Fisheries

Assessment of the South Australian Lakes and Coorong Fishery in 2021-22

J. Earl

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June 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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EXECUTIVE SUMMARY

This report is the fourth in a series for South Australia's Lakes and Coorong Fishery (LCF). It provides a description of the dynamics of the fishing fleet, a stock assessment for Mulloway, assigns stock status to five other finfish species that are harvested by the three gillnet sectors of the fishery (estuarine large-mesh gillnet [ELMGN]; estuarine small-mesh gillnet [ESMGN]; and freshwater large-mesh gillnet [FLMGN]), and for Pipi. The report provides species-specific information relating to fisheries biology, fishing access, management, and trends in commercial fishery statistics from 1 July 1984 to 30 June 2022. Of the seven species assessed in this report, five are classified as 'sustainable' and two are classified as 'depleted', based on the National Fishery Status Reporting Framework (Table E-1; Piddocke et al. 2021). Updated estimates of the performance indicators for finfish and Pipi are provided, as prescribed in the fishery's Management Plan (PIRSA 2022).

Fleet dynamics

The dynamics of the LCF fleet have changed considerably since 1984/85. Most have related to environmental changes associated with variation in freshwater inflows to the Coorong Estuary, as well as economic factors and are reflected in shifts in targeted effort among the fishery's five primary species (Mulloway, Yelloweye Mullet, Golden Perch, Carp and Pipi). In 2021/22, these species accounted for around 92% of the fishery's targeted effort, consistent with previous years.

Mulloway stock assessment

The assessment of the LCF for Mulloway used a weight-of-evidence approach that placed considerable emphasis on analyses of commercial catch, effort and targeted catch per unit effort (CPUE) trends to the end of June 2022, and contemporary fishery size and age structures.

The LCF has historically been the most productive of South Australia's fisheries for Mulloway, and in 2021/22 contributed 99% of the State's total commercial catch. The total catch by the LCF in 2021/22 of 55.5 t was similar to the long-term average for the fishery, but considerably lower than the annual catches during 2018/19–2020/21 when they ranged from 92.3 t to 120.5 t.

The main gears used by the LCF to target Mulloway are large mesh gillnets (LMGN; 115–150 mm mesh) and swinger nets (SN; >150 mm mesh). In 2021/22, targeted LMGN catches taken in the Coorong Estuary accounted for 53% of the total catch, while those taken using SN in the adjacent nearshore marine environment accounted for 33%. The remaining catch was taken as by-product.

Recent annual catches of Mulloway by the LCF have been associated with near record-high catch rates using LMGN and SN, which likley reflect high fishable biomass in the Coorong Estuary and the adjacent nearshore marine environment. In 2021/22, the $CPUE_{LMGN}$ of 7.1 kg.net-day^{-1} was the sixth highest on record, while the $CPUE_{SN}$ of 160.3 kg.net-day^{-1} was the highest on record.

Spatial differences were evident in the age structures for Mulloway between the Coorong Estuary and the adjacent nearshore marine environment from recent years. Those from the estuary were dominated by 2–4-year-old fish, while those from the nearshore marine environment comprised fish between 5 and 22 years of age and were dominated by 6 and 7-year-olds. Fish older than 12 years were rare, despite the potential for this species to live for 41 years. Mulloway mature at 5–6 years old.

The regular recruitment of juveniles to the fishable biomass over recent years, the presence of multiple age classes in the adult biomass, and the moderate catch and near-record high catch rates in 2021/22 indicate 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 this basis, the stock is classified as '**sustainable**'.

Mulloway is the primary target species in the ELMGN sector. The primary (environmental) performance indicator for habitat available to Mulloway in the Coorong Estuary for the 2022/23 reporting year (1 February 2022–31 January 2023) was 65.4%, which was above the target reference point of 55% (Table E-2). The secondary (biological) performance indicator for targeted Mulloway $CPUE_{LMGN}$ for the 2022 calendar year of 7.59 kg.net-day^{-1} was 146% above the target (Table E-3).

Stock status and performance indicators

Black Bream is a secondary target species in the ELMGN sector. Targeted catch and effort for Black Bream have been historically low since the 1980s, and this continued in 2021/22. These results suggest that biomass remains recruitment impaired. Since 2018, several temporary management arrangements have been implemented to recover the stock, but these have not yet resulted in measurable improvements in fishable biomass during 2021/22. This stock is classified as '**depleted**'.

Greenback Flounder is a secondary target in the ELMGN sector. In the Coorong Estuary, low targeted effort and catches since 2012/13 likely reflect low fishable biomass caused by low recruitment over recent years due to low freshwater inflows to the estuary. In 2021/22, recruitment to the fishable biomass was low primarily due to these environmental effects. The total catch of 4.5 t in 2021/22 was the highest catch since 2015/16, but low in a historical context. This stock is classified as '**depleted**'.

Yelloweye Mullet is the primary target species in the ESMGN sector. Catch fell to a moderate level of 206 t in 2021/22 and was associated with high $CPUE_{SMGN}$. This is indicative of high fishable biomass but could also relate to changes in fisher efficiency associated with changes in fishing practices to reduce interactions with Long-nosed Fur Seals. Nonetheless, the biomass of this stock is unlikely to be depleted and recruitment is unlikely to be impaired. This stock is classified as '**sustainable**'.

Golden Perch is a primary target in the FLMGN sector. Decreased market demand for Bony Herring and Carp contributed to a decline in fishing effort in this sector in 2019/20, which remained relatively low in 2021/22. For Golden Perch, the total catch of 35.2 t in 2021/22 was the lowest since 2012/13.

This low catch reflected low targeted effort (i.e., 5th lowest since 1984/85) and was associated with moderate $CPUE_{LMGN}$. The Golden Perch stock is classified as '**sustainable**'. For Bony Herring, catch and $CPUE_{LMGN}$ have increased over the past three years. This stock is classified as '**sustainable**'.

The harvest strategy for finfish in the Management Plan uses environmental (primary) and biological (secondary) performance indicators to guide setting of the total allowable commercial effort (TACE) for the three gillnet sectors (PIRSA 2022). Estimates of the environmental and biological performance indicators are provided for the 2022/23 reporting year (1 February 2022–31 January 2023) and 2022 calendar year, respectively (Table E-2 and Table E-3), to ensure that the most up-to-date information is available for the setting of the TACE for each sector for the 2023/24 financial year.

Pipi sector

Since 2007/08, annual catches of Pipi have been managed using annual total allowable commercial catches (TACC), with catches constrained by the TACC from 2009/10 onwards. The TACC was reduced to 400 t in 2021/22, following poor recruitment in 2018, thereby constraining catch to its lowest levels since 2011/12. The estimate of fishery-independent relative biomass of legal-sized Pipi (primary performance indicator) of 15.2 kg/4.5 m^2 in 2021/22 was 27% above the target reference point of 12 kg/4.5 m^2 (Table E-4). Pre-recruits (secondary performance indicator) were present (63%) in size structures from the survey in November 2021. This stock is classified as '**sustainable**'.

Table E-1. Key statistics for South Australia's Lakes and Coorong Fishery finfish stocks from 2019/20 to 2021/22, including stock status based on weight of evidence and the National Fishery Status Reporting Framework (Piddocke et al. 2021).

Species	F/Year	Catch (t)	Stock status
Mulloway	2019/20	120	Sustainable
	2020/21	92	Sustainable
	2021/22	**55**	Sustainable
Black Bream	2019/20	1.7	Depleted
	2020/21	3.2	Depleted
	2021/22	**3.4**	Depleted
Greenback Flounder	2019/20	0.2	Depleted
	2020/21	4.4	Depleted
	2021/22	**4.5**	Depleted
Yelloweye Mullet	2019/20	458	Sustainable
	2020/21	368	Sustainable
	2021/22	**206**	Sustainable
Golden Perch	2019/20	50.6	Sustainable
	2020/21	54.9	Sustainable
	2021/22	**35.1**	Sustainable
Bony Herring	2019/20	269	Sustainable
	2020/21	314	Sustainable
	2021/22	**360**	Sustainable

Table E-2. Results from annual assessments of the environmental performance indicators for the three finfish sectors from 2020/21 to 2022/23 (reporting years) against their reference points (RP). The annual TACE (net units) for each sector for each financial year from 2019/20 to 2021/22 is also shown.

Finfish sector	Financial year	TACE	Performance indicator	Limit RP	Trigger RP	Target RP	Reporting year	PI value
Estuarine LMGN	2019/20	1,175	Habitat available to Mulloway	10%	24.9%	55%	2020/21	52.3%
	2020/21	987					2021/22	56.9%
	2021/22	1,175					**2022/23**	**65.4%**
Estuarine SMGN	2019/20	1,175	Habitat available to YE Mullet	10%	30.9%	50%	2020/21	62.4%
	2020/21	1,175					2021/22	63.3%
	2021/22	1,175					**2022/23**	**87.1%**
Freshwater LMGN	2019/20	1,175	Water level in the Lower Lakes (m)	-1.2 m	-0.71 m	0.4 m	2020/21	0.71 m
	2020/21	1,175					2021/22	0.73 m
	2021/22	1,175					**2022/23**	**0.76 m**

Table E-3. Results from the annual assessments of the biological performance indicators for key species in the three finfish sectors from 2020 to 2022 (calendar years) against their target, trigger and limit reference points (RP). The biological performance indicators for non-standardised CPUE (kg.net-day^{-1}) is prescribed for the primary (^{P}) and secondary (^{S}) species taken in each sector. Crosses indicate confidential data.

Finfish sector	Key species	Secondary performance indicator	Limit RP	Trigger RP	Target RP	Calendar year	PI value (kg.net-day^{-1})
Estuarine LMGN	Mulloway ^{P}	Targeted $CPUE_{LMGN}$	0.80	1.39	2.68	2020	9.04
						2021	6.58
						2022	**4.59**
	Greenback Flounder ^{S}	Targeted $CPUE_{LMGN}$	0.65	0.93	1.86	2020	X
						2021	1.9
						2022	**2.79**
	Black Bream ^{S}	Targeted $CPUE_{LMGN}$	0.30	0.53	1.67	2020	X
						2021	X
						2022	**1.02**
Estuarine SMGN	Yelloweye Mullet ^{P}	Targeted $CPUE_{SMGN}$	6.32	7.23	11.11	2020	35.8
						2021	23.6
						2022	**32.3**
Freshwater LMGN	Golden Perch ^{P}	Targeted $CPUE_{LMGN}$	0.24	0.49	1.04	2020	1.22
						2021	1.12
						2022	**0.59**
	Bony Herring ^{S}	$CPUE_{LMGN}$	2.32	3.54	5.42	2020	4.57
						2021	6.36
						2022	**5.28**

Table E-4. Key statistics and stock status for South Australia's Lakes and Coorong Fishery Pipi resource from 2019/20 to 2021/22, including the results from the annual assessments of the primary performance indicator (fishery-independent relative biomass of legal-sized Pipi) from 2019/20 to 2021/22 against the target reference points (RP). The annual total allowable commercial catches (TACC) are also shown.

Pipi	Financial year	TACC (t)	LCF catch (t)	Primary performance indicator: relative biomass (kg/4.5 m²)				Secondary performance indicator: Pre-recruits present?	Stock status
				Limit RP	Trigger RP	Target RP	PI value		
	2019/20	450	394	4	9	11	10.7	Yes	Sustainable
	2020/21	450	444				8.9	Yes	Sustainable
	2021/22	400	419			12	**15.2**	**Yes**	**Sustainable**

** 2021/22 LCF catch of 419 t exceeded the TACC of 400 t due to carry-over of quota from 2020/21 (PIRSA pers.com.)*

Keywords: stock status, gillnets, Coorong Estuary, River Murray, fleet dynamics.

1 GENERAL INTRODUCTION

1.1 OVERVIEW

This is the fourth report in this series for the South Australian Commercial Lakes and Coorong Fishery (LCF) that provides a species-specific summary of information on fisheries biology, management arrangements, trends in commercial fishery statistics, and stock status at the biological stock or management unit scale. It includes a stock assessment for Mulloway (*Argyrosomus japonicus*), updating the previous 2020 assessment. It also assesses performance indicators against reference points for the finfish and Pipi (*Donax deltoides*) sectors of the fishery, as prescribed in the *Management Plan for the South Australian Commercial Lakes and Coorong Fishery* (hereafter referred to as the Management Plan; [PIRSA 2022]). As such, this report provides fundamental scientific information to support the management of this multi-species, multi-gear fishery. The fisheries data included in this report extends over a 38-year time series from 1 July 1984 to 30 June 2022.

This report comprises five main sections. The first section, including this overview, provides a description of the LCF, its management arrangements, and the performance indicators and reference points used to inform management of the finfish and Pipi sectors of the fishery. Section two describes the dynamics of the commercial fishing fleet, catch composition, and spatial and temporal trends in fishing effort.

Section three provides an assessment of the fishery for Mulloway. This assessment is based on commercial catch and effort statistics, information on the size and age of Mulloway taken by the LCF, and an environmental performance indicator that relates to the amount of habitat available for Mulloway in the Coorong Estuary.

Section four consists of a series of species-specific sub-sections that are arranged to align with the estuarine large and small-mesh gillnet sectors, the freshwater large-mesh gillnet sector and the Pipi sector of the LCF, as defined in the Management Plan (PIRSA 2022). For key species of each sector, the relevant biological information is provided, along with a description of the fishery and its management arrangements, an interrogation of the fishery data, and a classification of stock status using the definitions of the National Fishery Status Reporting Framework (NFSRF; Piddocke et al. 2021). For each finfish sector, environmental and biological performance indicators are also assessed against reference points prescribed in the Management Plan (PIRSA 2022) to inform setting of the 2023/24 total allowable commercial effort (TACE) for each sector. The final section, the General Discussion, discusses the overall performance of the fishery, details emerging trends within the fleet, and identifies research priorities that will improve future assessments.

1.2 DESCRIPTION OF THE FISHERY

The LCF is a small-scale, multi-species, multi-gear fishery that operates in the estuary of the River Murray and Coorong lagoons (the Coorong Estuary), the freshwater lower lakes of the River Murray (Lakes Alexandrina and Albert) and the nearshore marine environment adjacent the Coorong Estuary (Figure 1-1). Currently, there are 36 active licence holders in the fishery, who are permitted to take around 40 species/taxa that include fishes, molluscs, crustaceans, annelid worms, sharks, rays and skates (PIRSA 2022). Fishery production by weight of catch is mainly comprised of Bony Herring (*Nematalosa erebi*), Carp (*Cyprinus carpio*), Yelloweye Mullet (*Aldrichetta forsteri*), Mulloway, Golden Perch (*Macquaria ambigua*) and Pipi. Other species such as Black Bream (*Acanthopagrus butcheri*), Greenback Flounder (*Rhombosolea tapirina*) and Redfin Perch (*Perca fluviatilis*) have contributed significantly to the overall catch in some years.

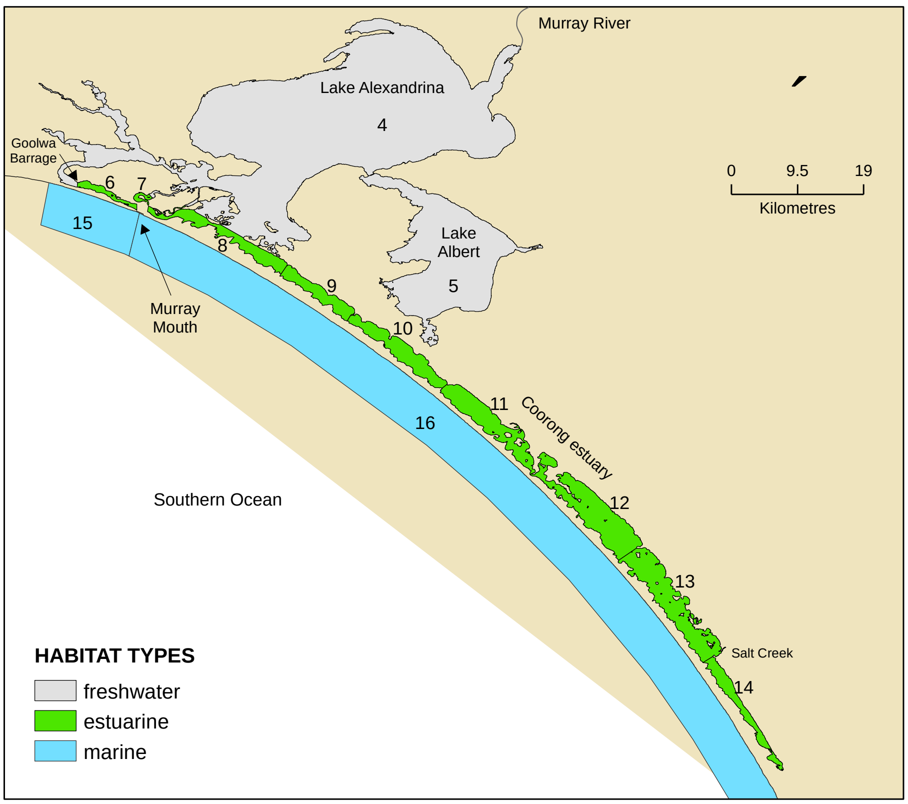

Figure 1-1. Commercial reporting blocks of the LCF showing the different habitats.

There are approximately 15 types of fishing gear (or devices) endorsed in the LCF (PIRSA 2022). The use of these gears differs depending on the location of fishing and the species being targeted. Mesh gillnets are the main gear used by fishers targeting finfish species (Ferguson et al. 2013). In the Lower Lakes, large-mesh gillnets (115–150 mm mesh) are used to target Golden Perch, Redfin Perch, Bony Herring and Carp. In the Coorong Estuary, large-mesh gillnets are used to target Mulloway, and occasionally Greenback Flounder and Black Bream, while small-mesh gillnets (50–64 mm mesh) are used to target Yelloweye Mullet. Mulloway are also targeted in the nearshore marine environment adjacent the Murray Mouth using extra-large-mesh gillnets (>150 mm mesh), known as swinger nets. Pipi is harvested using hand-held rakes along the ocean beach on the Younghusband Peninsula. Other methods permitted for use include drum nets, hauling nets, set lines and yabby pots.

The broad mixture of target species, gear types, habitats and regulations associated with the LCF make the task of assessing the status of the fish stocks challenging. This is compounded by the dynamic nature of fisher behavioural responses to markets, resource availability, environmental conditions, and in recent years, the presence of Long-nosed Fur Seals (*Arctocephalus forsteri*) (Earl et al. 2021), as fishers can readily switch their effort between species, gears and areas.

The recreational fishing sector has access to most LCF species. Recreational fishing occurs in freshwater, estuarine and marine waters in the region, with fishers permitted to use several gear types, including registered monofilament nylon nets in the Coorong Estuary. Recreational net fishing is prohibited in all other coastal waters of South Australia (PIRSA 2022).

1.3 RIVER MURRAY FLOWS

Freshwater flow from the River Murray is a major driver of ecological processes and biological responses in the Lakes and Coorong region, including the population dynamics and abundance of fish species that support the LCF. Freshwater inflow affects fish through changes in: (i) availability of habitat, primarily through changes in salinity and water level, (ii) connectivity within, and between marine, estuarine and freshwater environments, and (iii) trophic productivity by transporting carbon, nutrients, and microbiota (i.e., food resources) from upstream (Ye et al. 2016; Bice et al. 2018).

Over the last 50 years, annual freshwater inflow to the Coorong Estuary has been highly variable (Figure 1-2). A major flood event in Murray-Darling Basin (MDB) in the mid-1970s led to inflows of 26,644 GL in 1974/75 – the highest inflows since the 1950s. From 1984/85 to 2000/01, inflow averaged around 5,166 GL (SE ± 995 GL), with peaks of ~11,000 GL in 1989/90, 1990/91, 1992/93 and 1993/94. During the Millennium Drought (2001/02–2009/10) in the MDB, there were low or no annual freshwater flow releases through the barrages to the Coorong (DEW 2020). Since the drought, several years of moderate–high river flows (i.e., 2010/11–2012/13, 2016/17) and the delivery of water for the environment to the Lower Lakes have contributed to increased barrage releases. In 2021/22, flooding in the MDB led to substantial increases in River Murray flows, which culminated in annual barrage discharge of 16,259 GL—the annual highest inflow since the 1970s. Over the last five years, daily discharge has been highly variable with peaks occurring at different times in different years (Figure 1-2). Daily flows were considerably higher during 2021/22, with serval peaks >35,000 $ML.day^{-1}$.

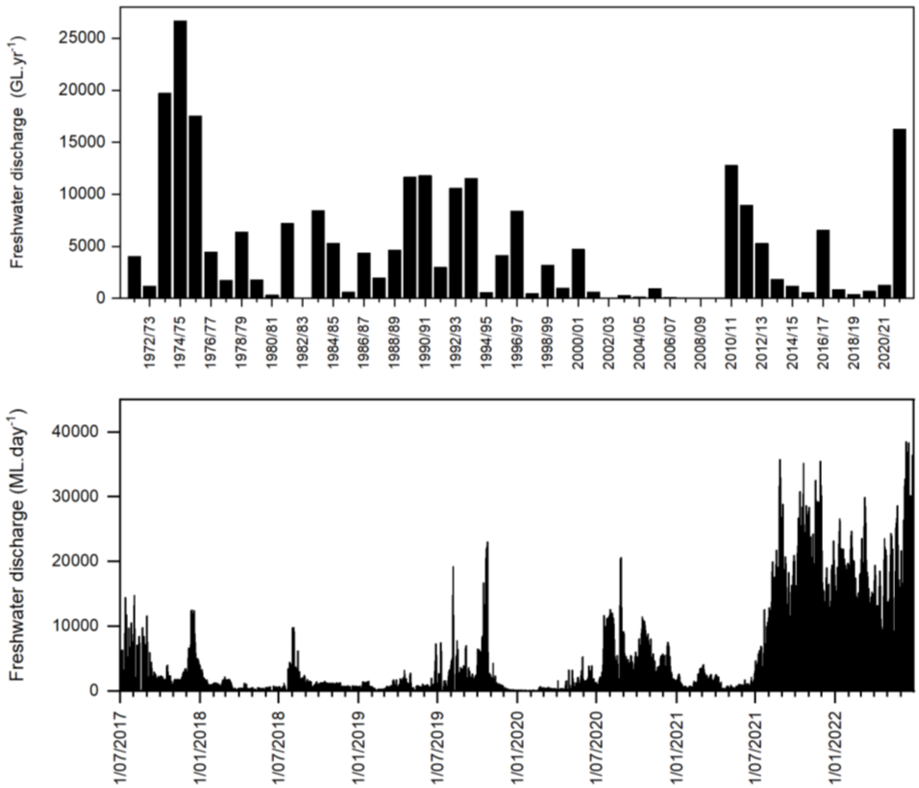

Figure 1-2. Freshwater flows across the barrages to the Coorong: (top) by financial year from July 1971 to June 2022, based on the estimates of the regression-based Murray hydrological model (MDM, BIGMOD, Murray-Darling Basin Authority); and (bottom) by day for the five-year period from 2017/18 to 2021/22, calculated by the Department for Environment and Water (DEW).

1.4 MANAGEMENT ARRANGEMENTS

The LCF is managed by the South Australian Government's Department of Primary Industries and Regions (PIRSA) Fisheries and Aquaculture in accordance with the legislative framework provided in the *Fisheries Management Act 2007*, and subordinate *Fisheries Management (General) Regulations 2017*, *Fisheries Management (Lakes and Coorong Fishery) Regulations 2009*, licence conditions and Management Plan. It is managed as a limited entry fishery. There are 36 licences with non-exclusive access within the Lakes and Coorong system and the adjacent beaches along the Sir Richard and Younghusband Peninsulas. Fishing effort is limited through gear entitlements, with each licence endorsed for the type and number of devices that can be used, and TACE is applied to gillnet fishing for finfish in the Lower Lakes and Coorong. Owner-operator provisions and a range of output controls also apply, including a legal minimum length (LML) for most species and quota management for Pipi.

The Management Plan provides a strategic policy framework for managing the fishery and an overview of the management changes that have occurred over the last four decades (PIRSA 2022). In 1984, licence amalgamations were permitted under the Scheme of Management introduced to promote economic efficiency by allowing fishers to rationalise individual gear entitlements from within the existing pool of licences. In 1990, following an agreement between PIRSA and the commercial industry, a policy directive was introduced to formalise a set of guidelines on licence amalgamations and transfers. A key element of the policy was the limitation placed on the amount of gear that may be endorsed on an individual licence upon transfer or amalgamation. Specific arrangements apply to licence transfers between members of a family. All applications for licence transfer or amalgamation must be considered in accordance with the *Fisheries Management (Lakes and Coorong Fishery) Regulations 2017.* This 'amalgamation scheme' has allowed for limited structural adjustment of the commercial sector by reducing the number of licences and the amount of gear operating in the fishery.

The recreational fishery is not licenced but is 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 protection of some species.

1.5 HARVEST STRATEGIES

The Management Plan includes harvest strategies for finfish and Pipi which provide strategic and transparent frameworks to guide annual management decisions on commercial harvesting (PIRSA 2022). The finfish harvest strategy defines the process for setting the annual TACE for each of three gillnet sectors of the fishery, which collectively account for around 98% of all finfish catches each year. The three sectors are: (i) estuarine large-mesh gillnet (ELMGN); (ii) estuarine small-mesh gill net (ESMGN); and (iii) freshwater large-mesh gill net (FLMGN).

Environmental conditions associated with river flows affect the distribution, abundance and availability of fish species targeted in the LCF. The finfish harvest strategy differs to traditional harvest strategies because it aims to manage the sustainable harvest of key species relative to the condition of environment within which the fishery operates, which is linked to the availability of the fished resources (Knuckey et al. 2015). It uses a combination of environmental (primary) and biological (secondary) performance indicators and decision rules to inform setting of the annual TACE for each sector. These performance indicators and associated reference points are not linked to classifications of stock status used in the NFSRF (Piddocke et al. 2021).

The primary environmental performance indicator for each finfish sector is: (i) ELMGN - suitable habitat available (%) for Mulloway in the Coorong Estuary; (ii) ESMGN – suitable habitat available (%) for Yelloweye Mullet in the Coorong Estuary; and (iii) FLMGN - mean annual water level (m) in the Lower Lakes. For key species in each sector, a secondary biological performance indicator based on non-standardised annual targeted catch per unit effort (CPUE) is used to monitor fishery performance. In this report, estimates of the environmental and biological performance indicators are provided for the 2022/23 reporting year (1 February 2022–31 January 2023) and 2022 calendar year, respectively, to ensure that the most up-to-date information is available to inform the setting of the TACE for each finfish sector for the 2023/24 financial year (PIRSA 2022).

The current harvest strategy for Pipi outlines the process for setting the annual total allowable commercial catch (TACC) (PIRSA 2022). The harvest strategy uses performance indicators and decision rules to inform setting of the annual TACC. The biological performance indicators used in the harvest strategy are: (i) fishery-independent mean annual relative biomass (primary performance indicator), and (ii) presence/absence of pre-recruits in size-frequency distributions (secondary performance indicator) (Ferguson and Ward 2014; Ferguson et al. 2015; Ferguson and Hooper 2021).

1.6 STOCK STATUS CLASSIFICATION

A national stock status classification system has been developed for the consistent 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 spawning stock abundance is not reduced to a point where the production of juveniles and subsequent and recruitment to the fishable biomass is impaired. The system combines information on both the current stock size and the level of catch into a single classification for each stock against defined biological reference points. Each stock is then classified as either: 'sustainable', 'depleting', 'recovering', 'depleted' or 'undefined' (Table 1-1). PIRSA has adopted this classification system to define the status of South Australian fish stocks.

Table 1-1. 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.	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

2 FISHING FLEET DYNAMICS

2.1 INTRODUCTION

The dynamics of a fishing fleet are a product of a series of decisions made by the fishers that relate to when and where to fish, what gear to use and what species to target. These decisions can be influenced by a range of factors such as the abundance of the target species, environmental conditions, management arrangements, markets, and other socio-economic considerations. For multi-species, multi-gear fisheries such as the LCF, understanding the dynamics of the fleet is an important first step toward assessing the status of the fish stocks they exploit. Understanding how fishing effort is directed among target species in particular areas over time is important for interpreting trends in fishery catch and effort data (Hilborn and Walters 1992).

This section of the report provides an overview of the fishery by examining trends in catches, effort, gear use, fishing areas and seasonality from 1 July 1984 to 30 June 2022. This summary explains the dynamic and complex nature of this fishery over different spatial and temporal scales and provides context for the assessments of stock status for individual species in subsequent sections of this report.

2.2 METHODS

The LCF is divided into 13 fishery blocks for the purpose of data reporting and monitoring of commercial fishing activity (Figure 1-1). All fishers are required to log their daily fishing activities by recording specific details such as the reporting block fished, species targeted, species caught, weight of each species caught, gear type used, and for gillnet fishing, the number of gillnets used. These daily catch and effort data have been collected by LCF fishers since 1 July 1984 and are submitted monthly to SARDI Aquatic and Livestock Sciences where they are entered into the LCF Information System. This database is routinely reviewed and cross-checked in accordance with quality assurance protocols (Vainickis 2010). The current database is a compilation of catch and effort data collected from 1 July 1984 to the present and provides the primary source of data used for the assessments of status in this report.

Daily catch and effort data were extracted from the LCF Information System for the 38-year period from 1 July 1984 to 30 June 2022. These data were aggregated to provide annual totals of catch (tonnes) by species, and targeted effort by species, gear, month and location, for each financial year from 1984/85 to 2021/22. These aggregations of data enabled analysis of the major trends in fisher behaviour and fleet dynamics for the fishery.

2.3 RESULTS

2.3.1 Trends in the number of active licences

There has been a 21% decline in the number of active fishers licensed to operate in the fishery over the past 38 years, declining from 42 licences in 1984/85 to 33 licences in 2021/22 (Figure 2-1). Since 1992/93, the number of active fishers has varied between 33 and 36 licences each year.

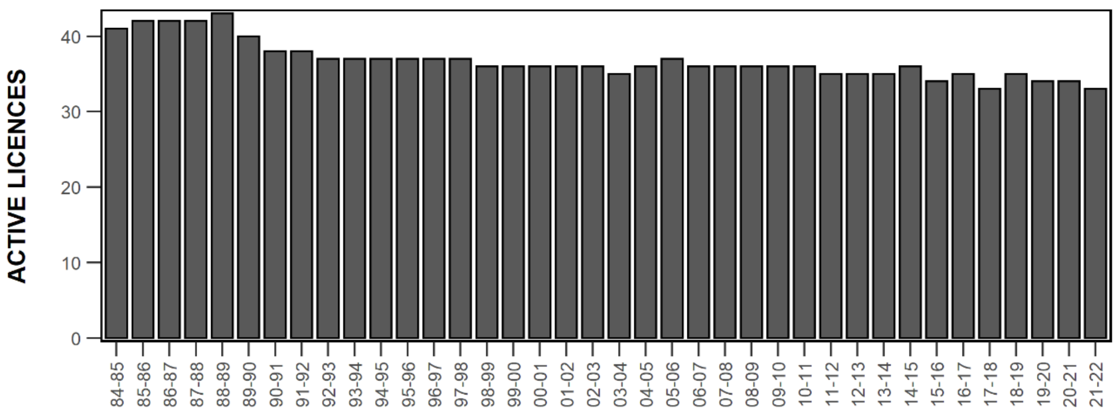

Figure 2-1. Long-term trend in the number of active licence holders that have access to the LCF.

2.3.2 Trends in commercial catch

Since 1984/85, there have been considerable changes in the composition of the commercial catches, which have contributed to high interannual variation in fishery production (Figure 2-2). This variation is mainly attributable to variation in catches of the primary species, which have consistently made up 65–85% of total annual production since the early 1990s. Most of the remaining catch in each year has comprised secondary species, with their contribution declining from >50% in the 1980s to 10% in the early 2000s. In 2021/22, the total catch of 1,492 t was dominated (73.2%) by the five primary species, with the secondary (24.7%), tertiary (0.2%) and other species (1.9%) making up the remainder.

Total catch of the primary species has varied cyclically over time, with three notable peaks since 1984/85. The highest peak of 2,101 t was recorded in 2005/06, with two smaller secondary peaks of 1,771 t and 1,561 t recorded in 1993/94 and 2019/20, respectively (Figure 2-2). In 2021/22, total catch of the primary species was 1,092 t. Among the primary species, catches of Carp (mean: 39%; range: 16–63%) and Pipi (37%; 5–62%) have consistently accounted for most of the annual catches since 1984/85, with smaller and variable contributions from Yelloweye Mullet (14%; 6–38%), Golden Perch (6%; 1–12%) and Mulloway (5%; 2–9%).

Total annual catches of the secondary and tertiary species peaked at 1,177 t in 1989/90, with 98.3% of that attributable to Bony Herring, and smaller contributions from the secondary species Black Bream (0.9%) and Greenback Flounder (0.3%, Figure 2-2). Since then, total catches have been considerably lower, reflecting lower catches of Bony Herring. In 2021/22, the total catch of 369 t comprised Bony Herring (87.4%), Black Bream (1.3%), Greenback Flounder (2.2%) and the tertiary species, Western Australian Salmon (*Arripis truttaceus,* 2.7%). No catches of the other tertiary species, Snapper and Australian Herring were reported in 2021/22.

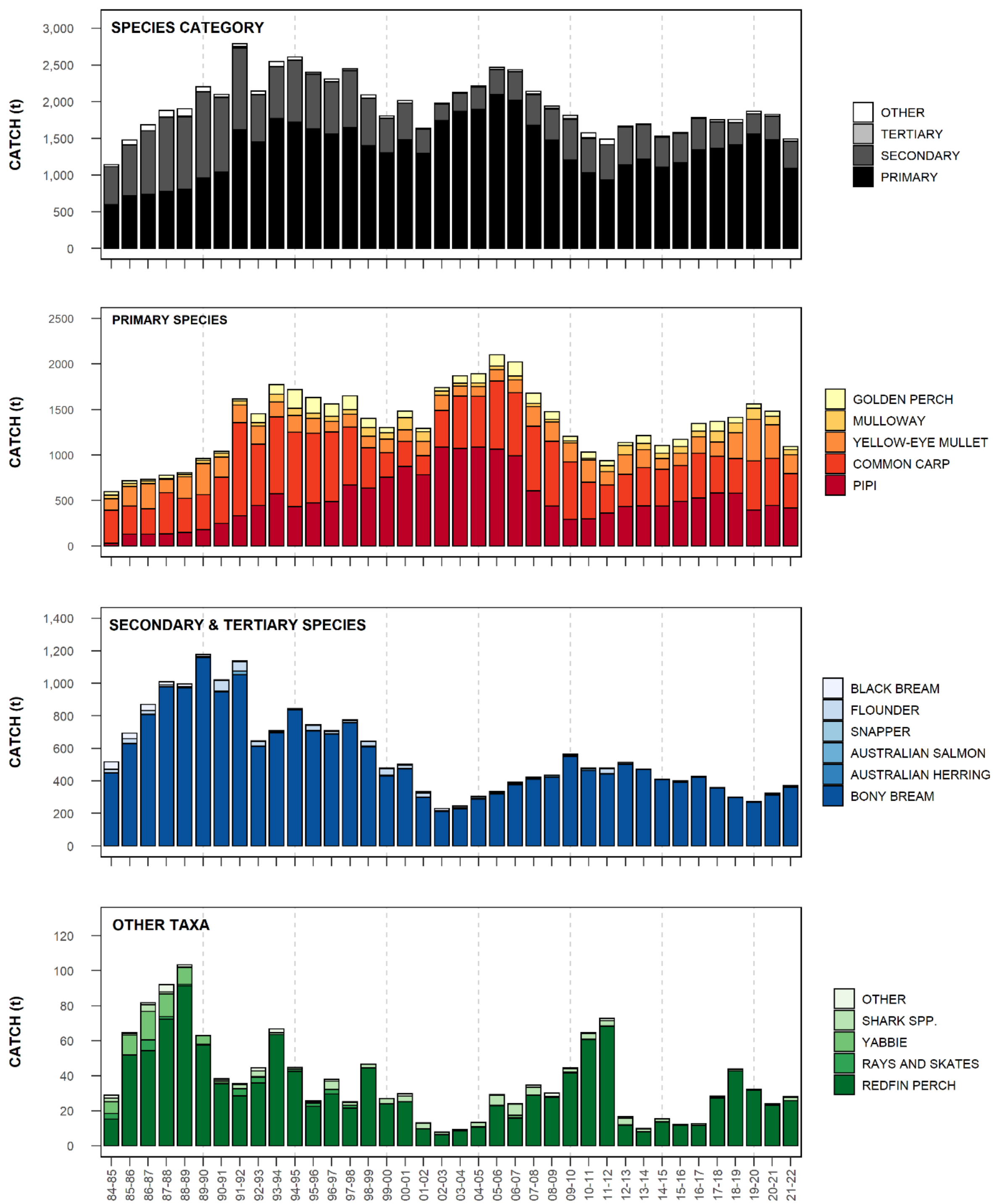

Figure 2-2. Long-term trends in total catch (t) in the commercial LCF from 1984/85 to 2021/22, presented by species category, primary species, secondary and tertiary species, and all other permitted taxa/species.

