Fisheries

Snapper (*Chrysophrys auratus*) Fishery

AJ Fowler, R McGarvey, P Burch,
JE Feenstra, WB Jackson and MT Lloyd

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September 2013

Fishery Assessment Report to PIRSA Fisheries & Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

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The data on catch and effort from the commercial sector of the Marine Scalefish Fishery were provided by Angelo Tsolos and Melleesa Boyle of the Information Systems and Database Support Program of SARDI (Aquatic Sciences). The report was reviewed by both Dr Stephen Mayfield (SARDI) and Dr Greg Ferguson (SARDI), whose comments helped improve its content and presentation.

1. EXECUTIVE SUMMARY

This is the 10th stock assessment report for the South Australian snapper fishery since 1997 and comes three years after the last assessment that was undertaken in 2010. Since then there has been significant change in this fishery. This includes a comprehensive review of the fishery by the Snapper Working Group that culminated in the introduction of significant reform to the management regulations in late 2012. This assessment establishes a baseline from which to consider the effects of these management changes.

The commercial catch and effort statistics were considered at the State-wide scale and for each of six fishery regions; Northern Spencer Gulf (NSG), Southern Spencer Gulf (SSG), Northern Gulf St. Vincent (NGSV), Southern Gulf St. Vincent (SGSV), the West Coast (WC), and the South East (SE). The total commercial catch taken in 2012 was 642 t, representing a significant decline from the record catch of 1,032 t that was taken in 2010. In 2012, catches declined in all regions except NGSV, which continued to produce record catches. Fishing effort declined in most regions in 2011 and 2012, with longline effort continuing to replace handlines as the dominant gear type. Catch rates declined in all regions for both handlines and longlines, except for NGSV where they remained at near record levels. These data are consistent with declining levels of biomass except for NGSV, where the results suggest a continuing high level of biomass.

The commercial fishery statistics for 2012 provided estimates of general fishery performance indicators that were assessed against trigger reference points at the State-wide and regional scales. Many of the trigger reference points were breached. The breaches for NSG, SSG, NGSV, SGSV and WC related to declining levels of catch, effort and catch rate. In contrast, for NGSV the breaches related to the high levels of catch, effort and catch per unit effort, particularly for longlines.

Two new fishery performance indicators, based on commercial catch data from 2004 to 2012 were also considered, i.e. the proportions of daily catches that exceeded 250 kg for the handline and longline sectors. Most regions showed declining trends for these indicators, with numerous breaches of trigger reference points. The exception was NGSV for which the trends increased over this period.

The annual size and age structures from market sampling throughout the 2000s, indicated that the regional populations involved numerous age classes, that reflected the influence of strong and weak year classes, ultimately related to inter-annual variability in recruitment. There was some consistency in the timing of strong year classes across regions, which involved the 1991, 1997, 1999, 2001, 2004 and 2006 year classes. Nevertheless, the relative strengths of these year classes varied amongst regions. The populations in NSG and SSG were dominated by recruitment that occurred during the 1990s, whilst those in SGSV and the SE involved no fish from the 1990s but were dominated by the 2001 and 2004 year classes. For NGSV, all six strong year classes were well represented in the population.

The fishery model SnapEst provided estimates of the output parameters of recruitment, fishable biomass, harvest fraction and egg production for the three regions of NSG, SSG and GSV over the period of 1984 to 2012. These output parameters demonstrated different trends for the three regions. There was relatively poorer recruitment through the 2000s for NSG and particularly SSG compared to GSV. Trends in fishable biomass for SSG and GSV were declining, which were also reflected in the estimates of egg production. However, the model estimated an increasing trend in fishable biomass for NSG based on increasing CPUE up to 2011. This model-predicted trend contrasts with the observed declining levels of catch and effort for this region and may represent a situation of hyperstability, that is not captured well by the SnapEst model.

A number of biological fishery indicators exceeded their trigger reference points. For SSG, the recent three-year average for fishable biomass was >10% below the previous three-year average. Recruitment levels for NSG and SSG between 2006 and 2008 were 39% and 78% below the historical means, respectively, whilst that for SSG was 16% below the previous 6-year average. Recruitment to GSV in 2006-08 was 112% above the historical mean and 11% above the previous 6-year average.

The declines in catches and catch rates in most regions are consistent with falling levels of fishable biomass in most regions. For NSG and SSG, this reflects the consequence of poor recruitment through the 2000s, whilst for SGSV and the SE it reflects depletion of the 2001 and 2004 year classes. Each of these regions was assigned the stock status level of 'transitional depleting'. NGSV was the only exception. This region continued to produce record levels of catch and catch rates reflecting the on-going high biomass in this region as a consequence of high recruitment through both the 1990s and 2000s. It was the only region assigned the stock status of 'sustainably fished'. The stock status of the WC fishery was classified as 'undefined' because of a poor understanding of the population demography of this region.

2. GENERAL INTRODUCTION

2.1 Background

Stock assessments for the South Australian snapper (*Chrysophrys auratus*) fishery have been done regularly since 1997, with this being the tenth in the series (McGlennon and Jones 1997, McGlennon 1999, McGlennon and Jones 1999, Fowler 2000, 2002; Fowler et al. 2003, 2005, 2007, 2010). The focus of each assessment has been to evaluate the status of South Australia's snapper stocks. The approach used here is consistent with that used throughout the 2000s. It was based on: commercial catch and effort data up to December 2012; results from the South Australian Recreational Fishery Survey 2007/08 (Jones 2009); and biological data that were collected up to September 2012. Selected data from these datasets were integrated using the fishery assessment model 'SnapEst' that was developed through the early 2000s (McGarvey and Feenstra 2004). This model produced as output, time-series of several fishery performance indicators, i.e. annual recruitment rates, fishable biomass, harvest fraction and egg production. The catch and effort data and output from the computer fishery model were used as fishery performance indicators and assessed and interpreted in terms of stock status.

In the various chapters, this report presents summaries of fishery statistics, new biological information, output from the fishery assessment model and the results of comparisons between fishery performance indicators and trigger reference points. The remainder of this first chapter provides an introduction to the South Australian snapper fishery, including a description of changes that have occurred over the past three years. It summarises the management regulations, including new recent changes, as well as our understanding of the biology of the different life history stages. Chapter 3 provides State-wide and regional catch and effort statistics, updating by a further three years the time-series of data that were reported by Fowler et al. (2010).

Chapter 4 summarises the results from the market sampling program that has operated for snapper since 2000. This program provides information on population structure that is interpreted in terms of demographic processes. Chapter 5 summarises the output of the 'SnapEst' computer fishery model. This model integrates all data available up to September 2012, including: regional estimates of catch and effort from the commercial fishery; data on the recreational catch obtained from both the National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003) and the 2007/08 State survey (Jones 2009); and regional size and age structure data that were collected from 2000 onwards. The model generated time-series of estimates for the four critical fishery indicators of recruitment, fishable biomass, harvest fraction and egg production for the period of 1984 to 2012.

In Chapter 6, the general and biological fishery performance indicators for 2012 were compared against appropriate trigger reference points calculated for the reference period of 1984 to 2012. This was done at the State-wide and regional scales, because of different temporal trends at different places. Furthermore, estimates of Biological Performance Indicators, based on output from the SnapEst model, were also considered for the three regions recognised in the model, as well as combined across regions.

The final chapter provides a synthesis of fishery statistics, the biological data and results from the 'SnapEst' model in the context of a discussion on the population dynamics for each region. This synthesis provides an assessment of the status of the different regional stocks.

2.2 Description of the South Australian snapper fishery

Each Australian mainland State supports a commercial snapper fishery, which together have provided historical annual national catches that have exceeded 2,400 tonnes (Kailola et al. 1993). Between 2005-06 and 2010-11, the national commercial catch ranged from approximately 1600 to 1900 tonnes (Table 2.1) (Anon 2012). The catches from New South Wales and Victoria were variable but showed no trend through this period, whereas those from Queensland and Western Australia decreased considerably. In contrast, through this period, South Australia's commercial catch has increased annually resulting in an increase in its proportional contribution to the national catch from 29.8% to 50.8%. As such, in 2010-11, South Australia remained the highest State-based contributor to the national catch of snapper, having exceeded that of Western Australia from 2006-07 onwards.

The snapper fishery of South Australia (SA) is geographically extensive and encompasses most of the State's inshore marine waters. For the purposes of stock assessment, these waters have historically been divided into six geographic regions; Northern Spencer Gulf (NSG), Southern Spencer Gulf (SSG), Northern Gulf St. Vincent (NGSV), Southern Gulf St. Vincent (SGSV), the South East (SE) and the West Coast (WC). Each region consists of a combination of adjacent Marine Fishing Areas (MFAs) that are indicated in Table 2.2 and Fig. 2.1. Note that for the first time in this report, MFAs 45 and 46 are considered as part of the SE region.

Snapper is an icon species for local and inter-state recreational fishers, who are particularly interested in the large 'trophy' fish that can be abundant in coastal waters of SA. There have been three broad-scale surveys that have provided data on the recreational catch and effort on snapper: a creel survey from 1994 to 1996 (McGlennon and Kinloch 1997); the National Recreational and Indigenous Fishing Survey (NRIFS) in 2000/01 (Henry and Lyle 2003); and the State-based recreational survey of 2007/08 (Jones 2009). The most recent survey indicated that the recreational catch was approximately 18% of the total in that year, which was divisible into 8% from the general recreational sector and 10% from the charter sector (PIRSA 2013). The survey also identified differences in the contributions of the six regions to the recreational catch with Gulf St. Vincent (GSV) and SSG contributing the higher catches. The recreational survey also identified that many thousands of snapper are discarded by the recreational sector, primarily for being undersized. There is considerable concern about the fate of such discarded fish because they are vulnerable to the effects of barotrauma (Fowler et al. 2009).

Table 2.1 Summary of commercial catches of snapper (tonnes) for six recent financial years from each of the mainland states of Australia (data from Anon 2009, Anon 2012).

State	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
NSW	236	238	294	244	276	287
Vic	92	108	113	101	90	120
Qld	228	186	155	106	95	77
WA	693	586	492	425	444	458
SA	529	644	741	780	916	972
Total	1,778	1,762	1,795	1,656	1,821	1,914

Table 2.2 Names of the fishery regions considered in the assessment of South Australia's snapper fishery, and the Marine Fishing Areas that comprise them. Refer to Fig. 2.1.

Region name	Marine Fishing Areas
Northern Spencer Gulf (NSG)	11, 19, 20, 21, 22, 23
Southern Spencer Gulf (SSG)	29, 30, 31, 32, 33
Northern Gulf St. Vincent (NGSV)	34, 35, 36
Southern Gulf St. Vincent (SGSV)	40, 41, 42, 43, 44
West Coast (WC)	7, 8, 9, 10, 15, 16, 17, 18, 27
South East (SE)	45, 46, 50, 51, 54, 55, 56, 57, 58
Others	all remaining MFAs

The commercial sector accounts for about 81% of the snapper catch in SA (Jones 2009, PIRSA 2013). License holders from four different commercial fisheries have access to the snapper stocks, i.e. the Marine Scalefish Fishery, the Northern Zone and Southern Zone Rock Lobster Fisheries and the Lakes and Coorong Fishery (PIRSA 2013). The main fishing gear types that commercial fishers use to target snapper are handlines and longlines since the use of hauling nets for taking snapper was prohibited in 1993. Commercial fishing vessels are generally 5-8 m in length and equipped with GPS systems for navigation and echo sounders to find specific fishing drops. Historically, handlines were the dominant gear type, however over the past five years many fishers have adopted new longline fishing techniques, which now account for the majority of effort in most regions.

Commercial snapper catches in SA demonstrate considerable inter-annual variation (Fowler et al. 2010, Fowler and McGlennon 2011). Typically they have increased and decreased in cycles over periods of a few years, related to cyclical variation in biomass. This variation reflects the consequence of natural demographic processes. Regional age structures reveal the presence of strong and weak year classes, which reflect high inter-annual variation in recruitment (McGlennon and Jones 1997, McGlennon et al. 2000, Fowler et al. 2003, 2005, 2007, 2010). At any time, the total catch and catch per unit effort (CPUE) of the fishery reflect the numbers of strong year classes and their ages in the population (McGlennon and Jones 1997).

Historically, when the fishery was largely based in NSG, the sizes of fish captured in the fishery related to the selectivity of the two major gear types. Snapper first recruited to the handline fishery from the age of about 3 years and were likely to be fully recruited by 5 years of age. Vulnerability to handlines decreased when fish were about 12 years old and size was around 80 cm caudal fork length (CFL), which means that few fish older than 15 years were taken with handlines (McGlennon and Jones 1997). However, such older fish were still targeted in the longline fishery and vulnerable at ages greater than 12 years, and continued to be fished to ages of greater than 30 years (McGlennon and Jones 1997, Fowler et al. 2003). CPUE of the handline fishery is thought to be highest when strong year class(es) are between 9 - 12 years old, and for the longline fishery for the ages of approximately 13 - 17 years (McGlennon and Jones 1997).

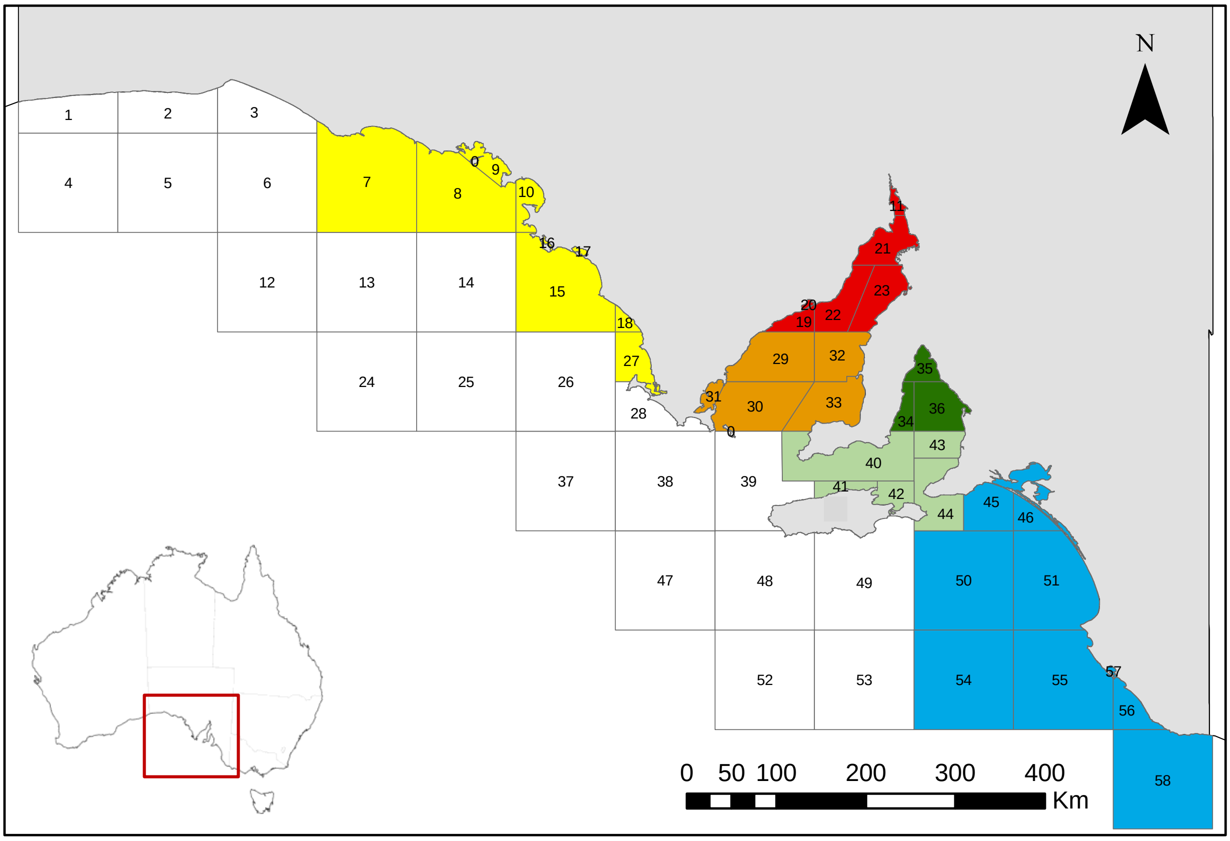

Fig. 2.1 Map of South Australia showing the Marine Fishing Areas that are used for the collection of fishery statistics in the Marine Scalefish Fishery. The six regions that are considered in this stock assessment of the snapper fishery are indicated, i.e. Northern Spencer Gulf (red), Southern Spencer Gulf (orange), Northern Gulf St. Vincent (olive), Southern Gulf St. Vincent (green), West Coast (yellow) and South East (blue).

