Developing management frameworks and harvest strategies for small-scale, multi-species, multi-method, community-based fisheries, using the South Australian Lakes and Coorong Fishery as a case study

Ian Knuckey, Sevaly Sen, Tim M. Ward,
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Acknowledgments

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Executive Summary

The commercial Lakes and Coorong Fishery (LCF) operates at the end of the Murray-Darling Basin where the river system meets the Southern Ocean, encompassing a diverse range of freshwater, estuarine and marine habitats and communities. This multi-gear fishery targets a range of species including Pipi (Goolwa cockle - *Donax deltoides*), Mulloway (*Argyrosomus japonicus*), Yelloweye Mullet (*Aldrichetta forsteri*), Black Bream (*Acanthopagrus butcheri*), Greenback Flounder (*Rhombosolea tapirina*), Golden Perch (*Macquaria ambigua*), and Bony Bream (*Nematalosa erebi*) as well as the introduced fish species European Carp (*Cyprinus carpio*) and Redfin (*Perca fluviatilis*).

The Lakes and Coorong region is characterised by periodic flooding and extended periods of drought. Following European settlement, increasing levels of water have been extracted from the system for agricultural purposes. During the late 1930s, a network of barrages was established to stabilise water levels, prevent saltwater intrusion into the lower Lakes and further provide for irrigation and human consumption. The extensive barrage system and altered natural flow regime has changed the natural fluctuations of the Lower Lakes and Coorong, which has modified the productivity and function of the entire ecosystem and has had a negative impact on fish habitat. Only during the last decade has catchment management changed sufficiently to improve the level of environmental flows into the Lakes and Coorong region.

Against this backdrop of environmental change, management of the small community-based commercial fishery in the Lakes and Coorong region has developed and evolved over its century of operation. Operating under the current LCF Management Plan (Sloan, 2005) and through the pro-active work and Code of Practice of the Southern Fishermen's Association (SFA), the LCF is regarded as a sustainable fishery that received Marine Stewardship Council (MSC) accreditation for four key target species in July 2008. Since implementation of the Management Plan, however, there have been rapid developments and significant improvements in harvest strategies applied across most Australian Commonwealth and State fisheries including the recent release of the *National Guidelines to Develop Fishery Harvest Strategies*. This development exposed a number of operational shortfalls in the Management Plan which include: lack of a quantitative indicator and defined management responses to varying environmental river flows; no effective limit reference point in the LCF Management Plan that defines an unacceptable risk of commercial fishing; and no *formal* mechanism to control the level of exploitation should any limit reference point be approached. Further, industry had concerns that current regulations were excessive and could be simplified; licence transfer provisions were restrictive and could be made more flexible; and transfer rules for net entitlements were affecting business restructuring.

The LCF is undergoing re-assessment for its MSC accreditation, and the new fisheries management plan is due in 2015. This presented a good opportunity to review the underlying management framework of the LCF, and develop a finfish harvest strategy for key species that could address the issues mentioned above.

In association with the SFA as the representative body for commercial finfish fishers in the LCF, Primary Industries and Regions SA (PIRSA) and the South Australian

Research and Development Institute (SARDI), we developed options for a new harvest strategy framework and appropriate performance indicators for this small-scale, multi-species, multi-method community-based fishery. Based on these, an operational management mechanism was then developed to facilitate flexible and adaptive fishery structures that are more responsive to management drivers. This was done through thorough examination of historical catch and effort data, evaluation of environmental, biological and economic drivers, engagement with fishers to help decide appropriate management options, and evaluation of the performance of options for control measures in the harvest strategy.

Relevant literature, information on management arrangements and data were obtained and analysed to describe the attributes that could be used as the basis for an optimal management framework. Results were presented to key stakeholders to:

1) determine that the appropriate and correct data were being used in the analyses;
2) ensure that the project team had a good understanding of the basic dynamics of the fishery;
3) ensure that the project team was focusing on the key species and years involved in the fishery; and,
4) get feedback from the stakeholders that the approach adopted in the project was in line with their expectations.

Once this was completed, the project team met on a number of occasions to present, and obtain feedback on options for a new LCF management framework. The most appropriate management frameworks derived during the consultation phase were developed further. A harvest strategy was also developed that that included performance indicators (target, trigger and limit reference points) and decision rules to enable management actions to be taken when a target, trigger or limit reference point was reached.

Based on the data and feedback from stakeholder meetings, three clear habitat x gear “sectors” were identified that could be used to effectively control effort in the fishery — Freshwater large-mesh gillnet, Estuarine large-mesh gillnet and Estuarine small-mesh gillnet. These sectors accounted for 80–100% of the catch of main target species. Three different management framework options for allocating Total Allowable Commercial Effort (TACE) within these sectors were developed and described. These were 1) TACE based on fishing days, 2) TACE based on net units, and 3) TACE based on net-days. Of these, we consider that net-days is the most appropriate unit of effort to effectively control fishing mortality and maintain sustainability in this fishery, as it accounts for all gillnets that are deployed. Furthermore, a TACE based on net-days would maintain operational flexibility around the number of days a licence holder can fish and the number of nets that can be deployed on each fishing day. The harvest strategy considered potential primary performance indicators based on environmental conditions important to productivity of main species caught in each habitat x gear “sector”. These were:

1) Freshwater large-mesh gillnet – water level in Lakes Alexandrina and Albert;
2) Estuarine large-mesh gillnet – estimates of the available habitat for Mulloway in the Coorong based on hydrodynamic modelling (Webster, 2010) and information on the salinity tolerance of the species (Ye *et al*., 2013); and,

3) Estuarine small-mesh gillnet – estimates of the amount of available estuarine habitat for Yelloweye Mullet based on similar hydrodynamic modelling and salinity tolerance information.

Limit reference points for each of these indicators were proposed and we explored options for decision rules that were developed based historical relationships between habitat availability and fishing effort for each sector using the three units of effort.

The outputs of this project will be used to improve the performance of the LCF and will be directly incorporated into the development of harvest strategies developed for finfish species under the new fishery management plan due in 2015. The longer term outcome from this project is that the approach used to develop this management framework can be adapted to other similar fisheries around Australia. Using the capacity of the Australian Fisheries Management Forum, the development of fishery management frameworks and performance indicators will be provided to other jurisdictions to support fishery management improvement in other small-scale, multi-species, multi-method, community-based fisheries.

Keywords: Harvest Strategy, small-scale fisheries, Lakes and Coorong Fishery, data-poor fishery

Key Messages

Introduction

Located at the end of the Murray-Darling Basin where the river system meets the Southern Ocean (Figure 1), the Lakes and Coorong region encompasses a diverse range of freshwater, estuarine and marine habitats and communities. The region is recognised as one of the most significant wetland habitats in Australia, and as an important refuge for migratory waders and waterfowl, particularly during periods of drought.

Figure 1. Map of the study site depicting the lower Murray, Lakes and Coorong region, South Australia (from Sloan 2005).

The Lakes and Coorong region is characterised by periodic flooding and extended periods of drought (Crabb, 1997). Following European settlement, increasing levels of water have been extracted from the system for agricultural purposes. During the 1930s, a network of barrages was established to stabilise water levels, prevent saltwater intrusion into the lower Lakes and further provide for irrigation and human consumption (Murray-Darling Basin Authority, 2011). The extensive barrage system and altered natural flow regime have changed the natural fluctuations of the Lower Lakes and Coorong, which has modified the productivity and function of the entire ecosystem and had a negative impact on fish habitat. Only during the last decade has catchment management changed sufficiently to improve the level of environmental flows into the Lakes and Coorong region.

The resources and cultural values of the Lakes and Coorong region have been important to the Ngarrindjeri Aboriginal people for at least 45,000 years, and they still practice traditional fishing and food gathering in the region. Recreational fishing is also a popular pastime in the Lakes and Coorong region. Mulloway (*Argyrosomus japonicus*) and Yelloweye Mullet (*Aldrichetta forsteri*) are the main target species, but Pipis (also called Goolwa Cockles — *Donax deltoides*) are also caught and either used for bait or for personal consumption. Whilst recognising the importance of the Lakes and Coorong region to both indigenous and recreational fishers, this report only focuses on the finfish sector of the commercial Lakes and Coorong Fishery (LCF).

Commercial fishing has operated in the Lakes and Coorong region for well over a century. Given the diversity of habitats, a range of species is targeted, including the Pipi, Mulloway, Yelloweye Mullet, Black Bream (*Acanthopagrus butcheri*), Greenback Flounder (*Rhombosolea tapirina*), Golden Perch (Callop - *Macquaria ambigua*), and Bony Bream (*Nematalosa erebi*) as well as the introduced fish species European Carp (*Cyprinus carpio*) and Redfin (*Perca fluviatilis*). Fishing methods and gears were developed to specifically suit the diversity of habitats in the region and species being targeted. These include drum nets, gill nets, yabbie pots, swinger nets, cockle rakes / nets, longlines, dab nets, fish spears and haul nets. Apart from now using synthetic fishing nets and aluminium dinghies with outboards, many of the same fishing methods are still used today (see Olsen and Evans, 1991; Sloan, 2005).

Management of the LCF has developed and evolved over time. The current Management Plan (Sloan, 2005) reflects the key goal of the then *SA Fisheries Act 1982* "to ensure that an appropriate balance exists between the need to ensure long term sustainability of the marine, estuarine and freshwater fisheries resources of the Lakes and Coorong region, and the optimum utilisation and equitable distribution of these resources, for all stakeholder groups and future generations". To this end it has a "…complex mix of input and output controls aimed at matching harvesting capacity with resource availability and controlling growth in aggregate harvesting capacity. Existing controls include limitations on the number of licences, a wide range of gear restrictions, spatial and temporal closures, restrictions on the number of commercial agents permitted to assist fishing operations and legal size limits for individual species" (Sloan, 2005).

It was under this Management Plan and through the pro-active work and Code of Practice of the Southern Fishermen's Association (SFA) that, the LCF was successful in achieving Marine Stewardship Council (MSC) accreditation for four key target species during 2008.

Since the implementation of the current LCF Management Plan, however, there have been rapid developments and significant improvements in harvest strategies applied across most Australian Commonwealth and State fisheries. Thus, seven years after it was introduced, a number of operational shortfalls in the Management Plan have become apparent:

1. it lacks a quantitative indicator and defined management responses to varying environmental river flows;

2. there is no effective limit reference point in the LCF Management Plan that defines an unacceptable risk of commercial fishing; and,

3. there is no *formal* mechanism to control the level of exploitation should any limit reference point be approached.

Further, industry had concerns that:

4. regulations are limiting the activities of fishers and could be simplified;

5. licence transfer provisions are restrictive and could be made more flexible; and,

6. transfer rules for net entitlements are affecting business restructuring.

A new fisheries management plan for the LCF is due in 2015. This presented a good opportunity to review the underlying framework of management of the LCF, and develop a finfish harvest strategy for key species that could address the issues mentioned above. The current project was designed to support this process.

Objectives

1 Identify the attributes required in an environmentally limited fishery that can be used to determine optimal management frameworks.

2 Develop a framework that supports more flexible and adaptive management processes to provide for business adaptability and structural adjustment in the Fishery while limiting effort to an appropriate sustainable level.

3 Develop a set of performance indicators that can be used to support management of an environmentally diverse suite of species in a highly variable ecosystem.

4 Create a management framework that can be adapted for use across a range of small-scale, multi-species, multi-method community-based fisheries.

Methods

Objective 1:

Identify the attributes required in an environmentally limited fishery that can be used to determine optimal management frameworks.

A literature review was conducted to collate relevant information on the LCF ecosystems, environmental flows, habitats, fisheries management and research. Information on management frameworks and harvest strategies used in other data-poor or low-value fisheries was also obtained.

Catch and effort data was requested from SARDI under a confidentiality agreement. Raw data spanning from 1 July 1984 to 30 June 2013 was provided, and included the fields described in Table 1 for the fishing methods shown in Table 2. Apart from obvious errors we corrected, we assumed this data was accurately reported.

Table 1. Lakes and Coorong Fishery database fields provided by SARDI Information Services

Field	Description
LIC_NO	Licence number
YEAR	Calendar year of fishing event
MONTH	Month of fishing event
DAY_FISHED	Day of fishing event
DATE_FISHED	Date of fishing event
TARGET	Target species code
TARGET_NAME	Target species name
AREA	Management area number
GEAR	Fishing ear code
GEAR_DESCRIPTION	Name of fishing gear
MAN_DAYS	Number of people fishing during a fishing event
CATCH_SPECIES	Code of fish species caught
CATCH_SPECIES_NAME	Common name of fish species caught
TOTAL_CATCH	Whole weight of fish species caught (kg)
EFFORT	Number of effort units used (see Table 2 for units used for each gear type)

Table 2. Fishing gear and measure of effort

CODE/GEAR		EFFORT
B	Dab net	number of hours fished
C	Drum net	number of net days
D	Electrofisher	number of hours fished
E	Mullet net (less than 7cm stretched mesh)	number of 50 metre net days
F	Gill net (7cm stretched mesh and above)	number of 50 metre net days
G	Handline	number of hours fished
H	Hauling net (less than 7cm stretched mesh)	number of hours fished
I	Hauling net (7cm stretched mesh and above)	number of hours fished
J	Purse seine net	number of hours fished
K	Ring net	number of hours fished
L	Set line	number of hook days
M	Swinger net	number of hours fished
N	Yabbie pot	number of pot days
X	Other (please specify)	number of hours fished

To be consistent with stock assessments (Greg Ferguson, SARDI, pers. comm.), MAN_DAYS was the unit of effort used unless otherwise specified. MAN_DAYS is the number of people fishing during a fishing event, and that was summed to provide effort in what we have called “fisher-days”. Again for consistency, financial year was used instead of calendar year.

The fishery is divided into 17 different management areas (Figure 2), and these were assigned to one of the three identified habitats: Freshwater, Estuarine or Marine. Allocation of habitat was consistent with Ferguson *et al.* (2013), and is described in Table 3. Data from the River Fishery (Areas 1-3) and Lake George (Area 17 in Table 3) were omitted from analyses. Catch and effort data were analysed and summarised by gear, region, habitat and season to build a picture of the dynamics of the fishery over time.

Over the last ten years, economic indicators for the LCF have been analysed and reported by an independent contractor, Econsearch. Data from the latest report, (Econsearch, 2013) provided the historical Gross Value of Production (GVP) in the LCF.

A separate harvest strategy with new quota management arrangements has recently been implemented specifically for the Pipi fishery of the LCF. As such, records with any catch of Pipi or records using cockle rakes, or records where the target species was Pipi were excluded from the analyses because they were not relevant to this project. It is also worth noting that while “cockle net” is listed as a device for targeting Pipis (see Table 4), reference to this method was not present in the data.

The biological productivity of most major fish species and the economic productivity of the LCF will continue to be affected by variations in freshwater outflows and other environmental conditions. Therefore, this project considered the relationship between environmental conditions and productivity of individual target species, and the level of effort that can be expended in the fishery during different environmental conditions.

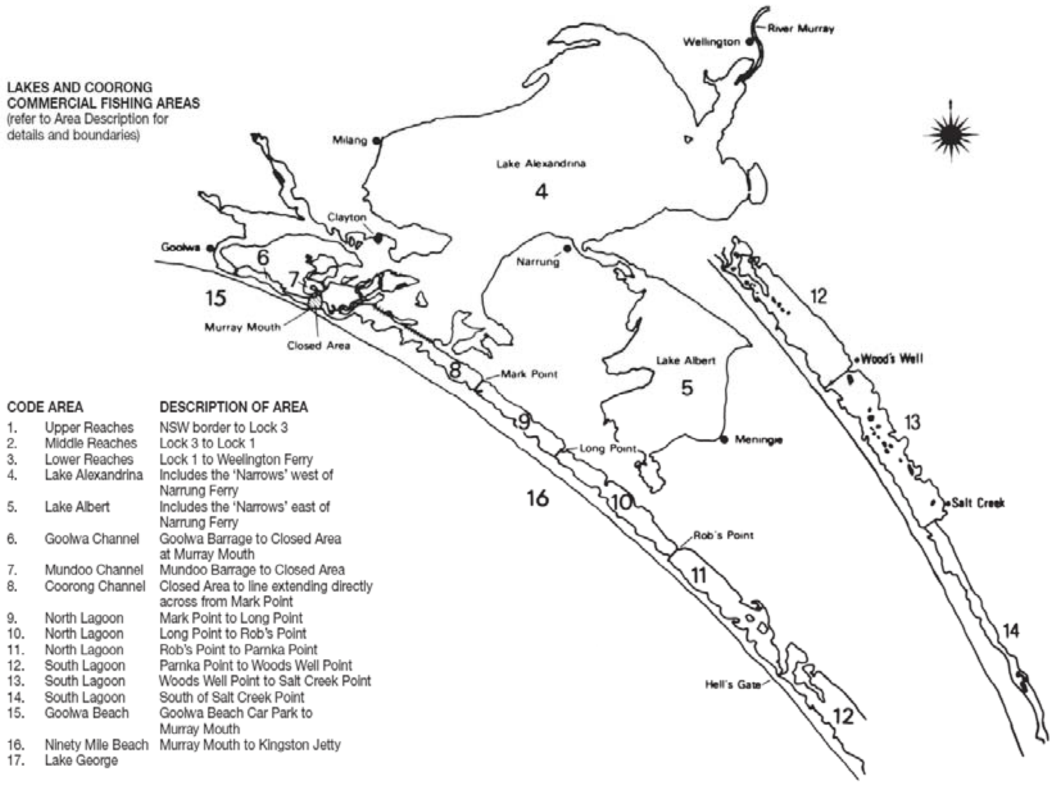


Figure 2. Map of the Lakes and Coorong commercial fishing areas (from daily catch and effort logbook, 2013).

Table 3. Classification of habitat for each management area shown in Figure 2. Note that Areas 1-3 are part of the River Fishery, not the Lakes and Coorong Fishery.

Code	Area	Habitat
1	Upper Reaches	Freshwater
2	Middle Reaches	Freshwater
3	Lower Reaches	Freshwater
4	Lake Alexandrina	Freshwater
5	Lake Albert	Freshwater
6	Goolwa Channel	Estuarine
7	Mundoo Channel	Estuarine
8	Coorong Channel	Estuarine
9	North Lagoon	Estuarine
10	North Lagoon	Estuarine
11	North Lagoon	Estuarine
12	South Lagoon	Estuarine
13	South Lagoon	Estuarine
14	South Lagoon	Estuarine
15	Goolwa Beach	Marine
16	Ninety Mile Beach	Marine
17	Lake George	Omitted

Table 4. Commercial fishing methods (from Sloan, 2005)

Device	Main Target Species
Mesh nets	Mulloway, Golden Perch, European Carp, Black Bream, Yelloweye Mullet, Greenback Flounder and Australian Salmon
Swinger nets	Mulloway
Hauling nets	Mulloway, Black Bream, Yelloweye Mullet, Greenback Flounder and Australian Salmon
Bait net	Bait species collection
Drop/hoop nets	Crabs
Dab net	Garfish, other
Drum net	Golden Perch and Murray cod
Cockle rake	Goolwa cockle
Cockle net	Goolwa cockle
Crab rake	Crabs
Yabbie trap	Yabbies
Shrimp trap	Shrimp
Set line	Murray Cod, Mulloway
Razor fish tongs	Razor fish
Fish spear	Greenback Flounder
Electro-fishing gear	European Carp

Objective 2:

Develop a framework that supports more flexible and adaptive management processes to provide for business adaptability and structural adjustment in the fishery while limiting effort to the appropriate sustainable level.

The project team evaluated the environmental, biological and economic drivers of the fishery based on information gathered for Objective 1. Once analysed, summaries of this information were presented to researchers, managers and industry representatives through a range of meetings. The initial purpose of these meetings was to: 1) determine that the appropriate and correct data were being used in the analyses; 2) ensure that the project team had a good understanding of the basic dynamics of the fishery; 3) ensure that the project team was focusing on the key species and gears involved in the fishery; and, 4) get feedback from the stakeholders that the approach adopted in the project was in line with their expectations. Once this was done, the project team used further meetings to present, and obtain feedback on options for an LCF management framework. In considering the pros and cons of each of the options, responses were gauged against the following criteria:

- Do they meet the biological / ecological / economic requirements?
- Are they suitable / practical for the fishery?
- Do they enable autonomous adjustment?
- Do they meet management requirements?
  - Are they able to control effort?
  - Can they be implemented under regulations/legislation?

Based on our understanding of the issues and feedback from these meetings, some of the options were deemed unsuitable and not progressed any further. The options that had most potential were further refined and developed.

Objective 3:

Develop a set of performance indicators that can be used to support management of an environmentally diverse suite of species in a highly variable ecosystem.

Based on the results of the Objectives 1 and 2, the most appropriate management framework options for the LCF were developed. Using these frameworks, the project team then investigated which performance indicators would be most suitable to underpin a robust harvest strategy for the fishery. The choice of performance indicators was considered at two levels: 1) at the individual species level; and, 2) at the habitat level, particularly with respect to freshwater flows and salinity.

The project team collated biological and environmental information available for monitoring the performance of the fishery. This included:

- fishery catch and effort data;
- information on life history characteristics for key species, including of information on demographic processes that influence their abundance in habitats exploited by the fishery;

- data on the key environmental factors that contribute to spatial and temporal variation in fishery production, including freshwater discharge from the Murray River, salinity, and water level; and,
- hydrodynamic model (Webster, 2010) output data for the estuary to monitor environmentally driven changes in the amount of habitat available for finfish.

A summary of this information, as well as information on the relationships between fishery catch and effort data, and available biological and environmental information, was presented to researchers, managers and industry representatives through a series of meetings. The purpose of these meetings was to get input and feedback from each stakeholder, and collectively determine the most appropriate performance indicators for the fishery. Based on these discussions, an assessment framework comprising a suite of primary (environmental) and secondary (biological) indicators was developed.

For each performance indicator, target, trigger and limit reference points were developed to identify when the fishery reaches a situation which requires changes to management arrangements. These were determined based on annual performance indicator values for the period from 1984/85 to 2012/13. Details of how these were determined are described in the results / discussion section of the report.

For each performance indicator, a set of decision rules were also developed to set out management actions to be taken when a target, trigger and limit reference point is reached. Decision rules were established to align with the preferred management framework options outlined under Objective 2. For each performance indicator, decision rules were developed based on the relationship between annual indicator values, the proposed reference points and estimates of annual fishing effort. Examples of potential decision rules were developed for three types of effort units for which historical data were available.

Objective 4:

Create a management framework that can be adapted for use across a range of small-scale, multi-species, multi-method community-based fisheries.

Identification of key sets of performance indicators and a framework for identifying the most effective management unit for any fishery can be based on the processes developed and adopted during this project. The process recognises the very specific components that comprise the key habitat areas of a fishery, given these may be quite different and driven by a variety of ecological factors. The key components of a fishery and the management framework should focus on ecosystems, ecological processes that drive productivity and the diversity of fishing gear that may be employed within a small-scale diversified fishery.

The outputs from objective two and three will be used to consult with the LCF to develop an appropriate management framework and harvest strategy for implementation in to the new management plan. The framework will be based upon the guidelines developed through the FRDC Project – National Guidelines to Develop Fishery Harvest Strategies (Project: 2010/061; Sloan *et. al.,* 2014).

Using the capacity of the Australian Fisheries Management Forum, the development of fishery management frameworks and performance indicators will be provided to other jurisdictions to support fishery management improvement in other small-scale, multi-species, multi-method community-based fisheries.

Results and Discussion

Lakes and Coorong Region

Habitats and water flows

The Murray-Darling Basin encompasses an area of about 1,060,000 km^2 extending into Queensland, New South Wales, Victoria, South Australia and the Australian Capital Territory. The catchment is characterised by periodic flooding and extended periods of drought (Crabb, 1997). The Lower Murray Lakes and Coorong region is situated at the tail end of the Murray-Darling Basin in South Australia, where the river system meets the Southern Ocean (Figure 1). This region is comprised of six broad ecosystem components: the River Murray Mouth; the Lower Lakes (Lake Albert and Lake Alexandrina); the Coorong lagoons; the River channel; the wetlands; and, the floodplain. Of these, only the first three support the LCF and represent the original estuary of the Murray River.

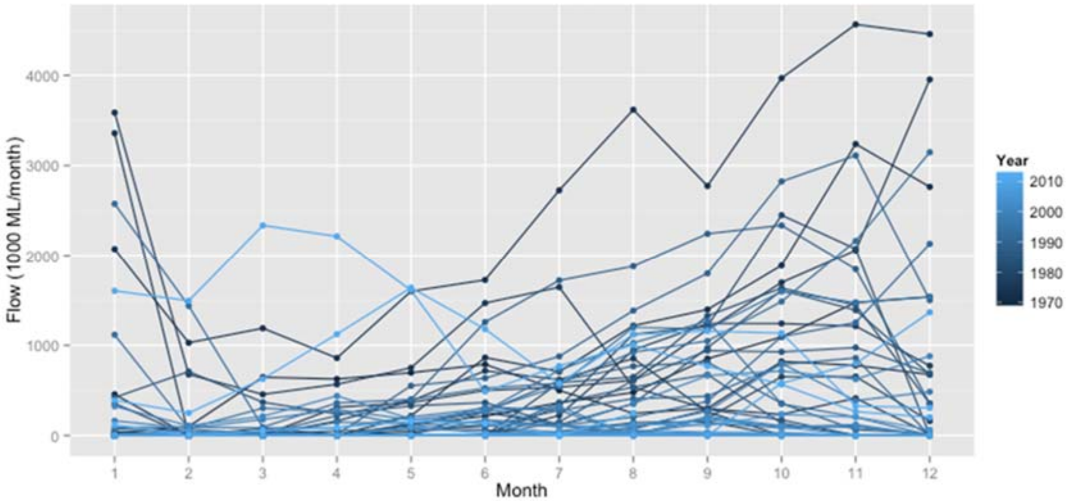
European settlement saw a dramatic change in land and water use throughout the region. Although there are different opinions, weight of evidence suggests that historically, the Lakes were mainly fresh, with short periods where some flows from the sea entered the Lakes (Murray-Darling Basin Authority, 2011). During the mid-1800s, vast tracts of land were sold for sheep and cattle grazing, and during the 1900s there was a focus on water extraction for agricultural purposes and controlling water flows through a network of five barrages (Goolwa, Boundary Creek, Mundoo, Ewe Island and Tauwitcherie). These barrages were constructed across each of the five channels to stabilise water levels, prevent saltwater intrusion into the Lower Lakes and provide for irrigation and human consumption (Murray-Darling Basin Authority, 2011). The combination of extensive water extraction and the network of barrages changed the morphology of the Murray Mouth and restricted the connectivity of the estuary to the Lower Lakes. Importantly, this has fundamentally changed the natural water flow regime of the region, changed salinity levels and reduced water quality in the Coorong estuary.

There has been a significant amount of work recently undertaken to determine the minimum water flow requirements to support a healthy ecosystem in both the freshwater and estuarine habitats of the Lakes and Coorong region (e.g. Heneker, 2010; Fairweather and Lester, 2010; Lester *et al.,* 2011). Lester *et al*., (2011) determined the minimum environmental water requirement to prevent a degraded ecosystem in the Coorong based on salinities in South Lagoon. They found that there should be no years of zero barrage flows, at least 2,500 GL flow is required over a two-year period, high flows of 6,000 GL/year were required every three years, and 10,000 GL/year every seven years.

The level of freshwater flows from the Murray River plays a critical role in maintaining freshwater and estuarine habitats and fish communities (Pierce and Doonan, 1999).

Accompanying changes in salinity levels and water quality in the Coorong estuary can disrupt the natural reproductive cycles and movement patterns of many fish species (for example see Ferguson *et al.,* 2013). Whilst there is a general seasonal cycle of low flows in autumn and winter, and high flows during spring and early summer (Figure 3), these can be overridden by larger cycles of flood — where high flows may occur throughout the year (e.g. mid-1970s, 2011–2013), and drought where there may be virtually no flow for many years (e.g. 2000s) (Figure 4, Figure 5).

The life cycles of many native freshwater, estuarine and marine fish species have adapted to synchronise with environmental conditions such as water temperature, water levels, salinity levels, food availability, lunar phase, photoperiod, and water flow rates (King, 1995). Ferguson *et al*. (2013) found that over a 25 year period, under variable freshwater inflows accompanied by high fishing pressure, species richness and diversity declined, and there was a truncated population age structure for some long-lived species.



Summer | Autumn | Winter | Spring |

Figure 3. Monthly (seasonal) river flows for each year (Data sourced from MSM BIGMOD Murray hydrological model, Murray-Darling Basin Authority (1969–2014)).