Annual catches of all other permitted LCF species peaked at 103 t in 1988/89, with a secondary smaller peak of 72 t in 2011/12 (Figure 2-2). Among the "other" species that have contributed to the commercial harvest since 1984/85, Redfin Perch have dominated catches, accounting for 79–98% of annual catches of species/taxa in this group. A summary of total annual catches for twelve LCF species from 1984/85 to 2021/22 is shown in Appendix 1.

2.3.3 Trends in commercial fishing effort

2.3.3.1 Species

Annual estimates of total fishing effort in the LCF peaked at 10,081 fishing days in 1988/89 (Figure 2-3). This peak represented a 17% increase in annual effort since 1984/85, after which, there was a 40% reduction in effort to 6,024 fishing days in 2010/11. This decline occurred over a long period, although a substantial annual reduction occurred in early 2000s coinciding with onset of the Millennium Drought, when large areas of the Coorong Estuary became increasingly uninhabitable for fish due to persistent hypersaline environmental conditions associated with a lack of freshwater inflows from the River Murray (Webster 2010). In the last decade, annual effort increased to 7,573 fishing days in 2014/15 and then steadily declined to a low of 5,083 fishing days in 2021/22, with 78% (3,971 fishing days) of the effort being targeted to a particular species.

Of the reported targeted effort (i.e., effort that was targeted at a particular species) since 1984/85, the primary species have consistently accounted for the highest proportion (mean: 90%, range: 75–99%), of which Yelloweye Mullet and Golden Perch have historically dominated (Figure 2-3). During the 1980s, Yelloweye Mullet and Carp accounted for the largest proportions of the targeted effort among the primary species. There was a shift in fleet dynamics during the early 1990s, as fishers directed some of their effort from Yelloweye Mullet and Carp towards Golden Perch and Mulloway. The relative proportion of effort targeted towards Pipi also increased during the 1990s and was highest during the mid-2000s. Over the past three years, the relative proportions of effort directed toward Yelloweye Mullet and Pipi have increased, while those for Mulloway and Golden Perch have declined.

Prior to 1992/93, the secondary species attracted up to 21% of the total fishing effort in some years, most of which was directed toward Bony Herring, Black Bream and Greenback Flounder (Figure 2-3). Of these species, Bony Herring and Black Bream accounted for most of the targeted effort during the 1980s, before there was a distinct shift in fishing activity in 1990/91 toward Greenback Flounder during the 1990s. Since then, targeted fishing for secondary species has been variable and accounted for < 5% of total effort in most years. The recent variation is largely due to changes in targeting of Greenback Flounder, as targeting of Bony Herring has been stable and targeting of Black Bream has been negligible in most years. Most of the remaining targeted effort in the fishery over the last 38 years has been directed toward Redfin Perch.

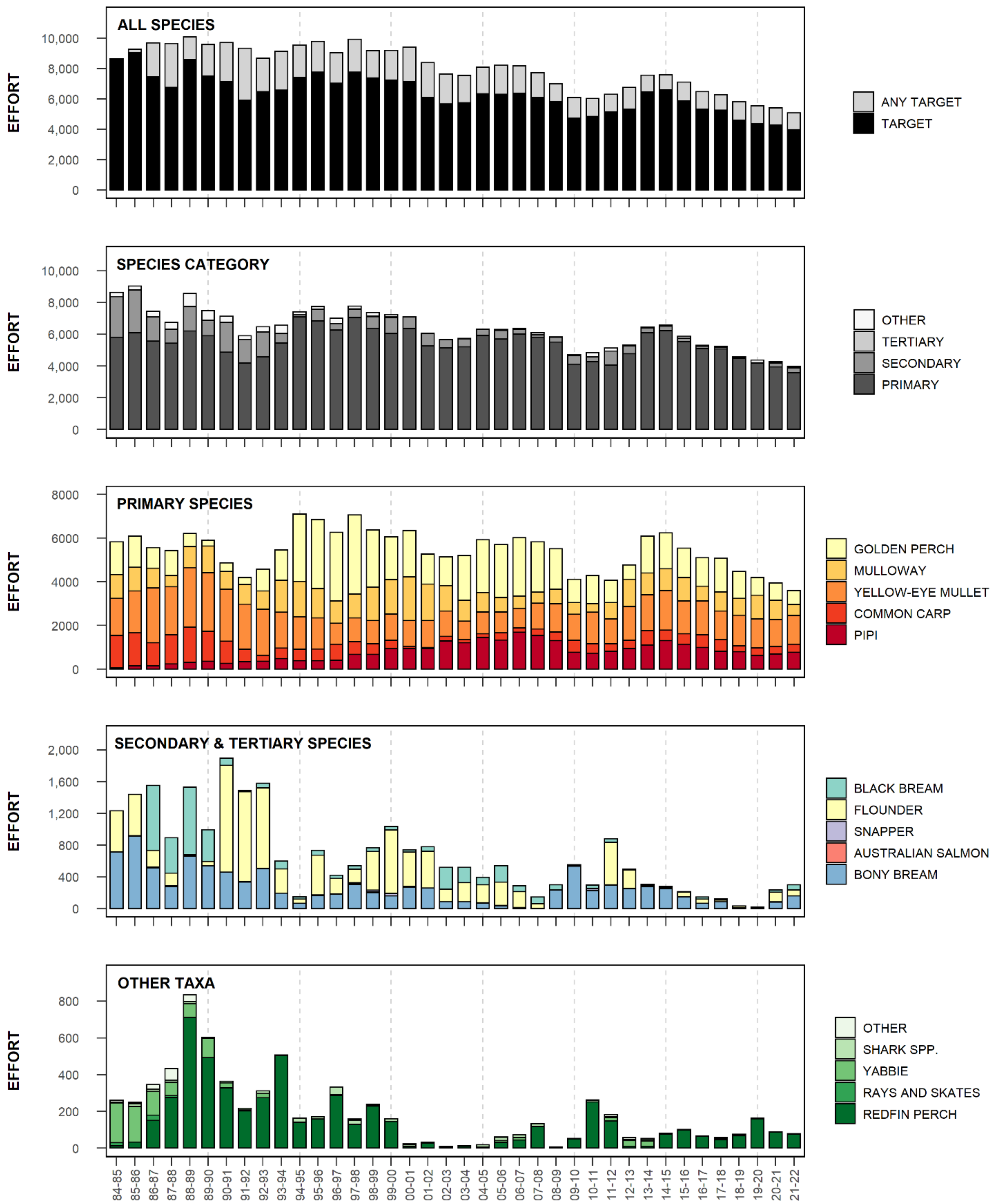

Figure 2-3. Long-term trends in total effort (fishing days) in the LCF from 1984/85 to 2021/22 presented by targeted and non-targeted ('any target') effort (top graph), and targeted effort by species category, primary species, secondary and tertiary species, and all other permitted species.

2.3.3.2 Gear

Large-mesh gillnets have consistently been the dominant gear type used in the fishery, accounting for 56–82% of the total fishing effort each year (57% in 2021/22) (Figure 2-4). Small-mesh gillnets have been the second most used gear type since 1984/85 (25% in 2021/22). The relative use of cockle rakes steadily increased from < 3% during the 1980s to 20% in 2006/07 before stabilising at 12–15% during the last decade (15% in 2021/22). Swinger nets have accounted for most of the remaining fishing effort in the fishery, with negligible contributions from hauling nets, drum nets and yabbie pots.

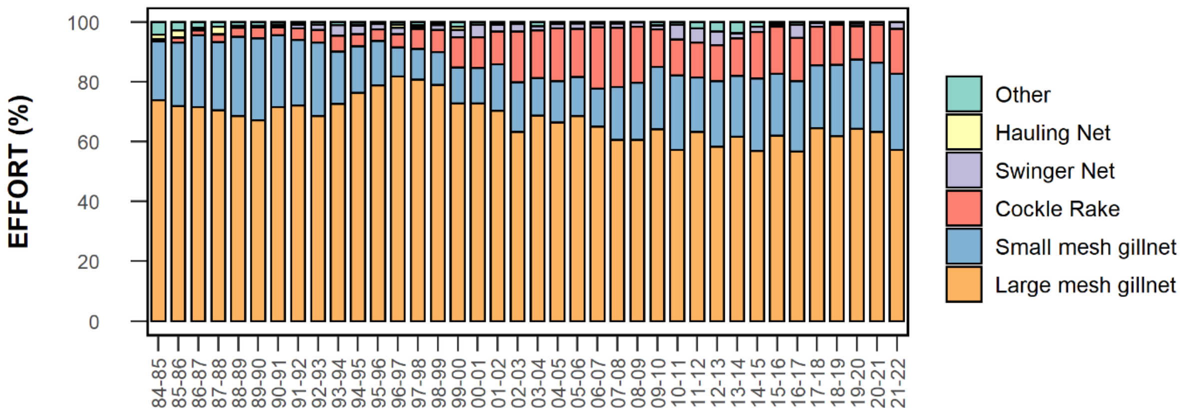

Figure 2-4. Gear usage (% of total fishing effort in fishing days) within the LCF.

2.3.3.3 Season

The multi-species, multi-gear nature of the LCF provides fishers with flexibility in terms of the species they can target at different times of the year (Figure 2-5). Among the five primary species over the last five years, Yelloweye Mullet was targeted throughout the year although average monthly targeted effort was highest during the cooler months, peaking at around 125 days per month during June–September. Targeted effort for Mulloway was highest in late spring, peaking at 145 fishing days in November. There was minimal seasonality in the targeted effort data for Golden Perch. Fishing effort for Pipi was highest during January–March, which is when weather conditions are typically most favourable for targeting the species, while Carp were targeted all through the year.

For the secondary species, fishing for Greenback Flounder was seasonal with around 70% of targeted effort occurring from January to April (Figure 2-5), while targeted fishing for Bony Herring was generally limited to between August and January. Targeted effort for Black Bream was highest in January and June, with lower levels of targeting from September to December likely due to the Black Bream fishery closure during these months in the 2018/19, 2019/20 and 2021/22 fishing seasons. Targeted fishing for Black Bream was also low from February to May.

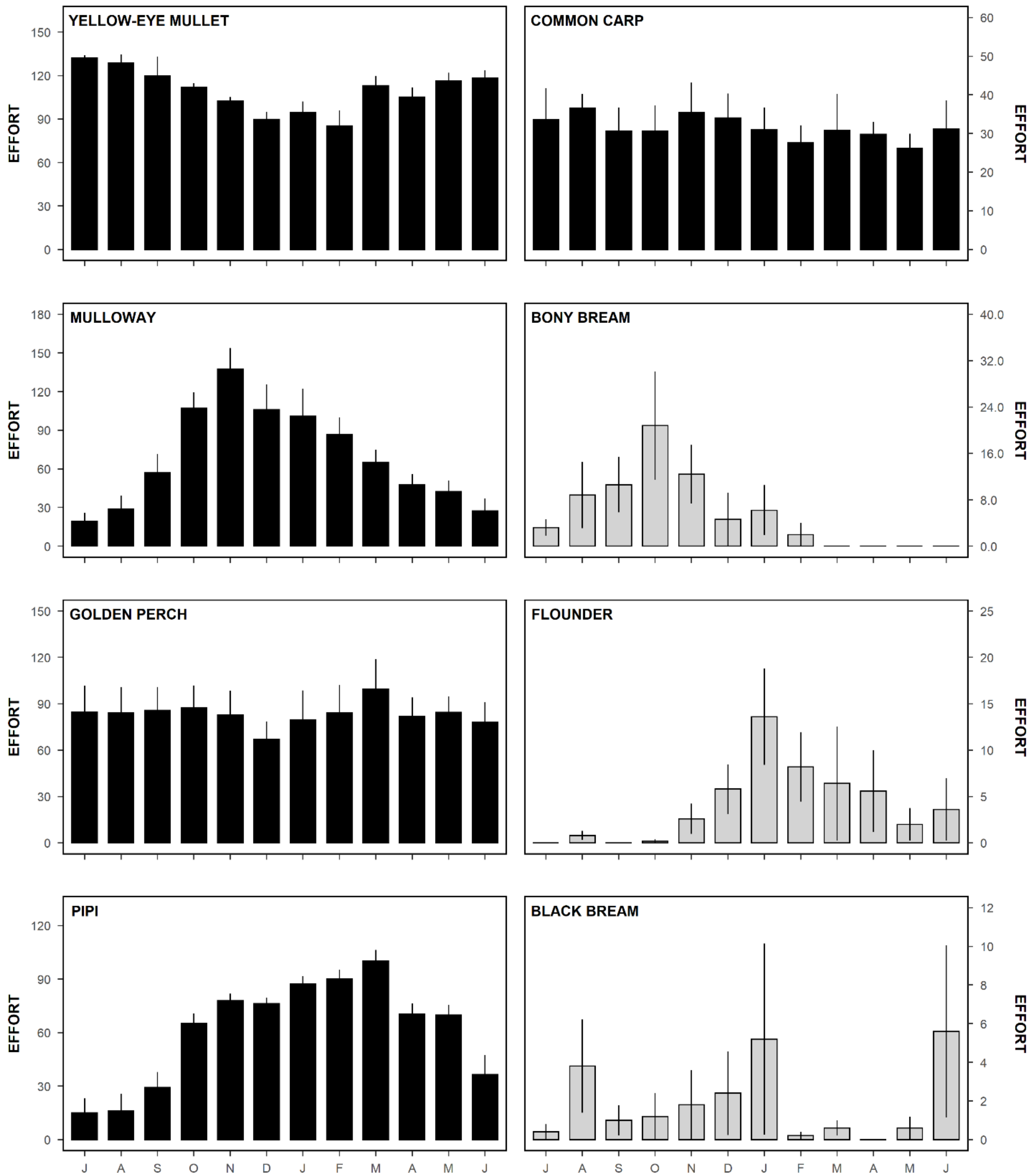

Figure 2-5. Monthly pattern of targeted fishing effort (fishing days averaged, ± se) averaged over the five-year period from 2017/18 to 2021/22 for each species/taxon assessed in this report. The different shades denote species category; primary (black) and secondary (grey).

2.3.3.4 Location

During the mid-1980s, the spatial distribution of fishing effort in the LCF was largely limited to the Lower Lakes (blocks 4, 5) and Coorong Estuary (blocks 6–12), with low levels of fishing along the adjacent ocean beaches (blocks 15, 16) (Figure 2-6). During this time, effort was highest in Lake Alexandrina (block 4) with moderate levels of targeting in the upper estuary (blocks 8–10). During the 1990s and 2000s, there was a progressive increase in fishing activity along the ocean beach of the Younghusband Peninsula (block 16) associated with increased targeting of Pipi, while Lake Alexandrina (block 4) continued to account for most of the effort. During 2004/05–2008/09, there was a contraction of the fishing ground in the Coorong Estuary associated with the Millennium Drought, with lower effort in the south lagoon (blocks 12–14). Increased river inflows in 2010/11 led to improved environmental conditions in the estuary and a subsequent expansion of the fishing ground into southern areas of the south lagoon. The low levels of fishing effort across the fishery during 2019/20–2021/22 (Figure 2-3) reflected lower effort in Lake Alexandrina and the Coorong's South Lagoon, compared to the preceding five-year period.

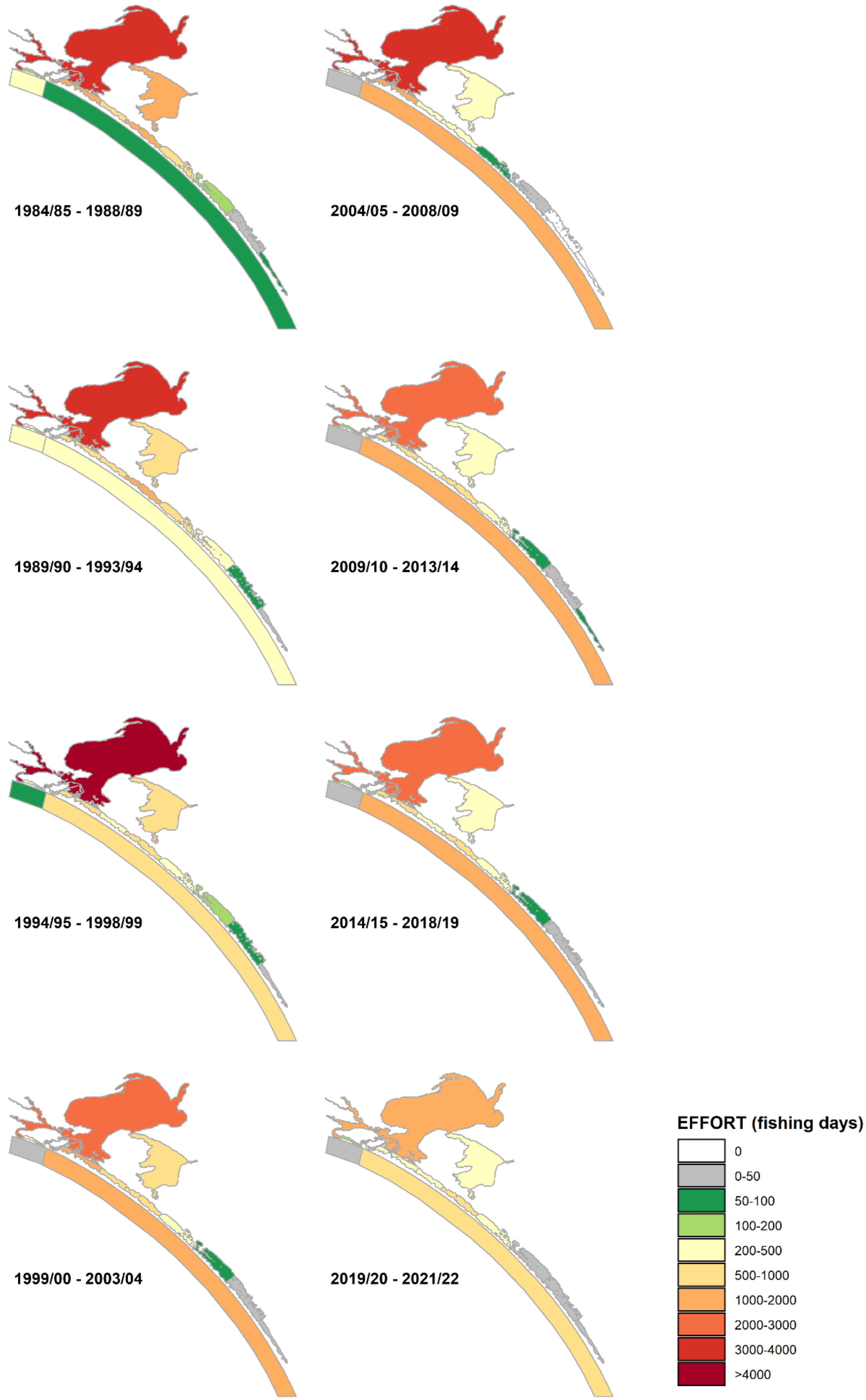

Figure 2-6. Spatial and temporal distribution of annual fishing effort (fishing days) in the LCF averaged over five-year periods from 1984/85 to 2018/19, and for the three-year period from 2019/20 to 2021/22.

2.4 DISCUSSION

The dynamics of the LCF fleet have changed considerably over the last 38 years with most of the changes relating to market shifts and environmental conditions. While the primary species have consistently accounted for most of the reported targeted effort in the fishery over that time, the most obvious changes in fisher behaviour have related to shifts in targeting among the primary species.

In the late 1980s, a large proportion of the fleet's targeted effort was directed to Yelloweye Mullet, Mulloway and Carp. These primary species continue to be key targets for the fishery, with Yelloweye Mullet and Mulloway sold for human consumption, and Carp primarily supplied as bait to local Rock Lobster fisheries, with small volumes sold for human consumption. During the 1990s, there was an increase in targeting of Golden Perch, and this species is now a primary target for the fishery due to its high wholesale value for human consumption compared to other species targeted by the fishery (EconSearch 2022). There was also a substantial increase in targeting of Pipi during the 1990s and 2000s, when most of the catch was supplied as relatively low-value product to the bait market. The introduction of a TACC under a quota management system for Pipi in 2007/08 has effectively constrained commercial harvest since 2009/10 (Ferguson and Hooper 2021), and since then, the fishery has increased its proportionate supply of Pipi for human consumption which has subsequently increased its wholesale market value.

Environmental conditions associated with freshwater inflow from the River Murray have a major influence on the function and productivity of the Lakes and Coorong ecosystem, including the abundance and distribution of most of the species that support the LCF. Since 1984/85, there have been several key environmental events that have resulted in Lakes and Coorong fishers modifying their fishing activities to optimise fishery production. For example, during the Millennium Drought (between 2002 and 2010), a lack of freshwater inflows resulted in the intensification of a longitudinal salinity gradient in the Coorong Estuary where extremely high salinities (>140 ppt) in parts of the south lagoon made it uninhabitable for fish. Consequently, the fishable area (i.e., the area that supported commercially important fish species) in the estuary contracted considerably, with fishing effort all but withdrawn from the south lagoon and becoming confined to areas adjacent the Murray Mouth and the upper north lagoon. This spatial contraction of the fishery reflected reductions in the amount of suitable estuarine habitat for Mulloway, Flounder, Yelloweye Mullet and Black Bream.

In contrast, a flood event in 2010/11 led to reduced salinities in the lower north lagoon and upper south lagoon and re-opening of fish habitat in these areas, and fishing activity in these areas has since resumed. These environmentally driven changes in fisher behaviour, along with the day-to-day behavioural responses of fishers to other factors such as markets, management changes, weather, and the presence of Long-nosed Fur Seals since 2010 (EconSearch 2022; Earl et al. 2021), highlight the dynamic and adaptive nature of the LCF fleet.

3 MULLOWAY STOCK ASSESSMENT

3.1 INTRODUCTION

3.1.1 Overview

This section of the report provides a stock assessment for Mulloway in the LCF, which builds on previous stock assessments completed in 2003, 2011, 2014 and 2020 (Ferguson and Ward 2003; Ferguson and Ward 2011; Earl and Ward 2014; Earl 2020), and recent assessments of stock status in 2021 and 2022 (Earl and Bailleul 2021; Earl et al. 2022). It provides a synopsis of information available for this species and an assessment of the current status of the fishery, based on: (i) commercial fishery catch and effort statistics from 1 July 1984 to 30 June 2022; (ii) results from State-wide recreational fishing surveys undertaken in 2000/01, 2007/08, 2013/14 and 2021/22 (Henry and Lyle 2003; Jones 2009; Giri and Hall 2015; Beckmann et al. 2023); (iii) information on the size and age of Mulloway taken by the LCF to inform on population structure and recruitment; and (iv) information on the condition of the environment in which the estuarine component of the LCF for Mulloway operates against reference points defined in the Management Plan (PIRSA 2022).

3.1.2 Biology

Mulloway (*Argyrosomus japonicus*) is a member of the Sciaenidae family (Gomon et al. 2008). It is broadly distributed throughout the Indo-Pacific region, including Australia where it occurs from the Gascoyne region on the west coast of Western Australia, around the southern coasts of the continental mainland, and up to the Wide Bay–Burnett region on the east coast of Queensland (Kailola et al. 1993). Within this distribution, Mulloway occur in bays, tidal creeks, estuaries and marine waters to depths of at least 100 m. In South Australia, juveniles are abundant in the Coorong Estuary, while larger Mulloway are common in exposed marine habitats, such as surf beaches.

Mulloway has a complex life-history that involves ontogenetic changes in habitats that are linked by movement at different life history stages (Ferguson et al. 2014). In South Australia's southeast, temporal analysis of gonadosomatic indices indicated that Mulloway has a prolonged spawning season that extends from October to January. Previous studies have suggested that spawning occurs in aggregations that form during spring/summer in the marine waters near the Murray Mouth (Hall 1986; Ferguson et al. 2008, 2014). Young juveniles then enter the Coorong Estuary when environmental conditions are favourable and utilise estuarine habitat as juveniles, before returning to the marine environment as 4–6-year-olds. Such movement results in a significant ontogenetic shift from protected estuarine habitats to more exposed marine habitats. As a result, population size and age structures vary among habitats. The Coorong Estuary generally supports a population with only a few young age classes, whereas the population in the adjacent marine environment generally involves multiple age classes of larger, older fish and has included individuals up to 41 years old (Ferguson et al. 2014; Earl 2020). The estimated length-at-50%-maturity (L_{50}) for Mulloway in South Australia is 850 mm total length (TL) for females and 778 mm TL for males, which is equivalent to the mean age of approximately 6 years and 5 years, respectively (Ferguson et al. 2014).

Biological stock structure for Mulloway in Australia is uncertain. It has been suggested that a single panmictic population occurs in Australia (Archangi 2008), but this is not supported by more recent studies that suggested sub-structuring between populations in New South Wales, South Australia and Western Australia (Ferguson et al. 2011; Barnes et al. 2016). These recent studies suggested that two stocks occur in South Australia. The eastern stock occupies marine and estuarine waters of the State's south-east including the Coorong Estuary and coastal waters along the Younghusband Peninsula, while the western stock occurs on the State's far west coast and may have some association with populations in southern Western Australia (Barnes et al. 2016). While there is evidence that fish in Gulf St Vincent may be part of the eastern stock and fish in Spencer Gulf may be part of the western stock, further research is required to confirm biological stock delineation for the species in South Australia. This assessment of stock status is undertaken at the management unit level–the LCF.

3.1.3 Fishery

Mulloway is a significant inshore species for multiple Australian fisheries across Western Australia, South Australia, New South Wales and Queensland (Kailola et al. 1993). Historically, the national commercial catch for this species has been dominated by that from South Australia, with moderate contributions from New South Wales and small contributions from Western Australia and Queensland (Earl et al. 2021b). Mulloway is also a popular target amongst recreational fishers in these States, as well as Victoria (Henry and Lyle 2003).

In South Australia, Mulloway is heavily targeted by commercial and recreational fishery sectors (PIRSA 2022; Beckmann et al. 2023). Several life history stages are targeted: juveniles in the Coorong Estuary; and mature adults in nearshore marine waters across the State, including near the Murray Mouth, the south-east and on the far west coast (Earl and Ward 2014; Rogers et al. 2014). As such, during their ontogenetic development the fish run the gauntlet of fishing lines and mesh nets that are used by both sectors to target them in different habitats. Because of this, South Australia's fishery for Mulloway can currently be described as a 'gauntlet' fishery (Smith 2013).

In the commercial sector of the LCF, fishers target juvenile Mulloway using large-mesh gillnets in the Coorong Estuary, while adults are targeted using swinger nets in the adjacent marine environment. Three other South Australian commercial fisheries have limited access to Mulloway: Marine Scalefish Fishery (MSF); Northern Zone Rock Lobster Fishery (NZRLF) and Southern Zone Rock Lobster Fishery (SZRLF), although catches from these sectors are relatively low and not considered in this report. For the recreational sector, Mulloway is an iconic species that is targeted using rod and line mainly from shore (Beckmann et al. 2023).

3.1.4 Harvest strategy

The Management Plan includes a harvest strategy for finfish (PIRSA 2022). The harvest strategy uses environmental (primary) and biological (secondary) performance indicators, reference points and decision rules to inform setting of the annual TACE for the three finfish sectors, as defined in Section 1.4. Mulloway is the primary target species in the ELMGN sector. The environmental performance indicator for the ELMGN sector, the amount (%) of suitable habitat available for Mulloway in the Coorong Estuary, was developed as a surrogate metric for fishable biomass of Mulloway in the Coorong Estuary (Knuckey et al. 2015). The biological (secondary) performance indicator for Mulloway, non-standardised annual targeted catch per unit effort (CPUE) using large-mesh gillnets, is used to monitor fishery performance. These performance indicators and associated reference points are not linked to classifications of stock status used in the NFSRF (Piddocke et al. 2021).

3.1.5 Management arrangements

The commercial LCF for Mulloway has undergone a number of management changes over the past 38 years that have seen the introduction of general gear restrictions, spatial and temporal restrictions and size limits. The most significant recent change occurred in 2016, when the LML for Mulloway taken in all State waters outside of the Coorong Estuary was increased from 750 to 820 mm TL. This increase was made to ensure that at least 50% of the Mulloway at that size would be sexually mature and had the opportunity to spawn at least once before capture (Ferguson et al. 2014). The LML for Mulloway in the Coorong Estuary was kept at 460 mm TL, which is 54% and 59% of the size-at-maturity for females and males, respectively (Ferguson et al. 2014).

The recreational sector of the LCF is managed through a combination of input and output controls, aimed at ensuring the total catch is maintained within sustainable limits and to ensure that recreational access to the fishery is equitably distributed between recreational fishers (PIRSA 2022). Bag and boat limits apply, which vary geographically and with fish size. In the Coorong Estuary, the daily bag limit is 10 fish for the size range of 460–820 mm TL, and two for fish more 820 mm TL. Boat limits also apply: when three or more people are onboard, the boat limit is 30 fish sized 460–820 mm TL, and six fish for fish above 820 mm. In all waters outside the Coorong, a daily bag limit of two fish, and a boat limit of six fish applies. Management arrangements also comprise general gear restrictions. A small number of registered mesh net owners can also use gillnets to target finfish in the Coorong. The mesh nets must be less than 75 m long with 50–64 mm mesh, and the registered net owner must be within 50 m of the net at all times when fishing. Temporal and spatial closures apply to the use of recreational nets in the region.

3.2 METHODS

The data sources considered in this stock assessment were: commercial fishery statistics; recreational fishery data; annual fishery size and age structures from commercial catch sampling; and estimates of the environmental and biological performance indicators for the ELMGN sector. These data were considered at the management unit scale for the LCF.

3.2.1.1 Fishery statistics

The commercial fishery data for Mulloway were extracted from the commercial Lakes and Coorong Fishery Information System for the 38-year period of 1984/85 to 2021/22. These data were aggregated to provide annual totals of total catch, targeted catch, and targeted effort in financial years. For targeted catch, targeted effort, and CPUE, the two main gear types (large-mesh gillnets and swinger nets) were differentiated. For each of these gear types, CPUE was estimated by dividing annual targeted catch by annual targeted effort in terms of the number of 50-m long gillnets that were deployed (net-days). Effort in fisher days was not considered in this assessment, because it does not account for the variation in the number of nets deployed on each fishing day, which could feasibly vary between 1 and 100 depending on the gear endorsements of a particular licence. Estimates of total catch, by month and reporting block (Figure 1-1), for each of the past 38 years is also presented to describe the fine-scale spatial and temporal trends in fishery production. Estimates of total annual State-wide recreational catches of Mulloway obtained from longitudinal phone surveys undertaken in 2000/01, 2007/08, 2013/14 and 2021/22 (Henry and Lyle 2003, Jones 2009, Giri and Hall 2015, Beckmann et al. 2023) are also presented.

3.2.1.2 Size and age structures

Biological samples for Mulloway were collected in the financial years 2001/02, 2002/03, 2011/12, 2013/14, 2014/15, 2016/17, 2019/20 and 2022/23, from several sources. Samples were available from commercial catches taken using: (i) large-mesh gillnets in the Coorong Estuary; (ii) and swinger nets in the nearshore marine environment along the ocean beaches adjacent the Murray Mouth. Catches were accessed at several locations, including the SAFCOL fish market. Samples from large-mesh gillnet catches were not available from 2011/12, 2014/15 and 2016/17, and were limited in 2022/23 due to a lack of targeted fishing effort in the Coorong Estuary. Additional samples were obtained from recreational catches taken in the nearshore marine environment adjacent the Coorong Estuary along Younghusband Peninsula using rod and line in 2001/02, 2013/14, 2014/15 and 2019/20.

On each sampling occasion, a two-stage sampling protocol was used to process catches. First, as many fish as possible from catches were measured for TL to the nearest mm. From these, a random sub-sample was taken for further biological analysis. The sub-sampled fish were dissected for the removal of their otoliths that were later used to determine fish age using an established ageing protocol

(Earl and Ward 2014). Subsequently, estimates of annual size and age structures were generated. Most fish had been gutted by fishers prior to processing, and so additional biological information (e.g., sex, gonad development) was usually not available.

3.2.1.3 Performance indicators

Two performance indicators were considered in this assessment for Mulloway: the environmental (primary) performance indicator for the ELMGN sector and the biological (secondary) performance indicator, targeted Mulloway CPUE using large-mesh gillnets.

The environmental performance indicator for the ELMGN sector is the amount (%) of suitable habitat available for Mulloway in the Coorong Estuary. Annual estimates of this performance indicator were determined based on: (i) modelled daily salinity for 109 locations, at 1-km increments, along longitudinal gradient of the Coorong Estuary from Goolwa Barrage to Salt Creek (Figure 1-1), as determined by the Coorong Hydrodynamic Model (Webster 2010); and (ii) the salinity tolerance of Mulloway (51 ppt), as determined by McNeil et al. (2013). Specifically, the annual environmental performance indicator values represent the proportion (%) of the mean 109 locations in the Coorong Estuary for which mean annual modelled salinity was below the tolerance threshold of Mulloway. Outputs from the Coorong Hydrodynamic Model were provided by the Water Science and Monitoring Branch, Water and River Murray Division, Department for Environment and Water. For this assessment, a time series of annual performance indicator values was calculated from 1984/85 to 2022/23. The value for the 2022/23 reporting year (1 February 2022–31 January 2023), was compared to the target, trigger and limit reference points from the reference period of 1984/85–2012/13 (PIRSA 2022). A salinity contour graph based on modelled daily estimates of salinity for the 109 locations in the Coorong Estuary is presented to show how the amount of habitat available for Mulloway varied during the 2022/23 reporting year.

The biological (secondary) performance indicator is based on annual targeted CPUE for Mulloway using large-mesh gillnets. For this assessment, a time series of annual CPUE in calendar years from 1985–2022 was calculated. Then, the value for the 2022 calendar year was compared against target, trigger and limit reference points prescribed in the Management Plan (PIRSA 2022).

3.3 RESULTS

3.3.1 Fishery statistics

3.3.1.1 State-wide

Total annual State-wide commercial catches of Mulloway increased from 25.9 t in 1987/88 to an historic peak of 145 t in 2000/01 (Figure 3-1). After this, catches declined steeply to 35.5 t in 2003/04 and then continued to decline through the 2000s to an historical low of 22 t in 2010/11. Since then, catches have been considerably higher, with peaks of 127.3 t and 123.9 t in 2017/18 and 2019/20, respectively. The total catch of 56.1 t in 2021/22 was the lowest since 2010/11.

The commercial LCF has been the main contributor to total annual State-wide catches of Mulloway over the past 38 years, with smaller contributions from the MSF (Figure 3-1). Between 1984/85 and 1993/94, the LCF contributed 53–86% of the total catch each year, and from 1994/95 to 2001/02, its contribution increased to 96%. In 2021/22, the LCF contributed 99% (55.5 t) of the total State-wide commercial catch with the remainder (0.5 t) taken by the MSF.

