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Southern Garfish (*Hyporhamphus melanochir*) Fishery

M.A Steer, R. McGarvey, A.J Fowler, P. Burch, J.E. Feenstra,
W.B Jackson and M.T Lloyd

SARDI Publication No. F2007/000720-3
SARDI Research Report Series No. 658

SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

October 2012

Report to PIRSA Fisheries and Aquaculture

Government of South Australia

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This Publication may be cited as:
Steer, M.A., McGarvey, R., Fowler, A.J., Burch, P., Feenstra, J.E., Jackson, W.B. and Lloyd, M.T (2012). Southern Garfish (*Hyporhamphus melanochir*) Fishery. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2007/000720-3. SARDI Research Report Series No. 658. 76pp.

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Printed in Adelaide: October 2012

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Date:	30 October 2012
Distribution:	PIRSA Fisheries and Aquaculture, SAASC Library, University of Adelaide Library, Parliamentary Library, State Library and National Library
Circulation:	Public Domain

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Acknowledgements

Funds for this research were provided by PIRSA Fisheries and Aquaculture, obtained through commercial licence fees. The commercial catch and effort data were provided by Angelo Tsolos of the Information Systems and Database Support Program of SARDI (Aquatic Sciences). We gratefully acknowledge Dr Qifeng Ye for providing the historic size and age raw data that was used in chapter five. We are also grateful for the numerous SARDI staff and volunteers that assisted in the collection of biological samples as part of the on-going market sampling program. This report was reviewed by Dr Stephen Mayfield, Dr Cameron Dixon and Michelle Besley (PIRSA) and formally released by Assoc. Prof. Tim Ward, principle scientist of SARDI's Fisheries Program.

1 Executive Summary

Stock assessments for the South Australian Southern Garfish Fishery have been produced since 1997, with this being the fifth in that 15-year period.

This stock assessment considered four types of fishery performance indicators that were assessed against limit reference points: (1) State-wide and regional commercial catch, effort and CPUE data by gear from 1983/84 to 2010/11; (2) estimates of recreational catch and effort obtained from two State-wide telephone/diary surveys that were undertaken in 2000/01 (Henry and Lyle 2003) and 2007/08 (Jones 2009); (3) population size and age structures for garfish harvested from the northern gulfs based on a contemporary market sampling program (2005-2011) and historic surveys (pre-2000); and (4) estimates of output parameters derived from the computer fishery assessment model GarEst for 1984 to 2010, which include seasonal and annual estimates of recruitment, fishable biomass and exploitation rate.

The Garfish Fishery has remained at depressed levels since the 2000/2001 decline. It has stabilised at those lower levels, but has not given any indication of a recovery since the implementation of the voluntary net buy-back and associated spatial closures in 2005. Biomass and average levels of recruitment have stabilised over the last six years. Harvest fractions have moderately reduced, however, they still remain high. The population demography continues to lack substantial quantities of 3+ and 4+ age classes and remains truncated. Thus South Australia's Garfish Fishery remains over-exploited.

The total catch of garfish was 260.9 t in 2010/11, combined across all gear types, including both targeted and untargeted catch. This was 20.3 t less than the previous year, representing an annual decrease of 7.2% and was the lowest on the contemporary record. Fishing effort continues to decline at an estimated rate of 573 fisherdays per year. Targeted hauling net catch rates in Northern Gulf St. Vincent have moderately declined (12%) over the past three years whereas they have continued to trend upwards in Northern Spencer Gulf. In the southern gulfs, catches have declined through the closure to the use of hauling nets. Dab net effort has also declined in these regions, consequently the southern gulfs only contribute a negligible (<5%) proportion of the State's total catch.

The recreational sector has accounted for about 20% (ranging 18.8% – 20.3%) of the State-wide garfish catch. This overall estimate has remained consistent, despite there being a 30% reduction in catch and effort from 2000/01 to 2007/08 and moderate changes in the spatial distribution of the recreational harvest.

The population demography of South Australia's Garfish Fishery has remained relatively unchanged since 2005 as the fishery continues to be dominated by moderate size garfish (240 – 280 mm TL) from the 1+ and 2+ age classes.

Across the commercial fishery statistics for 2010/11, a total of three limit reference points were breached. Two related to the low regional catches in the southern gulfs and one related to high catch rates in the hauling net sector of northern Spencer Gulf.

Seven of the ten biological performance indicators were breached. These were primarily related to high exploitation rates and low estimates of egg production in both gulfs.

The key feature of this fishery is that its status has remained largely unchanged since the last stock assessment despite the enhanced management framework that was implemented in 2005.

A new harvest strategy was introduced in June 2012 that aimed to reduce the exploitation rate (harvest fraction) from the current level of 69% to ≤30% by 2020. This strategy included the implementation of a series of temporal closures and increasing the legal minimum hauling net mesh size from 30 mm to 32 mm. The response of the fishery to these new management arrangements will be explored in the next stock assessment scheduled for July 2015.

2 General Introduction

2.1 Overview

Stock assessments for the South Australian Southern Garfish (hereafter referred to as garfish) Fishery have been produced since 1997 (McGlennon & Ye 1999), with this being the fifth in that 15-year period. Reporting obligations for this fishery have conformed to a triennial cycle since 2006 (McGarvey et al. 2006). These reports have two aims: (1) to present information from the fishery and biology of the species; and (2) to provide a current assessment of the status of the garfish stocks up to the time for which data are available. The last stock assessment was completed in September 2009 (McGarvey et al. 2009) and reported data up to June 2008. This report incorporates a further three years of commercial catch, effort and biological data up to June 2011.

This report is partitioned into seven chapters. The General Introduction (Chapter two) provides a description of the fishery; summarises the management regulations; and presents a detailed review of the population biology and life history of the species.

Chapter three presents a summary of the catch and effort data from the commercial fishery. This includes trends in the catch statistics over both State-wide and regional spatial scales for each of the two main gear types (hauling nets and dab nets).

Information available on catches of garfish from the recreational sector of the fishery is summarised in chapter four. This includes a State-wide and regional synthesis of the results of the National Recreational and Indigenous Fishing Survey (NRIFS) carried out in 2000/01 (Henry and Lyle 2003) and the South Australian Recreational Fishing Survey undertaken in 2007/08 (Jones 2009). The regional catches were compared between the two surveys and with the corresponding commercial catches to provide an assessment of their relative contribution to the State's total garfish catch.

Chapter five provides an analysis of the population demography with particular emphasis on the temporal and spatial trends in their size and age structures. Contemporary biological information relies exclusively on SARDI's market-sampling program that has occurred, with the exception of a six month hiatus in 2008 (July – December), almost weekly since July 2005. This chapter also includes historic size and age data, collected in the 1950s, 1970s and 1990s, to explore long-term trends in the population demography.

The output from the fishery stock assessment model, GarEst, is presented in Chapter six. This model integrates the catch and effort data from the commercial and recreational sectors of the fishery (Chapters three and four) with the population demographic data (Chapter five)

to ascertain the status of the fishery on the basis of its comparison against a series of biological performance indicators. The model output includes a time-series of estimates of annual recruitment, legal biomass, and harvest fraction (exploitation rate) the Spencer Gulf and Gulf St. Vincent.

Chapter seven extends the assessment by comparing the performance of the fishery against a series of prescribed limit reference points that are based on the commercial catch and effort statistics.

Chapter eight is the General Discussion which synthesises the information presented in the previous chapters, assesses the status of the fishery, highlights uncertainties associated with the assessment, and identifies future research priorities.

2.2 Description of the Fishery

The garfish (*Hyporhamphus melanochir*) is one of the most significant inshore fishery species of southern Australia, with fisheries in Victoria, Tasmania, South Australia and Western Australia. Historically, the national commercial catch for this species has been dominated by that from South Australia where the catch has usually exceeded 400 t per annum, with an approximate value of AUD$2 million (Knight and Tsolos 2011). This species is also a popular target amongst South Australian recreational anglers (Jones 2009).

In South Australia, the fishery is principally located in Spencer Gulf and Gulf St. Vincent (Figure 2.1) and is managed as part of the multi-species, multi-gear Marine Scalefish Fishery (MSF) through a series of input and output controls. Commercial fishers target garfish using hauling nets and dab nets. Hauling net fishers account for the majority (~90%) of the commercial catch even though their fishing activities are restricted by regulation to waters <5 m deep. There are also numerous areas around the State that are either permanently or seasonally closed to hauling net fishing. Recreational fishers are also permitted to use dab nets but predominantly use traditional hook and line as they fish from boats and shore-based platforms throughout the State. Current output controls for garfish caught in South Australia include a legal minimum length (LML) of 230 mm total length (TL) and a recreational bag and boat limit of 60 and 180 garfish, respectively. Commercial catches from both gulfs are similar, whereas recreational landings are higher in Gulf St. Vincent as a consequence of a greater number of recreational fishers residing in metropolitan Adelaide (Jones 2009).

2.3 Management Regulations

With an estimated total catch of 500-600 t per year across both sectors in South Australia, the garfish is a valuable natural resource and is one of the four priority species within the

MSF, along with King George whiting (*Sillaginodes punctatus*), snapper (*Pagrus auratus*) and southern calamary (*Sepioteuthis australis*). The commercial MSF has undergone significant management changes over the past 40 years that has seen the fishery restructured and limited through gear restrictions and configuration, licensing, spatial and temporal closures, and size limits. Although most of these management changes have been generic in nature there have been a few that have largely impacted the Garfish Fishery. The most notable have been a series of net fishing closures. Net closures were first implemented on the West Coast in 1958 and were subsequently followed by a depth-delimited ban in the early 1970s where net fishers were restricted to operate in coastal waters <5 m deep. Further netting closures were implemented in 1983, 1994, 1995, 1997 and 2005 (Figure 2.1, Table 2.1). In addition, deep water netting exemptions for a few commercial operators were revoked in 2006. These closures have significantly restricted the commercial garfish hauling net fishers to relatively small areas within the northern gulfs. More specific management arrangements were made in 2001, where the LML for garfish was increased from 210 mm to 230 mm TL. This increase was made to ensure that at least 50% of garfish at that size would be reproductively mature (Ye et al. 2002). Despite this increase, no corresponding changes to the mesh size regulations for hauling nets were implemented. Reduction in the recreational bag and boat limits were also implemented in 2001.

In May/June 2005, the State Government implemented a voluntary net buy-back scheme that aimed to reduce fishing effort amongst the commercial haul netters with a particular emphasis on those that harvest garfish. Of the 113 MSF hauling net licence holders, 61 (54%) accepted the offer and their endorsements were surrendered. This initiative effectively accounted for approximately 45% of commercial hauling net fishing effort during 2000 to 2003.

Table 2.1 Management history of the commercial Marine Scalefish Fishery that relate to garfish (1970 – 2011)

Date	Marine Scalefish Fishery Management Arrangements (Impacting Garfish)
1958	Denial Bay, Smoky Bay, Baird Bay and Venus Bay closed to net fishing.
Early 1970s	State-wide ban on netting in areas >5m deep. Minimum legal lengths introduced for most of the primary species.
1977	Freeze on the issue of new commercial licences. B-class licence holders able to convert to M-class licences if they met certain criteria.
1977-1982	Show cause provision - licence holders required to demonstrate a minimum level of involvement to qualify for licence renewal.
1979-1980	Some employees of MSF licence holders were allowed to apply for licences.
1980	Netting arrangements: • Limit on net length to 600 m for A-class licences and 400 m for B-class. • Nets cannot be joined, with the exception of a drain-off shot. • Net endorsements made non-transferable. • Freeze on issue of additional permits for use of nets. • B class licence holders no longer entitled to use nets other than bait nets. • Restriction on use of nets by northern rock lobster licence holders.
1980	B-class licences became non-transferable; owner-operator policy announced; family transferability introduced for M-class net and line licences.
1982	Licences became transferable, although net endorsements were not transferable with the licence unless a family transfer occurred, and B-class were still not transferable within families.
1983	Additional aquatic reserves (closed to both line and net fishing) and restricted netting areas were introduced.
1994	Licence amalgamation scheme introduced.
1994	Further areas closed to net fishing in Coffin Bay and areas near Adelaide.
1995-1996	Net review conducted and further netting restrictions introduced.
1996	Licence amalgamation scheme amended (26 point value).
1997	A further eight areas were closed to net fishing: Fowlers Bay, Edithburgh, Coobowie, Stansbury, Bay of Shoals, Germain Bay, Tumby Bay and Port Neill.
2001	Changes to legal minimum lengths and recreational bag and boat limits for several MSF species including snook and garfish.
2004	Licence amalgamation scheme amended (24 point value and incorporation of ‘B-class’ licences).
2005	Voluntary net buyback scheme implemented; New areas closed to net fishing.
2006	Deep water netting exemptions in GSV revoked.

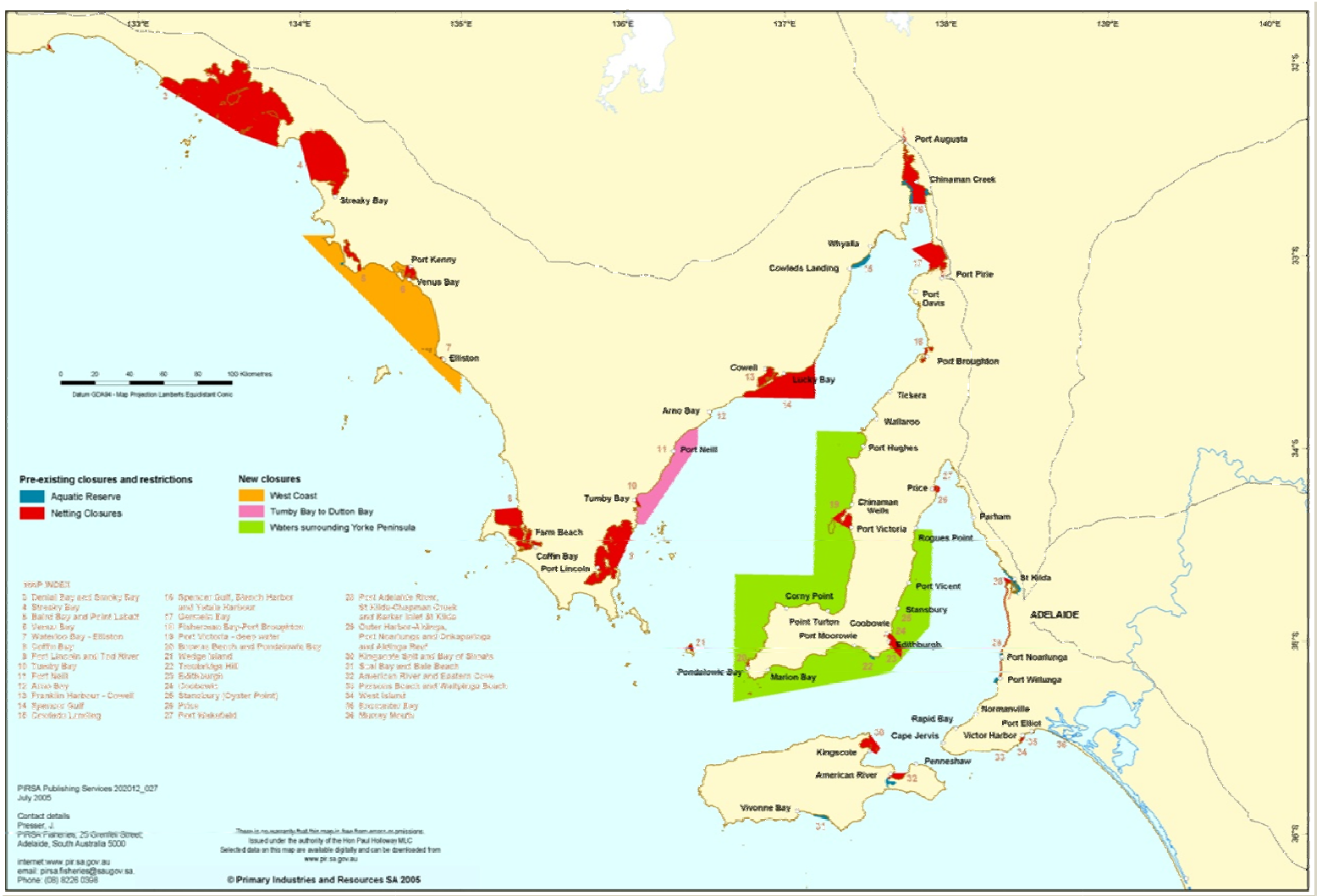

Figure 2.1 Map of South Australian coastal waters identifying areas closed to haul net fishing.

2.4 Population Biology and Life History

2.4.1 Taxonomy

The garfish (*Hyporhamphus melanochir* (Valenciennes 1847)) belongs to the Order Beloniformes, i.e. the needlefishes. This Order of fishes is divided into five families: the Exocoetidae (flying fishes); Scomberesocidae (sauries); Belonidae (longtoms); Adrianichthyidae (ricefishes); and Hemiramphidae (half beaks) (Gomon et al. 2008). The hemiramphids, of which garfish is a member, are characterised by having a distinct beak that protrudes from the lower jaw, which accounts for their colloquial name of 'half beaks' (Figure 2.2a). They are also elongate and have small pectoral and ventral fins. Worldwide, there are 12 genera and approximately 70 species of hemiramphids distributed throughout both tropical and temperate regions of the world that occupy inshore marine, estuarine and river systems. There are six genera and 17 species in Australia that are divisible into four primary ecological groups (tropical freshwater and estuarine, tropical marine, southwest and southeast estuarine endemics, and temperate marine endemics (Collette 1974).

The genus Hyporhamphus is the most speciose of the Hemiramphidae accounting for more than one third of the species of this family (Stewart et al. 2005). All species are restricted to the Indo-west Pacific geographic region. Of the eight species of Hyporhamphus in Australia, two morphologically similar species are found along the southern Australian coast (Gomon et al. 2008). The garfish occurs in shallow, inshore, marine waters, which places it amongst the 'temperate marine endemics' of Collette (1974). Alternatively, the river garfish (*H. regularis*) occurs in estuaries, rivers and coastal lakes.

2.4.2 Adult Distribution

The geographic distribution of garfish extends from Shark Bay in Western Australia, along the southern coast of mainland Australia and up the east coast to Eden in southern New South Wales, as well as the surrounding waters of Tasmania (Kailola 1993, Noell and Ye 2008) (Figure 2.2b). Throughout its distribution this schooling species occurs in sheltered bays and shallow, inshore, marine waters to depths of approximately 20 m. They are particularly abundant throughout the gulf regions of South Australia.

Approximately 70% of the national production of garfish is landed in South Australia (ABARE 2010). Although garfish are distributed throughout State waters, three areas consistently account for most of the catch, i.e. northern Gulf St. Vincent (GSV), northern Spencer Gulf (SG) and north-eastern Kangaroo Island (KI) (Fowler et al. 2008). These three areas are separated by considerable distances but nevertheless support similar habitats. The northern gulf areas are characterised by relatively low wave-energy environments (Middleton and Bye

2007) and support the two most extensive wetland systems of the State (Edyvane 2000). These wetland systems include mangroves, saltmarshes and large, tidal mudflats with extensive intertidal seagrass (*Zostera muelleri*) meadows (Edyvane 2000). Approximately 80% of the State's sub-tidal seagrass meadows which include *Posidonia sinuosa, P. angustifolia, Amphibolis antarctica* and *Heterozostera tasmanica* are located in the northern gulfs (Bryars 2003). The sheltered bays of KI have a northern aspect that provides protection from the southerly winds, thus also providing a low wave-energy environment. Like the northern gulfs, these bays are fringed with wetland systems with extensive meadows of intertidal and sub-tidal seagrasses (Edyvane 2000).

The highest catches of garfish are generally taken from coastal waters that support extensive beds of seagrasses from the Zosteracaea family. This family of seagrasses are commonly referred to as "garweed" by local fishers and the relationship between garfish and the seagrass was proposed to be based on diet (Ling 1958). The dietary hypothesis is supported by several studies that were carried out in Victoria during the 1980s that revealed both *Zostera muelleri* and *Heterozostera tasmanica* constituted significant components of the garfish's diet (Robertson and Klumpp 1983, Klumpp and Nichols 1983). A recent study undertaken in northern GSV confirmed that garfish consumed large quantities of Zosteracean seagrasses during the day and switched to hyperbenthic invertebrates, predominantly amphipods, in lower volumes during the night (Earl 2007). The significance of seagrasses in the diet was consistent throughout the year.

2.4.3 Reproductive Biology

Our understanding of the reproductive biology of garfish in South Australia is largely based on an extensive study undertaken in the late 1990s and early 2000s that sampled fishery catches throughout GSV and SG (Ye et al. 2002). That study determined that garfish is a serial spawner with asynchronous oocyte development. In this region, the species has an extended spawning season from October to March, based on gonadosomatic indices and the presence of ripe, running ripe and spent fish in the samples.

The examination of mature ovaries indicated that they contained oocytes that were at different sizes and stages of development, including: immature ova (<0.2 mm); maturing ova (0.2-1.0 mm); mature ova (~1.6 mm); and ripe ova that were large (~3.0 mm), transparent and covered with numerous chorionic filaments (Figure 2.2c). Once spawned these filamentous oocytes have been observed to adhere to drift algae or seagrasses (Jordan et al. 1998).

The estimated size at maturity ($L_{50\%}$) for female garfish in South Australia is 215 mm TL, which is equivalent to the mean age of 17.5 months (Ye et al. 2002). This is smaller in comparison to Victorian and West Australian garfish, and there is some evidence that the size and age at first maturity for South Australian garfish has decreased in possible response to the high rate of exploitation for this species.

In South Australia mean batch fecundity has been estimated at 960 oocytes (Ye et al. 2002). This estimate was based on the number of oocytes that were hydrated and had attained a diameter of 2.2 mm and deemed highly likely to be spawned within 24 hrs. This estimate, however, is considered low for a finfish species, and presumably reflects the large size of the eggs. Embryonic developmental time is relatively long (~30 days at 15°C), and as such results in relatively large, well-developed larvae at hatching (Jordon et al. 1998). Although there was minimal regional variation in batch fecundity, the estimates vary with both fish size and age. As yet, there are no estimates of total fecundity for garfish. This is because total fecundity is a function of batch fecundity, spawning frequency and duration of the spawning season over which an individual spawns. There are no estimates of spawning frequency for this species due to the difficulties in preparing histological sections from the gonads due to the size of the hydrated oocytes (Ye et al. 2002). There are also no estimates of how long throughout the spawning season an individual garfish continues to spawn.

The sex ratio of garfish caught by hauling nets in South Australia has been consistently biased towards females. This suggests that there are significant differences in the spatial distribution and spawning behaviour between sexes. It appears that females form large schools in the shallow, inshore waters (<5 m), while males are relatively dispersed and more patchy in distribution with a significantly higher proportion occupying deeper, offshore waters (>5 m). Garfish populations in Tasmania have also demonstrated similar sexual segregation (Jordan et al. 1998).

2.4.4 Early Life History

Plankton sampling for larval garfish has been done throughout Gulf St. Vincent on two occasions, i.e. December 1998 and 2000 (Noell 2003). A total of 428 larvae were captured. The greatest abundances of larvae were concentrated in northern GSV in the waters proximal to the extensive, dense seagrass beds. These larvae were generally 5-11 mm in body length, with larger (>15 mm) ones rarely sampled (Figure 2.2d). Prevailing winds from the southwest and southeast may have contributed to entraining the larvae in this region. There were also small numbers of larvae found at the entrance of the gulf in Backstairs Passage and Investigator Strait, which are likely to have originated from northeastern KI,

where dense seagrasses also occur. The patterns of distribution and abundance of the larvae suggested that spawning occurred in close association with the seagrass beds.

No garfish eggs were collected in the plankton samples, despite the distribution and abundance of mature fish and the distribution patterns of larvae indicating that garfish were likely to spawn over the seagrass beds in the northern gulfs. These observations suggest that, like other Beloniformes, the eggs of this species are demersal. This was essentially confirmed in a Tasmanian study where eggs stripped from running ripe garfish were negatively buoyant and sank to the bottom of the sample jars or attached to artificial substrate (Jordan et al. 1998). These eggs did not adhere to each other but rather dispersed throughout the jars and their numerous long, chorionic, filaments indicating that they have a propensity to entangle amongst drift algae (Jordan et al. 1998). It would be expected, based on the above observations, that eggs should be found in the northern gulfs attached to seagrasses. There have been several attempts to find garfish eggs in the field (Ling 1958, Noell 2003). In northern GSV, samples of a variety of seagrass species, including *Zostera muelleri, Posidonia sinuosa, P. angustifolia, Amphibolis antarctica* and *Heterozostera tasmanica* were collected and examined for adhering garfish eggs. However, no eggs were found. In contrast, garfish eggs have been found attached to seagrass and algae in KI's Bay of Shoals by a commercial dab net fisher. garfish eggs have, however, been consistently sampled using a beam trawl in Great Oyster Bay, Tasmania (Jordan et al. 1998). A total of 618 eggs were collected and found to be individually entangled by their long (~8 mm) chorionic filaments, within filamentous drift algae.

2.4.5 Age Structure

The demography of garfish has been better understood since a methodology was developed and validated to age adult fish (Ye et al. 2002). The transverse sections of otoliths of this species display an alternating sequence of opaque and translucent zones (Figure 2.2e). Furthermore, the results from marginal increment analysis and tetracycline staining indicated that increment formation occurred annually, and therefore, the fish could be aged in years. A universal birth date of 1st January was adopted as this date falls in the middle of the spawning season, and allows the age of the fish to be resolved on a monthly timescale.

During the 1990s, a total of 2,079 garfish were sampled from commercial catches in South Australia and successfully aged for a study on age and growth (Ye et al. 2002). There were seven age classes that contributed to the commercial catches (0+ to 6+), however, the catches were dominated (89%) by 1+ and 2+ fish. Less than 5% were from 4+ to 6+ age classes. A more recent study which compared the size and age structures of the fishery with that of the 1950s indicated that historically the fishery was once dominated by 4+ and 5+

garfish, but over numerous years of exploitation the fishery has become considerably truncated to consist of primarily one- and two-year-old garfish (Fowler and Ling 2010).

2.4.6 Stock Structure

Understanding stock structure is fundamental to developing the best protocol for spatial management of a fishery or stock. A genetic study carried out in 2002 which investigated the stock structure of garfish revealed four regional stocks across Australia, i.e. Western Australia, west coast of South Australia, the South Australian gulfs and Victoria, and Tasmania (Donnellan et al. 2002). No genetic differentiation was identified between GSV and SG populations. Historically, the stock assessment and management approach for garfish has been to treat the two regional, gulf populations as separate, independent and self-recruiting. This division was based on the assumption that the two gulfs are considered semi-enclosed systems and only modest levels of intermixing between the two gulfs is required to homogenise the genetic stock. However, in reality the patterns of movement and migration both within and between the two gulfs were unknown.

In 2009, a study adopted a combined approach to delineate potential garfish sub-populations, and determine the extent of mixing within South Australia's coastal waters, through the integration of multiple otolith-based techniques (Steer et al. 2009). Spatial differences in otolith chemistry (trace elements and stable isotopes) and morphometrics indicated that there were several groups of garfish that had spent significant parts of their lives in different environments and that there was some level of restriction that prevented complete mixing among the regions. At least five regional divisions were identified. Three of these were clearly defined as they exhibited negligible levels of inter-regional mixing: The West Coast; Northern Spencer Gulf; and South-Western Spencer Gulf. The remaining two, however, were less distinct: Northern Gulf St. Vincent and Southern Gulf St. Vincent, but demonstrated a level of population structuring that would regard them as separate as a precautionary management measure. This level of population structuring was sufficient to suggest that the historical management framework of two discrete, gulf-specific, stocks should be restructured to align with these five smaller, semi-discrete, regional units.

