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Greenback Flounder (*Rhombosolea tapirina*)
Stock Assessment Report 2014/15

J. Earl and Q. Ye

SARDI Publication No. F2007/000315-2
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Report to PIRSA Fisheries & Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

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EXECUTIVE SUMMARY

This report is the second assessment of stock status for Greenback Flounder (*Rhombosolea tapirina*) in South Australia. It provides a synopsis of information for the species and reports on trends in commercial catch and effort data and population size and age structures to provide a weight-of-evidence assessment of stock status for Greenback Flounder in the Coorong estuary.

Most catches of Greenback Flounder in South Australia are taken by the Lakes and Coorong Fishery (LCF). The long-term chronology of fishery production for the LCF indicated extreme inter-annual variability in population abundance in the Coorong estuary. Annual catches peaked at 232 t in the mid-1970s. Since then, catches have fluctuated periodically but have been substantially lower. The total catch of 0.27 t in 2014/15 was among the lowest on record. The low catch in 2014/15 was associated with low targeted fishing effort.

The main gear type used to target Greenback Flounder 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 35 kg.fisher day^{-1} in 2011/12. In 2014/15, $CPUE_{LMGN}$ declined to 11 kg.fisher day^{-1}, which was among the lowest on record.

For 2014/15, one of four fishery performance indicators was below its lower reference point. The total catch performance indicator was 93% below the lower reference point.

The age structure from 2014/15 comprised mostly one and two year old fish. While recruitment has occurred in each year since 2006/07, recruitment levels have been highly variable, as indicated by the trends in total catch and $CPUE_{LMGN}$. The low recruitment to the fishable biomass in 2014/15 appears to relate to low freshwater inflows and the subsequent lack of suitable estuarine habitat for Greenback Flounder in the Coorong estuary, rather than a low spawning biomass.

The current level of fishing mortality is unlikely to cause the stock to become recruitment overfished. On the basis of the information above and using the definitions from the national stock status framework, the Greenback Flounder stock in the Coorong is classified as **environmentally limited**.

The most important research needs for Greenback Flounder in the LCF and its management include: (i) delineation of stock structure in South Australia; (ii) improved understanding of the proportional use of habitats in the Coorong estuary and the adjacent marine environment; (iii) independent monitoring of discarding of non-targeted and sub-legal sized individuals from gill nets; (iv) improved understanding of the impacts of Long-nosed Fur Seals on the fishery; and (v) regular surveys to estimate the recreational harvest of Greenback Flounder from the Coorong estuary.

1. GENERAL INTRODUCTION

1.1 Overview

This assessment of Greenback Flounder (*Rhombosolea tapirina*) in the South Australian Lakes and Coorong Fishery (LCF) builds on a previous fishery assessment report in 2007 (Ferguson 2007) and annual fishery statistics reports since 2006 (Ferguson 2006b, 2008, 2010, 2011, 2012a, 2012b; Earl and Ward 2014; Earl 2015). The report aims to provide a synopsis of fisheries information available for assessing the status of the Greenback Flounder resource in the Coorong estuary. The assessment is based on commercial catch and effort data up to 30 June 2015 for the LCF and information on the size and age structure of the Greenback Flounder population in the Coorong estuary.

1.2 Description of the fishery

Greenback Flounder support commercial and recreational fisheries across southern Australia and also in New Zealand (Froese and Pauly 2013). In Australia, most commercial catches of Greenback Flounder are taken in South Australia and Tasmania, with smaller catches from New South Wales, Victoria and Western Australia (Kailola et al. 1993; PIRSA 1996; Knuckey et al. 2002; André et al. 2014). The main gear types used to harvest Greenback Flounder include gill nets, seine nets and hand-held spears (Kailola et al. 1993; Lyle and Campbell 1999). Incidental catches are also taken with Danish seines and otter trawls in Tasmania and Victoria (Kailola et al. 1993).

Commercial Fishery

The South Australian commercial fishery for Greenback Flounder comprises one main sector – the LCF. The Marine Scalefish Fishery and Northern and Southern Zone Rock Lobster fisheries also have limited access to the species, although 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 mainly use large mesh gill nets (115-150 mm mesh) to target Greenback Flounder, along with several other finfish species including Black Bream (*Acanthopagrus butcheri*), Mulloway (*Argyrosomus japonicus*) 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).

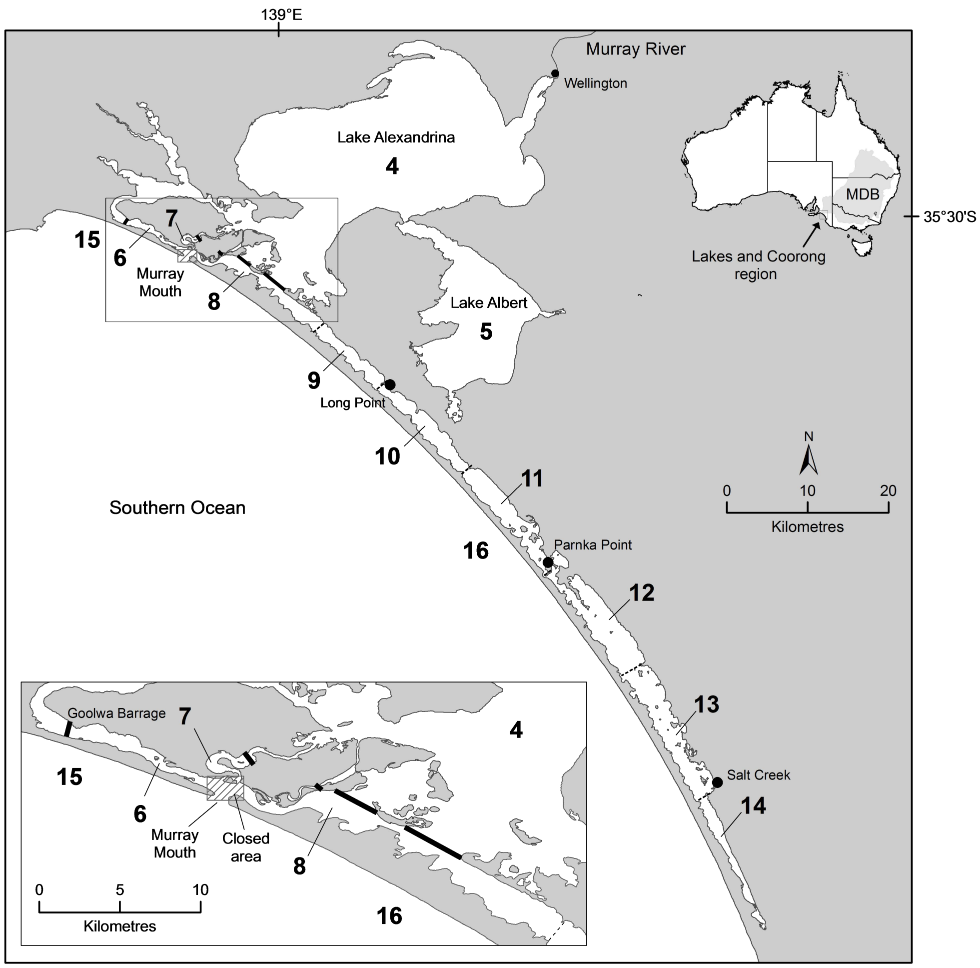

Figure 1. Map of the Lakes and Coorong region showing commercial reporting areas 4-16 of the LCF.

Recreational Fishery

In South Australia, recreational fishers target Greenback Flounder using hand-held spears in estuaries and protected nearshore habitats in the marine environment (Ferguson 2006a). Recreational fishers can also target flounder using registered monofilament nylons 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 had an estimated 3,000 people inhabiting the Coorong region in the 1800s, prior to European settlement (Sloan 2005). The Ngarrindjeri people continue to target flounder using a range of traditional apparatus, including nets and spears (Jenkin 1979; Olsen and Evans 1991). Estimates of annual catches of flounder 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 was recently finalised and took effect on 1 March 2016. A timeline of changes to management arrangements is shown in Table 1.

The LCF is managed as a limited entry fishery. Currently, there are 36 licences with non-exclusive access within the Lower Lakes, Coorong estuary and adjacent marine beaches along the Younghusband and Sir Richard Peninsulas. Fishing effort is limited 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 Management (Lakes and Coorong Fishery) Regulations 2009.* 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 a variety of migratory waterbirds.

Table 1. Management milestones for the Lakes and Coorong Fishery.

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 were introduced. Limit of one registered recreational net per person, with 70 m total length and max. drop of 1 m.
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 (reach) 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 (boat days, 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 Greenback Flounder comprise general gear restrictions, spatial and temporal closures and a legal minimum size (LMS) of 250 mm total length (TL) that applies to commercial fishing in all State waters.

Recreational Fishery

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, Long-snouted Flounder (*Ammotretis rostratus*) and Small-toothed Flounder (*Pseudorhombus jenysii*). 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 2015). There is no LMS for flounder taken by recreational fishers in South Australia.

Recreational fishers can also target Greenback Flounder in the Coorong estuary using registered nylon mesh nets. In 2014, there were 692 recreational fishers with 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 Greenback Flounder for traditional, domestic, non-commercial use subject to meeting requirements of the *Native Title Act 1994*.

1.4 Performance indicators

The Management Plan for the LCF (Sloan 2005) identifies four performance indicators (PIs) and their associated reference points (RPs) to monitor fishery performance for Greenback Flounder. 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 determined 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 fishery assessments

Commercial Fishery

<u>Lakes and Coorong Fishery</u>

Previous assessments of the LCF for Greenback Flounder include a stock assessment report in 2007 (Ferguson 2007) and annual fishery statistics reports since 2006 (e.g. Earl 2015). The report by Ferguson (2007) concluded that the assessment of stock status for Greenback Flounder was limited by a lack of biological and demographic information for the exploited population in the Coorong estuary. However, it suggested that the low catch and catch rate in 2005/06 was likely indicative of low fishable biomass in the system.

