GEAR INTERACTION OF NON-TARGETED SPECIES IN THE LAKES AND COORONG COMMERCIAL AND RECREATIONAL FISHERIES OF SOUTH AUSTRALIA

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FRDC FINAL REPORT

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2005/061 Gear interaction of non-targeted species in the Lakes and Coorong commercial and recreational fisheries of South Australia.

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OBJECTIVES:

The overarching goal of this project was to provide reference data for interactions of non-target species with gill nets used by commercial and recreational fishers in the Coorong lagoons, and to identify practices which may result in increased, or reduced, levels of interactions with non-target species.

There were four specific objectives:

1. Assess the composition and rates of capture of retained and discarded species in the main types of gear used by commercial and recreational fishers in the Coorong lagoons to establish a risk assessment framework for management (Chapters 2, 3),
2. Develop potential performance indicators and reference points related to bycatch of the main fishing gear used in the Coorong lagoons (Chapter 2),
3. To assess the survival of key species discarded from each of the main gear types employed by the commercial and recreational sectors (Chapter 2),
4. To identify methods for mitigating levels of discarding (Chapter 2).

NON-TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE

This study provides baseline data on gill nets used in the Murray River estuary and Coorong lagoons. This information includes; (i) species composition of discarded and retained catches, (ii) catch rates of retained and discarded species, (iii) levels of usage of gillnets by registered recreational fishers and qualitative levels of interactions with non-target species, (iv) estimates of survival at net retrieval for key species and gear, and (v) identification of potential methods for mitigating levels of discarding. A performance indicator was developed for levels of discarding, for incorporation into the commercial catch and effort log book.

This project was developed by SARDI, in consultation with PIRSA, Lakes and Coorong Fishery (LCF) licence holders and relevant stakeholders, over several years. Proposals to investigate interactions with non-target species and discarding from the LCF in the Murray River estuary and Coorong lagoons were submitted to South Australian Fisheries Advisory Board (SA FRAB) and FRDC in 2002 and SA FRAB in 2003 but failed to gain industry support. In 2004 the Southern Fishermen's Association expressed support for a study of non-target species to support their application for accreditation with the Marine Stewardship Council.

During the study the lower Murray River system was in drought, and high salinities and generally poor environmental conditions occurred in the Coorong lagoons. Consequently, the approaches to addressing objectives three and four (below) were changed. It was originally intended to estimate discard survival (Objective 3) from discards that had been held in sea cages over 5 days. Instead, discard survival was estimated from numbers of fish that were alive at net retrieval. The original approach to identify methods for mitigating levels of discarding (Objective 4) was to conduct experimental fishing. This objective was met using information available from the observer based monitoring program, from the peer reviewed literature and from several previous FRDC funded projects.

The main outcome of the project is the provision of information on catch species composition, quantified levels of discarding, and ongoing collection of data from the Lakes and Coorong Fishery. This was achieved using an observer based study of catches in the Lakes and Coorong Fishery. During 2005-06 a total of 53 observer trips were made (973 net shots), with 18 days (173 net shots) surveyed in the Murray River estuary and 35 fishing days (800 net shots) in the Coorong lagoons.

In 2005-06, 98% of nets used in the Murray River estuary and Coorong lagoons were either small mesh gill nets (>50 to ≤64 mm) used to target yellow-eye mullet (*Aldrichetta forsteri*) or large mesh gill nets (>115 to ≤150 mm) used to target mulloway, (*Argyrosous japonicus*), greenback flounder (*Rhombosolea tapirina*) and black bream (*Acanthopagrus butcheri*). Overall 21 species were observed in monitored catches, including 11 marine and estuarine finfish species, two crab and two bird species. The species composition of catches varied between the Murray River estuary and Coorong lagoons, among seasons and among the target species. Discarded mulloway that were below LML made a significant contribution to the similarity of catches within each region, within seasons and for catches where the target was yellow-eye mullet, mulloway, or greenback flounder.

Overall, discards accounted for 14.6% of catches (by number). The catch rate of retained fish in small mesh gill nets (15.88 $fish.net.day^{-1}$) was higher than for large mesh gill nets (1.65 $fish.net.day^{-1}$). Catch rates of discards were lower in small mesh gill nets (1.20 $fish.net.day^{-1}$) than large mesh gill nets (1.40 $fish.net.day^{-1}$). Discard ratios (number discarded/number retained) for catches from small mesh gill nets (0.08) were lower than for large mesh gill nets (0.85). Discard ratios were highest in spring-summer for small mesh gill nets and in summer-autumn for large mesh gill nets.

Distributions of fish lengths from catches provided relative size-selectivity for different mesh sizes. Modal lengths of yellow-eye mullet (262 to 264 mm TL), and Australian salmon (239 -261 mm TL) in small mesh gill nets were above LML, but for mulloway were below LML (274 mm TL). Lengths of mulloway in large mesh gill nets were bimodal due to entanglement of the maxillae of sub-legal sized individuals. Sub-legal sized greenback flounder were also present in catches from large mesh gill nets.

Few mulloway were alive when small (28.5%) and large mesh nets (25.9%) were retrieved. The percentage of mulloway alive at net retrieval appeared to be highest in winter. More than half of greenback flounder were alive in small (61.4%) and large mesh gill nets (63.1%) when retrieved.

There were 1,512 registered recreational small mesh gill nets in 2006-07, a decline of 33% from the number in 2004. Twenty one percent of recreational net fishers had used their nets for an average of 8.5 days each in 2006-07, and 21.5% had fished in 2005-06. Recreational effort was approximately 2,380 net days in 2005-06, which was 2.4% of the number of commercial net days during that period. Most fishers soaked nets for <3 hours (59.3%) with the remainder leaving nets in the water overnight. Most recreational fishing occurred in winter and greenback flounder were reported as the main discard species.

Discard ratios provide a suitable performance indicator for levels of bycatch in the Lakes and Coorong Fishery. This performance indicator may be incorporated, with appropriate reference points, into the Management Plan for South Australia's Lakes and Coorong Fishery (Sloan 2005) when it is updated in 2011. Modification to commercial catch and effort log books will provide on-going data on levels of discarding for each type of net, and for each target species in the LCF. Whilst data from this study provide baseline data on catch rates of retained and discarded species, and discard ratios, they were likely affected by drought conditions in the Murray River estuary and Coorong lagoons from 2002 to the present. This may have resulted in underestimation of catch rates of discarded species highlighting the importance of on-going data collection via commercial catch and effort log books.

The key issue concerning non-target species in commercial gill nets in the LCF is discarding of sub-legal sized mulloway because; (i) discarded mulloway contributed significantly to similarity of catches for all targets, except black bream, (ii) levels of discarding of mulloway were higher than levels of retained catch, (iii) large mesh gill nets selected mulloway over a wide range of lengths, likely including several year classes, and (iv) survival of discarded mulloway was low. Although

levels of fishing effort were low in the Murray River estuary and Coorong lagoons in 2005-06, the presence of sub-legal sized mulloway in large mesh gill net catches has the potential to impact on the sustainability of mulloway stocks. Sustainable commercial exploitation of these species may be enhanced by mitigation of levels of discarding and increased survival. Potentially useful mitigation measures for levels of discarding may include shorter soak times, attendance of nets, and reduced drop of nets.

KEYWORDS: gillnet, bycatch, discard, estuarine fish, observer program, Australia

ACKNOWLEDGEMENTS

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This report was reviewed by Dr Michael Steer and Cameron Dixon (SARDI Aquatic Sciences) and an anonymous reviewer nominated by FRDC. The report was formally approved for release by Dr Tim Ward, Wild Fisheries Principal Scientist, SARDI Aquatic Sciences.

LIST OF ACRONYMS

ANOSIM	Analysis of Similarities
ANOVA	Analysis of Variance
DEH	Department of the Environment and Heritage
DEWHA	Department of the Environment, Water, Heritage and the Arts
ESD	Ecologically Sustainable Development
EPBC Act	Environment Protection and Biodiversity Conservation Act, 1999
FRDC	Fisheries Research and Development Corporation
LCF	Lakes and Coorong Fishery
LMGN	Large Mesh Gill Net
LML	Legal Minimum Length
MDS	non metric Multi-Dimensional Scaling
MSF	Marine Scale Fish Fishery
SIMPER	Similarity percentage analysis
SFA	Southern Fishermen's Association
SMGN	Small Mesh Gill Net

DEFINITIONS

Bycatch	Includes all material, living or non-living, other than targeted sizes/species caught while fishing.
By-product	The component of the bycatch that is non-targeted and retained because it has commercial value to the fisher.
Catch	The total amount (number) of a species captured from within a specified area, over a given time. Includes any animals that are released, or returned to the water.
Ecologically Sustainable Development	Using, conserving and enhancing the community's resources so that ecological processes on which life depends are maintained and the total quality of life now and in the future, can be increased.
Non-retained species or discards	Those species caught or directly impacted by the fishery but not retained (Fletcher et al. 2002) (National Policy on Fisheries 1999).
Non-target species	Species that are unintentionally taken by a fishery.
Retained	The component of the catch that is retained and not discarded.
Target species	The most highly sought component of the catch taken by fishers.

1 GENERAL INTRODUCTION

1.1 Overview

This is the final report to the Fisheries Research and Development Corporation (FRDC) on FRDC project 2005/061 "Gear interaction of non-targeted species in the Lakes and Coorong commercial and recreational fisheries of South Australia". The report is divided into four chapters.

Chapter 1 is the General Introduction that outlines the structure of the report, summarises the need for an understanding of interactions of non-target species with gear used in the Lakes and Coorong Fishery (LCF), documents the aims and objectives of the project.

Chapter 2 describes the 12 month, on-board monitoring study of retained and non-retained catches conducted in the LCF, and a survey of recreational gill net fishing in the Coorong lagoons.

Chapter 3 provides an assessment of the risk to sustainability of populations for species identified in the observer based monitoring study, against the main targeting practices.

Chapter 4 is the General Discussion which synthesises the information presented in the previous Chapters and outlines future research directions.

1.2 Project background

In 1991, Commonwealth fisheries legislation was amended to ensure that an ecosystem-based approach to fishery management be adopted, based on principles of ecological sustainable management (Anon. 2001). In December 1998, the Commonwealth launched Australia's Oceans policy which established the broad principles and actions required to achieve ecologically sustainable development of fisheries throughout Australia's Exclusive Economic Zone (Anon. 2001). In 1999 the Ministerial Council on Forestry, Fisheries and Aquaculture endorsed the national Policy on Fisheries to ensure a unified national response to the issue of discarding fish from catches across all Australia fisheries. The goal of the policy is to ensure that direct and indirect fishery impacts on ecosystems are taken into account in management plans and that populations of fish subject to discarding are maintained at sustainable levels. These principles are now formally incorporated in South Australia's Fishery Management Act (2007).

In September 2005, PIRSA Fisheries submitted an ecological submission to DEWHA that detailed the management arrangements in place for the LCF. By November 2005, Commonwealth DEWHA had assessed the submission, with respect to the purposes of the Protected Species Provisions of Part 13 and the Wildlife Trade Provisions of Part 13A of the EPBC act, against the Guidelines for Ecologically Sustainable Management of Fisheries. This assessment identified the 'absence of an on-going monitoring system for each sector of the fishery' as an ecological risk. DEWHA made the following recommendation - 'PIRSA was to develop and implement, within 2 years, a system for the quantitative monitoring of bycatch in the LCF, sufficient to identify changes in the composition and quantity of bycacth in each sector of the fishery' (Anon. 2005).

This project was also identified as the top priority in the 5-year Strategic Research Plan by the Inland Waters Fishery Management Committee of SA, which comprises stakeholder representatives from industry, management, research, and the general community. The development and adoption of fishing techniques that minimize bycatch was also identified in the Environmental Management Plan of the Southern Fishermen's Association (SFA) (Anon, 1998/99). Several targeted priorities stated in Program 1 of the SAFRAB 5-Year R&D Strategy, aimed at ensuring sustainability of natural resources, also required data on levels of bycatch from the Coorong lagoons.

Needs addressed by the project included addressing industry, conservation and public concerns about the impact of commercial and recreational fishing on the ecological sustainability of the LCF. The primary need was for reference data on discarding in gill nets operated by commercial and recreational fisheries operating in the Coorong Lagoons. Baseline information on the nature of the species composition of discards, rates of capture of discards and size selectivity of nets for key species was required to guide management decisions and address requirements for Ecologically Sustainable Development under the EPBC Act. The project had additional relevance in supporting the application of the Lakes and Coorong Fishery submission for Marine Stewardship Accreditation. There was also a need for a preliminary assessment of the survival of discards.

This project was developed by SARDI, in consultation with PIRSA, Lakes and Coorong Fishery licence holders and relevant stakeholders, over several years. Proposals to investigate interactions with non-target species and discarding from the LCF gillnet fishery in the Coorong lagoons were submitted to South Australian Fisheries Advisory Board (SA FRAB) and FRDC in 2002 and again in 2003 but failed to gain industry support. In 2004 the Southern Fishermen's Association expressed support for a study of non-target species to support their application for accreditation with the Marine Stewardship Council. The scope of the project was discussed at a meeting at the South Australian Aquatic Sciences Centre in October 2004 and a full proposal submitted for the 2004/05 round of applications with additional support by South Australian Fisheries Industry Council (SAFIC) and SeaNet. Following reviewer comments, a preliminary study into survival of discarded fish was incorporated into the proposal. The project commenced in 2005.