Estimates of recreational catch for Mulloway in South Australia are available for four years: 2000/01, 2007/08, 2013/14 and 2021/22 (Figure 3-1). The estimated harvested catch of Mulloway was 90.2 t, 61.7 t and 59.5 t in 2001/02, 2007/08 and 2013/14, respectively. In 2021/22, the estimated number of Mulloway captured by recreational fishers in South Australia was 3,720 (standard error ± 1,243) fish. Approximately 49% of the Mulloway caught were released, although the precision around this estimate is poor (Beckmann et al. 2023). The estimated harvested catch of 23.97 t (standard error ± 10.72 based on confidence interval of retained fish numbers for comparison among surveys) in 2021/22, accounted for approximately 30% of the State's combined annual commercial and recreational harvest. Recreational catches were reported from the West Coast, Gulf St Vincent, South East and the Coorong, with 97% of the fish taken in inshore marine waters. The proportion of the total recreational catch taken in the inshore waters adjacent to the Coorong is not known, although a considerable proportion of the catches are likely to have been taken from spring/summer aggregations of Mulloway near the Murray Mouth. There are no catch and effort data for Aboriginal and traditional fishing.

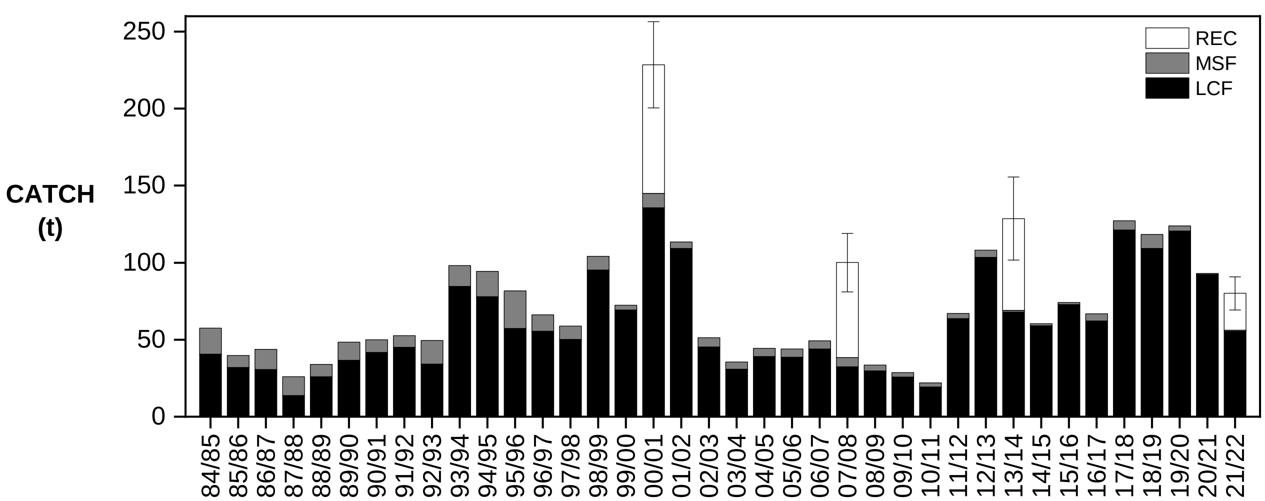

Figure 3-1. State-wide catch of Mulloway from 1984/85 to 2021/22, showing contributions by the Lakes and Coorong Fishery (LCF), Marine Scalefish Fishery (MSF) and the recreational sector for 2000/01, 2007/08, 2013/14 and 2021/22. For comparison among recreational fishing surveys, error bars were recalculated and represent the equivalent of the coefficient of variation of harvested fish numbers.

3.3.1.2 Lakes and Coorong Fishery

Trends in total catch, effort and CPUE

Total annual catches for Mulloway in the LCF increased from 13.8 t in 1987/88 to a peak of 135.7 t in 2000/01 (Figure 3-2). They then fell to 45.4 t in 2002/03 and continued to decline, although at a slower rate, to 19.4 t in 2010/11. This decadal decline in catch was associated with a decline in targeted effort for the dominant gear types – large-mesh gillnets and swinger nets. Since 2010/11, catches have been considerably higher in most years. From 2018/19 to 2020/21, they ranged from 92.3 t to 120.5 t, before declining to 55.5 t in 2021/22.

The main gear type used to target Mulloway has been the large-mesh gillnet (Figure 3-2). On average, targeted catches taken using large-mesh gillnets have accounted for 64% of the annual catch, while those taken using swinger nets along the ocean beaches adjacent the Murray Mouth have accounted for around 13%. The remaining catches have been by-product when other species were targeted. In 2021/22, targeted catches using large-mesh gillnets accounted for 53% (29.5 t) of all catches, while those taken using swinger nets accounted for 33% (18.7 t).

Estimates of mean annual targeted CPUE for large-mesh gillnets ($CPUE_{LMGN}$) have been highly variable since 1984/85 but have increased to record high levels in recent years (Figure 3-2). Catch rates were low during the 2000s before increasing to 5.4 kg.net-day^{-1} in 2011/12. Thereafter, $CPUE_{LMGN}$ increased rapidly and was >9 kg.net-day^{-1} during 2016/17–2018/19 before falling to around 8 kg.net-day^{-1} in 2019/20 and 2020/21. The $CPUE_{LMGN}$ of 7.1 kg.net-day^{-1} in 2021/22 was the sixth highest on record.

Estimates of mean annual CPUE for swinger nets ($CPUE_{SN}$) have also been highly variable and have increased to unprecedented high levels in recent years (Figure 3-2). Since falling to a low of 7.7 kg.net-day^{-1} in 1988/89, it has fluctuated periodically at much higher levels with peaks of between 71–82 kg.net-day^{-1} in the 1990/91, 1998/99, 2007/08 and 2016/17. In 2021/22, $CPUE_{SN}$ increased to its highest peak of 160.3 kg.net-day^{-1}. The interannual trend of annual $CPUE_{SN}$ in kg.net-day was similar to that for $CPUE_{SN}$ in kg.net-hour with both measures of effort linearly related (LR: $r^2 = 0.85$, $F_{1,37} = 199.99$, $p < 0.001$).

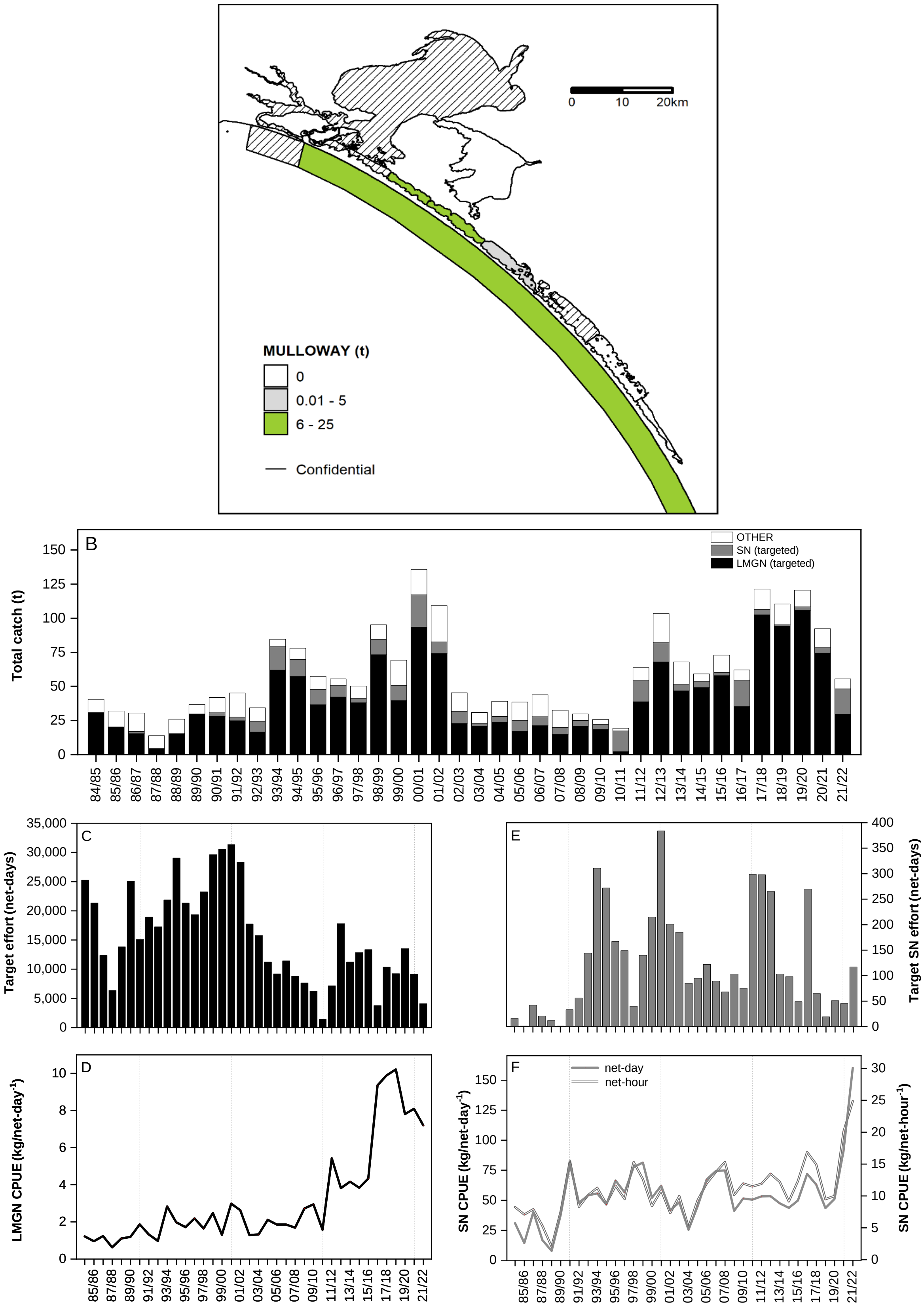

Figure 3-2. Fishery statistics for Mulloway. (A) Map of the LCF reporting blocks showing the catch distribution for 2021/22; long term trends in: (B) total catch, including targeted catch for large-mesh gillnets (LMGN) and swinger nets (SN) and by all other means (OTHER); targeted effort for (C) LMGN and (E) SN; and targeted CPUE for (D) LMGN and (F) SN.

Spatial and temporal trends in catch

Since 1984/85, reporting block 8 (i.e., upper Coorong Estuary) has consistently contributed most to the fishery's annual catches of Mulloway (Figure 3-3). An exception was in 2010/11, when 77% of the catch was taken in reporting block 16 (i.e., along the ocean beach, south-east of the Murray Mouth). This anomaly reflects the low level of targeted fishing effort in the Coorong Estuary in 2010/11 (i.e., the final year of the Millennium Drought), when the amount of suitable habitat in the Coorong Estuary was at an all-time low (Earl 2019). The spatial distributions of catches during 2017/18–2019/20 was also slightly different to that of most years. Reporting block 10 contributed most to the total catches in 2017/18 and 2018/19, while reporting block 9 contributed most to the catch in 2019/20. In 2021/22, 45% of the catch was taken from reporting blocks 8–10, with the highest proportion of catch taken from reporting block 16 (29%) (Figure 3-2). The fishery for Mulloway has been seasonal with the highest catches taken in the warmer months from October to March (Figure 3-3).

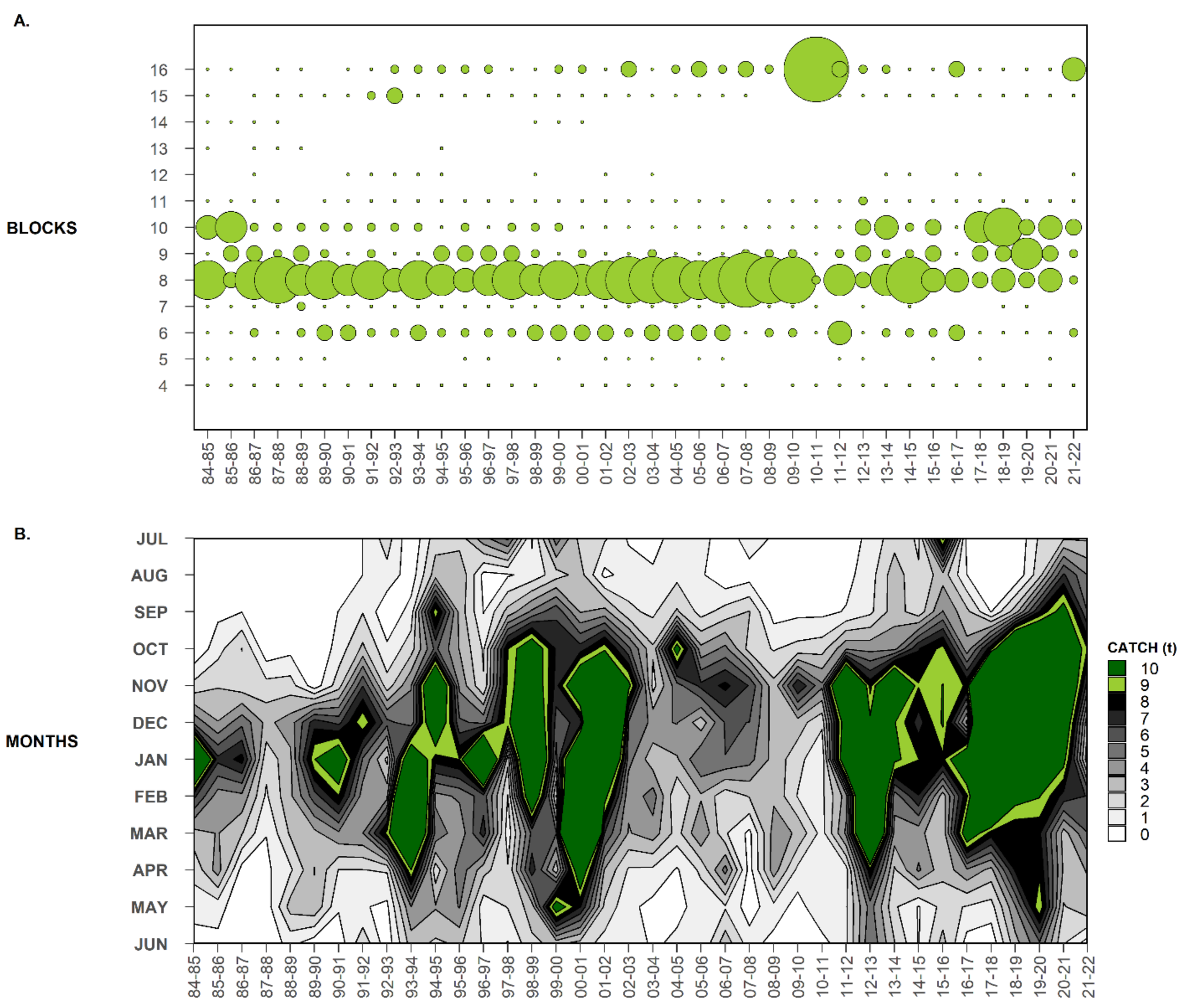

Figure 3-3. Fishery statistics for Mulloway. Long-term trends in (A) the annual distribution of catch among LCF reporting blocks (diameter of the bubbles represent the relative contribution of each reporting block to total catch); and (B) the distribution of catch among months for each year.

3.3.2 Size and age structures

3.3.2.1 Coorong Estuary

Size structures

The annual size structures from large-mesh gillnet catches taken in the Coorong between 2001/02 and 2022/23 were similar, i.e., they generally ranged from the LML of 460 mm TL to around 900 mm TL and were dominated by fish between 500 and 650 mm TL (Figure 3-4). The distribution for 2022/23 comprised a higher proportion of fish ≤550 mm TL compared to the earlier years.

Age structures

Annual age structures from large-mesh gillnet catches taken in the Coorong have generally comprised several juvenile year classes of 2–5 year-old fish, with a strong mode of three year-olds (Figure 3-4). In 2001/02 and 2002/03, the age structures comprised five young age classes and were dominated by three and four year-olds (Figure 3-4). Small proportions of two, five and six year-old fish were also represented. In 2013/14 and 2019/20, ages ranged from 2 to 8 years, with most fish ≤4 years old. The 2022/23 age structure was vastly different. It was dominated by 2-year-old fish which originated from spawning in 2020/21, and included a much lower proportion of fish ≥3 years of age compared to other years.

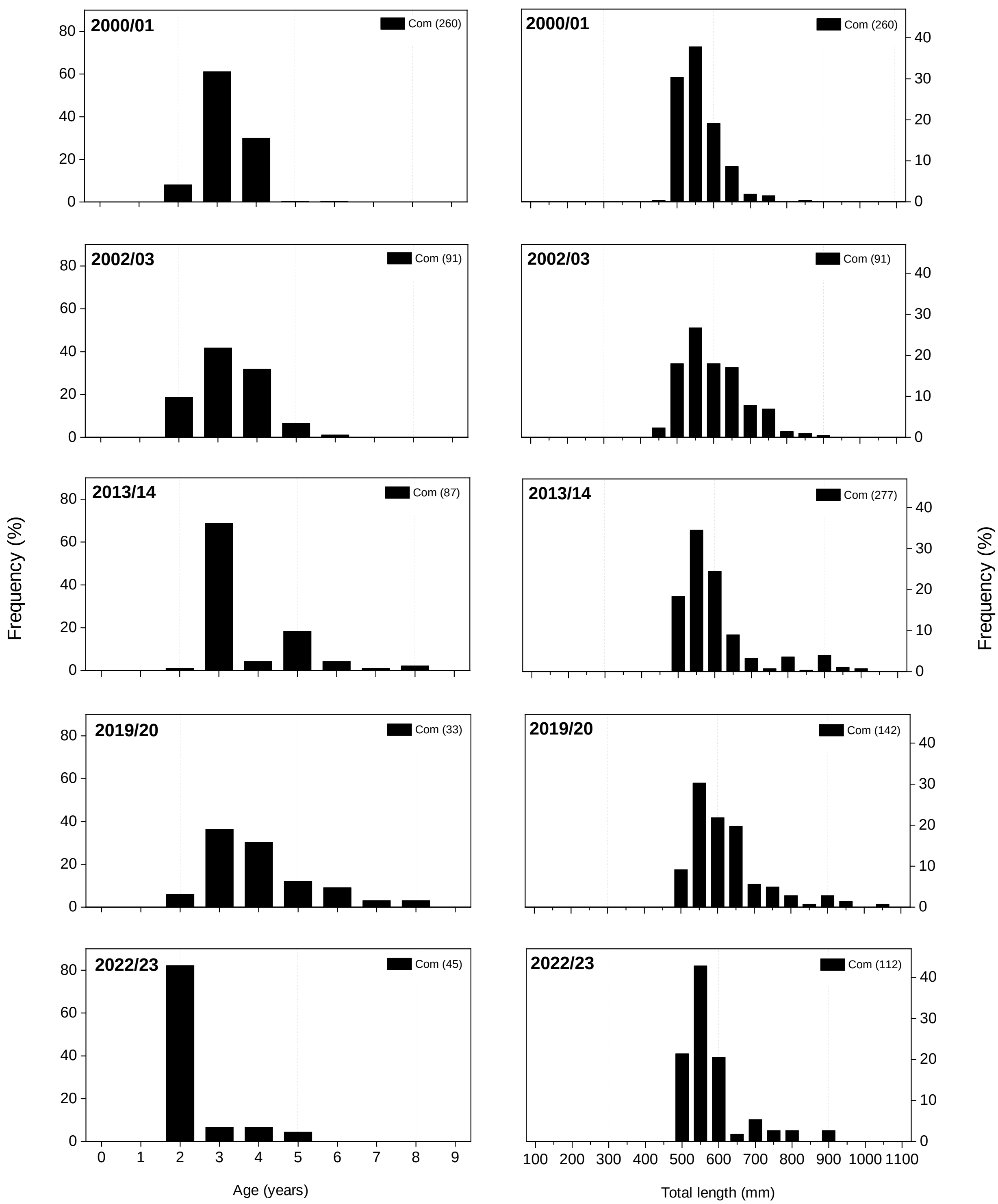

Figure 3-4. Age and size structures for Mulloway from commercial large-mesh gillnet catches taken in the Coorong Estuary in 2000/01, 2002/03, 2013/14, 2019/20 and 2022/23. Left hand graphs show the age structures. The number of fish processed in each year is shown in brackets.

3.3.2.2 Nearshore marine environment

Size structures

The size structures for Mulloway from the nearshore marine environment have varied considerably since 2001/02. For 2001/02 and 2002/03, the size distributions were relatively broad and included fish from the LML of 750 mm TL to 1,400 mm TL (Figure 3-5). For 2011/12 and 2013/14, the lengths of fish sampled were narrowly distributed around a dominant mode of 850 mm TL and 1000 mm TL, respectively, while fish >1050 mm TL were rare. The size distributions for 2016/17 and 2022/23 were broader than those for 2011/12 and 2013/14 and included fish up to 1,450 mm TL. The 2022/23 size structure comprised mostly fish between 850 mm TL and 1,350 mm TL, with a large mode at 950 mm TL and a smaller mode at 1,300 mm TL.

Age structures

The age structure from the nearshore marine environment for 2001/02 involved fish from 4 to 25 years of age, with 8-year-olds (1993/94 year class) dominating the distribution (Figure 3-5). For 2002/03, ages ranged from 5 to 24 years and the 1993/94 year class persisted as 9-year-olds. The age structures for 2010/11, 2013/14, 2014/15, 2016/17, 2019/20 and 2022/23 were similar, in that they comprised mostly 5–10-year-olds, while fish >12 years of age were rare (Figure 3-5). In 2011/12, the age distribution comprised eight relatively young age classes and was dominated by 6 and 7-year-old fish. In 2013/14, the ages were narrowly distributed around a mode comprising mostly 5–7-year-old fish, with no fish >9 years of age present. Catches from 2014/15 comprised fish between 5–11 years, with 86% of individuals between 6–9 years of age. A similar age range was represented in the age structure for 2016/17, which comprised a modal age of 6 years (i.e., 2010/11 year class). In 2019/20, the ages ranged from 4 to 24 years, with 7-year-olds (i.e., 2012/13 year class) dominating (55%) the distribution. The 2022/23 age structure was similar to that for 2019/20 – dominated by 7-year-old fish (i.e., 2015/16 year class), with a smaller mode of 10-year-olds which originated from spawning in 2012/13, and included fish up to 22 years old.

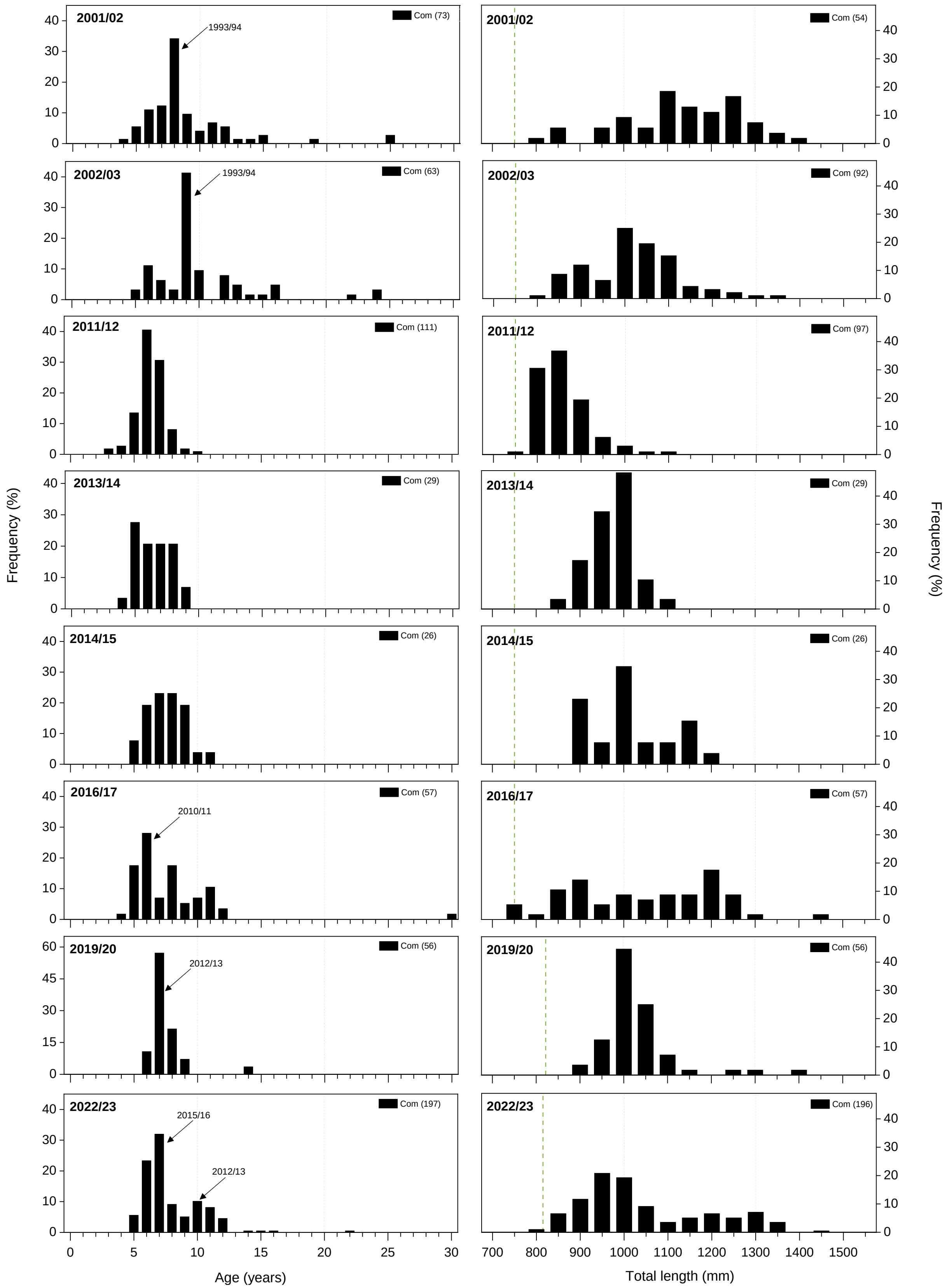

Figure 3-5. Age and size structures for Mulloway from the nearshore marine environment adjacent the Murray Mouth in each of eight different years. Years and arrows on some plots represent particular cohorts/year classes. Left hand graphs show the age structures. The number of fish processed from commercial swinger net (Com) catches in each year is shown in brackets.

3.3.3 Performance indicators

3.3.3.1 Environmental performance indicator

Modelled daily salinity concentrations for 109 locations in the Coorong Estuary were used to estimate the amount of suitable habitat available for Mulloway in the system during the 2022/23 reporting year (Figure 3-6). While consistent high freshwater inflows to the Coorong contributed to freshening of areas south of the Parnka Point from May onwards, the proportion of the system that was suitable habitat for Mulloway (i.e., salinity was < 51 ppt) was relatively stable at 65–75% throughout the year. The ELMGN performance indicator for habitat available to Mulloway in the Coorong Estuary for the 2022/23 reporting year was 65.4%, which was above the target reference point of 55% Figure 3-7).

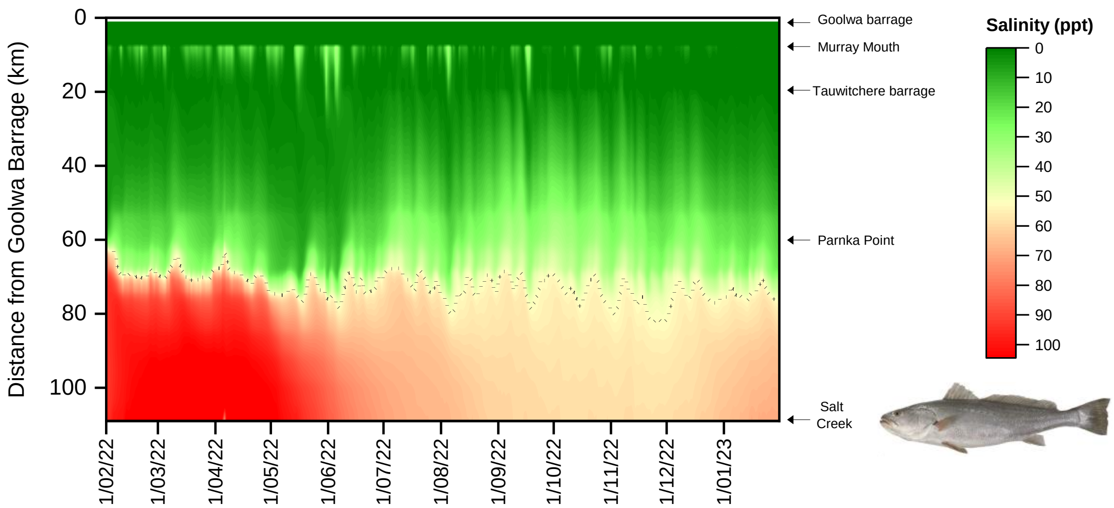

Figure 3-6. Modelled salinity concentration for the Coorong Estuary, with distance from the Goolwa Barrage to Salt Creek for the 2022/23 reporting year, with the approximate salinity threshold for Mulloway (51 ppt) shown as a dotted line. Salinity threshold represents the level of salinity that was lethal for 10% of test fish, as determined by Ye et al. (2013). The dark green contours (i.e., <10 ppt) indicate periods of freshwater inflow. Refer to Figure 1-1 for map of Coorong Estuary.

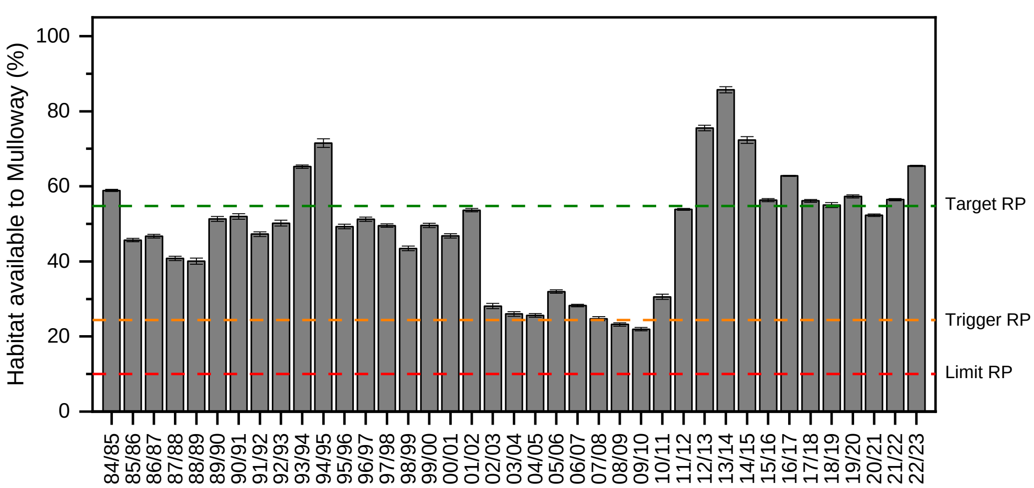

Figure 3-7. Estimates of the ELMGN performance indicator for habitat available to Mulloway in the Coorong Estuary from 1984/85 to 2022/23 (reporting years), showing target, trigger and limit reference points (RP).

3.3.3.2 Biological performance indicator

For the 2022 calendar year, the performance indicator for Mulloway targeted $CPUE_{LMGN}$ of 7.59 kg.net-day^{-1} was 146% above the target reference point (Figure 3-8).

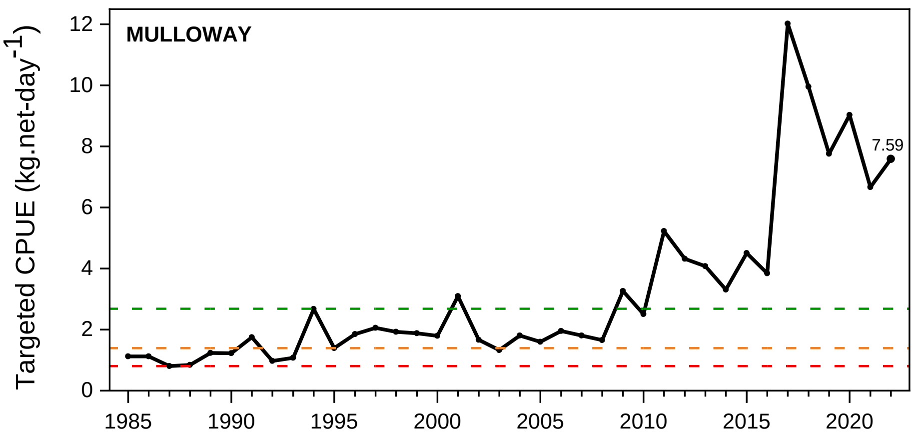

Figure 3-8. Time series of annual estimates of the ELMGN biological (secondary) performance indicator (targeted CPUE) for Mulloway from 1985 to 2022 (calendar years), showing target (green dashed line), trigger (orange dashed line) and limit (red dashed line) reference points.

3.4 DISCUSSION

3.4.1 Context of this assessment

The previous Mulloway stock assessment, which considered commercial catch and effort statistics from the LCF up to 30 June 2019, and contemporary size and age structures, classified the stock as sustainable (Earl 2020). Subsequent assessments of stock status undertaken in 2021 and 2022, retained the 'sustainable' classification (Earl and Bailleul 2021; Earl et al. 2021; 2022).

There have been few management changes that have directly impacted the LCF for Mulloway over recent years. The most significant change occurred in 2016, when the LML for Mulloway taken in all State waters excluding the Coorong Estuary, was increased from 750 to 820 mm TL. This increase was made to ensure that at least 50% of Mulloway retained are reproductively mature and had the opportunity to spawn at least once before capture. While this change did not impact the ELMGN sector of the fishery, which adhered to a separate LML of 460 mm TL, it had implications for the swinger net sector and these were considered when interpreting the size/age structures developed for this assessment.

Over the past 12 years, the number of interactions between Long-nosed Fur Seals and LCF gillnet fishers have increased and impacts to the LCF for Mulloway through depredation of fish caught in gillnets have been reported (Goldsworthy and Boyle 2019; Earl et al. 2021). The impacts occur as seals attempt to remove fish caught in gillnets which can result in catch losses and gear damage.

Quantitative information on the impacts of seals on the fishery in terms of catch losses, as well as changes to fisher behaviour in response to the presence of seals is not available. Nevertheless, seal depredation of Mulloway caught in gillnets is likely to have resulted in lower catches and CPUE than would otherwise have been realised. The need for quantitative information on the impacts of seals on the LCF is expected to be addressed through the collection of seal impact data by LCF fishers and SARDI observers as part of the Fisheries Research and Development Corporation (FRDC) Project 2018-036 *Seal-fisher-ecosystem interactions in the Lower Lakes and Coorong: understanding causes and impacts to develop longer-term solutions*.

3.4.2 Determination of stock status

The status of the LCF for Mulloway was assigned using the NFSRF (Table 1-1; Piddocke et al. 2021). The current harvest strategy for finfish (PIRSA 2022) lacks an index that explicitly defines stock status for Mulloway and does not provide a pre-defined limit reference point that determines when the stock is depleted (i.e., when recruitment is impaired because the adult biomass no longer has the reproductive capacity to replenish itself). Consequently, the assignment of stock status for Mulloway used a weight-of-evidence approach that placed considerable emphasis on trends in commercial catch and effort data and fishery size and age structures. This approach is consistent with that used in the Status of Key Australian Fish Stocks Reports (Piddocke et al. 2021).

Information available to assess the LCF for Mulloway included: (i) daily commercial catch and effort data from 1984/85 to 2021/22; (ii) annual estimates of relative abundance for Mulloway based on fishery-dependent $CPUE_{LMGN}$ and $CPUE_{SN}$ from 1984/85 to 2021/22; (iii) fishery size and age structures from a number of years between 2001/02 and 2022/23; and (iv) the environmental and biological performance indicators and associated reference points for the ELMGN sector used in the harvest strategy for finfish, as specified in the Management Plan (PIRSA 2016).

3.4.3 Stock status

Mulloway is a primary target species for the LCF (PIRSA 2022). This reflects its history of relatively high catches and high wholesale value compared to other species available to the fishery (EconSearch 2022). The most recent stock assessment for Mulloway was done in 2020 and used a weight-of-evidence approach that considered commercial catch and effort data to the end of June 2019, and fishery size and age structures to the end of June 2020 (Earl 2020).

