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Assessment of the South Australian Lakes and Coorong Fishery in 2018/19

J. Earl

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SARDI Aquatics Sciences
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May 2020

Report to PIRSA Fisheries and Aquaculture

SOUTH AUSTRALIA

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The report was formally reviewed by Dr Adrian Linnane and Dr Owen Burnell (SARDI Aquatic Sciences), and Keith Rowling (PIRSA Fisheries and Aquaculture). The report was approved for publication by Dr Stephen Mayfield (Science Leader, Fisheries, SARDI Aquatic Sciences).

EXECUTIVE SUMMARY

This report is the first in a new series for South Australia's Lakes and Coorong Fishery (LCF). It provides a description of the dynamics of the multi-species, multi-gear fleet, a comprehensive stock assessment for Mulloway, and assigns stock status to a further five finfish species that are harvested by the three gillnet sectors of the fishery (Estuarine large mesh gillnet; Estuarine small mesh gillnet; and Freshwater large mesh gillnet), as well as for Pipi. The report includes a summary of the species-specific fishery information relating to: population biology; fishing access; management arrangements; and trends in commercial fishery statistics from 1 July 1984 to 30 June 2019. The report also provides updated estimates of the performance indicators for the three gillnet sectors and for Pipi. 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 (NFSRF; Stewardson et al. 2018).

Fleet dynamics

The dynamics of the LCF fleet have changed considerably over the last 35 years. Most of the changes relate to the environment and markets, and are reflected in shifts in targeting among the fishery's six primary species (Mulloway, Yelloweye Mullet, Golden Perch, Pipi, Carp and Bony Herring). These species have accounted for 78–98% of the fishery's annual targeted effort since 1984/85.

Mulloway stock assessment

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

The LCF has historically been the most productive of South Australia's fisheries for Mulloway, and in 2018/19 contributed 93% of the State's total commercial catch. The total catch of Mulloway by the LCF in 2018/19 was 109 t, which was the third highest catch recorded in the fishery since 1984/85.

The main gear types used by the LCF to target Mulloway are large mesh gillnets (LMGN; 115–150 mm mesh) and swinger nets (> 150 mm mesh). In 2018/19, targeted catches taken using LMGN in the Coorong estuary accounted for 85% of the total catch. Most of the remaining catch (14%) was taken as by-product when other species were targeted, while a small proportion (1%) was targeted catch taken using swinger nets in the nearshore marine environment adjacent to the Coorong estuary.

The recent high catches of Mulloway in the LCF have been associated with historically high estimates of mean annual $CPUE_{LMGN}$. The $CPUE_{LMGN}$ of 10.2 kg.net-day^{-1} in 2018/19 was the highest on record and likely reflects high abundance of Mulloway in the Coorong estuary.

Clear spatial differences were evident in age/size structures for Mulloway between the Coorong estuary and the adjacent nearshore marine environment from recent years. Catches from the estuary

were dominated by 3 and 4 year old (juvenile) fish, while those from the ocean comprised fish between 6 and 24 years of age and were dominated by 7 and 8 year olds. Fish older than 10 years were rare, despite the potential for this species to live for 41 years. The presence of several age classes of juveniles in age structures from the estuary indicates that recruitment has occurred in recent years.

The regular 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 catches and catch rates 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'** under the NFSRF.

Mulloway is the primary target species in the Estuarine large mesh gillnet sector (ELMGN). The environmental performance indicator for habitat available to Mulloway in the Coorong estuary for the 2019/20 reporting year (1 February 2019–31 January 2020) was 59.6%, which was above the target reference point of 55%.

Stock status of other key species

Estuarine large mesh gillnet sector (ELMGN)

Black Bream is a secondary species in the ELMGN. Targeted catch and effort for Black Bream have been historically low in most of the last 30 years, and this continued in 2018/19. These results suggest that the biomass of this stock remains in a recruitment-impaired state. In 2018, temporary management arrangements were introduced to recover the stock but these have not yet resulted in measurable improvements. On this basis, the status of '**depleted**' that was applied to this stock in 2017/18 is retained.

Greenback Flounder is a secondary species in the ELMGN. The species is considered a 'marine estuarine-opportunist' – a marine species that enters estuaries in substantial numbers, particularly as juveniles and young adults, but uses marine waters as alternative habitat. In the Coorong estuary, low targeted effort and catches since 2012/13 likely reflect low fishable biomass as a consequence of low recruitment over several recent years due to the low freshwater inflows to the estuary (i.e. non-fishing effects). Biomass in the estuary has been reduced primarily through non-fishing effects and, as a consequence, recruitment is impaired. As such, the status of '**depleted**' that was applied to this stock in 2017/18 is retained.

Estuarine small mesh gillnet sector (ESMGN)

Yelloweye Mullet is the primary target species in the ESMGN. The total catch of 285 t in 2018/19 was highest catch of Yelloweye Mullet since 1989/90, and was associated with record-high $CPUE_{SMGN}$. On this basis, this stock is classified as '**sustainable**'.

For the ESMGN, the environmental performance indicator for habitat available to Yelloweye Mullet in the Coorong estuary for the 2019/20 reporting year was 65%, which was above the target reference point of 50%.

Freshwater large mesh gillnet sector (FLMGN)

Golden Perch, Bony Herring and Carp are the primary target species in the FLMGN. For Golden Perch, the total catch of 61 t in 2018/19 was the lowest since 2012/13. Nevertheless, $CPUE_{LMGN}$ in 2018/19 was among the highest on record. On this basis, this stock is classified as '**sustainable**'.

Bony Herring is mainly taken as by-product by fishers targeting other species. In 2018/19, the total catch of 294 t was the lowest since 2004/05, while $CPUE_{LMGN}$ was above the long-term average. This stock is classified as '**sustainable**'.

Carp is listed as a noxious aquatic species in South Australia under the *Fisheries Management Act 2007*. It is mostly taken as by-product by LCF fishers when other species are targeted. Total catches of Carp have been at moderate levels since 2009/10. No status is assigned to this stock.

For the FLMGN, the environmental performance indicator for mean annual water level in the Lower Lakes for the 2019/20 reporting year was 0.69 m (Australian Height Datum), which was above the target reference point of 0.4 m.

Pipi sector

Since 2009/10, annual catches of Pipi have been constrained by the total allowable commercial catch (TACC). The total catch of 646 t in 2018/19 was the equal highest catch since 2009/10. In 2018/19, the estimate of fishery-independent relative biomass of legal-sized Pipi (primary performance indicator) of 12.6 kg/4.5 m^2 was above the target reference point of the 11 kg/4.5 m^2. Pre-recruits (secondary performance indicator) comprised less than 30% of the size structures in November 2018 (12%), and February 2019 (16%), and were considered absent in 2018/19. The low recruitment in 2018/19 led to a 31% reduction in the TACC for the 2019/20 fishing season. This reduced catch under the harvest strategy will limit risks to the stock, by protecting the spawning biomass, and ensure that, on average, future levels of recruitment are adequate. This stock is classified as '**sustainable**'.

Keywords: multi-species, multi-gear, stock status, Mulloway, Black Bream, Greenback Flounder, Yelloweye Mullet, Golden Perch, Bony Herring, European Carp, Pipi, gillnets, Coorong estuary.

Table E-1. Key statistics for South Australia's Lakes and Coorong Fishery finfish resources from 2016/17 to 2018/19, including stock status based on weight of evidence and the National Fishery Status Reporting Framework (Stewardson et al. 2018). Crosses indicate confidential data. There was no targeting of Black Bream in 2018/19.

Species	F/Year	Catch (t)	CPUE (kg.net-day^{-1})	Stock status
Mulloway	2016/17	62	9.35	Sustainable
	2017/18	121	9.89	Sustainable
	2018/19	110	10.2	Sustainable
Black Bream	2016/17	1.6	1.32	Overfished
	2017/18	1.3	X	Depleted
	2018/19	0.68	-	Depleted
Greenback Flounder	2016/17	2.1	2.26	Environmentally limited
	2017/18	0.7	1.67	Depleted
	2018/19	1.85	1.63	Depleted
Yelloweye Mullet	2016/17	183	13.01	Sustainable
	2017/18	154	13.14	Sustainable
	2018/19	285	26.81	Sustainable
Golden Perch	2016/17	81	1.36	Sustainable
	2017/18	106	1.55	Sustainable
	2018/19	61	1.21	Sustainable
Bony Herring	2016/17	427	5.30	Not assessed
	2017/18	363	4.46	Sustainable
	2018/19	294	4.23	Sustainable
Carp	2016/17	490	6.00	Not assessed
	2017/18	403	4.71	
	2018/19	375	5.12	

Table E-2. Results from the annual assessments of the environmental performance indicators for the three finfish sectors from 2017/18 to 2019/20 (reporting years) against their target, trigger and limit reference points (RP). The annual total allowable commercial effort (TACE) for each sector is also shown.

Finfish sector	Performance indicator	Limit RP	Trigger RP	Target RP	Reporting year	PI value	TACE (net units)
Estuarine LMGN	Habitat available to Mulloway	10	24.9	55	2017/18	57.8%	1,250
					2018/19	55.0%	1,250
					2019/20	59.6%	1,175
Estuarine SMGN	Habitat available to YE Mullet	10	30.9	50	2017/18	66.9%	1,250
					2018/19	67.9%	1,250
					2019/20	65.1%	1,175
Freshwater LMGN	Water level in the Lower Lakes	-1.2	-0.71	0.4	2017/18	0.72 m	1,250
					2018/19	0.65 m	1,250
					2019/20	0.69 m	1,175

Table E-3. Key statistics and stock status for South Australia's Lakes and Coorong Fishery Pipi resource from 2016/17 to 2018/19. TACC = total allowable commercial catch.

	F/year	TACC (t)	Catch (t)	Relative biomass (kg/4.5 m²)	Pre-recruits present	Stock status
Pipi	2016/17	550	539	21.5	Yes	Sustainable
	2017/18	650	646	19.1	Yes	Sustainable
	2018/19	650	646	12.6	No	Sustainable

1 GENERAL INTRODUCTION

1.1 OVERVIEW

Over the past 17 years the stock status and fishery statistics for key species harvested in South Australia's Lakes and Coorong Fishery (LCF) have been reported in two annual reports. The first was a comprehensive stock assessment for Mulloway (*Argyrosomus japonicus*), Yelloweye Mullet (*Aldrichetta forsteri*), Golden Perch (*Macquaria ambigua*), Greenback Flounder (*Rhombosolea tapirina*), Black Bream (*Acanthopagrus butcheri*) and Pipi (*Donax deltoides*), which were sequentially delivered between 2003 and 2016. This report assessed the respective fishery at the management unit scale. The second report summarised the fishery statistics for key fishery species, and assessed fishery performance using performance indicators identified in the previous (Sloan 2005) and current fishery management plans (PIRSA 2016).

This report is the first in the new series for the LCF that will provide species-specific information on: population biology; fishing access; management arrangements; trends in fishery data; and stock status. The report will also assess suites of performance indicators against associated reference points for the finfish and Pipi sectors of the fishery, as prescribed in the management plan (PIRSA 2016).

There are five main sections. The first section, following this overview, provides a description of the LCF, its management arrangements, and details the indicators and reference points used to inform management of the finfish and Pipi sectors of the fishery, as defined in the current management plan (PIRSA 2016). 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 from 1 July 1984 to 30 June 2019; information on the size and age characteristics of the Mulloway harvested by the LCF; and an environmental performance indicator that relates to the amount of suitable habitat available for Mulloway in the Coorong estuary.

Section four consists of a series of species-specific sections that are arranged to align with the three habitat-based gillnet sectors of the LCF, as defined in the management plan (PIRSA 2016), and the Pipi sector of the LCF. For key species of each sector, the relevant biological information is provided, along with a description of the fishery, associated management regulations, an interrogation of the fishery data, and a classification of stock status. For each finfish sector, environmental conditions are also assessed against key reference points.

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 Murray River and Coorong lagoons (the Coorong estuary), the freshwater lower lakes of the Murray River (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, rays, skates and sharks (PIRSA 2016). Fishery production by weight of catch is mainly comprised of Bony Herring (*Nematalosa erebi*), Carp (*Cyprinus carpio*), Yelloweye Mullet, Mulloway, Golden Perch and Pipi. Other species such as Black Bream, Greenback Flounder and Redfin Perch (*Perca fluviatilis*) have historically contributed significantly to the overall catch in some years.

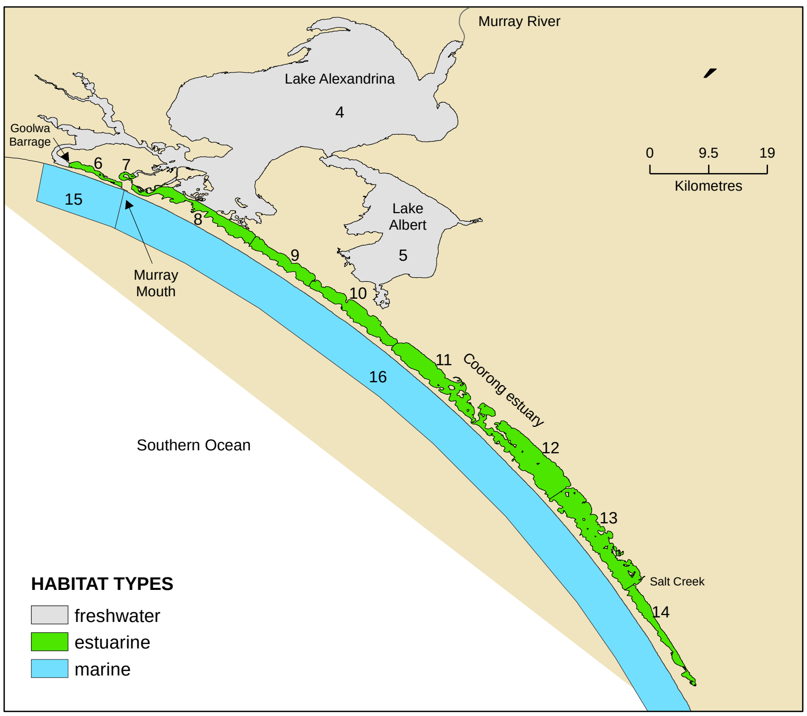

Figure 1-1. Commercial reporting blocks of the LCF showing the different habitats.

Currently there are around 15 types of fishing gear (or devices) endorsed in the LCF. 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, Bony Herring, Carp and Redfin Perch. 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 Younghusband Peninsula. Other methods permitted for use include drum nets, hauling nets and set lines (PIRSA 2016).

The broad mixture of target species, gear types, habitat types 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 seafood markets, resource availability, environmental conditions, and in recent years the impacts of Long-nosed Fur Seals (*Arctocephalus forsteri*), as fishers can readily switch their targeted fishing effort between species, gears and areas.

The recreational fishing sector has access to many of the LCF species. Recreational fishing effort occurs in freshwater, estuarine and marine waters in the region, with fishers permitted to use several gear types. Recreational fishers can also target finfish in the Coorong estuary using registered monofilament nylon nets. Recreational net fishing is prohibited in all other coastal waters of South Australia (PIRSA 2016).

1.3 MANAGEMENT ARRANGEMENTS

The LCF is managed by the South Australian Government's Department of Primary Industries and Regions South Australia Fisheries and Aquaculture Division in accordance with the legislative framework provided within the *Fisheries Management Act 2007*, and subordinate *Fisheries Management (General) Regulations 2017*, *Fisheries Management (Lakes and Coorong Fishery) Regulations 2009* and *licence conditions*.

The LCF is managed as a limited entry fishery. Currently, there are 36 licences with non-exclusive access within the Lakes and Coorong system and the adjacent beach along Younghusband Peninsula. Fishing effort is limited through gear entitlements, with each licence endorsed for the type and number of nets that can be used. Owner-operator provisions also apply. A range of output controls also apply, including a legal minimum size (LMS) for most targeted species and quota management for Pipi.

The *Management Plan for the South Australian Commercial Lakes and Coorong Fishery* (hereafter referred to as the management plan; PIRSA 2016) provides a strategic policy framework for the management of the fishery and a comprehensive overview of the management changes that have occurred over the last four decades. 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. Under the policy, a maximum of two agents may undertake fishing activity pursuant to each licence, following the transfer of a licence. 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 (Scheme of Management - Lakes and Coorong Fishery) Regulations*

1991. 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 over time.

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.

1.4 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 2016). The harvest strategy for finfish outlines the process for setting the annual total allowable commercial effort (TACE) for three finfish sectors, which collectively account for > 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). The finfish harvest strategy is different to that of a traditional harvest strategy, because it aims to manage the sustainable harvest of key finfish species relative to the condition of environment within which the fishery operates, which is linked to the availability of the fished resources (PIRSA 2016). It uses an environmental performance indicator and decision rules to inform setting of the annual TACE for each sector. The environmental performance indicator for each 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. Detailed descriptions of the performance indicators and associated reference points are provided in the management plan.

The second harvest strategy for the LCF for Pipi was developed in 2015/16 and outlines the process for setting the annual total allowable commercial catch (TACC) (PIRSA 2016). 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 2017). Detailed descriptions of the biological performance indicators and associated reference points are provided in the management plan (PIRSA 2016).

1.5 STOCK STATUS CLASSIFICATION

A national stock status classification system has been developed for the consistent assessment of key Australian fish stocks (Stewardson et al. 2018). 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 is significantly compromised. 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 (Stewardson et al. 2018).

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, weather and environmental conditions, management arrangements, markets and other socio-economics.

For multi-species, multi-gear fisheries such as South Australia's commercial Lakes and Coorong Fishery (LCF), understanding the dynamics of the fishing 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. In most cases a detailed breakdown of fishing effort by season, location, species and gear is considered to reveal patterns of fishing activity and fisher behaviour (Hilborn and Walters 1992).

This section of the report provides an overview of the LCF by examining and comparing trends in catches, fishing effort, gear use, fishing areas and seasonality from 1 July 1984 to 30 June 2019. This summary illustrates the dynamic and complex nature of this fishery over different spatial and temporal scales, and the relationships and trends between target species, and provides important context for the assessments of stock status for individual species in sections three and four 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. Daily catch and effort data have been collected by LCF fishers since 1 July 1984, and are submitted monthly to SARDI Aquatic 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 Lakes and Coorong Fisheries Information System for the 35-year period from 1 July 1984 to 30 June 2019. These data were aggregated to provide annual totals of catch (kg) by species, and targeted effort (fisher-day) by species, gear, month and location, for each financial year from 1984/85 to 2018/19. 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 number of active licences

There has been a 17% decline in the number of active fishers licensed to operate in the LCF over the past 35 years, declining from 42 licences in 1984/85 to 35 licences in 2018/19 (Figure 2-1). Since 1992/93, the number of active fishers has varied between 33 and 36 licences each year.

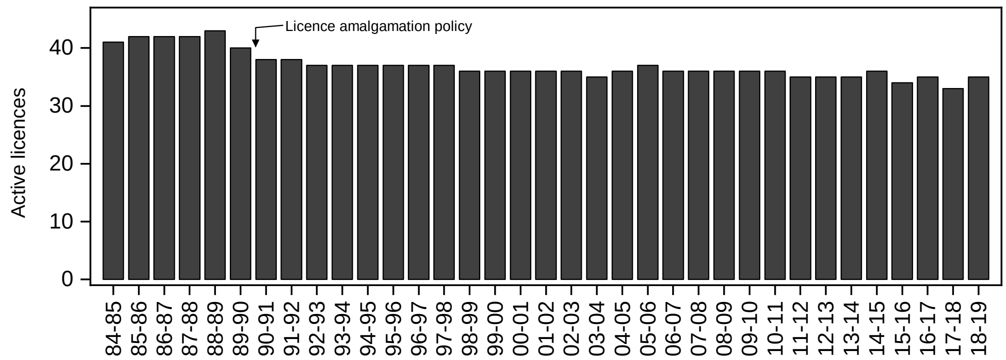

Figure 2-1. Long-term trend in the number of active licence holders that have access to the Lakes and Coorong Fishery. The introduction of the licence amalgamation policy in 1990 is noted.

2.3.2 Trends in commercial catch

Since 1984/85, there have been considerable changes in the composition of the commercial catches within the LCF, which have contributed to high inter-annual variation in fishery production (Figure 2-2). The variation in production is mainly attributable to variation in catches of the primary species, which have consistently made up 94–98% of total annual production. In 2018/19, production was dominated (97.32%) by the six primary species, with the secondary (0.14%), tertiary (0.03%) and the remaining permitted species (2.5%) contributing the remaining catch.

Total catch of the primary species peaked at 2,667 t in 1991/92, with a secondary peak of 2,420 t in 2005/06 (Figure 2-2). Total catch then declined to 1,379 t in 2011/12, before increasing to 1,707 t in 2018/19. Among the primary species, catches of Bony Bream, Carp and Pipi have collectively accounted for most (> 78%) of the annual catches since 1984/85, with smaller contributions from Yelloweye Mullet, Golden Perch and Mulloway.

Total catch of the secondary and tertiary species peaked at 85 t in 1991/92. Since then it has been highly variable but has steadily declined to an historic low of 3.1 t in 2018/19. The trends in fishery production for these species groups reflects the temporal trends in catches of Greenback Flounder and Black Bream (secondary species), and to a lesser extent Western Australian Salmon (*Arripis truttaceus*; tertiary species).

Annual catches of all other permitted LCF species peaked at 108 t in 1988/89, with a secondary smaller peak of 73 t in 2011/12. 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 2018/19 is shown in Appendix 1.

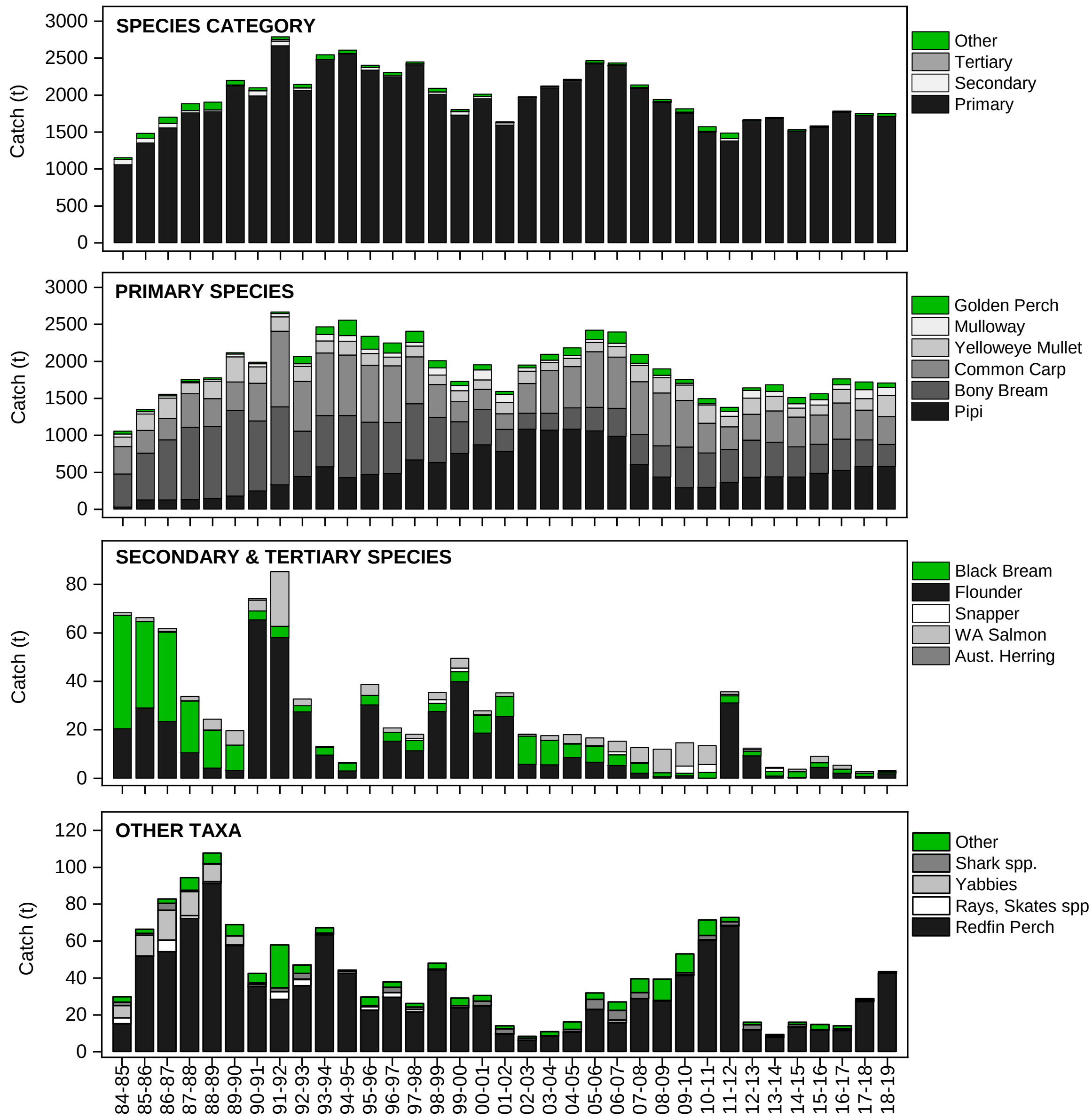

Figure 2-2. Long-term trends in total catch (t) in the commercial LCF from 1984/85 to 2018/19, presented by species category, primary species, secondary and tertiary species, and all other permitted species.