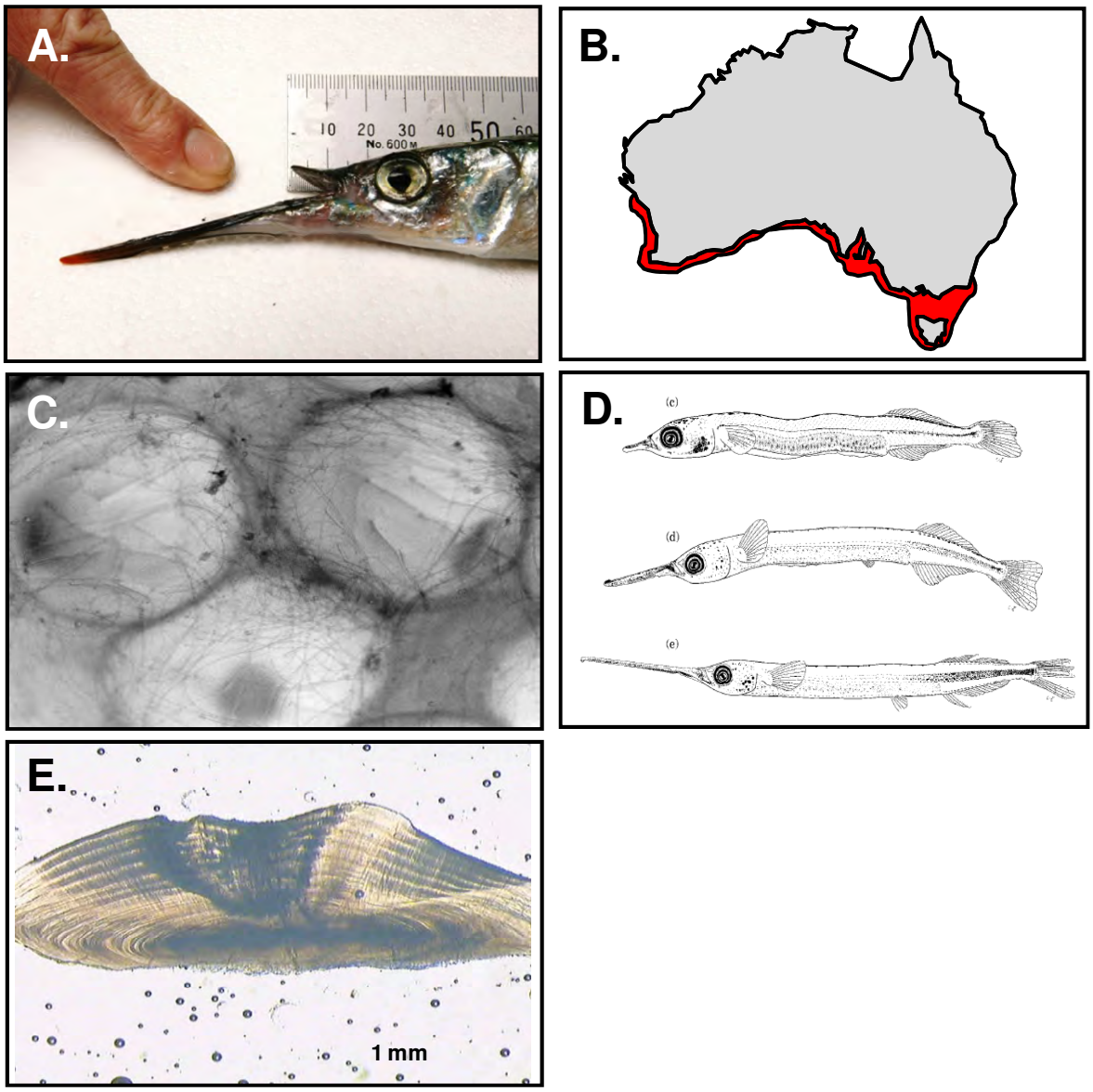

Figure 2.2 Southern garfish (*Hyporhamphus melanochir*) (A) distinct beak that protrudes from the lower jaw; (B) geographic range; (C) eggs with long chorionic filaments (40x); (D.) larval stages (Noell 2003); (E) Sectioned otolith.

3 Analysis of Commercial Fishery Statistics

3.1 Introduction

The South Australian Marine Scalefish Fishery (MSF) is divided into 58 Marine Fishing Areas (MFAs) for the purpose of statistical reporting and monitoring of commercial fishing activity (Figure 3.1). All licensed fishers are required to log their fishing activities, recording specific details such as MFA fished, number of fishers on board, species targeted, species caught, weight of catch, and method of capture. This level of detail was initially recorded on a monthly basis, but since 2003 fishers have been required to provide a daily log of fishing activity. These records must be submitted monthly to SARDI Aquatic Sciences where they are entered into a database which is routinely reviewed and cross-checked to ensure that the data satisfy management and research needs. The current database is a compilation of catch and effort data collected from 1983/84 to the present and provides the primary source of data used for stock assessment of the priority MSF species. The data used in this chapter were finalised up to 30th June, thus providing a complete 28 financial-year dataset.

This chapter quantitatively assesses trends in spatial and temporal commercial catch, effort and catch per unit of fishing effort (CPUE). The same dataset was used to assess the performance of the fishery against a series of prescribed limit reference points (Chapter seven) and also formed the basis of the GarEst fishery assessment model (Chapter six) used to calculate a time-series of output parameters which is integrated with population demographic information to ascertain the status of the fishery.

3.2 Materials and Methods

For this stock assessment the catch and effort data were aggregated across commercial fishers to provide annual totals (financial year) and CPUE at the State and regional level. State waters were partitioned into six regions; West Coast, Northern and Southern SG, Northern and Southern GSV and the South East (Figure 3.1). The data were also interrogated across the two main gear types; hauling nets and dab nets.

Fishing effort was reported in fisherdays, which relates to the number of days fished multiplied by the number of personnel involved. There are two components to fishing effort, targeted and untargeted. Targeted effort in this fishery is a more accurate indicator of fisher behaviour than total fishing effort. It is also the metric that is used, along with targeted catch, to calculate CPUE, which provides an estimate of the relative abundance of garfish. Determining target effort in the hauling net sector, however, is problematic as fishers can catch multiple commercial species in a single fishing event and are non-specific in their target species. Although one species may dominate their catch, these fishers typically

nominate “any species” (or record “000”) as their fishing target in their catch returns. Efforts were made in the last garfish stock assessment report to address this issue by making the assumption that all fishers that used floating hauling nets and caught garfish were actively targeting them and were subsequently re-classified within a ‘targetplus’ category (McGarvey et al. 2009). Since then, however, it is understood that the definition of floating hauling nets differ amongst the commercial fishing community and that there are five variant categories of hauling nets that are listed in the mandatory catch returns of which all are used interchangeably by the fishers. These include the generic hauling net (HN), floating hauling net (HNF), sinking hauling net (HNS), mesh hauling net (HNM), and other hauling net (HNX). To avoid confusion all five variants were simply re-classified as hauling nets (HN). The effort category of the non-specific hauling net fishers was then determined on the basis of what they caught rather than their net variant. This was calculated in relation to the contribution of garfish by weight to the total catch in comparison to fishers who either targeted garfish or targeted other species (Figure 3.2). It was determined that if garfish constituted more than half (≥50%) of the non-specific fishers’ total daily catch, then they were re-defined as targeting garfish. This refined effort category (“Any Target >50% garfish”) was included in all subsequent regional analysis of the commercial catch and effort statistics in this chapter, and could only be calculated from 2003/04 as this was when fishers began reporting their daily fishing activities.

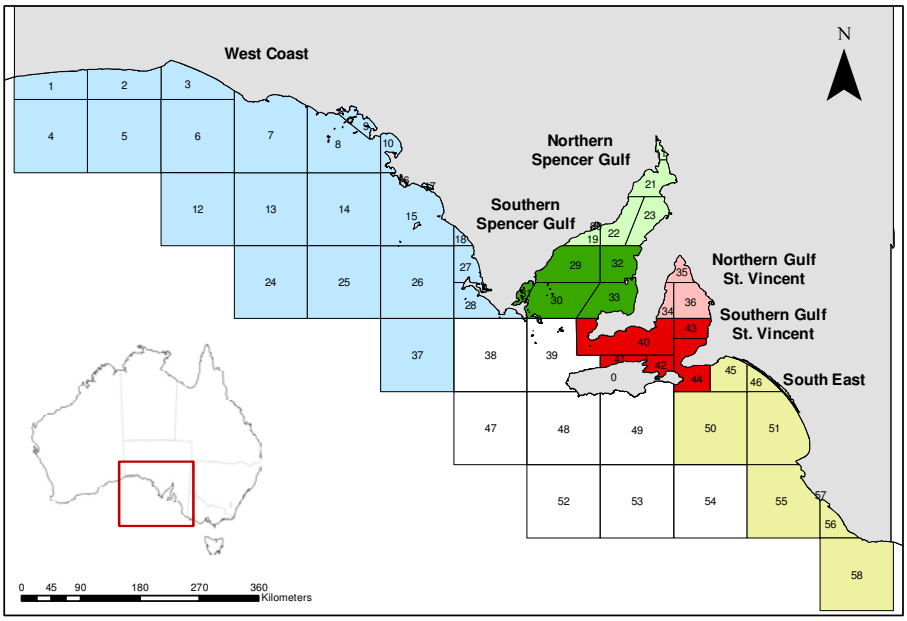

Figure 3.1 The commercial Marine Fishing Areas (MFAs) of the South Australian Marine Scalefish Fishery.

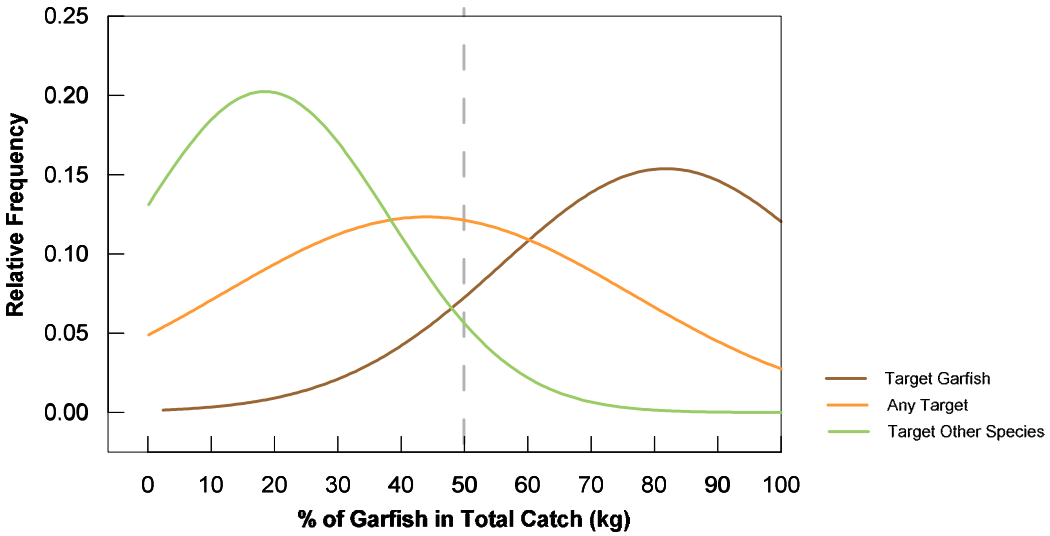

Figure 3.2 The frequency of the relative proportion of garfish catch to total catch for each of the three effort categories (i.e. fishers that target garfish, fishers who catch garfish, and fishers who target any species). Non-specific fishers (i.e. 'any target') where their daily catch consisted of ≥50% (arbitrary cut-off) garfish by weight, were reclassified as targeting garfish.

3.3 Results

3.3.1 Licence Holders

There have been two effective management strategies that have reduced the number of licence holders in South Australia's MSF. The first was the licence amalgamation scheme implemented in 1994, which initiated a long term decline in the number of commercial fishers who landed garfish. The second was the voluntary hauling net buy-back initiative, implemented in 2005. These two strategies have contributed to a 59% reduction in the number of commercial fishers landing garfish from 1995/96 to 2010/11 (Figure 3.3). The relative proportion of commercial fishers that nominated garfish as their specific target has remained relatively consistent at 75% throughout the last 28 years. The number of licence holders that reported landing and targeting garfish at the end of 2010/11 was 89 and 68, respectively (Figure 3.3).

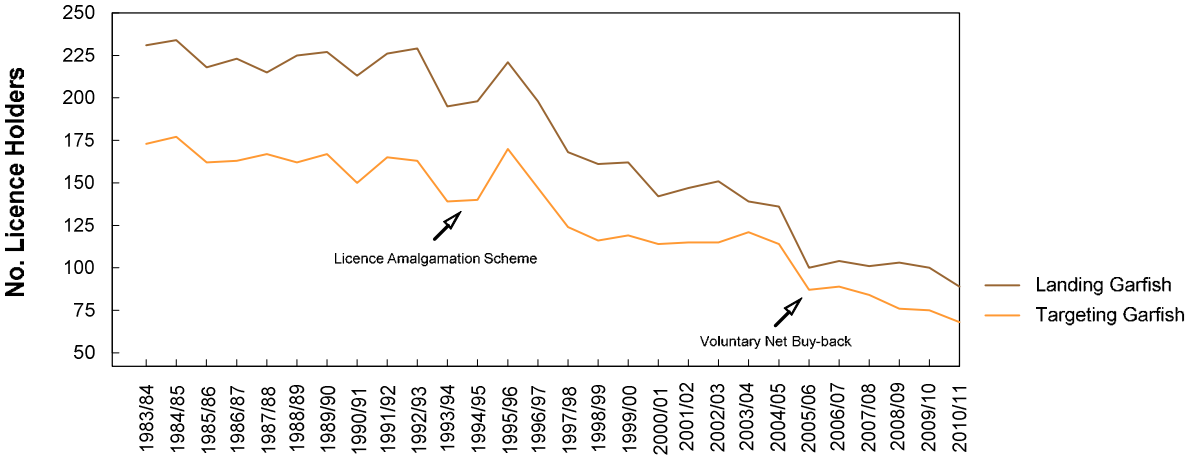

Figure 3.3 Long-term trends in the numbers of licences landing or targeting garfish by financial year.

3.3.2 State-wide Catch and Effort Trends

The total catch of garfish was 260.9 t in 2010/11, combined across all gear types, including both targeted and untargeted catch (Figure 3.4). This was 20.3 t less than the previous year, representing an annual decrease of 7.2% and was the lowest since 1983/84 (Figure 3.4a). With the exception of a two-year spike in 2004/05 and 2005/06, annual catches have sequentially declined from the peak of 532.3 t in 2000/01, representing a halving of the fishery over a ten-year period.

The hauling net sector has traditionally dominated total catch, having consistently accounted for about 90% of the State-wide harvest since 1983/84. Catches in this sector have oscillated from approximately 320 t to 480 t throughout the 1990's, averaging approximately 477 $t.yr^{-1}$. This average has dropped considerably over the last decade to about 346 $t.yr^{-1}$. Dab net annual catches have displayed a similar trend, yielding larger average catches throughout the 1990's (about 62 $t.yr^{-1}$) compared with the last ten years (37 $t.yr^{-1}$). Together, hauling net and dab net catches have accounted for about 99% of the total commercial catch over the last five years.

Total fishing effort for garfish has steadily declined from a peak of 17,392 fisherdays in 1988/89 to 5,352 fisherdays in 2010/11 (Figure 3.4b). This represents a 69.2% decrease declining at a rate of 573 fisherdays per year. This decline can be largely attributed to a sequential reduction in hauling net effort (Figure 3.4b). Dab net effort has displayed a similar declining trend over the same period, decreasing from a peak of 2,331 fisher days in 1995/96 to 543 fisherdays in 2010/11 at a rate of 79 fisherdays per year.

Catch rates have remained relatively high in the hauling net sector with fishers reporting an average daily catch of 67.3 kg over the past 12 years, which was approximately 16 kg more

than the average reported catch rates of the preceding 12-year period (Figure 3.4c). Catch rates in this sector have peaked at 82.5, 75.8 and 73.2 kg.fisherday^{-1} in 2000/01, 2005/06 and 2009/10, respectively (Figure 3.4c.). Dab net catch rates displayed a long-term increasing trend from 1983/84 to 2001/02, rising from 19.9 to a peak of 60.9 kg.fisherday^{-1}, at a rate of 1.9 kg.fisherday^{-1} per year. This increase, however, was not sustained, dropping to 36.8 kg.fisherday^{-1} in 2003/04, a level that has subsequently remained relatively stable (Figure 3.4c.).

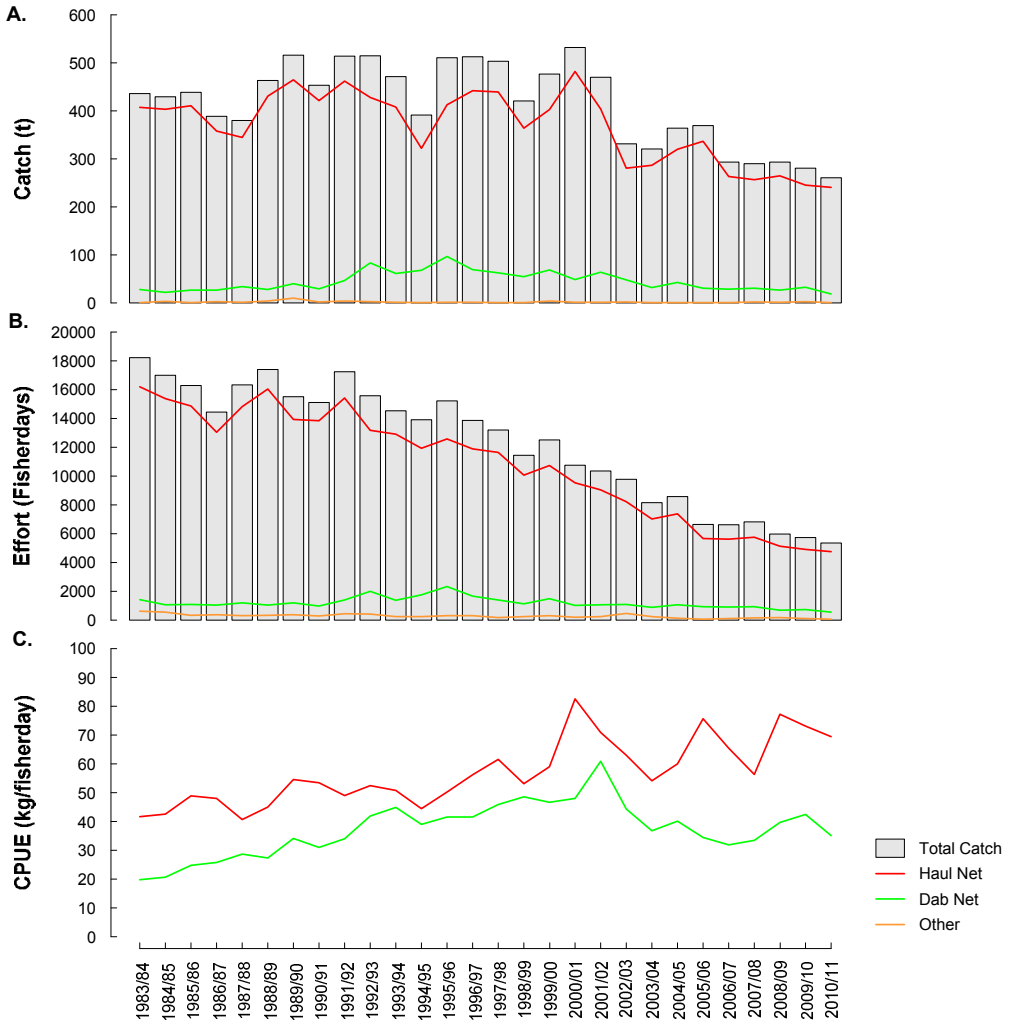

Figure 3.4 State-wide (A) commercial garfish catch, (B) effort, (C) CPUE by gear from 1983/84 until 2010/11.

Most of the State-wide catch of garfish has historically been landed in the northern parts of GSV and SG. Marine Fishing Areas 21 in SG and 35 in GSV have each consistently supported annual catches that have exceeded 60 t since 1983/84. During the 1980s and 1990s, the collective catch from these two MFAs accounted for approximately 45% of the State-wide commercial total. Since 2000/01, this relative contribution has increased to

approximately 56%, which emphasises the relative importance of these two areas to the commercial fishery. Annual catches have also remained relatively consistent (~50 t) in MFA 23 (Figure 3.5). The greatest regional dilution of garfish catch over the years has occurred in MFA 33. Prior to 2005/06, annual catches from this area averaged ~15 t, however over the last six years catches had decreased to ~2 t. A similar trend was also evident in MFAs 34, 42 and 44 (Figure 3.5).

Although the distribution of catch throughout the gulfs reflects the relative pattern of garfish abundance it is also accentuated by the spatial segregation of fishing gear. The hauling net sector of the fishery operates predominantly in the shallow, seagrass habitats of the northern gulfs, whereas the dab net fishers are mainly confined to the southern gulfs and around KI (Figure 3.6). Variation in annual catches in the southern gulf is, therefore, largely driven by the dab net sector of the fishery.

The seasonality of garfish catch is different for each of the gear types and it has slightly changed throughout the last 28 years. From 1983/84 until 1998/99 most of the garfish caught by the hauling net sector was landed during autumn (Figure 3.7). This was followed by two years during which high catches uncharacteristically peaked in mid–winter (July/August). Since then, overall monthly catches have declined considerably from the regular 40 t harvests during autumn, to more modest 10 t to 30 t monthly catches spread from January to August (Figure 3.7). Catches in the dab net sector, however, typically peaked during late spring and summer. This trend was most evident from 1992/93 to 2004/05, when peak catches were most frequent during November. Dab net fishers are capable of catching garfish throughout the year and during the late 1980s and 1990s fishers typically landed 2 – 6 t per month throughout autumn and winter. This trend did not continue and, from 2007/08, few garfish have been landed by the dab net sector during winter (Figure 3.7).

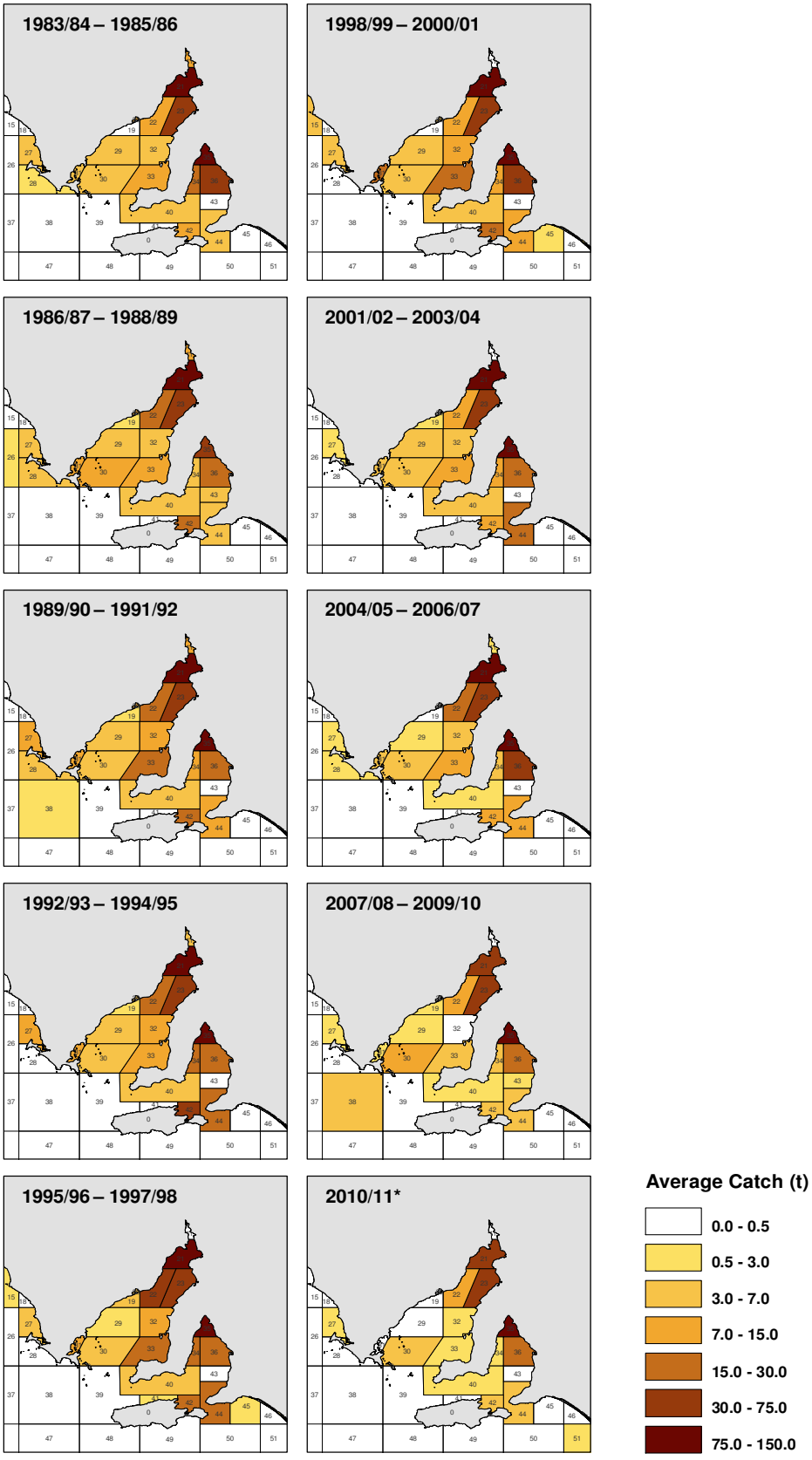

Figure 3.5 Spatial and temporal distribution of commercial catch (t) of garfish.
* Data were averaged over three-years with the exception of 2010/11.

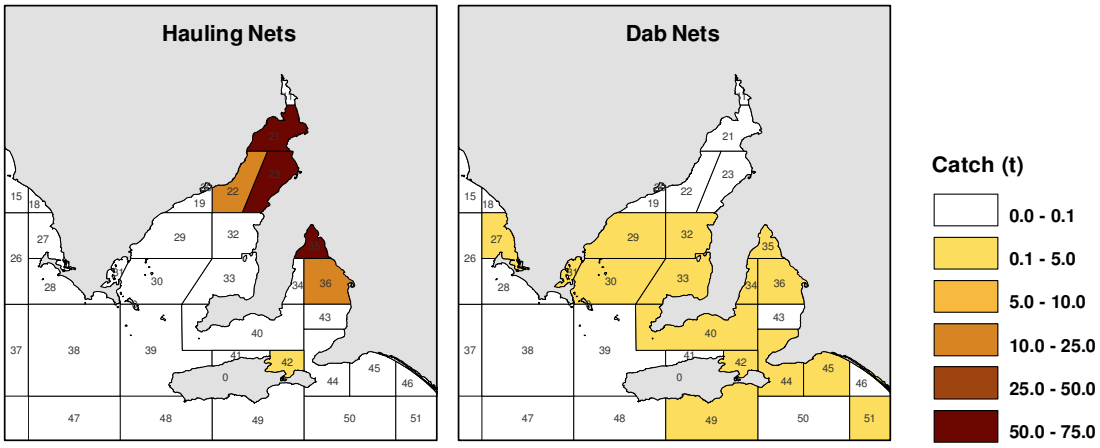

Figure 3.6 The spatial distribution of commercial catch (t) of garfish in 2010/11 by gear.