The LCF has historically been the most productive of South Australia’s fisheries for Mulloway, and in 2021/22, contributed 99% of the State’s total commercial catch of the species. The highest total annual catch of Mulloway for the LCF was 136 t in 2000/01. From then, catch declined to an historic low of 19 t in 2010/11. This catch decline was associated with a decline in targeted effort and relatively low $CPUE_{LMGN}$ during the Millennium Drought (2001/02–2009/10) and likely reflected low fishable biomass in the Coorong Estuary. Since 2010/11, catches have been considerably higher. Annual catches between 2017/18 and 2020/21 ranged from 92.3 t to 121.3 t, which represents the highest sustained catch of Mulloway on record. These high catches were associated with exceptionally high $CPUE_{LMGN}$. Catch declined to 55 t in 2021/22, reflecting a 55% decline in targeted large-mesh gillnet effort. High catch rates for large-mesh gillnets and swinger nets in 2021/22 were indicative of high fishable biomass of juvenile and adult Mulloway in areas of the LCF. The State-wide recreational catch of Mulloway was estimated at 23.97 t in 2021/22, although the proportion of the State-wide catch that was taken in the Coorong region is not known (Beckmann et al. 2023).

The environmental performance indicator for the ELMGN sector of the LCF was developed as a surrogate metric for fishable biomass for Mulloway in the Coorong Estuary (Knuckey et al. 2015; PIRSA 2022). The ELMGN performance indicator for habitat available to Mulloway in the Coorong Estuary for the 2022/23 reporting year was 65.4%, which was above the target reference point of 55%.

Annual age structures for Mulloway from the Coorong Estuary have been stable since 2001/02 (i.e., dominated by juveniles) and are consistent with those for Mulloway from other estuaries around Australia (Silberschneider et al. 2009; Stewart et al. 2020). The 2022/23 age structure was dominated (80%) by 2-year-olds that originated from spawning during 2020/21. The lack of older fish in the age structure likely relates to an ontogenetic migration of individuals from the Coorong Estuary to the adjacent marine environment and the removal of older fish by fishing. The higher proportion of 2-year-olds in the 2022/23 catch compared to previous years likley related to differences in growth rates, because the size composition of catches from 2022/23 was like that of previous years. Nevertheless, the presence of a strong age class of young fish in the catches from the estuary (i.e., the area that contributes most of the catch) in 2022/23 indicates that relatively strong recruitment occurred in 2020/21.

Since 2001/02, annual age information for Mulloway from the nearshore marine environment adjacent the Coorong Estuary has been limited due to the small number of samples and small sample sizes available in most years. The age structure from 2022/23, which was based on a relatively large sample size (n=197), was similar to those from a number of years since 2001/02, i.e., they had a wide range of ages (5–22 years), were dominated by 6–10-year-olds and comprised mostly (>70%) individuals above the age at maturity (5-6 years) for the species. The 2022/23 age structure was dominated by 7-year-olds (i.e., 2015/16 year class), with moderate contributions of 6-year-old fish from the 2016/17 year class. Fish older than 12 years were rare despite the potential for this species to reach 41 years of age in South Australia. The lack of older fish in the age structure likely relates to the removal of older fish by fishing and may also reflect an extended period of relatively poor recruitment during the Millennium Drought (2000s).

The recruitment of juveniles to the fishable biomass in the Coorong Estuary in recent years, the presence of multiple age classes in the spawning biomass and recent historically high annual catch rates for large-mesh gillnets and swinger nets indicate that the biomass of this stock is unlikely to be depleted, 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 this basis, and using the definitions from the NFSRF, the LCF for Mulloway is classified as a **'sustainable'** stock.

3.4.4 Uncertainty in the assessment

The main uncertainty in this stock assessment for Mulloway relates to the relationships between fishable biomass and the commercial fishery statistics, which along with the fishery age structures, were the primary data considered in this assessment. In a general sense it is expected that the parameters of commercial catch and CPUE are influenced by the biomass of Mulloway available to the fishery. However, there are other factors relating to fisher behaviour that may also influence these relationships. Fishers can switch their fishing effort between different target species, vary the time gillnets are soaked each day, and move between different areas of the fishery in order to optimise their financial gain. For example, over recent years, some fishers that target Mulloway have modified their fishing practices to try and avoid interactions with Long-nosed Fur Seals. These interactions occur as seals attempt to eat fish caught in gillnets, which can result in catch losses and damage to gillnets. Some of the operational modifications made by fishers have included: reducing the number of gillnets used each fishing day; attending their gillnets more often (i.e., reduced soak times); changing the time of the day that nets are in the water; and more regularly shifting between fishing areas to try and be less predictable to seals (Earl et al. 2021; EconSearch 2022). The influence of such changes in fisher behaviour on estimates of $CPUE_{LMGN}$ is difficult to assess because most of the changes are not currently able to be recorded in fishery logbooks. This could be partially addressed by incorporating additional reporting fields (e.g., gillnet soak time) in the Inland Waters Catch and Effort return.

Environmental variability contributes to additional uncertainty around the relationships between fishable biomass and the commercial fishery statistics. Variation in the timing and magnitude of freshwater inflows to the Coorong Estuary influences salinity along the system, and therefore, the size of the area of suitable habitat available for Mulloway (Ye et al. 2013). For example, low freshwater inflows during the Millennium Drought resulted in hypersaline conditions in the South Lagoon and this caused Mulloway to aggregate into a reduced area of favourable habitat near the Murray Mouth (Ferguson and Ward 2011). Such changes in the distribution of Mulloway in the Coorong Estuary may affect their catchability and potentially confound interpretation of $CPUE_{LMGN}$ as an indicator of biomass.

A further uncertainly relates to the lack of information on spatial trends in Mulloway catch by the recreational sector in South Australia. State-wide longitudinal phone surveys done in 2000/01, 2007/08, 2013/14 and 2021/22 estimated that Mulloway catches by the recreational sector in South

Australia accounted for between 30–62% of the State's combined commercial and recreational catch (Jones and Doonan 2005; Jones 2009; Giri and Hall 2015; Beckmann et al. 2023). Nevertheless, State-wide recreational surveys were not designed to provide harvest estimates at the scale of the Mulloway fishery in, or adjacent to the Coorong estuary, therefore these values are not known. This is of concern because: (i) recreational catch in the region may be equal to or larger than the commercial catch in some years; and (ii) recreational fishers target spring/summer aggregations of large Mulloway near the Murray Mouth and along Younghusband Peninsula, particularly in years of moderate freshwater discharge (Ferguson et al. 2008; 2014). Understanding the spatial and temporal trends in Mulloway catch by the recreational sector at the scale of the Coorong Estuary would improve future stock assessments for the LCF for Mulloway.

Although this study provided fishery age structures from commercial gillnet catches, LCF fishers have reported that the size range of Mulloway captured using these methods is limited by the mesh sizes of the gillnets they use (i.e., small Mulloway can swim through the mesh and avoid being caught, while larger Mulloway are too large to be "gilled" in the mesh sizes used). Sampling of recreational catches was done for previous stock assessments in 2001/02, 2014/15 and 2019/20 to investigate potential bias of gear type on the size range of Mulloway sampled. Despite the relatively low number of samples obtained from recreational catches in those years, statistical analysis did not detect any differences between the size distributions for commercial and recreational catches (Ferguson and Ward 2003; 2011; Earl and Ward 2014; Earl 2020). An ongoing sampling program that accesses commercial catches of Mulloway taken by multiple LCF licence holders who use a range of different gillnet mesh sizes is fundamental to support stock assessment.

Finally, a key uncertainty in this stock assessment relates to the levels of fishing mortality that are not accounted for in the commercial fishery statistics. Levels of incidental mortality of sub-legal sized Mulloway discarded by commercial and recreational fishers in the Coorong Estuary and adjacent marine environment are poorly understood. This is because estimates of discarding are only available for the ELMGN sector from limited sampling undertaken during the Millennium Drought (Ferguson 2010), when the biomass of juvenile Mulloway in the Coorong Estuary was low. For the commercial sector, this could be addressed by monitoring discards from gillnets by incorporating discard information into the Inland Waters Catch and Effort return. Another potential source of fishing-related mortality that is not accounted for in the fishery data but is frequently spoken about by fishers, relates to Mulloway that were (1) caught in gillnets and subsequently removed by Long-nosed Fur Seals before they could be landed, and (2) damaged by seals before they could be landed, and subsequently discarded by fishers without record. As such, fishing mortality of Mulloway in the Coorong Estuary is likely to be considerably higher than the levels reported in this assessment.

The current FRDC project (2018-036) is seeking to collate and analyse seal impact data recorded by LCF fishers and SARDI observers, as well as quantify the relative contribution of Mulloway to the diet of Long-nosed Fur Seals in the Coorong Estuary, to better understand the proportion of the commercial gillnet catches of Mulloway that are lost due to seal depredation. The success of this project depends on the participation of fishers, and their willingness to collect data on seal interactions and impacts.

3.4.5 Research priorities

The most important research needs for the Mulloway fishery and its management include: (i) ongoing development of a time series of annual age structures from the marine environment, based on appropriate sized samples (n>100) from the commercial sector; (ii) independent ongoing monitoring of discarding of sub-legal sized individuals from small-mesh gillnets (i.e., mullet nets) and large-mesh gillnets in the Coorong Estuary; (iii) regular on-site surveys to reliably estimate recreational harvest of Mulloway in the Coorong Estuary and the adjacent marine waters along Younghusband Peninsula; (iv) collecting more refined data on fishing effort from the commercial sector (e.g. soak time of gear); and (v) information on the proportion of the Mulloway catch that is lost to depredation of fish caught in commercial gillnets.

4 STOCK STATUS OF OTHER KEY SPECIES

4.1 INTRODUCTION

Assessing the status of fish stocks can be challenging, especially for stocks that have limited data. In these situations, a weight-of-evidence approach is required to support status determination. This approach involves the systematic consideration of a range of biological and fisheries information to estimate trends in fishable biomass and levels of fishing mortality to support a status determination. Additional information about the species' stock structure, biology and management arrangements can contribute to the decision-making process. This weight-of-evidence approach is the standard approach used in the Status of Australian Fish Stocks Reports (Piddocke et al. 2021) for data-poor stocks, i.e., stocks for which sophisticated stock assessment models are not available.

This section of the report uses a weight-of-evidence approach to assign stock status for six key LCF species that are distributed across the 'primary' and 'secondary' species categories defined in the Management Plan (PIRSA 2022). It comprises species-specific sections, which are arranged to align with the three finfish sectors of the fishery. These sectors are: (i) ELMGN; (ii) ESMGN; and (iii) FLMGN. For the key species in each sector, the relevant biological information is provided, along with a description of the fishery, associated management regulations, an interrogation of the fishery data from 1984/85 to 2021/22, and a classification of stock status using the definitions from the NFSRF (Table 1-1; Piddocke et al. 2021).

This section of the report also provides information to inform the harvest strategy for finfish, as prescribed in the Management Plan (PIRSA 2022). While catch and effort data for each species are provided by financial year to match the fishing season (i.e., when the finfish total allowable commercial effort [TACE] and Pipi total allowable commercial catch [TACC] are applied), the primary and secondary performance indicators are provided at different time scales to ensure that the processes for setting the TACE and TACC are based on the most up-to-date information available. For the ESMGN and FLMGN sectors, estimates of the environmental (primary) performance indicator are provided for the 2022/23 reporting year (1 February 2022–31 January 2023) and estimates of the biological (secondary) performance indicators for key species are provided for the 2022 calendar year (1 January–31 December 2022) and these are compared to target, trigger and limit reference points. This information will inform setting of the 2023/24 TACE for each gillnet sector. This section also summarises relevant biological information, fishery data and assessment of stock status for Pipi, including an assessment of biological performance indicators against reference points defined in the Management Plan.

4.2 METHODS

4.2.1 Fishery statistics

Daily commercial catch and effort data are the primary data considered in this section. These data have been collected by LCF fishers since 1 July 1984, which are submitted monthly to SARDI Aquatic and Livestock Sciences. Data include catch (kg), effort (fishing days; net-days, i.e., the number of nets) for targeted and non-targeted species, and location of the fishing activity by reporting block (Figure 1-1).

The appropriate data for each species were extracted from the Lakes and Coorong Fishery Information System, which is maintained by PIRSA Fisheries and Aquaculture. For Pipi, data on catches by the MSF are also included. The data span a 38-year time series from 1984/85 to 2021/22 and were aggregated to provide annual estimates of catch and effort for the main gear types.

The fishery data are presented by financial year from 1984/85 to 2021/22. For each species, a map is presented that shows total catch by reporting block for 2021/22. Then, annual estimates are provided for: (i) total catch; and for the dominant gear type(s); (ii) targeted catch; (iii) targeted effort; and (iv) catch per unit effort (CPUE; targeted catch divided by targeted effort). For species that are not typically targeted, CPUE was determined based on total catch and the amount of effort that produced catches of that particular species. The presentation of data was limited by constraints of confidentiality, i.e., data could only be presented when aggregated for five or more fishers. Where available, estimates of recreational catch obtained from four recreational fishing surveys (Jones and Doonan 2005; Jones 2009; Giri and Hall 2015; Beckmann et al. 2023) are also presented.

4.2.2 Performance indicators

4.2.2.1 Finfish

Two sets of performance indicators were considered for each of the ESMGN and FLMGN sectors of the fishery, i.e., the environmental (primary) performance indicators and the biological (secondary) performance indicators. The environmental performance indicator used in the finfish harvest strategy for each sector is: (i) ESMGN – suitable habitat available (%) for Yelloweye Mullet in the Coorong Estuary; and (ii) FLMGN – mean annual water level (m, AHD) in the Lower Lakes (Table 4-1). The time series of data in reporting years (1 February–31 January) from 1984/85–2021/22 for each of the three indicators were compared against their respective target, trigger and limit reference points (Table 4-1), as prescribed in the Management Plan (PIRSA 2022). An assessment of the environmental performance indicator for the ELMGN sector is provided in Section 3 of this report.

The biological (secondary) performance indicators are based on annual non-standardised CPUE (kg.net-day^{-1}) for the primary and secondary species in each sector (Table 4-2; PIRSA 2022). The time series of data in calendar years from 1985–2022 for each indicator was calculated. Then, the value for the 2022 calendar year was compared against target, trigger and limit reference points (Table 4-2) prescribed in the Management Plan. Detailed descriptions of the environmental and biological performance indicators and how their respective annual estimates are calculated are provided in the Management Plan.

Table 4-1. Environmental (primary) performance indicators and associated target, trigger and limit reference points used in the harvest strategy for finfish, as specified in the Management Plan (PIRSA 2022).

Finfish sector	Primary performance indicator	Limit RP	Trigger RP	Target RP
Estuarine LMGN	Habitat available to Mulloway (%)	10	24.9	55
Estuarine SMGN	Habitat available to Yelloweye Mullet (%)	10	30.9	50
Freshwater LMGN	Water level in the Lower Lakes (m, AHD)	-1.2	-0.71	+0.4

Table 4-2. Biological (secondary) performance indicators and associated target, trigger and limit reference points used in the harvest strategy for finfish, as specified in the Management Plan (PIRSA 2022). The biological performance indicators are prescribed for the primary(P) and secondary(S) species in each sector.

Finfish sector	Key species	Secondary performance indicator	Limit RP	Trigger RP (kg.net-day^{-1})	Target RP
Estuarine LMGN	Mulloway P	Targeted $CPUE_{LMGN}$	0.80	1.39	2.68
	Greenback Flounder S	Targeted $CPUE_{LMGN}$	0.65	0.93	1.86
	Black Bream S	Targeted $CPUE_{LMGN}$	0.30	0.53	1.67
Estuarine SMGN	Yelloweye Mullet P	Targeted $CPUE_{SMGN}$	6.32	7.23	11.11
Freshwater LMGN	Golden Perch P	Targeted $CPUE_{LMGN}$	0.24	0.49	1.04
	Bony Herring S	$CPUE_{LMGN}$	2.32	3.54	5.42

4.2.2.2 Pipi

The harvest strategy for Pipi uses biological performance indicators and decision rules to inform setting of the annual total allowable commercial catch (TACC) (PIRSA 2022). The biological performance indicators used in the harvest strategy are: (i) fishery-independent mean annual relative biomass (primary performance indicator), and (ii) presence/absence of pre-recruits in size frequency distributions (secondary performance indicator; Ferguson and Ward 2014; Ferguson et al. 2015; Ferguson and Hooper 2021). Estimates of these performance indicators relative to target, trigger and limit reference points for the 2021/22 financial year are presented to support status determination for Pipi. Detailed descriptions of the biological performance indicators and associated reference points are provided in the Management Plan (PIRSA 2022).

4.3 RESULTS

4.3.1 Estuarine large-mesh gillnet sector

4.3.1.1 Black Bream (*Acanthopagrus butcheri*)

Biology

Black Bream (*Acanthopagrus butcheri*) is a member of the Sparidae family of fishes (Gomon et al. 2008). It has a wide distribution in estuaries and coastal waters of southern Australia from central New South Wales (NSW) to central west coast Western Australia, including Tasmania, where it is a popular target for commercial and recreational fishers (Kailola et al. 1993).

Black Bream is an estuarine-dependent species, completing much of its life cycle within a single estuary (Chaplin et al. 1998). It is slow-growing, can grow to 600 mm TL and live for 32 years. In the Coorong Estuary, males and females mature (L_{95}) at around 334 mm TL and 309 mm TL, respectively (Cheesman 2022). Spawning is confined to estuaries and occurs between August and January. Growth and recruitment of Black Bream within estuaries are strongly influenced by environmental conditions associated with freshwater inflows (Williams et al. 2013). Thus, it is likely that at the local scale at least, annual recruitment strength is dependent on environmental conditions, with substantial inter-annual variation in recruitment affecting local stock demographics and biomass. Here, the assessment of status is undertaken at the biological stock level–the Coorong Stock.

Fishery

Black Bream supports recreational and commercial fisheries in South Australia. Historically, the LCF has been South Australia's main commercial fishery for Black Bream. In recent years, around 70% of the State's annual catches have been taken by LCF fishers, who target the species using large-mesh gillnets (Earl et al. 2016). Black Bream has traditionally had a high market value and is a premium product of the LCF (EconSearch 2022). The MSF, NZRLF and SZRLF also have access to this species, although catches from these sectors are negligible and are not considered in this assessment.

South Australian recreational fishers target Black Bream in coastal waters using rod and line, particularly in estuaries (Beckmann et al. 2023). The State-wide recreational survey in 2021/22 estimated that 30,878 (SE ± 7,853) Black Bream were captured, of which ~76% were released (Beckmann et al. 2023). The retained fish contributed to an estimated state-wide harvest weight of 5.55 t (SE = 2.71 t based on confidence interval of retained fish numbers for comparison among surveys). The proportion of the state-wide catch that was taken in the Coorong Estuary is not known. There are no catch and effort data for Aboriginal and traditional fishing.

Management arrangements

Black Bream is a secondary species of the LCF, making a relatively low contribution to the total production value over the last 30 years (PIRSA 2022). For the commercial sector, management arrangements are in place to manage targeted fishing and limit the take of Black Bream. These include temporal and spatial netting closures, restrictions to net lengths and mesh sizes, and a LML of 300 mm TL.

There are multiple management arrangements in place for Black Bream in the recreational sector. Input and output controls ensure the total catch is maintained within sustainable limits and that access is distributed equitably among fishers. These include gear restrictions, spatial closures and a daily bag limit of 10 fish and boat limit of 30 fish. The LML of 300 mm TL also applies.

Temporary management arrangements were implemented in 2018, 2019 and 2021 to recover the Black Bream stock in the Coorong, after it was classified as 'overfished' in 2016 (Earl et al. 2016) and 'depleted' in 2017 (Conron et al. 2018). The 'depleted' status classification was retained in 2022, based on commercial fishery data up until 30 June 2021 (Earl et al. 2022). The temporary arrangements applied to Black Bream in the Lower Lakes and Coorong Estuary from 1 September–30 November in 2018; from 21 September–30 November in 2019; and from 1 August–31 December 2021. Under the arrangements, commercial and recreational fishing nets could not be used within 300 metres of barrages located in the Coorong Estuary, including Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere barrages; and Black Bream could not be targeted, and all incidental catch of Black Bream had to be released by both the recreational and commercial sectors.

In October 2022, the Bream/Flounder Working Group (BFWG) was established to develop a recovery strategy for the Black Bream stock in the Coorong which includes performance indicators and reference points that can be used to monitor stock recovery. The BFWG comprises representatives from industry, PIRSA Fisheries and Aquaculture, SARDI Aquatic and Livestock Sciences, the recreational fishing sector and an independent chair. The Black Bream recovery strategy is expected to be completed by 30 June 2023.

Commercial Fishery statistics

Trends in total catch, effort and CPUE

Over the past 38 years, the highest total annual commercial catch of Black Bream in the LCF was 46.8 t in 1984/85 (Figure 4-1). Annual catches were around 35 t in 1985/86 and 1986/87 and then declined to 3.7 t in 1990/91. They remained low during the 1990s, averaging 3.7 $t.yr^{-1}$, before increasing to 11.6 t in 2002/03. Catches gradually declined to 1.7 t in 2008/09 and have been < 2 t in most years since. The total catch of 3.42 t in 2021/22 was the highest catch since 2007/08, recognising the fishery was closed from 1 August–31 December 2021.

The main gear type used to target Black Bream has been the large-mesh gillnet (Figure 4-1). The low catches since the early 1990s have been associated with low targeted effort using large-mesh gillnets, with most of the catches taken as by-product when other species were targeted. Over the past five years, on average, 84% of the catches taken each year have been by-product.

Estimates of annual targeted effort and targeted CPUE for large-mesh gillnet are confidential for most of the past 15 years, including 2020/21 (Figure 4-1). The available estimates of $CPUE_{LMGN}$ should be interpreted with caution due to considerable uncertainty around $CPUE_{LMGN}$ as a measure of relative abundance (Earl et al. 2016b). This is because spatial contraction of the fishery for this species, particularly during low inflow years, may increase their catchability and thus confound interpretation of $CPUE_{LMGN}$ as an indicator of relative abundance (Earl et al. 2016b; Ye et al. 2022). Given the high wholesale value of Black Bream (EconSearch 2022), catch is currently considered a more appropriate indicator of abundance for this species in the Coorong.

Spatial and temporal trends in catch

Between 1984/85 and 1998/99, reporting blocks 9 and 10 provided the highest catches of Black Bream, with lower catches taken in areas 6–8 (Figure 4-2). The spatial distribution of catches gradually shifted during the 1990s with most of the catches during the late 1990s and 2000s taken from blocks 6 and 8 (which are adjacent the Murray Mouth). This contraction of the fishing ground occurred when low freshwater inflows associated with the Millennium Drought reduced the amount of suitable habitat available for Black Bream in the estuary. The drought-breaking floods in 2010/11 led to a freshening of the estuary and an increase in the size of the fishable area for Black Bream with higher proportions of the annual catches coming from blocks 6–11 during recent years. In 2021/22, 78% of the total catch was taken in areas 10 and 11. Historically the fishery for Black Bream in the Coorong Estuary was seasonal with catches generally concentrated between July and December, with peaks in September and October (Figure 4-2).

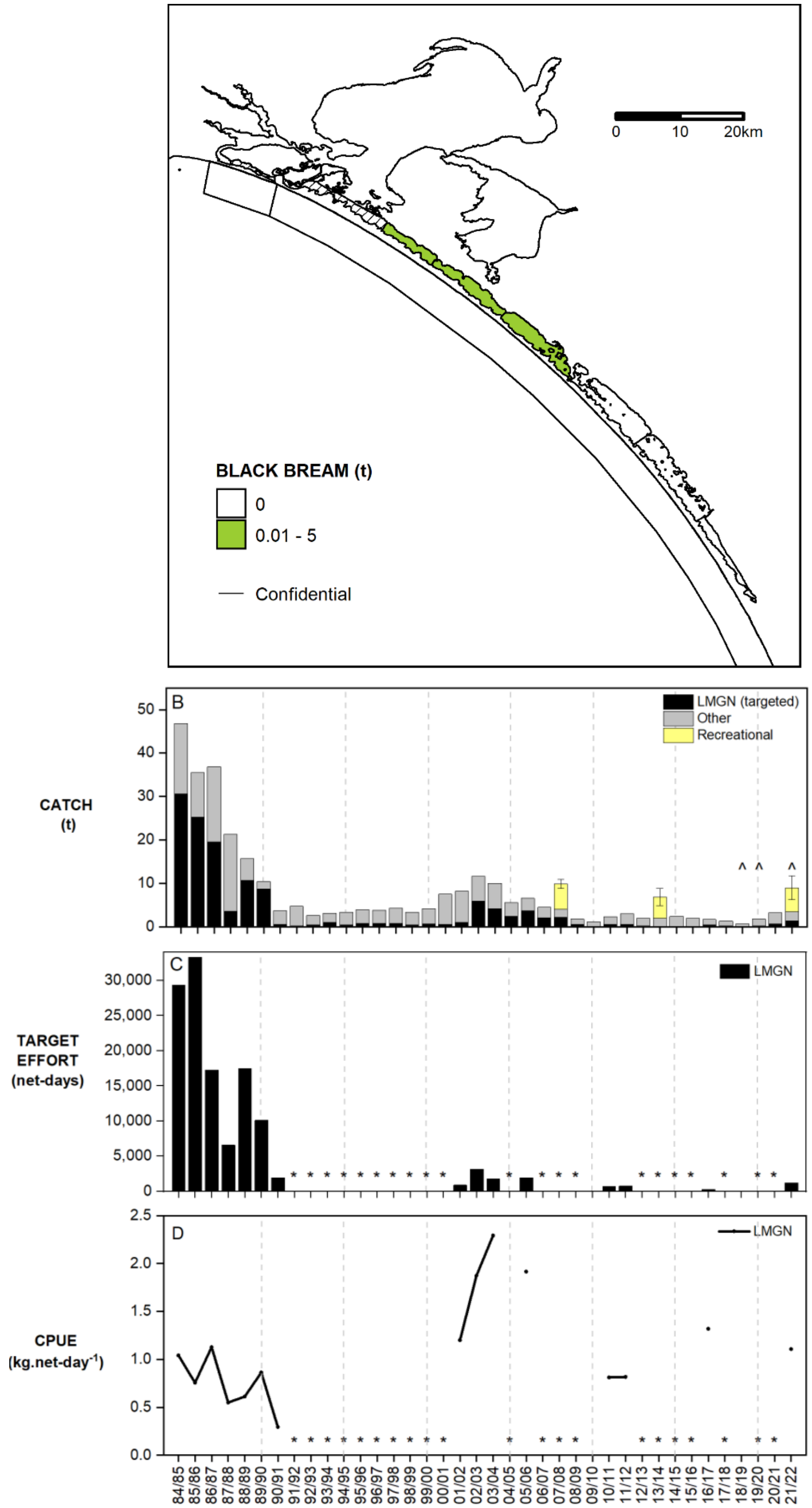

Figure 4-1. Fishery statistics for Black Bream. (A) Map of the LCF reporting blocks showing the catch distribution for 2021/22; long term trends in: (B) total catch, including targeted catch for the main gear type - large-mesh gillnets (LMGN), targeted and non-targeted catch for all gear types (OTHER), and for the recreational sector (from all State waters for 2007/08, 2013/14 and 2021/22); (C) targeted effort for LMGN; and (D) targeted CPUE for LMGN. For comparison among recreational fishing surveys, error bars were recalculated and represent the equivalent of the coefficient of variation of harvested fish numbers. Asterisks (*) indicate confidential data (i.e., from <5 fishers). Carets (^) indicate years for which seasonal fishery closures were in place for Black Bream.

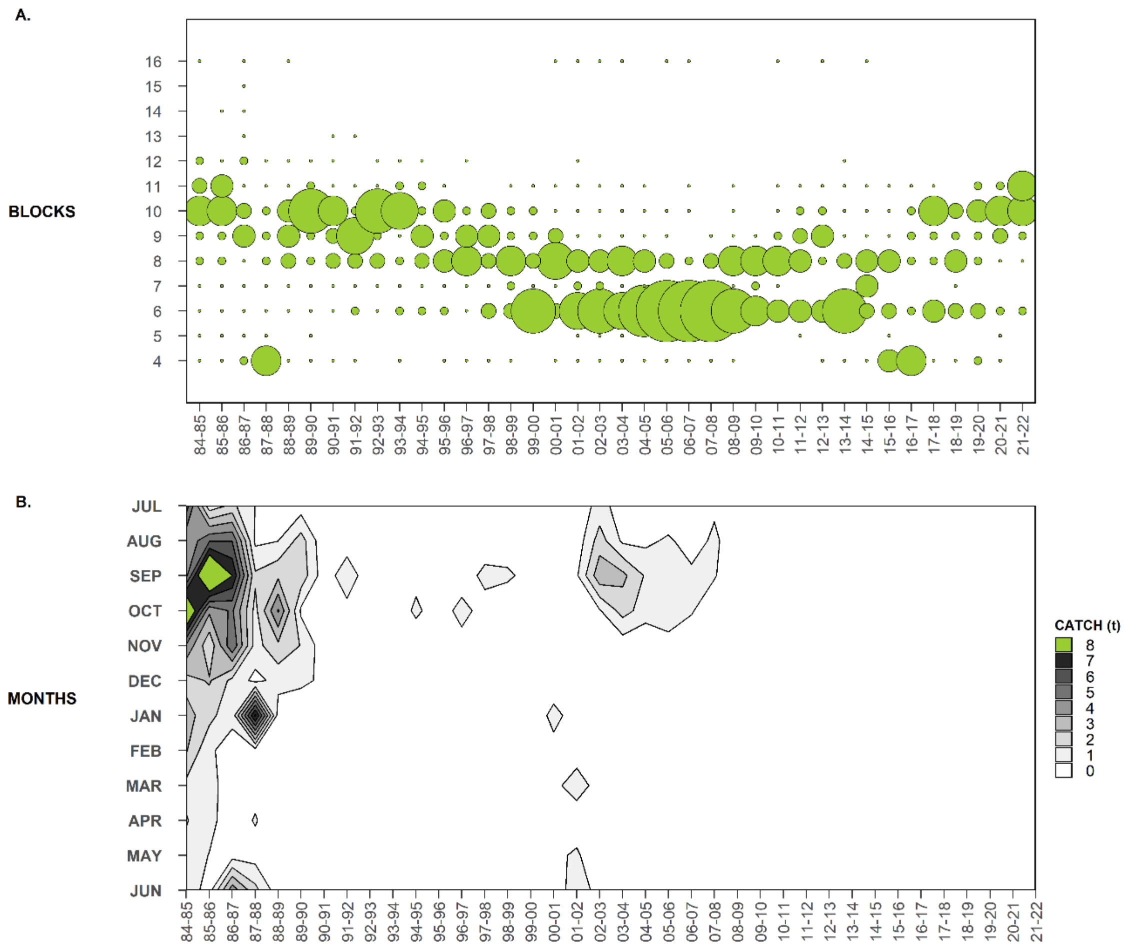

Figure 4-2. Fishery statistics for Black Bream. Long-term trends in (A) the annual distribution of catch among LCF reporting blocks (diameter of the bubbles represent the relative contribution of each reporting block to total annual catch); and (B) the annual distribution of catch among months.

Stock status

Black Bream is a secondary target species for the commercial LCF (PIRSA 2022). The most recent stock assessment for the Black Bream stock in the Coorong Estuary was in 2016 and used a weight-of-evidence approach that considered fishery data and fishery age structures up to 30 June 2015 (Earl et al. 2016b). Since then, catch sampling has been done to develop annual age structures for Black Bream as part of the Coorong Fish Condition Monitoring program (Ye et al. 2022).

Analysis of the long-term chronology of fishery production for Black Bream in the Coorong Estuary indicates high variability in fishable biomass. In the early 1990s, fishery catches dropped to historically low levels and have remained low. In 2021/22, catch increased slightly to a level that was similar to the long-term average annual catch since the early 1990s. The recent low catches have been associated with low targeted effort. Given the high wholesale value of Black Bream compared to other LCF species (EconSearch 2022), the lack of targeting and low catches in most years since the 1980s has been indicative of low fishable biomass. The lack of targeting in recent years may also relate to

(1) the implementation of seasonal fishery closures during what has historically been the most productive period for Black Bream fishery (i.e., spring and summer); and (2) the presence of Long-nosed Fur Seals in the region, which has reportedly resulted in fishers: (i) avoiding the long gillnet soak times required to effectively target Black Bream; and (ii) using heavier ply mesh gillnets than is optimal for targeting this species (Earl et al. 2021).

Annual fishery age structures from 2007/08 to 2021/22 comprised mostly 4 to 17-year-old fish, although fish older than 10 years were rare in most years, despite the potential for this species to live up to 32 years of age (Ye et al. 2022). Within any year, few age classes contributed most to the catch, reflecting the relative strength of these year classes. This variation in year class strength relates to inter-annual variation in recruitment. Larger year classes appear to be linked to freshwater releases to the Coorong Estuary in 1997/98, 2003/04, 2006/07, 2009/10, 2012/13, 2015/16 and 2016/17, suggesting that environmental conditions associated with freshwater inflow are important for successful reproduction of Black Bream in the Coorong (Ye et al. 2022). The recruitment of these year classes to the fishable biomass since the mid-1990s indicates that environmental conditions in the Coorong Estuary supported successful spawning in those years. In 2021/22, catches were dominated by fish from the 2017/18 and 2016/17 year classes (4 and 5 years old, respectively), whilst the 2006/07 year class was still distinct in the age structure, as 15-year-olds (Ye et al. 2022). In recent years fishery production has remained low despite the recruitment of young fish to the fishable biomass, which indicates that recruitment levels have not been strong enough to support recovery of the stock. In 2022, successful recruitment of Black Bream in the Coorong Estuary was evident by the detection of higher-than-average abundances of young-of-year that likely originated from spawning that occurred in 2020/21 (Ye et al. 2022). Recruitment of these juveniles to the fishable biomass has not yet occurred and is expected to take several years.

The above evidence indicates that the biomass of this stock has been reduced through fishing mortality, such that recruitment to the fishable biomass is impaired. Whilst management measures were put in place in 2018, 2019 and 2021 aimed at recovering the stock, there are not yet any data to demonstrate measurable improvements to the fishable biomass that warrant a change in stock status. Consequently, Black Bream is classified as a '**depleted**' stock.

4.3.1.2 Greenback Flounder (*Rhombosolea tapirina*)

Biology

Greenback Flounder (*Rhombosolea tapirina*) is a member of the family Rhombosoleidae (Gomon et al. 2008). Its Australian distribution extends from southern Western Australia, around the southern coasts of the continent and Tasmania, and up to southern NSW (Kailola et al. 1993). They are common over unvegetated substrates in coastal waters and are often abundant in bays and estuaries.

Greenback Flounder can grow to 450 mm TL and live to 10 years of age (Sutton et al. 2010). It is a fast-growing species, reaching around 220 mm TL in its first year (Earl et al. 2014a). The estimated size at maturity for females and males in the Coorong Estuary is 198 and 211 mm TL, respectively (Earl 2014). Spawning occurs from March to October (Kurth 1957; Crawford 1984; Earl 2014). In South Australia, Greenback Flounder is considered a 'marine estuarine-opportunist' – a marine species that enters estuaries in substantial numbers, particularly during the juvenile and early adult life stages, but use marine waters as alternative habitat (Earl 2014). This is supported by an acoustic telemetry study that showed that the population in the Coorong Estuary is likely part of a broader population that encompasses the adjacent marine environment (Earl et al. 2017). Nevertheless, the extent of the portion of the population in the marine environment adjacent to the Coorong Estuary is not known. Here, the assessment of stock status is undertaken at the management unit level – the LCF.