2.3 Changes since the last assessment

Since the last stock assessment (Fowler et al. 2010), there have been numerous significant developments in South Australia's snapper fishery that relate to both the stock status and fishery management. Summaries of that assessment and a description of the subsequent developments are presented here to provide context for this current assessment. The previous assessment concluded that the fishery status in late 2009 was generally positive. Most regional State waters were assessed as supporting relatively high levels of biomass and the stocks were considered to be healthy with no apparent sustainability issues, with the exception of SSG, for which there had been a recent decrease in biomass, due to poor recruitment over the past decade (Fowler et al. 2010).

In 2009, the State-wide commercial catch was at a record level and subsequently continued to increase even further over the following year. The increase was associated with a dramatic shift in the spatial structure of the fishery. Commercial catch and effort increased in two regions, i.e. NGSV and the SE, where snapper fishing effort had previously been very low. Furthermore, these increases involved a significant shift from handline to longline fishing effort, as fishers adopted new efficient longline technologies. Targeted catches, effort and catch rates in these regions increased exponentially to record levels, which helped to take South Australia's contribution to the national catch to greater than 50% (Anon 2012). At the same time, however, the contribution of the traditional snapper fishing grounds of Spencer Gulf (SG) continued to decline. In 2012, this decline resulted in the two stocks of NSG and SSG being assigned the status of 'transitional depleting' in the national stock status report, which indicated that they were moving towards being recruitment overfished (Jackson et al. 2012). Such a status is highly concerning, given that the former region had always been the mainstay of South Australia's snapper fishery (Fowler et al. 2010).

The dramatic and unprecedented levels of effort that produced record catches in some regions of South Australia's snapper fishery and the apparent decline in traditional fishing regions led to considerable concern in the industry and community about the long-term sustainability and economic viability of this fishery. In response to this concern, in May 2011, PIRSA established the Snapper Working Group (SWG), to review and make recommendations about the management arrangements for the fishery. This group involved a diversity of members that included industry representatives, fishery scientists and managers. Over approximately 18 months, the SWG reviewed the understanding of the biology of the species and the fishery and considered many potential management options. The process included a public consultation period for preferred management strategies that resulted in a record number of submissions. Through this period, it also became evident from the results of a recent study into snapper behaviour, that the spawning aggregations might be particularly susceptible to disturbance by the fishing activity that takes place after the seasonal closure (Fowler unpublished data). As such, the focus of the SWG became to establish management arrangements that would maintain a sustainable snapper fishery by not only limiting the impact of the commercial sector on snapper stocks but also optimise opportunities for spawning and recruitment.

Following the processes of the SWG, on the 1st January 2012 an interim daily catch limit of 800 kg.day^{-1} was introduced for the commercial sector for within SG and GSV. Then in October 2012, further new management arrangements were introduced by PIRSA Fisheries and Aquaculture. These changes included:

1. a 15-day extension to the annual State-wide snapper fishing closure that was implemented in 2012 for commercial fishers and will come into effect in 2013 for the recreational and charter sectors;

2. a daily commercial catch limit of 500 kg that was introduced for all South Australian coastal waters from 15th December 2012, to help control the level of commercial effort on snapper stocks;
3. a restriction for commercial fishers to using a maximum of 200 hooks on set lines (reduced from 400 hooks) when operating in SG and GSV, to assist in constraining catch and minimise the discarding of excess snapper.

These three measures will contribute to reducing commercial catch and effort. Furthermore, the two-week extension of the State-wide snapper closure will extend the period for which the spawning aggregations are undisturbed, and so provide opportunity to enhance spawning and recruitment.

Following the introduction of the management measures described above, PIRSA pursued action to develop and implement new spatial spawning closures. To this end, in June 2013, PIRSA announced the establishment of several specific spatial closures in the northern parts of both gulfs that are designed to protect important spawning aggregations for the entirety of the reproductive seasons of 1st November to 31st January. These will commence in the summer of 2013/14.

The extension of the seasonal closure for a further two weeks, the new daily catch limit (including restrictions on multi-day trips), and the new restrictions to hook numbers and future spatial spawning closures will directly restrict catch and effort and probably contribute to changes in fisher behaviour. This will influence the commercial fishery statistics and affect the comparability of all data from December 2012 onwards to the earlier catch and effort back to 1983/84. These changes are recognised in the harvest strategy in the new Management Plan for the Marine Scalefish Fishery (PIRSA 2013). This harvest strategy recognises the recent changes in the fishery, outlines the new management arrangements and provides direction for the future assessment of the fishery. The harvest strategy recognises that the relative significance of commercial statistics as fishery indicators has changed as a consequence of the new management arrangements and includes two new fishery performance indicators.

2.3 Management Regulations

Regulations for the commercial sector of South Australia's snapper fishery involve a suite of input and output controls (PIRSA 2013). The four commercial fisheries with access to snapper are limited-entry fisheries, i.e. the numbers of fishers who can target snapper have been limited for numerous years. There is a legal minimum length of 38 cm TL. There are several gear restrictions. Snapper cannot be taken with fish traps, whilst the use of all nets, including hauling nets and large mesh gill nets for targeting snapper was prohibited in 1993. From December 2012, the number of hooks on set lines was reduced from 400 to 200 for fishers operating within Spencer Gulf and Gulf St. Vincent, and remains at 400 for other regions. Simultaneously, a daily commercial catch limit of 500 kg was introduced across all South Australian waters. There is also a 50 kg bycatch trip limit for the Commonwealth-managed Southern and Eastern Scalefish and Shark Fishery. Commercial handline fishers are limited, with respect to the numbers of handlines and numbers of hooks per line that can be legitimately used.

For the recreational sector, the minimum legal length of 38 cm TL applies, whilst further regulation comes from a combination of size, bag and boat limits that vary geographically. In Gulf St. Vincent, Backstairs Passage and Investigator Strait the bag limit is 5 and boat limit 15 fish for the size range of 38 - 60 cm TL, whilst for all other State waters the bag limit is 10 and boat limit 30 fish. For fish >60 cm TL, there is a bag limit of 2 fish and boat limit of 6 fish for all State waters.

Since 2000, the management regime for snapper has involved at least one seasonal closure per year which applies for both fishing sectors. This resulted from significant management concern and action that was taken in the late 1990s. In 1998/99, a substantial decline in longline catch in NSG caused significant concern about the status of the stock, as it suggested a substantial reduction in the biomass of the larger, older fish in the population (Fowler and McGarvey 2006). This led to considerable deliberation by a Snapper Working Group, the Marine Scalefish Fishery Management Committee, PIRSA Fisheries and SARDI scientists as to an appropriate management response. Various options were considered that were compared using a yield-per-recruit analysis (McGarvey and Jones 2000, McGarvey 2004). That analysis identified that a 10% reduction in fishing mortality, would produce an 11% increase in egg production, and a slight increase in catch by weight of 1 - 2%. It was thought that the appropriate reduction in fishing effort could be achieved by introducing State-wide fishery closures (Shanks 2000). Consequently, in 2000 two such closures for snapper fishing were introduced, the first from 1st to 20th August and the second from 6th to 25th November. That regime of seasonal closures was also used in 2001 and 2002. However, in 2003, the August closure was discontinued and the November closure was extended to include the entire month. This protocol of a single, month-long closure throughout November was maintained in both 2004 and 2005, after which its effectiveness was assessed in mid 2006 (Fowler and McGarvey 2006). It was concluded by considering commercial catch and effort data at several temporal scales that the fishery closures were effective in reducing targeted effort, although the level of reduction that was achieved varied among regions, years and gear types. As such, the month-long fishery closure has been implemented in each November since 2006.

As part of the reforms to the management program of South Australia's snapper fishery that were introduced in late 2012, changes were also made to the duration of the seasonal State-wide fishery closure. During the review of management arrangements in 2011 and 2012, it was recognised that, in addition to reducing fishing effort, the seasonal closure also provided protection to spawning aggregations of snapper and so optimised opportunity for successful spawning and recruitment. In 2012, the seasonal closure was extended to December 15th for the commercial sector. From 2013 onwards, the seasonal closure until December 15th will apply for all fishing sectors. Furthermore, seasonal spatial closures will be introduced in 2013 that close specific places to fishing activity for the entire reproductive season from 1st November until 31st January. The seasonal fishing closure and seasonal spatial closures will provide protection to the spawning aggregations of snapper for a longer part of the spawning season, to minimise disturbance to the aggregations and maximise the opportunity for successful spawning and recruitment (PIRSA 2013).

2.4 Biology

Genetic Stocks

The snapper is a member of the family Sparidae. It is widely distributed throughout warm, temperate and sub-tropical waters of the Indo-Pacific region including Japan, the Philippines, India, Indonesia, as well as Australia and New Zealand (Kailola et al. 1993). In Australia, snapper have a continuous distribution around the southern coastline of the mainland below 18ºS and northern Tasmania (Kailola et al. 1993). They occur in a broad range of habitats from shallow, coastal, demersal areas to the edge of the continental shelf across a depth range of 1 – 200 m. The broad distribution is thought to be divisible into a number of separate genetic stocks. One division occurs at Wilson's Promontory in Victoria from where an east coast stock extends 2000 km up the coast of New South Wales (Sanders 1974). There is also strong evidence of a division between the Victorian and South Australian populations. Tagging studies have shown that fish caught in south-eastern South Australia (Port MacDonnell - Kingston) belong to a western Victorian stock, whilst those from the South Australian gulfs and west coast form a separate stock (Jones et al. 1990). The analysis of allozymes, mitochondrial DNA and tagging data all consistently indicate a stock division between the Victorian and South Australian stocks that is located around the mouth of the Murray River (McGlennon and Jones 1997).

Snapper can also form separate stocks at spatial scales smaller than the regional geographic scale. For Shark Bay in Western Australia studies on genetics (Johnson et al. 1986), adult movement (Moran et al. 2003), adult morphometrics (Moran et al. 1998), and chemical analysis of otoliths for trace elements and stable isotopes (Edmonds et al. 1999, Bastow et al. 2002), have revealed a stock structure for snapper that is unusually complex. These studies indicate that there is minimal exchange of individuals even over relatively short distances, and that populations in the Eastern and Western Gulfs of Shark Bay and the adjacent oceanic region are effectively separated. In fact, there is evidence for even finer scale structuring within the gulfs and oceanic sub-populations of Shark Bay (Moran et al. 1998). This unusual situation may relate to the particularly strong salinity gradients in this region (Bastow et al. 2002), but nevertheless warns that fine-scale population structuring could occur in other parts of the distribution of the species.

Adult Movement Patterns

The fine-scale population structuring evident for Shark Bay is consistent with results from some tagging studies that have identified long-term fidelity of some snapper for particular places. For example, one New Zealand study revealed that most tag recoveries were made within only 500 m of the tag site, even up to 3 years after tagging (Willis et al. 2001). This was the case even for relatively small fish, which have reputedly been the ones most likely to travel considerable distances (Jones 1981). Nevertheless, not all tagged snapper are long-term residents of small home ranges. Most studies have identified the existence of such 'resident' fish, but have also demonstrated that some fish move considerable distances. These fish constitute a 'migratory' component of the population (Paul 1967, Crossland 1976, Jones 1984). Both 'residents' and 'migrants', have been recognised in South Australia. Tagging studies done between 1977 and 1983 described size-specific movement patterns (Jones 1981, 1984). Of 274 fish recaptured by 1984, 16.4% had moved a substantial distance, with the younger fish demonstrating greater movement than larger, older ones. The longest recorded movements were from northern gulf waters to the continental shelf waters. Movement in the opposite direction was also evident with one fish that moved to the north of Spencer Gulf. The tagging studies also involved experiments where large numbers of small fish from one reef were tagged. Some of these were recaptured on the same reef up to 4 times over 2 years, suggesting long periods of residency, whilst others were recaptured up to 120 km away (Jones 1984). There is also the high probability that large snapper return to the same reef (Jones 1984).

In May 2011, a study into the movement patterns of snapper in NGSV was initiated. This is an on-going project funded by the Fishery Research and Development Corporation (FRDC), which is based on acoustic telemetry. To date, the results from this study have confirmed the tractability of using acoustic telemetry on snapper and demonstrated that their behaviour is complex at several different temporal scales (Fowler et al. 2012). At the daily scale, their movement is influenced by the timing of tidal currents and at the seasonal scale, the fish move over substantially greater distances during spring and summer than winter.

Life History in South Australia

A genetics study for snapper found no evidence for finer-scale stock structure other than the broad division between Victorian and South Australian populations near the mouth of the River Murray (Donnellan and McGlennon 1996). From this apparent panmixia, the State-wide fishery has been managed as a single stock. This approach was consistent with the early life history model for this species, which involves significant age-related fish migration (McGlennon and Jones 1997, Fowler 2008). This model suggests that when fish are a few years old they leave the nursery areas in the northern gulfs, and move southwards to the continental shelf. From there they make annual spawning migrations over a number of years back into the gulfs where they are vulnerable to the fishery. By approximately 12 years of age the fish become permanent residents to the northern gulfs. Thus, this life history model suggests that on the continental shelf there is a significant, mixed-age population that is derived from age-related migration from numerous different regions. Such a life history would clearly provide opportunity for the mixing of individuals that originate from different regions such as Spencer Gulf and Gulf St. Vincent.

Not all information is consistent with the life history model presented above. For example, the apparent collapse of the Gulf St. Vincent fishery through the late 1990s at the same time that the Spencer Gulf fishery flourished and produced record catches, challenges the 'single stock' hypothesis. To resolve such inconsistencies, a further study was done that considered stock structure of snapper in SA that was based on the analysis of otolith chemistry (Fowler et al. 2004, 2005b). That study provided data from which a new life history model was developed (Fowler 2005b, 2008). It identified some regional sub-structure to the State-wide population, but with regional differences only apparent for adult fish of four years of age and older. Data relating to the first three years of the fishes' lives showed little variation, indicating a lack of spatial differentiation with regards the origin of fish. This suggests that most fish came from only one or two nursery areas, i.e. NSG and NGSV. The data suggested that the fish remained in these regions for several years but that throughout their fourth and fifth years some fish moved to other regional State waters. Thus, this new life history model involves movement of 3-4 year old fish away from the nursery areas, which culminates in the dispersion of fish throughout State waters. Once this happens their subsequent movement appears to be limited.

The otolith chemistry study suggested that most fish, regardless of where they were captured, had a common origin. This is consistent with the lack of genetic differentiation amongst regional sub-populations throughout SA (Fowler et al. 2004). Nevertheless, the regional differences in population characteristics suggest that once the 3 – 4 year old fish had moved and joined the regional sub-populations there was minimal subsequent movement between them. This is consistent with the tagging work where most tagged fish were recaptured within 20 km of the tag site, and so should be considered 'residents', whereas relatively few adult snapper moved distances of several hundred kilometres that would justify them being recognised as 'migrants' (Jones 1981, 1984).

Our understanding of the large-scale movement patterns of snapper remains incomplete. The aim of the FRDC-funded project currently underway (FRDC Project 2012/020) is to refine our understanding of snapper movement and its influence on stock structure. This project will be completed in 2014.

