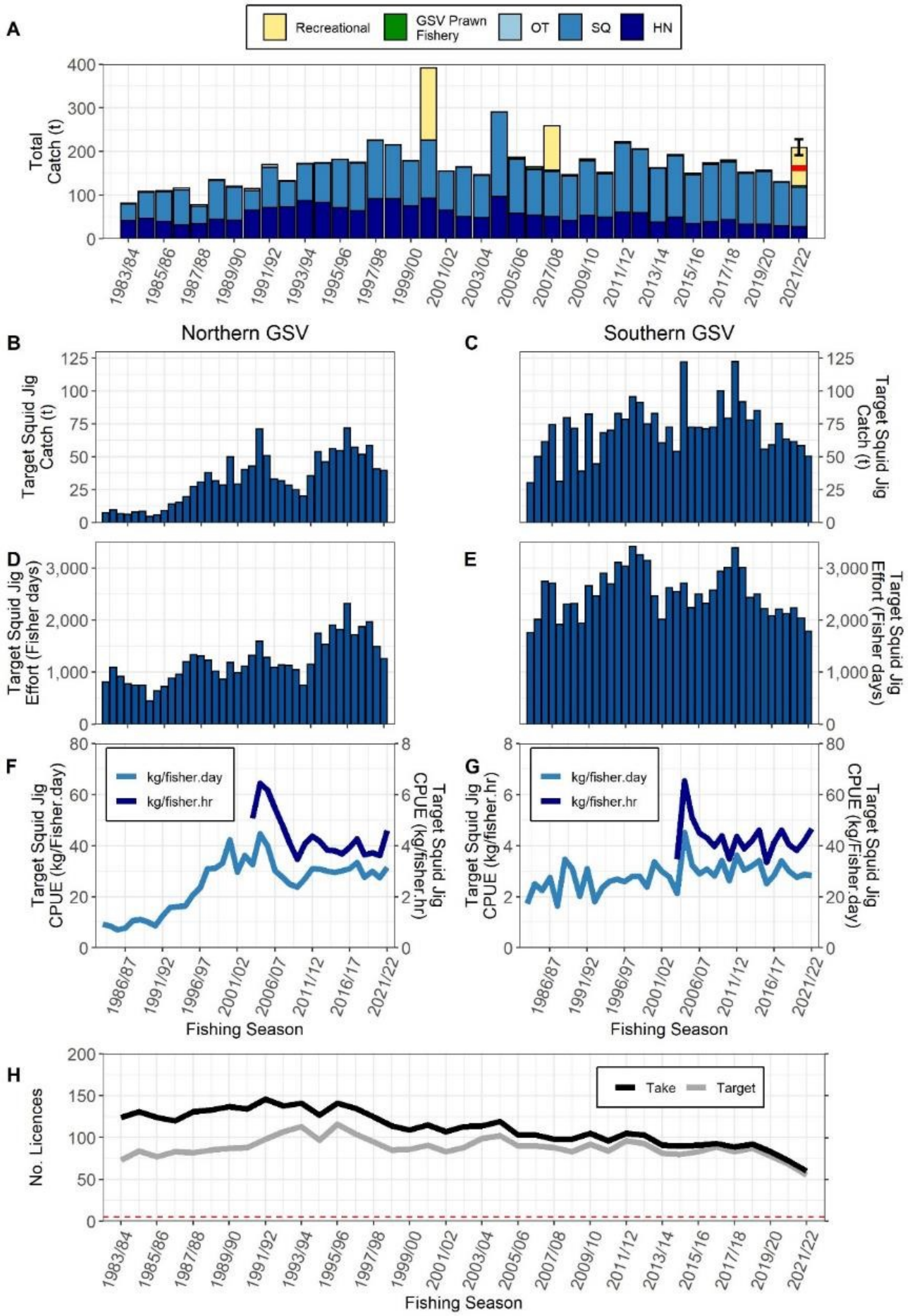


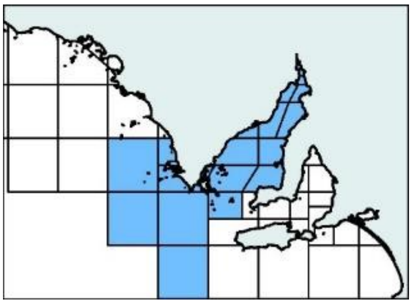
Figure 4.5-3. Key fishery statistics used to inform the status of Southern Calamari in the GSV/KI fishing zone. Long-term trends in (A) total catch by gear and sector; targeted squid jig catch in NGSV (B) and SGSV (C); targeted squid jig effort in NGSV (D) and SGSV (E); targeted squid jig CPUE by fisher day and fisher hour in NGSV (F) and SGSV(G); and (H) the number of active licences taking and targeting the species. Error bars on the 2021/22 recreational catch estimate (A) represent the standard error from that survey. The red line indicates the 2021/22 TACC. A red dashed line in panel H represents the number of licences where data becomes confidential.

4.5.7. Spencer Gulf Fishing Zone

Stock summary

Southern Calamari

Spencer Gulf Fishing Zone



Stock status	2019 - Sustainable	2020 - Sustainable	**2021/22 - Sustainable**
Fishery/stock trend	Total MSF catch declined in the 2021/22 fishing season but remained within the range of catches of the past ~15 years. Catch per unit effort has fluctuated for NSG while remaining stable in SSG over the past ten years. However, CPUE increased to the second highest on record for SSG and remained high for NSG in the 2021/22 fishing season.		

Commercial catch statistics and TACC

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target SQ CPUE *kg/fisher-day*	TACC *t*
2017/18	235	8,470	31.5	-
2018/19	164	7,339	24.9	-
2019/20	185	7,114	25.5	-
2020/21	206	6,732	33.5	-
2021/22	151	5,679	33.3	204
Stock Status Summary	The TACC in 2021/22 was under caught by 53 t (26%) in 2021/22 which is linked to a recent reduction in fishing effort. However, declines in catch and effort were determined to be responses to the recent reform of the fishery and the new operating conditions for licence holders. Stable CPUE for NSG and an increased in SSG for 2021/22 indicated that there are no sustainability concerns that can be detected from the data available.			

4.5.7.1. Catch Statistics

The TACC for the 2021/22 fishing season was 204 t for the SG fishing zone. However, this was not caught as the total MSF catch was the lowest since the 2008/09 fishing season at 151 t (Figure 4.5-4). This corresponds to the number of active licences in 2021/22 which were the lowest on record at 98 licences that caught Southern Calamari and 82 licences that targeted Southern Calamari (Figure 4.5-4). Total effort was the third lowest on record at 5,679 fisher days in 2021/22. Targeted squid jig CPUE in fisher days was 27.4 kg.fisher-day^{-1} for NSG and 35.1 kg.fisher-day^{-1} for SSG. Targeted squid jig CPUE in fisher hours has been closely aligned with trends in CPUE by fisher day since reporting began in 2003/04. In 2021/22 the targeted squid jig CPUE in fisher hours for NSG and SSG was 4.5 $kg.fisher.hr^{-1}$ and 6.0 $kg.fisher.hr^{-1}$, respectively (Figure 4.5-4). This was the second highest targeted squid jig CPUE by fisher hours on record for SSG. The Spencer Gulf Prawn Fishery (SGPF) caught 39.3 t of Southern Calamari in the SG fishing zone in 2021/22 (*c.f.* 42.9 t in 2020/21) while recreational fishers caught 115 t (Beckmann et al. 2023).

Historically, SSG has accounted for the greatest proportion of catch and effort for the SG fishing zone (Figure 4.5-4). This remained the case in 2021/22 where 22 t of Southern Calamari was caught by the MSF in NSG versus 98 t in SSG (Figure 4.5-4). Total effort was also higher in SSG at 2,783 fisher days versus 799 fisher days in NSG (Figure 4.5-4). Squid jigs account for the majority of the zone catch at 79% in 2021/22. Other gear types constituted <1% of the catch while the remaining ~20% was taken using haul nets, predominantly in NSG due to netting restrictions in SSG.

4.5.7.2. Stock Status

Similar to the GSV/KI fishing zone, reduced catches and effort are the result of fleet rationalisation and the unitisation that occurred through recent fishery reform. Catches that are lower than the TACC are common in newly unitised fisheries as fishers become familiar with trading ITQs and the additional reporting requirements that occur with unitisation.

These fishery statistics do not indicate any stock declines in the fishery in 2021/22. Previous assessments had identified declining CPUE in both NSG and SSG and highlighted that changes to stock status may have been needed should this had continued (Drew et al. 2021). However, the 2020 stock assessment and the current assessment both demonstrate that this decline has been halted, with the CPUE (by fisher hour) in SSG now the second highest on record. This alleviates some of the previous concern for Southern Calamari in the SG fishing zone. However, it should be noted that the fishery statistics for the SG fishing zone were examined at the finest spatial scale possible given current logbook reporting conditions. There is the possibility for localised population declines to occur for Southern Calamari which may go undetected through this analysis. Additionally, cephalopod populations are susceptible to environmental change and often fluctuate with environmental conditions (Arkhipkin et al. 2021). Given the economic importance of Southern Calamari to the MSF, there would be great benefit in enhancing the assessment program to ensure that stock declines do not unknowingly occur through examining fishery statistics alone.

The above evidence indicates that the biomass of Southern Calamari within the SG fishing zone is unlikely to be depleted and that recruitment is unlikely to be impaired. The current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, the SG stock was classified as **sustainable.**

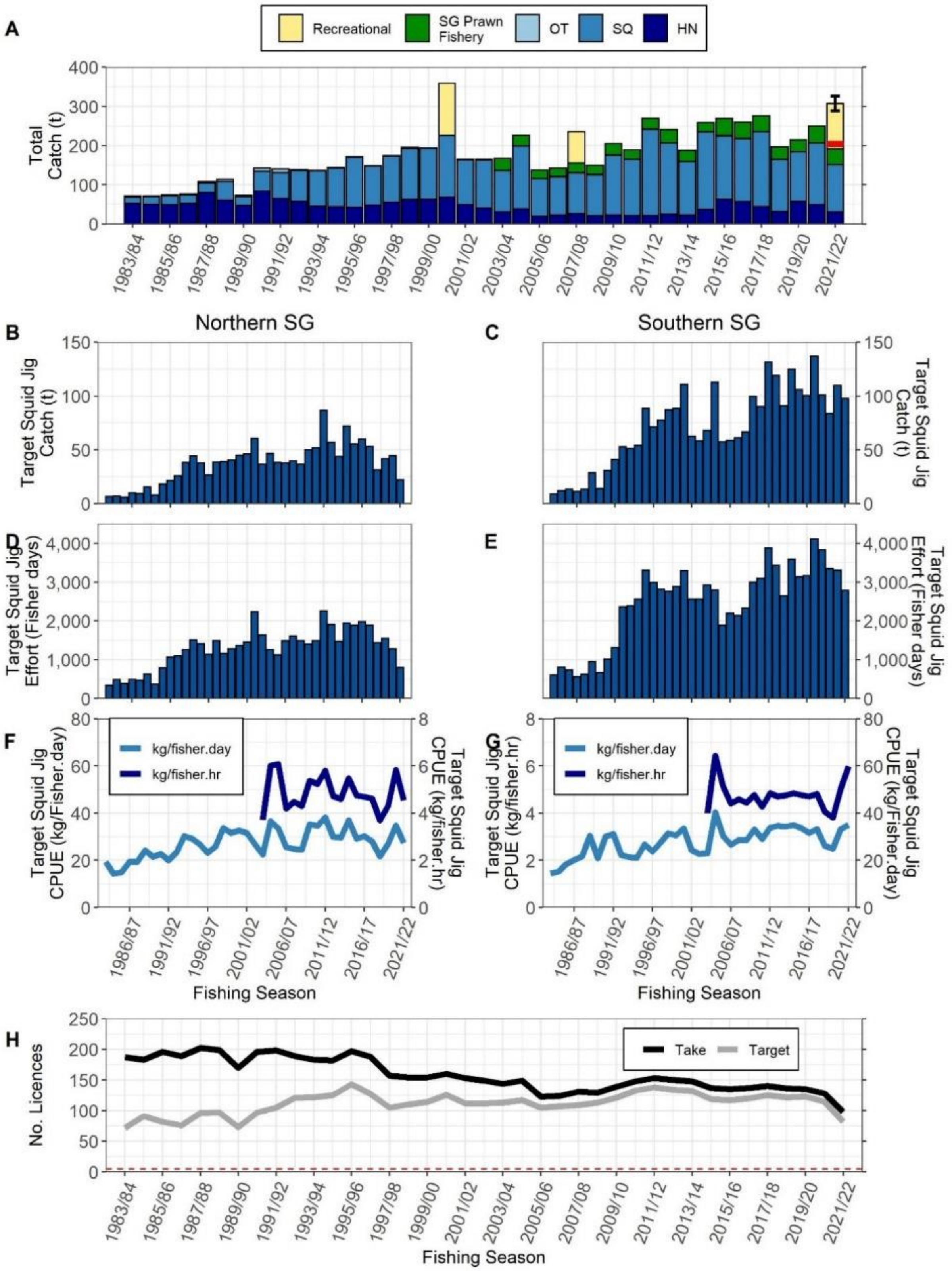


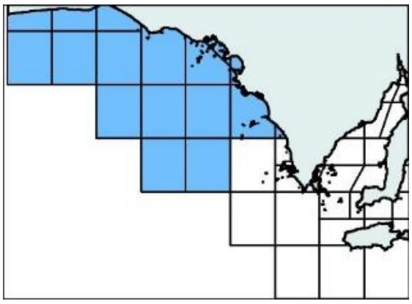
Figure 4.5-4. Key fishery statistics used to inform the status of Southern Calamari in the SG fishing zone. Long-term trends in (A) total catch by gear and sector; targeted squid jig catch in NSG (B) and SSG (C); targeted squid jig effort in NSG (D) and SSG (E); targeted squid jig CPUE by fisher day and fisher hour in NSG (F) and SSG (G); and (H) the number of active licences taking and targeting the species. Error bars on the 2021/22 recreational catch estimate (A) represent the standard error from that survey. The red line indicates the 2021/22 TACC. A red dashed line in panel H represents the number of licences where data becomes confidential.

4.5.8. West Coast Fishing Zone

Stock summary

Southern Calamari

West Coast Fishing Zone



Stock status	2019 - Sustainable	2020 - Sustainable	**2021/22 - Sustainable**
Fishery/stock trend	All fishery statistics have remained stable across recent fishing years.		

Commercial catch statistics

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target SQ CPUE *kg/fisher-day*
2017/18	10	407	25.3
2018/19	7	295	25.2
2019/20	9	407	22.5
2020/21	12	607	21.6
2021/22	9	447	20.0
Stock Status Summary	Generally, there appears to be no discernible upward or downward trend in any MSF fishery statistic for the WC fishing zone, demonstrating that this fishery is in a period of relative stability. These fishery statistics do not indicate any stock declines nor issues with the fishery in 2021/22 and therefore there are no sustainability concerns that can be detected from the data available.		

4.5.8.1. Catch statistics

The total MSF catch in 2021/22 was 9 t and equal to the ten-year average for the WC fishing zone but lower than historical catches of up to 30 t (Figure 4.5-5). The total effort was 447 fisher days in 2021/22 which produced a CPUE by fisher day of 19.4 kg.fisher-day^{-1} (Figure 4.5-5). The CPUE by number of fisher hours in 2021/22 was the highest since 2015/16 at 4.0 kg.fisher.hr^{-1}. Both CPUE series had strong alignment across fishing seasons with the exception of 2021/22 when CPUE by fisher hour had a 18% increase compared to the previous season while CPUE by fisher day had a 10% decrease. The number of licences targeting Southern Calamari was 34 in the WC fishing zone while a total of 38 licences caught Southern Calamari. Generally, there appears to be no discernible upward or downward trend in any MSF fishery statistic for the WC fishing zone, demonstrating that this fishery is in a period of relative stability. The catches of Southern Calamari by the West Coast Prawn Fishery (WCPF) are confidential due to the number of licence holders in the fishery while the while recreational catch was 9 t in 2021/22 (Beckmann et al. 2023).

4.5.8.2. Stock Status

These fishery statistics do not indicate any stock declines nor issues with the fishery in 2021/22. However, it should be noted that the fishery statistics for the WC fishing zone were examined at the finest spatial scale possible given current logbook reporting conditions. There is the possibility for localised population declines to occur for Southern Calamari which may go undetected through this analysis. Additionally, cephalopod populations are susceptible to environmental change and often fluctuate with environmental conditions (Arkhipkin et al. 2021). Given the economic importance of Southern Calamari to the MSF, there would be great benefit in enhancing the assessment program to ensure that stock declines do not unknowingly occur through examining fishery statistics alone.

The above evidence indicates that the biomass of Southern Calamari within the WC fishing zone is unlikely to be depleted and that recruitment is unlikely to be impaired. The current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, the WC stock was classified as **sustainable.**

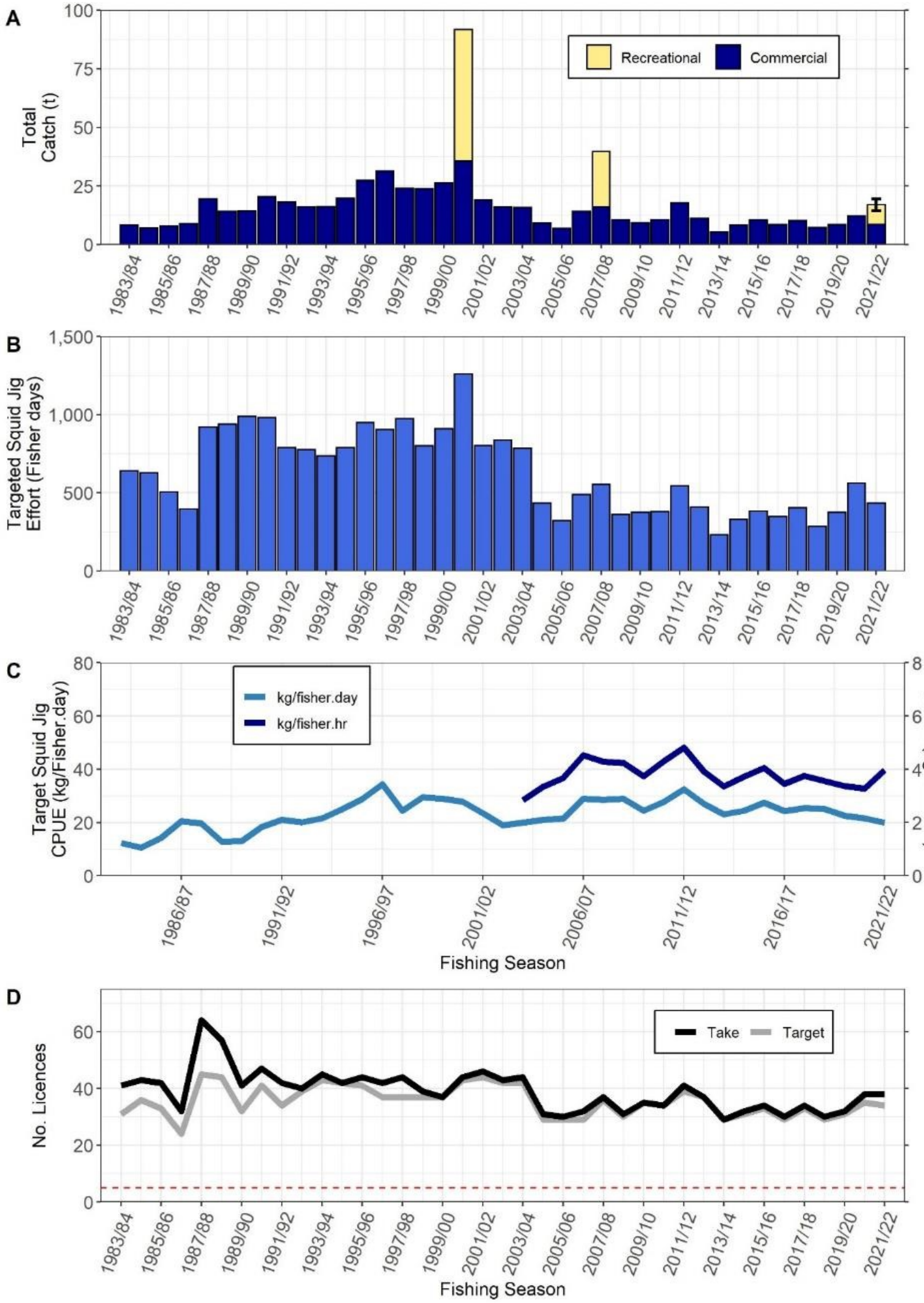
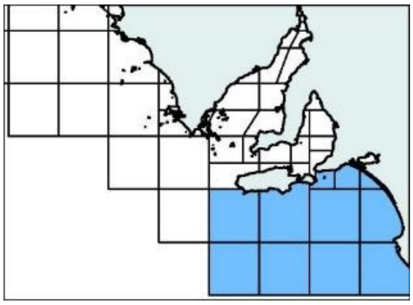


Figure 4.5-5. Key fishery statistics used to inform the status of Southern Calamari in the WC fishing zone. Long-term trends in (A) total catch by sector; targeted squid jig effort (B); targeted squid jig CPUE by fisher day and fisher hour (C) and the number of active licences taking and targeting the species. Error bars on the 2021/22 recreational catch estimate (A) represent the standard error from that survey. A red dashed line in panel D represents the number of licences where data becomes confidential.

4.5.9. South East Fishing Zone

Stock summary			
Southern Calamari ***South East Fishing Zone***			
Stock status	2019 - No status assigned	2020 – No status assigned	**2021/22 - Negligible**
Fishery/stock trend	The highest commercial catch on record was 4 t with commercial statistics being confidential in many fishing seasons. Squid jigs account for most of the effort in the South East fishing zone.		

Commercial catch			
Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target SQ CPUE *kg/fisher-day*
2017/18	*Confidential*	*Confidential*	*Confidential*
2018/19	*Confidential*	*Confidential*	*Confidential*
2019/20	*Confidential*	*Confidential*	*Confidential*
2020/21	2	54	*Confidential*
2021/22	<1	16	*Confidential*
Stock Status Summary	Negligible amounts of catch occur in the SE fishing zone and the limited amount of fishing effort prevents data from being presented in most fishing seasons due to confidentiality. There have never been any indications of overfishing that could have caused the stock decline or recruitment impairment to occur. Given that catches have never exceeded 5 t, a **negligible** stock status was assigned.		

4.6. Yellowfin Whiting

Species summary

Yellowfin Whiting

Sillago schomburgkii

Stock status (Fishing Zone)	**Gulf St Vincent/ Kangaroo Island**	**Spencer Gulf**
	Sustainable	**Sustainable**
Species Tier	**Tier 2 species in GSV/KI and SG fishing zones. Tier 3 in WC and SE fishing zones.**	
Species description	Yellowfin Whiting is endemic to Southern Australia and occurs in shallow, tidal creeks and coastal sand flats with the highest abundances occurring in the northern gulfs. There are two stocks in each of the GSV/KI and SG fishing zones.	
Fishery description	Yellowfin Whiting are caught in the northern region of both gulf zones. Catch and effort is largest in the SG fishing zone where the majority of fishing occurs through haul netting. There is a mix of gears used in the GSV/KI fishing zone with both haul and set nets used. Haul netting effort remains higher than set net effort in GSV/KI. Level of reported targeting for Yellowfin Whiting is low which precludes target CPUE from being interpreted for GSV/KI.	
Current assessment program	• Catch-MSY model. • Standardised CPUE index. • Annual commercial fishery statistics provided through a stock status report. • Recreational data collected every approximately five years through State-wide recreational survey. • No information is available for Aboriginal/Traditional fishing.	

Commercial fishery statistics (State-wide)			**Recreational Catch**			
Fishing Season	**Total MSF catch** *t*	**Total commercial effort** *Fisher-days*	Survey	**Estimated catch** *t (± SE)*	**Retained** *%*	**Released** *%*
2017/18	140	3,111				
2018/19	126	2,992	2000/01	53 (25)	78%	22%
2019/20	132	2,226	2007/08	23 (6)	72%	28%
2020/21	81	1,890	2013/14	45 (19)	61%	39%
2021/22	125	1,824	2021/22	28 (14)	70%	30%

4.6.1. Biology

The Yellowfin Whiting (*Sillago schomburgkii*) is endemic to Australian coastal waters from Dampier to Albany in Western Australia and in South Australia's gulf waters (Kailola et al. 1993). Uncertainty exists about the continuity of the species' distribution through the remote coastal waters between Western Australia and South Australia (Ferguson and Duffy 2021).

Fishery catches indicate that in South Australia, Yellowfin Whiting occur in highest abundances in the two northern gulfs, with lower abundances in the southern gulfs and the west coast of Eyre Peninsula. The life history of this species appears particularly adapted to habitation of relatively protected, shallow, near-shore gulf and coastal waters. Adults are generally associated with shallow, tidal creeks and coastal sand flats in waters of 1–10 m depth (Jones 1981). Spawning occurs during the summer months, and then between February and April, post-larvae are found along the shallow, protected, sandy beaches of the northern gulfs. Subsequently, juvenile fish occupy similar habitats as well as tidal creeks (Ferguson 2000). Yellowfin Whiting demonstrate different growth patterns between the sexes that culminates in females reaching larger sizes-at-age than males (Ferguson 2000). Furthermore, market sampling of commercial catches has demonstrated considerable bias in sex ratios towards females, with the sex ratio varying seasonally. Age estimation of Yellowfin Whiting using otoliths has indicated a longevity of ~12 years, although most fish taken in the commercial fishery were 2 to 4 years old.

Based on the possible discontinuous distribution between South Australian and Western Australian populations, there is the possibility of separate stocks as well as genetic differentiation (Ferguson and Duffy 2021). However, even within South Australia, the oceanographic separation of the two gulfs during the spawning season in summer must considerably reduce the opportunity for mixing by egg and larval advection. As such, the populations in the two gulfs may constitute separate stocks. This remains to be resolved.

4.6.2. Fishery

Yellowfin Whiting is a Tier 2 stock in both the GSV/KI and SG fishing zones due to its economic importance to the commercial MSF, it's level of targeting (when percentage of catch is considered during individual events) and its importance to recreational fishers (Smart et al. 2022a). Commercial catches have been variable as in the past it was targeted when demand for, or availability of, primary species was low. As the Yellowfin Whiting is a schooling species that occupies sandy, shallow habitats predominantly in the northern gulfs, it is particularly vulnerable to net gear types used in the MSF. As such, historically the commercial catches have been dominated by the net sector, with haul nets the predominant gear followed by set nets. Yellowfin Whiting is a popular target species of boat- and shore-based recreational fishers who target them using hook and line. In 2021/22, this sector took an estimated catch of 27.3 t (Beckmann et al. 2023).

4.6.3. Management Regulations

There is a minimum size limit of 240 mm TL for Yellowfin Whiting that applies to the commercial and recreational sectors. A bag limit of 20 fish and boat limit of 60 fish is in place for the recreational sector. Furthermore, for the commercial sector, the many regulations that are input controls for the net gear types contribute to minimising fishing effort directed at Yellowfin Whiting. These include restrictions to net lengths and mesh sizes, extensive spatial closures and temporal restrictions that limit net fishing activities.

4.6.4. State-wide Fishery Statistics

Estimates of total annual State-wide commercial catches of Yellowfin Whiting have ranged from 22 t in 1988/89 to 181 t in 2002/03 (Figure 4.6-1). During the last decade, total catch has averaged 121 $t.yr^{-1}$ (range: 81–152 $t.yr^{-1}$). In 2021/22, total catch was 125 t which was an increase of 43 t from 2020/21 (an anonymously low year). The economic value of the commercial catch of Yellowfin Whiting in 2021/22 was approximately $1.3 M (*c.f.* $0.9 M in 2019) (Figure 4.6-1).

Combined haul net and set net effort declined between 2002/03 and 2007/08 and has been relatively stable since (Figure 4.6-1). Haul nets account for most of the fishing effort that produces catches of this species at the State-wide level. State-wide annual estimates of targeted CPUE for haul nets have been highly variable, with an increasing trend over the history of the fishery. However, in 2021/22 the targeted haul net CPUE was a record 228 $kg.fisher\text{-}day^{-1}$ (Figure 4.6-1). Also, from 1984 to 2020, the total number of licence holders who reported taking Yellowfin Whiting has continuously declined over time and was 43 in 2021/22. The number of licences targeting Yellowfin Whiting has been considerably lower across all years and was 23 in 2021/22 (Figure 4.6-1). This demonstrates that a large amount of effort for Yellowfin Whiting reported as having no specified target species.

The SG fishing zone has consistently had the highest Yellowfin Whiting catches in SA with most of this catch occurring in the northern gulf (Figure 4.6-2). The other main fishing area has been northern GSV, although catches have been much lower in this zone. Only negligible catches occur in the WC and SE fishing zones and therefore Yellowfin Whiting are not assessed in these zones (Figure 4.6-2). Low levels of reported targeting has occurred across the history of the fishery as well as in recent years (Figure 4.6-2). In the past five fishing seasons, the majority of Yellowfin Whiting catch has occurred when fishers listed ‘Any Target’ on their logbooks. It is therefore difficult to quantify the extent to which Yellowfin Whiting are truly targeted. There are strong seasonal peaks in catches with the majority of catches occurring from May to July each year (Figure 4.6-2).

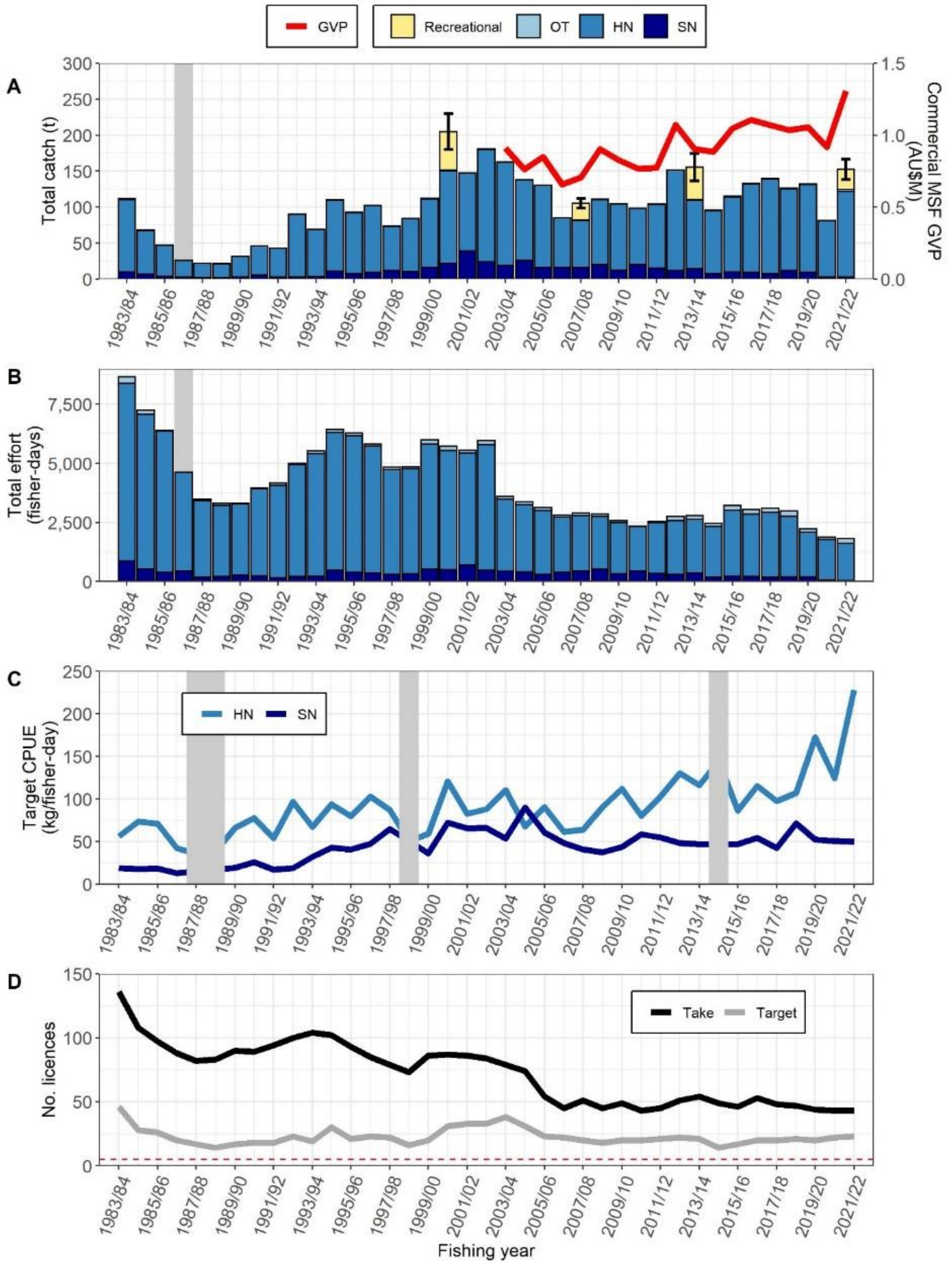


Figure 4.6-1. Long-term trends in State-wide estimates for Yellowfin Whiting of (A) total catch for the main gear types (haul net, set net), estimated recreational catch and gross production value; (B) Long-term total effort for haul nets and set nets; (C) target CPUE for haul nets and set nets; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. Grey shading represents a fishing season where one or more gear types are confidential and are not included on the panel.

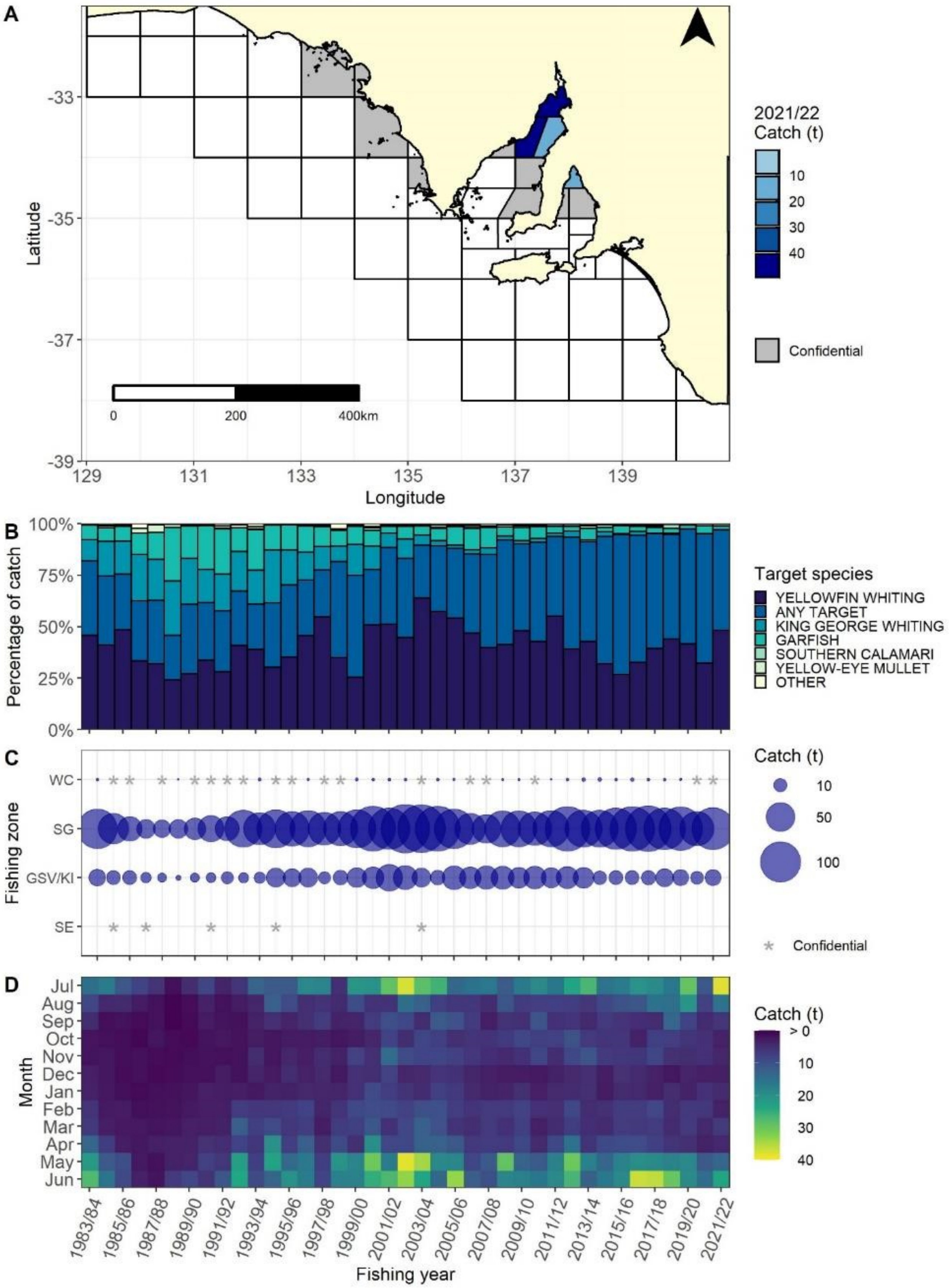


Figure 4.6-2. Regional dynamics of Yellowfin Whiting: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.6.5. Fishery Performance Indicators

The general fishery performance indicators for Yellowfin Whiting were assessed for 2021/22 for the GSV/KI and SG fishing zones. The limited amount of targeted fishing for Yellowfin Whiting in the GSV/KI fishing prevents target effort and CPUE performance indicators from being assessed. As a result, total catch is the sole performance indicator for this stock (PIRSA 2013). For the SG fishing zone, three UTRP were triggered for target haul net CPUE (Table 4.6-1).

Table 4.6-1. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the regional zone scale for Yellowfin Whiting in 2021/22. Lower trigger reference point (LTRP) breaches are indicated in light blue and upper trigger reference point (UTRP) breaches are indicated in blue. × indicates that no trigger has been breached.

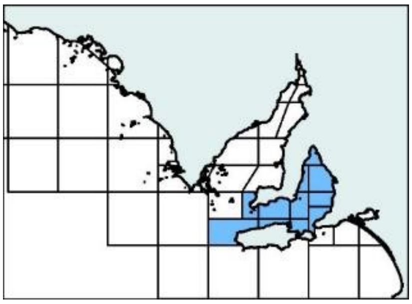
PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	GSV/KI	SG
TOTAL CATCH	G	3rd Lowest/3rd Highest	×	×
	G	Greatest % interannual change (+/-)	×	×
	G	Greatest five-year trend	×	×
	G	Decrease over five consecutive years	×	×
TARGET HAUL NET EFFORT	G	3rd Lowest/3rd Highest	N/A	×
	G	Greatest % interannual change (+/-)	N/A	×
	G	Greatest five-year trend	N/A	×
	G	Decrease over five consecutive years	N/A	×
TARGET HAUL NET CPUE	G	3rd Lowest/3rd Highest	N/A	UTRP
	G	Greatest % interannual change (+/-)	N/A	UTRP
	G	Greatest five-year trend	N/A	UTRP
	G	Decrease over five consecutive years	N/A	×

4.6.6. Gulf St Vincent/Kangaroo Island Fishing Zone

Stock summary

Yellowfin Whiting

Gulf St Vincent Fishing Zone



Stock status	2019 - Sustainable	2020 - Sustainable	**2021/22 - Sustainable**
Fishery/stock trend	Total MSF catch has been below 20 t since 2013/14 but was preceded by a 15-year period of catches that ranged from 13 – 43 t. Total set net CPUE has remained stable since 2001/02 and was the third highest on record in 2021/22. Despite these statistics, both commercial and recreational fishers have expressed concern with stock abundance.		

Commercial catch statistics

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target HN CPUE *kg/fisher-day*
2017/18	12 t	582	47.9
2018/19	19 t	648	79.3
2019/20	15 t	431	96.4
2020/21	10 t	422	108.7
2021/22	15 t	425	122.3
Stock Status Summary	Commercial catch statistics and raw CPUE do not indicate a stock decline. However, low levels of species-specific targeting complicates assessing raw CPUE as Yellowfin Whiting are commonly caught in mixed species catches. The current assessment has applied a cMSY model and estimated a standardised CPUE index to investigate the status of this stock. Both new lines of evidence independently demonstrated a recent stock decline which has stabilised in recent years. This evidence, along with reports from commercial and recreational fishers indicates that the Yellowfin Whiting stock in the GSV/KI fishing zone has declined but is now stable based on current commercial catch levels. A sustainable status has been assigned to this stock based on recent low levels of catch. However, it was noted that the population remains low and that its recovery should be closely monitored.		

4.6.6.1. Catch Statistics

The total catch of Yellowfin Whiting in the GSV/KI fishing zone was 15 t in 2021/22 (Figure 4.6-3). This was an increase from the previous season when catches dropped to 10 t in 2020/21 and were the lowest in over twenty years. Total catches were lowest prior to 2000/01 when they were often below 20 t per year. Total catches then rose and were regularly above 25 t per year from 2000/01 to 2013/14 before decreasing to 10 t in 2015/16. Catches have remained below 20 t since then (Figure

4.6-3). Unlike the SG fishing zone, the haul net sector does not dominate the catches and in several years most of the catch is attained by set net fishing. The recreational catch was 5 t in 2021/22.

Low levels of targeting for Yellowfin Whiting occur in in the GSV/KI fishing zone, with fishers often recording ‘Any Target’ in their logbooks even if large numbers of Yellowfin Whiting are caught. As a result, total effort and CPUE were assessed rather than targeted effort and CPUE. Total effort was highest in the late 1980’s at approximately 2,000 fisher days per year (Figure 4.6-3). Since then, total effort has varied with peaks of approximately 2,000 fisher days occurring in 1994/95 – 1995/96 and 1999/00 – 2002/03. While set net fishing has dominated catches, haul net effort has regularly been higher for Yellowfin Whiting and as a result, total set net CPUE has been higher than total haul net CPUE in most years. The total set net CPUE in 2021/22 was 63.9 kg.fisher-day^{-1} which was the second highest on record. An increasing trend has occurred for total haul net since 2016/17 when it increased from 7.5 kg.fisher-day^{-1} to 38.2 kg.fisher-day^{-1} in 2021/22. This was the highest total haul net CPUE on record (Figure 4.6-3). In 2021/22 18 licences caught Yellowfin Whiting in GSV/KI while only 7 reported it as the target species (Figure 4.6-3).

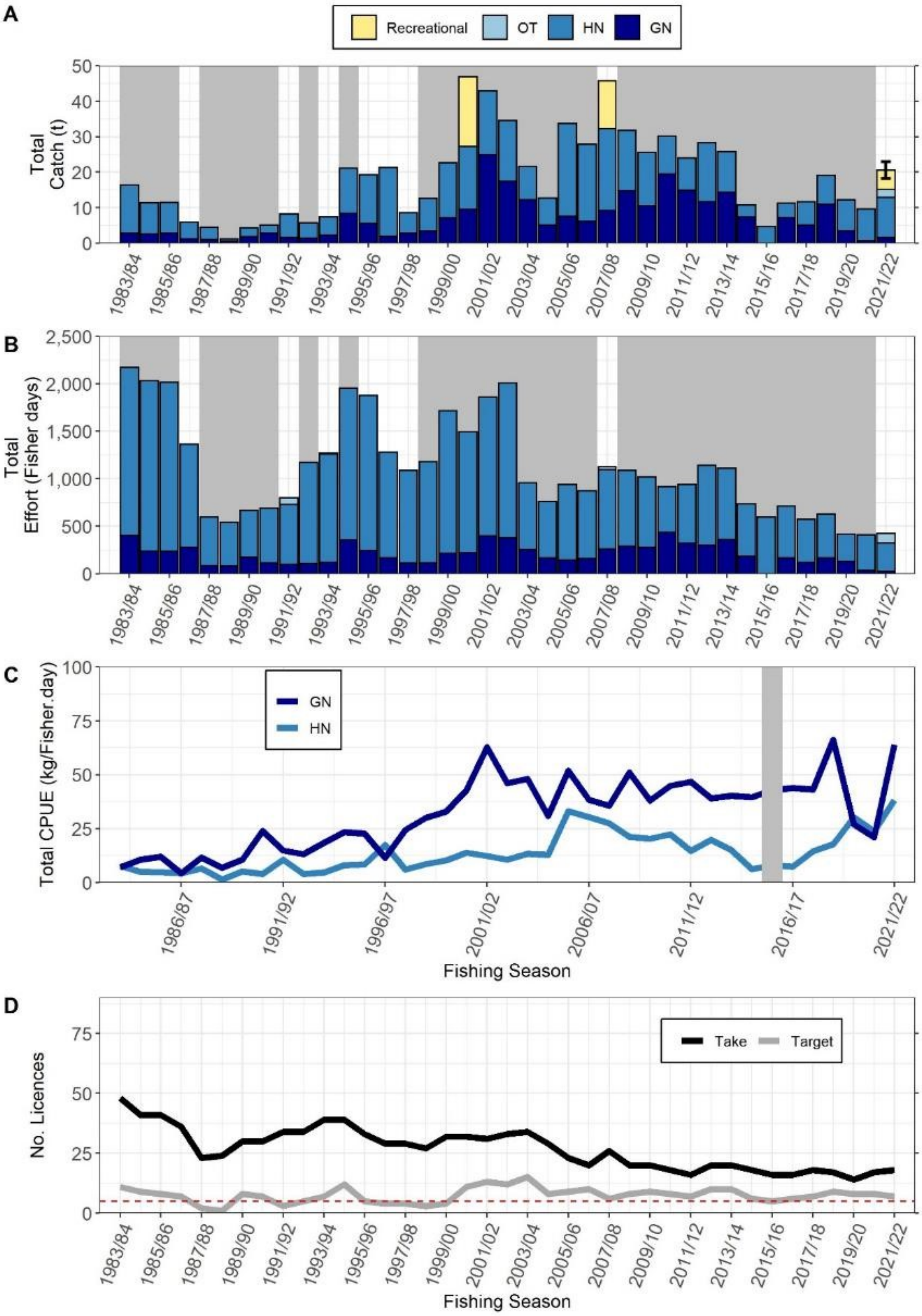


Figure 4.6-3. Key fishery statistics for Yellowfin Whiting in the GSV/KI fishing zone. (A) total catch for haul nets, set nets, estimated recreational catch and all other gear types; (B) total effort for haul nets, set nets and all other gear types; (C) total CPUE for haul nets ad set nets; and (D) the number of active licence holders taking or targeting the species. Error bars on the 2021/22 recreational catch estimate (A) represent the standard error from that survey. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

4.6.6.2. Catch-MSY model

A catch-MSY model (cMSY) was applied to MSF commercial catch data for Yellowfin Whiting in the GSV/KI fishing zone using a modified 'medium' resilience setting with *r* bounded from 0.3 – 1.2. This corresponds to approximate species productivity (Martell and Froese 2013). A sensitivity analysis was performed where each of the four resilience categories were applied to the cMSY model. Two out of the four resilience categories estimated a similar MSY, with one of the categories ('high' resilience), failing to provide a sufficient number of successful iterations. The 'very low' resilience category determined a lower MSY than 'low' or 'medium' categories. However, the biology of Yellowfin Whiting does not align with this category. The agreement between the 'low' and 'medium' categories demonstrates that this analysis was robust to resilience choice with regard to the key parameters for management (Table 4.6-2). Preferably, total catch should be applied in these models so that recreational harvest can be accounted for in the analysis. However, Yellowfin Whiting recreational catch estimates for the GVS/KI fishing zone were too uncertain to be included in these analyses, and therefore only commercial catch data were used. It is assumed that trends in recreational catch match those of the commercial sector and have not varied substantially over time. However, this is difficult to corroborate. Nothing its limitations, the results of the cMSY model can be interpreted as an assessment of the commercial fishery, such that the MSY estimate represents the long-term level of sustainable commercial catch. Biomass estimates will also be conservative as they are estimated through catch scaling and would therefore be higher if recreational data were available. The harvest fractions estimated from the cMSY model also only correspond to the commercial sector. This analysis was conducted using 20,000 iterations with no upper bound on the maximum harvest fraction. While the results of this analysis are appropriate for use in management, it should also be noted that cMSY models are a data-limited stock assessment approach that rely solely on catch data and coarse information on species productivity. Therefore, the results should be used in a precautionary approach to management with stock status set using a weight-of-evidence approach.

Table 4.6-2. Sensitivity analysis for the cMSY model applied to Yellowfin Whiting in the GSV/KI fishing zone. Parameter values are presented for identical cMSY models run using each of the four resilience settings.

Parameter	Resilience setting				
	Base Case	Very Low	Low	Medium	High
MSY	22 t	11 t	20 t	23 t	-
r	0.49	0.08	0.28	0.55	-
K	188 t	509 t	286 t	164 t	-
B_{MSY}	94 t	254 t	143 t	82 t	-
H_{MSY}	0.25	0.04	0.14	0.22	-

The results of the cMSY model demonstrate that recent low catches were due to low biomasses that have been less than B_{MSY} since 2008/09 (Figure 4.6-4). The estimated MSY was 22 t which was exceeded for several years between 1999/00 and 2013/14. Biomass was reduced during this period through harvest fractions that were above H_{MSY}. Since 2015/16, harvest fractions have been reduced and to approximated H_{MSY} and therefore declining biomass has halted and has remained reasonably stable. At the end of the 2021/22 fishing season the biomass was estimated at 65 t which represents a depletion of 34% (Figure 4.6-3). Based on this evidence, commercial catches of Yellowfin Whiting in the GSV/KI fishing zone were unsustainable for a prolonged period and have reduced the biomass below B_{MSY}. Current catch levels have been more appropriate and have not further reduced the biomass. However, the constraints of this data-limited analysis prevent sustainable catch levels that could support stock recovery from being identified.

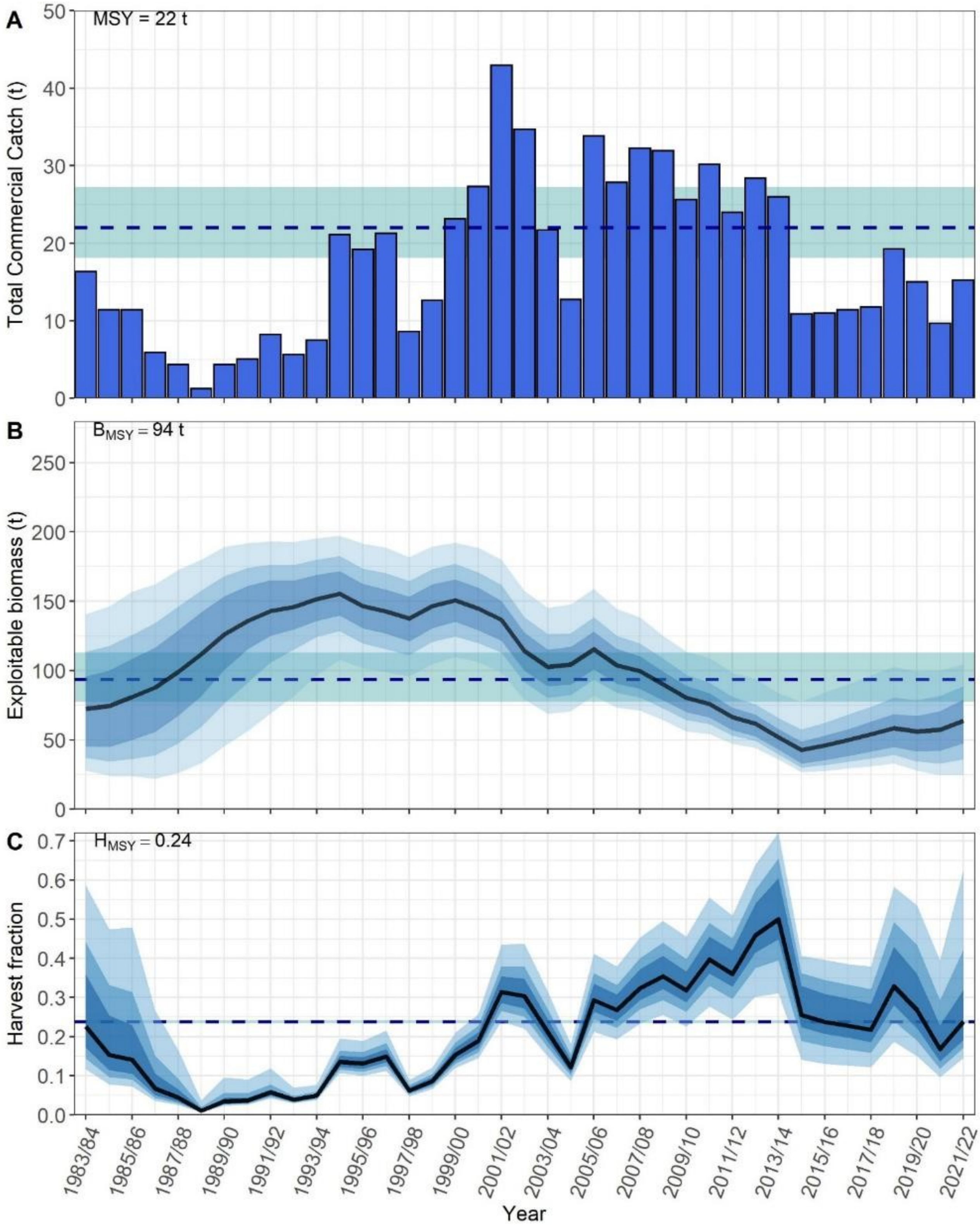


Figure 4.6-4. Outputs of the cMSY model for Yellowfin Whiting in the GSV/KI fishing zone that include (A) the annual commercial catch (B) time series of exploitable biomass (black solid line) with 50th, 75th and 95th percentiles (blue shading that goes from darker to lighter shades, respectively) and (C) the annual harvest fraction (*H*) (black line) with 50th, 75th and 95th percentiles (blue shading that goes from darker to lighter shades, respectively). Each panel displays its respective value relating to MSY (dark blue dashed line) and its 95th percentiles (blue shading). Grey shading on panel A represents a fishing season where the commercial catch was confidential and cannot be included on the panel.