Fishery

Greenback Flounder is an important species for commercial and recreational fisheries across southern Australia. Commercial catches of this species are taken in NSW, Victoria, Tasmania, South Australia and Western Australia (Kailola et al. 1993). In South Australia, the LCF accounts for most of the commercial catch of this species, which is targeted and taken as a by-product using large-mesh gillnets in the Coorong Estuary. The MSF, NZRLF and SZRLF also have limited access to the species, although catches from these fisheries are negligible. Recreational fishers target Greenback Flounder using hand-held spears in estuaries and protected coastal waters across South Australia. The estimated State-wide harvest of flounder (all species) by the recreational sector in 2021/22 was 0.49 t (SE ± 0.29 based on confidence interval of retained fish numbers) (Beckmann et al. 2023). There are no catch and effort data for Aboriginal and traditional fishing.

Management arrangements

Greenback Flounder is a secondary species of the commercial LCF, making a relatively low contribution to the total production value (PIRSA 2022). For this sector, management arrangements are in place to manage fishing effort and limit fishing mortality. These include temporal and spatial netting closures, restrictions to net lengths and mesh sizes, and a LML of 250 mm TL (PIRSA 2022).

The recreational sector is managed through a combination of input and output controls, aimed at ensuring that the total catch is maintained within sustainable limits and to ensure that recreational access to the fishery is equitably distributed between recreational participants. Management restrictions apply to all flounder species collectively, including Greenback Flounder. A daily bag limit of 20 flounder per person, and a daily boat limit of 60 flounder, applies to this fishery. Management arrangements also comprise general gear restrictions (PIRSA 2022). No LML applies for this sector.

Commercial Fishery statistics

Trends in total catch, effort and CPUE

Total annual catches of Greenback Flounder have been highly variable since 1984/85. Catch peaked at 65 t in 1990/91 and subsequently declined to 3 t in 1994/95. Catch was higher in the following seven years, increasing to a smaller peak of approximately 40 t in 1999/00 and averaging around 24 $t.yr^{-1}$, before progressively declining to <1 $t.yr^{-1}$ in the late 2000s (i.e., the later years of the Millennium Drought) (Figure 4-3). In 2011/12, catch increased to 31 t following the commencement of drought-breaking freshwater inflows to the Coorong Estuary in September 2010. This flow event led to an increase in the amount of suitable estuarine habitat for flounder in the Coorong. From 2013/14 to 2019/20, annual catches were considerably lower, ranging from 0.27 to 4.47 t and averaging 1.5 t. Catch increased to 4.5 t in 2020/21 and was stable at 4.6 t in 2021/22.

The trends in total catch reflect the trends in targeted fishing effort using large-mesh gillnets. In recent years, annual targeted effort declined from a peak of 9,773 net-days in 2011/12 to 76 net-days in 2014/15 and then remained low until 2020/21, when it increased to 2,093 net-days (Figure 4-3). In 2021/22, targeted effort using large-mesh gillnets was 1,853 net-days.

Estimates of targeted $CPUE_{LMGN}$ for Flounder should be interpreted with caution due to uncertainty around $CPUE_{LMGN}$ as a measure of relative abundance resulting from likely environmental influences on catchability (Earl and Ye 2016) (Figure 4-3). Given the high wholesale value of Greenback Flounder compared to other species available to the LCF (EconSearch 2022), catch is considered a more appropriate indicator of abundance for this species.

Spatial and temporal trends in catch

In most of the past 38 years, catches taken in reporting blocks 8–10 have contributed most to total annual catches of Flounder (Figure 4-4). In 2021/22, 80% of the catch was taken in block 10, while blocks 9 and 11 accounted for most of the remaining catch. In the years that produced the highest catches, the period between October and May was generally the most productive for the fishery.

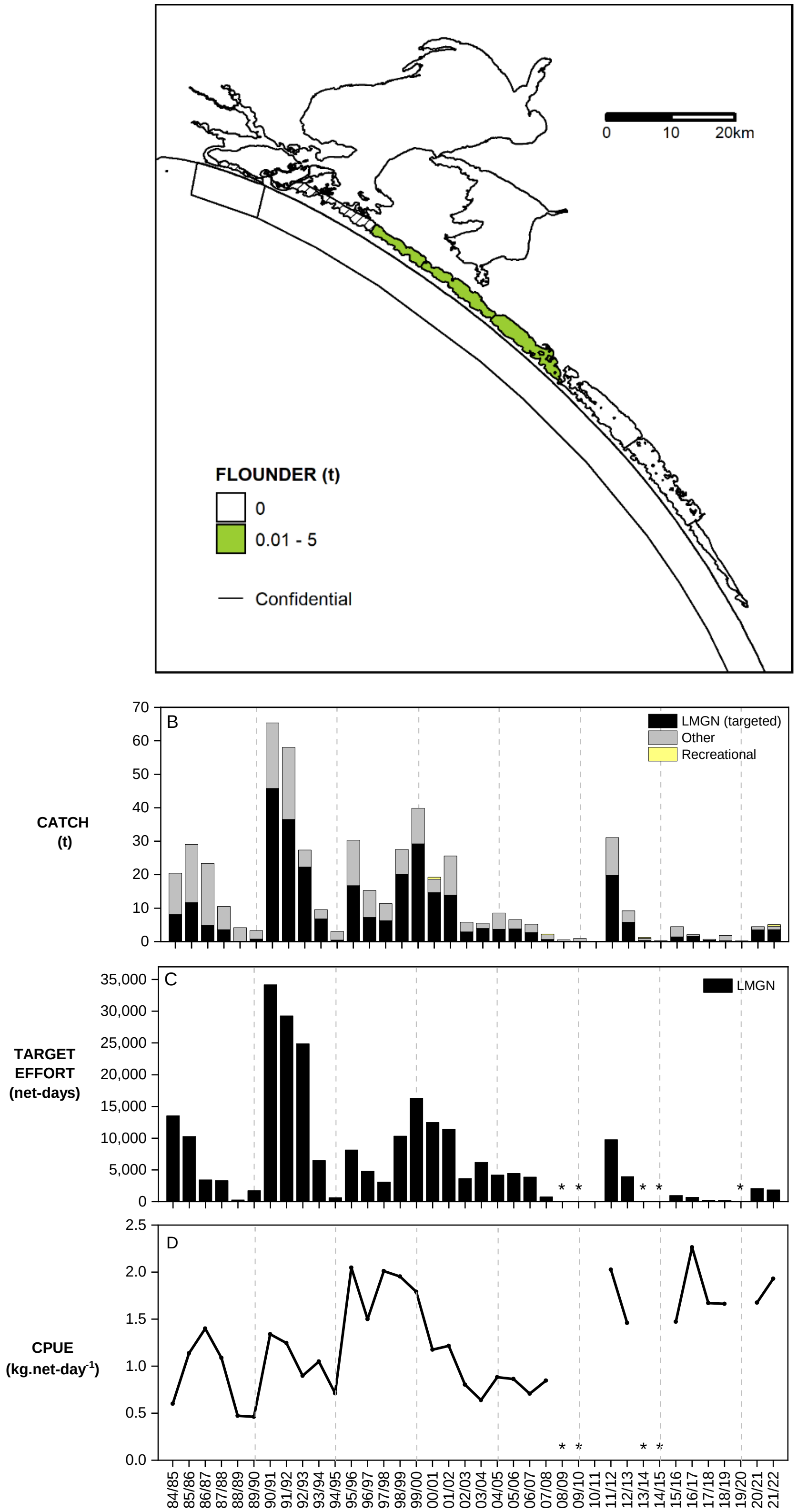

Figure 4-3. Fishery statistics for Greenback Flounder. (A) Map of the LCF reporting blocks showing the catch distribution for 2021/22; Long term trends in: (B) total catch, including targeted catch for the main gear type - large-mesh gillnets (LMGN), targeted and non-targeted catch for all gear types (OTHER), and for the recreational sector (from all State waters for 2000/01, 2007/08, 2013/14 and 2021/22); (C) targeted effort for LMGN; and (D) targeted CPUE for LMGN. Asterisks (*) indicate confidential data (i.e., from <5 fishers).

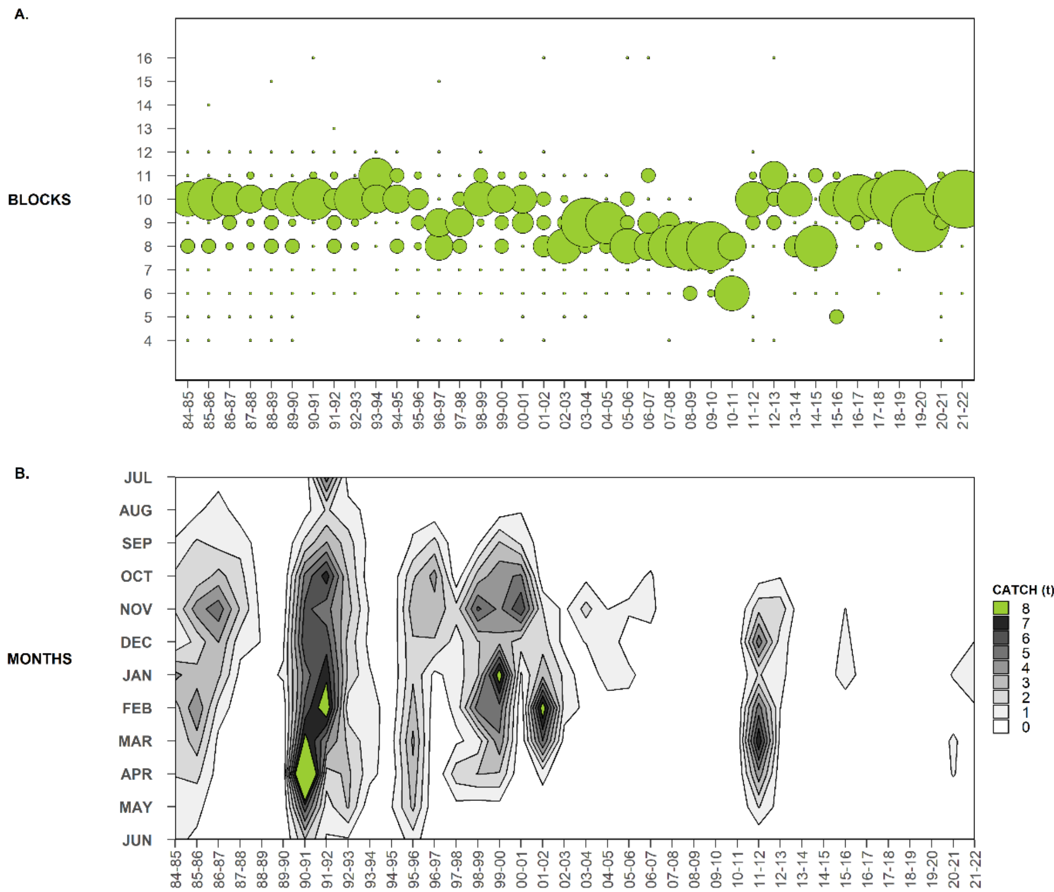

Figure 4-4. Fishery statistics for Greenback Flounder. Long-term trends in (A) the annual distribution of catch among LCF reporting blocks (diameter of the bubbles represent the relative contribution of each reporting block to total annual catch); and (B) the annual distribution of catch among months.

Stock status

The most recent stock assessment for Greenback Flounder was completed in 2016 and used a weight-of-evidence approach that considered fishery and age structure data to the end of June 2015 (Earl and Ye 2016). Since then, limited catch sampling has been done as part of the Coorong Fish Condition Monitoring program to develop annual fishery age structures (Ye et al. 2022).

Long-term trends in fishery production for Flounder indicate high interannual variability in fishable biomass in the Coorong Estuary. Annual catches were variable during the 1980s and 1990s, subsequently declined to historically low levels during the Millennium Drought of the 2000s and have since remained low. An exception was in 2011/12, (i.e., the year after drought-breaking River Murray flows reached the Coorong Estuary), when a large biomass of large Flounder moved into the estuary from the adjacent marine environment (Earl et al. 2017) and catch subsequently increased to its fourth highest level on record. This sudden and large increase in catch, which also occurred in 1990/91, 1995/96, 1998/99 following years of elevated freshwater inflows, was associated with near-record high catch rates and was not consistent with a spawning biomass that was recruitment overfished (Earl and

Ye 2016). The lack of targeted fishing effort and low catches in recent years have been associated with relatively low freshwater inflows and likely reflect low fishable biomass in the Coorong Estuary. Catch was stable at low levels in 2020/21 and 2021/22.

The high interannual variation in commercial catch since 1984/85 has been strongly associated with variation in freshwater inflow to the estuary, with a lag of 1–3 years (Earl and Ye 2016). This variation was because large areas of estuarine habitat that support high abundances of Flounder are only available after years of high freshwater inflow (e.g., 1990/91, 1996/97, 2010/11). It is likely that low flow conditions reduce the favourable habitat for Flounder in the estuary, during which time, some individuals move from the estuary to the ocean where they remain and can possibly return when estuarine conditions improve (Earl et al. 2017). This was evidenced by the immediate increase in Flounder catch in the Coorong Estuary in 1990/91, 1991/92 1995/96, 1998/99 and 2011/12, shortly after high inflow events (Earl and Ye 2016). The low biomass in the estuary in 2021/22 appears to relate to the relatively low freshwater inflows to the system in recent years, rather than a depleted spawning stock biomass (i.e., the spawning biomass is not likley to be recruitment overfished). The high inflow during 2021/22 are expected to support higher abundances of Greenback Flounder in 2022/23.

The lack of targeting of Flounder in recent years may also relate to the presence of Long-nosed Fur Seals in the region, which has reportedly resulted in fishers avoiding the long gillnet soak times required to effectively target this species (EconSearch 2022). Nevertheless, low targeted effort and catches of Greenback Flounder since 2012/13 likely reflect low fishable biomass in the Coorong Estuary, as a consequence of low recruitment to the fishable biomass over several recent years due to the low freshwater inflows (i.e., non-fishing effects). Biomass in the estuary has been reduced primarily through non-fishing effects and, as a consequence, recruitment to the fishable biomass is impaired. Consequently, under the definitions used in the NFSRF, Greenback Flounder is classified as a ‘**depleted**’ stock.

4.3.1.3 Performance indicators

Biological performance indicators

For the 2022 calendar year, the performance indicator for Black Bream targeted $CPUE_{LMGN}$ of 1.02 kg.net-day^{-1} was below the target reference point of 1.67 kg.net-day^{-1} and above the trigger reference point of 0.53 kg.net-day^{-1} prescribed in the Management Plan (Figure 4-5). For Greenback Flounder in 2022, targeted $CPUE_{LMGN}$ was 2.79 kg.net-day^{-1}, which was above the target reference point of 1.86 kg.net-day^{-1}.

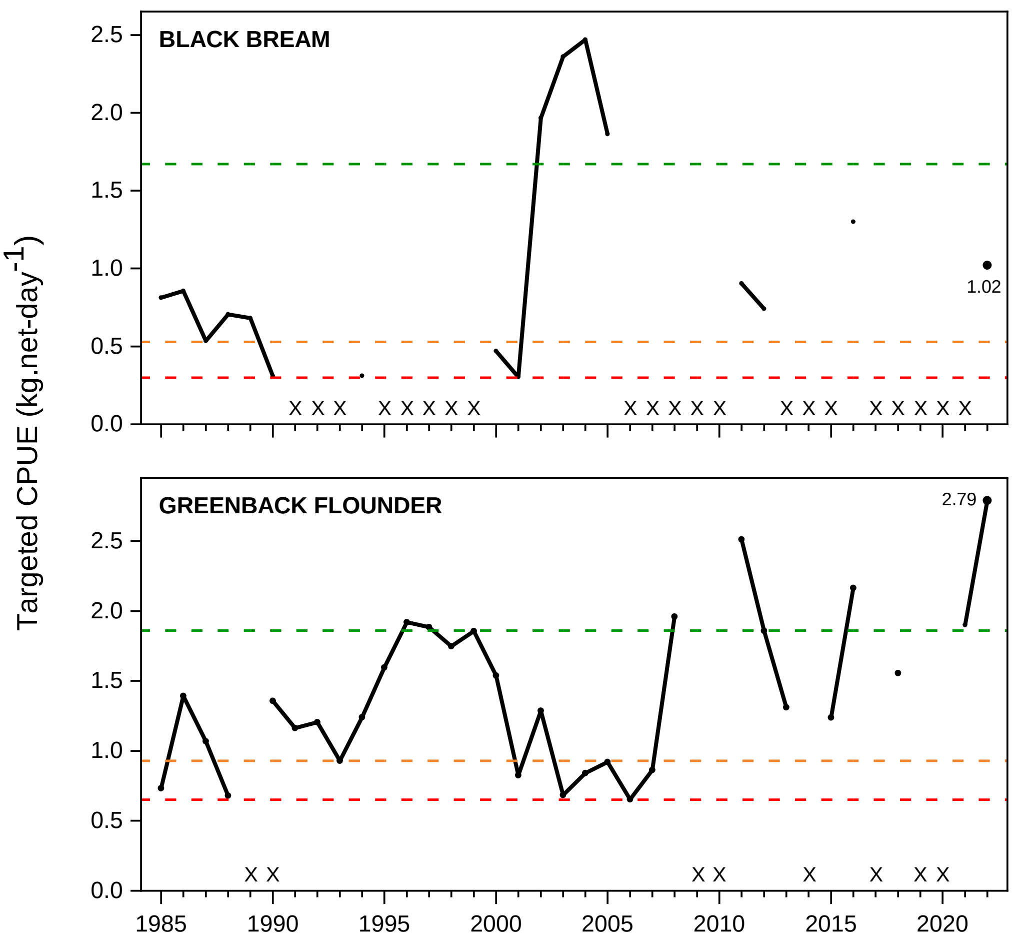

Figure 4-5. Time series of annual estimates of the ELMGN biological (secondary) performance indicator (targeted CPUE) for Black Bream (top) and Greenback Flounder (bottom) from 1985 to 2022 (calendar years), showing target (green dashed line), trigger (orange dashed line) and limit (red dashed line) reference points. Crosses represent confidential data reported by less than five licence holders.

4.3.2 Estuarine small-mesh gillnet sector

4.3.2.1 Yelloweye Mullet (*Aldrichetta forsteri*)

Biology

Yelloweye Mullet is a member of the Mugilidae family (Gomon et al. 2008). It is characterised by a slender, cigar-shaped small–medium bodied adult form that can reach around 440 mm TL and 10 years old (Thomson 1957; Gaughan et al. 2006). It occurs in estuaries and coastal waters in New Zealand and along the southern coast of Australia, from Murchison River in Western Australia to the Hunter River in New South Wales, and around Tasmania (Kailola et al. 1993). They typically occur in schools in inshore coastal waters over sandy and muddy substrates to depths up to 20 m. Larger fish prefer deeper habitats such as channels or gutters, whereas juveniles tend to occupy shallower areas (Higham et al. 2005). This species is well adapted to the dynamic environmental nature of estuaries and the nearshore coastal environment. They have a wide tolerance of water temperature and have been recorded in salinities up to 95 ppt in the Coorong Estuary (Ye et al. 2015).

Yelloweye Mullet is considered a marine estuarine-opportunist, i.e., it spawns at sea; regularly enters estuaries, particularly as juveniles, but uses coastal waters as alternative nursery habitat (Potter et al. 2015; Bice et al. 2018). For the Coorong population, macroscopic staging of gonads and gonadosomatic indices indicated a protracted reproductive season that extended from winter to early-autumn (Harris 1968; Ye et al. 2013). The estimated length-at-50%-maturity (L_{50}) for Yelloweye Mullet in the Coorong Estuary is around 245 mm TL (Earl and Ferguson 2013).

Biological stock structure for Yelloweye Mullet is uncertain. It has been suggested that populations in Australia form two stocks, i.e., the western and eastern stocks, based on the number of lateral scales and gill rakers (Pellizzari 2001). The Western Stock comprises populations in Western Australia and western South Australia (Smith et al. 2008), while the Eastern Stock comprises populations in South Australia's Spencer Gulf, Gulf St Vincent and South East, and extends eastwards to Victoria, New South Wales and Tasmania (Pellizzari 2001). While there is limited evidence that fish in the Coorong Estuary may be part of the Eastern Stock, further work is required to confirm biological stock delineation. This assessment of stock status is undertaken at the management unit level – the LCF.

Fishery

Yelloweye Mullet support commercial fisheries in Victoria, South Australia, Western Australia and Tasmania (Kailola et al. 1993). In South Australia, commercial and recreational catches are taken in most nearshore coastal waters, including the Coorong Estuary.

The commercial fishery for Yelloweye Mullet in South Australia has two main sectors: the LCF and the MSF. Over the past 25 years, the majority of the State's commercial catch has been taken by LCF fishers who target the species using small-mesh gillnets. The NZRLF and SZRLF also have limited access to Yelloweye Mullet, though catches from these sectors are low and not considered in this report.

Recreational fishers harvest Yelloweye Mullet using rod and line in semi-protected nearshore coastal waters of South Australia (Kailola et al. 1993). They can also target the species using registered monofilament nylon nets in the Coorong Estuary and Lake George (PIRSA 2022). Recreational net fishing is prohibited in all other coastal waters of South Australia. In 2021/22, an estimated 69,657 (standard error ± 21,612) Yelloweye Mullet were captured by the recreational sector, of which 11,033 fish were released, leaving 58,625 fish retained (Beckmann et al. 2023). This provided a total estimated State-wide harvest of 10.57 t (SE ± 3.56 t based on confidence interval of retained fish numbers for comparison among surveys). The proportion of the total recreational catch taken in areas of the LCF is not known. There are no catch and effort data for Aboriginal and traditional fishing.

Management arrangements

For the commercial sector of the LCF, management arrangements are in place to manage targeted fishing effort and limit the take of Yelloweye Mullet. These comprise general gear restrictions, spatial and temporal closures and a LML of 210 mm TL.

The recreational sector is managed through a combination of input and output controls, aimed at ensuring the total catch is maintained within sustainable limits and to ensure that recreational access to the fishery is equitably distributed between recreational participants (PIRSA 2022). Bag and boat limits apply to all State waters. The personal daily bag limit is 60 fish, and there is a boat limit (when three or more people are onboard) of 180 fish. The LML of 210 mm TL applies to the recreational sector. Management arrangements also comprise general gear restrictions. A small number of registered mesh net owners can use nylon gillnets to target finfish in the Coorong Estuary. Recreational mesh nets must be less than 75 m long with 50–64 mm mesh, and the registered net owner must be within 50 m of the net at all times when fishing. Temporal and spatial closures apply to the use of recreational nets in the region.

Commercial fishery statistics

Trends in total catch, effort and CPUE

Total annual catch of Yelloweye Mullet in the LCF increased from 128 t in 1984/85 to 342 t in 1989/90 (Figure 4-6). From then, catch progressively declined to a low of 110 t in 2004/05. It then increased and ranged between 206–243 t between 2007/08 and 2010/11, before declining to 121 t in 2014/15. Catches gradually increased between 2014/15 and 2017/18, before increasing exponentially to 458 t in 2019/20, which was by far the highest annual catch on record. Since then, catch has declined to moderate levels and was 206 t in 2021/22.

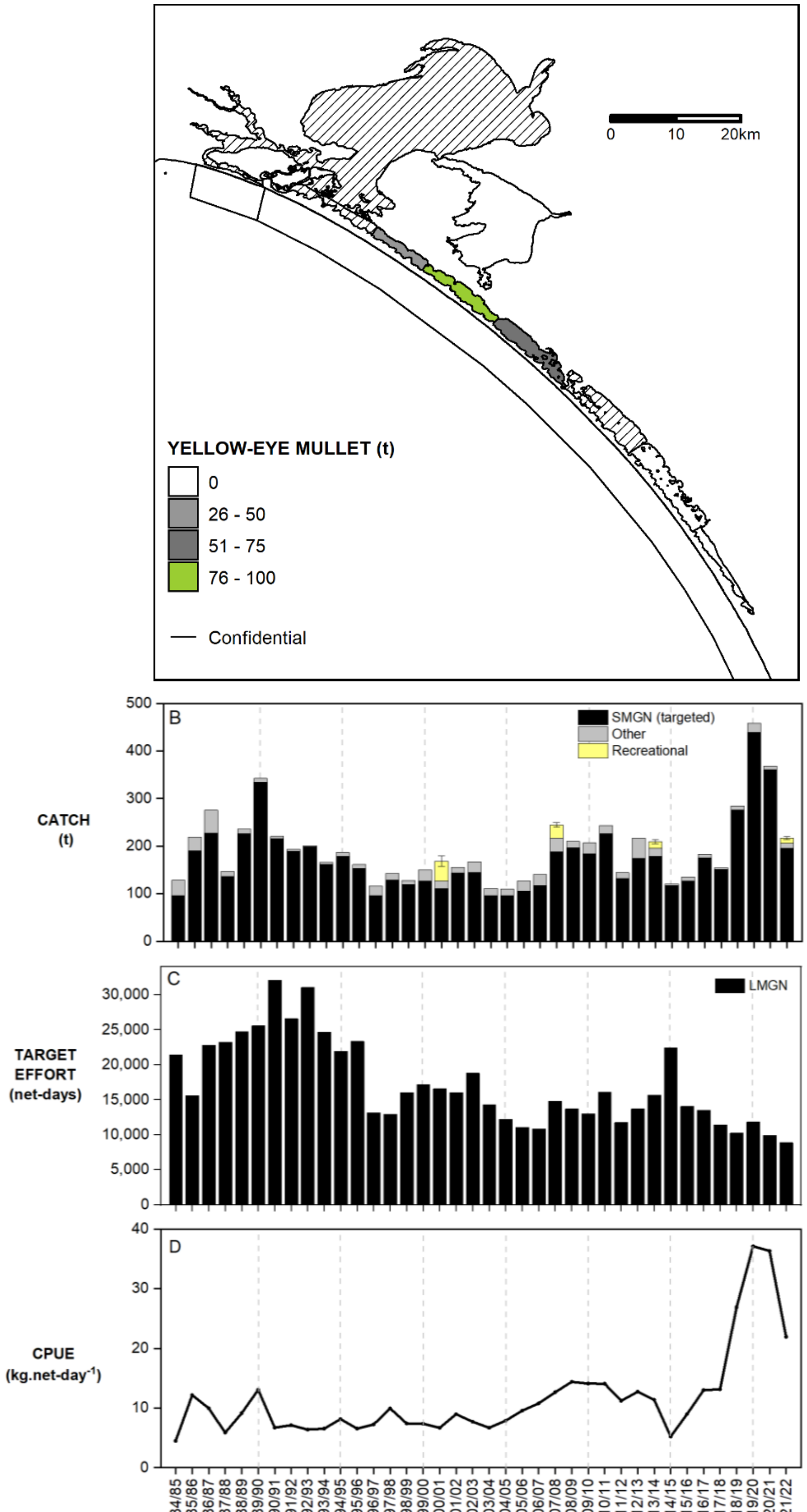

Figure 4-6. Fishery statistics for Yelloweye Mullet. (A) Map of the LCF reporting blocks showing the catch distribution for 2021/22; Long term trends in: (B) total catch, including targeted catch for the main gear type - small-mesh gillnets (SMGN), targeted and non-targeted catch for all gear types (OTHER), and for the recreational sector (from all State waters for 2000/01, 2007/08, 2013/14 and 2021/22); (C) targeted effort for SMGN; and (D) targeted CPUE for SMGN. For comparison among recreational fishing surveys, error bars were recalculated and represent the equivalent of the coefficient of variation of harvested fish numbers.

The dominant gear type used to target Yelloweye Mullet has been the small-mesh gillnet, which has accounted for an average of 91% of the annual catch over the past 38 years (Figure 4-6). Most of the remaining catch in each year was taken using haul nets, or as by-product when other species were targeted. In 2021/22, 95% of the catch was taken as targeted catch using small-mesh gillnets.

Estimates of annual targeted $CPUE_{SMGN}$ were stable at low levels from 1984/85 to 2003/04 (mean = 7.9; range: 4.5–13.1 kg.net-day^{-1}). They then progressively increased to 14.4 kg.net-day^{-1} in 2008/09 and remained above 11 kg.net-day^{-1} until 2013/14 (Figure 4-6). Catch rates subsequently declined to 5.2 kg.net-day^{-1} in 2014/15, before increasing to an unprecedented high of 37.2 kg.net-day^{-1} in 2019/20. The $CPUE_{SMGN}$ of 21.9 kg.net-day^{-1} in 2021/22 was the fourth highest on record.

Spatial and temporal trends in catch

Reporting blocks 9 to 11 have consistently contributed most to the annual catches of Yelloweye Mullet since 1984/85 (Figure 4-7). Over this time, the most notable change in the spatial distribution of catches occurred during the Millennium Drought of the 2000s, when there was an increase in the relative contributions of catches from blocks 8 and 9 to total annual catch. This spatial contraction of the fishery was associated with a reduction in the amount of suitable estuarine habitat available for the species in the Coorong Estuary (Earl 2020). In 2021/22, most of the catch was taken in reporting blocks 10 and 11. Historically, the LCF for Yelloweye Mullet was seasonal with higher catches taken between May and November. In 2021/22, catches were highest from July to February and lowest between March and May.

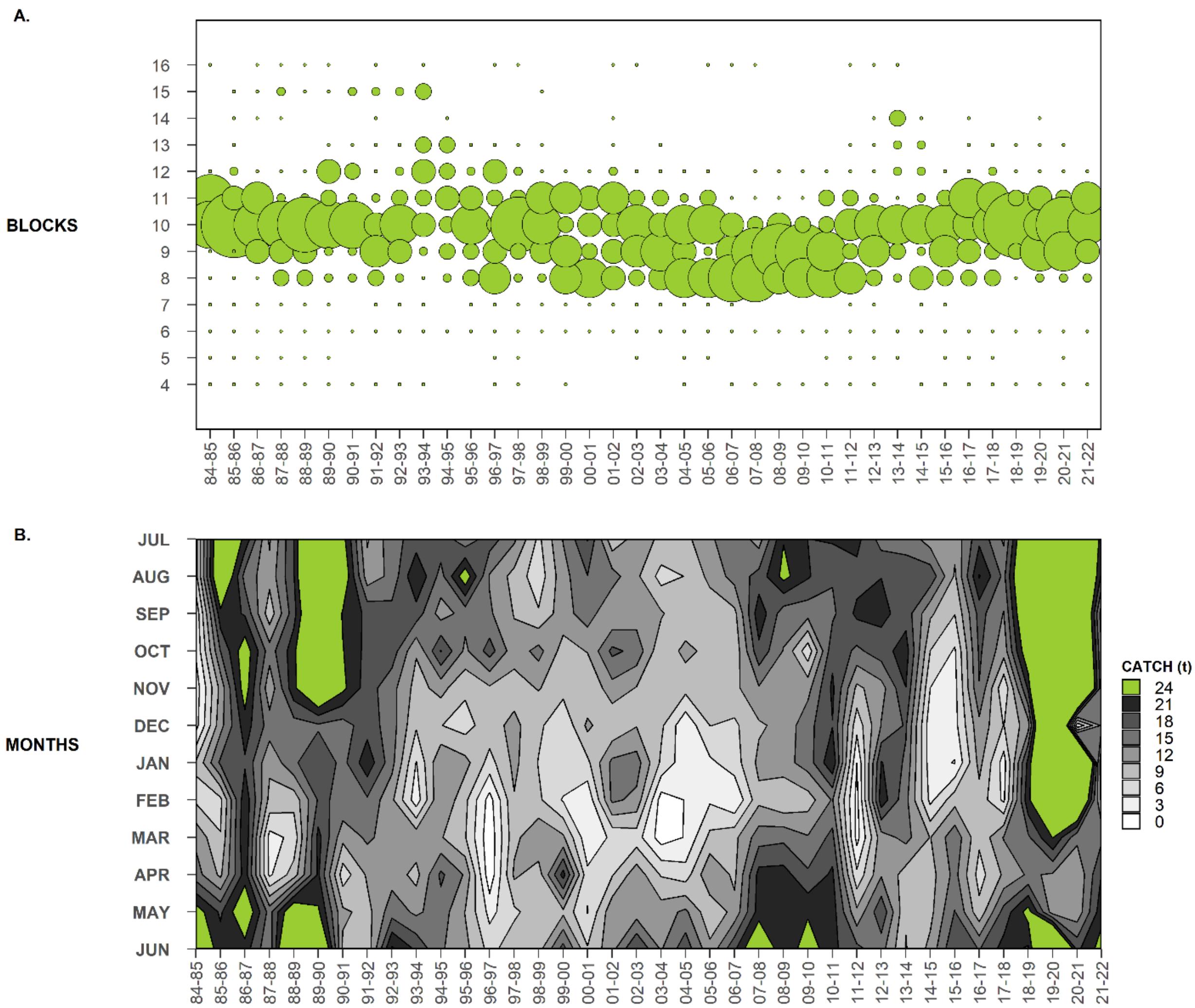

Figure 4-7. Fishery statistics for Yelloweye Mullet. Long-term trends in: (A) the annual distribution of catch among LCF reporting blocks (diameter of the bubbles represent the relative contribution of each reporting block to total annual catch); and (B) the annual distribution of catch among months.

Stock status

Yelloweye Mullet is a primary target species for the LCF. This reflects its history of high catches and wholesale value compared to most other species available to the fishery (EconSearch 2022). The most recent stock assessment for Yelloweye Mullet was done in 2021 and used a weight-of-evidence approach that considered commercial catch and effort data, and fishery age structures to the end of June 2020 (Earl and Bailleul 2021).

The LCF has historically been the most significant fishery for Yelloweye Mullet in South Australia, having contributed >90% of State's total commercial catch of this species in most of the past 15 years. Commercial landings in the LCF peaked in 1989/90 and then progressively declined to a historical low in 2004/05. This long-term decline likely reflected redirection of targeted fishing effort to higher-value species (i.e., Mulloway) rather than a declining biomass, because targeted $CPUE_{SMGN}$ was stable during this period. Catch rates declined from 2010/11 to 2014/15 suggesting a possible decline in fishable biomass in the Coorong Estuary. Since then, catches and catch rates have been considerably higher. The recent high catches have been associated with unprecedented, record-high targeted catch rates and are indicative of exceptionally high biomass. However, recent high catch rates could also relate to changes in fisher behaviour (e.g., shorter gillnet soak times, setting less gillnets each day (Earl et al. 2021)) and represent increased fisher efficiency. If fisher efficiency is increasing, then increased CPUE is not linearly related to stock size. Given this uncertainty, the recent high catches and CPUE must be considered with caution. Nevertheless, the information considered in this assessment 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 in unlikely to cause the stock to become recruitment impaired. On this basis, the LCF for Yelloweye Mullet is classified as a **sustainable** stock.

4.3.2.2 Performance indicators

Environmental performance indicator

Modelled daily salinity concentrations for the Coorong Estuary during the 2022/23 reporting year indicated that the amount of suitable habitat for Yelloweye Mullet increased from ~65% during February–April to 100% in August as a result consistent high freshwater inflows to the Coorong (Figure 4-8). The persistent high flows maintained salinities below the threshold for Yelloweye Mullet of 68 ppt throughout the entire system until January 2023, when the habitat availability started to reduce. The ESMGN performance indicator for habitat available to Yelloweye Mullet in the Coorong Estuary was 87.1% for the 2022/23 reporting year, which was above the target reference point of 50% (Figure 4-9).

