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Black Bream (*Acanthopagrus butcheri*)

Stock Assessment Report 2014/15

J. Earl, T.M. Ward and Q. Ye

SARDI Publication No. F2008/000810-2
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SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

January 2016

Report to PIRSA Fisheries and Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

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EXECUTIVE SUMMARY

This report is the second assessment of the South Australian Black Bream (*Acanthopagrus butcheri*) fishery, and updates the report from 2008. It provides a synopsis of information for the species and reports on trends in commercial catch and effort data and fishery size and age structures, to provide a weight-of-evidence assessment of stock status for Black Bream in the Coorong estuary.

Most catches of Black Bream in South Australia are taken by the Lakes and Coorong Fishery (LCF). Annual catches by the LCF peaked at 72 t in 1980/81 and remained >35 $t.yr^{-1}$ until 1986/87. Catches then declined and averaged 4.4 $t.yr^{-1}$ from 1990/91 to 2013/14. In 2014/15, the total catch of 2.4 t was among the lowest on record. The low catches since the late 1980s have been associated with low fishing effort.

The dominant gear type used to target Black Bream is the large mesh gill net (115 –150 mm mesh). Mean annual catch per unit effort for large mesh gill nets ($CPUE_{LMGN}$) peaked at 30 kg.fisher day^{-1} in 2007/08. In 2013/14, $CPUE_{LMGN}$ declined to 3.2 kg.fisher day^{-1}, which was the lowest on record. $CPUE_{LMGN}$ for 2014/15 is confidential (i.e. based on data reported by less than five licence holders).

For 2014/15, one of four fishery performance indicators was outside the range of limit reference points. Total catch was 20% below the lower limit reference point.

The age structure for Black Bream from 2014/15 comprised mostly fish from two age classes of 5 and 8 year old fish. Despite the recruitment of several year classes since 1997/98, recruitment levels have been low, as measurable improvements in adult biomass have not been detected. The low levels of recruitment appear to relate primarily to a low spawning biomass, rather than to environmental conditions. On this basis, the biological stock is considered to be recruitment overfished.

The current level of fishing mortality is unlikely to allow the stock to recover from its current weakened state. On the basis of the information above and using the definitions from the national stock status framework, the Black Bream stock in the Coorong estuary is classified as **overfished.**

The most important research needs for the Black Bream fishery and its management include: (i) ongoing development of a time series of annual age structures; (ii) surveys to estimate the recreational harvest in the Coorong estuary; and (iii) independent monitoring of discarding of non-targeted and sub-legal sized individuals from large and small mesh gill nets.

1. GENERAL INTRODUCTION

1.1 Overview

This assessment of the fishery for Black Bream (*Acanthopagrus butcheri*) in South Australia builds on a previous fishery assessment report in 2008 (Ferguson and Ye 2008) and annual fishery statistics reports since 2006 (Ferguson 2006; 2008; 2010; 2011; 2012a; 2012b; Earl and Ward 2014; Earl 2015). The report aims to provide a synopsis of fisheries information available for Black Bream and an assessment of the current status of the Black Bream resource in the Coorong estuary. The assessment presented here is mainly based on commercial catch and effort data up to 30 June 2015 for the Lakes and Coorong Fishery (LCF), and information on the size and age structure of the Black Bream population in the Coorong estuary.

1.2 Description of the fishery

In Australia, most commercial catches of Black Bream are taken in Victoria and Western Australia, while smaller catches are taken in South Australia, Tasmania and New South Wales (Kailola et al. 1993; Sakabe and Lyle 2008). Black Bream is also regarded as an important species by recreational fishers in these states (Kailola et al. 1993). In South Australia, commercial and recreational catches of Black Bream are taken in estuaries and nearshore coastal waters across the State (Kailola et al. 1993).

Commercial Fishery

The commercial fishery for Black Bream in South Australia has two main sectors, the LCF and Marine Scalefish Fishery (MSF). The Northern and Southern Zone Rock Lobster fisheries can also harvest Black Bream, though catches from these sectors are negligible and not considered further in this assessment.

<u>Lakes and Coorong Fishery</u>

The LCF is a small-scale, multi-species, multi-gear fishery that operates in, and adjacent to, the estuary of the Murray River and Coorong lagoons (hereafter referred to as the Coorong estuary), the lower lakes of the Murray River (Lakes Alexandrina and Albert) and the nearshore marine environment adjacent the Coorong estuary along Younghusband and Sir Richard Peninsulas (Figure 1). Fishers in the LCF use large mesh gill nets (115 – 150 mm mesh) to target Black Bream, along with several other finfish species including Mulloway (*Argyrosomus japonicus*), Greenback Flounder (*Rhombosolea tapirina*) and Golden Perch (*Macquaria ambigua*). Fishers also target Yelloweye Mullet (*Aldrichetta forsteri*) and have access to Pipi (*Donax deltoides*) through a quota management system on the ocean beach along Younghusband Peninsula and Sir Richard Peninsula (Sloan 2005).

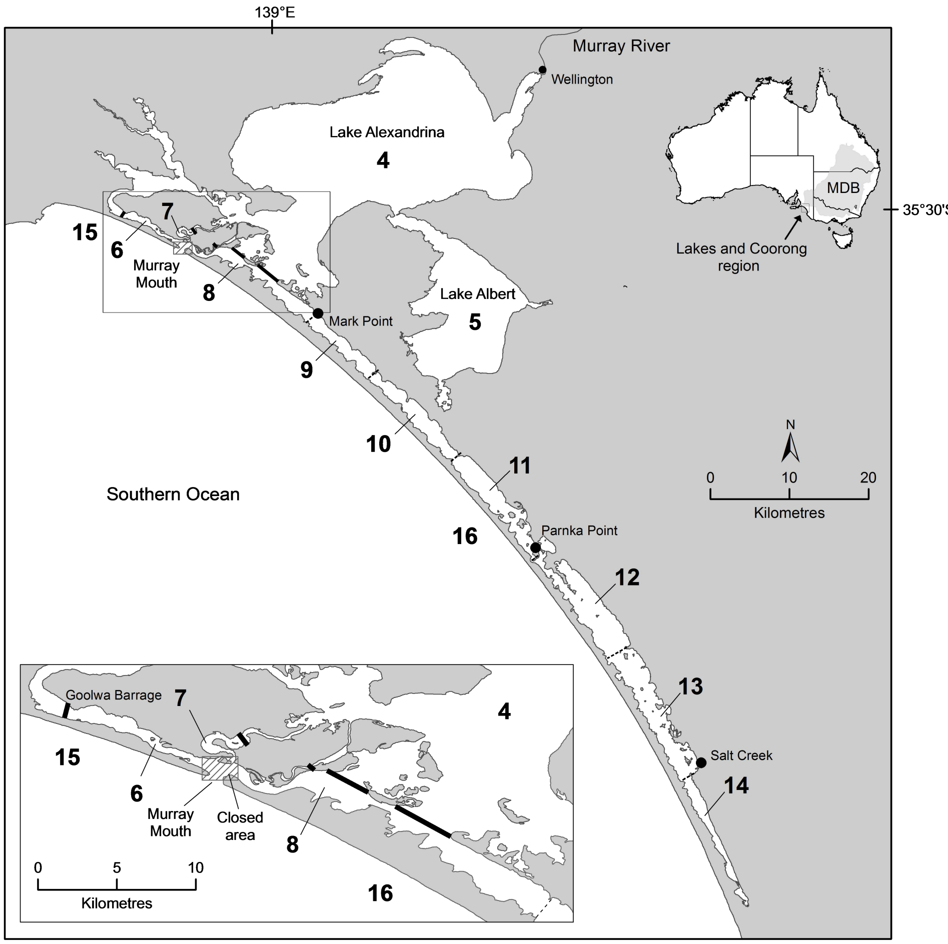

Figure 1. Map of the Lakes and Coorong region showing commercial reporting areas 4 – 16 of the LCF.

<u>Marine Scalefish Fishery</u>

Similar to the LCF, the MSF is a multi-species, multi-gear fishery. The MSF operates in all coastal waters of South Australia, excluding the Coorong estuary. Fishers in the MSF use mainly haul nets and gill nets to target Black Bream.

Recreational Fishery

Recreational fishers target Black Bream using rod and line in nearshore coastal waters of South Australia, particularly in estuaries and the lower reaches of rivers (Kailola et al. 1993). Recreational fishers can also target the species using registered monofilament nylon nets in the Coorong estuary and Lake George (Sloan 2005). Recreational net fishing is prohibited in all other coastal waters of South Australia.

Traditional Fishery

The Ngarrindjeri population an estimated 3,000 people inhabiting the Coorong region in the 1800s, prior to European settlement (Sloan 2005). The Ngarrindjeri people continue to target Black Bream as well as Mulloway, Greenback Flounder and Yelloweye Mullet using a range of traditional apparatus, including nets, spears and rod and line (Jenkin 1979; Olsen and Evans 1991). Estimates of annual catches of Black Bream are not available for the traditional fishery.

1.3 Management of the fishery

Commercial Fishery

Lakes and Coorong Fishery

Management of the LCF is governed by the *Fisheries Management (Lakes and Coorong Fishery) Regulations 2009* and *Fisheries Management (General) Regulations 2007.* The LCF Management Plan (Sloan 2005) provides a strategic policy framework for the management of the fishery. A new management plan for the fishery is currently being finalised. Table 1 provides a timeline of changes to management arrangements for the LCF.

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 marine beaches along Younghusband and Sir Richard Peninsulas. Fishing effort is controlled through gear entitlements. For example, each licence is endorsed for the type and number of nets that can be used. Owner-operator provisions also apply. The *Fisheries Management (Lakes and Coorong Fishery) Regulations 2009* provide that a person other than the holder of a LCF licence cannot be registered as a master of a vessel used under that licence, unless the licence holder is already the registered master of another fishery licence.

Licence amalgamations were permitted under the Scheme of Management introduced in 1984 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 amount of gear operating in the fishery over time.

The LCF is managed in the context of a number of international legal instruments including the Ramsar Convention and United Nations Convention on the Law of the Sea. In addition, the fishery operates within the boundaries of the Lakes and Coorong National Park, an area recognised internationally for its wetland habitats and importance for migratory waterbirds.

Table 1. Management milestones for the LCF.

Date	**Milestone**
1906	The South Australian Government introduced a requirement for all commercial fishers to hold a commercial fishing licence.
1971	Introduction of fishing licences for all commercial fishing in South Australia
1972	Licensed commercial fishers required to provide monthly catch data
1982	*South Australian Fisheries Act, 1982*
1984	*Scheme of Management (Lakes and Coorong Fishery) Regulations 1984*
1984	The Lakes and Coorong Fishery was divided into 16 areas for the purpose of data collection and more detailed fishing location information was collected from operators.
1986	Restrictions on commercial net type, mesh size, net depth and net length. Limit of one registered recreational net per person, with 70 m total length and maximum of 1 m drop.
1990	Guidelines formalised to limit the amount of gear that may be endorsed on an individual licence upon licence transfer or amalgamation.
1991	*Fisheries (Scheme of Management—Lakes and Coorong Fishery) Regulations 1991*
1997	Review of the recreational fishery
2003	Closure of the river fishery
2004	Amendments to the Scheme of Management to allow an individual to hold more than one licence
2005	Management Plan for the South Australian Lakes and Coorong Fishery
2006	*Fisheries (Scheme of Management - Lakes and Coorong Fishery) Regulations 2006*
2007	*The Fisheries Management Act 2007* Fishery Management Committees were discontinued from 31 March 2007
2008	Pipi quota management arrangements implemented into regulations
2009	*Fisheries Management (Lakes and Coorong Fishery) Regulations 2009*
2013	Amendments to the *Fisheries Management (Lakes and Coorong Fishery) Regulations 2009* to allow licence holders to transfer all entitlements to family members.