4.6.6.3. CPUE Standardisation

A Standardised CPUE index was developed for Yellowfin Whiting in the GSV/KI fishing zone using the same methods that were applied to the King George Whiting (Section 3.5.1). The GLM included the following variables: fishing season, fishing month, level of targeting (i.e., if Yellowfin Whiting were targeted, not targeted or whether ‘Any Target’ was recorded in logbooks), MFA sub-block, and fishing gear type (haul net or set net) nested within licence holder. This last variable allowed multiple gear types to be included in a single analysis and recognised that different licence holders use different gears with varying individual efficiencies. Models were also examined with haul net and set net gear types treated separately, including haul net CPUE based on number of hauls. However, these provided similar abundance trends and were combined to maximise the data available to the model.

The model selection process demonstrated that MFA sub-block should not be included in the final model and was therefore dropped as an independent variable. A histogram of fitted values, visual analysis of residuals and a Q-Q plot were used to confirm that the model provided a good fit to the data and that conclusions on stock abundance could be drawn from it. Lastly, the model coefficients for fishing season were extracted and normalised with a mean of one. These form the standardised CPUE index along with their estimated standard errors.

The standardised CPUE index demonstrated a declining abundance since 2008/09 that continued until 2016/17 and has since plateaued (Figure 4.6-5). Prior to this, abundance peaked in 2000/01 having been increasing since 1983/84. One possibility for this increasing trend, followed by a steady decline is that fishing efficiency has increased over time (i.e., ‘effort creep’) but was nullified from 2000/01 onwards due to declining abundances. Changes in fishing efficiency are difficult to detect from logbook data and are problematic to factor into CPUE standardisation as a result. There remains the possibility that abundance did increase over this period and stabilised between 2000/01 and 2008/09. What remains clear is that a demonstrable downward trajectory in abundance followed by a low-level stabilisation has occurred over the past 15 years.

The effect sizes of the explanatory variables were examined further to determine why the standardised CPUE deviated away from raw CPUE in recent years. These effect sizes demonstrated that licence holder was the dominant variable that determined daily CPUE. The individual catches of licence holders were then examined over time where it was determined that recent catch and effort is dominated by the fishery’s most efficient fishers, thus maintaining high levels of CPUE despite declining Yellowfin whiting abundance.

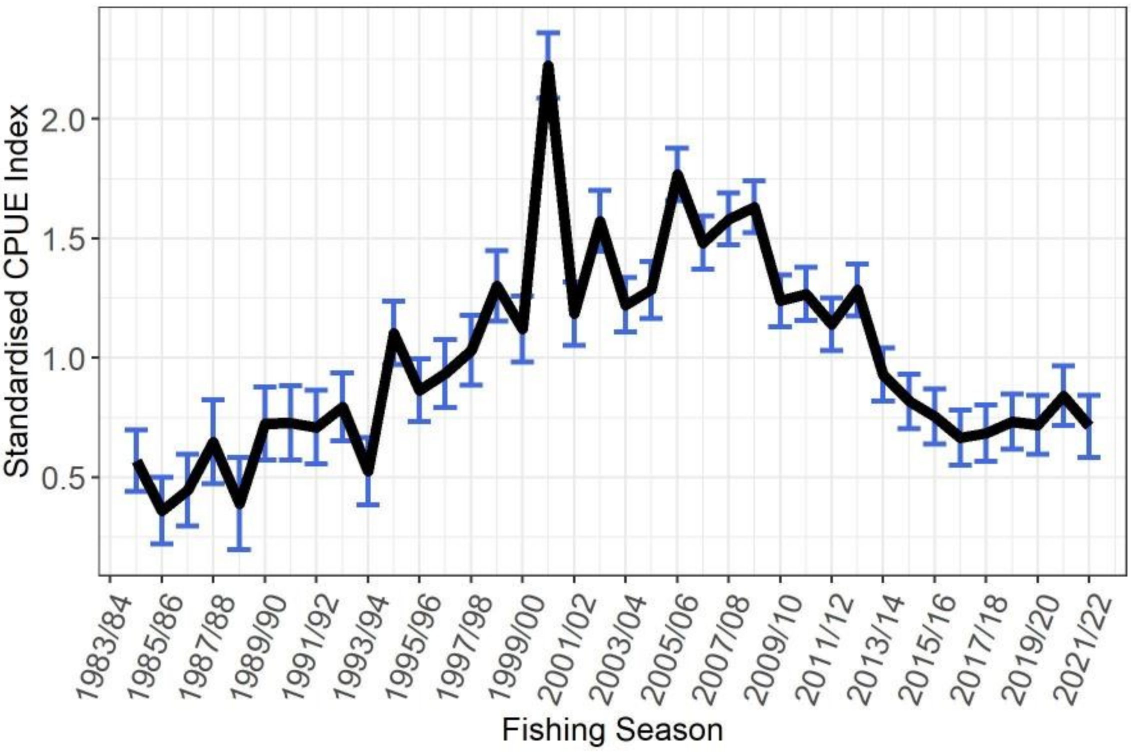


Figure 4.6-5. Standardised CPUE index for Yellowfin Whiting from the GSV/KI fishing zone. Black line is the standardised index and blue error bars are the standard error of the model coefficients. All results have been normalised to a mean of one.

4.6.6.4. Stock Status

There is conflicting evidence regarding the health of the GSV/KI Yellowfin Whiting stock that must be carefully considered. The raw catch and effort statistics demonstrate that total catch has been low for a number of years but that raw total CPUE has been high during this period. These statistics in isolation do not indicate issues with the stock as the reductions in catch correspond with the implementation of marine parks that would have impacted catch and effort from 2014 onwards. Therefore, past assessments have assigned a sustainable status on this basis. However, two new lines of evidence are presented in the current assessment which contradict these trends in raw CPUE. The historical trends of both the standardised CPUE index and the cMSY biomass were similar and began with increasing trends, then a period of stability at higher abundances, followed by a steady decline that stabilised in recent years. These trends have approximate timeframes, although do not match exactly as the cMSY model estimated a declining biomass before of the standardised CPUE index. These are independent analyses as the cMSY model was fitted to catch-only information and does not include a CPUE time-series. Therefore, the agreement between these two analyses provides strong evidence that stock declines have occurred but were not detectable in raw logbook data.

Commercial and recreational fishers have expressed concern regarding Yellowfin Whiting in the GSV/KI fishing zone in recent years, noting that abundances appear to have declined in northern GSV. These new lines of evidence agree with these observations and suggest that stock declines have been occurring and that fishing mortality has been too high. However, from the information available it was not possible to determine if Yellowfin Whiting in the GSV/KI fishing zone were recruitment impaired. Both the standardised CPUE and the cMSY model indicate that stock declines have stabilised since approximately 2015/16 due to lower catches since 2013/14.

The cMSY model and the standardised CPUE both demonstrate slight population increases due to the recent period of lower catches. However, the cMSY model must be treated cautiously as it's model mechanics will produce this result irrespective of actual population trend when lower catches occur. The standardised CPUE index is therefore the most appropriate analysis to consider in a weight of evidence approach. What is apparent is that the population has been reduced below B_{MSY} through fishing mortality that was unsustainable over a prolonged period. It is unknown as to whether the population has been reduced to a point where recruitment was impaired. However, recent catches have been substantially lower following the implementation of marine parks in 2013/14 and are now within sustainable levels according to both analyses.

Based on a weight of evidence approach, Yellowfin Whiting in the GSV/KI fishing zone is classified as **sustainable** based on current fishing mortality. However, it should be noted that the population has previously been overfished and is at a low level. Current catches appear to be sustainable as the population has stabilised at this low level, preventing a 'depleting' status from being considered according to the SAFS definitions (Table 1.6-1). It is not possible to determine if recruitment has previously been or is currently impaired. Therefore a 'depleted' status can also not be considered based on the current evidence, nor can a 'recovering' status be considered as the population has not previously been classified as 'depleted'.

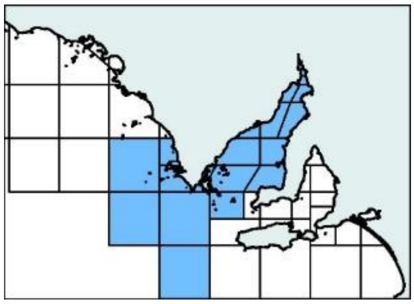
Future research should focus on better quantifying the extent of the stock's decline, whether there are any measurable signs of population recovery and whether recruitment impairment has occurred. Should future commercial catches exceed current levels (approximately 10-15 t), then there is a risk of further stock declines that would require a change in status to 'depleting'.

4.6.7. Spencer Gulf Fishing Zone

Stock summary

Yellowfin Whiting

Spencer Gulf Fishing Zone



Stock status	2019 - Sustainable	2020 - Sustainable	**2021/22 - Sustainable**
Fishery/stock trend	The Yellowfin Whiting fishery in the SG fishing zone is the most productive region of South Australia with regular catches of approximately 100 t. This fishery is dominated by the haul net sector, although levels of targeting are lower than other haul net species, such as Southern Garfish.		

Commercial catch statistics

Fishing Season	Total commercial catch *t*	Total commercial effort *Fisher-days*	Target HN CPUE *kg/fisher-day*
2017/18	128 t	2,410	102.8
2018/19	107 t	2,193	110.9
2019/20	117 t	1,697	189.9
2020/21	72 t	1,415	129.0
2021/22	109 t	1,372	263.7
Stock Status Summary	Several lines of evidence suggest that Yellowfin Whiting in the SG fishing zone are being fished at maximum sustainable levels and that there is no indications of stock decline. Raw catch and effort statistics as well as a standardised CPUE index demonstrate stable levels of catch and effort and increasing CPUE. A cMSY model indicates that biomass is above B_{MSY} and that H_{MSY} has never been exceeded. The MSY for this fishery is 112t. On this basis, a sustainable status has been assigned.		

4.6.7.1. Catch Statistics

The total catch of Yellowfin Whiting in the SG fishing zone was 109 t in 2021/22 (Figure 4.6-4). This was an increase from the previous season when catches dropped to 72 t in 2020/21 and were the lowest for nine years. Total catches were lowest prior to 2000/01 when they were often below 50 t per year. Total catches then rose and have often been above 100 t per year ever since. Catches have remained below 20 t since then (Figure 4.6-4). Catch and effort for Yellowfin Whiting in the SG fishing zone are dominated by the haul net sector, while there are also low levels of set net fishing (Figure 4.6-4). The recreational catch was 22 t in 2021/22.

Targeted effort was highest in the early 2000's at approximately 600 - 1,000 fisher days per year (Figure 4.6-4). Since then, target effort has been below 500 fisher days per year (Figure 4.6-4). Haul net CPUE by fisher day and by fisher hour have been increasing over time and were the highest on record in 2021/22 at 263.7 kg.fisher-day^{-1} and 285.5 kg.haul^{-1}, respectively (Figure 4.6-4). In 2021/22 27 licences caught Yellowfin Whiting in GSV/KI while only 16 reported it as the target species (Figure 4.6-4).

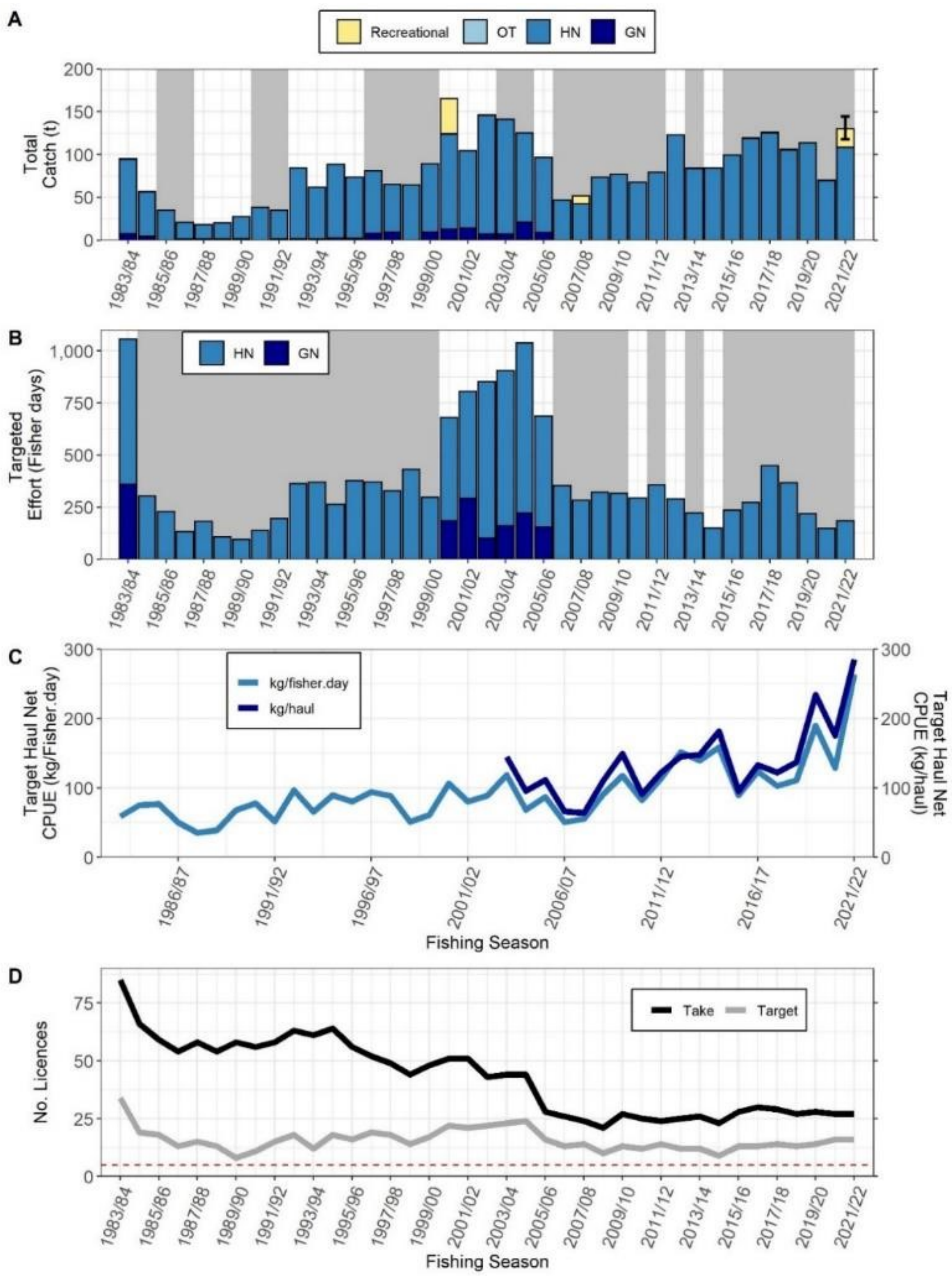


Figure 4.6-6. Key fishery statistics for Yellowfin Whiting in the SG fishing zone. (A) total catch for haul nets, set nets, estimated recreational catch and all other gear types; (B) total effort for haul nets, set nets and all other gear types; (C) target CPUE for haul nets by fisher day and fisher hour; and (D) the number of active licence holders taking or targeting the species. Error bars on the 2021/22 recreational catch estimate (A) represent the standard error from that survey. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

4.6.7.2. Catch-MSY model

A catch-MSY model (cMSY) was applied to MSF commercial catch data for Yellowfin Whiting in the SG fishing zone using the same methods and specifications as the cMSY model applied to the GSV/KI fishing zone (Section 4.6.6.2). A sensitivity analysis of resilience settings was also applied with the 'very low' resilience category determining a lower MSY than 'low', 'medium' or 'high' categories (Table 4.6-3). However, the biology of Yellowfin Whiting does not align with this category. The agreement between the 'low', 'medium' and 'high' categories demonstrates that this analysis was robust to resilience choice with regard to the key parameters for management (Table 4.6-3).

Table 4.6-3. Sensitivity analysis for the cMSY model applied to Yellowfin Whiting in the SG fishing zone. Parameter values are presented for identical cMSY models run using each of the four resilience settings.

Parameter	Resilience setting				
	Base Case	Very Low	Low	Medium	High
MSY	112 t	44 t	108 t	106 t	119 t
r	0.69	0.08	0.38	0.63	1.09
K	620 t	2,147 t	1,143 t	673 t	435 t
B_{MSY}	310 t	1,074t	571t	336 t	217 t
H_{MSY}	0.36	0.04	0.19	0.31	0.55

The results of the cMSY model demonstrate a sustainable stock (Figure 4.6-7). Recent catches have remained stable and close to, but rarely exceeding, the MSY of 112 t. As a result, biomass has remained above the B_{MSY} of 310 t and at the end of the 2021/22 fishing season the biomass was estimated at 364 t which represents a depletion of 59% (Figure 4.6-7). Accordingly, harvest fractions have remained beneath H_{MSY} throughout the history of the fishery (Figure 4.6-7). Based on this evidence, commercial catches of Yellowfin Whiting in the SG fishing zone are at maximum sustainable levels.

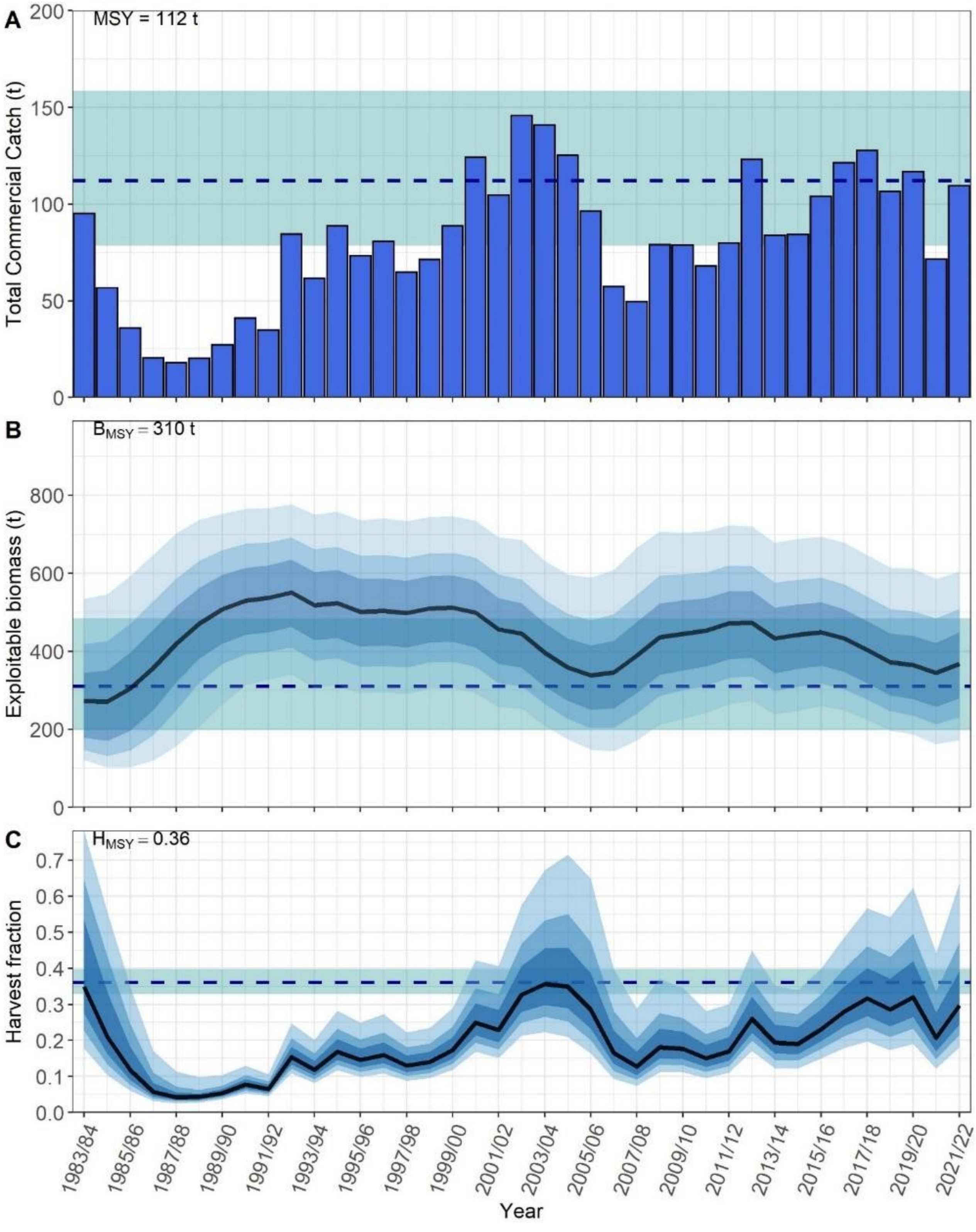


Figure 4.6-7. Outputs of the cMSY model for Yellowfin Whiting in the GSV/KI fishing zone that include (A) the annual commercial catch (B) time series of exploitable biomass (black solid line) with 50th, 75th and 95th percentiles (blue shading that goes from darker to lighter shades, respectively) and (C) the annual harvest fraction (*H*) (black line) with 50th, 75th and 95th percentiles (blue shading that goes from darker to lighter shades, respectively). Each panel displays its respective value relating to MSY (dark blue dashed line) and its 95th percentiles (blue shading). Grey shading on panel A represents a fishing season where the commercial catch was confidential and cannot be included on the panel.

4.6.7.3. CPUE Standardisation

A Standardised CPUE index was developed for Yellowfin Whiting in the SG fishing zone using the same methods that were applied to the King George Whiting (Section 3.5.1). The GLM applied to the SG fishing zone included only haul net data given the dominance of this gear type in this zone. The model selection analysis determined that the full model was the most appropriate.

The standardised CPUE index demonstrated an increasing abundance across the time-series which closely matches the raw target CPUE (Figure 4.6-8). The highest standardised CPUE (normalised to a mean of one) occurred in 2012/13 while the estimate for 2021/22 was the second highest (Figure 4.6-8). Similar to the analysis for the GSV/KI fishing zone (Section 4.6.6.3), effect sizes indicated that licence holder was the dominant variable that determined daily CPUE. However, in this analysis, trends in individual fisher activity did create differences between raw and standardise CPUE indices.

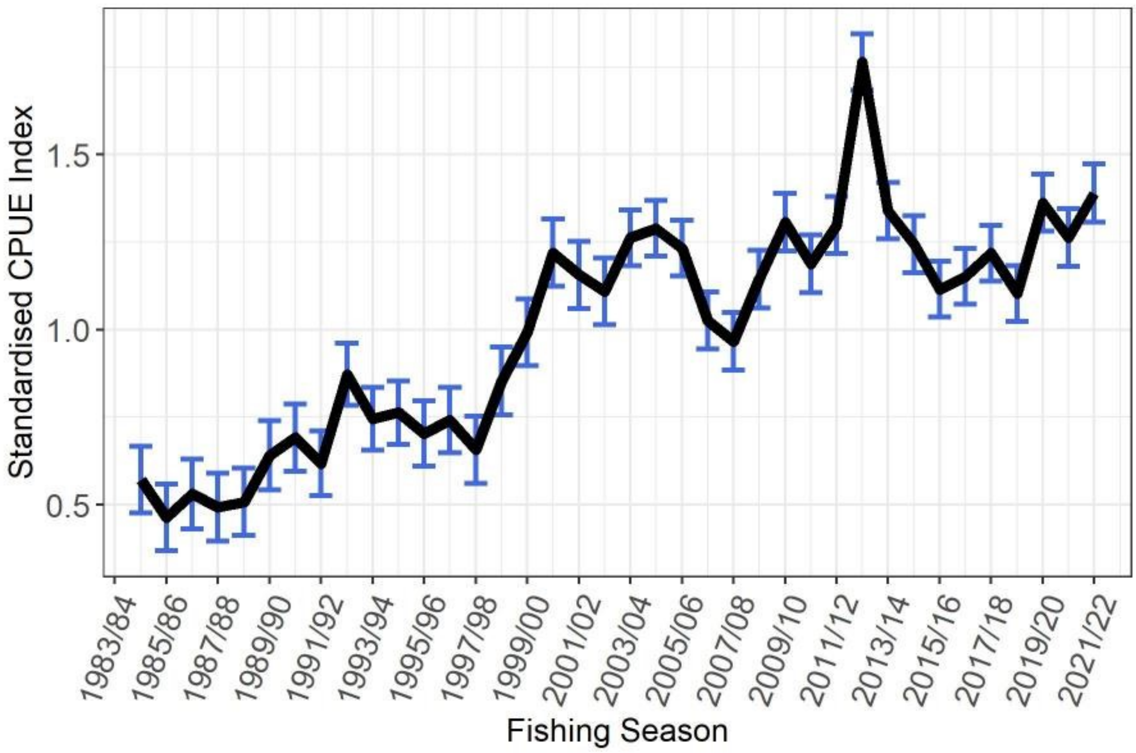


Figure 4.6-8. Standardised CPUE index for Yellowfin Whiting from the SG fishing zone. Black line is the standardised index and blue error bars are the standard error of the model coefficients. All results have been normalised to a mean of one.

4.6.7.4. Stock Status

State-wide commercial catches of Yellowfin Whiting have been dominated by those from Spencer Gulf, although the fishery performance indicators for this zone are characterised by high levels of variability. This reflects the variable nature of targeted fishing effort, with fishers either opportunistically targeting the species due to market demands, or when the availability of higher value species is low. Two additional analyses were included in the current assessment which included the cMSY model and a standardised CPUE index. These new information sources demonstrate that stock abundance is high and that the fishing is occurring at maximum sustainable levels according to the cMSY model. The raw catch and effort statistics align with this and do not demonstrate any issues with the fishery that would cause concern regarding stock health. Such evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current catch level is unlikely to cause the stock to become recruitment impaired. On this basis, Yellowfin Whiting in the SG fishing zone is classified as a **sustainable** stock.

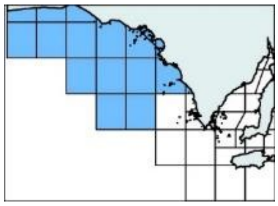
4.7. Blue Crab

Species summary

Blue Crab

Portunus armatus

West Coast Fishing Zone



Assessment scale	West Coast fishing zone	**Species Tier**	Tier 2 in WCFZ. Not applicable to remaining zones.
Stock status	2019 – Sustainable	2020 – Sustainable	**2021/22 – Sustainable**
Biology	• Distributed in a wide range of inshore habitats to a depth of at least 50 m in near-shore, bays and estuaries in Australia and New Zealand (Edgar 2000, Lai et al. 2010). • Highly mobile, short-lived, fast-growing, highly fecund species of portunid crab. • Maximum size ~200 mm carapace width (CW), maximum age ~three years, reach sexual maturity between 70 - 90 mm. • Reproduction and growth during warmer months (shallow inshore waters), reduced activity during colder months (adults move to deeper, offshore waters). • Spawning occurs for three to four months over summer/autumn (Kumar et al. 2000) • Separate sub-populations within Spencer Gulf, Gulf St Vincent and the West Coast (Bryars and Adams 1999). • Assessment of stock status for Blue Crab is undertaken at the management unit level (West Coast), while the Spencer Gulf and West Coast stocks are assessed for the Blue Crab Fishery (BCF) (Beckmann and Hooper 2022)		
Description of the fishery	• MSF licences are permitted to take Blue Crabs on the West Coast of South Australia (west of longitude 135°E). • Endorsed MSF licence holders can operate in the BCF in the Gulfs, however, as 99% of the TACC is allocated to BCF licence holders the MSF is effectively confined to the West Coast. • MSF operators mostly use hoop/drop nets or dab nets, BCF fishers use crab pots, recreational fishers mostly use hoop/drop nets or handheld rakes. • Following 1996/97 the majority of Blue Crab catches have been caught by the BCF in the two gulf zones. The remaining MSF Blue Crab catch predominantly occurs in the WC fishing zone (Figure. 4.7-1). Detailed catch and effort statistics for the WC fishing zone are presented in Figure 4.7-2. • Recreational catch cannot be estimated at the WC fishing zone scale due to the low number of households included in the recreational surveys from this zone.		
Management regulations	• LML 110 mm CW, females with external eggs are protected. • Spatial and temporal commercial closures. • Gear endorsement limits on MSF licences. • Recreational fishers have a combined Sand/Blue Crab bag and boat limit of 20 and 60 crabs, respectively.		

<table>
<tr><th rowspan="6">Commercial statistics</th><th>Season</th><th>Total catch
t</th><th>Targeted crab net effort
fisher-days</th><th>Targeted CPUE
kg/fisher-day</th></tr>
<tr><td>2017/18</td><td>31</td><td>648</td><td>47.5</td></tr>
<tr><td>2018/19</td><td>51</td><td>768</td><td>61.9</td></tr>
<tr><td>2019/20</td><td>51</td><td>813</td><td>62.7</td></tr>
<tr><td>2020/21</td><td>74</td><td>911</td><td>80.7</td></tr>
<tr><td>2021/22</td><td>58</td><td>998</td><td>58.1</td></tr>
<tr><th>Performance indicators</th><td colspan="4">• Total catch – No triggers breached.
• Targeted effort (crab net) – Upper trigger breached for third highest target effort.
• Targeted CPUE (crab net) – No triggers breached.</td></tr>
<tr><th>Catch-MSY model</th><td colspan="4">• A catch-MSY model (cMSY) was applied to MSF commercial catch data for Blue Crabs in the WC fishing zone using a ‘medium’ resilience setting, which corresponds to approximate species productivity (Martell and Froese 2013).
• The biomass remained high at approximately 280 t for a 20-year period from 1997/98 to 2007/08 when commercial catches were typically less than 25 t (Figure 4.7-3). Following this period, increased catches resulted in lower biomass as harvest fractions increased towards H_{MSY}.
• Catches in the past four seasons were above the MSY of 44 t while biomass at end of the 2021/22 fishing season was 138 t: below the B_{MSY} of 166 t (Figure 4.7-3).
• Commercial catches of Blue Crabs in the WC fishing zone are at levels of maximum production.</td></tr>
<tr><th>Assessment summary</th><td colspan="4">Status of Blue Crab in the MSF (West Coast fishing zone) was determined by a cMSY model, and catch, effort and CPUE trends using a weight-of-evidence approach (Figures 4.7-2; 4.7-3). The total MSF catch for the West Coast fishing zone in 2021/22 was 58 t which was above the previous ten-year average of 49 t for the WC fishing zone (Figure 4.7-2). The total targeted effort was 1,059 fisher days in 2021/22 which produced a CPUE (targeted crab net effort) by fisher day of 58 kg.fisher-day^{-1} (Figure 4.7-2). The CPUE in 2021/22 was the lowest since 2017/18 (51 kg.fisher-day^{-1}) and was similar to the previous ten-year average (60 kg.fisher.hr^{-1}).

The above evidence indicates that the biomass of this stock is unlikely to be depleted, that recruitment is unlikely to be impaired and that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On the basis of the evidence provided above, the West Coast biological stock is classified as a **sustainable** stock.</td></tr>
<tr><th>Research needs</th><td colspan="4">• Development of harvest strategy with performance indicators, reference points and harvest control rules.
• Standardisation of commercial CPUE, using improved measures of fishing effort.
• Targeted recreational surveys to improve the precision around catch estimates
• Fishery-independent surveys using a standardised design and standardisation of CPUE to account for changes in efficiency
• Improved understanding of Aboriginal/Traditional importance</td></tr>
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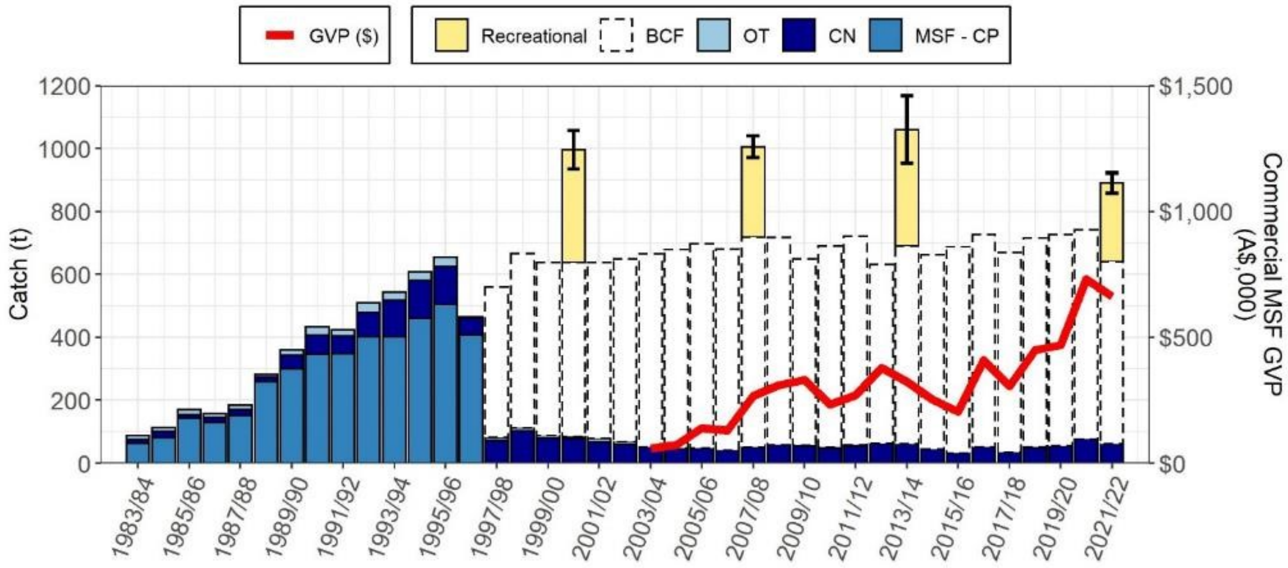

Figure 4.7-1. Long-term trends in State-wide catch for Blue Crab total catch for the main MSF gear types (crab net and crab pots), estimated recreational catch, Blue Crab Fishery catches following the establishment of the fishery and gross production value of the MSF component of Blue Crab catches. Error bars on the recreational catch estimates (State-wide estimates) represent the standard error of those surveys.

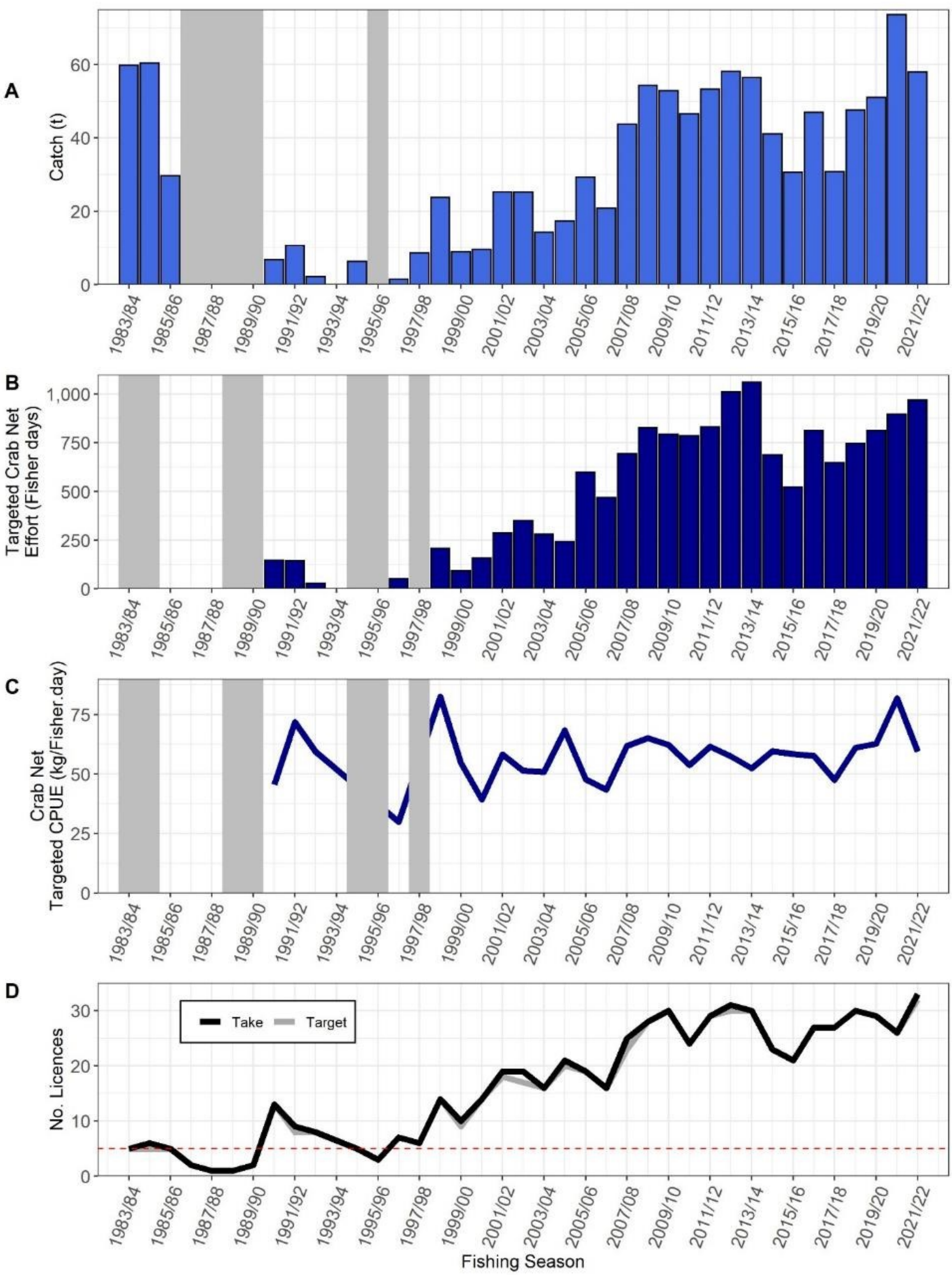

Figure 4.7-2. Key fishery statistics used to inform the status of Blue Crab in the WC fishing zone. Long-term trends in (A) total catch; targeted crab net effort (B); targeted crab net CPUE by fisher day and (C) and the number of active licences taking and targeting the species. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on the panel.

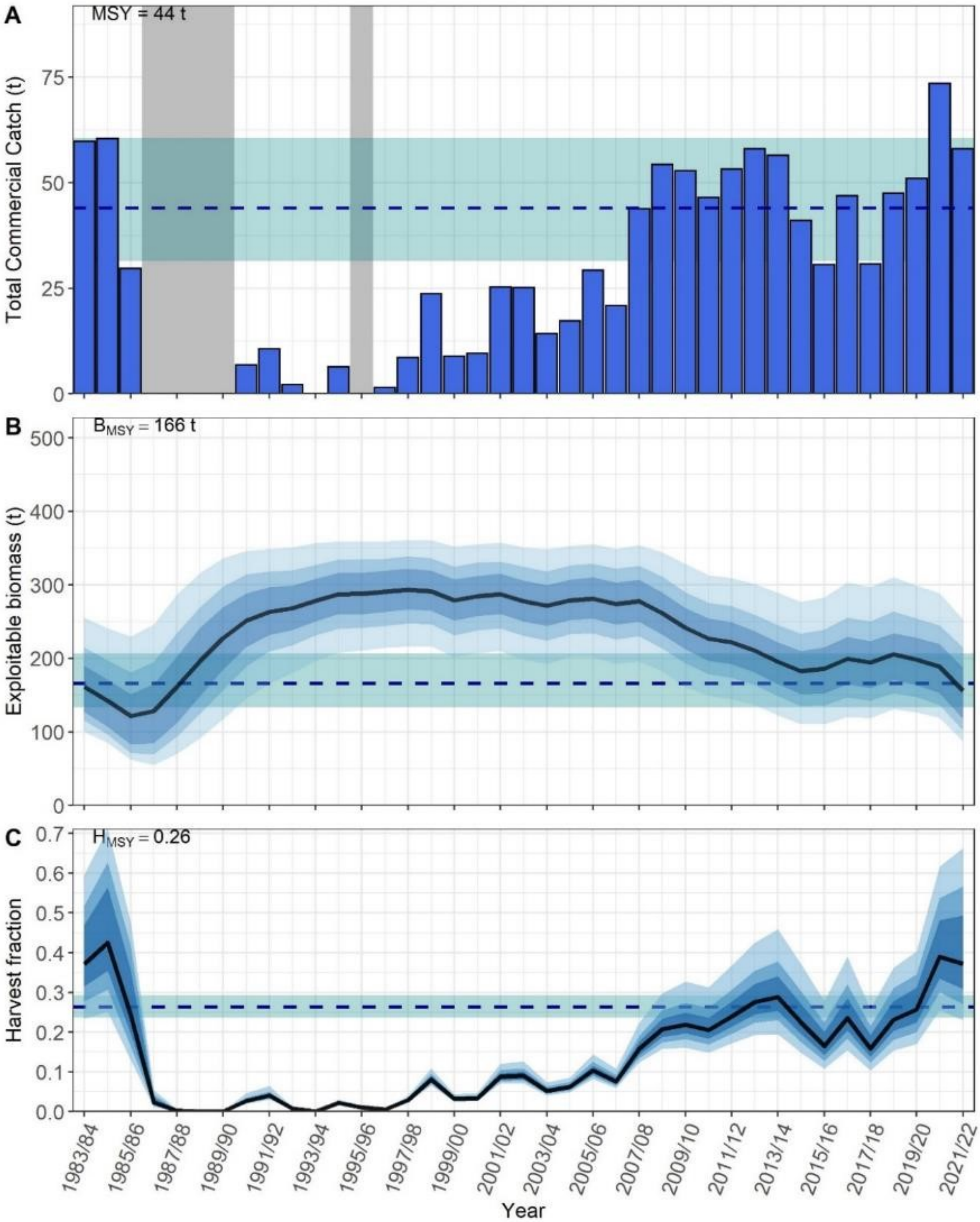

Figure 4.7-3. Outputs of the cMSY model for Blue Crab in the WCFZ that include (A) the annual commercial catch (B) time series of exploitable biomass (black solid line) with 50th, 75th and 95th percentiles (blue shading that goes from darker to lighter shades, respectively) and (C) the annual harvest fraction (*H*) (black line) with 50th, 75th and 95th percentiles (blue shading that goes from darker to lighter shades, respectively). Each panel displays its respective value relating to MSY (dark blue dashed line) and its 95th percentiles (blue shading). Grey shading on panel A represents a fishing season where the commercial catch was confidential and cannot be included on the panel.

4.8. Western Australian Salmon

Species summary			
Western Australian Salmon *Arripis truttaceus*			
Assessment scale	State-wide	**Species Tier**	Tier 2 in SG and GSV/KI fishing zones
Stock status	2019 – Sustainable	2020 – Sustainable	**2021/22 – Sustainable**
Biology	• WA Salmon comprises a single biological stock that extends from south-western WA to western coasts of TAS and VIC, where they occur in schools over seagrass and sand along high-energy beaches and around rocky outcrops (Gomon et al. 2008). • Pelagic, large-bodied, fast-growing species, max. age 12 years, max. length 900 mm TL, L_{50} 650 mm TL (4–5 years old) (Cappo 1987) . • Spawning occurs in large aggregations that form near Cape Leeuwin (WA) during autumn and early winter when the eastward flow of the Leeuwin Current is strongest. Eggs and larvae settle along the entire south-western coastline of Australia, with the main nurseries located in SA's gulfs (Jones and Westlake 2003). • Juveniles remain in coastal nursery areas for up to three years before moving to exposed coastal waters where they form large schools and begin to migrate westward to join the spawning biomass in WA as 5–6-year-olds (Cappo 1987). • There are no records of spawning in waters east of the WA/SA border. • As a result of these demographic processes, the MSF harvests mainly juveniles and sub-adults.		
Description of the fishery	• Supports commercial and recreational fisheries in SA. • The commercial harvest is mostly targeted by specialised seine (salmon) net fishers in SSG and haul net fishers in northern gulf waters (Figure 4.9-2). • The product is typically used for rock lobster bait with an increasing proportion of the catch used for human consumption. • An iconic recreational fishery species in SA, which is mostly taken by shore-based fishers using bait and lures in inshore coastal waters (Beckmann et al. 2023). • There are no catch and effort data for Aboriginal and traditional fishing.		
Management regulations	• Legal minimum length: 210 mm TL. • General haul net restrictions apply. Purse seine used to take salmon cannot have a drop greater than 13m, a mesh size of less than 5cm and exceed 900m in length. • The commercial harvest has been managed through the implementation of a 1,100 t catch limit with varying entitlements allocated to individual licence holders based on their net endorsements. • Recreational daily bag and boat limits apply and vary with size. For fish from 210 to 350 mm TL, the bag and boat limits are 20 and 60 fish, respectively. For fish >350 mm TL, the limits are 10 and 30 fish.		

Commercial statistics	**Season**	**Total catch** t	**Targeted HN effort** *fisher-days*	**Targeted HN CPUE** *kg/fisher-day*
	2017/18	321	66	232.3
	2018/19	182	54	288.5
	2019/20	189	107	263.3
	2020/21	90	66	261.1
	2021/22	323	64	308.8
Recreational catch estimate	**Survey**	**Estimated catch** *t (± SE)*	**Retained** *%*	**Released** *%*
	2000–01	335 (70)	75%	25%
	2007–08	91 (11)	64%	36%
	2013–14	56 (12)	67%	33%
	2021–22	82 (16)	55%	45%
Performance indicators	• Total catch – No TRPs breached. • Targeted effort (haul net) – No TRPs breached. • Targeted CPUE (haul net) – No TRPs breached.			
Assessment summary	The biological stock of Western Australian Salmon across southern Australia is accessed by fisheries in WA, SA, VIC and TAS. Historically, WA has been the main contributor to annual catches with smaller contributions from SA and minor contributions from VIC and TAS. The stock was classified as 'sustainable' in the 2020 Status of Australian Fish Stocks Report (Duffy et al. 2021). In SA, status of Salmon in the MSF is determined by catch, effort and CPUE trends using a weight-of-evidence approach. From 1983/84 to 2002/03, annual commercial catches were between 500–600 t, with most of the catch taken by specialised purse seine fishers and the remainder taken by haul netters (Figure 4.8-1). Catches have been low in most of the last 20 years as several key purse seiners exited the fishery in the early 2000s, while those that remained have been relatively inactive due to weak market demand and targeting in the haul net sector has been low. Catch increased during the mid-2010s as purse seine activity was reactivated, and subsequent higher economic value of the fishery suggested emerging markets for this species. However, it then progressively declined to 90 t in 2020/21 before increasing to 323 t in 2021/22 which was the second highest annual catch since 2002/03 (Figure 4.8-1). CPUE for both major gear types have been characteristically variable, with those of the purse seiners increasing to a record high level in 2021/22. The above evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On the basis of the evidence provided above, the the MSF-management unit for WA Salmon is classified as a **sustainable** stock.			
Research needs	• Development of harvest strategy with performance indicators, reference points and harvest control rules. • Standardisation of commercial CPUE, using improved measures of fishing effort. • Improved estimates of recreational catch and effort. • Improved understanding of Aboriginal/Traditional importance			

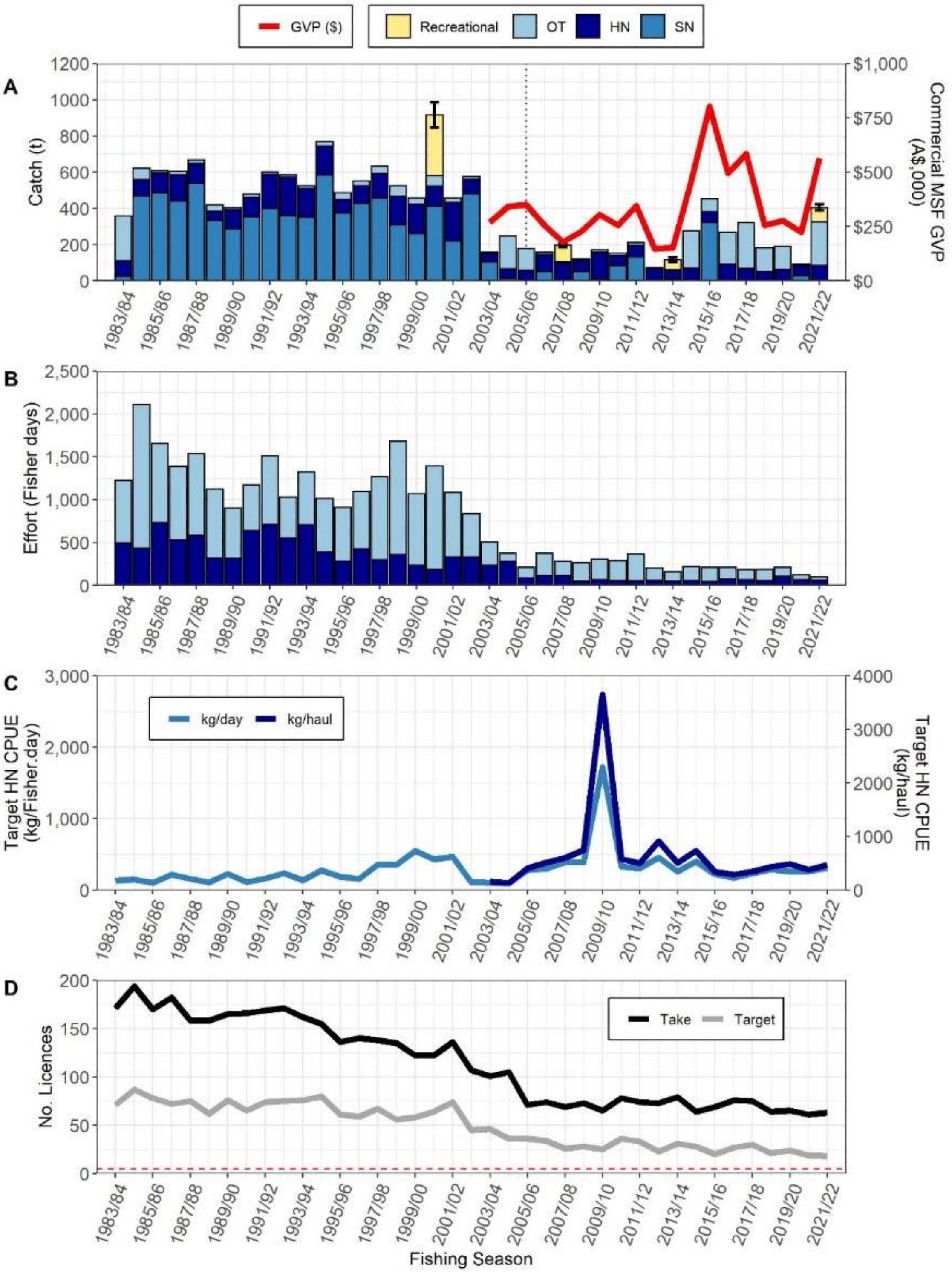

Figure 4.8-1. Long-term trends in State-wide estimates for Western Australian Salmon of (A) total catch for haul nets, set nets and all other gear types, estimated recreational catch and gross production value; (B) target effort for haul nets, set nets and all other gear types; (C) target CPUE for haul nets; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. A red dashed line in panel D represents the number of licences where data becomes confidential. The dotted vertical line on panel A indicates implementation of a net licence buyback scheme that reduced net fishing effort. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

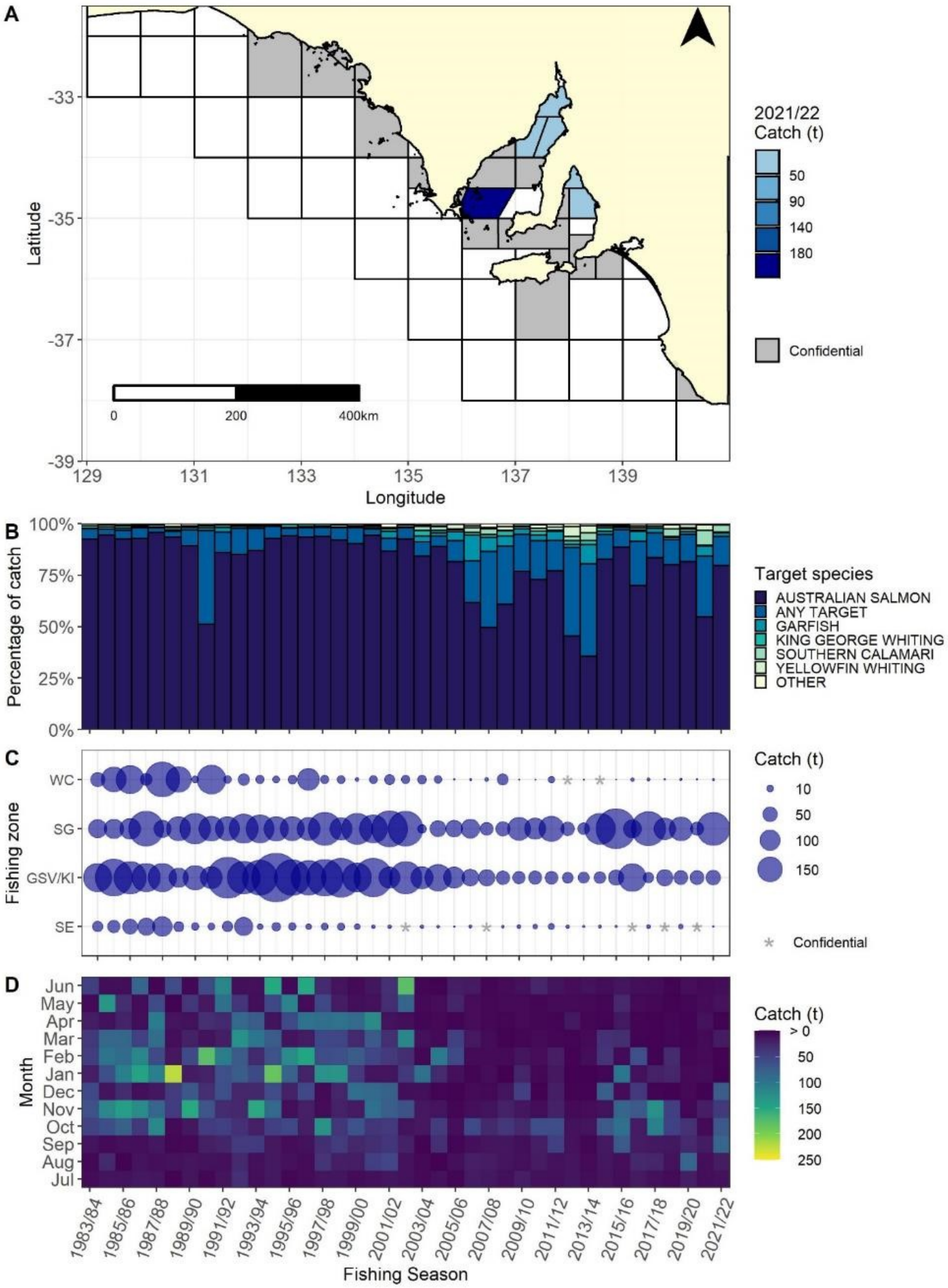

Figure 4.8-2. Regional dynamics of Western Australian Salmon: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.9. Australian Herring

<table>
<tr><th colspan="5">Species summary</th></tr>
<tr><td colspan="5">Australian Herring
Arripis georgianus
</td></tr>
<tr><td>Assessment scale</td><td colspan="2">State-wide</td><td>Species Tier</td><td>Tier 2 in SG and GSV/KI fishing zones. Tier 3 in WC and SE fishing zones</td></tr>
<tr><td>Stock status</td><td colspan="2">2019 – Sustainable</td><td>2020 – Sustainable</td><td>2021/22 – Sustainable</td></tr>
<tr><td>Biology</td><td colspan="4">
• Occur over seagrass, reef and sandy habitats in coastal marine and estuarine waters around southern Australia between Shark Bay in WA and Forster in NSW, although is uncommon east of Bass Strait (Duffy et al. 2021). It constitutes a single biological stock across this range (Ayvazian et al. 2000, Ayvazian et al. 2004).
• Pelagic, small-bodied, moderate-growth rate, max. age 12 years, max. length 410 mm TL, L_{50} 180–200 mm TL (2 years old) (Cappo 1987) .
• Spawning occurs in May/June in the south-west of WA, with eggs and larvae dispersed southwards and eastwards by the Leeuwin Current (Smith et al. 2013).
• Fish grow and mature in each jurisdiction before migrating back to the spawning area as 2–3-year-olds, where they remain as adults.
• As a result of these demographic processes, the MSF harvests mainly sub-adults.</td></tr>
<tr><td>Description of the fishery</td><td colspan="4">
• Supports commercial and recreational fisheries in SA.
• In the commercial sector, Australian Herring is mostly taken as by-product by fishers using haul nets to target higher value species in the gulfs.
• Most of the commercial catch is supplied for human consumption, with small quantities supplied as bait for commercial longlining or Rock Lobster fishing.
• An important recreational fishery species in SA that is mostly taken by shore-based fishers using bait and lures in inshore coastal waters (Beckmann et al. 2023).
• There are no catch and effort data for Aboriginal and traditional fishing.</td></tr>
<tr><td>Management regulations</td><td colspan="4">
• No legal minimum length.
• General haul net restrictions apply (e.g., max. length 600 m, max. drop 10 m).
• Recreational daily bag and boat limit of 40 and 120 fish, respectively.</td></tr>
<tr><td rowspan="6">Commercial statistics</td><td>Season</td><td>Total catch
t</td><td>Targeted HN effort
fisher-days</td><td>Targeted HN CPUE
kg/fisher-day</td></tr>
<tr><td>2017/18</td><td>85</td><td>24</td><td>123.4</td></tr>
<tr><td>2018/19</td><td>97</td><td>32</td><td>82.5</td></tr>
<tr><td>2019/20</td><td>88</td><td>confidential</td><td>confidential</td></tr>
<tr><td>2020/21</td><td>110</td><td>32</td><td>76.5</td></tr>
<tr><td>2021/22</td><td>109</td><td>44</td><td>234.1</td></tr>
</table>

<table>
<tr><th rowspan="5">Recreational catch estimate</th><th>Survey</th><th>Estimated catch
t (± SE)</th><th>Retained
%</th><th>Released
%</th></tr>
<tr><td>2000–01</td><td>254 (35)</td><td>77%</td><td>23%</td></tr>
<tr><td>2007–08</td><td>93 (12)</td><td>69%</td><td>31%</td></tr>
<tr><td>2013–14</td><td>157 (35)</td><td>87%</td><td>13%</td></tr>
<tr><td>2021–22</td><td>41 (6)</td><td>70%</td><td>30%</td></tr>
<tr><th>Performance indicators</th><td colspan="4">• Total catch – No TRPs breached.
• Targeted effort (haul net) – No TRPs breached.
• Targeted CPUE (haul net) – TRPs breached for highest targeted CPUE (haul net) and greatest interannual change (↑).</td></tr>
<tr><th>Assessment summary</th><td colspan="4">The biological stock of Australian across southern Australia is accessed by fisheries in WA, SA, VIC and NSW. Historically, WA has been the main contributor to annual catches with smaller contributions from SA and minor contributions from VIC and TAS. The stock was classified as ‘sustainable’ in the 2020 Status of Australian Fish Stocks Report (Duffy et al. 2021).