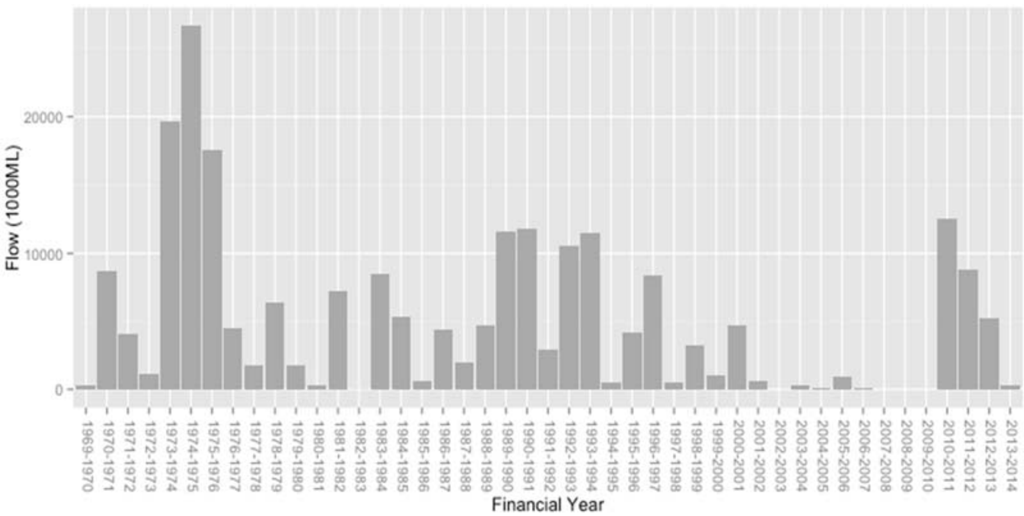


Figure 4. Total annual river flow (Data sourced from MSM BIGMOD Murray hydrological model, Murray-Darling Basin Authority (1969–2014)).

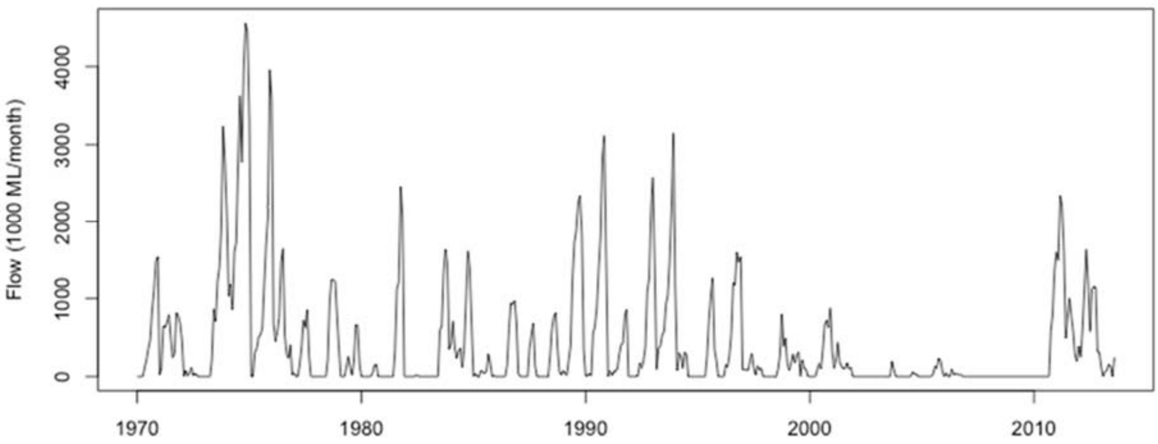


Figure 5. Monthly river flow (Data sourced from MSM BIGMOD Murray hydrological model, Murray-Darling Basin Authority (1969–2014))

Indigenous fishing

The estuarine and marine resources of the Lakes and Coorong region have been important to the Ngarrindjeri Aboriginal people for at least 45,000 years. Various nets, spears and traps were used to capture fish and Pipis that were prominent in the diet of Ngarrindjeri communities throughout the region. Although these communities were significantly reduced through European settlement, Ngarrindjeri people still practice traditional fishing and food gathering in the Lakes and Coorong region. This fishing is undertaken under the same management measures applied to the recreational sector, although current South Australian fisheries management Plans are being reviewed to recognise traditional or customary fishing as a separate type of fishing.

Recreational fishing

Recreational fishing is also a popular pastime in the Lakes and Coorong region. Mulloway and Yelloweye Mullet are the main target species, but Pipis are also caught and either used for bait or personal consumption. Recreational fishing is managed through a combination of input and output controls, to keep the catch within sustainable limits and to ensure equitable access to the fishery between recreational participants. Recreational fishers are able to use fishing rods, handlines and a variety of drop nets, hand nets, hoop nets, mesh nets, shrimp traps and yabby pots, but there are limitations on the type and amount of fishing gear that may be used, spatial and temporal closures, legal size limits for individual species and bag and boat limits for individual species.

Commercial fishing

Some level of commercial fishing has been operating in the Lakes and Coorong region for over 150 years, and its history is well summarised by Sloan (2005). The number of commercial fishermen operating in the region over the last century has ranged between 15 and over 100; there are now 32 licence holders. The main fish species taken from the region during this period were Mulloway, Black Bream, Yelloweye Mullet, Australian Salmon (*Arripis truttaceus*) and Australian Herring (*Arripis georgianus*), with total catches of over 1000 t recorded during the 1930s. Fishing methods and gears were developed over time to specifically suit the diversity of habitats in the region and species being targeted (Table 4). Apart from the change to using aluminium dinghies with outboards and the use of synthetic fibres in fishing nets, many of the same fishing methods are still used today (see Olsen and Evans, 1991; Sloan, 2005).

Whilst recognising the importance of the Lakes and Coorong region to both traditional and recreational fishers, this report focuses on developing management arrangements and harvest strategies for the finfish component of the commercial fishery only.

LCF Catch effort data

Fishery overview

Total annual effort decreased from a peak of about 13,000 fisher-days during the mid-1990s to around 6,300 fisher-days during the early 2010 (Figure 6), but the relative effort using different gear types has remained reasonably stable over time. Large and small mesh gillnets have been the mainstay of the fishery over the years, although during recent years there has been increased effort using ring nets in the Coorong and swinger nets within the marine area (Figure 6). Across all years, most of the catch (87% by weight) was taken with large mesh gillnets (Figure 7a). Small mesh gillnets and swinger nets caught about 11% and 1% of the total catch respectively, while all remaining gear types accounted for only about 1% of the total catch (remembering that cockle rakes were omitted from analyses). A range of other gear types were used, but these generally comprised less than 3% of total fishing effort (Figure 7b).

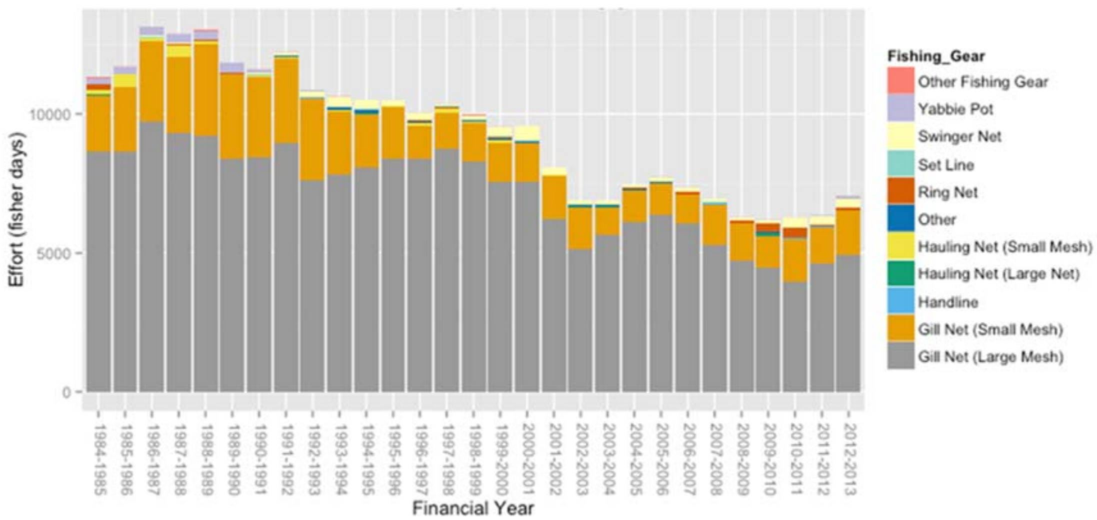


Figure 6. Annual fishing effort (fisher-days) of 10 most frequently used fishing gears from 1984/85 to 2012/13 (Note: effort targeting Pipis, effort using cockle rake and area 17 excluded).

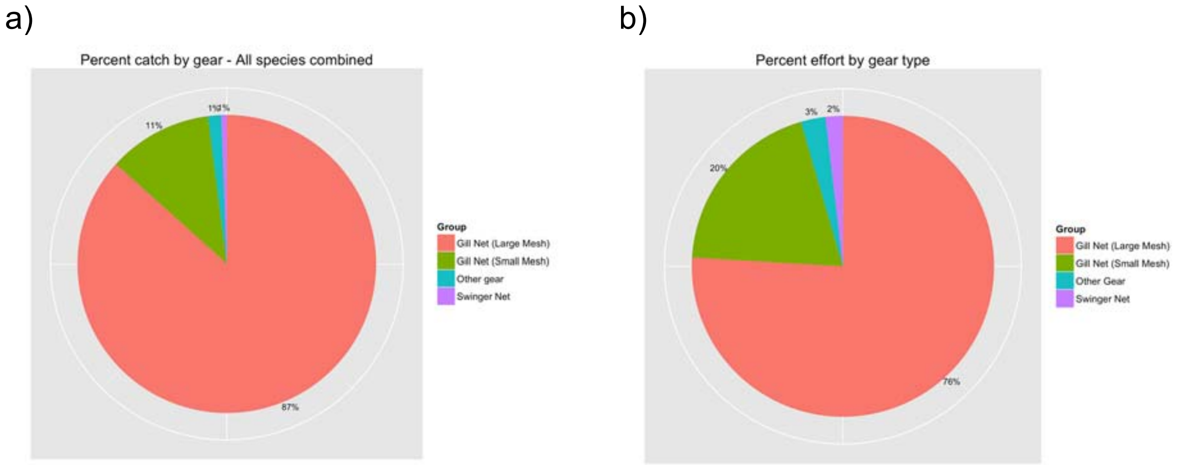


Figure 7. Percentage of a) catch taken by each main gear type since 1984 and b) effort (fisher-days) worked by each main gear type since 1984 (Note: effort targeting Pipis, effort using cockle rake and area 17 excluded).

Key Message 1. Large and small gillnets account for 98% of the LCF catch. An effective control of gillnets will manage effort in the fishery in the short to medium term.

Over all years, Bony Bream has comprised 39% of the weight of the catch (Figure 8) but only 10% of GVP (Figure 9), and European Carp comprised 35% of the weight and 30% of GVP. These are low value species usually sold as bait for the lobster and recreational fisheries. Yelloweye Mullet and Golden Perch (recorded as Callop in the catch and effort database) have comprised 12% and 5% of the weight of the catch respectively (and 20% and 46% of GVP respectively).

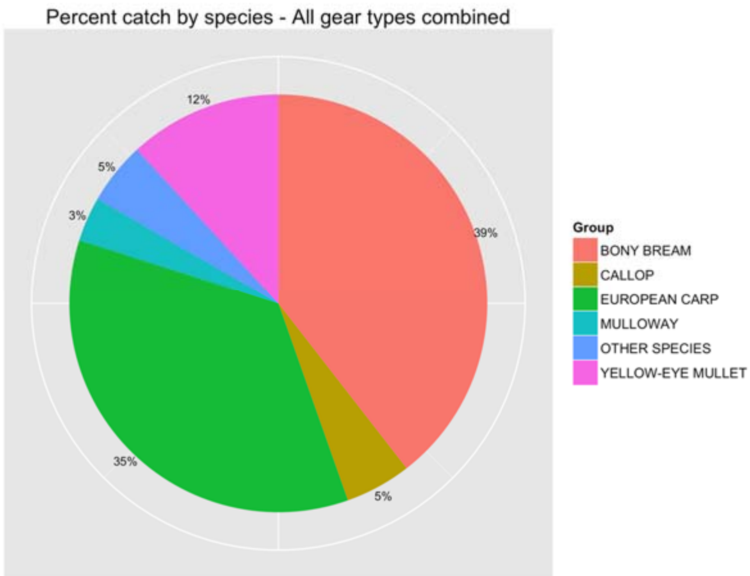


Figure 8. Overall species catch composition pooled across gear since 1984 (Note: catch and targeting of Pipis, catch using cockle rake and area 17 excluded). Golden Perch is recorded in the catch and effort database as Callop.

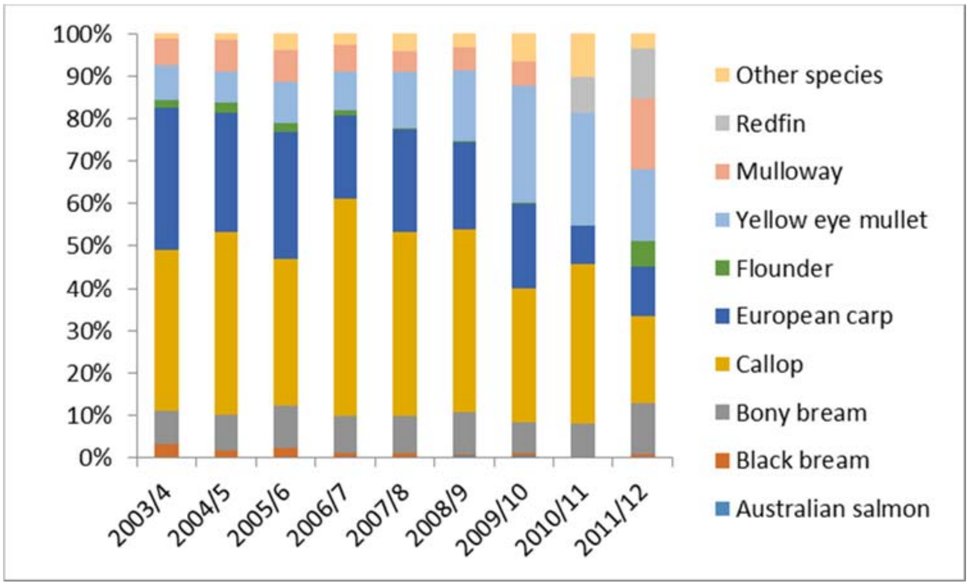


Figure 9. Annual GVP of main species in the fishery since 2003/04 excluding pipis. Golden Perch is recorded in the catch and effort database as Callop.

Total annual catch has fluctuated greatly over time, reaching a peak of nearly 2,500 t in 1991/92, and a low of about 850 t in 2001/02 (Figure 10). The relative catch composition has changed from year to year and over time, with the main differences being the increased relative catch of European Carp and decreased relative catch of Bony Bream during the 2000s drought period (Figure 11). The larger relative catches of Mulloway and Greenback Flounder, both prior and subsequent to the most recent drought, is also apparent. Interestingly, catch composition and tonnage in recent years is remarkably similar to that of the late 1990s and mid-1980s (Figure 10).

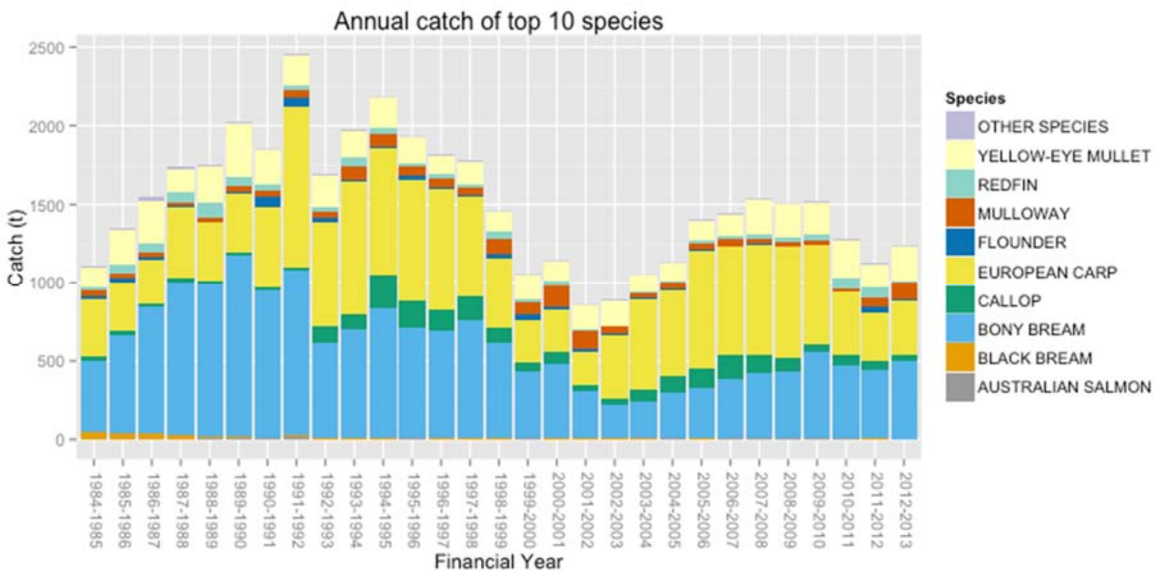


Figure 10. Annual catch (t) of the 10 most commonly caught species pooled across gear from 1984/85 to 2012/13 (Note: catch of Pipis, catch using cockle rake and area 17 excluded). Golden Perch is recorded in the catch and effort database as Callop.

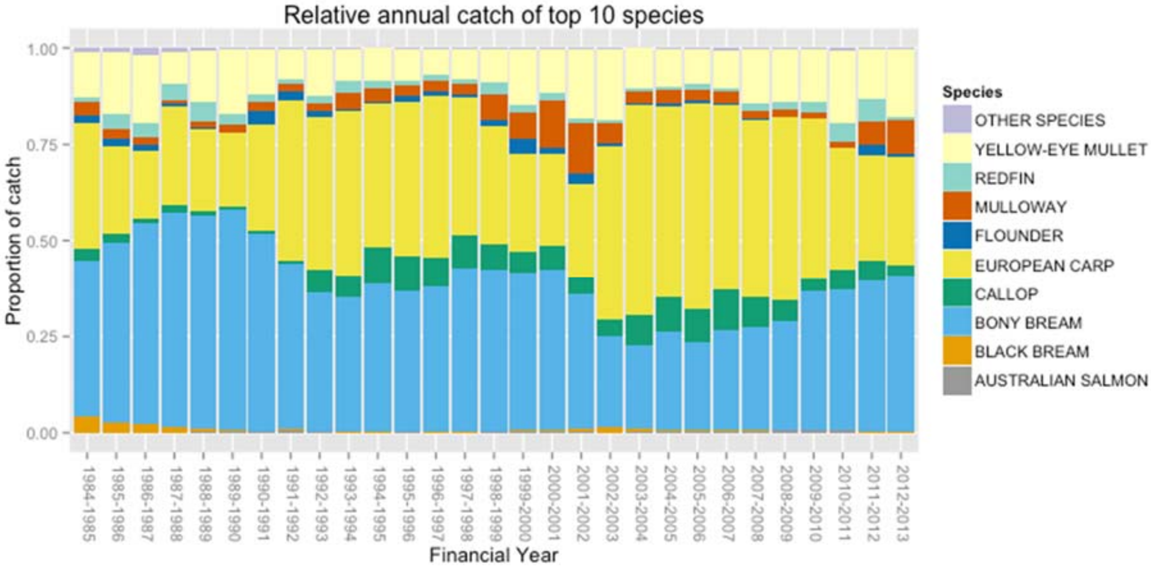


Figure 11. Relative annual catch of the 10 most commonly caught species pooled across gear from 1984/85 to 2012/13 (Note: catch of Pipis, catch using cockle rake and area 17 excluded). Golden Perch is recorded in the catch and effort database as Callop.

Key Message 2. Generally, the same range of species is caught in the LCF but the amount and composition of the catch changes with river flow, and particularly in flood and drought conditions. The flexibility to target this range of species is important to industry.

Most licencees fished in each month throughout the year even when overall annual effort decreased, and total fishing effort was usually spread out relatively evenly throughout the year, with slightly less effort during winter (Figure 12). That being said, the average number of days worked per licence each year varied greatly, from those that worked only a few days each month, to those that worked virtually every day in the year (Figure 13). Importantly, even those licences that were only worked rarely, generally still work throughout the year.

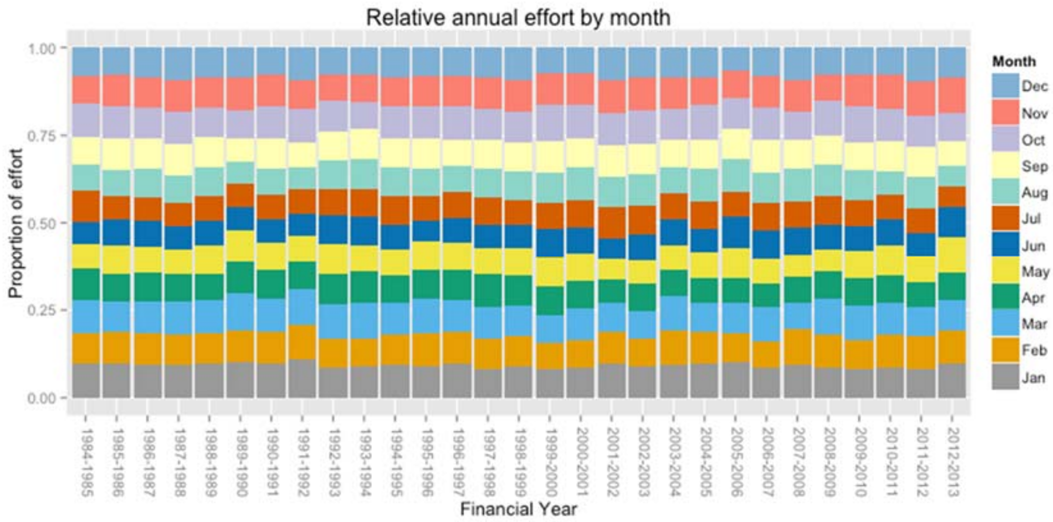


Figure 12. Total fishing days worked per year stacked by month since 1984 (Note: catch and targeting of Pipis, catch using cockle rake and area 17 excluded).

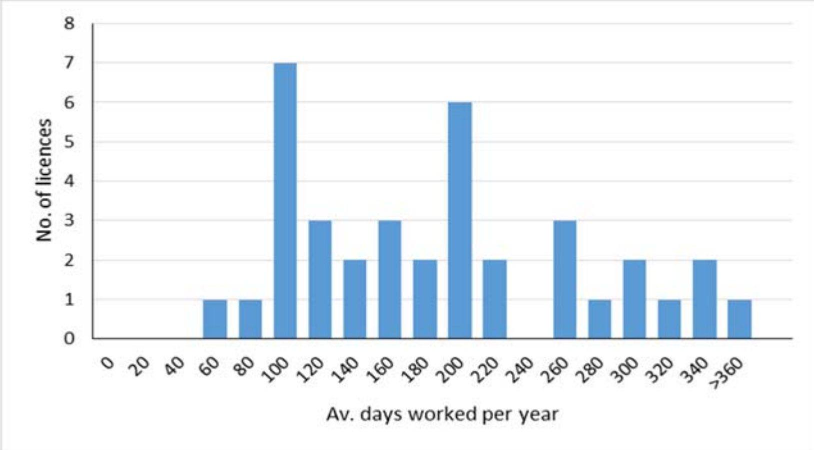


Figure 13. Frequency histogram of the average number of days worked per licence each year over the last 10 years.

Key Message 3. Regardless of periods of flood or drought or the annual level of effort, fishing effort occurs each month of the year. However the amount of effort / licence holder varies reflecting their social and economic choices. The flexibility to fish throughout the year is important to industry.

Analyses by habitat

Given the three very different habitats encompassed by the LCF and the different fish species that live within these habitats, catch and effort data was analysed using the categories of Freshwater, Estuarine and Marine habitats. Note that the salinity in the Estuarine habitat, particularly down the length of the Coorong can vary greatly from nearly freshwater, to marine, to hyper-saline depending on the level of water flow and the length of flood or drought conditions respectively.

Considering the breakdown of catch by habitat, there is an understandable association of main species with habitat type. In the Freshwater habitat, catches of European Carp and Bony Bream dominate with small catches of Golden Perch and Redfin (Figure 14a). Estuarine catches are dominated by Yelloweye Mullet, with lower catches of Mulloway and Greenback Flounder (Figure 14b). Notably, the catches of Mulloway and Greenback Flounder dropped off considerably in the drought years of the 2000s. In the earlier years, there were larger catches of Black Bream and some European Carp in the Estuarine habitat. Yelloweye Mullet were also a major part of the catch in Marine habitats, but only up until the mid-1990s (Figure 14c), and since the 1990s, Mulloway has become a major and consistent part of the Marine catch.

Total annual catch, effort and average annual CPUE for each habitat is shown in Figure 15. Only a small amount of effort (<10% of fisher-days) is reported from the Marine habitat each year, with the remaining (> 90%) of effort split relatively evenly between Freshwater and Estuarine habitats (Figure 15a). Similarly, a relatively low level of catch is taken from the Marine habitat, but a far larger proportion of the catch is taken in Freshwater habitat compared to the Estuarine habitat (Figure 15b). Effort reported in the latter two environments has fluctuated over time. For example during 1996/97, about 70% of the total effort was recorded from the Freshwater habitat, while during 2001/02, nearly 60% of the total effort was reported from the Estuarine habitat (Figure 15a). Although there is less effort during the winter months, relative distribution of fishing effort across habitats is consistent throughout the year, however there is less effort in Marine habitat during January to March, and slightly more effort in the Estuarine habitat during summer (Figure 18).

Analysis by habitat and gear

Figures showing patterns in fishing effort over time in the different habitats are shown for large mesh gillnet (net units), small mesh gillnet (net units) and swinger nets (hours fished) in Figure 16. The average monthly patterns in the different habitats are shown in Figure 17 and the total effort in fisher days by habitat is shown in Figure 18.

Annual catches have fluctuated since 1984, and peaked during 1989/90 at nearly 1,200 t before falling to about 200 t in 2002/03 (Figure 19a). Catches have risen since then to about 450 t per year since 2007/08.

Key Message 4. A management framework that includes habitat type (Freshwater, Estuarine and Marine) and gillnet mesh size (Large and Small) can effectively control effort directed at species or species groups

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Analysis by gear and species and habitat

LCF catch by each gear type is shown in Figure 21 and Figure 22. The main gear type used in the LCF — large mesh gillnet (Figure 21a) — has predominantly taken Bony Bream (45%), European Carp (40%) and Golden Perch (6%) from Freshwater habitats and Mulloway from Estuarine habitats. Small mesh gillnets (Figure 21b) take predominantly Yelloweye Mullet (96%), while swinger nets mostly take Mulloway from the Marine habitat (Figure 22a). An analysis of percentage of each main species caught within each sector of a habitat (Freshwater / Estuarine / Marine) x gillnet (Small / Large) management framework is summarised in Table 5.

Main gear types that catch each species are shown in Figure 23 and Figure 24. Apart from Mulloway (Figure 24d) that is taken by large mesh gillnets in Estuarine habitats and swinger nets in Marine habitats, each species is almost exclusively (90% or greater) caught by a single gear type.

Beginning with the freshwater species, Bony Bream (Figure 23a), European Carp (Figure 23b), Redfin (Figure 23c) and Golden Perch (Figure 23d) were all predominantly caught by large mesh gillnet. Bony Bream are almost exclusively caught using large mesh gillnet in Freshwater habitat (Figure 24b and Figure 14a), but a small amount is taken from the Estuarine habitat (Figure 14b). About 99% of European Carp was taken using large mesh gillnet (Figure 24d). Annual catches appear cyclic, fluctuating from about 250–300 t during the low catch years to 700–1,000 t during high catch years (Figure 19b). Low catch years were the mid to late 1980s, the early 2000s and the early 2010s. High catch years were the early to mid-1990s and mid to late-2000s. European Carp are taken predominantly in freshwater, while some is caught the Estuarine habitat (Figure 14).

Catches of Golden Perch were generally below 30 t per year from 1984/85 to 1991/92, after which catches peaks of just over 200 t during 1994/95 and 150 t during 2006/07, and lows of about 35 t during both 2001/02 and 2012/13 (Figure

19c). Nearly all of the catch has been taken from the Freshwater habitat, with a small about coming from the Estuarine habitat (Figure 14a, Figure 14b and Figure 19b).

Nearly all Redfin was landed using large mesh gillnets (Figure 23a), and they are almost exclusively caught in Freshwater habitats. (Figure 14a) Annual catches were greater than 50 t during 1995/96 to 1989/90, 1993/94 and 2010/11 to 2011/12, but in other years were generally less than 25 t (Figure 19d).

Key Message 5. The catch of Bony Bream, European Carp, Golden Perch and Redfin can be effectively controlled through effort restrictions of large mesh gillnet in the Freshwater habitat.