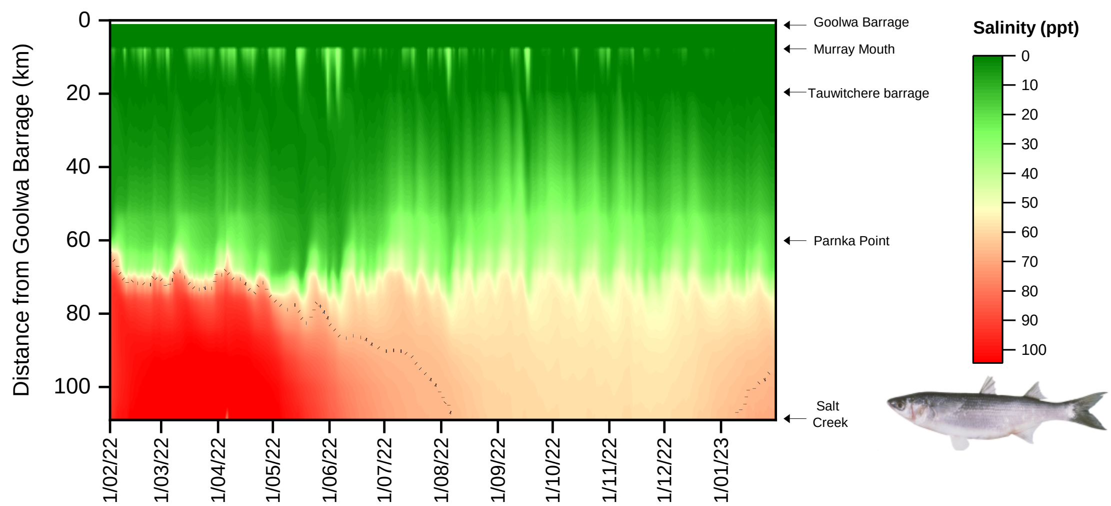

Figure 4-8. Estimated salinity concentration with distance from the Goolwa Barrage to Salt Creek for the 2022/23 reporting year, with the approximate salinity threshold for Yelloweye Mullet (68 ppt) shown as a dashed line. Salinity threshold represents the level of salinity that was lethal for 10% of test fish, as determined by Ye et al. (2013). The dark green contours (i.e., < 10 ppt) indicate periods of freshwater inflows through the barrage system.

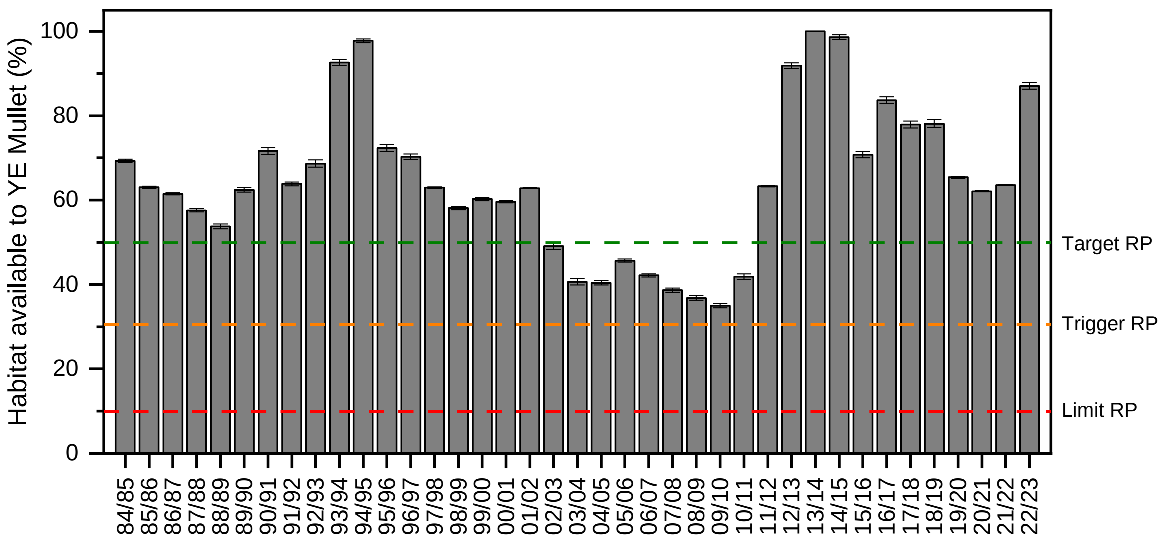

Figure 4-9. Time series of annual estimates of the ESMGN environmental (primary) performance indicator for habitat available to Yelloweye Mullet in the Coorong Estuary from 1984/85 to 2022/23 (in reporting years), showing target, trigger and limit reference points (RP).

Biological performance indicator

For the 2022 calendar year, the biological performance indicator for Yelloweye Mullet targeted $CPUE_{SMGN}$ of 32.3 kg.net-day^{-1} was 191% above the target reference point prescribed in the Management Plan (Figure 4-10).

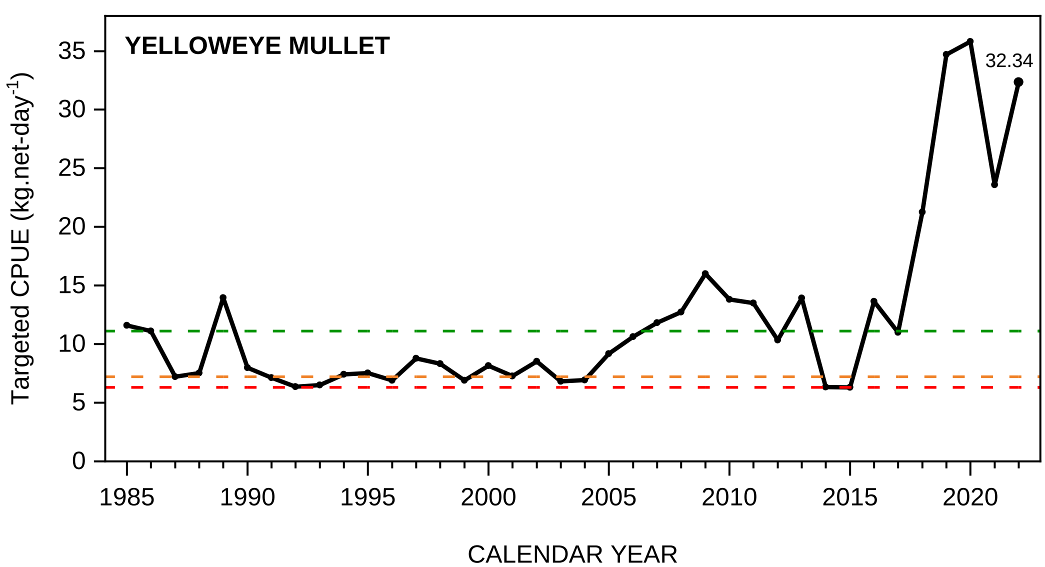

Figure 4-10. Time series of annual estimates of the ESMGN biological (secondary) performance indicator (targeted CPUE) for Yelloweye Mullet from 1985 to 2022 (calendar years), showing the target (green dashed line), trigger (orange dashed line) and limit (red dashed line) reference points.

4.3.3 Freshwater large-mesh gillnet sector

4.3.3.1 Golden Perch (*Macquaria ambigua*)

Biology

Golden Perch (*Macquaria ambigua*), also known locally as 'Callop', is a member of the Percichthyidae family (Classon and Booth 2002). It occurs throughout the MDB, except at high altitudes, as well as in the Lake Eyre and Bulloo drainage systems of Queensland, NSW and South Australia, and the Dawson-Fitzroy river system in Queensland (Lintermans 2007). Translocated fish occur in numerous other waterways and impoundments throughout south-eastern Australia.

Golden Perch can grow to 760 mm TL and live to 27 years of age (Mallen-Cooper and Stuart 2003). In the lower River Murray, individuals usually mature at 2–4 years of age, although the size-at-maturity for the Lower Lakes population is not known. Spawning occurs mainly during spring and summer (Battaglene and Prokop 1987).

Golden Perch in the MDB are genetically distinct from those in the Lake Eyre, Bulloo and Fitzroy systems (Faulks et al. 2010a, b; Beheregaray et al. 2017). Murray-Darling Golden Perch form a well-connected metapopulation with low-level basin-wide population structure, reflecting their ability to migrate and disperse long distances (Attard et al. 2018; Zampatti et al. 2018). However, subtle genetic differences and regional differences in population structures driven by unique recruitment sources suggest sub-structuring across some regions. Examples include the Lower Lakes (Earl et al. 2015) and Paroo River (Attard et al. 2018), and potentially the physically disconnected and hydrologically impacted Victorian tributaries of the River Murray and some NSW tributaries of the Barwon-Darling, e.g., Lachlan River (Shams et al. 2020). The assessment of stock status in this report is undertaken at the management unit level – the LCF.

Fishery

Golden Perch is an important species for commercial and recreational fisheries in South Australia. Historically, the commercial fishery had three main sectors: the LCF; the River (or Reach) Fishery; and the Lake Eyre Basin Fishery (LEBF). The LCF is the main commercial fishery for Golden Perch in the State. The LCF uses large-mesh gillnets to target the species in the Lower Lakes and the River Murray between Lake Alexandrina and Wellington. The commercial River Fishery was established in 1923 and operated along the main channel of the River Murray, before it was closed in 2003 (Earl et al. 2015). The LEBF was established 1992, and has one licensed fisher that operates on the pastoral holding of Mulka Station. The LEBF is a unique fishery due to the harsh environment in which it operates and its dependence on the dispersion of Golden Perch to the region during large scale flood events within the Cooper Creek system. Catch and effort data for the River Fishery and LEBF are not considered in this report.

Currently, Golden Perch is the only large-bodied native fish species that is permitted to be taken by recreational fishers along the River Murray in South Australia. Most recreational fishers target Golden Perch using rod and line. In 2021/22, the estimated State-wide retained recreational catch of Golden Perch was 11.21 t (standard error ± 3.5 t based on confidence interval of retained fish numbers for comparison among surveys) (Beckmann et al. 2023). There are no catch and effort data for Aboriginal and traditional fishing.

Management arrangements

Golden Perch is a primary species of the LCF, making a relatively high contribution to the total production value (PIRSA 2022). For the commercial sector, management arrangements are in place to manage targeted fishing effort and limit the take of Golden Perch. These include temporal and spatial netting closures, restrictions to net lengths and mesh sizes, and a LML of 330 mm TL.

There are multiple management arrangements in place for Golden Perch in the recreational sector. Input and output controls ensure the total catch is maintained within sustainable limits and that access is distributed equitably among fishers. These include gear restrictions and a daily bag limit of five fish and boat limit of 15 fish. The LML of 330 mm TL also applies.

Commercial fishery statistics

Trends in total catch, effort and CPUE

Total annual catches of Golden Perch have fluctuated cyclically over the past 37 years (Figure 4-11). They ranged from 17.8 to 36.3 t during the late 1980s, then increased to a peak of 206 t in 1994/95, before declining to 36 t in 2001/02. Catch increased to a smaller peak of 152 t in 2006/07 and then declined to 34 t in 2012/13. Between 2013/14 and 2016/17, annual catches ranged between 79 and 88 t, before increasing to 105 t in 2017/18. Since then, total catch has progressively declined to 35.2 t in 2021/22, which is the lowest catch since 2012/13.

Targeted catches taken using large-mesh gillnets have accounted for >75% of the total catch in most years since 1984/85 (Figure 4-11). Trends in targeted effort using large-mesh gillnets have been similar to total catch with peaks of 128,896 and 94,006 net-days in 1997/98 and 2006/07, respectively. Effort has been considerably lower over the past 13 years, declining to 19,307 net days in 2021/22, which is fifth lowest recorded in the fishery.

Estimates of targeted $CPUE_{LMGN}$ have followed the same cyclical pattern as catch and targeted large-mesh gillnet effort, with peaks in the early 1990s and mid-2000s (Figure 4-11). Since 2009/10, $CPUE_{LMGN}$ increased from 0.62 kg.net-day^{-1} to an all-time high of 1.55 kg.net-day^{-1} in 2017/18, before progressively declining to 0.81 kg.net-day^{-1} in 2021/22, which is similar to the long-term average.

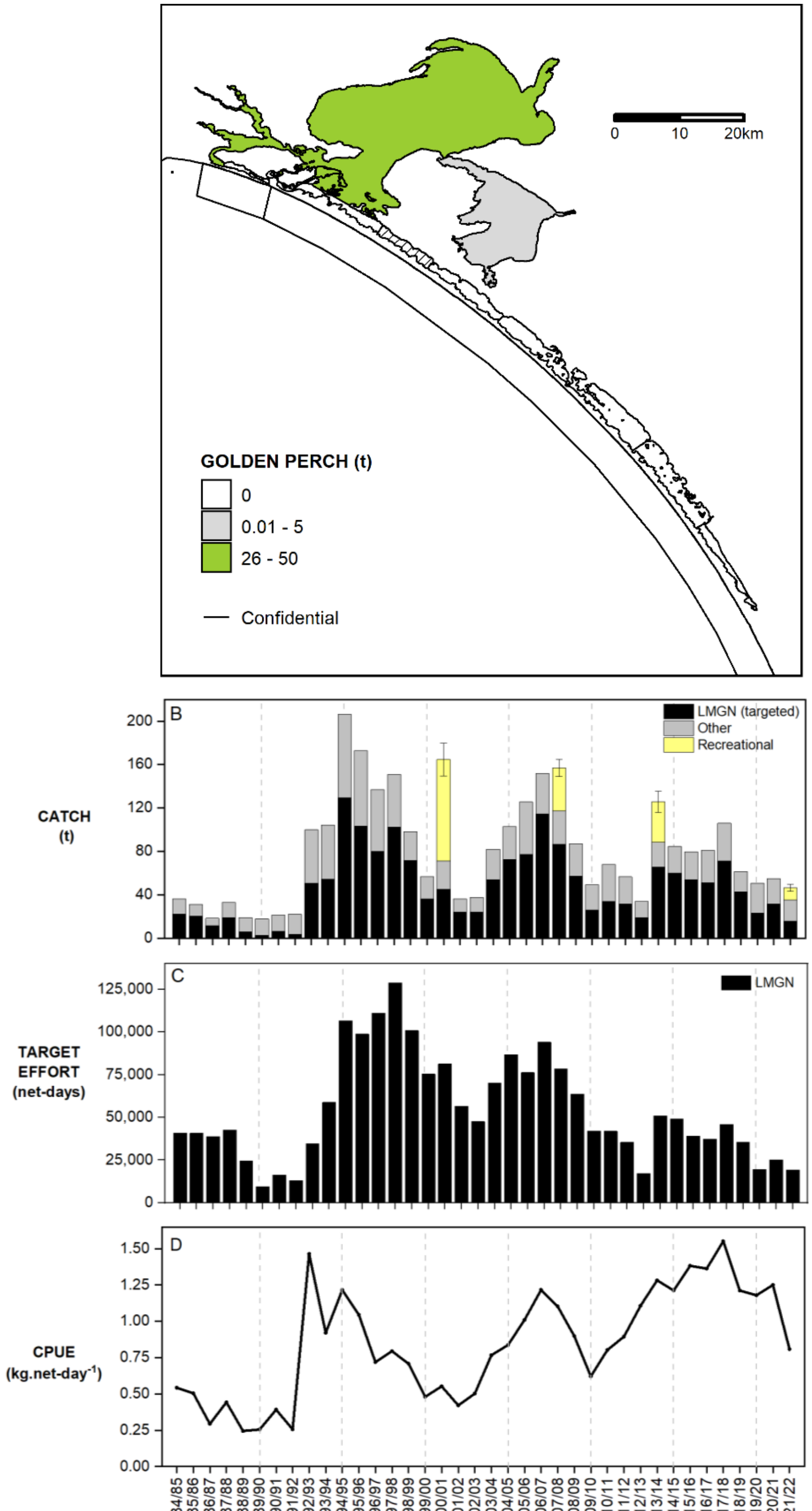

Figure 4-11. Fishery statistics for Golden Perch. (A) Map of the LCF reporting blocks showing the catch distribution for 2021/22; Long term trends in: (B) total catch, including targeted catch for the main gear type - large-mesh gillnets (LMGN), targeted and non-targeted catch for all gear types (OTHER), and for the recreational sector (from all State waters for 2000/01, 2007/08, 2013/14 and 2021/22); (C) targeted effort for LMGN; and (D) targeted CPUE for LMGN. For comparison among recreational fishing surveys, error bars were recalculated and represent the equivalent of the coefficient of variation of harvested fish numbers.

Spatial and temporal trends in catch

Catches taken in reporting block 4 (Lake Alexandrina) have consistently accounted for > 90% of annual total catches since 1984/85, with block 5 (Lake Albert) contributing most of the remaining catches (Figure 4-12). There has been no clear seasonality in fishery catches during the past decade.

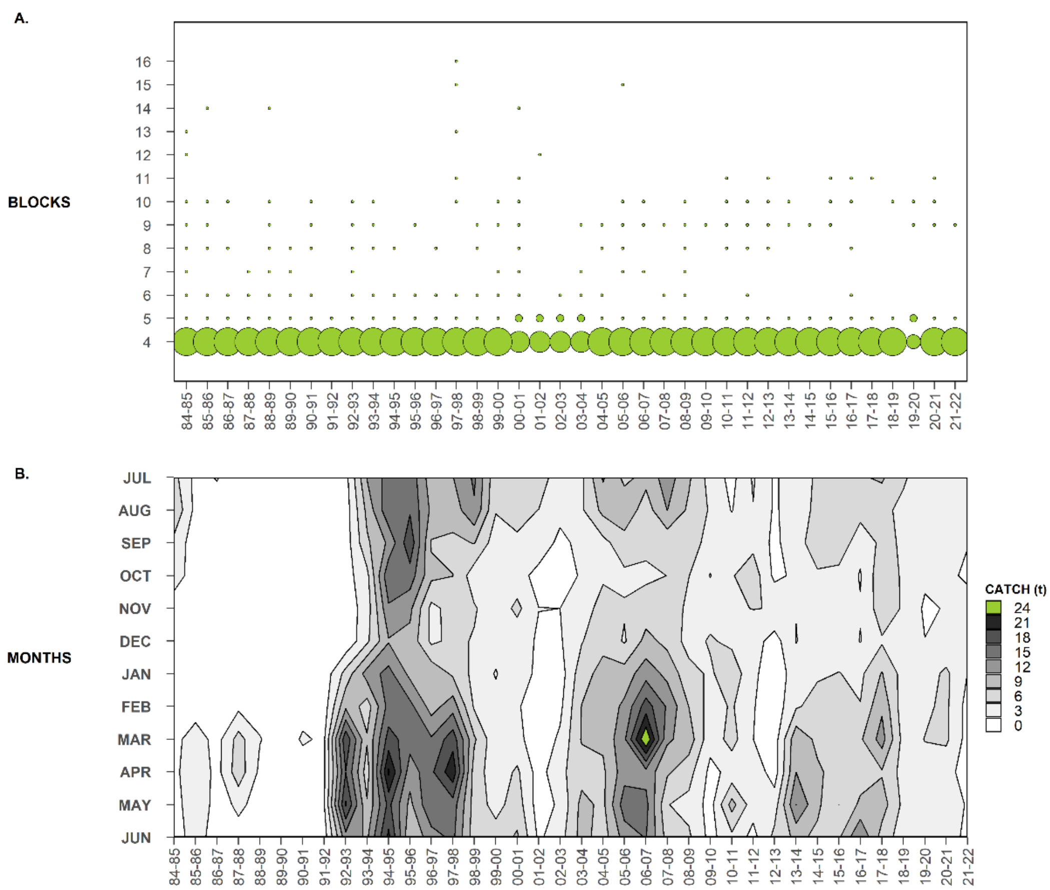

Figure 4-12. Fishery statistics for Golden Perch. Long-term trends in (A) the annual distribution of catch among LCF reporting blocks (diameter of the bubbles represent the relative contribution of each reporting block to total annual catch); and (B) the annual distribution of catch among months.

Stock status

Golden Perch is a primary target species for the commercial sector of the LCF (PIRSA 2022). The most recent stock assessment for Golden Perch in the Lower Lakes was completed in 2012 and used a weight-of-evidence approach that considered fishery catch and effort data and fishery age structures to the end of June 2012 (Ferguson and Ye 2012).

The most obvious long-term trend in the fishery data for Golden Perch is the cyclical nature of the interannual variation in total catch, which has been closely linked with variations in targeted effort and $CPUE_{LMGN}$. These temporal trends likley reflect trends in fishable biomass. Peaks in catch and catch rate occurred in the mid-1990s, mid-2000s and mid-2010s and likley followed years of strong recruitment to the fishable biomass. These peaks in catch and $CPUE_{LMGN}$ were followed by declines that were consistent with declines in biomass that likley resulted from the removal of fish by fishing, and low recruitment in the preceding years. In 2021/22, total catch declined to its lowest level since 2012/13, while $CPUE_{LMGN}$ declined to a level that was similar to the long-term average. While these results are indicative of low-moderate fishable biomass, both catch and $CPUE_{LMGN}$ were above their respective record-lows reported in the 1980s, from which the fishery has demonstrated its capacity to recover. This indicates the fishable biomass in the Lower Lakes 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 this basis, the LCF for Golden Perch is classified as a **sustainable** stock.

4.3.3.2 Bony Herring (*Nematalosa erebi*)

Biology

Bony Herring (*Nematalosa erebi*) is a member of the Clupeidae family (Classon and Booth 2002). It occurs throughout the MDB, in the Lake Eyre Basin and across Queensland, most of the Northern Territory and in northern Western Australia. In South Australia, the species is abundant in the River Murray and Lower Lakes. It is the only large native fish species in the lower River Murray whose abundance appears not to have declined since the advent of flow regulation in the 1940s (Puckridge and Walker 1990).

Bony Herring is a medium-sized, laterally compressed, deep-bodied fish with a small head and blunt snout (Lintermans 2007). It can grow to 470 mm TL but is commonly 150–270 mm TL (Classon and Booth 2002). Spawning occurs in spring and summer after reaching maturity at a size of approximately 80 mm TL and two years of age. Stock structure in South Australia is uncertain. The assessment of stock status in this report is undertaken at the management unit level–the LCF.

Fishery

Bony Herring is a secondary species for the LCF (PIRSA 2022). This reflects its low wholesale value. Most of the catch is taken as by-product in the Lower Lakes, which is supplied as bait to the SZRLF and NZRLF. This species is not generally targeted by recreational fishers in South Australia. There are no catch and effort data for Aboriginal and traditional fishing.

Management arrangements

For the commercial sector of the LCF, management arrangements are in place to manage targeted fishing effort and limit the take of Bony Herring. These include temporal and spatial netting closures, and restrictions to net lengths and mesh sizes (PIRSA 2022). No specific management arrangements are in place for Bony Herring in the recreational sector.

Commercial fishery statistics

Trends in total catch, effort and CPUE

Total catches of Bony Herring increased to a peak of 1,157 t in 1989/90, before steadily declining to a low of 212 t in 2002/03 (Figure 4-13). This decline corresponded with a decline in fishing effort that produced catches of Bony Herring and decreasing $CPUE_{LMGN}$. Catch increased to 550 t in 2009/10 and then progressively declined to 269 t in 2019/20, which was the lowest catch since 2004/05. This decline in catches was associated with a decline in fishing effort to a historical low of 52,840 net-days in 2019/20. In 2021/22, the total catch increased to 358 t. $CPUE_{LMGN}$ has been relatively stable at moderate–high levels since 2009/10. The $CPUE_{LMGN}$ of 5.8 kg.net-day^{-1} in 2021/22 was the highest since 2012/13.

Spatial and temporal trends in catch

Catches taken in reporting block 4 (Lake Alexandrina) have consistently accounted for >90% of annual total catches since 1984/85, with smaller quantities taken in block 5 (Lake Albert) (Figure 4-14). Over the last 20 years, spring and summer have been the most productive seasons for the Bony Herring fishery.

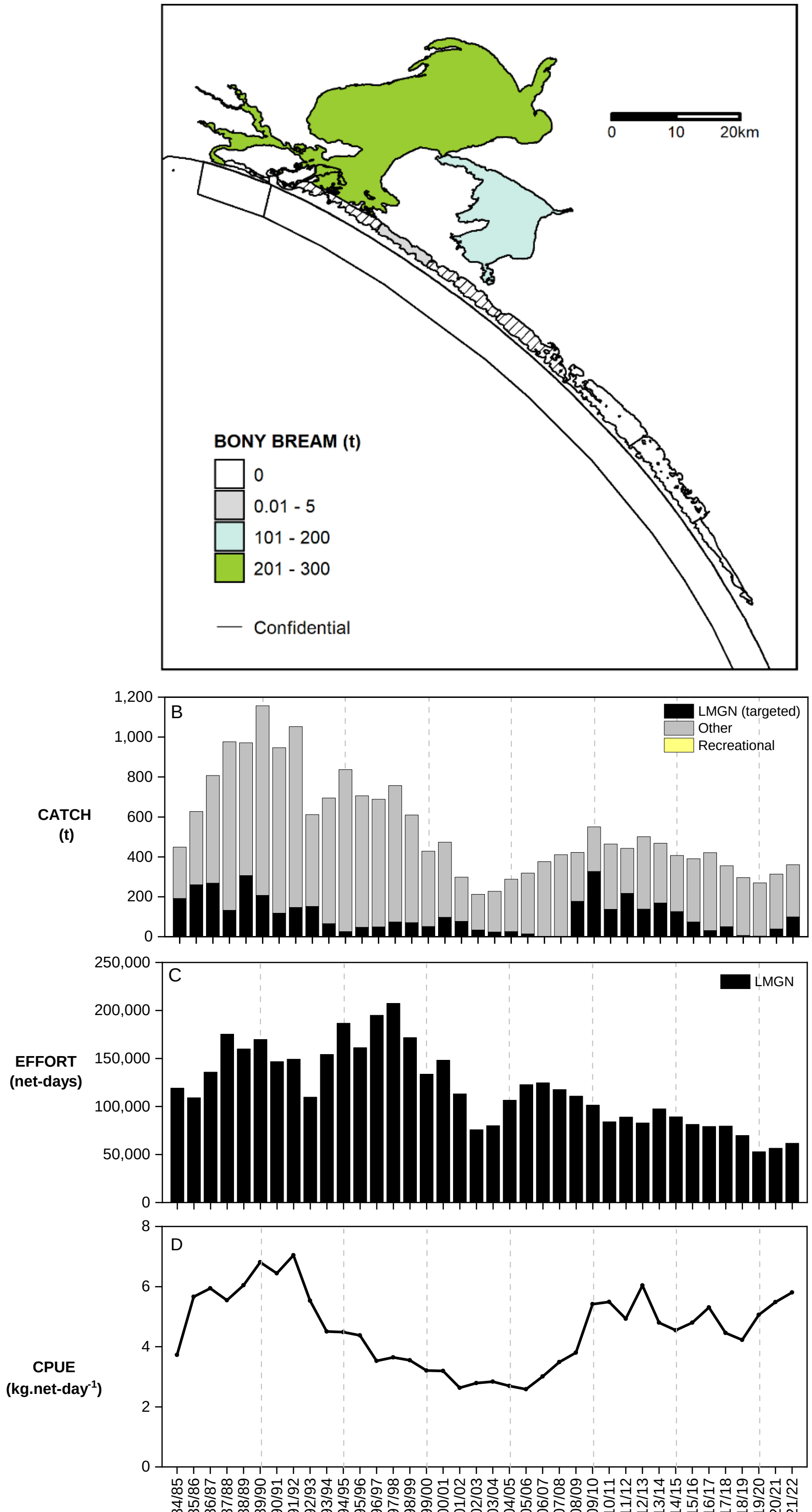

Figure 4-13. Fishery statistics for Bony Herring. (A) Map of the LCF reporting blocks showing the catch distribution for 2021/22; Long term trends in: (B) total catch, including targeted catch for the main gear type - large-mesh gillnets (LMGN) and targeted and non-targeted catch for all gear types (OTHER); (C) total effort that produced catches of Bony Herring for LMGN; and (D) CPUE for LMGN, based on total catch and total effort that produced catches of Bony Herring. No estimates of recreational catch are available for Bony Herring.

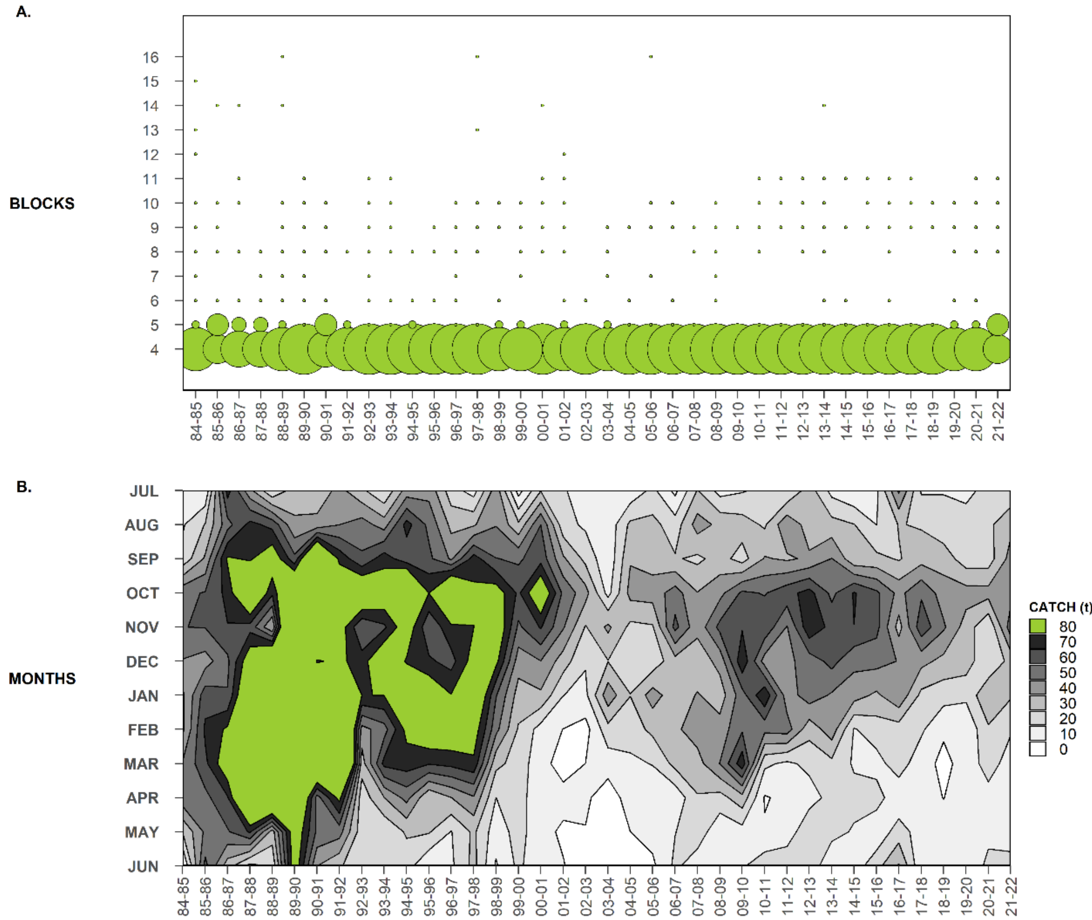

Figure 4-14. Fishery statistics for Bony Herring. Long-term trends in (A) the annual distribution of catch among LCF reporting blocks (diameter of the bubbles represent the relative contribution of each reporting block to total annual catch); and (B) the annual distribution of catch among months.

Stock status

Bony Herring is a secondary species for the commercial LCF (PIRSA 2022). This reflects its low wholesale value compared to other species that support the fishery. Most of the catch is taken as by-product and supplied as bait to local Rock Lobster fisheries. No stock assessments have been done for Bony Herring in the LCF.

Annual catches of Bony Herring declined considerably during the 1990s, owing to declines in large-mesh gillnet effort and catch rates in the Lower Lakes. Since then, catches have been higher in most years but have progressively dropped over the last decade. The recent low catches have been associated with low large-mesh gillnet fishing effort in the Lower Lakes. Catch rates have been stable at moderate–high levels since the 2000s. The high (and increasing) catch rates since 2019/20 indicate 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 this basis, the LCF for Bony Herring is classified as a **sustainable** stock.

4.3.3.3 Carp (*Cyprinus carpio*)

Biology

Carp (*Cyprinus carpio*) is a member of Cyprinidae family (Classon and Booth 2002). Native to China, Carp was introduced to Australian waterways in the 1850s and has since established populations in every state and territory, except the Northern Territory. It spread rampantly throughout the MDB in the 1980s and is now considered one of Australia's major aquatic pests. In South Australia, the species has been declared noxious under the *Fisheries Management Act 2007*.

Carp can tolerate a wide range of conditions including warm, low-oxygen and brackish water. Individuals can grow to 1,200 mm TL but are typically <500 mm TL, and mature at 1–3 years of age. Spawning occurs during spring and summer in shallow, slow-flowing areas such as wetlands, with each large female able to produce and release up to one million eggs each year.

Fishery

In Australia, commercial fishing for Carp occurs in Victoria, South Australia, and NSW. The species is a popular target for recreational fishers in these States, as well as Queensland and the Australian Capital Territory. The LCF is the main commercial fishery for Carp in South Australia. It targets Carp using large-mesh gillnets in the Lower Lakes, with most of the catch supplied as bait to local Rock Lobster fisheries, while a small and increasing proportion of the catch is sold for human consumption (EconSearch 2022). Recreational fishers harvest Carp using rod and line along the length of the River Murray in South Australia, as well as from numerous other freshwater catchments around the State. In 2021/22, the estimated State-wide recreational catch of Carp was 99 t (SE ± 17.94 t based on confidence interval of retained fish numbers for comparison among surveys) (Beckmann et al. 2023). There are no catch and effort data for Aboriginal and traditional fishing.

Management arrangements

Carp is a primary species of the commercial LCF, making a relatively high contribution to the total commercial production value of the fishery (PIRSA 2022). For the commercial sector, management arrangements are in place that limit targeted fishing effort for finfish. These include general gear restrictions, and spatial and temporal closures. For the recreational sector, management arrangements are limited to general gear restrictions. No LML applies to Carp.

Commercial fishery statistics

Trends in total catch, effort and CPUE

Total annual catches of Carp increased to a peak of 1,021 t in 1991/92, and subsequently declined to 209 t in 2001/02 before increasing to a smaller peak of 749 t in 2005/06 (Figure 4-15). Since 2010/11, catches have been lower, ranging from 308 t in 2011/12 to 538 t in 2019/20. The total catch of 375 t in 2021/22 was the lowest since 2012/13.

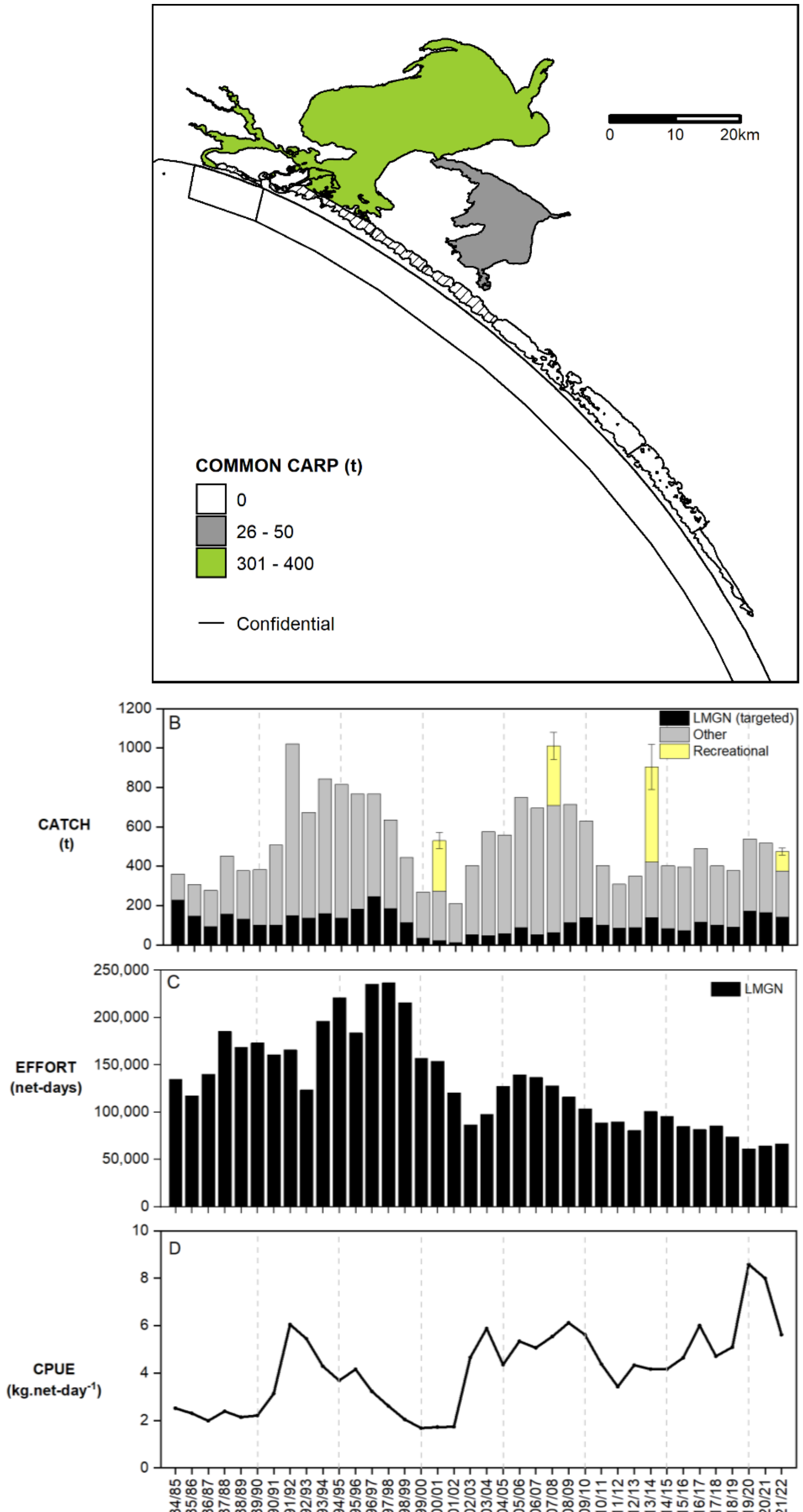

Figure 4-15. Fishery statistics for Carp. (A) Map of the LCF reporting blocks showing the catch distribution for 2021/22; Long term trends in: (B) total catch, including targeted catch for the main gear type - large-mesh gillnets (LMGN), combined targeted and non-targeted catch for all gear types (OTHER), and for the recreational sector (from all State waters for 2000/01, 2007/08, 2013/14, 2021/22); (C) total effort that produced catches of Carp for LMGN; and (D) CPUE for LMGN, based on total catch and total effort that produced catches of Carp. For comparison among recreational fishing surveys, error bars were recalculated and represent the equivalent of the coefficient of variation of harvested fish numbers.