In SA, status of Australian Herring in the MSF is determined by catch, targeted haul net effort and CPUE trends using a weight-of-evidence approach. Catches have been largest in the two gulf fishing zones, albeit through small amounts of targeting (Figure 4.9-2). Total catch peaked at 498 t in 1987/88 and has substantially declined over the past three decades, particularly following the implementation of a series of netting closures in 2005 (Figure 4.9-1). The total catch of 108 t in 2021/22 was similar to the average annual catch over the last 10 years. CPUE within the haul net sector have been highly variable with no clear trend. In 2021/22, haul net CPUE increased to 234 kg.fisher-day^{-1} which was the highest on record. The above evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired.

On the basis of the evidence provided above, the the MSF-management unit for Australian Herring is classified as a **sustainable** stock.</td></tr>
<tr><th>Research needs</th><td colspan="4">• Development of harvest strategy with performance indicators, reference points and harvest control rules.
• Standardisation of commercial CPUE, using improved measures of fishing effort.
• Improved estimates of recreational catch and effort.
• Improved understanding of Aboriginal/Traditional importance</td></tr>
</table>

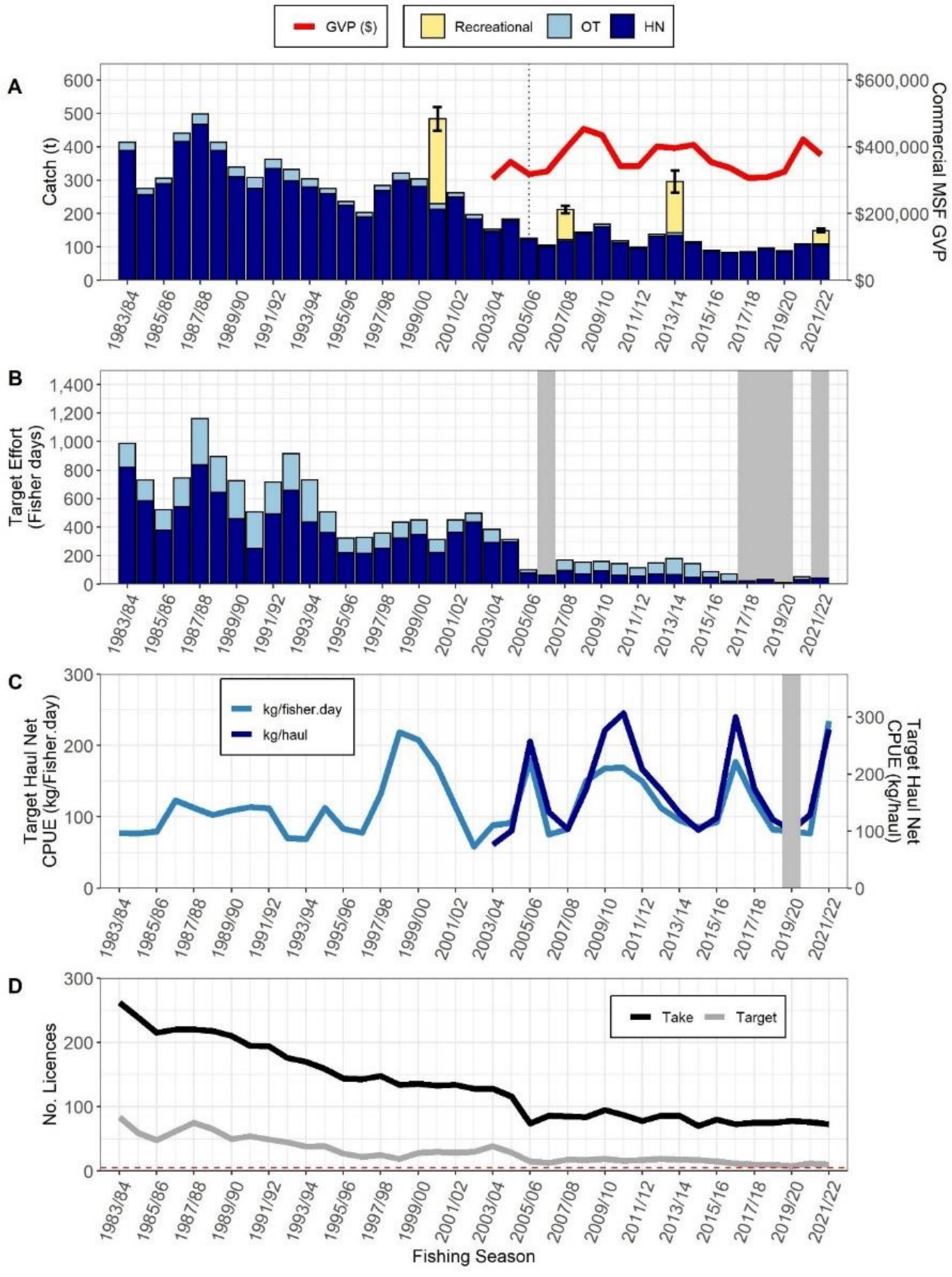

Figure 4.9-1. Long-term trends in State-wide estimates for Australian Herring of (A) total catch for haul nets and all other gear types, estimated recreational catch and gross production value; (B) target effort for haul nets and all other gear types; (C) target CPUE for haul nets; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. A red dashed line in panel D represents the number of licences where data becomes confidential. The dotted vertical line on panel A indicates implementation of a net licence buyback scheme that reduced net fishing effort. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

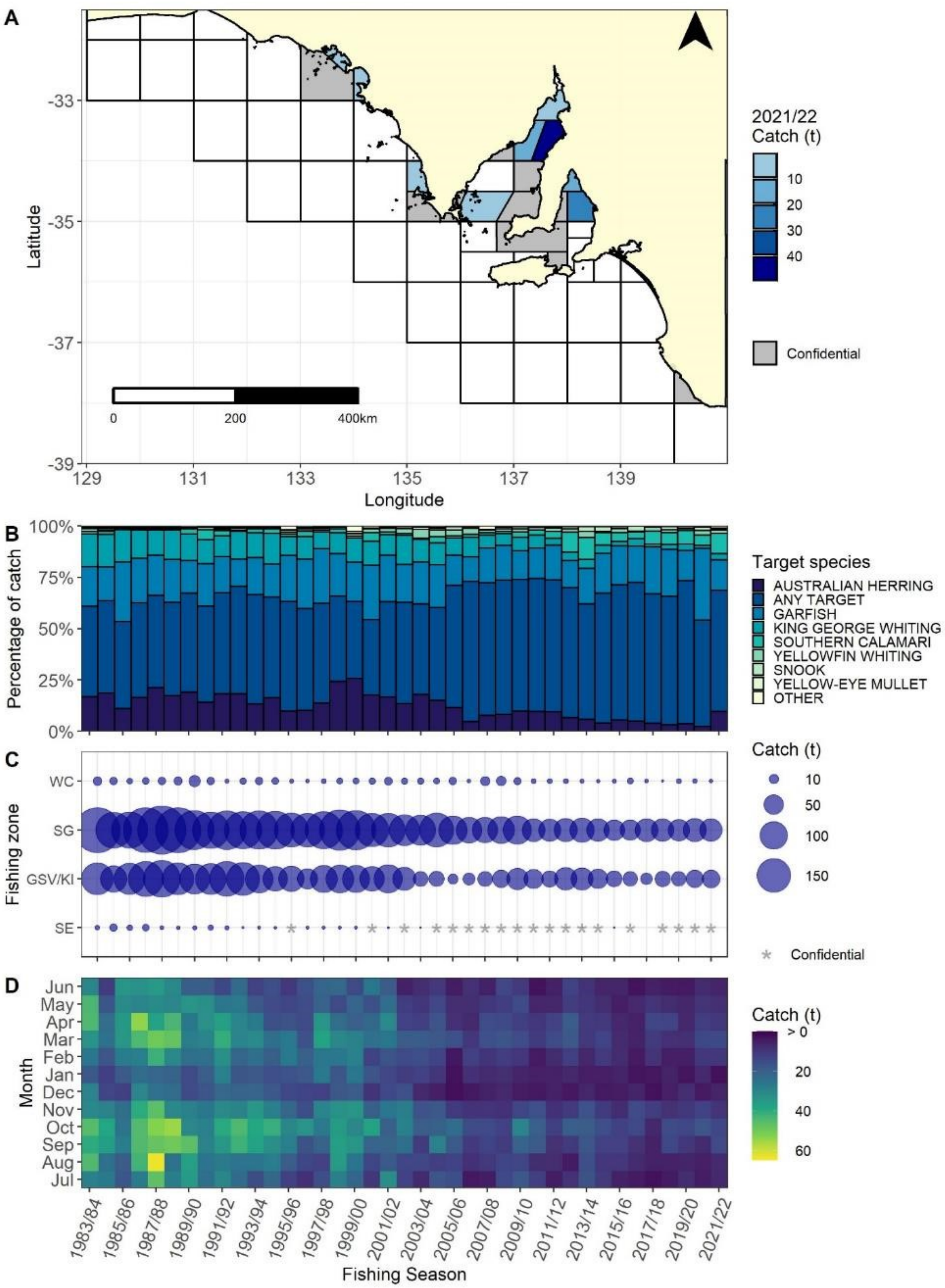

Figure 4.9-2. Regional dynamics of Australian Herring: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.10. Whaler Sharks

<table>
<tr><th colspan="4">Species summary</th></tr>
<tr><td colspan="2">Whaler Sharks
Carcharhinus spp.</td><td colspan="2"></td></tr>
<tr><td>Assessment scale</td><td>State-wide</td><td>Species Tier</td><td>Tier 2 in SG and GSV/KI fishing zones</td></tr>
<tr><td>Stock status</td><td>2019 – Undefined</td><td>2020 – Undefined</td><td>2021/22 – Undefined</td></tr>
<tr><td>Biology</td><td colspan="3">• Two species of Whaler Sharks, the Bronze Whaler (Carcharhinus brachyurus) and the Dusky Shark (C. obscurus) are taken in the MSF.
• Bronze Whalers are distributed through the warm temperate waters of southern Australia, from Geraldton in WA through to the QLD/NSW state boarder. This species is long-lived (~30 years), with late sexual maturity (16 years both sexes) at lengths of 2.2 m TL for males and 2.7 m TL for females (Drew et al. 2016).
• Australian Bronze Whaler population is panmictic and considered as a single biological stock.
• Dusky Sharks are broadly distributed through all Australian tropical to warm temperate coastal and continental shelf waters. They are long-lived (max ~50 years), slow growing, have a 3-year breeding frequency and only produce 3–12 pups per litter (McAuley et al. 2007, Romine et al. 2009).
• South Australian Dusky Shark population is considered the eastern component of the Western Australian biological stock.</td></tr>
<tr><td>Description of the fishery</td><td colspan="3">• Commercial catches are not resolved at species level.
• In recent years Whaler Sharks have been targeted with floating and demersal longlines during spring-autumn in WC, SG and GSV waters (Figure 4.10-1; Figure 4.10-2).
• MSF longline catches are mostly comprised of juvenile sharks (~90%).
• Recreational fishers target Whaler Sharks for both consumption and as a trophy fish from boats and shore-based fishing.</td></tr>
<tr><td>Management regulations</td><td colspan="3">• No size limits for commercial and recreational fishers.
• MSF gear restrictions for Whaler Sharks include daily hook limit 400 hook limit in all State waters, maximum leader diameter of 2mm, and 150mm minimum mesh size for nets.
• Recreational fishing regulations for Whaler Sharks (both species) include a daily bag limit of one shark per fisher and a daily boat limit of three sharks, when there are three or more fishers on-board.
• Recreational gear restrictions include the use of wire trace of 2mm or greater and fishing hook size greater than 12/0.
• Spatial and gear restrictions are in place along the Adelaide coastline between 5:00- and 21:00 for targeting sharks.</td></tr>
</table>

Commercial statistics	**Season**	**Total catch** *t*	**Targeted LL effort** *fisher-days*	**Targeted LL CPUE** *kg/fisher-day*
	2017/18	54	238	131.92
	2018/19	50	202	161.39
	2019/20	56	246	135.94
	2020/21	67	307	187.62
	2021/22	70	365	134.53
Recreational catch estimate	**Survey**	**Estimated catch** *t (± SE)*	**Retained** *%*	**Released** *%*
	2000/01	-	33%	67%
	2007/08	-	80%	20%
	2013/14	-	0%	100%
	2021/22	-	11%	89%
Performance indicators	• Total catch – TRPs were not breached. • Targeted effort (Longline) – 3rd highest targeted LL effort TRP was breached. • Targeted CPUE (Longline) - TRPs were not breached.			
Assessment summary	There is limited information for determining stock status, and the information available is compounded by a paucity of information on the catch composition (species) of Whaler Sharks harvested. The limited data prevents assessment of current stock size or fishing pressure. Consequently, there is insufficient information available to confidently classify the status of this stock. On the basis of the evidence provided above, the Southern Australia biological stock is classified as an **undefined** stock.			
Research needs	• Quantify the species composition of the combined Whaler Shark catch. • Development of harvest strategy with performance indicators, reference points and harvest control rules. • Standardisation of commercial CPUE, using improved measures of fishing effort. • Improved estimates of recreational catch and effort. • Improved understanding of Aboriginal/Traditional importance.			

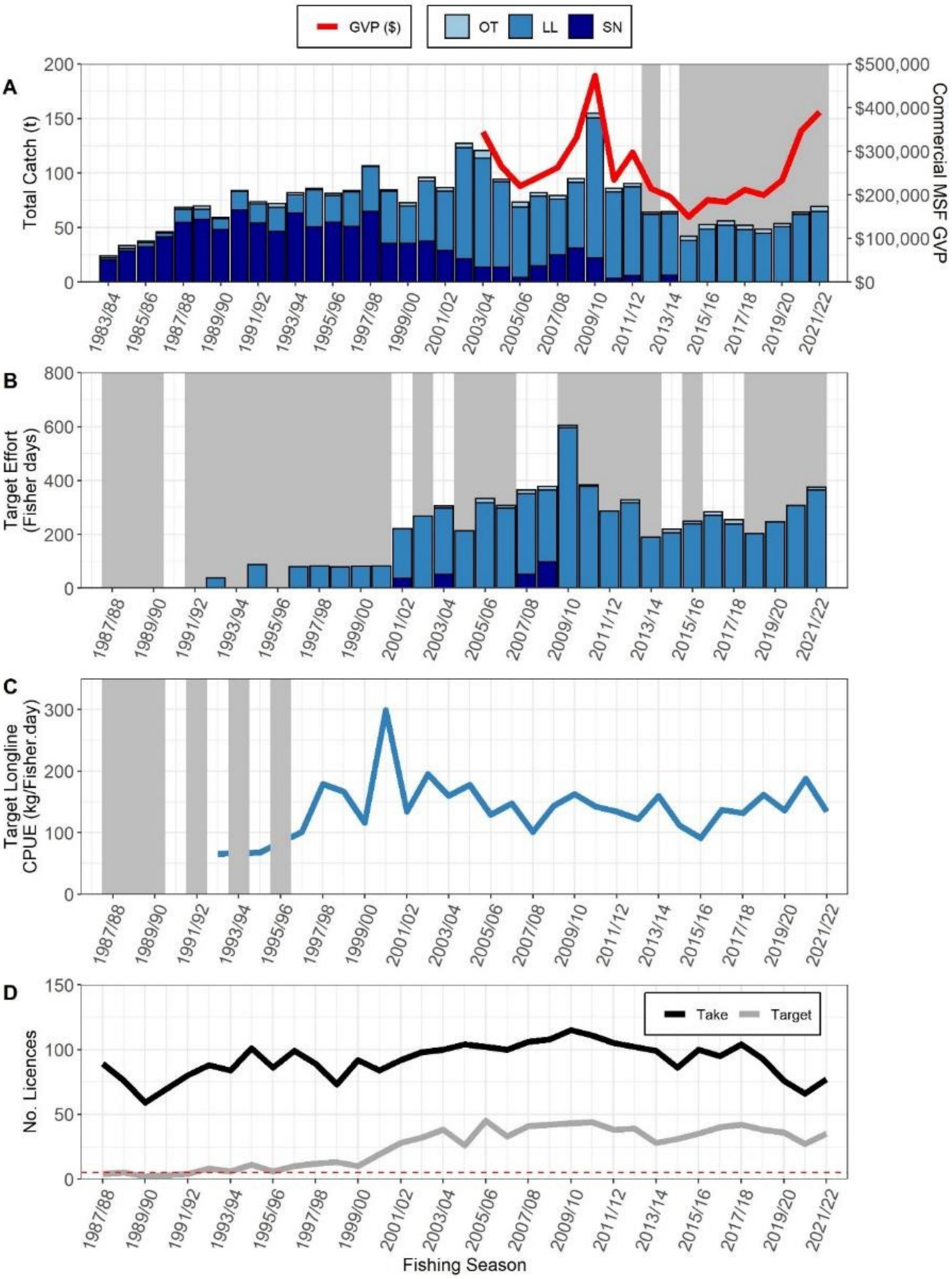

Figure 4.10-1. Long-term trends in State-wide estimates for Whaler Sharks of (A) total catch for longlines, set nets and all other gear types, estimated recreational catch and gross production value; (B) target effort for longlines, set nets and all other gear types; (C) target CPUE for longlines; and (D) the number of active licence holders taking or targeting the species. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

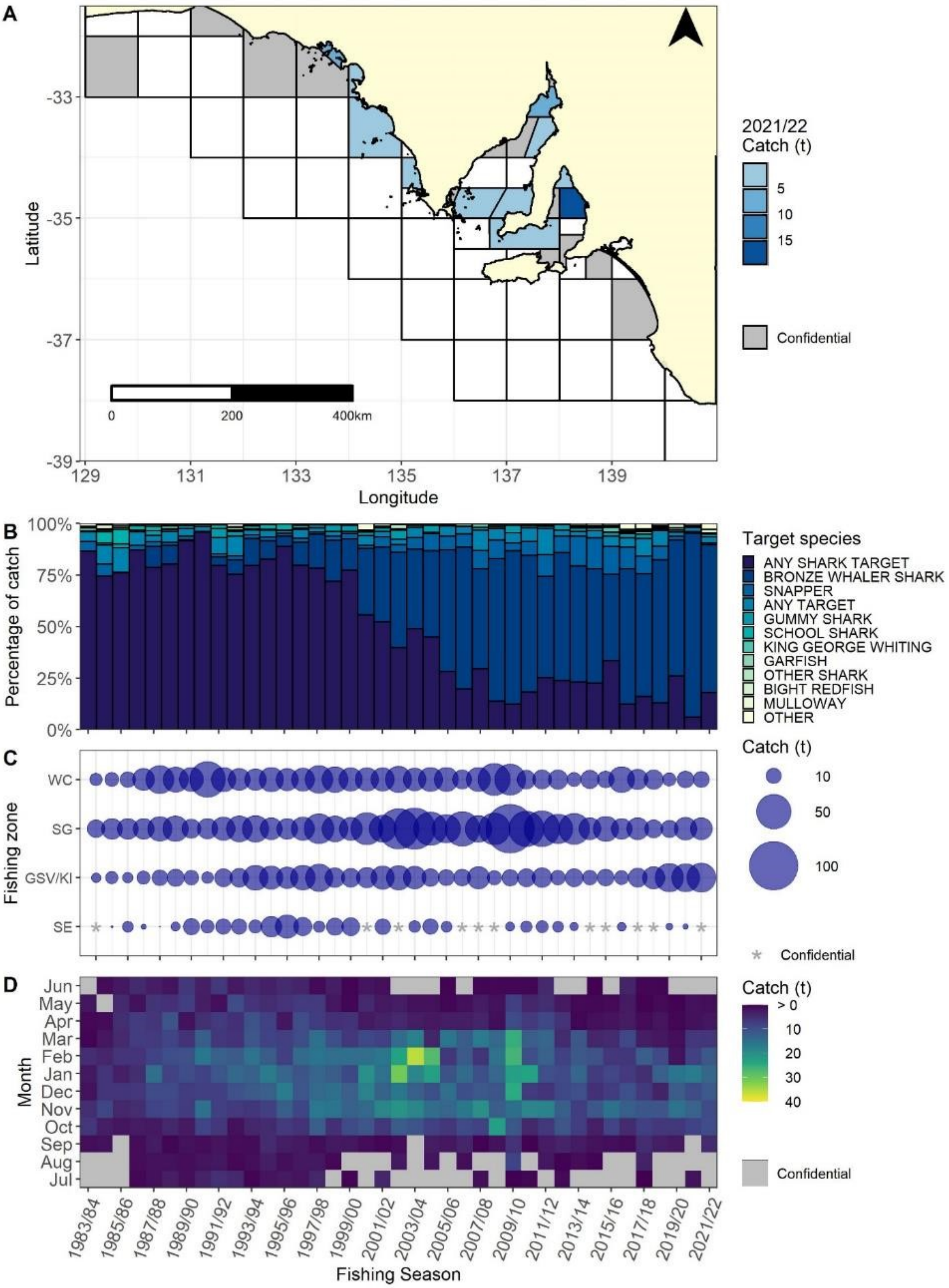

Figure 4.10-2. Regional dynamics of Whaler Sharks: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.11. Snook

Species summary

Snook

Sphyraena novaehollandiae

Assessment scale	State-wide	**Species Tier**	Tier 3 in all zones
Stock status	2019 – Sustainable	2020 – Sustainable	**2021/22 – Sustainable**

Biology

- Occur over seagrass beds and reefs in inshore and offshore waters across southern Australia from Perth to Sydney, including around TAS and NZ (Emery et al. 2016).
- Elongate, large-bodied, fast-growing, max. age 12 years, max. length 820 mm TL, L_{50} 391 mm TL for males and 403 mm TL for females (O'Sullivan and Jones 2003) .
- Spawning occurs from September to February (Bertoni 1994).
- Stock structure of Snook across southern Australia is uncertain.
- Assessment of stock status of Snook in the MSF is undertaken at the management unit level (State-wide).

Description of the fishery

- Supports commercial and recreational fisheries in SA.
- In the commercial sector, Snook are targeted using troll lines, and are taken as by-product by fishers using haul nets to target higher value species.
- Recreational fishers target Snook from boats with rods and lines using bait and lures in inshore and offshore waters.
- There are no catch and effort data for Aboriginal and traditional fishing.

Management regulations

- Legal minimum length: 450 mm TL.
- General haul net restrictions apply (e.g., max. length 600 m, max. drop 10 m)
- Commercial fishers are permitted to use only two handlines at a time with a maximum of three hooks/jigs/lures on each line.
- Recreational daily bag and boat limit of 20 and 60 fish, respectively.

Commercial statistics

Season	Total catch *t*	Targeted TL effort *fisher-days*	Targeted TL CPUE *kg/fisher-day*
2017/18	42	443	16.5
2018/19	41	456	13.3
2019/20	39	354	11.1
2020/21	32	243	12.9
2021/22	24	165	22.7

	Survey	Estimated catch *t (± SE)*	Retained *%*	Released *%*
Recreational catch estimate	2000/01	71 (16)	93%	7%
	2007/08	83 (23)	75%	25%
	2013/14	126 (60)	93%	7%
	2021/22	23 (7)	95%	5%

Performance indicators	• Total catch – TRP breached for lowest total catch. • Targeted effort (troll line) – TRP breached for lowest total effort (troll line). • Targeted CPUE (troll line) – TRPs breached for greatest interannual change (↑) and greatest 3-year trend (↑).
Assessment summary	Status of Snook in the MSF is determined by catch, effort and CPUE trends using a weight-of-evidence approach. Most of the commercial catch is taken as targeted catch by trolling line fishers and by-product by haul net fishers (Figure. 4.11-2). Total catches of Snook at the State-wide and zonal scales have declined considerably since the mid-1990s (Figure. 4.11-1). For the regional fisheries in the two northern gulfs, this largely reflects the declines in troll line effort that have occurred over this period. Nevertheless, from 1983/84 to the early 2000s, despite that targeted troll line CPUE was variable it showed an increasing trend. Subsequently, CPUE continued to fluctuate, increasing from to 29 kg.fisher-day^{-1} in 2012/13 before declining to a historical low of 11.1 kg.fisher-day^{-1} in 2019/20. In 2021/22, targeted troll line CPUE increased to 22.7 kg.fisher-day^{-1}, which is similar to the long-term average for the fishery. The above evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On the basis of the evidence provided above, the the MSF-management unit for Snook is classified as a **sustainable** stock.
Research needs	• Development of harvest strategy with performance indicators, reference points and harvest control rules. • Standardisation of commercial CPUE, using improved measures of fishing effort. • Improved estimates of recreational catch and effort • Improved understanding of Aboriginal/Traditional importance

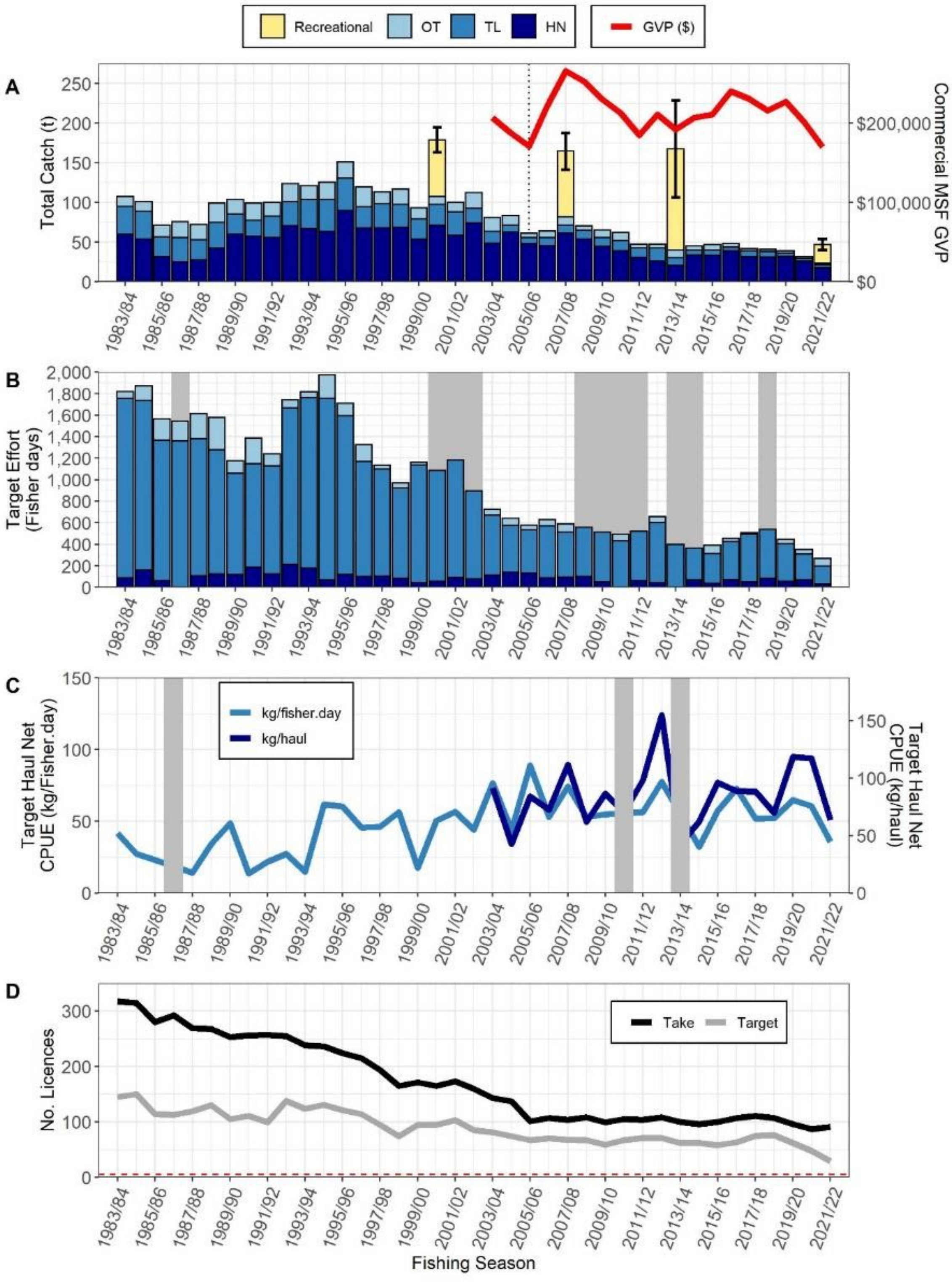

Figure 4.11-1. Long-term trends in State-wide estimates for Snook of (A) total catch for haul nets, troll lines and all other gear types, estimated recreational catch and gross production value; (B) target effort for haul nets, troll lines and all other gear types; (C) target CPUE for troll lines; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. A red dashed line in panel D represents the number of licences where data becomes confidential. The dotted vertical line on panel A indicates implementation of a net licence buyback scheme that reduced net fishing effort. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

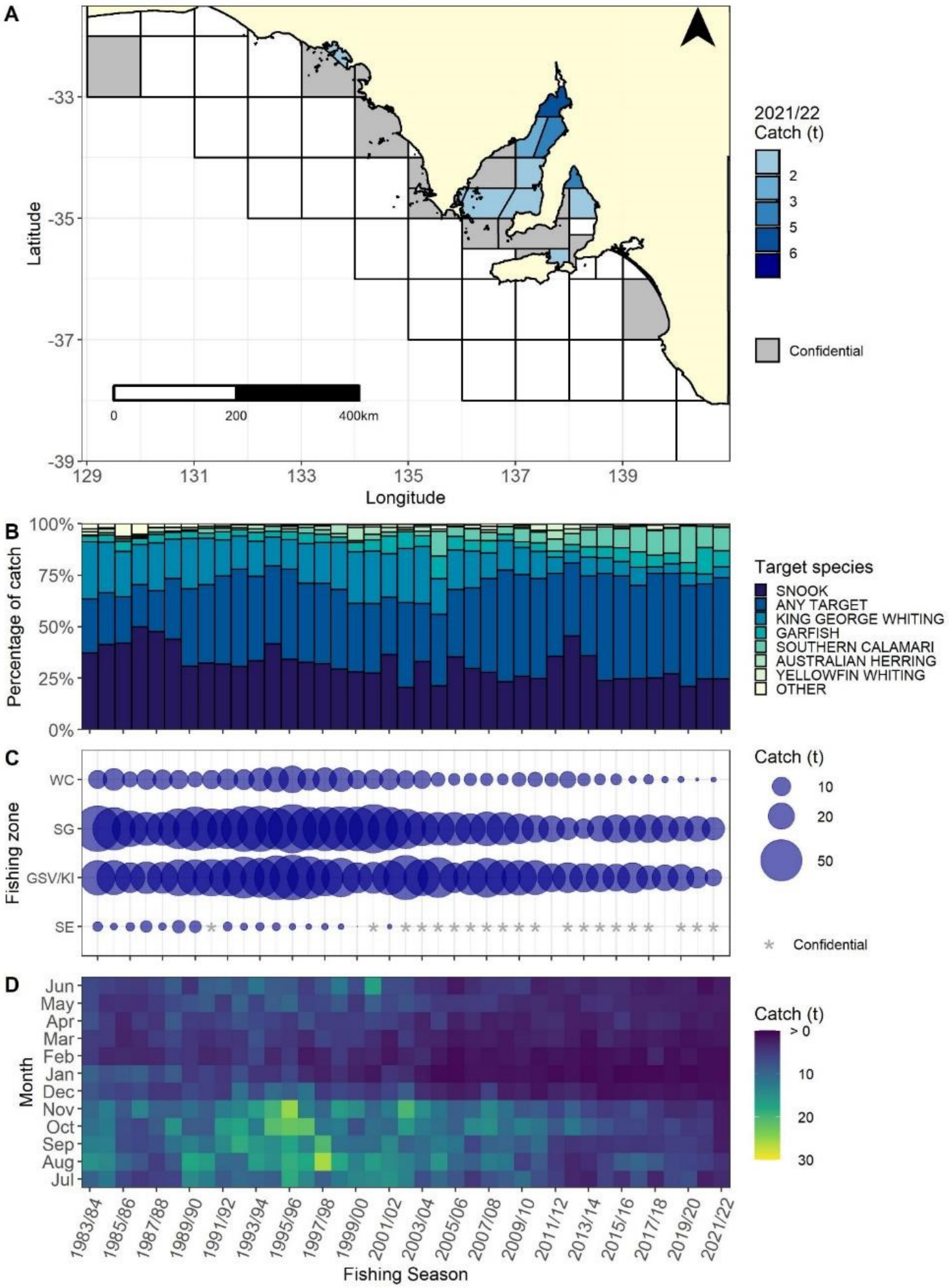

Figure 4.11-2. Regional dynamics of Snook: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.12. Sand Crab

Species summary

Sand Crab

Ovalipes australiensis

Assessment scale	State-wide	**Species Tier**	Tier 3 in all zones
Stock status	2019 – Sustainable	2020 – Sustainable	**2021/22 – Sustainable**

Biology

- Distributed along surf beaches, in sandy bays, inlets, and offshore waters to ~100 m depth across southern Australia from Wide Bay in Queensland to Rottnest Island in Western Australia, including the waters of TAS (Kailola et al. 1993).
- Maximum size ~100 mm carapace width (CW) (Jones and Morgan 1994).
- Longevity and stock structure is unknown.
- Sand Crabs in Coffin Bay are winter spawners for which reproductive activity peaks in July, with berried females present until late August (Jones and Deakin 1997).
- Female Sand Crabs attain sexual maturity at a smaller size than males.
- The fishery is largely based on the capture of male crabs, as most females are below the LML (Jones and Deakin 1997).
- Assessment of stock status for Sand Crab is undertaken at the State-wide scale.

Description of the fishery

- The commercial fishery was initially developed in Coffin Bay as an experimental trap or pot fishery in 1982 and subsequently extended to southern coastal areas, with active targeting of Sand Crabs using more efficient hoop and drop nets and implementing mechanical net haulers (Jones 1995, Jones and Deakin 1997).
- Recreational fishers target Sand Crabs using hoop or drop nets.

Management regulations

- LML 100 mm carapace width (measured across the widest point).
- Commercial fishers require a specific licence endorsement to target Sand Crabs and are restricted to a nominated quantity of crab net/pots.
- Recreational fishers have a combined Sand/Blue Crab bag and boat limit of 20 and 60 crabs, respectively.

Commercial statistics

Season	Total catch *t*	Targeted crab net effort *fisher-days*	Targeted CPUE *kg/fisher-day*
2017/18	35	327	102.3
2018/19	64	445	142.9
2019/20	51	360	141.9
2020/21	63	383	159.8
2021/22	56	277	176.8

Recreational catch estimate	**Survey**	**Estimated catch** *t (± SE)*	**Retained** *%*	**Released** *%*
	2000/01	19 (6)	47%	54%
	2007/08	11 (5)	43%	57%
	2013/14	10 (8)	52%	48%
	2021/22	2 (1)	35%	65%
Performance indicators	• Total catch – No trigger breaches. • Targeted effort (gear) – No trigger breaches. • Targeted CPUE (gear) – Trigger breached for 3rd highest CPUE and greatest five-year trend.			
Assessment summary	Status of Sand Crab in the MSF is determined by catch, effort and CPUE trends using a weight-of-evidence approach. The total MSF catch in 2021/22 was 56 t which was below the previous ten-year average of 61 t (SE = 5 t). The total targeted effort was 277 fisher days in 2021/22 which produced a CPUE (targeted crab net effort) by fisher day of 177 kg.fisher-day^{-1}. The CPUE in 2021/22 was the highest on record. Increasing CPUE and decreasing catch and effort levels are likely a result of increases in efficiencies in the fishery, rather than evidence of a decline in recruitment. The above evidence indicates that the biomass of this stock is unlikely to be depleted, that recruitment is unlikely to be impaired and that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On the basis of the evidence provided above, the MSF-management unit for Sand Crabs is classified as a **Sustainable** stock.			
Research needs	• Information on stock structure, longevity, size, and age at maturity. • Standardisation of CPUE to account for changes in efficiency. • Improved estimates of recreational catch and effort. • Improved understanding of Aboriginal/Traditional importance.			

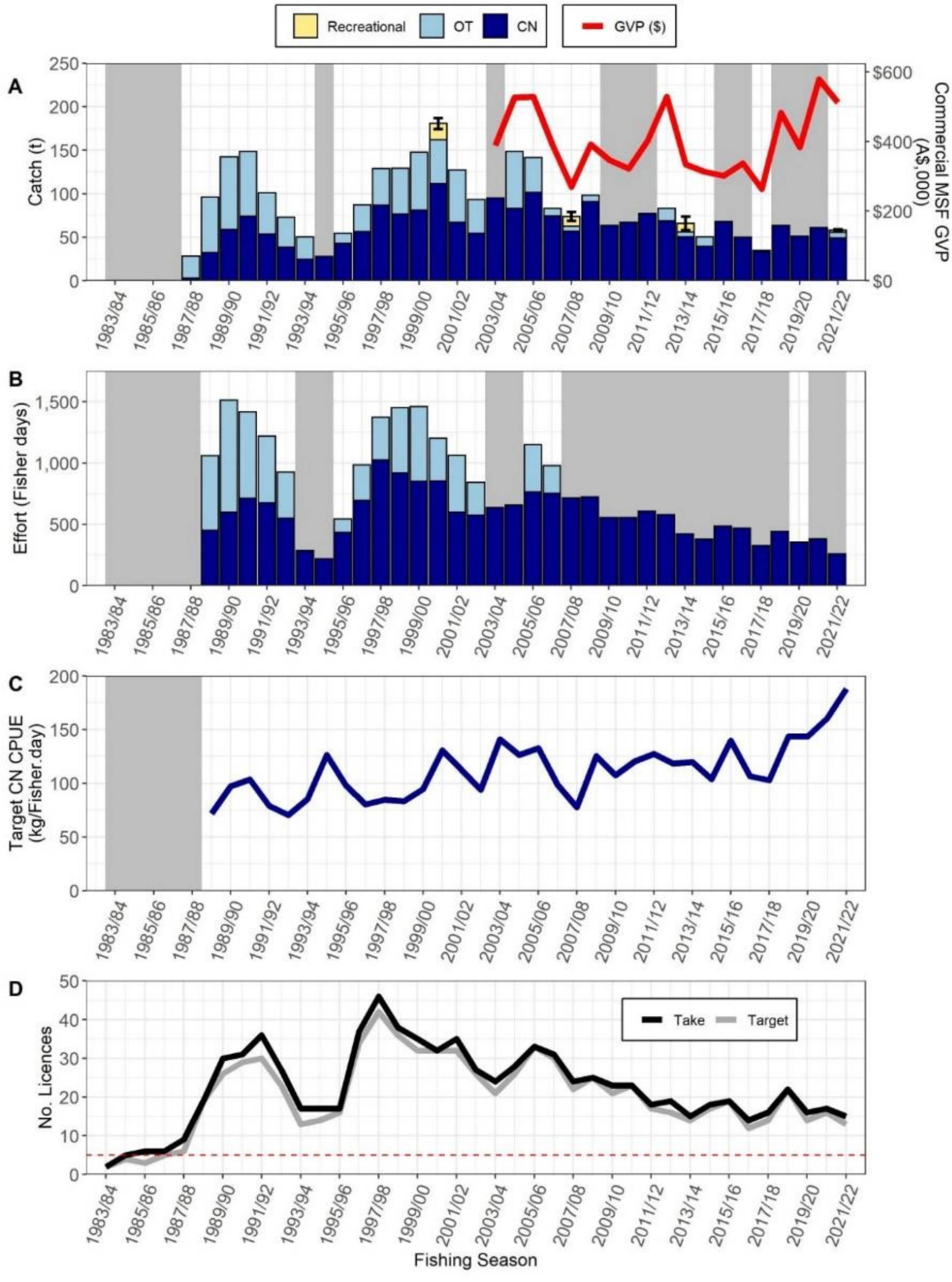

Figure 4.12-1. Long-term trends in State-wide estimates for Sand Crab of (A) total catch for crab nets and all other gear types, estimated recreational catch and gross production value; (B) target effort for crab nets and all other gear types; (C) target CPUE for crab nets; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

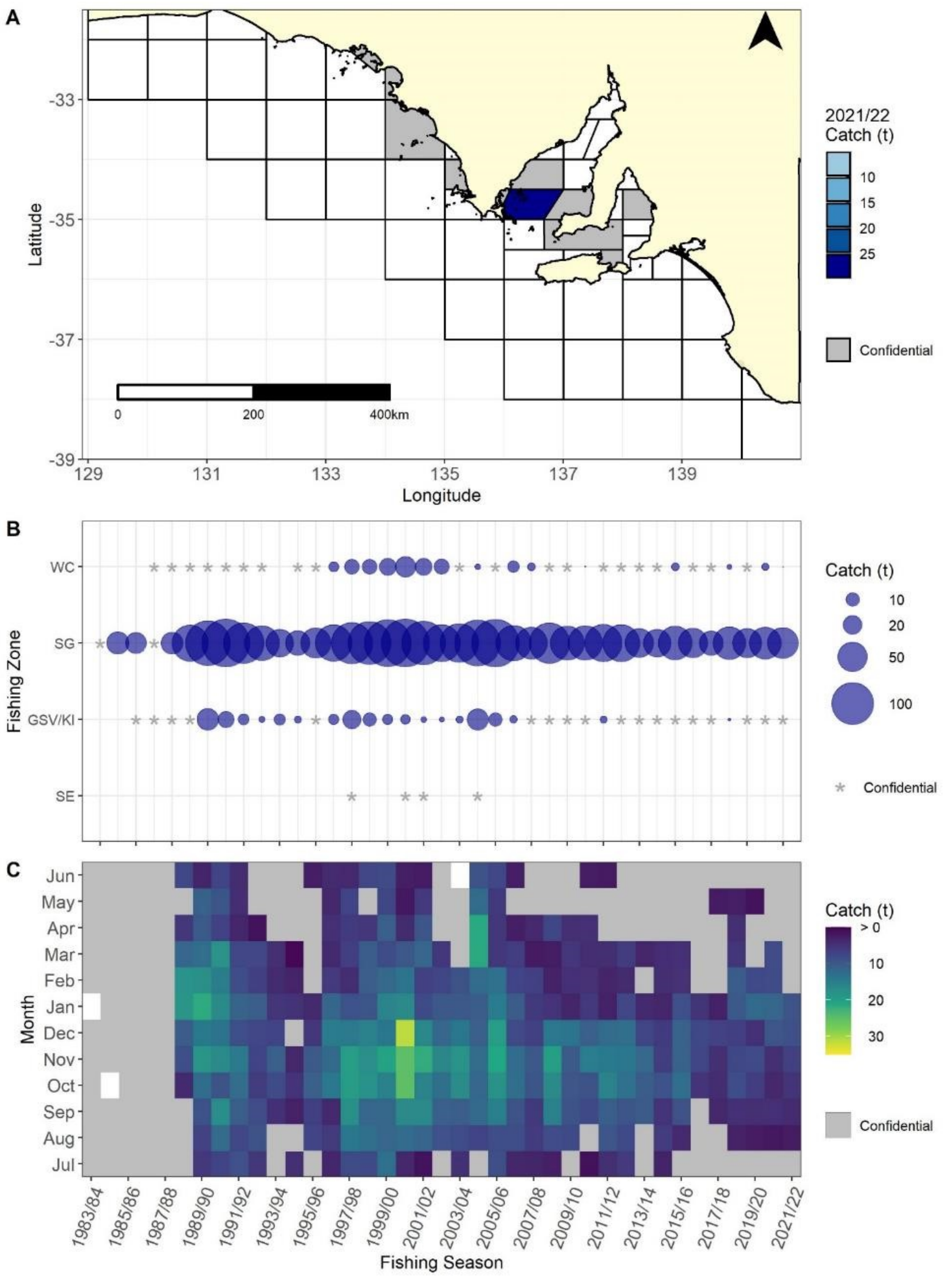

Figure 4.12-2. Regional dynamics of Sand Crab: (A) The spatial distribution of catch by the commercial sector in 2021/22. Long-term trends in: (B) the annual distribution of catch among zones, (C) months of the year.

4.13. Yelloweye Mullet

Species summary

Yelloweye Mullet

Aldrichetta forsteri

Assessment scale	State-wide	Species Tier	Tier 3 in all zones
Stock status	2019 – Sustainable	2020 – Sustainable	**2021/22 – Sustainable**

Biology

- Occur in estuaries and nearshore coastal waters of southern Australia from central NSW to central west coast WA, including TAS (Gomon et al. 2008).
- Common over sandy and muddy substrates to depths of 20 m (Kailola et al. 1993).
- Medium-bodied, fast-growing, max. age 10 years, max. length 440 mm TL, L_{50} 250 mm TL for males and 240 mm TL for females (Earl and Ferguson 2013).
- A marine estuarine-opportunist species, i.e., spawns at sea; regularly enters estuaries, particularly as juveniles, but also uses coastal marine waters as alternative nursery areas (Earl and Ferguson 2013).
- Spawning occurs from August to February each year.
- Biological stock structure across southern Australia is uncertain.
- Assessment of stock status of Yelloweye Mullet in the MSF is undertaken at the management unit level (State-wide).

Description of the fishery

- Supports commercial and recreational fisheries in SA.
- In most years, >90% of the commercial catch is taken by the LCF in the Coorong, with the remainder taken as by-product by the MSF using haul nets in gulf waters.
- Recreational fishers target Yelloweye Mullet from the shore using rod and line in inshore marine waters and estuaries.
- There are no catch and effort data for Aboriginal and traditional fishing.

Management regulations

- Legal minimum length: 210 mm TL.
- General haul net restrictions apply (e.g., max. length 600 m, max. drop 10 m).
- Recreational daily bag and boat limit of 60 and 180 fish, respectively.