During the study the lower Murray River system was in drought, and high salinities and generally poor environmental conditions occurred in the Coorong lagoons. Consequently, the approaches to addressing objectives three and four (below) were changed. It was originally intended to estimate discard survival (Objective 3) from discards that had been held in sea cages over 5 days. Instead discard survival was estimated from numbers of fish that were alive at net retrieval. The original approach to identify methods for mitigating levels of discarding (objective 4) was to be done using experimental fishing. Ultimately, this objective was met using information available from the observer based monitoring program, from the peer reviewed literature and from several previous FRDC funded projects.

1.3 Objectives

The overarching goal of this project was to provide reference data for interactions of non-target species with gill nets used by commercial and recreational fishers in the Coorong lagoons, and to identify practices which may result in increased, or reduced, levels of interactions with non-target species.

There were four specific objectives:

1. Assess the composition and rates of capture of retained and discarded species in the main types of gear used by commercial and recreational fishers in the Coorong lagoons to establish a risk assessment framework for management (Chapters 2, 3),
2. Develop potential performance indicators and reference points related to bycatch of the main fishing gear used in the Coorong lagoons (Chapter 2),
3. To assess the survival of key species discarded from each of the main gear types employed by the commercial and recreational sectors (Chapter 2),
4. To identify methods for mitigating levels of discarding (Chapter 2).

1.4 The Lakes and Coorong fishery

1.4.1 Commercial fishery

The LCF comprises 36 licensed fishers who operate in the Coorong, the freshwater Lower Lakes (Alexandrina and Albert), and the adjacent coastal marine waters along Sir Richard and Younghusband Peninsulas (Figure 1-1). The Coorong comprises the estuary of the Murray River and the Coorong lagoons which are separated from the Lower Lakes by a series of barrages.

The total catch from the LCF in 2005-06 was 2474 t, worth $4.9 million and represented 6% of the South Australian total catch (Knight and Tsolos 2010). The total LCF catch in 2008-09 was 2023 t which represented 5% of the South Australian catch and was worth $6.5 million (Knight and Tsolos 2010).

Gill nets are the dominant gear used in the Murray River estuary and Coorong lagoons. The key target species are mulloway *Argyrosomus japonicus* and yellow eye mullet *Aldrichetta forsteri* which comprise respectively, approximately 80 and 70% of the South Australian commercial catch for these species (Ferguson and Ward 2003; Higham et al. 2005). In 2005-06 the key finfish species that were targeted within the Coorong, in order of catch weight, were yellow-eye mullet (69%), mulloway (24%), greenback flounder (*Rhombosolea tapirina* 4%), and black bream (*Acanthopagrus butcheri* 4%) (Ferguson 2008). In 2008-09 yellow-eye mullet dominated catches (85%), with small catches contributed by mulloway (14%), and negligible catches contributed by greenback flounder (1%), and black bream (1%).

Management regulations recognise small and large mesh gill nets. Small mesh nets (>50 to ≤64 mm stretched), must not be deeper than 1.6 m (i.e. 1.6 m drop), and are used almost exclusively to target yellow-eye mullet. Large mesh nets (>115 to ≤150 mm stretched) may be up to 2 m deep and are used primarily to target mulloway, but also greenback flounder and black bream (Ferguson 2000; Higham et al. 2005; Ferguson 2007; Ferguson and Ye 2008).

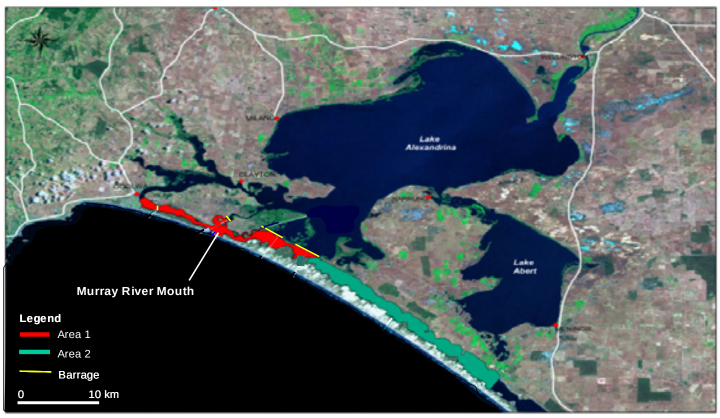

Figure 1-1. Map of the Lower Lakes, Murray River estuary (Management Area 1) and Coorong lagoons (Management Area 2).

1.4.2 Recreational fishery

The Coorong lagoons are a popular destination for recreational fishers (Jones and Doonan 2005; Sloan 2005; Jones 2009). Recreational fishers target yellow-eye mullet using small mesh gill nets (Higham et al. 2005; Sloan 2005). Registrations for recreational gill nets are limited in number and non-transferrable. Since 2004, the total number of net registrations declined from 2258, to 1512 in 2006, then to 1370 in 2007 (Sloan, 2005; Keith Jones pers. comm. PIRSA). Recreational fishers also target yellow-eye mullet, mulloway, and black bream and using hook and line, and greenback flounder using spears (Sloan 2005).

In 2000-01 the total estimated catch of mullet by recreational gill nets, in the Coorong lagoons, was 484 kg representing < 1% of the combined commercial and recreational catch (Henry and Lyle 2003; Jones and Doonan 2005). Fishing was mainly in June-September and was conducted at dusk with nets retrieved after several hours (Keith Jones pers. comm.. PIRSA). In 2007-08 the recreational catch of 27.6 t comprised 11% of combined commercial and recreational catches (Jones 2009).

The recreational gill net fishery is managed with gear restrictions, spatial and temporal closures and bag/boat limits. Key restrictions are that only small mesh gill nets (≥50 mm and ≤64) may be used and that they must not be deeper than 1 m. recreational gill net fishing is not permitted in Area 1 from November 1 to and March 31 inclusive (Figure 1-1). Important differences in the regulations for recreational nets are that nets must: (i) not exceed 75 m length, (ii) float when set, (iii) not be more than 1 m depth, and (iv) be attended by the operator i.e. should be within 50 m of the net at all times. Size limits are the same as for the commercial fisher with the exception of greenback flounder for which there is no size limit for recreational fishers.

2 ASSESSMENT OF INTERACTIONS BETWEEN NON-TARGET SPECIES AND GILL NETS

2.1 Introduction

The capture of non-targeted or unwanted fishes is one of the most significant environmental issues associated with fishing (Kennelly 1995; Alverson et al. 1996; Hall 1999; Kelleher 2005). Fishing can directly and indirectly affect the biomass of stocks, interactions among species and productivity of ecosystems (Jennings and Kaiser 1998; Hall 1999). Knowledge of retained and discarded catches, their variation spatially, temporally and between different fishing methods is essential for understanding the impact of fishing on stocks and ecosystems (Gray et al. 2003). Information on catch compositions along with data on net selectivity, behaviour of fishing gear, and the species captured, can assist in developing ways to mitigate the effects of discarding in fisheries (Hall 1999; Gray et al. 2003).

Studies of discarding have been conducted for trawl and seine net fisheries although fewer studies have been done on gill net fisheries (see Hall 1999). In Australia, however, several studies have focussed on commercial gill net fisheries in tropical (Halliday et al. 1997) and sub-tropical estuaries (Gray 2002; Gray et al. 2003; Gray et al. 2005) and temperate marine environments (Fowler et al. 2009). These studies have investigated species and size composition of catches, and discard rates in commercial fisheries (Gray 2002; Gray et al. 2003; Broadhurst et al. 2004; Gray et al. 2004; Fowler et al. 2009) but little is known about recreational gill net fisheries (Lenanton et al. 1996; Henry and Lyle 2003; Jones 2009). Several studies have investigated survival of fish that have been caught and released (Broadhurst and Barker 2000; Broadhurst et al. 2007; Broadhurst et al. 2008) while others have examined the potential for reducing discards or mitigating the effects of discarding (Gray et al. 2000; Broadhurst et al. 2004; Gray et al. 2005; Broadhurst et al. 2009).

The South Australian Inland Waters Catch and Effort Returns provide information on amounts of retained catches and levels of effort but there is currently no information on levels of discarding for the fishery. In this study on-board, observers collected information on commercial catches from fishing commercial operations with the aim to; (i) describe the species composition of retained and discarded catches, (ii) quantify rates of discarding, and (iii) develop a performance indicator for levels of discarding in the LCF. Qualitative information on the nature of recreational gillnet catches was obtained using a telephone survey.

2.2 Materials and Methods

2.2.1 On-board observer survey of commercial catches

Commercial gill net operations were surveyed in the Coorong lagoons (35º 32' S, 138º 52' E) from September 2005 to November 2006. Observers accompanied commercial fishers in the early mornings when nets, which had been set over-night were retrieved, or were present throughout the fishing trip when nets were set for short periods. As each net was retrieved observers recorded; species identification, numbers of fish captured per species, whether the fish was retained or discarded, and measured each fish to the nearest mm for total length (TL), or caudal fork length (CFL). Discards were defined as that part of the catch returned to the water, or not landed but killed as a result of interactions with fishing gear (National Policy on Fisheries 1999). Non target species were processed as quickly as possible and returned to the water to minimise mortality.

Operational details recorded for each net were; mesh size (stretched), ply, drop (no meshes), type of lead line (standard, hoop), set (floating, sinking), and soak time. The condition of a subset of captured fish was qualitatively described as either alive (sufficiently vigorous to swim away) or dead.

2.2.2 Survey of registered recreational gill net fishers

A telephone survey of recreational net licence holders was done from June 4-11, 2007. Respondents were asked if they used their nets in the Coorong lagoons in July to May, 2006-07 and July to June 2005-06 financial years. For those who had fished in the period July to May, 2006-07 the following information was recorded; (i) number of days fished, (ii) soak time (iii) main target species, (iv) main species discarded, and (v) why the fish were discarded.

2.2.3 Data analyses

To assess seasonal influences data were divided into five fishing periods; Spring 2005, Summer 2005, Autumn 2006, Winter 2006, and Spring 2006. All annual estimates such as catch rates per net day^{-1} (±1 S.E.) and discard ratios were calculated for the period from September 2005 to August 2006 so that each season was represented (Spring 2005, Summer 2005, Autumn 2006, Winter 2006).

Species composition of retained and discarded catches

Species composition was analysed using the non-parametric statistical package PRIMER v.6. (Clarke and Gorley 2006). For each analysis the species abundance data were arranged in a matrix with a row for each fishing day and a column for each individual species. Prior to analysis variables were standardised, then a fourth root transformation was applied. A similarity matrix comparing fishing operations was generated using the Bray-Curtis similarity coefficient. Interrelationships between catches were displayed using 2 dimensional multi-dimensional scaling (MDS) ordination plots. Grouping of samples provides an indication of similarity in each ordination and the stress coefficient indicates goodness of fit of the data. Stress values <0.15 indicate that the ordination is a relatively good representation of the data. Two-way Analysis of Similarity (ANOSIM) was used to test for differences in catches among spatial, temporal and target species groups. Similarity percentage (SIMPER) analyses were used to identify species that were most responsible for similarity of catches within each region, season, or target group.

Discard catch rates

Levels of retained and discarded catch were quantified using two measures; catch rates for discarded and retained fish, and discard ratio.

The ratios (*R*) for catch rate (number of fish discarded/number nets.day^{-1}) and discard ratio (number of discarded fish/number of retained fish) were estimated, where *S(R)*, was the estimated standard error of *R* using the following formulae (Cochrane 1963):

$$\hat{R} = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} r_i}$$

$$S(\hat{R}) = \frac{1}{(r.\sqrt{n})} . \sqrt{\frac{\sum d_i^2 - 2\hat{R}.\sum r_i d_i + \hat{R}^2.\sum r_i^2}{n-1}}$$

Where b_i and r_i are the numbers of discard and retained fish respectively for net-shot i, and n is the total number of shots sampled.

One-factor analysis of variance (ANOVA) was used to test for differences in quantities of retained and discarded catches. Data were checked for homogeneity of variances using Cochran's test and transformed (Log$_{10}$(x)) if necessary. When data failed to meet the assumption of normality, equivalent non-parametric tests were used.

Length compositions of discarded and retained catches

Observed length compositions were used to assess the relative selectivity of nets used in the fishery (pooled samples from September 2005 to November 2006). Where sufficient data were available frequency distributions were generated for each mesh size and species.

2.3 Results

2.3.1 Commercial fishery

Observer coverage

A total of 53 observer trips (973 net shots) were made, with 18 fishing days (173 net shots) surveyed in the Murray River estuary and 35 fishing days (800 net shots) surveyed in the Coorong lagoons. Seven of the 37 LCF (19%) fishers participated in the survey.

Catches were sampled from nets with mesh sizes from 54 to 165 mm diameter (stretched) (table 2-1). Most small mesh nets were constructed of 57 mm mesh (97.6%) with the remainder constructed of 54 mm diameter mesh. Most large mesh nets were constructed of 121 mm (57.5%) or 127 mm mesh (13.5%). All nets were constructed from monofilament nylon with ply ratings (relative diameter) from 5 to 14. Most small mesh nets (>97%) were constructed from 5 ply nylon. For nets with mesh sizes 114–121 mm the monofilament ranged from 5–14 ply. All nets with mesh greater than 127 mm were constructed of 6 ply monofilament (Table 2-1).

Small mesh nets were used exclusively to target yellow-eye mullet while large mesh nets were used primarily to target mulloway (68.4%), greenback flounder (20.7%), and black bream (10.9%). Greenback flounder were targeted (88.8%) using the largest mesh sizes (140 -165 mm) of large mesh gill nets.