2.3.3 Trends in commercial fishing effort

2.3.3.1 Species

Annual estimates of total fishing effort in the LCF peaked at 9,787 fishing days in 1988/89 (Figure 2-3). This peak represented a 14% increase in annual effort since 1984/85, after which, there was a 49% reduction in effort to a low of 5,006 fishing days in 2018/19. This decline in effort occurred over a long period, although a substantial annual reduction occurred in early 2000s (i.e. the initial stages of the Millennium Drought), when a large part of the Coorong estuary was uninhabitable for fish due to persistent hypersaline environmental conditions. Over the last decade, annual effort has been relatively stable and ranged between 5,006 and 6,503 fishing days, with around 80% of the effort being targeted to a particular species.

Of the reported targeted effort since 1984/85, the primary species have consistently accounted for the highest proportion (78–98%), 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 fishing activity during the early 1990s, as fishers directed some of their effort away 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. Since 2011/12, the relative proportions of the annual targeted fishing effort directed toward each of the primary species has been stable, with Yelloweye Mullet (28%), Golden Perch (25%), Pipi (18%) and Mulloway (16%) accounting for most.

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 Black Bream and Greenback Flounder (Figure 2-3). Of these species, Black Bream accounted for most of the targeted effort during the 1980s, before there was a distinct shift in fishing activity in 1990/91 away from Black Bream toward Greenback Flounder. Since then, targeted fishing for secondary species has been highly variable and accounted for < 5% of total effort in most years. The variation is largely attributable to variation in targeting of Greenback Flounder, as targeting of Black Bream has been negligible. Most of the remaining targeted effort in the LCF over the last 25 years has been directed toward Redfin Perch.

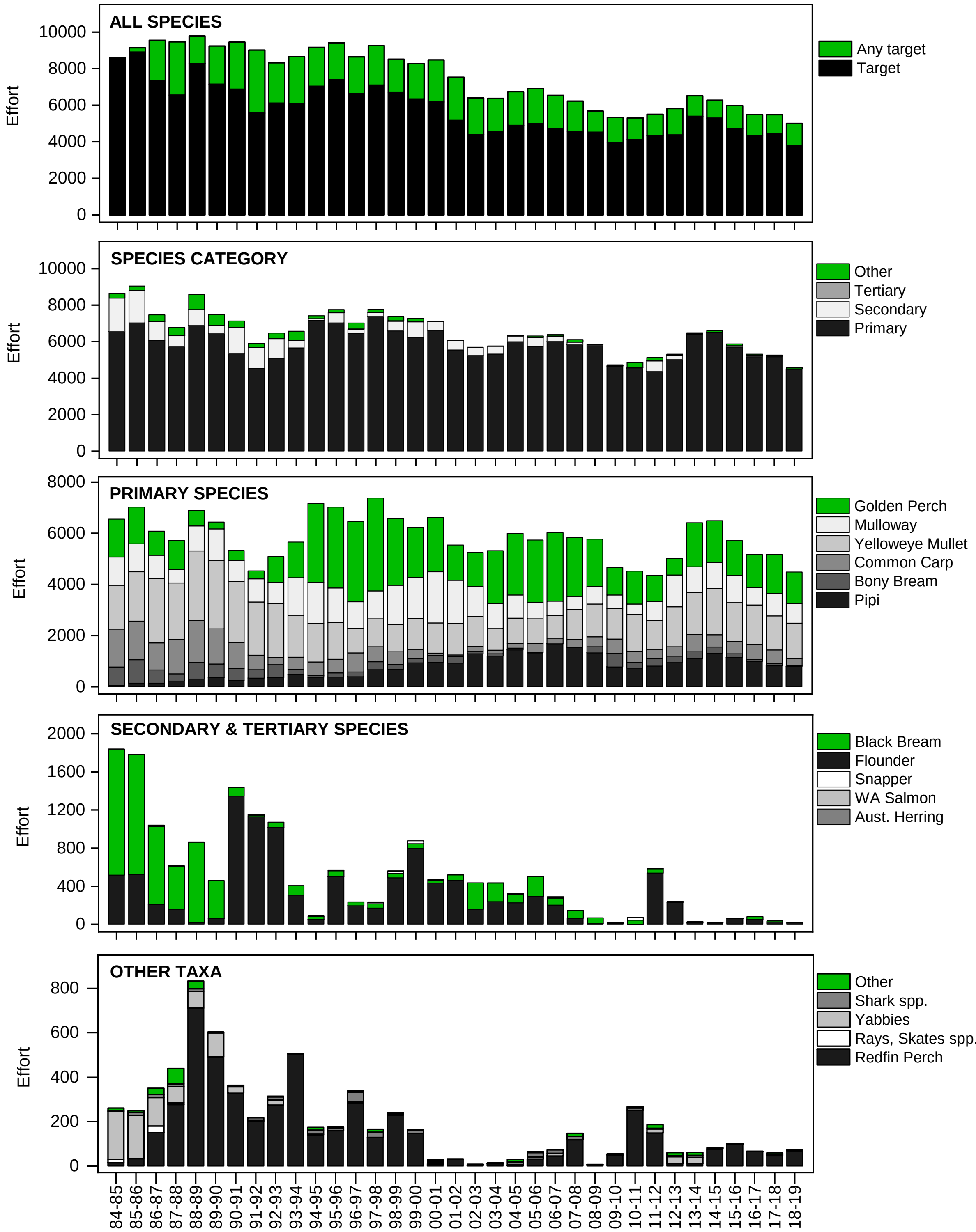

Figure 2-3. Long-term trends in total effort in the LCF from 1984/85 to 2018/19 presented by targeted and non-targeted ('any target') effort (top graph), and by species category, primary species, secondary and tertiary species, and all other permitted species.

2.3.3.2 Gear

Large mesh gillnets have consistently been the dominant gear type used in the fishery, accounting for 60–80% of the total fishing effort each year (Figure 2-4). Small mesh gillnets have been the second most utilised gear type since 1984/85. 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. Swinger nets have accounted for most of the remaining fishing effort in the fishery, with negligible contributions from hauling nets, and other gears such as drum nets, set lines and yabbie pots.

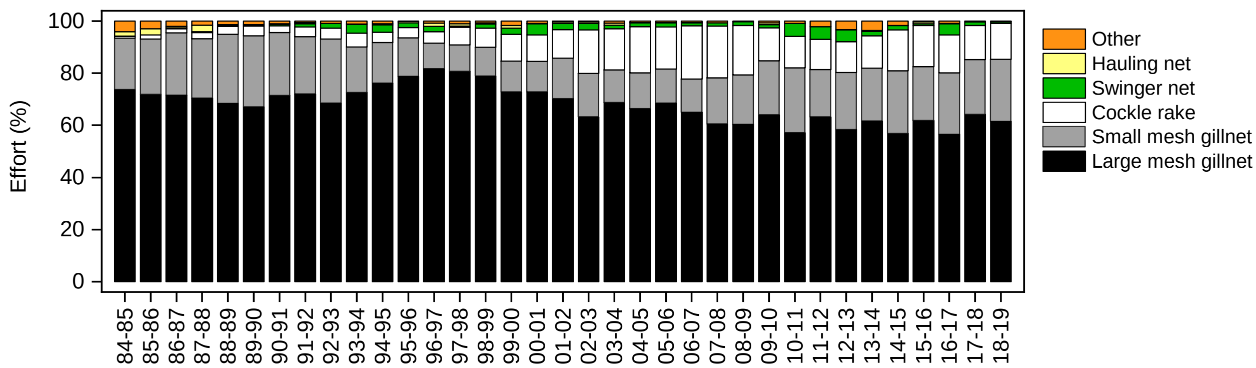

Figure 2-4. Gear usage (% of total fishing effort in fishing days) within the commercial LCF.

2.3.3.3 Season

The multi-species 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 six 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 with a peak of around 146 (±13) fishing days in August. The seasonal pattern for Golden Perch was similar, with a relatively high level of fishing effort throughout the year and peaks of 130–140 fishing days in spring and autumn. Conversely, targeted effort for Mulloway was highest in late spring, peaking at around 145 (±10) fishing days in November. Fishing effort for Pipi was highest in summer and autumn, which is when weather conditions are most favourable for targeting the species. Carp were targeted across the year, while fishing for Bony Herring was generally limited to between July and January.

For the secondary species, fishing for Greenback Flounder was seasonal with on average, around 77% of targeted effort occurring from November to March (Figure 2-5). In contrast, targeted effort for Black Bream was highest in July, with lower levels of targeting from September to November likely attributable to the Black Bream fishery closure during these months in 2018/19. Fishing for Black Bream was negligible from December to June.

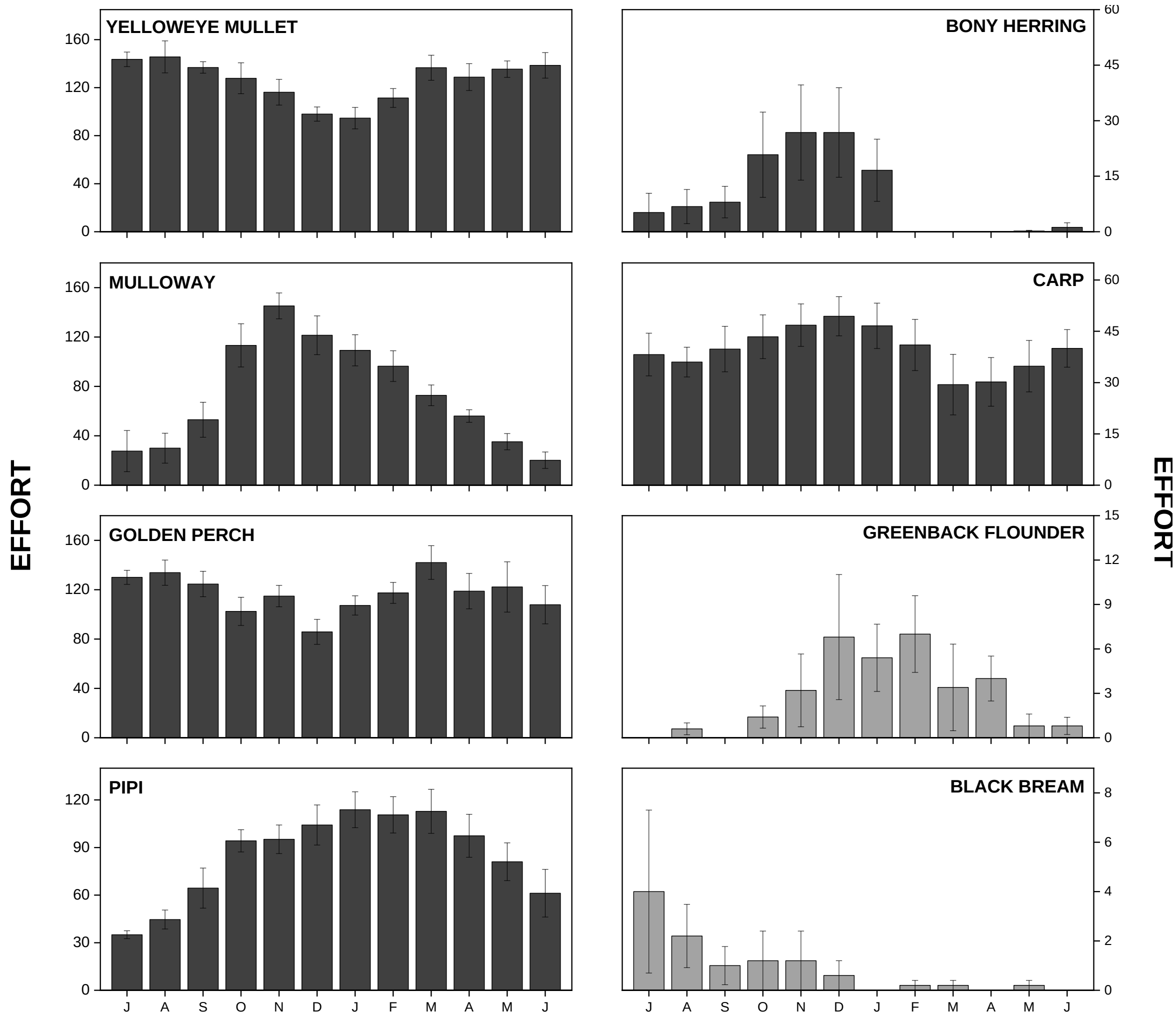

Figure 2-5. Monthly pattern of targeted fishing effort (fishing-days averaged, ± se) from 2014/15 to 2018/19 for each species/taxon assessed in this report. The different shades denote species category; primary (black) and secondary (grey).

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). During this time, effort was most intense 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 Younghusband Peninsula (block 16) associated with increased targeting of Pipi, while Lake Alexandrina (block 4) continued to account for most of the effort. During the 2000s, there was a gradual contraction of the fishing ground in the Coorong estuary associated with the Millennium Drought, with minimal fishing in the south lagoon (blocks 12–14). Drought-breaking river flows in 2010/11 led to improved environmental conditions in the estuary and a subsequent expansion of the fishing ground. Since then, the spatial distribution of fishing effort in the LCF has been relatively stable.

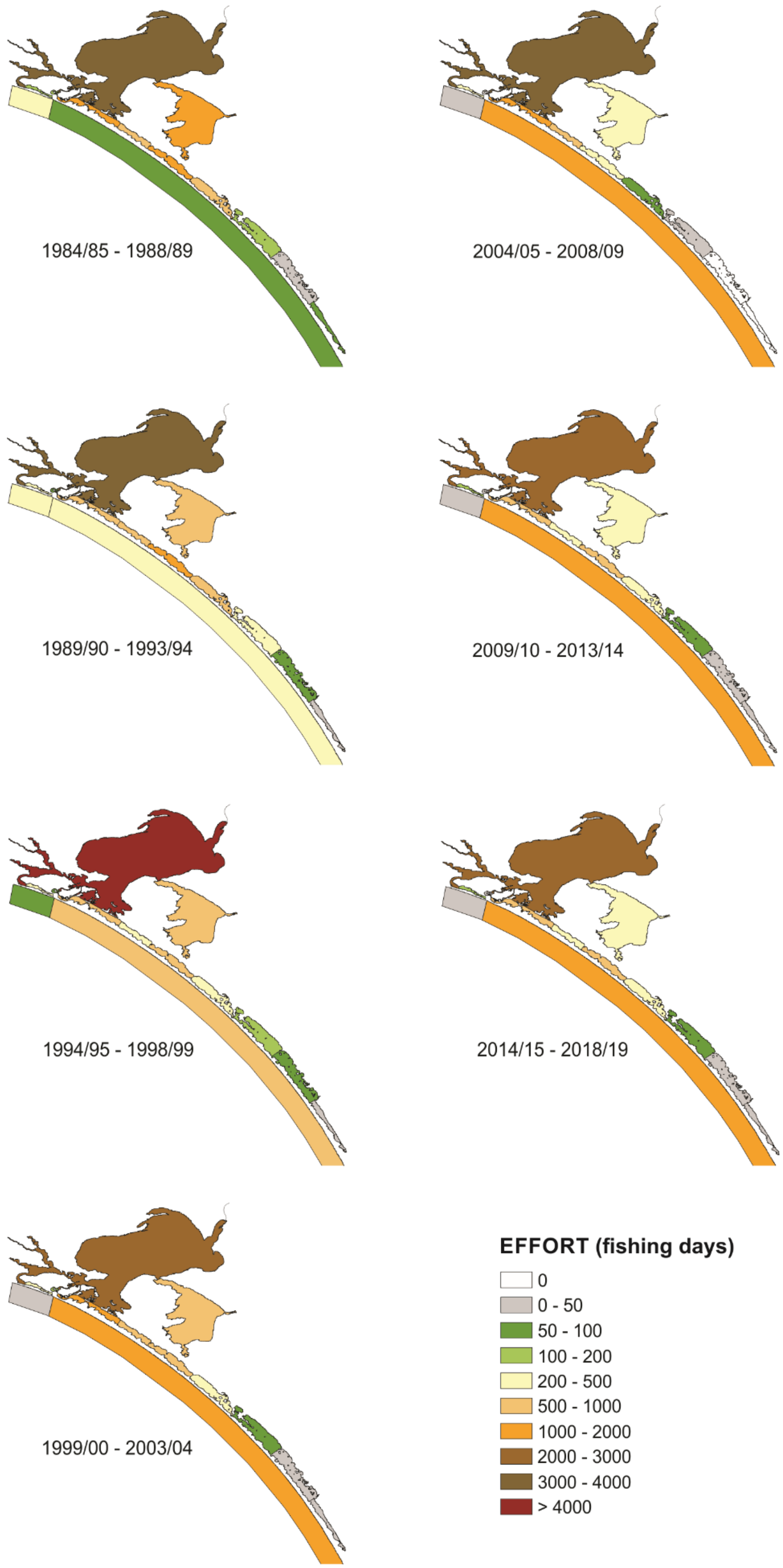

Figure 2-6. Spatial and temporal distribution of annual fishing effort (fishing days) in the LCF averaged over five years from 1984/85 to 2018/19.

2.4 DISCUSSION

The dynamics of the LCF fleet have changed considerably over the last 35 years and most of the changes appear to relate to markets and environmental conditions. While the primary species have consistently accounted for most of the reported targeted effort in the fishery, the most obvious changes in fisher behaviour have related to shifts in targeting among the primary species.

In the 1980s, a large proportion of the fleet's targeted fishing effort was directed to Yelloweye Mullet, Mulloway and Carp. These primary species continue to be key targets for the fishery to the present day, with Yelloweye Mullet and Mulloway supplied to the human consumption market, while Carp is supplied primarily to bait markets, with small (and increasing) volumes reportedly being sold for human consumption. During the 1990s, there was an increase in targeting of Golden Perch, and this species has since become one of the most valuable targets for the fishery in terms of its wholesale value on the human consumption market. 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 total allowable catch (TACC) under a quota management system for Pipi in 2007/08 has effectively constrained commercial harvest since 2009/10 (Ferguson and Hooper 2017), and since then, the fishery has increased its proportionate supply of Pipi to the human consumption market which has subsequently increased its wholesale market value (EconSearch 2019).

Environmental conditions associated with freshwater inflow from the Murray River have a major influence on the function and productivity of the Lakes and Coorong ecosystem, including the abundance and distribution of most LCF species. Over the last 35 years, there have been several major environmental events that have forced Lakes and Coorong fishers to modify their fishing activities to optimise fishery production. An example was during the Millennium Drought between 2002 and 2010, when a lack of freshwater inflows resulted in the intensification of a longitudinal salinity gradient within the Coorong estuary where extremely high salinities in parts of the south lagoon (blocks 12, 13, 14) made it uninhabitable for most fishes. As a result, there was spatial contraction of the fishable area in the Coorong estuary, with fishing effort virtually disappearing from the south lagoon and becoming confined to areas adjacent the Murray Mouth and the north lagoon (blocks 6–11). This spatial contraction of the fishery reflected reductions in the amount of suitable estuarine habitat for many species. A flood event in late 2010 reduced salinity in the upper south lagoon, and the fishing fleet has since extended its range back into these areas. These environmentally-driven changes in fisher behaviour, along with the day-to-day behavioural responses of fishers to other factors such as markets, management arrangements, weather and the presence of Long-nosed Fur Seals (EconSearch 2019), highlight the complex and dynamic nature of the LCF fleet.

3 MULLOWAY STOCK ASSESSMENT

3.1 INTRODUCTION

3.1.1 Overview

This section of the report provides an assessment of South Australia's Lakes and Coorong Fishery (LCF) for Mulloway, which builds on previous fishery assessments completed in 2003, 2011 (Ferguson and Ward 2003; Ferguson and Ward 2011) and 2014 (Earl and Ward 2014), and assessments of stock status in 2014, 2016 and 2018 (Earl et al. 2014b; Earl et al. 2016a; Earl et al. 2018). It provides a synopsis of information available for this species and an assessment of the current status of LCF for Mulloway, based on: (i) commercial fishery catch and effort statistics from 1 July 1984 to 30 June 2019; (ii) results from State-wide recreational fishing surveys done in 2000/01, 2007/08 and 2013/14 (Henry and Lyle 2003; Jones 2009; Giri and Hall 2015); (iii) information on the size and age characteristics of Mulloway taken by the LCF to inform on population structure; and (iv) information on the recent condition of the environment in which the Mulloway fishery operates against reference points prescribed in the management plan (PIRSA 2016).

3.1.2 Biology

Mulloway is a member of the Sciaenidae family of fishes (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 (WA), 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). Throughout this broad distribution, this schooling species occurs in bays, tidal creeks, estuaries and marine waters to depths of at least 100 m. In SA, juveniles are abundant in the Coorong estuary, while larger Mulloway are common in exposed marine habitats, such as the 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 SA's southeast region, temporal analysis of gonadosomatic indices indicated that Mulloway has a prolonged spawning season that extends from October to January. Spawning occurs in aggregations that form during spring/summer in the marine waters at the Murray Mouth. 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 5–6 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). The estimated size at maturity (L_{50}) for Mulloway in SA 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).

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

3.1.3 Fishery

Mulloway is a significant inshore fishery species of southern Australia with fisheries occurring in WA, SA, NSW and Queensland (Kailola et al. 1993). Historically, the national commercial catch for this species has been dominated by that from SA, with moderate contributions from NSW and small contributions from WA and Queensland (Earl et al. 2018). The species is also a popular target amongst recreational fishers in these States, as well as Victoria (Henry and Lyle 2003).

In SA, Mulloway is heavily targeted by both commercial and recreational fishery sectors (PIRSA 2016). Several life history stages are targeted: juveniles in the Coorong estuary; and mature adults in nearshore marine waters across the State, including on the far west coast near Yalata (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, the fishery for Mulloway in SA can currently be described as a 'gauntlet' fishery.