Commercial statistics

Season	Total catch *t*	Total HN effort *fisher-days*	Total HN CPUE *kg/fisher-day*
2017/18	23	646	31.3
2018/19	16	602	22.9
2019/20	11	508	18.7
2020/21	9	382	21.2
2021/22	7	303	20.3

<table>
<tr><th rowspan="5">Recreational catch estimate</th><th>Survey</th><th>Estimated catch
t (± SE)</th><th>Retained
%</th><th>Released
%</th></tr>
<tr><td>2000/01</td><td>41 (11)</td><td>67%</td><td>33%</td></tr>
<tr><td>2007/08</td><td>28 (5)</td><td>57%</td><td>43%</td></tr>
<tr><td>2013/14</td><td>13 (4)</td><td>71%</td><td>29%</td></tr>
<tr><td>2021/22</td><td>11 (4)</td><td>84%</td><td>16%</td></tr>
<tr><th>Performance indicators</th><td colspan="4">• Total catch – TRP breached for lowest total catch.
• Total effort (haul net) – TRP breached for lowest total effort (haul net).
• Total CPUE (haul net) – No TRPs breached.</td></tr>
<tr><th>Assessment summary</th><td colspan="4">Status of Yelloweye Mullet in the MSF is determined by catch, effort and CPUE trends using a weight-of-evidence approach. Yelloweye Mullet is predominantly taken as by-product within the haul net sector of the MSF (Figure 4.13-2). Annual catches peaked at 176 t in 1989/90 and have since progressively declined to 7 t in 2021/22 (Figure 4.13-1). This long-term decline reflects a gradual reduction in fishing effort in the haul net sector of the fishery due a combination of licence buy-backs and declining wholesale prices rather than a declining biomass. This is because despite haul net CPUE declining since 2005/06, it has been relatively stable at levels similar to those during the 1980s and 1990s when a larger proportion of the total catch was taken as targeted catch using haul nets (Figure 4.13-2). In SA, Yelloweye Mullet is predominantly caught in the LCF where it was recently classified as sustainable (Earl et al. 2022). The above evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current low level of fishing mortality is unlikely to cause the stock to become recruitment impaired.
On the basis of the evidence provided above, the the MSF-management unit for Yelloweye Mullet is classified as a sustainable stock.</td></tr>
<tr><th>Research needs</th><td colspan="4">• Development of harvest strategy with performance indicators, reference points and harvest control rules.
• Standardisation of commercial CPUE, using improved measures of fishing effort.
• Improved estimates of recreational catch and effort.
• Improved understanding of Aboriginal/Traditional importance.</td></tr>
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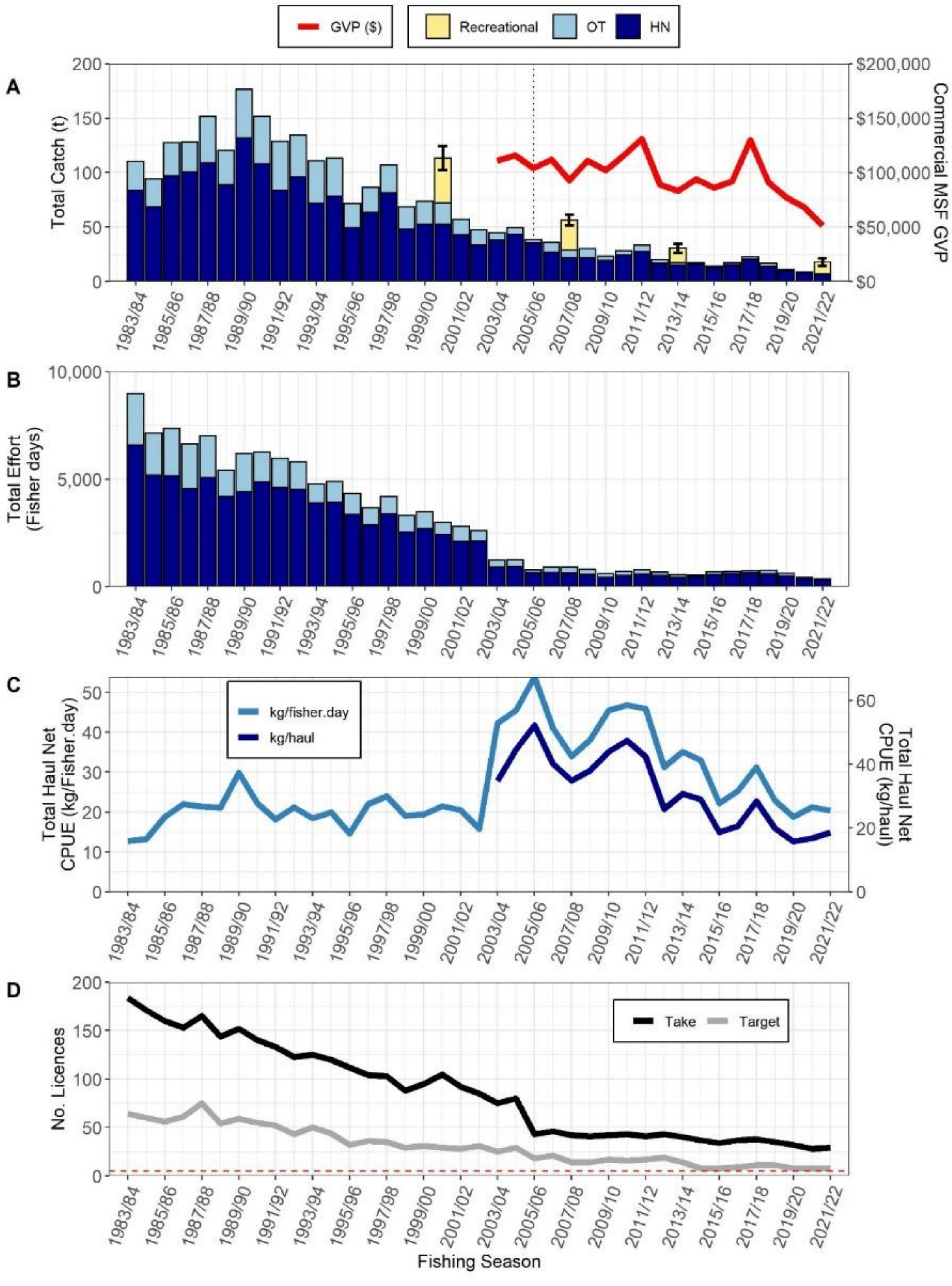


Figure 4.13-1. Long-term trends in State-wide estimates for Yelloweye Mullet of (A) total catch for haul nets, and all other gear types, estimated recreational catch and gross production value; (B) total effort for haul nets, and all other gear types; (C) total CPUE for haul nets; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. A red dashed line in panel D represents the number of licences where data becomes confidential. The dotted vertical line on panel A indicates implementation of a net licence buyback scheme that reduced net fishing effort. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

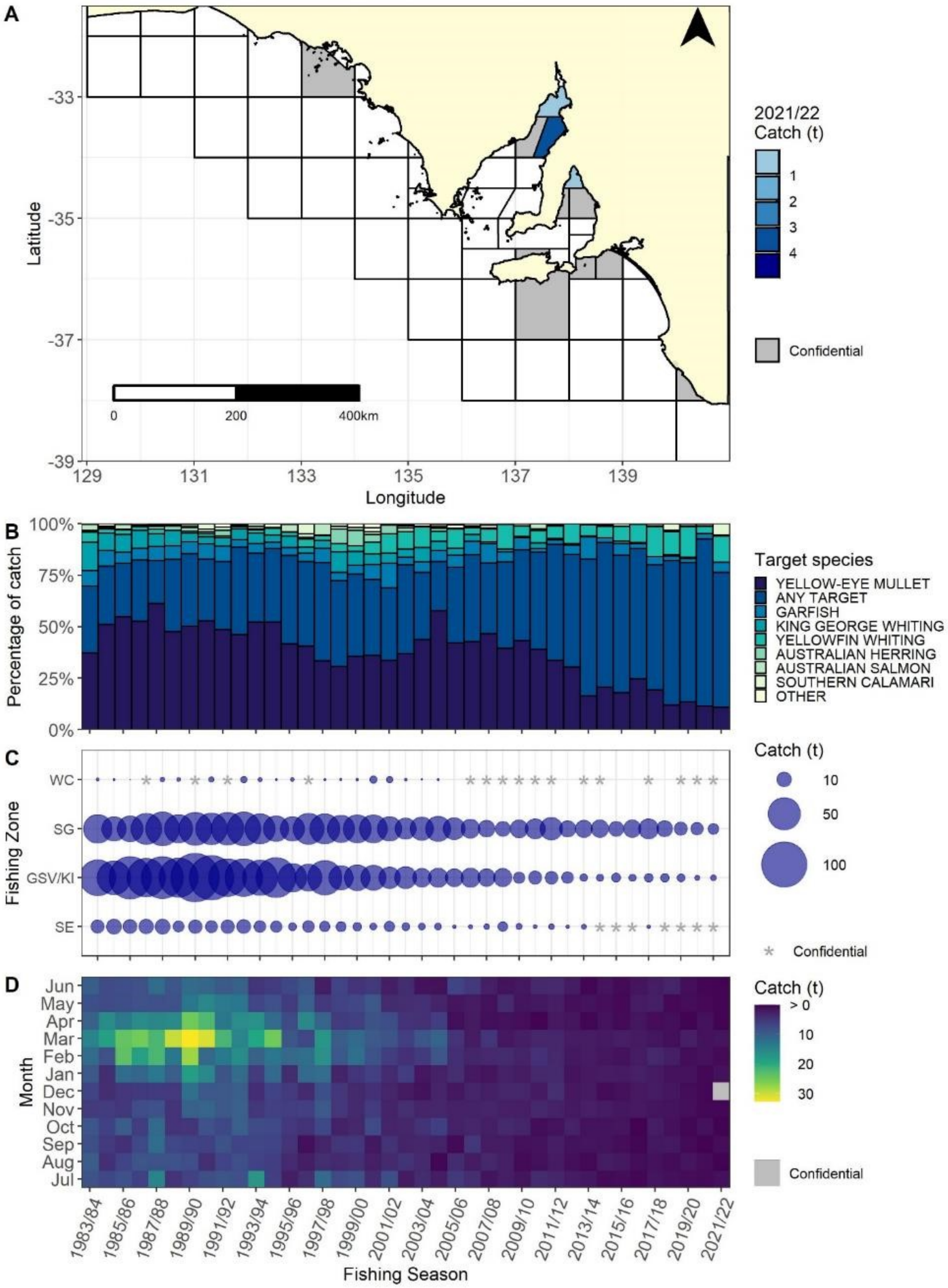


Figure 4.13-2. Regional dynamics of Yelloweye Mullet: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.14. Mulloway

Species summary

Mulloway

Argyrosomus japonicus

Assessment scale	State-wide	**Species Tier**	Tier 3 in all zones
Stock status	2019 – Sustainable	2020 – Sustainable	**2021/22 – Sustainable**

Biology

- Occur in estuaries and nearshore coastal waters in sub-tropical to temperate regions of the Atlantic, Pacific and Indian Oceans, including around southern mainland Australia from North West Cape in WA, to the Burnett River in QLD.
- Juveniles are common in estuaries, while adults predominantly occur in coastal waters, including the surf zone and around the mouths of rivers (Griffiths 1997).
- Large-bodied, fast-growing, late-maturing, max. age 42 years, max. length 1600 mm TL, L_{50} 780 mm TL for males and 850 mm TL for females (Ferguson et al. 2014).
- A marine estuarine-opportunist species, i.e., spawns at sea; regularly enters estuaries, particularly as juveniles, but also uses coastal marine waters as alternative nursery areas.
- Spawning occurs from October to January each year (Ferguson et al. 2014).
- Evidence of distinct populations along the eastern and western coasts of SA (Ferguson et al. 2014, Barnes et al. 2015).
- Assessment of stock status of Mulloway in the MSF is undertaken at the management unit level (State-wide).

Description of the fishery

- Supports commercial and recreational fisheries in SA.
- Most of the commercial catch is taken by the LCF in the Coorong Estuary and nearshore marine waters adjacent the Murray Mouth, with the remainder taken as by-product by the MSF using haul nets (Earl and Bailleul 2021).
- Recreational fishers target Mulloway from the shore using rod and line in estuaries and inshore marine waters.
- There are no catch and effort data for Aboriginal and traditional fishing.

Management regulations

- Legal minimum length: 820 mm TL.
- General haul net restrictions apply (e.g., max. length 600 m, max. drop 10 m).
- Recreational daily bag and boat limit of 2 and 6 fish, respectively.
- Mulloway can be taken by MSF fishers in all coastal waters of SA, except those accessible to the LCF.

Commercial statistics

Season	Total catch *t*	Total HN effort *fisher-days*	Total HN CPUE *kg/fisher-day*
2017/18	6	224	19.6
2018/19	9	202	36.4
2019/20	3	88	33.4
2020/21	<1	*confidential*	*confidential*
2021/22	1	*confidential*	*confidential*

Recreational catch estimate	**Survey**	**Estimated catch** *t (± SE)*	**Retained** *%*	**Released** *%*
	2000/01	83 (28)	32%	68%
	2007/08	62 (32)	19%	85%
	2013/14	59 (27)	21%	79%
	2021/22	24 (11)	51%	49%

Performance indicators	• Total catch – TRP breached for second lowest total catch. • Total effort (haul net) – confidential data precluded assessment of this PI. • Total CPUE (haul net) – confidential data precluded assessment of this PI.
Assessment summary	Status of Mulloway in the MSF is determined by catch, total haul net effort and total haul net CPUE trends using a weight-of-evidence approach. Total catch of Mulloway has been relatively stable at low levels since it declined from a historical peak of 24 t in 1995/96 to 3 t in 1999/00 (Figure 4.14-1). This decline reflects the reduction in set net fishing effort in the late-1990s rather than a decline in fishable biomass, because over the past 25 years, Mulloway has been predominantly taken as by-product within the haul net sector of the MSF, and CPUE using haul nets has been relatively high in most years during this period (Figure 4.14-2). In SA, Mulloway is predominantly caught in the LCF where it was recently classified as sustainable (Earl et al. 2022). The above evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current low level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On the basis of the evidence provided above, the the MSF-management unit for Mulloway is classified as a **sustainable** stock.
Research needs	• Development of harvest strategy with performance indicators, reference points and harvest control rules. • Standardisation of commercial CPUE, using improved measures of fishing effort. • Improved estimates of recreational catch and effort. • Improved understanding of Aboriginal/Traditional importance.

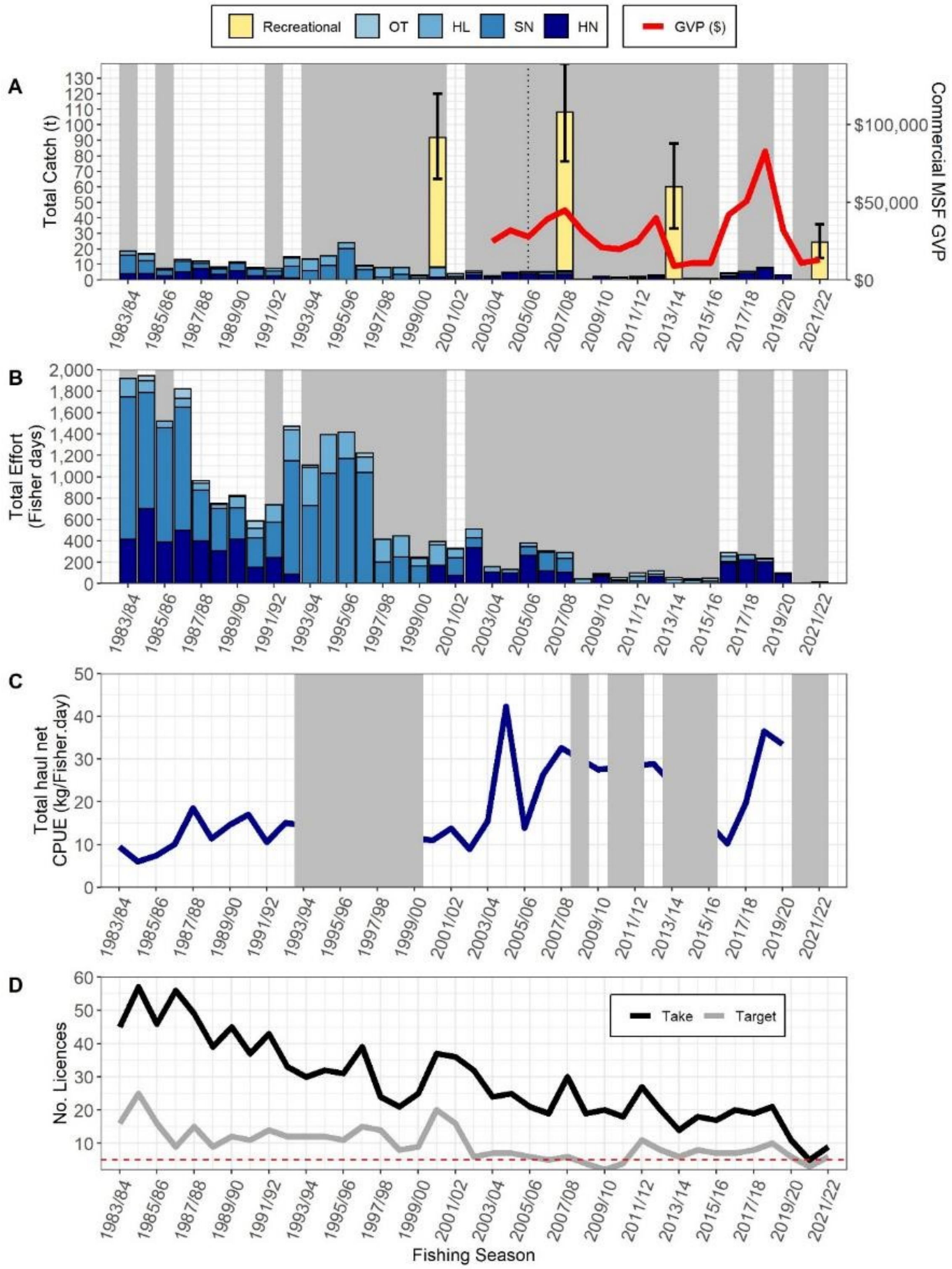


Figure 4.14-1. Long-term trends in State-wide estimates for Mulloway of (A) total catch for haul nets, set nets, handlines and all other gear types, estimated recreational catch and gross production value; (B) target effort for haul nets, handlines, set nets and all other gear types; (C) target CPUE for haul nets; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. A red dashed line in panel D represents the number of licences where data becomes confidential. The dotted vertical line on panel A indicates implementation of a net licence buyback scheme that reduced net fishing effort. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

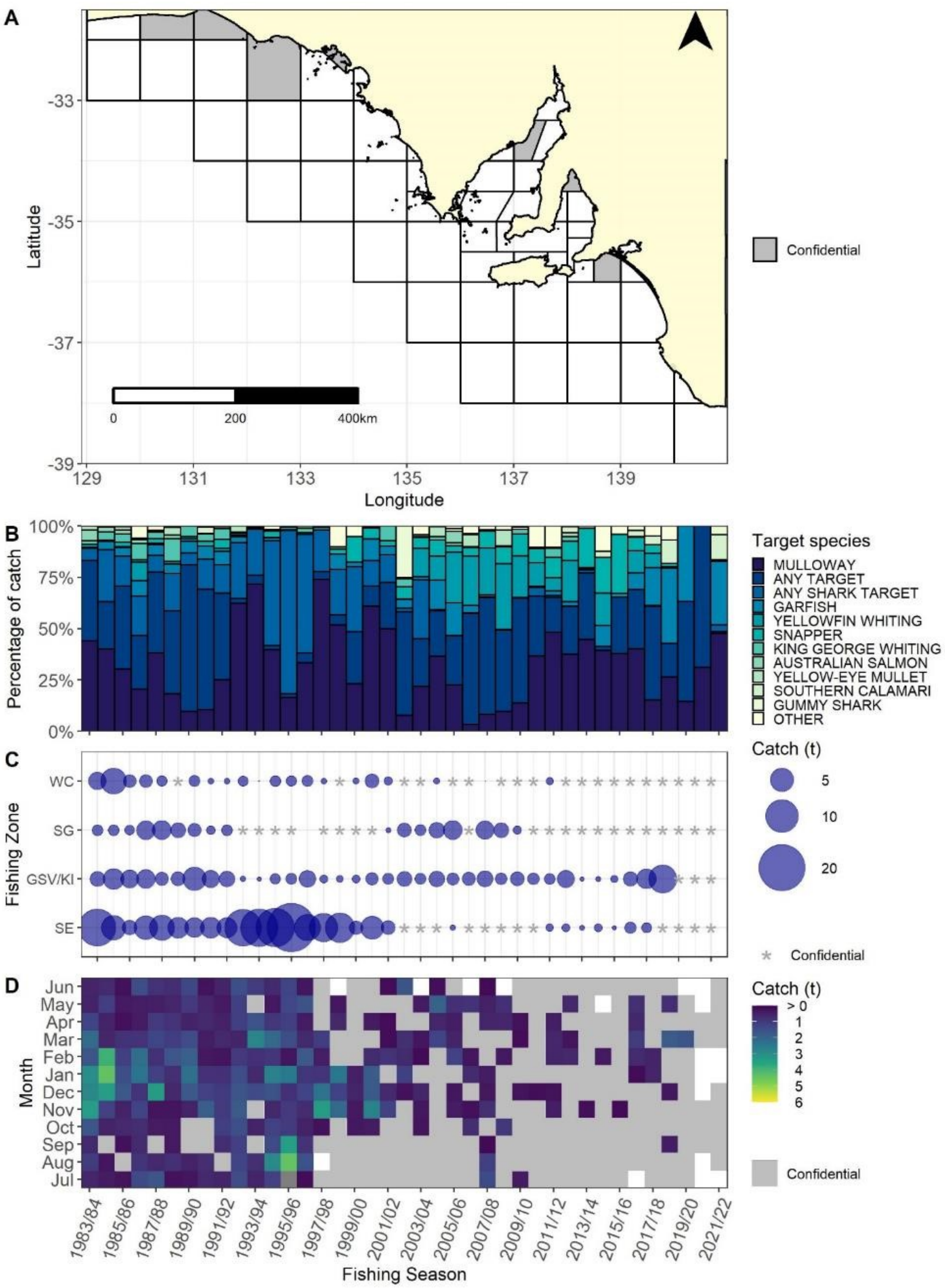
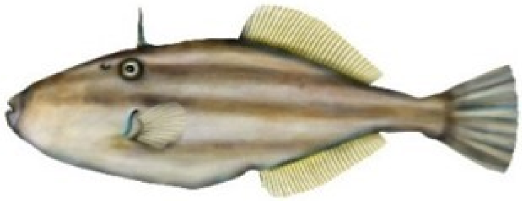


Figure 4.14-2. Regional dynamics of Mulloway: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.15. Ocean Jacket

<table>
<tr><th colspan="5">Species summary</th></tr>
<tr><td colspan="5">Ocean Jacket
Nelusetta ayraudi
</td></tr>
<tr><td>Assessment scale</td><td colspan="2">State-wide</td><td>Species Tier</td><td>Tier 3 in all zones</td></tr>
<tr><td>Stock status</td><td colspan="2">2019 – Sustainable</td><td>2020 – Sustainable</td><td>2021/22 – Sustainable</td></tr>
<tr><td>Biology</td><td colspan="4">• Distribution extends from the central coast of WA, along southern Australian coastal and continental shelf waters to the central QLD coast.
• Juveniles occur in shallow coastal bays, while adults occur over flat, sandy bottom in offshore, continental shelf waters at depths >60 m (Grove-Jones and Burnell 1991).
• Ocean Jacket is the largest species of leatherjacket of southern Australia, reaching 700 mm TL (Gommon et al. 2008).
• Sexually dichromatic species that is fast-growing and short-lived (≥7 years for males and 9 years for females), maturity occurs at 2–4 years of age and at 310 mm TL.
• Spawning in SA occurs in April and early May at depths >85 m.
• Stock structure throughout its distribution is currently unknown.
• Assessment of stock status of Ocean Jackets in the MSF is undertaken at the management unit level (State-wide).</td></tr>
<tr><td>Description of the fishery</td><td colspan="4">• Predominantly targeted by commercial fishers using species-specific baited fish traps in offshore waters of the WC and SG fishing zones.
• Negligible targeting by recreational fishers.</td></tr>
<tr><td>Management regulations</td><td colspan="4">• Regulations for ‘Ocean Jacket traps’ differ to those for ‘fish traps.’
• Four MSF licences have Ocean Jacket trap endorsements.
• Ocean Jacket traps can only be used in depths >60 m (other fish traps, used to target any species, are restricted to depths <60 m).</td></tr>
<tr><td rowspan="6">Commercial statistics</td><td>Season</td><td>Total catch
t</td><td>Total effort
fisher-days</td><td>Total CPUE
kg/fisher-day</td></tr>
<tr><td>2017/18</td><td>Confidential</td><td>Confidential</td><td>Confidential</td></tr>
<tr><td>2018/19</td><td>127</td><td>327</td><td>390.0</td></tr>
<tr><td>2019/20</td><td>Confidential</td><td>Confidential</td><td>Confidential</td></tr>
<tr><td>2020/21</td><td>Confidential</td><td>Confidential</td><td>Confidential</td></tr>
<tr><td>2021/22</td><td>254</td><td>370</td><td>687.1</td></tr>
<tr><td rowspan="5">Recreational catch estimate</td><td>Survey</td><td>Estimated catch
t (± SE)</td><td>Retained
%</td><td>Released
%</td></tr>
<tr><td>2000/01</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>2007/08</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>2013/14</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>2021/22</td><td>-</td><td>-</td><td>-</td></tr>
</table>

Performance indicators	• Total catch – confidential data precluded assessment of some TRP's, remaining TRP's were not triggered. • Targeted effort (Ocean Jacket trap) – confidential data precluded assessment of this PI. • Targeted CPUE (Ocean Jacket trap) – confidential data precluded assessment of this PI.
Assessment summary	Status of Ocean Jacket in the MSF is determined by catch, effort and CPUE trends using a weight-of-evidence approach. Ocean Jacket fishery developed quickly between 1989/90 and 1992/93 resulting in a rapid increase in total annual catch which peaked at 1006.4 t in 1991/92 (Figure 4.15-1). Catches predominantly occur in the SG fishing zone (Figure 4.15-2). The high total catch reflected both an increase in effort as new entrants came into the fishery and the geographic expansion of the fishery (Grove-Jones and Burnell 1991). The fast rate of fishery development caused concerns about sustainability, which led to the introduction of regulations to limit the numbers of fishers, fishing effort and gear type. As a result, the fishery attained its highest productivity in the early 1990s. Since then, the fishery statistics have been dominated by comparatively lower levels of catch, effort, and numbers of specialist fishers. In 2021/22, the fishery was comprised of moderate catches (254 t), low levels of fishing effort (370 fisher-days) and the highest record of fish trap CPUE of 704 kg.fisher-day^{-1}. The above evidence indicates that the biomass of this stock is unlikely to be depleted and recruitment is unlikely to be impaired, and that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, South Australia's Ocean Jacket fishery is classified as **sustainable**.
Research needs	• Development of harvest strategy with performance indicators, reference points and harvest control rules. • Standardisation of commercial CPUE, using improved measures of fishing effort. • Improved understanding of southern Australian stock structure • Improved estimates of recreational catch and effort • Improved understanding of Aboriginal/Traditional importance

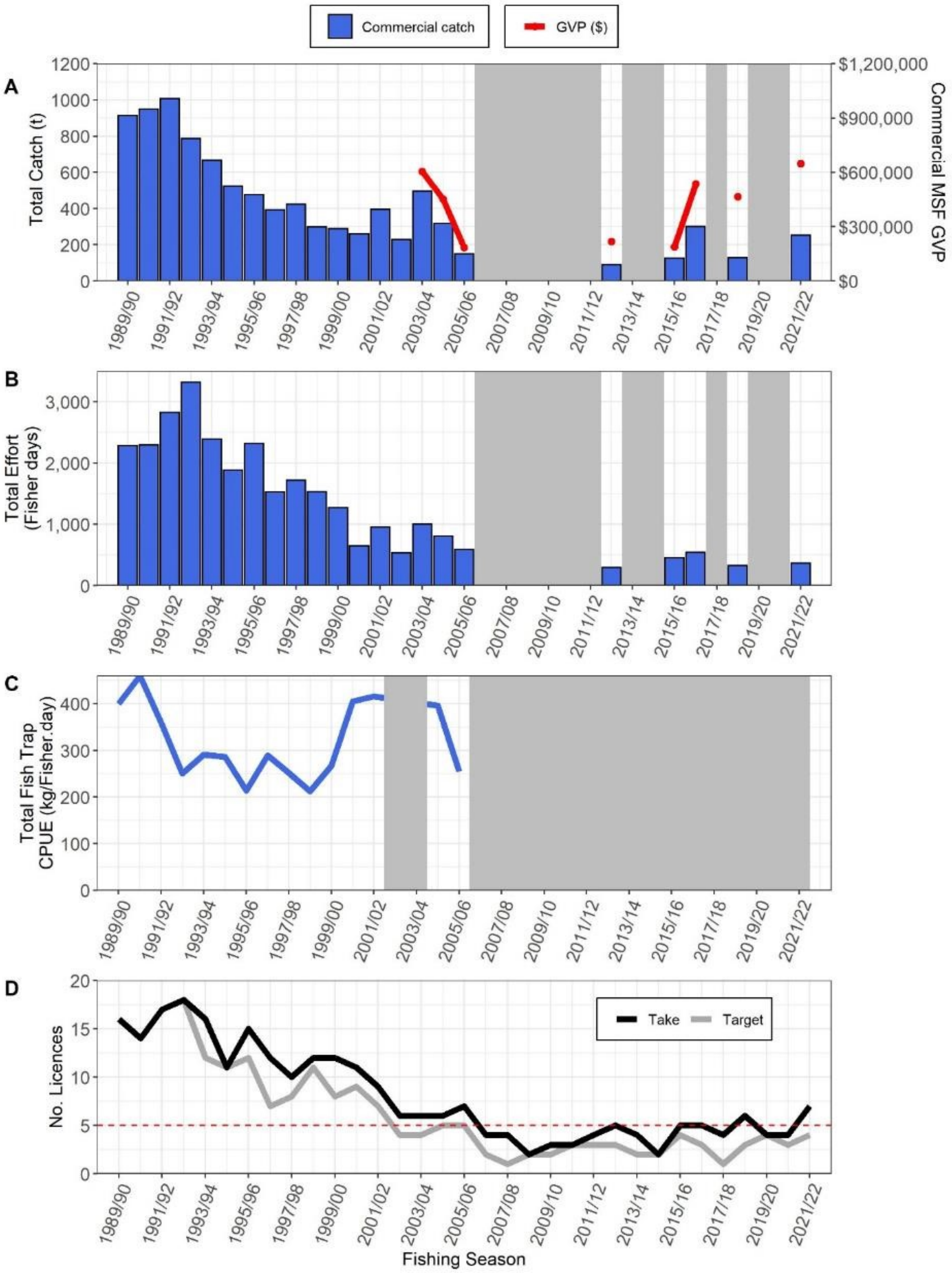


Figure 4.15-1. Long-term trends in State-wide estimates for Ocean Jacket of (A) total catch for all commercial gears and gross production value; (B) total commercial effort; (C) total CPUE for fish traps; and (D) the number of active licence holders taking or targeting the species. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

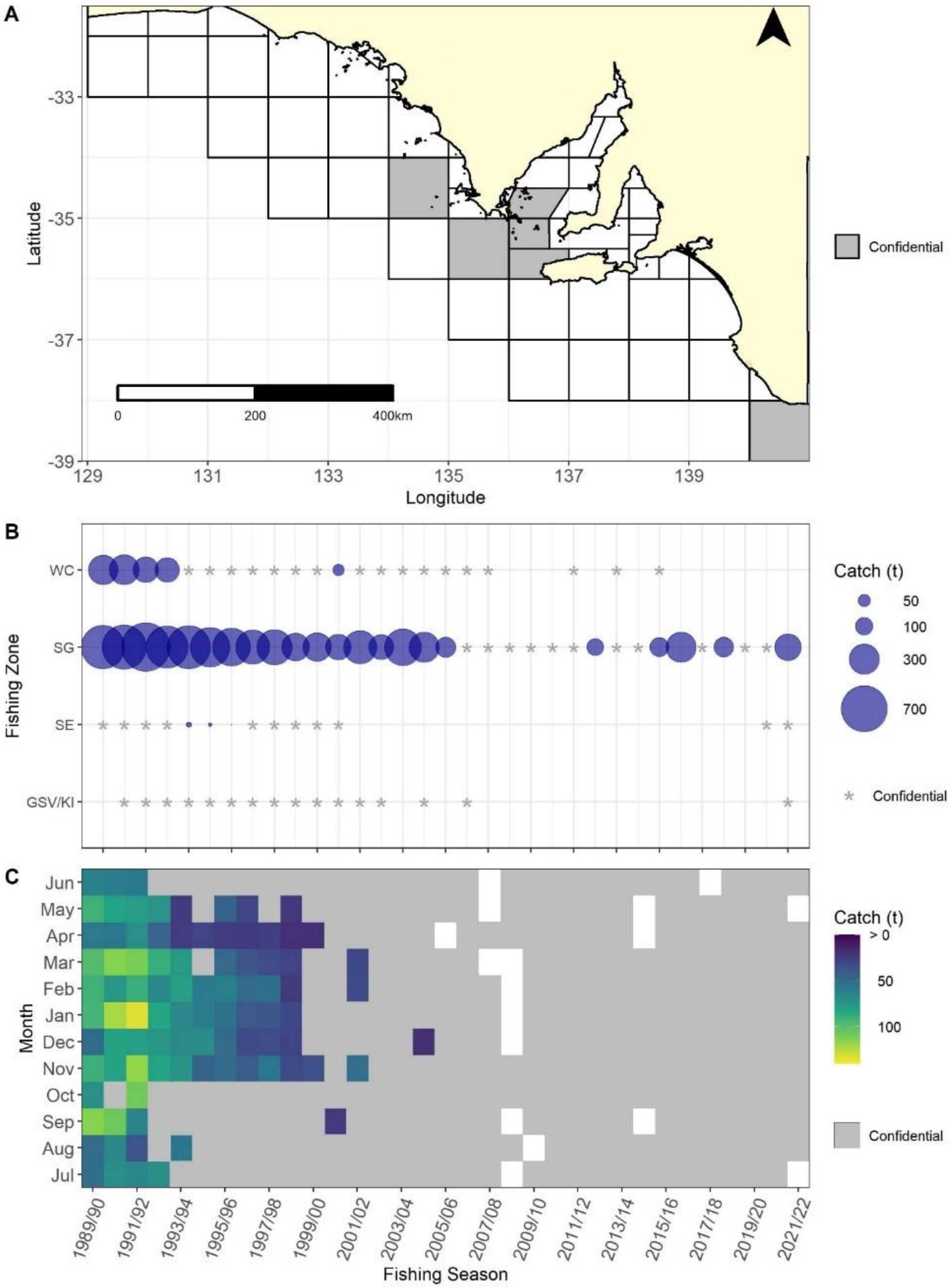


Figure 4.15-2. Regional dynamics of Ocean Jacket: (A) The spatial distribution of catch by the commercial sector in 2021/22. Long-term trends in: (B) the annual distribution of catch among zones, (C) months of the year.

4.16. Bluethroat Wrasse

Species summary

Bluethroat Wrasse

Notolabrus tetricus

Assessment scale	State-wide	Species Tier	Tier 3 in all 3 zones
Stock status	2019 – Sustainable	2020 – Sustainable	**2021/22 – Sustainable**

Biology

- Occur on near-shore rocky reefs in the coastal waters of SA, VIC, TAS, and NSW.
- Highly territorial with long-term residency and restricted home ranges on algal beds and near-shore reefs (0–50 m depth).
- Bluethroat Wrasse are a monandric, sequential protogynous hermaphrodite, i.e., adult males originate through a sex change from female fish.
- Complex social structure of a single male and a harem of smaller females.
- Maximum size is 400 mm TL at 11 years-of-age (Smith et al. 2003).
- Size and age at 50% maturity are 300mm TL and 8 years (Smith et al. 2003).
- No information is available on stock structure across the south-eastern Australian distribution.
- Assessment of stock status for Bluethroat Wrasse is undertaken at the management unit level–MSF (State-wide).

Description of the fishery

- Historically used as bait for Southern Rock Lobster fishery.
- Other labrid species also taken in low numbers and reported as Parrotfish in MSF logbooks.
- Targeted and retained as bycatch in commercial longline and handline fisheries.
- Majority of commercial catches from southern SG and WC zones.
- Recreational fishers catch as bycatch with high discard rates.

Management regulations

- Commercial fishers permitted use of two handlines at a time with a maximum of three hooks (≤12/0) per line.
- Recreational fishers are restricted by a slot size limit of 250 – 350 mm TL and a bag limit of 5 fish and a boat limit of 15 fish for recreational fishers.

Commercial statistics

Season	Total catch *t*	Targeted HL effort *fisher-days*	Targeted HL CPUE *kg/fisher-day*
2017/18	14	104	47.2
2018/19	7	50	31.5
2019/20	6	*confidential*	*confidential*
2020/21	6	36	19.4
2021/22	8	69	55.4

Recreational catch estimate	**Survey**	**Estimated catch** *t (± SE)*	**Retained** *%*	**Released** *%*
	2000/01	-		
	2007/08	-	22	78
	2013/14	-	32	68
	2021/22	3 (1)	37	63
Performance indicators	• Total catch – no TRPs breached. • Targeted effort (Handline) – TRP breached for highest inter-annual change. • Targeted CPUE (Handline) – no TRPs breached.			
Assessment summary	Status of Bluethroat Wrasse in the MSF is determined by catch, effort and CPUE trends using a weight-of-evidence approach. There is a small, targeted fishery for the Bluethroat Wrasse with the product directed towards the live fish trade, which accounts for considerable proportions of the total annual catches. The remaining catch is taken as by-product when other more valuable species are targeted (Figure 4.16-2). Total catch peaked at >20 t per annum between 1987/88 and 2004/05, which aligned with the highest level of targeted handline effort (Figure 4.16-1). Catch and targeted effort showed a continual declined from 2010/11 to 2020/21. Similarly, targeted handline CPUE declined from 2011/12 to the lowest recorded value of 19.38 kg.fisher-day^{-1} in 2020/21. In 2021/22 targeted handline CPUE increased by 186% to 55.44 kg.fisher-day^{-1}, breaching the TRP for the greatest inter-annual change. The increase in CPUE has returned to similar levels at the peak of the fishery in the 2000s. In 2021/22 both catch, and effort increased from the previous year, but are still at comparatively low levels. The above evidence indicates that the biomass of this stock is unlikely to be depleted and recruitment is unlikely to be impaired, and that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, South Australia's Bluethroat Wrasse fishery is classified as **sustainable**			
Research needs	• Resolve the stock structure of the south-eastern Australian population. • Development of harvest strategy with performance indicators, reference points and harvest control rules. • Standardisation of commercial CPUE, using improved measures of fishing effort. • Improved estimates of recreational catch and effort. • Improved understanding of Aboriginal/Traditional importance.			

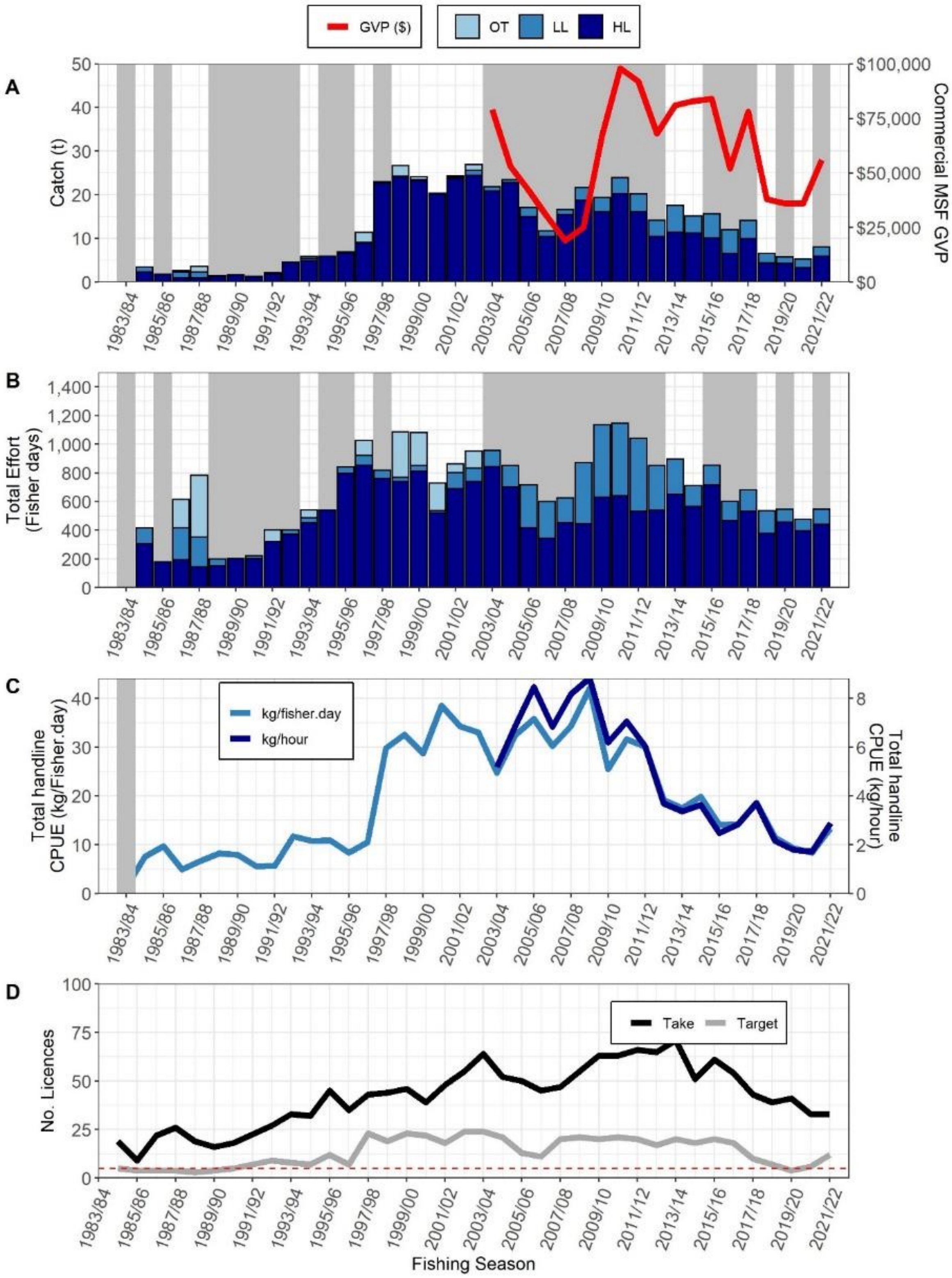


Figure 4.16-1. Long-term trends in State-wide estimates for Bluethroat Wrasse of (A) total catch for handlies, longlines and all other gear types, estimated recreational catch and gross production value; (B) total effort for handlies, longlines and all other gear types; (C) total CPUE for handlines; and (D) the number of active licence holders taking or targeting the species. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

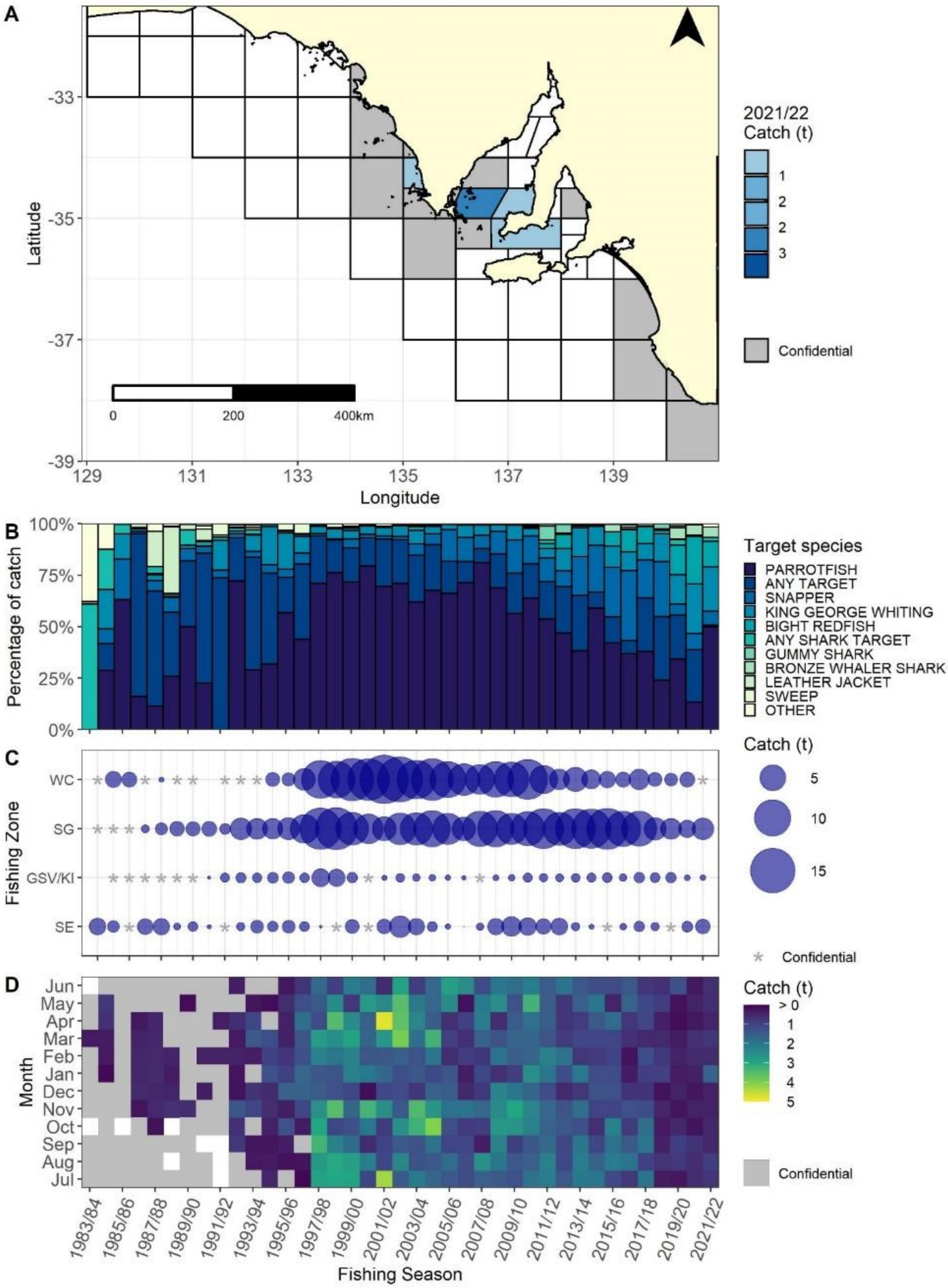


Figure 4.16-2. Regional dynamics of Bluethroat Wrasse: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.17. Silver Trevally

Species summary				
Silver Trevally *Pseudocaranx georgianus*				
Assessment scale	State-wide		**Species Tier**	Tier 3 in all zones
Stock status	2019 – Sustainable		2020 – Sustainable	**2021/22 – Sustainable**
Biology	• Inhabits coastal temperate waters across southern Australia from Coffs Harbour in NSW to Perth in WA. • Schooling species over sandy benthos in estuaries, nearshore coastal and shelf waters (10–230 m). • Large, (690–938mm TL), slow-growing and long lived up to 25 years in NSW waters (Stewart 2015) and 33 years in NZ waters. Length at 50% maturity is 190–200 mm TL. • Biological stock structure of southern Australian population is currently unresolved. • Assessment of stock status for Silver Trevally is undertaken at the management unit level–MSF (State-wide).			
Description of the fishery	• Targeted by commercial fishers in the MSF with the use of handlines. • Majority of catches from the southern SG, southern GSV and WC zones. • Annual recreational catch estimates higher than commercial landings.			
Management regulations	• Commercial and recreational minimum legal size of 240 mm TL. • Commercial gear restrictions for handlines and haul nets. • Recreational bag limit of 20 fish and a boat limit of 60 fish.			
Commercial statistics	**Season**	**Total catch** *t*	**Total HL effort** *fisher-days*	**Total HL CPUE** *kg/fisher-day*
	2017/18	7	546	12.49
	2018/19	5	554	8.78
	2019/20	8	841	9.09
	2020/21	8	823	9.31
	2021/22	9	503	16.21
Recreational catch estimate	**Survey**	**Estimated catch** *t*	**Retained** *%*	**Released** *%*
	2000/01	14 (3)	69%	31%
	2007/08	12 (2)	59%	41%
	2013/14	15 (7)	77%	23%
	2021/22	15 (6)	88%	12%

Performance indicators	• Total catch – no TRPs breached. • Total effort (handline) – LTRP breached for greatest inter-annual change. • Total CPUE (handline) – no TRPs breached.
Assessment summary	Status of Silver Trevally in the MSF is determined by catch, effort and CPUE trends using a weight-of-evidence approach. Silver Trevally are targeted by a small number of commercial fishers in the MSF, nevertheless, targeted catch accounts for a high proportion of the total handline catch. The remaining catch is taken as by-product by a considerably larger number of fishers when they target more valuable co-occurring species such as King George Whiting. However, targeting has increased in recent years due to potential increases in market prices (Figure 4.17-1). Total annual commercial catch has been variable since 1983/84, ranging between 1.3 t in 1985/86 and 21.9 t in 2000/01. Since 2009/10 total commercial catch has been steady averaging 9.1 t per year with total commercial catch in 2021/22 being 9.28 t (Figure 4.17-1). Since 2010/11, trends in total catch, effort, and CPUE have stabilised at relatively moderate levels (Figure 4.17-2). In 2021/22, catches remained consistent, however, a reduction in total handline effort yielded an 74% increase in total handline CPUE. This breached the trigger reference point of greatest inter-annual change in total effort. The above evidence indicates that the biomass of this stock is unlikely to be depleted and recruitment is unlikely to be impaired, and that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, South Australia's Silver Trevally fishery is classified as **sustainable.**
Research needs	• Determining the stock structure of the southern Australian population. • Estimating the population biological characteristics for SA. • Development of harvest strategy with performance indicators, reference points and harvest control rules. • Standardisation of commercial CPUE, using improved measures of fishing effort. • Improved estimates of recreational catch and effort. • Improved understanding of Aboriginal/Traditional importance.