Most small mesh gill nets had soak times <3 hours (65.3% of sets), with the remainder set overnight. Small mesh gill nets that were soaked for <3 hours were occasionally drifted with the licence holder in attendance. Large mesh gill nets used to target mulloway, greenback flounder or black bream were set overnight (77.3% of sets). When targeting greenback flounder the nets were set on the shallows either side of the Coorong channel.

Table 2-1. Mesh sizes of gill nets sampled.

	Mesh size (stretched)		
Net	(mm)	(in.)	No. nets
Small mesh gill net	54	2 1/8	134
	57	2 ¼	279
Large mesh gill net	114	4 ½	45
	121	4 ¾	322
	127	5	78
	140	5 ½	51
	152	6	51
	165	6 ½	13

Species composition of retained and discarded catches

Overall, 21 species were observed in monitored catches. This included 16 species of finfish, one species of stingray, two crab and two bird species. Of the 16 species of finfish, five were exclusively freshwater species that had entered the Coorong lagoons through opened barrages (Table 2-2).

Table 2-2. List of species interacting with commercial nets in the Coorong lagoons showing numbers of each species caught in order of abundance. Each species classified as target (T), non-target (N), freshwater (F) or protected (P).

Species	Scientific name	Classification	Total no. caught
Yellow-eye mullet	*Aldrichetta forsteri*	T	6173
Bony bream	*Nematalosa erebi*	F	1588
Mulloway	*Argyrosomus japonicus*	T	1100
Australian salmon	*Arripis trutta*	T	912
Greenback flounder	*Rhombosolea tapirina*	T	305
Black bream	*Acanthopagrus butcheri*	T	119
European carp	*Cyprinus carpio*	F	97
Jumper mullet	*Liza argentea*	N	89
Congolli	*Pseudaphritis urvilli*	N	31
Smooth toadfish	*Tetractenos glaber*	N	10
Common toadfish	*Tetractenos hamiltoni*	N	8
Golden perch	*Macquaria ambigua*	F	9
Australian anchovy	*Engraulis australis*	N	8
Gurnard perch	*Neosebastes scorpaenoides*	N	4
Redfin	*Perca fluviatilis*	F	4
Ray/skate	*unknown*	N	1
Sand crab	*Ovalipes australiensis*	N	1
Tench	*Tinca tinca*	F	1
Coorong crab	*Paragrapsis gaimardii*	N	-
Australian Pelican	*Pelecanus conspicillatus*	P	1
Little Black Cormorant	*Phalacrocorax sulcirostris*	P	1

A total of 10,459 fish were observed with 1,699 (16.2%) comprising freshwater species that were excluded from further analysis (Table 2-2). Freshwater species were mostly bony bream (93.4%) and European carp (5.7%) which had entered the lagoons via open barrages. The remaining 8,760 fish, included 13 estuarine and marine fish species. Yellow-eye mullet, mulloway, Australian salmon and greenback flounder, accounted for 96.9% of all catches (numbers of fish, retained and discarded combined). Yellow-eye mullet were most abundant (70.3%) with smaller contributions from mulloway (13.0%), Australian salmon (10.0%), greenback flounder (3.5%) and black bream (1.4%). One Australian pelican and one little black cormorant were also caught in nets and released alive (Table 2-3).

Species composition of the retained catch, in order of decreasing abundance, was yellow-eye mullet (70.5%), mulloway (12.6%), Australian salmon (10.4%), and greenback flounder (3.5%) (Table 2-3). Species composition of the discarded catch was dominated by mulloway (55.1%), Australian salmon (22.6%), greenback flounder (10.5%), and yellow-eye mullet (7.3%). All other species contributed less than 2% of total discards.

Table 2-3. Summary of the numbers, by species, pooled across all mesh sizes, regions and seasons showing contribution to total catch, the proportion retained, contribution to the total retained, proportion discarded and contribution to total discarded.

	Total caught	% total catch	Retained	% retained	% total retained	Discarded	% discarded	% total discarded
Yellow-eye mullet	6173	70.45	6079	98.48	80.58	94	1.52	7.34
Mulloway	1100	12.56	394	35.82	5.90	706	64.18	55.11
Australian salmon	912	10.41	622	68.20	8.03	290	31.80	22.64
Greenback flounder	305	3.48	170	55.74	2.91	135	37.90	10.54
Black bream	119	1.36	104	87.40	1.27	15	12.20	1.17
Jumper mullet	89	1.02	80	89.88	0.94	9	11.10	0.70
Congolli	31	0.35	30	96.77	0.35	1	3.20	0.10
Smooth toadfish	10	0.11				10	100.00	0.78
Australian anchovy	8	0.09				8	100.00	0.63
Common toadfish	8	0.09				8	100.00	0.63
Gurnard perch	4	0.05				4	100.00	0.31
Ray/Skate	1	0.01				1	100.00	0.08
Total	8,760		7479	85.38		1281	14.62	

MDS and ANOSIM tests showed that the structure of catch species varied spatially ($P < 0.001$) and temporally ($P < 0.001$). The SIMPER analysis identified the species that contributed greatest to similarity of catches between the (i) Murray River estuary and Coorong lagoons, across all seasons, and (ii) within each season across both regions. Retained mulloway (50.7%) contributed most to similarity of catches in the Murray River estuary and retained yellow-eye mullet contributed most to similarity of catches in the Coorong lagoons 35.4% (Table 2-4). Discarded mulloway also contributed significantly to similarity of catches in both regions. In spring and winter retained yellow-eye mullet contributed most to the similarity of catches (Table 2-5) and in summer and autumn retained mulloway contributed greatest to similarity of catches. Discarded mulloway made a significant contribution to similarity of catches in all seasons, particularly summer, when the contribution by discarded mulloway (33.8%) was similar to that of retained mulloway (35.4%). During summer and autumn discarded greenback flounder also contributed more than 10% to the similarity of catches.

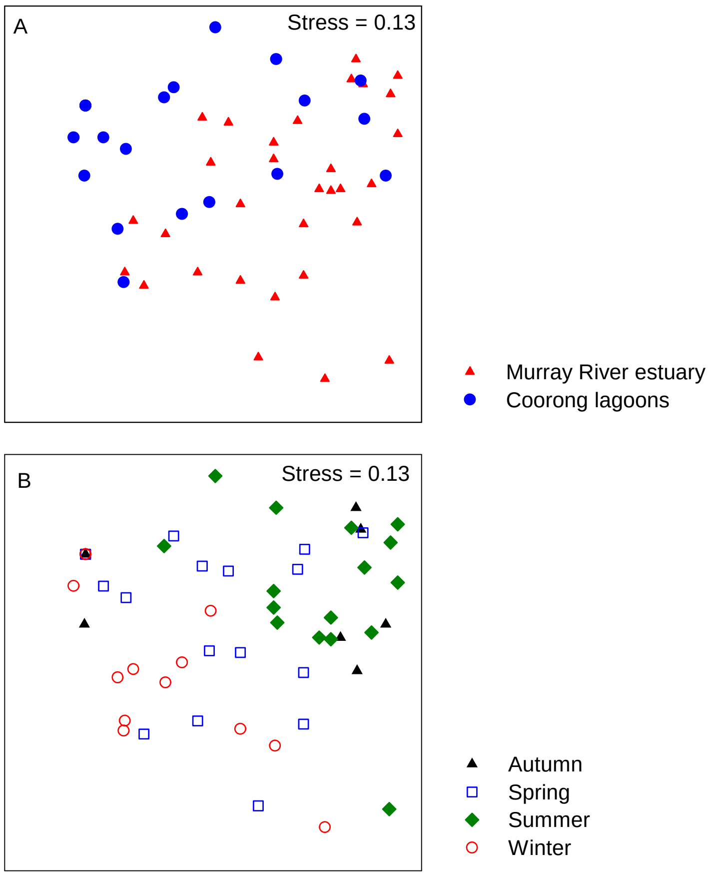

Figure 2-1. MDS ordinations of catch species compositions (A) between the Murray River estuary and Coorong lagoons, and (B) among seasons.

Table 2-4. Summary of SIMPER analyses listing the 5 species that contributed greatest to the percent contribution of similarity measure of total catches between the Murray River estuary and Coorong lagoons, across all seasons. r = retained, d = discarded.

Murray River estuary		Coorong lagoons	
Species	%	Species	%
Mulloway (r)	50.7	Yellow-eye mullet (r)	35.4
Mulloway (d)	15.0	Mulloway (d)	33.8
Yellow-eye mullet (r)	11.4	Greenback flounder (d)	10.8
Australian salmon (r)	5.8	Yellow-eye mullet (d)	6.1
Greenback flounder (d)	5.7	Mulloway (r)	5.5

Table 2-5. Summary of SIMPER analyses listing the 5 species that contributed greatest to the percent contribution of similarity measure of total catches in each season across the Murray River estuary and Coorong lagoons. r = retained, d = discarded.

Spring		Summer		Autumn		Winter	
Species	%	Species	%	Species	%	Species	%
Yellow-eye mullet (r)	50.7	Mulloway (r)	35.4	Mulloway (r)	31.9	Yellow-eye mullet (r)	57.6
Mulloway (d)	15.0	Mulloway (d)	33.8	Mulloway (d)	21.7	Australian salmon (r)	13.8
Mulloway (r)	11.4	Greenback flounder (d)	10.8	Yellow-eye mullet (r)	20.5	Mulloway (d)	5.9
Yellow-eye mullet (d)	5.8	Yellow-eye mullet (r)	6.1	Greenback flounder (d)	10.7	Yellow-eye mullet (d)	5.1
Australian salmon (r)	5.7	Greenback flounder (r)	5.5	-		Mulloway (r)	3.8

When the structure of catches was compared across both regions among fishing operations with different target species there was no difference spatially ($P > 0.001$) but significant differences among operations with different targets ($P < 0.001$) (Figure 2-2).

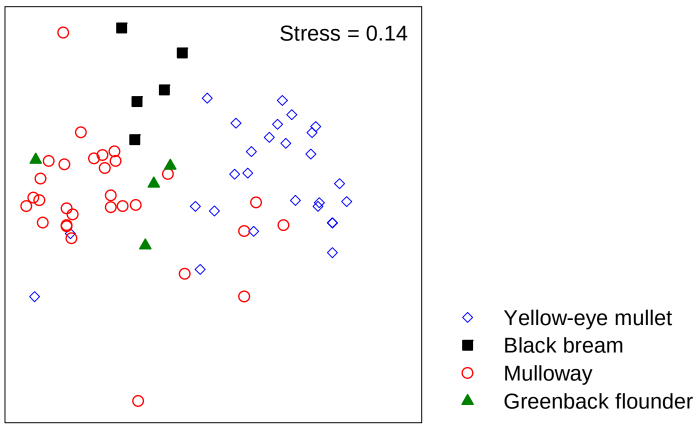

Figure 2-2. MDS ordination of catch species composition among target species.

Within each group of fishing operations retained target species contributed greatest to the similarity of catches. For example when target yellow-eye mullet was targeted, retained individuals of this species contributed 74.6% to the within-group similarity. When mulloway were targeted, retained mulloway contributed 36.3% to within-group similarity. Importantly, the contribution of discarded mulloway (35.5%) to within-group similarity was equivalent to that of retained individuals. Discarded mulloway also made a significant contribution to within-group similarity when greenback flounder was targeted.

Table 2-6. Summary of SIMPER analyses listing the species that contributed greatest to the percent contribution of similarity measure of total catches for each key target species across the Murray River estuary and Coorong lagoons. r = retained, d = discarded.

Target: Mulloway		Yellow-eye mullet		Greenback flounder		Black bream	
Species	%	Species	%	Species	%	Species	%
Mulloway (r)	36.3	Yellow-eye mullet (r)	74.6	Flounder (r)	35.0	Black bream (r)	26.8
Mulloway (d)	35.5	Mulloway (d)	7.7	Mulloway (d)	21.7	Australian salmon (r)	20.2
Yellow-eye mullet (d)	10.7	Yellow-eye mullet (d)	6.7	Mulloway (r)	18.8	Mulloway (r)	13.0
Australian salmon (r)	8.5	Australian salmon (r)	5.0	Flounder (d)	9.9	Yellow-eye mullet (r)	10.8
				Yellow-eye mullet (r)	7.3	Flounder (r)	9.4

Variations in catch rates of retained and discarded species

The overall retained catch rate (September 2005 to August 2006) was 7.69 fish.net day^{-1} (Table 2-7) compared to the overall discarded catch rate of 1.32 fish.net day^{-1}. Small mesh gill nets were the most efficient in terms of catching target species/sizes with 15.88 fish.net day^{-1} retained, compared to 1.20 fish.net day^{-1} discarded. Large mesh gill nets were less efficient with 1.65 fish.net day^{-1} retained compared to 1.40 fish.net day^{-1} discarded.

Table 2-7. Overall catch rates of retained and discarded fish, from small and large mesh gill nets combined, small mesh gill nets and large mesh gill nets.

	CPUE (fish.net day^{-1})				
Net type	Retained	SE	Discards	SE	n
All	7.69	<0.001	1.32	0.001	53
Small mesh gill net	15.88	<0.001	1.20	0.001	30
Large mesh gill net	1.65	0.002	1.40	0.001	35

In catches from small mesh gill nets the highest catch rates of retained fish were yellow-eye mullet (14.25 fish.netday-1 ± <0.001) and Australian salmon (1.34 fish.netday-1 ± 0.001) (Figure 2-3A). The highest catch rates for discards were for Australian salmon (0.67 fish.$netday^{-1}$ ± 0.05) and mulloway (0.28 fish.$netday^{-1}$ ± 0.009).