In the commercial sector of the LCF, licence holders target juvenile Mulloway using large mesh gillnets in the Coorong estuary, while adults are targeted using swinger nets in the adjacent nearshore marine environment. Three other South Australian commercial fisheries have limited access to Mulloway in SA: (i) the Marine Scalefish Fishery (MSF); and (ii) Northern Zone Rock Lobster Fishery (NZRLF); and (ii) Southern Zone Rock Lobster Fishery (SZRLF). For the recreational sector, Mulloway is an iconic species that is targeted using rod and line (Jones 2009).

3.1.4 Harvest strategy

The management plan (PIRSA 2016) includes a harvest strategy for finfish. The harvest strategy uses environmental performance indicators and decision rules to inform setting of the annual total allowable commercial effort (TACE) for three finfish sectors, which collectively account for > 98% of the fishery's total finfish catch each year. These sectors are: (i) estuarine large mesh gillnet (ELMGN); (ii) estuarine small mesh gill net; and (iii) freshwater large mesh gill net. Mulloway is the primary target species in the ELMGN sector (Earl 2019). The environmental performance indicator for the ELMGN sector is the amount (%) of suitable habitat available for Mulloway in the Coorong estuary. This indicator was developed as a surrogate metric for fishable biomass of Mulloway in the Coorong estuary (Knuckey et al. 2015; PIRSA 2016).

3.1.5 Management regulations

The commercial LCF has undergone a number of management changes over the past 35 years that have seen the introduction of general gear restrictions, spatial and temporal restrictions and size limits. A detailed description of these changes is provided in the management plan (PIRSA 2016). Although most of the management changes have been generic in nature, several have directly impacted the Mulloway fishery. The most significant change occurred in 2016, when the LMS for Mulloway taken in all State waters outside of the Coorong estuary was increased from 750 mm TL 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. The LMS 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 participants (PIRSA 2016). Bag and boat limits apply, and vary geographically and with fish size. In the Coorong estuary, the daily bag limit is 10 fish for the size range of 460–750 mm TL, and there is a boat limit (when three or more people are onboard) of 30 fish. For fish > 750 mm TL, a bag limit of two fish and a boat limit of six fish applies. In all waters outside the Coorong estuary, 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 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.

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 and recreational catch sampling; and estimates of the environmental performance indicator for the ELMGN sector. These data were considered at the management unit scale for the LCF.

3.2.1 Fishery statistics

The commercial fishery data for Mulloway were extracted from the commercial Lakes and Coorong Fishery Information System for the 35-year period of 1984/85 to 2018/19. 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 catch per unit effort (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 nets 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. Estimates of total catch, by month and reporting block (Figure 1-1), for each of the past 35 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 telephone/diary surveys done in 2000/01, 2007/08 and 2013/14 (Henry and Lyle 2003, Jones 2009, Giri and Hall 2015) are also presented.

3.2.2 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 and 2019/20, 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. No samples were available from large mesh gillnet catches from 2011/12, 2014/15 and 2016/17. Additional samples were obtained from recreational catches taken in the nearshore marine environment adjacent the Coorong 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.

The age structures based on commercial and recreational catch samples for some years were compared using the Kolmogorov-Smirnov 2-samples goodness of fit test. This test was also used to compare the combined commercial and recreational age structures from 2014/15 and 2019/20. These tests were done using SPSS® 26.

3.2.3 Environmental performance indicator

One performance indicator was considered in this assessment for Mulloway, i.e. the environmental performance indicator for the ELMGN sector. 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, 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 performance indicator values represent the proportion (%) of the 109 locations in the Coorong estuary for which modelled salinity was below the tolerance threshold of Mulloway.

For this assessment, a time series of annual environmental performance indicator values was calculated from 1984/85 to 2019/20. The value for the 2019/20 reporting year (1 February 2019–31 January 2020), was compared to the target, trigger and limit reference points from the reference period of 1984/85–2012/13 (PIRSA 2016). 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 2019/20 reporting year.

3.3 RESULTS

3.3.1 Fishery statistics

3.3.1.1 State-wide

Total annual State-wide 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 108 t and 127.3 t in 2012/13 and 2017/18, respectively. The total State-wide catch of 118 t in 2018/19 was the third highest on record.

The commercial LCF has been the main contributor to total annual State-wide catches of Mulloway over the past 35 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 2018/19, the LCF contributed 93% (109.3 t) of the total State-wide catch, while the remaining 8% (9.2 t) was taken by the MSF.

Estimates of recreational catch for Mulloway in SA are available for three years: 2000/01, 2007/08 and 2013/14 (Figure 3-1). In 2000/01, the estimated harvested catch of Mulloway was 90.2 t, which accounted for 44% of the State's combined commercial and recreational catch. In 2007/08, the harvested catch declined to 61.7 t. In 2013/14, the estimated number of Mulloway captured by recreational fishers in SA was 47,238 fish, of which 37,354 fish were released, leaving 9,833 fish harvested. The estimated total weight of these harvested fish was 59.5 t, which accounted for 46% of the State's combined commercial and recreational harvest. The proportion of the total recreational catch taken in, or adjacent to the Coorong estuary is not known, although a considerable proportion of the catches are likely to have been taken from spring/summer aggregations of adult fish near the Murray Mouth (Jones 2009). Nevertheless, the recreational sector has consistently contributed around half of the State's total catch of this species.

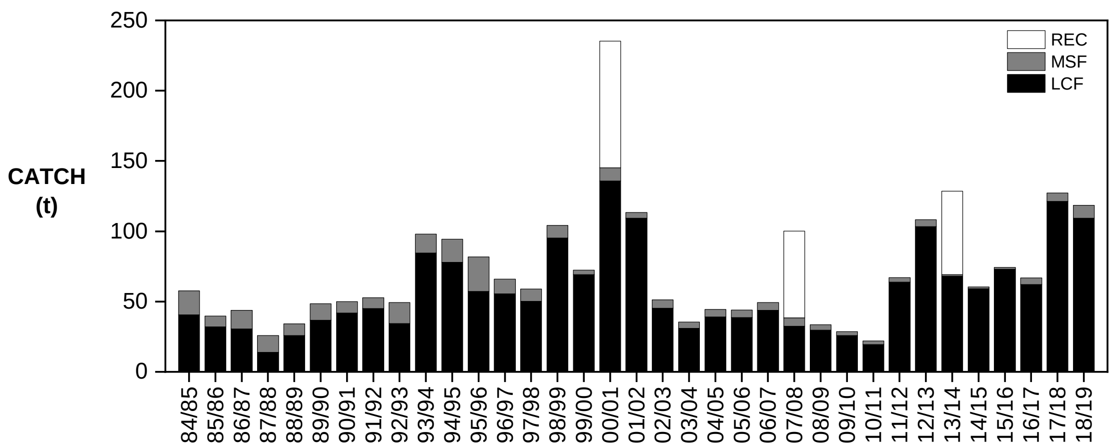

Figure 3-1. State-wide catch of Mulloway from 1984/85 to 2018/19, showing contributions by the commercial Lakes and Coorong Fishery (LCF), commercial Marine Scalefish Fishery (MSF) and the recreational sector.

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 a low of 13.8 t in 1987/88 to an historic peak of 135.7 t in 2000/01 (Figure 3-2). After this, catches fell sharply to 45.4 t in 2002/03 and continued to decline, although at a slower rate, to a low of 19 t in 2010/11. This decadal decline in catch was associated with a decline in targeted effort and low CPUE for the dominant gear types, i.e. large mesh gillnets and swinger nets. Since 2010/11, annual catches have been considerably higher with peaks of 103 t in 2012/13 and 121 t in 2017/18. The total catch of 110 t in 2018/19 was the third highest annual catch since 1984/85.

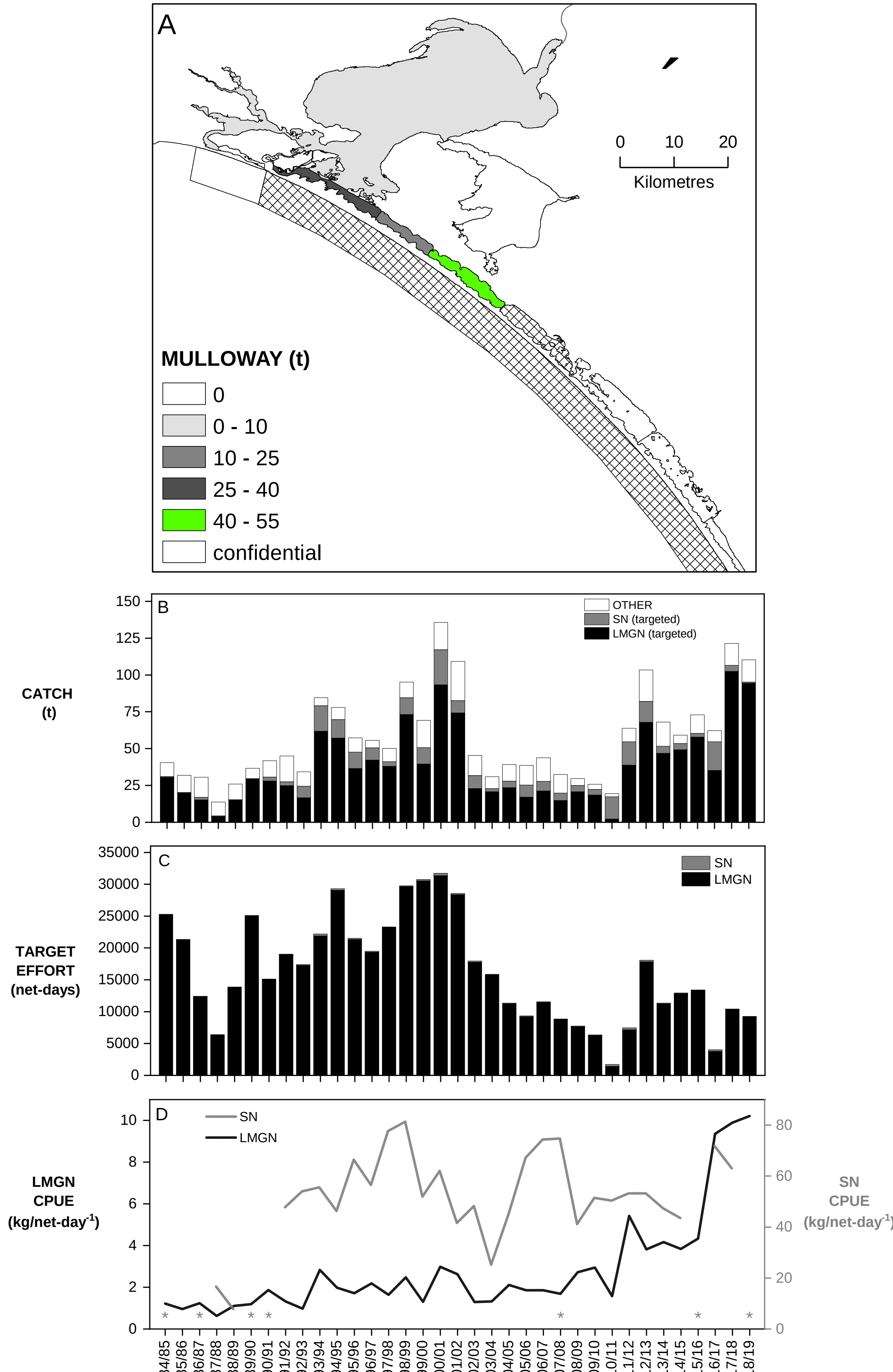

Figure 3-2 Fishery statistics for Mulloway. (A) Map of the LCF reporting blocks showing the catch distribution for 2018/19; long term trends in: (B) total catch for the main gear types (large mesh gillnets (LMGN), Swinger nets (SN), other); (C) targeted effort for LMGN and SN; and (D) targeted CPUE for LMGN and SN.

During the past 35 years, the dominant gear type used to target Mulloway in the LCF has been the large mesh gillnet. On average, targeted catches taken using large mesh gillnets in the Coorong estuary have accounted for 64% of the annual catch, with the most of the remaining catch taken using swinger nets along the ocean beaches adjacent the Murray Mouth. In 2018/19, targeted catches using large mesh gillnets accounted for 85% of the total catch, while those using swinger nets accounted for < 1%. The remaining catch was taken as by-product when other species were targeted.

Estimates of mean annual targeted CPUE for large mesh gillnets ($CPUE_{LMGN}$) have been highly variable since 1984/85, but have increased to unprecedented high levels in recent years (Figure 3-2). From 1984/85 to 1993/94, annual $CPUE_{LMGN}$ was < 1.85 kg.net-day^{-1} before increasing to 2.97 kg.net-day^{-1} in 2000/01. Catch rates were low during the 2000s before increasing to 5.4 kg.net-day^{-1} in 2010/11. Since then, annual $CPUE_{LMGN}$ has been higher, increasing to historically high levels of > 9 kg.net-day^{-1} in the past three years. The $CPUE_{LMGN}$ of 10.2 kg.net-day^{-1} in 2018/19 was the highest on record.

Estimates of mean annual CPUE for swinger nets ($CPUE_{SN}$) have also been highly variable. Since declining to a historic low of 8 kg.net-day^{-1} in 1988/89, $CPUE_{SN}$ has fluctuated periodically at considerably higher levels with peaks of between 71–82 kg.net-day^{-1} in the late 1990s, late 2000s and 2016/17. The moderate $CPUE_{SN}$ of 63 kg.net-day^{-1} in 2017/18 was associated with minimal targeted effort (65 net-days) and so should be interpreted with caution. The estimate of $CPUE_{SN}$ for 2018/19 is confidential (i.e. based on data reported by < 5 fishers).

Spatial and temporal trends in catch

Since 1984/85, reporting block 8 (i.e. upper Coorong estuary) has consistently contributed most to the annual catches of Mulloway in the LCF (Figure 3-4). An exception was in 2010/11, when 77% of the catch was taken in reporting block 16 (i.e. along the ocean beach). This anomaly reflects the historically 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 distribution of catches in 2017/18 and 2018/19 was also slightly different to that of most years, with reporting block 10 contributing most to the total catches, with moderate contributions from blocks 8 and 9. Historically, the fishery for Mulloway was seasonal with the highest catches taken in the warmer months from October to March (Figure 3-4).

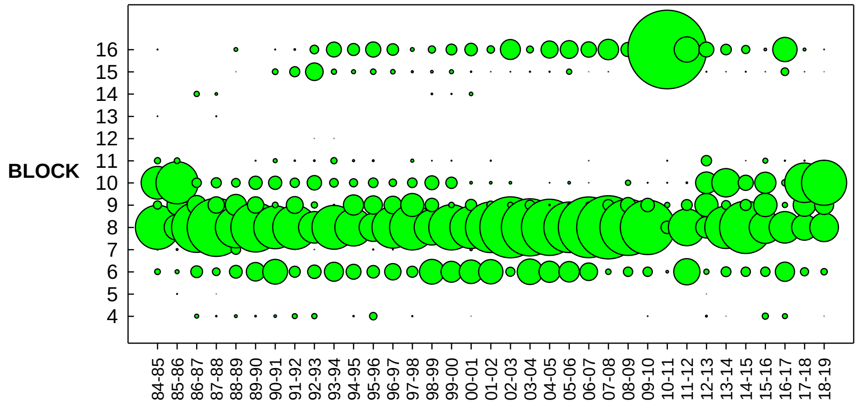

Figure 3-3. Mulloway. Long-term trends in the annual distribution of catch among LCF reporting blocks. The diameter of the bubbles represent the relative contribution of each reporting block to total annual catch.

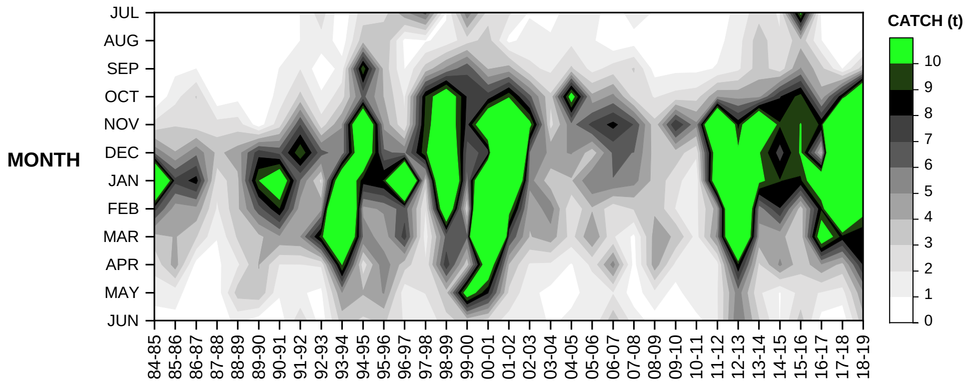

Figure 3-4. Mulloway. Long-term trends in the annual distribution of catch among months of the year.

3.3.2 Size and age structures

3.3.2.1 Coorong estuary

Size structures

The annual size structures for Mulloway from large mesh gillnet catches taken in the Coorong estuary between 2001/02 and 2019/20 were similar, i.e. they generally ranged from the LMS of 460 mm TL to around 950 mm TL and were dominated by fish between 500 and 650 mm TL (Figure 3-5). The size structure for 2019/20 comprised a higher proportion of fish ≥ 800 mm TL compared to earlier years.

Age structures

In 2001/02 and 2002/03, age structures from commercial catches taken in the Coorong estuary comprised five juvenile age classes and were dominated by three and four year old fish (Figure 3-5). Small proportions of two, five and six year old fish were also represented. In 2013/14, ages ranged from 2 to 8 years, with 69% of individuals three years of age. The age structure from 2018/19 was dominated by three and four year olds which originated from spawning in 2016/17 and 2015/16 respectively, and included a high proportion of 6–8 year old fish compared to other years.

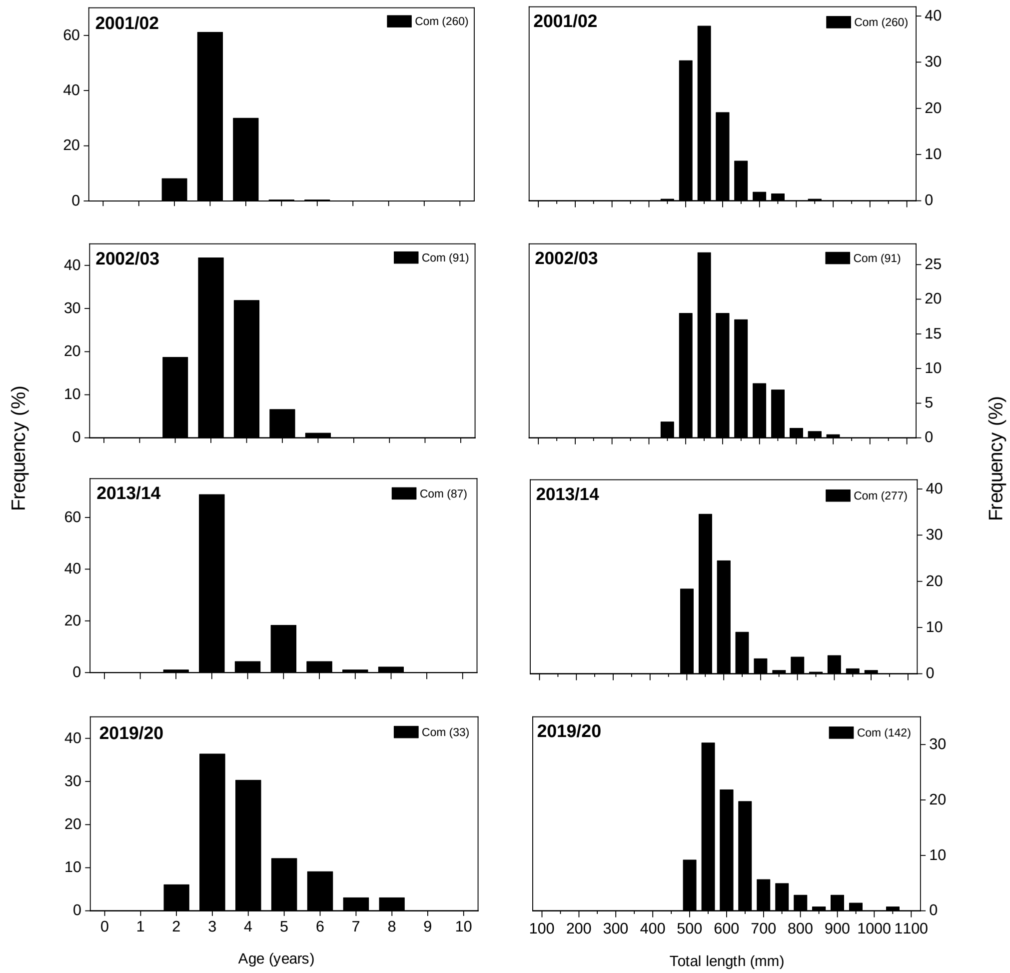

Figure 3-5. Age and size structures for Mulloway from commercial large mesh gillnet catches taken in the Coorong estuary in each of four different years. Left hand graphs show the age structures. The number of fish processed in each year is shown in brackets.

3.3.2.2 Nearshore marine environment

Size structures

The size structure for Mulloway from the marine environment from 2001/02 ranged between 650 and 1400 mm TL, with modal sizes of 1100 mm TL and 1150 mm TL for commercial swinger net and recreational line catches, respectively (Figure 3-6). The size structure from 2002/03 ranged between 800 and 1350 mm TL with a dominant mode at 1000 mm TL and a secondary mode at 900 mm TL. 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 2014/15 and 2016/17 were broader than those for 2011/12 and 2013/14, and included fish up to 1400 mm TL. The size structure for 2019/20 comprised mostly fish between 900 mm TL and 1100 mm TL, with a modal size of 1000 mm TL for commercial and recreational samples. The maximum sizes of Mulloway in commercial and recreational catches in 2018/19 were 1361 mm TL and 1530 mm TL, respectively.

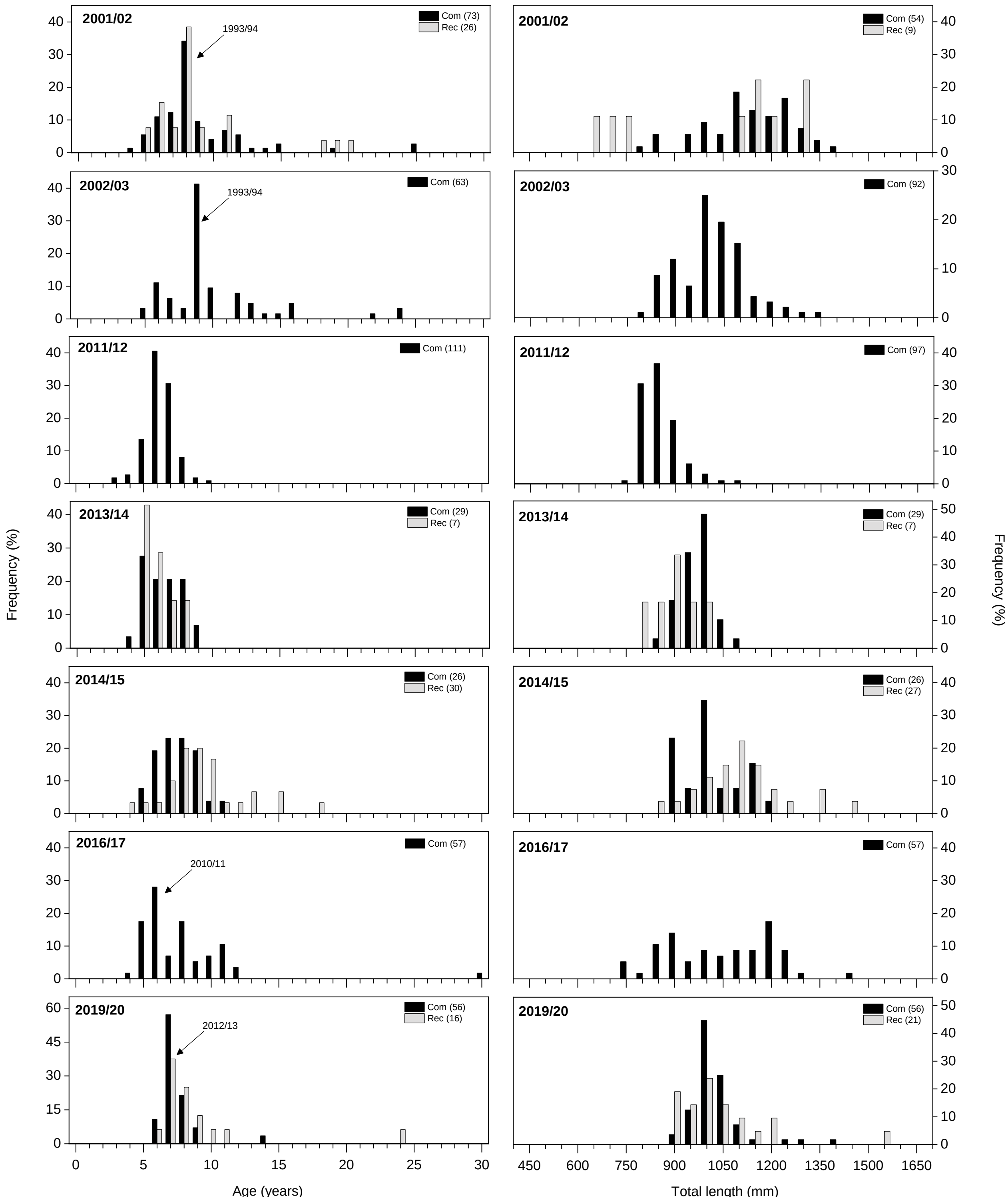

Figure 3-6. Age and size structures for Mulloway from the nearshore marine environment adjacent the Murray Mouth in each of seven different years. Left hand graphs show the age structures. The number of fish processed from commercial swinger net (Com) catches recreational rod and line (Rec) catches and in each year is shown in brackets.

