Fisheries biology of the greenback flounder *Rhombosolea tapirina* (Günther 1862) (Teleostei: Pleuronectidae) in South Australia

Report for PIRSA Fisheries

G Ferguson

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South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024

Telephone: (08) 8207 5400
Facsimile: (08) 8207 5481
http://www.sardi.sa.gov.au

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Author(s): G Ferguson
Reviewers: Dr. D McNeil and S Leigh
Approved by: Dr. A J Fowler

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1 INTRODUCTION

This report provides a synopsis of the information available for management of the greenback flounder fishery. This includes (i) taxonomy, (ii) distribution and habitat, (iii) stock structure, and (iv) fisheries biology. Further information is provided on the fishery for greenback flounder and management of the fishery.

2 TAXONOMY

The greenback flounder (*Rhombosolea tapirina* Günther, 1862) belongs to the family Pleuronectidae, commonly known as the right-eye flounders (Last *et al.* 1983). Of the four species in the temperate Australasian genus *Rhombosolea*, *R. tapirina* is the only species that occurs in Australia (Gomon *et al.* 1994). The key diagnostic features for identification of *R. tapirina* are; (i) the absence of ventral fins on the lower body surface, and (ii) a distinctive, pointed snout (Last *et al.* 1983).

3 GEOGRAPHICAL DISTRIBUTION AND HABITAT

Rhombosolea tapirina occur in Australia from southern New South Wales and Tasmania, to Western Australia (Last *et al.* 1983; Kailola *et al.* 1993; Gomon *et al.* 1994). They also occur in New Zealand, around the Auckland and Campbell Islands (Gomon *et al.* 1994).

Adult *R. tapirina* prefer sand, silt and muddy substrates in sheltered bays, estuaries, and inshore coastal waters (Last *et al.* 1983; Kailola *et al.* 1993; Gomon *et al.* 1994). They may also be found in the deeper channels of estuaries and to depths of 100 m (Last *et al.* 1983; Edgar 2000). Adults sexually partition habitat, with females more abundant in shallow water (5-10 m depth), and males more abundant in deeper water (10-25 m depth) (Kurth 1957; Crawford 1984a).

Post-settlement and juvenile *R. tapirina* tend to be found in shallower water and prefer unvegetated sand and mudflat habitat where they are well camouflaged (<1 m) (Connolly 1994b; Connolly 1994a; Edgar and Shaw 1995; Jenkins *et al.* 1997; Jenkins and Wheatley 1998). Juveniles tolerate a wide range of changes in salinity and are often found in the upper reaches of estuaries and occasionally upstream in rivers (Last *et al.* 1983).

4 STOCK STRUCTURE

Significant genetic differences exist between the Australian and New Zealand populations of *R. tapirina* based on polymorphic allozyme loci (van den Enden *et al.* 2000). Within

Australia, *R. tapirina*, from western Tasmania are genetically isolated from the population in Victoria, and northern and south-eastern Tasmania, although to a much lesser extent than from the population in New Zealand. The separation of western and eastern Tasmanian populations is supported by morphometric data, and has been suggested to have occurred as a consequence of the closure of Bass Strait during the last ice age (Kurth 1957).

The stock structure of Western Australian and South Australian populations of *R. tapirina* is not known. *R. tapirina* are rarely found in marine waters adjacent to the Coorong lagoons and it has been suggested that the Coorong population is estuarine-resident and completes it's life cycle within the Coorong (Hall 1984).

5 BIOLOGY

5.1 Diet

Larval *R. tapirina* prefer to feed during daylight hours (Chen *et al.* 1999; Cox and Pankhurst 2000) and feed mainly on bivalve veligers, tintinnids, invertebrate eggs, and copepod nauplii (Jenkins 1987b). As the larvae grow, larvaceans, cladocerans, and harpacticoid nauplii become increasingly important prey items (Jenkins 1987a). Newly metamorphosed juveniles are also daytime feeders and eat mostly amphipods, harpacticoid copepods and polychaetes (Crawford 1984a). Older juveniles consume epibenthic harpacticoids, harpacticoid nauplii, and gammaridean amphipods and polychaetes (Crawford 1984a; Shaw and Jenkins 1992).

Adult *R. tapirina* feed nocturnally, as the tide rises, by digging for benthic crustaceans and polychaetes on shallow mud or sand banks (Edgar *et al.* 1982; Edgar 2000).