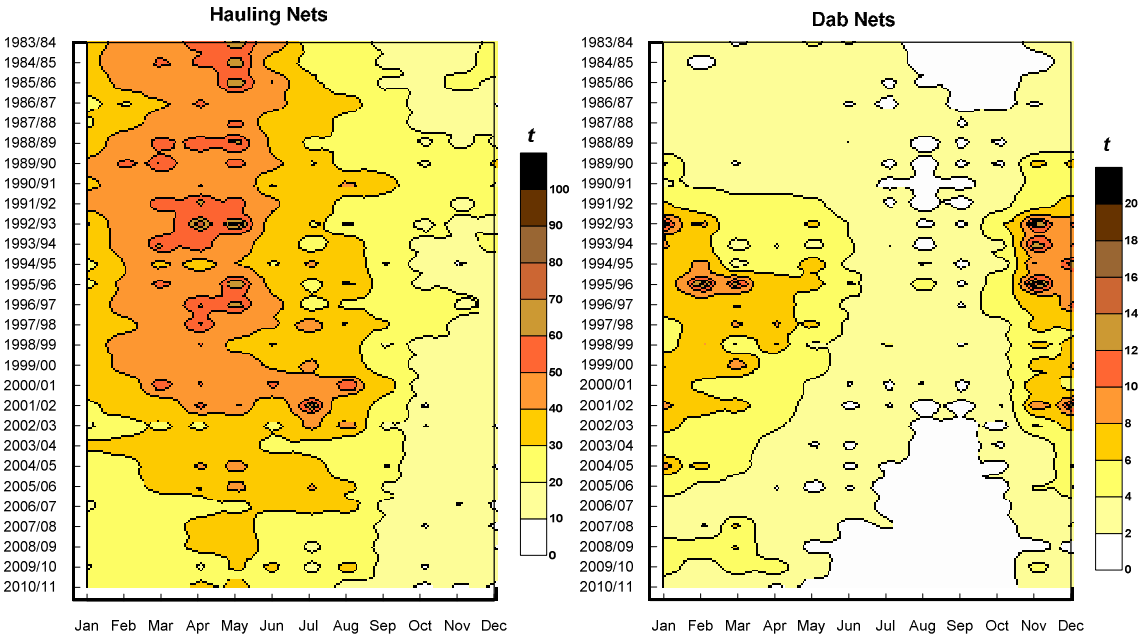

Figure 3.7 Long-term trends in seasonal commercial catch (t) of garfish separated by gear.

3.3.3 Regional Catch and Effort Trends

3.3.3.1 West Coast

From 1983/84 to 1998/99 the annual commercial catch of garfish from the West Coast accounted for approximately 7% of the State's catch. This has since declined to <2%. This decline has been driven by a reduction in hauling net effort (Figure 3.8b) and most likely related to a series of commercial netting restrictions that have been implemented in this region from 1958 to 2005 (Table 2.1). Annual garfish catch peaked at 37.8 t in 1987/88 of which hauling net fishers landed 82% (Figure 3.8a). The most recent catch of 3.6 t is the lowest on record with hauling net fishers landing 60% and the dab netters accounting for the remaining 40% (Figure 3.8a). The majority of the remaining hauling net fishers in this region have actively targeted garfish, and their relative catch rates peaked at 155.2 kg.fisherdays^{-1} in 2008/09 and again in 2010/11 at 107.4 kg.fisherdays^{-1} (Figure 3.8c). Dab netters have consistently landed ~35 kg.fisherdays^{-1} since 1999/00.

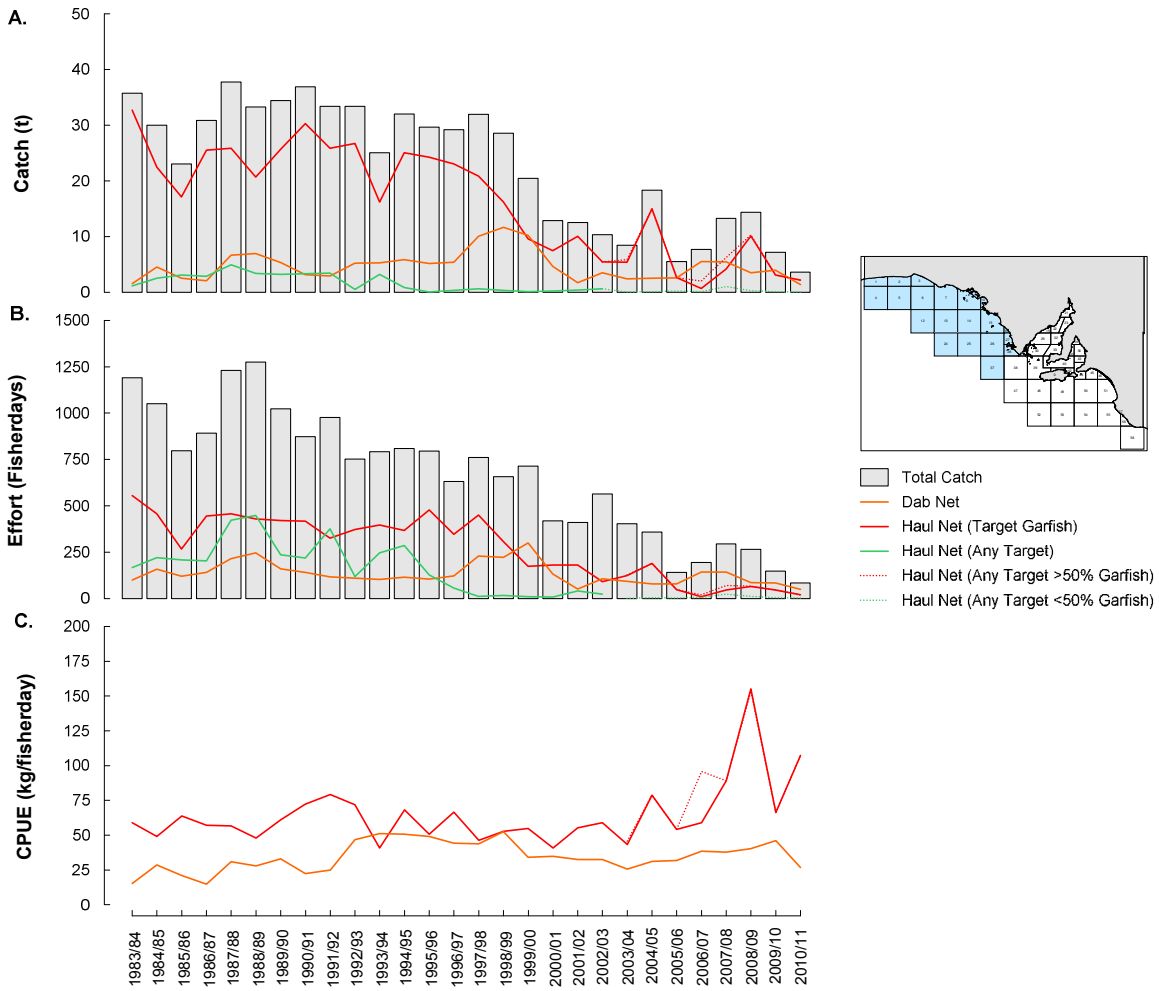

Figure 3.8 West Coast (A) commercial garfish catch, (B) effort, (C) CPUE by gear from 1983/84 until 2010/11. Insert shows the region of interest.

3.3.3.2 Southern Spencer Gulf

Like the West Coast, Southern Spencer Gulf has also had large areas closed to commercial hauling net fishing, and as a result the relative contribution of this region to the State-wide catch has decreased from ~10% pre-2005/06 to ~3% over the past six years. Most hauling net fishers that operated in this region were non-specific in their target species and during that late 1990s harvested the majority of the garfish catch (Figure 3.9a). Annual catch peaked at 76.1 t in 1997/98 and with the subsequent 'removal' of the hauling net sector in 2005/06 (Figure 3.9b), this region has become exclusively fished by the dab net sector and annual catches have remained below 14 t. Dab net fishing effort has decreased by 47% over the past four years (Figure 3.9b). Despite this decrease, the dab net CPUE has trended upwards and peaked over 50 kg.fisherday^{-1} in 2009/10 for the first time in ten years (Figure 3.9c).

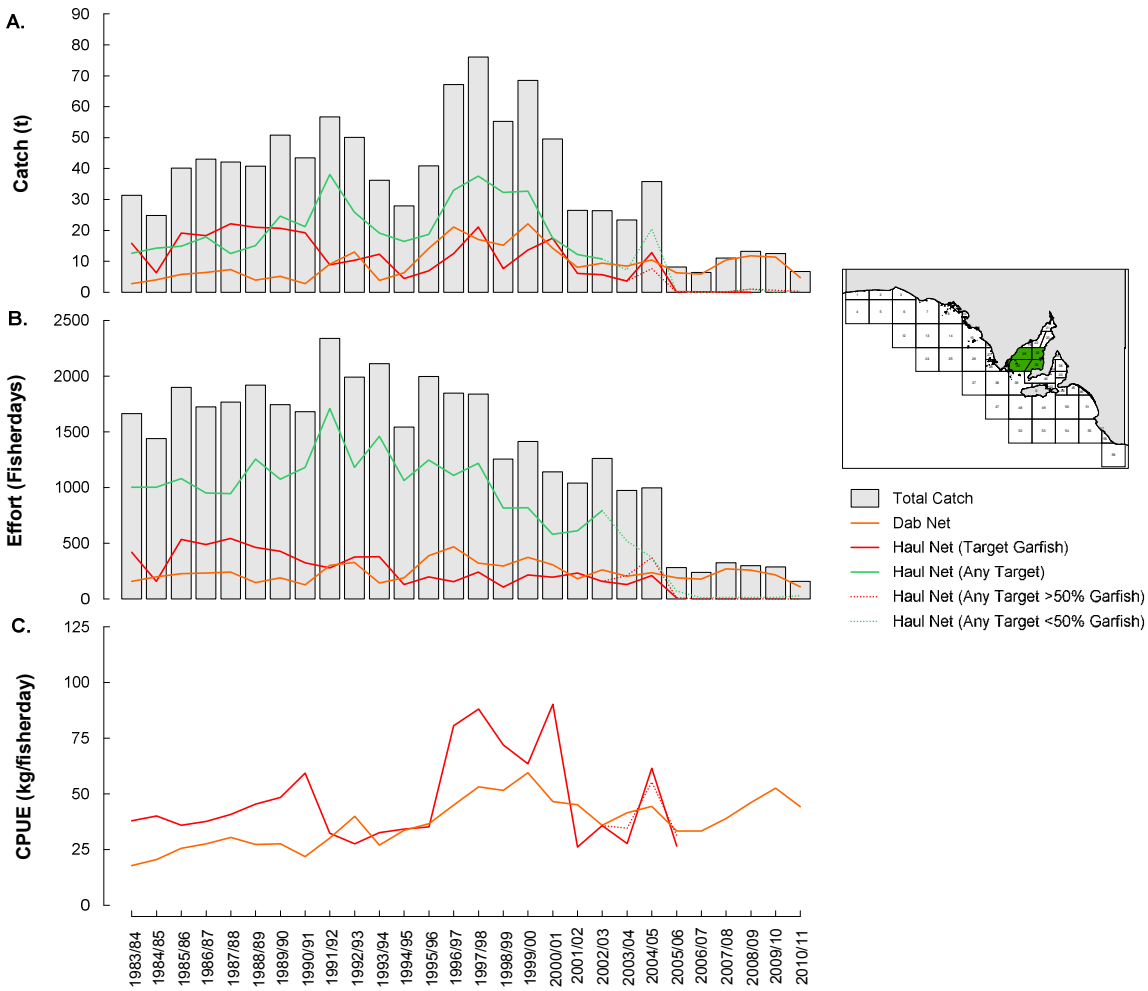

Figure 3.9 Southern Spencer Gulf (A) commercial garfish catch, (B) effort, (C) CPUE by gear from 1983/84 until 2010/11. Insert shows the region of interest.

3.3.3.3 Northern Spencer Gulf

Northern Spencer Gulf has been the most productive fishing ground for garfish in South Australia since 1983/84 and, in 2010/11 contributed to 53% of the State-wide catch. The highest recorded catch was 252.8 t in 1989/90. Annual catch declined considerably to 110 t in 2002/03 and with the exception of a peak of 169 t in 2006/07 subsequent catches have fluctuated around 125 t.yr^{-1} (Figure 3.10a). Catches have moderately increased over the past three years by 31% rising from 105 t in 2008/09 to 138 t in 2010/11. There has been a long-term trend of decreasing fishing effort in this region, where it has declined at a rate of 210 fisherdays^{-1}.yr^{-1} since 1983/84 (Figure 3.10b). This decrease has been driven by the hauling net sector, which has consistently contributed >95% of the fishing activity. Catch rates in the targeted hauling net sector have trended upwards since 1998/99 rising from 41.7 to 80.2 kgs.fisherday^{-1}, representing a 92% increase over a 13 year period (Figure 3.10c). Dab net catch rates peaked at 118 kgs.fisherday^{-1} in 1993/94, and have subsequently fluctuated around 40 kgs.fisherday^{-1}.

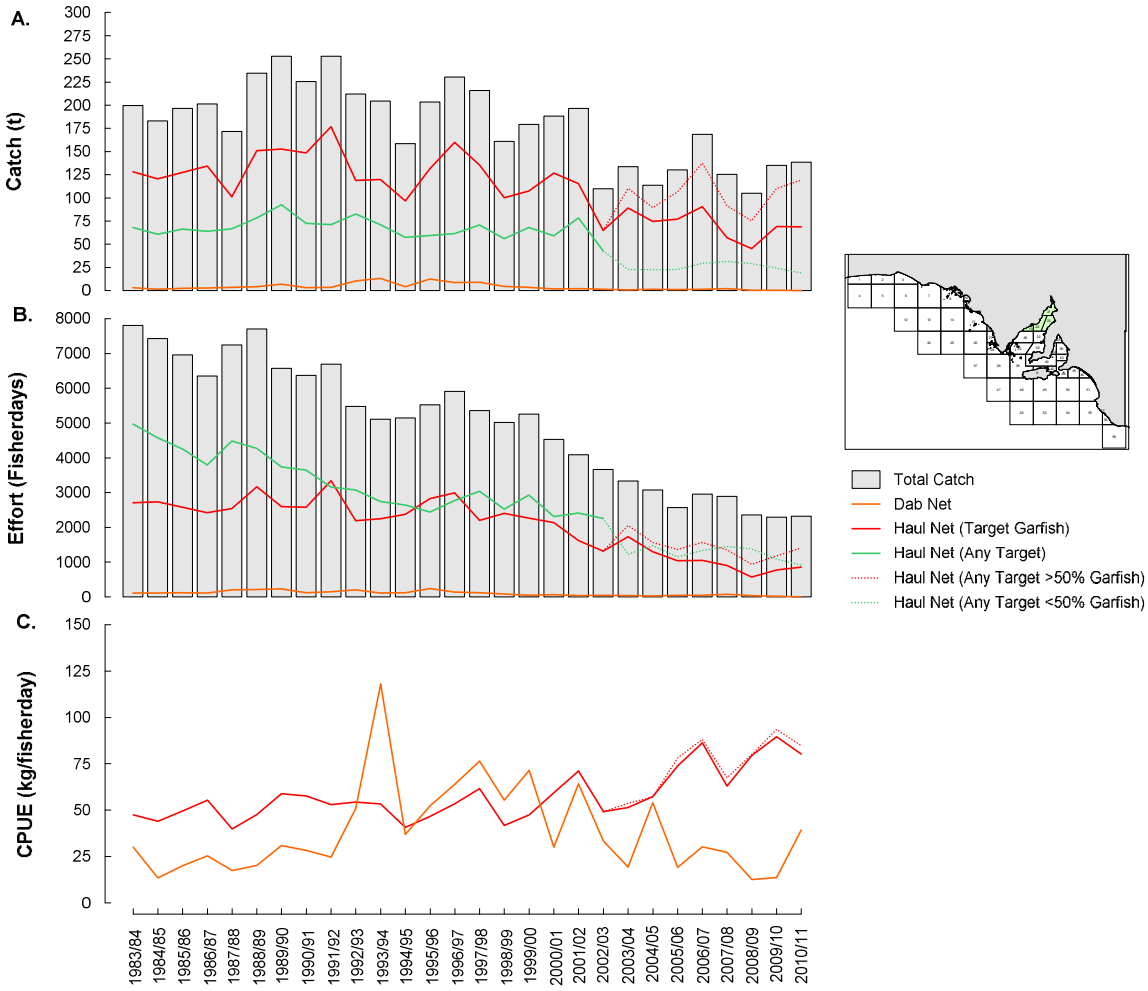

Figure 3.10 Northern Spencer Gulf (A) commercial garfish catch, (B) effort, (C) CPUE by gear from 1983/84 until 2010/11. Insert shows the region of interest.

3.3.3.4 Southern Gulf St. Vincent

The relative contribution of commercial garfish catch from this region to the annual State total has rarely exceeded 10%. Annual catches steadily increased from 21 t in 1983/84 to a peak of 78 t in 1992/93 with both the hauling and dab net sectors contributing equally (Figure 3.11a). From 1993/94, the contribution of garfish catch by the hauling net sector declined on the basis of a steady reduction in effort (Figure 3.11a). By 2005/06 the dab net sector became the dominant gear type as the implementation of hauling net restrictions virtually removed all haul netting from the region (Figure 3.11b). Consequently catches from this region declined to <12 t and have remained relatively stable over the past five years. Fishing effort and CPUE have also remained relatively stable over this period, at ~330 fisherdays.yr^{-1} and 35 kg.fisherday^{-1}, respectively (Figure 3.11c).

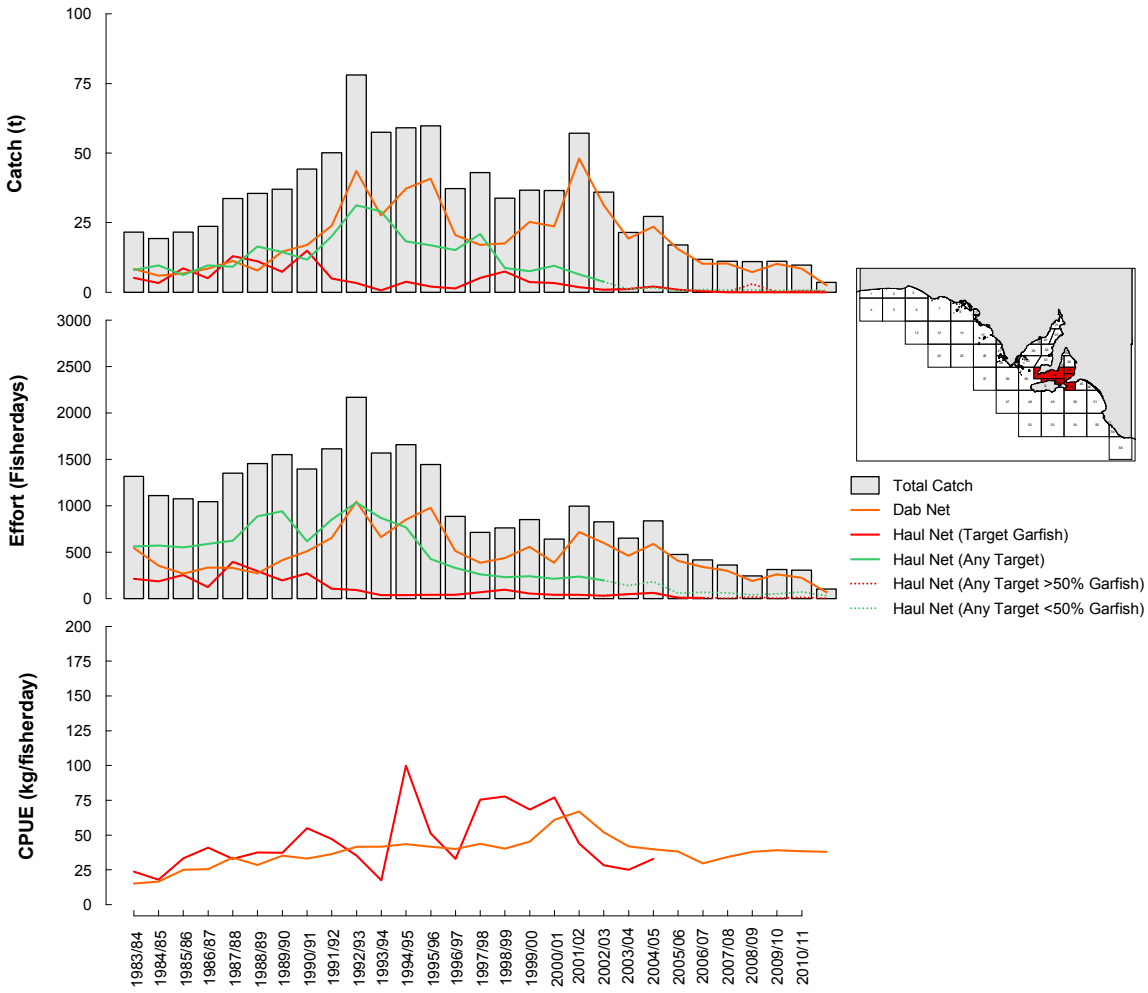

Figure 3.11 Southern Gulf St. Vincent (A) commercial garfish catch, (B) effort, (C) CPUE by gear from 1983/84 until 2010/11. Insert shows the region of interest.

3.3.3.5 Northern Gulf St. Vincent

Northern Gulf St. Vincent has historically been the second most productive region in the State, accounting for an average of 35% of its annual catch. Annual catches have exceeded 200 t twice in the last 28 years, the first at 244 t in 2000/01 and the second at 208 t in 2005/06 (Figure 3.12a). In 2006/07, catch was reduced by 53%, falling to 98 t which was the lowest level since 1986/87 (Figure 3.12a). This rapid decline corresponded with a 26% reduction in targeted hauling net effort and a 44% reduction in CPUE (Figure 3.12b). Like the other regions, fishing effort in Northern GSV has sequentially decreased as a result of a series of hauling net restrictions and the licence amalgamation scheme. This decline has occurred at a rate of ~118 fisherdays.yr^{-1} over 28 years. From 2006/07 to 2008/09 annual hauling net catch rates marginally improved from ~45 to 70 kg.fisherday, but have subsequently fallen to 60 kg.fisherday in 2010/11 (Figure 3.12c). Catch rates in the dab net sector have remained above 30 kg.fisherday over the past three years.

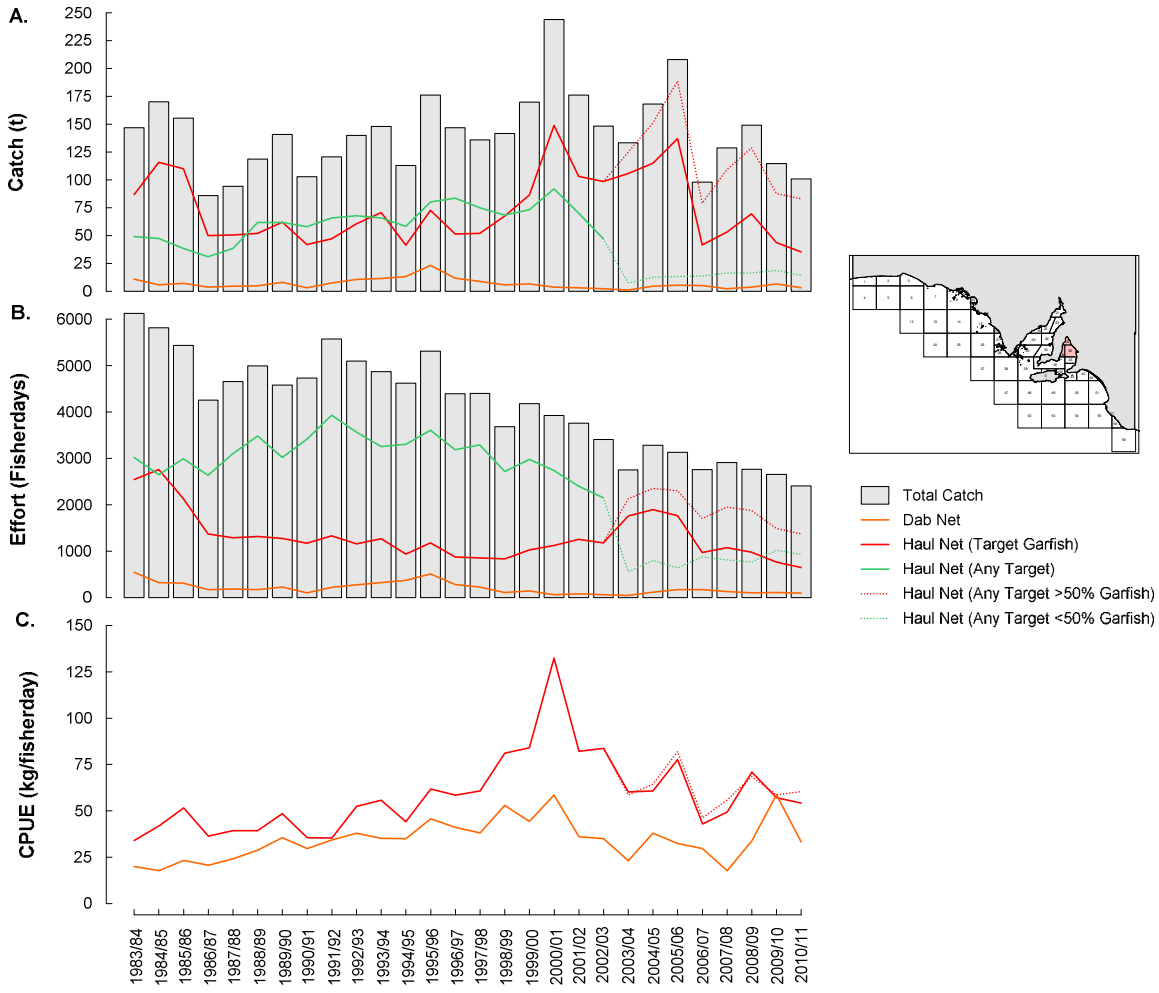

Figure 3.12 Northern Gulf St. Vincent (A) commercial garfish catch, (B) effort, (C) CPUE by gear from 1983/84 until 2010/11.

3.3.3.6 South East

A negligible amount of garfish is landed by the commercial sector in the South East, with the annual State-wide contribution rarely exceeding 0.3%. Despite some low-level hauling net activity during the 1980s and 1990s, most of the garfish were landed by dab net fishers (Figure 3.13a). Annual catch peaked at 3.2 t in 1986/87, and subsequent catches have fluctuated around 1 t. Fishing effort levels have been relatively stable over the past decade, averaging 33 fisherdays.yr^{-1} (Figure 3.13b). Catch rates have also been relatively stable during this time ranging from 11 to 26 kg.fisherday (Figure 3.13c).