<u>Growth, Longevity and Age Structures</u>

Transverse sections of the sagittae of adult snapper from SA generally display clear increments of opaque and translucent zones, which form annually and therefore indicate fish age (McGlennon et al. 2000). The ageing methodology, based on transverse sections, has been used to age samples of fish that were collected through market measuring in 1991, 1994 and 2000-2012. Results from 1991 and 1994, indicated that fish grew slowly and conformed to the von Bertalanffy growth equation: $L_t = 930.2\ [1 - \exp(-0.144(t - 0.8285))]$ (McGlennon et al. 2000). The oldest estimate of age obtained so far for a snapper from SA is 36 years, marginally less than the oldest from the remaining Australian waters of 40 years (Norriss and Crisafulli 2010).

The age structures of snapper from different regions of SA show the presence of strong and weak year classes, which appear to reflect the consequences of significant inter-annual variation in recruitment of 0+ fish (McGlennon and Jones 1997; Fowler 2000, 2002; Fowler et al. 2003, 2005, 2007, 2010; Fowler and McGlennon 2011). Ageing work done between 2000 and 2004 revealed the existence of two strong year classes of which the 1991 year class was particularly strong. That year class was largely responsible for the recovery of the fishery throughout all regions of SA after the poor catches of the mid 1990s. Further second strong year classes that recruited in 1997 and 1999 have contributed significantly to all the regional fisheries since 2000 (Fowler 2002; Fowler et al. 2003, 2005, 2007, 2010).

Reproductive Biology

Analysis of gonads indicates that South Australian snapper are multiple batch spawners that have indeterminate fecundity and asynchronous oocyte development (Saunders 2009, Fowler unpublished data). The individual fish spawn over consecutive days, which is consistent with findings from earlier studies in Japan and New Zealand (Matsuyama et al. 1988, Scott et al. 1993).

The best information on the timing of reproductive activity is for NSG through the years of 2005-2008 (Saunders 2009, Saunders et al. 2012). Intensive sampling of adult fish throughout this period indicated that gonad development commenced in October and spawning started in late November. Spawning activity peaked throughout December and then declined in January and was finished by early February. The consideration of data on gonad macroscopic stages and gonosomatic indices indicated that the timing of gonad development and spawning varied to some extent amongst the other geographic regions, i.e. reproductive activity persisted for longer in the southern parts of the two gulfs (Fowler unpublished data).

Analysis of the changes that occur in ovaries over the 24-hour period building up to spawning indicates that hydration of oocytes occurs throughout the afternoon, followed relatively quickly by ovulation and spawning at around dusk (Fowler unpublished data). The co-occurrence in ovaries of hydrated oocytes and post-ovulatory follicles at different stages of degeneration indicates that fish spawn over consecutive days (unpublished data). Estimates of batch fecundity in NSG ranged from 12,750 to >1,000,000 and up to 551,000 oocytes in SSG. In both regions batch fecundity increased with fish size, weight and ovary size.

In South Australia, fish of size >80 cm CFL and 15 years or older can be quite numerous in the two northern gulfs (Fowler et al. 2010, Fowler and McGlennon 2011). There has been some suggestion from the aquaculture industry that such snapper undergo 'senescence', which results in a reduction in the viability and fertilisation rate of their eggs relative to those of younger fish (Smith and Hataye 1982), to the extent that when they reach approximately 15 years of age their reproductive activity ceases (Foscarini 1988). The question about the viability of the reproductive contribution of older fish has been considered to some extent for South Australian fish (Fowler unpublished data). The results clearly suggest the likelihood that such older fish continue to be involved in spawning activity. This is based on observations that ovaries with advanced yolked oocytes and post-ovulatory follicles were obtained from fish that were up to 25 years old, whilst some fish with hydrated oocytes were up to 22 years of age (Fowler unpublished data). Such results are not consistent with senescence in older fish.

Early Life-History

Snapper eggs are approximately 0.85 – 1.0 mm in diameter, with unsegmented yolk and a narrow perivitelline space (Crossland 1976). They are pelagic and hatch after approximately 36 hours at 21°C, releasing larvae of 2 mm length, which remain pelagic during their development. The larvae metabolise yolk for 2-3 days and then begin to feed, taking approximately 20 - 30 days to reach 8-12 mm standard length (SL) when they are capable of settlement and becoming demersal juveniles (Fukuhara 1985, Tanaka 1985, Fowler and Jennings 2003). Snapper eggs have been sampled in NSG in studies aimed at estimating the adult spawning biomass using the Daily Egg Production Method (McGlennon and Jones 1999, Fowler 2002). The distribution pattern on both occasions was patchy suggesting distinct consistent spawning hotspots such as near Franklin Harbor, and also considerable differences between years. From the hydrodynamics in NSG (Tronson 1974, Bullock 1975), larvae are more likely to be retained in that region than to be advected southwards.

The patterns of distribution and abundance of the 0+ fish throughout NSG, were documented by an annual recruitment survey through the period of 2000 to 2010 (Fowler and Jennings 2003, Fowler et al. 2005, 2007, 2010). The new recruits were distributed consistently amongst years, being clumped both within and between adjacent stations that were dominated by bare, flat, muddy substratum, suggesting that specific nursery areas are actively selected by the 0+ fish. In both New Zealand and Japan, the 0+ fish are strongly associated with fine sediments typical of areas with low current regimes. This may reflect the reliance of small fish on a planktonic diet, particularly copepods, which aggregate in such benign conditions. In Japan, pelagic juveniles enter shallow bays and then settle to the demersal habitat where they feed primarily on copepods. They are then thought to follow a gradient of copepod abundance to the nursery grounds that are characterised by sandy, flat bottoms, where they feed on gammaridean amphipods (Tanaka 1985). Recruitment is highly variable and until recently was thought to be related to sea surface temperature (Fowler and Jennings 2003, Fowler et al. 2007), but subsequently the strength of this relationship has declined considerably.

Aspects of the early life history of juvenile snapper captured in the annual recruitment surveys were determined in each year through the retrospective analysis of the microstructure of their otoliths. These sagittal otoliths display daily increments formed from the third day after hatching, as well as a clear settlement mark. Therefore, age and pre-settlement duration were determined (Fowler and Jennings 2003, Saunders 2009). The estimated growth rates varied considerably both within and between years, as related to water temperature and the time of settlement. Growth was slowest in 2002 when the summer water temperatures were very low, which resulted in higher estimates of pre-settlement duration (Fowler and Jennings 2003). From the estimated spawn dates it was apparent that successful recruitment resulted from specific periods through the reproductive season, whose duration and timing varied between years.

3. ANALYSIS OF COMMERCIAL FISHERY STATISTICS

3.1 Introduction

Since 1983/84, commercial fishers in South Australia's Marine Scalefish Fishery have been required to submit, on a monthly basis, a catch return that relates details of their catches and effort for the preceding month. This now provides a data time series that constitutes the most fundamental dataset available as indicators of fishery status. These commercial fishery statistics are examined here at three spatial scales; State-wide, regional and Marine Fishing Area (MFA). In this chapter, the data are presented and trends described qualitatively, whilst in Chapter 6 they are used to calculate general fishery performance indicators that are assessed against target reference points (PIRSA 2013). Also, the catch and effort data reported here are used in the fishery assessment model, SnapEst, to calculate time series of output parameters that relate to population processes and fishery status (Chapter 5). The output parameters are assessed against target reference points to indicate the status of the fishery (Chapter 6).

3.2 Methods

Data from catch returns were accumulated across fishers to provide regional, annual totals of catch and effort by gear type, which were further aggregated into State-wide totals. Data are presented at the different spatial scales by calendar year to 2012. The data presented at the State-wide level are 'total catch' and 'targeted effort' as mandays. 'Untargeted effort' is not considered as it is unlikely to be meaningful from the perspective of stock status. The regional analysis of fishery statistics is presented here for six regions (Fig. 2.1 and Table 2.2), and is based on targeted fishery statistics of targeted catch, effort and CPUE for both handlines and longlines, which are considered the most meaningful indicators of stock biomass. The time series of combined targeted catch from both handlines and longlines, as well as the numbers of fishers who targeted snapper are presented for the MFAs that contributed most to the regional catches.

3.3 Results

<u>Trends in State-wide estimates of catch and effort</u>

The estimates of State-wide commercial catch show cyclical variation, with the cycles encompassing a number of years, i.e. increasing for several years and then decreasing again (Fig. 3.1a). Since 2003, State-wide catch increased to a record level of 1,032 t in 2010, before declining by 37.8% to 642 t in 2012. Handline catch has historically been the dominant component of total catch (Fig. 3.1a). It has been highly cyclical and largely drove the trends in total catch until 2008. Longline catch was generally low and relatively consistent until 2004. Since then, it has increased considerably, particularly since 2008 and has become the dominant gear type in the fishery. The contribution to total catch of gear types other than handlines and longlines is now minimal since the use of hauling nets for targeting snapper was banned in 1993. In 2012, fishers from the Marine Scalefish Fishery dominated the snapper catch, whilst there was a much lower reported catch from the Northern and Southern Zone Rock Lobster Fisheries and no reported catch from the Lakes and Coorong Fishery (Table 3.1).

There was a long-term declining trend of targeted commercial effort between the mid 1980s and 2008 that was interrupted by increases in 2009, 2010 and 2011 before declining again in 2012 (Fig. 3.1b). Between 1984 and 2008, handlines were the dominant gear type. However, targeted longline effort increased by 168% between 2008 and 2011, firmly establishing it as the dominant gear type in the modern fishery. Fishers from the Marine Scalefish Fishery accounted for the majority of targeted fishing effort (Table 3.1).

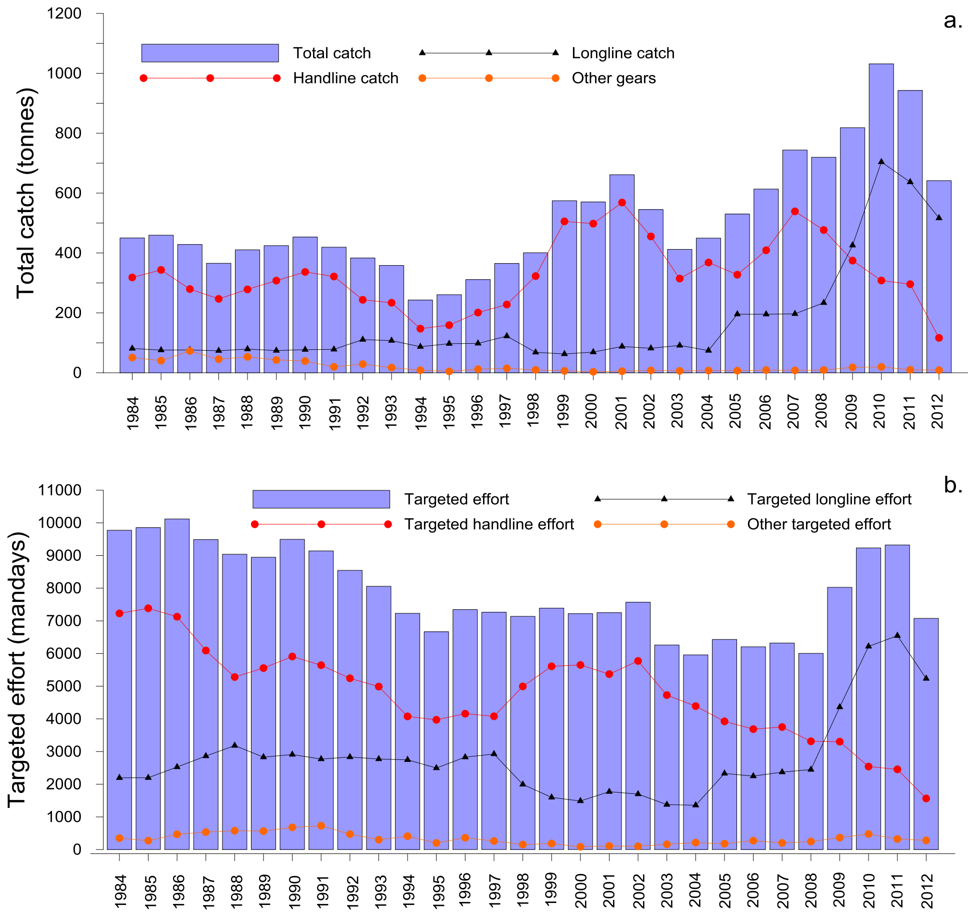

Fig. 3.1 a. Total annual commercial catches of snapper and catches by gear type from 1984 to 2012; b. annual estimates of total targeted fishing effort and targeted effort by gear type for the same period.

Regional Analysis of Catch and Effort Statistics (1984 – 2012)

The division of the total, annual, State-wide commercial catch of snapper into its regional components showed that the variation in total catch differed amongst regions (Fig. 3.2). NSG was the most significant region in the fishery from 1984 to 2004, but catches from this region have since dropped considerably. Between 2005 and 2009, SSG was the dominant regional contributor to total catch. Between 2007 and 2010, total catch from NGSV increased exponentially, resulting in it making the greatest regional contributions between 2010 and 2012. The catches in the SE increased over the same time frame in the latter 2000s, peaking in 2010 and declining considerably in 2011 and 2012. The contributions of SGSV and the WC have generally been relatively minor.

Table 3.1 Contributions in 2012 to the total reported catch and targeted effort from the four commercial fisheries with access to the snapper stocks, i.e. Marine Scalefish Fishery (MSF), Northern and Southern Zone Rock Lobster Fisheries (NZRL, SZRL) and Lakes and Coorong Fishery (L & C).

Fishery	Number of fishers reporting snapper catch	Total catch (t) of snapper (% of total)	Targeted effort (mandays) (% of total)
MSF	170	625.1 (97.4)	6,788 (95.8)
NZRL	9	1.6 (0.25)	113 (1.6)
SZRL	10	15.0 (2.3)	186 (2.6)
L & C	0	0	0
Total	189	641.7	7,077

<u>*Northern Spencer Gulf*</u>

Handline Fishery

Targeted handline catch of snapper was at record high levels between 1998 and 2002 with the highest annual catch of 319.4 t taken in 1999 (Fig. 3.3a). However, it decreased considerably to only 94.3 t in 2005, i.e. a decline of 70.5% in six years. It then increased back to 176.7 t in 2011, but in 2012, it fell again to 47.3 t, i.e. a decline of 73.2% in a single year to the lowest recorded level. Targeted handline fishing effort has also decreased since 1999, particularly between 2002 and 2012, falling from 3,405 to 690 mandays, i.e. a decline of 79.7% (Fig. 3.3b). The targeted CPUE increased from a minimum in 1994 to a peak in 1999, before gradually declining to a second minimum in 2005. After that there was a rapid increase to a record level in 2011. However, in 2012, handline CPUE declined by 51.3% to 68.5 kg.manday^{-1}.

Longline fishery

Targeted longline catch of snapper varied from 39.2 to 83.8 t in 1997, but has subsequently declined to the lowest level yet recorded of only 3.5 t in 2012 (Fig. 3.3c). Longline fishing effort shows a similar temporal pattern, with a maximum of 2,353 mandays in 1997 (Fig. 3.3d). Since then, longline effort has declined systematically to the lowest level of 105 mandays recorded in 2012, representing a reduction of 95.5% in 15 years. Targeted longline CPUE was relatively consistent until 2002 (Fig. 3.3d). Since then it has been highly variable, increasing to a maximum of 87.3 kg. manday^{-1} in 2007 before declining over a number of years to 33.1 kg.manday^{-1} in 2012, a decline of 62.1%. The recent variability probably reflects the lack of data because of minimal effort in these latter years.

Contributions of MFAs

There are six MFAs that comprise NSG, i.e. MFAs 11, 19, 20, 21, 22 and 23 (Fig. 2.1). Of these, the latter three have generally contributed the bulk of the snapper catches over the years (Fig. 3.4). The annual catches in MFA 21 were relatively consistent until 2004, but then decreased considerably. The catches in MFAs 22 and 23 have been more variable but attained their maxima in 1999 and 2000, respectively. Both have decreased since then, declining to their lowest levels in 2012.

The number of fishers who targeted snapper in MFA 21 has declined relatively consistently since 1992 (Fig. 3.4). In MFAs 22 and 23, the numbers of fishers have declined since their maxima in 2002, dropping to their lowest levels in 2012.