To measure and monitor fishery performance, catch and effort data for the LCF have been recorded since 1 July 1984 (Knight et al. 2001). Daily catch and effort information is provided to SARDI Aquatic Sciences on a monthly basis and includes: catch (kg) and effort (days fished, fisher days, net-days) data for targeted and non-targeted species; gear type used; and fishing location in relation to LCF reporting areas (Figure 1). Management arrangements for Black Bream comprise general gear restrictions, spatial and temporal closures and a legal minimum size (LMS) of 280 mm total length (TL) that applies to all State waters (Sloan 2005).

<u>Marine Scalefish Fishery</u>

The management of the MSF is governed by the *Fisheries Management (General) Regulations 2007* and *Fisheries Management (Marine Scalefish Fisheries) Regulations 2006.* Management arrangements have evolved since the South Australian Government first introduced a requirement for all commercial fishers to hold a commercial fishing licence in 1906.

Fishers in the MSF have access to Black Bream in all South Australian coastal waters except the Coorong estuary. The LMS of 280 mm TL applies to all catches. Catch and effort data for the MSF have been recorded since 1 July 1984 (Knight et al. 2001). Daily catch (kg) and effort (days fished, fisher days) data for targeted and non-targeted species; gear type used; and the location of fishing is provided on a monthly basis to SARDI Aquatic Sciences.

Recreational Fishery

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 participants. A daily bag limit of 10 Black Bream per fisher and a daily boat limit of 30 Black Bream applies to this sector. A fishery closure applies from 1 September to 20 November in the Onkaparinga River, upstream of the Main South Road Bridge. Management arrangements also comprise gear restrictions (PIRSA 2015).

Recreational fishers can target Black Bream in the areas of the LCF using registered nylon mesh nets. In 2014, approximately 692 recreational fishers possessed mesh nets that were registered with PIRSA Fisheries and Aquaculture for use in the Coorong estuary or Lake George. Recreational mesh nets for use in the Coorong must be less than 75 m long with 50 – 64 mm 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.

Traditional fishery

All of the management measures in place for recreational fishers apply to indigenous fishers when undertaking traditional fishing practices. However, indigenous fishers also have access to Black Bream for traditional, domestic, non-commercial use subject to meeting requirements of the *Native Title Act 1994*.

1.4 Performance indicators for the fishery

The Management Plan (Sloan 2005) identifies four performance indicators (PIs) and associated reference points (RPs) to monitor fishery performance of the Black Bream fishery. The PIs are: (i) total catch; (ii) 4-year total catch trend; (iii) mean annual catch per unit effort for large mesh gill nets ($CPUE_{LMGN}$); and (iv) 4-year mean annual $CPUE_{LMGN}$ trend. All PIs were derived from catch and effort data for the historical reference period from 1984/85 to 2001/02. Upper and lower RPs for catch and CPUE PIs were estimated on the basis of the three highest and three lowest values during the reference period, respectively. For the total catch trend and $CPUE_{LMGN}$ trend PIs, upper and lower RPs were determined based on the greatest rate of change (±) over four consecutive years during the reference period.

1.5 Previous stock assessments

Commercial Fishery

<u>Lakes and Coorong Fishery</u>

Previous assessments of the LCF for Black Bream include a stock assessment report in 2008 (Ferguson and Ye 2008) and annual fishery statistics reports since 2006 (e.g. Earl 2015). Key points from the report by Ferguson and Ye (2008) were:

- The total catch of 4.5 t in 2006/07 was among the lowest on record.
- $CPUE_{LMGN}$ increased to an historic peak of 30 kg.fisher day^{-1} in 2006/07.
- Three of the four fishery PIs for 2006/07 were within the range of associated RPs. The PI for $CPUE_{LMGN}$ breached the upper RP.
- Annual age structures had few individuals older than 9 years. Older year classes may be absent due to a combination of fishing/natural mortality and poor recruitment.
- At the conclusion of 2006/07, the Black Bream resource in the Coorong estuary was in a weakened state as indicated by trends in catch and effort.

Recreational Fishery

Estimates of recreational catch for Black Bream in South Australia are available for three years: 2000/01, 2007/08 and 2013/14. In 2000/01, the estimated recreational harvest of 31.9 t accounted for 80% of the State-wide combined commercial and recreational harvest (Jones and Doonan 2005). In 2007/08, the estimated recreational harvest declined to 5.8 t (Jones 2009). However, few fishers from the Coorong were surveyed (K. Jones, PIRSA, pers. comm.). The estimated harvest of Black Bream by recreational fishers in 2013/14 was 4.97 t, which represented 60% of the total combined commercial and recreational catch in South Australia (Giri and Hall 2015). The proportion of the recreational harvest taken from the Coorong estuary is not known.

1.6 Biology of Black Bream

Taxonomy and Distribution

Black Bream (*Acanthopagrus butcheri;* Munro 1949) is a member of the family Sparidae. Six sparid species occur in Australia, with five belonging to the genus *Acanthopagrus*, and one to the genus *Rhabdosagrus* (Munro 1949).

Black Bream is endemic to southern Australia, where it occurs in coastal waters from Myall Lakes in New South Wales to Shark Bay in Western Australia, and around Tasmania (Rowland 1984; Gomon et al. 2008). Throughout its distribution, Black Bream are common in estuaries, coastal lakes and the lower reaches of rivers, where it supports commercial and recreational fisheries, the largest of which operates in the Gippsland Lakes, Victoria (Rowland 1984; Gomon et al. 2008; Kemp et al. 2013). In South Australia, Black Bream are abundant in the Onkaparinga River, Port River/ Barker Inlet system and the rivers of Kangaroo Island (Scott et al. 1974; Jones et al. 1996; Norriss et al. 2002). It is also common in the intertidal areas of Gulf St. Vincent and Spencer Gulf, and in the Coorong estuary.

Black Bream is thought to be the only truly estuarine-dependent sparid and can tolerate a wide range of salinities and other physical conditions (Hindell et al. 2008). In the Blackwood River estuary, Western Australia, they were found in habitats with salinity, temperature and dissolved oxygen levels ranging from 0.3 to 36.8 ppt, 9.5 to 25.5 ^{o}C, and 5.2 to 8.6 mg/l, respectively (Lenanton 1997). In the Coorong estuary, Black Bream have been observed in salinities up to 60 ppt (McNeil et al. 2013). However, in most estuaries Black Bream are most abundant in areas where salinities range from 15 to 25 ppt (Hindell et al. 2008).

Stock structure

Numerous studies have confirmed the status of Black Bream as an 'estuarine resident', with limited evidence of large-scale migrations between estuaries (Hoeksema et al. 2006a). Butcher and Ling (1962) tagged and released 990 fish within the Gippsland Lakes system, Victoria. These authors described the migratory behaviour of the species as "very local in character", with minimal movement out of the system and concluded that the Gippsland Lakes population is likely to be a distinct stock. In a later study, acoustic telemetry was used to examine the movements of adult Black Bream throughout the Gippsland Lakes (Hindell et al. 2008). That study demonstrated the ability of Black Bream to undertake regular sub-daily migrations of 10+ km. However, the results also indicated little or no emigration from the lakes system, supporting the notion that the Gippsland Lakes population is likely to be a distinct stock.

In Western Australia, Black Bream rarely leave estuaries unless flushed out by floodwaters (Lenanton 1977; Holt 1978 in Norriss 2002). However, a tagging program in New South Wales identified limited coastal movement (Dunstan 1965). In South Australia, 1,383 Black Bream were tagged and released within the Coorong in 1982/83 (Hall 1984). All recaptures (7.2%) were reported within the Coorong (Hall 1984). Hall (1984) also suggested that individuals may also move between estuaries, but this was based on an anecdotal report of a single recaptured fish.

In addition, Gillanders et al. (2015) used otolith chemistry data to identify migratory and resident contingents of Black Bream within the Coorong population. Overall, 63% of fish sampled were estuary residents, with the remainder categorised as migratory. However, it is unknown if the movements of migratory fish were between the estuary and marine environment or between areas of contrasting salinity within the Coorong.

Genetic studies were conducted in Victoria and Western Australia (Farrington et al. 2000; Burridge et al. 2004). An investigation of allozyme variation at 32 loci (n=6 samples) of Black Bream in Victoria was consistent with the existence of a single panmictic population in this region (Farrington et al. 2000). This implied that dispersal between estuaries in Victoria is more extensive than was shown by tagging studies (Farrington et al. 2000). However, a later study concluded that gene flow occurred mostly between adjacent estuaries in south-eastern Australia and suggested that management of Black Bream should be conducted at the scale of individual or geographically proximate estuaries (Burridge et al. 2004). In south-western Australia, high levels of genetic divergence were reported among populations from nine sites representing permanently open and intermittently closed estuaries (Chaplin et al. 1998). This suggests that estuarine populations in this region should be managed as distinct unit stocks.

Whilst genetic information on Black Bream in South Australia is not available, the synthesis above suggests that the population in the Coorong estuary should be managed as a single biological stock that is dependent on localised spawning and recruitment for replenishment.

Size/age at maturity

The estimated size at maturity (SAM_{50}; i.e. the size at which 50% of the population is sexually mature) for male and female Black Bream in the Coorong estuary is 289 mm TL for females and 340 mm TL for males (Cheshire et al. 2013). These estimates were based on samples of Black Bream from commercial catches taken during a period of severe drought. When compared to other populations of Black Bream, individuals in the Coorong reached maturity at a larger size. SAM_{50} for females from the Swan/Moore Rivers and Walpole/Nornalup area in Western Australia was 176 mm TL and 226 mm TL, respectively, while males generally matured at a smaller size than females (i.e. 145 – 191 mm TL) (Sarre and Potter 1999).

Estimates of the age at maturity were provided by Sarre and Potter (1999) for several populations in Western Australia and ranged between 1.9 – 4.3 years. The age at maturity for Black Bream from the Onkaparinga estuary, South Australia, was 3+ years, although the method used to estimate the age is unknown (Harbison 1973). Estimates of age at maturity are not available for the Coorong population.

Reproductive Biology

For male and female Black Bream in the Coorong, reproductive development peaks from August to November, which is indicative of a spring spawning season (Cheshire et al. 2013). Black Bream in the Onkaparinga estuary, South Australia, conform to a similar temporal pattern of gonad development with peak spawning activity during October (Harbison 1973 in Norriss 2002). For Western Australian populations, reproductive development commenced in late September with spent gonads first observed in January (Lenanton 1977) and high mean monthly gonadosomatic indices (GSIs) from September to December and a peak in October (Sarre and Potter 1999).

Black Bream is a multiple batch spawner, with new batches of eggs forming continuously throughout the spawning season, i.e. indeterminate fecundity (Cashmore et al. 1998; Sarre and Potter 1999). Batch fecundity increases with fish TL (Coutin et al. 1997 in Norriss et al. 2002).

Freshwater flow rates restricted Black Bream spawning in the estuaries of the Hopkins and Glenelg Rivers, Victoria, (Sherwood and Backhouse 1982 in Norriss et al. 2002). It was suggested that Black Bream move downstream with the winter freshwater inflow then follow the salt wedge as it advances upstream during spring and summer. By maximising the time spent in favourable salinities, dissolved oxygen concentration and suitable habitat, spawning may be stimulated and extended. These results were supported by Newton (1996) who found that the eggs of Black Bream were restricted to the middle and upper reaches of the river during the post-flood period and re-formation of the salt wedge between November and January.

Nicholson et al. (2008) compared the dispersion and abundance of Black Bream eggs and yolk-sac larvae between two rivers in south-western Victoria. The riverine flow into the Glenelg River estuary was around eight times that into the Hopkins River estuary (Nicholson et al. 2008). Eggs occurred in a wide range of dissolved oxygen levels but yolk-sac larvae were less common at the lowest levels. Egg mortality was higher in the Hopkins than the Glenelg, which may be associated with the hypoxic conditions characteristic of low-flow conditions (Nicholson et al. 2008). These results have significant implications for populations of Black Bream with respect to climate change that is predicted to lead to drier conditions in south-eastern Australia, potentially increasing stratification and subsequent hypoxic zones in estuaries (Nicholson et al. 2008).