Age structures

For age structures from the nearshore marine environment adjacent the Coorong estuary in 2001/02, recreational line and commercial swinger catches had a similar distribution (K-S D = 0.056, P = 0.092) (Figure 3-6). Ages ranged from 4 to 25 years, with 8 year olds (1993/94 year class) dominating the distribution. Secondary modes occurred at 6 and 11 years. For the commercial sample from 2002/03, ages ranged from 5 to 24 years and the 1993/94 year class persisted as nine year olds.

The age structures from the marine environment in 2010/11, 2013/14, 2014/15, 2016/17 and 2019/20 were similar, in that they comprised mostly 5–10 year olds, while fish > 12 years of age were rare (Figure 3-6). In 2011/12, the age distribution from commercial catches comprised eight, relatively young age classes and was dominated by 6 and 7 year old fish. In 2013/14, the ages of Mulloway sampled from commercial and recreational catches were narrowly distributed around a mode comprising mostly 5–7 year old fish, with no fish > 9 years of age present. In 2014/15, the age distributions included mostly 6–10 year olds, with fish up to 18 years in the recreational catch. Commercial 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 of Mulloway sampled from commercial and recreational catches had a similar distribution (K-S D = 0.598, P = 0.0867) and were therefore combined (n = 72). Ages ranged from 4 to 24 years with 7 year olds (i.e. 2012/13 year class) dominating (55%) the distribution. Fish > 11 years of age were rare despite the potential for this species to reach 41 years of age in SA (Ferguson et al. 2014). Overall, the combined age distribution from 2019/20 was contracted compared to that from 2014/15 (K-S D = 1.773, P = 0.004) and included a lower proportion (4.2%) of fish > 10 years of age compared to 2014/15 (14.3%).

3.3.3 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 2019/20 reporting year (Figure 3-7). From February to June 2019, approximately 70% of the Coorong estuary was suitable habitat for Mulloway (i.e. salinity was < 51 ppt). The area of available habitat contracted to 55% in early October and then increased to around 70% by early November. This extension of suitable habitat was associated with freshwater releases to the estuary during October which contributed to lower salinity around Parnka Point. There were no freshwater releases to the estuary in December 2019 and January 2020 which led to a reduction in the amount of suitable habitat for Mulloway during the later stages of the 2019/20 reporting year. Nonetheless, the ELMGN performance indicator for habitat available to Mulloway in the Coorong estuary for the 2019/20 reporting year was 59.6%, which was above the target reference point of 55% (Figure 3-8).

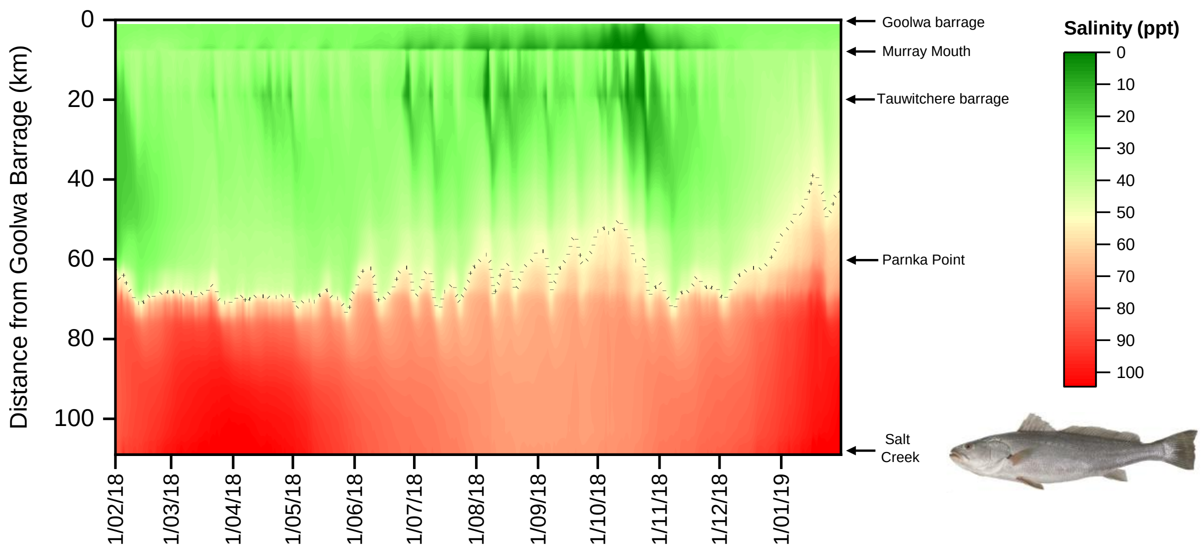

Figure 3-7. Modelled salinity concentration with distance from the Goolwa Barrage for the 2019/20 reporting year, with the approximate salinity threshold for Mulloway (51 ppt) shown as a dotted line. Salinity threshold represents the level of salinity that was lethal for 10% of test fish, as determined by Ye et al. (2013). The dark green contours (i.e. < 10 ppt) indicate periods of freshwater inflows through the barrage system.

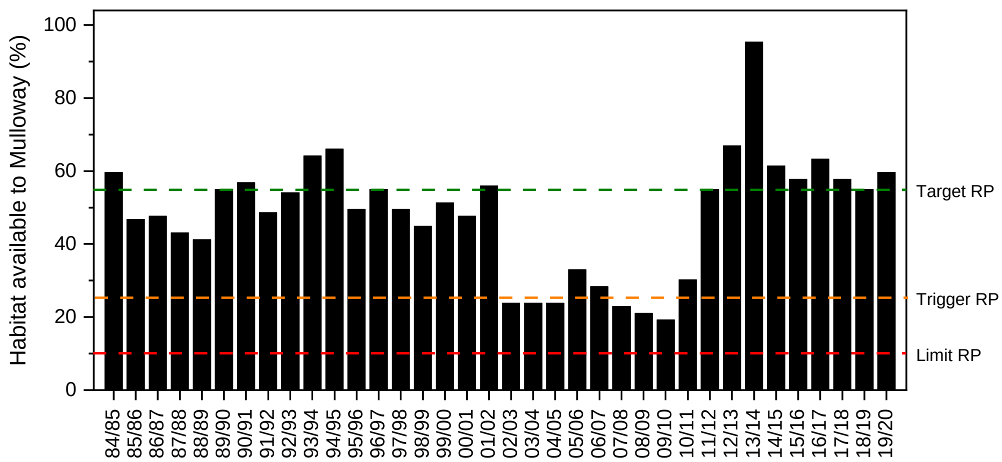

Figure 3-8. Estimates of the ELMGN performance indicator for habitat available to Mulloway in the Coorong estuary from 1984/85 to 2019/20 (reporting years), showing target, trigger and limit reference points (RP).

3.4 DISCUSSION

3.4.1 Context of this assessment

The previous Mulloway stock assessment, which considered commercial catch and effort statistics up to 30 June 2014, classified the stock as sustainable (Earl and Ward 2014). Subsequent assessments undertaken at the jurisdictional level for Mulloway in SA in 2016 and 2018 (Earl et al. 2016a; 2018), which placed considerable emphasis on analysing commercial fishery statistics from the LCF, retained the 'sustainable' classification.

Since 2014, there have been few management changes that have directly impacted the LCF for Mulloway. The most significant change occurred in 2016, when the LMS for Mulloway taken in all State waters, excluding the Coorong estuary, was increased from 750 mm TL 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, which adhered to a separate LMS 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.

Since 2010, the number of interactions between Long-nosed Fur Seals and LCF gillnet fishers have increased and impacts to the Mulloway fishery through depredation of fish caught in gillnets have been reported (Goldsworthy and Boyle 2019). The impacts occur as seals attempt to remove fish caught in gillnets which can result in catch losses and gear damage. Reliable, quantitative information on the impacts of seals on the fishery in terms of catch losses, as well as possible 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 Mulloway fishery will be addressed by 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', which commenced in 2019.

3.4.2 Determination of stock status

The status of the LCF for Mulloway was assigned using the National Fishery Status Reporting Framework (NFSRF; Table 1-1; Stewardson et al. 2018). The current harvest strategy for finfish (PIRSA 2016) 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. recruitment 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 (Stewardson et al. 2018).

Information available to assess the LCF for Mulloway included: (i) daily commercial catch and effort data from 1984/85 to 2018/19; (ii) annual estimates of relative abundance for Mulloway based on fishery-dependent $CPUE_{LMGN}$ and $CPUE_{SN}$ from 1984/85 to 2018/19; (iii) fishery size and age structures from a number of years between 2001/02 and 2019/20; and (iv) the environmental performance indicator 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

The LCF has historically been the most productive of SA's fisheries for Mulloway, and in 2018/19, contributed 93% 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 decline in catch was associated with a decline in targeted effort and low $CPUE_{LMGN}$ during the Millennium Drought (2002/03–2010/11) and likely reflected a decline in fishable biomass in the Coorong estuary. Since then, catches have been considerably higher with peaks of 103 t and 121 t in 2012/13 and 2017/18, respectively. The total catch in 2018/19 was 109 t, of which 85% was taken as targeted catch using large mesh gillnets in the Coorong estuary. The recent high catches have been associated with historically high $CPUE_{LMGN}$ and likely reflect high abundance of Mulloway in the Coorong estuary.

The state-wide recreational catch of Mulloway was estimated at 59.5 t in 2013/14, which represented approximately 60% of the State-wide combined commercial and recreational harvest (Giri and Hall 2015). The proportion of the state-wide catch that was taken in the Coorong region is not known.

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 2016). The ELMGN performance indicator for habitat available to Mulloway in the Coorong estuary for the 2019/20 reporting year was 59.6%, which was above the target reference point of 55%.

Annual age structures for Mulloway harvested by the LCF in the Coorong estuary have remained relatively similar since 2001/02 (i.e. dominated by three and four year old fish) and are consistent with those for Mulloway in other estuaries around Australia (Silberschneider and Gray 2008; Silberschneider et al. 2009; Stewart et al. 2020). The 2019/20 age structure included 2–8 year old fish and was dominated by three (36%) and four (30%) year olds which originated from spawning that occurred in 2016/17 and 2015/16, respectively. The lack of older fish in the age structure likely relates to an ontogenetic migration of individuals from the estuarine to the marine environment, and the removal of older fish by fishing. Nevertheless, the presence of multiple age classes in the age structure from the estuary in 2019/20 (i.e. the area that contributed most to the recent high catches) indicates that recruitment has occurred in recent years.

Since 2001/02, annual size and 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 2019/20, which were based on a relatively moderate sample size (n=72) from commercial and recreational catches, was similar to those from a number of years since 2001/02, i.e. they had a wide range of ages (5–24 years), were dominated by 6–9 year olds and comprised mostly (> 97%) individuals above the age at maturity (5-6 years) for the species. The 2019/20 age structure was dominated by seven year olds (i.e. from the 2012/13 year class), with moderate contributions of eight year old fish from the 2011/12 year class. Fish older than 11 years were rare despite the potential for this species to reach 41 years of age in SA. The lack of older fish in the age structure in 2019/20 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 regular 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 catches and catch rates 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, and using the definitions from the NFSRF, the stock is classified as **'sustainable'**.

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 with the fishery size and age structures, were the primary data considered in this assessment. In a general sense it is expected that the parameters of commercial catch, effort and CPUE are influenced by the biomass of Mulloway. 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 and also move between different areas of the fishery in order to optimise their financial gain. Furthermore, in recent years some LCF fishers have adapted their fishing practices to try and avoid interactions with Long-nosed Fur Seals (e.g. reduced soak times; fishing in suboptimal areas), and so the concept of the unit of fishing effort, i.e. 'net-day', has changed over time. These changes in fisher behaviour over time complicate interpreting fishing effort and CPUE in terms of fishable biomass.

Environmental variability contributes to additional uncertainty around the relationships between fishable biomass and the commercial fishery data. Variation in the timing and magnitude of freshwater inflows to the Coorong estuary influences salinity levels along the system, and ultimately the size of the area of habitat available for Mulloway (Ye et al. 2013). For example, low freshwater inflows during the Millennium Drought resulted in hypersaline conditions in the southern Coorong 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 range of Mulloway in the Coorong estuary may affect their catchability and potentially confound interpretation of $CPUE_{LMGN}$ as an indicator of fishable biomass.

A further uncertainly relates to the lack of information on spatial trends in Mulloway catch by the recreational sector in SA. State-wide telephone/dairy surveys done in 2000/01, 2007/08 and 2013/14 estimated that Mulloway catches by the recreational sector in SA accounted for between 44–62% of the State's combined commercial and recreational catch (Jones and Doonan 2005; Jones 2009; Giri and Hall 2015). Nevertheless, the proportion of the total recreational catch taken in, or adjacent to the Coorong estuary is 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 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. Sampling of recreational catches was done in 2019/20 to reduce any potential bias of gear type on the size range of fish sampled. Despite the relatively low number of samples obtained from recreational catches in 2019/20 (n =16), statistical analysis did not detect any differences between the size distributions for commercial and recreational catches. Nevertheless, an ongoing sampling program that accesses commercial and recreational catches of Mulloway is important 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 caught in gillnets and subsequently removed by Long-nosed Fur Seals before they could be landed. As such, fishing mortality of Mulloway in the Coorong estuary is likely to be higher than the levels reported in this assessment. The current FRDC project (2018-036) will provide estimates of the proportion of the commercial gillnet catches of Mulloway (and other species) that are lost due to seal depredation.

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 > 60) from both the commercial and recreational sectors; (ii) independent ongoing monitoring of discarding of sub-legal sized individuals from gillnets in the Coorong estuary;

(iii) regular surveys to 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 FISHERY 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 available biological and fisheries information, each used to provide a measure or proxy for 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 (Stewardson et al. 2018) for data-poor stocks, i.e. stocks for which sophisticated computer 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 2016). It comprises species-specific sections, which are arranged to align with the three finfish sectors of the fishery. These sectors are: (i) estuarine large mesh gillnet (ELMGN); (ii) estuarine small mesh gill net (ESMGN); and (iii) freshwater large mesh gill net (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 2018/19, and a classification of stock status using the definitions from the NFSRF (Table 1-1; Stewardson et al. 2018). The report also provides an assessment of the recent condition of the environment in which the ESMGN and FLMGN sector operates, using environmental performance indicators and reference points defined in the management plan. The assessment of the ELMGN performance indicator is provided in Section 3.3.3. 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 to SARDI Aquatic Sciences on a monthly basis. 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 SARDI Aquatic Sciences' commercial LCF Information System. For Pipi, data on catches by the MSF are also included. The data span a 35-

year time series from 1984/85 to 2018/19 and were aggregated to provide annual estimates of catch and effort for the main gear types

The fishery data for the key species are presented by financial year from 1984/85 to 2018/19. For each species, a map is presented that shows total catch by reporting block for 2018/19. 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 for years when summarised from five or more fishers. Where available, estimates of recreational catch obtained from three telephone/diary surveys (Jones and Doonan 2005; Jones 2009; Giri and Hall 2015) are also presented.

4.2.2 Performance indicators

4.2.2.1 Finfish

The harvest strategy for finfish uses environmental performance indicators and decision rules to inform setting of the annual total allowable commercial effort (TACE) for the three finfish sectors (PIRSA 2016). The environmental performance indicator for each 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. These indicators were developed as a surrogate metric for fishable biomass for the key target species within each sector (Knuckey et al. 2015). Estimates of the three environmental performance indicators relative to target, trigger and limit reference points for the 2019/20 reporting year (1 February 2019–31 January 2020) are presented (PIRSA 2016). Detailed descriptions of the performance indicators and associated reference points are provided in the management plan.

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 2016). 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 2017). Estimates of the these performance indicators relative to target, trigger and limit reference points for the 2018/19 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 2016).

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 WA, 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, long-lived and can grow to 600 mm TL and live for 32 years. In SA, males and females mature at around 340 mm TL and 289 mm TL, respectively (Cheshire et al. 2013). Spawning is confined to estuaries and occurs between August and December. 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 SA. Historically, the LCF has been SA’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. 2016b). Black Bream has a high market value and is a premium product of the LCF (EconSearch 2019). 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 and the lower reaches of rivers (Kailola et al. 1993). The State-wide recreational survey in 2013/14 estimated that 197,848 Black Bream were captured, of which 91% were released (Giri and Hall 2015). The retained fish contributed to an estimated harvest weight of 4.97 t.

Management regulations

Black Bream is a secondary species of the LCF, making a relatively low contribution to the total production value over the last 25 years (PIRSA 2016). For the commercial sector, regulations 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 LMS of 300 mm TL.

There are multiple management regulations 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 LMS of 300 mm TL also applies.

Temporary management arrangements were introduced in 2018 to recover the Black Bream stock in the Coorong, after it was classified as 'overfished' in 2016 (Earl et al. 2016b). The temporary arrangements applied to Black Bream in the Lower Lakes and Coorong estuary from 1 September 2018 until 30 November 2018, and from 21 September 2019 until 30 November 2019. 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.

Commercial Fishery statistics

Trends in total catch, effort and CPUE

Over the past 35 years, the highest total annual commercial catch of Black Bream in the LCF was 47.3 t in 1984/85 (Figure 4-1). Annual catches remained > 35 t until 1986/87 and then declined to 3.7 t in 1990/91 and have been historically low in most years since. Between 1990/91 and 2016/17 the average annual catch was 4.3 t. The total catch of 0.68 t in 2018/19 was the lowest on record.

Historically, 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, with the most of the catches taken as by-product when other species were targeted. Consequently, estimates of annual targeted effort and targeted CPUE for large mesh gillnet are confidential for most of the past 15 years. In 2018/19, there was no targeted fishing effort for Black Bream.

The catch rates for Black Bream should be interpreted with caution due to considerable uncertainty around CPUE as a measure of relative abundance. 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 as an indicator of population abundance (Earl et al. 2016). Given the high wholesale value of Black Bream (EconSearch 2019), catch is considered a more appropriate indicator of abundance for this species in the Coorong.

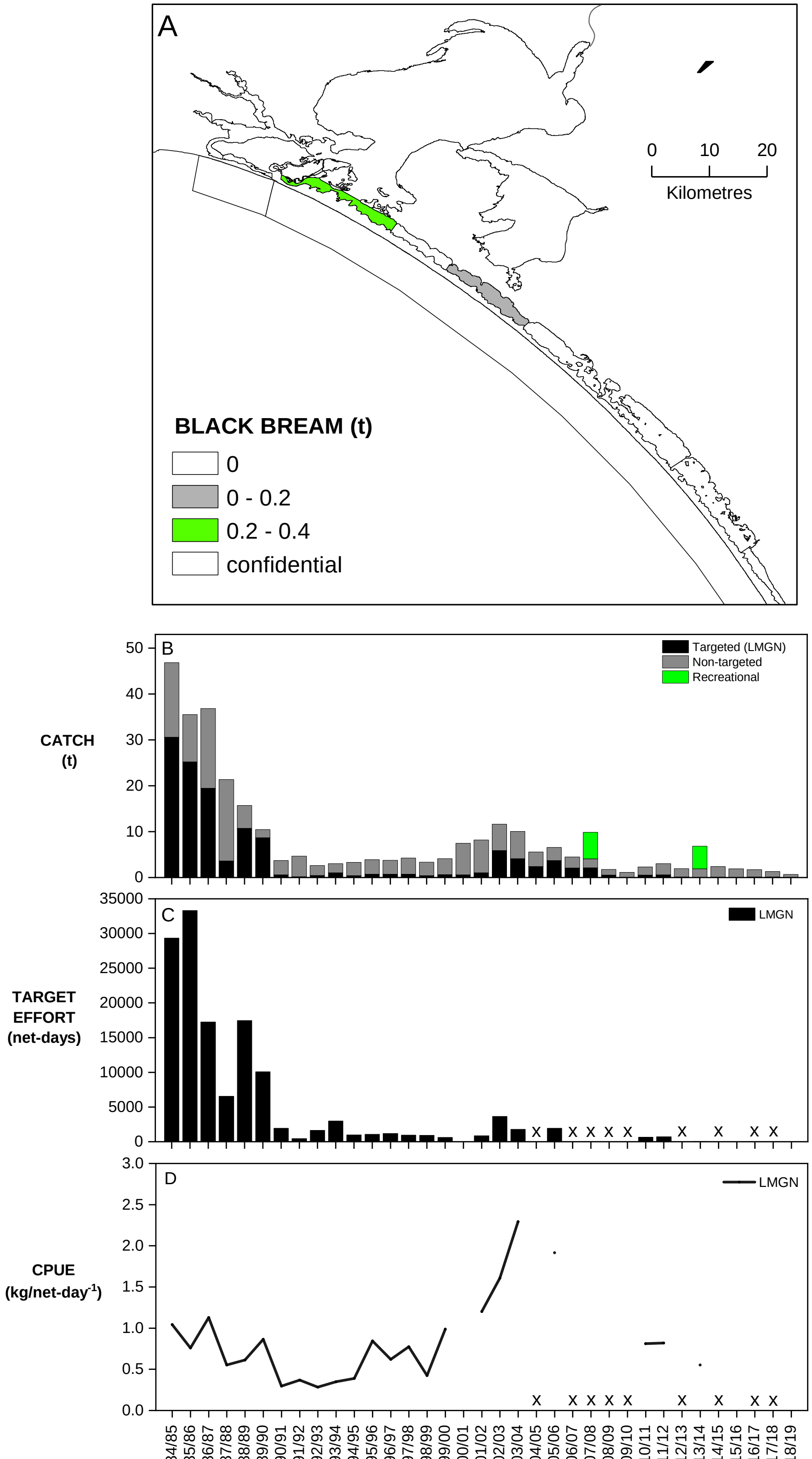

Figure 4-1. Fishery statistics for Black Bream. (A) Map of the LCF reporting blocks showing the catch distribution for 2018/19; long term trends in: (B) total catch for the main gear type (large mesh gillnets (LMGN), other) and the recreational sector (from all State waters for 2000/01, 2007/08, 2013/14 only; (C) targeted effort for LMGN. Crosses indicate confidential data (i.e. from < 5 fishers).