Recreational Fishery

Estimates of recreational catch for flounder (all species collectively) in South Australia are available for three years: 2000/01, 2007/08 and 2013/14. In 2000/01, the estimated recreational harvest of 0.61 t accounted for approximately 3% of the State-wide combined commercial and recreational harvest (Jones and Doonan 2005). However, few fishers from the Coorong were surveyed (K. Jones, pers. comm.). In 2007/08, the estimated recreational harvest declined to 0.25 t (Jones 2009). The estimated harvest of flounder by the recreational sector in 2013/14 was 0.27 t, which represented approximately 22% of the total combined commercial and recreational catch in South Australia (Giri and Hall 2015).

1.6 National stock status classification framework

A national stock status classification system was recently developed for the consistent assessment of key Australian fish stocks (Flood et al. 2014). It considers whether the current level of fishing pressure is adequately controlled to ensure that spawning stock abundance (biomass) is not reduced to a point where the production of juveniles (recruitment) is not significantly compromised. The classification system combines information on both the current stock size and the level of catch, and assesses the stock against a defined biological reference point – 'recruitment overfished' (see Flood et al. (2014) for a detailed explanation of classification system). Each stock is then classified as either: 'sustainable', 'transitional-recovering', transitional-depleting', 'overfished', 'environmentally limited' or 'undefined' (Table 2). PIRSA has adopted this classification framework to determine the status of South Australian fish stocks.

The harvest strategy in the current Management Plan for the LCF (Sloan 2005) lacks an index that explicitly defines stock status for Greenback Flounder. 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 Coorong population.

Table 2. Stock status terminology (Flood et al. 2014).

	Stock Status	Description	Potential implications for management of the stock
	Sustainable	Stock for which biomass (or biomass proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (i.e. not recruitment overfished) and for which fishing pressure is adequately controlled to avoid the stock becoming recruitment overfished	Appropriate management is in place
↑	Transitional–recovering	Recovering stock—biomass is recruitment overfished, but management measures are in place to promote stock recovery, and recovery is occurring	Appropriate management is in place, and the stock biomass is recovering
↓	Transitional–depleting	Deteriorating stock—biomass is not yet recruitment overfished, but fishing pressure is too high and moving the stock in the direction of becoming recruitment overfished	Management is needed to reduce fishing pressure and ensure that the biomass does not deplete to an overfished state
	Overfished	Spawning stock biomass has been reduced through catch, so that average recruitment levels are significantly reduced (i.e. recruitment overfished). 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
	Environmentally limited	Spawning stock biomass has been reduced to the point where average recruitment levels are significantly reduced, primarily as a result of substantial environmental changes / impacts or disease outbreaks (i.e. the stock is not recruitment overfished). Management has responded appropriately to the environmental change in productivity	Appropriate management is in place
	Undefined	Not enough information exists to determine stock status	Data required to assess stock status are needed

1.7 Biology of Greenback Flounder

Taxonomy

Fishes of the order Pleuronectiformes (flatfishes) are characterised by an adult form that has an asymmetrically flattened body shape with both eyes on the same side of the head (Chapleau 1993). The most common pleuronectid in Australian waters is the Greenback Flounder, *Rhombosolea tapirina* (van den Enden et al. 2000; Figure 2). This species is a member of Rhombosoleidae, otherwise known as the family of Austral right-eyed flounders, and is the only one of four species in the Australasian genus *Rhombosolea* (Gomon et al. 2008). Greenback Flounder can grow to 500 mm total length (TL) and is the only flatfish in southern Australia that is large and abundant enough to be commercially exploited (Kailola et al. 1993; Sutton et al. 2010).

Figure 2. Greenback Flounder, *Rhombosolea tapirina* (Gunther 1862). Source: Australian National Fish Collection, CSIRO (2014).

Distribution

The distribution of Greenback Flounder in Australia extends from southern New South Wales and Tasmania, to south-eastern Western Australia (Kailola et al. 1993). They also occur in New Zealand, around the Auckland and Campbell Islands (Gomon et al. 2008). Adults occur over sand, silt and mud substrates in estuaries and coastal waters, while juveniles occupy shallower areas and prefer unvegetated sand and mudflat habitats (Edgar and Shaw 1995; Jenkins et al. 1997; Gomon et al. 2008). In South Australia, Greenback Flounder occur in coastal waters, but are generally most abundant in the Coorong estuary.

Stock structure

The broad distribution of Greenback Flounder is thought to be divisible into a number of separate genetic stocks. The most significant division occurs between Australian and New Zealand populations (van den Enden et al. 2000). Within Australia, there is strong evidence that western Tasmania populations are genetically isolated from populations in Victoria and northern and south-eastern Tasmania, although genetic diversity was lowest among Tasmania populations (van den Enden et al. 2000). These results support those of Kurth (1957), who identified distinct western and eastern Tasmania populations on the basis of morphometrics. The stock structure for populations in Western Australia, South Australia and Victoria is not known.

In South Australia, the Greenback Flounder is considered a ‘marine estuarine-opportunist’ (Earl 2014). This group of fishes, as defined by Elliot et al. (2007), comprises marine species that enter estuaries in substantial numbers, particularly during the juvenile and early adult stages, but use, to varying degrees, nearshore marine waters as an alternative habitat. This was supported by an acoustic telemetry study that showed that the Coorong population is likely part of a broader population which encompasses the adjacent marine environment (Earl 2014). Whilst the extent of the offshore population is not known, fish observed emigrating from the estuary were likely to have moved a considerable distance offshore, as the extensive high-energy surf beaches immediately adjacent the Murray Mouth are unlikely to provide suitable habitat for Greenback Flounder (Earl 2014). In other parts of the species’ distribution, individuals have been recorded in offshore waters in depths of up to 100 m (Gomon et al. 2008). Further research is required to determine geographical extent of the biological stock in South Australia.

Reproductive Biology

Analysis of gonads indicated that Greenback Flounder are multiple batch spawners that have indeterminate fecundity and asynchronous oocyte development (Kurth 1957; Crawford 1984; Barnett and Pankhurst 1999; Earl 2014). Spawning is understood to occur in the deeper areas of tidal rivers and estuaries, as well as offshore, and is most frequent when water temperatures are below 14 ^{o}C (Kurth 1957; Crawford 1984; Earl 2014).

The estimated size at maturity (SAM_{50}) for female and male Greenback Flounder in the Coorong estuary is 198 mm TL and 211 mm TL, respectively (Earl 2014; Earl et al. 2014). This estimate of SAM_{50} for females is similar to that by Cheshire et al. (2013) for the Coorong population.

The sex ratio of the Greenback Flounder population in the Coorong estuary is consistently biased towards females (Cheshire et al. 2013; Earl 2014; Ye et al. 2015), suggesting differences in spatial distribution between sexes. Populations in Tasmania and New Zealand demonstrate similar sexual segregation, with males more common in deeper water (Kurth 1957; Crawford 1984; Sutton et al. 2010).

Early life history

Fully developed Greenback Flounder eggs are pelagic, approximately 0.94 mm in diameter, and hatch between 82 – 93 hours after fertilisation at 11 – 14 °C, releasing larvae of 1.9 mm TL (Crawford 1984, 1986; Hart 1994). Larvae remain pelagic for approximately 35 days, during which time they reach approximately 6 mm TL and rely on water movements for transport and dispersal to potential recruitment areas (Jenkins et al. 1993). Metamorphosis begins at approximately 35 days and is characterised by the morphological and behavioural transformation of larvae into benthic-dwelling juveniles. During this process, pigmentation develops on the eventual dorsal side of the fish and the left eye migrates across the top of the head and settles on the right side of the head (Crawford 1986). Metamorphosis is complete after 65 days, during which time they grow to approximately 8.8 mm TL and recruit to shallow, sandy, unvegetated habitats (Crawford 1986; Jenkins 1987; May and Jenkins 1992). Burchmore (1982) suggested that low salinities and sandy substrates of estuaries and bays were the preferred habitat of newly-settled juveniles.

Recruitment of post-larval Greenback Flounder in estuaries is likely influenced by freshwater inflows (Robins and Ye 2007). As this species spawns from late autumn to early spring, i.e. before the typical high flow season (spring), larval and juvenile growth may be enhanced by increased biological productivity related to freshwater inflows to estuaries, resulting in higher levels of recruitment success (Ye et al. 2015). In the Coorong estuary, freshwater inflow also affects salinity, which impacts on the amount of suitable nursery habitat available for Greenback Flounder in the system. In years of increased freshwater inflows the size of the nursery area is larger which may contribute to higher levels of recruitment success (Ye et al. 2015).

Age and growth

The demography of Greenback Flounder is better understood since a methodology was developed and validated to determine the age of adult fish (Earl et al. 2014). Transverse sections of otoliths of this species display an alternating sequence of opaque and translucent zones. Results from marginal increment analysis indicated that the incremental structure visible in the sections of otoliths formed annually, and therefore, individual fish could be aged in years. A universal birth date of 1 June was adopted, as this date falls in the middle of the spawning season, and allows sampled fish to be assigned an age in months, based on the time of capture and the number of opaque zones visible in the section of its otolith (Earl et al. 2014).

Estimates of fish size and age for male and female Greenback Flounder were used to generate von Bertalanffy growth curves for two areas in the Coorong estuary (Earl et al. 2014). There were no detectable differences in growth between males and females, despite the strong bias in number towards female fish. Spatial differences in growth were marginal. On average, fish grew to 231 mm TL and 220 mm TL in the ‘Estuary (i.e. LCF reporting areas 6 and 7)’ and ‘North Lagoon (reporting areas 8, 9 and 10)’, respectively, in their first 12 months of life (Figure 3). From then, growth rate decreased, but was the same for both areas, with size increases of 77 mm, 27 mm and 8 mm in their second, third and fourth years of life, respectively (Earl et al. 2014).

The maximum age recorded for female and male Greenback Flounder is ten and five years, respectively (Sutton et al. 2010). For the Coorong population, the maximum age recorded for both sexes is approximately four years (Earl et al. 2014; Ye et al. 2015).