Southern Spencer Gulf

Handline fishery

The targeted handline catch in SSG has shown considerable variation, particularly since 1994 (Fig. 3.5a). It peaked at 251 t in 2001 before decreasing to 79.6 t in 2003. It increased again to 236 t in 2007 before decreasing to only 14.1 t in 2012, the lowest yet recorded. Targeted handline fishing effort has also demonstrated considerable cyclical variation, increasing from 559 mandays in 1994 to peak at 1,631 mandays in 2001, but has subsequently declined to the lowest recorded level of only 172 mandays in 2012 (Fig. 3.5b). Targeted CPUE increased from 27.7 $kg.manday^{-1}$ in 1994 to 153.9 $kg.manday^{-1}$ in 2001 (Fig. 3.5b), but then dropped by 60.6% in the following two years to 60.6 $kg.manday^{-1}$. Since 2003, it increased rapidly to the record level of 182.6 $kg.manday^{-1}$ in 2007. However, from then until 2012, handline CPUE declined by 55.0% to 82.2 $kg.manday^{-1}$.

Longline fishery

The targeted longline catch in SSG remained a small fraction of the handline catch until 2005 when it increased rapidly to 116.3 t and then to 127.0 t in 2006 (Fig. 3.5c). Since then, longline catch declined substantially to only 16 t in 2012. The higher catches between 2005 and 2009 are attributable to a substantial increase in fishing effort from 274 mandays in 2004 to 940 mandays in 2005, with further increases in the following two years (Fig. 3.5d). As such, longline effort increased by 259.5% from 2004 to 2007. Targeted CPUE increased gradually through the late 1990s and early 2000s to levels of around 70 $kg.manday^{-1}$, but then increased substantially to >120 $kg.manday^{-1}$ in both 2005 and 2006 (Fig. 3.5d). However, from 2008 to 2011, longline CPUE declined from 137.8 to 55.1 $kg.manday^{-1}$ before increasing in 2012 to 96.0 $kg.manday^{-1}$.

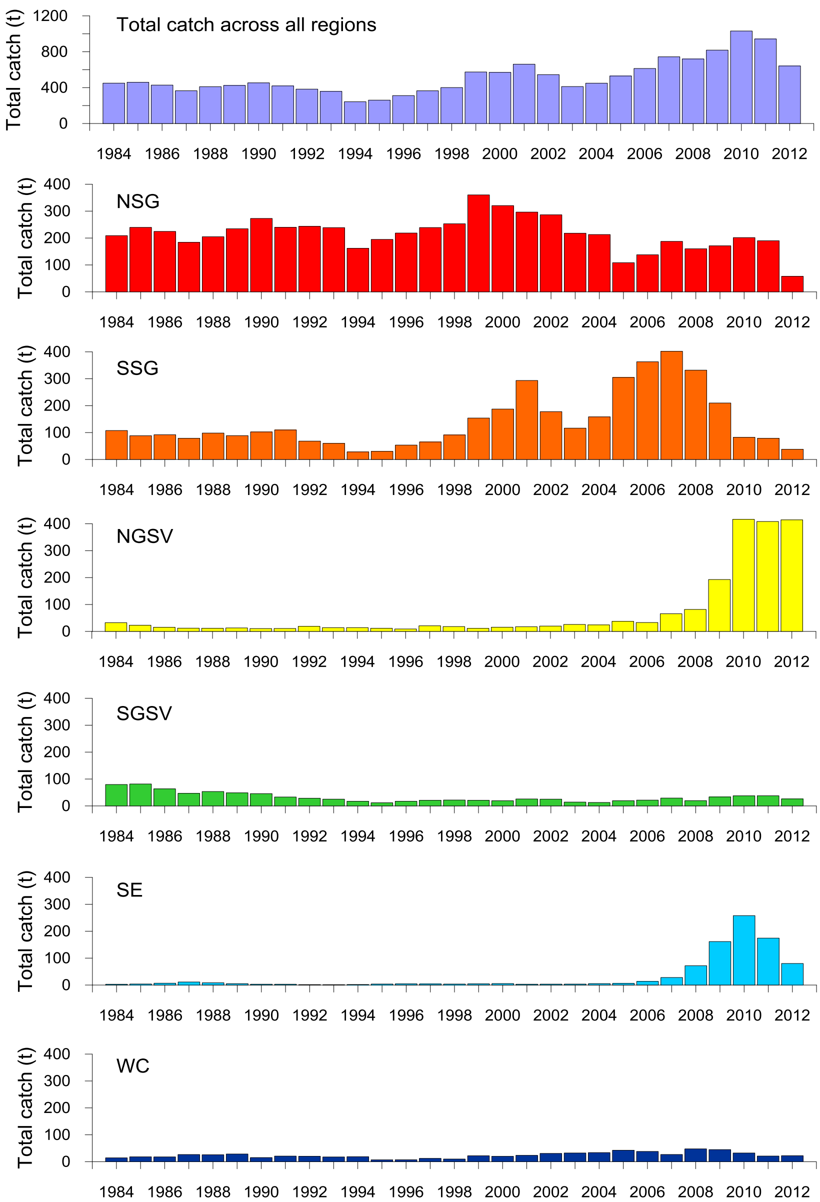

Fig. 3.2. Summary of annual commercial catches of snapper at the State-wide and regional scales from 1984 to 2012.

Contributions of MFAs

Across the four MFAs that contribute most of the catch of this region (Fig. 2.1), the pattern of distribution of snapper catches has changed over time. Until the mid-1990s, most snapper were caught in MFAs 32 and 33 (Fig. 3.6), with totals reaching their maxima in 2001. Catches from MFAs 29 and 30 were historically low, but increased from the late 1990s, particularly between 2005 and 2009. Subsequently, the catches from all MFAs have declined considerably.

The numbers of commercial fishers who targeted snapper in SSG partly reflect the trends in targeted catch. MFAs 32 and 33 have usually supported the highest number of participants, which have declined since the early 2000s (Fig. 3.6). Alternatively, the numbers who targeted snapper in MFAs 29 and 30 were low until the late 1990s before they increased and peaked in 2007 before declining again to 2012.

Northern Gulf St. Vincent

Handline Fishery

Handline catch in this region was generally low at <15 $t.yr^{-1}$ up to 2006 (Fig. 3.7a). From 2007, it increased considerably to between 23.9 and 46.5 $t.yr^{-1}$. These recent higher catches were associated with a large increase in handline effort between 2004 and 2010 (Fig. 3.7b), but which then declined in 2011 and 2012. CPUE was relatively stable until 1996, after which it has been variable, but nevertheless has increased considerably from 22.0 $kg.manday^{-1}$ in 1996 to 99.9 $kg.manday^{-1}$ in 2012 (Fig. 3.7b).

Longline Fishery

The longline fishery in NGSV has demonstrated a rapid increase since 2008. From then until 2012, the annual longline catch increased by 873.5% from 37.0 to 360.2 t (Fig. 3.7c). This increase was associated with a 484.9% increase in longline fishing effort from 390 to 2,281 $mandays.yr^{-1}$ (Fig. 3.7d). It also reflected a substantial increase in longline CPUE from 95.0 $kg.manday^{-1}$ in 2008 to 160.6 $kg.manday^{-1}$ in 2010. CPUE was relatively stable between 2009 and 2012.

Contributions of MFAs

NGSV is comprised of MFAs 34, 35 and 36 (Fig. 2.1, Table 2.2). Of these, MFA 35 has always contributed the highest catches (Fig. 3.8). There has been a large increase in the numbers of commercial fishers who have targeted snapper in this MFA. The catches and numbers of fishers operating in MFAs 34 and 36 have also increased in the recent three to four years.

Southern Gulf St. Vincent

Handline Fishery

The handline fishery in SGSV produced its highest catches in the 1980s and early 1990s, before dropping to the lowest level of 4.7 t in 1995 (Fig. 3.9a). Since then catch has remained low at <20 $t.yr^{-1}$, with particularly low catches from 2008 to 2012. Targeted handline effort also declined between 1984 and 1995, and has subsequently remained relatively low (Fig. 3.9b). Targeted CPUE was variable but increased consistently between 1995 and 2007 when it reached a local maximum of 48.2 $kg.manday^{-1}$ (Fig. 3.9b). Since then it has declined significantly to 19.1 $kg.manday^{-1}$ in 2012.

Longline Fishery

Targeted longline catch was generally <10 $t.yr^{-1}$ until 2009 when it increased to 18.4 t and then again to 27.5 and 28.6 t in the following two years (Fig. 3.9c). In 2012, it declined by 39.9% to 17.2 t. Effort was relatively stable at <250 $mandays.yr^{-1}$ between 1997 and 2004, but increased considerably up to 549 mandays in 2011 (Fig. 3.9d). Targeted longline CPUE has been highly variable but nevertheless demonstrated a general increasing trend between 1996 and 2010 from 15.2 $kg.manday^{-1}$ to a record level of 68.5 $kg.manday^{-1}$ (Fig. 3.9). It has subsequently declined to 31.5 $kg.manday^{-1}$ in 2012.

Contributions of MFAs

MFAs 40 and 44 have always accounted for the larger catches and attracted the higher number of fishers (Fig. 3.10). The increases in catch since 2004 have been taken from MFA 44.

South East

Handline Fishery

Targeted handline catch in the SE has always been low. It increased to 10-12 t in 2007 and 2008 but has declined to a fraction of a tonne since then (Fig. 3.11a). Such low catches reflect a low and variable level of fishing effort (Fig. 3.11b). CPUE has generally been less than 20 $kg.manday^{-1}$, but in each year between 2003 and 2009 was considerably higher. By 2012, it had declined again to a minimum level (Fig. 3.11b).

Longline fishery

Longline catches were always less than several $tonnes.yr^{-1}$ up to 2007 (Fig. 3.11c). From then, there was a rapid increase in longline catch to the maximum level of 239 t in 2010. However, longline catch has subsequently declined to 72.5 t in 2012. The increase in catch reflected increases in targeted longline effort and CPUE, both of which attained their maxima in 2010 (Fig. 3.11d). Targeted effort and CPUE have both declined in 2011 and 2012, with CPUE falling by 51.6% between 2010 and 2012.

Contributions of MFAs

There are nine MFAs that constitute the SE region (Fig. 2.1). The recent increases in catches from the SE are evident for each of MFAs 45, 46, 50, 51 and 56 (Fig. 3.12). Nevertheless, MFA 51, i.e. the one adjacent to the southern Coorong, has contributed the majority of the increase in catch. There were also increases in the numbers of fishers who targeted snapper in each MFA, with the maximum being 20 in MFA 51 in each of 2009 and 2010.

West Coast

Handline Fishery

Targeted handline catches in the WC have generally been <12 $t.yr^{-1}$, which are low relative to those in the gulfs (Fig. 3.13a). Since then, targeted handline catch has fallen to the low level of 2.5 t in 2012. Handline effort has also been quite variable (Fig. 3.13b), but increased between 1995 and 2005 before declining to only 98 mandays in 2012. Targeted CPUE increased between 1995 and 2008, before declining to 24.7 $kg.manday^{-1}$ in 2012 (Fig. 3.13b).

Longline fishery

Longline catch was relatively low until the early 2000s when it increased considerably to between 14.0 and 27.4 $t.yr^{-1}$ (Fig. 3.13c). Targeted effort displayed similar variation increasing from 1999 to a maximum in 2009, before declining considerably to 2012 (Fig. 3.13d). Targeted CPUE increased after 1998 reaching a maximum of 93.5 $kg.manday^{-1}$ in 2003 (Fig. 3.13d). It has decreased systematically since then to 34.9 $kg.manday^{-1}$ in 2012.

Contributions of MFAs

Historically, most of the snapper catch from this region has come from MFAs 8, 9 and 10, i.e. the two small MFAs that include Denial Bay and Murat Bay and the adjacent coastal MFA (Fig. 2.1). Snapper catch has been most variable in MFA 10, which recorded its highest catch in 2008 (Fig. 3.14). MFA 27, i.e. Coffin Bay, has generally contributed low catches of snapper. The numbers of fishers who targeted snapper in these MFAs have been relatively consistent since the late 1980s.

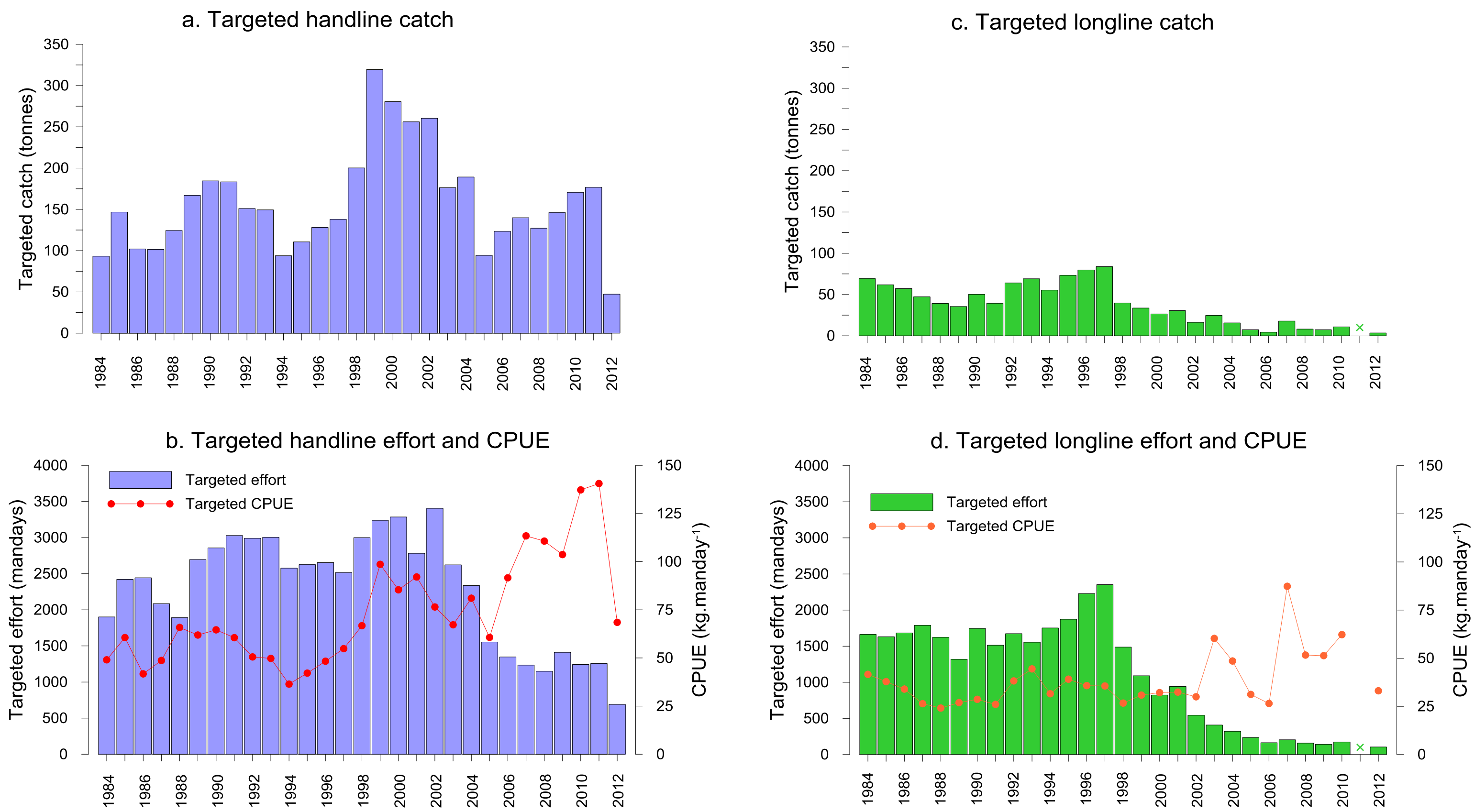

Fig. 3.3 Northern Spencer Gulf. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted effort and CPUE in the commercial longline sector. Crosses indicate confidential data, i.e. < 5 fishers.