Spatial and temporal trends in catch

Between 1984/85 and 1998/99, reporting blocks 9–11 provided the highest catches of Black Bream (Figure 4-2). The fishery contracted to blocks 6–8 (those adjacent the Murray Mouth) during the 2000s, 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 catches coming from blocks 6–11 during recent years. 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.

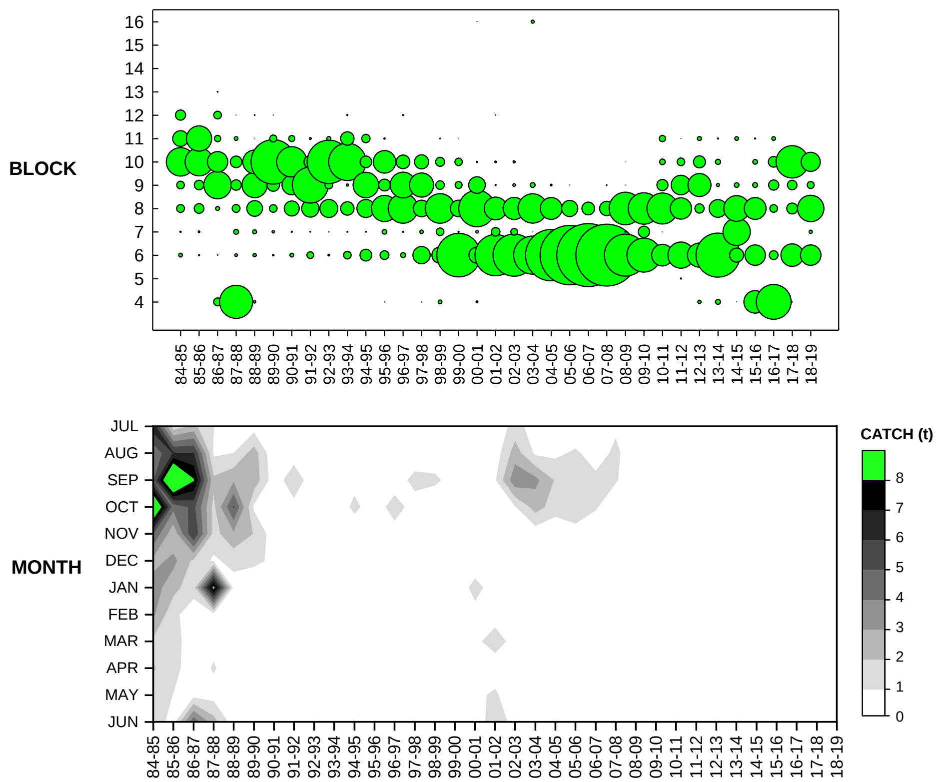

Figure 4-2. Black Bream. Long-term trends in the annual distribution of catch among LCF reporting blocks, with the diameter of bubbles representing the relative contribution of each reporting block to total annual catch (top) and months of the year (bottom).

Stock status

Black Bream is a secondary species for the commercial LCF (PIRSA 2016). The most recent stock assessment for Black Bream in the Coorong estuary was in 2016 and used a weight-of-evidence approach that considered fishery catch and effort data and fishery age structures up to 30 June 2015 (Earl et al. 2016b). No catch sampling has been done for Black Bream since 2015.

Analysis of the long-term chronology of fishery production for Black Bream in the Coorong estuary indicated high variability in biomass. In the late 1980s, fishery catches dropped to historically low levels and have remained low. The low catches since the 1980s have been associated with low targeted effort. Given the high wholesale value of Black Bream compared to other LCF species, the lack of targeting and low catches since the 1980s likely reflects low biomass.

Annual fishery age structures from 2007/08 to 2015/16 comprised 4–17 year old fish, although fish older than 10 years were rare, despite the potential for this species to live to at least 32 years of age (Earl et al. 2016b). 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 and 2012/13, confirming that environmental conditions associated with freshwater inflow are important for successful reproduction of Black Bream in the system (Ye et al. 2017). 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. Despite this recruitment, fishery production has remained historically low. Recruitment levels over the past 25 years have not been strong enough to support recovery of the stock following the decline in the 1980s. In 2018, successful recruitment of Black Bream in the Coorong estuary was evident by the detection of higher than average abundances of young-of-year. Recruitment of these juveniles to the fishable biomass is expected to take at least several years (Ye et al. 2019).

The above evidence indicates that the biomass of this stock has been reduced through fishing mortality, such that recruitment is impaired. In 2018 and 2019, management measures were put in place to recover the stock, but have not yet resulted in measurable improvements. On this basis, the status of '**depleted**' that was assigned to this stock in 2017/18 is retained.

4.3.2 Greenback Flounder (*Rhombosolea tapirina*)

Biology

Greenback Flounder (*Rhombosolea tapirina*) is a member of the Rhombosoleidae family of fishes (Gomon et al. 2008). Its Australian distribution extends from southern WA, around the southern coasts of the continent and Tasmania, and up to southern NSW (Kailola et al. 1993). Juveniles and adults occur 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 grows fast, reaching around 220 mm TL in its first year of life (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 SA, 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 a recent 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 throughout its distribution (Kailola et al. 1993). In Australia, most commercial catches are taken in Tasmania and SA, with smaller landings taken in NSW, Victoria and WA. In SA, 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 sectors are not considered in this assessment. Recreational fishers target Greenback Flounder using hand-held spears in estuaries and protected coastal waters across SA. The estimated harvest of flounder by the recreational sector in 2013/14 was 0.27 t (Giri and Hall 2015).

Management regulations

Greenback Flounder is a secondary species of the commercial LCF, making a relatively low contribution to the total production value (PIRSA 2016). For this sector, regulations are in place to manage fishing effort and limit the take of Greenback Flounder. These include temporal and spatial netting closures, restrictions to net lengths and mesh sizes, and a LMS of 250 mm TL (PIRSA 2016).

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 2016). No LMS applies for this sector.

Commercial Fishery statistics

Trends in total catch, effort and CPUE

Total annual catch has been highly variable since 1984/85. It increased to a peak of 65 t in 1990/91 and subsequently declined to < 1 $t.yr^{-1}$ during 2007/08–2010/11 (Figure 4-3). In 2011/12, catch increased sharply to 31 t and then declined to 1.85 t in 2018/19.

The trends in total catch reflect the trends in targeted fishing effort. In recent years, annual targeted effort declined from a peak of 9,773 net-days in 2011/12 to 76 net-days in 2013/14 and then remained low. Catch rates for this species should be interpreted with caution due to considerable uncertainty around CPUE as a measure of relative abundance resulting from likely environmental influences on catchability (Earl and Ye 2016). Given its high wholesale value (EconSearch 2019), catch is considered a more appropriate indicator of abundance for this species.

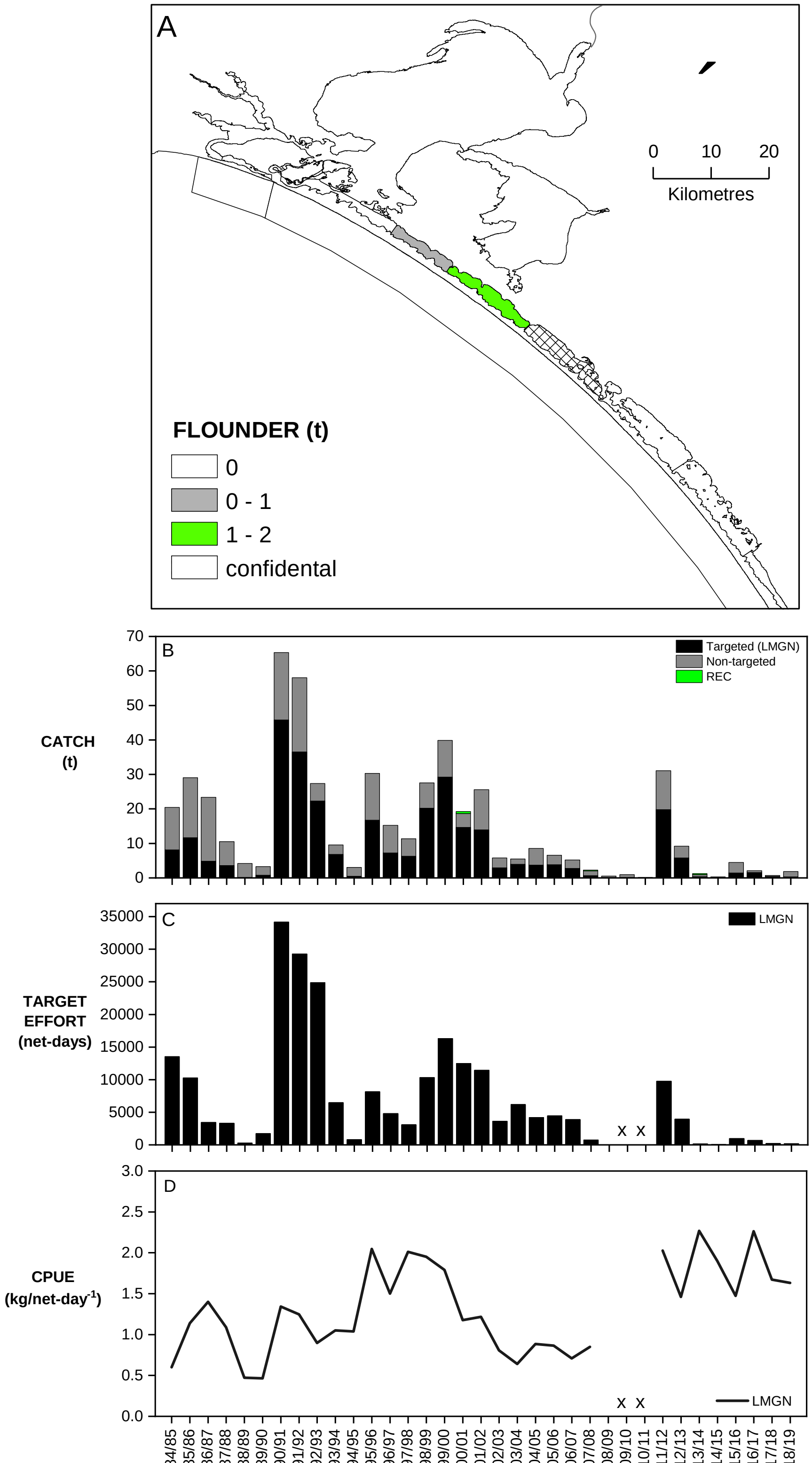

Figure 4-3. Fishery statistics for Greenback Flounder. (A) Map of the LCF reporting blocks showing the catch distribution for 2018/19; Long term trends in: (B) total catch for the main gear type (large mesh gillnets (LMGN), other) and the recreational sector (from all State waters for 2000/01, 2007/08, 2013/14 only; (C) targeted effort for LMGN; and (D) targeted CPUE for LMGN. Crosses indicate confidential data (i.e. from < 5 fishers).

Spatial and temporal trends in catch

In most of the past 35 years, catches taken in reporting blocks 8–10 have contributed most to total annual catches of Greenback Flounder (Figure 4-4). In the years that produced moderate to high catches of this species, the period between October and May was generally the most productive for the fishery.

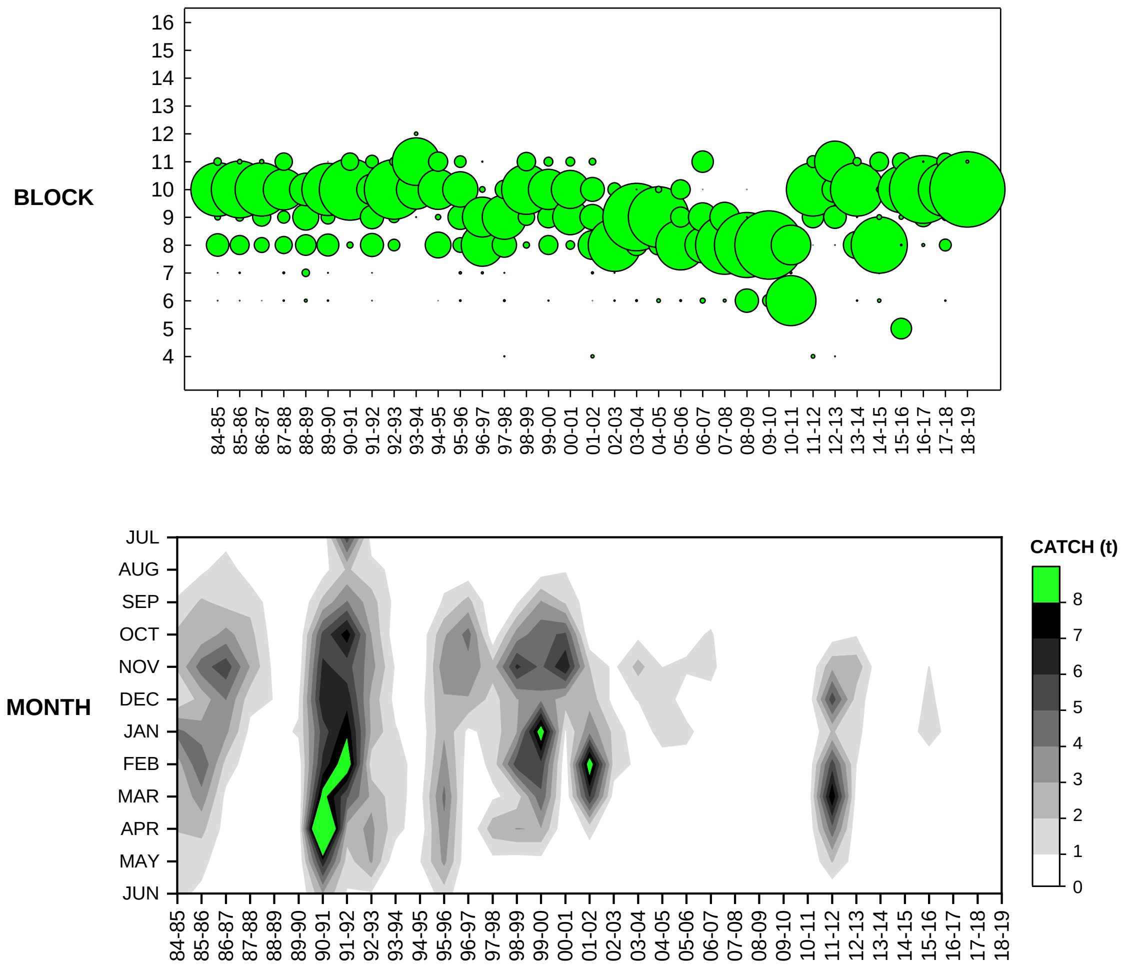

Figure 4-4. Greenback Flounder. Long-term trends in the annual distribution of catch among LCF reporting blocks, with the diameter of bubbles representing the relative contribution of each reporting block to total annual catch (top) and months of the year (bottom).

Stock status

Greenback Flounder is a secondary species for the LCF (PIRSA 2016). The most recent stock assessment for this species was completed in 2016 and used a weight-of-evidence approach that considered fishery data and fishery age structures to the end of June 2015 (Earl and Ye 2016).

Long-term trends in fishery production for Flounder indicate high inter-annual variability in fishable biomass in the Coorong estuary (Earl and Ye 2016). Annual catches were highly variable during the 1980s–early 2000s, and subsequently declined to historically low levels during the Millennium Drought. In 2011/12, (i.e. the year after drought-breaking Murray River flows reached the Coorong estuary), a large biomass of large Flounder moved into the estuary from the adjacent marine environment (Earl et al. 2017), and catch increased abruptly to 31 t. This sudden increase in biomass was not consistent with a spawning biomass that was in a recruitment-overfished state (Earl and Ye 2016). The lack of targeted fishing effort and low catches in recent years have been associated low freshwater inflows and likely reflect a low fishable biomass in the Coorong estuary.

The high inter-annual variation in Greenback Flounder abundance in the Coorong estuary has been strongly associated with variation in freshwater inflow to the estuary, with a lag of 1–2 years (Earl and Ye 2016). This is because large areas of estuarine habitat that support high abundances of Flounder are only available after years of high freshwater inflow (1990/91, 1996/97, 2010/11). Alternatively, during periods of low inflow (2001/02–2009/10, 2012/13–2015/16, 2017/18–2018/19), abundance in the estuary is typically very low. 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 large biomass of Flounder in the estuary in 2011/12, after the most recent high inflow event as indicated by trends in catch (Earl and Ye 2016). The current low biomass in the estuary appears to relate to the lack of freshwater inflow to the system in recent years, rather than a depleted spawning stock biomass (i.e. the spawning biomass is not considered to be recruitment overfished).

Low targeted effort and catches since 2012/13 likely reflect low fishable biomass in the Coorong estuary as a consequence of low recruitment over several recent years due to the low freshwater inflows to the estuary (i.e. non-fishing effects). Biomass in the Coorong estuary has been reduced primarily through non-fishing effects and, as a consequence, recruitment is impaired. On this basis, the status of '**depleted**' that was assigned to this stock in 2017/18 is retained.

4.3.3 Estuarine small mesh gillnet sector

4.3.3.1 Yelloweye Mullet (*Aldrichetta forsteri*)

Biology

Yelloweye Mullet (*Aldrichetta forsteri*) is a member of the Mugilidae family of fishes (Gomon et al. 2008). It occurs along the southern coasts of Australia, from Murchison River in WA to the Hunter River in NSW and around Tasmania. Yelloweye Mullet typically occur in schools in coastal waters (< 20 m depth), and are often abundant in estuaries (Kailola et al. 1993). This species is considered a marine estuarine-opportunist, i.e. it spawns at sea; regularly enters estuaries, particularly as juveniles, but uses, to varying degrees, coastal waters as alternative nursery habitat (Potter et al. 2015).

Yelloweye Mullet can reach 440 mm TL and 10 years of age (Earl and Ferguson 2013). Females and males mature at around 240 and 250 mm TL, respectively. Spawning occurs from early spring to early autumn, and is most frequent between December and February. Biological stock structure for

Yelloweye Mullet throughout southern Australia is uncertain. It has been suggested that the populations in this region form two stocks, i.e. the Western and Eastern Stocks. The populations on SA's west coast are thought to contribute to the Western Stock (Smith et al. 2008), while populations in the gulfs and the South East, are thought to be part of the Eastern Stock (Pellizzari 2001). Here, the assessment of stock status is undertaken at the management unit level – the LCF.

Fishery

In Australia, Yelloweye Mullet support commercial fisheries in Victoria, SA, WA and Tasmania (Kailola et al. 1993). Yelloweye Mullet is also regarded as an important species by recreational fishers in these States, as well as New South Wales. In SA, commercial and recreational catches of the species are taken in estuaries and most nearshore coastal areas around the State.

The commercial fishery for Yelloweye Mullet in SA has two main sectors: the LCF; and the MSF. Over the past 20 years, the majority of the State's commercial catch has been taken by LCF fishers who use mainly small mesh gillnets to target the species. The fishery statistics from the MSF are not considered in this report. The NZRLF and SZRLF also have limited access to Yelloweye Mullet.

Recreational fishers harvest Yelloweye Mullet using rod and line in semi-protected nearshore coastal waters of SA (Kailola et al. 1993). Recreational fishers can also target the species using registered monofilament nylon nets in the Coorong estuary and Lake George (PIRSA 2016). Recreational net fishing is prohibited in all other coastal waters of South Australia. In 2013/14, an estimated 100,598 mullet were captured by the recreational sector, of which 29,598 fish were released, leaving 71,278 fish retained (Giri and Hall 2015). This provided a total estimated State-wide harvest of 19.4 t.

Management regulations

Yelloweye Mullet is a primary species of the LCF, making a relatively high contribution to the total production value of the fishery (PIRSA 2016). For the commercial sector, regulations 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 LMS 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 2016). A bag limit of 60 Yelloweye Mullet per fisher per day, boat limit of 180 Yelloweye Mullet, and a LMS of 210 mm TL applies to this fishery. Management arrangements also comprise general gear restrictions. Netting by recreational fishers is permitted within the Coorong estuary by a small number registered net owners. Recreational mesh nets must be less than 75 m long with 50–64 mm (4 1/4" to 6") mesh size, and the registered net owner must be within 50 m of the net at all times when fishing. Temporal and spatial closures also apply to the use of recreational nets in the Coorong.

Commercial fishery statistics

Trends in total catch, effort and CPUE

The highest total annual catch of Yelloweye Mullet was 346 t in 1989/90 (Figure 4-5). From then, catch 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. This decline in catch was associated with a decline in targeted CPUE for small mesh gillnets (i.e. the dominant gear type used to target this species) from a moderate peak of 14.4 $kg.net\text{-}day^{-1}$ in 2008/09 to 5.2 $kg.net\text{-}day^{-1}$ in 2014/15. In 2018/19, CPUE increased to an unprecedented historic high of 26.8 $kg.net\text{-}day^{-1}$ which culminated in the fishery's second highest annual catch on record of 285 t.

Spatial and temporal trends in catch

Since 1984/85, reporting blocks 9–11 have consistently contributed most to the annual catches of Yelloweye Mullet in the LCF (Figure 4-6). Over this time, the most notable change in the spatial distribution of catches occurred during the Millennium Drought (2000s) when there was an increase in the relative contributions of catches from blocks 8–9 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 2019). In 2018/19, most of the catch was taken in reporting block 10. Historically, the fishery was seasonal with higher catches taken between May and November. In 2018/19, catches were highest between July and October.

Stock status

Yelloweye Mullet is a primary species for the commercial LCF (PIRSA 2016). This fishery has traditionally accounted for around 90 per cent of SA's total commercial catch of the species. The most recent assessment for Yelloweye Mullet in the LCF was completed in 2013, and used a weight-of-evidence approach that considered fishery statistics up to June 2012 (Earl and Ferguson 2013).

Commercial landings of Yelloweye Mullet in the LCF peaked in 1989/90 and then progressively declined to a historical low in 2004/05. This long-term decline likely reflects redirection of targeted fishing effort to higher value species rather than a declining biomass, because estimates of annual gillnet CPUE steadily increased during and after this period to an historic peak in 2008/09. The subsequent decline in catch rates through to 2014/15 was indicative of a possible decline in fishable biomass in the Coorong estuary. However, the historically high estimates of CPUE and high total catch in 2018/19 suggests 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, the LCF for Yelloweye Mullet is classified as a **sustainable** stock.