Recruitment

Natural variability in the environment has long been recognised as a key driver of spawning success for Black Bream. In the Hammersley and Culham Inlets in south-western Australia, high recruitment and successful year classes were reported after periods of increased rainfall and subsequent flows (Chapman 1995 in Norriss et al. 1998). An age-based study in Western Australia showed that the population in Stokes Inlet bred successfully in all but one year between 1992 and 2003, and that annual recruitment of juveniles was highest when moderate flows were recorded in the months preceding and during the spawning period (Heoksema et al. 2006). In contrast, year class strength in the Gippsland Lakes was highly variable with weaker year classes coinciding with high river flows and below average temperatures, while dominant year classes resulted from spawning during relatively dry springs (Hobday and Moran 1983).

An environment-recruitment model, based on age structures, was developed for Black Bream in the Gippsland Lakes (Walker et al. 1998). Results of that model suggested that temperatures during spring, was an important factor in year class strength. Nicholson and Gunthorpe (2006) reported that unfavorable environmental conditions over consecutive years in the Gippsland Lakes contributed to successive years of poor recruitment which ultimately resulted in several large gaps in year classes.

Analysis of the age structure of Black Bream from several Victorian estuaries showed that recruitment was highly variable and episodic (Jenkins et al. 2010). However, the timing of strong and weak year classes varied among estuaries. That study found that water column stratification and freshwater flow are key environmental variables that influence the recruitment of Black Bream in the Gippsland Lakes and that variation in recruitment between estuaries relates to differences in freshwater flow regimes and salinity structure. In a separate study, Jenkins et al. (2015) concluded that recruitment dynamics may be more complex with strong year classes apparently resulting from a two-phase mechanism where low freshwater flow occurs over the spawning season (i.e. spring/summer), followed by higher flows after the spawning season during the first year of life.

Newton (1996) reported that aligning the timing of spawning with inflows and subsequent higher food supply for larval fish was an important part of the spawning strategy of Black Bream and may be a critical factor for spawning success. Appropriately timed freshwater flow releases into estuaries may form suitable salt wedge or halocline habitat conditions that, coupled with increased primary productivity and zooplankton abundance (North et al. 2005), provide favourable conditions for early life stages and enhanced recruitment (Williams et al. 2012).

Age and growth

The demography of Black Bream is better understood since a methodology was developed to determine the age of juvenile and adult fish (Morison et al. 1998). Sectioned sagittae (i.e. the largest pair of otoliths) of Black Bream display an alternating sequence of opaque and translucent zones. Furthermore, results from marginal increment analysis indicated that the incremental structure in the otolith sections was formed annually, and therefore, can be interpreted in terms of fish age in years.

Numerous studies have provided age and growth information for Black Bream in Australia (Table 2). Morison et al. (1998) sampled fish from the Gippsland Lakes in Victoria, between 1993 and 1996, to estimate growth based on age estimates from structures visible in sectioned otoliths. The ageing technique was validated by following the annual progression of age classes over a four year period. The results of the study by Morison et al. (1998) indicated that Black Bream grew relatively slowly and reached a maximum age of at least 29 years.

Growth has been described for Black Bream populations in Victoria and Western Australia. Estimates of size-at-age for each population are shown in Table 2. Overall, growth of male and female Black Bream is initially rapid and similar for the first 1 – 2 years of life, after which the rate of growth declines, with females growing faster and attaining a larger size than males.

Growth of Black Bream in Victoria (Morison et al. 1998) and Western Australia (Sarre and Potter 1999; Hoeksema et al. 2006) vary greatly between estuaries. In Western Australia, a study for three estuaries showed marked differences in growth, particularly during the early years of life (Hoeksema et al. 2006). The differences in growth were independent of diet, although the lowest growth rate was recorded from the estuary with the highest population density, suggesting a possible density-dependent effect. Anecdotal evidence from populations in estuaries on Kangaroo Island, South Australia, supports the hypothesis of an inverse relationship between population density and growth (Ferguson and Ye 2008).

Table 2. Comparison of total length-at-age (mm) between Black Bream populations in southern Australia.

Source	Location	Sex	Estimated age (years)								
			1	**2**	**3**	**4**	**5**	**10**	**15**	**20**	**25**
Morison et al. 1998	Gippsland Lakes, VIC	F	131	150	168	185	201	274	334	383	423
		M	131	153	174	193	211	281	328	359	380
Sarre and Potter 1999	Lake Clifton, WA	M	183	268	329	374	407	476	490	492	493
	Swan estuary, WA	F	138	228	295	344	381	462	480	484	485
		M	175	252	308	350	380	446	460	463	464
	Moore River, WA	F	76	120	160	195	227	343	410	448	471
		M	70	107	141	171	198	295	352	385	403
	Nornalup Walpole, WA	F	90	137	177	211	239	331	373	391	399
		M	84	136	178	212	239	316	343	352	356
	Wellstead, WA	F	104	174	228	270	303	385	409	416	418
		M	102	169	219	258	287	357	375	380	381
Coutin et al. 1997	Lake Tyers, VIC	F, M	195	212	230	246	262	337	400	455	503
	Gippsland Lakes, VIC	F, M	119	143	165	185	203	274	319	348	366

Diet

Black Bream is an opportunistic carnivore that feeds on small fish (including gobies, hardyheads, mudskippers), crustaceans (including crabs, prawns, amphipods and copepods), algae (including *Ruppia megacarpa*, *Ulva* spp., *Enteromorpha* spp.), worms, insects and molluscs (including bivalves and gastropods) (Wallace 1976; Holt 1978; Sarre 1999; Sarre et al. 2000; Hoeksema et al. 2006). Conspecific predation has also been detected in several estuaries in southwestern Australia (Griffiths 1997) and South Australia (Ostle unpublished data, cited in Norriss et al. 2002), with small Black Bream found in the stomachs of larger adult fish.

The composition of the diet varies spatially and with fish size. Sarre et al. (2000) determined the dietary compositions for Black Bream from five southwestern Australian estuaries using gut contents analysis. Although the fish from each estuary always consumed amphipods, bivalve molluscs, polychaetes and macrophytes, the overall dietary composition for each of the five populations differed significantly from each other. The diet also varied amongst habitats within the same estuary, which likely related to variation in prey availability. Furthermore, these authors also indicated that Black Bream preferred to feed on prey taxa that are found on and/or above the substratum. Clear ontogenetic changes were also evident in each of the five estuaries, which likely related to an increase in the mouth size and ability to handle and crush prey, and the difference habitats occupied by juvenile and adult fish.

2. COMMERCIAL FISHERY STATISTICS

2.1 Introduction

Two commercial sectors harvest Black Bream in South Australia: the Lakes and Coorong Fishery (LCF) and the Marine Scalefish Fishery (MSF). This section of the report documents the historical trends in fishery production for Black Bream in South Australia compiled from several historical sources, but focusses primarily on commercial fishery-dependent data reported by the LCF. It provides analyses of all commercial data for the species from the LCF and assesses spatial and temporal trends in commercial catch, effort and catch per unit of effort (CPUE) from 1984/85 to 2014/15. The same dataset was used to assess the recent performance of the LCF for Black Bream against a series of prescribed limit reference points (Section 4), and along with key population demographic information (Chapter 3) formed the basis of a weight-of-evidence assessment of stock status for Black Bream in the Coorong estuary.

Freshwater inflow from the Murray River is an important factor that affects fishery performance for key species in the LCF (Pierce and Doonan 1999; Ferguson et al. 2013). This section of the report also examines the influence of inflows on the temporal and spatial patterns of commercial catch for Black Bream in the LCF.

2.2 Methods

Compilation of fishery data

Estimates of annual commercial catch of Black Bream in South Australia were reconstructed from several historical sources dating back to 1960/61 (i.e. July 1960 to 30 June 1961). From that year until 1972/73, the only data available were estimates of the total weight of Black Bream processed annually at South Australia's main fish market, as presented in the Official Year Books of South Australia (Aitchison 1966; 1969; 1973; 1974). During that period, it was not compulsory for fishers to transport their entire catch to this market each day, thus these data are only indicative of the minimum State-wide commercial catch at that time. From 1973/74 to 1983/84, total catch data for Black Bream were recorded by commercial fishers across South Australia and reported in annual reports of the South Australian Fishing Industry Council Inc. Estimates of the proportions of annual State-wide catches taken in the Coorong were only available from 1976/77 to 1983/84.

Since 1 July 1984, commercial catch and effort data have been collected by fishers in the LCF completing a research logbook (Inland Waters Catch and Effort return) for each fishing day. Daily catch and effort data include catch (kg), effort (days, fisher days, number of nets) for targeted and non-targeted species, and fishing location, which is reported against reporting areas (Figure 1). These data are submitted to SARDI Aquatic Sciences on a monthly basis and maintained in a catch and effort database as part of the Lakes and Coorong Fishery Information System. Similar data collection and handling processes are used to manage the daily catch and effort data collected by fishers in the State-wide MSF (see Fowler et al. 2014).

Analysis of fishery data

Estimates of annual commercial catch of Black Bream in South Australia from several sources were collated by financial year from 1960/61 to 2014/15 to describe the long-term trends in fishery production for Black Bream in South Australia.

All subsequent data analyses were undertaken on the fishery statistics extracted from the Lakes and Coorong Fishery Information System, for each financial year from 1984/85 to 2014/15. These data were used to assess: (i) inter-annual patterns in total catch by gear type; (ii) intra-annual patterns in total catch; and (iii) spatial trends in total catch. Trends in targeted catch, effort and mean annual CPUE (± S.E) for the dominant gear type (i.e. large mesh gill nets) were also assessed. For some years, the presentation of data was limited by constraints of confidentiality (i.e. the data could only be presented for aggregated data from five or more fishers). Nonetheless, the time series of fishery data presented for the LCF constitutes the most fundamental dataset available for assessing the status of the fishery for Black Bream.

Relationship between freshwater inflow and catch data

Estimates of mean monthly freshwater inflow to the Coorong estuary were obtained from the regression-based Murray hydrological model (MSM-BIGMOD, Murray–Darling Basin Authority) from 1970/71 to 2014/15. All inflow data were aggregated into financial years to align with the catch and effort data. The relationship between freshwater inflow and the proportion of the total catch taken from areas south of Mark Point (Figure 1) from 1984/85 to 2014/15 were examined using linear regression (α=0.05). Additional regression analysis was done to examine the relationship between inflow and total catch with a lag of three years (i.e. the age of recruitment to the fishery). All statistical analyses were done using the statistical package OriginPr0 2015 for Windows (OriginLab Corporation., Northampton, Massachusetts, USA).

2.3 Results

Total annual State-wide catches (1960/61 – 2014/15)

Between 1960/61 and 1968/69, estimates of total annual catch of Black Bream taken from South Australian waters ranged from 22 t in 1964/65 to 59 t in 1967/68 (Figure 2). From that time, catches declined and ranged from 4 – 23 $t.yr^{-1}$ until 1977/78, before increasing to ~70 $t.yr^{-1}$ in several years in the early 1980s. Catches declined to 3 t in 1992/93 and subsequently remained low in the remaining years of the 1990s and then the 2000s. These catches ranged from 0.9 – 12.1 $t.yr^{-1}$, but were <5 t in most years. In 2014/15, total catch was 9.4 t.

Information on the specific location from where commercial catches were taken was not available between 1960/61 and 1975/76. However, catches taken by the LCF from the Coorong estuary accounted for approximately 95% of the State's annual catch from 1976/77 to 1995/96. This suggests that most of the catch taken prior to 1975/76 was also likely to have been taken from the Coorong estuary (Figure 2). Since the mid-1990s, contributions from the LCF to the total annual State-wide catch have decreased slightly but were >70% in most years, with the remaining taken by the MSF. An exception was 2014/15, when ~72% of the annual catch was taken by the MSF.