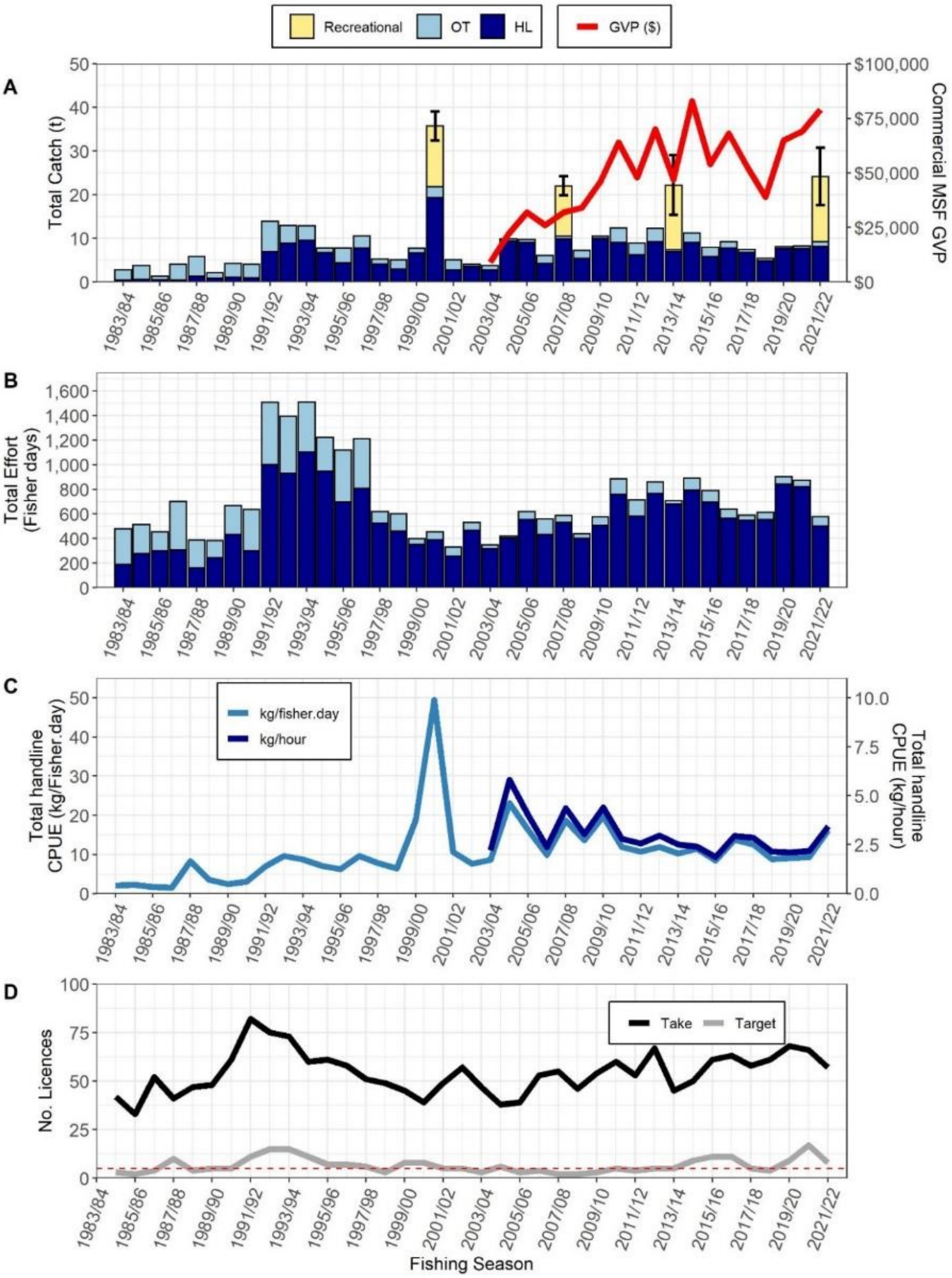


Figure 4.17-1. Long-term trends in State-wide estimates for Silver Trevally of (A) total catch for handlines and all other gear types, estimated recreational catch and gross production value; (B) total effort for handlines and all other gear types; (C) total CPUE for handlines; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

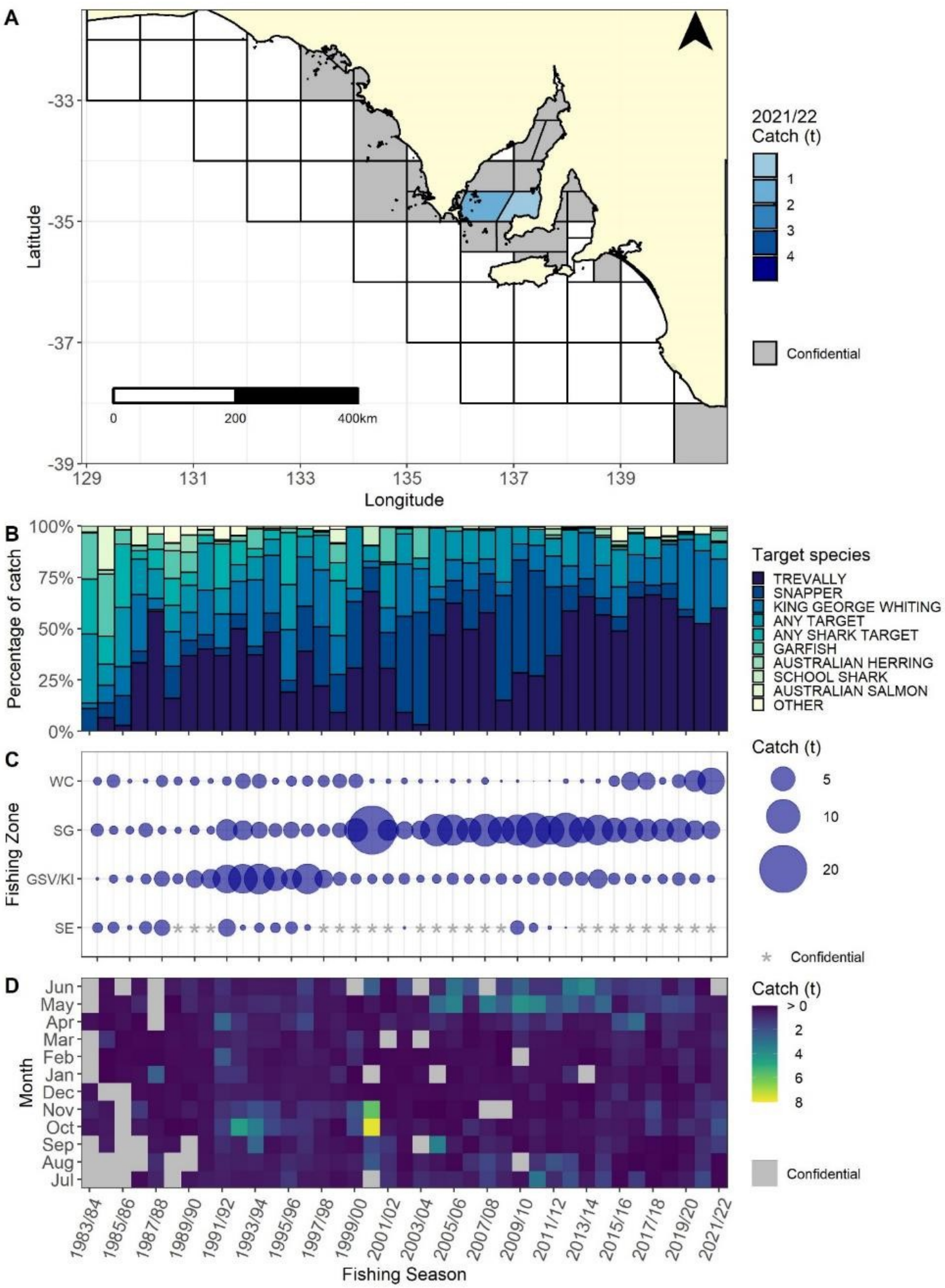


Figure 4.17-2. Regional dynamics of Silver Trevally: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.18. Leatherjackets

<table>
<tr><th colspan="5">Species summary</th></tr>
<tr><td colspan="5">Leatherjackets
Monacanthidae spp.</td></tr>
<tr><td>Assessment scale</td><td colspan="2">State-wide</td><td>Species Tier</td><td>Tier 3 in all zones</td></tr>
<tr><td>Stock status</td><td colspan="2">2019 – Undefined</td><td>2020 – Undefined</td><td>2021/22 – Undefined</td></tr>
<tr><td>Biology</td><td colspan="4">• Leatherjacket catch in the MSF is a multi-species stock of up to 19 species that occur in SA waters.
• Inhabit the inshore reefs and seagrass meadows of coastal South Australia.
• Characterised by compressed, deep-bodied shape, prominent dorsal spine above the eye and rough/leathery skin (Gommon et al. 2008).
• Most species are sexually dimorphic in body shape and colouration (Gommon et al. 2008).
• Assessment of Leatherjackets is undertaken at the management unit level–MSF (State-wide).</td></tr>
<tr><td>Description of the fishery</td><td colspan="4">• Two species are commonly caught in the MSF, the Horseshoe Leatherjacket (Meuschenia hippocrepis) and the Six spine Leatherjacket (M. freycineti).
• Predominately taken as by-product, with a small number of fishers targeting these species.
• Mostly caught with haul nets or handlines, also susceptible to fish traps.
• Majority of catch has come from northern SG and GSV waters.
• Recreational fishing captures Leatherjackets using rod and line</td></tr>
<tr><td>Management regulations</td><td colspan="4">• No size, bag, or boat limits for commercial and recreational fishers.
• Standard commercial gear restrictions on haul nets, set nets, fish traps and handlines.
• Spatial netting closures restrict Leatherjacket catches.</td></tr>
<tr><td rowspan="6">Commercial statistics</td><td>Season</td><td>Total catch
t</td><td>Total HN effort
fisher-days</td><td>Total HN CPUE
kg/fisher-day</td></tr>
<tr><td>2017/18</td><td>30</td><td>1,337</td><td>21.3</td></tr>
<tr><td>2018/19</td><td>21</td><td>1,034</td><td>18.0</td></tr>
<tr><td>2019/20</td><td>10</td><td>716</td><td>12.1</td></tr>
<tr><td>2020/21</td><td>11</td><td>682</td><td>13.3</td></tr>
<tr><td>2021/22</td><td>12</td><td>847</td><td>13.6</td></tr>
</table>

<table>
<tr><th rowspan="5">Recreational catch estimate</th><th>Survey</th><th>Estimated catch
t (± SE)</th><th>Retained
%</th><th>Released
%</th></tr>
<tr><td>2000/01</td><td>38 (8)</td><td>40%</td><td>60%</td></tr>
<tr><td>2007/08</td><td>10 (2)</td><td>37%</td><td>63%</td></tr>
<tr><td>2013/14</td><td>0</td><td>62%</td><td>38%</td></tr>
<tr><td>2021/22</td><td>6 (2)</td><td>42%</td><td>58%</td></tr>
<tr><th>Performance indicators</th><td colspan="4">• Total catch – no TRPs breached.
• Total effort (haul net) no TRPs breached.
• Total CPUE (haul net) no TRPs breached.</td></tr>
<tr><th>Assessment summary</th><td colspan="4">There is limited information for determining stock status, and the information available is confounded by a paucity of information on the catch composition (species) of Leatherjackets harvested. The limited data prevents assessment of current stock size or fishing pressure. Consequently, there is insufficient information available to confidently classify the status of this stock.

On the basis of the evidence provided above, the Southern Australia Leatherjacket stock is classified as an **undefined** stock.</td></tr>
<tr><th>Research needs</th><td colspan="4">• Quantify the species composition of catch within MSF.
• Development of harvest strategy with performance indicators, reference points and harvest control rules.
• Standardisation of commercial CPUE, using improved measures of fishing effort.
• Improved estimates of recreational catch and effort.
• Improved understanding of Aboriginal/Traditional importance.</td></tr>
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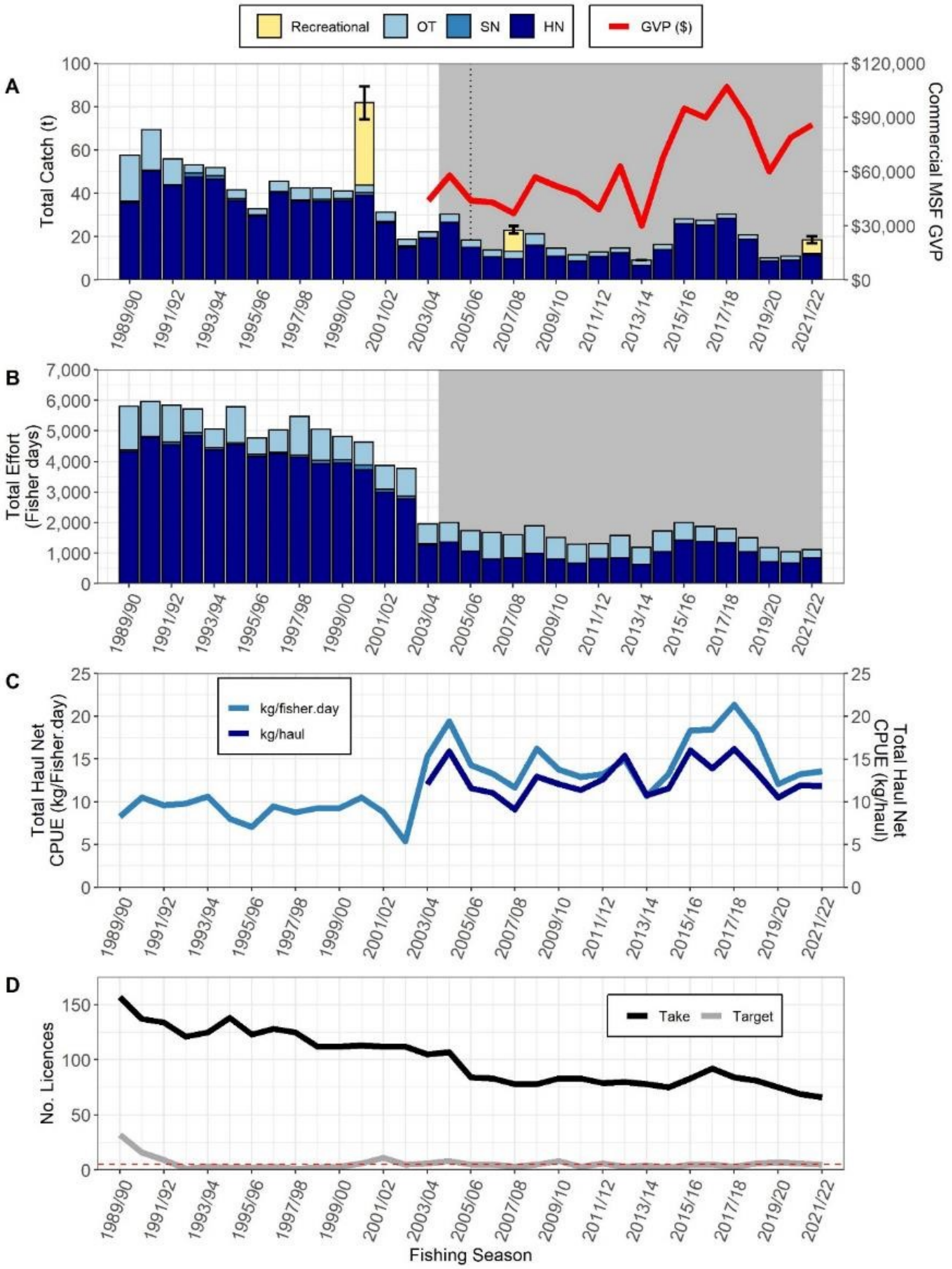

Figure 4.18-1. Long-term trends in State-wide estimates for Leatherjackets of (A) total catch for haul nets, set nets and all other gear types, estimated recreational catch and gross production value; (B) total effort for haul nets, set nets and all other gear types; (C) total CPUE for haul nets; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. A red dashed line in panel D represents the number of licences where data becomes confidential. The dotted vertical line on panel A indicates implementation of a net licence buyback scheme that reduced net fishing effort. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

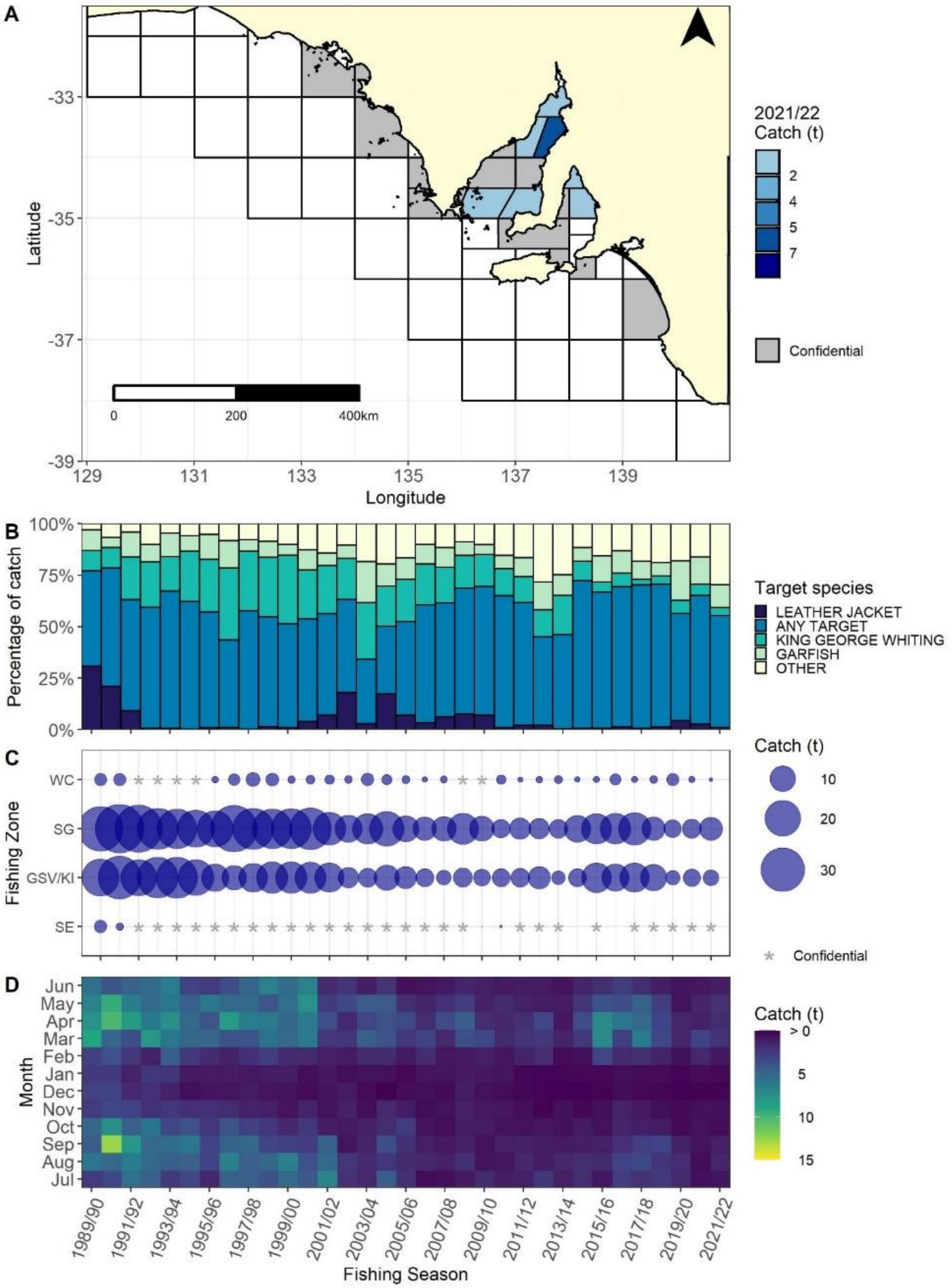

Figure 4.18-2. Regional dynamics of Leatherjackets: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.19. Rays and Skates

Species summary

Rays and Skates

Myliobatiae, Dasyatidae, and Rajidae spp.

Assessment scale	State-wide	Species Tier	Tier 3 in all zones
Stock status	2019 – Undefined	2020 – Undefined	**2021/22 – Undefined**

Biology

- Ray and skates catches are not differentiated by species.
- Catches comprised of species from Myliobatiae (Eagle Rays), Dasyatidae (Stingrays), and Rajidae (Skates) families.
- Southern Eagle Ray (*Myliobatis tenuicaudatus*) is the most prominent species landed within the reported Rays and Skates catch.
- Southern Eagle Ray inhabits mud flats, seagrass, and sand habitats in the temperate coastal waters of southern Australia, from Jurien Bay (WA) to Moreton Bay (QLD) in Australia (Last and Stevens 2009). They are also found in the waters of New Zealand, Norfolk Island and Kermadec Islands.
- Southern Eagle Rays have a maximum size of 160 cm disc width (300 cm TL), males mature at 65 cm and females at 80 cm disc width (Last and Stevens 2009). Estimates of longevity are > 15 years from males and >26 years for females in New Zealand.
- Genetic connectivity across multi-jurisdictional sub-populations.
- Assessment of stock status for Rays and Skates is undertaken at the management unit level–MSF (State-wide)

Description of the fishery

- Rays and Skates are mostly taken as bycatch in the MSF with the use of longlines and haul nets.
- Highest catches come from the WC, southern GSV and northern SG zones.
- Recreational fishers mostly land rays and skates as bycatch with rod and line, most are released. Limited targeted effort for rays and skates by recreational fishers.

Management regulations

- No size, bag or boat limits are enforced for commercial or recreational fishers.
- Gear restrictions for longlines and haul nets in the MSF.

Commercial statistics

Season	Total catch *t*	Total LL effort *fisher-days*	Total LL CPUE *kg/fisher-day*
2017/18	12	259	25.7
2018/19	10	251	20.6
2019/20	11	211	33.3
2020/21	11	189	45.2
2021/22	12	309	26.8

Recreational catch estimate	**Survey**	**Estimated catch** *kg (± SE)*	**Retained** *%*	**Released** *%*
	2000–01	-	-	-
	2007–08	-	3%	97%
	2013–14	-	0%	100%
	2021–22	-	0%	100%

Performance indicators

- Total catch – no TRPs breached.
- Total effort (longline) – no TRPs breached.
- Total CPUE (longline) – TRP of greatest decrease in inter-annual change was triggered.

Assessment summary

There is limited information for determining stock status, and the information available is confounded by a paucity of information on the catch composition (species) of Rays and Skates harvested. The limited data prevents assessment of current stock size or fishing pressure. Consequently, there is insufficient information available to confidently classify the status of this stock.

On the basis of the evidence provided above, the Southern Australia Rays and Skates stock is classified as an **undefined** stock.

Research needs

- Quantify the species composition of catch within MSF.
- Development of harvest strategy with performance indicators, reference points and harvest control rules.
- Standardisation of commercial CPUE, using improved measures of fishing effort.
- Improved estimates of recreational catch and effort.
- Improved understanding of Aboriginal/Traditional importance.

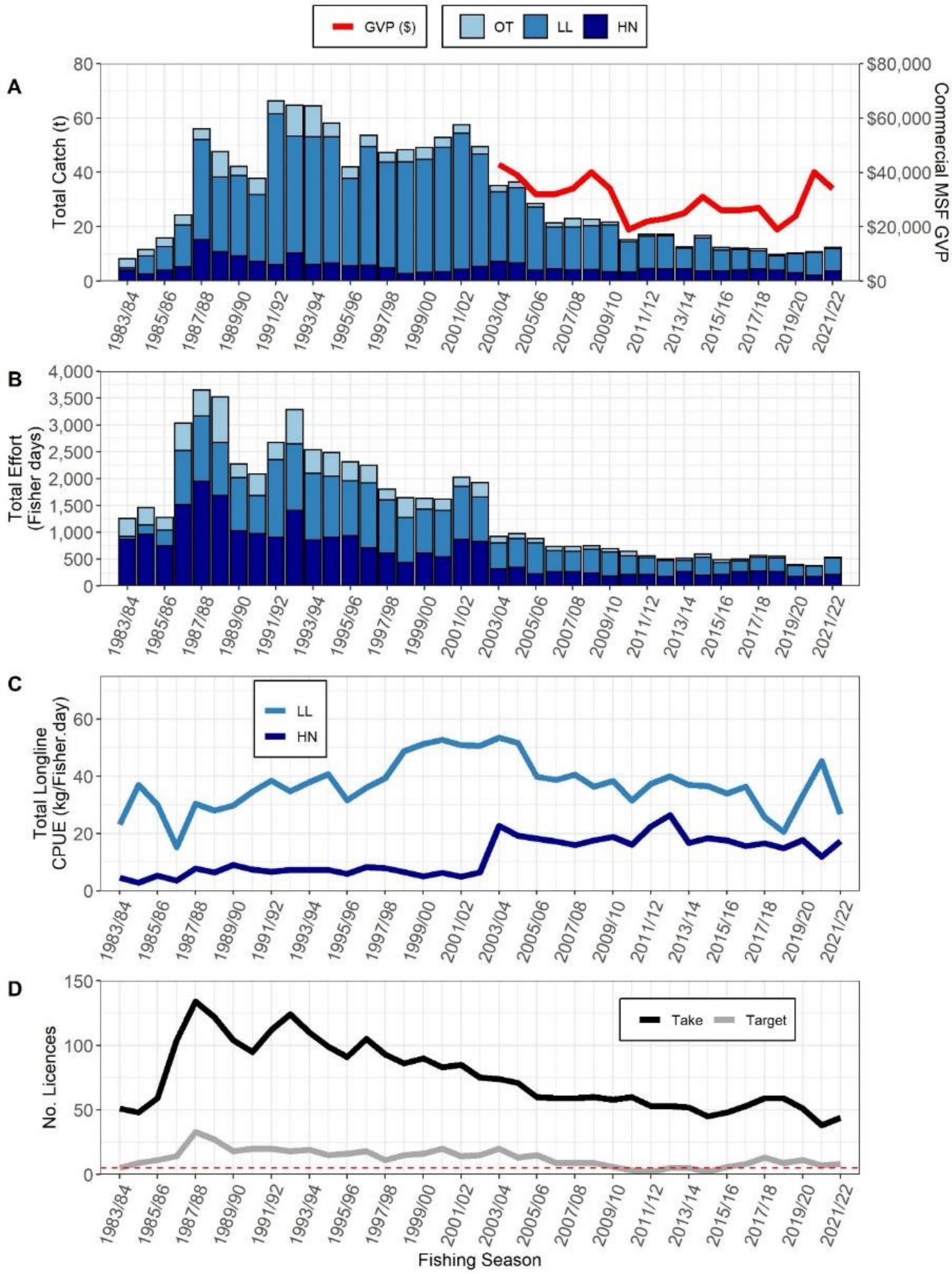

Figure 4.19-1. Long-term trends in State-wide estimates for Rays and Skates of (A) total catch for haul nets, longlines and all other gear types, estimated recreational catch and gross production value; (B) total effort for haul nets, longlines and all other gear types; (C) total CPUE for longlines; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

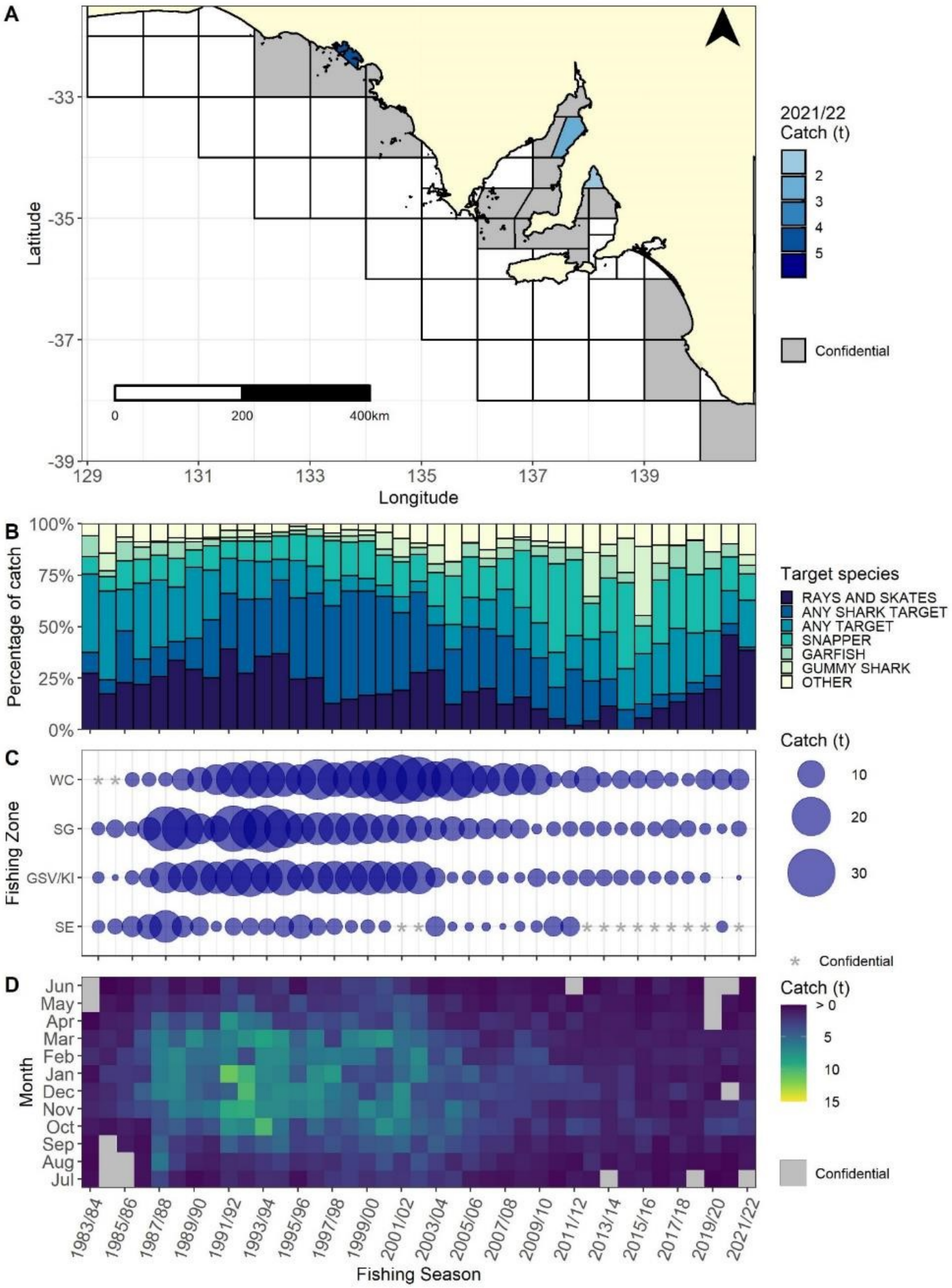

Figure 4.19-2. Regional dynamics of Rays and Skates: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.20. Cuttlefish

Species summary

Cuttlefish

Sepia apama
Sepia novaehollandiae

Assessment scale	State-wide	**Species Tier**	Tier 3 in all zones
Stock status	2019 – Sustainable	2020 – Sustainable	**2021/22 – Sustainable**
Biology	• Giant Australian Cuttlefish (*Sepia apama*) and Nova's Cuttlefish (*S. novaehollandiae*) are commercially and recreationally harvested in SA. • The Giant Australian Cuttlefish is the largest and most abundant local cuttlefish species (Edgar 2000) reaching a maximum size of 500 mm mantle length and weighing up to 10.5 kg (Jereb and Roper 2005). • This species is broadly distributed around southern Australia, from Point Cloates in WA to Moreton Bay in QLD, including TAS (Edgar 2000), where they occur over seagrass and rocky reef in water depths up to 100 m (Jereb and Roper 2005). • Two populations of Giant Australian Cuttlefish have been identified in SA (Gillanders et al. 2016). While the Cuttlefish stock in southern SG extends into GSV, the northern stock is restricted to NSG with individuals returning to the site of hatching to breed at either one or two years of age (Hall et al. 2007). The NSG population forms a breeding aggregation at Point Lowly in False Bay (Steer et al. 2013, Gillanders et al. 2016) during late autumn and early winter each year. The species is semelparous, dying soon after spawning (Hall 2003). • Assessment of stock status of Cuttlefish in the MSF is undertaken at the management unit level (State-wide).		
Description of the fishery	• Supports commercial and recreational fisheries in SA. • In the commercial sector, Cuttlefish are targeted using squid jigs on handlines and are taken as by-product by fishers using jigs to target Calamari in gulf waters. • Recreational fishers mostly take Cuttlefish using squid jigs when targeting Calamari in inshore waters from boats and the shore (Beckmann et al. 2023). • There are no catch and effort data for Aboriginal and traditional fishing.		
Management regulations	• No legal minimum length. • Commercial fishers are permitted to use only two handlines at a time with a maximum of three squid jigs/lures on each line. • For the recreational sector, there is a combined Cuttlefish/ Calamari daily bag and boat limit of 15 and 45 fish, respectively. • Permanent Cephalopod Exclusion Zone: The targeting and taking of cephalopods, including Cuttlefish, from False Bay, NSG, is prohibited at all times. • A temporary Cuttlefish fishing closure was in place from 14 May 2022 to 13 May 2023 in the waters of NSG (i.e., waters north of a line from Wallaroo to near Arno Bay) and this was made permanent closure in May 2023		

Commercial statistics	**Season**	**Total catch** *t*	**Targeted SQ effort** *fisher-days*	**Targeted SQ CPUE** *kg/fisher-day*
	2017/18	1	374	3.7
	2018/19	<1	286	2.9
	2019/20	20	328	61.3
	2020/21	5	401	12.4
	2021/22	1	286	4.6
Recreational catch estimate	**Survey**	**Estimated catch** *t (± SE)*	**Retained** *%*	**Released** *%*
	2000/01	12 (3)	81%	19%
	2007/08	1 (1)	80%	20%
	2013/14	0 (0)	54%	46%
	2021/22	1 (0)	32%	68%

Performance indicators

- Total catch – No TRPs breached.
- Total effort (squid jig) – No TRPs breached.
- Total CPUE (squid jig) – No TRPs breached

Assessment summary

Status of Cuttlefish in the MSF is determined by trends in catch and total squid jig CPUE, and annual fishery-independent estimates of Cuttlefish abundance in the breeding aggregation at Point Lowly in NSG since 2008, using a weight-of-evidence approach.

There is a small, targeted fishery for Cuttlefish in SA, although most of the catch each year is taken as by-product by fishers targeting Southern Calamari (Figure 4.20-2). This is reflected in the considerably higher numbers of fishers that take Cuttlefish each year compared to the number of fishers that actively target the species. Total catch of Cuttlefish increased to 262 t in 1996/97 and then declined sharply in 1998/99, corresponding with the implementation of spatial and temporal closures to limit the take of the species in NSG (Steer 2015). During 2002/03–2018/19, total catch and total jig CPUE were historically low, with catches averaging 5 t per annum (range: 0.8–10.8 t). In 2019/20, catch increased to 20 t reflecting higher CPUE and a small number of fishers targeting Cuttlefish where some previously closed areas in NSG were temporarily reopened to commercial fishing in 2020. In 2021/22, the total catch of 1.3 t was associated with low targeted and non-targeted jig effort, while jig CPUE was similar to the average catch rate during 2008/09–2018/19 (Figure 4.20-1).

Fishery independent surveys of Cuttlefish abundance in the Point Lowly breeding aggregation have been undertaken annually since 2008 (Steer et al. 2013). Annual estimates of abundance were relatively high from 2015-2022, consistently exceeding 100,000 cuttlefish and the 2020 estimate of 247,146 Cuttlefish being the highest on record (Heldt 2020). In 2021, abundance decreased 56% to 107,847, but then increased 28% in 2022 to 137,999, a value above the average abundance over the 24 years of surveys. The recent estimates of abundance indicate that the population has remained relatively high over the past eight years. The above evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired.

On the basis of the evidence provided above, the the MSF-management unit for Cuttlefish is classified as a **sustainable** stock.

Research needs

- Development of harvest strategy with performance indicators, reference points and harvest control rules.
- Standardisation of commercial CPUE, using improved measures of fishing effort.
- Improved estimates of recreational catch and effort.
- Improved understanding of Aboriginal/Traditional importance.

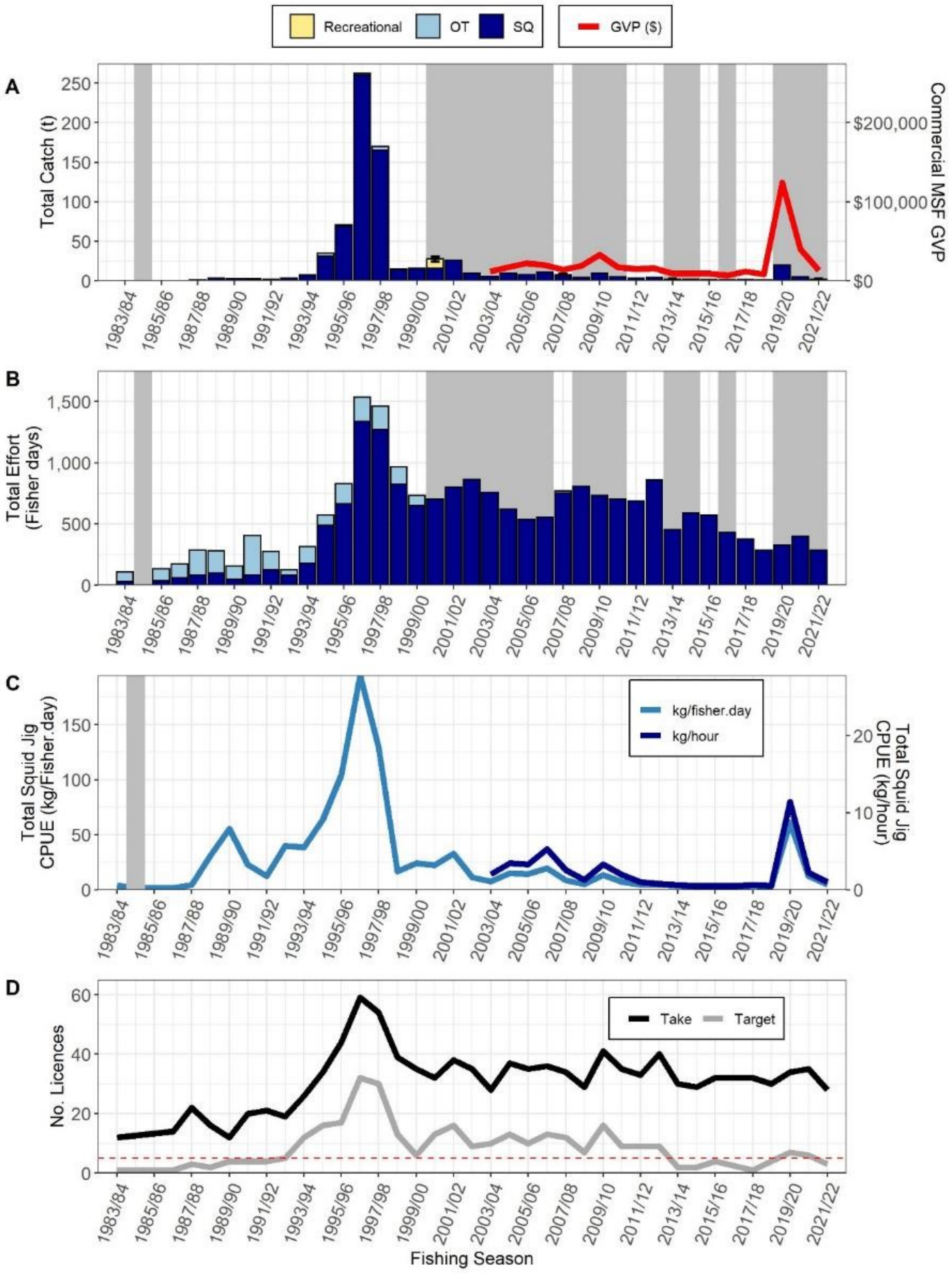

Figure 4.20-1. Long-term trends in State-wide estimates for Cuttlefish of (A) total catch squid jigs and all other gear types, estimated recreational catch and gross production value; (B) total effort for squid jigs and all other gear types; (C) total CPUE for squid jigs; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

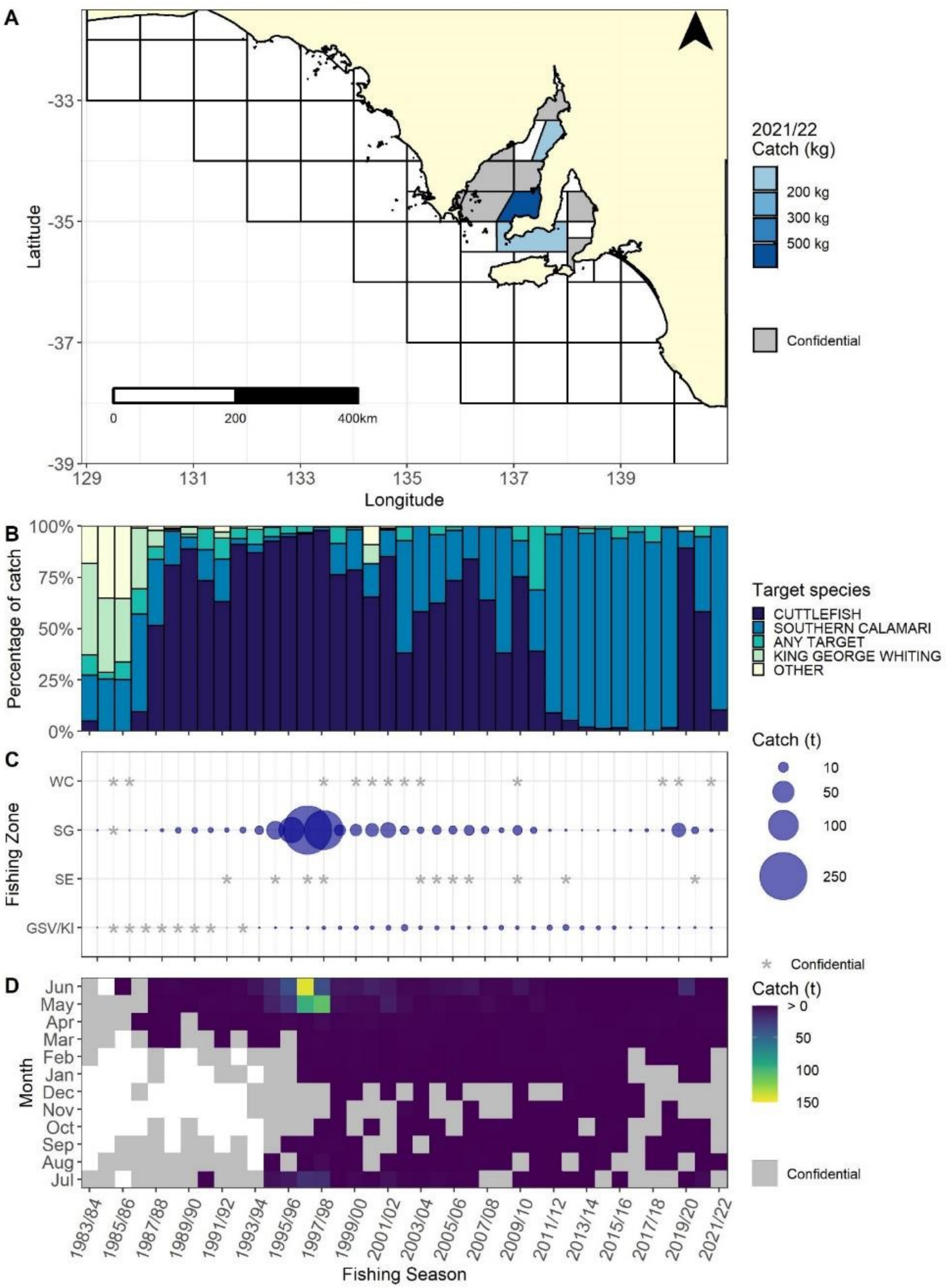

Figure 4.20-2. Regional dynamics of Cuttlefish: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.21. Black Bream

Species summary

Black Bream

Acanthopagrus butcheri

Assessment scale	State-wide	Species Tier	Tier 3 in all zones
Stock status	2019 – Sustainable	2020 – Sustainable	**2021/22 – Sustainable**

Biology

- Occurs in estuaries and nearshore coastal waters of southern Australia from central NSW to central west coast WA, including TAS (Gomon et al. 2008). In SA, common in the tidal creeks, inlets, and estuaries, including the Coorong.
- Medium-bodied, slow-growing, max. age 32 years, max. length 550 mm TL, L_{50} 340 mm TL for males and 289 mm TL for females (Ye et al. 2013).
- Estuarine-dependent, completing much of their life cycle within a single estuary
- Multiple studies have found limited or no evidence of coastal migration or emigration between estuaries across southern Australia (Butcher and Ling 1962, Norriss et al. 2002, Hindell et al. 2008).
- Growth and recruitment within estuaries are strongly influenced by environmental conditions associated with freshwater inflows (Norriss et al. 2002, Cottingham 2008).
- It is likely that, at local scales at least, annual recruitment strength is dependent on environmental conditions, with substantial inter-annual variation in recruitment affecting local stock demographics and biomasses.
- Assessment of stock status of Black Bream in the MSF is undertaken at the management unit level (State-wide).

Description of the fishery

- Supports commercial and recreational fisheries in SA.
- In most years, >70% of the commercial catch is taken by the LCF in the Coorong Estuary, with the remainder taken as by-product by the MSF using haul nets.
- Recreational fishers target Black Bream from the shore using rod and line in inshore marine waters and estuaries.
- There are no catch and effort data for Aboriginal and traditional fishing.

Management regulations

- Legal minimum length: 300 mm TL.
- General haul net restrictions apply (e.g., max. length 600 m, max. drop 10 m).
- An annual fishery closure prohibits the take of Black Bream from 1 September–30 November in the area upstream of the South Road Bridge of the Onkaparinga River.
- Recreational daily bag and boat limit of 10 and 30 fish, respectively.

Commercial statistics

Season	Total catch *t*	Total effort *fisher-days*	Total CPUE *kg/fisher-day*
2017/18	2	54	32.2
2018/19	3	92	34.2
2019/20	*confidential*	*confidential*	*confidential*
2020/21	*confidential*	*confidential*	*confidential*
2021/22	*confidential*	*confidential*	*confidential*

<table>
<tr><td rowspan="5">Recreational catch estimate</td><td>Survey</td><td>Estimated catch
t (± SE)</td><td>Retained
%</td><td>Released
%</td></tr>
<tr><td>2000/01</td><td>32 (14)</td><td>37%</td><td>63%</td></tr>
<tr><td>2007/08</td><td>6 (1)</td><td>13%</td><td>87%</td></tr>
<tr><td>2013/14</td><td>5 (2)</td><td>9%</td><td>91%</td></tr>
<tr><td>2021/22</td><td>6 (3)</td><td>24%</td><td>76%</td></tr>
<tr><td>Performance indicators</td><td colspan="4">• Total catch – confidential data precluded assessment of this PI.
• Total effort (all gears) – confidential data precluded assessment of this PI.
• Total CPUE (all gears) – confidential data precluded assessment of this PI.</td></tr>
<tr><td>Assessment summary</td><td colspan="4">Status of Black Bream in the MSF is determined by catch, effort and CPUE trends using a weight-of-evidence approach. Generally, the stock is not subjected to targeted fishing (Figure 4.21-2), commercial catches between 1983/84 and 2021/22 have averaged less than 1 t per annum (Figure 4.21-1), and Black Bream is not a major component of recreational landings. Consequently, fishing is unlikely to be having a negative impact on the stock.
The above evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired.
On the basis of the evidence provided above, the the MSF-management unit for Black Bream is classified as a sustainable stock.</td></tr>
<tr><td>Research needs</td><td colspan="4">• Development of harvest strategy with performance indicators, reference points and harvest control rules.
• Standardisation of commercial CPUE, using improved measures of fishing effort.
• Improved estimates of recreational catch and effort
• Improved understanding of Aboriginal/Traditional importance</td></tr>
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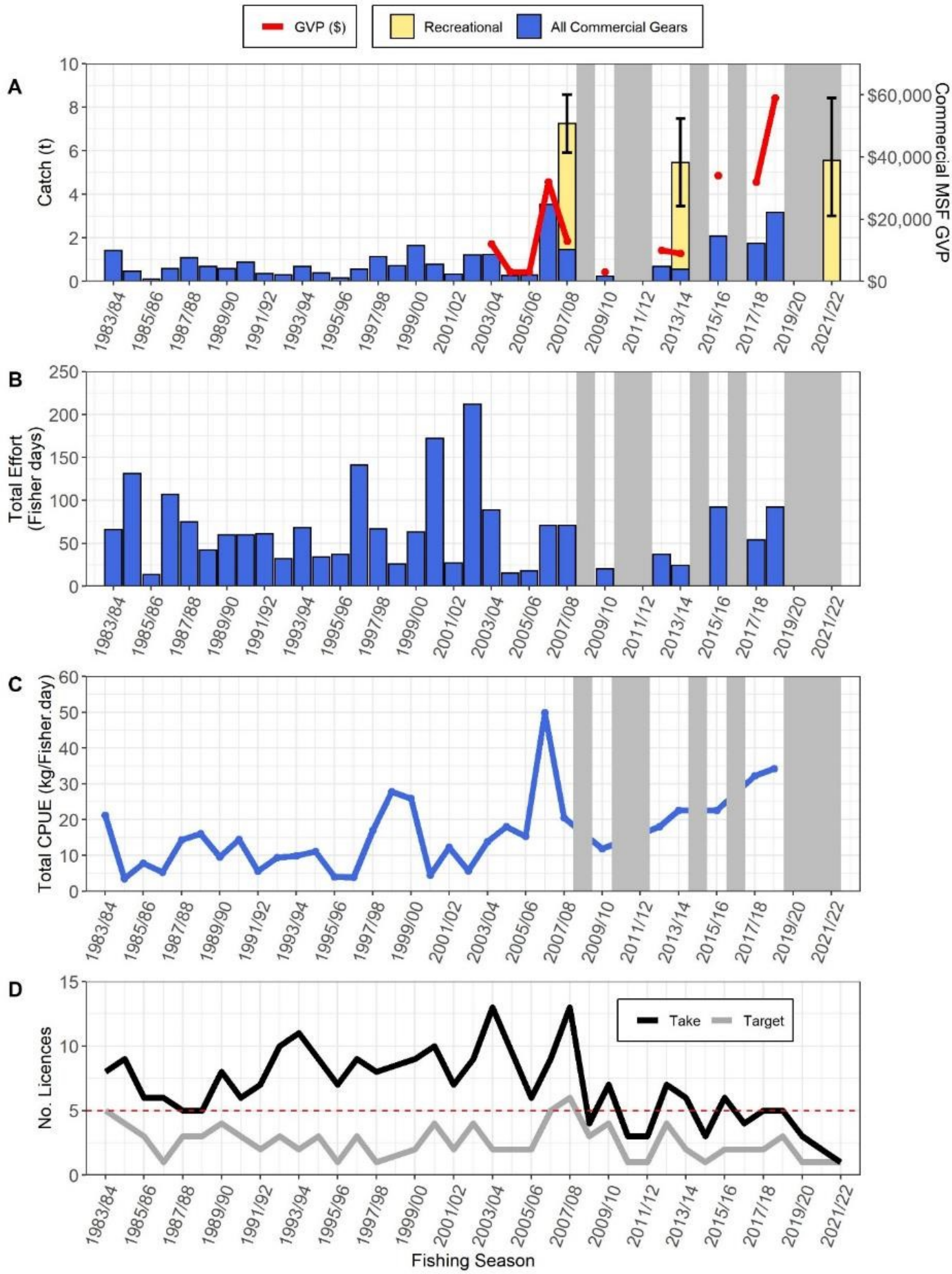

Figure 4.21-1. Long-term trends in State-wide estimates for Black Bream of (A) total catch for all commercial gear types, estimated recreational catch and gross production value; (B) total commercial effort; (C) total CPUE for all gear types; and (D) the number of active licence holders taking or targeting the species. Error bars on the recreational catch estimates (A) represent the standard error of those surveys. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

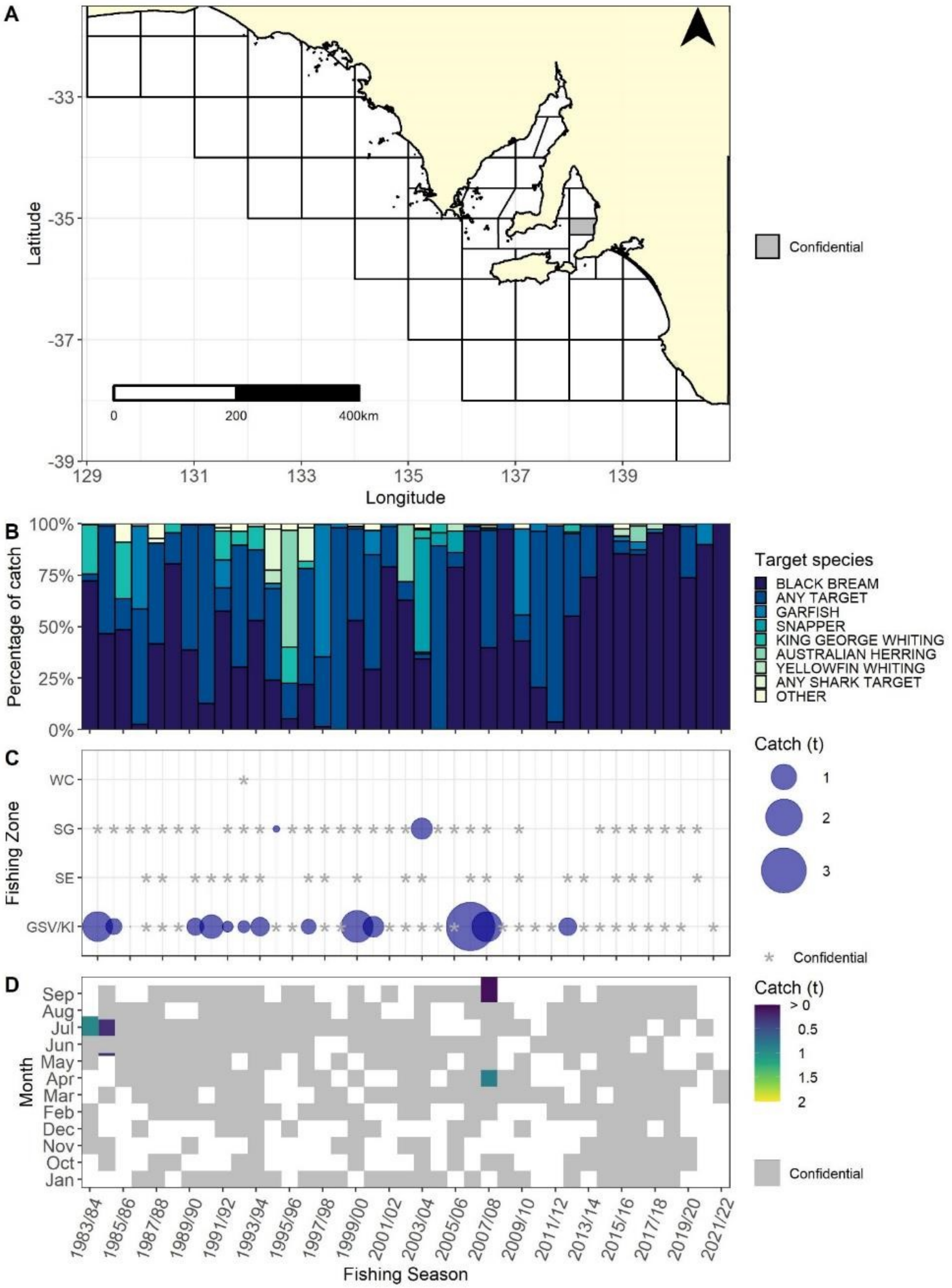

Figure 4.21-2. Regional dynamics of Black Bream: (A) The spatial distribution of catch by the commercial sector in 2021/22. (B) Percentage of targeted catch by species across fishing seasons. Long-term trends in: (C) the annual distribution of catch among zones, (D) months of the year.

4.22. Gummy Shark

Species summary

Gummy Shark

Mustelus antarcticus

Assessment scale	State-wide	**Species Tier**	No tier assigned
Stock status	2019 – Not assessed	2020 – Not assessed	**2021/22 – Not assessed**

Biology	• Distributed through the temperate waters of southern Australia, from Geraldton (WA) to Jervis Bay (NSW) and in TAS (Woodhams et al. 2020a). • Demersal species inhabiting the continental shelf from nearshore to 80m depth, sometimes found on the continental slope to 350m depth (Last and Stevens 2009). • Slender body shape, with pre-dorsal, inter-dorsal and post-dorsal ridges. Pavement-like crushing teeth. • Bronze to grey colour dorsally with numerous white spots (Last and Stevens 2009). • Born at 30–35 cm TL and reaches a maximum size of 185 cm TL, matures at 95 cm TL and at 4 years for males and 111cm TL and at 5 years for females. • Viviparous reproduction, with ~14 pups per litter after a 11–12-month gestation. • Assessment of stock status for Gummy Shark is undertaken at the biological stock level for the Southern Australia and Eastern Australia stocks by AFMA.
Description of the fishery	• Historically a targeted species using demersal large mesh set nets, longlines (including droplines) and handlines. • Transfer to Commonwealth management (AFMA) in 2000, MSF licence holders could retain a combination of 5 Gummy and School Sharks per day with a multiday trip limit of 10 sharks. • Since 1999, retained as a by-product species when using longlines (including droplines), handlines, and haul nets. • Prior to Commonwealth management, majority of catch came from the SE, WC, and southern SG zones. Since 2000, the WC zone has produced most of the catches. • Recreational fishers target Gummy Shark using rod and line from boats and shore-based fishing.
Management regulations	• Minimum size limit of 45 cm, measured from 5th gill slit to base of the tail for commercial and recreational fishers. • MSF fishers restricted to a combination of 5 Gummy and School Sharks per day (midnight to midnight) with a multiday trip limit of 10. • Gear restrictions include a 400-hook limit for longlines and a 150mm mesh diameter for set nets and haul nets. • Recreational bag limit of a combination of two Gummy and School Sharks per day, with a daily boat limit of a combination of six Gummy and School Sharks when three people or more are fishing on board.