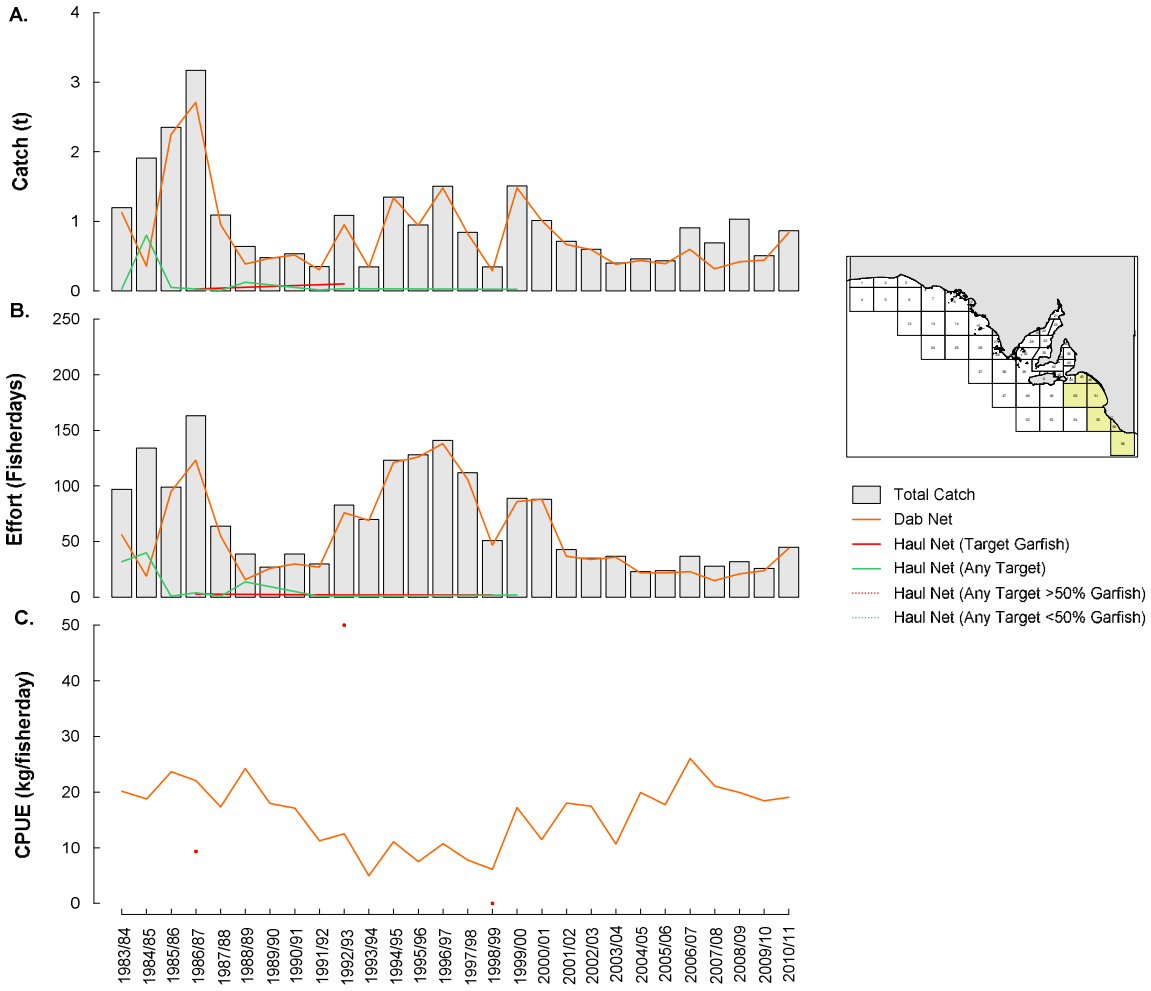

Figure 3.13 South East (A) commercial garfish catch, (B) effort, (C) CPUE by gear from 1983/84 until 2010/11.

3.3.4 Market Value

The total annual production value of South Australia's commercial garfish fishery peaked at $2.27 million in 1995/96 and subsequently exceeded $2 million three more times (2001/02, 2005/06 and 2007/08) (Figure 3.14). Production value has sequentially decreased by 26% since 2007/08 from $2.06 million to $1.53 million in 2010/11 (Figure 3.14). Over the long-term, the relative value of garfish has increased by an average of ~$0.50 kg^{-1} per year, peaking in 2007/08 at $7.10 kg^{-1} (Figure 3.14). However, the short-term trend, displays a 17% decrease over the last four years, with the market value decreasing to $5.86 kg^{-1} in 2010/11 (Figure 3.14).

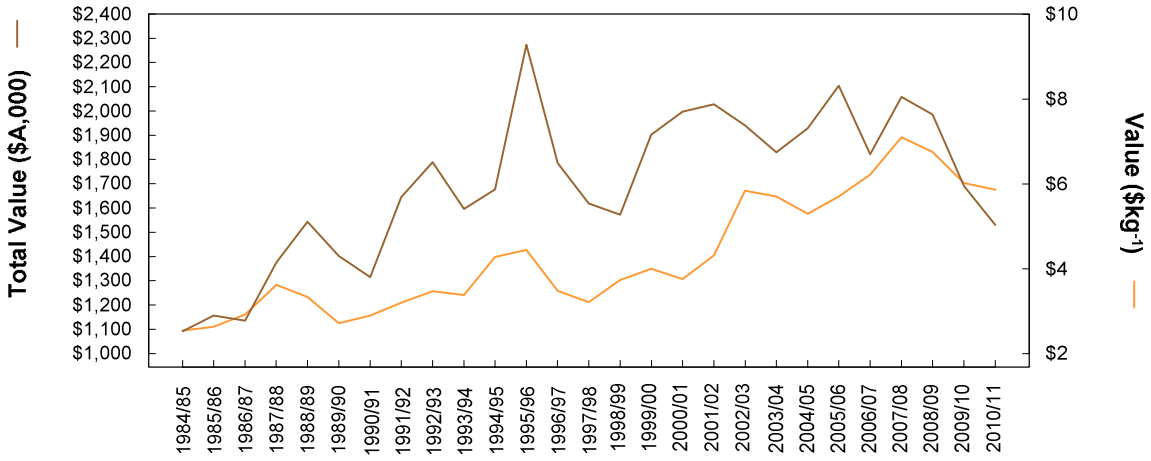

Figure 3.14 Long-term trends in total value and value per kg for garfish in South Australia.

3.4 Discussion

The total catch of garfish was 260.9 t in 2010/11, combined across all gear types, including both targeted and untargeted catch. This was 20.3 t less than the previous year, representing an annual decrease of 7.2% and was the lowest on the contemporary record. Annual decline in fishing effort continues to remain a feature of this fishery as it is perpetuated by the licence amalgamation scheme that was implemented in 1993/94. Annual fishing effort has reduced at a rate of 79 fisherdays per year. Despite the decline in total catch and sequential reduction in fishing effort, catch rates in both the haul net and dab net sectors are relatively high at 69.5 and 35.2 kg.fisherdays^{-1}, respectively.

In this assessment the commercial catch and effort analysis was partitioned into six regions. Traditionally the assessment of garfish stocks has relied exclusively on data obtained from the northern and southern gulfs where the majority (~98%) of garfish is harvested

(McGarvey et al. 2006, 2009). The decision to include the West Coast and South East regions in this assessment was made on the basis of providing a more comprehensive account of the State-wide fishery, particularly as a new harvest strategy is currently being developed (PIRSA). There has been low level hauling net activity on the West Coast and over the past four years catch rates in this sector have exceeded 100 kg.fisherdays^{-1}. Dab net catches in this region have also been relatively stable over the past 12 years. The commercial harvest of garfish from the South East is exclusively landed by dab net fishers, and like the West Coast, catches in this region have remained temporally stable. These trends in commercial catch and effort for these two regional fisheries suggest that there are no clear concerns about the status of their respective garfish populations.

The overall assessment of South Australia's garfish fishery relies heavily on data obtained from the hauling net sector which accounts for about 90% of the State-wide commercial catch. Similarly, the assessment places considerable emphasis on analysing catch and effort trends in the northern gulfs as these regions are almost exclusively fished by commercial hauling net fishers. Of the two northern gulf regions, northern Spencer Gulf has generally been the most productive accounting for approximately 53% of the State-wide commercial catch. Catches in this region have fluctuated around 125 t since 2002/03 and have moderately increased over the past three years. Targeted catch rates by hauling net fishers in this region have also trended upward since 1998/99, representing a 92% increase over a 13 year period. These trends contrast with that of northern GSV, where catches and targeted hauling net catch rates have declined over a similar period by 58% and 60%, respectively.

4 Analysis of Recreational Fishery Statistics

4.1 Introduction

Quantifying the recreational sector's contribution to the State's total catch is important in determining the overall status of fish stocks and resolving resource allocation issues. There have been three extensive recreational fishing surveys carried out in South Australia over the past 20 years. The first was a creel survey that was undertaken throughout 1994 to 1996 (McGlennon and Kinloch 1997). Second, State-wide telephone/diary surveys were done in 2000/01 (Henry and Lyle 2003) and 2007/08 (Jones 2009). Of these three surveys, only the results from the two most recent can be reliably compared as their data were collected using the same methodology.

The objective of this chapter is to provide a summary of the data available for the recreational catch and effort for garfish in South Australian coastal waters, based on the two most recent recreational fisher surveys.

4.2 Materials and Methods

The specific details of the methodology used in the two recreational surveys considered in this chapter can be found in their respective reports (2000/01: Henry and Lyle 2003, 2007/08: Jones 2009). Unfortunately, not all of the regional reporting boundaries that were used in the surveys aligned with South Australia's MFAs. To achieve relative continuity throughout this report, the recreational survey data were re-partitioned to correspond as closely as possible to the MFAs. It should also be noted that the 2000/01 survey data have been re-analysed using more precise expansion weights (used to scale-up the regional estimates in proportion to the local population) and, as a consequence, the results differ slightly from previous reports.

Although data were collected over 12 months in each survey, their timing did not correspond with either a calendar or financial year. The 2000/01 survey collected data from May 2000 to April 2001 and the 2007/08 survey from November 2007 to October 2008. In order to accurately determine the relative contribution of the recreational sector to the State-wide garfish catch, data from the commercial sector were extracted from the same time periods.

4.3 Results

4.3.1 Temporal Comparison

The estimated State-wide recreational harvest of garfish by South Australian residents in 2007/08 was 806,517 fish, with an estimated total weight of 75.0 t (Table 4.1). This was 35% lower than the 2000/01 estimate for which recreational fishers caught 1,238,919

garfish, weighing 115.2 t (Table 4.1). The highest catches of garfish by number and weight, were taken from GSV in 2000/01 and SG in 2007/08.

Estimates of total fishing effort also decreased over the course of the two surveys, with recreational fishers expending less time catching garfish (44.7% decrease) and less time targeting garfish (37.4% decrease) in 2007/08 compared with the 2000/01 estimates. Despite the difference in targeted effort, relative catch rates of garfish remained relatively consistent, with fishers who targeted garfish catching them at a rate of about 0.6 kg/hr. Catch rates were consistently highest for those fishers who targeted garfish on the West Coast whereas KI recreational fishers had the lowest catch rates (Table 4.1).

Table 4.1 Summary of results of catch and effort on garfish based on the 2000/01 National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003) and the 2007/08 South Australian Recreational Fishing Survey (Jones 2009).

Survey	Region	Estimated numbers (n)	Estimated catch (t)	Total effort (hrs)	Targeted effort (hrs)	Targeted CPUE (kg/hr^{-1})	CPUE (no/hr^{-1})
2000/01	WC	144,992.12	13.48	81,279.93	13,960.80	0.97	1.78
	SG	358,959.98	33.38	266,221.74	86,364.19	0.39	1.35
	GSV	598,550.81	55.67	337,147.27	65,990.49	0.84	1.78
	KI	21,012.68	1.95	9,376.99	5,192.04	0.38	2.24
	SE	115,403.86	10.73	66,008.99	18,210.19	0.59	1.75
	Total	*1,238,919.46*	*115.22*	*760,034.92*	*189,717.71*	0.61	1.63
2007/08	WC	79,955.64	7.44	56,669.19	3,007.02	2.47	1.41
	SG	369,122.86	34.33	149,296.23	63,345.88	0.54	2.47
	GSV	324,082.48	30.14	198,367.32	43,756.48	0.69	1.63
	KI	1,705.55	0.16	1,482.41	704.71	0.23	1.15
	SE	31,650.14	2.94	14,480.59	7,913.85	0.37	2.19
	Total	*806,516.66*	*75.01*	*420,295.74*	*118,727.93*	0.63	1.92

4.3.2 Distribution of Catch

The majority of the State-wide recreational catch in 2000/01 was taken from the Adelaide metropolitan coast (MFA 36) and near the popular tourist destinations of Moonta Bay and Port Hughes (MFA 32). The estimated catches from these two fishing blocks were 34.4 t and 14.1 t, respectively, and collectively represented 42.1% of the State's recreational harvest (Figure 4.1). These two regions also contributed to the same relative proportion of the total estimated recreational harvest in 2007/08 (42.5%), however, in the latter survey a greater quantity of garfish was harvested from MFA 32 (20.3 t) than MFA 36 (12.1 t) (Figure 4.1).

Relatively large quantities of garfish were also landed by recreational fishers in Coffin Bay (MFA 27) and near to Port Vincent (MFA 34) in 2000/01, estimated at 11.9 and 10.4 t, respectively. This, however, did not recur in 2007/08 as catches from these areas declined

and a greater proportion was taken from the Port Victoria/Hardwick Bay area (MFA 33) (Figure 4.1).

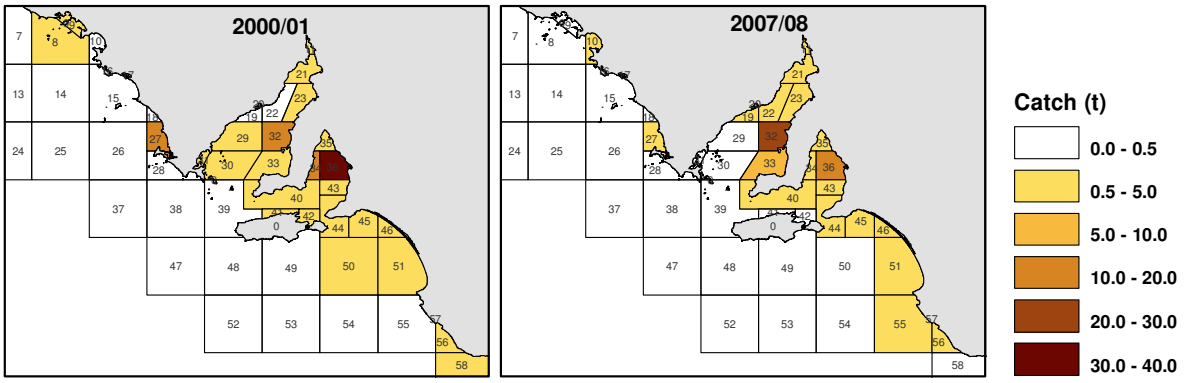

Figure 4.1 The spatial distribution of the recreational catch (t) of garfish across the two surveys.

4.3.3 Distribution of Catch among Sectors

Overall, both surveys indicated that South Australia's recreational fishing sector harvested approximately 20% of the State's total garfish catch (Figure 4.2). There was considerable regional variation in the relative contribution of the recreational sector, which was generally consistent across the two surveys (Figure 4.3). The recreational sector has consistently dominated the regional catch of garfish in the South East (>76%) where, historically, the commercial garfish harvest has been negligible (Figure 4.3). The distribution of catch is relatively even among the two sectors on the West Coast. In Spencer Gulf and Gulf St. Vincent, however, where commercial fishers target and catch garfish, the recreational sector has consistently harvested approximately 17% of the total regional catch. Recreational fishers operating around KI have contributed the least accounting for 9.5% and 1.8% of the total regional catch over the past two surveys (Figure 4.3).

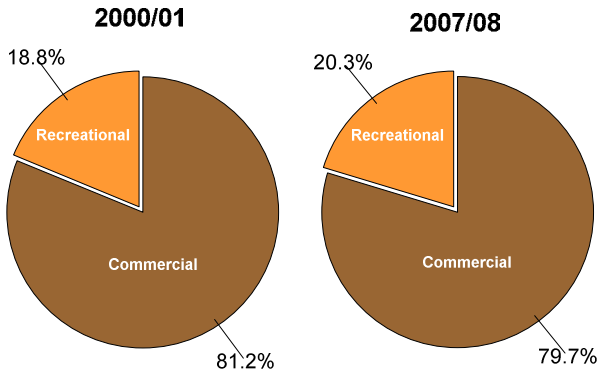

Figure 4.2 The break-down of South Australia's total catch of garfish by sector for each of the two surveys.

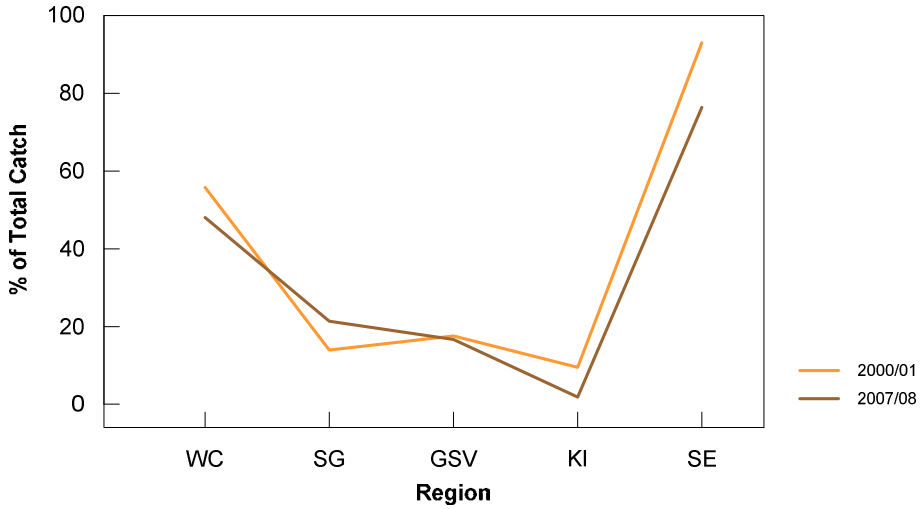

Figure 4.3 The regional contribution of the recreational garfish harvest to total catch for each of the two surveys.

4.4 Discussion

In order to produce a comprehensive fishery stock assessment and provide an estimate of total catch, data from all contributing sectors must be considered. The broad-scale recreational fishing surveys that have captured catch and effort data from South Australian residents in 2000/01 and 2007/08 have added considerable value to the assessment of the State's commercial fish stocks. These data are particularly relevant in ascertaining the relative contribution of the recreational sector to the State's total catch. This metric is important as it ensures that any management plan specific to the fishery will consider each sector's relative allocation. For South Australia's Garfish Fishery, the recreational sector has consistently accounted for about 20% (ranging from 18.8% – 20.3%) of the State-wide catch. This overall estimate has remained consistent, despite there being a reduction in catch and effort from 2000/01 to 2007/08 and moderate changes in the spatial distribution of the recreational harvest. It should be acknowledged, however, that estimates from these two recreational surveys are conservative as they do not include the contribution from inter-state fishers.

5 Population Structure

5.1 Introduction

Natural demographic processes such as growth, recruitment and mortality govern the relative strength and age composition of fish populations. For an unexploited species, losses due to mortality are generally balanced by gains through recruitment, and stock abundance would typically fluctuate around a mean level (King 1995). For highly exploited species, the composition of the population may become unbalanced, as the harvesting of adult fish may be at a level where reproduction and recruitment are unable to replace the numbers lost. Fishers generally harvest the larger and older fish from a population (or stock) and it is a challenge for fishery managers and scientists to ensure that the quantity of the harvest does not reach a level that compromises the sustainability of the stock. Reduced biomass and truncation in the size and age structures of a population are indications that the fishery has been over-exploited. Consequently, understanding the life history of a species and tracking population demography trends in terms of size and age data are fundamental components of fishery assessment.

SARDI has relied heavily on the South Australian Fisherman's Co-Operative Limited (SAFCOL) market to access the commercial catch and gain valuable biological information that is used to determine the population structure for South Australia's primary marine scalefish species. There have been several market sampling programs for garfish throughout the history of the fishery that has provided demographic data. Size and age data have been previously collected for garfish in 1954/55 for both GSV and SG (Ling 1958); 1977/78 for SG (Jones 1979) and; 1986/87 for GSV (Jones et al. 1990); 1998/99 for both gulfs (Ye et al. 2002). In 2005/06, SARDI initiated a new market-measuring program as part of the core research activities of the MSF (McGarvey et al. 2006). With the exception of a six month hiatus from July to December 2008, SARDI's market sampling program for garfish has occurred almost weekly since July 2005 and has primarily targeted samples from the northern gulfs. The aim of this chapter is to present the results on the population structure for the northern gulfs from both the contemporary and historic sampling programs and to provide a qualitative comparison of the spatial and temporal demography.

5.2 Materials and Method

5.2.1 Market Sampling

Each week a small team of SARDI researchers accessed the commercial catch of garfish at the SAFCOL market prior to the morning auction. Efforts were made to access the available catches from the northern regions of both gulfs to ensure that the information collected was

representative of the fishery. Occasionally, samples from KI were also considered, however, these sample sizes were typically much lower than for the other two regions.

The sampling methodology followed the two-stage protocol developed by Ye et al. (2002). This involved haphazardly selecting a prescribed number of boxes from a commercial catch. If a commercial catch from an individual fisher was <4 boxes, then all boxes were selected; if there were 4-30 boxes, every second box was selected; and if there were >30 boxes, then every 6th box was selected. Once selected, a maximum of five boxes were weighed to provide an average box weight. From each selected box, a 1 kg sub-sample of garfish was selected and each fish's total length (TL) was measured. A small number of garfish (~3 garfish per box) were purchased and returned to the laboratory for biological processing.

5.2.2 Laboratory Processing

All garfish purchased from the SAFCOL market were measured for both TL and standard length (SL) to the nearest mm, and weighed individually to the nearest 0.01 g. Each garfish was dissected to determine its sex and stage of reproductive development using the criteria of Ling (1958). The largest pair of otoliths (i.e. sagittae) were removed and subsequently used for age determination.

One otolith from each garfish was embedded in resin and sectioned using a diamond saw to produce a thin transverse section (Figure 2.2e). This section was mounted on a glass slide using super glue and then examined and interpreted by two trained readers. The number of opaque zones within the sectioned otolith, the characteristics of the edge of the otolith, the date of capture and the universal birth date (1st January) were recorded and used to estimate the age of the garfish. The universal birth date of 1st January was used as it approximates the middle of the spawning season (Ye et al. 2002b). Estimates of age in months was calculated using the following formula:

$Age_m = N^* \times 12 + M_c$

Where:

Age_m is the age of the garfish in months, M_c is the number of months from the nominated birthdate (1st January) to the month of capture, and N^* is the number of opaque zones (N) modified by the width of the otolith edge and month of capture (i.e. If a garfish is caught between August and December and has a narrow otolith edge, $N^* = N-1$, as the last opaque zone has only been recently formed. Alternatively, for garfish caught in January and have a wide otolith edge, $N^* = N+1$, as they should have deposited a new opaque zone by this time of the year, see Ye et al. (2002)).

The opaque zones in garfish otoliths are often difficult to discern and as such each prepared section was assigned a confidence index (CI) to categorise its overall clarity and interpretability. The CI ranged from 1-4, where 1 indicated that the otolith could not be interpreted to 4 where the otolith structure was clear and unambiguous. All otoliths that were categorised as having a CI of 1 were excluded from further analysis.

The processing of garfish otolith and subsequent age estimation typically occurred in large batches and there were often significant periods of time in between processing events. To ensure that the readers were interpreting the otolith structure consistently through time, each had to be reacquainted with the methodology and otolith characteristics before an ageing session. This was achieved through testing their interpretation against a random selection of garfish otoliths from a reference collection.

5.3 Results

5.3.1 Regional Growth Rates and Condition

A test was undertaken to compare the rates of garfish growth in GSV and SG. The GarEst model provides a maximum likelihood method for estimating growth rates which corrects for bias that would accrue from the faster-growing fish reaching legal size sooner. In this heavily exploited stock, faster growing garfish are under-represented in length-age samples because they are removed from the population at much faster rates once they reach legal size. The GarEst maximum likelihood estimates were used to perform a likelihood ratio comparison of garfish growth rates in the two gulfs, quantified by estimated values of von Bertalanffy *K* and L_∞. L_∞'s were fixed at 383 mm for females and 363 mm for males.

The results (Table 5.1) showed similar *K* values for males and females in each gulf, but *K*'s differed considerably between gulfs, with GSV garfish growing at a significantly faster rate. The *K*'s for females and males in GSV were about 0.38 (Table 5.1), while those in SG were 0.33-0.34. The likelihood ratio test showed these difference to be highly significant, with the maximised log likelihood for the full model (all 4 *K*'s independently estimated) being about 40 log-likelihood units smaller (3281 versus 3321), implying the overall GarEst model fit to data was much closer when separate levels of growth, by sex, in the two gulfs were assumed.

The relative condition of garfish was the same for both gulfs ($F_{1, 8280} = 0.31$, $p = 0.6$). The length-weight relationships were almost congruent (Figure 5.2).

Table 5.1 Likelihood ratio comparison of von Bertalanffy *K* parameters from growth curves for garfish collected from GSV and SG.

Hypothesis	*K*: SG females	*K*: SG males	*K*: GSV females	*K*: GSV males	log-likelihood
All 4 *K*'s independent	0.329	0.337	0.382	0.380	3281.37***
$K_{GSV,fems} = K_{SG,fems}$ & $K_{GSV,mals} = K_{SG,mals}$	0.346	0.353	0.346	0.353	3320.99

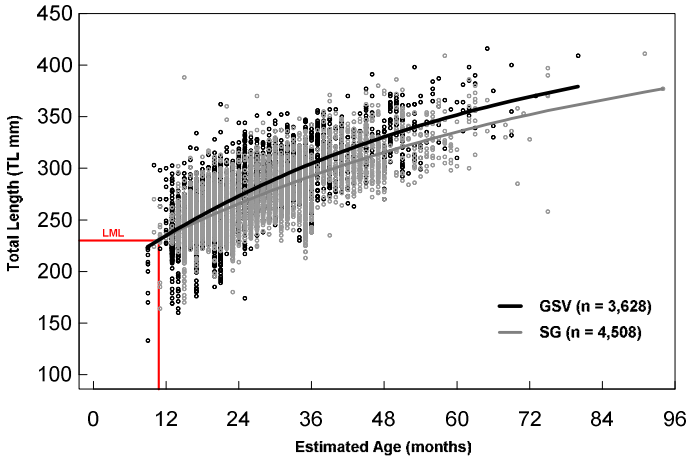

Figure 5.1 Von Bertalanffy growth curves for garfish collected from GSV and SG. The red line indicated the legal minimum length (LML).