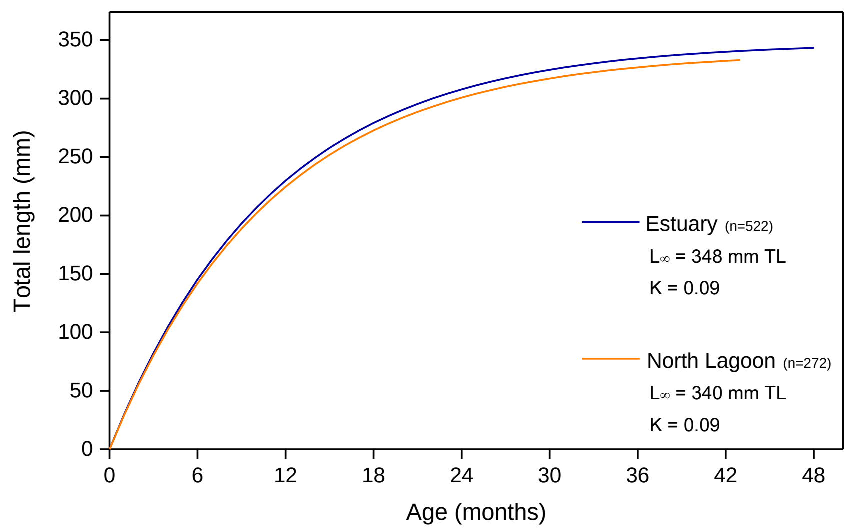

Figure 3. Von Bertalanffy growth (VBG) curves for Greenback Flounder from two areas in the Coorong estuary: the ‘Estuary’ represents LCF reporting areas 6 and 7; and the ‘North Lagoon’ represents reporting areas 8, 9 and 10 (Source: Earl et al. 2014). Estimates of VBG parameters (L_∞ and K) are also shown. The parameter t_0 was constrained to zero.

Life history in the Coorong estuary

The Coorong estuary provides an important nursery area for Greenback Flounder through the first 2-3 years of life (Earl et al. 2014). Post-larvae recruit to shallow, unvegetated sandy habitats from winter through to summer in each year (Livore et al. 2013). During their first year of life, individuals grow rapidly and reach approximately 225 mm TL, i.e. ~65% of the asymptotic length of the species (Earl et al. 2014). Both male and female fish reach maturity early in their second year, which enables them to spawn in the winter following the year they themselves were spawned. Despite a strong bias in numbers toward females in the population, spawning occurrs within the estuary and involves the release of multiple batches of eggs over a protracted period from March to October in each year. Whilst the estuarine spawning biomass is likely to contribute to localised recruitment within the system, the contribution of recruits that originate from spawning in the marine environment adjacent the estuary is unknown.

The abundance and dispersion of juvenile and adult Greenback Flounder in the Coorong estuary is strongly influenced by the amount of estuarine habitat available within the system, which is regulated through inflows of freshwater from the Murray River (Webster 2010; Earl 2014). Under a regime of consistent seasonal inflow, extensive areas of estuarine habitat are available and commonly support high densities of Greenback Flounder. Alternatively, during prolonged periods of low inflow, abundance is generally very low and the distribution of individuals is restricted to the vicinity of the Murray Mouth, because the majority of the Coorong becomes hypersaline. It is likely that such spatial contractions of the population within the estuary force some individuals into the marine environment, where they remain and can possibly return when estuarine conditions inside the Coorong improve (Earl 2014).

Flow-related increases in population abundance observed by Earl (2014) highlighted: (1) the strong relationship between the amount of available estuarine habitat and population abundance of Greenback Flounder in the Coorong estuary; (2) the opportunistic nature of the species use of the Coorong; (3) the movement capabilities and sensitivity of the species to environmental changes within the estuary; (4) the ability of the species to live in the marine environment if required; and (5) the potential for a large biomass of adult fish to move into the estuary when environmental conditions are suitable. Such information is important to consider in the context of this assessment of stock status for Greenback Flounder in the Coorong estuary.

2. COMMERCIAL FISHERY STATISTICS

2.1 Introduction

The assessment of stock status for Greenback Flounder relies heavily on fishery-dependent data provided by the LCF. This section provides analyses of all commercial fishery-dependent data available for Greenback Flounder in South Australia and assesses spatial and temporal trends in catch, effort and CPUE from 1 July 1984 to 30 June 2015. The same dataset was used to assess the recent performance of the fishery against a series of limit reference points (Section 4), and along with information on the size and age structure of the Coorong population (Section 3) formed the basis of a weight-of-evidence assessment of the current status of the Greenback Flounder resource in the Coorong estuary (Section 5).

Freshwater inflow has been identified as a key factor affecting fishery performance for finfish species in the Coorong estuary (Pierce and Doonan 1999; Ferguson et al. 2013; Earl 2014). This section of the report also examines the influence of freshwater inflow on total catch for Greenback Flounder by the LCF.

2.2 Methods

Compilation of fishery data

Estimates of annual commercial catch of Greenback Flounder taken in South Australia were reconstructed from several sources dating back to 1951/52 (i.e. 1 July 1951 to 30 June 1952). From that year until 1957/58, the only catch data available were estimates of the total weight of flounder (all species) processed annually at South Australia's main fish market, as presented in the annual reports of the South Australian Fisheries and Game Department. During that period, it was not compulsory for commercial fishers to transport their catch to this market each day, thus these data are only indicative of the minimum State-wide commercial catch at that time.

From 1958/59 to 1975/76, quantities of flounder processed at the South Australian fish market were not recorded. Rather they were categorised into a broad group of 'mixed finfish species', which included numerous other species that were presumably processed in low quantities. As such, no catch estimates were available for this period. From 1976/77 to 1983/84, total catches of Greenback Flounder were recorded in logbooks by commercial fishers across South Australia and reported in annual reports of the South Australian Fishing Industry Council Inc.

Since 1 July 1984, commercial catch and effort data have been collected by fishers in the LCF who complete a logbook for each fishing day. Daily catch and effort data include catch (kg), effort (days, fisher days, net-days) for targeted and non-targeted species, and fishing location which is reported against commercial 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 LCF Information System.

Analysis of fishery data

Total annual catch data were collated by financial year to describe trends in fishery production for the species in South Australia from 1951/52 to 2014/15. All subsequent data analyses were undertaken on the fishery statistics extracted from the LCF Information System 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 for 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 data presented for the LCF constitutes the most fundamental dataset available for assessing stock status.

Relationship between freshwater inflow and catch data

Estimates of mean annual 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.

Cross-correlation analysis was done to assess the influence of freshwater inflows on total catch. This method estimated the degree to which the time series of total catch data, with annual time lags of up to five years, are correlated with the time series of freshwater inflow data. Correlation coefficients (r) vary from -1 to +1 and represent the degree to which catch is correlated with a previous year's flow. An r value of zero indicates no correlation, while an r value of +1 indicates a perfect positive correlation. The analyses was done using SPSS version 22.

Regression analysis was performed on commercial catch and environmental flow data to examine the relationship between inflow and the proportion of the total catch taken from areas south of Long Point (Figure 1), using the statistical package OriginPro 2015 for Windows.

2.3 Results

Total annual State-wide catches (1951/52–2014/15)

From 1951/52 and 1957/58, estimates of total annual catch taken from South Australian waters ranged between 1 t and 32 t (Figure 4). The absence of fish market records from 1958/59 to 1975/76 is likely to reflect low catches during this period. In 1976/77 and 1977/78, annual catches exceeded 231 t, and to this day, represent the highest annual catches of Greenback Flounder taken in South Australia. From then, catches fluctuated periodically until the early 2000s, but were lower and ranged between 3.2 t and 65.3 t.yr^{-1}. During the 2000s, catches were low and peaked at 8.5 t.yr^{-1} in 2004/05, before declining to 0.1 t in 2010/11. Catch increased to 31 t in 2011/12 and then declined to <1 t.yr^{-1} in 2013/14 and 2014/15.

Information on where catches were taken was not available prior to 1975/76. From 1976/77 to 2013/14, catches taken by the LCF from the Coorong estuary accounted for approximately 98% of the State's catch in each year. In 2014/15, LCF catches contributed 94% (0.27 t) of the total State-wide catch, while the remaining 6% (0.02 t) was taken by the MSF.

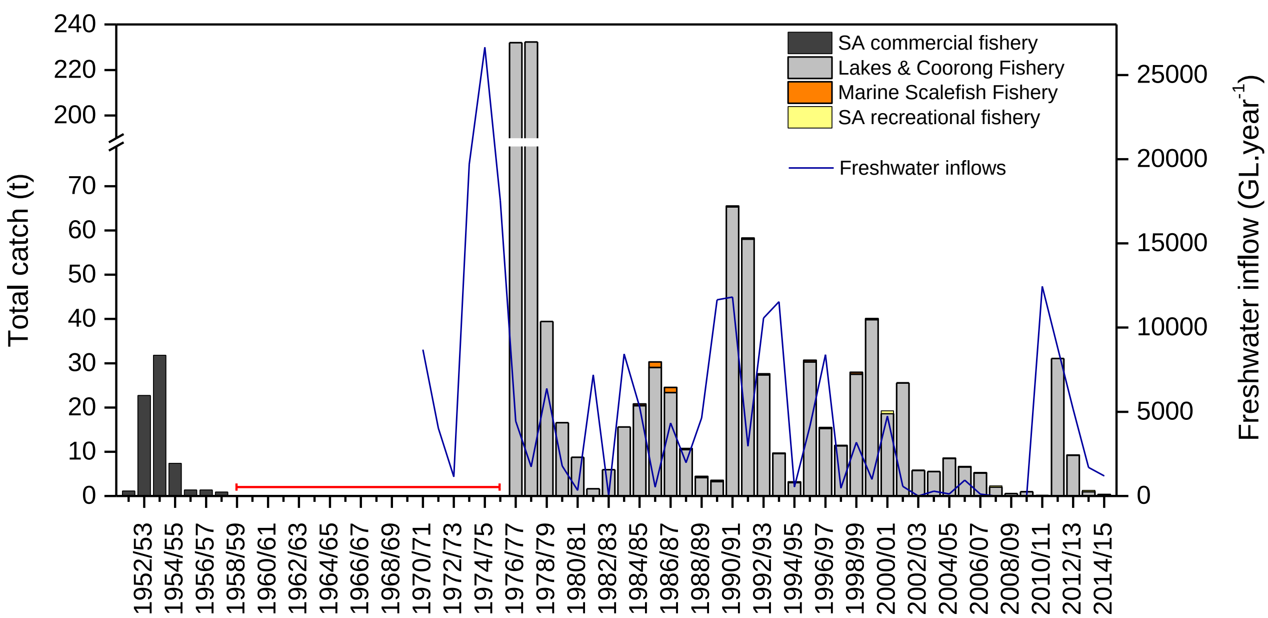

Figure 4. Total annual catches of Greenback Flounder in South Australia from 1951/52 to 2014/15, by fishing sector. Information on the sector by which catches were taken was not available from 1951/52 to 1957/58. Estimates of recreational harvest were available for 2000/01, 2007/08 and 2013/14. Horizontal red capped line indicates the period for which catch estimates were unavailable.