Commercial statistics	**Season**	**Total catch** *t*	**Total LL effort** *fisher-days*	**Total LL CPUE** *kg/fisher-day*
	2017/18	77	1,655	41.1
	2018/19	79	1,698	41.8
	2019/20	62	1,413	39.4
	2020/21	38	914	37.3
	2021/22	51	1323	35.8
Recreational catch estimate	**Survey**	**Estimated catch** *t*	**Retained** *%*	**Released** *%*
	2000/01	-	-	-
	2007/08	19	69%	31%
	2013/14	37	76%	24%
	2021/22	8	65%	35%
Performance indicators	• No performance indicators are assessed for the MSF catch of Gummy Sharks as it is a by-catch allocation of the Commonwealth managed stock.			
Assessment summary	Management of Gummy Shark fishing transitioned from state-based to Commonwealth management in 2000, resulting in a significant decline in catch in the MSF as Gummy Shark catch was restricted to limited bycatch. Catches prior to 2000/01 averaged 660.1 t per year, with a peak in catch of 1017 t in 1988/89 (Figure 4.22-1). Since 2000/01, annual catch declined and averaged 86.0 t per year, in 2021/22 total catch was 50.8 t – all catch is expressed as whole weight. The prominent gear type for taking Gummy Shark has been longline (including droplines), with over 82% of the catch taken using these gears since 2000/01. Gummy Sharks are caught in all four MSF fishing zones (Figure 4.22-2). Note that fishers can report catches as a combined 'Gummy and School Shark' logbook category which prevents these catches from being included in either Gummy or School shark statistics. These catches are presented in Appendix 7.2 for completeness. The Southern Australian stock extends across multiple state jurisdictions and is managed by the commonwealth, it is managed as a single biological stock. Gummy sharks are targeted by fishers of the Southern and Eastern Scalefish and Shark Fishery (SESSF). The stock status for Gummy Shark has been assessed at the biological stock level by the Commonwealth and Western Australian jurisdictions. The Southern Australian stock is classified as a sustainable stock.			
Research needs	• Quantify the post-release survival of commercial and recreational captured Gummy Shark. • Improved estimates of recreational catch and effort • Improved understanding of Aboriginal/Traditional importance			

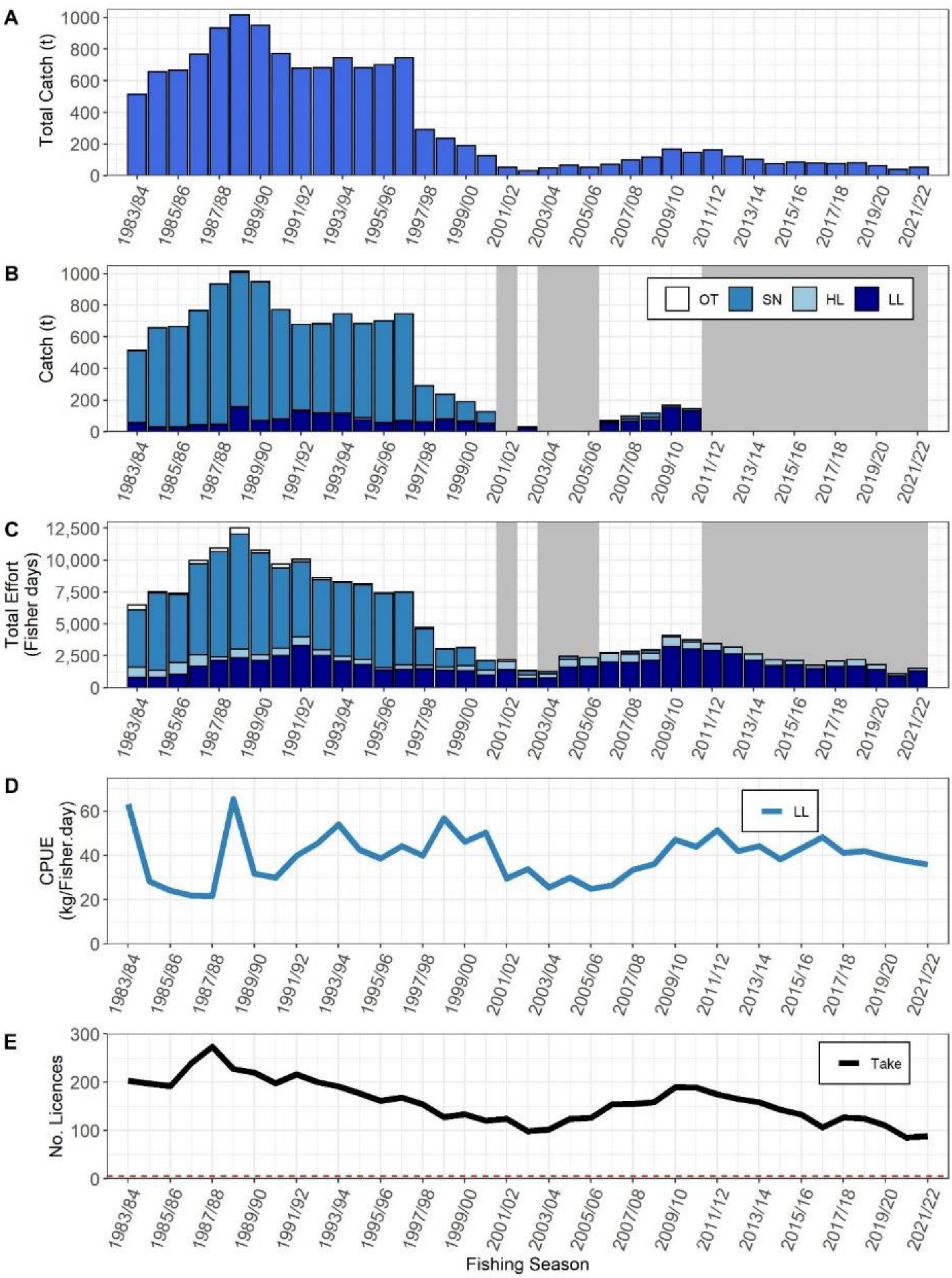

Figure 4.22-1. Long-term trends in State-wide estimates for Gummy Sharks caught in the MSF of (A) total catch for all commercial gear types; (B) total effort for handlines, longlines, set nets and all other gear types; (C)total effort for handlines, longlines, set nets and all other gear types; (D) total CPUE for longlines; and (E) the number of active licence holders taking the species. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

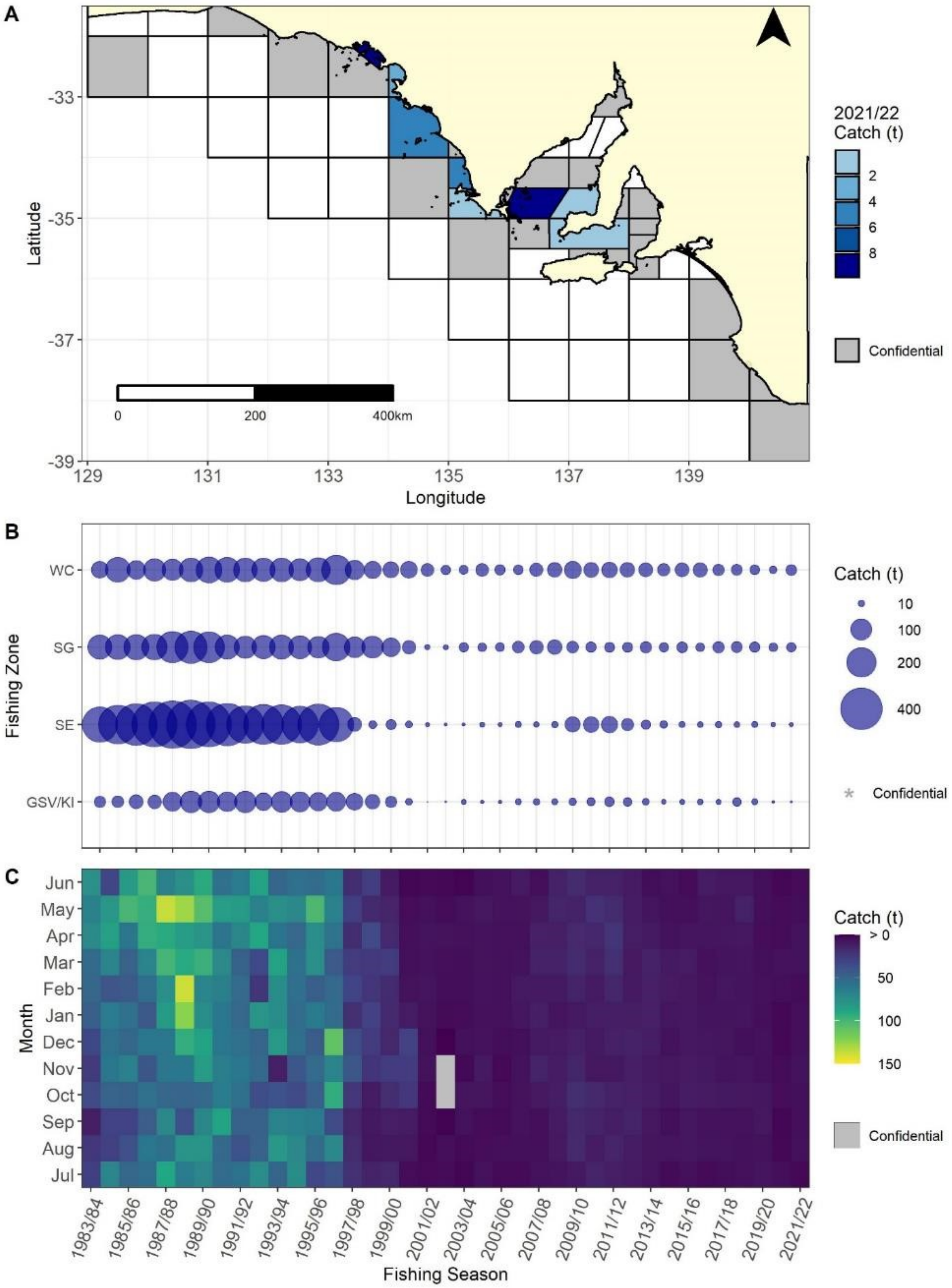

Figure 4.22-2. Regional dynamics of Gummy Shark: (A) The spatial distribution of catch by the commercial sector in 2021/22. Long-term trends in: (B) the annual distribution of catch among zones, (C) months of the year.

4.23. School Shark

Species summary

School Shark

Galeorhinus galeus

Assessment scale	State-wide	**Species Tier**	No tier assigned
Stock status	2019 – Not assessed	2020 – Not assessed	**2021/22 – Not assessed**
Biology	• Widespread distribution through the temperate waters of northeastern and southeastern Pacific, northeastern and southwestern Atlantic and Southern Ocean. • In Australia, range extends from Perth (WA) along the southern coast to Moreton Bay (QLD) (Last and Stevens 2009). • Inhabits coastal to continental shelf and upper continent slope waters, and to well offshore. Depth ranges from nearshore to ~600 m (Last and Stevens 2009). • Fusiform, slender body with bronze to greyish brown dorsal coloration. Pale ventrally with ventral surface near snout tip translucent (Last and Stevens 2009). • Born at 30 cm TL, reaches maximum size of 175 cm TL and ~60 years of age. Matures at 126–131 cm TL and 8 years for males and 124–135 cm TL and 12 years for females (Woodhams et al. 2020b). • Viviparous reproduction with an average 30 pups per litter (range 15–54), 12-month gestation period in a three-year reproduction cycle. • Assessment of stock status for School Shark is undertaken at the biological stock level for the Southern Australia stock by Commonwealth management authority (AFMA).		
Description of the fishery	• Historically a targeted species using demersal large mesh set nets, longlines (including droplines) and handlines. • Transfer of management from state to Commonwealth (AFMA) in 2000, MSF licence holders could retain as bycatch a combination of 5 Gummy and School Sharks per day with a multiday trip limit of 10. • Since 1999, retained as a by-product species when using longlines (including droplines), handlines, and haul nets. • Prior to Commonwealth management, majority of catch came from the SE, WC, and southern SG zones. Since 2000, the WC zone has produced most of the catches. • Recreational fishers target School Shark using rod and line from boats and shore-based fishing.		
Management regulations	• Minimum size limit of 45 cm, measured from 5th gill slit to base of the tail for commercial and recreational fishers. • MSF fishers restricted to a combination of 5 Gummy and School Sharks per day (midnight to midnight) with a multiday trip limit of 10. • Commercial gear restrictions include a 400-hook limit for longlines and a 150mm mesh diameter for set nets and haul nets. • Recreational bag limit of a combination of two Gummy and School Sharks per day, daily boat limit of a combination of six Gummy and School Sharks when three or more people are fishing on board. • Metropolitan recreational shark fishing restrictions (temporal and gear) apply.		

Commercial statistics	**Season**	**Total catch** *t*	**Total LL effort** *fisher-days*	**Total LL CPUE** *kg/fisher-day*
	2017/18	18	396	38.9
	2018/19	24	531	42.4
	2019/20	18	402	39.7
	2020/21	15	371	39.2
	2021/22	23	598	37.7
Recreational catch estimate	**Survey**	**Estimated catch** *t (± SE)*	**Retained** *%*	**Released** *%*
	2000–01	-	-	-
	2007–08	10	61%	39%
	2013–14	54	93%	7%
	2021–22	9 (5)	100%	0%

Performance indicators

- No performance indicators are assessed for the MSF catch of School Sharks as it is a bycatch allocation of the Commonwealth managed Southern Australian stock.

Assessment summary

Management of School Shark fishing transitioned from state-based to Commonwealth management in 2000, resulting in a significant decline in catch in the MSF as School Shark could only be retained as incidental bycatch (Figure 4.23-1; Figure 4.23-2). Catches prior to 2000/01 peaked at 1,322 t in 1988/89 and averaged 885 t per annum between 1983/84 and 1996/97 (Figure 4.23-1; 4.23-2). Since 2000/01, MSF catch declined and has averaged 12.4 t per year, in 2021/22 total catch was 23.7 t – all catch is expressed as whole weight.

Most of the catch since 200/01 in the MSF was incidentally caught by longlines (including droplines), with 95% of the catch taken by this gear category in 2021/22 (Figure 4.23-1)

Note that fishers can report catches as a combined 'Gummy and School Shark' logbook category which prevents these catches from being included in either Gummy or School shark statistics. These catches are presented in Appendix 7.2 for completeness.

The Southern Australian stock extends across multiple state jurisdictions and is managed by the commonwealth, it is managed as a single biological stock, however stock structure remains uncertain (Woodham et al. 2020b). Currently, School Shark cannot be targeted and are taken as bycatch when fishers of the Southern and Eastern Scalefish and Shark Fishery (SESSF) are targeting Gummy Shark. School Shark is listed as Conservation Dependent under the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC) and this species is being managed under a rebuilding strategy (AFAM 2015) (Woodhams et al. 2020b).

The status of the Southern Australian biological stock is classified as a depleted stock in SAFS 2020 (Woodham et al. 2020b).

Research needs

- Quantify the post-release survival of commercial and recreational captured School Shark.
- Improved estimates of recreational catch and effort
- Improved understanding of Aboriginal/Traditional importance

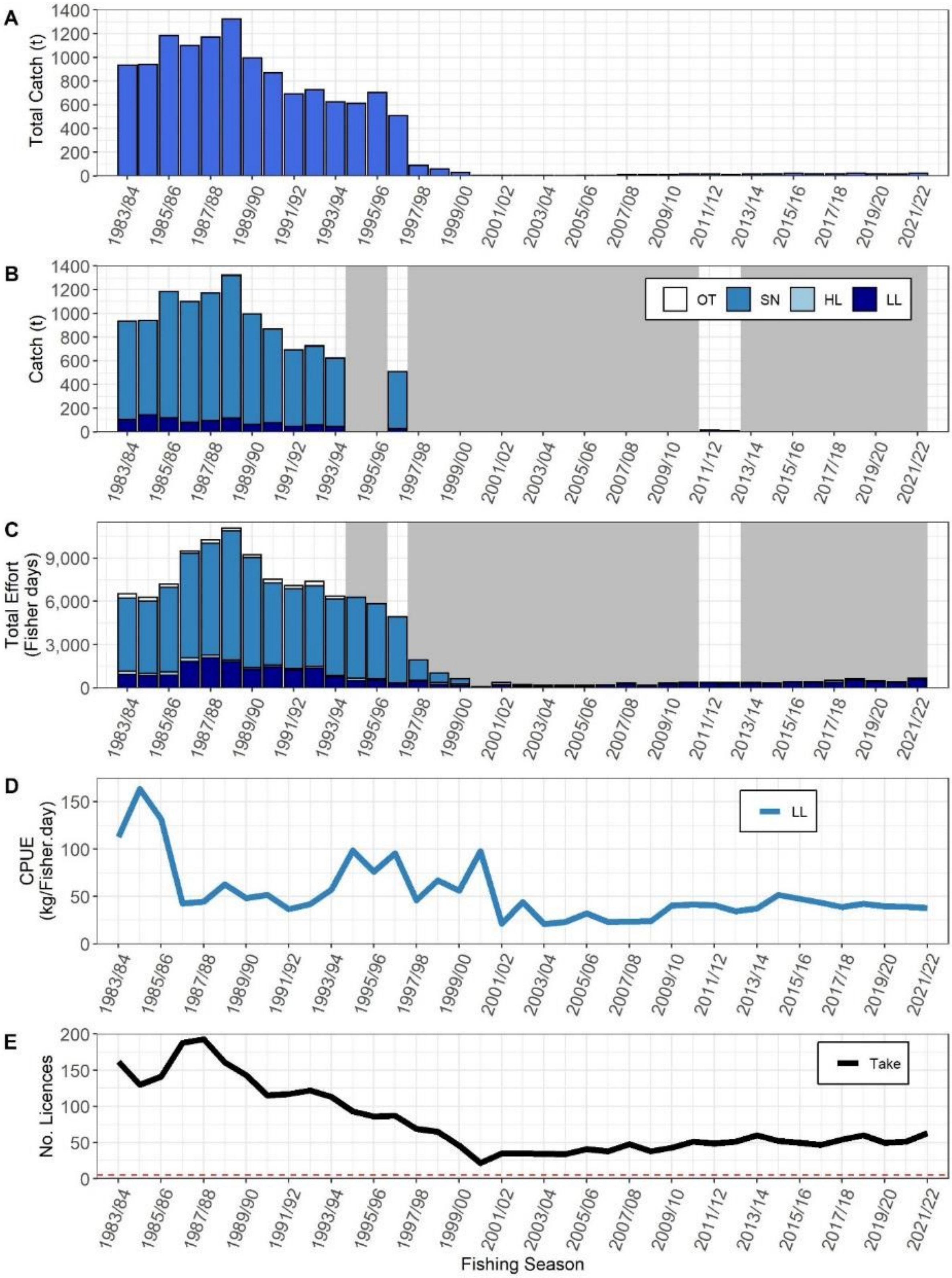

Figure 4.23-1. Long-term trends in State-wide estimates for School Sharks caught in the MSF of (A) total catch for all commercial gear types; (B) total effort for handlines, longlines, set nets and all other gear types; (C)total effort for handlines, longlines, set nets and all other gear types; (D) total CPUE for longlines; and (E) the number of active licence holders taking the species. A red dashed line in panel D represents the number of licences where data becomes confidential. Grey shading represents a fishing season where one or more gear types are confidential and are not included on a panel.

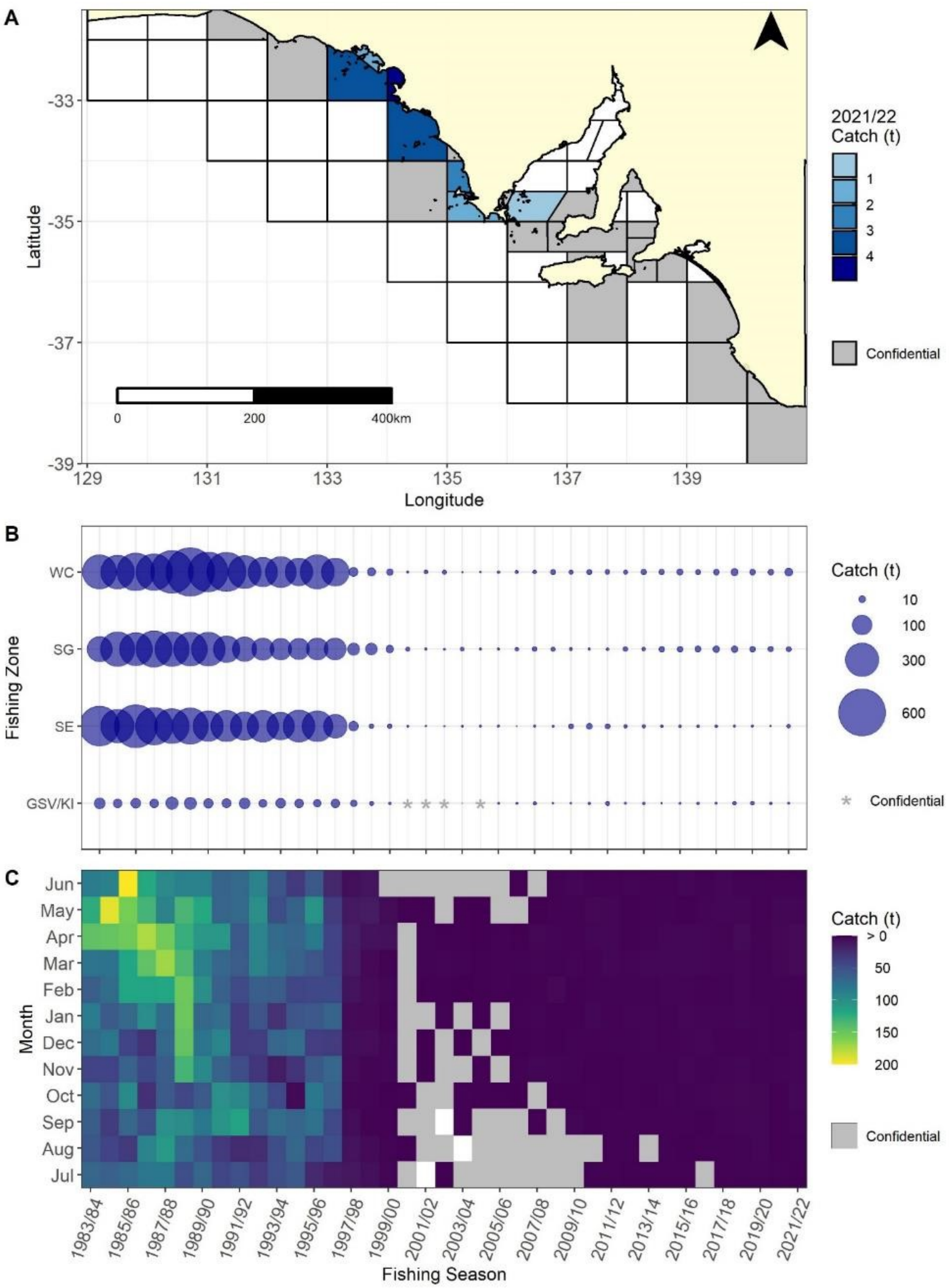

Figure 4.23-2. Regional dynamics of School Sharks: (A) The spatial distribution of catch by the commercial sector in 2021/22. Long-term trends in: (B) the annual distribution of catch among zones, (C) months of the year.

5. DISCUSSION

5.1. Assessment Updates and Overview

This report assessed the fishery performance of 20 species/taxonomic groups taken in the MSF based on data available until the end of the 2021/22 fishing season. Collectively, these taxa were considered across 31 management units, at a resolution that aligned at the State-wide, zone or biological stock scale. Of these, 23 (~74%) stocks were classified as sustainable, two (~6%) were classified as depleted, two (~6%) were classified as recovering, one was classified as negligible (~3%) and the remaining three (~10%) were classified as undefined as there was insufficient information to assign a stock status. Gummy and School Sharks were presented in this assessment but no status was assigned to these species in this report as they are part of the AFMA managed fisheries.

Recent stock assessments for King George Whiting (Steer et al. 2018a), Southern Garfish (Steer et al. 2018b) and Snapper (Fowler et al. 2020b) have identified different levels of concern regarding stock sustainability. The previous King George Whiting assessment classified all three stocks as sustainable based upon model outputs up to and including 2019 (Drew et al. 2021). The current assessment maintained these statuses following several model updates that were undertaken to align stock boundaries with the new zones of management. No signs of stock decline were detected for the GSV/KI and WC stocks in the current assessment, with both stocks triggering the UTRP for biomass above 280 mm TL. However, while the SG stock remained within the TRPs for biomass above 280 mm TL, signs of recent recruitment declines were detected, and these should be carefully monitored in future assessments.

For Snapper, the SG/WC Stock and the GSV Stock were both classified as depleted in the most recent stock assessments (Fowler et al. 2020b, Drew et al. 2022). This reflected a significant reduction in the spawning biomass, as well as declining catches and CPUE, and recent poor recruitment in both gulf stocks (Fowler et al. 2020b, Drew et al. 2022). In each case, the stock status classifications have supported the development and implementation of specific management arrangements to recover each stock. In this assessment, only the SE Regional population of Snapper (i.e., the western extremity of the cross-jurisdictional Western Victorian Stock) could be assessed as there were no catch and effort data available since 2019 from the SG/WCS and GSVS owing to their closure. The current assessment has not updated the stock statuses for Snapper given the recent release of a dedicated assessment (Drew et al. 2022).

The previous Southern Garfish assessment assigned recovering statuses to the NSG and NGSV stocks, and a sustainable status to the remaining stocks (Smart et al. 2022b). The current assessment updated the spatial scale of assessment from biological stocks to fishing zones. As a result, the NSG and NGSV recovering statuses were assigned to both GSV/KI and SG fishing zones, given that these biological stocks account for most of the biomass and catch in each zone (Fowler 2019, Smart et al. 2022b). The WC fishing zone retained a sustainable status, while catches in the SE fishing zone were so low as to be considered negligible and inadequate information exists to determine stock status. Alignment of spatial scale of assessment to management zone boundaries was necessary as this now aligns the assessment and management scales for the Southern Garfish fishery, facilitating TACC setting. However, sub-regional biological stocks were still considered in this assessment by assessing catch and effort statistics for the northern and southern gulfs, as well as at the zone scale. Therefore, this approach maintains the benefits of considering the spatial and population dynamics of the Southern Garfish fishery, while providing assessment advice at the appropriate management scale. The stock statuses for Southern Calamari and Blue Crab were similarly updated to match the new management zone boundaries. The same justifications and approach applied to Southern Garfish were also extended to Southern Calamari. For Blue Crab, MSF catch and effort mostly occurs in the WC fishing zone due to the establishment of the BCF in both gulfs. Therefore, assessing Blue Crabs for the WC fishing zone, rather than State-wide was the most appropriate approach.

The four primary species, King George Whiting, Snapper, Southern Garfish and Southern Calamari, have historically accounted for more than half of the State-wide total commercial catch in the MSF. However, this has declined in recent years with primary species accounting for 33% of the total MSF catch in 2021/22. There were several reasons for this including the increasing importance of secondary and tertiary species to the fishery. The first and third ranked species by State-wide catch in 2021/22 were Western Australian Salmon (a secondary species) and Ocean Jackets (a tertiary species), respectively. Catches for both of these species have fluctuated in recent years depending on market demands, as has been typical for many secondary species in the MSF. However, given that several primary species are now managed via ITQs as Tier 1 stocks, there is potential for greater effort to be focused on the more profitable secondary species by fishers who do not own, or have not yet had the opportunity to buy, Tier 1 quota. Previous research has identified that both of these species could support higher catches and would have the lowest risk to sustainability should fishing effort be displaced to them from Tier 1 stocks (Fowler et al. 2020a). If higher catches were to persist, it would be valuable to develop appropriate assessment programs for both species to ensure increased catches do not jeopardise their sustainability. A current FRDC project "Fisheries biology of Western Australian Salmon: improving our understanding of population dynamics in South Australia to enable quantitative stock assessments and improved fisheries management" (FRDC 2018-035) will provide further information for Western Australian Salmon that could be used in an assessment for this species.

Several important updates were applied within this assessment. Firstly, all catch and effort statistics, along with associated PI's were presented using the new fishing seasons, which following the reform, were changed from a calendar to a financial year time step. Secondly, updates to CPUE series recommended from previous assessments were applied to many of the species within this assessment (Smart et al. 2022b). This predominantly included a new CPUE series for gear specific effort types, which provide a more appropriate unit of effort for CPUE series to be based on. This was achieved for handlines, haul nets, squid jigs and longlines, which are the dominant gears for the majority of species. The remaining gear types will be resolved in future assessments. Importantly, many of these gear specific CPUE indices matched the general trends of CPUE by fisher day. This was a valuable result as CPUE by fisher day can be calculated for every fishing season, whereas gear specific effort units have only been available since 2003/04 when daily logbooks were introduced. This increases the confidence in CPUE by fisher day as an appropriate long-term index for raw CPUE abundance. Standardised CPUE was also estimated for King George Whiting and Yellowfin Whiting using GLM based methods. These standardised values provided useful information for assigning stock status as an additional piece of evidence to include in a weight-of-evidence approach. Their continued application for the remaining species will be a useful update in future assessments. Lastly, cMSY models were applied to Blue Crabs in the WC fishing zone and both Yellowfin Whiting stocks. These cMSY models are a data-limited approach and are not sufficient as the sole justification for assigning stock status. However, they can also be used in a weight-of-evidence approach, with the cMSY model for Yellowfin Whiting in GSV/KI providing useful results in the current assessment. These models can only be applied under specific assumptions and therefore cannot be applied to all species within this assessment. However, other data-limited approaches may be available that could play a similar role to cMSY for species where catch-only models are precluded.

5.2. Challenges and Uncertainties in the Assessment

Recreational data remains one of the largest knowledge gaps for assessing the status of the MSF stocks. The recreational sector's total harvest has traditionally been determined through infrequent telephone/diary surveys that are undertaken at six-to-seven-year intervals (Henry and Lyle 2003, Jones 2009, Giri and Hall 2015, Beckmann et al. 2023). Although these surveys adopt a standard methodology that allows the results to be compared through time, their estimates of catch and effort have been infrequent and typically imprecise, especially for more minor species. Improving the precision of the estimates of the recreational catches, either through more frequent surveys or increased participation rates, will improve assessments of stock status. Challenges around the collection of recreational fishing data were highlighted at a workshop in 2018 (Beckmann et al. 2019). Alternative survey methods such as app-based data collection are currently being investigated as part of a research project associated with the recent 2021/22 recreational survey (FRDC 2020-056). The current information available on recreational catches has strong implications for the assessments of King George Whiting, for which the recreational contribution to overall State-wide catch has been highest. In 2021/22, a greater proportion of catch in the SG and GSV/KI fishing zones was caught by recreational fishers during the recreational survey than the commercial fishery (Beckmann et al. 2023). This has implications for the King George Whiting assessment as uncertainty in catches can add substantial uncertainty to model BPIs (Van Beveren et al. 2017, Van Beveren et al. 2020). The sensitivity analyses performed in the current assessment identified that model estimates must be treated conservatively given the uncertainty in SA recreational catch. However, it should also be noted that recreational catch estimates for King George Whiting in SA are estimated with much greater precision than other species due to their magnitude. Additionally, State-wide catches have been relatively stable through time, indicating that the years between surveys are likely to have similar levels of catch. This provides some additional confidence around the results of this stock assessment, despite the large levels of recreational catch that cannot be estimated in most years and which must be acknowledged.

Southern Calamari has recently become the most profitable species in the commercial MSF and has the highest GVP ($5.8 M in 2021/22) in the fishery. This has occurred through the relatively low costs of squid jig fishing and continually increasing market prices. Southern Calamari is a highly productive species with a short life span (< 1 year), allowing it to sustain higher harvest fractions than most other MSF species. However, a 7-year decline in CPUE was previously documented in the SSG region, indicating that regional depletion may be occurring (Drew et al. 2021). Concerns regarding localised declines in productivity have also been raised by industry reports that Southern Calamari have become increasingly difficult to catch in areas that were previously highly productive. In addition, there is currently a lack of eggs in known spawning areas; and there has been a notable absence of large animals in catches. However, targeted squid jig CPUE in SSG has increased since this assessment, arresting this decline. This suggests that some stock recovery may have occurred in this region, possibly through a period of stronger recruitment. However, the reliance of the Southern Calamari assessment on commercial fishery data is problematic for several reasons: (1) the spatial coverage of the Southern Calamari fishery can only be examined at the MFA level which may be too broad to detect regional or more localised depletion; (2) a potentially weak correlation between abundance and CPUE prevents the effects of fishing on the population from being determined; and (3) the impact of recreational fishing on Southern Calamari stocks has not been regularly determined but may be a substantial source of fishing mortality. The importance of this species to MSF warrants future research to determine an appropriate stock assessment program that befits the fishery's highest value species.

Yellowfin Whiting is another species which may require new assessments to be developed as it is an important secondary species for the MSF. This species has large catches in the SG fishing zone and has been identified as one of the most economically important species in the fishery (Section 2.3.2; Smart et al. 2022a) and it is anticipated that this species could become increasingly targeted due to effort displacement from other Tier 1 stocks. Commercial catches increased in 2021/22 for both GSV/KI and SG fishing zones, providing some support for this prediction for the first post-reform fishing season. While both Yellowfin Whiting stocks were classified as sustainable in this assessment, a notable stock decline was detected for the GSV/KI fishing zone through CPUE standardisation and the cMSY model. This decline was not detected by raw catch and effort statistics, demonstrating the value of improving the level of scientific assessment for additional species in the fishery. Commercial and recreational fishers have communicated concern over this stock, providing a mounting body of evidence that a recent decline has occurred. However, both the CPUE standardisation and the cMSY model indicate that this decline has stabilised and the population has stabilised. As a result, a sustainable status was assigned as a depleting status was only appropriate for a stock that is in decline, while a depleted status requires evidence of recruitment impairment, which was not available. Furthermore, detailed assessments are required to support these conclusions and determine the exact level of stock deterioration. However, a challenge for these future assessments is the lack of accurate and precise data on recreational catch, particularly for a fishery as small as the Yellowfin GSV/KI stock, as well as information on length and age structures.

New performance indicators are required for the MSF, following the new management arrangements in effect since July 2021. Several current PIs for MSF species are based on catch and effort statistics with the entire time series of the fishery used as a reference period. This has proven to be problematic for some species, including Blue Crab where total catch has substantially reduced since the creation of the BCF. This was addressed in the current assessment through assessing Blue Crabs for the WC fishing zone and applying the PIs at this spatial scale. This has solved previously identified issues where consideration of Blue Crabs at the State-wide scale rendered TRPs ineffective (Smart et al. 2022b). However, the TRPs based on catch are now also ineffective for Tier 1 stocks since TACCs have been applied; essentially capping catches at a prescribed level. Therefore, the ability to exceed the three highest or lowest years on record is no longer of relevance for these stocks. Similarly, the removal of 100 licences has reduced effort across the fishery and therefore a comparison to pre-reform effort levels provides little useful information. Research undertaken during the reform identified that changes in CPUE were unlikely to occur from these licence removals due to the degree of associated latent effort (Smart et al. 2022a). These results were substantiated in this year's assessment but this will need to be examined over subsequent fishing seasons before it can be confirmed that CPUE indices were unaffected by the reform.

Smart et al. (2022a) also identified that most TACCs would not be caught in 2021/22 as most TACCs for this inaugural season were set using recent average catches which preceded the licence surrenders from the reform (Smart et al. 2022a). Based on the catch histories of remaining licence holders and the likely quota transfers that would be required, individual fishers would have had to increase their catches in 2021/22 to account for the reduced number of licences in the fishery. It is not unusual for TACCs to be uncaught in the seasons following their initial implementation. The operating environment for a fishery can change substantially after ITQs are implemented due to the requirements for initial autonomous quota trades. Therefore, for periods of the 2021/22 fishing season, many fishers may not have owned enough quota to maintain their regular annual catch. Only one Tier 1 stock (GSV/KI Southern Garfish) had most of its TACC caught in the 2021/22, while the remaining Tier 1 stocks had substantial under-catches. This will likely be resolved in the coming seasons as quota trading continues and TACCs are set off more appropriate methods than pre-reform catch levels. This will be supported through imminent harvest strategy development as part of the new MSF management plan.

The tiered management framework (TMF) was designed as part of the MSF reform research project (Smart et al. 2022a) which assigned each species to a tier of management in each of the four fishing zones. Tier 1 stocks will be managed via a TACC that may be further unitised into ITQs, Tier 2 stocks will be assessed according to a recommended biological catch (RBC) that demonstrates fishing levels are within sustainable limits, and Tier 3 stocks will be assessed using fishery statistics in a similar manner to what was done in this report. Each stock was assigned to a tier based on six diverse indicators that include stock status, commercial importance, recreational importance, Aboriginal/Traditional importance, level of targeting, and management need. The final recommendation of which Tier each species in a zone should be assigned to will be provided by the MSFMAC. Currently, MSF species are categorised as Primary, Secondary or Tertiary species in the Management Plan (PIRSA 2013). However, this Management Plan is due to be updated and it is possible that these categories will be replaced with the classifications from the TMF. Therefore, the structure of the current MSF assessment report may need to be adjusted to match the requirements of the new management plan.

5.3. Research Priorities

An updated stock assessment program is required for Southern Calamari, given its importance to the commercial MSF in recent years. Following the MSF reform, 11 stocks of King George Whiting, Snapper, Southern Garfish and Southern Calamari, have been assigned a Tier 1 status and are managed via annual TACCs. The current assessment programs for King George Whiting, Snapper, and Southern Garfish are provide sufficient information to set TACCs and can form the foundation of upcoming harvest strategy development, if required. However, no such assessment program exists for Southern Calamari which is only assessed through fishery dependent information. Therefore, the current assessment program does not match the importance of this species to the fishery and cannot provide sufficient management advice for setting TACCs. A priority of MSF research should include the development of such an assessment program which will provide appropriate advice for TACC setting. Cephalopods such as Southern Calamari have well known assessment difficulties as most such species have biological characteristics and life histories that are markedly different from fish or crustacean species, for which standard fisheries modelling techniques have been developed.

Therefore, many cephalopod fisheries have struggled to develop appropriate assessments (Arkhipkin et al. 2021). As Southern Calamari are short-lived and highly productive, it was thought that their populations were resilient to fishing. However, this has recently been challenged as the Tasmanian stock is currently classified as 'depleting' (Fraser et al. 2021), and fishers have expressed concerns about stock health in SA. This suggests that Southern Calamari may not be as tolerant to high levels of fishing as previously thought and that methods to assess their population status need development. Furthermore, cephalopod population dynamics are influenced by prevailing environmental conditions, obfuscating the impact of fishing, and causing management complications. Therefore, there are numerous assessment difficulties that must be overcome in order to provide a science program that can support this fishery.

The previous stock assessment presented a hypothesis regarding the density dependence of Southern Garfish and its potential impact on biomass (Smart et al. 2022b). Discussions with industry members have identified the benefits of establishing fishery independent surveys for Southern Garfish which could help further explore this hypothesis. The design, testing and implementation of these fishery independent surveys remains a priority for these stocks.

Another challenge is the complication of having a multi-species complex in three of the stocks assessed in this report and are classified as 'undefined'. Currently, there are uncertainties and limited data around the proportion of species in the catches of Whaler shark, Rays and Skates, and Leatherjackets. As a result of these uncertainties and limited data, these stocks have been assessed as undefined. A greater level of detail in species identification is required to be able to untangle the relative stock composition, and this will be potentially resolved as the MSF catch reporting moves to an electronic reporting system. Currently, the stocks which have been assessed as undefined as a result of the unknown species composition, have predominately one main species in each stock (e.g., Southern Eagle Ray in Rays and Skates). Improving species identification in catch reporting will allow us to potentially remove these species from the multi-species complex and assess them individually or appropriately weight the fishery statistics to the known contribution of each species in a stock. This may become a priority for Whaler Sharks which have been assigned a Tier 2 status in several fishing zones following the MSF reform (Smart et al. 2022a). Therefore, research may be required to separate these species as part of an ongoing assessment program.

Following the reform of the fishery, many of the PI's in the current management plan are becoming increasingly outdated and provide little guidance to fishery managers. A new management plan will soon be developed for the MSF which will include a more appropriate harvest strategy framework. The PI's and TRPs included in this harvest strategy should improve our ability to assess stock status and provide clear scientific advice to the MSFMAC and fisheries managers. However, for this harvest strategy to successfully developed, more appropriate PI's must be developed for several species. For

Tier 2 stocks, this should ideally include an expansion of assessment methods that provide a greater level of information on stock health. The current information available for assessed species has already been determined, as well as potential techniques that could improve this information for each Tier 1 and Tier 2 stock (Smith and Smart 2022). One of the first species to receive this attention should be Yellowfin Whiting, given the concerns raised for the GSV/KI stock.

Given the continuing closure of Snapper fishing in the GSV/KI, SG and WC fishing zones, there is also a need to develop a recovery plan for Snapper. There are several areas of scientific research that have been identified to support this recovery plan which include: (i) continuation of the adult sampling program to access biological data and monitor regional age structures; (ii) to better understand and monitor inter-annual recruitment variability of 0+ juveniles; (iii) continuation and refinement of DEPM surveys to estimate spawning biomass; (iv) developing forecasting capability in the SnapEst model; (v) improving our understanding of the Snapper population on the WC; (vi) understanding post-release mortality; and (vii) continuing stock enhancement (Drew et al. 2022). All these research projects will be pursued through the $5 million Snapper Science Program recently announced and jointly funded by the FRDC and SA Government.

Lastly, a better understanding of the importance of MSF fish stocks to Aboriginal/Traditional fishers and communities is required. The recent development of the TMF highlighted the paucity of information on Aboriginal/Traditional fishing that is available. Subsequently, it was not possible to appropriately determine which stocks would be of most importance to different Aboriginal/Traditional fishers and communities as a part of this framework. This has highlighted that a greater research focus is required to better understand the significance of the MSF to the Aboriginal/Traditional sector and to incorporate this in decision making. Although Aboriginal/Traditional fishers are defined as one sector under the Fisheries Management Act 2007, they encapsulate multiple groups with different languages, values, and cultures. The value to Indigenous peoples of Sea Country's marine, intertidal and estuarine resources is more than just for subsistence; it has value both culturally or spiritually, and includes all living things, beliefs, values, creation spirits and cultural obligations connected to that area. Recognising which stocks are most important to Aboriginal/Traditional fishers and their communities is therefore important and needs to be determined.

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7. APPENDICES

7.1. Appendix 1. Annual commercial catches (in tonnes) of assessed species taken in the MSF between 1983/84 and 2021/22.

	PRIMARY				SECONDARY									TERTIARY						
	KGW	GARFISH	SNAPPER	SOUTHERN CALAMARI	YELLOWFIN WHITING	WA SALMON	AUSTRALIAN HERRING	SNOOK	BLUE CRAB	SAND CRAB	YELLOW-EYE MULLET	MULLOWAY	WHALER SHARKS	OCEAN JACKET	BLUE-THROAT WRASSE	TREVALLY	LEATHER JACKET	RAYS AND SKATES	CUTTLEFISH	BLACK BREAM
1983/84	668	436.4	466.2	160.5	111.9	356.8	414.2	107.4	86.8	conf.	110.4	19	23.9	NA	2.8	2.8	35.6	8.3	0.3	1.4
1984/85	597	428.7	469.1	186.8	68.3	621.8	274.8	101	113.9	28.7	94.3	17	33.5	NA	3.4	3.8	83.2	11.6	0.2	0.5
1985/86	654	438.9	453.8	192.3	47.4	609	305.4	71.6	170.2	24.9	127.2	7.7	37.6	NA	1.8	1.3	168.5	15.9	0.3	0.1
1986/87	644	388.8	404.3	202	26.5	604.6	440.8	75.6	157.4	25.8	128	13.3	46.1	NA	2.6	4	359.2	24.3	0.2	0.6
1987/88	589	381.4	332.8	206.1	22.3	667.5	498.4	71.9	183.7	28.5	151.7	12.1	68.3	NA	3.5	5.8	727.2	56	1.1	1.1
1988/89	620	465.4	421.3	264.7	21.6	417.9	414	99	282.2	96.2	120	8.2	69.6	conf.	2.5	2.2	1056.1	47.6	3.2	0.7
1989/90	634	516.4	423	208.4	31.7	403.8	339.5	103.5	359.7	142.4	176.3	11.7	59.4	913.2	2.5	4.3	57.5	42.2	3	0.6
1990/91	692	453.6	456.6	278.9	46	479.1	308.1	98.9	433.6	148.6	151.9	8.1	83.9	949.1	2.1	4	69.3	37.7	2.7	0.9
1991/92	750	514.2	437.2	329	43.1	601.2	362.5	100.1	425.1	101	128.5	7.7	73.5	1006.4	2.1	14	55.7	66.4	1.8	0.3
1992/93	700	514.8	385.3	287.2	90.2	586.1	331.7	123.7	510.7	73	134.3	15.1	72.1	787.5	5	12.9	53	64.6	3.4	0.3
1993/94	665	472	317.5	325.4	69.4	524	304.2	121.2	543.8	50.6	110.7	13.5	82.2	664.7	5.8	12.8	51.9	64.4	7.5	0.7
1994/95	615	391.9	222.9	337.3	110.1	769.2	275	125.7	607.7	36.8	113.4	16.3	85.8	524.9	6.4	7.8	41.5	58.1	34.8	0.4
1995/96	534	510.9	305.5	381.9	92.6	486.7	236.4	151.2	654.7	54.3	71.4	24.4	81.4	476.3	7.3	7.8	33	42	70.6	0.1
1996/97	586	512.9	302.9	355.7	102.1	552.1	203.6	119.9	463.9	87.2	86.4	10.5	84.1	392.4	11.4	10.5	45.6	53.5	262.7	0.6
1997/98	552	503.9	390.6	424.9	73.5	631.8	283.5	113.4	80.6	129	106.6	8.6	106.7	424.5	26.5	5.3	42.6	47.2	170.1	1.1
1998/99	594	421.1	445.2	435	84.1	523.7	321.6	117.2	111.9	129.4	68.5	8.9	84.6	299.7	26.6	5.1	42.4	48.3	14.8	0.7
1999/00	517	476.7	575.2	400.5	112.3	456.7	303.6	93.3	88	147.7	73.7	3.1	72.6	288.2	24.1	7.7	41.1	49	15.8	1.6
2000/01	453	532.3	577.4	487.8	151.8	581	230	107.7	84.6	162.1	72	9.4	95.9	259.9	20.3	21.9	43.8	52.8	19.3	0.8
2001/02	389	470	647.4	339.7	148	455.2	262.2	99.8	77.7	127.1	57	4.2	86.7	394.8	24.3	5.1	31.3	57.5	26.8	0.3
2002/03	398	331.7	532.4	346	180.9	575.7	197.2	112.5	67.8	93.3	47.3	5.8	127.2	227.5	26.9	4.1	18.8	49.5	10.6	1.2
2003/04	357	320.8	410.8	302.6	162.9	157.9	152	81	52.9	96.1	44.7	4.6	120.3	497.9	21.9	3.8	22.1	35.1	5.7	1.2
2004/05	345	364.2	503.8	503.6	138.2	248.5	184	83.5	47.3	148.3	49.6	5.2	94.4	318.6	24.3	9.8	30.4	36.4	9.4	0.3
2005/06	333	369.3	533	310.7	130.4	176.6	125.9	61.3	48.2	141.7	38.4	5.4	73.2	149.1	17.6	9.7	18.8	28.5	7.8	0.3
2006/07	354	293.3	642.9	297.4	85.2	156.8	104.9	63.9	41.9	83.1	35.9	5.4	82	conf.	12.3	6.1	14	21.3	10.9	3.5
2007/08	330	290.1	742.7	303.2	81.9	105.3	122	81.9	50.3	62.7	28.8	5.9	79.5	conf.	16.7	10.5	13.3	22.9	6.4	1.5
2008/09	339	293.8	785.7	281.2	110.9	120.3	143.4	70.5	58.5	98.2	30.3	3.7	94.8	conf.	21.9	7.2	21.3	22.6	4	conf.
2009/10	343	281.1	916.5	366.1	104.5	170.6	167.8	65.3	56.9	71.3	22.8	2.8	154.7	conf.	19.7	10.5	14.6	21.7	9.7	0.2
2010/11	340	260.9	971	326.4	98.2	153.6	118	62.2	51.2	72	28.1	2.6	86.2	conf.	23.9	12.4	11.6	15.3	5.2	conf.
2011/12	307	249.5	877.5	481.9	103.9	211.1	99.1	47.3	57.5	83.6	33.2	3.2	90.3	conf.	20.4	8.9	12.8	17.1	3.2	conf.
2012/13	307	242.4	548.8	424.3	151.7	74.1	137.5	47.5	62.5	83.1	19.9	4.7	65.4	91	14.2	12.3	14.8	17.1	3.9	0.7
2013/14	265	261.1	548.7	328.5	110.3	60.9	143.1	40.1	61.4	56	17.5	1.1	64.7	conf.	17.6	7.3	9.1	12.6	1.8	0.5
2014/15	310	216	586.5	435.9	95.8	275	116.2	45.3	44.3	50.5	17	1.3	44.6	conf.	15.2	11.2	16.3	16.8	1.8	conf.
2015/16	272	163.5	428.6	382.8	115.3	453.6	89.6	46.8	32.7	69.6	14.3	1.3	54.3	125.3	16.1	7.9	28.2	12.3	1.6	2.1
2016/17	268	185.5	342.6	397.4	133.3	269.7	82.9	48.3	51.6	50.1	17.2	4.6	57.4	300.1	12	9.2	27.6	12.1	0.9	conf.
2017/18	243	174.4	304.4	422.4	139.7	321.1	85.5	42.1	35.3	35	22.5	6	53.9	conf.	14.1	7.5	30.5	11.9	1.4	1.7
2018/19	234	192.1	280.7	322	126.2	182.5	96.6	41	51.8	63.8	16.5	9.1	50.3	127.5	6.6	5.4	20.7	9.7	0.9	3.2
2019/20	234	168.2	115	348.9	131.9	188.8	88.4	38.6	54.7	51.1	11	3.3	55.5	conf.	5.8	8	10.3	10.4	20.1	conf.
2020/21	181	181.8	42.9	349.9	81.4	90	109.9	31.6	76.3	62.7	8.5	0.9	67.2	conf.	5.3	8.2	11.1	10.8	5	conf.
2021/22	176	156.4	25.2	278.2	124.8	323.5	108.7	23.7	61.5	55.9	7	1.1	69.5	254.2	8.1	9.3	12.4	12.3	1.3	conf.

7.2. Appendix 2. Annual commercial catches (t) of remaining permitted species and species groups taken in the MSF between 1983/84 and 2021/22.