In catches from large mesh gill nets the highest catch rates of retained fish were for mulloway (0.69 fish.$netday^{-1}$ ± 0.005), yellow-eye mullet (0.35 fish.$netday^{-1}$ ± 0.04), and greenback flounder (0.30 fish.$netday^{-1}$ ± 0.005) (Figure 2-3B). Discards were dominated by mulloway with the catch rate of discards (1.05 fish.$netday^{-1}$ ± 0.003) higher than for than retained fish. For greenback flounder the catch rate of discards (0.25 fish.$netday^{-1}$± 0.010) was similar to the catch rate of retained fish.

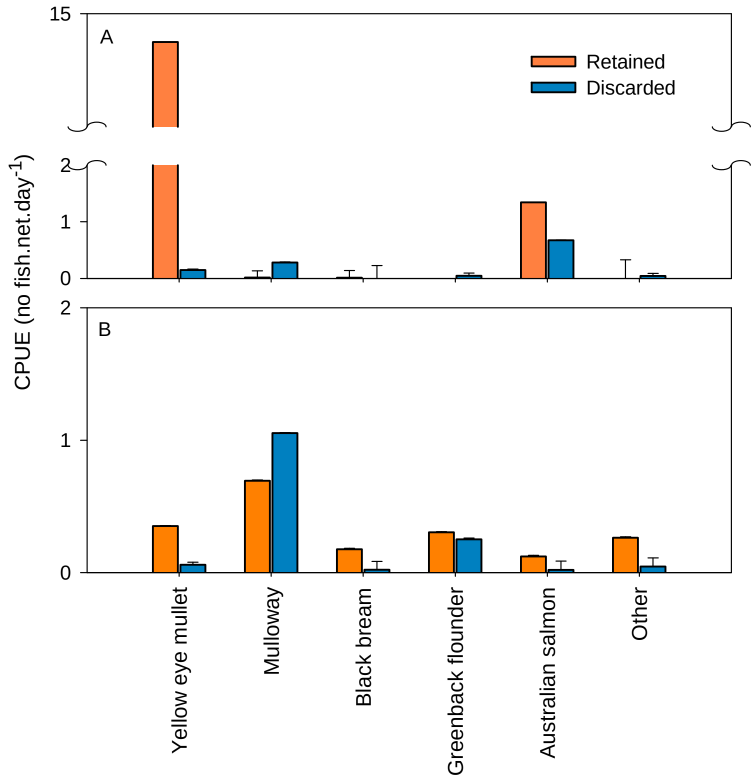

Figure 2-3. Catch rates for key species from (A) small and (B) large mesh gill nets from September 2005 to August 2006.

Variations in discard ratios

The overall discard ratio from observed catches was 0.171. The discard ratio for small mesh gill nets was less than for large mesh gill nets (Kruskall Wallis: χ^2= 29.246, $P < 0.001$) (Table 2-8).

Discard ratios differed among seasons for small and (Kruskall Wallis: χ^2= 8.319, $P < 0.05$) and large mesh gill nets (Kruskall Wallis: χ^2= 9.833, $P < 0.05$). The discard ratios in small mesh gill nets were highest in spring (0.26 ± 0.003) and summer (0.20 ± 0.051) and lowest in winter (0.03 ± 0.012). Discard ratios from large mesh gill nets were higher than those for small mesh nets in all seasons. For large mesh nets the highest discard ratios occurred in summer (1.25 ± 0.122) and lowest in spring (0.39 ± 0.062).

Table 2-8. Discard ratios for small and large mesh gill nets combined, small mesh gill nets and large mesh gill nets.

Net type	Discarded	Retained	Discard ratio	SE
All	1,282	7,479	0.171	0.0001
Small mesh gill net	497	6,557	0.076	0.0001
Large mesh gill net	785	922	0.851	0.0013

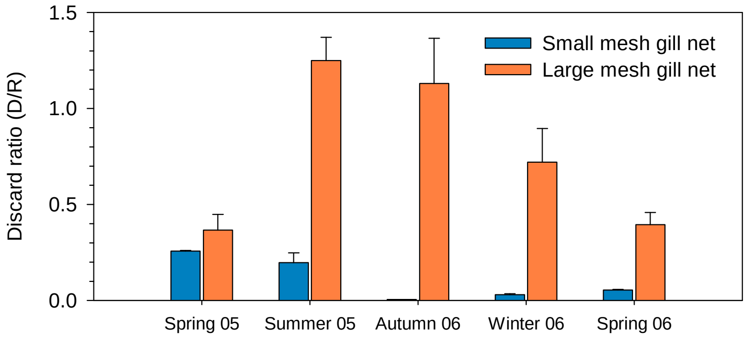

Figure 2-4. Discard ratios for small and large mesh gill nets by season.

The discard ratios differed among target species (Kruskall Wallis: χ^2= 19.092, P < 0.001) and were 0.98 and 0.85 respectively, when mulloway and greenback flounder were targeted. When yellow-eye mullet were targeted the discard ratio was 0.2 (Table 2-9).

Table 2-9. Discard ratios for catches by target species.

Target	Discarded	Retained	Discard ratio	SE
Mulloway	556	566	0.982	0.0023
Greenback flounder	178	209	0.852	0.0005
Black bream	51	145	0.352	0.0054
Yellow-eye mullet	496	6,516	0.076	0.0000

Discard ratios generally increased with increasing mesh size (LR: y = 0.009 L_{10}(x) + 0.367, r^2= 0.81, $F_{1,6}$=25.301, P=0.02) to 140 mm, then decreased for mesh sizes 152 and 165 mm (Figure 2-5).

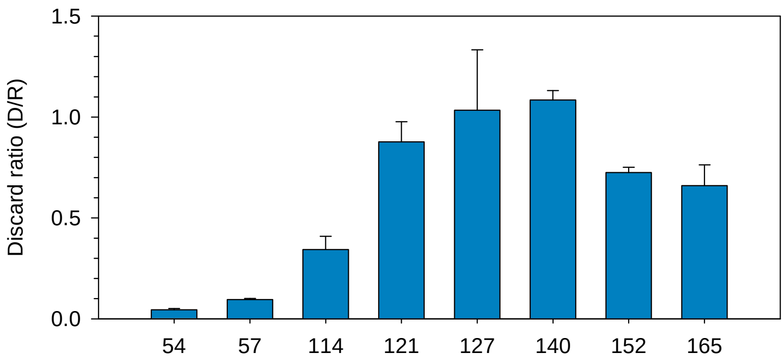

Figure 2-5. Discard ratios for a range of gill net mesh sizes.

Length composition of discarded and retained catches

The distributions of lengths for each species are presented for catches from small (Figure 2-6) and large mesh gill nets (Figure 2-7, Figure 2-8), and are summarised in Table 2-10.

Small mesh nets selected yellow eye mullet and Australian salmon over a relatively narrow size range that was above the LML of 210 mm TL. Lengths of yellow-eye mullet ranged from 132 to 399 mm with few (<1%) below legal minimum length (LML). Modal lengths of yellow eye mullet from 54 and 57 mm mesh nets were 239 and 264 mm TL respectively. Lengths of mulloway in 57 mm mesh ranged from 158 to 523 mm TL with the modal size of 274 mm TL approximately half the legal minimum length of 460 mm TL.

For large mesh gill nets the distribution of lengths of mulloway and greenback flounder occurred over a broad range. When gill nets with mesh sizes 114 and 121 mm were used to target mulloway, lengths ranged from 138 to 856 mm TL, and were bi-modal. The primary mode at ~515 mm TL represented the target size class of mulloway, while a secondary mode of ~320-340 mm TL comprised sub-legal sized individuals (Figure 2-7). For 121 mm mesh nets the secondary mode represented more than half (53%) the catch. Mulloway in nets with 127 mm mesh had a length range of 227 – 823 mm TL, which was also bimodal, and sub-legal sized individuals comprising the smaller mode represented 49% of the catch.

Large mesh nets with mesh size 152 mm, used to target greenback flounder, caught flounder with lengths from 218 – 398 mm, and modal length of 320 mm TL. Most (83%) greenback flounder were above LML. Lengths of mulloway in these nets ranged from 138 - 555 mm, with a modal length of 355 mm TL. Sub-legal sized mulloway accounted for 81 per cent of the total catch.

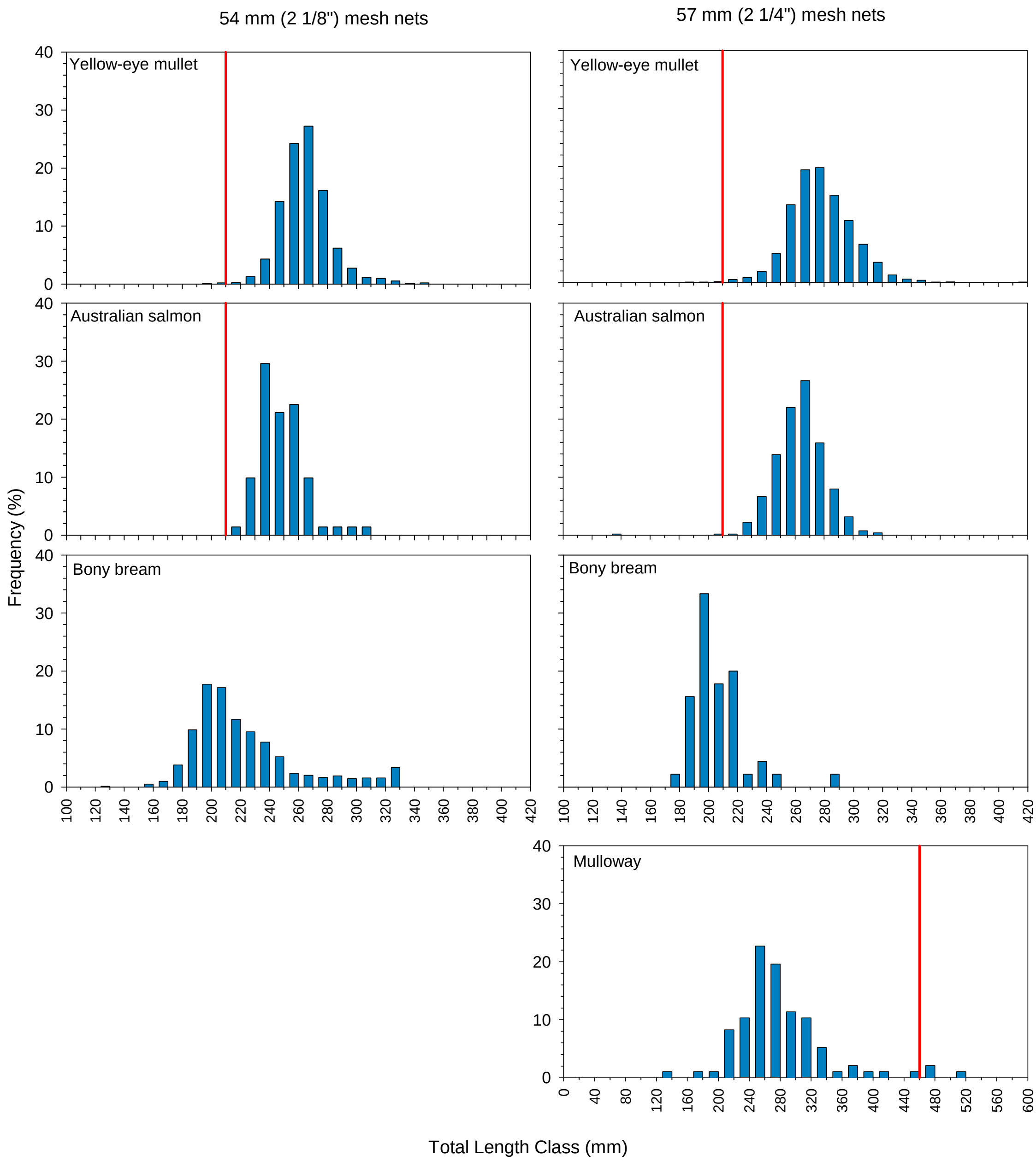

Figure 2-6. Length composition of key species caught in small mesh gill nets (54 and 57 mm mesh) in the Lakes and Coorong Fishery. Red line represents legal minimum length (Note: length class intervals for mulloway are wider than for other species).