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

Total annual catches

Annual catches from the LCF were highly variable between 1984/85 and 2000/01, and ranged from 3 t in 1989/90 to 65 t in 1990/91 (Figure 5). Catches were low during the 2000s, dropping to <1 t in each year from 2007/08 to 2010/11. Catch increased to 31 t in 2011/12, and then progressively declined to 0.27 t in 2014/15.

The dominant gear type used to catch Greenback Flounder was the large mesh gill net (115-150 mm mesh), which contributed an average of 95% to the annual catch from 1984/85 to 2014/15 (Figure 5). Most of the remaining catch was taken using haul nets, with smaller contributions taken using other gears types, including small mesh gill nets (50-64 mm mesh) and ring nets.

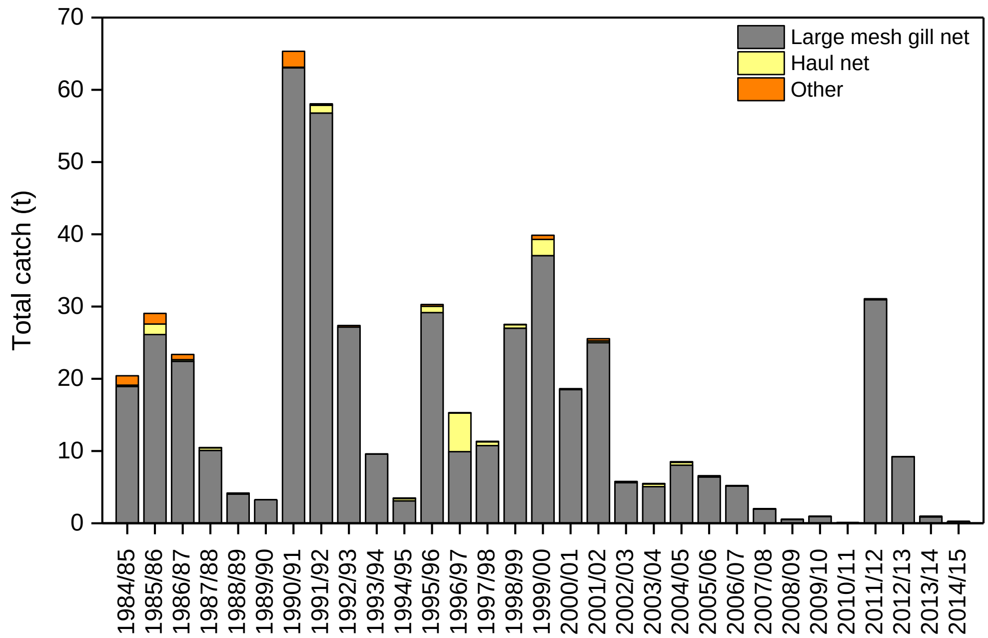

Figure 5. Annual catches of Greenback Flounder by the LCF from 1984/85 to 2014/15, by gear type.

Intra-annual trends in total catch

From 1984/85 to 2014/15, catches of Greenback Flounder from the Coorong estuary were seasonal with on average, 62% of the annual catch taken from October to February (Figure 6). Catches were highest in November and lowest in June and July.

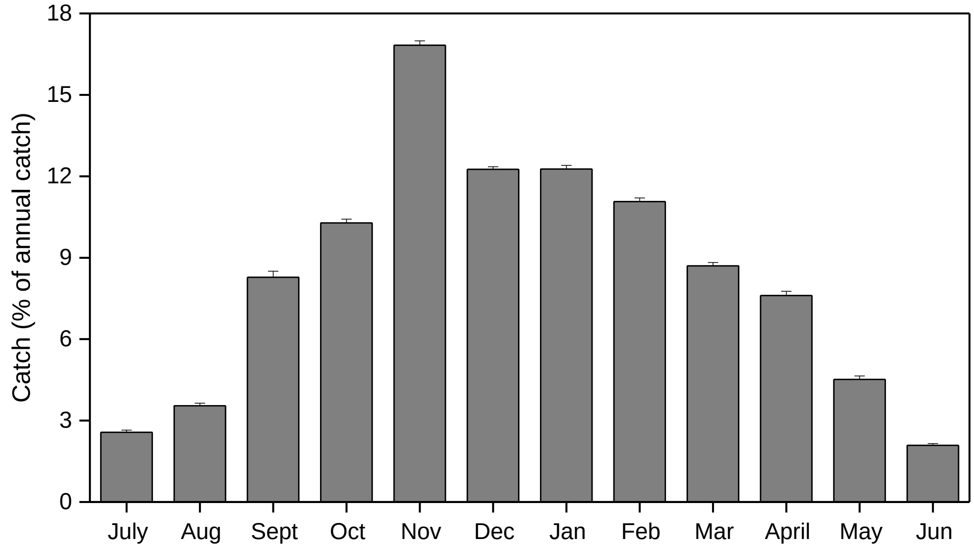

Figure 6. Average monthly catches (±S.E.) of Greenback Flounder by the LCF from 1984/85 to 2014/15, expressed as a percentage of annual catch.

Targeted catch, effort and CPUE – large mesh gill nets

Inter-annual trends in targeted catch using large mesh gill nets (Figure 7A) were similar to those of total catch (Figure 5). Targeted catches were low (<1 $t.yr^{-1}$) during the late 1980s, before increasing to 45.8 t in 1990/91. Annual targeted catch declined to 0.8 t in 1994/95, and was highly variable from 1995/96 to 2000/01, ranging between 6.2 t and 29.2 t. Annual targeted catches were <4 $t.yr^{-1}$ from 2002/03 to 2010/11, before increasing to 19.8 t in 2011/12. The targeted catch of 0.14 t in 2014/15 was among the lowest recorded in the fishery.

The contribution of targeted catches to total catches varied substantially among years (Figure 7A). From 1984/85 to 1989/90, targeted catch contributed 3-35% of the total annual catches. Its contribution increased to 70% in 1990/91 and then fluctuated between 40% and 80% in most years to 2014/15.

Targeted fishing effort using large mesh gill nets (Figure 7B) was also highly variable among years. It was highest in the early 1990s, with a peak of 1,562 fisher days in 1991/92. It decreased to 93 fisher days in 1994/95 and was highly variable until 2003/04, ranging between 158 fisher days and 799 fisher days. In 2007/08, effort declined to 62 days and remained low until 2010/11. Effort increased to 571 fisher days in 2011/12, before declining to 13 and 15 fisher days in 2013/14 and 2014/15, respectively. Annual effort in net-days was linearly related to effort in fisher days (LR: $r^2 = 0.96$, $F_{1,29} = 680.9$, $p < 0.001$).