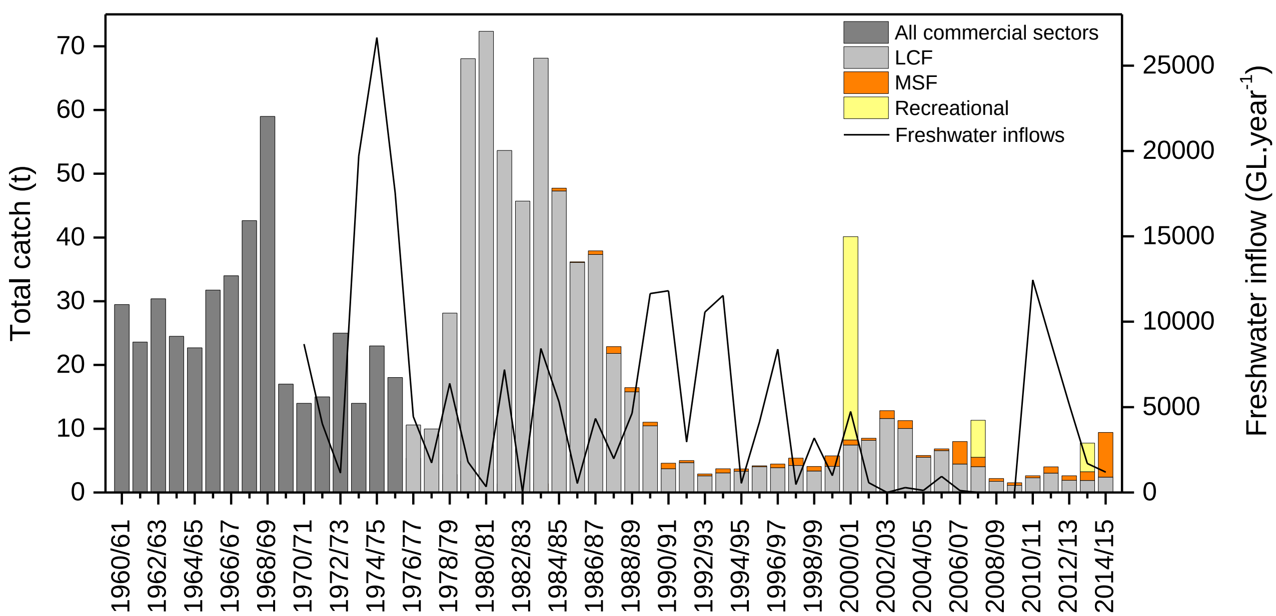

Figure 2. Estimates of total annual catch of Black Bream (bars) in South Australia from 1960/61 to 2014/15, by fishing sector. Information on the sector by which catches were taken was not available between 1960/61 to 1975/76. Estimates of annual freshwater inflows to the Coorong estuary (line) from 1970/71 to 2014/15 are also shown.

Lakes and Coorong Fishery (1984/85 – 2014/15)

Total annual catches

Estimates of total annual catch for the LCF peaked at 47.3 t in 1984/85 (Figure 3). Catch declined to 3.7 t in 1990/91 and remained low to 1999/00. From then, it increased to a small peak of 11.6 t in 2002/03, before progressively declining to an historic low of 1.1 t in 2009/10. In 2014/15, the total catch of 2.4 t was among the lowest on record.

The dominant gear type used to catch Black Bream was the large mesh gill net (115 – 150 mm mesh) which contributed an average of 91% (landed weight, ± 2% S. E.) of the annual catch from 1984/85 to 2014/15 (Figure 3). Most of the remaining catch in each year was taken using haul nets, with smaller catches taken using small mesh gill nets (50 – 64 mm mesh) and ring nets.

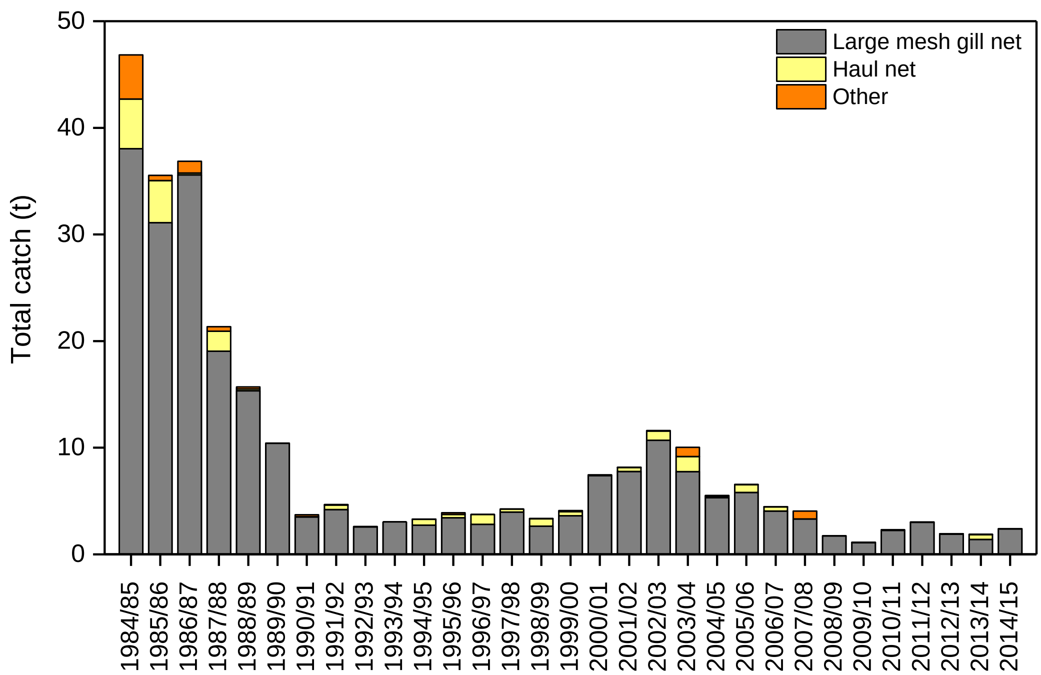

Figure 3. Annual catches of Black Bream from the LCF from 1984/85 to 2014/15, by gear type.

Intra-annual trends in total catch

Catches of Black Bream from 1984/85 to 2014/15 were seasonal with, on average, approximately 60% of the annual catch taken from August to November (Figure 4). Catches were highest in September (20%) and October (18%) and lowest from February to May.

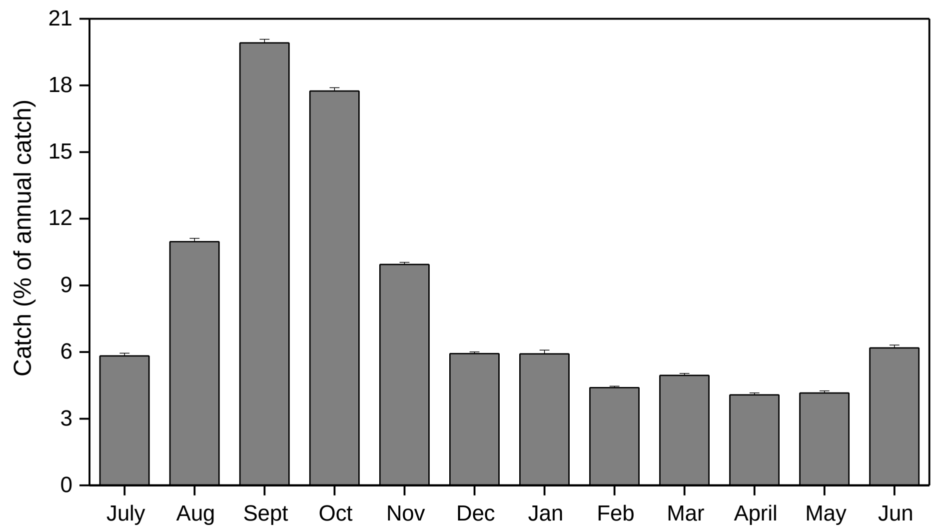

Figure 4. Average monthly catches (± S. E.) of Black Bream from the LCF from 1984/85 to 2014/15, expressed as a percentage of annual catch.

Targeted catch, effort and CPUE - large mesh gill nets

Inter-annual trends in targeted catch using large mesh gill nets (Figure 5A) generally followed those of total catch (Figure 3). The highest targeted catch was 30.6 t in 1984/85. This declined to 0.6 t in 1990/91 and was <3 t.yr^{-1} until 2013/14, with the exception of 2002/03 (5.9 t), 2003/04 (4.1 t) and 2005/06 (3.7 t). The contribution of targeted catches taken using large mesh gill nets to total catches varied substantially among years. In 1984/85 and 1985/86 (i.e. the peak catch years), targeted catch accounted for 65% and 70% of the total catch, respectively (Figure 5A). While from 1990/91 to 2001/02 targeted catch contributed to < 30% of the total catch in most years. From 2002/03 to 2007/08 the contribution increased to 41–57%. Targeted catch, effort and CPUE data for 2014/15 are confidential.

The trend in targeted effort for large mesh gill nets (fisher days) was similar to that for targeted catch with a peak (1,372 fisher days) in 1985/86 and a decline through the late 1980s to a low (18 fisher days) in 1991/92 (Figure 5B). From then, effort remained relatively low until 2002/03 when it increased to 278 fisher days and remained above 100 fisher days until 2005/06. Effort then declined and was 11 fisher days in 2013/14. Annual effort in fisher days was linearly related to effort in net-days (linear regression, LR: $r^2 = 0.96$, $F_{1,29} = 732.9$, $p < 0.001$).