Yelloweye Mullet have been predominantly caught by small mesh gillnet (91%), while some is also taken by large mesh gillnet (4%), ring net (3%) and small mesh haul net (1%) (Figure 24a). Annual catch has been relatively consistent at 125–150 t per year apart from some higher catches during 1985/86 to 1992/93 and 2007/08 to 2012/13 (Figure 20a). Most of the catch has come from the Estuarine habitat, but small amounts are taken from the Freshwater habitat, and during 1985/86 to 1993/94 as much as 20% of the catch from any one year was taken from the Marine habitat (Figure 20a).

Key Message 6. The catch of Yelloweye Mullet can be effectively controlled through effort restrictions of small mesh gillnet in the Estuarine habitat.

About 81% of Mulloway were caught using large mesh gillnets, 15% using swinger nets and small amounts by small mesh gillnet, small mesh haul net and ring net (Figure 24d). Annual catches have generally ranged 25–50 t, with sporadic years of large catches (>50 t) recoded for 1993/94, 1994/95, 1998/99, 2000/01, 2001/02 and 2012/13 (Figure 20b). Up until 1990, Mulloway were almost exclusively caught in the Estuarine habitat, but since then, about 20% of the catch each year has been taken from the Marine habitat (Figure 20b) in swinger nets. Small amounts are also taken from Freshwater.

Large mesh gillnet accounted for 95% of the Greenback Flounder catch, while 3% was taken using small mesh haul nets (Figure 24c). Greenback Flounder catches have been highly variable, ranging from 0.1 t during 2010/11 to 65 t during 1990/91 (Figure 20c). Nearly all Greenback Flounder was taken from the Estuarine habitat, with small amounts caught in Freshwater and Marine habitats (Figure 20c).

Black Bream are predominantly caught by large mesh gillnet (90%), while 4% was taken using small mesh haul net (Figure 24b). Annual catches of Black Bream decreased from greater than 30 t during the mid-1980s to less than 5 t from 1990/91 onwards, with the exception of 2002/03 when the catch reached about 12 t (Figure 20d). Most of the catch came from the Estuarine habitat, but during 1987/88, more than 40% of the catch came from the Freshwater habitat (Figure 20d). Small amounts of catch were taken from Marine habitats, particularly during 2003/04.

Key Message 7. The catch of Mulloway, Greenback Flounder and Black Bream can be effectively controlled through effort restrictions of large mesh gillnet in the Estuarine habitat.

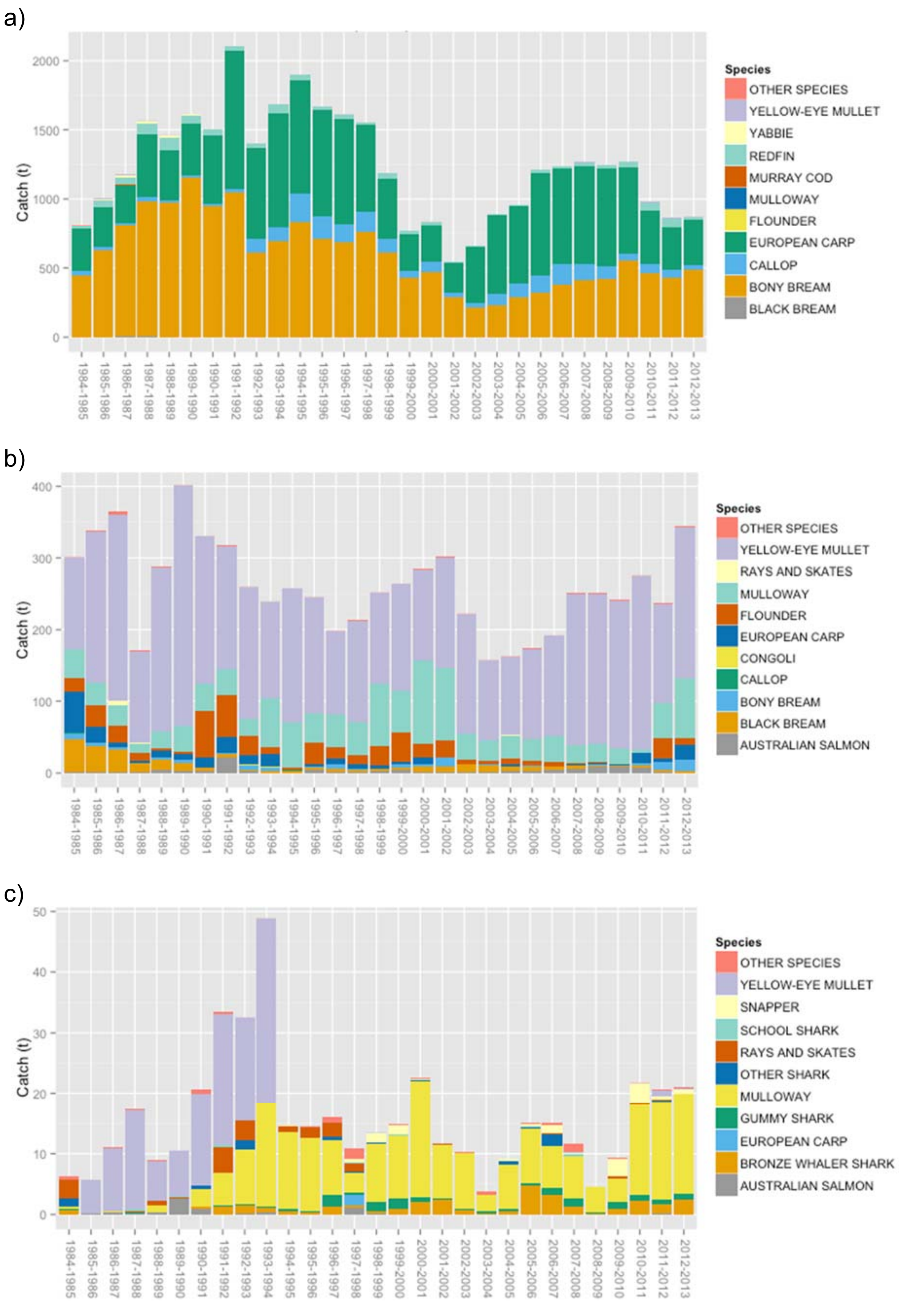

Figure 14. Annual catch of main species in a) Freshwater, b) Estuarine, and C) Marine habitats. (Note: catch and targeting of Pipis, catch using cockle rake and area 17 excluded).

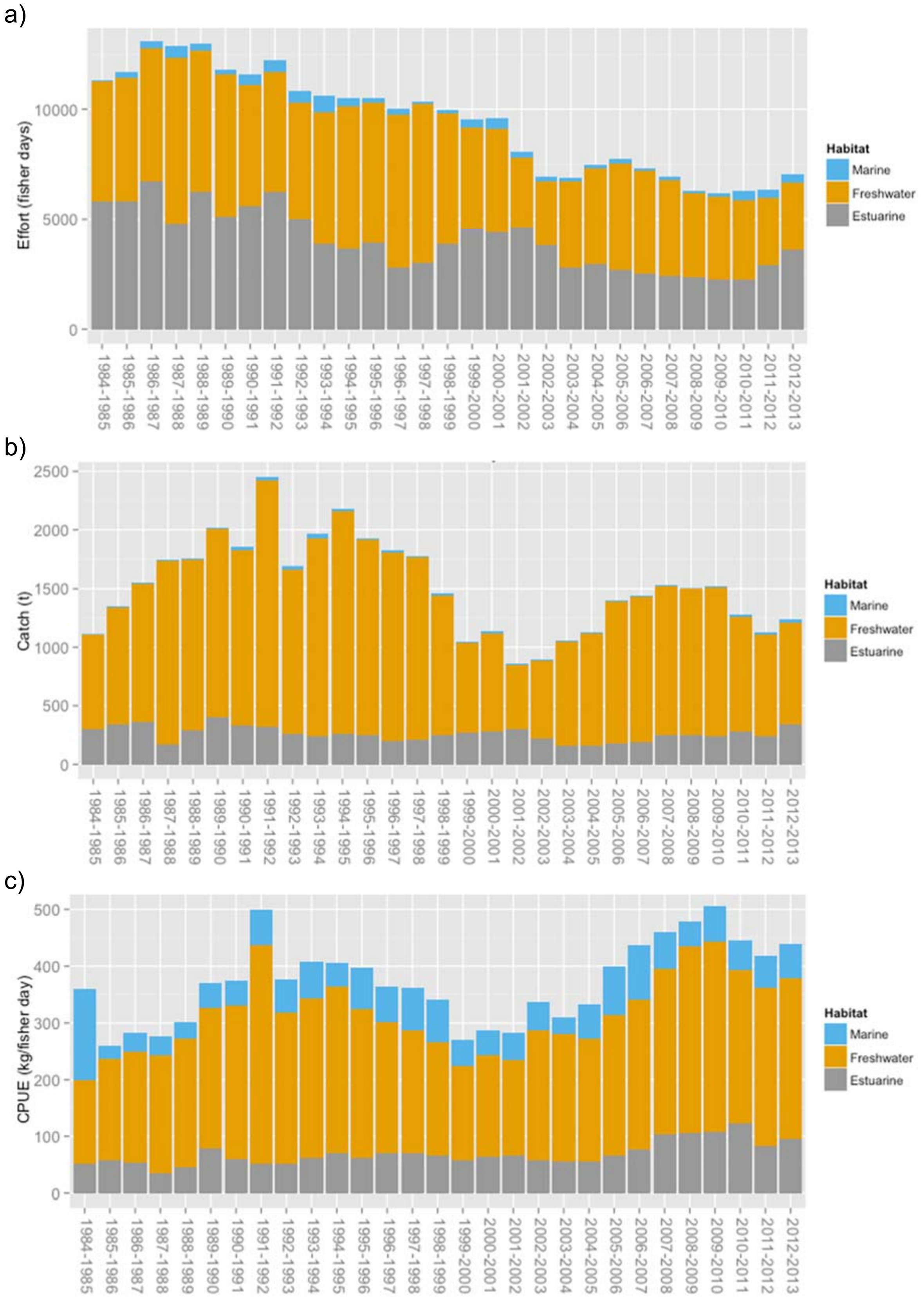

Figure 15. Total annual a) effort, b) catch and c) average annual CPUE by habitat. (Note: catch and targeting of Pipis, catch using cockle rake and area 17 excluded).

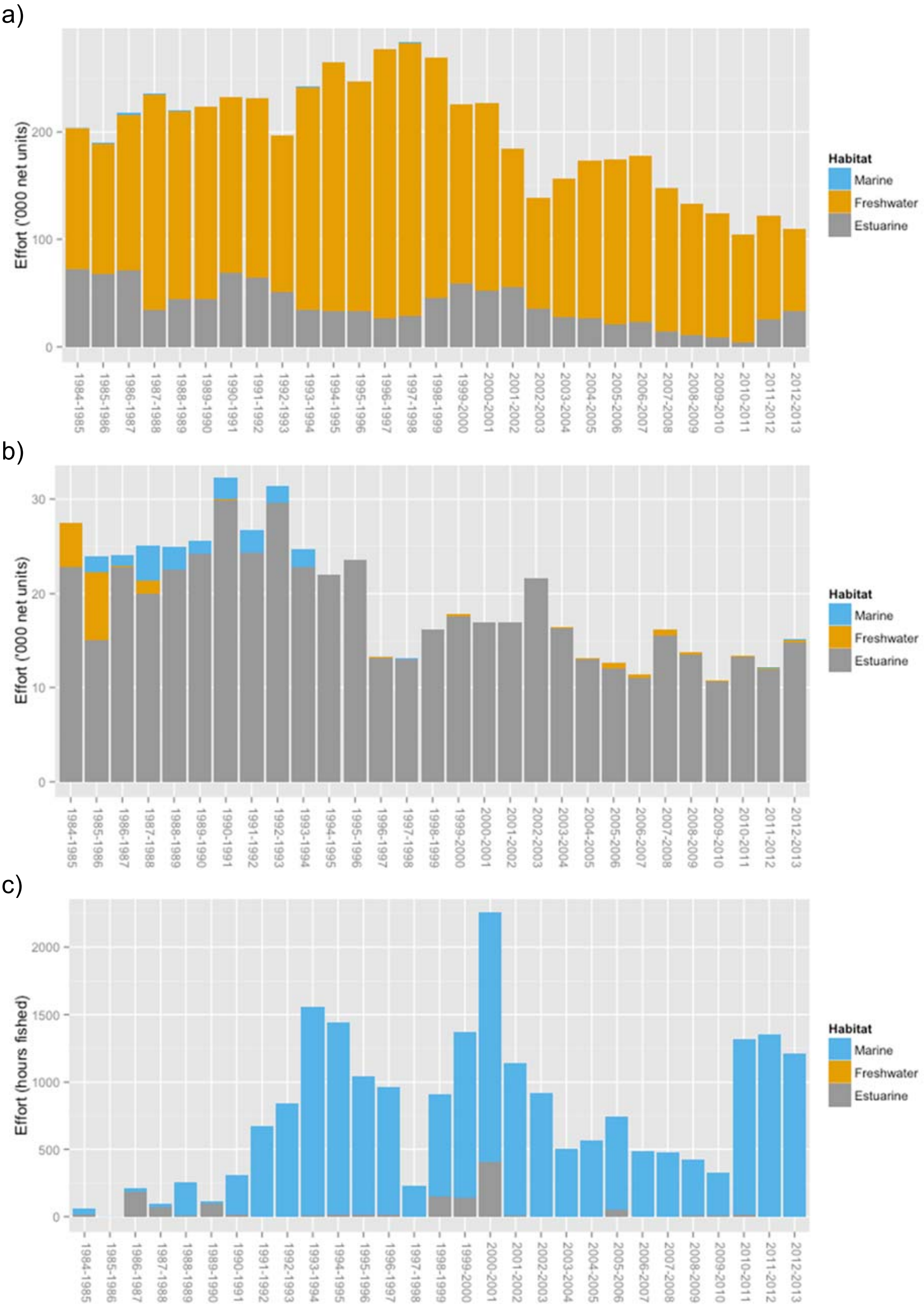

Figure 16. Annual effort by habitat since 1984 (net units) using a) large mesh gillnets, b) small mesh gillnets and c) swinger nets. (Note: catch and targeting of Pipis, catch using cockle rake and area 17 excluded).

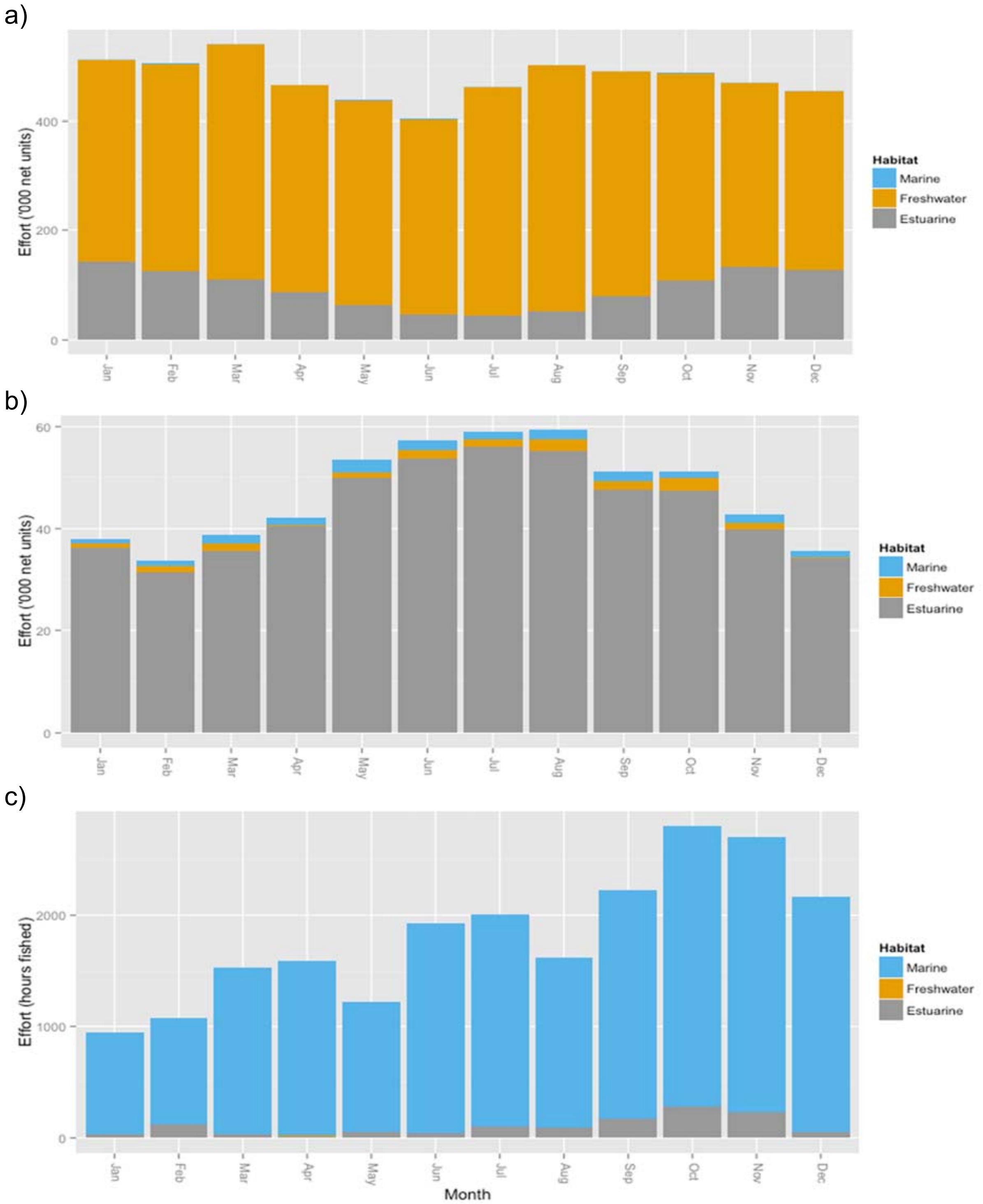

Figure 17. Total effort (net units) by month and habitat since 1984 using a) large mesh gillnets, b) small mesh gillnets and c) swinger nets. (Note: catch and targeting of Pipis, catch using cockle rake and area 17 excluded).

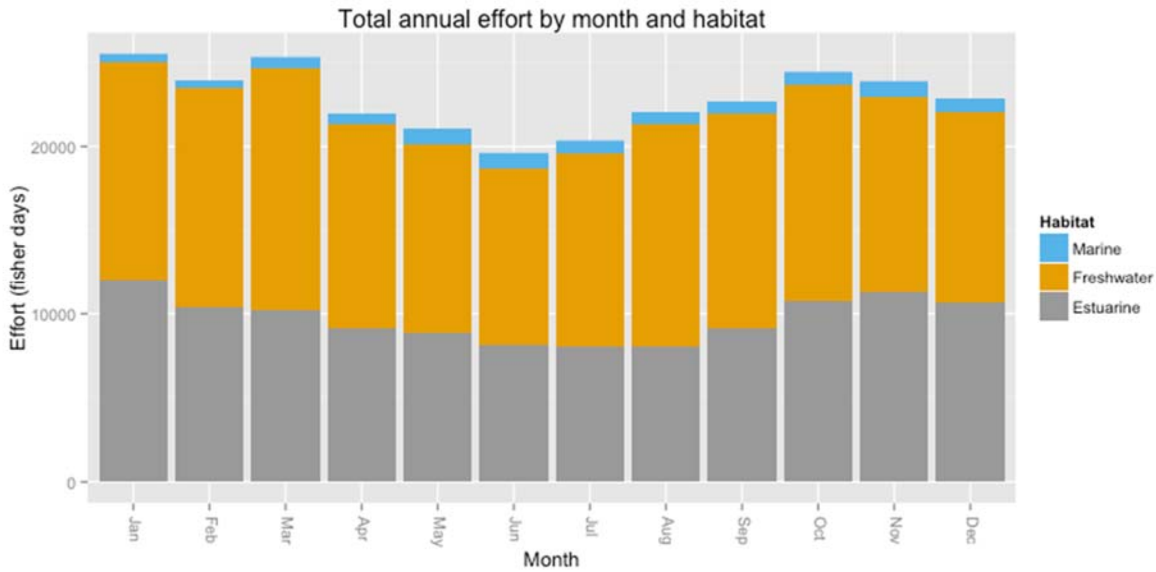

Figure 18. Total effort (fisher-days) per month stacked by habitat. since 1984 (Note: catch and targeting of Pipis, catch using cockle rake and area 17 excluded).

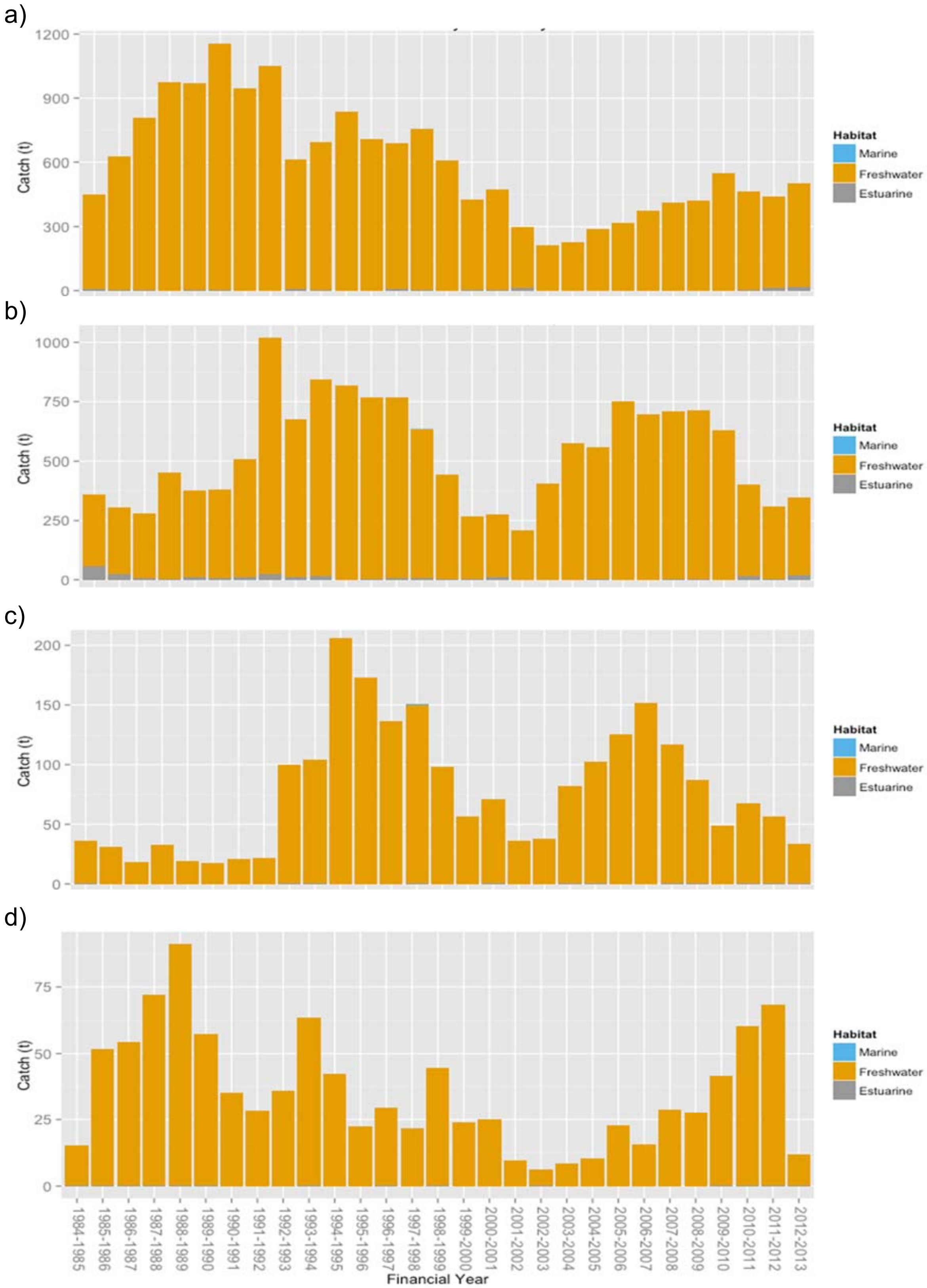

Figure 19. Total annual catch by habitat of a) Bony Bream, b) European Carp, c) Golden Perch and d) Redfin. (Note: catch and targeting of Pipis, catch using cockle rake and area 17 excluded).

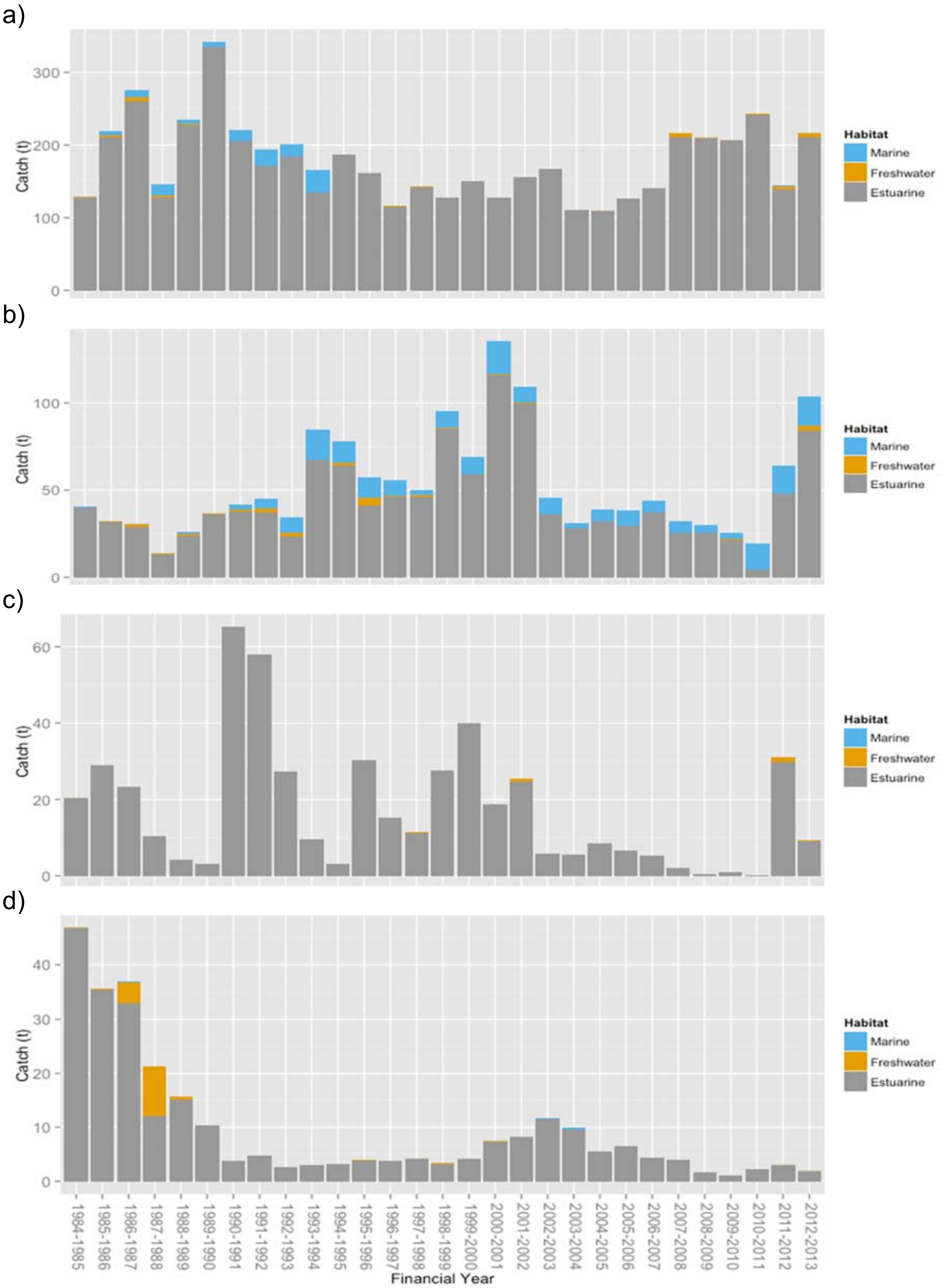

Figure 20. Total annual catch by habitat of a) Yelloweye Mullet, b) Mulloway, c) Greenback Flounder, and d) Black Bream.