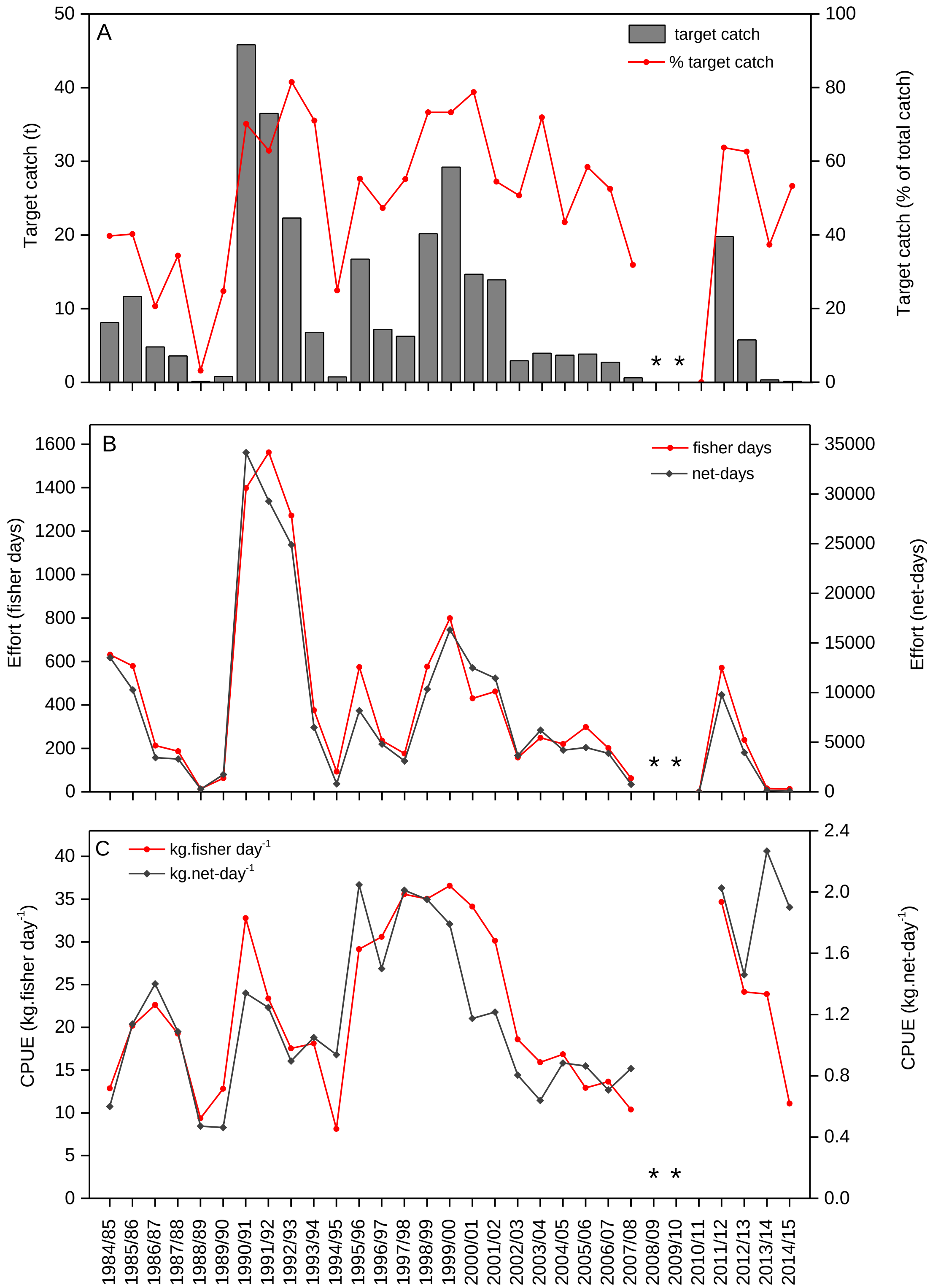

Figure 7. Annual targeted catch and effort for Greenback Flounder using large mesh gill nets from 1984/85 to 2014/15. (A) Targeted catch is shown in t, and as a percentage of total catch for the LCF; (B) Comparison of two measures of targeted effort for large mesh gill nets, i.e. fisher days, net days; (C) Comparison of two measures of $CPUE_{LMGN}$ based on the two measures of targeted effort. (*) represents confidential data reported by less than five licence holders (does not represent actual values). No targeted fishing effort was reported for 2010/11.

Mean annual CPUE for large mesh gill nets ($CPUE_{LMGN}$; kg.fisher day^{-1}) was positively correlated with total catch (LR: $r^2 = 0.31$, $F_{1,29} = 15.03$, $p < 0.001$), but not with targeted effort (LR: $r^2 = 0.11$, $F_{1,29} = 4.03$, $p = 0.071$). $CPUE_{LMGN}$ was highly variable from 1984/85 to 1995/96, ranging from 9.4 kg.fisher day^{-1} to 32.8 kg.fisher day^{-1} (Figure 7C). $CPUE_{LMGN}$ increased to 35 kg.fisher day^{-1} in the late 1990s, before progressively decreasing through the 2000s. It increased to 35 kg.fisher day^{-1} in 2011/12, before declining to 11 kg.fisher day^{-1} in 2014/15. Temporal patterns in $CPUE_{LMGN}$ (kg.fisher day^{-1}) were similar to those of $CPUE_{LMGN}$ (kg.net-day^{-1}).

Spatial distribution of catches

Catches from some reporting areas (Figure 1) were pooled to provide an indication of their cumulative contribution to total annual catches, as they were reported by less than five licence holders in some years (Figure 8).

The contribution of catches from different reporting areas to total catches varied among years (Figure 8). From 1984/85 to 2000/01, catches in most years were dominated by contributions from the mid-Coorong between Long Point and Parnka Point (areas 10 and 11), with most of the remainder taken from the upper Coorong between the Murray Mouth and Long Point (areas 8 and 9). From 2001/02 to 2007/08, the fishery contracted north-west toward the Murray Mouth, as contributions from areas 10 and 11 declined. From 2008/09 to 2010/11, all catches were taken from areas north-west of Long Point (areas 6-9). The fishing ground expanded in 2011/12, with approximately 70% of catches taken from areas 10 and 11, before again contracting northward to areas 8 and 9 in 2013/14 and 2014/15.

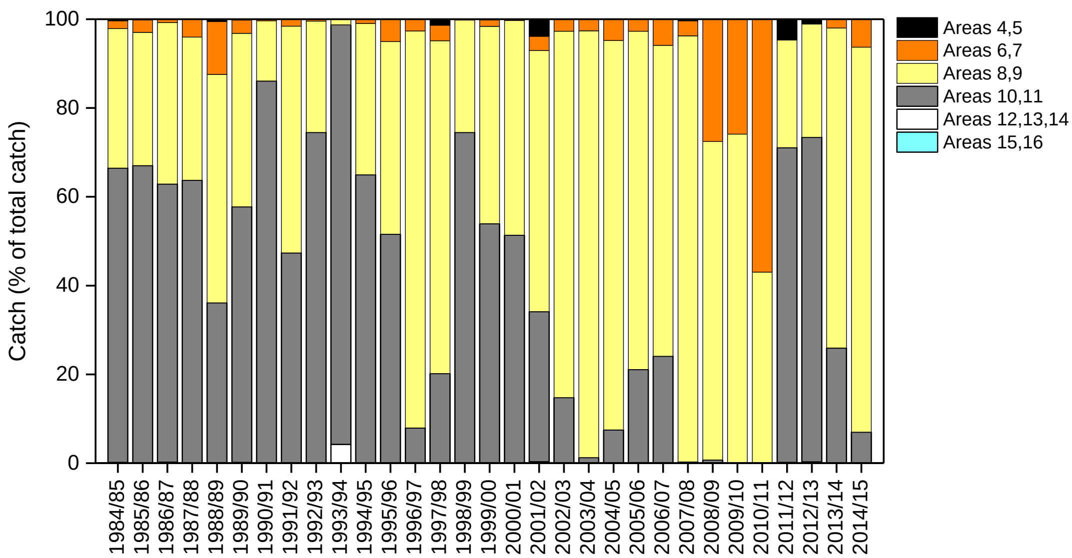

Figure 8. Contribution of catches from commercial reporting areas to total annual catches for the LCF from 1984/85 to 2014/15, expressed as a percentage of total annual catch.

Temporal variation in freshwater inflows

Since 1970/71, annual freshwater inflows to the Coorong have been highly variable (Figure 4). Inflow was highest in the mid-1970s when it averaged approximately 22,000 $GL.yr^{-1}$, after which 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 estuary and Southern Ocean. Due to reduced flows in 2013/14 and 2014/15, dredging of the Murray Mouth recommenced in January 2015.

Influence of freshwater inflow on fishery production

The relationship between annual freshwater inflows to the Coorong estuary and total catch taken from 1976/77 to 2014/15 was examined using cross-correlation analysis (Figure 9). There was a significant correlation between freshwater inflow and total catch for lags of two (r = 0.68) and three (r = 0.64) years. This indicates that years of increased freshwater inflow resulted in an increase in annual catches 2-3 years later (Figures 4 and 9).

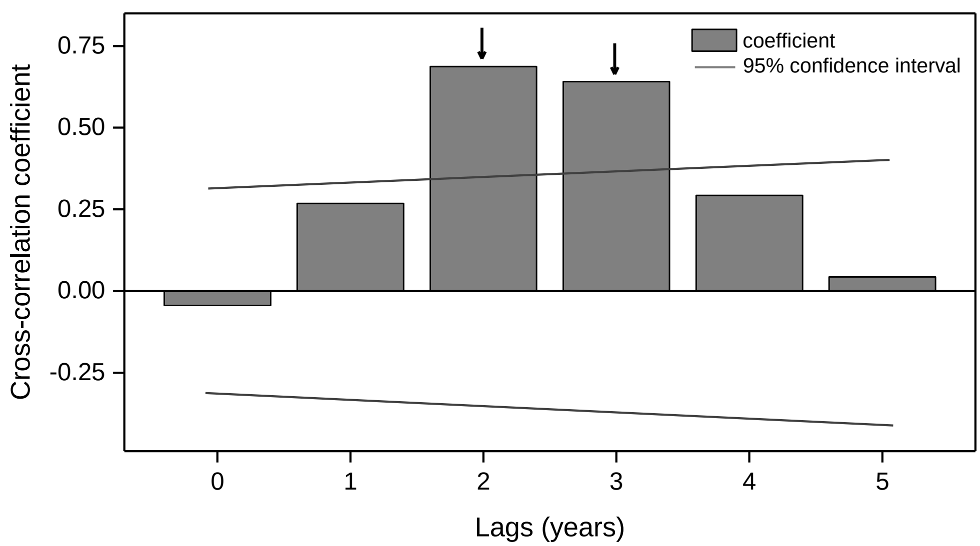

Figure 9. Summary of cross-correlation analyses performed on annual freshwater inflow data and total catch data for Greenback Flounder from 1976/77 to 2014/15, with annual lags of up to five years. Arrows denote significant correlation between freshwater inflow and total catch variables (α = 0.05).

From 1984/85 to 2014/15, freshwater inflows to the Coorong explained 36% of the variability in the contribution of catches from south of Long Point to the total catch (LR: $r^2 = 0.36$, $F_{1,28} = 17.26$, p <0.001; Figure 10). This positive relationship indicates that the size of the available fishing grounds were reduced during years of low inflow and increased in years of high inflow. The spatial distribution of catches over time further suggests that the size of the fishable area in the Coorong contracted north-west to areas adjacent to the barrages during years of low freshwater inflows (Figure 8).