The temporal trends in total annual LMGN effort that produced catches of Carp have followed those of total catch since 1984/85, with a peak of 236,804 net-days in 1997/98 and a subsequent decline to 86,785 net-days in 2002/03 (Figure 4-15). From 2010/11 to 2017/18, total effort was relatively stable and ranged between 80,588 and 100,462 net-days, before it declined to 61,300–66,590 net-days during 2019/20–2021/22. Annual $CPUE_{LMGN}$ also followed a similar temporal trend up until 2019/20, when $CPUE_{LMGN}$ increased sharply to 8.8 kg.net-day^{-1}, which was the highest catch rate recorded in the fishery. In 2021/22, $CPUE_{LMGN}$ declined to a moderate level of 5.6 kg.net-day^{-1}.

Spatial and temporal trends in catch

The commercial fishery for Carp is mostly limited to the Lower Lakes, with most of the catch taken in Lake Alexandrina (block 4) (Figure 4-16). Catches of Carp are taken throughout each year, with the largest quantities harvested usually during the warmer months from September to March.

No stock status is assigned to Carp.

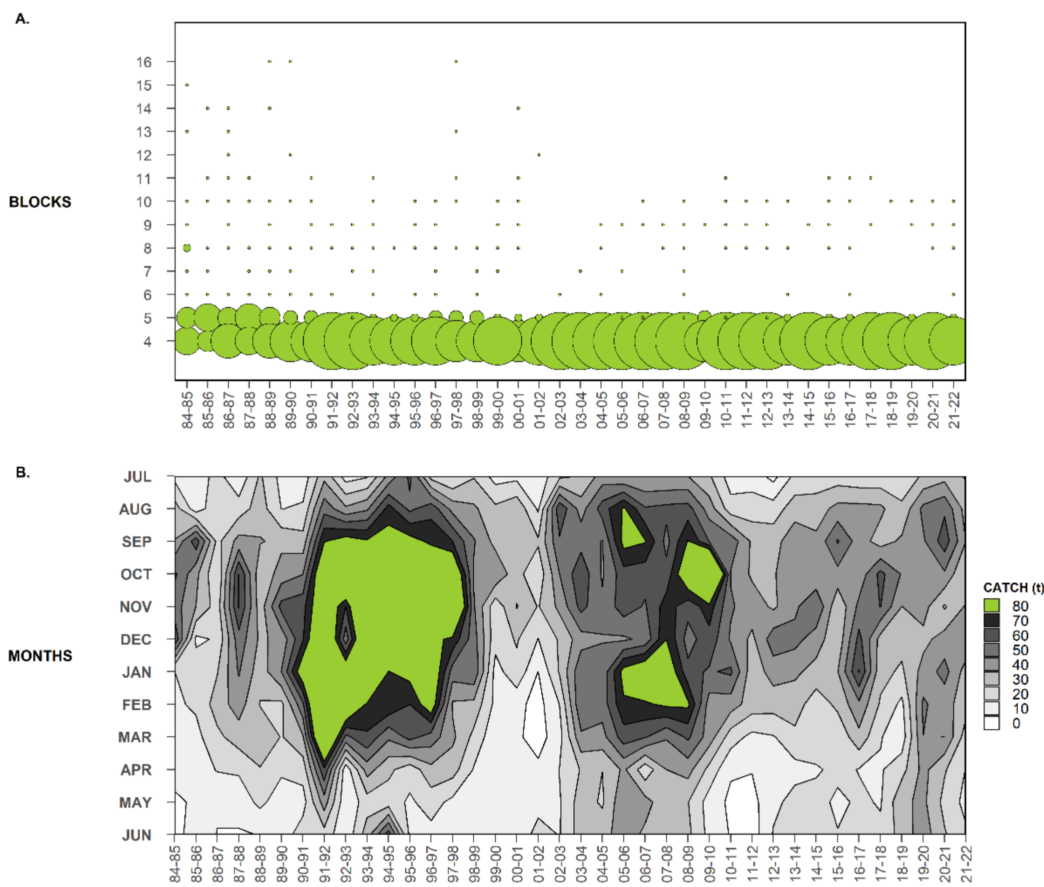

Figure 4-16. Fishery statistics for Carp. Long-term trends in (A) the annual distribution of catch among LCF reporting blocks (diameter of the bubbles represent the relative contribution of each reporting block to total annual catch); and (B) the annual distribution of catch among months.

4.3.3.4 Performance indicators

Environmental performance indicator

The FLMGN performance indicator for mean water level in the Lower Lakes was 0.76 m for the 2022/23 reporting year, which was above the target reference point of 0.4 m (Figure 4-17). Since 1984/85, the target reference point for this performance indicator has only been breached four times, while the trigger reference point has only been breached once. These breaches all occurred during the Millennium Drought (2007/08–2010/11), following several years of exceptionally low or no river flows.

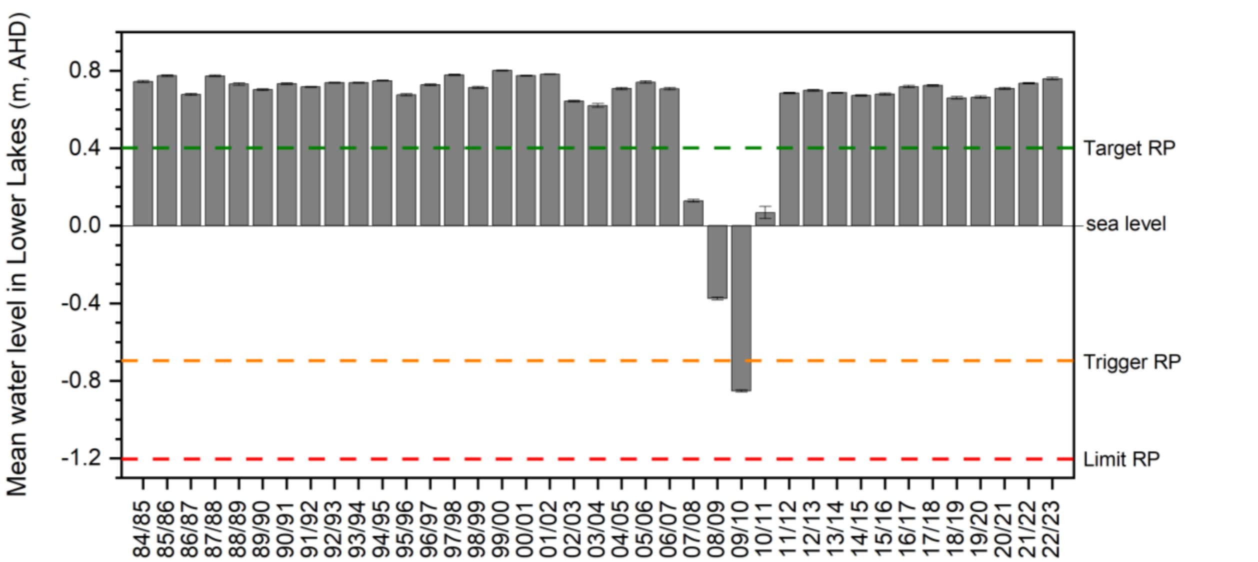

Figure 4-17. Time series of annual estimates of the FLMGN environmental performance indicator for mean water level in the Lower Lakes (± S. E.) from 1984/85 to 2022/23 (reporting years), showing target, trigger and limit reference points (RP).

Biological performance indicators

For the 2022 calendar year, the biological performance indicators for targeted Golden Perch $CPUE_{LMGN}$ declined by 47% from 2021 to 0.59 kg.net-day^{-1}, which was slightly above the trigger reference point prescribed in the Management Plan (Figure 4-18). For Bony Herring, the $CPUE_{LMGN}$ of 5.28 kg.net-day^{-1} was 2.7% below the target.

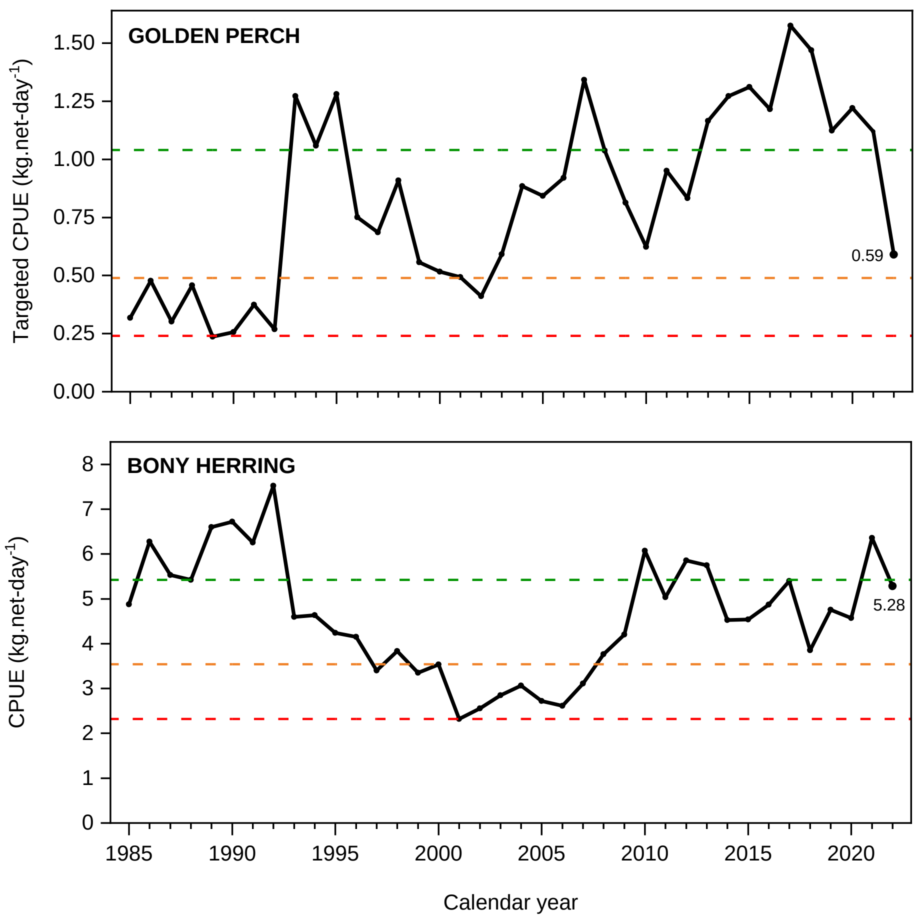

Figure 4-18. Time series of annual estimates of the FLMGN biological (secondary) performance indicator (targeted CPUE) for Golden Perch (top) and Bony Herring (bottom) from 1985 to 2022 (calendar years), showing target (green dashed line), trigger (orange dashed line) and limit (red dashed line) reference points.

4.3.4 Pipi sector

4.3.4.1 Pipi (*Donax deltoides*)

Biology

Pipi (*Donax deltoides*) is a member of the Donacidae family of marine bivalves (Edgar 2000). It is common on high-energy sandy beaches from southern Queensland to the mouth of the River Murray in South Australia (Murray-Jones and Ayre 1997). The Coorong beaches adjacent to the Murray Mouth provide high quality habitat for Pipi, and it is likely that the stock in the Coorong region represents the largest single population of this species in Australia (King 1976).

For the population of Pipi on the Younghusband Peninsula, the sizes (shell width) at which 50% and 95% were reproductively mature were 28.4 mm and 32.5 mm, respectively (Ferguson and Mayfield 2006). Spawning typically occurs between September and November (Ferguson and Ward 2014). Despite several genetic studies, the biological stock delineation for Pipi is unclear. Here, assessment of stock status is presented at the management unit level–the LCF.

Fishery

Pipi is an important target species for the commercial and recreational fishery sectors in South Australia (Hall et al. 2015). The commercial Pipi fishery is located on the ocean beach of the Younghusband Peninsula and comprises three sectors: (i) the LCF; (ii) MSF; and (iii) SZRLF. The commercial fishery harvests Pipi manually using cockle rakes, which consist of a pole and frame with a net attached. As of June 2022, there were 15 licence holders with Pipi catch quota entitlements (13 from the LCF and two from the MSF). Other licence holders in the MSF and SZRLF have access to 10 kg of Pipi per day for personal bait use only.

Recreational fishers in South Australia catch Pipi using cockle rakes (nets), bait spades, bait forks or collect them by hand (Durante et al. 2022; Beckmann et al. 2023), with most of the catch taken from Sir Richard Peninsula (Goolwa Beach) (Murray-Jones and Johnson 2003; Giri and Hall 2015; Durante et al. 2022).

Management arrangements

Pipi is a primary species of the commercial LCF, making a relatively high contribution to the total production value of the fishery (PIRSA 2022). The commercial sector is managed using a combination of input and output controls including: (i) restrictions on the number of operators and agents; (ii) gear restrictions; (iii) a LML of 35 mm; and (iv) spatial and temporal closures. Since 2007/08 the fishery has been managed under a total allowable commercial catch (TACC) with individual transferable quotas. The TACC has effectively constrained commercial catches since 2009/10. Under current fisheries regulations, the Pipi season is from 1 November to 31 May, although exemptions have been allowed for commercial fishers to harvest year-round since 2010/11.

The Management Plan includes a harvest strategy for Pipi (PIRSA 2022). The harvest strategy uses two biological performance indicators and a set of decision rules to inform setting of the annual TACC: (i) primary biological performance indicator – mean annual relative biomass of legal-sized Pipi (harvestable biomass); secondary biological performance indicator – presence/absence of pre-recruits in size distributions from November to February of the previous year (Ward et al. 2010; Ferguson et al. 2015). The objectives of the harvest strategy are to: (i) maintain mean annual relative biomass of legal-sized Pipi above the target reference point of 12 kg/4.5 m^2; but (ii) not less than the trigger reference point of 9 kg/4.5 m^2; and (iii) to ensure that mean annual relative biomass does not fall below the limit reference point of 4 kg/4.5 m^2.

The recreational sector for Pipi is managed through a combination of input and output controls, aimed at ensuring the total catch is maintained within sustainable limits and to ensure that recreational access to the fishery is equitably distributed between recreational participants (PIRSA 2022). Daily bag and vehicle limits apply and vary geographically. For areas east of longitude 136ºE, which includes Goolwa Beach, a personal daily bag limit of 300 Pipi applies, and there is a vehicle limit (when three or more people are present) of 900 Pipi. For areas west of longitude 136ºE, the daily bag limit is 100 Pipi and a vehicle limit (when three or more people are onboard) of 300 Pipi applies. A temporal closure applies from 1 June to 31 October each year (inclusive) and recreational fishing for Pipi is prohibited in the commercial fishing grounds on the Younghusband Peninsula between the Murray Mouth and 28 Mile Crossing. The legal minimum size of 35 mm (across the widest part of the shell) also applies to the recreational sector.

Commercial fishery statistics

Trends in total catch, effort and CPUE

Total annual commercial catches (combined catches from LCF and MSF) of Pipi ranged from 310 to 457 t between 1984/85 and 1989/90, and then increased to an historic peak of 1,250 t in 2000/01 (Figure 4-19). Annual catches exceeded 1,000 t between 1999/00 and 2006/07 and then declined to 470 t in 2008/09. From 2009/10, catches were constrained by annual TACCs, which steadily increased from 300 t in 2009/10, to 650 t in 2017/18 and 2018/19, before decreasing to 450 t in 2019/20 and 2020/21. In 2021/22, the TACC was further reduced to 400 t, which constrained catch to its lowest levels since 2011/12. The total catch of 419 t in 2021/22 was higher than the annual TACC of 400 t due to carry-over of quota from 2020/21 (PIRSA pers.comm.).

Annual CPUE for cockle rakes (LCF only) increased from 483 kg.fisher-day^{-1} in 1988/89 to a peak of 531 kg.fisher-day^{-1} in 1996/97 (Figure 4-19). From then, CPUE progressively declined to 132 kg.fisher-day^{-1} in 2008/09 and then remained low at 128–177 kg.fisher-day^{-1} until 2016/17, before increasing to 194–199 kg.fisher-day^{-1} during 2018/19–2020/21. In 2021/22, CPUE declined to 168 kg.fisher-day^{-1} which is similar to the average annual catch rate for the last 15 years.

The estimates of CPUE for Pipi should be interpreted with caution due to considerable uncertainty around CPUE (kg.fisher-day^{-1}) as a measure of relative abundance resulting from differences in reporting effort among individual licence holders and changes in fisher practices when targeting different size classes of Pipi for bait and human consumption markets (Ferguson et al. 2015; Ferguson and Hooper 2021). Data on catch and CPUE for the MSF are not presented due to data confidentiality (i.e., reported by <5 fishers).

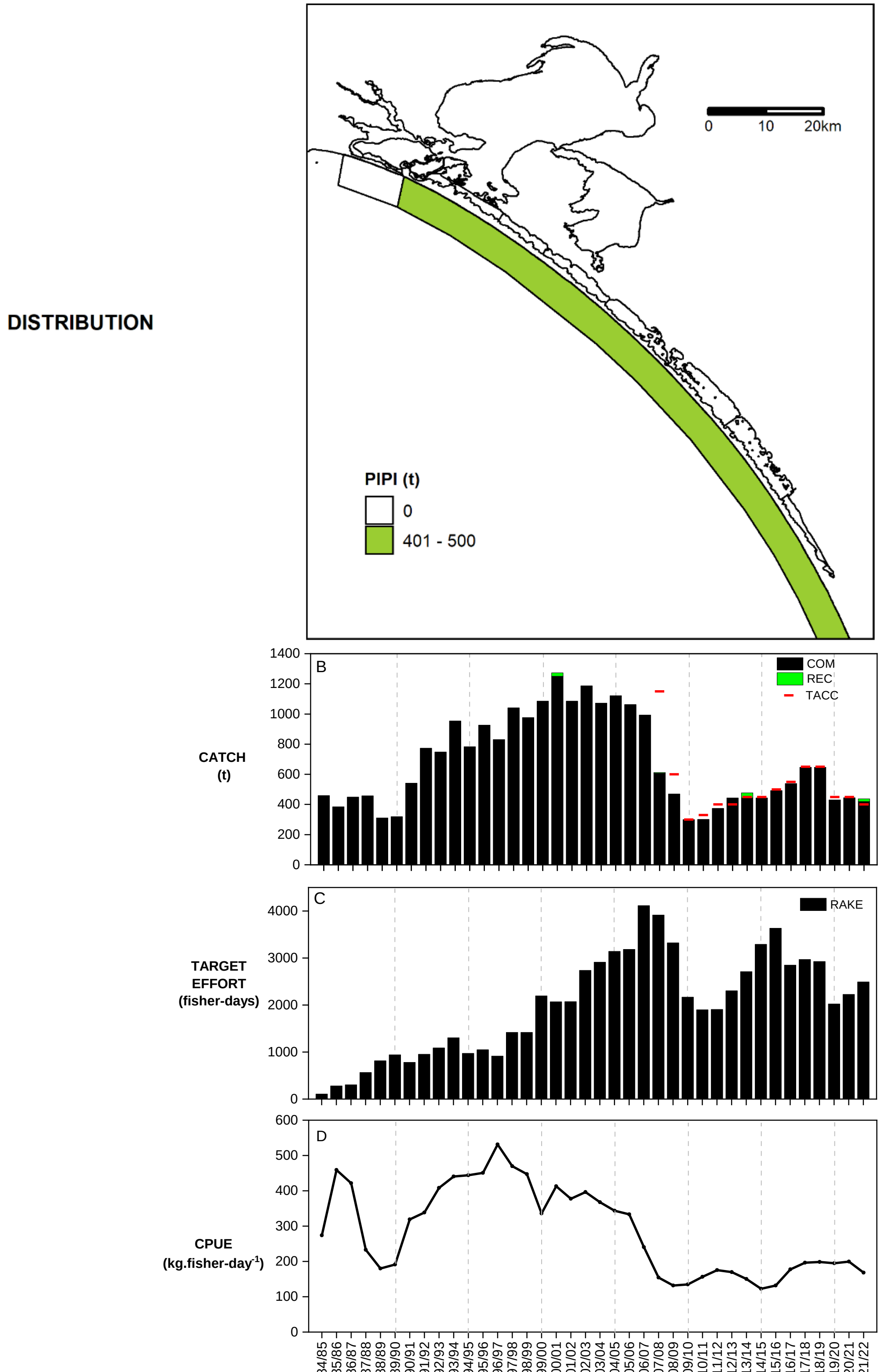

Figure 4-19. Fishery statistics for Pipi. (A) Map of the LCF reporting blocks showing the catch distribution for 2021/22; Long term trends in: (B) total catch for the LCF and the recreational sector (for 2000/01, 2007/08, 2013/14, 2021/22); (C) targeted effort in fisher-days for cockle rakes; and (D) CPUE (kg.fisher-day^{-1}) for cockle rakes. Note: (i) total catch has been constrained by the TACC since 2009/10; (ii) catch rates should be interpreted with caution due to considerable uncertainty around CPUE (kg.fisher-day^{-1}) as a measure of relative abundance (see Ferguson and Ward 2014; Ferguson et al. 2015).

Seasonal trends in catch

Prior to 2010/11, the fishery for Pipi was closed from 1 May to 30 September each year, with the months of November to April being the most productive for the fishery (Figure 4-20). Since 2010/11, fishing has occurred throughout the year under Ministerial Exemption (Ferguson and Hooper 2017). In 2021/22, catches taken between November and May accounted for around 90% of the total catch.

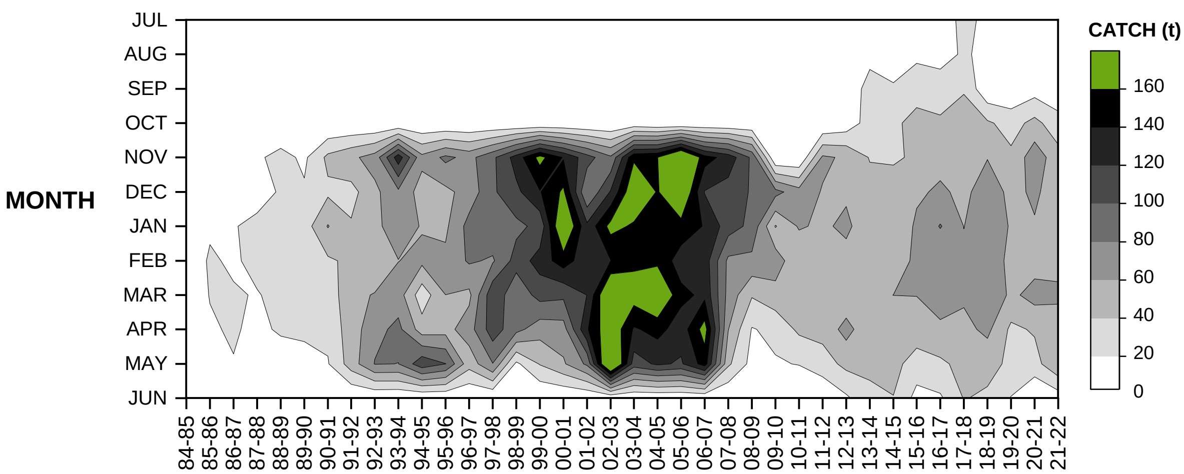

Figure 4-20. Fishery statistics for Pipi. Long-term annual distribution of catch among months of the year.

Biological performance indicators

The harvest strategy for Pipi aims to maintain mean annual relative biomass above a target reference point of 12 kg/4.5 m² and not less than a trigger reference point of 9 kg/4.5 m² (PIRSA 2022). In 2021/22, the estimate of mean annual relative biomass was 15.2 kg/4.5 m² which was 27% above the target reference point of 12 kg/4.5 m² (Figure 4-21). Pre-recruits comprised 63% of size structures in November 2021, and so were considered present in 2021/22 (Figure 4-22).

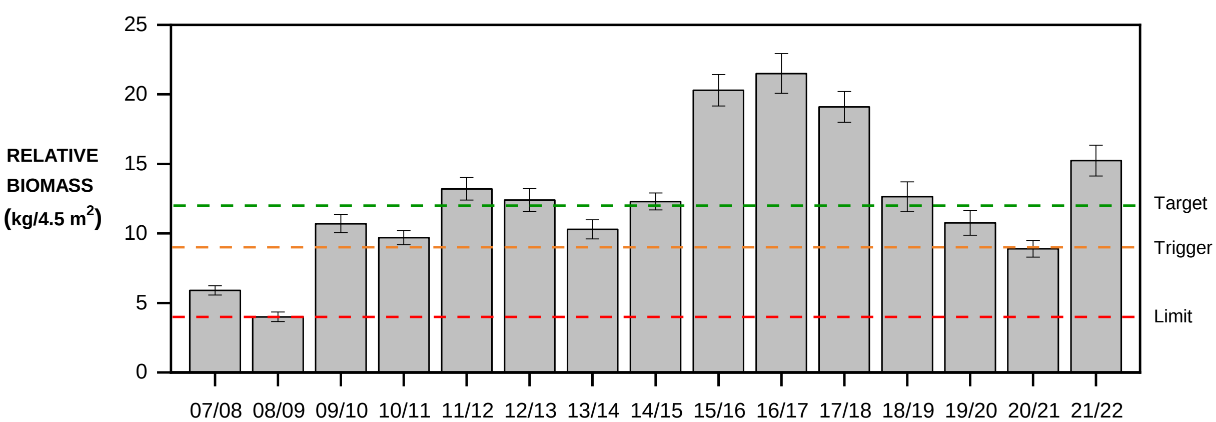

Figure 4-21. Estimates of fishery-independent mean annual relative biomass of Pipi from 2007/08 to 2021/22 showing target, limit and trigger reference points. The harvest strategy aims to maintain relative biomass above a target of 12 kg/4.5 m² (green dashes) and not less than the trigger reference point of 9 kg/4.5 m² (orange dashes). The lower limit reference point (red dashes) represents a historically low mean annual relative biomass of 4 kg/4.5 m² below which there may be risk of recruitment overfishing.

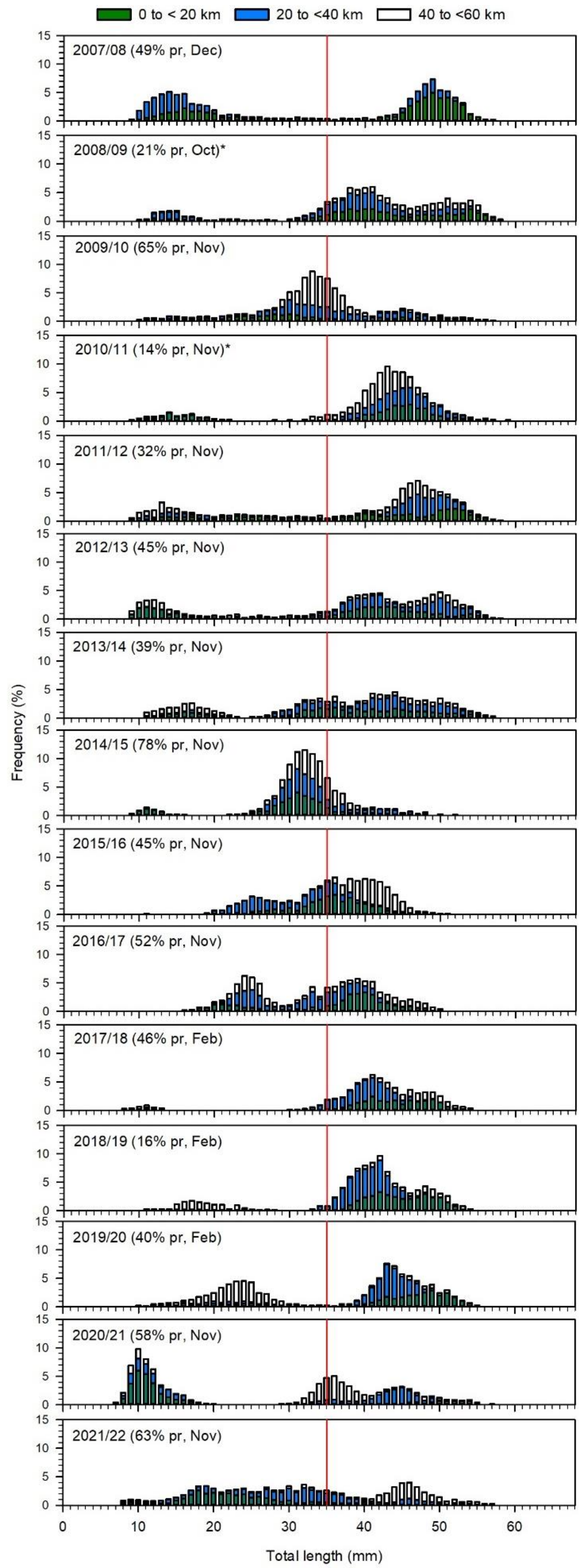

Figure 4-22. Estimates of the secondary biological performance indicator for Pipi: presence/absence of pre-recruits (pr) during November from 2007/08 to 2021/22, and in February 2018, 2019 and 2020. Vertical red line represents legal minimum size of 35 mm.

Stock status

Pipi is a primary species for the commercial LCF (PIRSA 2022). The most recent stock assessment for Pipi was completed in 2021 and reported fishery data up to June 2020 and biological information up to 2020/21 (Ferguson and Hooper 2021). The status of the Pipi fishery is determined primarily from the ongoing fishery-independent research program that undertakes structured surveys to determine the relative biomass and size structure of the Pipi resource across the fishing ground on the Younghusband Peninsula (Ferguson and Hooper 2017). The key objective of these surveys is to collect the biological information required to inform the harvest strategy for Pipi (PIRSA 2022), which is used to set the annual TACC.

The primary measures for biomass and fishing mortality for Pipi are fishery-independent estimates of mean annual harvestable biomass (Ferguson et al. 2015) and population size structure. From 2009/10, increasing relative biomass and increasing complexity of size structures indicated recovery of the resource after a period of steeply declining catches and long-term declining catch rates in the mid-2000s (Ferguson et al. 2015). From 2015/16 to 2017/18, following several years of strong recruitment, estimates of annual relative biomass were the highest on record. Then, from 2017/18–2019/20, annual relative biomass decreased to levels that were similar to those observed during 2009/10–2014/15, likely due to combined effects of natural mortality of Pipi originating from spawning during 2012/13–2014/15 and exploitation. In 2021/22, relative biomass increased and was 27% above the target reference point in the harvest strategy and pre-recruits were present (63%) in the population size structure. 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 this basis, the LCF for Pipi is classified as a **sustainable** stock.

5 GENERAL DISCUSSION

5.1 SYNTHESIS

This report for South Australia's multi-species, multi-gear Lakes and Coorong Fishery (LCF) provided an overview of the dynamics of the fishery's fleet from 1984/85 to 2021/22, a stock assessment for Mulloway, assigned stock status to a further six species using the NFSRF, and provided the catch statistics for Carp. The assessments of status undertaken for each species used a weight-of-evidence approach that considered a range of species-specific information relating to: population biology; fishing access; management; and trends in commercial fishery data from 1 July 1984 to 30 June 2022. Updated estimates of the environmental and biological performance indicators for the three finfish sectors of the fishery, as well as the biological performance indicators for Pipi were also provided.

Of the seven stocks assessed in this report, five were classified as 'sustainable' and two were classified as 'depleted'. For each stock, the status classification in 2021/22 was the same as that from 2020/21 (Earl et al. 2022). The five 'sustainable' stocks are those of four primary species—Mulloway, Yelloweye Mullet, Golden Perch and Pipi, and of one secondary species—Bony Herring, which along with Carp have consistently accounted for most of the fishery's annual catches since 1984/85. The two 'depleted' stocks are those of the secondary species—Black Bream and Greenback Flounder. Targeted catch and effort for these two species were stable at low levels in 2021/22.

The stock assessment for Mulloway in this report was the second of its kind since 2014 (Earl and Ward 2014; Earl 2020). The 2020 stock assessment classified the stock as 'sustainable' and this status was retained in 2021/22 on account of: (i) near-record high catch rates of juvenile and adult Mulloway in 2021/22; (ii) the presence of a strong age class of juvenile fish in the age structure from the Coorong Estuary in 2022/23; (iii) the presence of multiple strong age classes in the spawning biomass in 2022/23; and (iv) contemporary estimates of the environmental and biological performance indicators for the ELMGN sector (i.e., the sector that contributes most of the catch) being above their respective target reference points (PIRSA 2022). The next Mulloway stock assessment is planned for 2025/26.

While Mulloway continued to be the primary target of the ELMGN sector in 2021/22, there have been subtle improvements in fishery performance for the secondary species, Black Bream and Greenback Flounder, for the second successive year. For Black Bream, total catch has marginally increased over the past two years, despite the fishery being closed from 1 August–31 December 2021. This closure, along with a suite of other temporary management arrangements implemented in 2018, 2019 and 2021 to recover the stock have not yet resulted in measurable improvements to the fishable biomass that warrant a change in stock status. Any benefit from the management arrangements within the fishable biomass are expected to take at least several years to develop. This is because Black Bream is a long-lived, periodic-strategist, whose populations are characterised by episodic recruitment (Williams et al. 2013; Ye et al. 2022), and the magnitude of recruitment when it does occur is dependent on levels of egg production and appropriate environmental conditions to support the survival and growth of eggs and larvae (Jenkins et al. 2015; Earl et al. 2016b; Ye et al. 2017, 2019). Moreover, juvenile Black Bream that originated from spawning in 2018, 2019 and 2021 (i.e., when temporary management arrangements were in place) will take several years to recruit to the fishable biomass and contribute to egg production (Ye et al. 2020, 2022). Anecdotal reports from industry suggest that fishery performance for Black Bream has improved substantially since 1 July 2022.

A recovery strategy is currently being developed to recover the Black Bream stock in the Coorong Estuary. It will prescribe ongoing management arrangements to promote stock recovery and fishery-independent sampling to collect information on relative abundance and population age structure to monitor stock recovery. A stock assessment for Black Bream that builds on the previous stock assessment undertaken in 2016 (Earl et al. 2016b) and evaluates the effectiveness of the recent and any future management intervention, should be considered within the next few years.