5.2 Growth

Most ageing work on *R. tapirina* has been done on the larvae and juveniles. Daily growth increments begin to form in the sagittal otoliths 5 days after hatching, as exogenous feeding commences (Jenkins 1987a; Stewart and Jenkins 1991). After 35 days a transition zone forms, corresponding with metamorphosis and settlement, and causes the rings to become indiscernible (May and Jenkins 1992). Visible daily increments resume after this transition zone.

The growth of early larval *R. tapirina* is exponential, ranging from 0.1 to 0.23 $mm.day^{-1}$ (Jenkins 1987a). During metamorphosis, growth is slow, and from post-settlement is linear at 0.29 mm d^{-1} (May and Jenkins 1992). In Victoria, growth rates of juveniles were shown to be higher when the food supply was higher (Jenkins *et al.* 1993). No ageing work has been done on juveniles longer than 40 mm total length (TL) in Australia.

Adult *R. tapirina* in Australia appear to be fast growing (Edgar *et al.* 1982; Last *et al.* 1983; Gomon *et al.* 1994). The maximum length of 36 to 45 cm occurs at approximately 600 g in Tasmania, although the average size for adults was generally less than 30 cm (Jordan *et al.* 1998).

Otolith based ageing studies were conducted in New Zealand on several species of the genus *Rhombosolea* showing that they had fast growth rates and low maximum ages (Colman 1974; Francis 1988; Paul 1992; Stevens *et al.* 2005). The maximum age of *R. tapirina* in New Zealand was 6 years (D.W. Stevens unpublished data, in, Stevens *et al*. (2005)), although the ages reported in these studies may have been underestimated because they were based on whole otoliths (Stevens *et al.* 2005). Stevens *et al* (2005) used thin sections of sagittal otoliths to estimate the ages of the Pleuronectids, brill (*Colistium guntheri*) and turbot (*C. nudipinnis*). Formation of annuli were validated, for younger fish, using marginal increments. This latter method may potentially be used to characterise age structures and growth patterns of *R. tapirina* in South Australia.

In New Zealand, adult stocks of Pleuronectid species generally appeared to be made up of one or two year classes and the stock size appeared to be recruitment driven for most species (Annala *et al.* 2003).

5.3 Size of maturity

In Tasmania the size of maturity (SOM) was estimated to be 218.6 and 190 mm TL for female and male *R. tapirina*, respectively (Crawford 1984a) (Table 5-1). The estimate of SOM for males was consistent with that of Kurth (1957), although that for females was not, possibly due to the use of different criteria to determine maturity. There are no estimates of SOM for greenback flounder in South Australia.

Table 5-1. Size of maturity for greenback flounder (*Rhombosolea tapirina*) in Tasmania.

Source	Method	Sex	Size of maturity (mm TL)
Crawford (1984)	LD_{50} (macroscopic gonad staging)	F	218.6 (± 36)
"	"	M	190.4 (± 75)
Kurth (1957)	Oocyte diameters (60% of fish mature)	F	240
"	"	M	190

5.4 Reproduction

In Tasmania, the spawning season, based on gonadosomatic indices, occurs when the water temperature is low, from late autumn to spring (June to October) (Kurth 1957; Crawford 1984a). Larval abundances are also greatest between June and August (Crawford 1984b; Jenkins 1986).

Females move from the shallows, prior to spawning which occurs in the deeper areas of tidal rivers and estuaries as well as offshore (Kurth 1957; Crawford 1984a).

Instantaneous fecundity ranged from 820,880 to 1,969,070 eggs and was linearly related to length for females from 247 to 343 mm TL (LR: Fecundity = -1053.65 + 85.85*Length (cm), r^2 = 0.72, Crawford 1984a). Oocyte development is multiple group-synchronous with the capacity for multiple ovulations within a reproductive season (Kurth 1957; Crawford 1984a; Barnett and Pankhurst 1999). However, neither the spawning fraction nor total fecundity have been quantified (Hunter *et al.* 1985; Hunter *et al.* 1992).

The reproductive strategy of *R. tapirina* involves serial spawning and relatively high fecundity, over a prolonged spawning season (Crawford 1984a). This strategy may maximise reproductive potential and appears best suited to survival of newly metamorphosed juveniles which have a narrow distributional range in the intertidal zone (Crawford 1984a). Recruitment over several months may enhance the opportunity for larvae and juveniles to find favourable environmental conditions and thus alleviate crowding in nursery areas (Crawford 1984a).