	ANNELIDS	MUSSEL	OCTOPUS	PACIFIC OYSTER	KING SCALLOP	GOULDS SQUID	ANCHOVY	BARRACOUTA	SOUTHERN ROCK COD	DORIES	FLATHEAD	FLOUNDER	RED MULLET	YELLOWTAIL KINGFISH	LING	BLUE MACKEREL	JACK MACKEREL	COMBINED MORWONGS	OTHER MULLET	BIGHT REDFISH	SWEEP	SWALLOW TAIL	DEEP SEA TREVALLA	SCHOOL WHITING	GUMMY SHARK	SCHOOL SHARK	GUMMY And SCHOOL SHARK	ALL REMAINING SHARK SPECIES
1992/93	1.2	NA	9.8	NA	NA	conf.	conf.	3.2	conf.	NA	4.7	0.2	4.5	2.2	1.3	0.4	0.5	14.7	NA	13	4.7	0.2	49.6	0.1	682	726.2	246.1	323.7
1998/99	0.5	conf.	conf.	NA	NA	NA	conf.	conf.	conf.	NA	2.7	0.4	4.5	conf.	conf.	3.1	0.2	3.3	conf.	4.7	4.2	conf.	conf.	conf.	236.5	58.7	20.3	50.1
1999/00	0.7	conf.	6.7	conf.	conf.	NA	conf.	0.5	conf.	NA	2.1	0.2	3.8	conf.	conf.	3.7	conf.	3.6	conf.	5.1	1.4	conf.	conf.	conf.	189.5	29.2	7.3	56.3
2000/01	3.1	conf.	conf.	NA	conf.	NA	conf.	conf.	conf.	conf.	2.3	conf.	4.6	conf.	conf.	0.3	conf.	0.2	conf.	1.2	1.4	NA	NA	conf.	126.3	5.9	NA	71.1
1983/84	1.4	NA	conf.	NA	NA	NA	NA	78.3	0.3	conf.	5.2	0.1	2.6	1.2	conf.	NA	2	10.7	conf.	3.1	2.7	conf.	conf.	NA	513.8	934.1	NA	11.3
1984/85	1.4	NA	conf.	NA	conf.	NA	NA	21.4	0.3	conf.	3.9	0.4	2.2	0.7	conf.	conf.	conf.	12.2	conf.	7.9	2.6	conf.	6.2	NA	656.2	939	NA	25.2
1985/86	1	NA	0.1	NA	NA	NA	NA	9.9	NA	NA	3.5	1.3	3.2	conf.	conf.	conf.	conf.	16.6	conf.	14.9	2.7	conf.	6.8	conf.	665.5	1184.8	NA	27.8
1986/87	1.4	NA	0.7	NA	conf.	conf.	NA	5	conf.	NA	2.9	1.2	3.6	0.6	0.2	3.6	14.6	21.9	NA	12.5	1.5	conf.	93.5	NA	766.8	1101.5	NA	53.2
1987/88	1.5	NA	3	NA	NA	conf.	NA	6.6	0.5	conf.	4.1	0.2	3.4	conf.	1.2	conf.	37.5	21	conf.	15.7	2.3	conf.	128.1	conf.	934.3	1172.7	NA	87.6
1988/89	0.7	NA	2.4	NA	conf.	NA	NA	11.6	0.3	conf.	4.9	0.3	4.5	conf.	0.3	1.6	conf.	30.8	conf.	18.4	4.4	conf.	57.6	conf.	1017	1322.7	NA	78.7
1989/90	1.3	NA	3.2	NA	NA	NA	NA	12.5	conf.	NA	4.5	conf.	5.4	NA	0.2	0.3	conf.	27.7	conf.	19.1	11.8	0.3	75.6	conf.	948.5	996.7	NA	69
1990/91	1.5	conf.	5	NA	NA	NA	NA	6.9	conf.	NA	6.5	0.2	4.9	conf.	0.1	1.5	conf.	20.5	NA	11.1	10.9	0.3	82	conf.	771.6	871	297.2	93.2
1991/92	1.3	conf.	7.6	NA	NA	NA	NA	4.5	NA	NA	7	0.2	4.8	0.8	0.4	0.8	0.2	19.4	conf.	10.2	3.2	0.4	61.7	0.1	679.1	693.7	221.8	233
1993/94	1.1	NA	4.5	NA	NA	conf.	NA	0.4	conf.	NA	4	conf.	4.7	1.9	1.6	5.9	0.3	16.6	NA	12.2	8.5	0.5	49.8	0.1	743.6	622.5	200.1	193.8
1994/95	3.8	NA	5.5	NA	NA	NA	NA	0.4	NA	conf.	3.6	0.2	4.6	0.4	0.5	5.8	0.3	25.5	NA	19.7	4.6	0.2	19.3	0.1	681.1	610.8	191.2	109.5
1995/96	2.9	conf.	9.2	NA	NA	conf.	NA	0.4	conf.	NA	2.2	0.4	4.6	0.4	1.2	5.5	0.2	22.9	NA	12.6	6.1	0.4	8.3	0.1	701.2	700.4	120.4	130.4
1996/97	2.2	conf.	8.9	NA	NA	NA	NA	0.9	conf.	NA	2.3	0.2	4.1	conf.	1	3.6	conf.	26.7	NA	10.3	8	0.2	4.7	conf.	743.9	509.4	90.1	101.3
1997/98	1.7	conf.	6.2	NA	NA	NA	NA	1.5	conf.	NA	2.4	conf.	4.1	conf.	conf.	4.6	conf.	11.1	conf.	5.5	7.3	0.1	conf.	0.1	290.2	88.6	50.4	67
2001/02	1	NA	conf.	NA	conf.	NA	NA	0.2	conf.	conf.	2.1	conf.	3.8	conf.	NA	5.1	conf.	1.4	conf.	3	2.3	conf.	NA	conf.	51	4.9	conf.	59.9
2002/03	1.5	NA	5.1	NA	conf.	conf.	NA	2	conf.	NA	2.3	conf.	3.8	0.5	conf.	1.2	NA	1.9	conf.	4	1.6	conf.	NA	conf.	29.8	4.6	conf.	40.2
2003/04	1.3	NA	4.6	NA	conf.	NA	NA	4.2	conf.	NA	1.9	conf.	3.5	conf.	conf.	1.7	NA	1.7	conf.	3.5	1.9	conf.	NA	0.1	46.3	4.2	NA	32.9
2004/05	1.1	NA	conf.	NA	conf.	NA	NA	7.2	conf.	NA	2.4	0	3.6	0.1	0	3.2	conf.	5.1	conf.	7.7	1.7	conf.	NA	conf.	64.7	3.1	conf.	27.5
2005/06	1.3	NA	5.7	NA	conf.	NA	NA	1	conf.	NA	1.8	conf.	4.9	0.3	conf.	2.4	NA	2	conf.	4.4	1.3	conf.	NA	conf.	50.5	4.7	NA	24.8
2006/07	1	NA	10.9	NA	conf.	NA	NA	0.7	NA	conf.	2	conf.	5.1	conf.	conf.	2.8	conf.	2.4	conf.	4.9	0.9	0.1	NA	conf.	69.1	5.3	conf.	25.3
2007/08	0.8	conf.	22.5	NA	NA	NA	NA	0.5	conf.	NA	2.4	conf.	4.8	conf.	NA	4.2	conf.	1.7	conf.	3.2	1.2	0.1	NA	conf.	98.2	11.5	NA	13.9
2008/09	1.3	conf.	29.8	NA	conf.	NA	NA	1.7	conf.	conf.	2.8	NA	4.6	0.5	conf.	3.2	conf.	3	2.4	3.8	1.7	0.3	NA	0.3	116.7	11.1	NA	13
2009/10	1.2	conf.	conf.	NA	conf.	conf.	NA	1.2	0.3	NA	3.5	conf.	4.7	0.3	conf.	2.5	conf.	2.1	0.2	9	2.2	0.5	NA	NA	166.6	11.7	NA	19.8
2010/11	1.9	conf.	11.5	NA	conf.	NA	NA	conf.	conf.	NA	6.2	NA	3.9	conf.	conf.	1.5	conf.	4.1	conf.	11.8	3.5	0.2	NA	conf.	144.6	15.2	NA	23.3
2011/12	1.8	conf.	12.8	NA	conf.	NA	NA	conf.	conf.	NA	3.5	NA	2.9	0.2	conf.	1.9	conf.	1.7	conf.	12.9	3.4	0.2	conf.	conf.	161	15.1	conf.	13.9
2013/14	2.1	conf.	conf.	NA	NA	NA	NA	conf.	conf.	NA	1.4	conf.	5.3	0.4	conf.	2	NA	0.7	conf.	6.4	2.4	0.2	conf.	conf.	103	13.1	NA	8.1
2014/15	2.2	conf.	11.1	NA	NA	NA	NA	conf.	NA	NA	2.5	0	3.6	2.6	conf.	2.4	NA	0.8	conf.	9.3	1.7	0	conf.	0.3	73.9	15.9	NA	6.6
2015/16	2.5	conf.	9.6	NA	conf.	conf.	NA	conf.	NA	NA	1.1	conf.	3.5	1.2	conf.	3	conf.	0.8	conf.	13.4	1	0.1	conf.	conf.	85	18.8	NA	5.6
2016/17	2.6	conf.	14	NA	conf.	NA	NA	conf.	conf.	NA	0.9	conf.	3.4	2.3	conf.	3.9	conf.	1	conf.	12.8	0.7	0.1	conf.	conf.	77.3	16.5	NA	5.8
2018/19	2.7	conf.	conf.	NA	conf.	NA	NA	conf.	conf.	NA	1	conf.	3.5	1.8	conf.	4.7	conf.	1.1	conf.	17.3	0.8	0.2	NA	conf.	80	24.4	NA	13
2012/13	2.4	conf.	8.8	NA	conf.	NA	NA	NA	conf.	NA	1.7	conf.	3.7	conf.	conf.	1.4	NA	1	conf.	12.8	1.7	0.4	NA	0.1	121.6	12.2	conf.	10.5
2017/18	2.5	conf.	conf.	NA	conf.	NA	NA	NA	0.1	NA	1.1	conf.	3.5	1.8	conf.	3.4	conf.	1.2	3.1	25.1	1.5	0.2	NA	conf.	76.3	18.4	NA	4.6
2019/20	2.2	conf.	11.6	NA	NA	NA	NA	NA	conf.	NA	1.2	0.1	3.6	4.1	conf.	4.6	conf.	1.3	1.8	19.2	1	0.1	conf.	conf.	62.7	18.3	NA	13.1
2020/21	1.8	conf.	22.2	NA	conf.	NA	NA	NA	conf.	NA	1.3	0.1	2.5	5.2	conf.	4.5	conf.	1.2	conf.	33.1	0.5	0.1	conf.	conf.	37.7	15.2	conf.	6.7
2021/22	1.3	conf.	conf.	NA	conf.	NA	NA	NA	conf.	NA	0.6	0.1	2.4	0.8	conf.	2.8	conf.	0.7	conf.	23	0.4	0.1	conf.	NA	50.8	23.7	NA	4.6

7.3. Appendix 3. Recreational catch data in 'WhitEst'

The recreational sector constitutes the majority of the catch of King George Whiting in South Australian waters. But the data available to estimate the catch from that sector is relatively limited and imprecise, provided predominantly by four telephone and diary surveys conducted in 2000/01, 2007/08, 2013/14 and 2021/22. Since 2007, charter boats have reported their catch totals in logbooks, providing high quality data input. In this Appendix we summarise the pre-processing of the non-charter recreational harvest survey data for use as input to the WhitEst stock assessment model. We specifically summarise how recreational survey catch totals are allocated among months of the year for each model spatial cell. This method for pre-processing the recreational survey data was first applied for the 2017 assessment (Steer et al. 2018b).

The recreational fishing survey of 2013/14 (Giri and Hall 2015) did not provide the estimated King George Whiting catch number broken down by month, as the two previous and the most recent (2021/22) surveys did, and it included no species-specific effort estimates. For all surveys, the monthly survey estimates have wide confidence intervals due to the generally small samples of households reporting recreational catches for every combination of movement cell and survey month. As WhitEst uses a monthly time step, we introduced several additional modelling steps to obtain the required data inputs of recreational catch by model spatial cell and month. The principal goal is to derive the average seasonal (monthly) proportions of the yearly recreational catch in number. These monthly proportions are assumed to apply in all model years, with a separate monthly break-down for each spatial cell. We give details of this pre-processing in first subsection below.

In the second subsection, we outline modifications to the WhitEst model fitting procedure undertaken in the absence of recreational effort data for 2013/14. Recreational surveys measure catch-in-number landed rather than weight, so the model accordingly fits to recreational catch number by month and spatial cell.

In the last subsection we plot model-estimated recreational catches of King George Whiting in weight (tonnes) landed for comparison with commercial catches.

7.3.1.1. Catches for the 2013/14 recreational survey and by regional movement cell

The telephone and diary survey of Giri and Hall (2015, Table 8) reported a single total number of $\hat{C}_{rec,2013/14} = 1{,}467{,}601$ King George Whiting harvested by recreational fishers (including charter boats and onshore) in the 12-month period from December 2013 to November 2014.

This has an estimated standard error of $\widehat{\mathrm{SE}}(\hat{C}_{rec,2013/14}) = 253{,}416$ and excludes the 534,335 King George Whiting (Giri and Hall 2015, Table 8) that were caught and subsequently released.

They also reported percentages by region (Giri and Hall 2015, p. 34, Figure 11B) that we applied to the total yearly harvest number, giving estimates of total yearly King George Whiting recreational harvest by region for the year in Table A3.1. We further separated the catches of northern GSV from southern GSV and KI, which are separate spatial cells in the WhitEst spatial model, using the average northern (0.571) and southern (0.429) GSV catch proportions from the other three recreational surveys (2000/01, 2007/08, 2021/22). Furthermore, catches of the previous West Coast movement cell are now separated from the new Western Eyre Peninsula cell (that covers the MFA blocks off Coffin Bay) which is now part of the Spencer Gulf management zone. This was done using the catch proportions from the 2007/08 recreational survey of 0.662 for West Coast and 0.338 for Western Eyre Peninsula.

We denote the resulting 2013/14 yearly recreational King George Whiting regional catches in number harvested as $\{\hat{C}_{rec,2023/14,cell}\}_{cell\in\{1,\ldots,6,8\}}$, where $cell$ is the subscript indexing the 7 model spatial cells in the three stocks for which indicators are estimated and presented (Figure A4.1). By definition,

$$\hat{C}_{rec,2013/14} = \sum_{cell\in\{1,\ldots,6,8\}} \hat{C}_{rec,2013/14,cell} = 1{,}467{,}601.$$

Table A3.1. Scaled KGW catch estimates from the 2013/14 recreational survey by movement cell.

Movement cell number, $cell$	Movement cell name	Estimated total catch, $\hat{C}_{rec,2013/14,cell}$
4	Northern St Vincent Gulf	125,735
5	Southern St Vincent Gulf	94,405
1	West Coast	349,759
8	Eastern Eyre Peninsula (Coffin Bay)	178,578
6	All outlying areas (offshore and SE)	29,352
2	Northern Spencer Gulf	161,436
3	Southern Spencer Gulf	528,336
	Total South Australia	1,467,601

7.3.1.2. Pre-processing to obtain catches by month for the 2013/14 recreational survey

To obtain monthly numbers harvested from the reported yearly totals $\{\hat{C}_{rec,2013/14,cell}\}_{cell\in\{1,\dots,6,8\}}$ by spatial cell, we estimated monthly proportions harvested by fitting to the monthly recreational catch total estimates available from the other three recreational surveys of 2000/01, 2007/08 and 2021/22. The 2000/01 survey covered the months of May 2000 to April 2001, the 2007/08 survey covered November 2007 to October 2009, and the 2021/22 survey spanned March 2021 to February 2022. Let $\mathbb{T}_{rec\backslash\{2013/14\}}$ be the time domain consisting of these 36 months for which survey catch estimates data is available for model fitting. Then the monthly recreational catch total estimates available are $\{\hat{C}_{rec,t,cell}\}_{t\in\mathbb{T}_{rec\backslash\{2013/14\}}}$, for each given movement cell $cell \in \{1,\dots,6,8\}$.

Specifically, we fitted the following statistical model in R for each movement cell $cell \in \{1,\dots,6,8\}$:

$$\hat{C}_{rec,t,cell} = \beta_{1,cell}1_{m(t)=1,cell}(t) + \cdots + \beta_{12,cell}1_{m(t)=12,cell}(t) + \varepsilon_{t,cell}, \quad t \in \mathbb{T}_{rec\backslash\{2013/14\}},$$

where $\varepsilon_{t,cell}$ are independent Normal random variables with zero mean and constant variance of $\sigma^2_{\varepsilon,cell}$. The mapping $m: t \mapsto m(t)$ extracts the month of the year for a given time step t. Note that the regressor variables are indicator functions that flags the treatment level of the month factor. In R code, this linear model is

CATCH_SCALED ~ -1 + factor(*Month*),

applied on the recreational survey data filtered for a given movement cell.

This GLM model fit generated parameter estimates $\{\hat{\beta}_{month,cell}\}_{month=1}^{12}$ for each movement cell $cell \in \{1,\dots,6,8\}$, yielding the average catch for each combination of $cell$ and $month$ over the three surveys. That is, for a given $cell$,

$$\hat{\beta}_{month,cell} = \frac{1}{3} \sum_{t\in\{\mathbb{T}_{rec\backslash\{2013/14\}}:m(t)=month\}} \hat{C}_{rec,t,cell}\,, month \in \{1,\dots,12\},$$

where 3 is the number of survey year observations available for each month and cell combination.

Then for each movement cell, we calculate the estimated proportion of the yearly catch that falls in a given month as

$$\hat{p}_{month,cell} = \frac{\hat{\beta}_{month,cell}}{\sum_{month=1}^{12} \hat{\beta}_{month,cell}}, month \in \{1, \dots, 12\}.$$

Then given the estimated total number harvested $\hat{C}_{rec,2013/14,cell}$ for each movement cell in Table A3.1, the estimated monthly number harvested during the 2013/14 recreational survey period is

$$\hat{C}_{2013/14,t,cell} = \hat{p}_{m(t),cell}\hat{C}_{rec,2013/14,cell}, t \in \mathbb{T}_{rec,2013/14},$$

where $\mathbb{T}_{rec,2013/14}$ consists of the months of December 2013 to November 2014 that was covered by the 2013/14 recreational survey.

7.3.1.3. Modelled estimates of monthly catch by regional movement cell during surveys

The recreational survey estimates are subject to relatively high survey imprecision, and in particular, only very low sample sizes are available for these finer-scale units of breakdown in time and space. Because of this relatively high survey imprecision for each individual combination of month and movement cell, the 2000/01, 2007/08 and 2021/22 recreational survey estimates by month are recalculated for each movement cell using the same estimated monthly proportions $\hat{p}_{month,cell}$. This keeps the seasonality of catch proportion by month consistent within each cell through all years. That is,

$$\hat{C}_{2000/01,t,cell} = \hat{p}_{m(t),cell}\hat{C}_{rec,2000/01,cell}, t \in \mathbb{T}_{rec,2000/01},$$

$$\hat{C}_{2007/08,t,cell} = \hat{p}_{m(t),cell}\hat{C}_{rec,2007/08,cell}, t \in \mathbb{T}_{rec,2007/08},$$

and

$$\hat{C}_{2021/22,t,cell} = \hat{p}_{m(t),cell}\hat{C}_{rec,2021/22,cell}, t \in \mathbb{T}_{rec,2021/22}.$$

By letting $T_{rec} = \mathbb{T}_{rec,2000/01} \cup \mathbb{T}_{rec,2007/08} \cup \mathbb{T}_{rec,2013/14} \cup \mathbb{T}_{rec,2021/22}$ be the monthly time domain of all the months covered by the four recreational surveys, the modelled estimates of monthly catch can be written as the set $\{\hat{C}_{t,cell}\}_{t\in\mathbb{T}_{rec}}$ for each regional movement cell $cell \in \{1, \dots, 6, 8\}$.

7.3.1.4. Adjusting survey estimates with an interstate factor by region

The 2000/01 recreational survey, being a national one of which South Australia was a part of, could provide estimates of the increase in fishing in the South Australian regions due to fishers travelling in from interstate. This additional fishing activity is accounted for by an interstate adjustment factor IA_{cell}, one for each movement cell. The estimates $\widehat{IA}_{cell}$ from the 2000/01 survey are listed in Table A3.2.

Table A3.2. Interstate adjustment factor estimates from the 2000/01 recreational survey by movement cell region.

Movement cell number, $cell$	Movement cell name	Estimated interstate adjustment factor, $\widehat{IA}_{cell}$
1	West Coast	1.100615456
2	Northern Spencer Gulf	1.026215924
3	Southern Spencer Gulf	1.047771407
4	Northern St Vincent Gulf	1.002269456
5	Southern St Vincent Gulf	1.090362374
6	All outlying areas (offshore and SE)	1.307326408
8	Eastern Eyre Peninsula (Coffin Bay)	1.100615456

We have assumed that cell 8 has the same interstate factor as cell 1. Then the interstate adjusted survey estimate of catch by month and movement cell is

$$\hat{C}_{t,cell}^{adjusted} = \widehat{IA}_{cell}\hat{C}_{t,cell}, t \in \mathbb{T}_{rec},$$

for each movement cell $cell \in \{1, \ldots, 6, 8\}$.

7.3.1.5. Extrapolation before and interpolation between the recreational survey time periods

The final recreational WhitEst input data set of monthly catches, after interpolating between the four surveys and extrapolating back from the first survey to the model-start 1983/84 season according to population growth figures, are shown in Figure A3.1. The summer holiday month of January is the highest recreational catch month in all spatial cells. Other seasonal peaks (around March or April, and October) also appear to coincide with yearly times of school holiday.

The yearly recreational catch numbers, showing the breakdown between charter and non-charter sub-sectors, are shown in Figure A3.2.

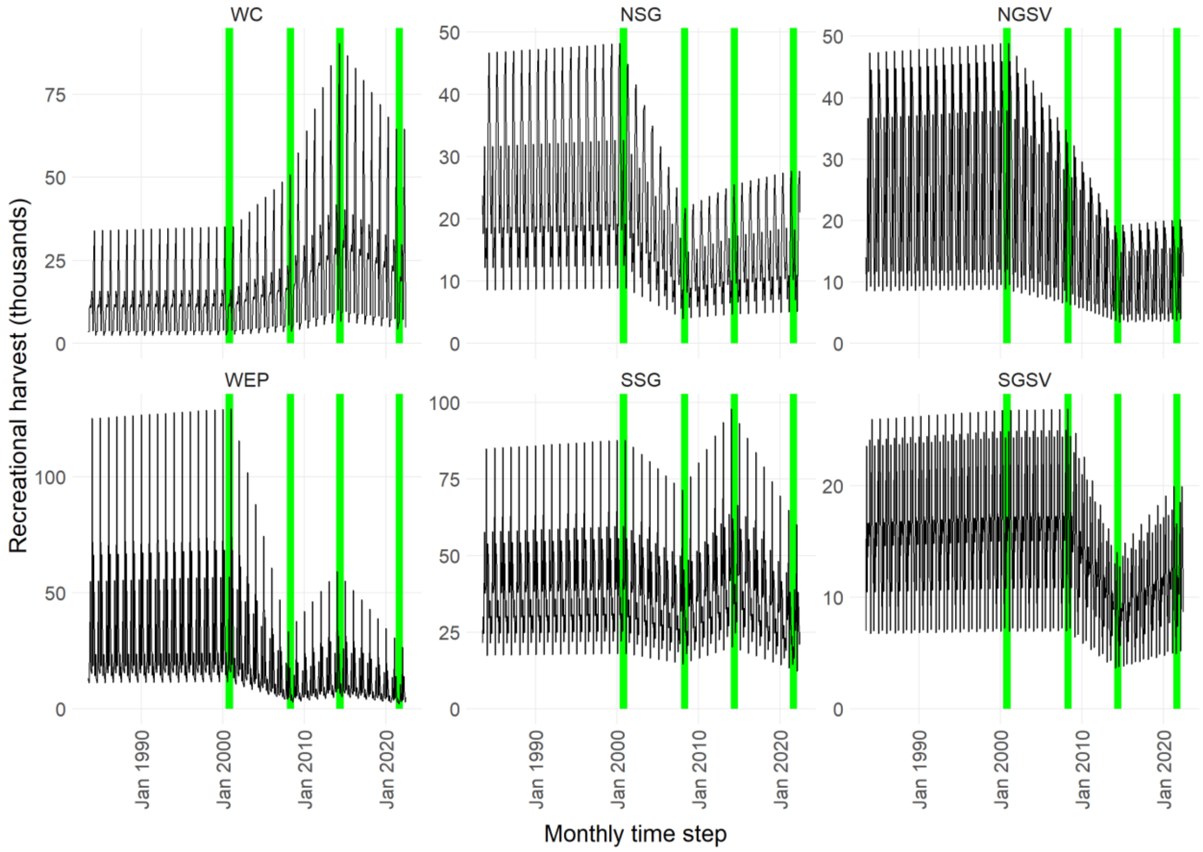

Figure A3.1. Monthly catches of King George Whiting by the recreational sector used as data input into the WhitEst model. From November 2007 onward, charter boat catches have been reported in logbooks by that sub-sector, and these were subtracted from the survey estimates which included both charter and non-charter recreational catch. The charter boat catches are fitted separately in WhitEst from the time when charter logbooks commenced in November 2007. Green bands indicate the years of the four recreational surveys. Between those survey years, catches were obtained by linear interpolation. Recreational catches for all years preceding the first 2000/01 survey were extrapolated backwards linearly based on the South Australian State estimated resident population number from 1983.

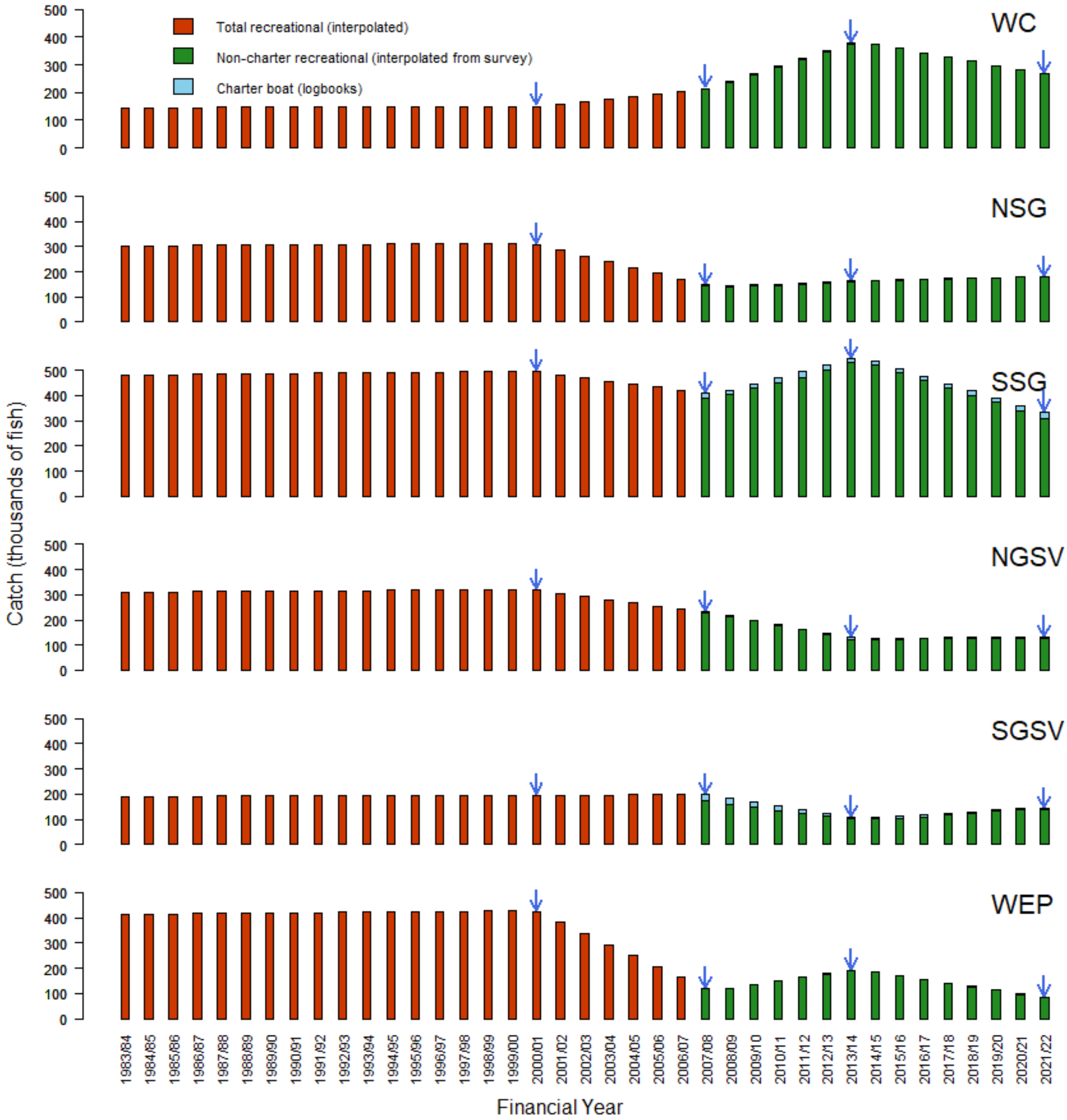

Figure A3.2. Yearly catches of King George Whiting by recreational sector. The blue arrows indicate the four years when telephone and diary recreational harvest surveys were undertaken. Charter boat logbook-reported catches are shown in light blue. Uncertainty in the survey estimates is wide, implying that the temporal trends indicated for non-charter recreational catches (green bars) and charter-recreational combined catches (red bars) are relatively uncertain.

7.3.1.6. Fitting WhitEst to recreational catches in the absence of effort data from the 2013/14 survey

To address the absence of effort estimates from the 2013/14 recreational survey (Giri and Hall 2015), and the weak confidence generally in survey estimates of total recreational effort broken down by month and movement cell, the WhitEst fitting procedure to recreational catches was modified. For all other effort types, the model assumes a linear relationship between fishing mortality (*F*) and logbook-reported fishing effort (broken down by monthly model time step, spatial cell, and effort type). This relationship is incorporated into the corresponding Baranov relationships used to model catches and population survival in each time step (Equations A4.1-A4.4). The principal modifications to account for the absence of recreational effort data were to (1) set recreational effort equal to 1 for all time steps, and (2) freely estimate the remaining cell- and month-specific catchability parameters (see Appendix 4, Equation A4.2b). With effort set to 1, these catchabilities effectively equal fishing mortality F for this recreational effort type, thereby obviating the need for recreational effort data. The final step (3) was to substantially reduce the weighting assigned to fitting recreational catches by cell and model time step so that they have little effect on model-estimated trends in stock biomass but still accurately account for recreational catch in number.

7.3.1.7. Model computed catches of King George Whiting in weight

As a natural output of the WhitEst model, estimates of recreational catch in weight harvested (Figure A3.3) are produced as a consequence of the fit to reported recreational catch in numbers. This uses the tracking of catches by length bin (i.e., by model 'slice') of each cohort as it passes through the fishery. For comparing fishery sectors, the total yearly harvest by commercial and two sectors of the recreational King George Whiting fishery are plotted by year in Figure A3.3. The trend is evident of increasing proportions taken by the recreational sector over time, driven mainly by greatly reduced commercial fishing effort in the two gulfs since the late 1990's (Figure 3-5, 3-6)

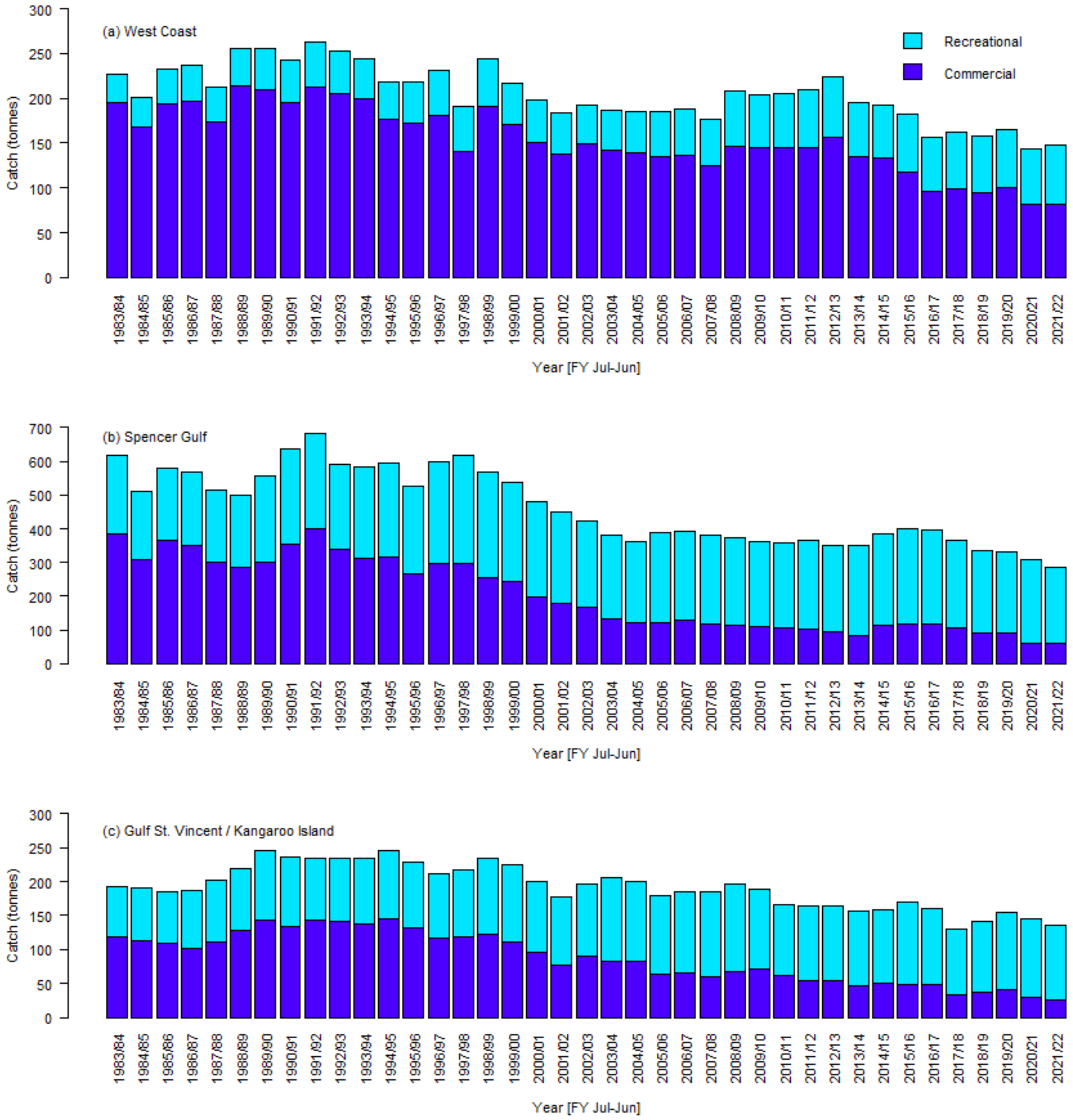

Figure A3.3. Yearly recreational (light blue) and commercial (dark blue) harvests of King George Whiting for the three South Australian stocks, given in tonnes landed.

7.4. Appendix 4: Specifications of the 'WhitEst' Stock Assessment Model.

7.4.1.1. Introduction

The biological performance indicators of biomass (280+ mm), harvest fraction, and recruitment for South Australian King George Whiting are estimated using the WhitEst stock assessment model. In this Appendix we present the details of WhitEst, with equations. The WhitEst model is coded in the ADMB language for statistical (likelihood) modelling and parameter estimation.

WhitEst uses a method developed in South Australia to represent both the length and age of modelled fish stocks by partitioning the continuous length-at-age distribution of each age cohort into length bins called slices (McGarvey et al. 2004; McGarvey et al. 2007). Rather than pre-chosen length bins of say 1 cm in width, we allow the slices, and so also the partition lengths separating neighbouring slices, to grow with the cohort. The slice partition points (i.e., fish lengths separating neighbouring bins) specify this growing length partition. These were chosen to achieve two objectives: (1) to permit the creation of one new length bin for each model time step, and (2) in each model time step, to cleanly separate fish above and below the slice partition length of 280 mm. In each model time step, as each cohort crosses into legally harvestable size, a calculated proportion of the sublegal fish below 280 mm are assigned to the newly created length slice, namely the proportion reaching or exceeding 280 mm in that time step. This length-and age-based fishery model formalism is also used for South Australian Snapper and Garfish. Here we outline the WhitEst model equations used to assess King George Whiting.

South Australian King George Whiting (*Sillaginodes punctatus*) are heavily exploited in the year or two immediately following recruitment to legal size. The larvae settle out in the near-shore, and reach legal size around ages 2-3 years in seagrass and shallow-water habitats, notably in the northern reaches of the two gulfs in South Australian waters (Figure 7.4-1). In early summer of ages 2 and 3 years, they migrate from inshore habitats to spawning grounds in deeper water, moving southward in the two gulfs (Fowler et al. 2002). For this reason, modelling both movement and on-going monthly growth of each cohort using monthly slice partitioning enhances model assessment accuracy. For this assessment, the length of 280 mm, which is the legal minimum size limit applicable in July 1983 across all parts of South Australian waters, was used as the slice partition length to define reported biomass for all financial years (FY) 1983-2021. For calculating fishing mortality and catch, the legal minimum length increases over time are modelled via a knife-edge truncation selectivity function.

Tag-recovery data gathered over three decades were previously used to estimate a yearly movement matrix for King George Whiting among 12 South Australian spatial cells (McGarvey and Feenstra 2002). Since then, we have aggregated and thereby reduced the number of spatial cells to 7. These estimated movement rates, refined by integration into the WhitEst stock assessment model described below, were consistent with qualitative analysis of this migration (Fowler et al. 2002). A principal advantage of the recapture-conditioned movement estimation method (McGarvey and Feenstra 2002) employed with these standard fishery single tag-recovery data was that, unlike previous movement estimators (e.g. Hilborn 1990; Anganuzzi et al. 1994), a number of prior assumed inputs, such as tag-reporting rate, tag-release mortality, survival in the release cell, and, to a good approximation, tag shedding and natural mortality rates, cancel from the recapture-conditioned movement proportions, and are thus not required to estimate movement rates.

A growth submodel, using prior-estimated parameters, was also incorporated into the slice-based stock assessment model. WhitEst uses a monthly time step. For each cohort of South Australian King George Whiting, there is strong seasonality in growth, which is linked to seasonal changes in the predicted catch numbers-at-age and the catch totals by weight. Fast growth in late summer autumn bring the next cohort into legal size, resulting in high CPUE and effort in later autumn and winter. Thus, model-predicted catches vary markedly over relatively short time scales in the approximately 6-20 months of intensive exploitation. The stock assessment model sought to capture on-going growth of fish into the size range above 280 mm, especially in the high-growth months of late summer and autumn and the simultaneous rapid harvest of legal-size fish from the population, with monthly catches peaking in winter following recruitment of two- and three-year-olds and prior to subsequent summer migration. Estimates of mortality, and thereby most important fishery management indicators, must therefore be inferred from monthly rather than yearly change in catch data. These estimates benefited from a spatial age- and length-specific population model, running on a monthly time scale.

7.4.1.2. Data

There were four principal King George Whiting data sets: (1) commercial logbook totals of catch in weight (kg) and effort (fisher-days) since July 1983, (2) catch proportions by age and sex from otoliths sampled in selected months and spatial cells during 1994-2022, (3) four separate years of recreational catch (numbers) and effort obtained from three national telephone and diary surveys (Appendix 3), and (4) tag-recoveries used to estimate movement rates.

The catch and effort data sets, and the fitted model quantities, were partitioned by 'effort type', that is, by recreational and commercial sector, and for the commercial sector, by gear and species targeted. Commercial harvest reported on catch logbooks was broken down by 4 categories of gear type, namely (1) handline, (2) haul net, (3) set net, (4) all other gear types, and by 3 categories of target type: (1) specifically targeting King George Whiting, (2) specifically targeting any other single species, (3) not specifically targeting any particular species. Catch and effort totals were earlier partitioned into 13 'effort types', corresponding to 4 commercial fishing gears, and 3 categories of species targeted, plus recreationals. In November 2007, charter boats began reporting catches in number landed (Appendix 3), permitting the creation of a 14^{th} effort type; thus, non-charter recreational catch, modelled still as the last effort type, is indexed as effort type 14, while charter catch is effort type 13.

Data variable names are denoted by a tilde (˜). For example, $\tilde{C}^{w}[t, cell, Etype]$ and $\tilde{E}[t, cell, Etype]$, give catch and effort totals by month, spatial cell, and effort type. A catch sample of 10,800 King George Whiting were aged by otoliths, measured for length, and sexed during dissection (Fowler and Short 1998; Fowler et al. 2000) over 1994-1998, and a further 17,674 were sampled over 2004-2022. Counts of fish by age and by sex are written $\tilde{n}[a, sex \mid i_{AX}]$ for each sampled month and spatial cell, where i_{AX} is an index over all months and sexes for which age-sex samples were taken.

In (SAFCOL) market sampling, the sampling by length was controlled and representative, while the sub-sampling of ages from each length sample varied in non-representative fashion. For some combinations of month and spatial cell, more or fewer fish were aged relative to the (representative) sample size by length. The 2004-2022 age-sex sample counts by length bin, for each month and spatial cell, were corrected for non-representative age sampling by using the sample size ratios of the (presumed representative) fraction sampled in each length bin to the subsample fraction in each length bin that were aged and sexed. Similar correction for length representation in aged-sex sampled animals was applied for garfish and snapper (McGarvey and Feenstra 2004).

7.4.1.3. Cohort Length Partition by Slices and Recruitment

The slice partition algorithm by which length bin slices are created uses the length-at-age growth submodel. To partition cohorts by length, the underlying growth submodel must describe the full distribution of fish lengths for every cohort age, notably those crossing into legal size. This is derived from the estimated probability density function (pdf) for every monthly age, specified by length-at-age parameters estimated using a normalised likelihood of the growth model fitted to catch samples of King George Whiting of measured length and (otolith-inferred) age (McGarvey and Fowler 2002). A normal likelihood pdf was used, though the slice partition method can assume any pdf for the lengths-at-age, specifically any growth curve giving mean length and quantifying the spread of lengths for each model age. Separate length-at-age growth parameters were estimated for each of three growth regions comprising spatial cells mc 8 – mc 1, mc 2 - mc 3, and mc 4 - mc 5 in South Australian waters (Figure 7.4-2), and both sexes (McGarvey and Fowler 2002). Growth as increasing mean length (and modestly increasing spread of lengths-at-age) is modelled as increases in the slice partition points that separate individual slices with successive ages.

From the growth (length-at-age pdf) submodel, an algorithm was constructed to effectively 'slice off' that portion of the length-at-age distribution above a specified slice partition length (280 mm) in each time step (Drew et al. 2021, Appendix 5). Once a new slice is created and fish transferred into it from the sublegal component below 280 mm, fish within each slice can only die or move between designated spatial cells. Since reporting of biological performance indicators, notably biomass, is defined as fish of length 280 mm and above, WhitEst now employs a single fixed slice partition length of 280 mm in all years.

The 'birth' (i.e., creation) of each new King George Whiting cohort to the model population happens at the age of 1 year after spawning, which is about a year and a half prior to first reaching legal size. The number of fish born into each cohort at age 1 serves as the model estimate of yearly recruitment and was a freely estimated parameter for each year class. Yearly recruit numbers were estimated for each of the following four South Australian regions (Figure 7.4-3) namely WC (mc 1), WEP (mc 8), SG (mc 2 - mc 3), and GSV (mc 4 – mc 5). For reporting purposes, the WEP recruitment and biomass values are added together with those of NSG and SSG in calculation of these quantities for fishing zone SG. Regional recruit numbers by sex assumed a 50:50 sex ratio, while the apportionment of recruits among spatial cells within each of the two gulf regions (SG and GSV) was achieved by estimation of a parameter that models the proportion splitting the recruit number between upper (mc 2 - mc 4) and lower (mc 3 - mc 4) cells in each gulf. Subsequent to cohort creation at age 1 year, cohort number is reduced only by natural mortality until reaching the regulated legal minimum length. Faster growing fish (the upper tail of the pdf) reach and grow beyond legal minimum length sooner. In each model time step, slices are created, 'sliced' off of the still sub-280 mm fish with proportions computed from growth parameters (e.g., Table A4.1). Once they exceed the regulation legal minimum length, which was increased over years, with more increases in the two gulfs, model fish become subject to harvesting.

The slice-creation algorithm assumes the existence of a “slice partition length”, which in this 2023 assessment is now assumed to equal 280 mm for all years for purposes of creating slices of population numbers by length within each cohort. The entire cohort is classified as ‘sublegal’ until at least 2% of the length-at-age pdf falls above the slice partition length. “Sublegal” in this context is defined as fish below the slice partition length of 280 mm. When this criterion is reached, the first slice is created comprising that component of the length-at-age pdf having length ≥ 280 mm. In subsequent model time steps, the number of fish (a real number) to be transferred from the surviving sublegal component of each cohort and assigned to each newly created slice is calculated. When 99.999% or more of the original cohort (the pdf) is above legal size, all remaining sublegal fish are summed into the last slice.

The numerical inputs needed to implement the slice-partition form of length-based modelling inside a stock assessment model are threefold: (1) the proportions transferred from the sublegal component below 280 mm (the slice partition length) of each cohort to each newly created slice, at the cohort age when each slice, that portion of the length-at-age pdf, grows above 280 mm (Table A4.1), (2) the slice length partition points (Table A4.2) (from which are derived the slice midpoints), and (3) the mean weight of each slice (Table A4.3). The derivation of these slice-partition inputs to WhitEst is given in Appendix 5 in Drew et al. (2021). These three slice quantities were computed in Mathematica (for WhitEst, prior to, not integrated) for each combination of sex and region (fish in each region and sex having different growth parameters). For this assessment each fishery change in legal minimum length (Table 7.4-1) regulation requires the model to re-calculate a knife-edge truncation length selectivity so that predicted fishing mortality and catch are applied only to fish of legal size in each model time step. No re-mapping of old population numbers by slice into a new partition of slice bins occurs because instead the length cut-off value used in the knife-edge truncation rises to equal the new legal minimum length.

The slice partition points (or slice midpoints) were not used explicitly with the King George Whiting stock assessment since it contained no selectivity by length other than knife-edge truncation selectivity. Using a length-weight relationship (McGarvey and Fowler 2002), and numerically integrating under the length-at-age pdf inside each slice, we calculated the mean weight of fish in each slice, $w[slice \mid sex, region, a]$, one slice partition for each possible monthly age in the model population. This triangular matrix of mean weights by age and slice (e.g., Table A4.3; see also Drew et al. 2021, Appendix 5) is multiplied by catch numbers by age and slice to yield model catch in weight per slice. The model-predicted total catch in weight is computed by summing the individual catch weights (fish number times mean weight) over all cohorts and sexes, and over slices whose midpoint lengths are above the regulated legal size applying to the fishery in each model time step. These model catch totals are fitted to data catch totals from logbooks which are reported as weight landed. To reduce WhitEst computation time, once each cohort had fully grown to legal size, we re-aggregated the population numbers by slice into a single number of fish by age (creating ‘post-legal cohorts’).

7.4.1.4. King George Whiting stock assessment model

In this section, we describe the basic dynamic model components (submodels), and how they fit together to describe the change in the exploited King George Whiting population over time. In the next subsection we explain how this population model is fitted to fishery data.

The stock assessment model has four principal submodels: (1) recruitment, (2) growth, via the slice formalism, (3) harvest and natural mortality, and (4) yearly migration. The recruitment and slice-growth submodels were described above. In this section, we detail submodels of harvest and movement and mortality equations of the model population array.

7.4.1.5. Model Population Array

The model population array, $N[t, cell, sex, cohort, slice]$, is 5-dimensional, fish numbers broken down by (1) monthly model time step, (2) spatial “cell”, (3) sex, (4) cohort year, and (5) slice (i.e. length bin).

Ages ran from 13 months (1 year) to 157+ months. The highest age is a 'plus' group, comprising fish of the oldest monthly age (12 years 12 months) and older. Higher level independent variables of $month$, $gear$, and a specify seasonal month of the year, gear, and cohort age. In model coding practice, these were calculated as functions of the primary independent variables given in section *Symbols of index quantities*.

7.4.1.6. Effort and Catch

The catch equations assumed are effort conditioned. That is, fishing mortality is written as a linear function of reported monthly effort totals, which are assumed to be reported without error. The equation for each component of fishing mortality has the following form:

$$F[t, cell, sex, cohort, slice, Etype] = q[cell, month, sex, Etype, a] \cdot \tilde{E}[t, cell, Etype]. \tag{A4.1}$$

The catchability, q, can vary with spatial cell, calendar month, sex of the fish, age (a), and the effort type, multiplicatively separable. For commercial catch and effort, the catchability is written:

$$q[cell,\ month,\ sex,\ Etype, a] = q_{CE}[region,\ Etype] \cdot s_m[cell, month] \cdot s_X[sex] \cdot s_3[a].$$ (A4.2a)

with $q_{CE}[region,\ Etype]$ being an absolute catchability that varies among four regions (*region:* mc 1, mc 8, mc 2 - mc 3 combined, mc 4 - mc 5 combined) and by effort type, $s_m[cell, month]$ accounting for differing relative vulnerability among the 12 calendar months and for each spatial cell (January = 1), $s_X[sex]$ accounting for differing relative vulnerability by sex (females = 1), and a scalar $s_3[a]$ permitting a higher selectivity for fish of age 3 years (= 1 for *a* < 37 or *a* > 48), the age at which King George Whiting are primarily targeted.

For the recreational effort type, the code includes the same structure as for commercial catch. But from the 2017 assessment onwards, due to the absence of effort data in the 2013/14 (Giri and Hall, 2014) recreational survey, we set all effort data values equal to 1 for all time steps and spatial cells. See Appendix 3 for details.

$$q_{rec}[cell,\ month,\ sex, a] = q_{rec}[cell,\ month] \cdot s_X[sex] \cdot s_3[a]$$ (A4.2b)

The absolute recreational catchability parameter $q_{rec}[cell,\ month]$ was then freely estimated for each spatial cell and calendar month but shared among all years. With recreational effort input values all set equal to 1, the catchability $q_{rec}[cell,\ month]$ estimates recreational fishing mortality that is stationary over years.

The instantaneous fishing mortality rate for each element of the population array is given by a sum of fishing mortalities over all fishing effort types, each of which are multiplied by knife-edge truncation selectivity by length $s_{cutoff}[t, cell, slice]$:

$$F[t,cell,sex,cohort,slice] = \sum_{Etype=1}^{nEtype} F[t,\ cell,\ sex,\ cohort,\ slice,\ Etype] * s_{cutoff}[t,cell,slice] \tag{A4.3}$$

where

$$s_{cutoff}[t,cell,slice] = \begin{cases} 0, & t > 230 \ \ \& \ \bar{l}(slice) < 300 \\ 0, & t > 339 \ \ \& \ \bar{l}(slice) < 310 \ \& \ cell = 2,3,4,5 \\ 0, & t > 485 \ \ \& \ \bar{l}(slice) < 320 \ \& \ cell = 2,3,4,5 \\ 1, & otherwise \end{cases} \tag{A4.4}$$

and $\bar{l}(slice)$ is the mid-point length of slice *slice,* with time steps 230, 339, and 485 equaling respectively August 1995, September 2004, and November 2016.

For King George Whiting, changes in selectivity are primarily mediated by offshore movement to cells of lower exploitation, and no explicit length selectivity is postulated other than knife-edge truncation selectivity. Fishing mortality is thus constant among legal slices in any cohort and spatial cell.

7.4.1.7. Mortality

The depletion equation for each element of the population array was written:

$$\begin{aligned} &N[t+1,cell,sex,cohort,slice] = \\ &\qquad N[t,cell,sex,cohort,slice] \cdot \exp\left[-\left(M + F[t,cell,sex,cohort,slice]\right) \cdot p_{yr}[t]\right] \end{aligned} \tag{A4.5}$$

where $p_{yr}[t]$ quantifies the proportion of a year spanned by the days in each monthly time step. The yearly rate of instantaneous natural mortality, $M = 0.45$ yr^{-1}, was taken from a prior-estimated constant.

7.4.1.8. Movement

Yearly summer migration was modelled by applying movement rates among movement cells, as movement transition matrices in the three months of November, December and January. A yearly movement rate matrix was estimated previously from tag-recoveries (McGarvey and Feenstra 2002). Each movement rate probability, P_{ij}, gives the proportion of fish moving from cell *i* to cell *j* in early summer of each year. Likelihood ratios implied that a single matrix was optimal, applicable to both ages of migrating King George Whiting, ages 2 and 3 years (McGarvey and Feenstra 2002). Essentially all King George Whiting aged 4 years or older are caught offshore on spawning grounds. All but a few of the 2000 tagged fish remained within their region, and within regions most movement was from upper gulf to lower gulf cells or, in the West Coast and Western Eyre Peninsula, from inshore to an unknown area offshore. Therefore, P_{ij} = 0 for cells *i* and *j* lying in different four regions designated as cells 1, 8, 2-3, and 4-5, and for movement from the southerly spawning gulf cells (cell 3 in Spencer Gulf, and cell 5 in Gulf St. Vincent, Figure 3.5-1) to upper gulf cells, and thus P_{ii} = 1 for gulf spawning cells (*i* = 3, 5) where fish are assumed to remain once they migrate in. For age 4 King George Whiting (55-57 months of age in November to January), all remaining fish are moved to the spawning cells of each gulf.

In West Coast cells, the destination of migratory fish remains uncertain. No West Coast harvest samples have shown evidence of spawning and nearly all were aged 3 years or less. Thus, the King George Whiting fishery on the West Coast does not overlap with spawning aggregations and tag recaptures supplied no information about rates of movement to the (presumed offshore) spawning locations. Consequently, a 7th spatial cell was defined as the hypothetical destination of West Coast spawning migration. An attempt to estimate these rates of offshore migration from the absence of older fish in commercial catch samples was not successful. Instead, we assumed that all fish migrate from the West Coast fishery cell (1) and Western Eyre Peninsula cell (8) to the hypothetical cell (7, effectively out of the modelled population) at age 3 (43-45 months).

In the gulfs, we integrated the tag-recovery movement rate estimation, refining, by freely re-estimating, the specific movement rate parameters which were not 0 or 1 in the two gulf regions. Movement rate estimates are sensitive to mortality rates, notably fishing mortality in each cell. The converse is also true; mortality estimates can be strongly affected by movement. Integrating the estimation of movement with mortality can improve both.

Movement of fish occurring over three migration months (November-January) rather than just once yearly in January provided a more realistic migration time frame of several months and smoothed the impact of movement on the model population and thus on model-predicted catches in early summer. For age-3 movement to hypothetical spawning cell 7 from the West Coast and Western Eyre Peninsula, we moved 1/3 of the fish in November, 1/2 of the remaining fish in December and the rest in January. In this way, an equal number of fish (namely 1/3 of those originally present prior to November movement) are moved in each of those three months.