An inferred low fishable biomass of Greenback Flounder in the Coorong Estuary over recent years also continued in 2021/22, although there were some positive signs with total catch increasing to its highest level since 2012/13. The low levels of targeted effort and annual catches in recent years – a period of relatively low freshwater inflows to the estuary; is consistent with the significant long-term correlation between fishery production and freshwater inflow to the estuary (Earl and Ye 2016). Since the 1970s, the spawning biomass of this stock, which likely extends beyond the spatial constraints of the fishery and into the Southern Ocean (Earl et al. 2017), has repeatedly demonstrated its capacity to replenish the Coorong population in the 1–2 years after a year of high freshwater inflow (e.g., 1990/91, 1996/97, 2010/11). On this basis, fishery performance is expected to improve substantially in 2022/23 because freshwater inflows to the estuary were high during late 2022 and early 2023.

Yelloweye Mullet continued to be the sole target of the ESMGN sector in 2021/22. Near-record high catch rates have been characteristic of this sector since 2018/19, and these continued in 2021/22. The high catch rates are indicative of high fishable biomass but may also relate to changes in fishing strategy as fishers continue to adapt to the presence of Long-nosed Fur Seals. Due to some uncertainty around whether $CPUE_{SMGN}$ has increased due to changes in biomass and/or fisher efficiency, trends in the fishery data must be interpreted with caution. Additional information relating to fisher behaviour (e.g., shorter soak times; shifting gillnets more often each fishing day) may help explain why $CPUE_{SMGN}$ has increased in such a short period of time and allow this uncertainty to be evaluated appropriately.

For the FLMGN sector, Golden Perch remained the primary target in 2021/22 with large volumes of Bony Herring and Carp taken by fishers that reported "any target" in their logbooks. For Golden Perch, declines in targeted effort and targeted CPUE in 2021/22 culminated in the lowest total annual catch since 2012/13. The low catch was also partly attributable to an overall decline in fishing effort in the FLMGN sector over the past three years due to reduced market demand for Bony Herring and Carp, which are primarily supplied as bait to commercial fishers in the SZRLF. Rock Lobster fishing in South Australia effectively ceased in February 2020 in direct response to the COVID-19 pandemic and the weakening of export markets. While commercial Rock Lobster fishing has since resumed, the pandemic continues to impact the LCF with some fishers reluctant to catch and store (freeze) large volumes of bait due to market uncertainty. Nevertheless, the assessments for Golden Perch and Bony Herring raised no sustainability concerns.

For each of the three finfish sectors, updated estimates of the environmental (primary) and biological (secondary) performance indicators were assessed against their respective reference points, as prescribed in the finfish harvest strategy (PIRSA 2022). The results of these comparisons will guide setting of the annual TACE for each sector for the 2022/23 fishing season. Estimates of the environmental performance indicator for each sector for the 2021/22 reporting year (1 February 2022 to 31 January 2023) were above their target reference points. Estimates of the biological performance indicators for Mulloway, Greenback Flounder and Yelloweye Mullet for the 2022 calendar year were all above their respective target reference point, while those for Black Bream, Golden Perch and Bony Herring were above their respective triggers but below their targets.

For Pipi, 2017/18 and 2018/19 were the most productive years for the LCF in terms of total catch since a TACC was introduced under a quota management system for the species in 2007/08. Fishery independent surveys undertaken in 2021/22 indicated that relative biomass of legal-sized Pipi had increased to its highest level in four years and was above the target reference point. The survey also determined that pre-recruits were present in 2020/21. These results indicate that the biomass of the Pipi stock along the ocean beach of the Younghusband Peninsula is in a strong position.

5.2 CHALLENGES AND UNCERTAINTIES IN THE ASSESSMENT

The weight-of-evidence approach used to determine stock status for the LCF stocks considered in this report relied heavily on fishery-dependent data. The assessments placed considerable emphasis on analysing trends in catch, effort and CPUE for the primary gear types used to target or take each species. For most species considered in this report, the primary measure of fishable biomass is targeted CPUE using gillnets, whereby CPUE is assumed to be proportional to abundance and is therefore used as an index of relative abundance. However, CPUE likely also incorporates changes in the relative efficiency of the fleet over time, but especially since 2009/10, because fishers have modified their fishing practices to try and avoid negative interactions with seals (Earl et al. 2021). CPUE standardisation may help improve the usefulness of CPUE as an index of relative abundance and may help account for differences in the relative contributions of targeted and non-targeted catches to the total catch. Improving the reliability of CPUE as an indicator of biomass would improve the confidence in assessments of stock status, particularly for Mulloway and Yelloweye Mullet for which catch rates have been at unprecedented high levels over recent years.

A key challenge with the assessments of stock status for Black Bream and Greenback Flounder relates to the lack of targeted CPUE data from recent years, which for most other species assessed in this report, have provided a meaningful measure of relative abundance. This is because targeted effort for Black Bream and Greenback Flounder has been negligible for most of the past 10 years and most of the catches of these species have been taken as by-product by fishers targeting Mulloway. Given the poor stock status' assigned to these species, there is a need for reliable information on abundance and recruitment, to determine if recovery is occurring. To address this need, a fishery-independent survey (FIS) is currently being developed by SARDI, in conjunction with PIRSA Fisheries and Aquaculture and industry, to provide reliable information on relative abundance and population age structure for Black Bream and Greenback Flounder. The FIS is planned to commence in 2023/24.

An additional source of uncertainty in the assessments of stock status undertaken in this report relates to levels of incidental mortality of sub-legal sized individuals of LCF species discarded by commercial and recreational fishers in the Coorong Estuary and Lower Lakes. This is because estimates of discarding for the commercial fishery are only available from limited sampling undertaken during the Millennium Drought (Ferguson 2010). Furthermore, although recreational release rates are available at State-wide level for the LCF species, estimates lose precision when results are disaggregated. For the commercial sector, this could be addressed by ongoing monitoring of discards from gillnets.

Interactions between LCF fishers and Long-nosed Fur Seals has been a major issue for the fishery over the last 12 years (EconSearch 2022). Despite recent mitigation initiatives, reports from industry suggest that the seal-fisher conflict and associated economic impacts continued in 2021/22. A key uncertainty in the assessments of status for LCF stocks relates to the lack of quantitative information on the extent of the impacts of seals on the fishery, with respect to catch losses and damaged discarded catch, both of which represent a source of fishing mortality that is not currently able to be accounted for in fishery assessments. Such information would also assist in assessing how CPUE for key species may be affected by changes in fisher behaviour. A FRDC-funded Project (2018-036 'Seal-fisher-ecosystem interactions in the Lower Lakes and Coorong: understanding causes and impacts to develop longer-term solutions') is seeking to acquire this information. The utility of the data will be heavily dependent on the engagement of the LCF commercial fishers in the data collection process.

A further challenge for assessing the status of LCF stocks is determining the relative contribution of catches taken by the recreational fishing sector to total State-wide catch. The total harvest by the recreational sector has traditionally been determined through longitudinal phone surveys that are undertaken on an approximate five-year cycle (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, phone surveys were designed to provide estimates of participation, catch and effort at State-wide level, resulting in low sample sizes and high uncertainty of estimates when survey data is disaggregated. The lack of recreational estimates at smaller scales has implications for the assessments of Mulloway, Golden Perch, Black Bream, and Pipi, for which the estimated relative recreational contribution to overall State-wide catch is significant. Probability-based on-site surveys is an alternative method to estimate recreational catch of species with a land-based access and limited geographic distribution, as observed for Pipi in South Australia (Durante et al. 2022), also allowing for the inclusion of interstate catches. However, depending on the number of access points, it's likely that supplementary data (e.g., remote cameras and recreational App) would be required to improve temporal coverage (Beckmann et al. 2023).

5.3 RESEARCH PRIORITIES

The most important research needs for the LCF fishery and its management are: (i) CPUE standardisation to improve the usefulness of CPUE as an index of relative abundance for key species; (ii) independent monitoring of discarding of sub-legal sized individuals of LCF species from commercial and recreational gillnets in the Coorong Estuary and Lower Lakes; (iii) commencement of a FIS for Black Bream and Greenback Flounder to provide reliable information on relative abundance and recruitment that can be used to monitor stock recovery; (iv) quantitative information on the extent of seal impacts on the fishery, with respect to catch losses and damaged discarded catch; and (v) ongoing development of a time series of annual age structures, particularly for long-lived species, Mulloway, Black Bream and Golden Perch.

REFERENCES

Attard, C. R. M., Brauer, C. J., Sandoval-Castillo, J., Faulks, L. K., Unmack, P. J., Gilligan, D. M. and Beheregaray, L. B. (2018) Ecological disturbance influences adaptive divergence despite high gene flow in golden perch (*Macquaria ambigua):* implications for management and resilience to climate change. Molecular Ecology 27(1), 196–215.

Archangi, B. (2008) Levels and patterns of genetic diversity in wild and cultured populations of mulloway (*Argyrosomus japonicus*) using microchondrial DNA and microsatellites. PhD Thesis. Queensland University of Technology, Brisbane.

Barnes, T. C., Junge, C., Myers, S. A., Taylor, M. D., Rogers, P. J., Ferguson, G. J., Lieschke, J. A., Donnellan, S. C. and Gillanders, B. M. (2016) Population structure in a wide-ranging coastal teleost (*Argyrosomus japonicus*, Sciaenidae) reflects marine biogeography across southern Australia. Marine and Freshwater Research 67(8), 1103–1113.

Battaglene, S. and Prokop, F. (1987) Golden Perch N.S.W. Department of Agriculture No. A3.2.2, Sydney.

Beckmann, C. L., Durante, L. M., Graba-Landry, A., Stark, K. E. and Tracey, S.R. (2023). Survey of Recreational Fishing in South Australia 2021–22. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2022/000358-1. SARDI Research Report Series No. 1161. 185pp.

Beheregaray, L. B., Pfeiffer, L. V., Attard, C. R. M., Sandoval-Castillo, J., Domingos, F. M. C. B., Faulks, L. K., Gilligan, D. M. and Unmack, P. J. (2017) Genome-wide data delimits multiple climate-determined species ranges in a widespread Australian fish, the golden perch (*Macquaria ambigua*). Molecular Phylogenetics and Evolution111: 65–75.

Bice, C. M., Wedderburn, S. D., Hammer, M. P., Ye, Q. and Zampatti, B. P. (2018) Fishes of the Lower Lakes and Coorong: A summary of life-history, population dynamics and management, in L. Mosley, Q. Ye, S. Shepherd, S. Hemming and R. Fitzpatrick (eds) Natural History of the Coorong, Lower Lakes and Murray Mouth Region (Yarluwar-Ruwe). Royal Society of South Australia Inc.

Chaplin, J. A., Baudains, G. A., Gill, H. S., McCulloch, R. and Potter, I. C. (1998) Are assemblages of black bream (*Acanthopagrus butcheri*) in different estuaries genetically distinct? International Journal of Salt Lake Research 6(4), 303-321.

Cheesman, C. (2022) Age determination, growth and reproductive biology of black bream (Acanthopagrus butcheri) in a highly modified estuary. Honours Thesis. Flinders University, Adelaide.

Classon, B. and Booth, S. (2002) 'Freshwater fishes of Australia.' (Australian Fishing Network: Croydon South, Victoria).

Conron, S., Moore, B., Earl, J., Broadhurst, M. and Duffy, R. (2018) Black Bream *Acanthopagrus butcheri*, in C. Stewardson, J. Andrews, C. Ashby, M. Haddon , K. Hartmann, P. Hone, P. Horvat, Klemke, J., S. Mayfield, A. Roelofs, K. Sainsbury, T. Saunders, J. Stewart, Nicol, S. and B. Wise (eds) 2018, Status of Australian fish stocks reports 2018, Fisheries Research and Development Corporation, Canberra.

Crawford, C. M. (1984) An ecological study of Tasmanian flounder. PhD Thesis. University of Tasmania, Hobart.

CSIRO (2008). Water availability in the Murray-Darling Basin. Report to the Australian Government from the CSIRO Murray–Darling Basin Sustainable Yields Project. CSIRO, Australia, 67pp.

Durante, L. M., Bailleul, F. and Beckmann, C. L. (2022). On-site survey of recreational fishing for Pipi in Goolwa, South Australia 2020-21. Final Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2022/00269-1. SARDI Research Report Series No. 1160. 27pp.

DEW (2020) https://www.waterconnect.sa.gov.au

Earl, J. (2014) Population biology and ecology of the greenback flounder (*Rhombosolea tapirina*) in the Coorong Estuary, South Australia. PhD Thesis. School of Biological Sciences, Flinders University, Adelaide.

Earl, J. (2019) Fishery statistics, stock status and performance indicators for the South Australian Lakes and Coorong Fishery. Report for PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2009/000669-10. SARDI Research Report Series No. 1020. 43pp.

Earl, J. (2020) Assessment of the South Australian Lakes and Coorong Fishery in 2018/19. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2020/000208-01. SARDI Research Report Series No. 1059. 81pp.

Earl, J. and Bailleul, F. (2021) Assessment of the South Australian Lakes and Coorong Fishery in 2019/20. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2020/000208-02. SARDI Research Report Series No. 1092. 81pp.

Earl, J., Rogers, T. A. and Bailleul, F. (2022) Assessment of the South Australian Lakes and Coorong Fishery in 2020/21. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2020/000208-3. SARDI Research Report Series No. 1128. 78pp.

Earl, J., Gorfine, H., Duffy, R. and Krueck, N. (2021b) Yelloweye Mullet *Aldrichetta forsteri*, in Toby Piddocke, Crispian Ashby, Klaas Hartmann, Alex Hesp, Patrick Hone, Joanne Klemke, Stephen Mayfield, Anthony Roelofs, Thor Saunders, John Stewart, Brent Wise and James Woodhams (eds) 2021, *Status of Australian fish stocks reports 2020*, Fisheries Research and Development Corporation, Canberra.

Earl, J. and Ferguson, G. J. (2013) Yelloweye Mullet (*Aldrichetta forsteri*) Stock Assessment Report 2011/12. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2007/001048-1. SARDI Research Report Series No. 737. 54 pp.

Earl, J., Fairclough, D., Staunton-Smith, J. and Hughes, J. (2018) Mulloway *Argyrosomus japonicus*, in C. Stewardson, J. Andrews, C. Ashby, M. Haddon , K. Hartmann, P. Hone, P. Horvat, Klemke, J., S. Mayfield, A. Roelofs, K. Sainsbury, T. Saunders, J. Stewart, Nicol, S. and B. Wise (eds) 2018, Status of Australian fish stocks reports 2018, Fisheries Research and Development Corporation, Canberra.

Earl, J., Fowler, A. J., Ye, Q. and Dittmann, S. (2014a) Age validation, growth and population characteristics of greenback flounder (*Rhombosolea tapirina*) in a large temperate estuary. New Zealand Journal of Marine and Freshwater Research 48(2), 229-244.

Earl, J., Fowler, A. J., Ye, Q. and Dittmann, S. (2017) Complex movement patterns of greenback flounder (*Rhombosolea tapirina*) in the Murray River estuary and Coorong, Australia. Journal of Sea Research 122, 1-10.

Earl, J., Green, C., Smith, K. A. and Emery, T. (2016) Yelloweye Mullet Aldrichetta forsteri, in C. Stewardson, J. Andrews, C. Ashby, M. Haddon , K. Hartmann, P. Hone, P. Horvat, S. Mayfield, A. Roelofs, K. Sainsbury, T. Saunders, J. Stewart, I. Stobutzki and B. Wise (eds) 2016, Status of Australian fish stocks reports 2016, Fisheries Research and Development Corporation, Canberra.

Earl, J., Hughes, J., Roelofs, A. and Fairclough, D. (2014b) Mulloway *Argyrosomus japonicus*, in Flood, M., Stobutzki, I., Andrews, J., Ashby, C., Begg, G., Fletcher, R., Gardner, C., Georgeson, L., Hansen, S., Hartmann, K., Hone, P., Horvat, P., Maloney, L., McDonald, B., Moore, A., Roelofs, A., Sainsbury, K., Saunders, T., Smith, T., Stewardson, C., Stewart, J., Wise, B. (eds), Status of Australian fish stocks reports 2014, Fisheries Research and Development Corporation, Canberra.

Earl, J., Mackay, A. and Goldsworthy, S. (2021) Developing alternative strategies for managing seal-fisher interactions in the South Australian Lakes and Coorong Fishery. FRDC Project 2016/001. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. 68 pp.

Earl, J. and Ward, T. M. (2014) Mulloway (*Argyrosomus japonicus*) Stock Assessment Report 2013/14. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2007/000898-3. SARDI Research Report Series No. 814. 55 pp.

Earl, J., Ward, T. and Ye, Q. (2016b) Black Bream (*Acanthopagrus butcheri*) Stock Assessment Report 2014/15. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development

Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2008/000810-2. SARDI Research Report Series No. 885. 44 pp.

Earl, J. and Ye, Q. (2016) Greenback Flounder (*Rhombosolea tapirina*) Stock Assessment Report 2014/15. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2007/000315-2. SARDI Research Report Series No. 889. 40 pp.

Earl, J., Ye, Q. and McPhail, J. (2015) Golden Perch *Macquaria ambigua*, in Status of South Australian Fisheries Report. South Australian Fisheries Management Series, Paper number 69. Primary Industries and Regions SA, Adelaide.

EconSearch (2022) Economic and social indicators for the South Australian Lakes and Coorong Fishery 2020/21. A report to PIRSA Fisheries and Aquaculture, prepared by BDO EconSearch, Adelaide. 101 pp.

Edgar, G. J. (2000) 'Australian Marine Life: The Plants and Animals of Temperate Marine Waters.' 2nd edn. (Reed New Holland: Sydney).

Faulks, L. K., Gilligan, D. M. and Beheregaray, L. B. (2010a) Clarifying an ambiguous evolutionary history: range-wide phylogeography of an Australian freshwater fish, the golden perch (*Macquaria ambigua*). Journal of Biogeography 37(7): 1329–1340.

Faulks, L. K., Gilligan, D. M. and Beheregaray, L. B. (2010b) Islands of water in a sea of dry land: Hydrological regime predicts genetic diversity and dispersal in a widespread fish from Australia's arid zone, the golden perch (*Macquaria ambigua*). Molecular Ecology 19: 4723–4737.

Ferguson, G. and Mayfield, S. (2006) The South Australian Goolwa Cockle (*Donax deltoides*) Fishery. Fishery Assessment report to PIRSA Fisheries, SARDI Research Report Series 150, RD06/005-1, Adelaide.

Ferguson, G. and Ye, Q. (2012) Stock Assessment of Golden perch (*Macquaria ambigua*). Fishery Stock Assessment For PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2007/001051-1. SARDI Research Report Series No. 656. 52 pp.

Ferguson, G. J. (2010) Gear interaction of non-targeted species in the Lakes and Coorong commercial and recreational fisheries of South Australia. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. FRDC project No. 2005/061, Final Report.

Ferguson, G. J. and Hooper, G. E. (2021) Pipi (*Donax deltoides*) Fishery 2020/21. Fishery Assessment Report for PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2007/000550-3. SARDI Research Report Series No. 1099. 43 pp.

Ferguson, G. J. and Hooper, G. E. (2017) Assessment of the South Australian Pipi (*Donax deltoides*) Fishery in 2016/17. Fishery Assessment Report for PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2009/000550-2. SARDI Research Report Series No. 957. 47 pp.

Ferguson, G. J. and Ward, T. (2003) Mulloway (*Argyrosomus japonicus*) Fishery. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. RD03/0040.

Ferguson, G. J. and Ward, T. M. (2011) Mulloway (*Argyrosomus japonicus*) Fishery. Fishery Stock Assessment Report for PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2007/000898-2. SARDI Research Report Series No. 573. 104 pp.

Ferguson, G. J. and Ward, T. M. (2014) Support for harvesting strategy development for South Australia's Lakes and Coorong Fishery for Pipi (*Donax deltoides*). South Australian Research and Development Institute (Aquatic Sciences), Adelaide. FRDC project No. 2008/008, Final Report.

Ferguson, G. J., Ward, T. M. and Geddes, M. C. (2008) Do recent age structures and historical catches of mulloway, *Argyrosomus japonicus* (Temminck & Schlegel, 1843), reflect freshwater inflows in the remnant estuary of the Murray River, South Australia? Aquatic Living Resources 21, 145-152.

Ferguson, G. J., Ward, T. M. and Gillanders, B. M. (2011) Otolith shape and elemental composition: complementary tools for stock discrimination of mulloway (*Argyrosomus japonicus*) in southern Australia. Fisheries Research 110(1), 75-83.

Ferguson, G. J., Ward, T. M. and Gorman, D. (2015) Recovery of a Surf Clam *Donax deltoides* population in Southern Australia: successful outcomes of fishery-independent surveys. North American Journal of Fisheries Management 35(6), 1185-1195.

Ferguson, G. J., Ward, T. M., Ivey, A. and Barnes, T. (2014) Life history of *Argyrosomus japonicus*, a large sciaenid at the southern part of its global distribution: Implications for fisheries management. Fisheries Research 151, 148-157.

Ferguson, G. J., Ward, T. M., Ye, Q., Geddes, M. C. and Gillanders, B. M. (2013) Impacts of drought, flow regime, and fishing on the fish assemblage in southern Australia's largest temperate estuary. Estuaries and Coasts 36(4), 737-753.

Gaughan, D., Ayvazian, S., Nowara, G. and Craine, M. (2006) The development of a rigorous sampling methodology for a long-term annual index of recruitment for finfish species from south-western Australia. Final FRDC Report Project 1999/153, Fisheries Research Report No. 154, Department of Fisheries, Western Australia.

Giri, K. and Hall, K. (2015) South Australian Recreational Fishing Survey 2013/14. Fisheries Victoria, Internal Report Series No. 62. 66 pp.

Goldsworthy, S. D. and Boyle, M. (2019) Operational interactions with Threatened, Endangered or Protected Species in South Australian Managed Fisheries: 2017/18. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2009/000544-9. SARDI Research Report Series No. 1032. 39 pp.

Gomon, M. F., Bray, D. J. and Kuiter, R. H. (2008) Fishes of Australia's southern coast. (Reed New Holland: Chatswood, NSW).

Griffiths, M. H. (1997) Management of the South African Dusky kob *Argyrosomus japonicus* (Sciaenidae) based on pre-recruit models. South African Journal of Marine Science 18, 213-228.

Hall, K., Giri, K. and Jones, K. (2015). South Australian Recrational Pipi Fishing Estimates of Harvest 2013-14 – Goolw on-site surveys. Fisheries Victoria Internal Report Series No. 60.

Harris, J. A. (1968) Age structure, growth rate and spawning cycle of a population of yellow-eye mullet *Aldrichetta forsteri* (Cuv. and Val.) from the Coorong Lagoon, South Australia. Transactions of the Royal Society of South Australia 92, 37-50.

Henry, G. W. and Lyle, J. M. (2003) The National Recreational and Indigenous Fishing Survey. Fisheries Research and Development Corporation, No. 99/158, Canberra.

Higham, J., Ferguson, G. and Ye, Q. (2005) Lakes and Coorong Yelloweye Mullet (*Aldrichetta forsteri*) Fishery. South Australian Research and Development Institute (Aquatic Sciences), No. RD04/0162, Adelaide.

Jenkins, G. P., Spooner, D., Conron, S. and Morrongiello, J. R. (2015) Differing importance of salinity stratification and freshwater flow for the recruitment of apex species of estuarine fish. Marine Ecology Progress Series 523, 125-144.

Jones, K. (2009) 2007/08 South Australian Recreational Fishing Survey. Primary Industries and Resources South Australia, Adelaide.

Jones, K. and Doonan, A. M. (2005) 2000/01 National Recreational and Indigenous Fishing Survey: South Australian Regional Information. Primary Industries and Resources South Australia, No. 46, Adelaide.

Kailola, P. J., Williams, M. J., Stewart, P. C., Reichelt, R. E., McNee, A. and Greive, C. (1993) Australian Fisheries Resources. Canberra, Australia. Vol. Australian Fisheries Resources (Bureau of Resource Sciences, Fisheries Research and Development Corporation: Brisbane).

Keenan, C., Watts, R. J. and Serafini, L. (1995) Population genetics of golden perch, silver perch and catfish within the Murray-Darling Basin, In Banens, R. J. and Lehane R. (eds) 'Proceedings of the 1995 Riverine Environment Research Forum', Attwood, Victoria.

King, J. R. and McFarlane, G. A. (2003) Marine fish life history strategies: applications to fishery management. Fisheries Management and Ecology 10, 249-264.

King, M. G. (1976) The life-history of the Goolwa cockle, *Donax* (*Plebidonax*) *deltoides*, (Bivalvia: Donacidae), on an ocean beach, South Australia. Department of Agriculture and Fisheries, No. 85, Adelaide.

Knuckey, I. A., Sen, S., Ward, T. M., Koopman, M., Earl, J., McPhail, J., MacDonald, N. and Fistr, A. (2015) Developing management frameworks and harvest strategies for small-scale, multi-species, multi-method, community-based fisheries, using the South Australian Lakes and Coorong Fishery as a case study. FRDC Project 2013/225. Fishwell Consulting. 84 pp.

Kurth, D. (1957) An investigation of the greenback flounder, *Rhombosolea tapirina* Günther. PhD Thesis. University of Tasmania, Hobart.

Lintermans, M. (2007) Fishes of the Murray-Darling Basin: An introductory guide. Murray-Darling Basin Commission, Canberra.

Mallen-Cooper, M. and Stuart, I. G. (2003) Age, growth, and non-flood recruitment of two potamodromous fishes in a large semi-arid / temperate river system. River Research and Applications 19(7), 697-719.

McLeay, L. J., Jones, G. K. and Ward, T. M. (2002) National Strategy for Survival of Released Line-Caught Fish: A Review of Research and Fishery Information. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. FRDC project No. 2001/101, Final Report.

McNeil, D. G., Westergaard, S., Cheshire, K., Noell, C. and Ye, Q. (2013) Effects of Hyper-saline Conditions Upon Six Estuarine Fish Species from the Coorong and Murray Mouth. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2009/000014-4. SARDI Research Report Series No. 700. 26 pp.

Murray-Jones, S. and Johnson, J. (2003) Goolwa Cockle (*Donax deltoides*). Fisheries Assessment Report for PIRSA Fisheries and Aquacutlure. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Murray-Jones, S. E. and Ayre, D. J. (1997) High levels of gene flow in the surf bivalve *Donax deltoides* (Bivalvia: Donacidae) on the east coast of Australia. Marine Biology 1(128), 83-89.

Pellizzari, M. (2001) A preliminary investigation of the biology of yelloweye mullet in South Australian waters. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

PIRSA (2022) Management Plan for the South Australian Lakes and Coorong Fishery. PIRSA Fisheries and Aquaculture, Adelaide. South Australian Fisheries Management Series Paper No. 82. 70pp.

Piddocke, T., Ashby, C., Hartmann, K., Hesp, A., Hone, P., Klemke, J., Mayfield, S., Roelofs, A., Saunders, T., Stewart, J., Wise, B. and Woodhams, J. eds. (2021) Status of Australian fish stocks reports 2020. Fisheries Research and Development Corporation, Canberra.

Potter, I. C., Tweedley, J. R., Elliott, M. and Whitfield, A. K. (2015) The ways in which fish use estuaries: a refinement and expansion of the guild approach. Fish and Fisheries 16(2), 230-239.

Puckridge, J. T. and Walker, K. F. (1990) Reproductive biology and larval development of a gizzard shad, *Nematalosa erebi* (Gunther) (Dorosomatinae: Teleostei), in the River Murray, South Australia. Australian Journal of Marine and Freshwater Research 41, 695-712.

Rogers, P. J., Barnes, T. C., Wolf, Y., Gregory, P., Williams, N., Madonna, A. and Loisier, A. (2014) On-site recreational fishery survey and research of Mulloway (*Argyrosomus japonicus*) in the Yalata Indigenous Protected Area and Far West Coast Marine Park between 2009 and 2013. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2014/000074-1. SARDI Research Report Series No. 759. 46 pp.

Rowell, K., Flessa, K. W., Dettman, D. L., Roma, M. J., Gerberc, L. R. and Findley, L. T. (2008) Diverting the Colorado River leads to a dramatic life history shift in an endangered marine fish. Biological Conservation 141, 1138-1148.

Shams, F., Dyer, F., Thompson, R., Duncan, R. P., Thiem, J. D., Enge, T. G. and Ezaz, T. (2020) Multiple lines of evidence indicate limited natural recruitment of Golden Perch (*Macquaria ambigua*) in the highly regulated Lachlan River. Water 12(6): 1636.

Silberschneider, V. and Gray, C. A. (2008) Synopsis of biological, fisheries and aquaculture-related information on mulloway *Argyrosomus japonicus* (Pisces: Sciaenidae), with particular reference to Australia. Journal of Applied Ichthyology 24, 7-17.

Silberschneider, V., Gray, C. A. and Stewart, J. (2009) Age, growth, maturity and the overfishing of the iconic sciaenid, *Argyrosomus japonicus*, in south-eastern, Australia. Fisheries Research 95(2-3), 220-229.

Sloan, S. (2005) Management Plan for the South Australian Lakes and Coorong Fishery. Primary Industries and Resources South Australia, No. 44, Adelaide.

Smith, A. D. M. (2013) Review of the 2011 stock assessment for Mulloway in South Australia. Advice note to PIRSA Fisheries and Aquaculture.

Smith, K. A., Brown, J., Hammond, M. and Nardi, A. (2008) Development of cost-effective indices to monitor the nearshore fish communities of the Swan Region. Department of Fisheries (Western Australia).

Stewart, J., Hughes, J. M., Stanley, C. and Fowler, A. M. (2020) The influence of rainfall on recruitment success and commercial catch for the large sciaenid, *Argyrosomus japonicus*, in eastern Australia. Marine Environmental Research 157, 104924.

Sutton, C. P., MacGibbon, D. J. and Stevens, D. W. (2010) Age and growth of greenback flounder (*Rhombosolea tapirina*) from southern New Zealand. New Zealand Fisheries Assessment Report 2010/48. Ministry of Fisheries, Wellington.

Thomson, J. M. (1957) Interpretation of the scales of the yellow-eye mullet, *Aldrichetta forsteri* (Cuvier and Valenciennes). (Mugilidae). Australian Journal of Marine and Freshwater Research 8, 14-28.

Vainickis, A. (2010) SARDI Aquatic Sciences Information Systems Quality Assurance and Data Integrity Report 2010. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2009/000267-2. SARDI Research Report Series No. 497. 20 pp.

Ward, T. M., Ferguson, G., Payne, N. and Gorman, D. (2010) Effectiveness of fishery-independent surveys for monitoring the stock status of pipi (*Donax deltoides*) on the Younghusband Peninsula, South Australia. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2010/000824-1. SARDI Research Report Series No. 504. 35 pp.

Webster, I. T. (2010) The hydrodynamics and salinity regime of a coastal lagoon – The Coorong, Australia – seasonal to multi-decadal timescales. Estuarine, Coastal and Shelf Science 90(4), 264-274.

Williams, J., Jenkins, G. P., Hindell, J. S. and Swearer, S. E. (2013) Linking environmental flows with the distribution of black bream *Acanthopagrus butcheri* eggs, larvae and prey in a drought affected estuary. Marine Ecology Progress Series 483, 273-287.

Winemiller, K. O. and Rose, K. A. (1992) Patterns of life-history diversification in North American fishes: implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences 49, 2196-2218.

Ye, Q., Bucater, L, Short, D. A. and Giatas, G. (2022) Coorong Fish Condition Monitoring 2008–2021: Black bream (*Acanthopagrus butcheri*), greenback flounder (*Rhombosolea tapirina*) and smallmouthed hardyhead (*Atherinosoma microstoma*) populations. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000471-9. SARDI Research Report Series No. 1129. 77pp.

Ye, Q., Bucater, L., Furst, D., Lorenz, Z., Giatas, G. and Short, D. (2019) Monitoring salt wedge dynamics, food availability and black bream (*Acanthopagrus butcheri*) recruitment in the Coorong Estuary during 2018-19. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2018/000425-2. SARDI Research Report Series No. 1045. 48 pp.

Ye, Q., Earl, J., Bucater, L., Cheshire, K., McNeil, D., Noell, C. J., Short, D. A. (2013) Flow related fish and fisheries ecology in the Coorong, South Australia. FRDC Project 2006/045. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. 88pp.

Ye, Q., Bice, C. M., Bucater, L., Ferguson, G. J., Giatas, G. C., Wederburn, S. D. and Zampatti, B. P. (2016) Fish monitoring synthesis: Understanding responses to drought and high flows in the Coorong, Lower Lakes and Murray Mouth. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2016/000348-1. SARDI Research Report Series No. 909.

Zampatti, B. P., Leigh, S. J., Bice, C. M. and Rogers, P. J. (2018) Multiscale movements of golden perch (Percichthyidae: *Macquaria ambigua*) in the River Murray, Australia. Austral Ecology 43(7): 763–774.

APPENDIX

Appendix 1. Summary table showing annual total commercial catches (tonnes) for twelve LCF species defined as ‘primary’, ‘secondary’, ‘tertiary’ or ‘other’ species in the Management Plan (PIRSA 2022). Total catches for Pipi include LCF and MSF catches. Crosses indicate confidential data.

	Primary					Secondary			Tertiary			Other
	Mulloway	Yelloweye Mullet	Golden Perch	Carp	Pipi	Bony Herring	Greenback Flounder	Black Bream	Snapper	Australian Salmon	Australian Herring	Redfin Perch
84/85	41	128	89	370	459	449	20	47	0	1	0	15
85/86	32	219	62	311	385	629	29	36	x	2	0	52
86/87	31	277	64	292	449	808	23	37	0	1	0	54
87/88	14	147	63	456	457	977	10.5	22	0	2	0	72
88/89	26	235	95	378	308	972	4.2	16	x	4	0	92
89/90	37	346	133	383	311	1157	3.3	10	0	8	x	59
90/91	42	224	164	508	533	947	65	3.7	0	4	x	37
91/92	45	198	157	1021	758	1053	58	4.7	0	23	x	32
92/93	34	210	279	673	737	612	27	2.6	0	3	0	40
93/94	85	181	299	842	942	695	10	3.1	0	1	x	69
94/95	78	239	286	816	783	838	3	3.3	x	x	0	44
95/96	57	195	292	767	927	706	30	4	0	5	0	24
96/97	56	161	235	767	829	688	15	3.9	0	3	0	30
97/98	50	158	190	635	1041	757	11	4.3	1	4	0	22
98/99	95	139	154	444	932	609	28	3.4	1	3	0	45
99/00	69	150	97	269	1024	429	39.9	4.1	2	4	0	24
00/01	136	127	173	274	1211	474	18.6	7.5	0	2	0	25
01/02	109	155	97	210	1046	299	25.6	8.2	0	1	0	10
02/03	45	167	64	404	1180	212	5.8	11.6	0	1	x	6
03/04	31	111	82	575	1073	228	5.5	10	x	2	0	9
04/05	39	110	103	558	1108	287	8.5	5.5	0	4	0	11
05/06	39	127	125	749	1062	319	6.6	6.6	0	3	0	23
06/07	44	141	152	694	990	376	5.2	4.7	1	4	0	16
07/08	32	216	117	709	607	411	2	4	0	6	0	29
08/09	30	210	87	713	470	422	0.5	1.8	0	10	0	28
09/10	26	207	49	630	301	550	1	1.1	3	10	0	41
10/11	19	243	68	404	301	464	0.1	2.3	3	8	0	61
11/12	64	144	57	308	374	443	31.1	3	1	1	0	68
12/13	103	217	34	349	443	502	9.2	1.9	x	1	0	12
13/14	68	196	88	422	444	469	1	1.9	x	0	0	8
14/15	59	121	85	403	443	407	0.3	2.4	0	1	0	14
15/16	73	135	77	395	492	397	4.5	1.9	0	3	0	12
16/17	62	183	81	490	539	421	2.1	1.7	0	1.6	0	12
17/18	121	154	106	403	646	356	0.7	1.3	0	0.6	0	27
18/19	109	284	61	376	646	296	1.8	0.7	0.3	0.3	0	43
19/20	120	458	50.6	538	430	269	0.24	1.76	0	1.1	0	32
20/21	92	368	54.9	518	444	313	4.5	3.23	0	2.6	0	23
21/22	56	206	35	376	420	361	5.6	3.42	0	3.3	0	26