5.5 Early Life History

The fully developed eggs of *R. tapirina* are buoyant, pelagic, 0.7-1.0 mm in diameter, and hatch between 82 and 93 hours after fertilisation at 11-14°C (Crawford 1986; Hart 1994). They also contain oil droplets and are transparent (Crawford 1984a).

Larvae hatch, at 1.9 mm, between May to November and float passively at the surface with yolk sac uppermost (Crawford 1984a). Five days after hatching yolk absorption is complete and feeding commences. Larvae remaining in the plankton for over 30 days where they attain a length of approximately 6 mm (Jenkins *et al.* 1993).

Metamorphosis occurs after approximately 35 days and coincides with migration of the left eye which is completed approximately 65 days after hatching (8.8 mm) (Crawford 1984b;

Crawford 1986; Jenkins 1986; May and Jenkins 1992). During metamorphosis there is an ontogenetic shift in preferred salinity and position in the water column, as well as a preference for fine sand, which may play a role in guiding the larvae towards settling on shallow estuarine sandflats which provide nursery habitat (Crawford 1984a). The larvae are weak swimmers and rely on water currents or wind-induced surface water movements to drift inshore to settle (Crawford 1984a). Metamorphosis is completed about 65 days after hatching (Crawford 1986). Settlement occurs during late winter to early summer and substrate type and salinity preferences appear to be the major determinants of the distribution of recently settled juveniles (Burchmore 1982). Estuaries are important nursery grounds for *R. tapirina* although low salinities may be a preferred, but not essential, requirement (Crawford 1984a).

Newly metamorphosed juveniles of *R. tapirina* were observed in most months (Crawford 1984a), and the widespread distribution of *R. tapirina* across southern Australia is probably related to the duration of the planktonic larval stage in the open ocean (Gomon *et al.* 1994).

6 THE FISHERY

6.1 Australia

Flounder support commercial and recreational fisheries in south-eastern Australia with smaller catches also taken in Queensland and Western Australia (Kailola *et al.* 1993; PIRSA 1996). Catches of flounder are mainly composed of *R. tapirina* because it is the only flatfish species in southern Australia that is sufficiently large and abundant to be exploited (Edgar 2000). In eastern Victoria and the Coorong in South Australia low volume catches are sold primarily on the domestic market (Kailola *et al.* 1993; PIRSA 1996).

Harvesting is conducted with bottom-set gillnets, seine nets and by spearing (Kailola *et al.* 1993; Lyle and Campbell 1999). Incidental catches are also made with Danish seines and otter trawls in Tasmania and Victoria (Kailola *et al.* 1993).

6.2 South Australia

6.2.1 Commercial Fishery

In South Australia, almost all catches of greenback flounder are from the Coorong lagoons (Figure 6-1). The Lakes and Coorong Fishery is a multi species, multi-method fishery and is the only commercial fishery operating in the Coorong lagoons. The dominant gear is the large-mesh gill net (mesh size > 115 mm) which is set on the bottom when targeting flounder (Ferguson 2006).

There is anecdotal evidence that when abundance of Coorong crabs (*Paragrapsis gaimardii*) is high, fishers are less likely to target greenback flounder because damage caused by crabs causes the product to be unsaleable (Pierce and Doonan 1999).

6.2.2 Recreational Fishery

Recreational fishers harvest greenback flounder using spears and gill nets. However, there is little information available for recreational fishing for greenback flounder in South Australia.

6.2.3 Traditional Fishery

The Ngarrindjeri population density is likely to have been the largest of any aboriginal group in Australia with an estimated 3000 people inhabiting the Coorong region in the 1800's, prior to European settlement (Sloan 2005). The Ngarrindjeri people targeted flounder as well as bream, mulloway and yellow-eye mullet. Smoked and dried fish were stored and traded (Jenkin 1979).

6.2.4 Stock Assessment

Previous information available for the greenback flounder fishery are (i) general information on catches within the Coorong lagoons (Hall 1984) and (ii) stock status reports for the Lakes and Coorong fishery (Pierce and Doonan 1999; Ferguson 2006).

In South Australia, the catches of greenback flounder tend to be highest from February to April (Kailola *et al.* 1993), and catches and catch rates have varied greatly among years (Hall 1984; Pierce and Doonan 1999; Ferguson 2006). In 1976-77 the catch was 232 t, then declined to 6 t in 1982-83 (Hall 1984). During this period, CPUE ranged from 40 $kg.day^{-1}$ in 1976-77 to 10 $kg.day^{-1}$ in 1978-79 then was approximately 2 $kg.day^{-1}$ each year until 1982-83 (Hall 1984).