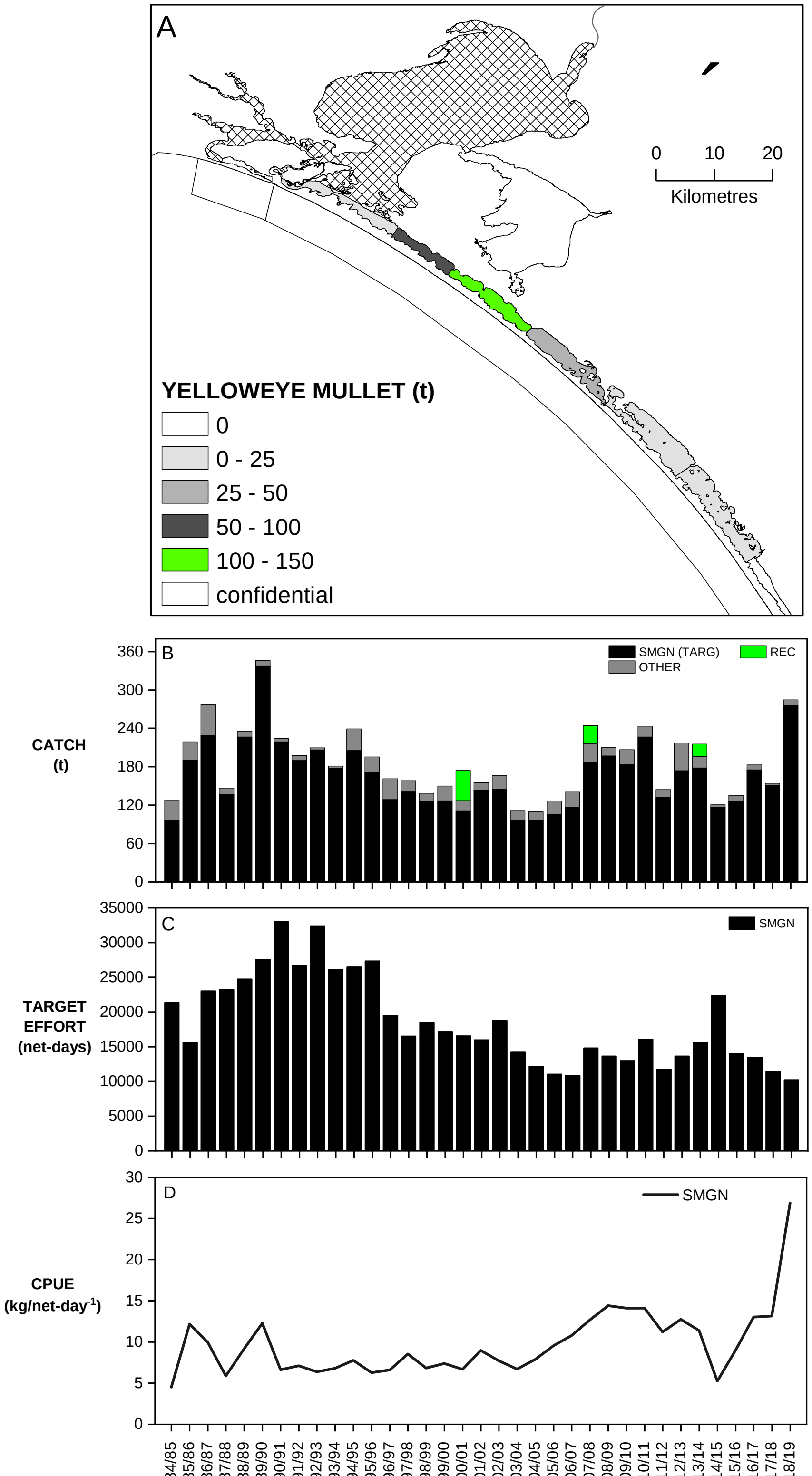

Figure 4-5. Fishery statistics for Yelloweye Mullet. (A) Map of the LCF reporting blocks showing the catch distribution for 2018/19; Long term trends in: (B) total catch for the main gear type (small mesh gillnets (SMGN), other) and the recreational sector (from all State waters for 2000/01, 2007/08, 2013/14 only; (C) targeted effort for SMGN; and (D) targeted CPUE for SMGN.

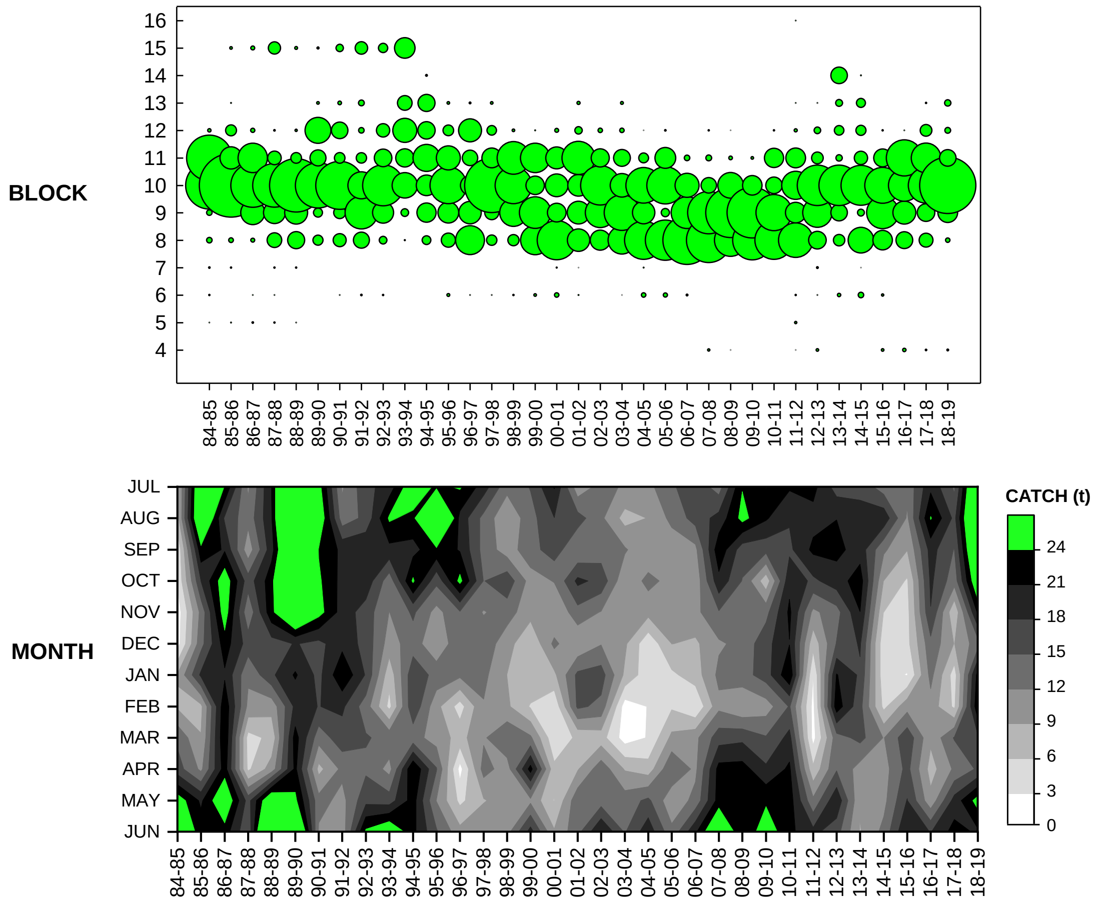

Figure 4-6. Yelloweye Mullet. Long-term trends in the annual distribution of catch among LCF reporting blocks, with the diameter of bubbles representing the relative contribution of each reporting block to total annual catch (top) and months of the year (bottom).

4.3.3.2 Environmental performance indicator

Modelled daily salinity concentrations for the Coorong estuary for the 2019/20 reporting year indicated that the amount of suitable habitat for Yelloweye Mullet was stable at 65-75% between February and December 2019 before declining to < 60% in January 2020 (Figure 4-7). The ESMGN performance indicator for habitat available to Yelloweye Mullet in the Coorong estuary was 65.1% for the 2019/20 reporting year, which was above the target reference point of 50% (Figure 4-8).

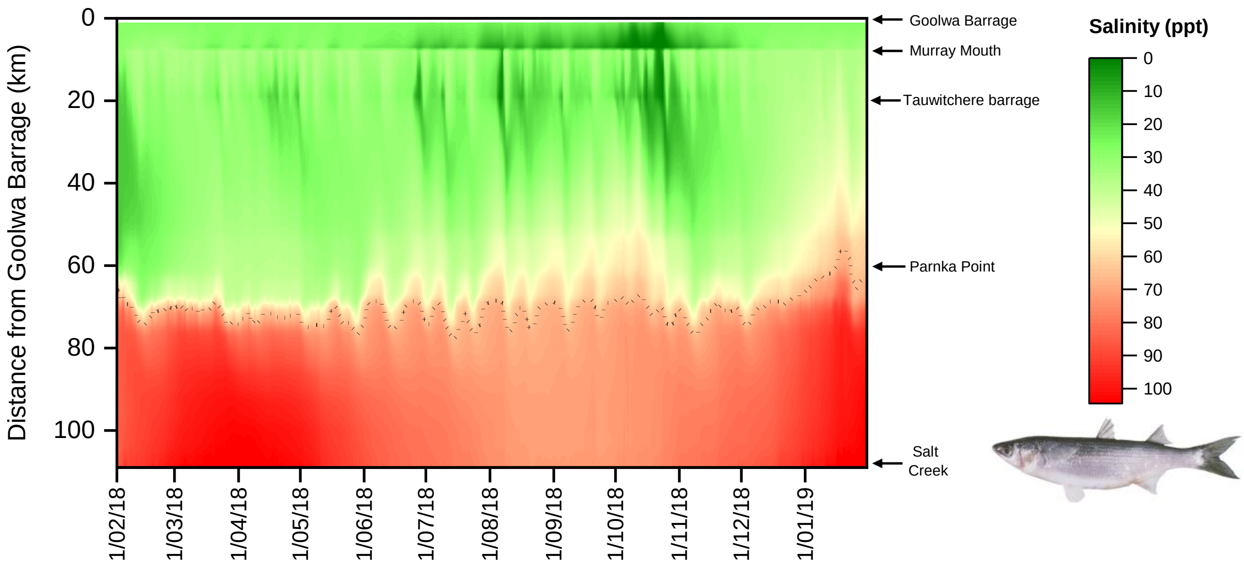

Figure 4-7. Estimated salinity concentration with distance from the Goolwa Barrage for the 2019/20 reporting year, with the approximate salinity threshold for Yelloweye Mullet (68 ppt) shown as a dashed line. Salinity threshold represents the level of salinity that was lethal for 10% of test fish, as determined by Ye et al. 2013.

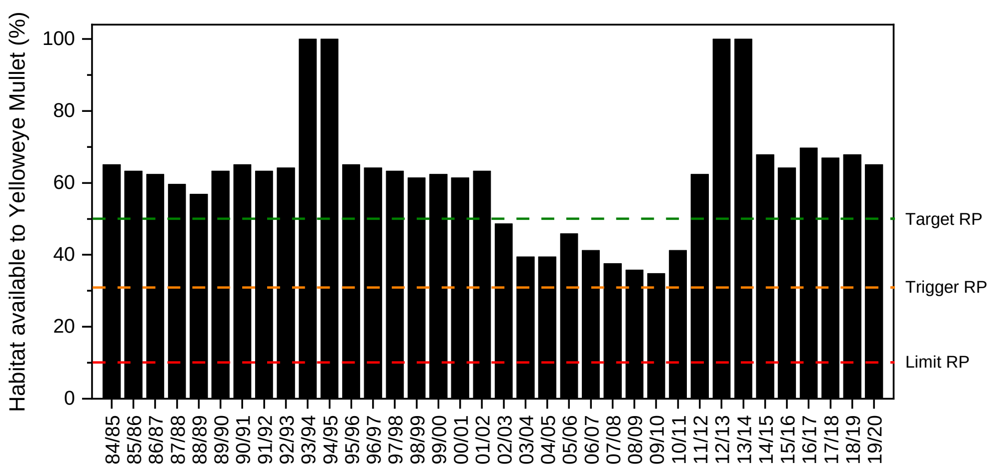

Figure 4-8. Estimates of the ESMGN performance indicator for habitat available to Yelloweye Mullet in the Coorong estuary from 1984/85 to 2019/20 (reporting years), showing target, trigger and limit reference points (RP).

4.3.4 Freshwater large mesh gillnet sector

4.3.4.1 Golden Perch (*Macquaria ambigua*)

Biology

Golden Perch (*Macquaria ambigua*) is a member of the Percichthyidae family of fishes (Classon and Booth 2002). It occurs throughout most of the Murray-Darling Basin, as well as numerous other freshwater systems in NSW, SA, Victoria and southern Queensland (Battaglene and Prokop 1987). In SA, it is common throughout the lower Murray River system, including the Lower Lakes.

Golden Perch can grow to 760 mm TL and live to 26 years of age (Mallen-Cooper and Stuart 2003). In the lower Murray River, individuals usually mature at 2–4 years of age. No estimate of size-at-maturity exists for the Lower Lakes stock. Spawning occurs mainly during spring and summer (Battaglene and Prokop 1987). Several biological stocks of Golden Perch occur in the Murray-Darling Basin (Keenan et al. 1995). This includes two main stocks: (1) the Central Stock, which is situated in the lower–mid basin waters (i.e. NSW, Victoria, SA); and (2) the Lakes Stock, which occurs in the Lower Lakes, and extends upstream to Renmark. Here, the assessment of stock status is undertaken at the management unit level – the LCF.

Fishery

Golden Perch is an important species for commercial and recreational fisheries in SA. Historically, the commercial fishery in SA had three main sectors: the LCF; the River (or Reach) Fishery; and the Lake Eyre Basin Fishery (LEBF). Of these, the LCF is the principal commercial fishery for Golden Perch in the State. Licence holders in the LCF use large mesh gillnets to target the species in the Lower Lakes. The commercial River Fishery was established in 1923 and operated in the South Australian section of the River Murray, before it was formally closed in 2003 (Earl et al. 2015). The commercial 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. As such, the fishery has operated and reported catches of Golden Perch in only seven of the past 27 years, including in 2012/13. Catch and effort data for the River Fishery and LEBF are not considered in this report.

Currently, Golden Perch is the only native fish species that is permitted to be taken by recreational fishers along the River Murray in SA. Recreational fishers target Golden Perch mainly with rod and line using baits and lures. In 2013/14, the estimated retained catch of Golden Perch by recreational fishers in SA was 37.4 t (Giri and Hall 2015).

Management regulations

Golden Perch is a primary species of the commercial LCF, making a relatively high contribution to the total production value (PIRSA 2016). For the commercial sector, regulations 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 LMS of 330 mm TL.

There are multiple management regulations in place for Golden Perch in the recreational sector of the LCF. 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 5 fish and boat limit of 15 fish. The LMS 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 since the early 1990s (Figure 4-9). They increased to a peak of 206 t 1994/95, then declined to around 37 t in 2001/02 and 2002/03, before increasing to a secondary smaller peak of 152 t in 2006/07. Since then, catch has been considerably lower. Between 2013/14 and 2016/17, annual catches were relatively stable and ranged between 79 and 88 t, before increasing to 105 t in 2017/18. In 2018/19, catch declined to 61 t, representing a 42% decline from the previous year.

Trends in targeted effort using large mesh gillnets were similar to those of total catch with peaks in the mid-1990s and mid-2000s, and a relatively stable period between 2013/14 and 2016/17 (Figure 4-9). This period of relatively consistent total catch and targeted effort was associated with an increasing trend in annual CPUE, which continued to increase to a historical peak of 1.55 kg.net-day^{-1} in 2017/18. The decline in total catch in 2018/19 was associated with a decline in CPUE. Nevertheless, the annual CPUE of 1.21 kg.net-day^{-1} in 2018/19 was among the highest recorded in the fishery.

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 4-10). There has been no clear seasonality in fishery catches during the past decade.

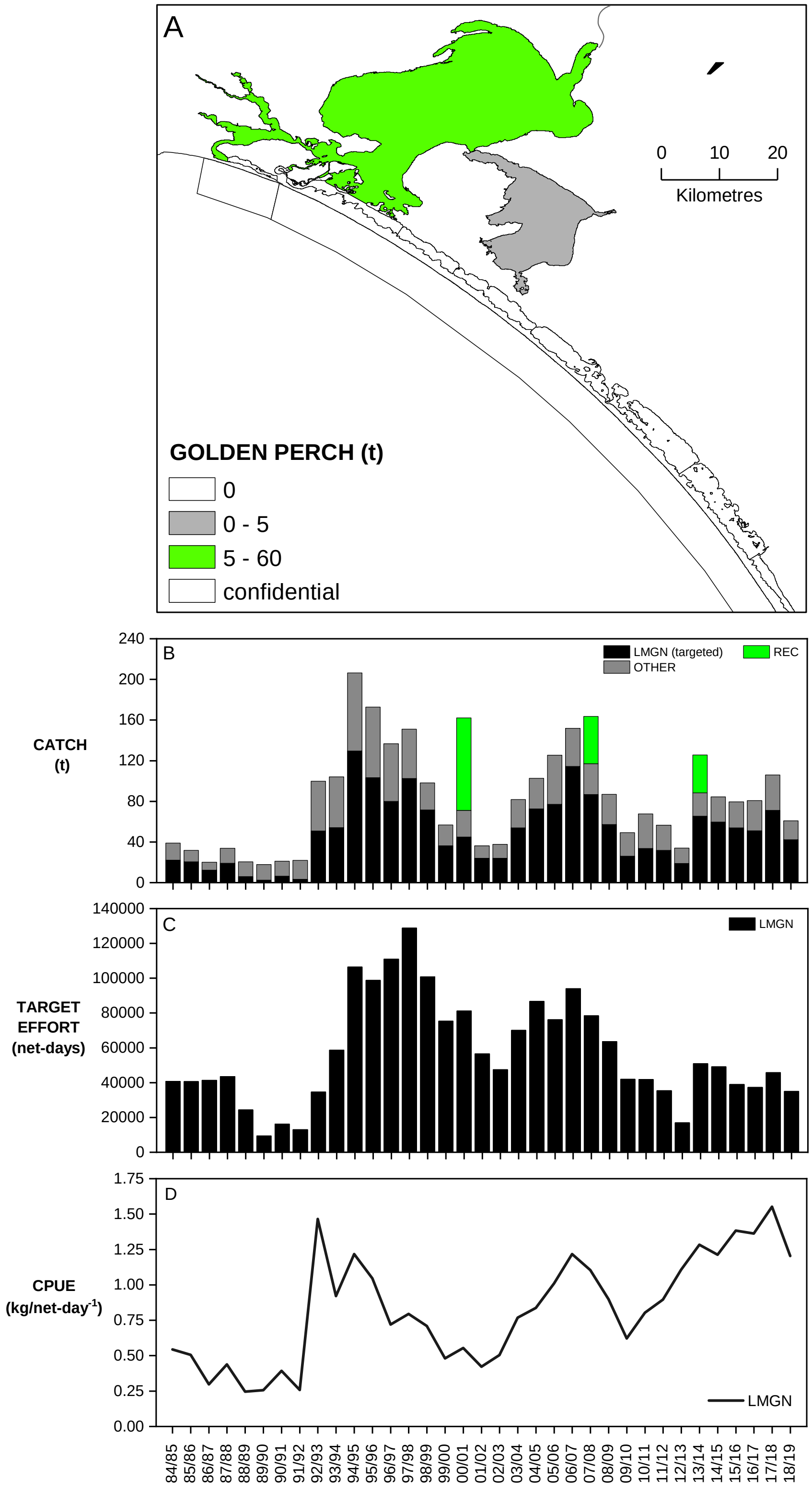

Figure 4-9. Fishery statistics for Golden Perch. (A) Map of the LCF reporting blocks showing the catch distribution for 2018/19; Long term trends in: (B) total catch for the main gear type (large mesh gillnets (LMGN), other) and the recreational sector (from all State waters for 2000/01, 2007/08, 2013/14 only; (C) targeted effort for LMGN; and (D) targeted CPUE for LMGN.

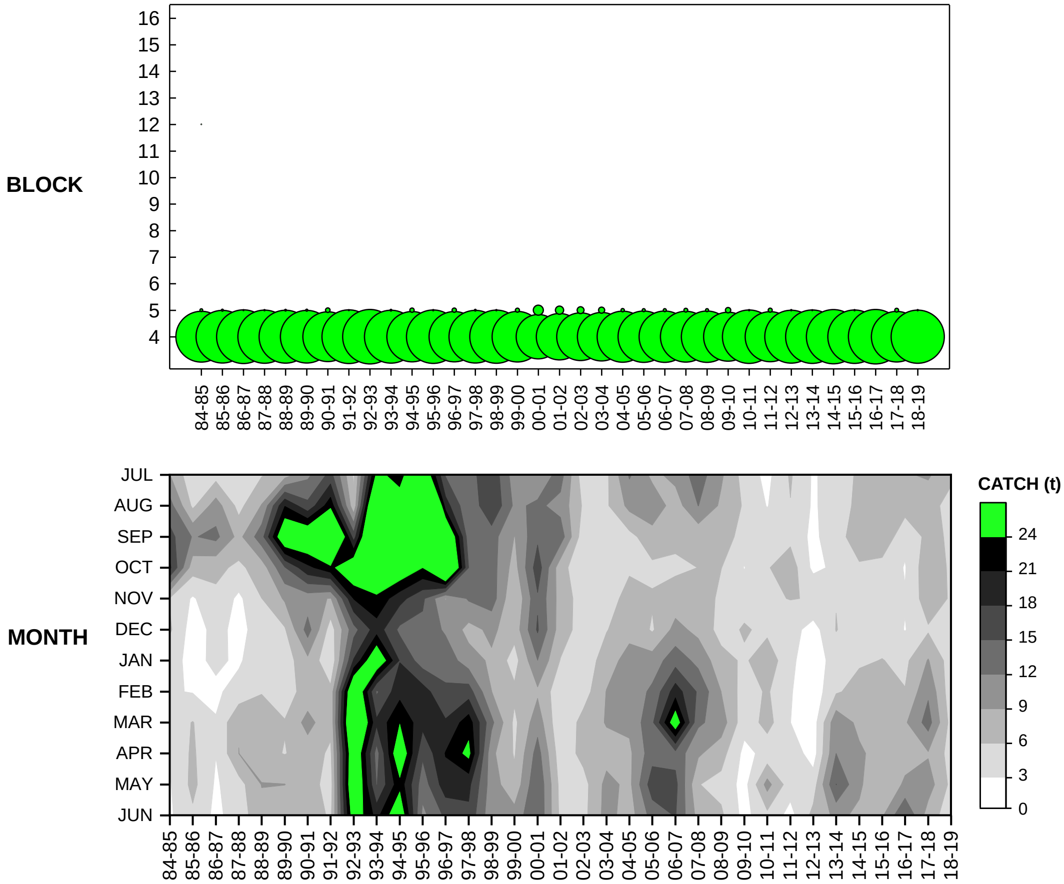

Figure 4-10. Golden Perch. Long-term trends in the annual distribution of catch among LCF reporting blocks, with the diameter of bubbles representing the relative contribution of each reporting block to total annual catch (top) and months of the year (bottom).

Stock status

Golden Perch is a primary species for the commercial sector of the LCF (PIRSA 2016). 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 fishing effort and CPUE. The increasing and exceptionally high estimates of annual CPUE between 2015/16 and 2017/18 were indicative of high fishable biomass in the Lower Lakes during that period. In 2018/19, CPUE declined slightly but remained relatively high in an historical context. 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 Golden Perch is classified as a **sustainable** stock.

4.3.4.2 Bony Herring (*Nematalosa erebi*)

Biology

Bony Herring (*Nematalosa erebi*) is a member of the Clupeidae family of fishes (Classon and Booth 2002). It occurs throughout the Murray-Darling Basin, in the Lake Eyre drainage system and across Queensland, most of the Northern Territory and parts of north-western WA. In SA, the species is abundant throughout the lower Murray River system, including in the 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 150–250 mm TL (Classon and Booth 2002). Bony Herring spawn in spring and summer after reaching maturity at a size of around 80 mm TL and an age of around two years. Stock structure in SA is uncertain. Here, the assessment of stock status is undertaken at the management unit level–the LCF.

Fishery

Despite its relatively low wholesale market value, Bony Herring is a primary species for the LCF (PIRSA 2016). This reflects the relatively high catches of this species taken by the commercial sector compared to other species. Most of the catch is taken as by-product by gillnet fishers targeting Golden Perch and Carp in the Lower Lakes. Bony Herring is mostly sold as bait to the SZRLF and NZRLF. This species is not generally targeted by recreational fishers in South Australia.