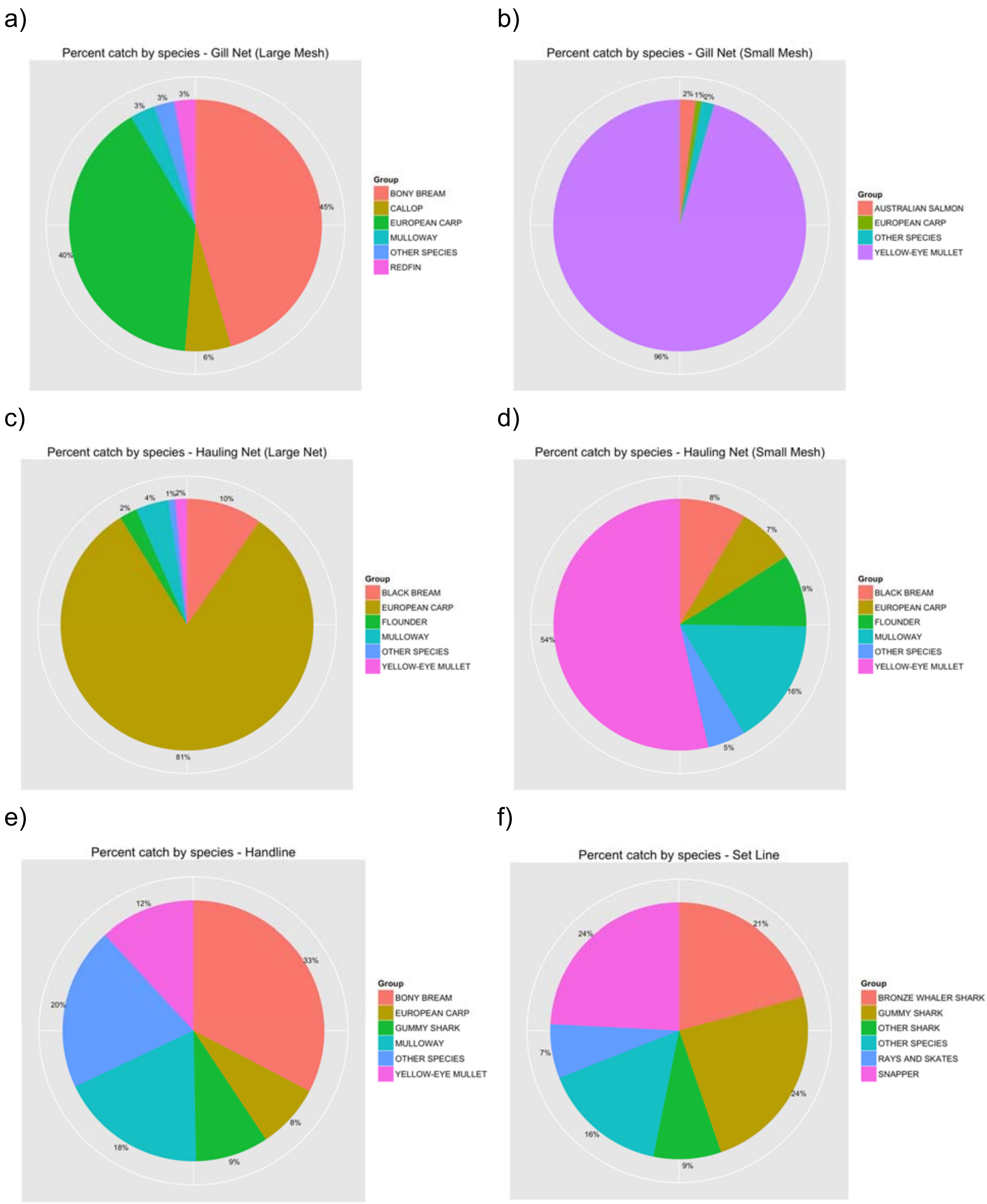

Figure 21. Percentage composition of catch caught by a) large mesh gillnets, b) small mesh gillnets, c) large haul nets, d) small haul nets, e) handline and f) set lines since 1984 (Note: catch and targeting of Pipis, catch using cockle rake and area 17 excluded).

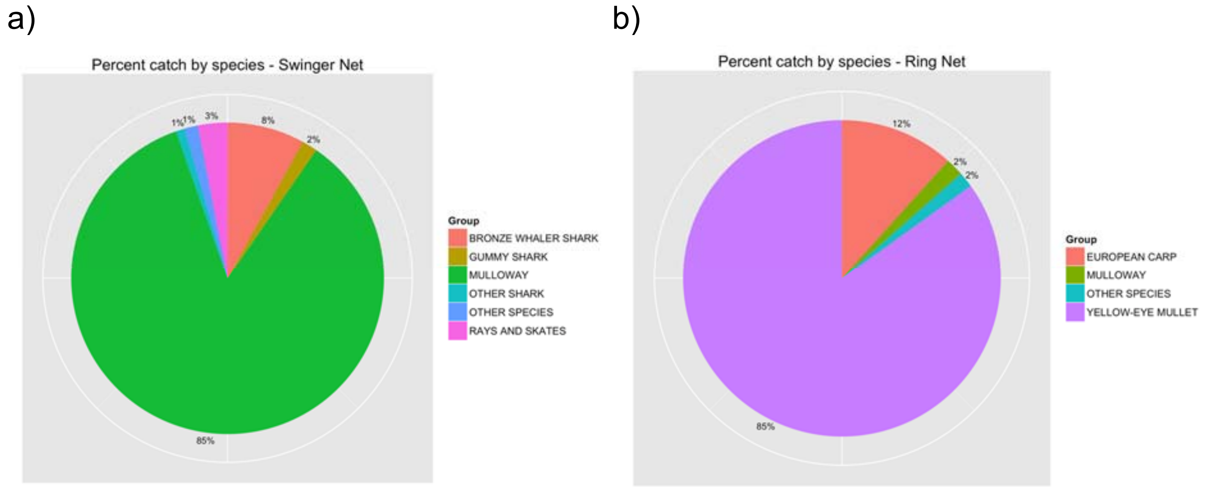

Figure 22. Percentage composition of catch caught by a) swinger net and b) ring net since 1984.

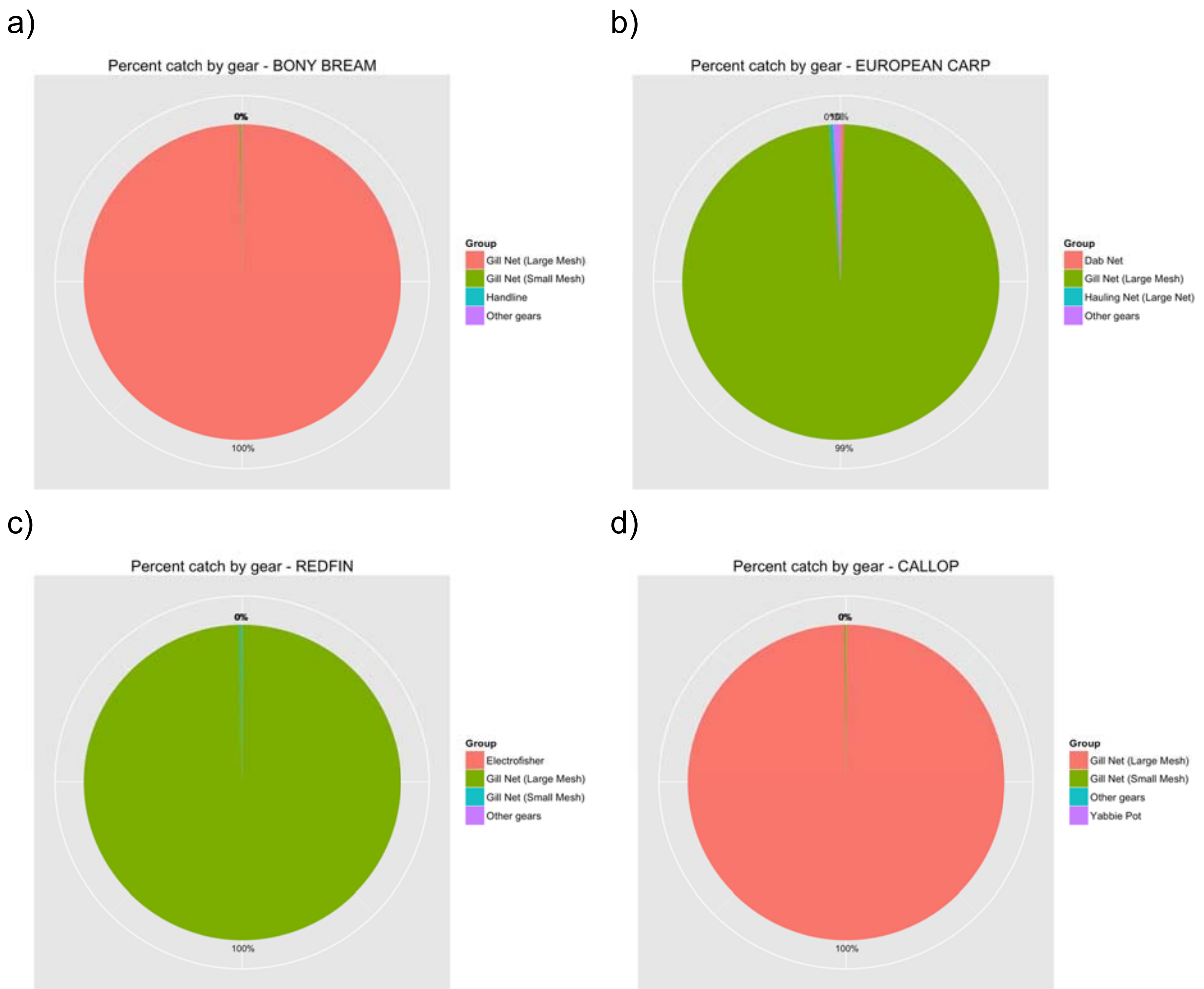

Figure 23. Percentage of the Freshwater species a) Bony Bream, b) European Carp, c) Redfin and d) Golden Perch caught by the different gears since 1984.

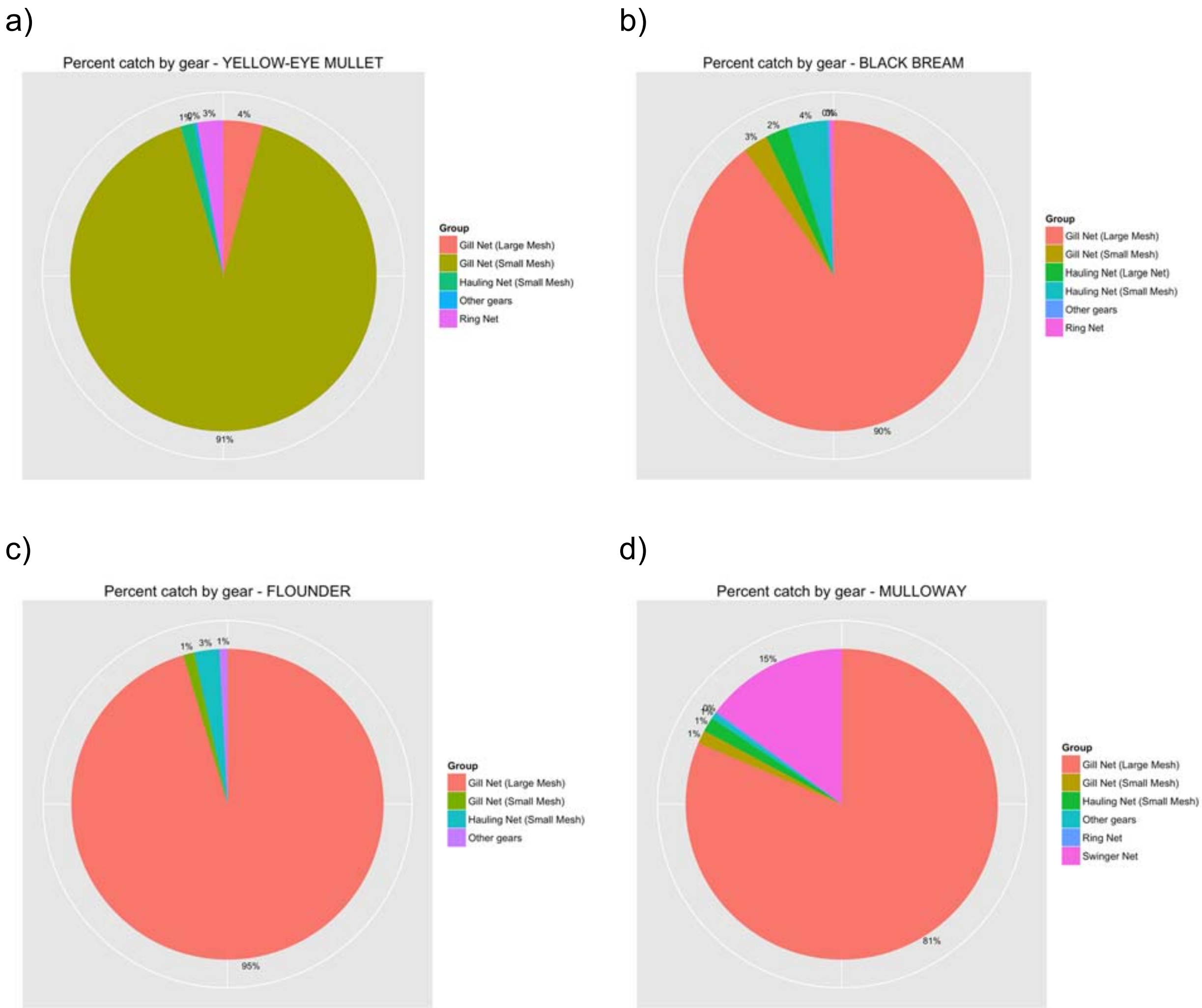

Figure 24. Percentage of Estuarine species a) Black Bream, b) Yellow-eye Mullet, c) Greenback Flounder and d) Mulloway caught by the different gears since 1984.

Table 5. Percentage of the catch of key LCF species taken within each sector of a habitat (Freshwater / Estuarine / Marine) x gillnet (small / large) management framework.

	Freshwater	Estuarine	Marine
Large mesh gillnet	Bony Bream 99% European Carp 98% Golden Perch 100% Redfin 99%	Mulloway 80% Greenback Flounder 95% Black Bream 85%	
Small mesh gillnet		Yelloweye Mullet 89%	
"Swinger Net" (large mesh gillnet)			Mulloway 14%

Characteristics of current entitlements

There are 36 licences (entitlements) and 32 current licence holders in the LCF. Entitlements allow the holder to use a variety of gear types. In Inland Waters, these include drum nets, gill nets, and yabbie pots; in Marine Waters they include swinger nets, cockle rakes / nets, longlines, dab nets, fish spears and hauling nets. Currently the regulations stipulate that each entitlement must have a minimum holding of 25 Inland Waters Gill Net units and a maximum holding of 100 Inland Water Gill Nets and yabbie pots. Pipi quota can only be held if the entitlement includes a cockle rake endorsement. According to the SFA, the principal value in a licence at present is the number of nets registered as Inland Waters Gill Nets (equal to a 50 metre net). These nets can be of any regulated mesh size and may be substituted by the use of a drum net in the Lakes.

Other gear such as a hauling net, swinger nets, and longlines exist within endorsements in the Fishery at present. Swinger nets are used in the marine component of the fishery to target large Mulloway in the surf zone. Gears (and endorsements) which are infrequently used include fish spears and dab nets. See Section: Analysis of Fishing Patterns).

Entitlements may only be traded in their entirety with the exception of net units, which can be traded in 25 unit blocks. For example, an operator requiring an additional 10 net units to improve economic performance is only able to do so with a whole package transfer of 25 net units. Approximately 8–12 licence holders hold net units above the minimum holding. Two fishers hold the maximum holding of 100 units, which they use to target the high-volume, low-value Bony Bream and European Carp. A licence amalgamation policy requires surrender of all net entitlements over and above 25 net units. Family transfers allow a LCF licence to be transferred to family members without being subject to the 25 net unit entitlement limitation.

The rationale for a minimum holding entry requirement is based on the need to limit the numbers of operators participating in the fishery, and as such, is clear as a tool for limiting entry. However, the economic rationale for the establishment of this minimum holding of 25 net units is not clear.

Current regulations concerning transfers of net entitlements restrict the flexibility required to operate efficiently.

Key Message 8. Current restrictions on transfers of net entitlements is reducing the flexibility required to operate efficiently.

Median annual catch varies greatly between licences (Figure 25). Ten of the 36 active licences had a median catch of greater than 50 t per year, and only two were greater than 100 t per year. Median catch of most licences is less than 30 t per year.

Most licences greatly favour one habitat over the other, fishing predominantly in either Freshwater of Estuarine habitats (Figure 26). Only ten licences caught more than 50% of their fish from Estuarine habitat, while 30 licences caught more than 50% of their fish from Freshwater habitat and 14 of those took more than 90% of their catch from Freshwater habitat (Figure 27). The proportion of total catch (Figure 29) and effort (Figure 28) reported from each habitat has changed over time for some licences (e.g. AG and BF), while for others it has remained very consistent (e.g. AV and BB). Shifts in habitats fished from Freshwater to Estuarine and vice versa were both common, and there were three instances of shifts to predominantly Marine habits in recent years (AF, AG and AO).

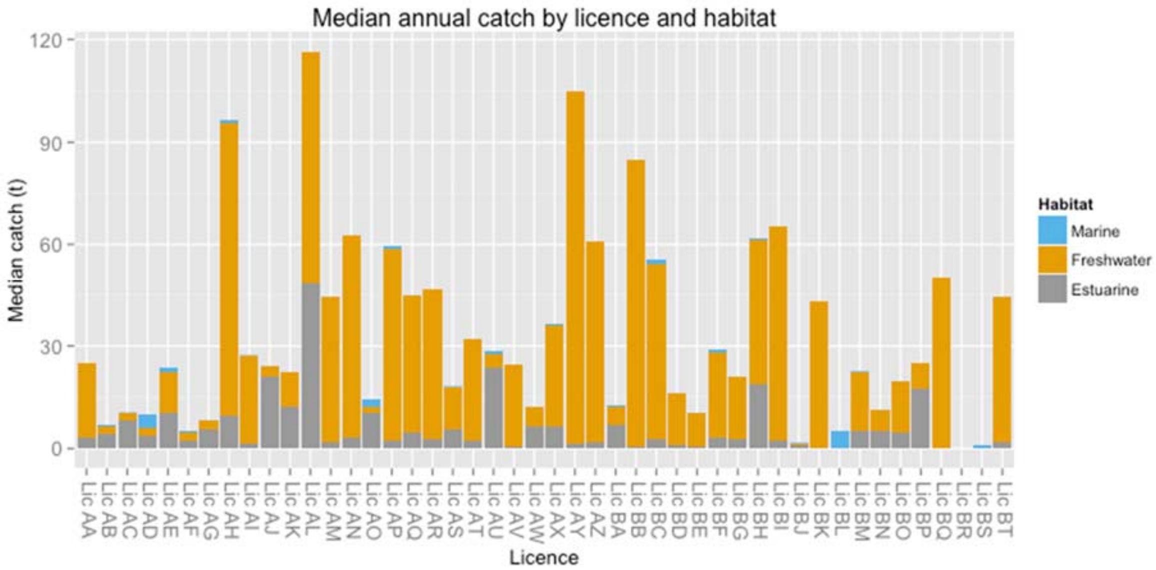

Figure 25. Median annual catch (t) of individual licence holders during years fished. Note: licence numbers have been randomised and recoded for privacy reasons.

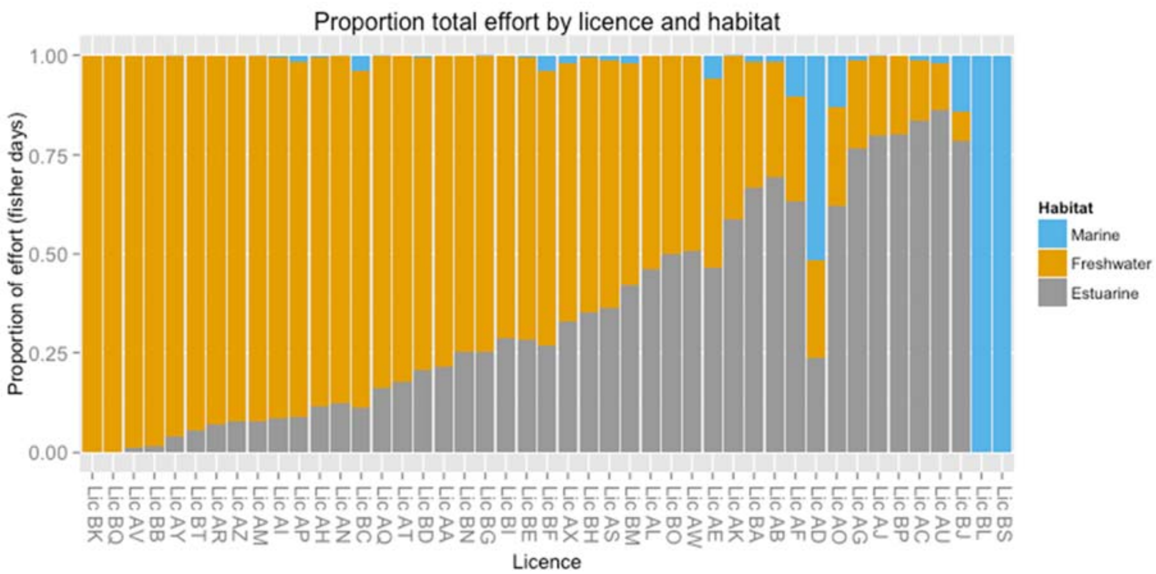

Figure 26. Proportion of total effort (fisher-days) by habitat for each licence since 1984. Note: licence numbers have been randomised and recoded for privacy reasons.

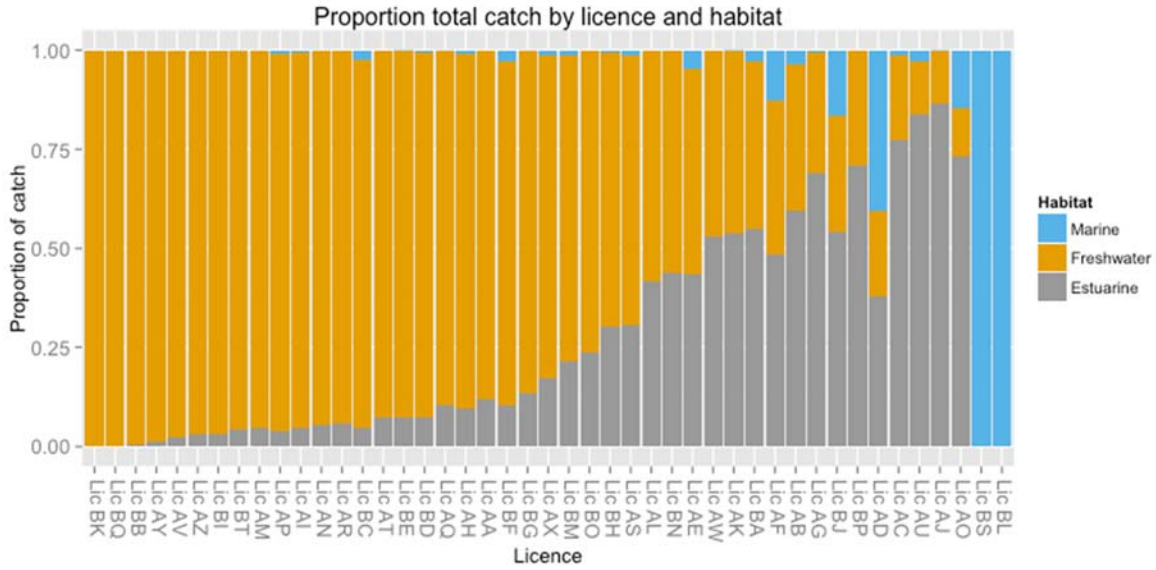

Figure 27. Proportion of total catch (t) by habitat for each licence since 1984. Note: licence numbers have been randomised and recoded for privacy reasons.

Figure 28. Proportion of annual effort (fisher-days) expended in each habitat type reported by each licence from 1984/85 to 2012/13. Note: licence numbers have been randomised and recoded for privacy reasons.

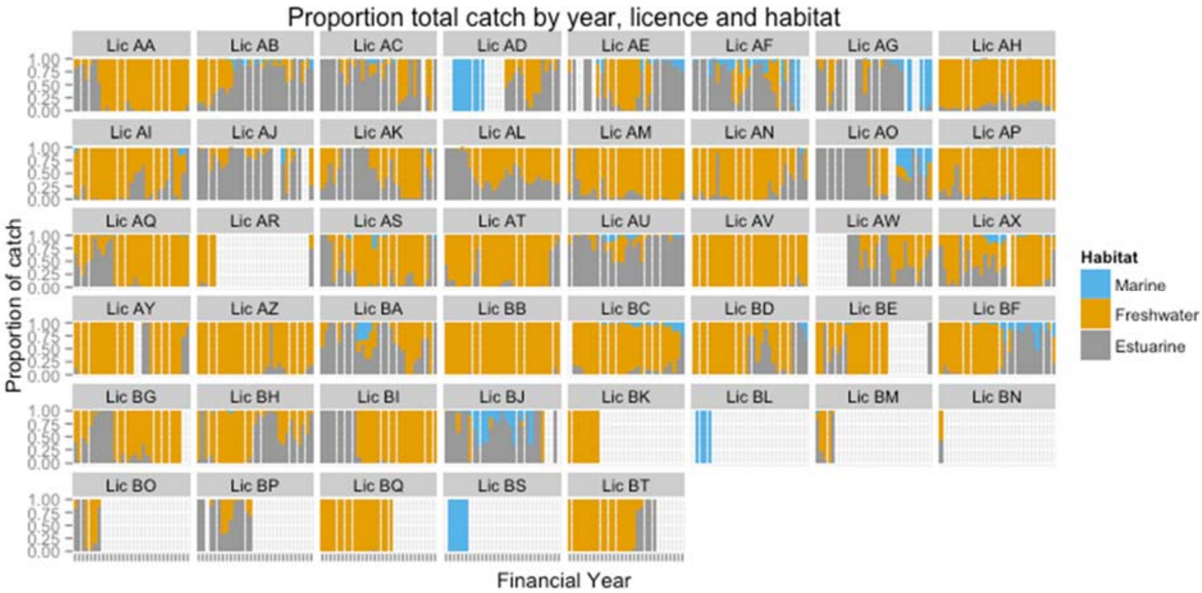

Figure 29. Proportion of annual catch taken from each habitat type reported by each licence from 1984/85 to 2012/13. Note: licence numbers have been randomised and recoded for privacy reasons.

Economics of the fishery

An independent contractor has carried out a report on economic indicators for the fishery for the past 10 years. In their most recent report, Econsearch (2013) found that the Gross Value of Production (GVP) in the LCF followed an increasing trend between 2002/03 and 2008/09 due to increases in both catch and price over the period (Figure 30). GVP fell sharply in 2009/10 reflecting a fall in both catch and price. In 2010/11 and 2011/12 GVP increased by 2.4 per cent and 7.4 per cent respectively as a result of an increase in prices in the fishery (and despite a fall in catch in both years). Notably, increases in price are predominantly due to the threefold price increase for Pipis since 2002/03. Figure 31 shows the GVP (real prices) in the fishery with and without the Pipi fishery.

For other species in the fishery, the average annual price of most LCF species has fluctuated between years but has generally followed an increasing trend in nominal terms over a 15 year period. There has been a 126% increase in nominal average price of Lakes and Coorong species, equivalent to a 50% rise in the real price. Profits have generally followed an increasing trend over the last ten years, however, the historically low profits in 2009/10 and 2010/11 which were driven by price falls have highlighted the exposure of the fishery to price fluctuations. Price recovery in 2011/12 to historically high levels has led to improved measures of profitability.

Several licence holders commented that having the ability to shift effort between different species was an integral part of the economic viability of their fishing business.

The economic rent, as estimated by Econsearch for the years 2002/03 to 2011/12 for the LCF is shown in Figure 32. Economic rent is defined as the difference between GVP obtained from the fishery and the total costs (including depreciation and opportunity cost of capital). Over the ten year period, with the exception of 2004/05 and 2009/10 economic rent in the LCF has been increasing. The catch and GVP data would suggest that negative economic rents in these two years were largely attributable to both a decline in catches of all species due to drought conditions, highlighting the economic sensitivity of the fishery to external environmental factors. Despite drought conditions easing in recent years the environmental condition of the Lakes and Coorong is still of concern to licence holders.

Key Message 9. Profits have generally followed an increasing trend over the last ten years but are particularly vulnerable to environmental conditions and price volatility.