More recently, the annual catch of greenback flounder by the Lakes and Coorong Fishery ranged from 58 t in 1991-92 to 8 t in 2004-05 (Ferguson 2006). CPUE increased from 7 to 25 $kg.fisherday^{-1}$ from 1994-95 to 1999-00. CPUE then declined to 12 $kg.fisherday^{-1}$ in 2004-05 (Ferguson 2006).

The only available estimate of the recreational catch of flounder (all species) in South Australia was 2994 kg (± 647, SE) in 2000-01 (Jones and Doonan 2005). There is currently no estimate of the size composition of greenback flounder harvested by the recreational fishery in South Australia.

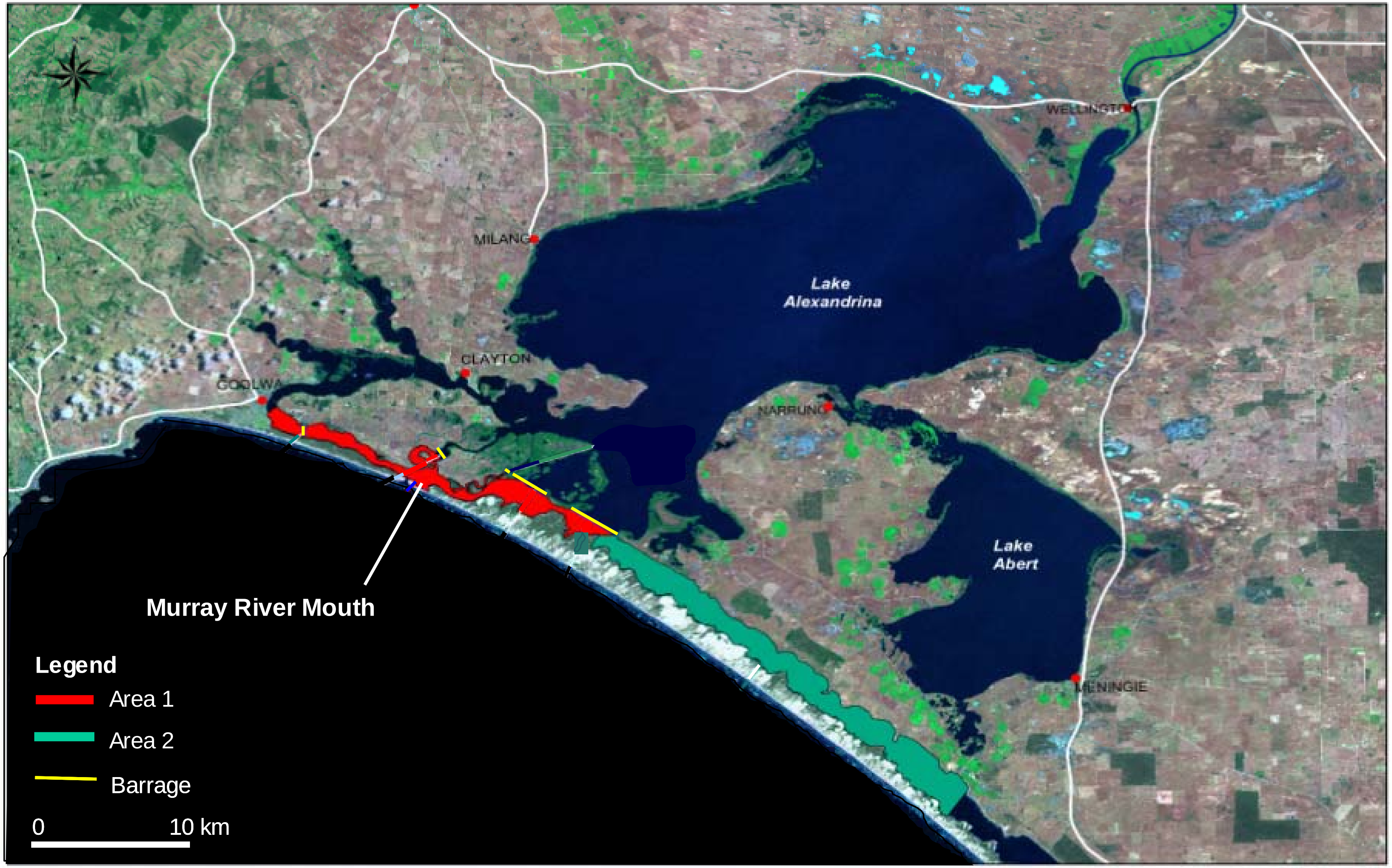

Figure 6-1. Map of Coorong showing Lakes and Coorong Fishery management Areas 1 (red) and 2 (green)