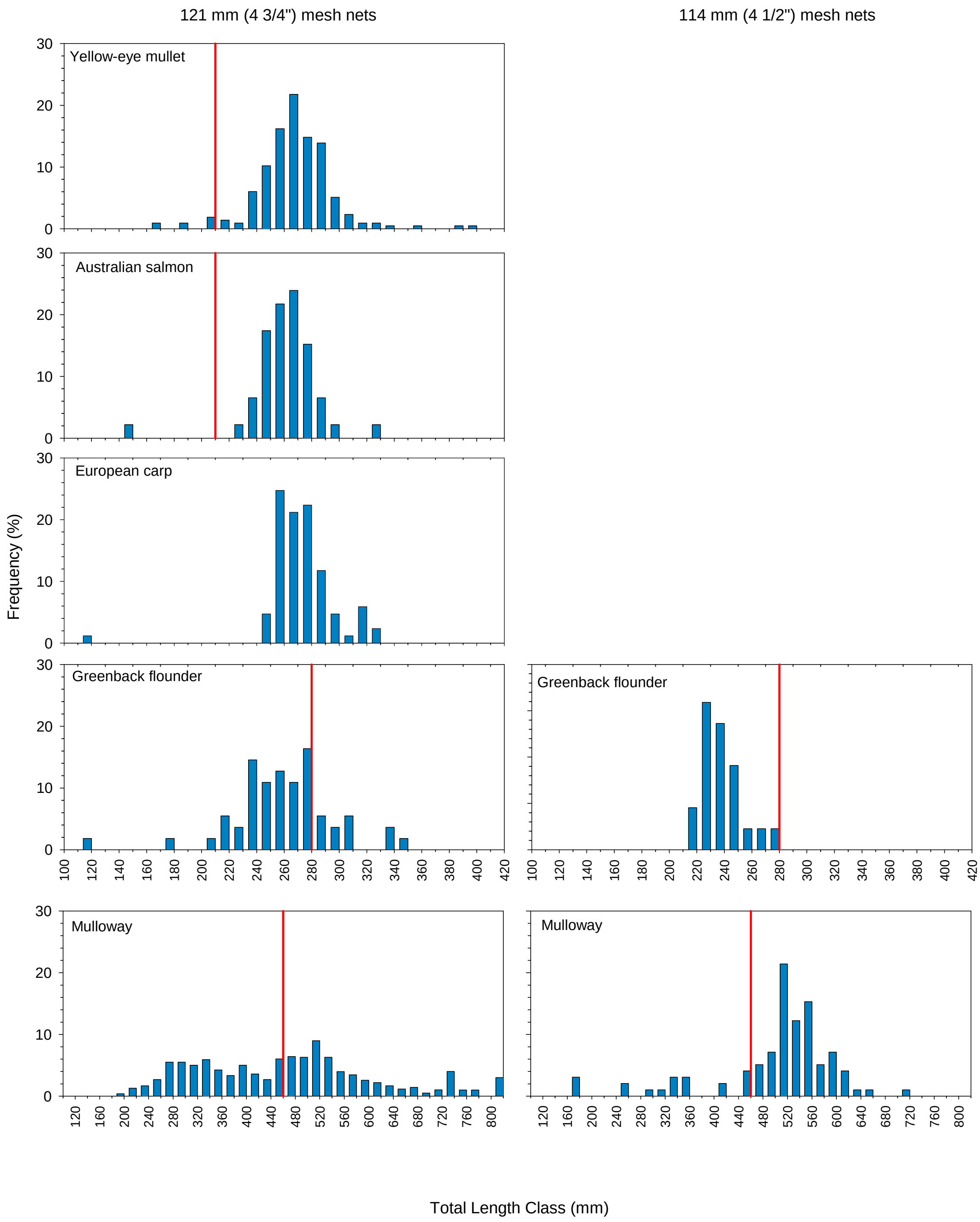

Figure 2-7. Length composition of key species caught in large mesh gill nets (121 and 114 mm mesh). Red line represents legal minimum length (Note: length class intervals for mulloway are wider than for other species).

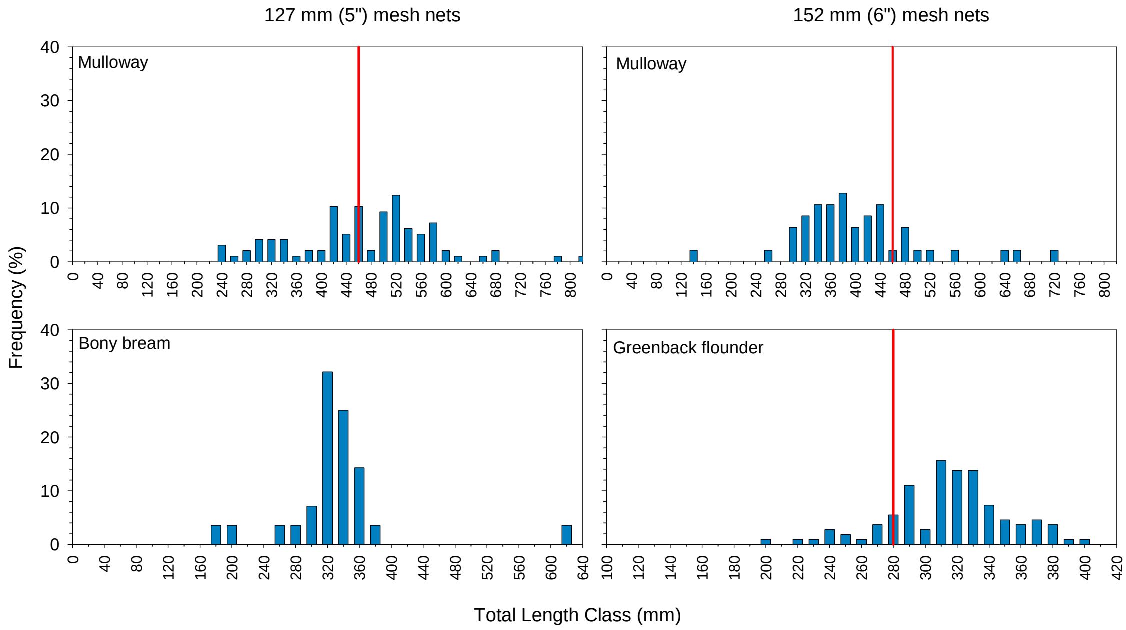

Figure 2-8. Length composition of key species caught in large mesh gill nets (5 and 6 inch) for key species in the Lakes and Coorong Fishery. Red line represents legal minimum length (Note: length class intervals for mulloway are wider than for other species).

Table 2-10. Summary of relative size selectivity of gill nets for species caught by the Lakes and Coorong Fishery. (* indicates bimodal distribution).

Mesh size	Species	Range (mm)	Mode	Average	SE	n
Small mesh gill net						
54 mm (2 1/8 in)	Australian salmon	209 - 308	239.4	247.3	1.85	71
	Bony Bream	176 - 287	192.9	204.5	2.94	45
	Yellow-eye mullet	132 - 286	262.0	259.9	0.30	2141
57 mm (2 ¼ in)	Australian salmon	201- 244	261.7	234.1	0.70	541
	Bony Bream	192 - 212	201.1	204.8	1.34	841
	Mulloway	158 - 523	274.0	283.4	6.06	97
	Yellow-eye mullet	132 - 399	264.2	275.8	0.30	3896
Large mesh gill net						
114 mm (4 ½ in)	Greenback Flounder	218 - 275	225.0	236.1	3.20	22
	Mulloway	166 - 705	500.7*	498.0	9.91	102
121 mm (4 ¾ in)	Australian salmon	142 - 362	263.9	259.1	4.10	45
	European carp	388 - 557	448.0	445.14	4.10	84
	Greenback Flounder	217 - 345	236.0	263.1	3.90	55
	Mulloway	191 - 856	515.0*	438.3	4.45	779
	Yellow-eye mullet	164 - 391	266.4	265.9	1.87	215
127 mm (5 in)	Mulloway	227 - 823	409.8*	460.1	11.39	97
152 mm (6 in)	Greenback flounder	218 - 398	320.0	311.9	3.41	108
	Mulloway	138 - 555	355.0	375.2	11.12	44

The distributions of lengths of mulloway differed among 3 ply ratings of monofilament used to construct large mesh gill nets (121 mm); 8 (n = 202), 10 (n = 464), and 14 ply (n = 66) (Kruskall-Wallis χ^2 = 17.376, n_1 = 202, n_2 = 464, n_3 = 66, df = 2, P = 0.000)(Figure 2-9). However the range of lengths was broad with 47, 56 and 61% of all individuals below LML in 8, 10 and 14 ply respectively.

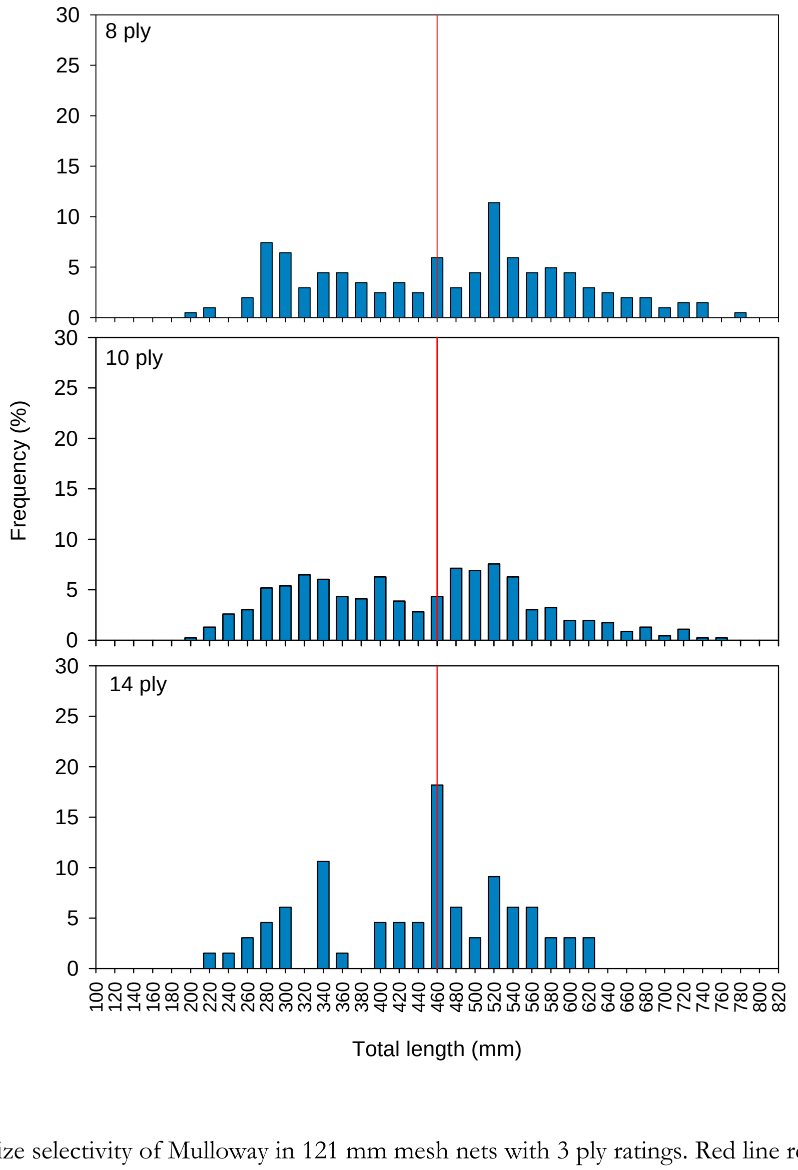

Figure 2-9. Size selectivity of Mulloway in 121 mm mesh nets with 3 ply ratings. Red line represents legal minimum length.

Condition of discards

Overall, 32.3% of fish caught in gill nets were alive at retrieval. More fish were alive in large mesh nets (38.4%) than small mesh gill nets (23.1%, Mann–Whitney U=24713.0, n_1=397, n_2=167, P=0.00 two-tailed). When discards only were considered, 28.5% of fish were alive when the nets were retrieved. More discards were alive in large mesh gill nets (31.3%) than small mesh gill nets (21.8%) although this was not statistically significant (Mann–Whitney U=9002.0, n_1=273, n_2=73, P=0.175 two-tailed).

The condition of retained and discarded fish at net retrieval was species specific (Table 2-11) with higher percentages of black bream and greenback flounder alive compared with mulloway, yellow-eye mullet and Australian salmon.

Table 2-11. Condition of key species at time of net retrieval.

		All (retained and discarded)			Discards only		
Net	Species	No. alive	No. dead	Alive (%)	No. alive	No. dead	Alive (%)
Small mesh gill nets	Mulloway	326	817	28.5	32	32	50.0
	Yellow-eye mullet	604	2120	22.2	15	110	12.0
	Australian salmon	139	414	25.1	4	260	1.5
	Black bream	3	4	42.9			
	Greenback flounder	232	146	61.4	66	51	56.4
Large mesh gill net	Mulloway	238	682	25.9	120	402	23.0
	Black bream	85	25	77.3	6	5	54.5
	Greenback flounder	209	122	63.1	66	51	56.4

Overall, 25.9% of discarded mulloway were alive at net retrieval and this appeared to vary with season, although the trend was not statistically significant (Kruskal-Wallis test: χ^2 = 8.886, n_1=56, n_2=137, n_3=50, n_4=27, n_5=47, df = 4, P > 0.5). Survival of discards ranged from 22.7% in summer 2005 to 46.0% in winter 2006. After this, survival declined to 35.7% in spring 2006. Survival of retained mulloway followed a similar trend but was higher in all seasons except spring 2005.

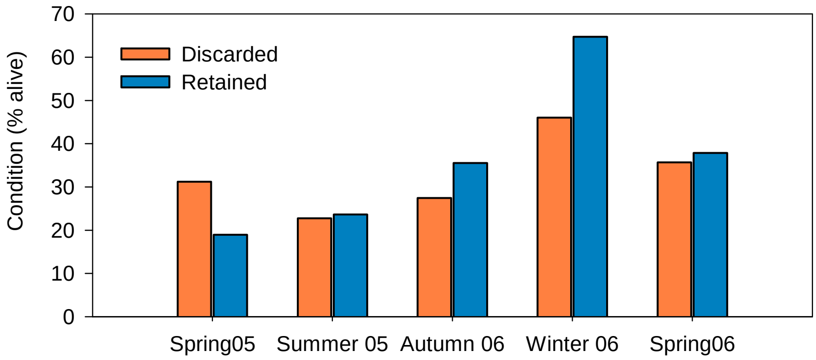

Figure 2-10. Condition of mulloway at time of retrieval from large mesh gill nets set overnight.