7.4.1.9. Parameters

Estimated parameters for the model fall into four general categories: (1) yearly recruit numbers for each region (WC, WEP, SG, and GSV), and proportions allocated among cells within each gulf region (SG and GSV), (2) catchabilities, (3) relative selectivities, (4) movement rate parameters in the two gulf regions.

7.4.1.10. Initialization: Population State Array

The initial population state array (among cells, cohorts, sex, and slices) for start of July 1983 are fixed values obtained using a two-stage method. First, the full estimated population array was obtained from end of June 1985 using a model run that assumed last assessment's initial population state. In the second stage, the end of June 1985 values were then taken as fixed but which were then multiplied by an estimated scaling parameter, one for each of the three regions WC-WEP, SG, and GSV.

7.4.1.11. Model likelihood

The fitting procedure generally followed that of Fournier and Archibald (1982), with catch proportions by age and sex fitted using a multinomial likelihood and catch totals fitted with a normal likelihood.

The likelihood function has four components for fitting to the four data sets: (1) commercial catch totals by weight (kg) in each cell and monthly time step; (2) recreational catch totals by number in each cell and monthly time step; (3) catch number proportions partitioned into a matrix by both age and sex, from catch samples taken in selected months and cells during 1994 to 2022; (4) movement tag-recovery data from the two gulfs.

The movement likelihood component was the same form used in prior fitting to tag-recoveries (McGarvey and Feenstra 2002) but a much more limited set of parameters (those not 0 or 1 in the two gulfs) were re-estimated. This integration of the movement likelihood into the WhitEst model involved provision of a) predicted average yearly total mortality (M+F) by *cell* and calendar month, and b) a predicted yearly movement matrix as the cube of the monthly movement matrix (the one used to move animals among *cells* in three months of the year as part of the population dynamics model).

The remaining likelihood components are described below.

7.4.1.12. Catches-by-weight

Model commercial catch totals by weight (kg) were fitted to data using a normal likelihood, though a lognormal was also tested. The catch by weight was calculated using the standard Baranov formula as:

$$\hat{C}^{w}\left[t,\ cell,\ sex,\ cohort,\ slice, Etype\right] = N\left[t,\ cell,\ sex,\ cohort,\ slice\right]\cdot w[slice \mid sex, region, a]\cdot \frac{F\left[t,\ cell,\ sex,\ cohort,\ slice, Etype\right]}{M+F\left[t,\ cell,\ sex,\ cohort,\ slice, Etype\right]}\cdot\left\{1-\exp\left[-\left(M+F\left[t,\ cell,\ sex,\ cohort,\ slice, Etype\right]\right)\cdot p_{yr}[t]\right]\right\} \quad \text{(A4.6)}$$

where derivation of weights by age and slice $w[slice \mid sex, region, a]$ are given in Appendix 5 in Drew et al. 2021.

The likelihood for each choice of spatial *cell*, and effort type, *Etype,* was written:

$$L_{Cw} = \prod_{t=1}^{nt}\prod_{Etype=1}^{nEtype-2}\prod_{cell=1}^{ncell}\frac{\exp\left[-\frac{1}{2}\left(\frac{\hat{C}^{w}[t, cell, Etype]\ -\ \tilde{C}^{w}[t, cell, Etype]}{\sigma^{C}[region, gear]}\right)^{2}\right]}{\sqrt{2\pi}\cdot\sigma^{C}[region, gear]} \quad \text{(A4.7)}$$

where

nt and *ncell* are the numbers of model time steps and spatial cells respectively, and where, for each *cell*, and each commercial *Etype*, of which there are *nEtype*–2,

$\sigma^{C}[region, gear]$ = estimated standard deviation parameter, which varies only by region and gear type;

$\tilde{C}[t,\ cell,\ Etype]$ = reported catch by weight total for each time step, *t*, *cell*, and *Etype*;

$\hat{C}[t,\ cell,\ Etype]$ = predicted catch by weight total for each time step, *t*, *cell*, and *Etype*.

The *region* and *gear* are specified by their *cell* and *Etype* respectively, namely as mc 8 - mc 1 combined, mc 2 - mc 3 combined, and mc 4 - mc 5 combined, and for effort type groups 1-3, 4-6, 7-9, 10-12, 13-14.

The normal likelihood for fitting to the remaining effort types of charter and recreational catch in numbers was similar, with a separate set of σ-parameters.

A reduced log-likelihood weighting (of 0.1) was applied for the gulf regions to the catch total fits for model time steps prior to May 1994 when catch sampling by age and sex commenced. The recreational catch log-likelihood for the entire period was further down-weighted (by 0.01).

The $\sigma^C[region, gear]$ parameters were not directly estimated, and a concentrated likelihood form of L_{Cw} was computed as described in Appendix 6 in Drew et al. (2021).

7.4.1.13. Catch samples by age and sex

A two-dimensional multinomial likelihood was used to fit to both observed sex ratios in the catch and to the relative proportions by age, since both were contained in the same set of catch samples. The fitted data, in each month and spatial cell where catch was monitored, consisted of the counts of sampled fish falling into each possible combination of sex and age, $\tilde{n}[a, sex \mid i_{AX}]$. The multinomial likelihood was written:

$$L_{AX} = \prod_{i_{AX}=1}^{n_{AX}} \prod_{a=1}^{12+} \prod_{sex=0}^{1} \hat{p}[a, sex \mid i_{AX}]^{\tilde{n}[a, sex \mid i_{AX}]} \quad \text{(A4.8)}$$

where

i_{AX} = index over the full set of n_{AX} catch samples by age and sex;

$\hat{p}[a, sex \mid i_{AX}]$ = two-dimensional array of model-predicted fish proportions captured by age and sex, for each sampled month and cell indexed by i_{AX};

$\tilde{n}[a, sex \mid i_{AX}]$ = observed fish numbers sampled, corrected to be representative by length for each age and sex, obtained from catch-at-age sample i_{AX}.

7.4.1.14. Objective Function Minimization

The negative logarithm of likelihood components were summed to form the model objective function. The objective function was minimized using the AD Model Builder parameter estimation software. This package uses a powerful algorithm for calculating derivatives, reverse auto-differentiation, which allows model solution convergence in computation times one or several orders of magnitude faster than conventional minimization methods. With 347 free parameters, convergence takes about 30 minutes, and hessian calculations another two and a half hours (laptop, Intel Core i7, RAM 32 GB).

7.4.1.15. Slice Length Partition

The slice length partition of each cohort of fish as it crosses into legal size, based on calculations carried out prior to model stock assessment fitting (Drew et al. 2021, Appendix 5), produces three principal model inputs. Each slice partition is specified by the sequence of slice left-hand-side length-partition points, one partition of legal lengths derived for each age of growth (e.g., Table A4.2). One of these triangular matrices of slice left-hand-sides was generated for each set of growth parameters, of which there were 6, with separate growth curves derived for each of the three regions and two sexes. The WhitEst model implements a state-wide increase in the legal minimum length at the end of August 1995 from 28 cm to 30 cm, and in the two gulfs only from 30 to 31 cm at end of September 2004 and from 31 to 32 cm at end of November 2016, with this being carried out by the length selectivity knife-edge truncation function (see above).

Mean weights (kg) of each slice (e.g., Table A4.3) were used to calculate model-predicted catch by weight. The quantity $P_{sublegslice}(a)$ (derived in Drew et al. 2021, Appendix 5, Equation A5.3) needed to create a new slice in each model time step, by transferring a designated proportion of fish from the sublegal component (sized below the slice partition length) to each newly created slice, is a vector over age (e.g., Table A4.1). This was derived from the probability, for each slice, and thus each monthly age *a*, under the normal length-at-age pdf curve of each newly-created slice subinterval (Drew et al. 2021, Appendix 5), denoted $P_{slice}(a)$ (Table A4.1).

The explicit representation of population numbers by length in each cohort altered the (1) shape of the length distribution (Figure A4.2), and thus the (2) mean length and (3) mean weight of harvested fish. For example, for the 1992 cohort of Gulf St. Vincent females, after 13 months in legal size (thus 13 slices, age 34 months, Figure A4.2), the mean legal-size length of modelled King George Whiting was 321 mm, while when the more rapid removal of larger fish is accounted for using a slice partition by length, the legal-size mean length was 316 mm, and mean weight of legal fish was similarly reduced from 199 to 190 g. The first-recruiting (right-hand tail) slice population number was reduced to 30% of its recruiting size after 13 months; the newest (left-hand) slice was reduced to 94% after one month.

7.4.1.16. Symbols of index quantities

These symbols are used to index data and model quantities in this appendix. Further symbols are defined near each of the equations further above.

- t = monthly time step. Model time runs from July 1983 to June 2022.
- a = month of age of a *cohort* at time t, ranging from 13 to 157.
- i_{AX} = index over the months and spatial cells in which age-sex samples were taken.
- *cohort* = year class designated by the year each cohort was spawned. New cohorts are created in the model population array as one-year old fish the year following spawning in May, at age 13 months. Over the period modelled this ranges from 1983 to 2020.
- *month* = calendar month, January to December.
- *cell* = model spatial cell. There are 7 spatial cells (Figure 3.5-1), plus a hypothetical cell to which West Coast and Western Eyre Peninsula fish migrate. The remaining outlying regions (cell 6 – "Other", Figure 3.5-1), from which King George Whiting catches are very small, was excluded from this model assessment.
- *sex* = female (*sex* = 0) and male (*sex* = 1).
- *slice* = dynamic length bin, which partitions the fish in each cohort age by length.
- *gear* = including four commercial gear types (handline, haul net, set net, other) and a recreational gear.
- *Etype* = fundamental classification into which catch and effort data are partitioned, as a matrix of commercial combinations of four gear types by three target types (targeting King George Whiting, targeting some other species, or not declaring any target type), plus charter boats and recreational. *Etype* ranges from 1 to *nEtype* = 14.

7.4.1.17. Tables

Table A4.1. Portion of fish in slice as a proportion of total normal length-at-age cohort (P_{slice}) and as a proportion of the sublegal component ($P_{sublegslice}$). Gulf St. Vincent females, slice partition length = 280 mm (LML of July 1983). A subset of values is shown to age 37 months.

Age (month)	Month legal	Pslice	Psublegslice
22	1	0.023	0.023
23	2	0.052	0.053
24	3	0.095	0.103
25	4	0.116	0.140
26	5	0.104	0.145
27	6	0.076	0.124
28	7	0.053	0.099
29	8	0.044	0.091
30	9	0.051	0.116
31	10	0.068	0.176
32	11	0.083	0.259
33	12	0.083	0.350
34	13	0.065	0.425
35	14	0.041	0.468
36	15	0.022	0.470
37	16	0.025	1.000

Table A4.2. Left-hand length boundaries for each slice length subinterval: Gulf St. Vincent females, LML = 28 cm. Similar slice model inputs are produced for males and combinations of stock (i.e. region). A subset of values is shown to age 37 months.

		Slice number															
Age (month)	Month legal	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
22	1	280.0															
23	2	294.1	280.0														
24	3	306.7	292.5	280.0													
25	4	317.0	302.7	290.1	280.0												
26	5	324.6	310.2	297.6	287.4	280.0											
27	6	329.8	315.4	302.7	292.5	285.1	280.0										
28	7	333.4	318.9	306.2	296.0	288.5	283.5	280.0									
29	8	336.4	321.9	309.2	298.9	291.5	286.4	282.9	280.0								
30	9	340.0	325.5	312.7	302.4	294.9	289.8	286.4	283.4	280.0							
31	10	345.0	330.5	317.6	307.3	299.8	294.7	291.2	288.3	284.8	280.0						
32	11	351.9	337.2	324.4	314.0	306.5	301.3	297.8	294.9	291.4	286.6	280.0					
33	12	360.3	345.6	332.6	322.3	314.7	309.5	306.0	303.0	299.6	294.7	288.1	280.0				
34	13	369.6	354.8	341.8	331.4	323.7	318.5	315.0	312.0	308.5	303.6	297.0	288.8	280.0			
35	14	378.8	363.9	350.8	340.3	332.7	327.4	323.9	320.9	317.4	312.4	305.8	297.6	288.7	280.0		
36	15	387.0	372.1	358.9	348.4	340.7	335.4	331.8	328.8	325.3	320.3	313.6	305.4	296.5	287.8	280.0	
37	16	393.7	378.7	365.5	354.9	347.1	341.9	338.3	335.3	331.7	326.8	320.0	311.8	302.8	294.0	286.3	280.0

Table A4.3. Weight in kilograms of an average fish in each age and slice. Gulf St. Vincent females, LML = 280 mm. A subset of values is shown to age 37 months.

Age (month)	Month legal	Slice number															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
22	1	0.140															
23	2	0.164	0.135														
24	3	0.187	0.155	0.134													
25	4	0.207	0.172	0.150	0.133												
26	5	0.223	0.186	0.163	0.144	0.131											
27	6	0.234	0.196	0.172	0.153	0.139	0.130										
28	7	0.242	0.203	0.178	0.158	0.144	0.135	0.128									
29	8	0.249	0.209	0.183	0.163	0.149	0.139	0.133	0.128								
30	9	0.257	0.216	0.190	0.170	0.155	0.145	0.138	0.133	0.128							
31	10	0.269	0.227	0.200	0.178	0.163	0.152	0.145	0.140	0.136	0.129						
32	11	0.286	0.242	0.213	0.191	0.175	0.164	0.156	0.151	0.146	0.139	0.131					
33	12	0.309	0.262	0.231	0.207	0.190	0.178	0.170	0.165	0.159	0.152	0.143	0.132				
34	13	0.334	0.284	0.252	0.226	0.208	0.195	0.187	0.181	0.175	0.167	0.158	0.146	0.133			
35	14	0.361	0.308	0.273	0.246	0.227	0.213	0.204	0.198	0.191	0.183	0.173	0.160	0.146	0.133		
36	15	0.386	0.330	0.294	0.265	0.244	0.230	0.221	0.214	0.207	0.199	0.187	0.174	0.159	0.145	0.132	
37	16	0.407	0.349	0.311	0.281	0.259	0.244	0.234	0.227	0.220	0.211	0.200	0.186	0.170	0.155	0.142	0.131

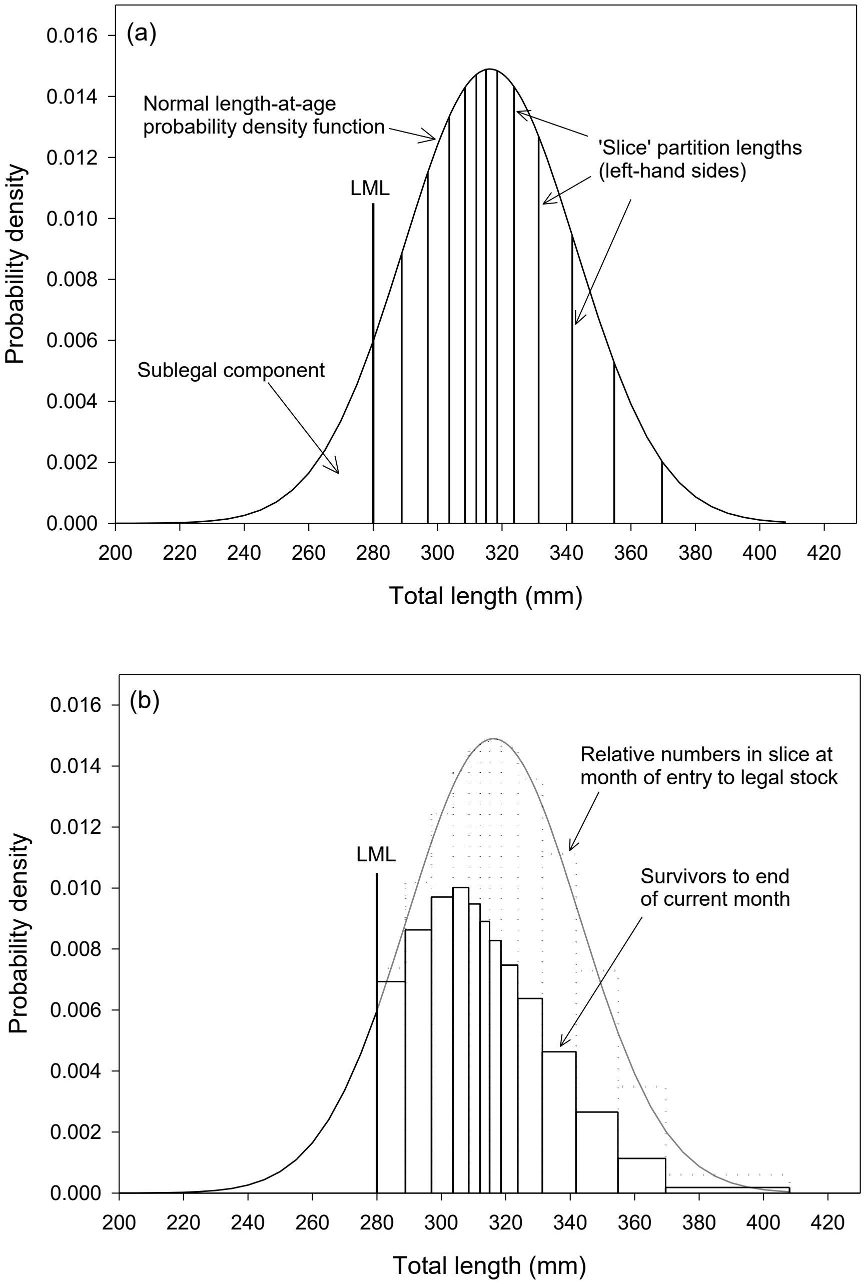

Figure A4.2. Length partition of a Gulf St. Vincent female model cohort, here having been of legal size for 13 monthly time steps. Fish are transferred from the sublegal component to each newly created slice (dotted bars). Thinner slices are created during slow-growth months. The normal length-at-age distribution for these age-34-month-old fish (in the absence of harvesting) is shown in both graphs. The greater reduction in numbers of faster growing fish, which were subject to harvesting for longer time, is shown in (b), where dotted bars are the slice-created proportions and the solid bars are proportional to the model population numbers by slice after mortality has occurred in that (January 1993) time step.

7.5. Appendix 5: Model fits to data.

Parameters, and thus biological performance indicators, are estimated in the WhitEst model by fitting to data for commercial catch totals by weight, recreational catch total numbers, and to commercial catch proportions by age and sex from each month when sampling occurs. In this Appendix, we present graphs of model fits for these three data inputs: (1) to the reported monthly commercial King George Whiting catch totals for the 6 principal subregions (Figure A5.1), (2) to catch age composition samples for the 24 most recent fitted combinations of region, month and sex (Figure A5.2), and (3) to sex ratios for the 24 most recent fitted combinations of region and month (Figure A5.3). Age and sex composition data were obtained predominantly as weekly samples prior to the Wednesday auction at SAFCOL fish market.

It is visually evident that the fits to the catch totals by the effort-conditioned WhitEst model (Figure A5.1) are quite close for most months and regions. This is a positive indication of model fit to this primary data source.

The fits to the catch-at-age proportions (Figure A5.2) show greater variability. This reflects differences in sample size, the number of fish aged and sexed (*n*) in each month and spatial cell among the 24 example graphs of model fit shown. Low sample size results in higher sample variation, which in turn means less close expected fit to model prediction. The fit is less close for small samples due to both greater random variation of the data away from the true overall population, and also a lower weighting of the model fitting to smaller samples. Given random variation, and the high number of cases that are fitted (all combinations of month, sex and spatial cell), the overall trend of model predictions agrees with these age sample proportions.

The to fit sex ratios (Figure A5.3) shows more variation unexplained by model prediction. The sample sizes in these sex ratio proportions are larger than the proportions by age shown in Figure A5.2 which appear to fit better. However, for the larger samples shown ($n \geq 25$) the model follows the data trend in sex ratio reasonably well, of modestly more females in the catch. Some of the small samples ($n \leq 10$) show relatively poor agreement

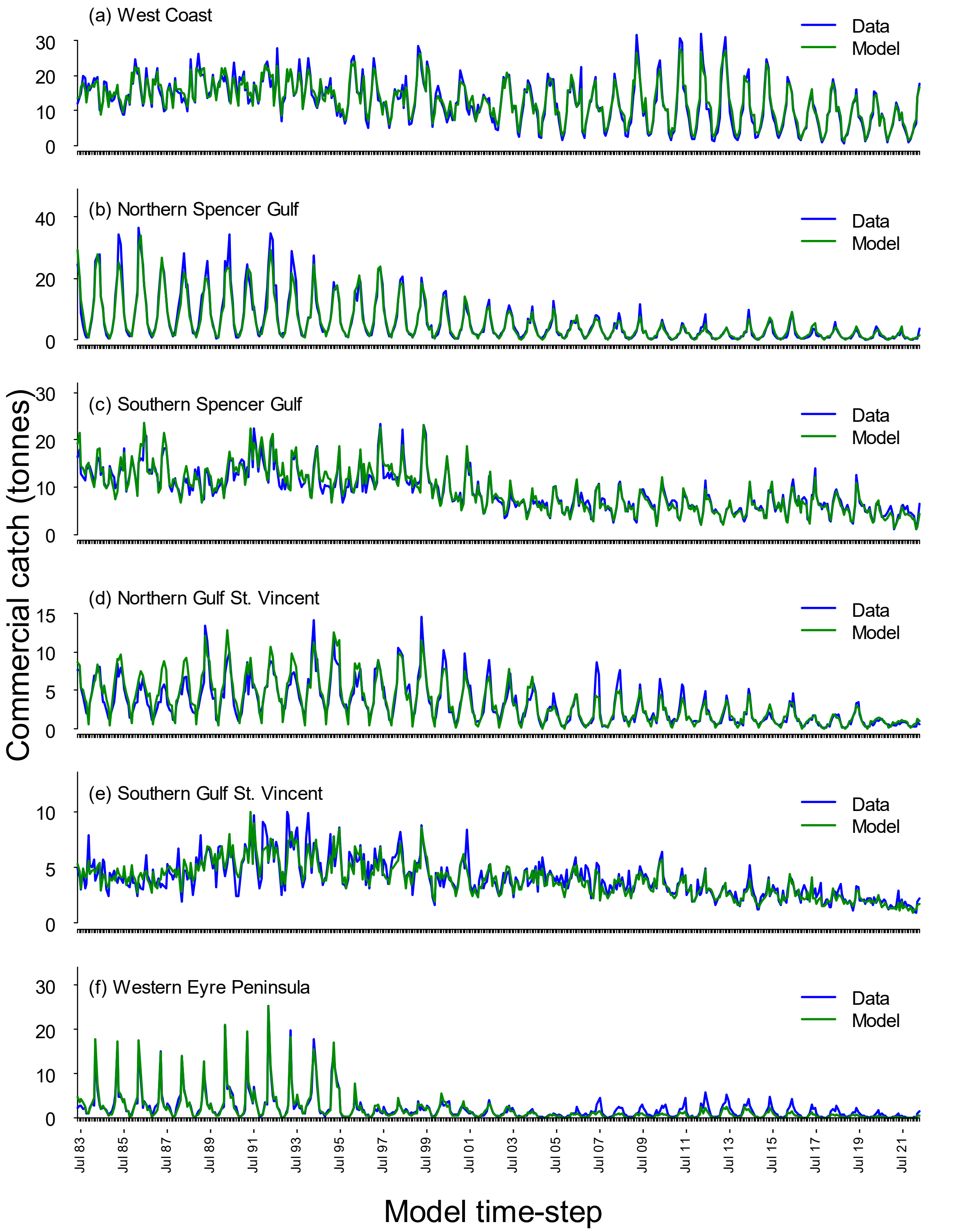

Figure A5.1. Fits of model to data monthly commercial catch totals (all gears and target types combined), for the six King George Whiting spatial cells of South Australia.

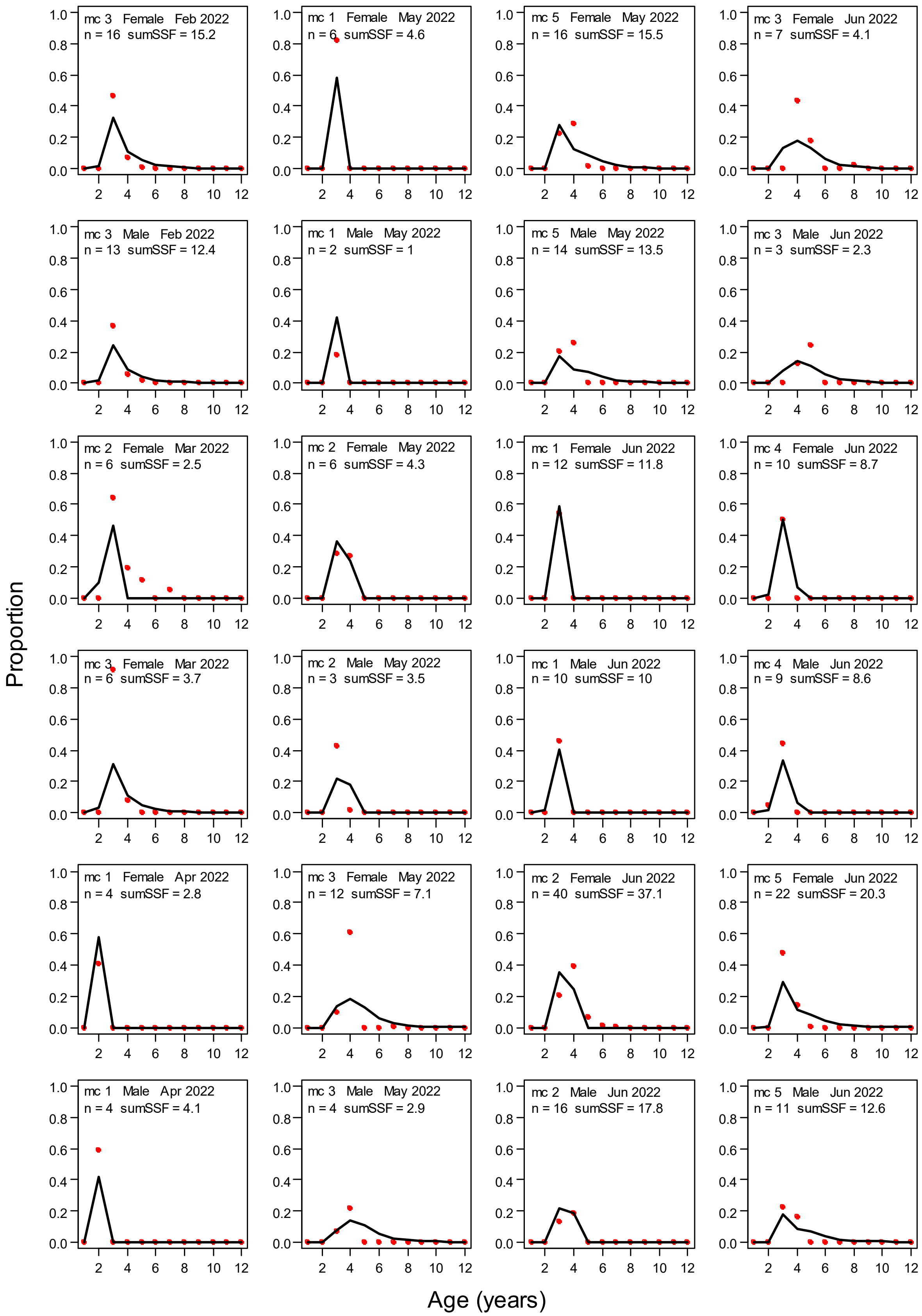

Figure A5.2. Fits of model to sample data relative catch-at-age proportions (all gears and target types combined), in the combinations of sex, month and model spatial cell (denoted mc 1 - mc 5 shown in the map of Figure 3.5 1). Solid red circle markers are data proportions and solid lines are model predictions. The sample size of fish aged is given by *n*.

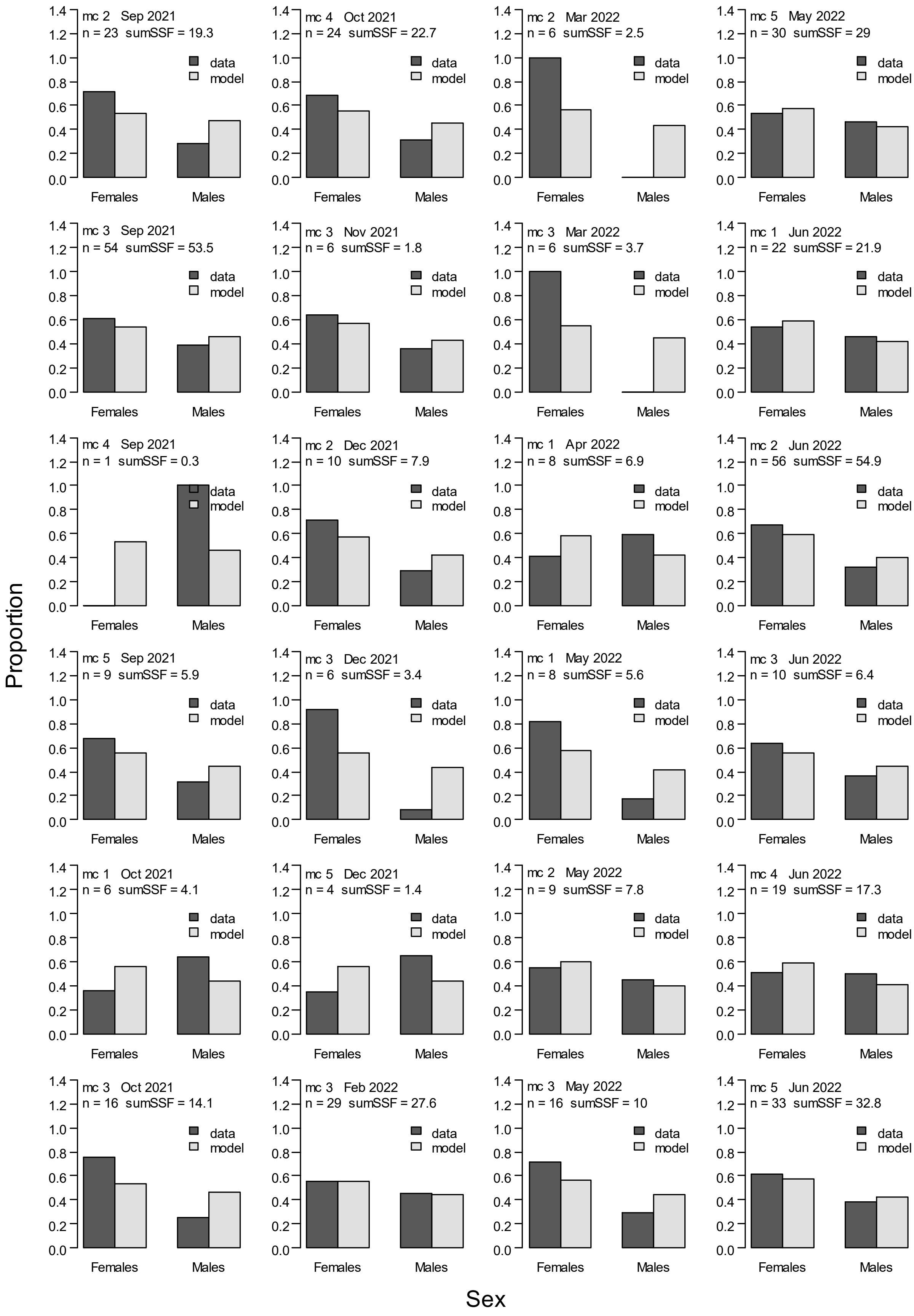

Figure A5.3. Fits of model to sample catch-by-sex proportions (all gears and target types combined), in the movement cells (denoted mc 1 - mc 5) and months shown.

7.6. Appendix 6. WhitEst Model Sensitivity Analysis: Assumed Rate of Natural Mortality.

7.6.1.1. Introduction

Natural mortality rate is an assumed input to WhitEst which accounts for removals of fish from the population due to causes other than fishing. In this Appendix, we present WhitEst model sensitivity testing under different assumed levels of natural mortality rate.

7.6.1.2. Method

The choice of instantaneous natural mortality rate (M) is made prior to estimation in most fishery assessment models because fishery data provides information only about fish that were captured, and so data about the fates of fish that are not captured is lacking. To test for sensitivity of WhitEst model biomass estimates to the choice of M, we have run several alternatives to the WhitEst baseline value of M = 0.45, namely M = 0.55, M = 0.35, and M = 0.25. These values roughly cover those obtained by the range of methods applied to estimate M for South Australian King George Whiting in Appendix 8.

7.6.1.3. Results

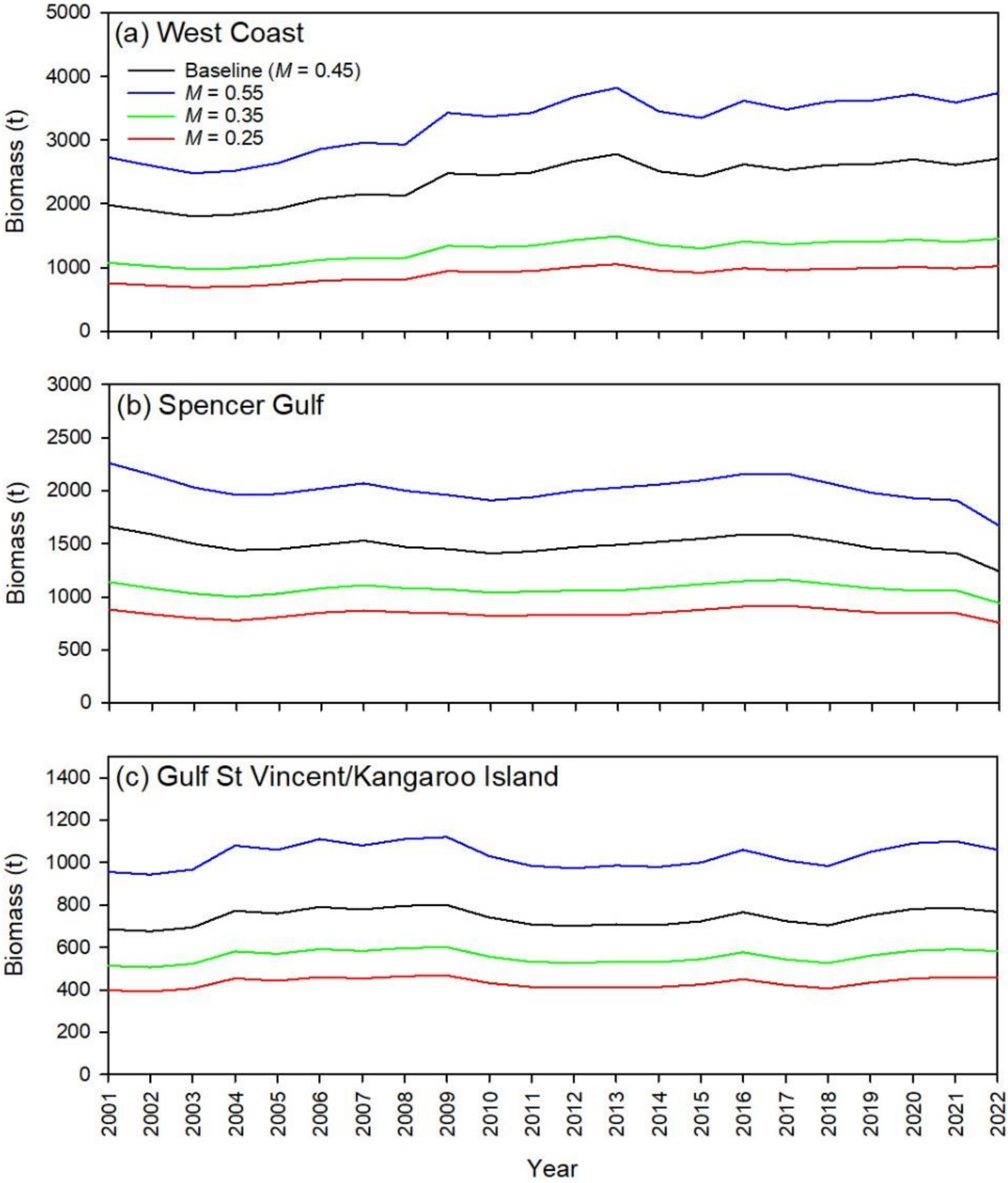

Figure A6.1. Sensitivity analysis for different assumed values of natural mortality rate. Plot of biomass by region from four runs of WhitEst: the baseline (with M = 0.45), and three alternatives of M = 0.55, M = 0.35, and M = 0.25.

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7.6.1.4. Discussion

The result we observe for all three regions is that higher assumed values of M yield higher estimates of absolute biomass.

This effect is expected due to the nature of fishery assessment inference based on age samples and total catch. Basically, this is expected because age samples give information on total mortality rate $Z = F + M$, not on F directly. If the assumed M is higher, in order that their sum equals age-based Z, F is estimated lower. A lower F means a lower yearly fraction of biomass harvested. So, in order for the model to accurately predict the reported total catch, it infers a higher biomass, because the fraction (F) of that biomass harvested is lower when M is assumed to be higher. Other factors can intervene but this form of fishery inference underpins many age-based models, and is why we can expect the outcome observed in Figure A6.1.

For fishery management, this result shows WhitEst biomass estimates are quite sensitive to assumed M. The strongest sensitivity was observed for the highest value of $M = 0.55$ which shows considerably higher biomass estimates across all years in all three regions. Between the baseline biomass estimates (M = 0.45) and those assuming M = 0.35, there is still a substantial difference. If quota is being set using a pre-chosen harvest fraction, these biomass differences between assumed M values of 0.45 and 0.35 will indicate meaningfully different quotas.

7.7. Appendix 7. WhitEst Model Sensitivity Analysis (2): Different assumed input data sets for recreational catch.

7.7.1.1. Introduction

A crucial data input to the WhitEst model is the total catch taken in each model time step and model spatial cell. For South Australian King George whiting, recreational catch comprises about two-thirds in the two gulfs (Figure A3.3). The charter-boat and commercial sectors report total catch in daily catch logs. For the non-charter recreational sector, the numbers of King George Whiting taken were estimated from the four recreational catch surveys held since 2000/01 (Appendix 3). These survey estimates have relatively wide confidence intervals and interpolated values must be generated for all years between surveys (Appendix 3). As input to Whitest, these survey catches must be allocated across time and space, which we have done with additional assumptions and linear modelling as detailed in Appendix 3. To evaluate the impact of different methods for constructing recreational data, a set of three additional recreational catch time series by spatial cell were derived under different plausible assumptions. In this Appendix 7, we present model sensitivity testing of these alternative recreational data sets for comparison with the baseline WhitEst biomass estimates presented in Section 3.6.

7.7.1.2. Method

In this section we describe the three alternative recreational catch data sets.

In the first, all data from the most imprecise survey, 2013/14, were removed from the analysis of Appendix 3. Thus, the recreational catches for the years between 2007/08 and 2021/22 were interpolated directly across that time span. Monthly variation was unaffected since this survey was not used in the linear model analysis.

In the second data set, recreational catches were assumed to be constant across years. The survey confidence intervals in any given year were sufficiently wide that differences between years have relatively low statistical significance. This data set provides a test of how much this weak temporal signal affects stock assessment outcomes. Here, the same total number harvested by the recreational sector is applied for all years, separately by spatial cell. The monthly variation is retained as in the baseline.

The third data set varies an assumption made to generate recreational catch data for the new spatial cell, Western Eyre Peninsula (WEP), that includes Coffin Bay. For each survey, the WEP catch was computed from the total for West Coast (WC) using a ratio, WEP/WC. In the baseline analysis, a difference was noted in this ratio in the 2000/01 survey. This is consequential given that this 2000/01 estimate is extended backwards to 1983/84, the start of the model time series. As a sensitivity run, we changed this WEP/WC ratio to match the ratio computed from the other surveys. In other words, we increased recreational catches in WEP from 1983 – 2001 and decreased the catches in WC by the corresponding amount over those years.

7.7.1.3. Results

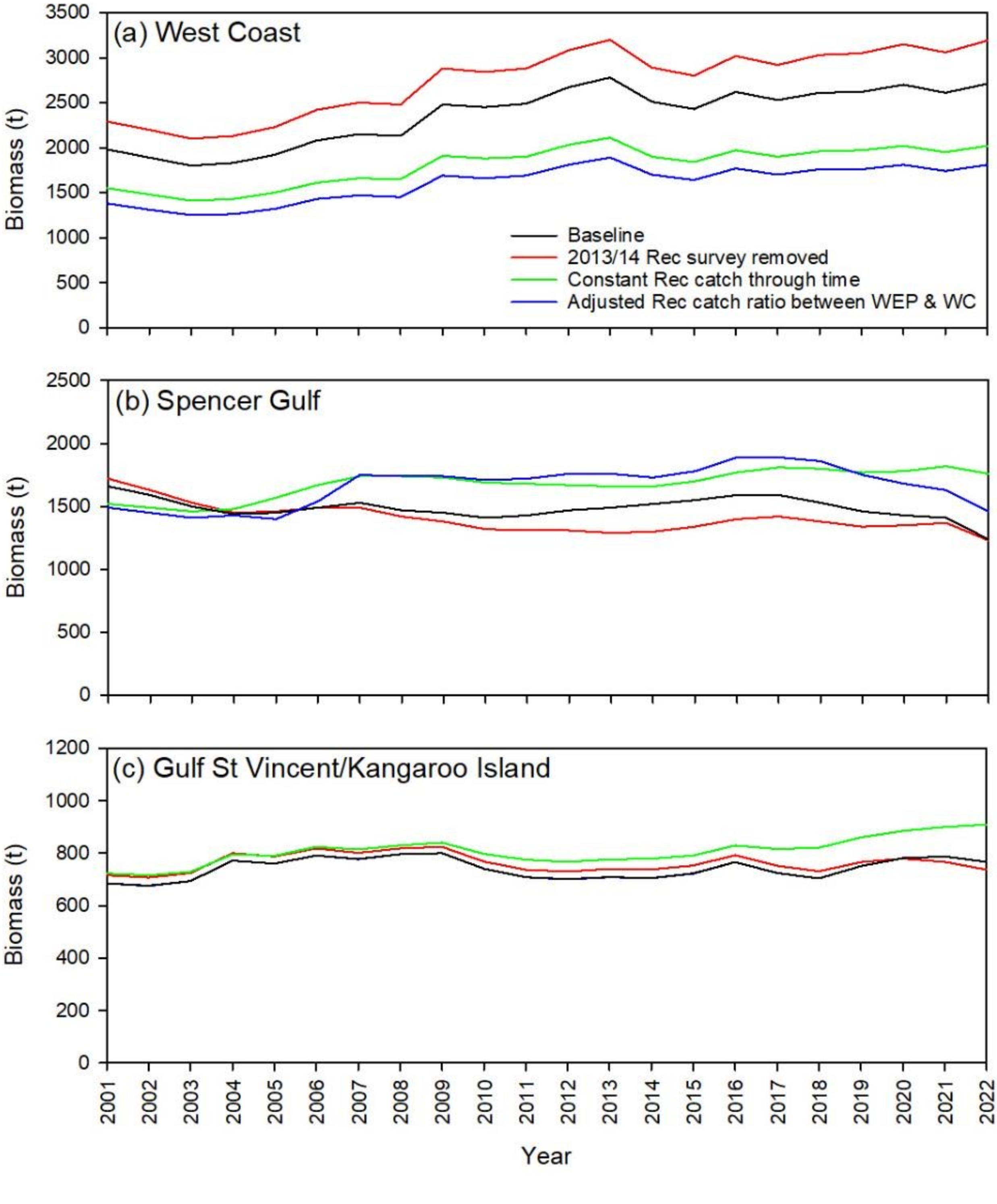

Figure A7.1. Sensitivity analysis for different recreational catch data sets. Plot of biomass by region from four runs of WhitEst. See Methods of this Appendix for descriptions of the three alternative data sets. The baseline (black) is the same as reported in the main text (Section 3.6). Some reference to the blue line sitting underneath the baseline?

7.7.1.4. Discussion

These results for the two gulf regions, and especially for GSV, show that WhitEst biomass estimates are not strongly sensitive to the assumed method for generating recreational catches. This is a favourable outcome. For WC, the different recreational data sets gave more divergent outcomes. Overall, less sensitivity was found to the method used to interpolate recreational catch than to assumed natural mortality rate *M* (previous section).

The greater sensitivity we observe here for WC region biomass is consistent with the wide baseline confidence intervals on WC biomass estimates (Figure 3.6 3). That is, higher sensitivity to assumed data inputs can reflect a less precise determination overall of model parameter estimates given all the other available data. Both outcomes for model measures of uncertainty (higher sensitivity to inputs and wider model-estimated confidence intervals) can reflect data that are insufficient to more precisely determine the most probable outcome. It is reasonable on this basis to take precaution in using WC absolute biomass estimates directly for quota setting.

7.8. Appendix 8. Applying a Range of Published Methods to Estimate Natural Mortality Rate.

The WhitEst model currently assumes a value of *M* = 0.45 yr^{-1} for natural mortality rate. This estimate for South Australian King George Whiting was first published by Jones et al. (1990) who used the average of two estimates: 0.56 from (Pauly 1980) based on growth and 0.33 from (Vetter 1988) based on the age of the oldest fish observed of 14 years. These exemplify the two basic approaches: those based on growth rate of the population and those based on oldest fish observed.

Growth methods rely on mortality and growth being broadly anti-correlated. Fish that reach a larger maximum size (high L_∞) and which grow more slowly at young ages (low *K*) tend to have lower rates of natural mortality.

The methods relying on oldest fish observed make two implicit assumptions: that mortality is constant for all ages, which ignores both senescence at old age and a higher mortality rate of smaller animals due to predation, and that the oldest fish is representative of some assumed proportion of those surviving to that age. Neither of these assumptions can be reliably controlled and so oldest fish observed is a less statistically formal approach. A constant natural mortality implies exponential decline in population number with age, and mathematically this implies that some fish will be present at low numbers at ages older than the oldest fish observed, so some assumed proportion like 0.1% or 0.01% surviving to this oldest age must be implicit. This method of oldest fish also ignores fishing mortality.

In real populations natural mortality rates can and usually do vary with age, environment, density of predators, susceptibility to pathogens, population density, and senescence, so any approach that assumes a single fixed value for natural mortality rate (as most fishery models do) is approximate.

7.8.1.1. Method

With these caveats in mind, we computed a wide range of estimates based on different variations of these two approaches. In this Appendix, we present an analysis using the R package of Simple Fisheries Stock Assessment Methods to re-compute *M* using a range of published estimation methods. Bearing in mind that these methods are not sophisticated and not based directly on measurement of natural mortality, we adopt a strategy of applying a broad suite of these *a priori* methods to assess whether the current value of 0.45 lies within the resulting range of estimates.

The growth parameters used for the growth-based method were estimated from the age and length samples of gulf King George Whiting, specifically, Spencer Gulf females, L_∞ = 492.6 mm, *K* = 0.49 yr^{-1}, t_0 = 0 yr). For the oldest age observed, two values were chosen, as either 13 years the oldest age (the plus group) in the WhitEst model age structure, or 22 years which is the oldest fish recorded in South Australian fishery age samples.

7.8.1.2. Results

The full set of *M* estimates from all methods tested are listed in Table A8.1. These range from M = 0.93 to 0.16 yr^{-1}.

Table A8.1. Estimates of natural mortality rate for South Australian King George Whiting from all methods tested.

METHOD	M	KEY INPUTS	REFERENCES
K1	0.83	VBGF	Pauly (1980)
K2	0.86	VBGF	Then et al (2015)
PaulyL	0.73	VBGF	Jensen 1996
PaulyLNoT	0.68	VBGF	Jensen 1996
JensenK1	0.74	VBGF	Then et al 2015
JensenK2	0.93	VBGF	Hoenig (1983)
HoenigNLS	0.29	Max Age = 22 years	Hoenig (1983)
HoenigO2	0.2	Max Age = 22 years	Hoenig (1983)
HoenigO2F	0.16	Max Age = 22 years	Hoenig (1983)
HoenigO	0.2	Max Age = 22 years	Then et al (2015)
HoenigOF	0.19	Max Age = 22 years	Then et al 2015
tmax1	0.23	Max Age = 22 years	Hoenig (1983)
HoenigNLS	0.47	Plus group age = 13 years	Hoenig (1983)
HoenigO2	0.35	Plus group age = 13 years	Hoenig (1983)
HoenigO2F	0.31	Plus group age = 13 years	Hoenig (1983)
HoenigO	0.34	Plus group age = 13 years	Then et al (2015)
HoenigOF	0.32	Plus group age = 13 years	Pauly (1980)
tmax1	0.39	Plus group age = 13 years	Then et al (2015)

These estimates cluster into three broad groupings shown in Figure A8.1. The growth-based estimates whose key inputs were the estimated parameters of the von Bertalanffy growth function (indicated in Figure A8.1 by VBGF) were higher. Those based on oldest fish observed fell into two broad clusters, those in a middle range using the plus group age from the WhitEst model (13 years) and those assuming a value of 22 years for the oldest observed fish which comprised the lowest *M* estimates obtained.

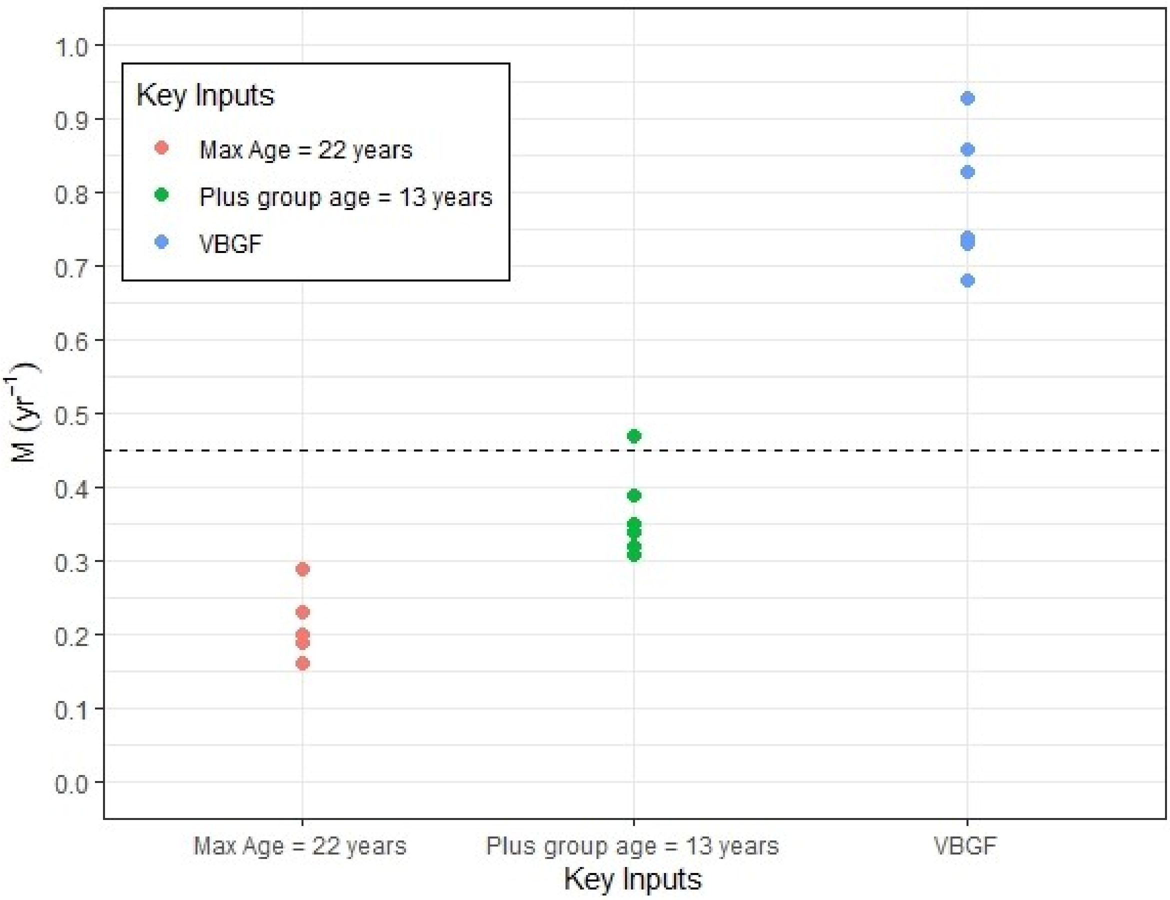

Figure A8.1. Estimates of *M* for King George Whiting grouped by method type (coloured points). Black dashed line is the current WhitEst value of 0.45 yr^{-1}.

7.8.1.3. Discussion

The very wide range of *M*'s obtained point to the challenge of choosing an accurate value for natural mortality rate. The value of 0.45 currently assumed by WhitEst falls well within the middle of this range.

With the principal outcome of this analysis being that the current baseline value of *M* lies well within the range of estimates obtained here, that value of 0.45 will be retained as the baseline *M* input to WhitEst.

This analysis was valuable also for informing the sensitivity testing of different values of *M* presented in Appendix 6. The range of values tested as alternatives to the baseline 0.45, namely 0.25, 0.35 and 0.55 also fall within the central span of the values estimates in this Appendix. Thus, *M* values used in sensitivity testing are also consistent with the estimates obtained from this set of published methods. The main difference is that the estimates of Table A8.1 and Figure A8.1, notably those based on the growth parameters, extend well above 0.55. We did not test such high values of *M* in Appendix 6.