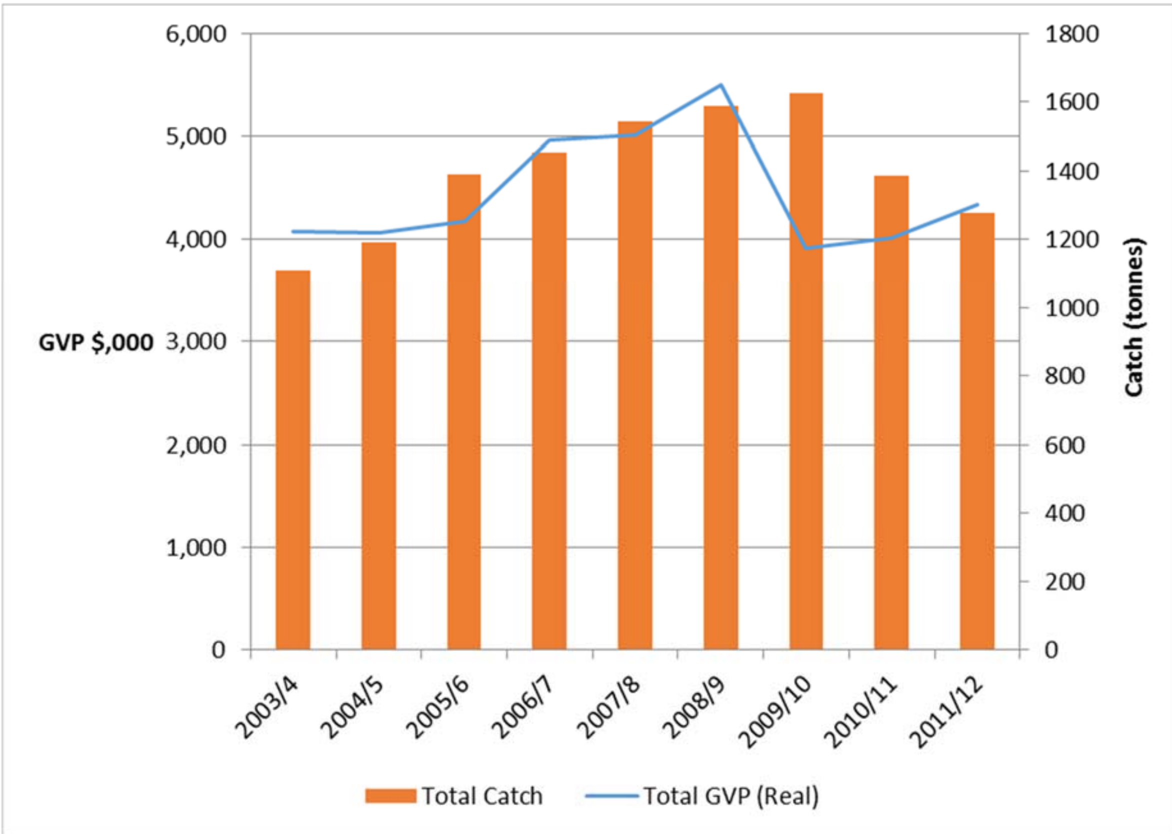

Figure 30. Total Catch and GVP in Lakes and Coorong Fishery 2003/04–2011/12 (from Econsearch 2013).

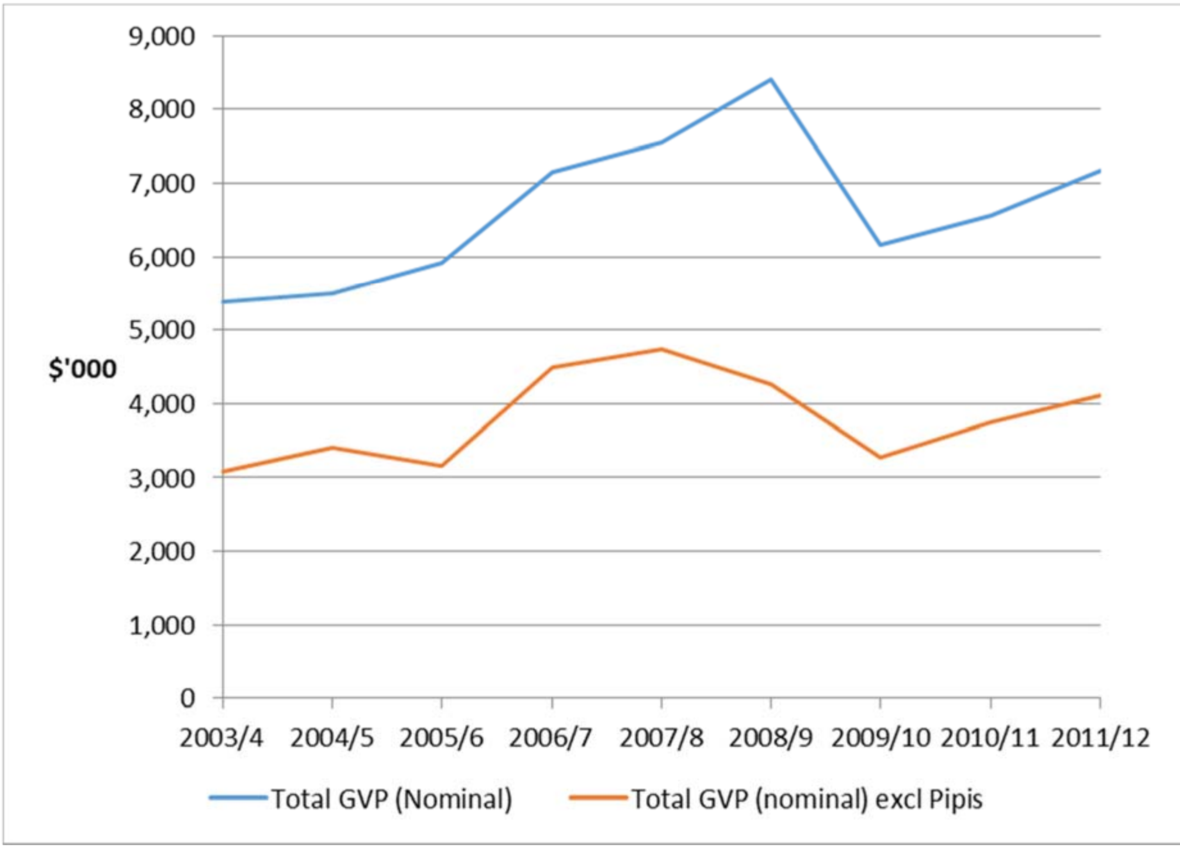

Figure 31. Nominal and Real GVP in Lakes and Coorong Fishery 2003/04–2011/12 (from Econsearch, 2013).

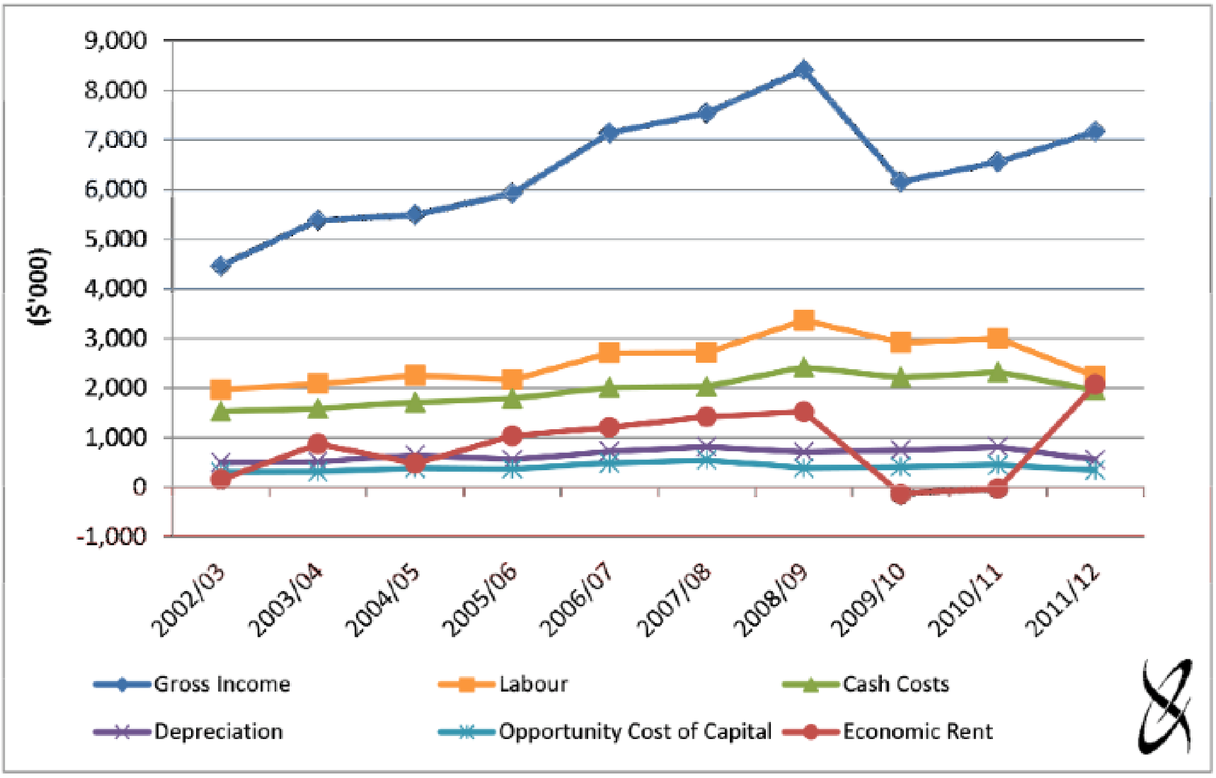

Figure 32. Economic rent in the Lakes and Coorong Fishery 2002/03–2011/12 (from Econsearch, 2013). All indicators are expressed in nominal terms.

Current management framework

In 1984, the *Scheme of Management (Lakes and Coorong Fishery) Regulations 1984* was introduced to formally manage the LCF as a distinct fishery, separate from the Marine Scalefish Fishery. The Scheme of Management was updated in 1991 (Sloan, 2005) and 2007, and the regulations are now called the *Fisheries Management (Lakes and Coorong Fishery) Regulations 2009*. The LCF is also subject to the *Fisheries Management (General) 2007 Regulations*.

The Lakes and Coorong Management Plan aligns with the key goal of the then *SA Fisheries Act 1982* "to ensure that an appropriate balance exists between the need to ensure long term sustainability of the marine, estuarine and freshwater fisheries resources of the Lakes and Coorong region, and the optimum utilisation and equitable distribution of these resources, for all stakeholder groups and future generations" (Sloan, 2005).

The following management goals are stipulated under the current management plan:

Goal 1. Sustainable harvesting of fisheries resources.

- *a. Fishing is conducted at a level that maintains ecologically viable stock levels and protects fish stocks from overfishing;*
- *b. Sufficient biological and environmental information is collected and analysed to make informed management decisions; and*
- *c. For fish stocks that are determined to be operating outside of established reference levels, the fishery will be managed to promote recovery to ecologically viable stock levels, within agreed timeframes.*

Goal 2. Optimum utilisation and equitable distribution of fisheries resources, within the constraints of sustainability imperatives.

- *a. Maintain a flow of economic benefit from the fishery to the broader community through the wise use of Lakes and Coorong fisheries resources;*
- *b. Maintain equitable public access and recreational fishing opportunities;*
- *c. Provide opportunities for indigenous communities to access fish stocks for traditional purposes;*
- *d. Maintain equitable levels of commercial access and the regional development nature of the commercial fishery; and*
- *e. Sufficient economic information exists to make informed management decisions.*

Goal 3. Minimise impacts on the structure, productivity, function and biological diversity of the ecosystem.

- *a. Monitor any external impacts on fish stocks associated with broader environmental or ecosystem health;*
- *b. Minimise fishery impacts on by-catch species and the ecosystem;*
- *c. Avoid the incidental mortality of endangered, threatened and protected species; and*
- *d. Reduce the population size and ecological impact of non-native fish species.*

Goal 4. Cost-effective and participative governance of the fishery.

- *a. Promote cost-effective and efficient management of the fishery;*
- *b. Have regard to the range of social, cultural and wider community values attached to the fishery; and*
- c. *Promote compliance with management controls.*

Consultation and co-management are an integral part of fisheries management in South Australia. The Fisheries Council has prepared the *Policy for the Co-Management of Fisheries in South Australia* to inform discussion with the wider commercial fishing industry and other stakeholder groups as to how best to promote and implement co-management. The policy proposes that implementation of a preferred co-management model should be through a phased approach that allows industry and key stakeholders to build their capacity over time and allows for a government audit process to measure performance and success. The SFA and the Goolwa Pipi Harvester's Association (GPHA) have been recognised as the representative industry bodies for the commercial LCF. The Minister has oversight of the management of the fishery under this management plan, but day-to-day management is conducted by PIRSA in association with the SFA and GPHA.

The current management plan encourages better integration of ecosystem-based principles with standard species and gear based fisheries management. To this end, it recognises the importance of the relationship between the fishery and the health of the ecosystem, particularly the influence of droughts and floods on salinity and water flows in the estuarine environment. It has endeavoured to allow fishermen to transfer effort between a diversity of species in the marine, estuarine and freshwater ecosystem components of the fishery and give them flexibility to respond to inter- and intra-annual variations in overall ecosystem health and fish stock abundance, or to changes in the market. This has been achieved somewhat informally however, through the close cooperation between fishers, managers and researchers rather than through any specific harvest strategies, reference points or decision rules.

Future management options

Since the implementation of the current LCF Management Plan there have been rapid developments and significant improvements in harvest strategies applied across most Australian Commonwealth and State fisheries. These harvest strategies set out the management actions necessary to achieve defined social, environmental and economic objectives of a fishery. To do this, they have a process for monitoring and assessing the performance of the fishery against these objectives and most importantly, they contain "decision rules" that have pre-agreed management responses that can govern the intensity of fishing under certain conditions. To be effective, the objectives of a harvest strategy therefore need to be expressed in the form of quantifiable reference points and indicators. These reference points commonly include a 'target' reference point that expresses the desired status of the stock or fishery, and 'limit' reference points that express situations to be avoided because the risk to the stock or fishery is regarded as unacceptably high (Australian Government, 2007). These target and limit reference points often relate to stock or ecosystem sustainability, but can equally apply to social and economic fishery objectives. Furthermore, a good harvest strategy must make sense, be easy to understand, be unambiguous, be precautionary and should be implemented with a high level of stakeholder participation and acceptance (Sloan *et al.,* 2014).

Main issues to be addressed

Although the current LCF Management Plan contained some of the above aspects of a harvest strategy, it became apparent over time that it was inadequate in three important areas.

1) Notably, although the current Management Plan recognised the critical importance of climatic conditions and water flow on the habitats and resources of the LCF, it had no quantitative indicator or defined management responses to this major fishery driver. In this respect, WWF-Australia has noted that the reproduction and early life stage survival of most LCF target species are reliant to a greater or lesser degree on healthy freshwater inflows, and for these reasons “there must be a strong connectivity between the fisheries management system and the existing and likely future environmental conditions wherever this is possible”.

2) There is no effective limit reference point (either explicit or implicit) in the LCF Management Plan that defines an unacceptable risk of commercial fishing on the fishery or individual stock. This issue was highlighted in the recent MSC review of the LCF regarding the four key target species.

3) Despite the framework of limited entry, gear restrictions and spatial closures contained in the current Management Plan, there is no *formal* mechanism to control the level of exploitation should any limit reference point be approached. In saying this, it is recognised that there has been a long standing *informal* ecosystem-based approach to management of the fishery, and a range of flexible management measures have been introduced in response to fish stock declines or significant environmental disturbances. Examples of these are extended periods of drought, low freshwater flow or closure of the River Murray Mouth.

In addition to the issues above, industry wanted to modernise and improve the Management Plan (as required by the Act) to address the following areas.

4) Explore whether existing regulations limiting the activities of fishers within the LCF could be simplified.

5) Re-establish the former licence transfer provisions that allowed for the rationalisation of licences, which could then be maintained as a single package without further rationalisation.

6) Provide for more flexibility in the nature of the rights associated with net entitlements, to enable fishers to transfer nets between each other within an agreed overall limit on the number of nets.

With the new Fisheries Management Plan for the LCF due in 2015, we used the information from the data analysis and discussions with managers, researchers and industry to review the underlying framework of LCF management, and develop a harvest strategy that could address the issues mentioned above.

Proposed options

Any new management framework developed for the LCF should endeavour to address the above issues and reflect the key sustainability, social and economic attributes of this multi-gear, multi-species fishery. This is a holistic and planned approach compared with how many frameworks (including those previously applied to the LCF) are developed: beginning with specific target species and gear management; evolving (and becoming more complicated) as more target/non-target species and gears are incorporated; and then endeavouring to incorporate ecosystem based fishery management (EBFM), economic and social objectives.

Following analysis of the data on catch and effort by gear and habitat, and discussions with industry regarding their operational requirements from an environmental, economic and social perspective, a number of management options were presented to industry and the LCF Management Plan Steering Committee (LCFMPSC) for further exploration and discussion of their advantages and disadvantages. Identification of management options was based on the following criteria, which had been raised in discussions with PIRSA, SARDI, SFA and NMAC SA:

- Flexibility to fish throughout the year;
- Flexibility to fish across the range of areas;
- Flexibility to fish with different gears;
- Flexibility to target a range of species;
- Ability to control effort;
- Greater transferability / autonomous adjustment; and,
- Administrative simplicity and cost.

With these criteria in mind and based on the characteristics of the fishery, three potentially appropriate options were identified (Table 6). This section discusses these options in more detail and provides outcomes from consultation with PIRSA, SARDI, SFA Executive Officer, licence holders and members of the Lakes and Coorong Management Plan Steering Committee (LCFMPSC).

Based on the knowledge gained from the analysis of catch and effort data and discussions with stakeholders, the project team was adamant that habitat type needed to be one of the fundamental components of the management framework under which any harvest strategy would need to operate. There were numerous reasons for this:

1) the species composition in each of the habitat types is markedly different;

2) the effect of periods of drought and flood has differing impacts on Freshwater, Estuarine and Marine habitats and their species;

3) any management control designed to reduce fishing impacts on a particular species or habitat in the fishery would be rendered ineffective if effort could simply be transferred in from other areas of the fishery. The corollary of this is that effort restrictions would have to be extremely stringent over the entire fishery to be effective for a particular species or habitat.

Thus, as a first step, there was the need to gain consensus from stakeholders that any management framework would be habitat-based. This was achieved over numerous meetings and discussion during the project.

Within this habitat-based management framework, options were explored based on three types of effort units: fishing days; net units; and a combination of both these: net fishing days. The units of effort are defined as:

- fishing days — total number of days worked by all licences in any one year;
- net units — number of 50 m mesh nets that all licences are entitled to use; and,
- net-days — product of the net units used for each fishing day summed across the year (i.e. If a fisher fishers 365 days of the year and uses his entitlement of 25 units he would have fished 9,125 net-days).

Table 6. Management Options considered

	Management Option
1	Habitat TACE* (fishing days)
2	Habitat TACE (net units)
3	Habitat TACE (net-days)

***TACE= Total Allowable Commercial Effort**

Gear included in the management options

The key messages outlined in the previous section highlight that controlling large and small mesh gillnets will achieve the management outcomes desired because practically all the catch is caught with these gear types in the Estuarine and Freshwater habitats. Therefore in exploring options, it has been assumed that other gear entitlements remain on each licence and continue to be non-transferable.

Whilst other gear have been excluded in this project, it is recommended that scope for their inclusion in the selected management option in the future should be explicitly be made in the next LCF management plan should there be concern about the use of other effort.

Management Option 1: Habitat Total Allowable Commercial Effort (TACE) based on fishing days

Under this option, a Total Allowable Commercial Effort (TACE) in fishing days would be set for each habitat. The total number of fishing days would be based on the number of days fished as reported in logbooks. It would not account for the number of nets used on each day fished and thus is a relatively weak effort control.

Each licence holder would be allocated a proportion of the TACE as Individual Transferable Effort units (fishing days) using a specified allocation formula determined by the Minister and based on the recommendations of a specifically appointed independent allocation advisory panel. Variables in the allocation formula could include for example, effort (fishing days) history based on logbook data, equal allocation of days by net unit or a combination of both. Should effort history be included as a variable in the recommended allocation formula, a verification process would be required. The implications of this allocation option would be that there are likely to be two tradeable rights in the fishery to enable the degree of flexibility required by industry regarding transfers: net units and fishing days.

Outcomes

There was limited support for this option. The use of fishing days would not allow for effective control of effort, as limitations on the number of fishing days would not account for differences among fishers in the number of nets that can be deployed on each fishing day. The scope for increasing effort by activating currently latent net units through transfers also exists. Furthermore, this option would be unlikely to address the demands of MSC re-certification without explicit management rules and strategies.

Management Option 2: Habitat TACE based on Net Units

Under this proposed option, PIRSA would set a total number of net units that could be used in each habitat — a Habitat TACE based on net units. Initially, this would most likely be based on the total number of 50 m net units held (i.e. the entitlement) in the fishery.

Licence holders would then be asked to self-allocate what net units they wish to fish in each habitat to tailor to their own business needs. This self-allocation would avoid the need for an independent allocation process.

Leasing and permanent transfers should be allowed (with no minimum or maximum) within each habitat, but not between habitats. Following self-allocation, PIRSA would calculate a value of each net unit allocated by habitat. This would be the TACE (in net units) divided by the total number of nominated net units per habitat. This would give a value of each net unit by habitat.

Table 7 and Table 8 show some possible scenarios under this option.

Table 9 shows what happens to the value of net units if the TACE changes due to the need to reduce or increase effort and total allocated net units stays constant.

Table 7. Example of a self-allocation scenario A

	Freshwater	Estuarine
Fisher 1 has 30 net units	60%= 18 net units	40% = 12 net units
Fisher 2 has 50 net units	50% = 25 effort units	50% = 25 effort units

Table 8. Example of the value of net unit value under self-allocation scenario A

	Freshwater	Estuarine
TACE	**250**	**400**
Total number of net units nominated by all fishers	500	300
Net unit value	250 ÷500= 0.5	400 ÷300= 1.3
Fisher 1 will be able to use*:	9 mesh nets (18 units *0.5)	16 mesh nets (12 units*1.3)
Fisher 2 will be able to use*:	13 mesh nets (25 units*0.5)	33 mesh nets (25 units*1.3)

*rounded

Table 9. Example of a self-allocation scenario B.

	Freshwater	Estuarine
TACE	**400**↑	**200**↓
Total number of net units allocated by all fishers	500	300
Net unit value	400 ÷500= 0.8	200 ÷300= 0.7
Fisher 1 will be able to use*:	14 mesh nets (18*0.8 units)	8 mesh nets (12 units*0.7)
Fisher 2 will be able to use*:	20 mesh nets (25 units*0.8)	18 mesh nets (@5 units * 0.7)

*rounded

Refinement of Option 2: Separation of small and large mesh sizes

Particularly within the Estuarine habitat, the use of large mesh and small mesh nets to target very different species is common. Similar to the argument about management by habitat, to have effort controls that did not distinguish between the two gear types would result in either ineffective controls, or overly stringent restrictions to achieve a desired management outcome.

A further refinement to Option 2 that would enable greater control of effort for species such as Yelloweye Mullet, would be a nomination of net units based on mesh size. For example, a licence holder currently holding 25 net units would nominate how many of these units were (a) to be used in each habitat, and of those, (b) how many would be small or large gillnets. This would require a separate TACE set for small and large gillnets. For example, Operator A could nominate the following:

	Freshwater	Estuarine
Large Gill Net	10	7
Small Gill Net	1	7

Operator B could nominate the following:

	Freshwater	Estuarine
Large Gill Net	5	10
Small Gill Net	×	10

<u>Nomination process under Option 2</u>

As mentioned above, without the need for an independent allocation process, operators need to nominate (self-allocate) the proportion of units they wish to fish in each habitat. Discussions at industry meetings highlighted that in moving to a new management framework, there would be a considerable degree of uncertainty and nervousness regarding this self-allocation process because operators may lock themselves into an inflexible management arrangement that was inappropriate to their business. To address this concern, we explored four potential nomination processes:

1) One-off self-allocation
2) Annual self-allocation
3) Self-allocation every three years (or another specified time period)
4) Self-allocation for first three years with no permanent transfers and then final self-allocation.

1. One-off self-allocation

A one-off nomination would provide the greatest certainty for operators, as they would then know what the structure of their business would be in terms of net units. The data indicates that most operators are consistent over time in the amount of effort (fishing days) that they spend in each habitat. If operators wish to alter their allocations, this could be achieved by allowing full transferability of net units through leasing or sale.

To allay concerns about the risks of making a mistake with a one-off allocation, the self-allocation process could be undertaken over three rounds so that licence holders get an idea of what their likely unit value would be, and submit a second round self-allocation taking into account any adjustments they wish to make. The third round would be the final allocation.

2. Annual self-allocation

Industry has expressed a preference for an annual self-allocation rather than a one-off self-allocation to enable them to retain some level of annual flexibility. They are understandably concerned that if they get their self-allocation “wrong”, then they are locked into that fishing business structure which can only be rectified if they invest money in leasing or buying effort units in another habitat and sell / lease the habitat effort units they do not require. There is clearly a good argument for this approach to enable operators a level of operational flexibility on an annual basis.

However, there are two main disadvantages to an annual self-allocation process. Firstly, annual self-allocations would slow down / reduce trading, as operators wishing to tailor their net units to their operation may be reluctant to do so if individual allocations change annually. A second disadvantage is that annual self-allocation may penalise those licence holders who specialise in one habitat, as they will continue to face uncertainty as to the value of their net units each year. For example, it is conceivable that a licence holder may want to always allocate 90% of their units to freshwater, but the value of their units, and hence what gear they would be able to use could vary every year depending, on the number of other licence holders who self-allocate to that habitat, and the amount of net units they nominate. As shown in Table 10 this could potentially lead to wildly fluctuating unit values, and affect the viability of their business. To some extent, this is no different to the current situation whereby operators concentrating on a particular habitat never know how many other operators will fish in this habitat each year.

Table 10. Effect of annual self-allocation on a habitat specialised fisher

TACE : 200 effort units		Unit value of a net unit	Fisher with 25 net units allocated all to freshwater
Nominations Year 1	300	0.66	37.5
Nominations Year 2	200	1	25
Nominations Year 3	400	0.5	12.5
Nominations Year 4	100	2	50

3. *Self-allocation every three years (or another specified time period)*

Under this approach, nominations are made every three years (or another specified time period). Periodic nominations (e.g. every three years) would allow more flexibility as to which habitats licence holders choose to fish in. The disadvantage is that there is less certainty for licence holders wishing to trade units and tailor their operations, as allocations will change periodically.

4. *Self-allocation for first three years with no permanent transfers and then final self-allocation*

An approach which combines the certainty provided by a one-off allocation and the flexibility afforded by annual allocations, is to implement an annual self-allocation for three years to allow licence holders to familiarise themselves with the new system, followed with a final self-allocation in the third year. During this period, it would be advisable to prohibit permanent transfers, as licence holders would be trading units that may change substantially in value at the end of three years. Clearly a one off nomination is both administratively simpler and less costly, but until licence holders are familiar with the system, there may be a good argument for undertaking annual nominations for a specified period and then moving to a final nomination process.

Outcomes

There was some support for this option from all stakeholders, as it enabled a control on effort, without requiring an allocation process and enabled transferability with no minimum or maximum. There was some concern as to how the TACE would be set (and its level), as well as how nominations would affect businesses, especially regarding licence sales as the buyer may not want to be locked into a particular net unit structure. This option also limits the capacity to use a full entitlement of nets in any one habitat. However, full transferability would address some of the flexibility concerns. New buyers into the fishery, as with a buyer of any other business, would have the choice and flexibility of which structure best suited their needs.

Similar to Option 1, there is scope for increasing effort by using allocated net units over a greater number of days than currently used, thereby undermining the effectiveness of this control of effort.

Setting the TACE

Analysis of the river flow data revealed that rather than changing dramatically from one year to the next, periods of droughts and floods often occur of longer (decadal) timeframes. Consideration should be given to setting TACEs for longer than one year, for example every three / five years to increase the certainty of the outcomes of the self-allocation process, enabling operators to better plan their business. Should the option to have periodic nominations be selected, these would be done at the same time as the TACE setting process.

Option 3: Habitat TACE based on net-days

This option is the strongest form of effort control proposed in this report. Under this option, Habitat TACEs would be estimated using information on net-days from logbooks. A proportion of the habitat TACE, in the form of Individual Transferable Effort (ITE), would then be allocated to individual licence holders using a specified allocation formula determined by the Minister, based on the recommendations of a specifically appointed independent allocation advisory panel. For example, criteria may include effort history (net-days), an equal allocation of net-days by net unit holdings or a combination. A possible allocation formula would be the one that was used in the Pipi component of the LCF fishery. Under this allocation formula, each licence holder was allocated 1% of the Total Allowable Commercial Catch (TACC) as an Access Entitlement and the remainder of the TACC was allocated based on effort history resulting in a 32:68 split.

Table 11 gives an example of a split allocation based on the Pipi allocation formula. As there are 36 licence holders in the fishery, 36% of the TACE would be divided equally amongst each licence holder as an access entitlement, and 64% divided amongst licence holders proportionally based on effort (net-days) history. Hypothetical TACEs of 2500 net-days in the Estuarine habitat and 2000 net-days in the Freshwater habitat are used in these examples.

Transferability of net-days could take place within habitats and possibly between habitats according to an agreed ratio e.g. 1 net-day Estuarine is equal to 2 net-days Freshwater. The simpler option would be to allow transferability within habitats but not between habitats.