Overall survival of greenback flounder was 60.2%. Survival in winter and spring 2006 was 100 and 87.5% respectively, however the sample size in winter was small (n=3). Survival in summer 2006 was 59.4%.

2.3.2 Recreational gill net fishery

There were 1,512 recreational net registrations current in 2006. Forty five percent of registered netter were contacted by telephone and 13.5% agreed to participate in the survey (Table 2-12).

Table 2-12. Summary of survey of registered recreational net fishers.

Survey details	Number	Percentage of registered users that were surveyed
Total number of registered nets	1512	(including 6.3% expired) 13.5
Total number contacted	685	
No of expired registrations	43	6.3
Number that participated in the survey	191	27.9

Of those registered net holders who participated in the survey 28% (n=54) and 21% (n=41) had used their nets in the Coorong lagoons in 2005-06 and 2006-07. Of those that had not fished in the previous 2 years, 21% had not used their nets in the previous 5 years, and a further 19% had never used their nets in the Murray River estuary or Coorong lagoons.

Of those who had used their nets in 2006-07, 56.1 and 31.6% had fished the Coorong lagoons (Area 2) and Murray River estuary (Area 1) respectively, while those remaining had fished on both areas. The number of days fished ranged from 1 to 100 days, with an average of 8.5 (±1.99) in 2006-07. Forty one percent of fishers soaked nets overnight. The remaining 59.3% of fishers soaked nets for an average of 2.4 (±0.30) hours per trip.

Nets were set in all months with 4 of the registered netters fishing in all months. However netting activity was seasonal with approximately twice as many fishers fishing in May and July than in other months (Figure 2-11). Yellow eye mullet was reported as the main target and main harvested species of 94.8% of fishers. Yellow eye mullet and greenback flounder were reported as the main discard species by 12.7 and 6.9% of fishers respectively, and were discarded because they were below LML. Fishers also reported discarding Australian salmon (5.2% of fishers) because they were an unwanted species. Several recreational netters also reported discarding congolli and European carp.

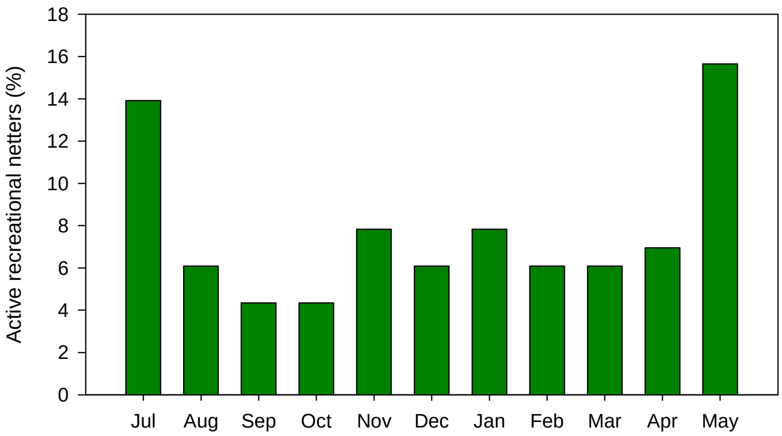

Figure 2-11. Effort by registered recreational net fishers from July 2006 to May 2007.

2.4 Discussion

2.4.1 Species composition of catches

Overall, 11 marine and estuarine species of finfish were observed in gillnet catches taken by the LCF in the Murray River estuary and Coorong lagoons during 2005-06. The species composition was dominated by yellow-eye mullet (70%), mulloway (13%), and Australian salmon (10%). These results were supported by a subsequent research study in 2006-08, which used multi panel gill nets in the Murray River estuary and Coorong lagoons and found 15 marine and estuarine species with catches dominated by Australian salmon, (41.6%), yellow-eye mullet (37.3%), and mulloway (14.8%) (Noell et al. 2009).

Compositions of catches varied spatially and temporally. Retained yellow-eye mullet dominated catches in spring and winter and retained mulloway in summer and autumn. This likely reflects seasonal redirection of effort from mulloway in the warmer months to yellow-eye mullet in winter (Ferguson and Ward 2003; Ferguson 2007; Ferguson and Ye 2008). Discarded mulloway comprised a significant component of catches in all seasons, particularly spring, summer and autumn with discarded greenback flounder also contributing significantly. Sub-legal sized mulloway and greenback flounder were also present in research gill net catches in the Murray River estuary and Coorong lagoons in all seasons in 2006-07 (Noell et al. 2009).

When yellow-eye mullet, mulloway, greenback flounder or black bream were targeted, retained individuals of the target species contributed most to the similarity of catches. However, discarded mulloway were the second most important contributor to similarity of catch composition for all targets except black bream. Discarded mulloway and greenback flounder were mostly (>95% by number) sub-legal sized individuals although small numbers were also discarded due to loss of product quality caused by Coorong crabs.

Results of this study are consistent with other studies of estuarine fisheries where captures of non-target fish typically include undersized individuals of species that are targeted by that fishery (Gray et al. 2001; Ueno 2001; Gray 2002; Gray et al. 2004). The occurrence of sub-legal sized mulloway, observed in this study, was also consistent with a previous report on gill net catches in the LCF (Hall 1986).

2.4.2 Discarding

Discarding across all mesh sizes, areas and seasons, observed in this study was 14.6% of the total sampled catch (by numbers) which was less than half of the estimate of 33.0% (by numbers) reported for a multi-species gill net fishery in estuaries in New South Wales (Gray 2002).

Discard ratios varied significantly between small and large mesh gill nets. Catch rates of discards were relatively low in small mesh gill nets used to target yellow-eye mullet suggesting these nets were effective in catching the target species yellow eye mullet with minimum wastage. Discard ratios were higher for large mesh gill nets used to target mulloway and greenback flounder indicating that that harvesting of these species was relatively inefficient. These results contrast with those from a study in New South Wales estuaries which found increasing rates of discarding with decreasing mesh size (Gray 2002).

Differences in discard ratios between small and large mesh gill nets likely reflect the different fishing practices used to target different species. This was supported by differences in discard ratios among target species. The relatively low discard ratios observed in small mesh gill net catches, which were used almost exclusively to target yellow-eye mullet, may be attributed to the practice of floating the nets (79% of sets), attendance by the fisher, and the legal requirement for a relatively shallow drop (33 meshes, 1 m). Higher discard ratios from large mesh gill net catches may be partly due to the practice of overnight setting, bottom setting of the nets, and the deeper drop (2m) of these nets.

2.4.3 Size composition of retained and discarded species

Knowledge of net selectivity is important in assessing solutions to mitigate and manage discarding (Hall 1999; Broadhurst 2000). We found that small mesh gill nets were selective for sizes of yellow-eye mullet and Australian salmon that were above the LML. Additionally, the mean size of yellow-eye mullet increased with increasing mesh size as has been reported in other studies (Marais 1985; Gray 2002). Small mesh gill nets also caught mulloway that were mostly (>95%) below LML. Conversely, large mesh gill nets were poorly selective for lengths of the target species mulloway and greenback flounder. In these nets lengths of mulloway occurred over a wide range and were bimodal. The larger mode represented the target size class that was above LML and the smaller mode indicated that significant numbers of sub-legal sized mulloway were entangled in the mesh by the pre-maxilla. This is consistent with a study by Hall (1986) which also reported increased levels of entanglement of sub-legal sized mulloway with net meshes >100 mm. Similarly poor selectivity for length by gill nets has been reported for other fish species which may be entangled as well as meshed (Hamley 1975; Bjordal 2002) and bimodal selectivity curves, that increase in amplitude as the mesh size increases, are typical of these species (Hamley and Regier 1973; Hamley 1975). Although there were few data for length selectivity of black bream, entanglement of spines of sub-legal individuals was also observed.

Factors which may affect the length selectivity of a net once fish have encountered it include; hanging ratios, fishing height (mesh depth) and mesh size (Dickson 1989; Acosta and Appeldoorn 1995; Millar and Fryer 1999; Gray et al. 2005). The diameter (ply) of a net may also affect length selectivity for a particular species (Dickson 1989; Gray et al. 2005) due to its affect on visibility, elasticity and flexibility, and therefore the efficiency of gillnets (Holst et al. 2002). Several studies have suggested that the greatest catches and widest size selection of individual species occurs in gillnets made from the thinnest twine (Hamley 1975; Henderson and Nepzy 1992; Hovgard 1996; Yakota et al. 2001; Holst et al. 2002). Although we found significant differences in the distribution of lengths of mulloway in 121 mm mesh, constructed of 3 different ply, the range of lengths in each mesh size was broad (200 mm to > 600mm TL) and significant numbers of mulloway (47-61%) below LML were caught regardless of the ply. A similar result was found in a comparison of ply in gill nets in estuaries in New South Wales (Gray et al. 2005).

2.4.4 Condition of discards

We found that 28.5% of discards were alive when removed from nets. This was significantly less than that reported for discards from gill net catches in estuaries in New South Wales (>82% alive) (Gray 2002). However, it is important to note that survival rates estimated from the percentage of live fish at retrieval must be treated as maximal because significant morbidity and mortality may also occur after initial capture (Davis and Olla 2001; Gray 2002).

Survival rates tend to be species specific due to differences in susceptibility of each species to a particular type of gillnetting; i.e. soak time and water temperature. For discarded mulloway overall survival (25.9%) was lower than that reported for gill net catches from estuaries in New South Wales (57.8%) (Gray 2002). Survival of discarded greenback flounder was relatively high (60%) compared to that for mulloway.

Survival of discards depends on a range of factors including; length of time retained in the gear, water temperature, and handling by fishers (Chopin and Arimoto 1995). Survival of discarded mulloway and greenback flounder was lowest in summer. This is consistent with other studies which have reported lower survival of discarded fish during summer when water temperatures are higher (Murphy et al. 1995; Davis and Olla 2001; Buchanan et al. 2002; Price and Rulifson 2004; Broadhurst et al. 2009). In New South Wales estimates of the survival of luderick *Girella tricuspidata*, large-tooth flounder *Pseudorhombus arsius*, yellowfin leatherjacket, *Meuschenia trachylepis,* were negatively related to water temperature (Broadhurst et al. 2009). The combination of soak time and water temperature were related to survival of paddlefish, *Polyodon spathula*, in a freshwater gillnet fishery in Tennessee (Bettoli and Scholten 2006).

Understanding survival of sub-legal sized mulloway after capture by gillnet is important because this species contributed most to levels of discards in gill nets in the LCF. While several studies have reported on longer term survival of mulloway from hook and line and trawl fishing (3-6 days) (Broadhurst and Barker 2000; Miller et al. 2005; Butcher et al. 2007) no study has addressed longer term survival of discards from gill nets. Estimates of survival range from 27.3 to 96.7% for line caught fish depending on hook location (Butcher *et al.* 2007) and 97% for 0+ individuals passed through an experimental, modified trawl net (Miller et al. 2005). This suggests that there may be potential for mitigating the low survival rate observed in this study.

2.4.5 Potential indicator for levels of discards

Estimates of retained to discarded catch ratios (by number) have been used to describe bycatch in several multi-species fisheries (Alverson et al. 1994; Gray 2001; Kelleher 2005). However, because discard ratios may vary considerably in time and space within a given fishery (Gray et al. 2001; Gray et al. 2003), generalised retained to discard ratios need to be interpreted with caution (Ye 2002; Gray et al. 2004).

Discard ratio (by number) may however provide a convenient indicator of overall levels of discarding because counts of retained and discarded catch can be done during normal fishing operations with minimal disruption, and discards that are alive can be returned to the water immediately. Additionally, where most discards are sub-legal sized individuals of targeted species, numbers of discarded fish, combined with information on ages may be used in estimates of overall mortality to inform stock assessment.

Daily catch and effort statistics from the Lakes and Coorong Fishery include information on mesh size (small or large mesh gill nets) and the primary target species. Inclusion of additional information on numbers of retained and discarded fish will provide estimates of (i) generalised discard ratio across all mesh sizes, areas and seasons, (ii) specific discard ratios for small and large mesh gill nets, and (iii) specific discard ratios for each target species, and (iv) specific discard ratios for the Murray River estuary and Coorong lagoons, or potentially for smaller spatial reporting blocks.

2.4.6 Recreational gill net fishers

Use of recreational nets in the Coorong lagoons was low, although significant latent effort exists. Between 2004 and 2006 numbers of registered nets had declined by 33.0% which was likely due to drought conditions in the Coorong lagoons since 2001. Of the 1512 registered nets in 2006-07, 21% of netters had used their registered net for an average of 8.5 days each, with most fishers leaving nets in the water for less than 3 hours. This equates to approximately 2,380 recreational net days in 2005-06, or 2.4% of the number of commercial net days during that period.

The main discard species from registered recreational nets were sub-legal sized yellow-eye mullet and greenback flounder. Management requirements for nets to be set floating and for registered owner to be in attendance, combined with short soak times, may have resulted in reduced interactions with non-target species and sizes, particularly sub-legal sized mulloway.

Fewer recreational gill net fishers reported using nets in the Murray River estuary, than in the Coorong lagoons. This was probably due to the closure of the Murray estuary (Area 1) to recreational nets from November 1 to March 31 each year.

2.4.7 Conclusion

Discarding may have a range of impacts on fish stocks and ecological interactions among species (Jennings and Kaiser 1998; Hall 1999). In fisheries that operate in estuarine environments, such as the Murray River estuary and Coorong lagoons, captures of non-target fish typically include undersized individuals of species that are targeted (Gray et al. 2001; Ueno 2001; Gray 2002; Gray et al. 2004) which may potentially impact on stocks (Gray et al. 2003).