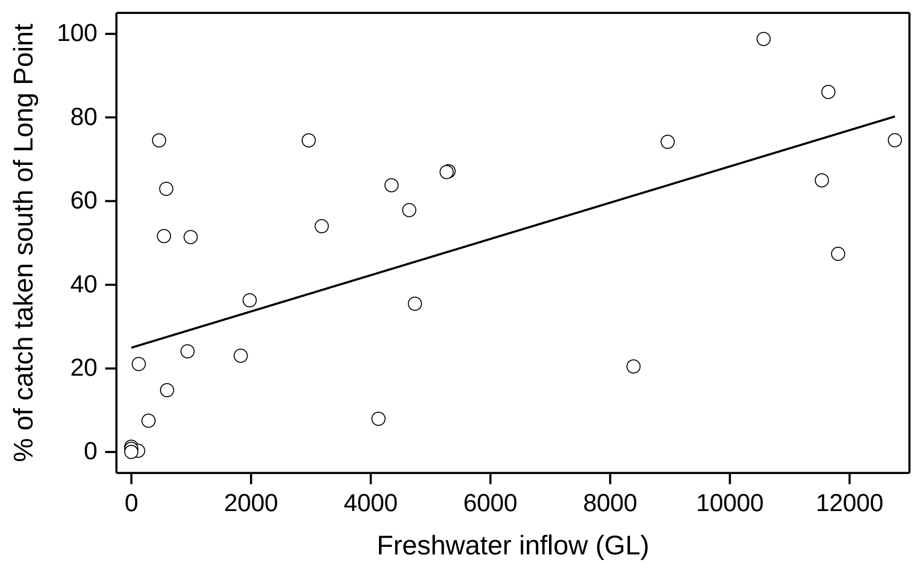

Figure 10. The relationship between freshwater inflow to the Coorong estuary and the proportion of the total catch taken from areas south of Long Point, for the period from 1984/85 to 2014/15.

2.4 Discussion

Estimates of annual catch dating back to 1951/52 were examined to provide a chronology of the variability in the biomass of Greenback Flounder harvested by commercial fisheries in South Australia. The majority (>95%) of the total catch in each year was taken from the Coorong estuary by the LCF.

Catches by the LCF were highly variable among years and ranged from 232 $t.yr^{-1}$ in the mid-1970s, to <1 t in several years during the 2000s and in 2013/14 and 2014/15. The total catch of 0.27 t in 2014/15 was among the lowest on record. The high inter-annual variation in catch was related to variation in targeted fishing effort. Given the high value of Greenback Flounder (EconSearch 2014), the lack of fishing effort and low catches in 2014/15 is likely to reflect low fish abundance in the Coorong estuary.

Annual estimates of $CPUE_{LMGN}$ provided a measure of relative abundance for Greenback Flounder in the Coorong estuary. While $CPUE_{LMGN}$ data were only available from 1984/85 onwards, they suggest that relative abundance was highly variable among years during that period. The estimate of relative abundance for 2014/15 was among the lowest on record.

Variation in the abundance and dispersion of Greenback Flounder in the Coorong estuary was strongly associated with fluctuations in the magnitude of freshwater inflows to the system. Under a regime of consistent, relatively high seasonal inflows, a larger area of estuarine habitat is available and commonly supports higher densities of Greenback Flounder (Earl 2014; Ye et al. 2015). Alternatively, during periods of low flow, abundance is low and the dispersion of individuals is restricted to areas adjacent the Murray Mouth, because the southern part of the Coorong (i.e. southern parts of the North Lagoon and the entire South Lagoon) become hypersaline. It is likely that such spatial contractions of the population within the estuary force some individuals into the marine environment where they remain and can possibly return when conditions within the estuary improve (Earl 2014). The strong relationship between freshwater inflows and total catch suggests that the inflows have a major influence on the size of the fishable biomass of Greenback Flounder in the Coorong estuary.

Overall, analyses of catch and effort data for the LCF provided evidence that the Greenback Flounder biomass in the Coorong estuary was low at the conclusion of 2014/15.

3. SIZE AND AGE STRUCTURES

3.1 Introduction

Determining the status of a fishery resource requires some understanding of the demographic processes that influence the size and structure of the fishable biomass. As well as helping to understand the dynamics of the population, this may also help to determine the response of the population to fishing pressure and/or changes in the environment. Knowledge of the demographic processes of a fish population is facilitated by obtaining length at age data that provide information on growth, recruitment, and mortality. The rates at which these processes occur are best determined using fish age as a time reference (Campana 2001).

Growth increments in the otoliths of Greenback Flounder are formed annually and provide an indication of age for individual fish (Earl et al. 2014). In this study, commercial and research survey catches of Greenback Flounder taken in the Coorong estuary by the LCF were sampled to develop size and age structures. The objective of this section was to analyse the size and age structures for 2014/15, to be compared with those determined for previous years and interpreted in terms of the processes that may account for the variation in the size of the fishable biomass of Greenback Flounder in the Coorong estuary.

3.2 Methods

Sample collection

Greenback Flounder were collected annually between 2008/09 and 2014/15 from the Coorong estuary to develop population size and age structures. Samples of fish were collected from: (i) commercial gill net catches (>115 mm mesh size); and (ii) research survey catches taken using multi-panel gill nets (38-150 mm mesh size) and haul nets (90 mm mesh size), which provided a wider size range of fish. On each sampling occasion fish were randomly sub-sampled (up to 30 fish) from catches and stored for processing. No samples were available from commercial catches in 2010/11, while research samples were not available in 2011/12 and 2012/13.

Laboratory processing

Each fish was measured for TL to the nearest mm. The gonads were examined to determine the sex of the fish. The sagittae, i.e. the largest pair of otoliths, were removed, cleaned, and stored for processing. The left otolith from each fish was prepared for ageing by embedding it in polyester resin and then cutting a transverse section of approximately 500 µm thickness that incorporated the core, using a diamond saw. The section was mounted on a microscope slide using Cyanoacrylate glue. Mounted sections were ground and smeared with immersion oil to improve visibility of their internal structure, and examined under reflected light using a dissecting microscope.

Each sectioned otolith was read and assigned a confidence rating according to the readability of its internal structure, where a rating of 'one' is poor and a rating of 'five' is good readability. Otoliths assigned a rating of 'two' or below were excluded from subsequent analyses, while those assigned a rating of 'three' were re-read by a second reader. If the second reading did not agree with the result from the earlier reading, the sample was excluded from subsequent analyses.

An algorithm was used to estimate the age of individual fish in months (Earl et al. 2014). The algorithm considers the annual periodicity of opaque zone formation, the number of completed opaque zones within the otolith, the date the fish was captured, and the universal birthdate of 1 June, i.e. the middle of the spawning season (Barnett and Pankhurst 1999; Earl 2014).

Size/age structures

Size and age frequency distributions for Greenback Flounder from the Coorong were prepared and presented in financial years. The sex ratio of commercial catch samples was also determined for each financial year. A chi-square test for goodness-of-fit was used to assess whether the relative frequency of males and females from commercial samples conformed to a 1:1 ratio using the statistical program SPSS v.20.

3.3 Results

Size structures

Annual size structures from commercial catches were similar among years for the period from 2008/09 to 2014/15 (i.e. they included fish from the current LMS of 250 mm TL to 385 mm TL) and were dominated by fish between 270 mm TL and 320 mm TL (Figure 11). The size structure for 2014/15 comprised a narrower distribution of sizes, i.e. from 250 mm TL to 310 mm TL, with a single, dominant mode at 275 mm TL.

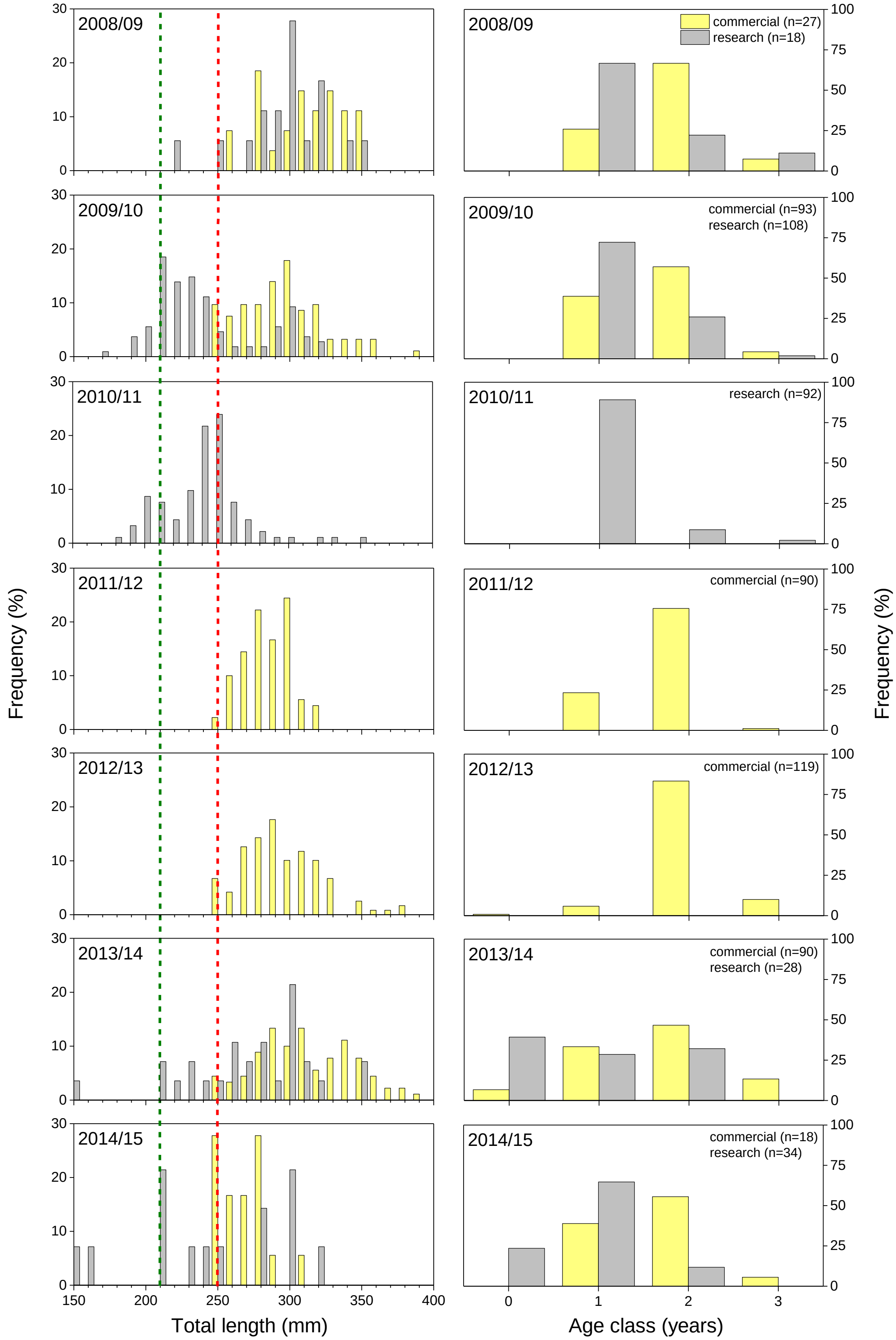

Figure 11. Annual size (left) and age (right) structures for Greenback Flounder from commercial catches and research survey catches taken in the Coorong estuary. Samples from research survey catches were not available for 2011/12 and 2012/13, while samples from commercial fishery catches were not available for 2010/11. Green line indicates size-at-maturity of 211 mm TL for females in the Coorong estuary (Earl 2014). Red line indicates the LMS of 250 mm TL.