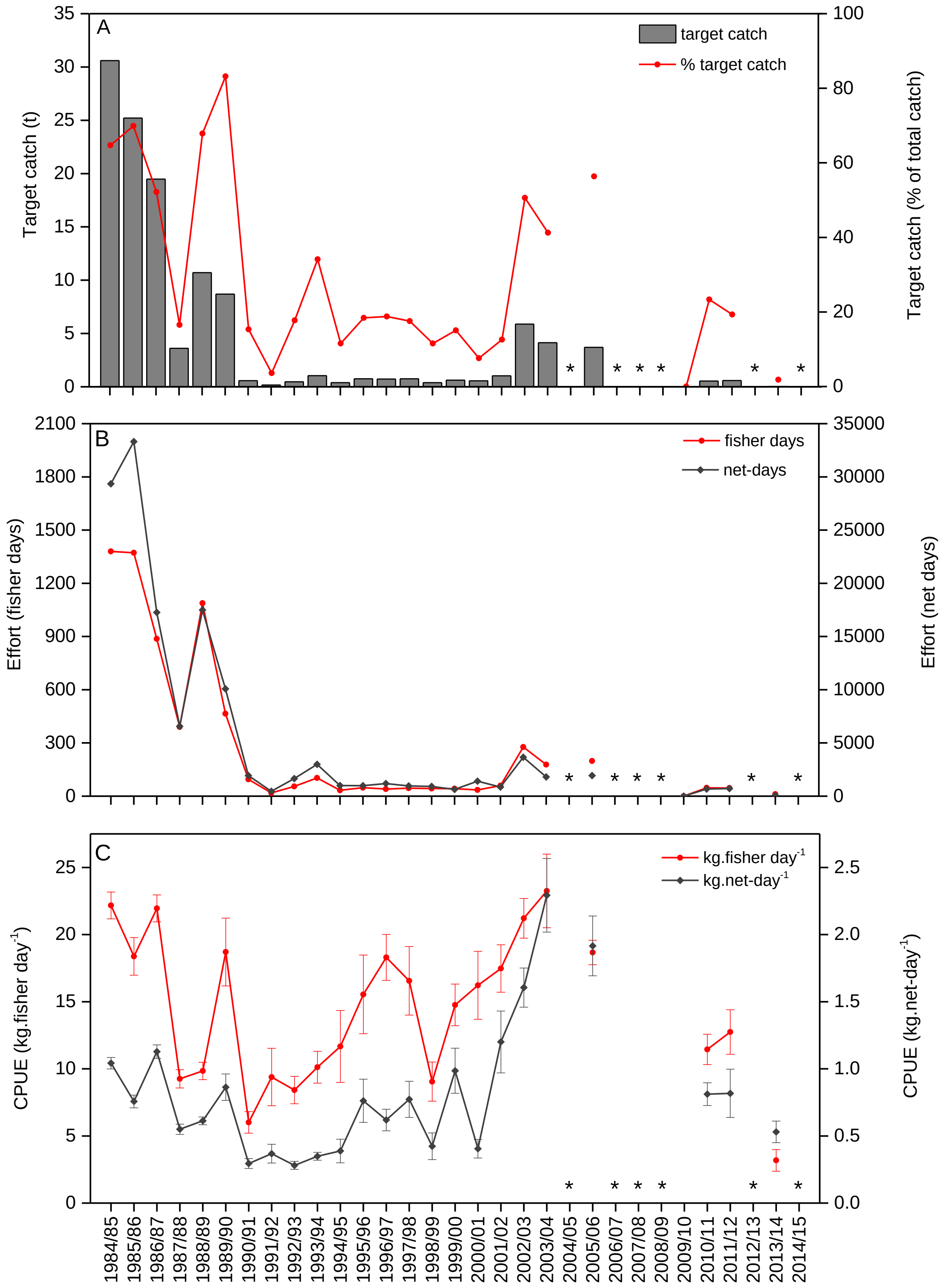

Figure 5. Annual targeted catch and effort for Black Bream using large mesh gill nets. (A) Targeted catch shown in tonnes, and as a percentage of total catch. (B) Comparison of two measures of targeted effort for large mesh gill nets, i.e. fisher days, net-days. (C) Comparison of two measures of $CPUE_{LMGN}$ (± S. E.). Estimates of $CPUE_{LMGN}$ were not available for 2009/10, as no targeted effort was reported for Black Bream. (*) represents confidential data.

Mean annual CPUE for large mesh gill nets ($CPUE_{LMGN}$; kg.fisher day^{-1}) increased from a low of 6 kg.fisher day^{-1} in 1990/91 to 23 kg.fisher day^{-1} in 2003/04 (Figure 5C). From then, $CPUE_{LMGN}$ declined to 3.2 kg.fisher day^{-1} in 2013/14, which is the lowest on record. Temporal patterns in $CPUE_{LMGN}$ (kg.net-day^{-1}) were similar to those of $CPUE_{LMGN}$ (kg.fisher day^{-1}) from 1984/85 – 2013/14, and the two measures of relative abundance were linearly related (LR: r^2 = 0.88, $F_{1,29}$ = 197.6, p <0.001).

Spatial distribution of catches

Catch and effort data in the LCF is reported against commercial reporting areas across Lakes Alexandrina and Albert, the Coorong estuary and the adjacent marine environment (Figure 1). Catches from some areas were pooled to provide an indication of their cumulative contribution to the catch, as they were reported by less than five licence holders in some years.

From 1984/85 to 1993/94, catches were dominated by the contributions from areas located between Mark Point and Parnka Point (i.e. Areas 9 – 11; Figure 6). From then until 2004/05, the contribution of catches from areas adjacent the barrage network (i.e. Areas 6 – 8) increased, while that from Areas 9 – 11 declined. Between 2004/05 and 2009/10, >98% of catches were taken from Areas 6 – 8. In 2014/15, 88% of the total catch was taken from Areas 6 – 8.

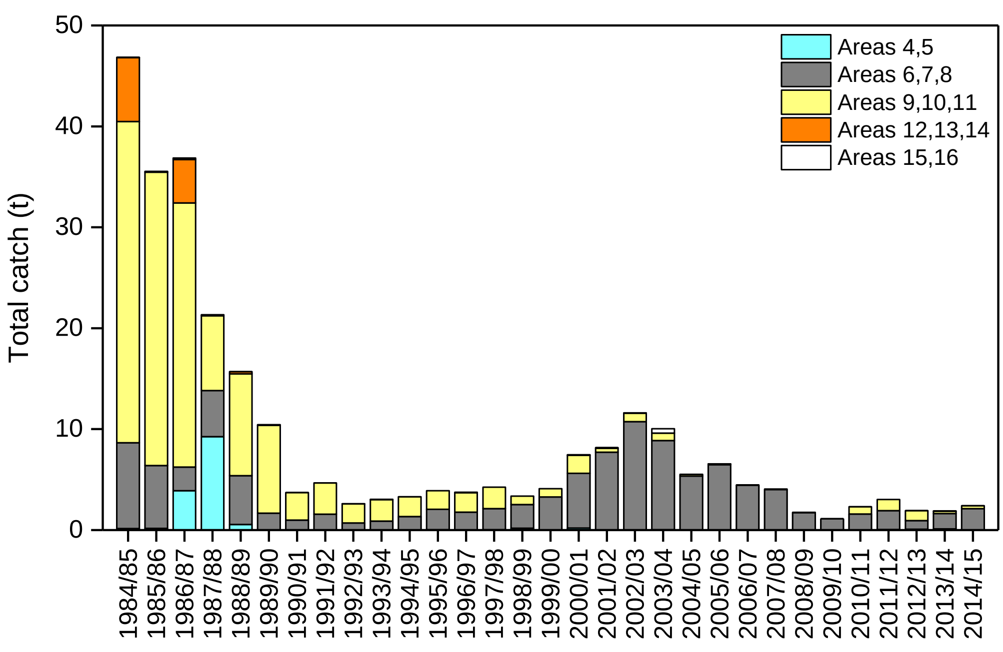

Figure 6. Annual catches of Black Bream from LCF commercial reporting areas from 1984/85 to 2014/15.

Prior to 1994/95, catches from south of Mark Point contributed between 59% and 93% of the total catch (Figure 7). From then it declined, while that from north of Mark Point increased. From 2001/02, the area north of Mark Point contributed > 92% of the total catch. Trends in catch were influenced mostly by reporting Area 6 which contributed to 58% of the total catch in 2014/15.

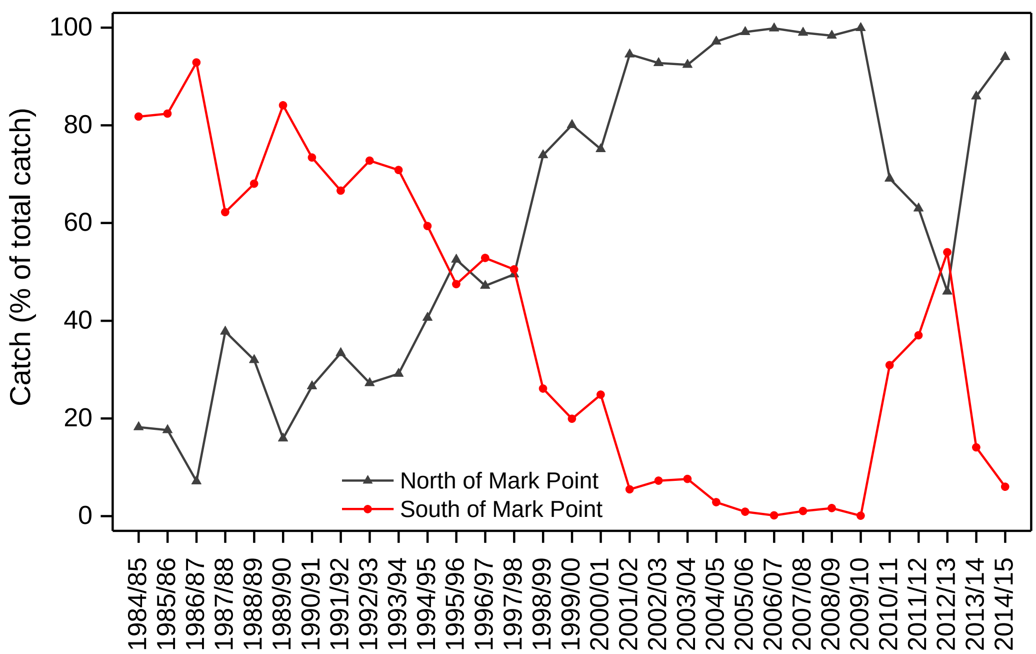

Figure 7. Contribution (%) of catches of Black Bream taken from areas north and south of Mark Point to the total catch for the LCF between 1984/85 and 2014/15.

Relationship between freshwater inflow and fishery production

Since 1970/71, annual freshwater inflows to the Coorong have been highly variable (Figure 8). Inflow was highest in the mid-1970s when it averaged approximately 22,000 GL.yr^{-1}. From then, it did not exceed 12,000 GL.yr^{-1} until 2010/11. Inflows increased to >10,500 GL.yr^{-1} in several years during the 1990s, before declining to <1,000 GL in 2001/02. From that year to 2009/10, severe drought in the Murray-Darling Basin contributed to a prolonged period of low flow, including no flow in 2002/03 and from 2007/08 to 2009/10. A dredging program commenced in 2002 to keep the mouth of the estuary open. Dredging ceased in 2010/11 after a major rainfall event in the Murray–Darling Basin resulted in large-scale inflows to the Coorong, which restored natural connection between the Coorong and Southern Ocean. Due to reduced flows in 2013/14 and 2014/15, dredging of the Murray Mouth recommenced in January 2015.

There was no detectable relationship between freshwater inflow and catches with a lag of three years (i.e. the age of recruitment to the fishery; linear regression: r^2=0.01, $F_{1,28}$=0.146, P=0.704). However, inflows explained 32% of variability in the contribution of catches from south of Mark Point made to the total catch (LR: r^2=0.32, $F_{1,28}$=13.148, P=0.001; Figure 9). This positive relationship suggests that the available fishing grounds were reduced during periods of low inflow. The spatial distribution of catches over time further suggests that the population in the Coorong contracted northwards to areas adjacent the barrages during the recent drought (2000s).

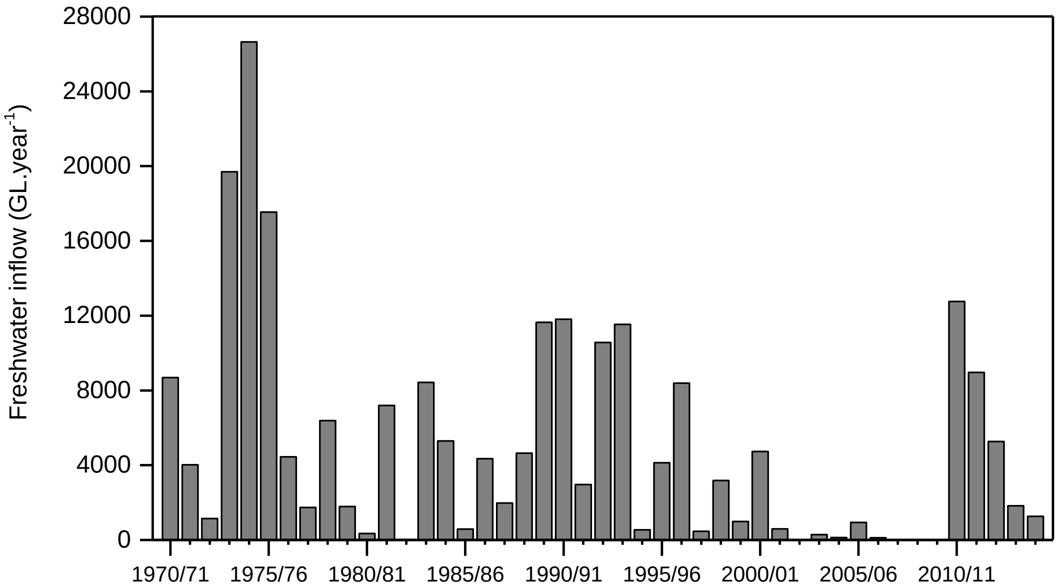

Figure 8. Annual freshwater inflows to the Coorong estuary from 1970/71 to 2014/15. Flow estimates were obtained from the regression based Murray hydrological model (MSM-BIGMOD, Murray–Darling Basin Authority).