Management regulations

For the commercial sector of the LCF, regulations 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 2016). No specific management regulations 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 averaged around 1,000 t.yr^{-1} during the late 1980s and early 1990s, before steadily declining to a low of 212 t in 2002/03 (Figure 4-11). This decline corresponded with a decline in fishing effort that produced catches of Bony Herring and decreasing CPUE. Since 2002/03, total catch and CPUE increased to smaller secondary peaks during 2009/10–2012/13 and then gradually declined. In 2018/19, the total catch of 294 t was the lowest catch since 2004/05, while the estimate of CPUE of 4.23 kg.net-day^{-1} was slightly above the long-term average for the fishery.

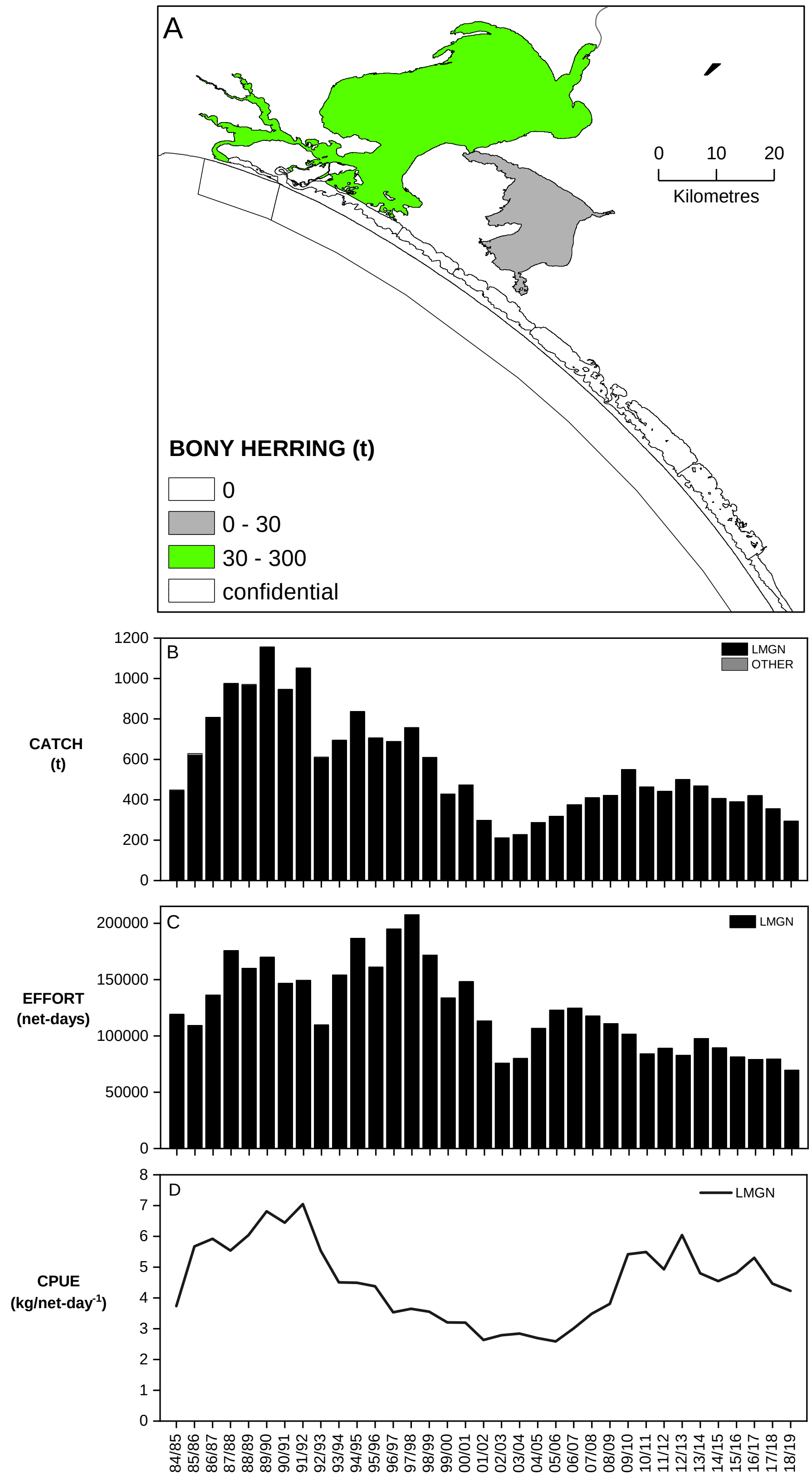

Figure 4-11. Fishery statistics for Bony Herring. (A) Map of the LCF reporting blocks showing the catch distribution for 2018/19; Long term trends in: (B) total catch for the main gear type (large mesh gillnets (LMGN), other); (C) total effort that produced catches of Bony Herring for LMGN; and (D) CPUE for LMGN, based on total catch and total effort that produced catches of Bony Herring. Note: no estimates of recreational catch are available for Bony Herring.

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 4-12). Over the last 35 years, the spring and summer period from October to December has generally been the most productive for the Bony Herring fishery.

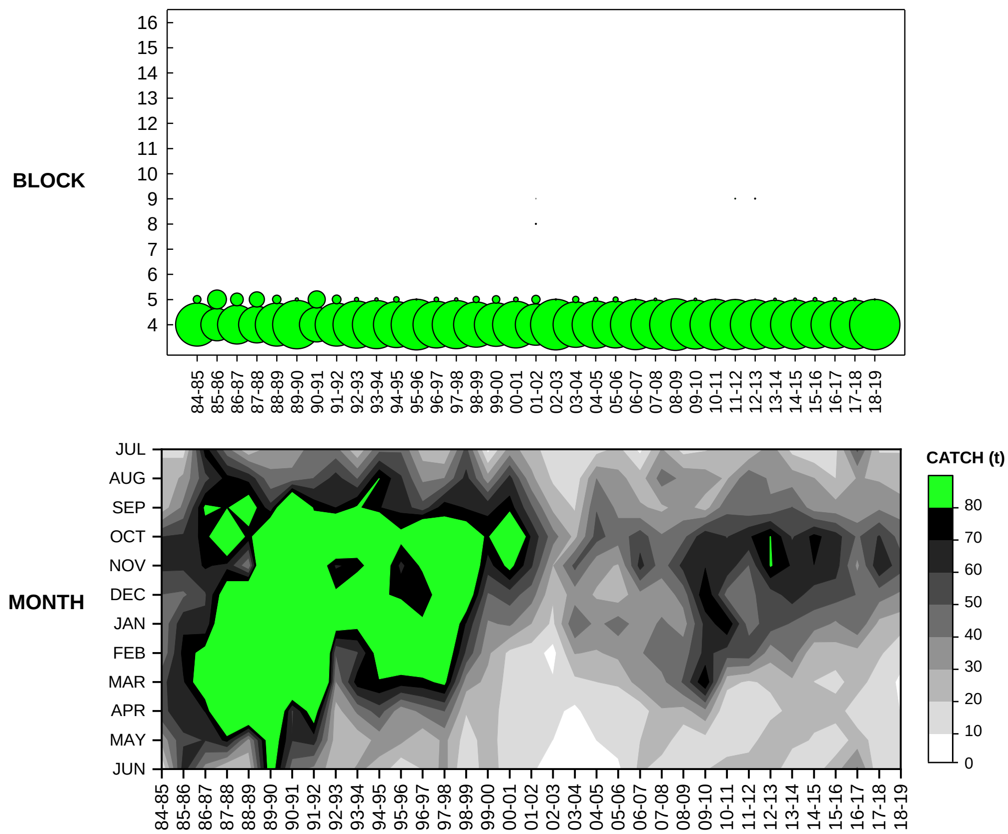

Figure 4-12. Bony Herring. Long-term trends in the annual distribution of catch among LCF reporting blocks, with the diameter of bubbles representing the relative contribution of each reporting block to total annual catch (top) and months of the year (bottom).

Stock status

Bony Herring is a primary species for the commercial sector of the LCF (PIRSA 2016). This reflects the relatively high catches of this species taken compared to other species that support the fishery. Most of the catch is taken as by-product by the fishers targeting Golden Perch and Carp. Annual catches of Bony Herring declined considerably from the early 1990s to mid-2000s, which largely reflected the decline in gillnet fishing effort over that period. Catch rates also declined during this time, but subsequently increased to a secondary peak in 2012/13. Estimates of CPUE have followed a declining trend since 2016/17, suggesting a possible decline in fishable biomass in the Lower Lakes. Nevertheless the moderate catch rates in 2018/19 suggest 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.

4.3.4.3 Carp (*Cyprinus carpio*)

Biology

Carp (*Cyprinus carpio*) is a member of Cyprinidae family of fishes (Classon and Booth 2002). Native to China, Carp was first introduced to Australian waterways in the 1850s and has since established populations in every state except the Northern Territory. Able to tolerate a wide range of conditions including warm, low-oxygen and brackish water, Carp is considered one of the country's major aquatic pests since it spread rampantly throughout the Murray-Darling Basin in the 1980s. In SA, the species has been declared noxious under the *Fisheries Management Act 2007*.

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

Fishery

In Australia, commercial fishing for Carp occurs in Victoria, SA, 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 SA. Lakes and Coorong fishers target this species using large mesh gillnets in the Lower Lakes, with most of the catch sold as bait to local rock lobster fisheries, while a small proportion of the catch is sold for human consumption. Recreational fishers harvest Carp using rod and line along the length of the River Murray in SA, as well as from numerous other freshwater catchments around the State. In 2013/14, the estimated State-wide harvest of Carp by recreational sector was 482.7 t (Giri and Hall 2015).

Management regulations

Carp is a primary species of the commercial LCF, making a relatively high contribution to the total commercial production value of the fishery (PIRSA 2016). For the commercial sector, regulations are in place that limit targeted fishing effort for finfish, including Carp. These include general gear restrictions, and spatial and temporal closures. For the recreational sector, management arrangements are limited to general gear restrictions. No LMS applies to Carp.

Commercial fishery statistics

Trends in total catch, effort and CPUE

Total annual catches of Carp have fluctuated over the last 30 years (Figure 4-13). They ranged from 278 to 360 t between 1984/85 and 1986/87 and then increased to a peak of 1,004 t in 1991/92. Catches subsequently declined to 208 t in 2001/02 before increasing to a second smaller peak of around 700 t in 2005/06 and remained around that level until 2008/09. Catch declined to 308 t in 2011/12 and has since fluctuated between 349 $t.yr^{-1}$ and 485 $t.yr^{-1}$. The total catch in 2018/19 was 375 t, of which 99% was taken in the Lower Lakes using large mesh gillnets.

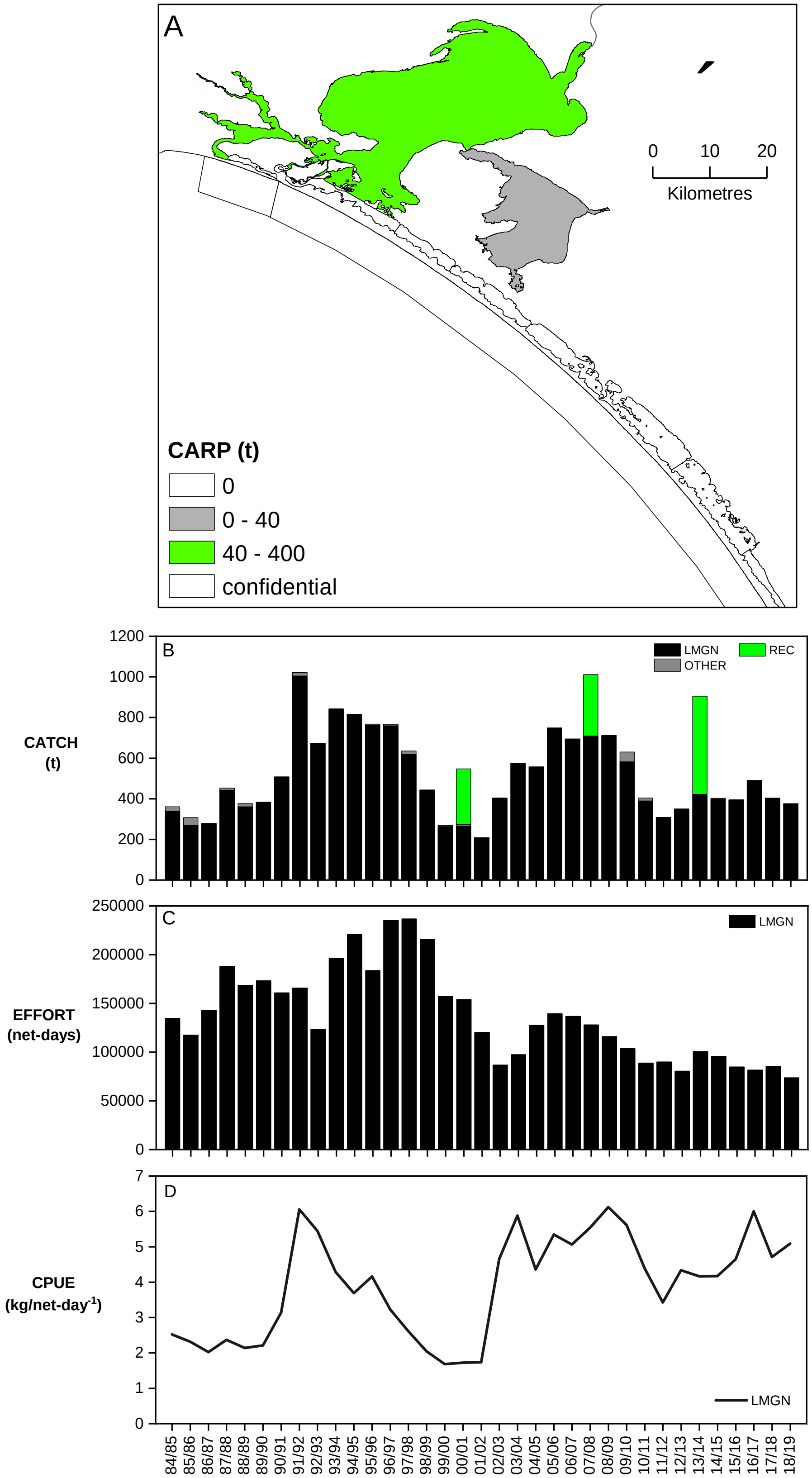

Figure 4-13. Fishery statistics for Carp. (A) Map of the LCF reporting blocks showing the catch distribution for 2018/19; Long term trends in: (B) total catch for the main gear type (large mesh gillnets (LMGN), other) and the recreational sector (from all State waters for 2000/01, 2007/08, 2013/14 only; (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.

The temporal trends in total annual large mesh gillnet effort (targeted and untargeted) that produced catches of Carp has 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 4-13). From 2010/11 to 2017/18, total effort was relatively stable and ranged between 80,648 and 100,542 net-days, before it declined to a historical low of 73,711 net-days in 2018/19. Annual CPUE also followed a similar temporal trend. The CPUE of 5.1 kg.net-day^{-1} in 2018/19 was higher than the long-term average.

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 4-14). During some years of high freshwater flows from the Murray River to the Coorong estuary, small catches of this species are occasionally taken in areas below the barrages (i.e. blocks 8 and 9). Catches of Carp are taken throughout each year, with the largest quantities harvested during the warmer months from September to February.

No stock status is assigned to Carp.

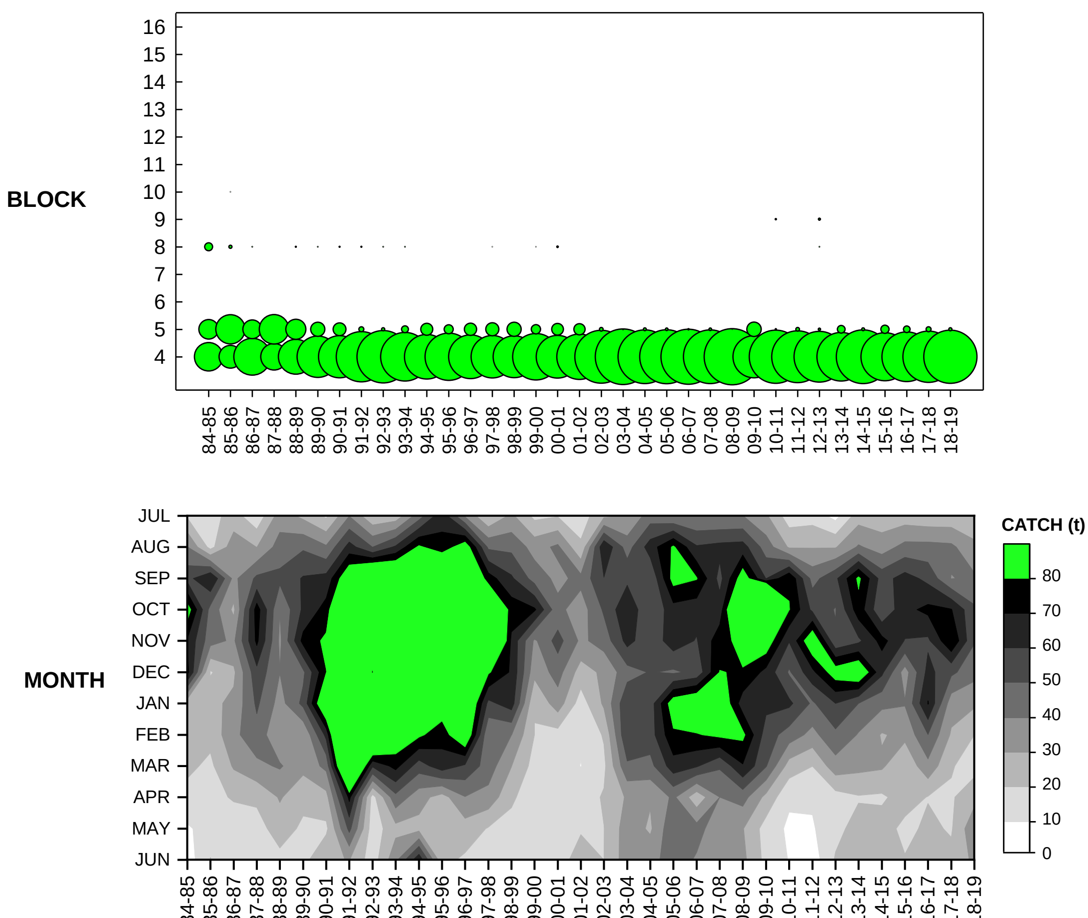

Figure 4-14. Carp. Long-term trends in the annual distribution of catch among LCF reporting blocks, with the diameter of bubbles representing the relative contribution of each reporting block to total annual catch (top) and months of the year (bottom).

4.3.4.4 Environmental performance indicator

The FLMGN performance indicator for mean water level in the Lower Lakes was 0.69 m for the 2019/20 reporting year, which was above the target reference point of 0.4 m (Figure 4-15).

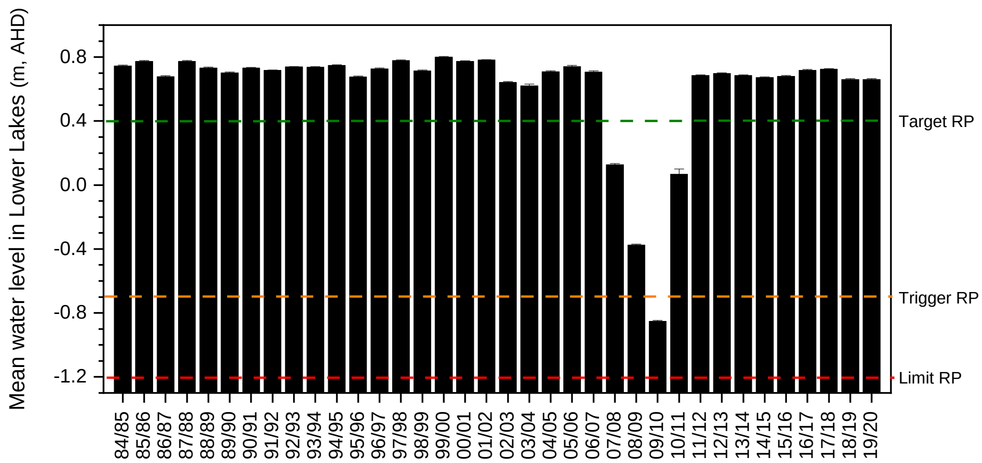

Figure 4-15. Estimates of the FLMGN performance indicator for mean water level in the Lower Lakes (± S. E.) from 1984/85 to 2019/20 (reporting years), showing target, trigger and limit reference points (RPs).

4.3.5 Pipi sector

4.3.5.1 Pipi (*Donax deltoides*)

Biology

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

For the population of Pipi on Younghusband Peninsula, the size at which 50% and 95% were reproductively mature were 28.35 mm and 32.48 mm, respectively (Ferguson and Mayfield 2006). Spawning typically occurs between September and November (Ferguson and Ward 2014). Despite numerous 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 SA. 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 2019, there were 18 licence holders with Pipi catch quota entitlements (16 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.

There is little information on SA's recreational fishery for Pipi. Anecdotal information suggests that most recreational fishers who harvest Pipi live locally and harvest most of their catch from Sir Richard Peninsula (Goolwa Beach) during summer (Murray-Jones and Johnson 2003; Giri and Hall 2015).

Management regulations

Pipi is a primary species of the commercial LCF, making a relatively high contribution to the total production value of the fishery (PIRSA 2016). 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 LMS 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 fishers to harvest year round since 2010/11.

The management plan includes a harvest strategy for Pipi (PIRSA 2016). 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 11 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 2016). 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 on the Younghusband Peninsula between the Murray Mouth and 28 Mile Crossing. The LMS 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 307 to 457 t between 1984/85 and 1989/90, and then increased progressively to an historical peak of 1,251 t in 2000/01 (Figure 4-16). Catches exceeded 1,000 $t.yr^{-1}$ between 1999/00 and 2006/07 and then declined steeply to 470 t in 2008/09. From 2009/10, catches were constrained by annual TACCs, which have steadily increased from 300 t in 2009/10, to 650 t in 2017/18 and 2018/19. In 2018/19, the total annual catch was 646.9 t, which was the highest catch since 2006/07.

Annual CPUE increased from 483 $kg.fisher\text{-}day^{-1}$ in 1988/89 to a historical peak of 1,235 $kg.fisher\text{-}day^{-1}$ in 1995/96 (Figure 4-16). From then, CPUE declined consistently to 329 $kg.fisher\text{-}day^{-1}$ in 2008/09 and remained at relatively low levels (334–456 $kg.fisher\text{-}day^{-1}$) until 2016/17. Over the last three years, CPUE has increased to 720 $kg.fisher\text{-}day^{-1}$ in 2018/19. These catch rates should be interpreted with caution due to considerable uncertainty around CPUE ($kg.fisher\text{-}day^{-1}$) 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 2017). Data on catch by the MSF are not presented due to data confidentiality (i.e. reported by < 5 fishers).