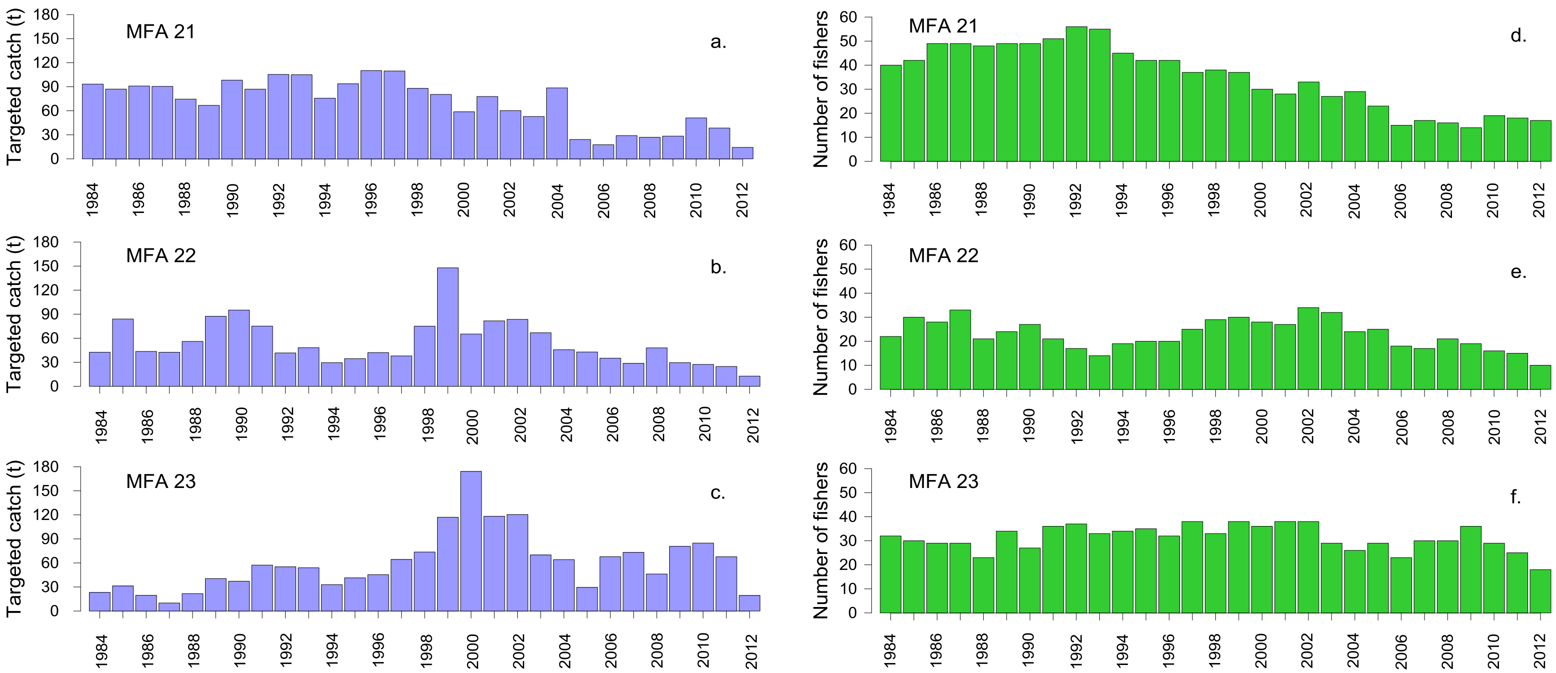

Fig. 3.4 Northern Spencer Gulf. a-c. Historical record of combined targeted handline and longline catch for MFAs 21, 22 and 23; d-f. Historical record for the number of fishers who targeted snapper in MFAs 21, 22 and 23. For locations of MFAs refer to Fig. 2.1.

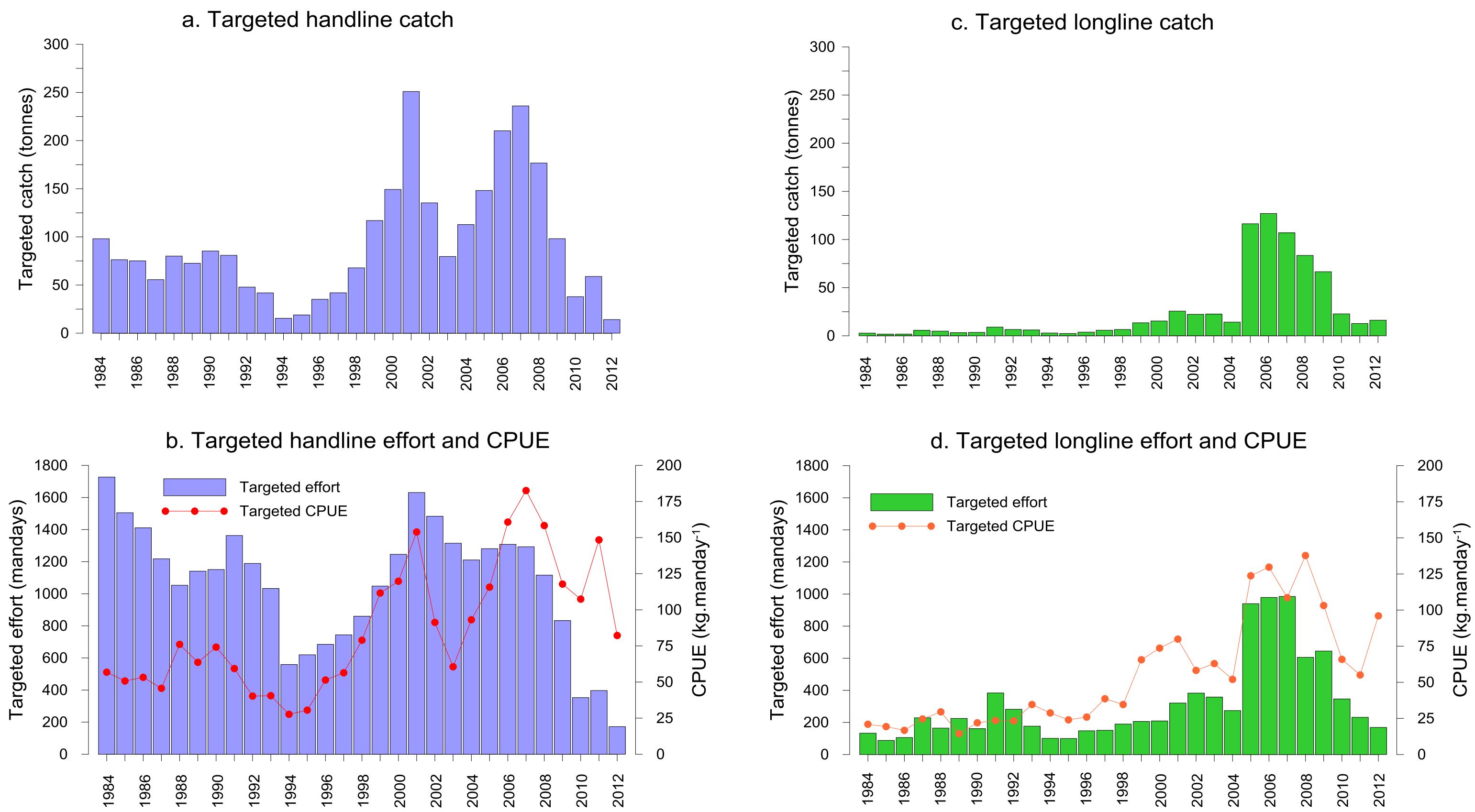

Fig. 3.5 Southern Spencer Gulf. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted effort and CPUE in the commercial longline sector.

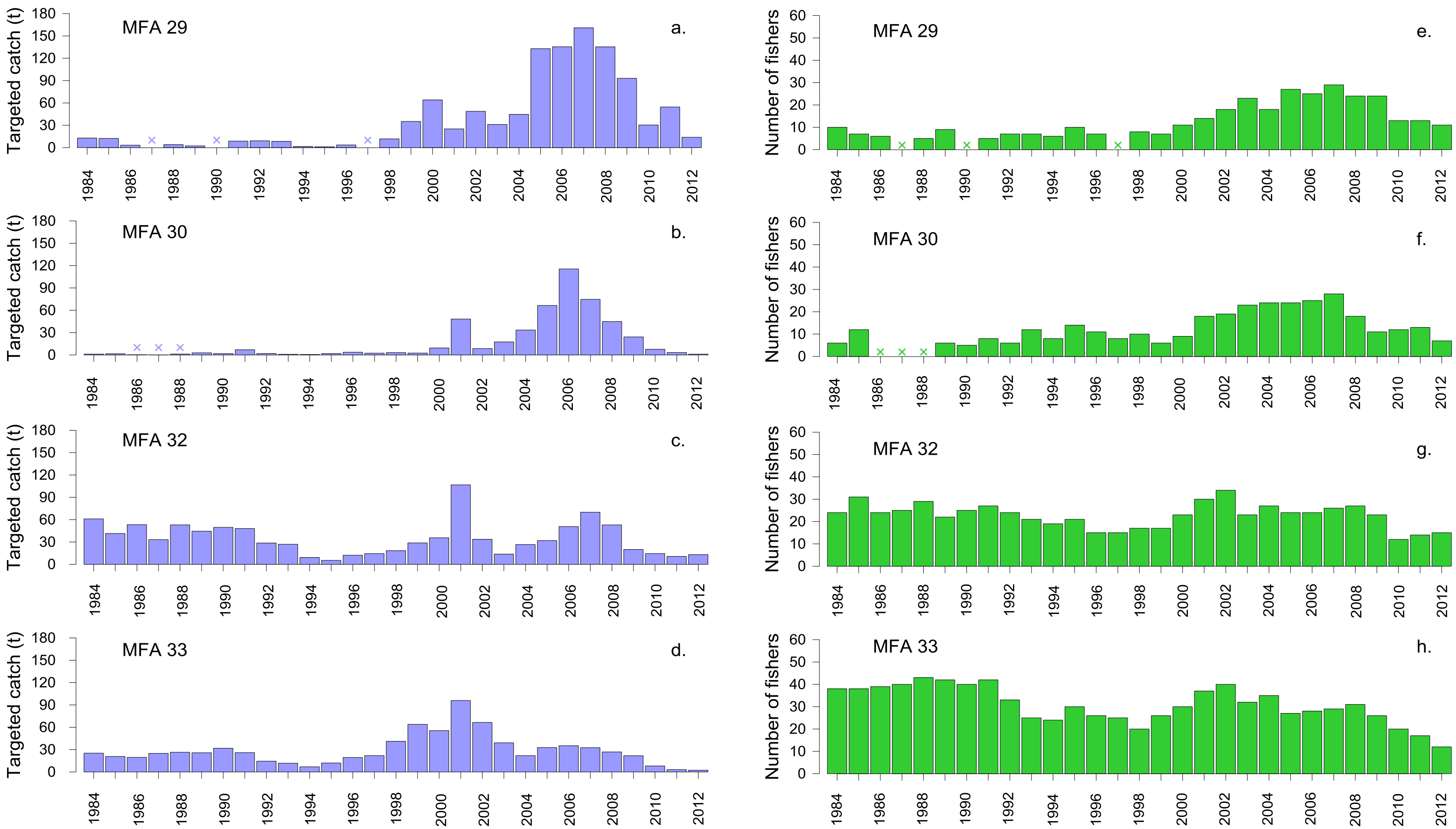

Fig. 3.6 Southern Spencer Gulf. a-d. Historical record of combined targeted handline and longline catch for MFAs 29, 30, 32 and 33; e-h. Historical record for the number of fishers who targeted snapper in MFAs 29, 30, 32 and 33. Crosses indicate confidential data, i.e. <5 fishers. For locations of MFAs refer to Fig. 2.1.

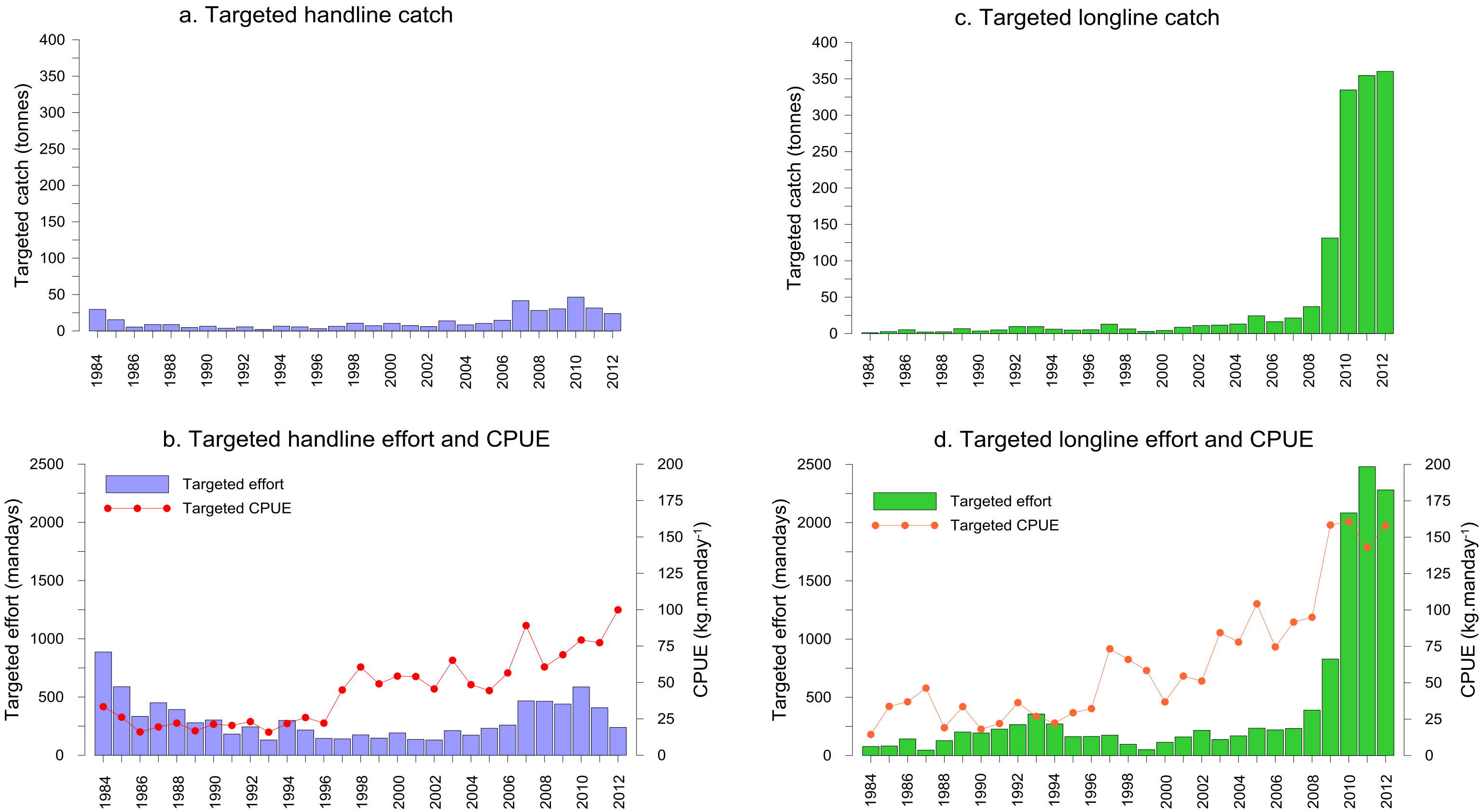

Fig. 3.7 Northern Gulf St. Vincent. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted effort and CPUE in the commercial longline sector.