The key issue concerning non-target species in the Lakes and Coorong commercial gill net fishery is discarding of sub-legal sized mulloway because; (i) discarded mulloway contributed significantly to similarity of catches for all targets, except black bream, (ii) catch rates of discards were higher than catch rates of retained catch, (iii) large mesh gill nets selected mulloway over a wide range of lengths, which include several year classes, and (iv) survival of discarded mulloway was low. Contributing to this was seasonal distribution of targeted effort directed at mulloway which are highest in spring-to autumn (Ferguson and Ward 2003; Ferguson 2007) when rates of discarding of sub-legal sized individuals were highest and survival lowest.

This study provides baseline data on catch species composition and levels of discarding during 2005-06. These results should be interpreted with caution because during this study the Murray River estuary and Coorong lagoons were impacted by the most severe drought in Australia's recorded history (Noell et al. 2009). For example, the appearance of strong year classes of mulloway is likely related to freshwater inflows (Ferguson et al. 2008) and this may also be the case for black bream (Newton 1996; Norriss et al. 2002; Hoeksema et al. 2006). Therefore, abundances of sub-legal sized mulloway and black bream may have been low during the period of this study. Consequently, catch rates of discards, and discard ratios in this study may be low compared to years when freshwater inflow to the Murray River estuary occurs.

On-going estimates of discard ratios will provide a useful indicator for levels of discarding. However, separate estimates of discard ratios are required for small and large mesh gill nets, and for target species; yellow-eye mullet, mulloway, greenback flounder, and black bream. Because survival is likely affected by a combination of soak time and water temperature additional information on soak time of nets would complement estimates of discard ratios.

3 RISK ASSESSMENT OF INTERACTIONS WITH FISHING GEAR FOR KEY SPECIES IN THE LAKES AND COORONG COMMERCIAL AND RECREATIONAL FISHERIES

3.1 Introduction

The risk assessment approach is commonly applied to ecosystem impacts of fisheries and used to prioritise management issues to manage the take of non-retained species at ecologically-viable stock levels (Francis 1992; Fletcher 2005). The approach has also been used to prioritise management issues around non retained species such as seals, cetaceans, turtles and birds (Harwood 1999; Lewison and Crowder 2003; Kaplan 2005; Goldsworthy and Page 2007). For example, this approach has also been used to prioritise management responses to non-retained species from the Victorian southern rock lobster fishery (Jenkins et al. 2005).

The scope of this risk assessment is to investigate risks associated with levels of interactions of non-retained species with fishing gear in the recreational and commercial fisheries in the Coorong lagoons, under the current management arrangements.

In addition to information describing interactions with fishing gear in the current study (2005-06) the risk assessment was supported by information from several other recent studies. Understanding the potential impacts on populations of interaction with fishing gear requires knowledge of the spatial and temporal distribution of fishing effort (Harwood 1999; Goldsworthy and Page 2007) which was also available from stock assessment and stock status reports. Information on the commercial fishery was available from LCF fishery stock status reports (Ferguson 2010) and stock assessments for yellow eye mullet, mulloway, greenback flounder, and black bream (Ferguson and Ward 2003; Ferguson 2007; Ferguson and Ye 2008). Information on the recreational fishery was available from the National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003; Jones and Doonan 2005; Jones 2009) and a boat ramp survey of recreational fishing in the Coorong lagoons (Ferguson 2006).

In this study risk is defined as the chance of something happening that will have an impact on objectives and "Risk analysis" is the consideration of the sources of risk, their consequences and the likelihood that those consequences may occur (AS/NZS 4360-1999). The assessment was done at the level of unit stock (locally reproducing population) for each species. Non retained species were defined as "those species caught or directly impacted by the fishery but not used" (Fletcher et al. 2002).

3.2 Methods

The risk assessment framework follows that of the national ESD reporting framework for wild capture fisheries (Fletcher et al. 2001; Fletcher et al. 2002; Fletcher 2005) which was based on the principles and practises within the Australian and New Zealand Standards for Environmental

Risk Assessment (AS/NZS4360). Risk Assessment involves three stages: (i) an identification of the hazard; (ii) an assessment of the probability of exposure, and (iii) of the consequences of different levels of exposure, which are then combined to provide a risk characterization. Information from this analysis can be used to inform development of a strategy for risk management (Harwood 1999) and can be extended to include the potential effects of the additional probability of death for individuals of particular species on the dynamics of their populations.

The risk value for each issue was calculated as the mathematical product of the consequence and likelihood levels, producing risk values between 0 and 30 (Fletcher 2005). Table 3-1 details criteria for (i) assigning levels of likelihood that an event may occur, (ii) assigning a level of consequence to a population of species that interact with the fishing gear, and (iii) assigning a level of consequence for protected species. Table 3-2 shows rankings for the risk matrix.

Table 3-1. Definitions for (a) likelihood of a risk occurring (Fletcher 2005), (b) consequence categories for major retained/non-retained species (Fletcher et al. 2002; Fletcher 2005), and (c) consequence levels for the impact of a fishery on protected species (Fletcher et al. 2002).

(a) Likelihood		
Level	Descriptor	
Likely	6	It is expected to occur
Occasional	5	May occur sometimes
Possible	4	Some evidence to suggest this is possible here
Unlikely	3	Uncommon, but has been known to occur elsewhere
Rare	2	May occur in exceptional circumstances
Remote	*1*	Never, heard of, but not impossible
(b) Consequence		
Level		Ecological
Negligible	0	Almost none are impacted Occasional undersize, low or high mortality of discards
Minor	1	Some are impacted but there is no impact on stock Small numbers, low or high level of mortality of discards
Moderate	2	Levels of impact are at the maximum acceptable level Moderate numbers caught, high mortality of discards
Severe	3	Same as target species Large numbers, high mortality of discards
Major	4	Same as target species Large numbers, high mortality of discards
Catastrophic	5	Same as target species Large numbers, high mortality of discards
(c) Consequence for protected species		
Negligible	0	Almost none are impacted
Minor	1	Some are impacted but there is no impact on stock
Moderate	2	Levels of impact are at the maximum acceptable level
Severe	3	Same as target species
Major	4	Same as target species
Catastrophic	5	Same as target species

Table 3-2 Risk matrix – numbers in cells indicate risk value, colours/shades indicate risk rankings (grey = 0, negligible; green = 1-5, low; yellow = 6-12, moderate; orange = 13-18, high; red = >19, extreme) (Fletcher et al. 2001; Fletcher et al. 2002).

		Consequence					
		Negligible	Minor	Moderate	Severe	Major	Catastrophic
Likelihood		0	1	2	3	4	5
Remote	1	0	1	2	3	4	5
Rare	2	0	2	4	6	8	10
Unlikely	3	0	3	6	9	12	15
Possible	4	0	4	8	12	16	20
Occasional	5	0	5	10	15	20	25
Likely	6	0	6	12	18	24	30

3.3 Results

In 2005-06 13.5% of targeted effort (net days) in the LCF was directed at species in the Murray River estuary and Coorong lagoons; yellow-eye mullet (4.1% of total targeted effort in LCF in 05-06), mulloway (5%), greenback flounder (3.1%), and black bream 1.3%). Most effort (67.2%) within the Murray River estuary and Coorong lagoons was directed at species within the estuary. The key targets were mulloway and yellow-eye mullet in the estuary and lagoons respectively (Table 3-3).

Table 3-3. Spatial distribution of effort for each target species in the Murray River estuary and Coorong lagoons.

	Spatial distribution of effort (% targeted effort for species)	
Target	Estuary	Coorong lagoons
Yellow-eye mullet	17.4	82.6
Mulloway	91.9	9.1
Greenback flounder	48.8	51.2
Black bream	100.0	0

Although, several types of gear i.e. seine nets may be used in the LCF results from the observer based study, and from stock status reports for the LCF (Ferguson 2010) indicate that >97% of catches were taken in gill nets. Yellow-eye mullet were targeted almost exclusively with small mesh gill nets, while large mesh gill nets were used to target mulloway, greenback flounder and black bream. The attributes of targeting practices associated with key species are listed in Table 3-4.

Table 3-4. Attributes of the impacts associated with risks for target species in commercial and recreational sectors of Murray River estuary and Coorong lagoons.

Risk (Target species)	Attributes
Yellow-eye mullet	Small mesh gill net. 1m drop. Mesh relatively efficient at selecting yellow-eye mullet, Australian salmon above LML.
	Low overall discard ratio(0.076 D/R).
	Catch rate of sub-legal sized mulloway high (~2 fish net day^{-1})
	Soak time: commercial nets mostly (65% of sets) <3hrs
	Most effort in Coorong lagoons
	65% nets soaked < 3hr
	Most effort in Coorong lagoons
	Seasonal – months in 2001-06 with highest targeted effort from July to November also, (Higham et al. 2005)
	Post release survival of discards; yellow-eye mullet 12%, mulloway 50%, greenback flounder 56.4%.
	Recreational fishery: mostly (59%) soak <3hr, set floating, fisher in attendance. 10.1% by weight of combined recreational-commercial harvest in 2007-08 (Jones 2009).
Mulloway	Large mesh gill net. 2m drop. Mesh inefficient at selecting mulloway, greenback flounder above LML.
	High overall discard ratio relative to small mesh gill nets (0.98 D/R)
	Catch rate of sub-legal sized mulloway high (2 fish net day^{-1})
	Targeted effort mostly spring, summer, autumn
	Soak time mostly (65.3% of sets) overnight
	Most effort in Murray River estuary
	Post release survival of discards; mulloway 23%, greenback flounder 56.4%, black bream 54.5%.
	Season – months in 2001-06 with highest targeted effort December to March, also (Ferguson and Ward 2003)
	Ninety per cent of legal sized commercial catch of mulloway in the LCF is below the size of sexual maturity (Ferguson and Ward 2003).
	Recreational line fishery: 61.2% of combined recreational-commercial harvest in 2007-08, Release rate 85.1% (Jones 2009). Post-release survival of line caught fish 73 -81% (Butcher et al. 2007)
Greenback flounder	Large mesh gill net. Mesh inefficient at selecting mulloway, greenback flounder above LML
	High overall discard ratio relative to small mesh gill nets (0.85 D/R)
	Post release survival of discards; mulloway 23%, greenback flounder 56.4%, black bream 54.5%.
	Overnight soak
	Targeted effort mostly in spring
	Effort distributed approximately evenly between estuary and lagoons
	Season –months in 2001-06 with most targeted effort August to November
	Post release survival of discards; mulloway 23%, greenback flounder 56.4%, black bream 54.5%.
	Recreational fishery: 1,774 flounder harvested in South Australia, 11% of combined recreational-commercial harvest in 2007-08, release rate 29.6% (Jones 2009). No estimate for post-release survival, spear fishery.
Black bream	Large mesh gill net
	Low overall discard ratio relative to large mesh gill nets for other targets (0.35 D/R)
	Soak time (100%) overnight
	All effort in Murray River estuary
	Season –months in 2001-06 with most targeted effort August to October
	Post release survival of discards; mulloway 23%, greenback flounder 56.4%, black bream 54.5%.
	Recreational line fishery: 51.5% of combined recreational-commercial harvest in 2007-08, Release rate 87.4% (Jones 2009).No estimate for post-release survival of black bream, for yellowfin bream *Acanthopagrus australis*, 75% survival after or ingested hooks, laboratory study (Broadhurst et al. 2007).

The risk to the status of mulloway stocks due to interactions with large mesh gill nets, when used to target mulloway or greenback flounder, was categorised as high. The likelihood of sub-legal sized mulloway encountering large mesh gill nets was given the highest score (1, "expected"), because; (i) catch rates of mulloway discards were high (1.05 fish.net.day^{-1}), length distributions of mulloway in large mesh gillnets were bimodal with a strong size class of sub-legal sized individuals, and (iii) nets were mostly (77%) set overnight, thus increasing exposure of individual fish to encountering the net. The consequence level (3, "severe") was considered appropriate because (i) a greater number of mulloway were discarded, than retained, (ii) most discards were sub-legal sized mulloway, (iii) overall survival at net retrieval was low (25.9%), (iv) most effort was targeted at mulloway in the warmer months when survival was likely lowest, and (v) >90% of the commercial catch is sexually immature. The consequence level was not scored higher (4, major) because levels of effort during 2005-06 were historically low.

The risk to the status of mulloway stocks in large mesh gill nets when black bream were targeted was scored as "moderate" because discard ratios were lower when targeting this species compared to catches when mulloway or greenback flounder were targeted.

The risk to the status of mulloway stocks when yellow-eye mullet were targeted was categorised as "moderate" because; (i) the catch rate of mulloway was low (0.28 fish.net.day^{-1}) relative to when large mesh gill nets were used, (ii) soak time for small mesh nets was short (63% <3 hours) compared to large mesh gill nets (60.2% overnight), thus reducing time that sub-legal sized mulloway were exposed to the nets, and likely increasing survival of discards.

Table 3-5. Summary of levels of risk for species, associated with the targeting of key species in the Murray River estuary and Coorong lagoons.