The implication of this option would be that the tradeable right in the fishery shifts from net units to net-days. This means that licence holders with identical net-day history in a habitat, but who currently own / use different numbers of net units (say 25 and 100) would receive the same proportion of the TACE.

Table 11. Example of application of an allocation formula applied to the Estuarine and Freshwater habitats.

Estuarine Habitat Hypothetical TACE equivalent to 2500 net-days	Allocation formula	Net-days
Access Entitlement: All licence holders	36% of TACE allocated equally	900 net-days = 25 days per licence holder
Allocation for effort history	64% of TACE allocated proportionally to those who have effort history	1700 net-days
Freshwater Habitat **Hypothetical TACE equivalent to 2000 net-days**	**Allocation formula**	**Net-days**
Access Entitlement: All licence holders	36% of TACE allocated equally	600 fishing days= 16.7 days per licence holder
Allocation for effort history	64% of TACE to those who have effort history	1400 net-days

Outcomes

Initial discussions with industry indicated some support for the idea of managing effort through ITE units, but there was some reluctance concerning the time and cost of an allocation process. However, after analysis of the logbook data and further consideration by industry of alternative options, support is growing for this option.

Table 12 summarises the management options described against the criteria specified by stakeholders.

Table 12. Summary of Options Addressing Specified Criteria compared to the current situation.

CRITERIA \ OPTION	1 Habitat TACE	2 Habitat TACE	3 Habitat TACE
Unit of Effort Control	**Fishing Days**	**Net Units**	**Net-days**
Flexibility to fish throughout the year	✓	✓	✓
Flexibility to fish across the range of areas	More restricted	More restricted	More restricted
Flexibility to fish with different mesh sizes	✓	More restricted	✓
Flexibility to target a range of species	✓	✓	✓
Ability to control effort. Note: scope for effort creep will require monitoring	✓	✓✓	✓✓✓
Greater transferability/autonomous adjustment	✓✓	✓	✓✓
Administrative simplicity and cost	Individual allocation will increase initial costs	Costs will increase if nominations occur regularly; some administrative complexity	Individual allocation will increase initial costs

Key Message 10. Any management option must provide a formal mechanism to control effort, enable operational flexibility and autonomous adjustment. Providing there is reliable data on net-days, Option 3, setting a Habitat TACE based on net-days and allocating ITEs to all licence holders is the strongest form of effort control and allows for operational flexibility.

Harvest strategies

A harvest strategy specifies the management actions necessary to achieve defined resource objectives in a given fishery, resulting in a formal and proactive management approach that is transparent to all stakeholders (Smith *et al*., 2009). There are inherent challenges in managing multi-species, multi-method fisheries that require careful consideration in the development of appropriate harvest strategies.

While there can be a significant degree of targeting involved in multi-species fisheries, target species may not always dominate the catch during individual gear sets, and the species composition of the catch may be spatially or temporally specific, particularly when there are very different habitats such as in the LCF. It can be difficult to ensure that all species caught (not only the target species) are fished sustainably because of their various life-history characteristics, differing productivities, and different degrees of susceptibility to different fishing gears.

Many species are caught by a variety of gears, and it is often difficult for assessments to account for all sources of mortality across the different life stages caught by various gear types. This issue is exacerbated in the case of small-scale or artisanal fisheries where there is limited availability of data and low financial resources (Dowling *et al*., 2008). In these cases, there are often no formal stock assessments, and even indirect biomass estimates are unavailable and unlikely to be developed in the foreseeable future.

Regardless, there is an increasing expectation for decision makers to use robust scientific advice to determine the status of exploited fish stocks. The challenge for those tasked with providing management advice for such fisheries has been reconciling the need to achieve specific risk-related sustainability objectives, with the reality of the available data and assessments for data-poor species and fisheries (Smith *et al.,* 2009). Dowling *et al*. (2008) developed four general principles for the pragmatic development and implementation of harvest strategies for small, low-value, data-poor fisheries: (i) the development of sets of triggers with conservative response levels, with progressively higher data and analysis requirements at higher response levels; (ii) identifying data gathering protocols and subsequent simple analyses to better assess the fishery; (iii) archiving biological data for possible future analysis; and (iv) the use of spatial management, either as the main aspect of the harvest strategy or an augmentation with other measures.

Obviously, the development of harvest strategies for data-poor fisheries presents challenges in attempting to reconcile available information and capacity with formal, defensible strategies that achieve the desired management and legislative objectives for the fishery. There is a need for harvest strategies, particularly for community-based multi-species, multi-gear fisheries, to be pragmatic, cost effective and easily understood, and accepted by key stakeholders. The LCF is a fishery that is grappling with many of the issues mentioned above.

There has been a long-standing informal ecosystem-based approach to management of the LCF, which is underpinned by allowing commercial fishers the necessary individual flexibility to respond by transferring effort. Those flexible fishing practices were adopted by fishers in response to fish stock declines, or significant environmental disturbances such as extended periods of drought, low freshwater flow or closure of the Murray Mouth. A more formal system is now required.

Performance Indicators

A range of indicators can be used to measure fishery performance for key species depending on the level of information available. For data-poor fisheries, performance is commonly measured using indicators derived from fishery-dependent information such as catch and effort data (Newman *et al.,* 2015). These indicators are often considered in context of other available information on the life-history and demography of individual species, to determine when fishery performance warrants a review and possible changes to management arrangements for the fishery.

The LCF is a data-poor fishery, with limited information on the processes that contribute to changes in fishery production for key species. Furthermore, there is uncertainty around the usefulness of fishery-dependent catch and CPUE data as indicators of relative abundance for key species due to: (i) environmentally driven changes in the amount of available habitat for finfish in estuarine and freshwater areas of the fishery, which may potentially affect the catchability of key species; and (ii) differences among licence holders in how they operate and the way that fishing effort is reported. Uncertainty also exists around the proportional use of Freshwater and Estuarine habitats of the LCF by key species targeted by the fishery (i.e. Golden Perch, Mulloway and Yelloweye Mullet), as the fishable biomass of each species occupying these habitats are components of biological stocks that extend well beyond the spatial constraints of the fishery (Thomson 1957; Keenan *et al.* 1995; Barnes *et al.* 2014). Based on the evidence provided above, explicit biological performance indicators derived from fishery-dependent catch and effort data are not effective measures population abundance for key species of the LCF and must be interpreted carefully when used to inform stock status.

Environmental processes play a critical role in regulating fishery production in the LCF, particularly in Freshwater and Estuarine habitats. Over at least the last 30 years, levels of fishery production for key species have fluctuated considerably among years, often in relation to changes in the environment (Ferguson *et al.,* 2013). Variation in the timing, magnitude and duration of freshwater inflows to the system drive changes to salinity and water level in Estuarine and Freshwater habitats, which directly influences the quality and size of the area available for fish to occupy within the spatial constraints of the fishery (Ye *et al*., 2013). Whilst the relationship between stock status and habitat availability is not explicit for some species, recent fishery assessments indicate that the varying levels of exploitation over recent decades, typically in response to flow-related changes in the environment, have been sufficient to maintain the sustainability of key fish stocks (i.e. Mulloway, Yelloweye Mullet and Golden Perch) targeted by the fishery (Ferguson and Ye, 2012; Earl and Ferguson, 2013; Earl and Ward, 2014).

In the absence of an appropriate biological performance indicator to monitor stock biomass for key species targeted by the LCF, a suite of potential environmental (primary) performance indicators were developed to monitor habitat availability (environmental condition) for finfish within the Freshwater and Estuarine habitats of the fishery. The proposed indicators were developed as surrogate metrics for population abundance (biomass) for key species within each sector, based on the fact that historical levels of exploitation — which typically varied in relation to the condition of the environment — have effectively maintained sustainability for key species over a long period. Specific performance indicators were developed to align with the three proposed habitat / gear-based sectors of the fishery: (i) Freshwater – large mesh gillnets (LMGN); (ii) Estuarine – LMGN; and (iii) Estuarine – small mesh gillnets (SMGN).

Assessment of the primary performance indicators against a series of reference points may be used to identify situations in the fishery that require a management response. This may also be used to guide a well-defined management decision-making framework, which involves a series of decision rules that govern the intensity of fishing pressure on key species within each sector.

Periodic, ecosystem-based fishery assessments may be used to evaluate the suitability of the proposed primary performance indicators as surrogate metrics for population biomass for key species, and review the effectiveness of the proposed reference points and associated decision rule framework for controlling exploitation to levels that ensure the future sustainability of key fish stocks. Such assessments could be undertaken once every three years for each of the three habitat / gear-based sectors of the fishery and include a comprehensive, weight-of-evidence assessment of stock status for key species. Such information could be used to assess the validity of the proposed harvest strategy framework and ensure exploitation is being controlled to levels that maintain high fishery productivity relative to the state of the environment, and ensure stock levels remain well above the point at which reproductive capacity (recruitment) may be impaired. The proposed ecosystem-based assessment will provide an important linkage between the proposed primary performance indicators and stock status for key species – a key requirement for MSC certification of the fishery.

Assessment of stock status for key species may be guided by several potential secondary (biological) performance indicators which have been developed to monitor fishery performance for key species, as they provide the only long-term (29 years) time-series available for assessing the status of the fishery (Sloan, 2005). The potential secondary performance indicators are:

- (i) total annual commercial catch;
- (ii) mean annual CPUE for the dominant gear type(s); and
- (iii) commercial catch composition (among key target species).

Age composition of fished populations may also be a useful secondary performance indicator, as it can be an important determinant of fishery status, particularly for long-lived species such as Mulloway, Golden Perch and Black Bream. However, the availability of samples to produce information population age structures is limited by the lack of a formal sampling program for the LCF. Secondary indicators will not be formally assessed against reference points due to: (i) uncertainty around the usefulness of fishery-dependent information (CPUE); and (ii) uncertainty around the interpretation of age structure information relative to the demographic processes that may influence population structure and abundance for some species. Rather they will form a critical part of the weight-of-evidence approach for assessing stock status for key species of the fishery.

This section provides a description of the proposed primary performance indicators for each of the three habitat / gear-based sectors of the LCF.

Primary performance indicators

Freshwater habitat– large mesh gillnet sector

An appropriate indicator to measure changes in the amount of habitat available for finfish in the Freshwater LMGN sector of the fishery is mean annual water level (Australian Height Data (AHD)) in the Lower Lakes (Lakes Alexandrina and Albert) (Figure 2). This indicator represents the area available for fish to occupy within the spatial constraints of the fishery (confined to waters below Wellington at the end of the River channel). Monitoring of water levels will identify situations in the Lower Lakes (i.e. a reduction in the size of the fishable area) for which management intervention is required to ensure that exploitation of key species (Golden Perch) is controlled to levels that maintain fishery productivity, relative to the condition of the environment, and that stock levels remain well above the point at which reproductive capacity (recruitment) may be impaired.

Water level in the Lower Lakes is influenced by freshwater inflows from the storages upstream in the main river channel and other small tributaries (Finniss, Bremer and Angas Rivers), and the amount of water released through the barrages to maintain environmental flows into the Coorong estuary. Estimates of mean annual water level will be derived from data recorded daily on up to twelve fixed water monitoring stations located throughout the Lakes system. Data will be obtained from the Department for Environment, Water and Natural Resources, and / or the Murray-Darling Basin Authority.

Estuarine habitat – large mesh gillnet sector

An appropriate indicator for the Estuarine LMGN sector of the fishery is the mean annual amount of habitat available for Mulloway, i.e. the key target species of the sector. Estimates of habitat availability for Mulloway will be determined based on: (i) outputs from the Coorong hydrodynamic model developed by CSIRO (Webster, 2010); and (ii) information on the salinity tolerance of Mulloway (Ye *et al.,* 2013).

The Coorong hydrodynamic model considers a broad range of input data including estimates of daily freshwater discharge through the barrages, local rainfall, wind speed and direction, sea levels (tidal data) and freshwater inflows to the Coorong from Salt Creek, to produce an estimate of salinity (ppt), for 109 locations that are distributed at 1-km intervals along the longitudinal gradient of the Coorong from the Goolwa Barrage to Salt Creek, for each day of each year (Figure 2). Daily estimates of salinity will then be used to calculate mean annual salinity for each of the 109 locations in the system. Examples of the mean salinity level at each of the 109 locations are presented for several years in Figure 33.

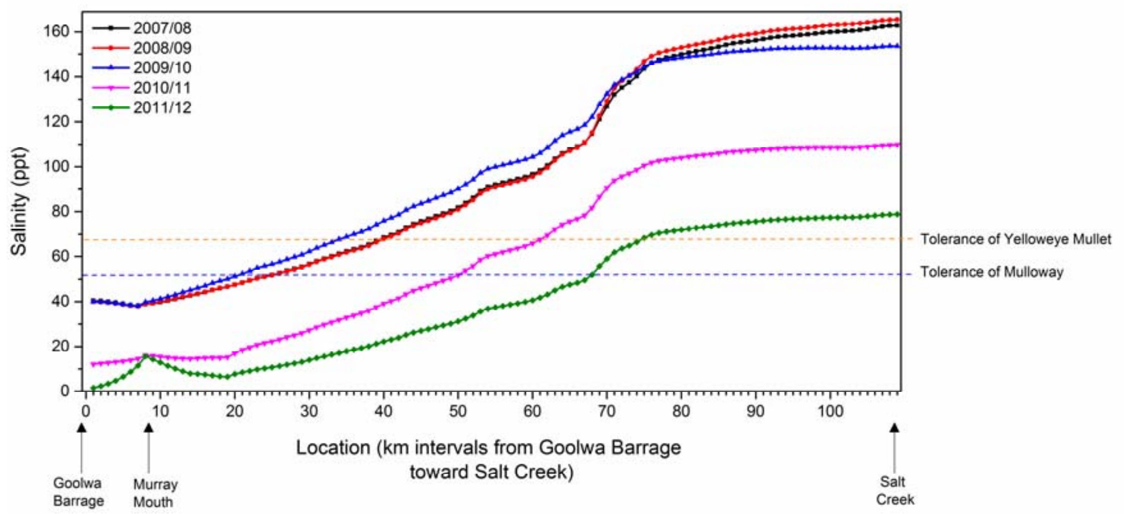

Figure 33. Mean annual salinity (ppt) estimates for each of the 109 locations (at 1-km intervals) along the longitudinal gradient of the Coorong estuary from Goolwa Barrage to Salt Creek for 2007/08, 2008/09, 2009/10 (drought years) and 2010/11, 2011/12 (flow years), as determined by the Coorong hydrodynamic model. Dashed lines indicate the salinity tolerance of Yelloweye Mullet (orange line) and Mulloway (blue line).

The salinity tolerance of Mulloway was assessed in a recent study, which examined the behavioural and stress response of the species under summer and winter temperature regimes (Ye *et al*. 2013). As part of this study, Mulloway were observed in the Coorong in salinities up to 62 ppt, although reduced feeding and increased stress levels were first observed in laboratory trials at 51 ppt. As such, a salinity threshold of 51 ppt will be used to determine what proportion of the 109 locations within Coorong (as identified by the hydrodynamic model) between the Goolwa Barrage and Salt Creek, would have provided suitable habitat (i.e. salinity levels are below or equal to 51 ppt) for Mulloway. The amount of suitable habitat available for Mulloway in each year will be presented as a percentage of the total amount of habitat in the Coorong.

Estuarine habitat – small mesh gillnet sector

An appropriate primary indicator for the Estuarine SMGN sector of the fishery is the mean annual amount of habitat available for Yelloweye Mullet, i.e. the major target species of the sector. Estimates of the amount of habitat available for Yelloweye Mullet will be determined following the same methodology described above for the Estuarine – LMGN sector. However, the recent study by Ye *et al.* (2013) demonstrated that Yelloweye Mullet are able to tolerate much higher salinity levels than Mulloway. In that study, Yelloweye Mullet were observed in the Coorong in salinities up 74 ppt, although reduced feeding and increased stress levels were first observed in laboratory trials at 68 ppt. As such, a salinity threshold of 68 ppt will be used to determine what proportion of the 109 locations within Coorong (as identified by the hydrodynamic model) between the Goolwa Barrage and Salt Creek (Figure 2), would have provided suitable habitat (i.e. salinity levels are below or equal to 68 ppt) for Yelloweye Mullet. The amount of suitable habitat available for Yelloweye Mullet in each year will be presented as a percentage of the total amount of habitat in the Coorong.

Reference points

Reference points are essentially ‘benchmarks’ of performance and are used to define acceptable levels of impact on an ecosystem, fish stock, and / or desired environmental conditions (Sloan *et al.,* 2014). For each of the primary performance indicators proposed for the LCF, three types of potential reference points were developed to indicate when the fishery reaches a situation which may require a management response. These are:

- *Target reference points* - the level of a primary performance indicator that is desirable, and at which the fishery could effectively operate within ecologically sustainable limits;
- *Trigger reference points* - the level of a primary performance indicator at which precautionary management intervention is required to address the deteriorating state of the environment; and
- *Limit reference points* - the levels of a primary performance indicator at which significant management action is required to ensure fish stocks are maintained at a level well above the point where there is an appreciable risk of recruitment failure.

Freshwater habitat – large mesh gillnet sector

The proposed primary performance indicator for the Freshwater LMGN sector is mean annual water level in the Lower Lakes. The proposed target reference point of +0.6 m AHD (Table 13) was determined based on the current operational rules for the lower Murray River (below Lock 1), which aim to manage lake levels between +0.6 m and +0.85 m AHD (Murray-Darling Basin Authority, 2014). The LCF for Golden Perch has effectively operated within ecologically sustainable limits under similar water levels in most years since at least the mid-1980s (Figure 33).

The proposed trigger reference point of -0.7 m AHD (Table 13) represents the lowest mean annual water level (2009/10) recorded in the lakes since 1984/85 (Figure 34), and a situation in the environment for which precautionary management intervention is required to address the deteriorating state of the environment. Since this environmental low point in 2009/10, the Golden Perch population in the Lower Lakes has sustained high levels of productivity and regular recruitment of young fish to the fishable biomass (Ferguson and Ye, 2012). This demonstrates that a mean annual water level of -0.7 m AHD does not present an unacceptable risk to the Golden Perch stock exploited by the LCF.

The proposed limit reference point of -1.2 m AHD represents a level of environmental deterioration that would only occur during a prolonged period of severe drought and a situation for which significant management action is required to maintain reproductive capacity for the Golden Perch population. The Golden Perch population in the Lower Lakes is part of a biological stock (spawning biomass) that extends well beyond the spatial constraints of the fishery (upstream to Renmark) (Keenan *et al*., 1995). In 2012/13, the spawning biomass in the main channel of the Murray River between the Lower Lakes and Renmark, which is fully protected from commercial fishing, comprised numerous strong age classes (Qifeng Ye, unpublished data). Thus, in a situation whereby lake levels decline to -1.2 m AHD, overall stock levels for Golden Perch are likely to be well above the point where there is an appreciable risk of recruitment failure.

Table 13. Summary of the proposed primary performance indicators and an example of target, trigger and limit reference points for the three proposed habitat/gear-based sectors of the LCF.

		Reference Points		
Sector	**Primary performance indicator**	**Target**	**Trigger**	**Limit**
Freshwater - LMGN	Water level (m - Australian Height Datum)	0.6	-0.7	-1.2
Estuarine - LMGN	Available habitat (%) for Mulloway	60	17	10
Estuarine - SMGN	Available habitat (%) for Yelloweye Mullet	55	31	10

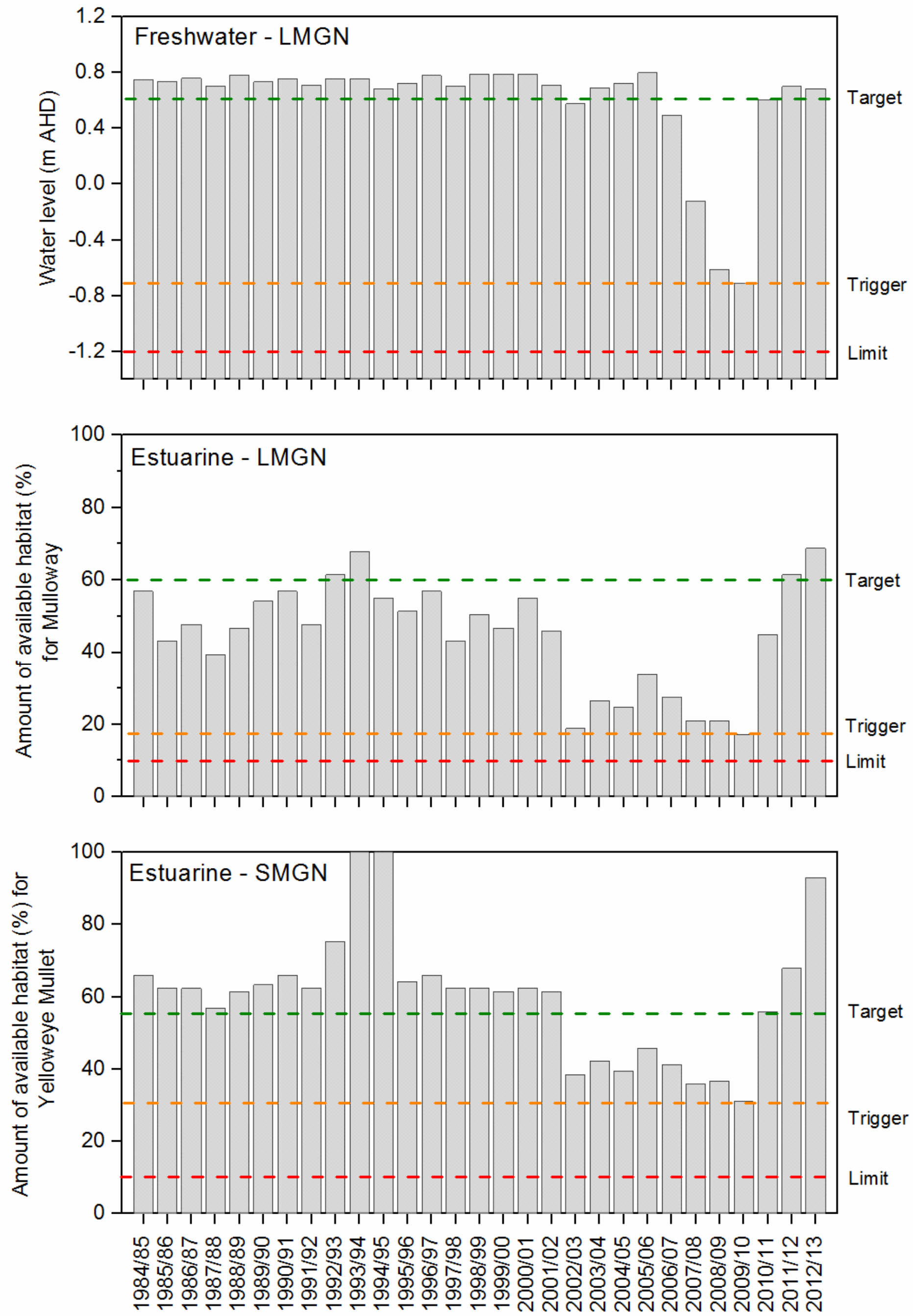

Figure 34. Time series of the three primary performance indicators developed for the three proposed habitat / gear-based sectors (Freshwater LMGN (top); Estuarine LMGN (middle); and Estuarine SMGN (bottom)) of the LCF showing the potential target (green dashed lines), trigger (orange dashed lines) and limit (red dashed lines) reference points.

Estuarine – large mesh gillnet sector

The proposed primary performance indicator for the Estuarine LMGN sector is the mean annual amount (%) of habitat available for Mulloway in the Coorong. The proposed target reference point of 60% (Table 13) represents the area of the Coorong, from Parnka Point to the Goolwa Barrage (i.e. the entire North Lagoon and the estuary; Figure 1), and a situation in the environment in which the Mulloway population has sustained high levels of fishery productivity in recent years (Earl and Ward, 2014).

The proposed trigger reference point of 17% represents the lowest level of habitat availability for Mulloway recorded in the Coorong since 1984/85, and a significant reduction in the size of the area available for fish to occupy within the spatial constraints of the fishery (Figure 34). This environmental low point occurred during the recent drought, during which time a sand dredging program was implemented to maintain the opening of the Murray Mouth. Despite the extreme environmental degradation during this period, the Mulloway population that supports the LCF has since sustained relatively high levels of productivity, regular recruitment of young fish to the fishable biomass and a spawning biomass which includes numerous relatively strong size/age classes (Earl and Ward, 2014). This demonstrates that a level of habitat availability for Mulloway of 17%, will not present an unacceptable risk to the Mulloway stock exploited by the LCF.

The proposed limit reference point of 10% represents a level of environmental deterioration that would likely occur during a prolonged period of no freshwater inflow that resulted in the closure of the Murray Mouth. Given the Mulloway population in the Coorong is part of a biological stock, of which the majority of the spawning biomass exists in areas well beyond the spatial constraints of the Estuarine LMGN sector of the LCF (Barnes *et al.,* 2014), a level of habitat availability of 10%, is likely to be well above the point where there is an appreciable risk of recruitment failure.

Estuarine – small mesh gillnet sector

The proposed primary performance indicator for the Estuarine SMGN sector is the mean annual amount (%) of habitat available for Yelloweye Mullet. The life history characteristics of this species make it far more resilient to the impacts of environmental degradation compared to long-lived, slow-growing, late maturing species such as Mulloway (Ferguson *et al.*, 2013). As such, the proposed reference points for the Estuarine – SMGN sector are slightly less precautionary compared to those developed for the Estuarine – LMGN sector.

The proposed target reference point of 55% for the Estuarine SMGN sector represents an area of habitat in the Coorong that includes the majority of North Lagoon and the estuary, and a situation in the environment in which the fishery for Yelloweye Mullet has sustained high levels of fishery production for many years (Earl and Ferguson, 2013). The proposed trigger reference point of 31% represents the lowest level of habitat availability for Yelloweye Mullet recorded in the Coorong since 1984/85, and a significant reduction in the size of the area available for fish to occupy within the spatial constraints of the fishery (Figure 34). During the late 2000s when habitat availability in the Coorong declined to 31%, the Yelloweye Mullet population maintained high levels of fishery productivity, with regular recruitment of young fish to the fishable biomass and a spawning biomass that comprised numerous relatively strong size/age classes (Earl and Ferguson, 2013). This demonstrates that a level of habitat availability for Yelloweye Mullet of 31%, will not present an unacceptable risk to the Yelloweye Mullet stock exploited by the LCF.

The proposed limit reference point of 10% represents a level of environmental deterioration that would likely only occur during a prolonged period of no freshwater inflows that resulted in the closure of the Murray Mouth. The sand dredging program implemented during the recent drought period successfully maintained the opening of the Murray Mouth and level of habitat availability for Yelloweye Mullet above 31%.

Given the Yelloweye Mullet population in the Coorong is part of a biological stock, of which the majority of the spawning biomass exists in areas well beyond the spatial constraints of the Estuarine SMGN sector of the LCF (Thomson 1957), a level of habitat availability of 10%, is likely to be well above the point where there is an appreciable risk of recruitment failure.

Decision rules

For each primary performance indicator, a set of potential decision rules were developed to set out management actions to be taken when a target, trigger or limit reference point is reached. The proposed decision rules involve staged adjustment to TACE for each habitat / gear-based sector of the fishery in relation to the proposed target, trigger or limit reference points (Table 13).

Decision rules were developed based primarily on relationships between annual performance indicator values and annual fishing effort for the period from 1984/85 to 2012/13. The rationale for this approach was based on evidence compiled in recent fishery assessment reports (Ferguson and Ye, 2012; Earl and Ferguson, 2013; Earl and Ward, 2014) that indicate that historical levels of fishing pressure applied to stocks of key species (i.e. Mulloway, Yelloweye Mullet and Golden Perch) relative to the state of the environment, have been sufficient to maintain the capacity for future high levels of fishery and biological productivity and ensure stock levels remain well above the point at which reproductive capacity (recruitment) may be impaired. This section of the report discusses the usefulness of three effort units (fishing days, net units and net-days) available for setting / adjustment of the TACE, and presents several examples of potential decision rules for each sector of the fishery.

Effort units available for setting and adjustment of the TACE

Three types of effort units are available to govern the intensity of fishing pressure in each year through adjustment of the TACE. These are: (i) fishing days; (ii) net units; and (iii) net-days. For the three habitat / gear-based sectors of the fishery, the time series of annual fishing effort, in terms of fishing days, net units and net-days, from 1984/85 to 2012/13 is presented in Figure 35.