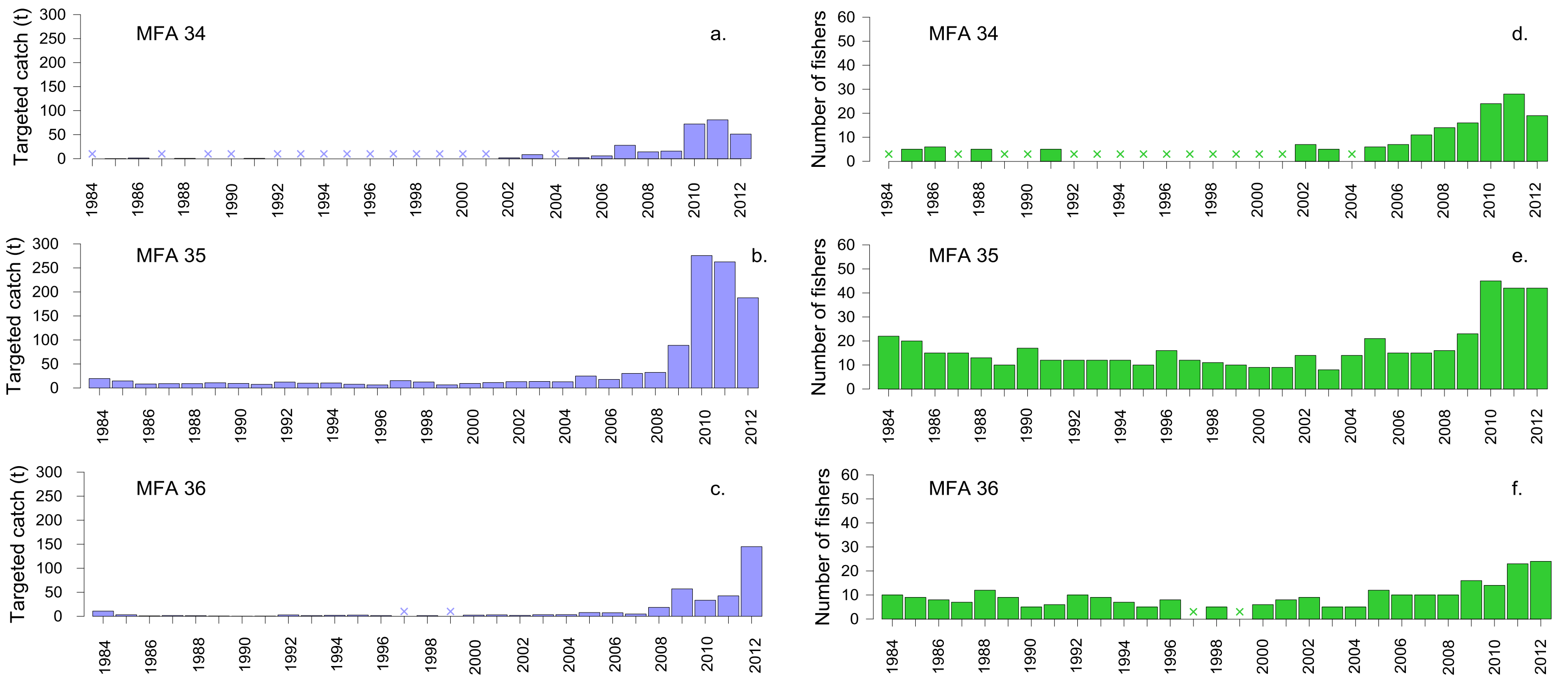

Fig. 3.8 Northern Gulf St. Vincent. a-c. Historical record of combined targeted handline and longline catch for MFAs 34, 35, and 36; d-f. Historical record for the number of fishers who targeted snapper in MFAs 34, 35 and 36. Crosses indicate confidential data, i.e. <5 fishers. For locations of MFAs refer to Fig. 2.1.

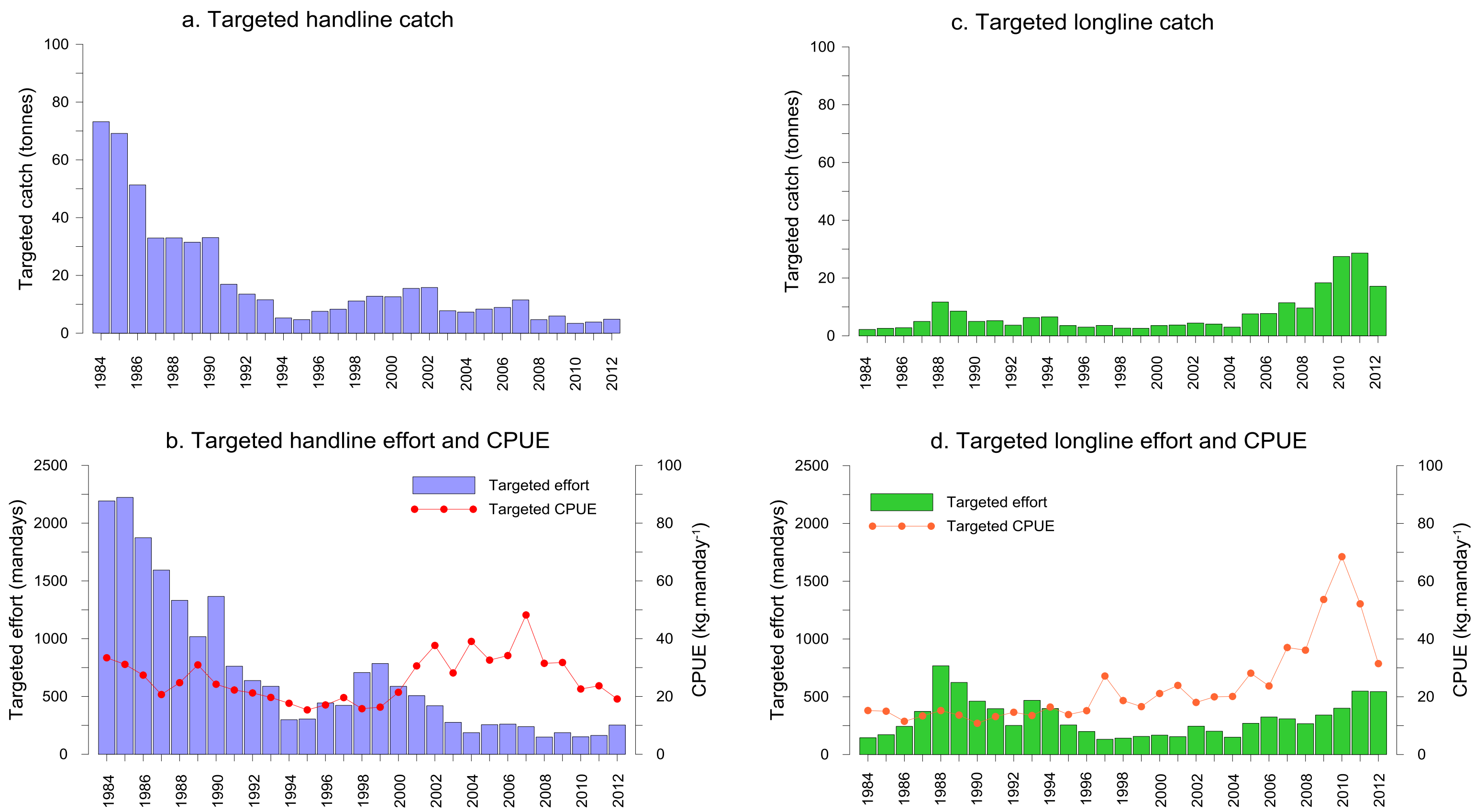

Fig. 3.9 Southern Gulf St. Vincent. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted effort and CPUE in the commercial longline sector.

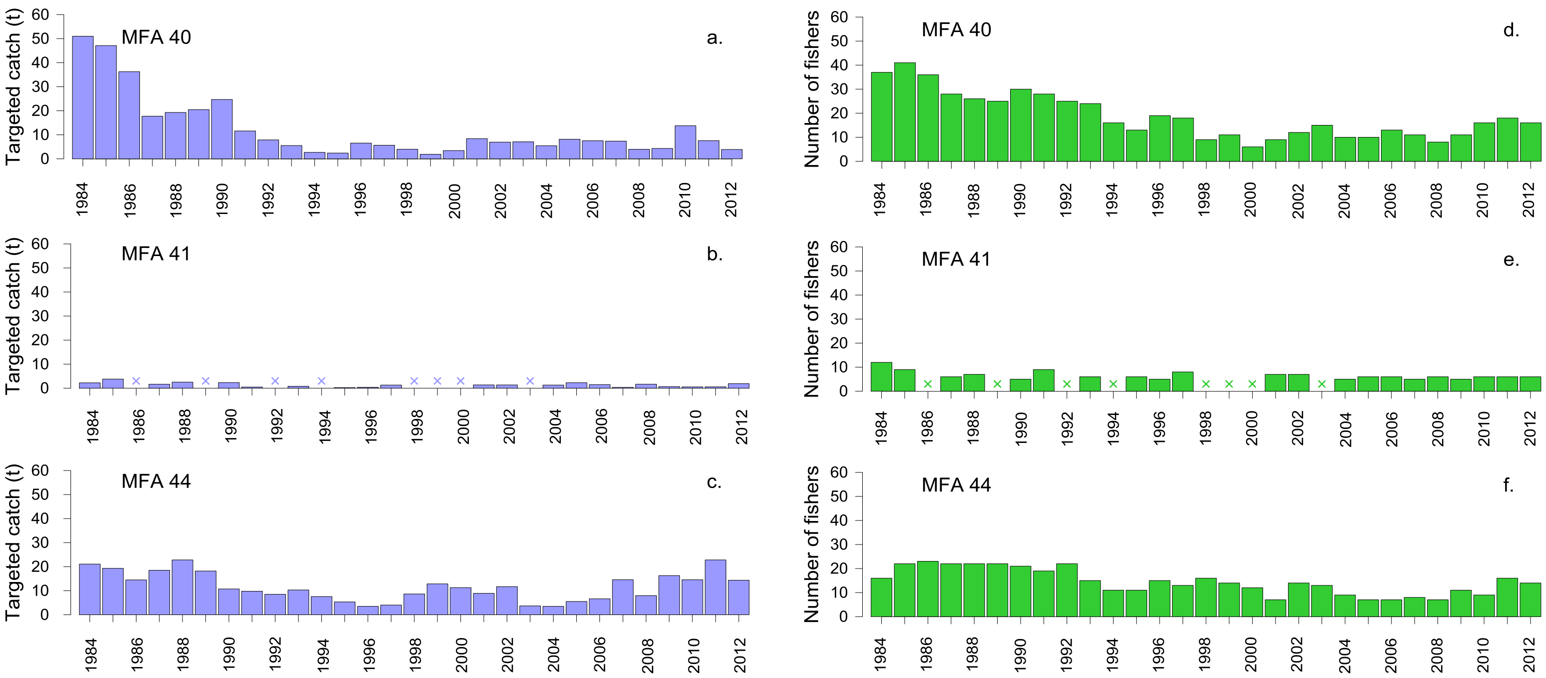

Fig. 3.10 Southern Gulf St. Vincent. a-c. Historical record of combined targeted handline and longline catch for MFAs 40, 41 and 42; e-h. Historical record for the number of fishers who targeted snapper in MFAs 40, 41 and 42. Crosses indicate confidential data, i.e. <5 fishers. For locations of MFAs refer to Fig. 2.1.

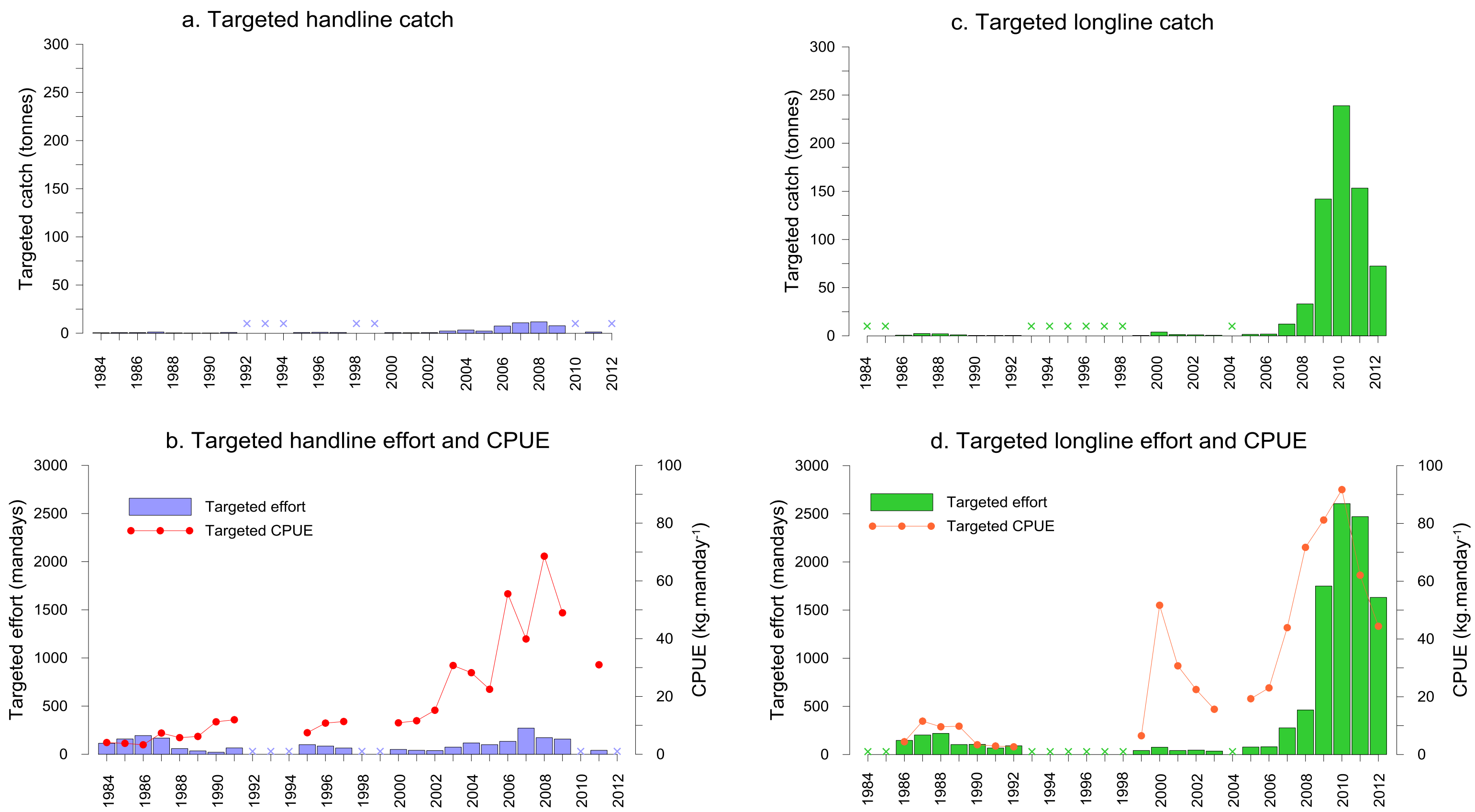

Fig. 3.11 South East. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted effort and CPUE in the commercial longline sector. Cross indicate confidential data, i.e. < 5 fishers.