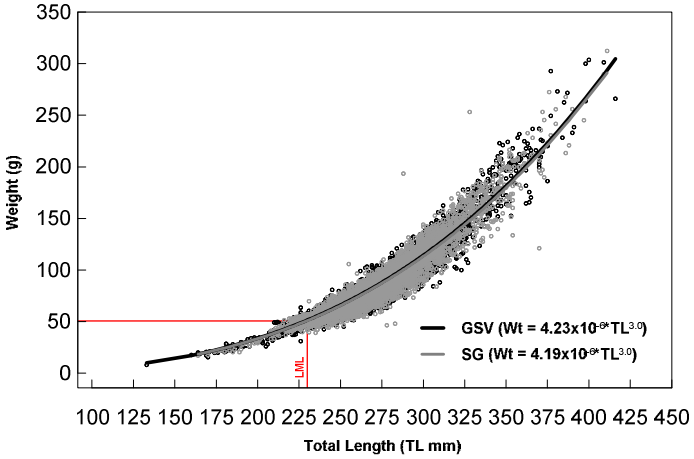

Figure 5.2 Length-weight relationship, as an estimate of relative condition for garfish caught in each gulf. Model parameters are provided. The red line indicated the legal minimum length (LML).

5.3.2 Annual Size and Age Structure

5.3.2.1 Gulf St. Vincent

With the exception of the relatively small sample (n = 385) of garfish collected over a four-month period in 2009, since 2005, the annual sampling program has successfully collected biological information from at least 1,750 animals per year from GSV (Figure 5.3). Similar quantities were also sampled by a series of historic garfish programs carried out in 1954/55 (Ling 1958), 1986/87 (Jones et al. 1990) and 1998 (Ye et al. 2002).

Comparisons between the historic and contemporary size and age structures demonstrate the degree of truncation that is apparent in the contemporary garfish fishery (Figure 5.3). This re-iterates the work previously carried out by Fowler and Ling (2010). Clearly a greater proportion of larger/older garfish were present in the fishery in 1954/55 compared with 2011. In 1954/55, over half (56%) of the fished population consisted of garfish that were >280 mm TL and approximately 67% were at least three years of age (3+). In 2011, 37% of garfish exceed 280 mm and 13% of the population were 3+ (Figure 5.3). This degree of truncation appears to have occurred back in the 1990s as there is a clear absence garfish >280 mm (~22%) in the 1998 sample with only 8% within the 3+ age cohort. Three and four-year-old fish were rare in 2005, collectively contributing to 1.3% of the population and this was the first year when the fishery was dominated by a single age cohort, in which 89% of garfish were 1+. Since 2005, the size and age structures have remained relatively stable, and although the modal sizes have ranged between 240 mm to 280 mm, the relative proportion of >280 mm garfish has fluctuated around 33%. One and two-year-old garfish have also continued to dominate (>85%) the population age structure over the past six years. Two six-year-old (6+) garfish have been sampled over the course of the program, one in 2006 and the other in 2011 (Figure 5.3).

Both the 2004 and 2007 cohorts appeared to be relatively strong as they maintained their prevalence over two consecutive years. The 2004 cohort dominated the 2005 population as 1+ (89%) fish and the 2006 population as 2+ (55%) fish (Figure 5.3). A similar trend, although to a lesser extent, was evident for the 2007 cohort, where the 1+ fish contributed 58% of the 2008 population and the 2+ fish contributed 55% of the 2009 population (Figure 5.3). All other age cohorts (2005, 2006, 2008 and 2009) maintained their dominance for one year.

The seasonal size distributions of garfish sampled from GSV displayed considerable variation (Figure 5.4). As such it was difficult to identify any clear temporal trends. There appeared to be a general influx of small garfish (<250 mm) during the January to March

quarter in most years, with the relative contribution of this size class ranging from 31% (2006) to 59% (2007) of the population. Alternatively, large (>280 mm) garfish were more evident during cooler periods (April to September). These larger garfish typically accounted for 30-50% of the population during this period. The age distributions, however, were more consistent as they were typically dominated (~90%) by 1+ and 2+ garfish, with relatively minor contributions by the older age classes (Figure 5.4). The greatest proportion of garfish that were at least three-years of age was observed in the first quarter (January – March) of 2011, when they comprised 22% of the sampled population (Figure 5.4).

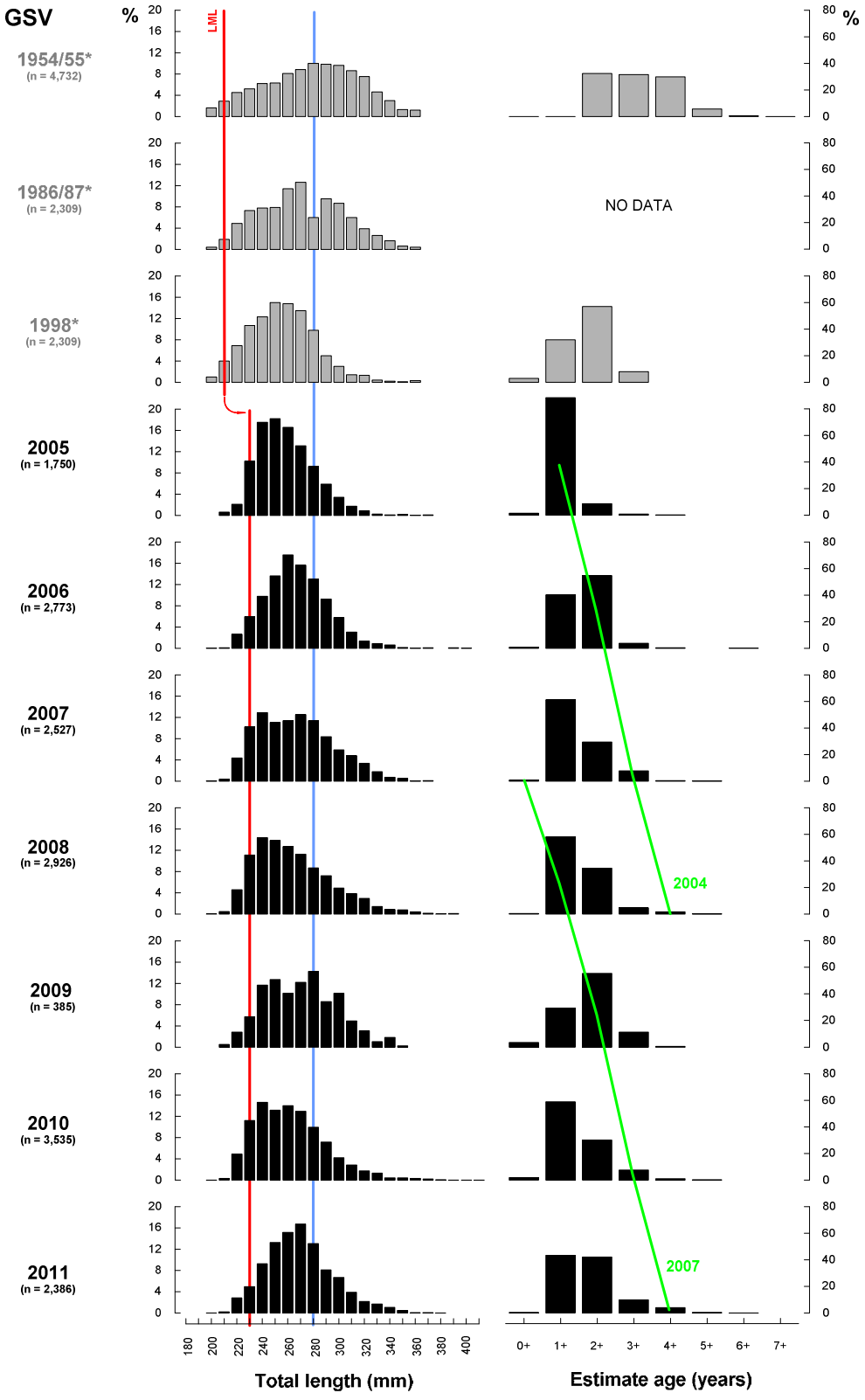

Figure 5.3. Annual size and age structures for garfish sampled from GSV from 1954 to 2011. *Historic data collected from: 1954/55 (Ling 1958); 1986/87 (Jones et al. 1990); and 1998 (Ye et al. 2002). The red line denotes the legal minimum length (LML); the blue line indicates the 280 mm size class; and green lines track nominal age cohorts.

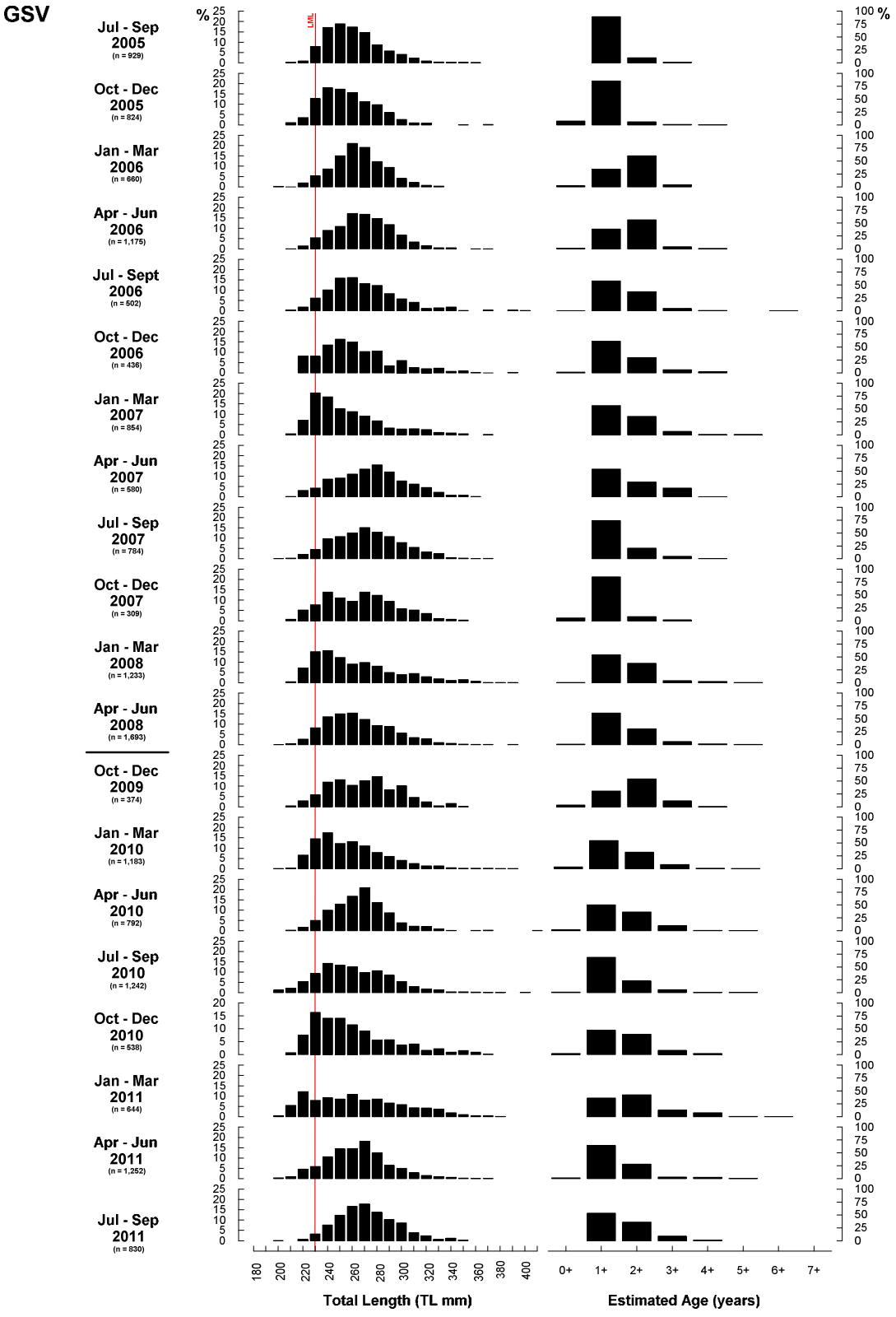

Figure 5.4 Seasonal size and age structure of garfish from GSV. Age structures were generated from a spatially and temporally resolved age/length key. Note the break in seasonal sampling between June 2008 and October 2009. The red line denotes the legal minimum length (LML).

5.3.2.2 Spencer Gulf

In comparison to GSV, considerably more garfish were sampled from SG as part of the biological sampling program, ranging from 870 in 2009 (over a four month period) to 5,243 in 2006 (Figure 5.5). Large quantities of garfish were also sampled during the historical programs when biological information was collected from more than 5,000 garfish in 1954/55 (Ling 1958) and 1998 (Ye et al. 2002); and 57,066 garfish in 1977/78 (Jones 1979) (Figure 5.5).

Like GSV, the size and age structures of the garfish population in SG have become truncated over time (see Fowler and Ling 2010). In 1954/55, 60% of the population consisted of large (>280 mm) garfish and 87% were at least 3+. This contracted to 19% and 7%, respectively, in 1998 (Figure 5.5). Moderately more larger garfish were evident in the 2005, with fish >280 mm making up 27% of the population, and this size structure remained relatively stable until 2011, with the modal size ranging from 240 to 260 mm. The age structure has remained relatively consistent since 2005, with 1+ and 2+ garfish dominating (>83%) the fished population. Seven-year-old garfish were sampled on two occasions, once in 2005 and again in 2010 (Figure 5.5).

The 2004, 2006 and 2007 cohorts were the only three that dominated the population over two consecutive years. The 2004 cohort contributed to 70% of the 2005 population as 1 year-olds and 58% of the 2006 population as 2 year-olds (Figure 5.5). Similarly the 2006 cohort was strongly represented in 2007 and 2008, contributing to 55% (1+) and 49% (2+), respectively. The 2007 cohort also made a significant contribution to the 2008 (46%) and 2009 (56%) population (Figure 5.5).

The seasonal variation in the size composition of garfish sampled from SG largely reflected that of GSV. There was a general influx of small animals during the summer months, particularly from January to March. This size class typically contributed 40-60% of the sampled population (Figure 5.6). Larger garfish made their greatest relative contribution (33-43%) during the cooler half of the year (April to September). The age distributions were also similarly dominated (~88%) by 1+ and 2+ garfish (Figure 5.6). The greatest proportion of garfish that were at least three-years of age was observed in the last quarter (October - December) of 2010, when they comprised 24% of the sampled population (Figure 5.6).

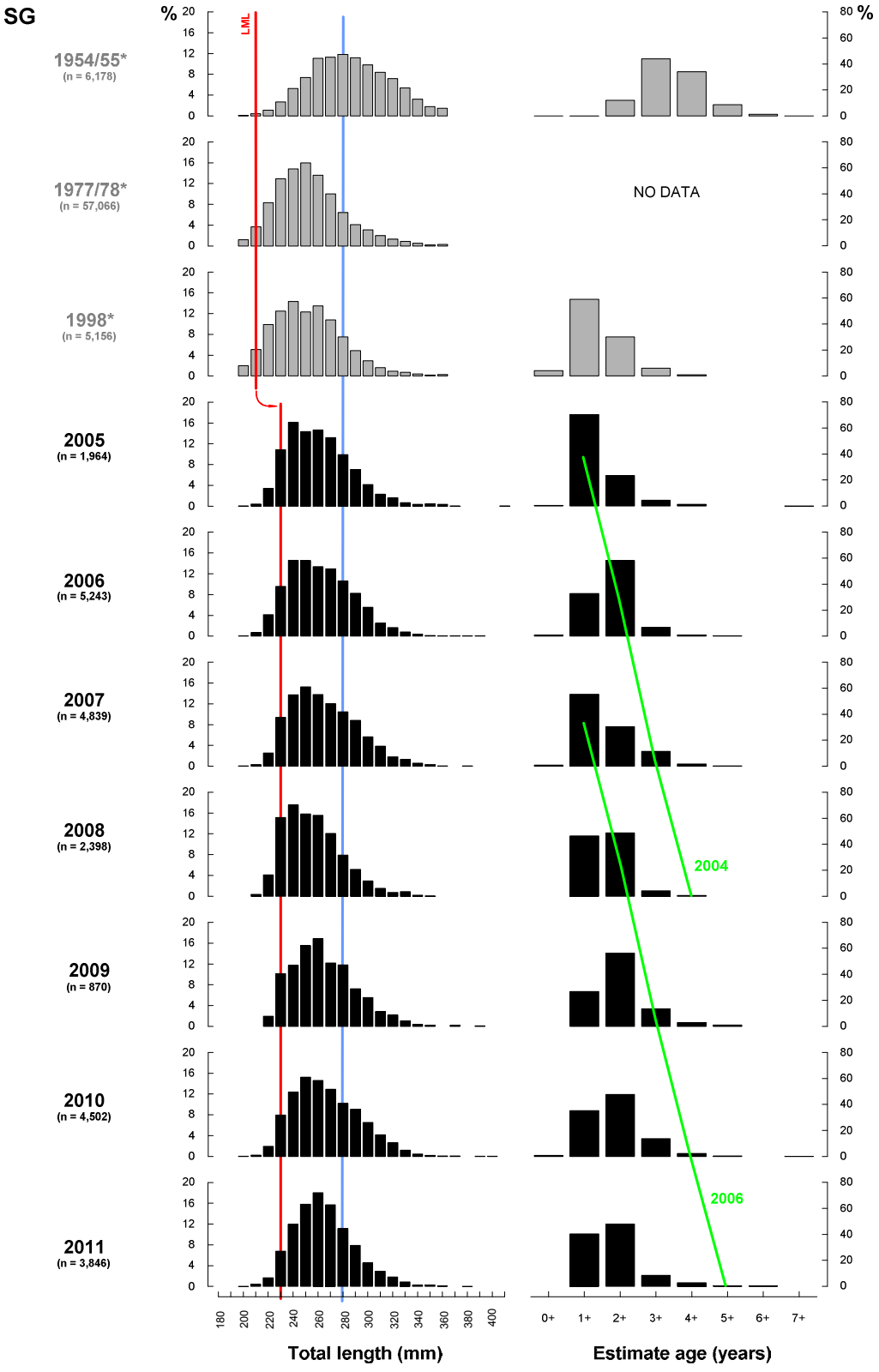

Figure 5.5 Annual size and age structures for garfish sampled from SG from 1954 to 2011. *Historic data collected from: 1954/55 (Ling 1958); 1998 (Ye et al. 2002); 1977/78 (Jones 1979). The red line denotes the legal minimum length (LML); the blue line indicates the 280 mm size class; and the green lines track nominal age cohorts.

SG

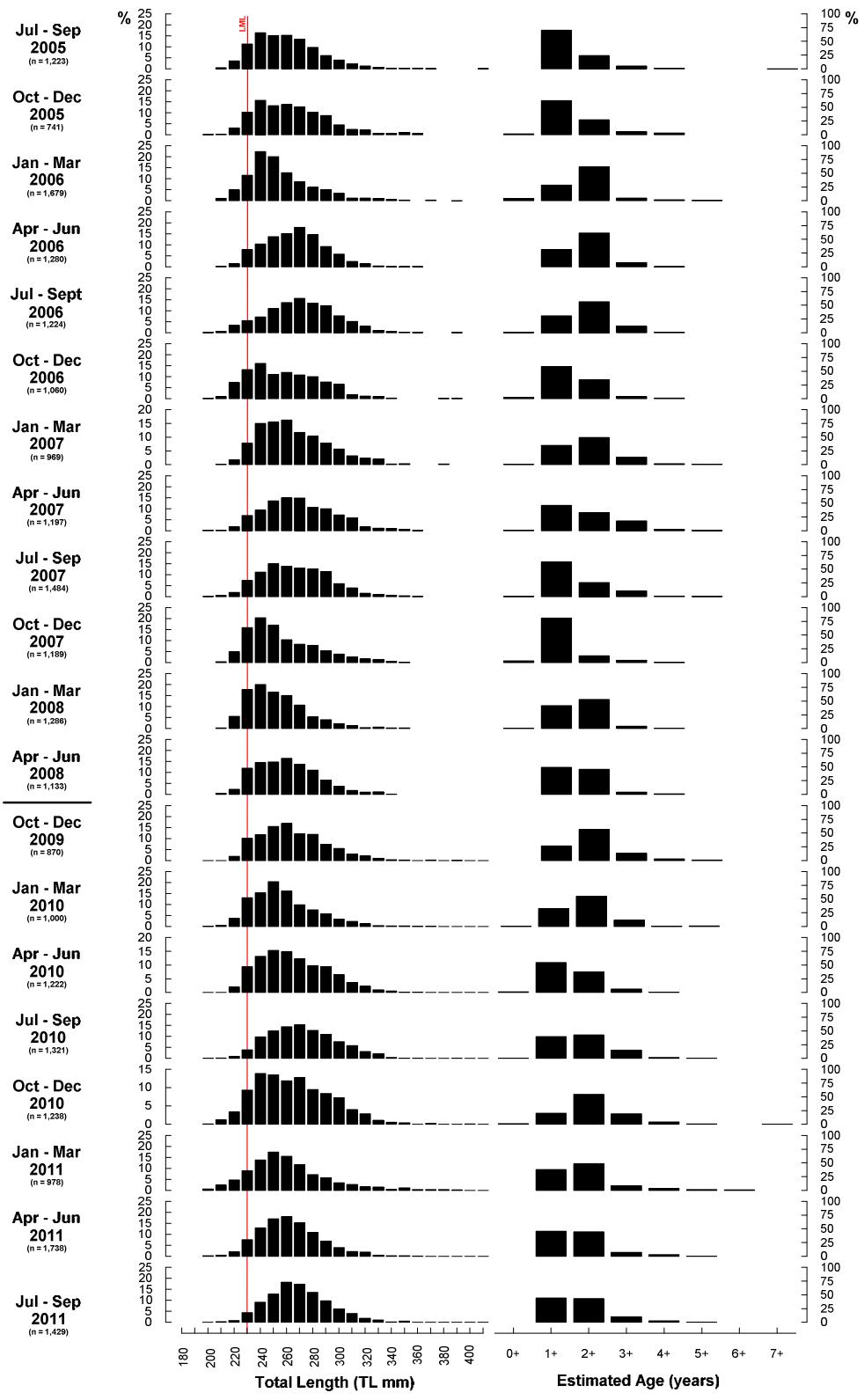

Figure 5.4 Seasonal size and age structure of garfish from SG. Age structures were generated from a spatially and temporally resolved age/length key. Note the break in seasonal sampling between June 2008 and October 2009. The red line denotes the legal minimum length (LML).

5.3.3 Sex Ratio

For both gulfs, the composition of the commercial catch of garfish is typically dominated by females. The sex ratio is most strongly biased towards females during the warmer months (October to March) (Figure 5.8). Although this trend is relatively consistent in both gulfs, the proportion of females in SG was generally higher than GSV and frequently exceeded 85% (Figure 5.8). The relative proportion of females declined during winter. However, they still out-number the males by 1.5 to 3 times.

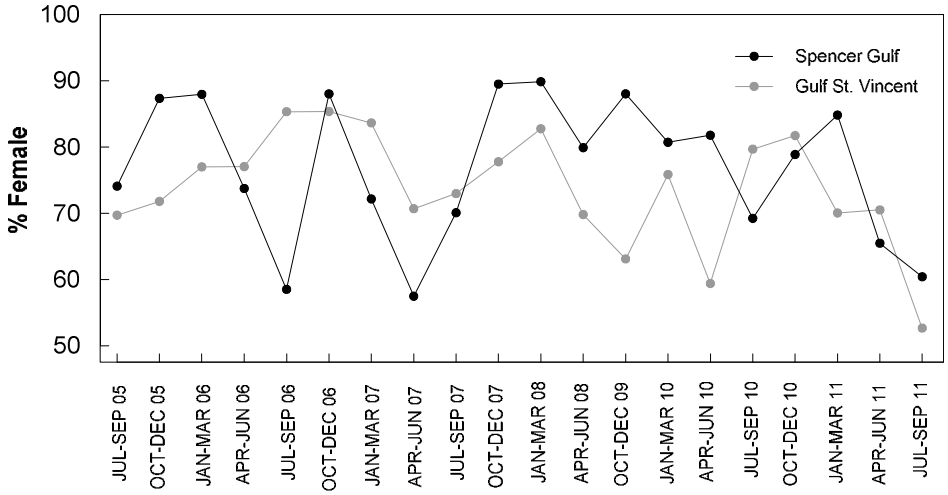

Figure 5.5 Quarterly sex ratio of garfish from July-September 2005 until July-September 2011 in each gulf.

5.4 Discussion

The population demography of South Australia's Garfish Fishery has remained relatively unchanged since 2005. The fishery has continued to be dominated by moderate size garfish (240 – 280 mm TL) from the 1+ and 2+ age classes, a trend that has been consistent in both gulfs. Occasionally a few older 5+ garfish appeared in the biological samples. However, their rarity was not indicative of any significant shift or improvement in the population's overall age structure.

It is now well established that the population structure of the garfish fishery is truncated when compared to the size and age structure of the 1954/55 population (see Fowler et al. 2008; Fowler and Ling 2010). There is a clear absence of 3+ and 4+ age classes, which historically contributed to the bulk of the commercial catch. This level of truncation appears to have occurred in the 1990s for the GSV population and perhaps earlier (~1970s) in SG as this was the approximate time from which the 3+ and 4+ age classes were poorly represented. This means that egg production and recruitment has depended on the 1+ and 2+ age classes for decades, and despite this the garfish fishery has demonstrated considerable resilience.

6 Model Assessment

6.1 Introduction

To monitor changes in the South Australian garfish population, the GarEst model (McGarvey et al. 2007) was developed as part of an FRDC-funded project (McGarvey and Feenstra 2004). The model covers the fisheries in the two South Australian gulfs, which accounted for 96% of the State-wide garfish catch over the past five years.

The principal input data for the model are (1) logbook catch and effort totals, (2) market-sampled garfish catch proportions by sex, age and length, and (3) the estimated recreational catch from the National Recreational and Indigenous Fishing Survey (NRFIS) (Henry and Lyle 2003) and South Australian Recreational Fishing Survey (Jones 2009).

This chapter presents: (1) a brief model description, (2) plots of model fits to data, and (3) the model outputs as time series of estimated biological performance indicators.

6.2 Materials and Methods

The GarEst model accounts for changes in garfish population numbers by age and length within each age group. Accounting for dynamic change by both the age and length of fish in the population allows the model to use all data optimally (notably catches sampled by age and length) and to account for the on-going gradual recruitment of garfish as each age group grows into the legal size range where they can be harvested, and for the much higher mortality incurred by legal size garfish (regardless of age).

The model assesses the South Australian garfish catch and effort data broken down into four effort types (haul net targeting garfish, haul net non-targeting, dab net plus all other gears, and recreational). CPUE for targeted haul net from the newly refined effort type category ("Any Target >50% Garfish"; Section 3.2) was used for model time steps starting in October 2005 (subsequent to the voluntary net buy-back program).

Recreational garfish catches, by time step and gulf, for all model half-yearly time steps, were inferred from the two telephone and diary surveys, 2000/01 (Henry and Lyle 2003) and 2007/08 (Jones 2009), as summarised in Chapter four. Prior to 2000/01, the recreational catches were computed by extrapolating backward from the NRIFS catch number estimates (Chapter four; Henry and Lyle 2003) based on change in South Australian human population size. Between the two surveys, catches were assumed to vary linearly. Subsequent to the second survey in 2007/08, these estimates again varied in proportion to South Australian human population numbers.

Yearly recruitment is defined as the number of garfish spawned in each summer year class that survive to reach age 1. Fast growing garfish reach LML (210 or, since 2001, 230 mm TL) at age 1, i.e., the summer after they were spawned.

Model estimates of half-yearly biomass assume a 2.1% rising effective effort over the years up to 2001, when the size limit was raised. The yearly estimated harvest fractions were calculated by summing model catch in weight across each annual time period divided by average biomass from the two model time steps in each year.