	Target species								Other species										TEPS	
Risk	Yellow-eye mullet	Mulloway	Greenback flounder	Black bream	Australian salmon	Australian anchovy	Congolli	Gurnard perch	Jumper mullet	Common toadfish	Smooth toadfish	Ray/skate	Sand crab	Coorong crab	European carp	Golden perch	Redfin	Tench	Australian pelican	Little black cormorant
Target (commercial fishery)																				
Yellow-eye mullet	5	10	6	5	6	4	4	3	5	5	5	0	0	6	5	5	5	5	5	5
Mulloway	5	18	12	5	5	0	3	3	3	5	5	0	0	6	5	6	5	5	5	5
Greenback flounder	3	18	12	5	3	0	3	3	3	5	5	0	0	6	5	6	5	5	5	5
Black bream	3	10	10	5	3	0	3	3	3	5	5	0	0	6	5	6	5	5	5	5
Target (recreational fishery)																				
Yellow-eye mullet	4	10	3	4	4	3	2	3	3	5	5	0	0	6	5	5	5	5	5	5
Mulloway	4	18	3	4	3	0	3	3	3	5	5	0	0	6	5	6	5	5	5	5
Greenback flounder	2	4	3	4	3	0	3	3	3	5	5	0	0	6	5	6	5	5	5	5
Black bream	4	12	3	4	3	0	3	3	3	5	5	0	0	6	5	6	5	5	5	5

Key
Extreme (>19)
High (13-18)
Moderate (7-12)
Low (1-6)
Negligible (0)

The risk to the status of greenback flounder when mulloway, greenback flounder or black bream were targeted with large mesh gill nets, was categorised as moderate because; (i) the catch rate of discarded greenback flounder was low (0.25 fish.net.day^{-1}), relative to that for mulloway, (ii) survival at net retrieval was higher for greenback flounder than mulloway.

Most species for which the status to stock were categorised as low, were freshwater species that had been washed into the Murray River estuary and Coorong lagoons when the barrages were open (redfin, tench, bony bream, golden perch, European carp), or were marine species caught in very low numbers. Similarly, one Australian pelican and one little black cormorant were observed in catches and were released alive and were thus categorised as "low" risk.

The risk to the status of mulloway stocks from targeting of yellow-eye mullet by recreational fishers with registered small mesh gill nets was categorised as "high" which was the same as that for the commercial fishery. The risk was at the lower end of the scale ("high", 13-20) because; (i) soak times are short (60% of fishers, < 3 hours), effort was low (21% of 1512 registered net owners fished for an average of 8 days each in 2006-07) compared the commercial fishery.

The risk to the status of mulloway stocks from recreational line fishers targeting mulloway was categorised as high because; (i) estimated catches were high (Jones and Doonan 2005; Jones 2009), and (ii) release rates were high (85%) (Jones 2009), although post-release survival was also high compared to gill nets (73-81%) (Butcher et al. 2007).

3.4 Discussion

The key issue highlighted by this risk assessment is the presence sub-legal sized mulloway in large mesh gill net catches which has the potential to impact on the sustainability of mulloway stocks. While the overall catch rate of discards is similar between small and large mesh gill nets, the discarded catch in large mesh gill nets comprises mostly sub-legal sized mulloway. Ongoing reporting of levels of discarding from all nets, particularly large mesh nets, is an important requirement for future assessment of the status of this stock.

4 GENERAL DISCUSSION

This study presents baseline information on discard rates for gill netting in the Murray River estuary and Coorong lagoons. Data provided by this study show that, during the period of the study (2005-06) a limited number of species were caught, or discarded, in the commercial Lakes and Coorong Fishery and that the composition of catches varied spatially and temporally.

Overall rates of discarding from gillnets in the Murray River estuary and Coorong lagoons, during 2005-06, were lower than for other published studies (Gray 2002; Gray et al. 2004). Discard ratios varied significantly between small and large mesh gill nets with the highest discard ratios from catches in large mesh gill nets used to target mulloway and greenback flounder. These differences likely reflect the different fishing practices associated with different target species. The relatively low levels of discards observed in small mesh gill nets, which were used almost exclusively to target yellow-eye mullet, may be attributed to the practice of floating the nets (79% of sets), attendance by the fisher, and the legal requirement for a relatively shallow drop (33 meshes 1 m). The higher catch rates of discards in large mesh gill nets may be partly due to the practice of overnight setting, bottom setting of the nets, and the deeper drop (2m) of these nets.

Results from observer based monitoring, and the risk assessment presented in this study, suggest that the key issue concerning non-target species in the LCF commercial gill net fishery is discarding of sub-legal sized mulloway. This is because; (i) discarded mulloway contributed significantly to similarity of catches in all seasons and for all targets, except black bream, (ii) length selectivity for mulloway in large mesh gill nets was poor, (iii) most discarded mulloway were sub-legal sized, (iv) levels of discarded mulloway in catches from large mesh gill nets were higher than levels of retained catch, and (iv) survival of discarded mulloway was low. Contributing to this was seasonal distribution of targeted effort directed at mulloway which are highest in spring-to autumn (Ferguson and Ward 2003; Ferguson 2007) when rates of discarding of sub-legal sized individuals were also highest and survival lowest.

Rates of discarding of sub-legal sized mulloway have the potential to impact stocks. The concern surrounding the capture of juvenile fish is that potential yields are reduced by growth overfishing, or if insufficient fish in the affected population survive to maturity, recruitment overfishing may occur (Bohnsack and Ault 1996). Approximately 90% of the commercial catch of mulloway from the Coorong region comprises sexually immature fish (Ferguson and Ward 2003), suggesting that discarding may have the potential to double the mortality of juvenile mulloway.

Potential methods for mitigation of discard rates

Anecdotal evidence has been documented describing net setting practices used by fishers to reduce discard levels of bycatch in the LCF, although experimental work has not been done to verify the efficacy of these methods (Leadbitter 1999; Anon. 2002).

Spatial and temporal closures

Seasonal and area closures may be used to mitigate discarding of sub legal sized individuals of target species. In the Murray River estuary restrictions to the use of small mesh gill nets apply from 1 from November 1 to March 31 each year and small mesh gill nets must not be set with anchors, and must be set to float with the fisher in attendance. These measures were originally put in place in an attempt to reduce interactions between small mesh nets and juvenile mulloway (Stenning, PIRSA pers. comm.).

The presence of mulloway in research gill net samples in all seasons from the Murray River estuary (Noell et al. 2009), and results from this study, suggest that the current spatial-temporal closure, may not provide the most effective mitigation of levels of discarding of sub-legal sized mulloway. Restriction on the use of small mesh gill nets during the spatial/temporal closure may have limited effect on levels of discarding of mulloway, at least under the environmental conditions that occurred in 2005-06. This was because small mesh gill nets were relatively efficient at catching the target species with catch rates of discarded mulloway relatively low compared to large mesh gill nets. Contrastingly, large mesh gill nets, which were not subject to the closure, had comparatively high overall discard ratios because size selectivity for mulloway was poor. Additionally, the closure occurs during summer-autumn, when seasonal discard ratios are highest and levels of effort directed at mulloway and greenback flounder are also highest (Ferguson and Ward 2003; Ferguson 2007).

Net construction

A number of factors which may affect the length selectivity once fish have encountered a net include; optimising hanging ratios, fishing height (mesh depth) and mesh diameter (ply) of the net (Dickson 1989; Acosta and Appeldoorn 1995; Millar and Fryer 1999; Gray et al. 2005).

Hanging ratio is the length of rope on which the net panel is mounted divided by the actual length of stretched netting (Sainsbury 1996). Adjustment to the hanging ratios of gill nets has been suggested a bycatch mitigating measure for gill netting in the LCF (Anon. 2002) although this has not been tested empirically. High hanging ratios of nets are thought to result in reduced size range of fish compared to low hanging ratios (Hamley 1975). However, this was not supported by a study comparing 3 hanging ratios (0.50, 0.65, 0.80) of gill nets in estuaries in New South Wales which found little difference in either catch rate or size selectivity (Gray et al. 2005).

Decreasing the fishing depth of gill nets has been suggested as a way to improve species selectivity (Gray et al. 2005). In a study of gillnets in estuaries in New South Wales decreased net depth was found to change species selectivity by up to 46% (Gray et al. 2005).

Soak time and attendance of nets

Reduced soak time has been recommended for lowering levels of discarding, and subsequent mortalities, of fish in several fisheries (Acosta 1994; Chopin and Arimoto 1995; Lenanton et al. 1996; Gray et al. 2003; Gray et al. 2005; Buckel et al. 2006). The convenience of unattended gillnetting may be offset by the higher risk of interactions with non target species, damage to enmeshed fish by seals and birds, and loss of product quality particularly in warm weather (Leadbitter 1999).

In Western Australia the affects of attendance and non-attendance of recreational gill nets were studied in estuarine and coastal waters (Lenanton et al. 1996). This study found that attended gill nets with reduced soak time, caught similar numbers of fish to unattended nets left overnight, caught reduces numbers of discards, caught lower number of species overall, and that fish were of higher quality (Lenanton et al. 1996).

Additionally, reduced soak time has also been identified as a means to reduce interactions with marine mammals and quick release of tangled birds, by the attendant fisher, will likely reduce mortality (Lenanton et al. 1996; Harwood 1999; Gray et al. 2005; Buckel et al. 2006).

Conclusion

Discard ratio (by number) will provide an effective and convenient indicator of overall levels of discarding. This can be achieved by provision for counts of discards and retained fish in the South Australian Inland Waters Catch and Effort Returns. Discard ratios should be estimated separately for small and large mesh gill nets, and for each target species, to provide information on variation in discarding from different fishing operations. Incorporation of information on soak time would provide valuable additional data on the impact of overnight setting of nets on levels of discarding.

Baseline levels of discarding have been provided in this study. It is important to note that the study was conducted during the most severe drought in recorded history and that the ecological health of the Coorong was considered poor and at an historic low (Geddes 2003; Geddes 2005). Drought conditions, subsequent lack of freshwater input, and increases in salinity throughout the Murray Mouth and Coorong may have strongly influenced the composition of fish assemblages and severely limited distributions (Noell et al. 2009). Recruitment of mulloway may be enhanced when freshwater inflows have occurred in the Murray River estuary and Coorong lagoons (Ferguson et al. 2008). Because freshwater inflows have not occurred since 2002, numbers of sub-legal sized mulloway were likely low during the observer based monitoring survey. Consequently, estimates of the level of discarding for this species may be underestimated.

Commercial exploitation of mulloway may be enhanced by mitigation of levels of discarding and by increased survival. Potential mitigation measures may include shorter soak times, attendance of nets, and reduced depth of nets.

5 APPENDIX

5.1 Planned outcomes

We achieved the planned outcomes by (i) quantifying the composition and quantities of discards taken in the commercial gill net fishery in the Coorong lagoons Levels, (ii) providing qualitative information on levels of use and character of discards in registered recreational nets, and used this information to develop an indicator for discarding from gill nets. We also provided maximal estimates of discard survival for key species and gear, and identified methods that may potentially reduce levels of discarding from gill nets.

It was originally intended that Objectives three and four be addressed using an experimental approach. However, poor environmental conditions in the Coorong lagoons during the study period may have compromised results from experiments. Discard survival (Objective 3) was to have been estimated discards that had been held in sea cages for five days. Instead discard survival was estimated from numbers alive at net retrieval during the observer based monitoring study. This provided maximal estimates of survival for key species taken in small and large mesh gill nets. The original approach to identify methods for mitigating levels of discarding (Objective 4) was to conduct experimental fishing. This objective was met using information available from the observer based monitoring program, from the peer reviewed literature and from several previous FRDC funded projects.

5.2 Benefits and adoption

This study has provided quantitative data on spatial and temporal variations in catch composition and levels of retained and discarded catches taken in gill nets in the commercial sector of the Lakes and Coorong Fishery. This study also provided qualitative information on use of registered recreational nets in the Coorong lagoons. Information on the short term survival of discarded fish was also provided.

This information has provided an indicator of levels of bycatch that will be incorporated into commercial catch and effort reporting. Data from this study, combined with ongoing collection of data on overall levels of discarding, will inform management decisions related to biodiversity issues under the EPBC Act. These data will also be available for consideration by the Marine Stewardship Council.

Adoption of a successful discard mitigation strategy within the LCF will require ongoing communication between fishers. An existing code of conduct for mitigating levels of discarding from gill nets has been evaluated and updated and may be included in an induction kit that is currently being developed by the Southern Fishermen's Association for new licence holders. There is considerable potential for more experienced fishers to provide new licence holders with "hands on" information on the methods that they use to reduce levels of discarding, in particular the methods used successfully with small mesh gill nets i.e. reduced soak times, reduced drop of nets and attendance of nets. There is also potential for fishers to pool information during periods when levels of discarding may be high i.e. during periods of freshwater inflow to the Coorong lagoons.

5.3 Further Development

Discard ratios presented in this report represent levels of discarding during the current drought conditions in the Murray River estuary and Coorong lagoons. Reporting of discard information in the South Australian Inland Waters Catch and Effort Returns will provide information that can be related to conditions in the Coorong lagoons. Reference points for discard ratios should be further developed by monitoring discard ratios over several years, including a range of environmental conditions, i.e. freshwater inflows, salinities.

Catch species composition, and length compositions of individual species will likely be affected should significant freshwater inflows into the Murray River estuary and Coorong lagoons resume. Observer based monitoring of catch species composition should be conducted at regular intervals i.e. each 5 years, to complement the overall estimates of levels of discarding from commercial catch and effort reporting.

5.4 Intellectual property

There are no intellectual property issues associated with this project.

5.5 Staff Involved

Greg Ferguson	SARDI Aquatic Sciences	Principal Investigator
Garry Hera-Singh	Southern Fishermen's Association	Co-investigator
Paul Jennings	SARDI Aquatic Sciences	Senior Technical Officer
Louise Smith	SeaNet	Extension Officer

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