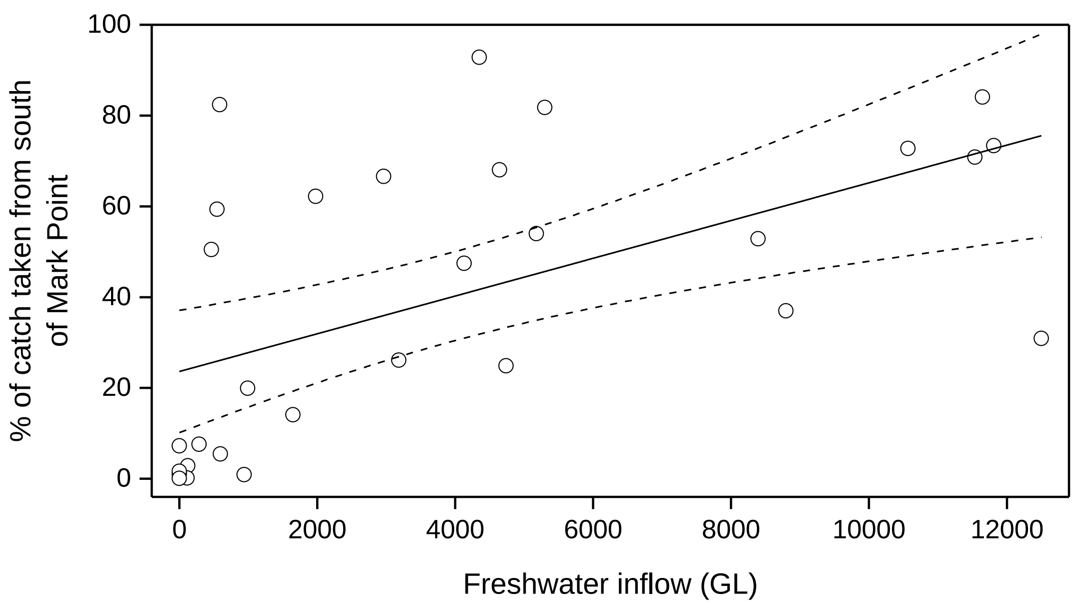

Figure 9. The relationship between freshwater inflow to the Coorong estuary and the proportion of the total catch taken from areas south of Mark Point from 1984/85 to 2014/15. Dashed lines represent 95% confidence intervals.

2.4 Discussion

Historical estimates of annual commercial catch dating back to the 1960s were compiled and examined to provide a long-term chronology of the variability in the biomass of Black Bream harvested by commercial fisheries in South Australia. Although information on the location from which catches were taken was not available prior to 1975/76, catches of Black Bream taken by the LCF from the Coorong estuary accounted for approximately 95% of the State's annual catches between 1976/77 and 2014/15. This suggests that most of the catch taken between 1960/61 and 1975/76 were also likely to have been taken from the Coorong by the LCF.

Estimates of total annual catch for the LCF peaked at 72 t in the early 1980s, declined steeply in the late 1980s and remained at historically low levels through the 1990s. Catch increased slightly through the early 2000s, suggesting an increase in population abundance, before it declined to ~1 t in 2008/09. In 2014/15, the total catch of 2.4 t was among the lowest on record. The historically low catches in most years over the past two decades have been associated with low fishing effort. Given the relatively high market value of Black Bream (EconSearch 2014), the lack of targeted fishing effort the species since the 1980s likely relates to low fish abundance rather than economic factors.

Uncertainty surrounds the reliability of estimates of commercial CPUE as an indicator of relative abundance for Black Bream in the Coorong estuary. This is because spatial contraction of the fishery for Black Bream, particularly during drought years, may affect their catchability and thus confound interpretation of CPUE as an indicator of population abundance. Therefore, given the high market value of Black Bream (EconSearch 2014), we consider catch a more appropriate indicator of abundance for the species in the Coorong.

In summary, analyses of fishery-dependent catch and effort data for the LCF provided evidence that the Black Bream biomass in the Coorong estuary was low at the conclusion of 2014/15.

3. SIZE AND AGE STRUCTURES

3.1 Introduction

Fish population dynamics are driven by a range of demographic processes (e.g. recruitment, mortality, growth, egg production) that are most effectively measured using fish age as a time reference (Campana 2001). The most robust method for providing estimates of fish age is through the interpretation of the incremental structure in their otoliths (Campana 2001), as they often contain distinct growth increments which are formed periodically throughout their life (Fowler 1995; Campana and Thorrold 2001). As well as helping to understand the dynamics of a fish population, knowledge of its age structure may also help to determine the response of the population to fishing and the environment.

Growth increments in the otoliths of Black Bream are formed annually and provide an indication of age for individual fish (Morison et al. 1998). The objective of this section was to analyse fishery size and age structures for the Black Bream population in the Coorong estuary from 2014/15, to be compared with those determined for previous years and interpreted in terms of the processes that may be affecting fishery performance.

3.2 Methods

Sample collection

Annual sampling of Black Bream from commercial catches was done from 2007/08 to 2014/15 to develop fishery size and age structures. Samples were available from gill net catches (mesh size >115 mm) taken during spring/summer each year by the LCF. On each sampling occasion, fish were randomly sub-sampled from catches and stored for processing.

Laboratory processing

In the laboratory, each fish was measured to the nearest mm. The sagittae, i.e. the largest pair of otoliths, were removed via an incision through the ventral ex-occipital region of the skull. Sagittae were cleaned, dried and stored in labelled plastic bags for processing. Additional biological information, including the sex, the stage of reproductive development and fish weight were recorded for each fish. These data are reported for some years as part of a project funded by The Living Murray Initiative of the Murray–Darling Basin Authority through the South Australian Department of Environment, Water and Natural Resources (Ye et al. 2011).

In the fish ageing laboratory, the left otolith from each fish was prepared using the 'break and burn' method, as described in Ye et al. (2002). The age of individual fish was estimated from counts of opaque zones, which for Black Bream form annually along the ventral axis of the otolith (Morison et al. 1998). All otoliths were read and assigned a confidence rating according to the readability of its internal structure, where a rating of 'one' is poor readability and a rating of 'five' is good readability. Counts of opaque zones for otoliths assigned a rating of 'two' or below were excluded from subsequent analyses, while those assigned a rating of 'three' were re-read by the same reader. If the second reading did not agree with the result from the earlier reading, the sample was excluded from subsequent analyses.

3.3 Results

Age structures

The ages of Black Bream sampled from commercial catches taken in the Coorong estuary ranged from 2 to 32 years (Figure 10). Annual age structures demonstrated several characteristics. Firstly, they comprised mostly fish between 4 and 10 years, while older fish were rare. Furthermore, within any year there were particular age classes that contributed most to the commercial catch. For example, the dominant age class in 2008/09 was 5 year olds, which persisted in 2009/10 and 2010/11 as 6 and 7 year olds, respectively. This variation in age class strength ultimately related to strong and weak recruitment years, which then persisted in the population for numerous and subsequent years.

The dominant mode of 4 year old fish in the age structure for 2007/08 related to spawning in 2003/04 (Figure 10). The 2003/04 year class persisted in the fishery catches as 5, 6 and 7 year olds in 2008/09, 2009/10 and 2010/11, respectively, although their relative contribution varied among years. The 1997/98 year class contributed a relatively high proportion of the annual catches from 2007/08 to 2010/11, but was displaced from 2011/12 onwards. In 2011/12, the age structure comprised a single dominant mode of 5 year old fish from the 2006/07 year class, with a small proportion of fish between 12 and 17 years of age. The 2006/07 year class was the most significant contributor to the catch in 2012/13, 2013/14 and 2014/15, although the age structure for 2013/14 and 2014/15 also comprised a secondary mode of 4 and 5 year olds, respectively, from the 2009/10 year class.

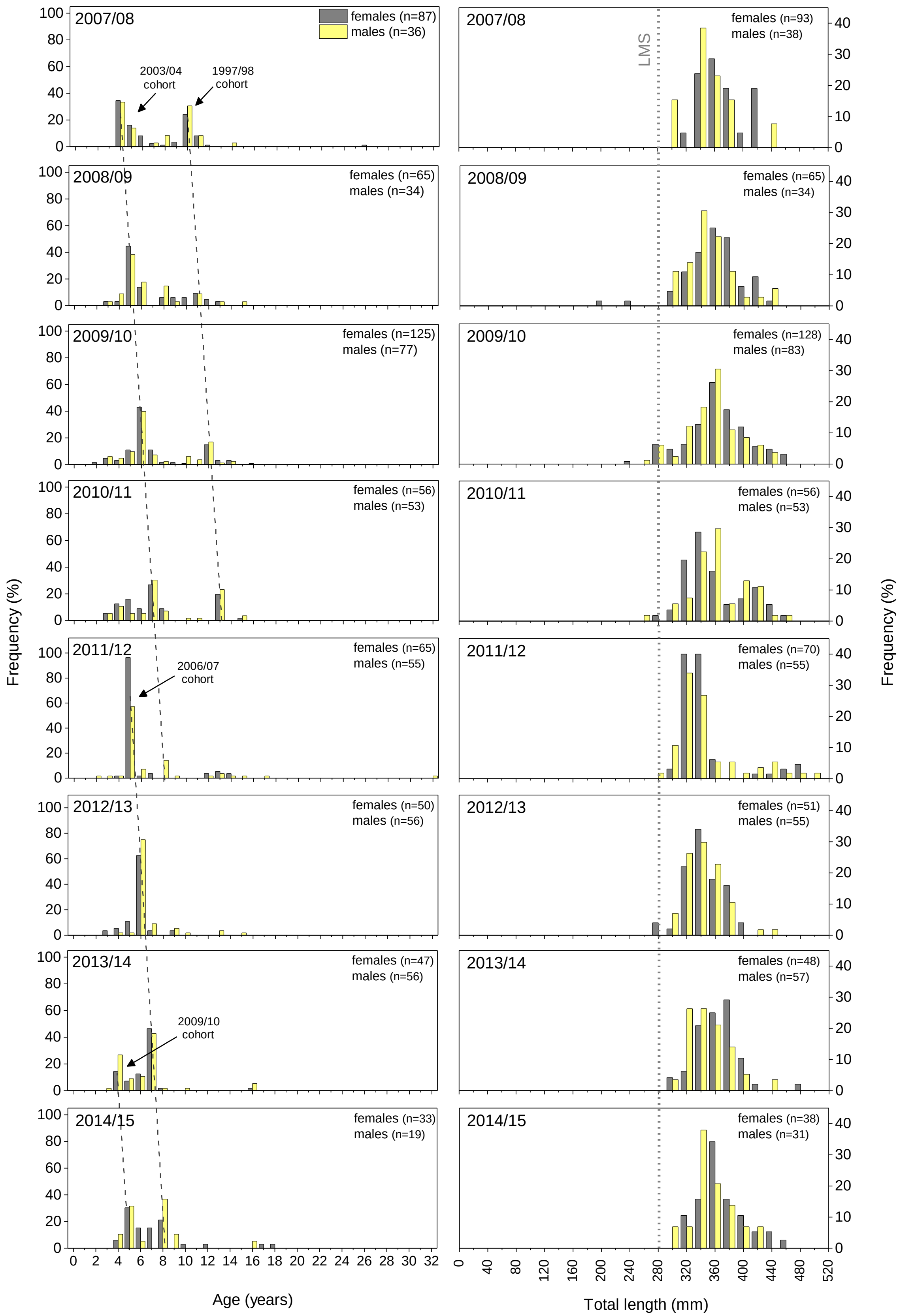

Figure 10. Annual age (left) and size (right) structures for Black Bream from commercial catches from the Coorong estuary from 2007/08 to 2014/15. Grey dashed lines show the progression of cohorts. Vertical grey line indicates LMS of 280 mm TL for Black Bream in South Australia.