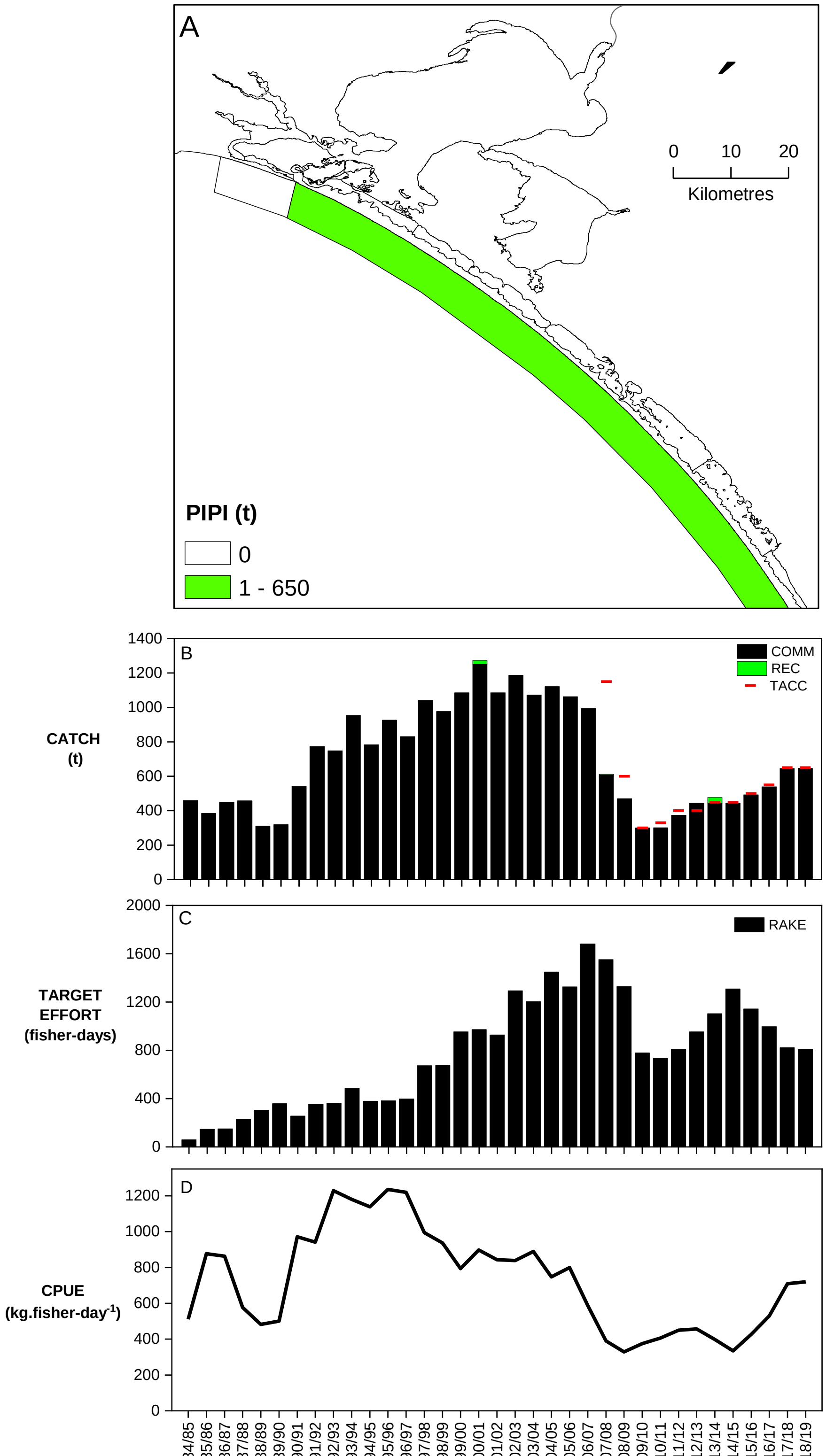

Figure 4-16. Fishery statistics for Pipi. (A) Map of the LCF reporting blocks showing the catch distribution for 2018/19; Long term trends in: (B) total catch for the LCF and MSF combined and the recreational sector (for 2000/01, 2007/08, 2013/14); (C) targeted effort for cockle rakes; and (D) CPUE for cockle rakes. Note: (i) total catch has been constrained by the TACC since 2009/10; (ii) total catch for 2012/13 was higher than the TACC due to a shift in the quota period from calendar years to financial years; and (iii) 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. Since 2010/11, fishing has occurred throughout the year under Ministerial Exemption (Ferguson and Hooper 2017). In 2018/19, catches taken between November and April accounted for around 70% of the total catch.

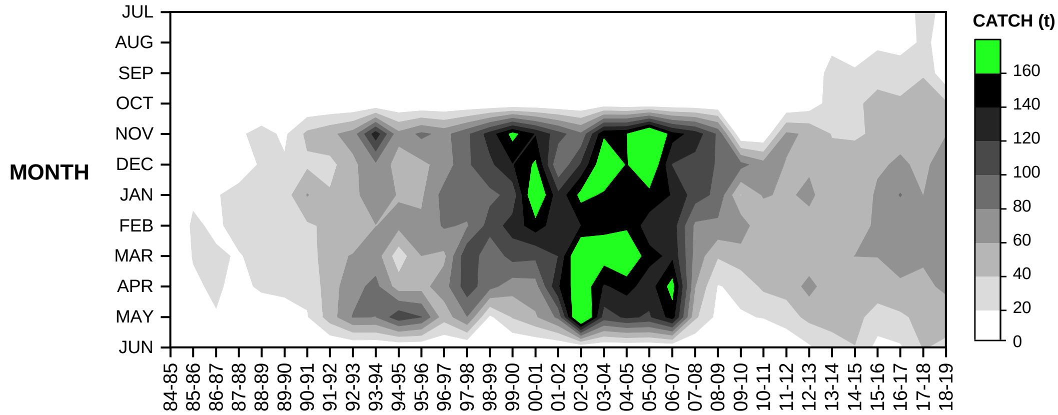

Figure 4-17. Pipi. Long-term trends in the annual distribution of catch among the months of the year.

Biological performance indicators

The harvest strategy for Pipi aims to maintain mean annual relative biomass above a target reference point of 11 kg/4.5 m² (PIRSA 2016). In 2018/19, the estimate of mean annual relative biomass was 12.6 kg/4.5 m² which was 15% above the target reference point of 11 kg/4.5 m² (Figure 4-18). Pre-recruits comprised 26% of size structures in November 2017, with this increasing to 46% in February 2018, thus pre-recruits comprised > 30% of size structures and were considered present in 2017/18 (Figure 4-19). In 2018/19, pre-recruits comprised less than 30% in size structures in November 2018 (12%), and February 2019 (16%), and were considered absent in 2018/19.

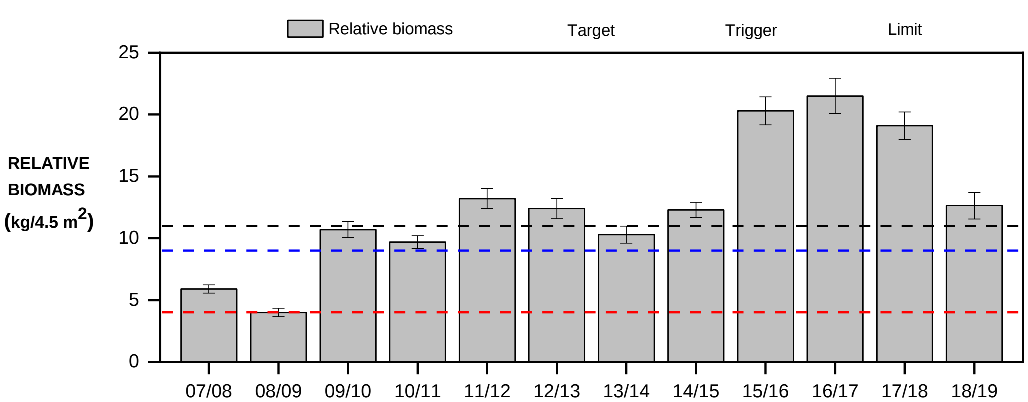

Figure 4-18. Estimates of fishery-independent mean annual relative biomass of Pipi from 2007/08 to 2018/19 showing target, limit and trigger reference points. The harvest strategy aims to maintain relative biomass above a target of 11 kg/4.5 m² (black dashes) and not less than the trigger reference point of 9 kg/4.5 m² (blue 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.

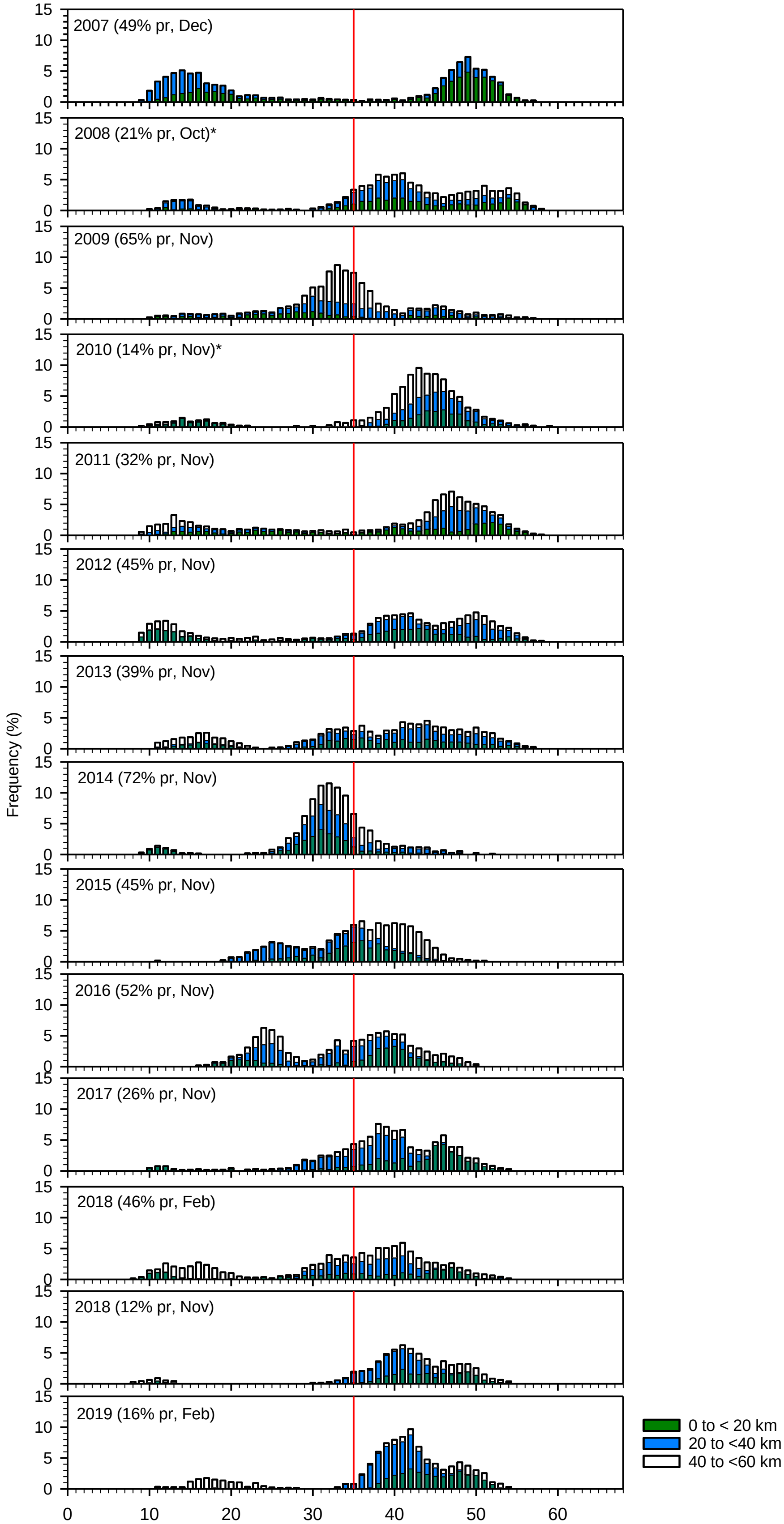

Figure 4-19. Estimates of the secondary biological performance indicator for Pipi: presence/absence of pre-recruits (pr) during November from 2007/08 to 2018/19, and in February 2018 and 2019. Vertical red line represents legal minimum size of 35 mm.

4.3.5.2 Stock status

Pipi is a primary species for the commercial sector of the LCF (PIRSA 2016). The most recent stock assessment for Pipi was completed in 2017 and reported up to the conclusion of 2015/16 (Ferguson and Hooper 2017). The status of the LCF for Pipi 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 2016), 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 relative biomass (Ferguson et al. 2015) and population size structure. From 2009/10, increasing mean annual relative biomass and increasing complexity of size structures indicated recovery of the resource after a period of low catches and catch rates in the mid-2000s (Ferguson et al. 2015). In 2018/19, the estimate of fishery-independent relative biomass of legal-sized Pipi (primary performance indicator) of 12.6 kg/4.5 m^2 was above the target reference point of the 11 kg/4.5 m^2. Nevertheless, relatively low contributions of pre-recruits to the population size distributions in 2018/19 (12% in November 2018; 16% in February 2019) led to a 31% reduction in the TACC for the 2019/20 fishing season from the previous year. This conservative management under the harvest strategy for Pipi aims to protect the spawning biomass and ensure that, on average, future levels of recruitment are adequate. 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 in 2018/19 is classified as a **sustainable** stock.

4.4 SUMMARY

This section of the report used a weight-of-evidence approach to assign stock status for six key species of the commercial LCF and describes trend in the commercial fishery statistics for Carp. The assessment of each stock relied heavily on fishery-dependent data, and placed considerable emphasis on analysing trends in catch, effort and CPUE from 1984/85 to 2018/19. Additional information about the species' stock structure, biology and management arrangements also contributed to the determination of stock status.

Of the six LCF species assessed in this section, four are classified as 'sustainable', and two (Black Bream and Greenback Flounder) are classified as 'depleted'. For each species, the stock status classification that was applied in the 2017/18 assessment report is retained (Earl 2019).

This section of the report also provided an assessment of the recent condition of the environment in which the fishery's ESMGN and FLMGN sectors operate, based on the environmental performance indicators and reference points used in the harvest strategy for finfish (PIRSA 2016). For the ESMGN, the performance indicator for habitat available to Yelloweye Mullet in the Coorong estuary for the 2019/20 reporting year was 65%, which was above the target reference point of 50%. For the FLMGN, the environmental performance indicator for water level in the Lower Lakes for the 2019/20 reporting year was 0.69 m, which was above the target reference point of 0.4 m. An assessment of the environmental performance indicator for the Estuarine large mesh gillnet sector (ELMGN) is presented Section 3.3.3, as part of the stock assessment for Mulloway. The ELMGN performance indicator for habitat available to Mulloway in the Coorong estuary for the 2019/20 reporting year was 59.6%, which was above the target reference point of 55%.

5 GENERAL DISCUSSION

5.1 SYNTHESIS

This report for South Australia's multi-species, multi-gear Lakes and Coorong Fishery (LCF) provided a historical overview of the dynamics of the LCF fishing fleet from 1984/85 to 2018/19, a comprehensive stock assessment for Mulloway, and assigned stock status to a further six species using the National Fishery Status Reporting Framework (Stewardson et al. 2018). The assessments of stock 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 arrangements; and trends in commercial fishery data from 1 July 1984 to 30 June 2019. Updated estimates of the environmental performance indicators for the three gillnet sectors of the fishery, as well as the biological performance indicators for Pipi were also provided.

Overall, of the seven stocks assessed in this report, five (71%) were classified as 'sustainable', and two (29%) were classified as 'depleted'. For each stock, the status classification from the 2017/18 fishery assessment report was retained (Earl 2019). The 'sustainable' stocks are those of five primary species of the LCF, i.e. Mulloway, Yelloweye Mullet, Golden Perch, Bony Herring and Pipi, which together with Carp (also a primary species) have consistently accounted for 94–98% of the fishery's total annual catches since 1984/85. This continued in 2018/19, with the six primary species accounting for 97% of the fishery catch. The two 'depleted' stocks relate to the secondary species – Black Bream and Greenback Flounder. Catches of these two species remained low in 2018/19.

The stock assessment for Mulloway in this report was the first of its kind since 2014 (Earl and Ward 2014). The previous stock assessment classified the stock as 'sustainable' and this status was retained in 2018/19 on account of: (i) regular recruitment of juveniles to the fishable biomass in the Coorong estuary in recent years; (ii) the presence of multiple age classes in the spawning biomass in 2019/20; and (iii) the historically high annual catches and catch rates in the Coorong estuary (i.e. the area that contributes most of the catch) in 2017/18 and 2018/19. These results 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. The next stock assessment for Mulloway in the LCF is planned for 2022/23.

The poor fishery performance of the Black Bream stock in the Coorong over the last 30 years has persisted, with historically low levels of catch and targeting continuing in 2018/19. The temporary management arrangements introduced in 2018 to recover the stock have not yet resulted in measurable improvements. Any benefit from these management arrangements within the population would likely take at least several years to develop. This is because Black Bream is a long-lived species and the Coorong Stock has historically been characterised by irregular recruitment events, the magnitude of which has depended on levels of egg production and appropriate environmental conditions relating to freshwater inflows to support the survival and growth of eggs and larvae (Jenkins et al. 2015; Earl et al. 2016b; Ye et al. 2017; Ye et al. 2019). Moreover, juvenile Black Bream that originated from spawning in 2018 (i.e. when the temporary management arrangement were in place) will take at least several years to recruit to the fishable biomass and contribute to egg production. A comprehensive stock assessment for Black Bream that builds on the previous stock assessment (Earl et al. 2016b) and evaluates the effectiveness of the temporary management arrangements should be considered within the next 2–4 years.

The low fishable biomass of Greenback Flounder in the Coorong estuary over recent years also continued in 2018/19. The lack of targeted effort and low annual catches during the past six 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 LCF 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). The sustainable management of the Greenback Flounder population in the Coorong estuary would benefit from an ecosystem-based management approach that aims to: (i) provide a regime of consistent seasonal freshwater inflow to restore and maintain extensive areas of favourable estuarine habitat for the species; and (ii) maintain connectivity between the estuary and the marine environment to facilitate fish passage and accommodate the opportunistic use of the system by the species.

Yelloweye Mullet continues to be the sole target species of the estuarine small mesh gillnet sector of LCF. The high total catch of Yelloweye Mullet in 2018/19 was associated with an estimate of mean annual $CPUE_{SMGN}$ that was double that of any other year since 1984/85. The high $CPUE_{SMGN}$ in 2018/19 was indicative of high fishable biomass in the Coorong estuary, but may also reflect changes in the relative efficiency of the fleet in recent years. Representatives from the Southern Fishermen's Association – the representative body for LCF fishers – have indicated that many fishers, particularly those targeting Yelloweye Mullet, 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 results in catch losses and damage to nets. Some of the operational changes made by fishers have included: reducing the number of gillnets used per fishing day which has allowed them to attend their nets more regularly (i.e. reduce soak time of individual gillnets); 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 foraging seals (EconSearch 2019). The influence of such changes in fisher behaviour on estimates of CPUE is difficult to assess, because most of the changes are not currently able to be recorded in fishery logbooks. This could be addressed by incorporating additional reporting fields (e.g. soak time) into the Inland Waters Catch and Effort return. Nevertheless, the influence of changes in fisher behaviour on CPUE for Yelloweye Mullet will be investigated using the available fishery data in the next stock assessment for Yelloweye Mullet which is planned for 2020/21.

For the freshwater large mesh gillnet sector in 2018/19, the total catch of Golden Perch declined to its lowest level since 2012/13, although $CPUE_{LMGN}$ remained high, while annual CPUE for the low-value Bony Herring remained at a moderate level. The Golden Perch and Bony Herring stocks were classified as sustainable. While no stock status was assigned to Carp, the moderate catches and catch rates in recent years indicate that the biomass of this stock is unlikely to be depleted.

For each of the three finfish sectors, the environmental performance indicator for the 2019/20 reporting year (1 February 2019 to 31 January 2020) was assessed against the reference points used in the finfish harvest strategy. The results of these comparisons will guide setting of the annual total allowable commercial effort (TACE) for each sector for the 2020/21 fishing season. All three performance indicators for the 2019/20 reporting year were above their respective target reference points.

For Pipi, 2017/18 and 2018/19 were the most productive years for the commercial fishery in terms of total catch since annual total allowable commercial catch (TACC) was introduced under a quota management system for the species in 2007/08. The estimate of fishery-independent relative biomass of legal-sized Pipi (primary performance indicator) in 2018/19 was above the target reference point used in the harvest strategy for Pipi (PIRSA 2016). This indicates that the biomass of the Pipi stock along the ocean beach of Younghusband Peninsula is unlikely to be depleted. Despite this, the Pipi fishery was subjected to a 31% reduction in TACE for the 2019/20 fishing season, after fishery-independent surveys in November 2018 and February 2019 identified relatively low abundances of pre-recruits in the population. This reduced catch under the harvest strategy will limit risks to the stock, by protecting the spawning biomass, and ensure that, on average, future levels of recruitment are adequate. The next stock assessment for Pipi is planned for 2020/21.

5.2 RESEARCH PRIORITIES

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 each species. These data will continue to form the basis of the assessments of LCF stocks. However, consideration of contemporary information on the size and age composition of exploited populations is fundamental for assessments of stock status, particularly for long-lived species (King and McFarlane 2003). The life histories of Mulloway, Black Bream and Golden Perch are characterised by high longevity (26–41 years) and delayed maturity. Such a life history (periodic strategist) generally relies on the establishment of one or several strong year classes at regular intervals to maintain the population (Winemiller and Rose 1992). Currently the most significant gap in our knowledge relevant to the assessments of stock status for these species relates to the lack of demographic information (e.g. size/ age structures) for populations that support the LCF. A catch sampling program to support development of a time series of annual age structures for Mulloway, Black Bream and Golden Perch would improve assessments of stock status and facilitate appropriate fishery management.

For most species considered in this report, the primary measure of fishable biomass is targeted CPUE from gillnets. For these species, CPUE is assumed to be proportional to abundance and is therefore used as relative index of abundance. However for several other species, especially those that are taken in low quantities (e.g. Black Bream, Greenback Flounder) and for which most of the recent annual catches have been taken as by-product, targeted CPUE is considered a poor indicator of relative abundance. Catch per unit effort standardisation may help improve the usefulness of CPUE as a relative index of abundance for these species, by accounting for differences in the relative contributions of targeted and non-targeted catches to the total catch. Improving the reliability of CPUE as indicator of biomass for these species would improve assessments of stock status.

A key gap in our knowledge for assessing the status of the stocks that support the LCF is determining the relative contribution of the recreational fishing sector to total State-wide catch. The total harvest by the recreational sector has traditionally been determined through telephone/diary surveys that are undertaken on a five-year cycle (Henry and Lyle 2003, Jones 2009, Giri and Hall 2015). Although these surveys adopt a standard methodology that allows the results to be compared through time, their estimates of catch and effort are typically imprecise, and even more so at the regional scale for the Lakes and Coorong. This imprecision has implications for the assessments of Mulloway, Golden Perch and Black Bream, for which the relative recreational contribution to overall State-wide catch is significant. Improving the precision of the estimates of the recreational catches, either through more frequent surveys or increased participation rates, will improve assessments of stock status.

Levels of incidental mortality of sub-legal sized individuals of key LCF species discarded by commercial and recreational fishers in the Coorong estuary and Lower Lakes are poorly understood. This is because estimates of discarding are only available for the commercial fishery from limited sampling undertaken during the Millennium Drought (Ferguson 2010). For the commercial sector, this could be addressed by ongoing monitoring discards from gill nets.

Conflict between LCF fishers and Long-nosed Fur Seals has been an important issue for the fishery over the last 10 years (EconSearch 2019). Despite recent mitigation initiatives (e.g. implementation of seal crackers as a management tool), reports from industry suggest that the seal-fisher conflict and associated economic impacts have intensified in recent years. A key gap in our knowledge for assessing the status of LCF stocks is 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. The need for this information will be addressed by the FRDC Project 2018-036 ‘Seal-fisher-ecosystem interactions in the Lower Lakes and Coorong: understanding causes and impacts to develop longer-term solutions’, which commenced in 2019.

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APPENDIX

Appendix 1. Summary table showing total commercial catches by financial year for twelve LCF species defined as 'primary', 'secondary', 'tertiary' or 'other' species in the Management Plan (PIRSA 2016). Total catches for Pipi includes LCF and MSF catches. Crosses indicate confidential data.

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