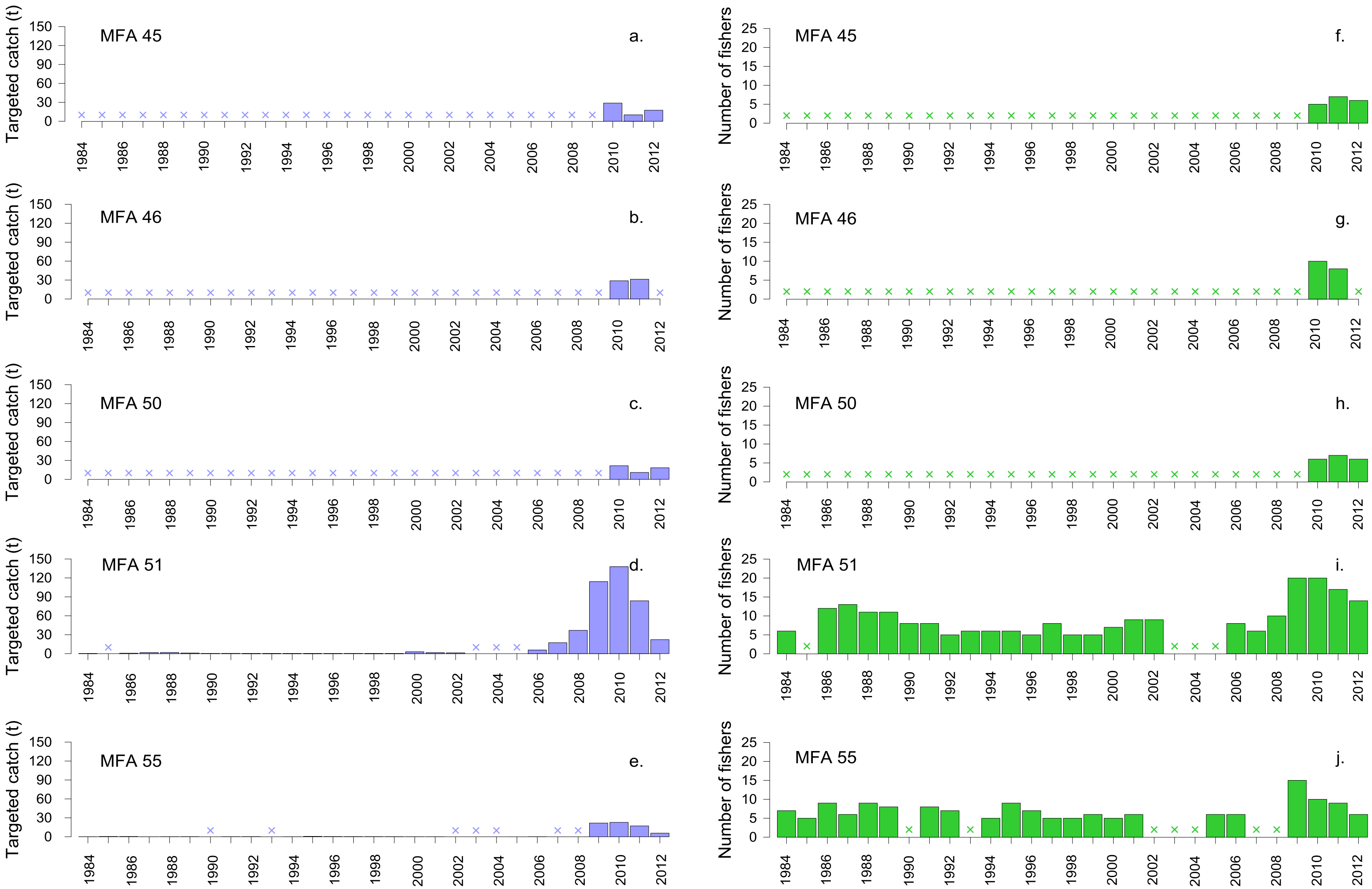

Fig. 3.12 South East. a. Historical record of combined targeted handline and longline catch for MFA 51. b. Historical record for the number of fishers who targeted snapper in MFA 51. Crosses indicate confidential data, i.e. <5 fishers. For locations of MFAs refer to Fig. 2.1.

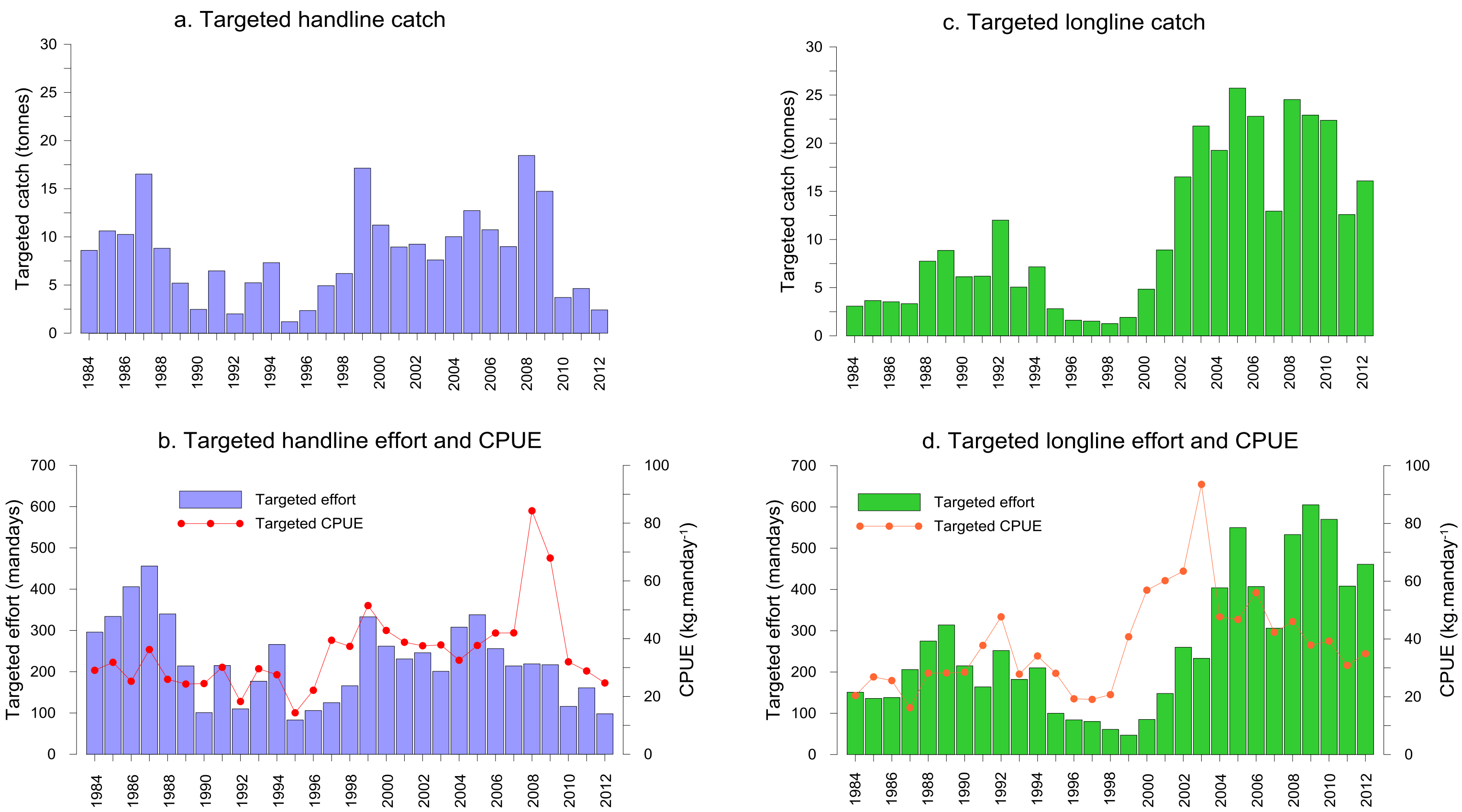

Fig. 3.13 West Coast. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted effort and CPUE in the commercial longline sector.

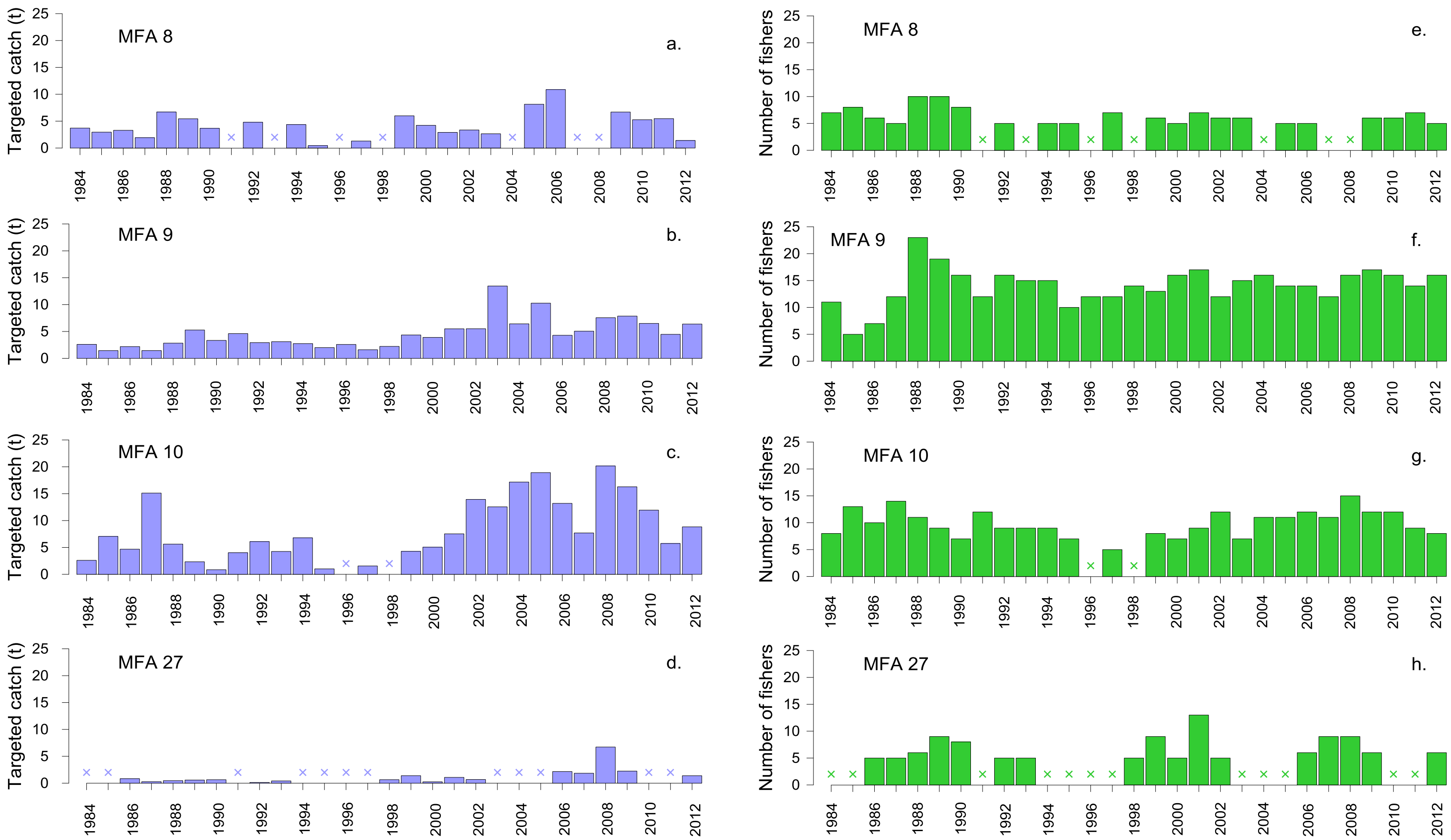

Fig. 3.14 West Coast. a-c Historical record of combined targeted handline and longline catch for MFAs 9, 10, and 27; d-f. Historical record for the number of fishers who targeted snapper in MFAs 9, 10, and 27. Crosses indicate confidential data, i.e. <5 fishers. For locations of MFAs refer to Fig. 2.1.

3.4 Discussion

The period from 2008 to 2012 was one of significant change in SA's snapper fishery. Over this period there was considerable variation in the annual catches, which increased from 720 t in 2008 to 1,032 t in 2010 before declining to 642 t in 2012. The recent record commercial catches were associated with increases in targeted effort. Furthermore, there was a significant shift in the dominant gear type from handlines to longlines that reflected the uptake by commercial fishers from some regions of new longline fishing technologies, which substantially increased their catch rates. Simultaneously, there was a significant change in the spatial structure of the fishery. Several regions where the new longline gear was used produced record catches and catch rates, whereas there were notable declines in catches and catch rates in several other regions.

Historically, NSG has been the most significant region in SA's snapper fishery. Over the 20 years to the early 2000s, it contributed up to 346 $t.yr^{-1}$, and an annual average of 58% of the State's commercial catch. However, from 2004 to 2012, its relative contribution fell to only 9.0%. The very low catch of 2012 reflects exceptionally low levels of both handline and longline effort, as well as large reductions in catch rates. SSG also recorded declines in handline and longline effort and CPUE after 2007. The recent levels of catch, effort and CPUE are fractions of what they were through the record period of the mid 2000s during which this region was the most significant in the State's snapper fishery. That record period was partly due to a significant increase in longline fishing in MFA 29, which had previously attracted little attention from fishers. The recent declines in the fishery statistics of both regions of Spencer Gulf are consistent with significant reductions in the biomass of snapper.

Through the 1980s and 1990s, the catches from NGSV were relatively insignificant. However, they increased slowly from 2000 to 2007 after which the rate increased dramatically until 2010, after which they levelled off in 2011 and 2012. Whilst there were increases in catches and catch rates for both gear types, the majority of the recent catches were taken with longlines. These changes in catches and catch rates in NGSV during the mid to late 2000s are consistent with a considerable increase in the biomass of snapper. Smaller increases in longline catch and CPUE for SGSV are also consistent with increases in biomass in this region in the late 2000s, however by 2012 the decline in longline statistics suggest that the biomass had declined to some extent.

The SE region had not previously supported a consistent snapper fishery. However, from 2007 to 2010, longline catches rose exponentially to levels never previously recorded. There is some uncertainty about whether this increase in fishery statistics related to an increase in biomass or the opening up of a new fishing ground. More recently, the catches and catch rates have declined, indicative of declining levels of biomass available to the fishers.

The WC region demonstrated the same decline that occurred in the gulfs during the early 1990s. After that, the catches and catch rates demonstrated a long and protracted recovery culminating in record handline catch and catch rate in 1999 and high longline catches and catch rates in the early 2000s. Catches from both gear types were relatively stable through the 2000s, but along with catch rates have declined considerably since 2010. Such recent data are indicative of declining biomass of snapper.

In summary, at the end of 2012, catches and catch rates had declined in nearly every region since 2009 and 2010. The exception was NGSV for which longline catches, effort and catch rates remained high after the exponential increases that occurred between 2007 and 2010. To some extent, marginally lower catches and effort were expected for 2012 particularly in the gulfs due to the introduction of the 800 kg daily catch limit in January 2012 which was revised down to 500 $kg.day^{-1}$ in December 2012, as well as the extension of the seasonal closure to include the first two weeks of December. However, decreases in catch associated with the new fishery management measures are unlikely to account for the dramatic declines in catch, effort and CPUE that are particularly apparent for NSG, SSG, SE and WC. Rather, the data are more consistent with declines in the levels of biomass of snapper available to the fishers.

4. POPULATION STRUCTURE

4.1 Introduction

Determining the appropriate way to manage a fishery depends on developing some understanding of the functionality of the natural demographic processes of that fish population. As well as helping to understand the dynamics of the population, this may also help to determine the response of the population to fishing. Understanding the demographic processes of a fish population is facilitated by obtaining estimates of size-at-age of fish that can then be used to construct size and age structures that subsequently provide information on recruitment, growth and mortality. Such age-based demographic information is particularly significant in this context because it provides the temporal basis against which the rates for such demographic processes can be measured (Campana 2001). The determination of the age of fish is generally done by interpreting the structure of their hard anatomical structures such as their otoliths (Campana 2001).

For snapper in South Australia, a market measuring and biological research program has been underway since 2000. One aim of this program has been to produce estimates of the size and age structures of the different regional populations. In this study, commercial fishery catches were accessed from various sources from which the individual fish were measured, in order to develop the size structures. Some of the measured fish were aged from their otoliths to develop population age structures (McGlennon et al. 2000, Fowler et al. 2005). Size-at-age data are now available for snapper to generate regional size and age structures for numerous years between 2000 and 2012. The aim of this chapter was to generate these regional size and age structures through the 2000s, to be interpreted later in the context of the temporal trends in regional catches and catch rates (Chapter 3). Furthermore, the aim was to generate region-specific recruitment histories and growth curves to also be interpreted with the fishery statistics in terms of the demographic processes that take place in each regional population. Such results were then compared between regions. The size and age structures were also used to update the SnapEst computer fishery model that simulates the natural population dynamics and demographics, and outputs biological fishery indicators (Chapter 5).