Size structures

Size structures did not reflect the distinct modal progression evident in the age structures (Figure 10). From 2007 to 2014 the size distributions were essentially unimodal and mainly involved fish that ranged from 280 mm TL to 400 mm TL, with modal sizes of between 320 mm TL and 360 mm TL. One exception was the bi-modal size distribution in 2010/11 which comprised a large mode at 360 mm TL and smaller mode at 420 mm TL.

3.4 Discussion

Black Bream is a slow-growing, long-lived estuarine resident that relies on the establishment of one, two or several strong year classes to maintain a population (Winemiller and Rose 1992; Ferguson et al. 2013). Annual age structures for the Black Bream population in the Coorong estuary were relatively stable between 2007/08 and 2014/15 and dominated by fish from one or two young age classes. The dominant age classes in each year related to the recruitment and persistence of year classes from spawning in 1997/98, 2003/04, 2006/07 and 2009/10. Whilst these year classes persisted in the age structures for numerous years, they were typically displaced after approximately 11 years. Thus, the majority of the catch in each year involved individuals that were well below the reported maximum age of 32 years (Ye et al. 2015). Nonetheless, the presence of multiple year classes in the age structures indicates that recruitment has occurred in several years since 1997/98.

Similarly, the age structures from 2014/15 were dominated by two relatively young age classes of 5 and 8 year old fish. A few older individuals were evident in the samples, although their contribution to the catch was negligible. The lack of older fish in the age structures may relate to one or a combination of: (i) removal of older/larger fish from fishing; (ii) low recruitment to the adult biomass over recent decades; (iii) emigration of older fish from the estuary to the marine environment; and/or (iv) insufficient sampling/sample sizes. However, given Black Bream complete their lifecycle within estuaries (Norriss et al. 2002), the most likely explanation is that fishing, which removes older and larger individuals (Hilborn and Walters 1992; Planque et al. 2010), has impacted this species over a prolonged period of relatively poor recruitment (Sarre 1999; Ferguson et al. 2013; Ye et al. 2015). While the reported commercial harvest has been historically low in most years since the late 1980s, uncertainty exists around the level of recreational harvest of Black Bream in the Coorong estuary. Future assessments of the size and age characteristics of the Coorong population should seek to include samples from recreational catches.

Several studies have related recruitment success for Black Bream to freshwater flows and associated factors (Newton 1996; Norriss et al. 2002; Nicholson and Gunthorpe 2008; Williams et al. 2012, 2013; Jenkins et al. 2010, 2015). For the Coorong population, the dominant age classes in the annual age structures since 2007/08, related to the recruitment and persistence of year classes that may be linked to freshwater releases during spring in 1997/98, 2003/04 and 2006/07 (Ferguson and Ye 2008; Ye et al. 2015). Notably, none of these freshwater releases were major flow events. This suggests that recruitment of Black Bream in the Coorong may be enhanced by appropriately timed, small-scale inflows (Ye et al. 2015). This is supported by Williams et al. (2012; 2013), who showed that successful spawning and increased larval survival of Black Bream occurred under low-flow conditions in the Gippsland Lakes. Similarly, Jenkins et al. (2015) showed that strong year classes of Black Bream tended to be associated with small-scale freshwater inflows and higher salinity stratification within the estuary.

Although the recent prolonged period of low freshwater inflows to the Coorong during the 2000s is likely to have limited recruitment opportunities for Black Bream, the recruitment of several year classes at irregular intervals (2003/04, 2006/07, 2009/10) during this period indicates that environmental conditions were suitable for successful spawning in several years (Ye et al. 2015). Such periodic recruitment is generally adequate to maintain the populations of long-lived species such as Black Bream (Winemiller and Rose 1992; Ferguson et al. 2013), provided the reproductive capacity of the population (i.e. spawning biomass) is adequate. For the Coorong population, fishery production for this species has remained at a consistent, historically low level since 2008/09 and measurable improvements in adult biomass have not been detected (Section 2). This suggests that the spawning biomass in the Coorong estuary is currently at a low level.

Although this study provided age structures for commercial gill net catches, the samples are likely to accurately represent those of the adult population because the range of sizes was consistent across numerous years, and dominant year classes persisted in samples over multiple years. Nonetheless, a formal sampling program which includes samples from commercial fishery-independent sources (e.g. research survey catches; recreational catches) is needed for a more robust age structure to support stock assessment.

Conclusion and implications for management

This study contributed important demographic information for Black Bream in the Coorong. The current LMS for Black Bream in South Australia is 280 mm TL, which is approximately 4% and 18% less than the SAM_{50} for females and males, respectively (Cheshire et al. 2013). The size structures from commercial catches indicated that the LCF for Black Bream harvests mainly individuals above the SAM_{50}, with only a small proportion of the catch comprising sexually immature fish. An increase in the proportion of immature fish harvested by the fishery would reduce the number of fish recruiting to the spawning biomass of the population in each year. Furthermore, sustained exploitation of mature Black Bream during periods of low recruitment is likely to further reduce the reproductive capacity of the population. There is a need to rebuild the age structures for Black Bream in the Coorong and increase the capacity of the population to produce strong year classes when environmental conditions are favourable for successful reproduction (Ferguson et al. 2013; Ye et al. 2015).

4. PERFORMANCE INDICATORS

4.1 Introduction

The Management Plan for the LCF provides a framework for management (Sloan, 2005). For Black Bream, PIs based on catch and effort data are used to monitor and assess fishery performance. The fishery is assessed by comparing the most recent estimates of these PIs against upper and lower RPs. When a RP is breached, management responses are prescribed. This section provides an overview of the current status of the LCF for Black Bream, based on the PIs and associated RPs in the Management Plan. A new management plan for the fishery is currently being finalised.

4.2 Methods

To assess the status of the LCF for Black Bream, there are four PIs: (i) total catch; (ii) mean annual CPUE for large mesh gill nets ($CPUE_{LMGN}$); (iii) 4-year total catch trend; and (iv) 4-year mean annual $CPUE_{LMGN}$ trend. These were assessed against RPs that were defined on the basis of historical catch and effort data for the reference period from 1984/85 to 2001/02. For the PIs of total catch and CPUE, the upper and lower RPs were based on the three highest and three lowest values during the reference period. For the 4-year trend PIs for total catch and $CPUE_{LMGN}$, the upper and lower RPs were determined based on the greatest rate of change (±) over four consecutive years during the reference period.

4.3 Results

In 2014/15, one of the four PIs for Black Bream was outside the range of the RPs (Table 3; Figure 11). The PI for total catch was 20% below the lower RP. The PIs for total catch trend, $CPUE_{LMGN}$ and $CPUE_{LMGN}$ trend were within the range of their respective upper and lower RPs.

Table 3. Performance indicators and reference points for the LCF for Black Bream in 2014/15. $CPUE_{LMGN}$ data for 2014/15 were confidential, i.e. they were reported by less than five licence holders.

Performance Indicator	Lower reference point	Upper reference point	2014/15 estimate	Within range of reference points
Total catch (t)	3	47	2.4	N
4-year total catch trend	-15	15	-0.2	Y
$CPUE_{LMGN}$ (kg.fisher day^{-1})	8	21	confidential	Y
4-year $CPUE_{LMGN}$ trend	-3.8	3.8	confidential	Y

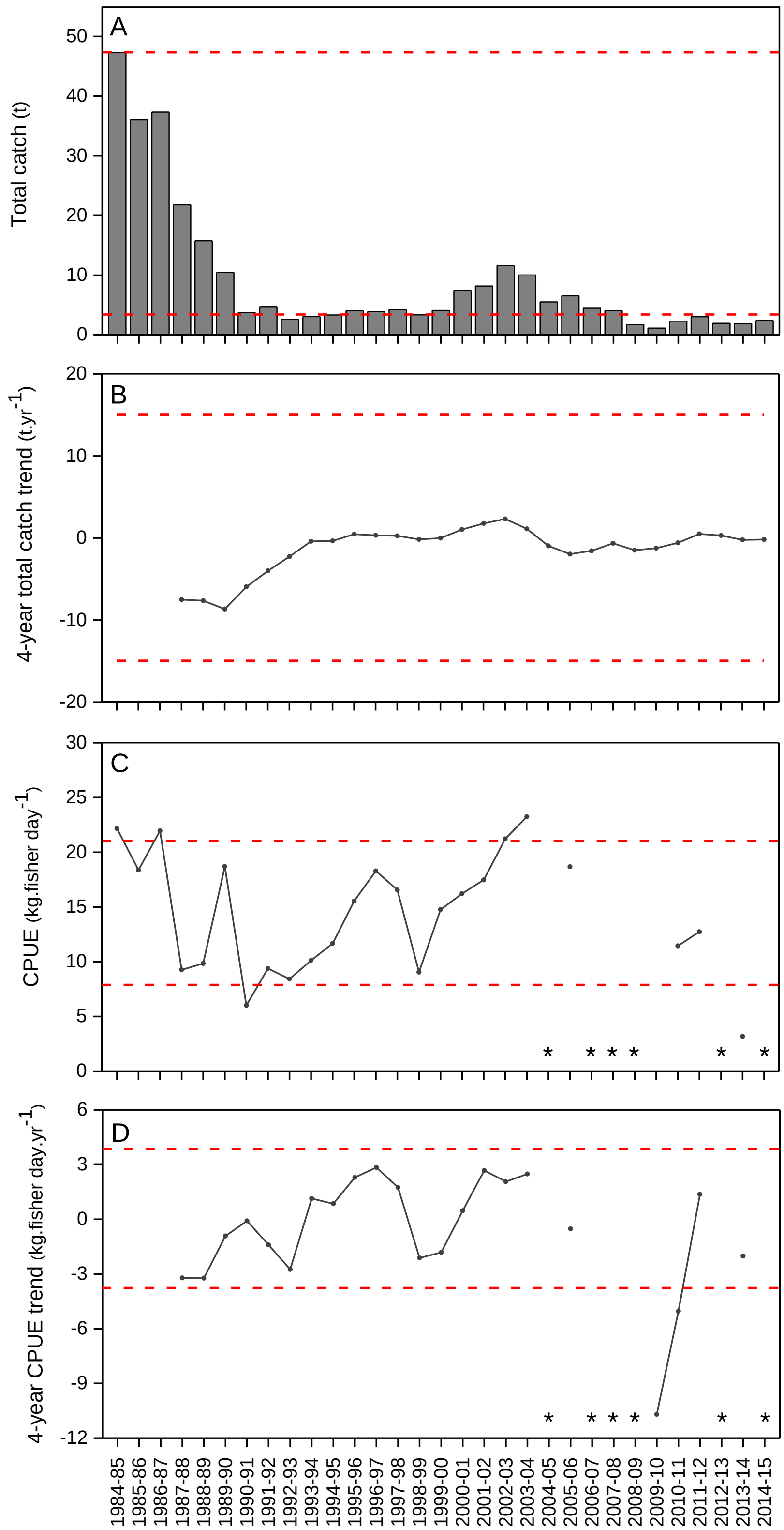

Figure 11.Time series of annual PIs and upper and lower limit RPs (red dashed lines) for the LCF for Black Bream from 1984/85 to 2014/15. (A) total catch; (B) 4-year total catch trend; (C) mean annual $CPUE_{LMGN}$; (D) 4-year $CPUE_{LMGN}$ trend. (*) represents confidential data reported by less than five licence holders (does not represent actual values). Estimates of $CPUE_{LMGN}$ were not available for 2009/10, as no targeted effort was reported for Black Bream.

4.4 Discussion

The recent performance of the LCF for Black Bream was considered by assessing fishery PIs against RPs prescribed in the Management Plan (Sloan 2005). For 2014/15, one of the four PIs was outside of the range of the upper and lower RPs.