The size range of fish in the research samples was wider than for commercial gill net samples (Figure 11), with research samples comprising mostly individuals from 150 mm TL to 350 mm TL. Although the modal size of individuals collected from research samples varied among years, it was generally smaller than the modal size of samples collected from commercial gill net catches.

<u>Age structures</u>

Annual age structures from commercial catches were relatively stable from 2008/09 to 2014/15 (Figure 11). For most years, ages ranged from one to three years, with one and two year olds dominating the distribution. Exceptions were 2012/13, 2013/14 and 2014/15, when small numbers of young-of-the-year were also present in the samples. The age structure for 2014/15 was dominated by one (39%) and two (55%) year old fish and included a small number of three year olds (6%).

Annual age structures from fishery-independent samples varied considerably among years due to the small sample sizes (Figure 11). Samples comprised mostly one year old fish, and included a small number of young-of-the-year, as well as low numbers of two and three year old fish. No three year olds were present in the samples from 2014/15.

<u>Sex ratios</u>

Sex ratios differed from 1:1 for samples from commercial catches (Table 3). In each year, females accounted for between 86% and 100% of the fish sampled in each year. For each year, Chi-square goodness-of-fit tests confirmed a strong bias in sex ratio toward females at the 0.001 level of significance.

Table 3. Sex ratios for Greenback Flounder samples from commercial catches taken from the Coorong estuary from 2008/09 to 2014/15. Chi-square goodness-of-fit test statistics are also shown. No tests were done for 2008/09, 2012/13 and 2014/15.

Year	$n_{females}$	n_{males}	$n_{females}$:n_{males}	χ^2	P
2008/09	27	-	-	-	-
2009/10	92	1	92:1	96.04	<0.001
2011/12	87	3	29:1	85.63	<0.001
2012/13	119	-	-	-	-
2013/14	80	10	8:1	55.7	<0.001
2014/15	18	-	-	-	-

3.4 Discussion

The size and age characteristics of the Greenback Flounder population in the Coorong estuary were examined to investigate population structure and processes that may account for variation in population abundance (Section 2). Size structures comprised mainly fish between 220 mm TL and 320 mm TL and the age structures were dominated by one and/or two year old fish, while older fish were rare. Given the potential for this species to attain 10 years of age (Sutton et al., 2010), the fishable biomass in the Coorong estuary consisted of fish in the youngest age classes. Whilst the presence of young (<2 year olds) fish in the age structures since 2008/09 indicates that recruitment has occurred each year since 2006/07, recruitment levels have been highly variable as indicated by trends in commercial catch and $CPUE_{LMGN}$ (Section 2).

Age structures from this study were consistent with those from a previous study undertaken in the Coorong estuary in the late 2000s (Earl et al. 2014). Results from that study, which also considered samples from both commercial gill net catches and fishery-independent haul/seine net catches, indicated that the population mainly consisted of one and two year old fish, with low contributions from three and four year olds. Such population truncation has also been observed for estuarine populations in Tasmania (Kurth 1957).

Similarity in age structures from 2008/09 to 2014/15 suggests that the previously documented variation in population abundance for Greenback Flounder relates to a combination of demographic events and/or processes that occur during the first 2-3 years of its life history. The most significant of which likely involves: (i) the movement of individuals between the Coorong estuary and the marine environment in response to changes in the amount of estuarine habitat available within the Coorong estuary (Earl 2014); (ii) inter-annual variation in egg production and spawning success; and (iii) the removal of individuals by the fishery. However, the lack of information on the distribution, abundance and demography of the species in the marine environment adjacent the Coorong estuary, limits understanding of recruitment patterns that could otherwise inform trends in spawning stock biomass.

The current LMS for Greenback Flounder in South Australia of 250 mm TL (applies to commercial fisheries only), is well above the size at maturity (SAM_{50}) of 198 mm TL and 211 mm TL for females and males, respectively (Earl et al. 2014). For fast growing species such as Greenback Flounder, this allows individuals to spawn at least once before recruiting to the fishable biomass.

4. PERFORMANCE INDICATORS

4.1 Introduction

The Management Plan for the LCF provides a framework for management (Sloan 2005). For Greenback Flounder, PIs based on catch and effort data are used to 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 status of the LCF for Greenback Flounder, based on the PIs and associated RPs in the Management Plan. A new management plan was recently finalised and took effect on 1 March 2016.

4.2 Methods

For Greenback Flounder, there are four PIs: (i) total catch; (ii) mean annual $CPUE_{LMGN}$; (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 (Sloan 2005). For the PIs of total catch and $CPUE_{LMGN}$, the upper and lower RPs were based on the three highest and three lowest values during the reference period. The trend PIs for total catch and $CPUE_{LMGN}$ were determined using the greatest rate of change (±) over four consecutive years for total catch and $CPUE_{LMGN}$ during the reference period.

4.3 Results

In 2014/15, three of the four PIs were within the range of their associated RPs (Table 4). The PI for total catch was 93% below the lower RP. The PI for $CPUE_{LMGN}$ and the trend PIs for total catch and $CPUE_{LMGN}$ were within the range of their respective RPs. Inter-annual trends for the four PIs from 1984/85 to 2014/15 are shown in Figure 12.

Table 4. Performance indicators and reference points (RP) for Greenback Flounder for 2014/15.

Performance Indicator	Lower RP	Upper RP	2014/15 estimate	Within range of RPs
Total catch (t)	4	54	0.27	N
4-year total catch trend	-22	22	-10.1	Y
$CPUE_{LMGN}$ (kg.fisher day^{-1})	10	36	11.1	Y
4-year $CPUE_{LMGN}$ trend	-8.2	8.2	-7.1	Y

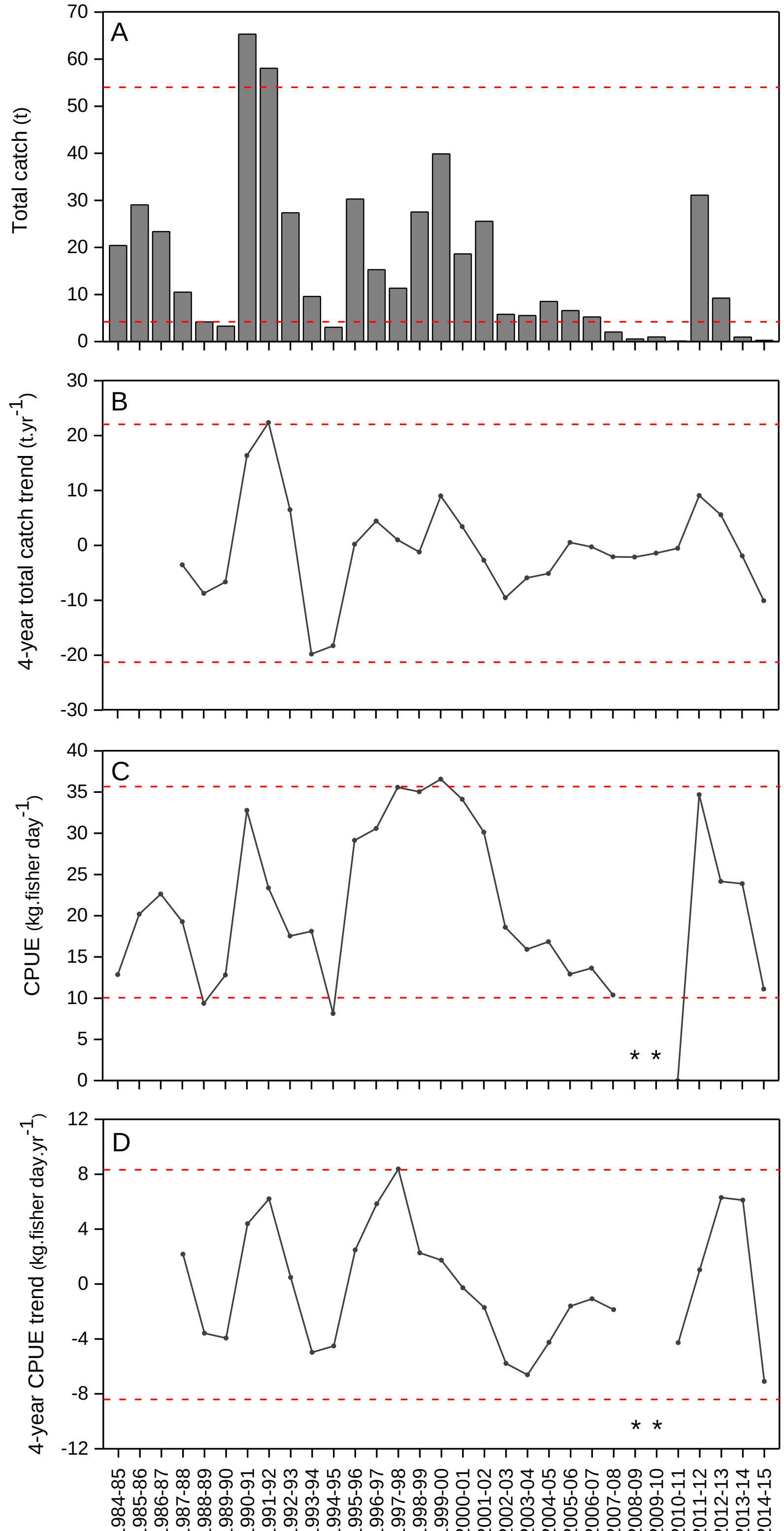

Figure 12. Annual time series of performance indicators and upper and lower limit reference points (red dashed lines) for Greenback Flounder from 1984/85 to 2014/15. (A) Total catch; (B) 4-year total catch trend; (C) mean annual $CPUE_{LMGN}$; and (D) 4-year $CPUE_{LMGN}$ trend. (*) represents confidential data reported by less than five licence holders (does not represent actual values).