For this report, percent virgin egg production was computed as a ratio over average egg production for the last 15 years from a run of GarEst with *F* set equal to 0. In previous years, this ratio was taken for each year individually. The change, which means percent egg production now exactly tracks total egg production, caused the percent virgin index to produce variously smaller values. For example, the percentage egg production values reported in the last report, for 2008 were 14% and now for that year, they are 11% for both gulfs.

Mathematical details of the GarEst garfish stock assessment model are provided in McGarvey and Feenstra (2004). The slice-partition modelling method of accounting for the dynamically changing fish population numbers by length within each yearly (age) cohort is reported in McGarvey et al. (2007) (Figure 6.1). While under development, the GarEst model was externally reviewed during three visits by Prof. André Punt (CSIRO & University of Washington, Seattle, USA). His review and our responses are included as an Appendix in McGarvey and Feenstra (2004).

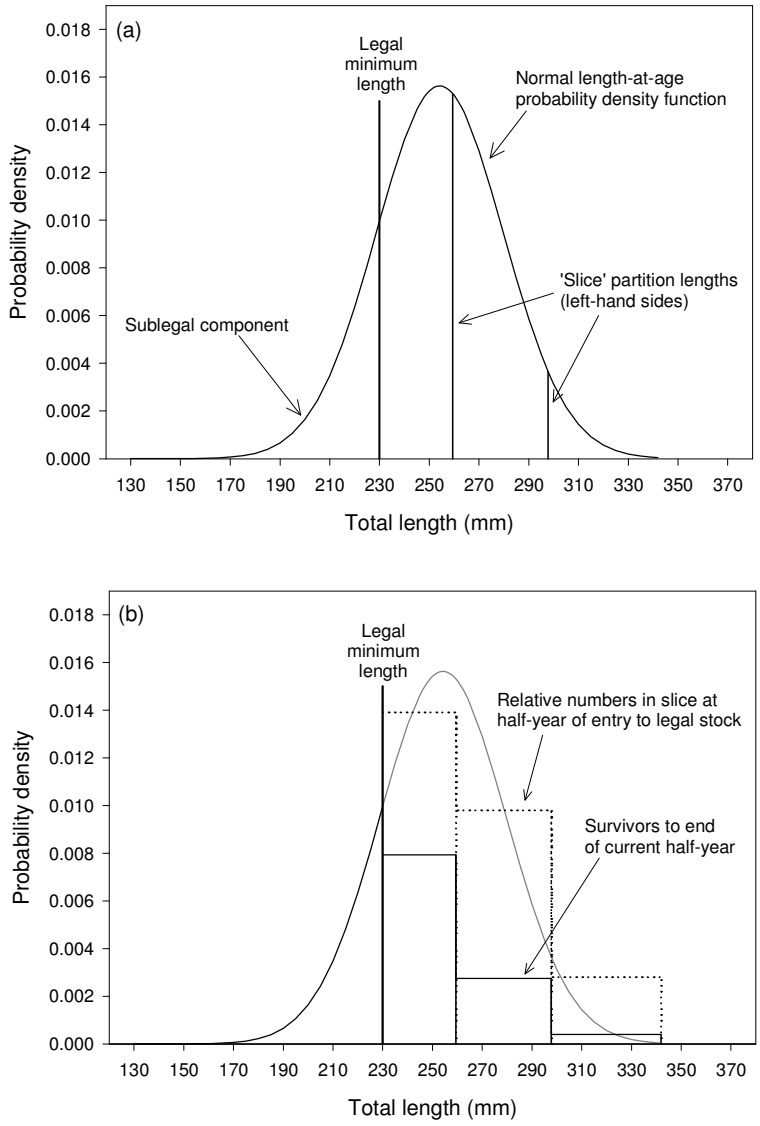

Figure 6.1 Illustration of the growth of a garfish cohort above legal size, and the creation of new slices in the GarEst model, which permits accounting for model population numbers of garfish in each cohort by length.

6.3 Results

6.3.1 Model Representation of Catch Proportions by Sex and Age

Mortality and, in part, yearly variation in recruitment, are inferred in the model from length and age samples of the commercial catch. In this section, we present the GarEst model-predicted fits to the age and sex market sample catch proportions from 2005-2008 in the half-yearly time steps used by the model, by gulf.

In summer, when aggregated schools of spawning females are targeted inshore, females comprise about 85% of the catch in both gulfs (Figure 5.8; Section 5.3.4). In winter, females are also more numerous than males by approximately 1.5 – 3.0 times.

However, proportions by age do not show lower proportions of females surviving to older ages despite the far higher number of females removed by the fishery (Figure 6.2). This implies that correspondingly higher numbers of females are recruiting each year to the fish stock. Accordingly, model-estimated mean recruit numbers are about three times higher for females than males. The life history implications of this imbalance in sex-ratio are not known.

As discussed in Chapter five, garfish above the fully recruited age of one or two years are rare in GSV and SG (Figures. 5.3-5.4 and Figure 6.3). From these age samples in which few fish survive longer than one year in the fishery, the model estimates high levels of mortality. These heavily truncated age compositions from the two gulfs contrast strongly with an age sample of garfish collected using a gill net from the lightly fished population in Baird Bay, which is located on the West Coast and outside of the model area (Jones 1990). The fishery-independent sampling from Baird Bay showed high proportions of garfish present up to five years of age for females and seven years for males. On this basis, the model estimated high levels of exploitation for South Australian garfish. More recent comparisons of age and length structures by Fowler and Ling (2010) confirm that levels of exploitation in the two gulfs have increased substantially from the 1950s, when the catch was dominated by garfish of age four and five. Thus, assuming natural mortality rates have not changed greatly since the 1950s, the highly truncated age structures observed in the last two decades reflect unusually high levels of fishing mortality rate. These direct qualitative comparisons to both a virgin stock and the gulf populations from the 1950s are thus consistent with high model estimates of fishing mortality rate.

The GarEst model closely fits the catch proportions by sex and age (Figures 6.2 and 6.3). These close fits reflect both model and data, that is, a fishery which conforms to model assumptions and catch samples (by length) which are representative from a regular systematic market sampling survey design. In particular, these close fits to age samples, and high by standards of most fishery models, imply an accurate model description of the garfish population age structure in the two gulfs, from which garfish mortality estimates are inferred. Close fits of the model to age data are also consistent with the assumption of minimal movement (see Steer et al. 2009) by garfish, at least over the age range where garfish are harvested in the northern gulfs.

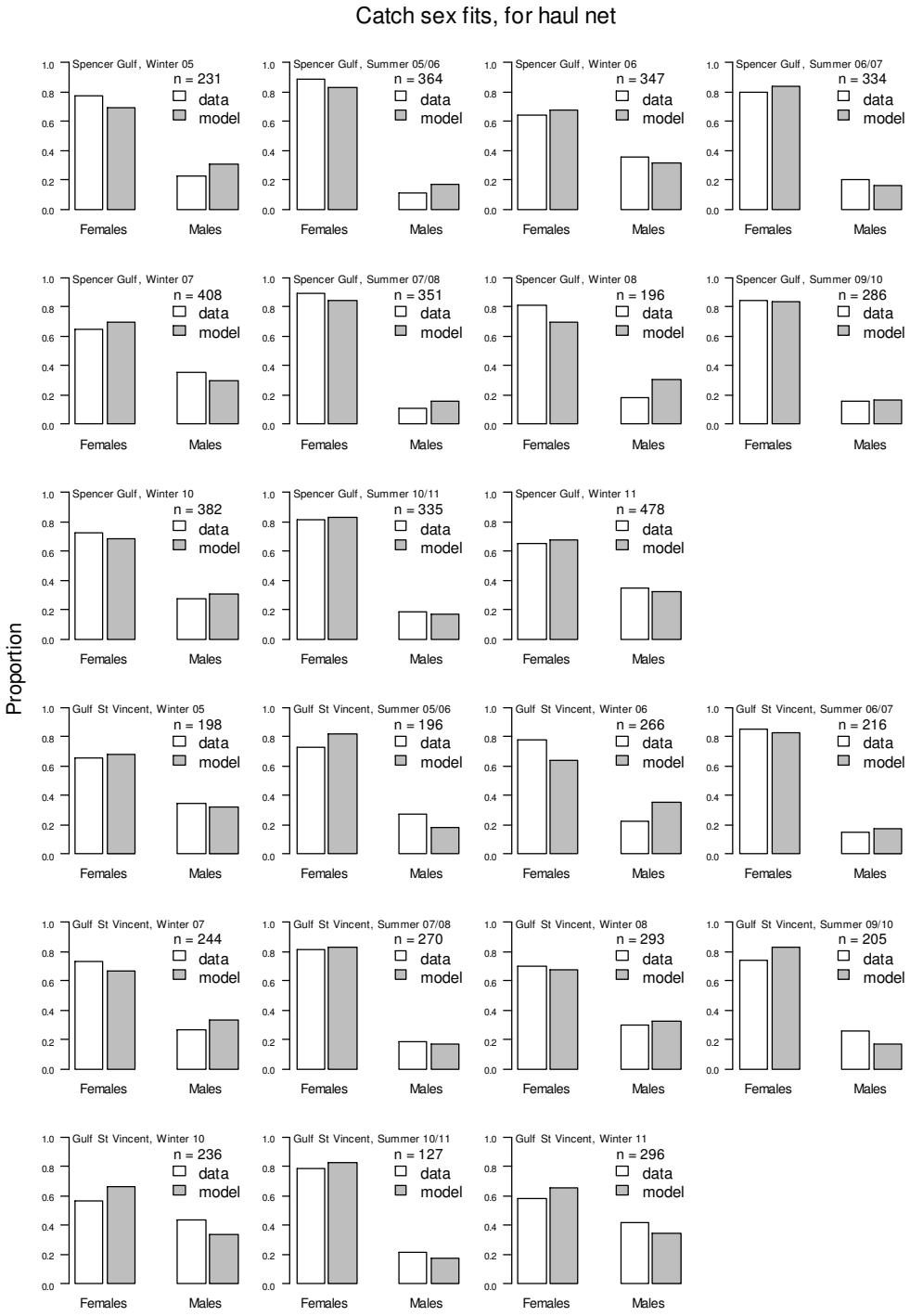

Figure 6.2 Haul-net catch proportions by sex: Data shown have been corrected for uneven sub-sampling for age and sex from representative samples by length. Fitted GarEst model sex proportions are shown for both gulfs by model half-year from April 2005 – September 2011. Garfish sampling re-commenced in July 2005, and for the Winter 2005 and 2008 half-years shown, only 3 months of the half-yearly model time step were sampled. No sampling was undertaken in the Summer 2008/09 and Winter 2009 half-years.

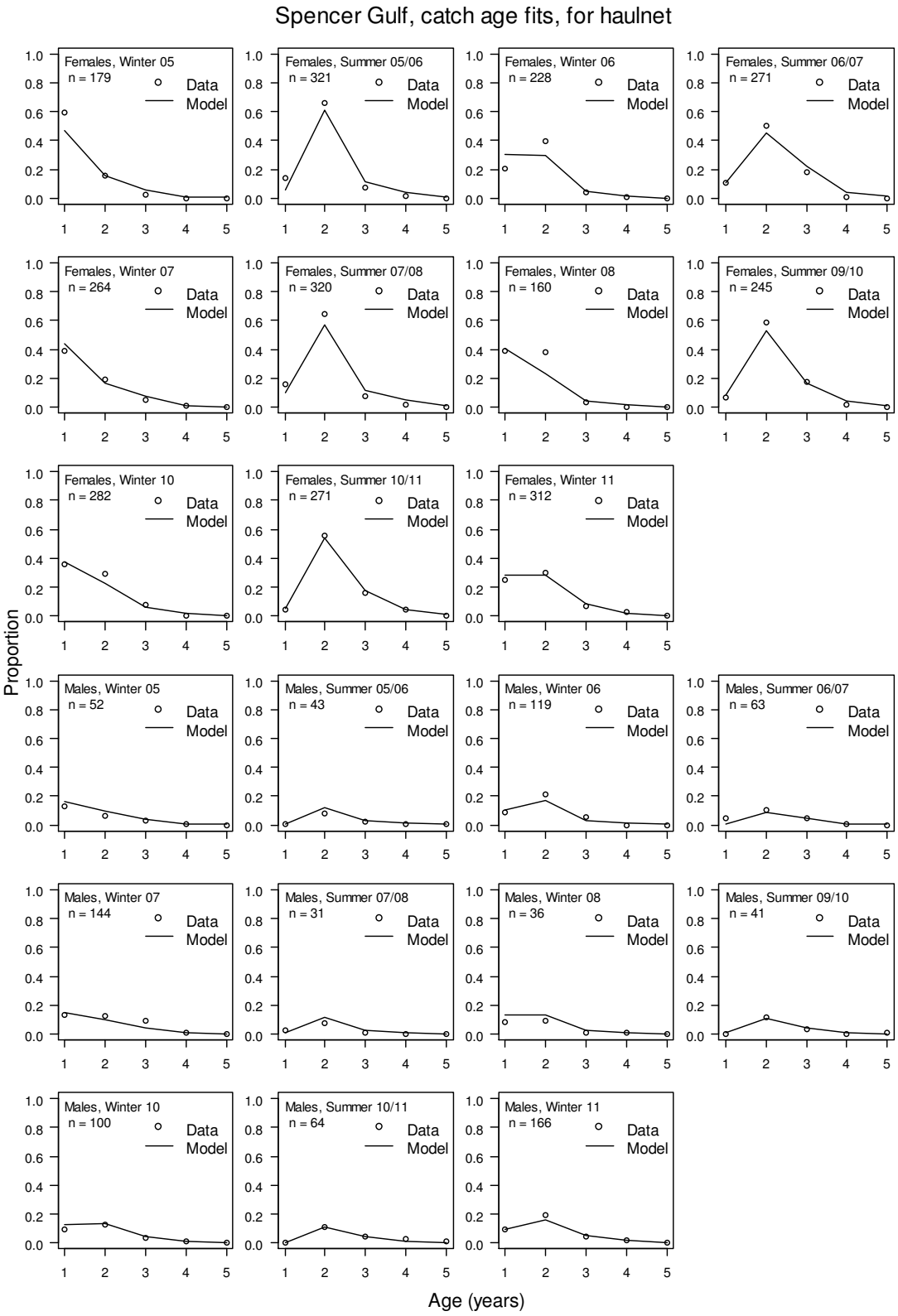

Figure 6.3 Haul net catch-at-age proportions for Spencer Gulf: sample-size corrected catch (principally SAFCOL) market samples (open circles) and GarEst model-predicted garfish number proportions by age (plotted line) in the landed commercial catch. Half-yearly time periods covered are given in the caption of Figure 5.1.

6.3.2 Model Representation of Length-at-Age and Growth

The model displayed close agreement with length data (Figure 6.4 and 6.5) confirming that the garfish growth and mean lengths inferred by the model are accurate. Model lengths were fitted by moment properties (mean, standard deviation, skewness and kurtosis), integrated with growth estimation.

The growth of garfish is visually evident in the increasing shift to larger mean lengths as age increases, for males and females separately in the two gulfs (Figures 6.6). Because growth estimation is integrated into the overall model fit, the GarEst model adjusts growth parameters to account for the changing shape of the distributed lengths of fish within each cohort, as faster growing garfish reach legal size sooner and are then removed by fishing much more rapidly from the population.

Thus, unlike standard fishery models fitted to age data, the GarEst model dynamically accounts for garfish population numbers by both age and length, fitting to both the proportions by age and the larger representative sample of proportions by length (Figure 6.7).

One principal advantage of this age- and length-based approach is in modelling recruitment. Because the proportion of garfish in each cohort that are of a length greater than the LML is explicit, the model can predict with greater accuracy the proportions of fish in the legal-size catch for the three or four half-yearly ages over which the cohort is recruiting into the fishery by growing into legal size (Figure 6.7). Faster growing fish reach legal size sooner, followed by the bulk of the cohort, and the last fish to recruit to legal size are the slow-growing left-hand tail of the length-at-age distribution. But only garfish above legal size are available in the observed catch samples. By predicting more accurately the proportion of garfish from each age group that are of legal size, and by accounting for the earlier removal of faster growing fish, model-predicted proportions by age in the catch, and thus estimates of mortality, are more accurate.

6.3.3 Model Representation of Commercial Catch

Half-year commercial catch totals are the third principal data input, aggregated by gulf and effort type (Figures 6.8 and 6.9). Individual catchability parameters have been defined to improve haul net catch fits for some half-years in each gulf, from 1998-2006.

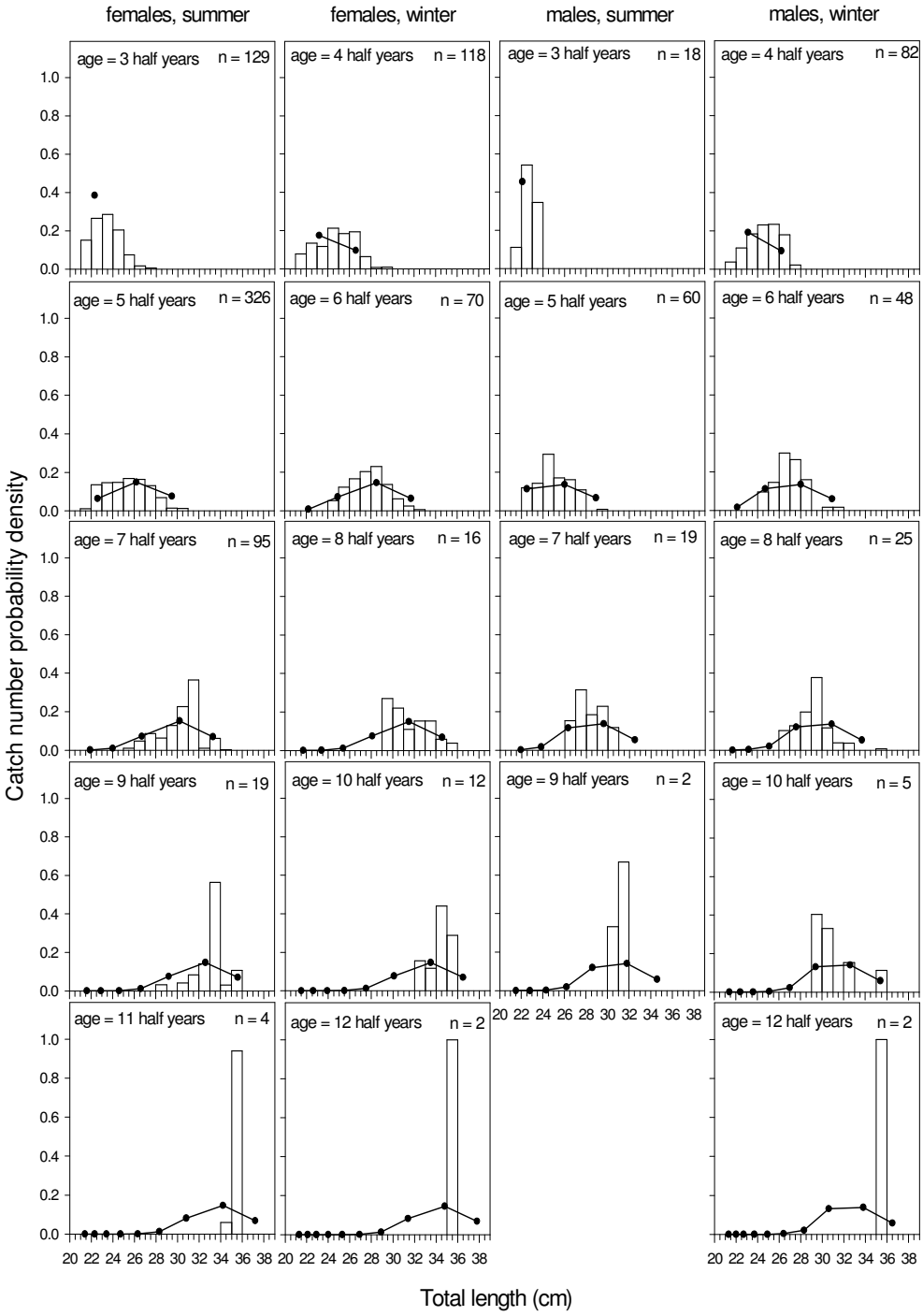

Figure 6.4 Comparison of data and 2006 model hauling net cohort lengths from Spencer Gulf, 1997/98. Both data garfish catch numbers sampled per 1-cm length bin (bars) and model number proportions per slice (line and points) are scaled as probability densities, i.e. proportions captured per unit (1-cm) total length. Data are from summer and winter of October 1997 - September 1998, prior to the increase in legal minimum length. The ages shown increase from 3 half-years (i.e. age 1, garfish spawned the summer before), through subsequent summers of 5, 7, 9 and 11 half-years, which correspond to ages 2, 3, 4, and 5 years. Winter ages are 4, 6, 8, 10 and 12 half years, corresponding to ages 1.5, 2.5, 3.5, 4.5, and 5.5 years. Sample sizes (n) are given for each graph, e.g. n = 129 female garfish of age 3 half-years were measured for length during summer in SG (upper left graph).

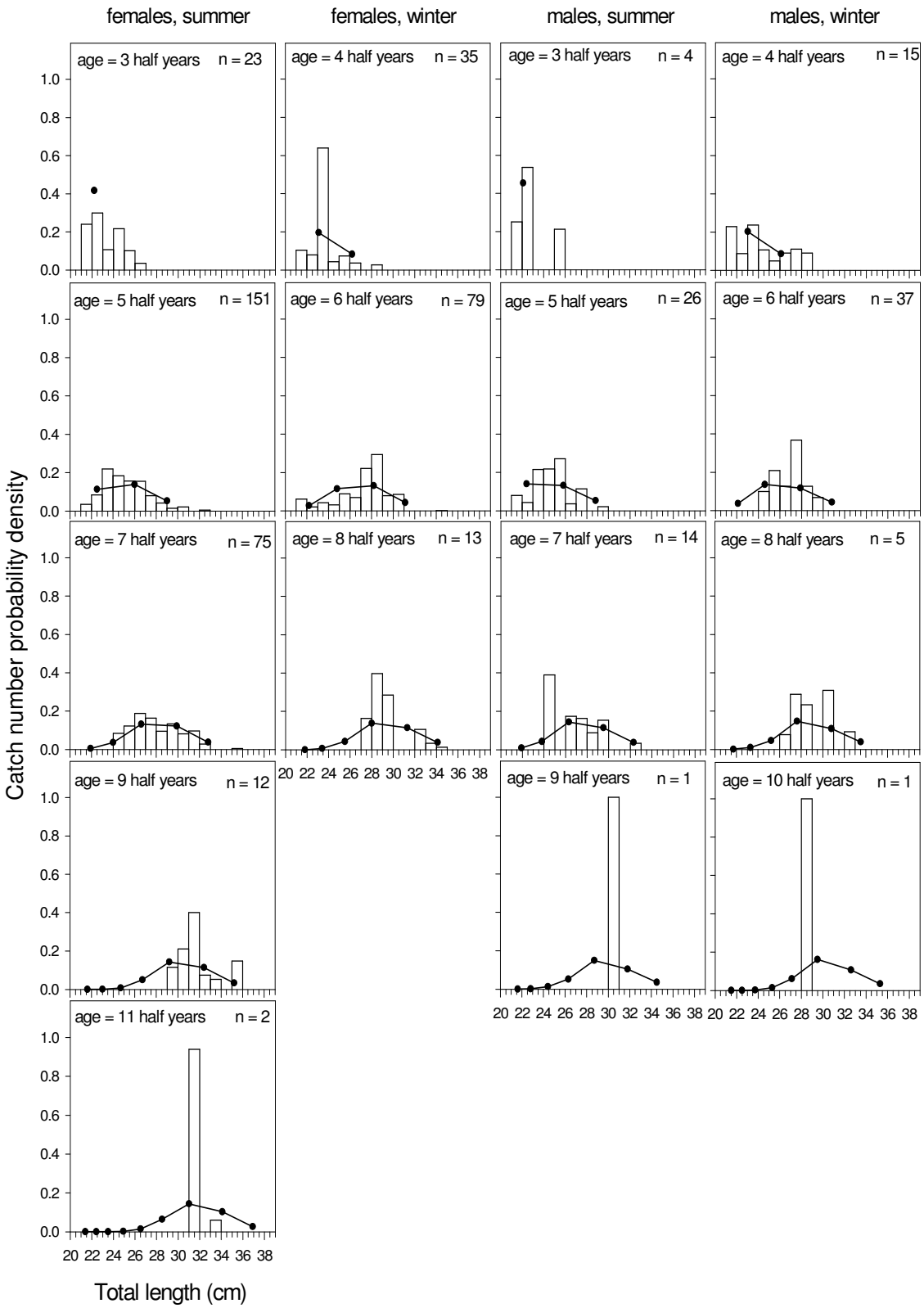

Figure 6.5 Comparison of data and 2006 model hauling net cohort lengths from GSV, 1997/98. Comparisons of data and model haul-net length frequencies. Data (bars) and model (lines and points) frequencies scaled as probability densities, as described in Figure 6.3.

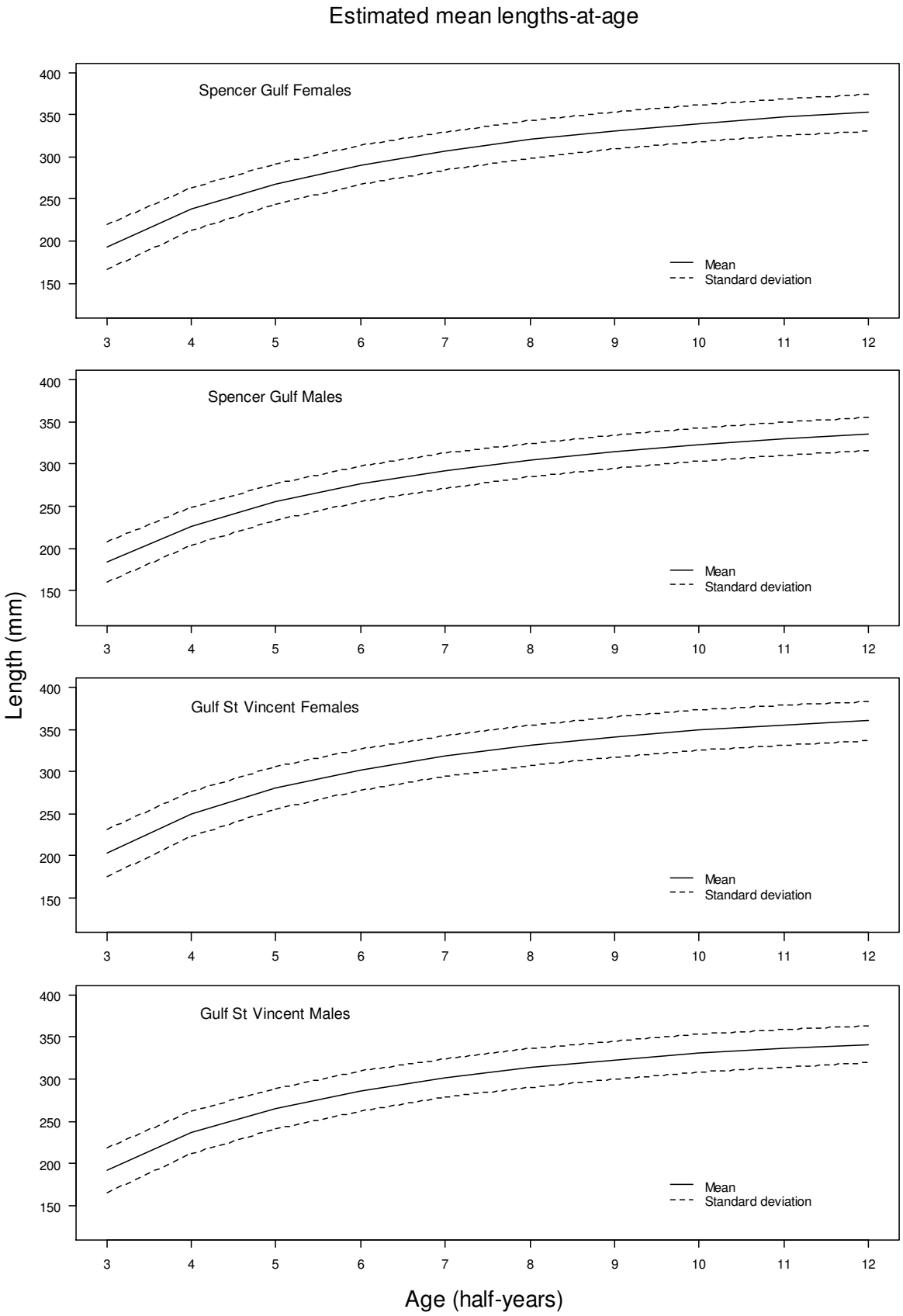

Figure 6.6 Growth curves (solid lines) as estimated mean length at age from GarEst model. The dotted lines demarcate modelled standard deviations of cohort lengths-at-age about the estimated mean lengths at age.