The time series for each effort unit is presented in two ways, i.e. *reported* and *entitlement*, to demonstrate how reported levels of effort compare to permitted levels of effort in each year. Estimates of annual *entitlement* effort assume that on each reported fishing day, licence holders that fished deployed their full entitlement of gillnets. To account for differences in the way licence holders reported effort (i.e. most fishers appear to have reported accurately, while others appear to have consistently reported their full entitlement of nets on each fishing day), estimates of annual *reported* effort were determined, based on the sum of the total number of gillnets deployed by fishers whom reported properly, and an interpolated estimate of the total number of nets deployed by fishers whom appeared to have reported incorrectly. Information on the gillnet entitlement for each licence was not available for the period 1984/85 to 1997/98, thus all annual estimates of fishing effort in net units and net-days for that period, were based on their gillnet entitlement in 1998/99 (Figure 35).

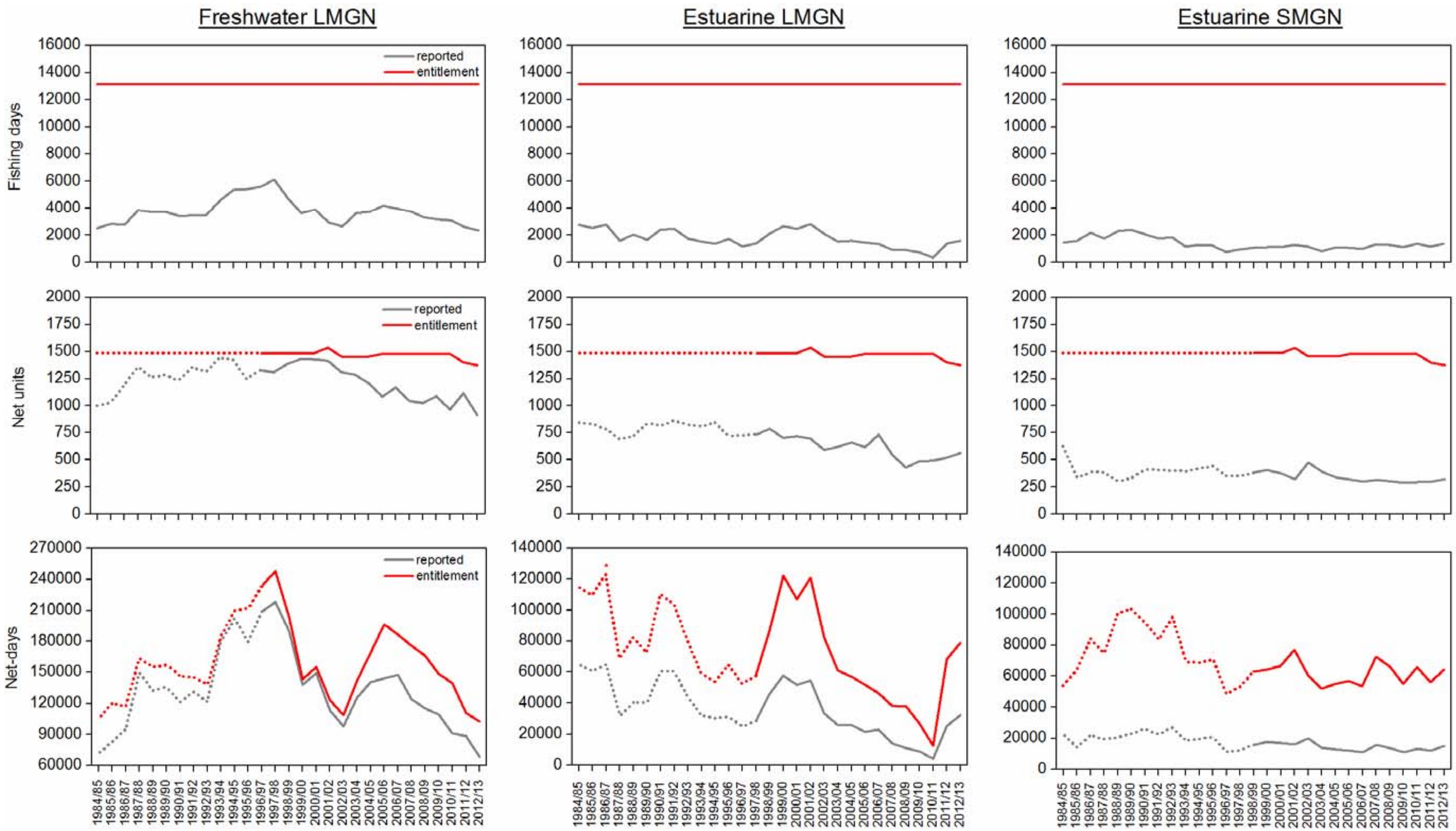

Figure 35. Annual time series of the three types of effort units (fishing days (top); net units (centre); net-days (bottom)) in each gillnet sector of the LCF, i.e. Freshwater – large mesh gillnets (left); Estuarine – large mesh gillnets (centre); and Estuarine – small mesh gillnets (right) from 1984/85 to 2012/13. Each unit of effort is presented in terms of the full entitlement of effort and reported effort, to demonstrate the proportion of the TACE actually utilised by the fishery. Annual net entitlement data was not available from 1984/85 to 1997/98, thus all annual estimates for that period are based on the gillnet entitlements for 1998/99 (dotted lines).

Comparisons between the inter-annual trends for *reported* effort and *entitlement* effort highlight the potential fishing capacity of the fishery in each sector (Figure 35). Since 1984/85, the number of fishing days reported in the Freshwater LMGN, Estuarine LMGN and SMGN sectors of the fishery accounted for, on average, approximately 29%, 13% and 10% of the total annual number of fishing days available in each sector, respectively. In terms of net units, on average, fishers using LMGN in the Freshwater habitat deployed approximately 81% of their full entitlement of nets on each fishing day (Figure 35); those fishing with LMGN in the Estuarine habitat deployed approximately 42% of their full entitlement of nets on each fishing day; and those fishing with SMGN in the Estuarine habitat deployed approximately 23% of their full entitlement of nets on each fishing day (Figure 35).

Based on these results, effort controls using fishing days would be relatively ineffective, as this unit of effort does not account for the number of nets that may be deployed on each fishing day. Similarly, limitations on the number of net units an individual licence holder can deploy on each fishing day is also unlikely to be an effective management unit for effort control, as it would not account for the variation among fishers in the number of days fished in a year and may limit the operational flexibility of individual licence holders. In contrast, effort controls using net-days would account for all gillnets that are deployed, and maintain operational flexibility around the number of days a licence holder can fish in each year and the number of gillnets that can be deployed on each fishing day.

Key Message 11. Net-days is the most appropriate unit of effort for controlling fishing mortality compared to fishing days or net units, as it accounts for all gillnets that are deployed, and would maintain operational flexibility around the number of days a licence holder can fish and the number of nets that can be deployed on each fishing day.

Development of potential decision rules

For each of the proposed habitat / gear-based sectors, a set of potential decision rules was developed for each unit of effort (fishing days, net units and net-days), to define management actions that could be taken when a target, trigger or limit reference point is breached. The proposed decision rule framework involves staged adjustments to the TACE based on annual performance indicator values and the proposed target, trigger and limit reference points (Table 13). Under the proposed framework, several staged adjustments would occur from a maximum (100%) TACE, when primary performance indicator values are above the target reference point, to a situation where the sector would be forced to close when performance indicator values are below the limit reference point (Figure 36). Such a management approach is consistent with the national guidelines for the development of fishery harvest strategies (Sloan *et al.* 2014)

The development of each set of decision rules was based primarily on the relationship between annual primary performance indicator values and fishing effort reported in daily commercial fishery logbooks from 1984/85 to 2012/13. For each sector, the maximum (100%) TACE (for the three units of effort) was determined based on the maximum annual level of fishing effort recorded in the sector over the past 15–20 years (Figure 35), as such levels have been sufficient to maintain capacity for future high levels of fishery and biological productivity for key species.

Under the proposed decision rule framework, the rate of the staged adjustments to the TACE as primary performance indicator values falls to between the target and trigger reference points was determined based on a regression line for the historical relationship between the performance indicator value and annual effort (Figure 36). This approach was also used to define the rate of staged adjustments to the TACE when indicator value lie between the trigger and limit reference points. However, as the latter situation would require more severe management response to alleviate fishing pressure on fish stocks, a more precautionary regression line with the same slope yet lower y-intercept value was adopted (Figure 36). In cases where no significant linear relationship between performance indicator values and effort was detected, two hypothetical 'regression' lines (one more precautionary than the other) were drawn through the data points to provide reasonable rate of staged adjustment to the TACE from 100%, to the point at which the sector would be closed.

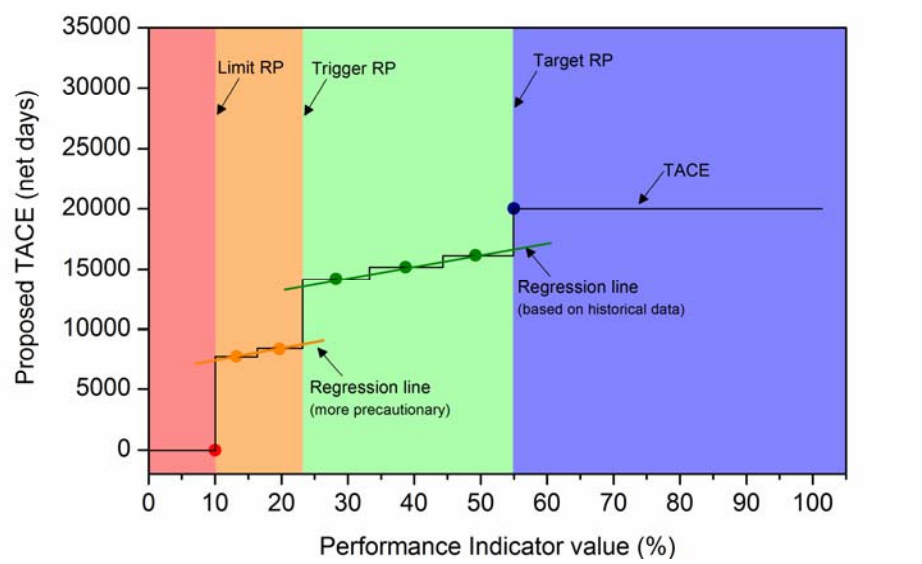

Figure 36. Schematic showing the two-tiered regression line approach used to determine the rate of the staged adjustments of the TACE (black line) when the performance indicator values lie between the target and trigger reference points (RP) (green regression line; green shaded zone) and between the trigger and limit reference points (orange regression line; orange shaded zone).

Examples of potential decision rules for the three units effort

Fishing days

<u>Freshwater – large mesh gillnets</u>

Since 1984/85, annual fishing effort in fishing days in the Freshwater LMGN sector has ranged between ~2,350 fishing days in 2012/13 and ~6,000 fishing days in the late 1990s (Figure 35). There was no significant linear relationship (LR: r^2 = 0.03, $F_{1,28}$ = 0.70, P = 0.41) between effort in fishing days and mean annual water level in the Lakes (primary performance indicator), from which decision rules could be directly derived (Figure 37).

The following example of a set of potential decision rules that could be applied to this sector to control effort using fishing days is structured around the proposed reference points, and the maximum level of effort recorded in the sector of ~6,000 fishing days (Table 14). The proposed rate of the staged adjustments to the TACE when mean annual water level is between the target and trigger reference points is based on a hypothetical regression line drawn through the historical data points (Figure 37). A more precautionary hypothetical regression line was used to determine the rate of adjustment between the trigger and limit reference points.

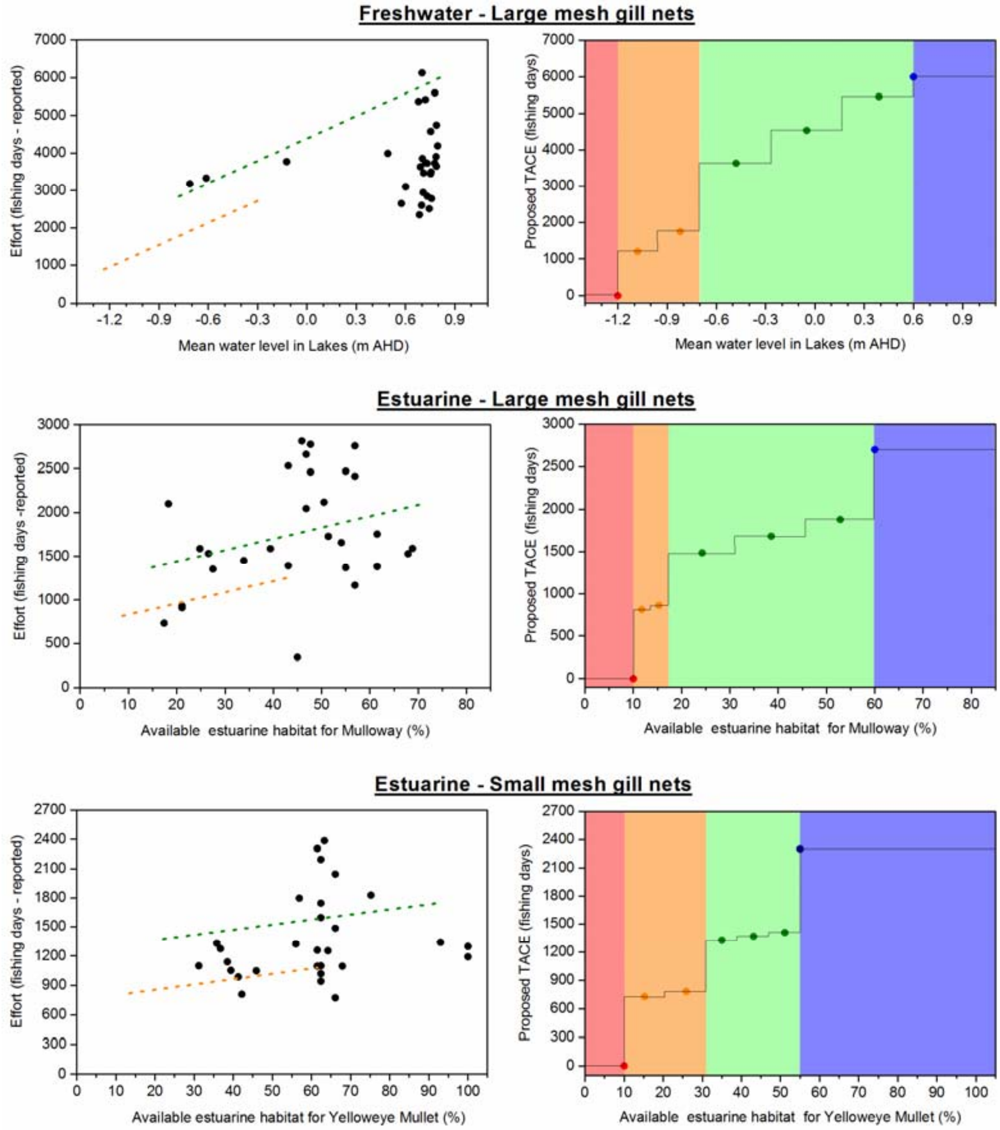

Figure 37. LEFT - Relationships between annual primary performance indicator values and fishing effort (net units) for the three sectors of the fishery for the period from 1984/85 to 2012/13 (left hand side). Where a significant linear relationship was detected, a non-broken green regression line is shown. The broken lines represent the hypothetical regression lines used to determine the rate of the staged adjustments of the TACE when the Indicator values are between the target and trigger (green broken line) reference points and the trigger and limit (orange broken line) reference points. RIGHT - The proposed staged adjustments of the TACE based on the examples of decision rules for each sector.

Table 14. The proposed decision rules for the Freshwater – large mesh gillnet sector of the LCF involving staged adjustments to the TACE in fishing days, based on mean annual water level in the Lakes (m AHD) and the reference points proposed in Table 13.

	If mean annual water level (m AHD) in the Lakes is :	TACE setting
(blue)	Above +0.6 m	6,000 fishing days
(green)	Between +0.17 m and +0.6 m	5,460 fishing days
(green)	Between -0.26 m and 0.16 m	4,550 fishing days
(green)	Between -0.7 m and -0.27 m	3,630 fishing days
(amber)	Between -0.9 m and -0.71 m	1,750 fishing days
(amber)	Between -1.2 m and -0.91 m	1,200 fishing days
(red)	Below -1.2 m	Closure of sector

Estuarine– large mesh gillnets

Since 1984/85, annual fishing effort in fishing days in the Estuarine LMGN sector ranged between ~350 days and ~2,700 fishing days (Figure 35). There was no significant relationship between fishing effort in fishing days and the amount of estuarine habitat available for Mulloway (primary performance indicator) (LR: $r^2 = 0.1$, $F_{1,28} = 2.99$, $P = 0.095$) from which decision rules could be directly derived (Figure 37).

The following example of a set of potential decision rules that could be applied to this sector to control fishing effort using fishing days is structured around the proposed reference points, and the maximum level of effort recorded in the sector of ~2,700 fishing days (Table 15). The proposed rate of staged adjustments to the TACE when habitat availability is between the target and trigger reference points is based on a hypothetical regression line drawn through the historical data (Figure 37). A more precautionary hypothetical regression line was used to determine the adjustments between the trigger and limit reference points.

Table 15. The proposed decision rules for the Estuarine – large mesh gillnet sector of the LCF involving staged adjustments to the TACE in fishing days, based on amount of estuarine habitat available for Mulloway (%) and the reference points proposed in Table 13.

	If the amount of estuarine habitat available for Mulloway is :	TACE setting
(blue)	Above 60%	2,700 fishing days
(green)	Between 45.7% and 60%	1,880 fishing days
(green)	Between 31.5% and 45.6%	1,680 fishing days
(green)	Between 17.1% and 31.4%	1,480 fishing days
(amber)	Between 13.6% and 17%	860 fishing days
(amber)	Between 10% and 13.5%	810 fishing days
(red)	Below 10%	Closure of sector

Estuarine – small mesh gillnets

Since 1984/85, annual fishing effort in the Estuarine SMGN sector has varied between 770 fishing days in 1996/97 and ~2,300 fishing days in the late 1980s (Figure 35). There was no significant relationship between fishing effort in fishing days and the amount of estuarine habitat available for Yelloweye Mullet (primary performance indicator) (LR: r^2 = 0.12, $F_{1,28}$ = 4.74, P = 0.068) from which decision rules could be directly derived (Figure 37).

The following example of a set of potential decision rules that could be applied to this sector to control fishing effort using fishing days is structured around the proposed reference points, and the maximum level of effort recorded in the sector of ~2,300 fishing days (Table 16). The proposed rate of staged adjustments to the TACE when habitat availability is between the target and trigger reference points is based on a hypothetical regression line drawn through the historical data (Figure 36), while a more precautionary hypothetical regression line was used to determine the rate of the proposed adjustments between the trigger and limit reference points.

A comparison of historical levels of fishing effort in fishing days and the proposed TACE based on the decision rule framework example for fishing days is shown in Appendix 2.

Table 16. The proposed decision rules for the Estuarine – small mesh gillnet sector of the LCF involving staged adjustments to the TACE in fishing days, based on amount of estuarine habitat available for Yelloweye Mullet (%) and the reference points proposed in Table 13.

	If the amount of estuarine habitat available for Yelloweye Mullet is :	TACE setting
	Above 55%	2,300 fishing days
	Between 47.1% and 55%	1,350 fishing days
	Between 39.1% and 47%	1,390 fishing days
	Between 31.1% and 39%	1,340 fishing days
	Between 20.6% and 31%	800 fishing days
	Between 10% and 20.5%	765 fishing days
	Below 10%	Closure of sector

Net units

Freshwater – large mesh gillnets

From 1984/85 to 2012/13, annual fishing effort in net units in the Freshwater LMGN sector ranged between ~900 net units in 2012/13 and ~1450 net units in the early 1990s (Figure 35). There was no significant linear relationship (LR: r^2 = 0.09, $F_{1,28}$ = 2.12, P = 0.071) between effort in net units and mean annual water level in the Lakes (primary performance indicator), from which decision rules could be directly derived (Figure 38).

The following example of a set of potential decision rules that could be applied to this sector to control fishing effort in net units is structured around the proposed reference points, and the total number of gillnets permitted for use in the sector in 2013/14 (i.e. 1,250 net units) (Table 17). The proposed rate of staged adjustments to the TACE when mean annual water level is between the target and trigger reference points is based on a hypothetical regression line drawn through the historical data (Figure 38), while a more precautionary hypothetical regression line was used to determine the rate of adjustment between the trigger and limit reference points.

Table 17. The proposed decision rules for the Freshwater – large mesh gillnet sector of the LCF involving staged adjustments to the TACE in net units, based on mean annual water level in the Lakes (m AHD) and the reference points proposed in Table 13.

	If mean annual water level (m AHD) in the Lakes is :	TACE setting
	Above +0.6 m	1,250 net units
	Between +0.17 m and +0.6 m	1,140 net units
	Between -0.26 m and 0.16 m	950 net units
	Between -0.7 m and -0.27 m	760 net units
	Between -0.9 m and -0.71 m	365 net units
	Between -1.2 m and -0.91 m	250 net units
	Below -1.2 m AHD	Closure of sector

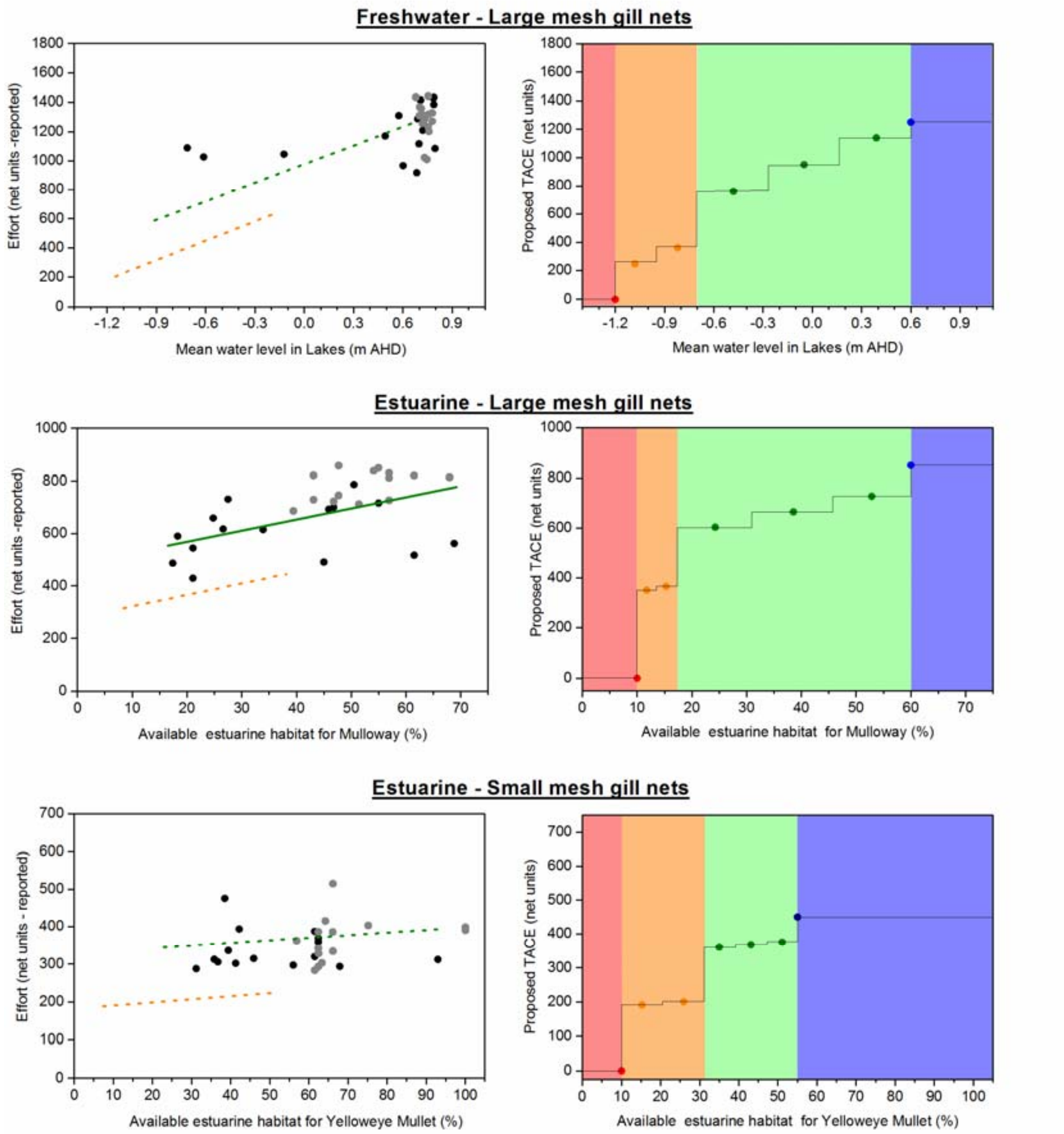

Figure 38. LEFT - Relationships between annual primary performance indicator values and fishing effort (net units) for the three sectors of the fishery for the period from 1984/85 to 2012/13 (left hand side). Where a significant linear relationship was detected, a non-broken green regression line is shown. The broken lines represent the hypothetical regression lines used to determine the rate of the staged adjustments of the TACE when the Indicator values are between the target and trigger (green broken line) reference points and the trigger and limit (orange broken line) reference points. RIGHT - The proposed staged adjustments of the TACE based on the examples of decision rules for each sector.

Estuarine – large mesh gillnets

Since 1984/85, annual fishing effort in net units in the Estuarine LMGN sector ranged between ~420 net units in 2008/09 and ~850 net units in the early 1990s (Figure 35). There was a significant linear relationship between annual fishing effort in net units, and the amount of estuarine habitat available (%) for Mulloway (primary performance indicator) (LR: r^2 = 0.28, $F_{1,28}$ = 10.5, P = 0.003) from which the decision rules could be derived (Figure 38).

The following example of a set of potential decision rules that could be applied to this sector to control fishing effort in net units is structured around the proposed reference points, and the maximum level of effort recorded in the sector of ~850 net units (Table 18). The proposed rate of the staged adjustments to the TACE when habitat availability is between the target and trigger reference points is based on the regression line for the historical relationship between effort and habitat availability shown in Figure 38, while a more precautionary regression line was used to determine the adjustments between the trigger and limit reference points.

Table 18. The proposed decision rules for the Estuarine – large mesh gillnet sector of the LCF involving staged adjustments to the TACE in net units, based on amount of estuarine habitat available for Mulloway (%) and the reference points proposed in Table 13.

	If the amount of estuarine habitat available for Mulloway is :	TACE setting
	Above 60%	850 net units
	Between 45.7% and 60%	725 net units
	Between 31.5% and 45.6%	665 net units
	Between 17.1% and 31.4%	605 net units
	Between 13.6% and 17%	365 net units
	Between 10% and 13.5%	350 net units
	Below 10%	Closure of sector

Estuarine – small mesh gillnets

Since 1984/85, annual fishing effort in the Estuarine SMGN sector has varied between ~280 net units and ~450 net units during the early 2000s (Figure 35). There was no significant relationship between fishing effort in fishing days and the amount of estuarine habitat available for Yelloweye Mullet (primary performance indicator) (LR: r^2 = 0.04, $F_{1,28}$ = 1.26, P = 0.272) from which decision rules could be directly derived (Figure 38).

The following example of a set of potential decision rules that could be applied to this sector to control fishing effort in net units is structured around the proposed reference points, and the maximum level of effort recorded in the sector of ~450 net units (Table 19). The proposed rate of the staged adjustments to the TACE when habitat availability is between the target and trigger reference points is based on a hypothetical regression line drawn through the historical data (Figure 38), while a more precautionary regression line was used to determine the rate of adjustment between the trigger and limit reference points.

A comparison of historical levels of fishing effort in net units and the proposed TACE based on the decision rule framework example for net units is shown in Appendix 2.

Table 19. The proposed decision rules for the Estuarine – small mesh gillnet sector of the LCF involving staged adjustments to the TACE in net units, based on amount of estuarine habitat available for Yelloweye Mullet (%) and the reference points proposed in Table 13.

	If the amount of estuarine habitat available for Yelloweye Mullet is :	TACE setting
	Above 55%	450 net units
	Between 47.1% and 55%	375 net units
	Between 39.1% and 47%	368 net units
	Between 31.1% and 39%	360 net units
	Between 20.6% and 31%	200 net units
	Between 10% and 20.5%	190 net units
	Below 10%	Closure of sector

Net-days

Freshwater – large mesh gillnets

Annual fishing effort in net-days in the Freshwater LMGN sector ranged between ~68,000 net-days in 2012/13 and ~190,000 net-days in the mid-1990s (Figure 35). There was no significant linear relationship (LR: r^2 = 0.03, $F_{1,28}$ = 1.01, P = 0.323) between effort in net-days and mean annual water level in the Lakes (primary performance indicator) from which decision rules could be directly derived (Figure 39).

The following example of a set of potential decision rules that could be applied to this sector to control fishing effort in net-days is structured around the proposed reference points, and the maximum level of effort recorded in the sector since the mid-1990s of ~190,000 net-days (Table 20). The proposed rate of the staged adjustments to the TACE when the mean annual water level is between the target and trigger reference points is based on a hypothetical regression line drawn through the historical data, while a more precautionary hypothetical regression line was used to determine the rate of adjustment between the trigger and limit reference points (Figure 39).