4.4 Discussion

The recent performance of the LCF for Greenback Flounder was examined by assessing fishery PIs against RPs prescribed in the Management Plan (Sloan 2005). For 2014/15, three of the four PIs were within the range of the upper and lower RPs. The PI for total catch was 93% below the lower RP and indicated that fishery production was at a historically low level 2013/14 in 2014/15. The recent low annual catches related to levels of annual targeted fishing effort that were among the lowest recorded in the fishery (Section 2).

The PI for $CPUE_{LMGN}$ was within the range of associated RPs, but has progressively declined since 2011/12, as indicated by the $CPUE_{LMGN}$ trend PI for 2014/15. The low annual catch and low $CPUE_{LMGN}$ in 2014/15 is indicative of low abundance of Greenback Flounder in the Coorong estuary.

Uncertainty surrounds the PIs and associated RPs for Greenback Flounder. This is because: (i) RPs were determined from a fixed, relatively short time period (1984/85 to 2001/02); and (ii) there is no consideration of the influence of the environment on fishery performance. There is a need to develop new PIs to improve assessments of stock status for the species. Options for a new assessment framework for finfish species harvested by 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 would be appropriate for Greenback Flounder, because variation in population abundance for this species in the Coorong estuary is strongly associated with variation freshwater inflows and associated changes in the availability of estuarine habitat within the system.

5. GENERAL DISCUSSION

5.1 Information available for assessing fishery status

Information available to assess the LCF for Greenback Flounder included: (i) estimates of annual commercial fishery production in South Australia from 1951/52 to 2014/15; (ii) daily commercial catch and effort data from 1984/85 to 2014/15; (iii) annual estimates of relative abundance based on commercial fishery-dependent $CPUE_{LMGN}$ from 1984/85 to 2014/15; (iv) annual population size and age structures from 2008/09 to 2014/15; and (v) fishery PIs and associated RPs. This information formed the basis of a weight-of-evidence assessment of fishery status for Greenback Flounder in the Coorong estuary (Flood et al. 2014). The assessment is aided by a previous stock assessment report (Ferguson 2007), several fishery statistics reports (e.g. Earl and Ward 2014; Earl 2015) and the Management Plan (Sloan 2005).

Knowledge gaps in the biology of Greenback Flounder identified in the previous stock assessment (Ferguson 2007) were addressed in a recent PhD study (Earl 2014). In that study, several aspects of the biology of the Coorong population were described. These included: (i) reproductive characteristics and spawning dynamics; (ii) size and age at maturity; (iii) feeding habits and dietary composition; and (iv) movement patterns and habitat use. That study also developed an ageing protocol based on otolith interpretation and provided estimates of age and growth.

Otolith-based estimates of age from the current study (Section 3) provided age structures for the Coorong population, 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 population that will ultimately improve understanding of impacts of environmental variability and demographic process/events that may contribute to variation in fishery production for the species.

5.2 Current status of the LCF for Greenback Flounder

The harvest strategy in the current Management Plan for the LCF (Sloan 2005) lacks an index that explicitly defines stock status for Greenback Flounder. 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 Coorong population.

The LCF has historically been the most significant fishery for Greenback Flounder in South Australia. Since the 1970s, it has consistently contributed >98% of the State's commercial catch.

Analysis of the long-term chronology of fishery production for the LCF indicated extreme inter-annual variability in population abundance in the Coorong estuary. Annual catch peaked at 232 t in the mid-1970s. Since then, catches have fluctuated periodically, but have been substantially lower. The total catch of 0.27 t in 2014/15 was among the lowest on record. The recent low catches were associated with low targeted fishing effort. Given the high market value of the species, the lack of fishing effort in 2014/15 is likely to reflect low abundance in the Coorong.

Annual estimates of $CPUE_{LMGN}$ provided a measure of relative abundance for Greenback Flounder in the Coorong estuary. Trends in $CPUE_{LMGN}$ followed those of total catch. This suggests that the variation in fishery production was likely driven by changes in fish abundance in the Coorong estuary. The $CPUE_{LMGN}$ of 11 kg.fisher day^{-1} in 2014/15 was among the lowest on record.

Of the four fishery PIs for 2014/15, three were within the range of the RPs described in the Management Plan. The PI for total catch was 93% below the lower RP, while the PI for $CPUE_{LMGN}$ was close to breaching the lower RP.

The high inter-annual variation in population abundance in the Coorong estuary since the 1970s has been associated with fluctuations in freshwater inflow from the Murray River to the estuary. This is because large areas of estuarine habitat that support high abundances of Greenback Flounder are typically only available after years of increased inflow (Earl 2014). Alternatively, during periods of low inflow (i.e. 2013/14, 2014/15), abundance was low and the dispersion of individuals within the estuary was restricted to areas adjacent the Murray Mouth, because most of the system becomes hypersaline (Webster 2010). It is likely that such spatial contractions of the population within the estuary forced some individuals into the marine environment where they remain and can possibly return when estuarine conditions improve (Earl 2014).

Annual age structures for the Coorong population were relatively stable from 2008/09 to 2014/15, and comprised mostly one and two year old fish. Older fish were rare despite the potential for this species to attain 10 years of age (Sutton et al. 2010). The lack of older fish is consistent with estuarine populations in Tasmania (Kurth 1957; Crawford 1984), and likely relates to: (i) an ontogenetic migration of individuals from the estuarine to marine environment that occurs during the second or third years of life (Earl 2014); and (ii) the removal of older fish by fishing.

The presence of young fish in the age structures indicated that recruitment has occurred in recent years. In particular, the recruitment of a large biomass of mostly one and two year old fish to the fishable biomass in the Coorong estuary in 2011/12 (i.e. one year after a significant high flow event), suggests that the spawning biomass of Greenback Flounder is unlikely to be recruitment overfished. The low recruitment in 2014/15 appears to relate to low freshwater inflows and the associated decline in the amount of estuarine habitat available for the species in the Coorong estuary, rather than a low spawning biomass. The current level of fishing mortality is unlikely to cause the stock to become recruitment overfished. Consequently, on the basis of the information above and using the definition from the National Status of Key Australian Fish Stocks Report (Flood et al. 2014), the Greenback Flounder stock in the Coorong estuary is classified as **environmentally limited**.

5.3 Uncertainty in the assessment

The proportional use of habitats in the Coorong estuary and adjacent marine environment by Greenback Flounder is poorly understood. While the Coorong estuary provides an important nursery for the species through the first 2-3 years of life (Earl et al. 2014), the extent and demography (i.e. size and age structure, sex ratio) of the population in the nearshore marine environment is not known. Such information would improve understanding of the environmental and demographic processes that contribute to variation in population abundance in the Coorong, which would reduce uncertainty in future assessments of stock status.

There is uncertainty around: (i) levels of sub-legal sized Greenback Flounder taken as bycatch by the commercial fishery, particularly in higher flow years; and (ii) post-release mortality. The FRDC funded bycatch study indicated that undersize Greenback Flounder are taken as bycatch in large mesh gill nets, with discard rates highest in autumn and summer (Ferguson 2010a). Of those Greenback Flounder discarded, approximately 56% were released alive, although post-release mortality is not known. It is planned to incorporate discard information into the Inland Waters Catch and Effort logbook return in 2016/17.

Uncertainty surrounds the levels of recreational catches of Greenback Flounder in the Coorong estuary. Recreational fishing surveys estimated that recreational catches of flounder in South Australia accounted for 22% of the combined commercial and recreational State-wide catch in 2013/14 (Giri and Hall 2015). However, the proportion of the total State-wide recreational harvest taken in the Coorong estuary is not known.

Uncertainty exists around each of the PIs and RPs defined for Greenback Flounder 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 (1984/85-2001/02); and (ii) there was no explicit consideration of the influence of the environment on fishery performance. Caution is also required when interpreting trends in CPUE, because environmentally-driven changes in the size of the fishable area for Greenback Flounder in the Coorong estuary may affect their catchability and potentially confound interpretation of CPUE as an indicator of population abundance. Thus, 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 the recent FRDC project (Knuckey et al. 2015). This included the development of a set of environmental PIs, based on habitat availability, as surrogate metrics for biomass for Mulloway and Yelloweye Mullet. Similar environmentally-based PIs would be appropriate for Greenback Flounder given the relationship between abundance and river inflows. 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 age structure data, is likely to be the most appropriate means for assessing stock status for the species in the Coorong.

With the recent recovery of Long-nosed Fur Seal (*Arctocephalus forsteri*) populations in South Australia (Shaughnessy et al. 2015), fur seal interactions with LCF gill net fishers 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 Greenback Flounder in the LCF, as depredation rates and levels of discarding of seal-damaged flounder 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 Greenback Flounder and its management include: (i) delineation of stock structure in South Australia; (ii) improved understanding of the proportional use of habitats in the Coorong estuary and adjacent marine environment; (iii) independent monitoring of discarding of non-targeted and sub-legal sized individuals from gill nets; (iv) improved understanding of the impacts of Long-nosed Fur Seals on the fishery; and (v) regular surveys to estimate the recreational harvest of Greenback Flounder from the Coorong estuary.

To prioritise the research needs for Greenback Flounder, there is a need for knowledge of stock structure in South Australia, and the degree to which the Coorong population is limited by recruitment from spawning events that occur in the marine environment. The issue of stock structure is crucial for understanding the capacity to which the Coorong population can be replenished.

Surveys to estimate recreational harvest of Greenback Flounder from the Coorong estuary that are conducted on a regular basis would improve future assessments of stock status, 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 the species.

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