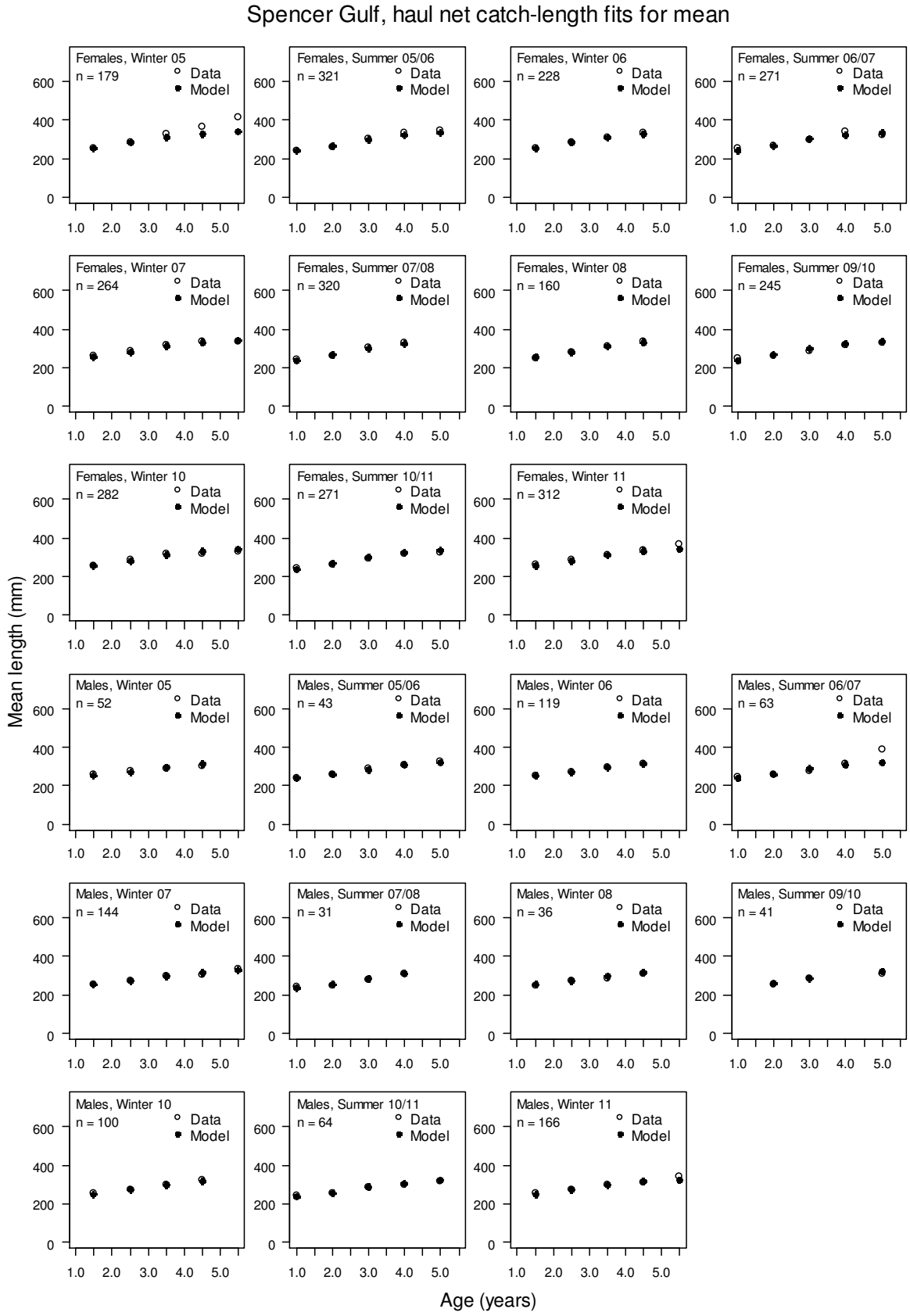

Figure 6.7 Fits of model and data mean lengths at age, from catch samples for Spencer Gulf for haul net, by sex, in the summer (ages 1.0, 2.0, etc) and winter (ages 1.5, 2.5, etc) half years of July 2005 – September 2011.

6.3.4 Model-Estimates for Biological Performance Indicators

The GarEst model estimates four principal biological performance indicators for the garfish populations in the two gulfs, as mandated in the 2006 Management Plan (Noell et al. 2006): (1) yearly recruitment, (2) legal biomass, (3) harvest fraction (or exploitation rate), and (4) percent virgin egg production.

6.3.4.1 Annual Recruitment

In both gulfs, the mean levels of recruitment over the last six years have trended flat at the lower levels of post-2000 (Figure 6.10). Recruitment estimates (garfish recruiting to age 1 in summer) showed a further one year decline in the last model year (2010) in both gulfs. Overall, recruitment estimates in the two gulfs, suggest that mean levels of recruitment remain at historical lows, showing no sign of recovery since the decline around 2001, which prompted the re-structuring of the fishery in 2005. Since 1986, recruitment has shown synchronous yearly variation between the two gulfs (Figure 6.10).

6.3.4.2 Legal Biomass

Trends in estimated biomass have tracked trends in model recruitment. In both gulfs, biomass has been at slightly lower mean levels over the last six years. Although in SG biomass has shown a gently rising trend since 2003. Overall, the biomass of legal-size garfish in the two gulfs is stable at moderately low levels.

6.3.4.3 Harvest Fraction

Harvest fraction trended downward in recent years, with a steeper decline for GSV evident since 2006, despite relatively stable levels of biomass and recruitment (Figure 6.12). Lower harvest rate thus reflects corresponding slow declines in total effort levels. Nevertheless, harvest fractions remain very high, at 69% and 63% for SG and GSV for 2010, respectively. Averages over the last three years (2009-2011) gave 63% and 66%, down from 71% and 74% for the three years prior (2006-2008).

6.3.4.4 Egg Production

Egg production has shown no long-term trends since 1983 (Figure 6.13). For SG there has been a slight rise in the last five years, but this was not the case for GSV. Overall, percent virgin egg production levels for South Australian garfish are low, averaging 11-12% in both gulfs.

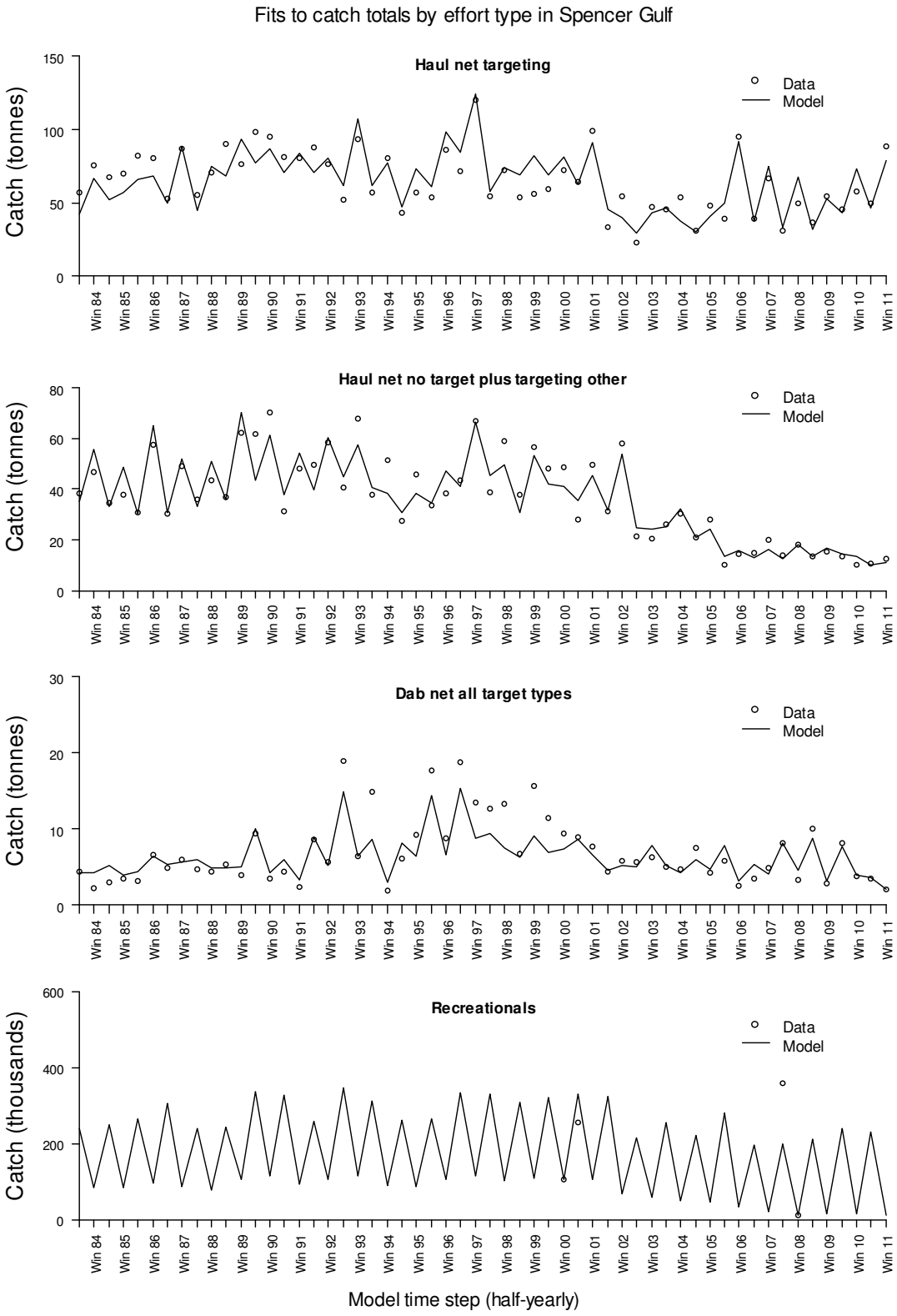

Figure 6.8 Spencer Gulf model fits to reported half-yearly commercial garfish catch (in weight) and recreational catch numbers.

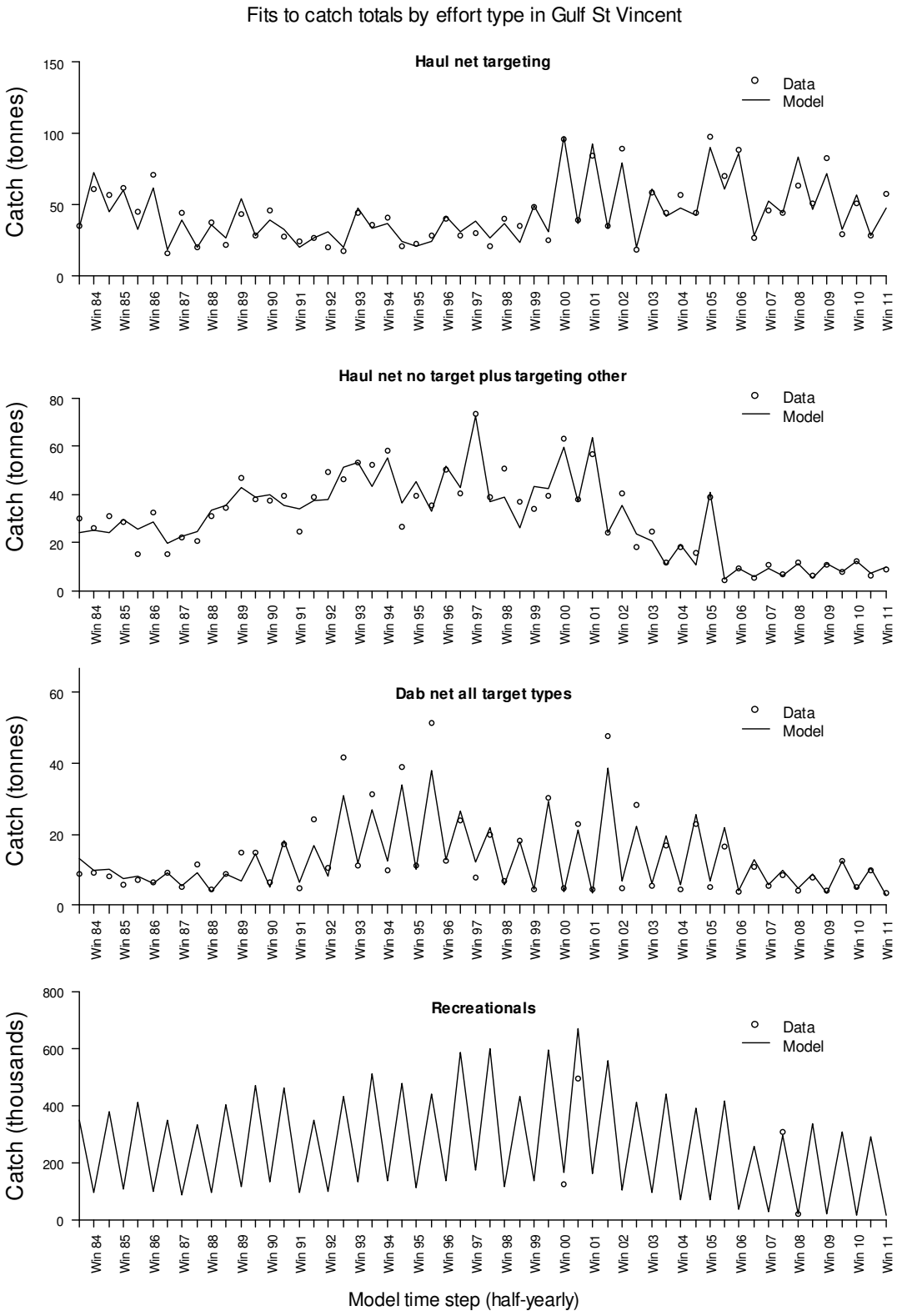

Figure 6.9 Gulf St. Vincent model fits to reported half-yearly commercial garfish catch (in weight) and recreational catch numbers.

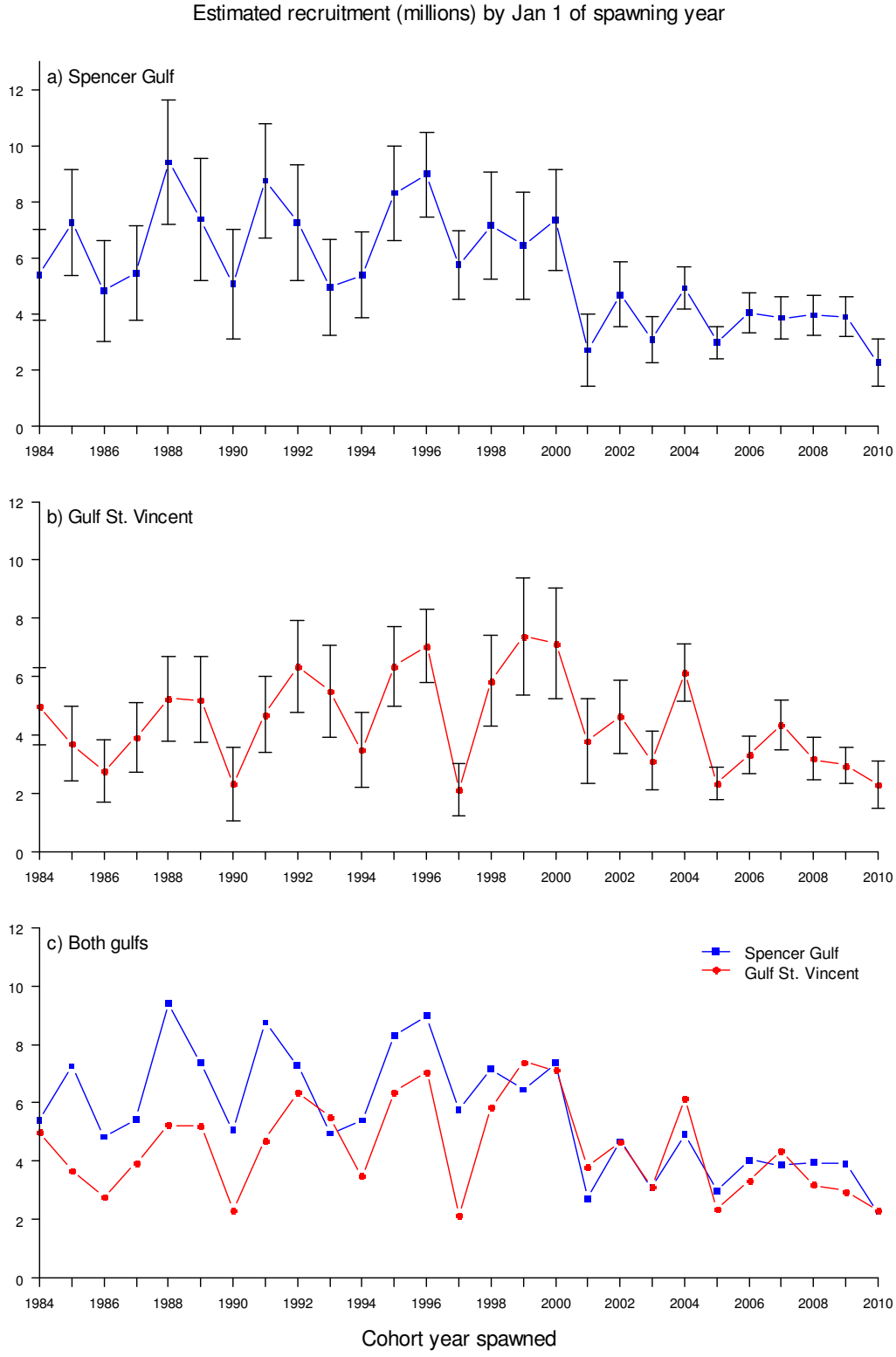

Figure 6.10 Annual recruitment, October 1983 - September 2011, for garfish in the two gulfs. Estimates from the FRDC-sponsored stock assessment estimation model (GarEst). Model estimates with 95% confidence interval bars (±1.96*SE) are given (a and b) separately by gulf, and (c) the two time series from both gulfs are shown for comparison.

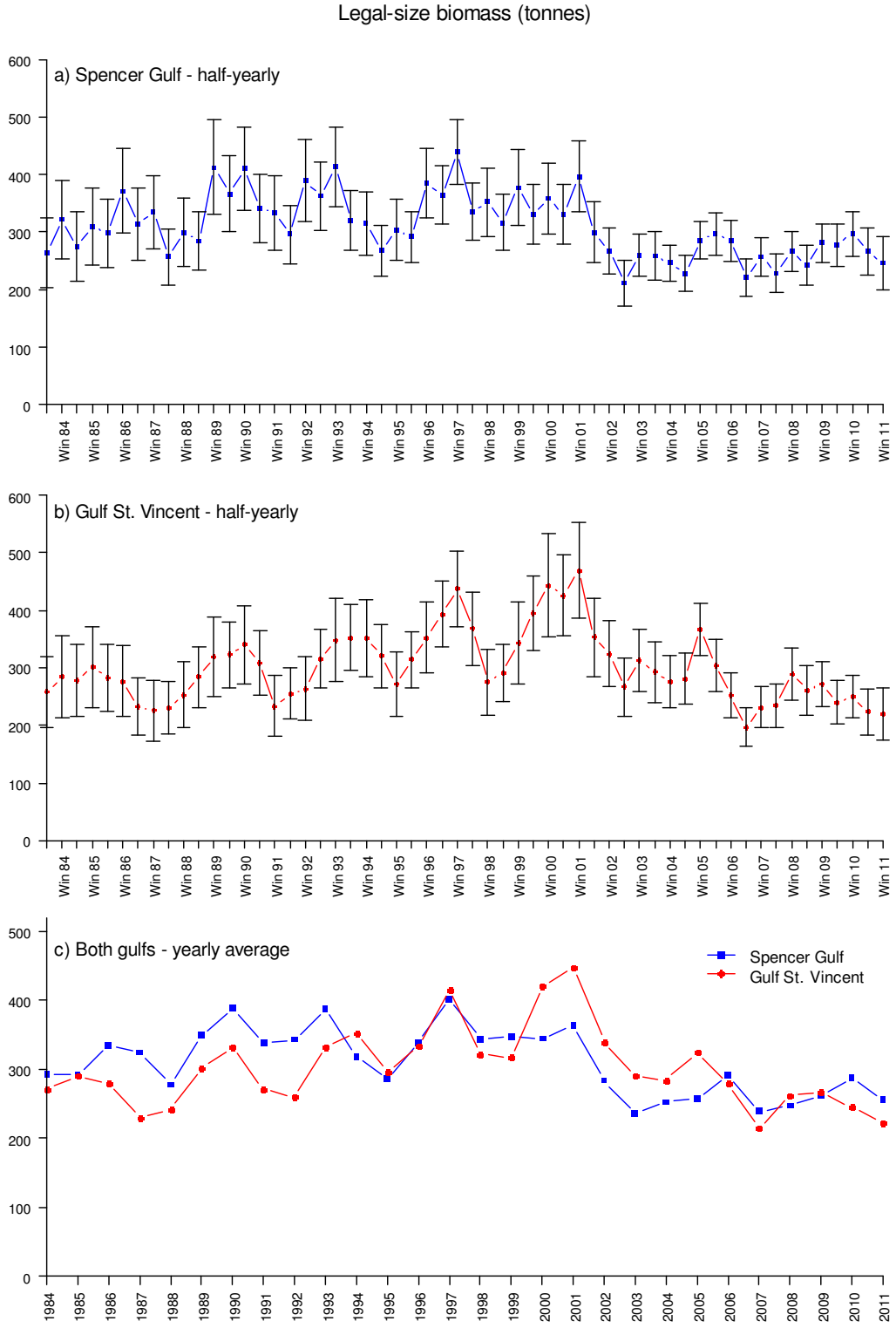

Figure 6.11 Fishable biomass, October 1983 - September 2011, for garfish in the two gulfs. Estimates from the stock assessment model (GarEst). Half-yearly model estimates with 95% confidence interval bars (±1.96*SE) are given (a and b) separately by gulf. (c) The yearly averages from both gulfs are shown.

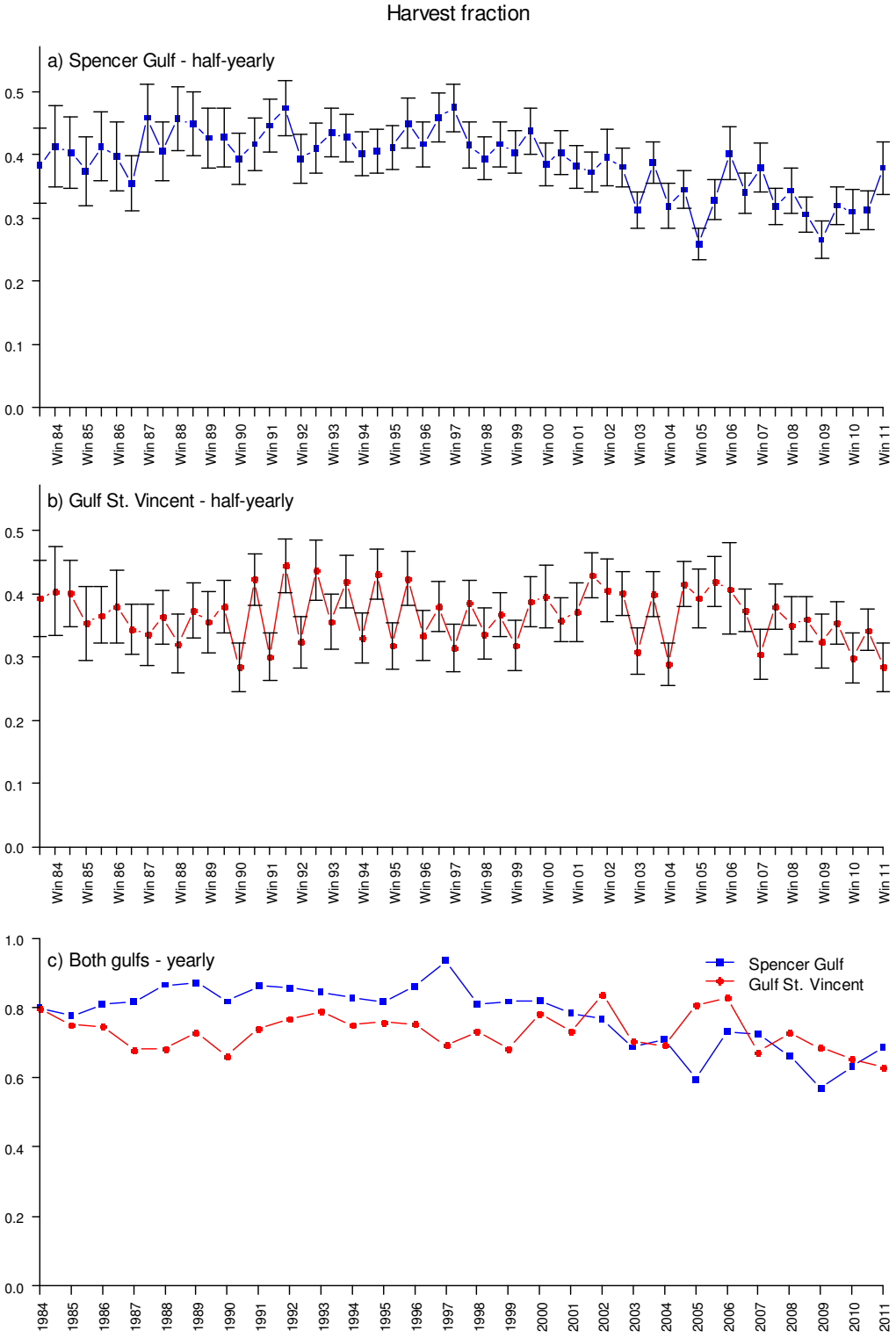

Figure 6.12 Harvest fraction (i.e. exploitation rate), October 1983 - September 2011, half-yearly for garfish in the two gulfs, with average yearly harvest fractions shown for the two gulfs for comparison. Estimates are from the stock assessment model (GarEst). Harvest fraction is defined as the model estimated catch for each biological year (October – September), divided by the yearly average model biomass, the latter calculated as the average of the two model-estimated biomasses from the start of the two half-yearly model time steps covering each biological year.