The PI for total catch was 20% below the lower RP and indicated that fishery production has been at historically low levels in most years since the early 1990s. The low catches in recent years were related to levels of targeted effort that were among the lowest on record (Section 2). The PIs for $CPUE_{LMGN}$, total catch trend and $CPUE_{LMGN}$ trend were within the range of their respective upper and lower RPs. In general, the PIs are indicative of a fishery that has operated at low capacity since the late 1980s.

For multi-species fisheries, the use of fishery-dependent PIs for assessing stock status of individual species requires careful interpretation, as fluctuations in production levels may result from one or a combination of factors, including changes in fish availability/abundance and market/economic factors. For Black Bream in the LCF, $CPUE_{LMGN}$ is not likely a reliable indicator of population abundance. This is because the dispersion of Black Bream in the Coorong estuary is strongly influenced by the magnitude of freshwater inflows from the Murray River (Ferguson et al. 2008; McNeil et al. 2013; Ye et al. 2013). For example, during prolonged periods of no inflow, hypersaline conditions in the southern Coorong force Black Bream to aggregate in a smaller area of favourable habitat which may increase their catchability and potentially affect CPUE as an indicator of population abundance. Alternatively, during periods of high flow, Black Bream expand their range to include the southern parts of the North Lagoon, while some individuals move as far as the South Lagoon (Ye et al. 2015; Bice et al. unpublished data). Consideration of a broader suite of environmental and biological performance indicators may provide a more meaningful assessment of stock status for Black Bream in the Coorong estuary.

5. GENERAL DISCUSSION

5.1 Information available for assessing fishery status

Information available to assess the Black Bream stock in the Coorong estuary included: (i) historical estimates of annual fishery production of Black Bream in South Australia since 1960/61; (ii) daily commercial catch and effort data from 1984/85 to 2014/15; (iii) annual estimates of relative abundance for Black Bream based on fishery-dependent $CPUE_{LMGN}$ from 1984/85 to 2014/15; (iv) annual size and age structures from 2007/08 to 2014/15; and (v) four performance indicators (PIs) and associated reference points (RPs). This information formed the basis of a weight-of-evidence assessment of stock status for Black Bream in the Coorong estuary (Flood et al. 2014). The assessment is aided by a previous stock assessment report (Ferguson and Ye 2008), several fishery statistics reports (Ferguson 2006; 2008; 2010; 2011; 2012a; 2012b; Earl and Ward 2014; Earl 2015) and the Management Plan (Sloan 2005).

Key knowledge gaps in the biology of Black Bream identified in the previous stock assessment for the species (Ferguson and Ye 2008) were addressed in a study on flow-related ecology of fish and fisheries in the Coorong (Ye et al. 2013). In that study, several aspects of the biology of the species were described. These included: (i) estimates of size at maturity for the Coorong population; and (ii) the effects of salinity on the survival and dispersion of Black Bream in the Coorong estuary.

Biological information on demography, growth and maturity are available for several populations of Black Bream across southern Australia (Norriss et al. 2002). Otolith-based estimates of age from the current study (Section 3) provided age structures for Black Bream in the Coorong estuary, which are comparable to those determined for previous years. This information will contribute to the ongoing development of a time series of age structures for the Coorong population that will ultimately improve understanding of impacts of environmental variability and fishing on stock status.

5.2 Current status of the LCF for Black Bream

The harvest strategy in the current Management Plan for the LCF (Sloan 2005) lacks an index that explicitly defines stock status for the Black Bream fishery. Consequently, considerable emphasis is placed on analysing trends in commercial catch and effort data and fishery size and age structures, to support a weight-of-evidence assessment of stock status for the species in the Coorong estuary (Flood et al. 2014).

Analysis of the long-term chronology of commercial fishery production for Black Bream in the Coorong estuary indicated high variability in population abundance. Estimates of total annual catch peaked at 72 t in the early 1980s, declined steeply in the late 1980s and remained at historically low levels through the 1990s and 2000s. In 2014/15, the total catch of 2.4 t was among the lowest on record. The low catches since the late 1980s have been associated with low fishing effort. Given the relatively high market value of Black Bream harvested by the LCF (EconSearch 2014), the lack of targeted fishing effort since the 1980s is likely to reflect low abundance/biomass of Black Bream in the Coorong estuary.

Of the four fishery PIs for 2014/15, three were within the range of the RPs described in the Management Plan. The total catch PI was 20% below the lower RP. The PIs for $CPUE_{LMGN}$, total catch trend and $CPUE_{LMGN}$ trend were within the range of their upper and lower RPs.

In 2013/14, the estimated recreational harvest of Black Bream in South Australia was 4.97 t, which was approximately 60% of the State-wide combined commercial and recreational harvest (Giri and Hall 2015).

Black Bream is a slow-growing, long-lived estuarine resident that relies on the establishment of one, two or several strong year classes to maintain the adult population (Winemiller and Rose 1992; Ferguson et al. 2013). Thus, a time series of annual age structures for the adult population is important information for assessing stock status for Black Bream.

Annual fishery age structures for Black Bream in the Coorong estuary were relatively stable from 2007/08 to 2014/15, and mostly comprised fish between 4 and 11 years of age. Older fish were rare despite the potential for this species to reach 32 years of age (Ye et al. 2015). It is likely that fishing has removed older individuals (Sarre 1999; Ferguson et al. 2013). Within any year, particular year classes contributed most to the commercial catch. This variation in age class strength reflects variations in recruitment among years. Larger year classes appear to be linked to freshwater releases to the Coorong in 1997/98, 2003/04 and 2006/07 (Ye et al. 2015), suggesting that environmental conditions associated with freshwater inflow are potentially important for successful reproduction in the Coorong. This is supported by several studies that have related spawning success to freshwater inflows and associated factors (Newton 1996; Nicholson and Gunthorpe 2008; Williams et al. 2012, 2013; Jenkins et al. 2010, 2015).

The prolonged period of low freshwater inflows to the Coorong during the 2000s is likely to have limited recruitment opportunities for Black Bream. However, the recruitment of several year classes into the fishable biomass during this period (2003/04, 2006/07, 2009/10), indicates that environmental conditions supported successful reproduction in some years (Ye et al. 2015). Despite this recruitment, fishery production for this high-value species has remained historically low (EconSearch 2014). Recruitment levels over the past 25 years have not been strong enough to support recovery of the population and fishery, despite the occurrence of conditions suitable for successful spawning in some years. This finding suggests that the spawning biomass of Black Bream in the Coorong has been reduced to a level where recruitment is severely impaired. On this basis, the biological stock is considered to be recruitment overfished. Current levels of commercial and recreational fishing mortality are unlikely to allow the stock to recover from its current weakened state. On the basis of the evidence presented above and using the definition from the National Status of Key Australian Fish Stocks Report (Flood et al. 2014), the Black Bream stock in the Coorong estuary is classified as **overfished**.

The recent low levels of recruitment may be exacerbated by the current LMS for Black Bream in South Australia of 280 mm TL, which is 9 mm and 50 mm lower than the estimated SAM_{50} for females and males, respectively (Cheshire et al. 2013). Although, the LCF mainly harvests individuals above the SAM_{50}, the size of Black Bream harvested by the recreational sector is poorly understood. This may be significant because annual recreational harvest is slightly higher than the commercial catch (Jones 2009).

5.3 Uncertainty in the assessment

Uncertainty surrounds the reliability of estimates of commercial CPUE as an indicator of relative abundance for Black Bream in the Coorong estuary. This is because spatial contraction of the fishery for Black Bream to a smaller area of favourable habitat, particularly during drought, may affect their catchability and thus confound interpretation of CPUE as an indicator of population abundance. Given the high market value of Black Bream (EconSearch 2014), catch is a more appropriate indicator of biomass for the species in the Coorong.

Uncertainty also exists around the PIs and associated RPs defined for Black Bream in the Management Plan (Sloan 2005). This is because: (i) RPs were determined for total catch and CPUE data from a fixed, relatively short time period; and (ii) there is limited consideration of the influence of the environment on fishery performance.

Uncertainty surrounds the levels of recreational catches of Black Bream in the Coorong estuary. Recreational fishing surveys estimated that recreational catches of Black Bream in South Australia accounted for 60% of the combined commercial and recreational State-wide catch in 2013/14 (Giri and Hall 2015). However, the contribution of recreational catches taken in the Coorong estuary to the total State-wide catch is not known.

Levels of incidental mortality of sub-legal sized Black Bream discarded by commercial and recreational fishers in the Coorong estuary are also poorly understood. This is because estimates of discarding are only available for the commercial fishery from limited sampling undertaken during the recent drought (Ferguson 2010a). For the commercial sector, this will be addressed by monitoring discards from gill nets. It is planned to incorporate discard information into the Inland Waters Catch and Effort return in 2016/17.

Estimates of size and age of maturity for Black Bream vary considerably among populations across southern Australia (Norriss 2002) and there is uncertainty around the timing of maturity for the Coorong population (Cheshire et al. 2013). This knowledge gap could be addressed with data collected as part of SARDI's Coorong Fish Condition Monitoring program which is funded by The Living Murray Initiative of the Murray-Darling Basin Authority through the South Australian Department of Environment, Water and Natural Resources (Ye et al. 2015).

Given the uncertainty around the reliability of the current PIs for Black Bream in the Coorong estuary, there is a need to develop a new assessment framework to improve assessments of stock status for the species. Options for a new assessment framework for finfish in the LCF were developed as part of a recent Fisheries Research and Development Corporation (FRDC) project (Knuckey et al. 2015). This included the development of a set of environmental PIs, based on habitat availability, as surrogate metrics for population biomass for key fishery species, including Mulloway and Yelloweye Mullet. Similar environmental-based PIs are unlikely to be appropriate for Black Bream, because fishery production for this species has remained at a low level, despite extreme environmental variation in the Coorong estuary over past 25 years. In the short term, the weight-of-evidence approach adopted in this assessment, which places considerable emphasis on analysing trends in commercial catch data and population size and age structures, is likely to be the most appropriate means for assessing the status of the Black Bream stock in the Coorong estuary. However, development of a population model or a prescriptive biological indicator (e.g. a recruitment index) of stock status warrants consideration.

With the recent recovery of Long-nosed Fur Seal (*Arctocephalus forsteri*) populations in South Australia (Shaughnessy et al. 2015), fur seal interactions with the LCF have increased (Tsolos and Boyle 2014). Interactions typically involve the depredation of fish caught in, and damage to gill nets. Uncertainty surrounds the impacts of fur seal interactions on the Black Bream fishery, as depredation rates and levels of discarding of seal-damaged Black Bream have not been quantified. This knowledge gap may be addressed with data collected as part of the FRDC project: '*Developing alternative strategies for managing seal-fisher interactions in the South Australian Lakes and Coorong Fishery'* (Project No. 2016-001).

5.4 Future research needs

The most important research needs for the Black Bream fishery and its management include: (i) ongoing development of a time series of annual age structures; (ii) regular surveys to estimate the recreational harvest of Black Bream from the Coorong estuary; (iii) independent monitoring of discarding of non-targeted and sub-legal individuals from large and small mesh gill nets; and (iv) robust estimates of size and age of maturity for the Coorong population.

Surveys to estimate recreational harvest of Black Bream from the Coorong estuary, that are conducted on a regular basis would improve future stock assessments for Black Bream, and could be done in conjunction with surveys of other recreational fisheries. On-site, interview-based surveys would provide invaluable information on catch, effort, catch composition of target, non-target and discarded species and an opportunity to collect important demographic information (size, age, sex, reproduction) for Black Bream in the Coorong.

Knowledge of the movement of Black Bream between the Coorong and other estuaries in South Australia is limited. Understanding movement patterns would inform on demographic processes that may contribute to changes in population size and structure, and could be achieved by: (i) an acoustic tagging study; (ii) a mark and release (tagging) study; or (iii) an otolith chemistry-based study of the connectivity/exchange between populations.

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