6.2.5 Potential environmental influences on catches of greenback flounder

The abundance of greenback flounder in the Coorong lagoons may be related to freshwater inflow from the Murray River and the available area of estuarine habitat (Hall 1984; Pierce and Doonan 1999). In South Australia, in the 1940's, a series of barrages were constructed between the mouth of the Murray River and Lakes Alexandrina and Albert that effectively reduced the area of estuarine habitat to 11% of its original size. It is likely that this severely reduced the area of habitat available for greenback flounder.

Hall (1984) related CPUE ($kg.day^{-1}$) from commercial catches to the amount of freshwater spill over the barrages for the period from 1976-77 to 1982-83 and found that the maximum correlation coefficient occurred when barrage spill was lagged by 38 months. This implied that spawning or recruitment success may have been enhanced during periods of freshwater inflow to the Coorong lagoons.

7 MANAGEMENT OF THE FISHERY

7.1 Commercial fishery

The regulations that govern the management of the Lakes and Coorong Fishery (LCF) are the *Fisheries (Scheme of Management - Lakes and Coorong Fishery) Regulations 1991* and the *Fisheries (General) Regulations 2000*. The Management Plan for the SA Lakes and Coorong Fishery was finalised in 2005 (Sloan 2005), and provides a strategic policy framework for the management of the fishery (Table 7-1).

Table 7-1. Management milestones for marine scale-fish species in South Australia (Jones et al 1990; Rohan et al. 1991; Anon, 1988, 1995, 2003; Sloan, 2004).

Date	Milestone
1971	Introduction of fishing licences for all commercial fishing in South Australia
1972	Licensed commercial fishers required to provide monthly catch data
1984	*Scheme of Management (Lakes and Coorong Fishery) Regulations* *Scheme of Management (Marine Scalefish Fisheries) Regulations* *Scheme of Management (Restricted Marine Scale Fishery) Regulations*
1986	Restrictions on commercial net type, mesh size, net depth and net length. Prohibition of net use adjacent to the Murray Mouth from November 1 to March 31. Limit of one registered recreational net per person, with 70m total length and maximum of 1m drop. Total prohibition on recreational netting in coastal marine waters from Goolwa Beach Road to Kingston Jetty. Recreational bag limit of 20 flounder per person per day in Coorong waters (boat limit 50 per person per day). Prohibition of all forms of netting in the Coorong, adjacent to the Murray Mouth from December 25 to January 7.
1991	*Fisheries (Scheme of Management—Lakes and Coorong Fishery) Regulations* *Fisheries (Scheme of Management—Marine Scalefish Fisheries) Regulations*
1997	Review of the recreational fishery
2005	Management Plan for the South Australian Lakes and Coorong Fishery

The Lakes and Coorong Fishery is managed in the context of a number of international legal instruments including the Ramsar Convention and the 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 primarily for its wetland habitats and importance for a variety of migratory waterbirds. The population of greenback flounder in the Coorong is managed as a distinct unit stock (Sloan 2005).

The LCF is limited entry with 37 owner-operators (Knight *et al.* 2000). Licence holders have non-exclusive access within the Lakes and Coorong system and effort is limited through gear entitlements and owner-operator provisions as designated under *Scheme of Management (Lakes and Coorong Fishery) Regulations 1991* (Pierce and Doonan 1999; Knight *et al.* 2000).

The LCF operates in the northern and southern Coorong lagoons, the freshwater lower lakes of Lake Alexandrina and Lake Albert, and the adjacent coastal marine waters along Sir Richard and Younghusband Peninsulas (Figure 6-1).

Effort data for the commercial fishery for greenback flounder in South Australia have been recorded since 1984 (Knight *et al.* 2001). Daily catch and effort information is provided on a monthly basis to SARDI Aquatic Sciences; catch, effort (days), effort (fisher days), effort (number of nets) and fishing location. Target and catch species are recorded as "flounder" but are not differentiated into species. The species present in the Coorong lagoons are greenback (*Rhombosolea tapirina*) and long-snouted flounder (*Ammotretis rostratus*), although almost all commercial catch comprises *R. tapirina*.