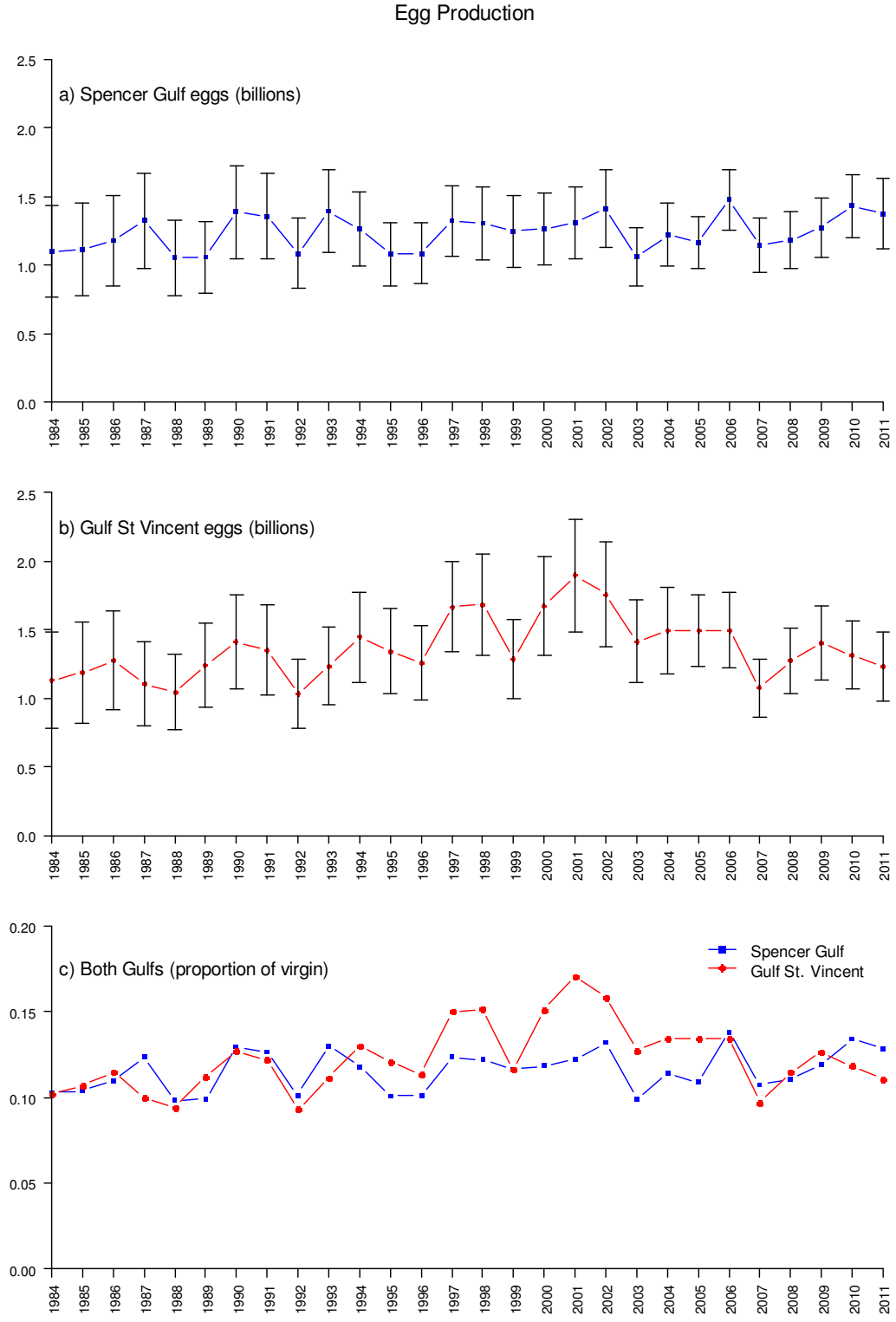

Figure 6.13 Annual egg production, October 1983 - September 2011, for garfish in the two gulfs. Model estimates with 95% confidence interval bars (±1.96*SE) are given (a and b) separately by gulf, and (c) the two time series from both gulfs are shown as the proportion of virgin egg production.

6.4 Discussion

The slice partition breakdown of the garfish population provides a high quality, relatively detailed description of how the numbers of garfish change over time, giving numbers by age, length within each age cohort, sex, and in each gulf. The model description yielded close fits to catch totals by effort type, age composition of the catch, sex and length composition of the catch. In particular, the very close fit to mean lengths by (half-yearly) length imply reliable growth estimates. It was demonstrated that slice partition modelling corrects for underestimation bias in the growth estimates that would otherwise result from faster growing fish being removed more rapidly from the population (McGarvey and Feenstra 2007). Among all fishery models operating in South Australia, GarEst has the closest fits to size and age composition, and gives generally the most favourable measures of model self-consistency and overall fit. This is, in part, due to the high quality age and length composition data available from the northern gulf commercial fisheries, and relatively low evidence of movement by this species (Steer et al. 2009).

The principal limitations of the model result from the data being nearly all obtained from one sector, namely commercial hauling nets. These predominantly operate in the northern gulfs since the spatial closures to netting were implemented in 2005. Thus, there are little or no data available to inform the model about the population age and size composition in the southern gulf regions which remain open to fishing by recreational and commercial dab netters.

A second avenue for improvement to the GarEst model will be to use a shorter model time step. Reducing the time step from its current half-year to quarterly will improve temporal resolution. The quarters would also align with known qualitative changes in the seasonal pattern of the fishery, including the relatively low catches typical of October-December, and high catches in April-June. It is intended to implement this relatively major model upgrade to a quarterly time-step for the next stock assessment in 2015.

The principle output of this model run indicated that the two gulf fisheries remain over-exploited as exemplified by very high harvest rates compared to most fisheries worldwide (Worm et al. 2009). Estimated harvest fractions on garfish have fallen slightly since the fishery restructure due to lower effort levels, however, they still remain approximately double that considered optimal by international standards.

7 Performance Indicators

7.1 Introduction

The Management Plan for the Marine Scalefish Fishery outlines a strategic framework to guide fishery management decisions (Noell et al. 2006). Essential to this process are performance indicators that relate to the status of the fishery. The stock is assessed by comparing the most recent estimates of these indicators against limit reference points (trigger points). When these limit reference points are exceeded, management responses are prescribed (Noell et al. 2006).

For the MSF there are two categories of fishery performance indicators: (1) general performance indicators that are based directly on reported commercial catch and effort statistics, including CPUE (Chapter three); and (2) biological performance indicators of yearly egg production, estimated biomass, recruitment, and harvest fraction that are determined by the GarEst model (Chapter six). For garfish the general performance indicators are calculated over financial years, whereas the biological performance indicators are calculated over biological years, from October to September.

7.2 Materials and Methods

7.2.1 General Performance Indicators

For garfish, there are three general fishery performance indicators that were calculated from the commercial fishery statistics; total commercial catch, targeted effort, and targeted CPUE. These were assessed against the following limit reference points:

1. the 3rd highest and 3rd lowest values of the reference period;
2. the greatest (%) inter-annual variation (+ and -) over the reference period;
3. the greatest rate of change (+ and -) over periods of three years through the reference period.

Given South Australia's Garfish Fishery is spatially segregated by gear, i.e. the haul nets predominantly operate in the northern gulfs and the dab netters in the southern gulfs, it was necessary to assess the status of the fishery in each of the four regions (NSG, SSG, NGSV, SGSV). Estimates of total commercial catch, targeted effort and targeted CPUE were calculated for hauling nets in NSG and NGSV and for dab nets in SSG and SGSV. In each case, the limit reference points were then derived based on the time series of data from 1983/84 to 2010/11 (reference period). The estimates of general performance indicators for 2010/11 (or ending in 2010/11 for change indicators) were then compared to the limit reference points determined for the whole time series. Note that the new 'Any Target >50%'

haul net effort type, which commenced with the adoption of mandatory daily reporting in 2003, could not be used for general performance indicator assessment since the reference time period for the baseline indicators should, where possible, cover the full time series of catch and effort data, i.e. 1983/84 to 2010/11.

7.2.2 Biological Performance Indicators

For garfish, the five biological performance indicators that were assessed were egg production, fishable biomass, exploitation rate on the fishable biomass, recruitment, and population age structure (Noell et al. 2006). The first four of these were outputs from the GarEst model (Chapter five), and the last is based on the population structure information (Chapter four).

Egg production, expressed as a percentage of virgin egg production, was calculated using GarEst by setting the harvest rate to zero. The calculated value was then compared against an international standard of 20-35%. Fishable biomass, specifically legal-size garfish biomass by weight in each gulf, was calculated by averaging the two half-yearly estimates for each biological year (starting 1st October). For performance indicators of fishable biomass and recruitment (model estimates of 1-year olds for each cohort), the limit reference points were triggered if the indicator in the most recent year was a $\pm$ 10% change from the previous five years (Noell et al. 2006). Harvest fraction was compared against the reference standard of 32%. The final biological indicator related to assessing whether there had been any significant change in population age structure over the past five years. This was done qualitatively based on the information in Chapter four. Here, the estimates of all biological performance indicators were evaluated for each of the two main regions that were considered in the GarEst model, i.e. SG and GSV.

7.3 Results

7.3.1 General Performance Indicators

Tables 7.1-7.4 show the results of the comparison of general performance indicators against limit reference points, for the four fishery regions of NSG, SSG, NGSV and SGSV.

Across the four regions, there were three breaches: one for each of NSG, SSG, and SGSV. NGSV had no general performance indicator LRP breaches. In NSG, the breach was a positive one, with CPUE in 2010/11 being the third highest on record, at 80.2 kg.fisherday^{-1}. In SSG, the 2010/11 commercial catch of 6.7 t, from dab nets, was the second lowest on record. Similarly, for SGSV, the 2010/11 commercial dab net catch was the lowest on record, at 9.7 t.

Table 7.1. Results of comparisons between general performance indicators and limit reference points for NSG. Target effort and CPUE were for hauling nets only.

Performance Indicator	Limit Reference Point	Breached ?	Details
Total Commercial Catch	3rd lowest/ 3rd highest	NO	
	Greatest ± change	NO	
	Greatest 3-year trend	NO	
Targeted Haul Net Effort	3rd lowest/ 3rd highest	NO	
	Greatest ± change	NO	
	Greatest 3-year trend	NO	
Targeted Haul Net CPUE	3rd lowest/ 3rd highest	YES	3rd highest @ 80.2
	Greatest ± change	NO	
	Greatest 3-year trend	NO	

Table 7.2. Results of comparisons between general performance indicators and limit reference points for SSG. Target effort and CPUE were for dab nets only.

Performance Indicator	Limit Reference Point	Breached ?	Details
Total Commercial Catch	3rd lowest/ 3rd Highest	YES	2nd lowest @ 6.7t
	Greatest ± change	NO	
	Greatest 3-year trend	NO	
Targeted Dab Net Effort	3rd lowest/ 3rd Highest	NO	
	Greatest ± change	NO	
	Greatest 3-year trend	NO	
Targeted Dab Net CPUE	3rd lowest/ 3rd Highest	NO	
	Greatest ± change	NO	
	Greatest 3-year trend	NO	

Table 7.3. Results of comparisons between general performance indicators and limit reference points for NGSV. Target effort and CPUE were for hauling nets only.

Performance Indicator	Limit Reference Point	Breached ?	Details
Total Commercial Catch	3rd lowest/ 3rd Highest	NO	
	Greatest ± change	NO	
	Greatest 3-year trend	NO	
Targeted Haul Net Effort	3rd lowest/ 3rd Highest	NO	
	Greatest ± change	NO	
	Greatest 3-year trend	NO	
Targeted Haul Net CPUE	3rd lowest/ 3rd Highest	NO	
	Greatest ± change	NO	
	Greatest 3-year trend	NO	

Table 7.4. Results of comparisons between general performance indicators and limit reference points for SGSV. Target effort and CPUE were for dab nets only.

Performance Indicator	Limit Reference Point	Breached ?	Details
Total Commercial Catch	3rd lowest/ 3rd Highest	YES	lowest @ 9.7t
	Greatest ± change	NO	
	Greatest 3-year trend	NO	
Targeted Dab Net Effort	3rd lowest/ 3rd Highest	NO	
	Greatest ± change	NO	
	Greatest 3-year trend	NO	
Targeted Dab Net CPUE	3rd lowest/ 3rd Highest	NO	
	Greatest ± change	NO	
	Greatest 3-year trend	NO	

7.3.2 Biological Performance Indicators

Biological performance indicators were only assessed for the two regions considered in the GarEst model. Seven out of 10 of the biological performance indicators for the fishery breached their limit reference points, which included 3 of 5 in SG and 4 of 5 in GSV (Table 7.5). Egg production levels in both gulfs, compared with the expected egg production from a virgin stock, were well below the range recommended in the Marine Scalefish Fishery Management Plan (Noell et al. 2006). By either definition, this indicator was well below the limit reference point for both gulfs. As in previous years, harvest fraction estimates were approximately double the limit reference levels of 32%. In 2010, recruitment in both gulfs fell 39% and 29% below the previous 5-year average, in both cases breaching the limit reference point. While these large declines reflect a very low year in 2010, mean levels of recruitment over the past three years were more stable, although at historically low levels. The assessment of no significant change in the age structure (Section 5.3.2) reflects a garfish population in the northern gulfs that remains truncated due to high rates of removal in the fishery.

Table 7.5. Yearly biological performance indicators for both gulfs. Breached limit reference points are highlighted in yellow. The current performance year covers October 2010 – September 2011

Biological Performance Indicator	Biological Reference Point (BRP)	Spencer Gulf	Gulf St Vincent & Kangaroo Island	Reference
1. Egg production (% of pristine population)	20—35%	13%	11%	MSF Management
2. Fishable biomass	Last yr value differs from previous 5-yr average > +/- 10%.	3% below average of previous 5 years	13% below average of previous 5 years	
3. Harvest fraction	Exceeds international standards (32% yearly)	69%	63%	
4. Recruitment	Last yr value differs from previous 5-yr average > +/- 10%.	2010 cohort is 39% below average of previous 5 years.	2010 cohort is 29% below average of previous 5 years.	
5. Significant change in age composition over previous five years		No significant change	No significant change	Figs. 4.3-4.6

7.4 Discussion

The general performance indicators, showed little change over recent years. They are consistent with the assessment of a fishery resource which has stabilised before the impact of new management strategies that aim to reduce exploitation rate and come into effect in 2011/12. The results from the biological performance indicators, however, are of more concern as most breached the limit reference points. They indicate that the northern gulf populations of garfish are still being exploited at high levels, despite the restructure of the haul net sector, which included the closure of most of Yorke Peninsula to net fishing and the voluntary net buy-back program that was implemented in 2005. Furthermore, egg production in both regions is well below the internationally acceptable level. These results highlight the continued concerns about the status of the garfish stocks, which have motivated strong action by management and industry in the past financial year (2011/12).

8 General Discussion

8.1 Context of this Assessment

This stock assessment determined the current status of South Australia's garfish resource from the analysis of several long-term monitoring programs. These included: the commercial catch and effort data from 1983/84 to 2010/11; the recreational fisheries statistics obtained from two State-wide telephone/diary surveys that were carried out over the last 12 years; and data on the population size and age structures that have been routinely collected since 2005. The data from these three sources were integrated into the GarEst fishery model to produce a time series of estimated biological performance indicators. The current status of the stock was then determined through the assessment of the fishery against a series of prescribed general and biological limit reference points outlined in the management plan for the South Australian MSF (Noell et al. 2006).

The results of this stock assessment report largely reflect those concerns that were raised in the previous report (McGarvey et al. 2009). These concerns related to three principle features of the fishery: (1) levels of exploitation were very high; (2) the population appeared to have stabilised since the decline of 2001-2003; and (3) there had been minimal evidence of a recovery since that decline. Since then, fishery managers, relevant stakeholders and scientists have been in the process of developing and implementing a harvest strategy that aims to promote the recovery of the resource. The harvest strategy for garfish is part of the draft management plan which has been developed for South Australia's MSF and is currently available for public comment (PIRSA 2012). Consequently, the timing of this stock assessment occurs during a period of significant change.

8.2 Current Status of the Garfish Fishery

The overall assessment of South Australia's garfish fishery relies heavily on data obtained from the hauling net sector which accounts for about 90% of the State-wide commercial catch. Similarly the assessment places considerable emphasis on analysing catch and effort trends in the northern gulfs as these regions are almost exclusively fished by commercial hauling net fishers.

8.2.1 State-wide

The GarEst model output implies a fishery resource which has remained at depressed levels since the 2000/2001 decline. It has stabilised at those lower levels, but has not given any indication of a recovery. Biomass, inferred principally from half-yearly CPUE in each gulf, has been stable over the last six years. This is consistent with similarly low, but relatively

stable average levels of recruitment. Harvest fractions have moderately reduced in both Northern Gulf St. Vincent and Northern Spencer Gulf, due to slowly declining fishing effort. However, they still remain twice as high as the internationally recognised standard. In the last three years, catches have slowly trended downward, re-affirming that there is no evidence of an appreciable 'recovery' following the implementation of the voluntary net buy-back and associated spatial closures in 2005. The population demography continues to lack substantial quantities of 3+ and 4+ age classes and remains truncated. In synthesising all these lines of evidence it can be clearly stated that the fishery remains over-exploited.

8.2.2 Northern Spencer Gulf

Historically, Northern Spencer Gulf has been the most productive in South Australia and in 2010/11 contributed to 53% of the State-wide garfish catch. This regional commercial fishery is exclusively fished by the hauling net sector. Catches have moderately increased over the past three years, despite there being a long-term trend of decreasing fishing effort in this region. This reduction of effort may be partly due to the licence amalgamation scheme, which is an on-going program geared to reduce the number of licences within the MSF, or it could relate to fishers diversifying their fishing effort and targeting other commercial species such as King George whiting, yellowfin whiting, or southern calamary (Steer 2009). Although fishing effort has decreased, catch rates have trended upwards since 1998/99. The most recent CPUE estimate of 80.2 kgs.fisherdays^{-1} is the 3rd highest on record and consequently breached a prescribed general limit reference point. The composition of the commercial harvest continues to be dominated by 1+ and 2+ garfish, indicating that the population structure has remained largely unchanged since the 1998 demographic study carried out by Ye et al. (2002). The lack of biomass stored within the older age classes of garfish (i.e. 3+ and 4+) continues to be a concerning factor and re-affirms this fishery's over-exploited status.

8.2.3 Northern Gulf St. Vincent

Northern Gulf St. Vincent is the second most productive region in the State, accounting for 35% of the total garfish catch. Annual catches have declined in this fishery by 32% over the past three years; however, the magnitude of this decline was not substantial enough to breach any of the prescribed general limit reference points. Like the other regional fisheries, fishing effort in Northern Gulf St. Vincent has sequentially decreased as a result of a series of management arrangements. Targeted hauling net effort and the associated catch rates have also moderately declined over the past three years by 30% and 12%, respectively. The size and age structure of the harvested garfish continues to be dominated by 1+ and 2+ fish, indicative of a fishery that remains over-exploited.

The characteristics of the Northern Gulf St. Vincent garfish fishery have historically been similar to that of Northern Spencer Gulf. They have typically demonstrated similar trends in their respective commercial harvest, fishing effort levels and population size and age structure. However, in recent years, catch rates in Northern Gulf St. Vincent have moderately declined whereas they have trended upwards in Northern Spencer Gulf. Recent research has indicated that garfish tend to be relatively site-attached during their first two years of life (Steer et al. 2009) and, as such, are at risk to high fishing pressure and consequently localised depletion. It is possible that this risk is slowly being manifested in Northern Gulf St. Vincent. The same risk does not appear to be threatening Northern Spencer Gulf. This discrepancy may simply be a function of the available fishing area, as Spencer Gulf hauling net fishers have access to more extensive fishing grounds and, as a consequence, are able to spread their effort more widely.

8.2.4 Southern Spencer Gulf

Large areas of Southern Spencer Gulf have been closed to hauling net fishing, with the most recent closure being implemented around southern Yorke Peninsula in 2005. Consequently the hauling net sector has been effectively removed from this region and it has become predominantly fished by commercial dab netters. The relative contribution of this region to the State-wide catch has consequently decreased to <5%. The 2010/11 commercial catch of garfish from this region was 6.7 t, which was the second lowest on record and breached one of the prescribed general limit reference points. Fishing effort has also substantially decreased (by 47%) in the dab net sector over the past four years. Catch rates, however, have remained relatively high (50 kgs.fisherdays^{-1}) for those dab net fishers who continue to target garfish in this region. Given the relatively small size of this regional fishery it is difficult to sample meaningful quantities of garfish to ascertain trends in the local population demography. As such, it is unknown whether the size and age structures of garfish in Southern Spencer Gulf remain truncated. Despite this lack of information, the relatively low levels of fishing activity and commercial catch of garfish from this region, coupled with the extensive netting closures, indicates that this regional fishery is unlikely to be over-exploited.

8.2.5 Southern Gulf St. Vincent

Prior to 1993, the commercial catch of garfish from Southern Gulf St. Vincent was equally shared among the hauling net and dab net sectors. Since then, the hauling net sector declined as a function of a steady reduction in fishing effort and by 2006 dab nets became the dominant gear type. This dominance was exacerbated by the implementation of the voluntary net buy-back scheme and spatial netting closures of 2005. Prior to this management restructure, the commercial garfish catch from this region rarely exceeded 10%

of the State-wide harvest, however, after its implementation it considerably reduced to <5%. The history of this regional fishery and its current status is almost identical to that observed for Southern Spencer Gulf. There has been a trend in decreasing annual catch to a level that has breached the associated general limit reference point (2010/11 is the 2nd lowest on record), dab net fishing effort has remained at relatively low levels and catch rates have consistently been above average (38 kgs.fisherdays^{-1}) over the past three years. Like Southern Spencer Gulf, little is known about the size and age structures of the commercial catch of garfish, as it is difficult to access adequate biological samples from this relatively small regional fishery. Given the large areas that are closed to hauling net fishing in this region and the steady reduction of fishing effort in the dab net sector, it can be concluded that, like Southern Spencer Gulf, this regional fishery is unlikely to be over-exploited.

8.3 Promoting Stock Recovery

8.3.1 Effort Reduction

The fact that the fishable biomass and recruitment have not declined precipitously despite such high levels of exploitation is a positive sign. However, the question remains whether the current levels of recruitment reflect recruitment overfishing. Specifically, is low egg production limiting recruitment? This is a challenging question to answer, but it remains a possibility. Percent virgin egg production levels of 13% (SG) and 11% (GSV) are well below accepted safe levels. Despite this, egg production has remained relatively stable since 1984 which implied that the risk of stock collapse due to recruitment overfishing was most likely low. This situation is likely to be a result of the sustaining effect of an extended spawning period, a life history strategy that has provided the garfish population some level of resilience to high exploitation rates. Promoting the recovery of the fishery to resemble a 1950s population demography, or at least to incorporate a greater proportion of older (3+ and 4+) garfish, would ensure that females in the population have more years to spawn, will inherently produce more eggs as a function of their larger size, and will subsequently yield increased levels of recruitment. Currently, the strength of this process for garfish stocks in the two gulfs is unknown. Management is, however, aiming to explore this scenario by adopting a strategy that will reduce the exploitation rate (harvest fraction) from the current level of about 69% to ≤30% by 2020 (PIRSA 2012). It is planned to achieve this through the introduction of a series of annual management measures, which to date have included gulf-specific closures. As exploitation levels are sequentially lowered over the next eight years, we will be able to gauge whether recruitment is enhanced. Preliminary model simulations that have investigated the response of the fishery to theoretical reductions in fishing effort have indicated rapid increases in biomass and egg production along with improvements in

the net economic return to the fishery (Steer et al. 2011). There is an implicit assumption that higher recruitment will result from higher biomass and egg production, however, it has not been incorporated into extended model simulation runs testing specific management strategies to date. There are plans to incorporate this assumption as a tested scenario in this year's (2012/13) development of a management strategy simulation tool for the fishery.

8.3.2 Mesh Size

In the previous stock assessment (McGarvey et al. 2009) concerns were raised about the mismatch of the LML of garfish and the regulated minimum mesh size of hauling nets. Initially the LML for garfish was 210 mm TL but this was increased to 230 mm in 2001. At that time no corresponding amendments were made to the regulated mesh size of 30 mm despite an earlier mesh selectivity experiment indicating that the 30 mm mesh nets catch a large quantity of undersize (<230 mm) garfish and a 32 mm mesh size would be more appropriate (Jones 1982). Furthermore, it is generally estimated that the release mortality of undersize garfish is close to 100% (Knuckey et al. 2002, Fowler et al. 2009), which represents both wasted catch and compromises sustainability as there is reduced capacity of garfish to reach legal size and contribute to egg production. On the basis of these concerns the commercial fishers instigated, through the Garfish Working Group (GWG), the need to identify a standard net configuration that would reduce the capture of undersized garfish. This led to the development of an extensive mesh selectivity experiment that trialled the relative performance of three hauling net pocket variants: 30 mm standard knot, 32 mm standard knot and a 34 mm knotless constructions (Steer et al. 2011). The findings of this study confirmed that the 30 mm mesh size was sub-optimal and the larger two variants were preferred, but displayed very similar performance in their size selection of garfish. A model simulation indicated that standardising the fishing fleet to use nets constructed from one of these two larger mesh sizes demonstrated the capacity to promote stock recovery, through increases in biomass, value and egg production. However, the extent of this recovery was relatively minor, as there was a marginal (<5%) improvement in all of the fishery parameters modelled over a seven year timeframe. Despite the marginal improvement, the model output indicated that there was merit in standardising hauling net gear to promote stock recovery. PIRSA Fisheries and Aquaculture subsequently increased the 30 mm regulated minimum mesh size for hauling net pockets to 32 mm for a standard knot construction or 34 mm for a knotless design.

8.4 Future Research Needs

In the current financial year (2012/13), two projects will seek to optimise management strategies that aim to reduce the high exploitation rates that are evident in the fishery. The

first project will extend the mesh selectivity experiment to include trials of 34 mm and 38 mm standard knot pockets. The extension of this project was partly based on a theoretical modelling exercise that demonstrated that increasing the minimum mesh size to 38 mm would subsequently increase estimates of biomass and egg production by >30% within three years (Steer et al. 2011). Furthermore, the selectivity results of the 34 mm knotless mesh trialled in the previous study did not meet the expectations of the commercial fishers and it was decided to investigate the relative performance of a knotted equivalent. The results of these additional net variants will then be incorporated into the second dedicated garfish project of 2012/13. This second project will extend the use of the GarEst model to provide a management strategy evaluation tool (GarSim). The objective of this project is to assess the relative benefits, both in egg production and net economic return, of different management strategies (i.e. effort reduction, gear configuration) to continue PIRSA's mandate to reduce exploitation levels by half over eight years. EconSearch data on hauling net fishing costs will be used to compute net profit under each strategy tested. Management discussions have, so far, focused on temporal closures and increases in mesh size as the two most feasible strategies for reducing garfish exploitation rates, however, the evaluation tool with have the capacity to assess other management options.

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