Table 20. The proposed decision rules for the Freshwater – large mesh gill-net sector of the LCF involving staged adjustments to the TACE in net-days, based on mean annual water level in the Lakes (m AHD) and the reference points proposed in Table 13.

	If mean annual water level (m AHD) in the Lakes is :	TACE setting
	Above +0.6 m	190,000 net-days
	Between +0.17 m and +0.6 m	173,000 net-days
	Between -0.26 m and 0.16 m	143,650 net-days
	Between -0.7 m and -0.27 m	115,000 net-days
	Between -0.9 m and -0.71 m	55,400 net-days
	Between -1.2 m and -0.91 m	38,000 net-days
	Below -1.2 m AHD	Closure of sector

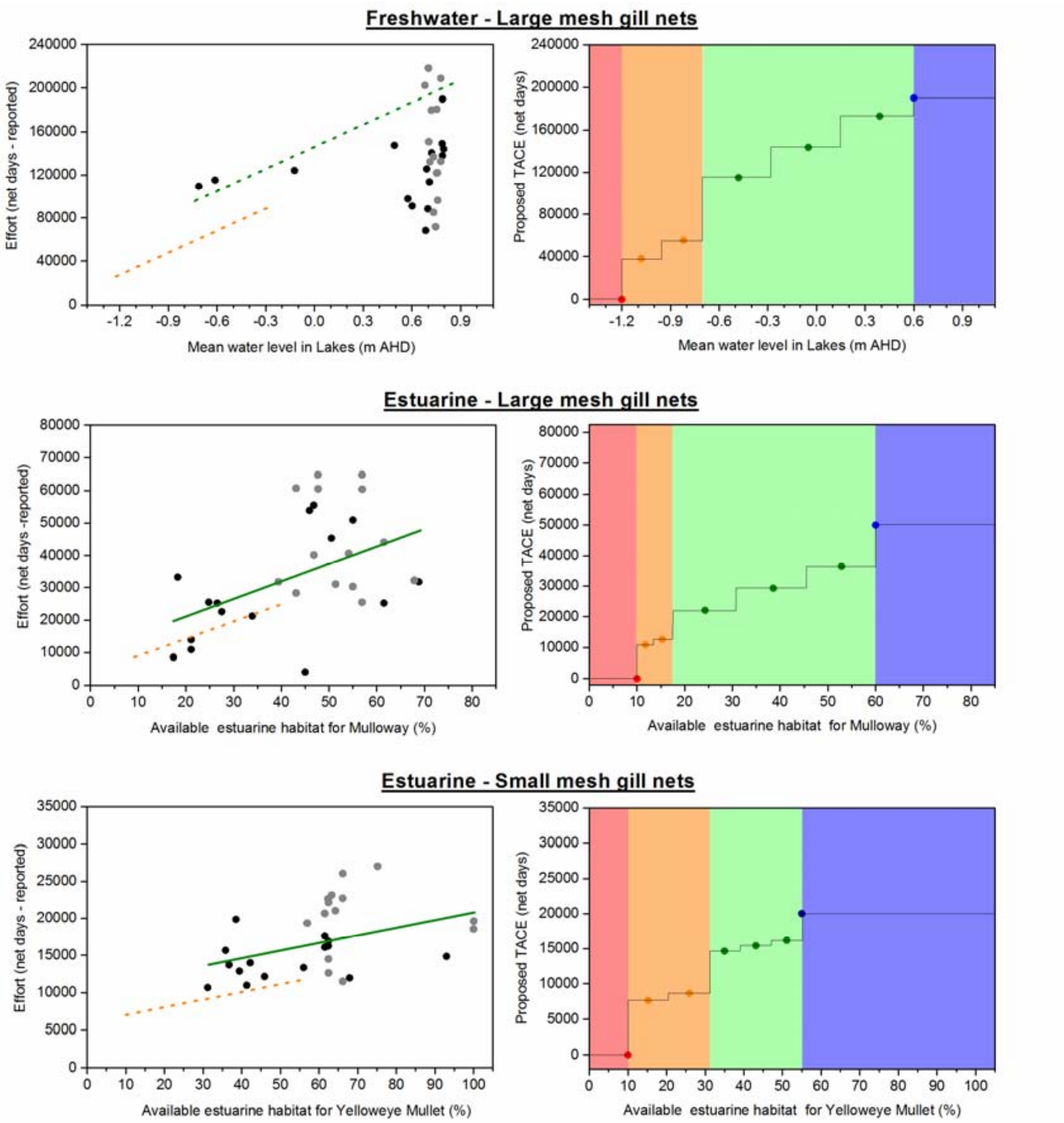

Figure 39 LEFT - Relationships between annual primary performance indicator values and fishing effort (net units) for the three sectors of the fishery for the period from 1984/85 to 2012/13 (left hand side). Where a significant linear relationship was detected, a non-broken green regression line is shown. The broken lines represent the hypothetical regression lines used to determine the rate of the staged adjustments of the TACE when the Indicator values are between the target and trigger (green broken line) reference points and the trigger and limit (orange broken line) reference points. RIGHT - The proposed staged adjustments of the TACE based on the examples of decision rules for each sector.

Estuarine– large mesh gillnets

Annual fishing effort in net-days in the Estuarine LMGN sector has ranged between ~4,000 net-days in 2010/11 (during the drought) and ~60,000 net-days in several years during the 1980s, and has not exceeded 55,000 net-days since the early 1990s (Figure 35). There was a significant linear relationship between annual fishing effort in net-days and the amount of estuarine habitat available (%) for Mulloway (primary performance indicator) (LR: $r^2 = 0.22$, $F_{1,28} = 7.45$, P = 0.011) from which the decision rules could be derived (Figure 39).

The following example of a set of potential decision rules that could be applied to this sector to control fishing effort in net-days is structured around the proposed reference points, and the approximate maximum level of effort recorded in the sector since the early 1990s of 50,000 net-days (Table 21). The rate of the staged adjustments to the TACE when habitat availability is between the target and trigger reference points is based on the regression line for the historical relationship between effort and habitat availability shown in Figure 39, while a more precautionary regression line was used to determine the adjustments between the trigger and limit reference points.

Table 21 The proposed decision rules for the Estuarine – large mesh gillnet sector of the LCF involving staged adjustments to the TACE in net-days, based on amount of estuarine habitat available for Mulloway (%) and the reference points proposed in Table 13.

	If the amount of estuarine habitat available for Mulloway is :	TACE setting
	Above 60%	50,000 net-days
	Between 45.7% and 60%	36,425 net-days
	Between 31.5% and 45.6%	29,750 net-days
	Between 17.1% and 31.4%	22,125 net-days
	Between 13.6% and 17%	12,625 net-days
	Between 10% and 13.5%	10,875 net-days
	Below 10%	Closure of sector

Estuarine – small mesh gillnets

Over the past 20 years, annual fishing effort in net-days in the Estuarine SMGN sector has ranged between ~10,000 net-days in 2009/10 and ~20,000 net-days in 2002/03 (Figure 35). There was a significant linear relationship between annual fishing effort in net-days and the amount of estuarine habitat available (%) for Yelloweye Mullet (primary performance indicator) (LR: $r^2 = 0.15$, $F_{1,28} = 4.74$, $P = 0.038$) from which the decision rules could be derived (Figure 39).

The following example of a set of potential decision rules that could be applied to this sector to control fishing effort in net-days is structured around the proposed reference points, and the approximate maximum level of effort recorded in the sector since the 1990s of 20,000 net-days (Table 22). The rate of the staged adjustments to the TACE when habitat availability is between the target and trigger reference points is based on the regression line for the historical relationship between effort and habitat availability shown in Figure 39, while a more precautionary regression line was used to determine the adjustments between the trigger and limit reference points.

A comparison of historical levels of fishing effort in net-days and the proposed TACE based on the decision rule framework example for net-days is shown in Appendix 2.

Table 22 The proposed decision rules for the Estuarine – small mesh gillnet sector of the LCF involving staged adjustments to the TACE in net-days, based on amount of estuarine habitat available for Yelloweye Mullet (%) and the reference points proposed in Table 13.

	If the amount of estuarine habitat available for Yelloweye Mullet is :	TACE setting
(blue)	Above 55%	20,000 net-days
(green)	Between 47.1% and 55%	16,155 net-days
(green)	Between 39.1% and 47%	15,395 net-days
(green)	Between 31.1% and 39%	14,625 net-days
(amber)	Between 20.6% and 31%	8,655 net-days
(amber)	Between 10% and 20.5%	7,650 net-days
(red)	Below 10%	Closure of sector

Assessment and reporting of performance indicators

Primary performance indicators will be reported and assessed against associated reference points in two types of reports. One of these will be an annual fishery performance report that: (i) assesses primary performance indicators against their associated reference points; (ii) presents a historical summary of the commercial and recreational fishery statistics for key finfish species harvested in LCF; and (iii) considers the recent performance of the fishery by presenting the secondary performance indicators (excluding age composition) for key finfish species from the previous year.

The second of these reports will be a detailed ecosystem-based assessment report produced once every three years for each of three habitat / gear-based sectors of the fishery, providing a triennial reporting cycle upon which the overall performance of each sector and the status of key fish stocks will be assessed. In addition to the information presented in the annual fishery performance report, the ecosystem-based assessment report will include: (i) a detailed analysis of fishery performance, including assessment of fishery statistics for the dominant and non-dominant gear types used to target key species in the fishery; (ii) a review of all biological and ecological research relevant to key species and the Fishery; (iii) the findings of strategic research projects relevant to each sector of the fishery, including fishery-dependent and fishery-independent assessments of fish assemblage structure and where possible, the population size and age structures for key species; and (iv) a weight-of-evidence approach to determine the stock status for individual key species. A detailed scientific interpretation of all results presented in this report will be provided to address all relevant primary and secondary indicators.

The periodic, ecosystem-based fishery assessments will also be used to evaluate the suitability of the proposed primary performance indicators as surrogate metrics for population biomass for key species, and review the effectiveness of the proposed reference points and associated decision rule framework for controlling exploitation to levels that ensure the future sustainability of key fish stocks. Management implications, including potential changes to the management framework, and future research needs would also be identified.

Conclusions

The Lakes and Coorong Fishery operates in multiple habitats that are subject to large variations in environmental flow associated with the drought and flood cycles of the Murray River. Not only does this have a large impact on the species composition and abundance of finfish resources available to the commercial fishery, but the fishery needs to be able to control fishing effort to sustainable levels under these various environmental conditions. In a data-poor, small-scale, multi-species, multi-method, community-based fishery, there are insufficient resources to conduct multiple quantitative stock assessments, ecosystem modelling or bio-economic evaluations to underpin sound commercial fisheries management. Instead, similar outcomes may be achieved through the development of an appropriate management framework that recognises environmental, economic and social fishery objectives and is supported by a pragmatic approach to the development of harvest strategies.

In this project we re-examined potential management frameworks that could be applied to the LCF. We found that through close examination of the catch and effort data, information on the environment in which the fishery operates, and open discussion with stakeholders about their requirements and expectations, we were able to suggest an appropriate management framework and harvest strategies that are likely to be a significant improvement on that currently operating. The current Management Plan suffers from a lack of target and limit reference points, quantitative indicators, and rules to control the level of exploitation. From an economic and business perspective, there are existing regulations limiting the activities of fishers that could be simplified and a lack of licence transfer flexibility that is affecting business restructuring.

This project developed a management framework and harvest strategy options that could be responsive to, and effectively control effort in, a fishery operating in multiple habitats that are impacted differently by large and long-term changes in environmental flows. Various options for the implementation of effort control were explored, and the positives and negatives of each were explained.

In the absence of quantitative stock assessment models for key species of the LCF, an environmental (habitat-based) performance indicator was developed for each of the three proposed habitat / gear-based sectors of the fishery — Freshwater large-mesh gillnet, Estuarine large-mesh gillnet and Estuarine small-mesh gillnet. The environmental indicators were developed as surrogate metrics for stock biomass for key species within each sector, based on the fact that historical levels of fishing mortality — which has typically varied in relation to the condition of the environment — have effectively maintained sustainability for key species over a long period. Quantitative target, trigger and limit reference points were then developed to identify situations in the environment for which a management response is required to control fishing mortality to a sustainable level. Finally, historical relationships between annual fishing effort and habitat availability for each sector were used to develop a series of decision rules to define management actions to be taken when a target, trigger or limit reference point is breached.

For each sector, the proposed decision rule framework involves annual staged adjustments to the TACE to control fishing effort. For each sector, the maximum

(100%) TACE was determined based on the maximum annual level of fishing effort recorded over the past 15–20 years, as such levels effectively maintained sustainability. The rate of the staged adjustments to the TACE when the level of habitat availability is between target and trigger reference points was determined based on a regression line for the historical relationship between the performance indicator value and annual effort. This approach was also used to define the rate of staged adjustments to the TACE when the indicator value lies between the trigger and limit reference points. However, as the latter situation would require more severe management response to alleviate fishing pressure on fish stocks, a more precautionary regression line was adopted.

Three types of effort units are available to govern the intensity of fishing pressure in each year through adjustment of the TACE. These are: (i) fishing days; (ii) net units; and (iii) net-days. Of these, only the use of net-days would be effective at controlling fishing mortality to maintain sustainability as it accounts for all gillnets that are deployed. Furthermore, effort controls using net-days would maintain operational flexibility around the number of days a licence holder can fish and the number of nets that can be deployed on each fishing day — an important requirement of new harvest strategy for the Fishery

The effectiveness of the proposed assessment and decision rule framework for maintaining sustainability in the Fishery should be comprehensively reviewed as part of a detailed ecosystem-based assessment, undertaken once every three years, for each of three habitat / gear-based sectors of the fishery. Such assessments should compile a range of environmental, ecological and species-specific demographic information to support a comprehensive, weight-of-evidence assessment of stock status for individual key species. Management implications, including potential changes to the management framework, should also be considered as part these periodic assessment reports.

The management frameworks and harvest strategy options developed in this project can be implemented at relatively low cost, without the need for additional data collection or expensive stock assessments. Importantly, the approach adopted here for application in the LCF could be easily applied to other data-poor, small-scale, multi-species, multi-method, community-based fisheries around Australia.

Implications

This project has been conducted in association with representative bodies for commercial fishers in the LCF (the Southern Fishermen's Association), PIRSA and SARDI. Outcomes of this project are being incorporated into the 2015 commercial LCF Fishery Management Plan. It is anticipated that changes in the Management Plan resulting from this project will lead to increased performance of the LCF, which can only be assessed after implementation for the new plan.

Recommendations

The scope of this project was to develop a management framework and harvest strategy for the LCF that could be applied to other data-poor small-scale, multi-species, multi-method, community-based fisheries. The outputs of this project will be used to improve the management of the LCF and will be directly incorporated into the development of harvest strategies for finfish species under the new Fishery Management Plan due in 2015. What remains to be done is to conduct a formal management strategy evaluation to determine that it is likely to meet the expected environmental, economic and social objectives of the fishery. In addition, consideration should be given to changing fisheries reporting to capture finer scale data than is currently reported.

Age composition of fish may be a useful secondary performance indicator, as it can be an important determinant of fishery status, particularly for long-lived species such as Mulloway, Golden Perch and Black Bream. Collection of otoliths will be maintained, and it is recommended that investigation is undertaken to potential inclusion of those data as primary performance indicators with reference points.

Using the capacity of the Australian Fisheries Management Forum, the process adopted for the development of fishery management frameworks and harvest strategies for the LCF, will be made available to other jurisdictions to support fishery management improvement in other small-scale, multi-species, multi-method community-based fisheries.

Extension and Adoption

Consultation discussions have been held with the Southern Fishermen's Association as the representative body for commercial finfish fishers in the LCF. Industry and PIRSA have agreed to work together to use the LCF as a case study to develop a framework and appropriate performance indicators for small-scale, multi-species, multi-method community-based fisheries and to determine an operational management mechanism to facilitate flexible and adaptive fishery structures that are more responsive to management drivers. The Lakes and Coorong Management Plan Steering Committee (a sub-committee of The Fisheries Council of South Australia) has endorsed this project to improve the performance of the Fishery, and to assist in the development of new and innovative harvest strategies to be adopted for finfish species under the new Fishery Management Plan due in 2015. PIRSA has consulted with FRDC on the ability to utilize outcomes of this project in a national context.

The final report will be made available to the broader fishing industry via the Australian Fisheries Management Forum. The Forum has networks established to ensure that stakeholders (including fisheries managers) of small-scale, multi-species, multi-method community-based fisheries are informed about this project and can access the final report.

Other extension activities will include submitting abstracts for oral presentations for the Australian Society for Fish Biology, Australian Marine Sciences Association and Seaford Directions conference and any fisheries management forums that may arise. Further, we have been invited to submit a paper for the Special Issue of Fisheries Research on "Fishery Systems in Australia and New Zealand: Success and Challenges".

Abbreviations

AHD	Australian Height Data
B_{MSY}	Biomass – Maximum Sustainable Yield
CPUE	Catch per unit effort
EBFM	Ecosystem based fishery management
GPHA	Goolwa Pipi Harvester's Association
GVP	Gross Value of Production
ITE	Individual Transferable Effort
LCF	Lakes and Coorong Fishery
LCFMPSC	Lakes and Coorong Management Plan Steering Committee
LMGN	Large mesh gillnets
MSC	Marine Stewardship Council
PIRSA	Primary Industries and Regions SA
SARDI	South Australian Research and Development Institute
SFA	Southern Fishermen's Association
SMGN	Small mesh gillnets
TACC	Total Allowable Commercial Catch
TACE	Total Allowable Commercial Effort

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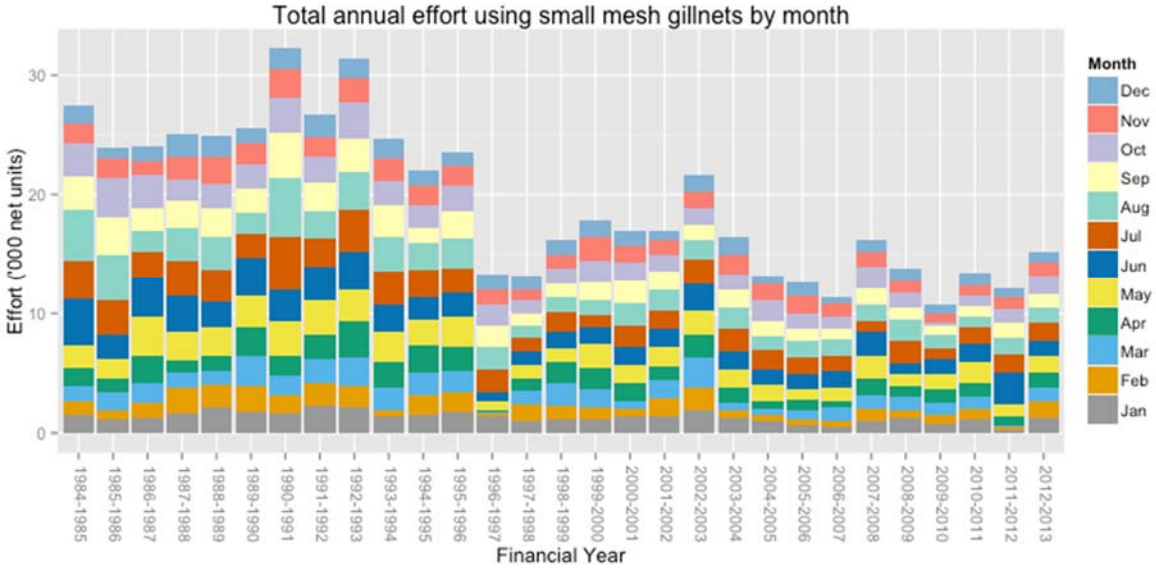
Appendix 1 – Additional figures

a)



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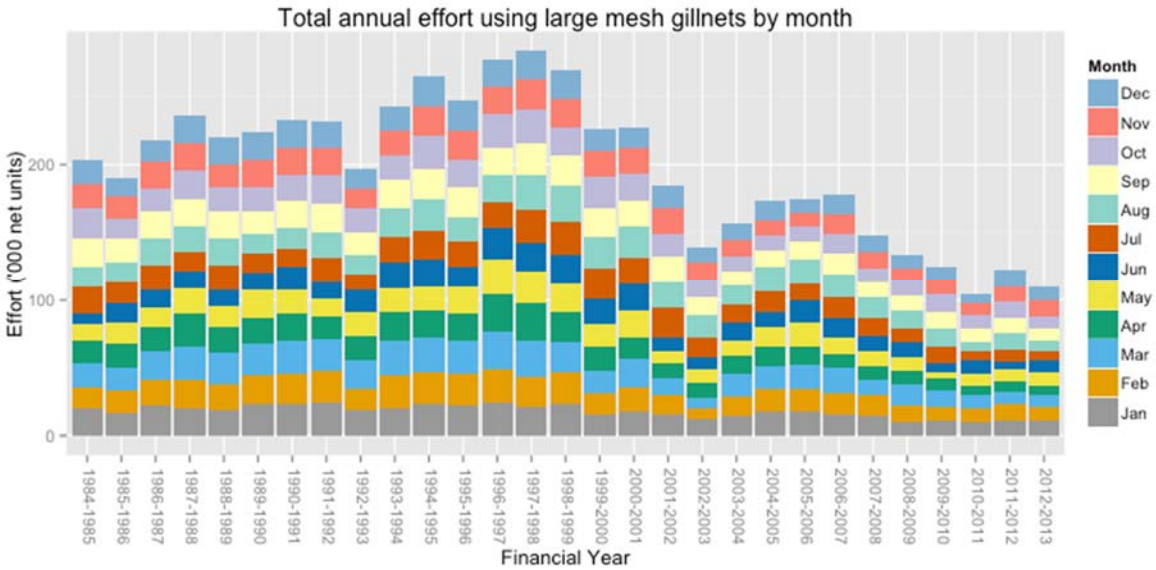

Figure 40. Annual effort (net units) using a) small mesh gillnets and b) large mesh gillnets by month since 1984 (Note: catch and targeting of Pipis, catch using cockle rake and area 17 excluded).

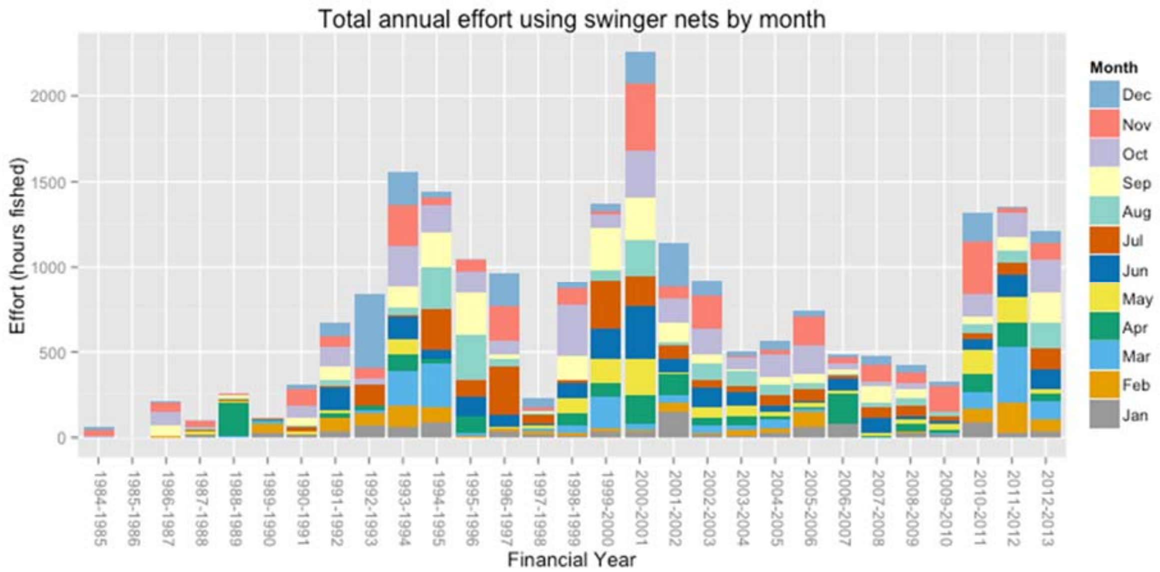

Figure 41. Annual effort (net units) using swinger nets by month since 1984.

Appendix 2 – Historical levels of effort vs proposed TACE levels

The tables below provide a comparison between the actual reported level of effort and proposed TACE if the finfish harvest strategy was implemented in 1998/99.

Table 23. Visual comparisons of actual reported levels of annual effort in fishing days and proposed TACE setting in fishing days, for the three proposed habitat / gear-based sectors of the LCF for the period from 1998/99 to 2012/13.

	Freshwater - LMGN		Estuarine - LMGN		Estuarine - SMGN	
Fishing year	Reported	Proposed TACE	Reported	Proposed TACE	Reported	Proposed TACE
1998/99	4,743	6,000	2,120	1,880	1,018	2,300
1999/00	3,646	6,000	2,663	1,880	1,096	2,300
2000/01	3,903	6,000	2,473	1,880	1,099	2,300
2001/02	2,944	6,000	2,815	1,880	1,259	2,300
2002/03	2,651	5,460	2,102	1,480	1,139	1,340
2003/04	3,629	6,000	1,532	1,480	808	1,390
2004/05	3,740	6,000	1,588	1,480	1,052	1,390
2005/06	4,193	6,000	1,450	1,680	1,048	1,390
2006/07	3,989	5,460	1,354	1,480	986	1,390
2007/08	3,769	4,550	929	1,480	1,329	1,340
2008/09	3,328	3,630	910	1,480	1,274	1,340
2009/10	3,175	1,750	733	860	1,099	800
2010/11	3,098	5,460	345	1,680	1,323	2,300
2011/12	2,602	6,000	1,383	2,700	1,095	2,300
2012/13	2,349	6,000	1,590	2,700	1,339	2,300

Table 24. Visual comparisons of actual reported levels of annual effort in net units and proposed TACE setting in net units, for the three proposed habitat / gear-based sectors of the LCF for the period from 1998/99 to 2012/13.

	Freshwater - LMGN		Estuarine - LMGN		Estuarine - SMGN	
Fishing year	Reported	Proposed TACE	Reported	Proposed TACE	Reported	Proposed TACE
1998/99	1,385	1,250	787	725	359	450
1999/00	1,432	1,250	701	725	387	450
2000/01	1,428	1,250	717	725	369	450
2001/02	1,415	1,250	693	725	320	450
2002/03	1,309	1,140	591	605	476	360
2003/04	1,287	1,250	618	605	394	368
2004/05	1,209	1,250	660	605	336	368
2005/06	1,085	1,250	616	665	315	368
2006/07	1,170	1,140	731	605	302	368
2007/08	1,045	950	545	605	313	360
2008/09	1,026	760	429	605	306	360
2009/10	1,089	365	488	365	288	200
2010/11	966	1,140	492	665	297	450
2011/12	1,117	1,250	519	850	294	450
2012/13	918	1,250	563	850	312	450

Table 25. Visual comparisons of actual reported levels of annual effort in net-days and proposed TACE setting in net-days, for the three proposed habitat / gear-based sectors of the LCF for the period from 1998/99 to 2012/13.

	Freshwater - LMGN		Estuarine - LMGN		Estuarine - SMGN	
Fishing year	Reported	Proposed TACE	Reported	Proposed TACE	Reported	Proposed TACE
1998/99	189,962	190,000	45,994	36,425	16,242	20,000
1999/00	137,995	190,000	57,632	36,425	17,604	20,000
2000/01	149,022	190,000	51,641	36,425	16,899	20,000
2001/02	113,516	190,000	54,521	36,425	16,081	20,000
2002/03	97,815	173,000	33,437	22,125	19,865	14,625
2003/04	125,618	190,000	25,931	22,125	13,991	15,395
2004/05	140,509	190,000	25,831	22,125	12,870	15,395
2005/06	144,092	190,000	21,509	29,750	12,151	15,395
2006/07	147,469	173,000	22,892	22,125	10,974	15,395
2007/08	124,167	143,650	14,069	22,125	15,662	14,625
2008/09	115,120	115,000	11,015	22,125	13,710	14,625
2009/10	109,337	55,400	8,834	12,625	10,682	8,655
2010/11	91,121	173,000	4,167	29,750	13,356	20,000
2011/12	88,465	190,000	25,270	50,000	11,971	20,000
2012/13	68,374	190,000	32,261	50,000	14,854	20,000

Appendix 3 - Staff

Name	Organisation	Project Involvement
Ian Knuckey	Fishwell Consulting	Principal Investigator
Sevaly Sen		Co-Investigator
Matt Koopman	Fishwell Consulting	Co-Investigator
Tim Ward	SARDI	Co-Investigator
Jason Earl	SARDI	Co-Investigator
Jonathan McPhail	PIRSA	Co-Investigator
Neil McDonald	SFA	Co-Investigator