Management arrangements for the commercial fishery for greenback flounder comprise general gear restrictions, spatial and temporal closures and a legal minimum length of 25 cm total length.

7.2 Recreational Fishery

The recreational fishery is open access and is managed with general gear restrictions, spatial and temporal closures and bag/boat limits (Sloan, 2005). The restrictions are applied to flounder generally, which includes both greenback and long-snouted flounder (Bothidae: *Ammotetris rostratus*).

There is little information on recreational fishing for greenback flounder in South Australia but the main gear used to target greenback flounder in the Coorong lagoons is probably the hand spear. A study in Tasmania found that undersize fish (<250 mm TL) were a significant component (22%) of catches from spears, graball net and hook and line (Lyle and Campbell 1999). Management arrangements for the recreational fishery for greenback flounder include general gear restrictions and a requirement that nets be attended when set. There is no prescribed LML. There is a bag limit of 20 flounder per person per day and 60 per boat per day applicable to all state waters as well as a possession limit of 50 flounder.

7.3 Traditional Fishery

All of the management measures in place for the recreational sector currently apply to indigenous fishers when undertaking traditional fishing practices.

8 DISCUSSION

The key knowledge gaps for greenback flounder fall into two categories: (i) those that relate to the fishery and its management and (ii) those concerning the biology of greenback flounder. Fishery knowledge gaps are (i) the size and age structure of the commercial and recreational catches, (ii) the amount of recreational catch, and (iii) the types of gear used in the recreational fishery. Biological knowledge gaps are (i) the SOM for greenback flounder from the Coorong lagoons, (ii) a suitable ageing methodology for developing age structures for the Coorong population, (iii) an understanding of the role of environmental factors in determining year class strength, and (iv) an understanding of the extent of dependence of greenback flounder on the Coorong lagoons.

The commercial fishery provides catch and effort data from the Coorong lagoons with catches and CPUE characterised by high inter-annual variability. The underlying mechanisms affecting the variability of catches are poorly understood but may be informed by an understanding of age and size structures. Currently there are no size structure data available for greenback flounder from the Coorong lagoons. Size frequency sampling of commercial catches of greenback flounder, either at the point of landing, or Adelaide Fish Market, would provide useful information on selectivity of the large mesh gill nets used to target this species. However, fishery independent sampling is required for an unbiased size structure to be constructed.

Currently there is no validated ageing methodology available for greenback flounder from the South Australia. The ageing methodology developed for other Pleuronectid species in new Zealand may be successful in South Australia but would require validation in South Australian conditions (Stevens *et al.* 2005).

Freshwater flows from the Murray River into the Coorong lagoons have been suggested as one factor that may explain variability in the abundance of greenback flounder (Hall 1984). This relationship may be investigated using multiple regression of CPUE and environmental parameters or by relating environmental variables to residuals from catch curve regressions (Hall 1984; Staunton-Smith *et al.* 2004; Robbins *et al.* 2005).

Inter-annual variability in catches of adult flounder may be due to variability in recruitment. Recruitment data may be obtained sampling juvenile abundance with small beach seine nets on a monthly, or seasonal, basis. Development of a recruitment index would provide further opportunity to investigate the role that environmental factors such as freshwater inflow have on the abundance of greenback flounder in the Coorong Lagoons.

Data for (i) development of a recruitment index, (ii) size structures, and (iii) age structures could, potentially, be obtained by fishery independent sampling with small seine nets on a regular and ongoing basis. A tagging study could provide (i) validation of growth rates (ii) information on migration, and (iii) and if migration is limited, to estimates of the biomass.

The extent and nature of the recreational fishery is poorly understood. The requirement for recreational nets to float when set implies that hand spears are probably the main gear used to target greenback flounder. Currently the absence of a LML for recreational catches of greenback flounder, and the likely reliance on hand spears, may mean that significant numbers of immature flounder are harvested.

In summary, the biological and demographic characteristics of greenback flounder in the Coorong lagoons are currently poorly understood. Basic demographic information on greenback flounder could be obtained by conducting a fishery independent survey, using seine nets on a monthly basis, over a 12-month period. These data could provide estimates of sex ratio, SOM and recruitment and could be further enhanced by developing a validated ageing protocol based on otoliths and construction of age structures.

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