4.2 Materials and Methods

For the calendar years of 2000 to 2003, and 2007 to 2012, as well as the financial year of 2005/06, market sampling was undertaken for snapper captured by the commercial fishing sector of the Marine Scalefish Fishery of South Australia. This market sampling was concentrated at the SAFCOL fish market, but occasionally catches were accessed from elsewhere. Generally, once per week, a team of three researchers processed catches of snapper prior to the morning auction at the SAFCOL market. Catches were selected from those available to ensure as broad a geographic coverage as possible. A two-stage sampling protocol was used to process catches. First, as many fish as possible from each chosen catch were measured. Some fish were then processed for the collection of their otoliths. The latter fish were measured for CFL, weighed, gutted, and their sex and stage of reproductive development were determined. The otoliths were collected for determination of fish age. Later, in the laboratory, one otolith from each fish was embedded in resin and sectioned using a diamond saw to produce a thin transverse section. The section was mounted on a glass microscope slide and then interpreted using low power microscopy by counting the opaque zones. This count, along with the relative size of the most recent increment and the time of year of capture, were used to estimate the fish's age (McGlennon et al. 2000). For each region in each year, an age/length key was developed, based on the sizes and ages of fish that were aged during that year, regardless of season or gear type.

Data processing

The analytical procedures that were used to develop the annual size and age structures were the same as those used by McGlennon et al. (2000), as originally based on the computational procedures developed by Davis and Walsh (1995). The first objective for data analysis for each region and 12-month period was to develop an annual size structure. Each size structure was based on all fish measured from handline and longline catches, but was weighted according to the sizes of the catches of the two gear types in the commercial fishery. The proportional length data were then converted to a biomass distribution using a region-specific, length – weight relationship.

An age/length key was generated for each region and year, based on the sizes and ages of fish that were aged during that year from each region, regardless of season and gear type. The age/length key was then applied to the length frequency distribution to generate an annual, region-specific age structure. The annual age structures were then compared graphically. Then, the various annual age structures were used to generate a recruitment time series, whereby year class strength was estimated using a catch curve regression (Maceina 1997, Staunton-Smith et al. 2004, Jenkins et al. 2010). A linear regression was fitted to the natural log of the numbers of fish per age class. The deviations of the observed counts from the expected abundances determined from the regression equation were assumed to reflect the variation in year class strength. Therefore, for each age structure the residuals from the catch curve regression were considered indices of year class strength, i.e. large positive and negative residuals represented strong and weak year classes, respectively. The regression analyses were restricted to the 4+ age class and older, to minimise the bias of under-representation in the age structures of the younger age classes. Then, for each region, an average recruitment time series was calculated from the numerous annual recruitment time series.

For each of the five regions, the size-at-age data collected between 2000 and 2012 were used to generate region-specific von Bertalanffy growth curves. The "R" software package for statistical computing was used to fit the non-linear equation to the data and generate estimates of L_∞, K and t_0. Furthermore, the growth curves for NSG and SSG were compared as were those from NGSV and SGSV using the 95% confidence regions of the von Bertalanffy growth parameters L_∞, and K using the method of Kimura (1980).

4.3 Results

<u>Population size and age structures</u>

<u>Northern Spencer Gulf</u>

Size structures are available for NSG for numerous calendar years and a single financial year between 2000 and 2012 (Fig. 4.1). The annual size structures essentially reflect modes of fish in four size categories, i.e. 'small' fish in the 30 – 40 cm CFL range, 'medium' fish that were 40 – 60 cm CFL, 'large' fish that were 60 – 80 cm CFL and 'very large' fish that were >80 cm CFL. There were some consistencies amongst years in these size structures, but also some considerable differences. Throughout the early-mid 2000s, the sample sizes were large due to the high catches from this region. The 'small' fish constituted the most numerous size class, whilst there were also modes of 'medium' and 'large' fish. In contrast, in the latter 2000s, the sample sizes were considerably smaller as there were fewer fish available in the SAFCOL market from the commercial sector. Also, the relative numbers of 'small' and 'large' fish were quite variable, but in general there were fewer 'small' fish relative to the earlier years in the decade. This is obvious in the biomass distributions which show that from 2007 to 2012 the fishers' catches were dominated by the 'large' fish with the 'small' and 'medium' size classes making relatively minor contributions.

Most of the fish captured from NSG were less than 15 years of age, but some fish were considerably older, i.e. up to 36 years old. In each year, there were particular year classes that contributed more to the catch than others (Fig. 4.2). From 2000 to 2002, the catches were dominated by the strong 1991 and 1997 year classes. In 2003 and 2005/06, the 1999 year class was also a significant contributor. From 2007, the 1997 and 1999 year classes were the dominant ones in the catches, although with considerable annual variation. They were augmented by several others, i.e. the 2004 and 2006 year classes, whose contributions were quite variable. For example, the 2004 year class accounted for >10% of the numbers in each year between 2007 and 2010, but its contribution dropped to much less in 2011 and 2012. Furthermore, the 2006 year class contributed >20% of the numbers only in 2010, otherwise its contribution was <10% of the numbers. Therefore, this comparison of annual age structures indicated that the strong year classes persisted over numerous years, but from year-to-year their relative contributions were variable and relatively unpredictable.

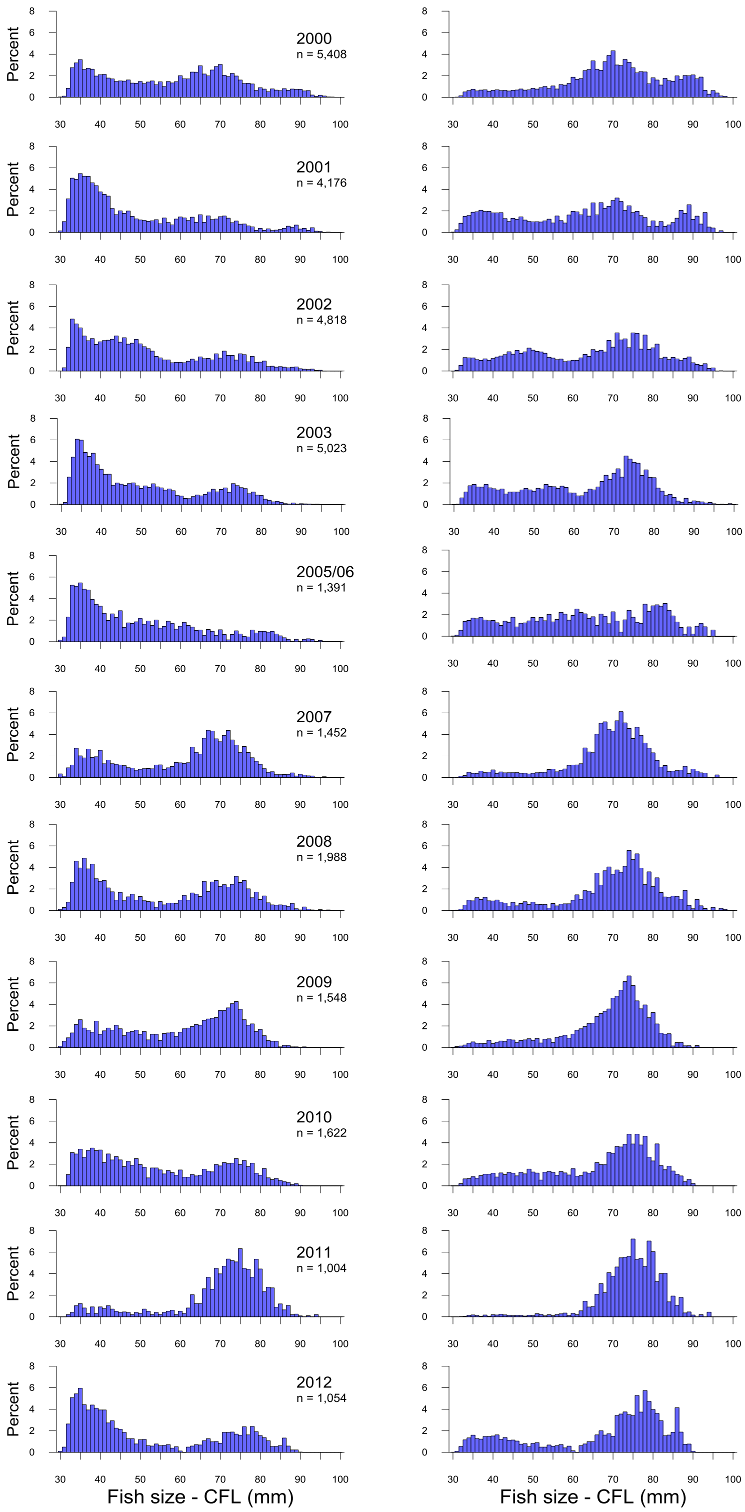

Fig. 4.1 Size and biomass distributions for snapper caught in NSG in each of eleven years through the 2000s. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catches accounted for by each size class of fish.

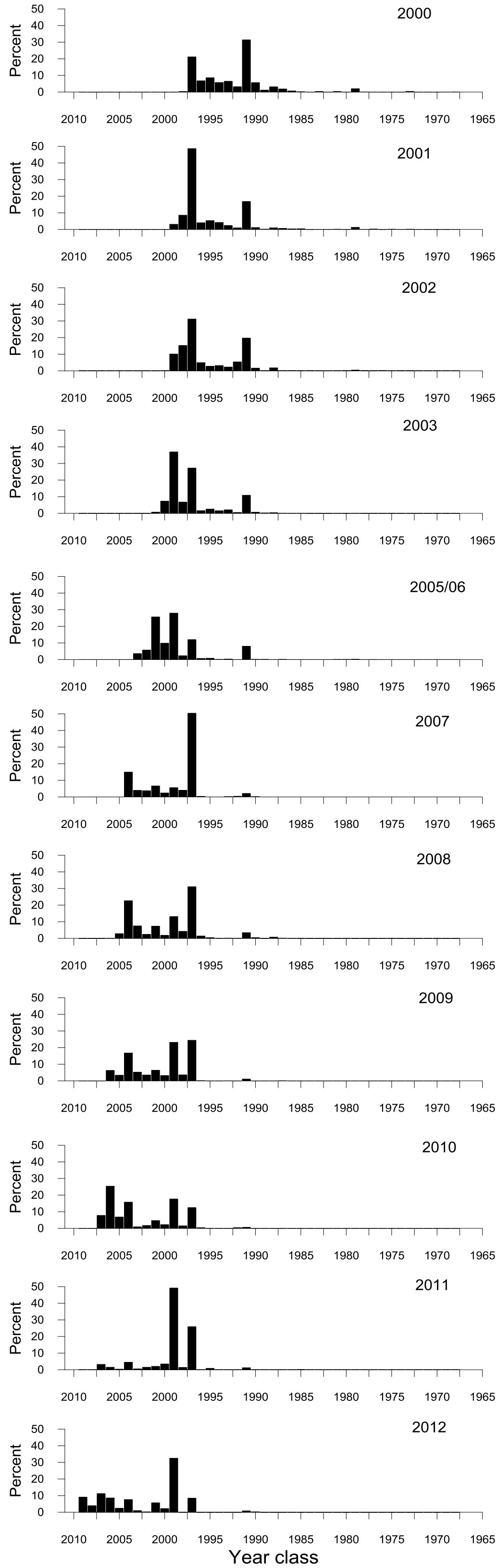

Fig. 4.2. Estimated age structures of fish caught in NSG in each of eleven years. For each year, data are presented as the relative percentage of total catch accounted for by each year class, i.e. the years in which they were spawned.

Southern Spencer Gulf

Population size and age structures for SSG are available from 2000 to 2011, with sample sizes declining from 2008 onwards due to the decline in availability of catches from this region in the market (Fig. 4.3). In fact, in 2012 it was not possible to develop a size structure because too few fish were available throughout this year to measure. The annual size structures usually involved modes of 'small' and 'large' fish, whose relative sizes varied between years. The 'large' fish always dominated the biomass distributions in this region. In these size structures, the 'very large' fish were always rare.

Each of the annual age distributions were dominated by up to three age classes that related to particular year classes (Fig. 4.4). Between 2000 and 2003, the 1991 and 1997 year classes dominated the age structures. In 2005/06, the 1999 year class also emerged as another strong year class. Then, from 2007 until 2011, the 1997 and 1999 year classes persisted as the dominant contributors to the age structures. Based on the age structures collected up to 2011 there was no evidence of any further strong year classes subsequent to the 1999 year class contributing to the age structures.

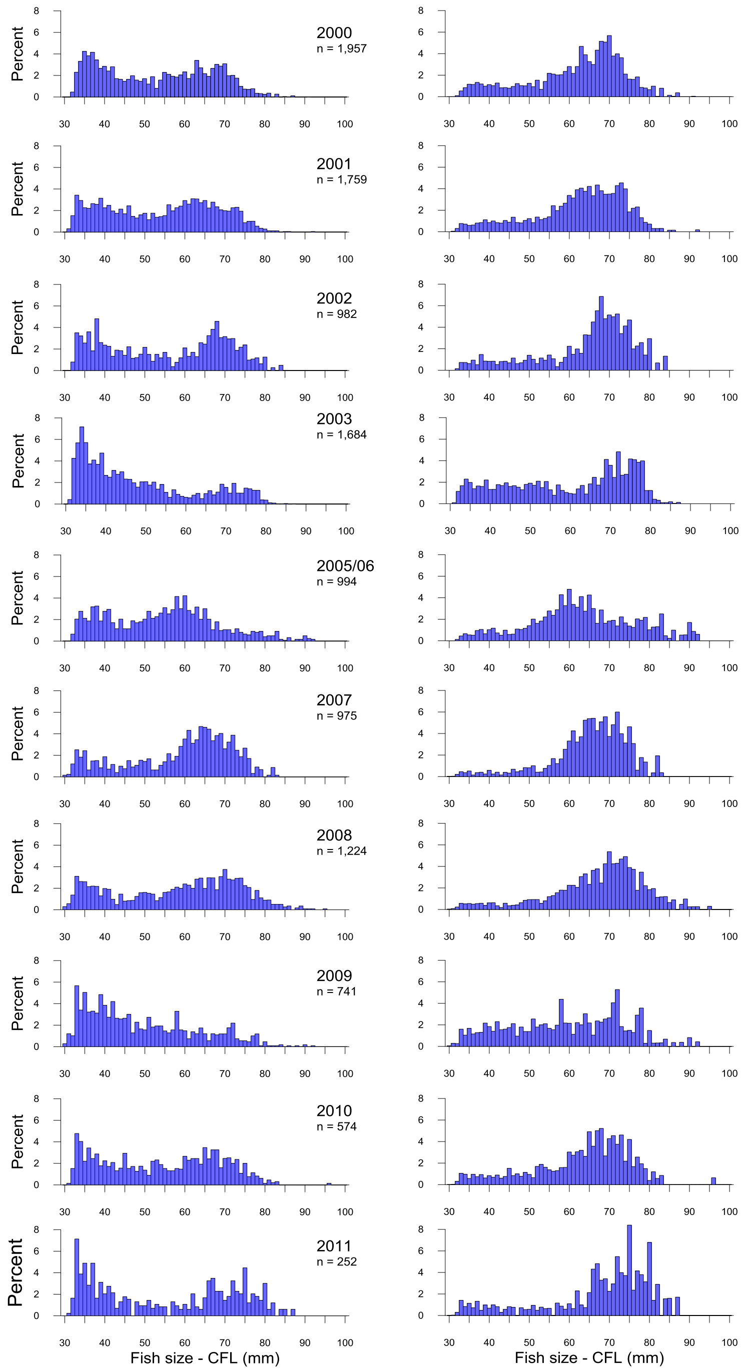

Fig. 4.3 Size and biomass distributions for snapper caught in SSG in ten years through the 2000s. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catches accounted for by each size class of fish.

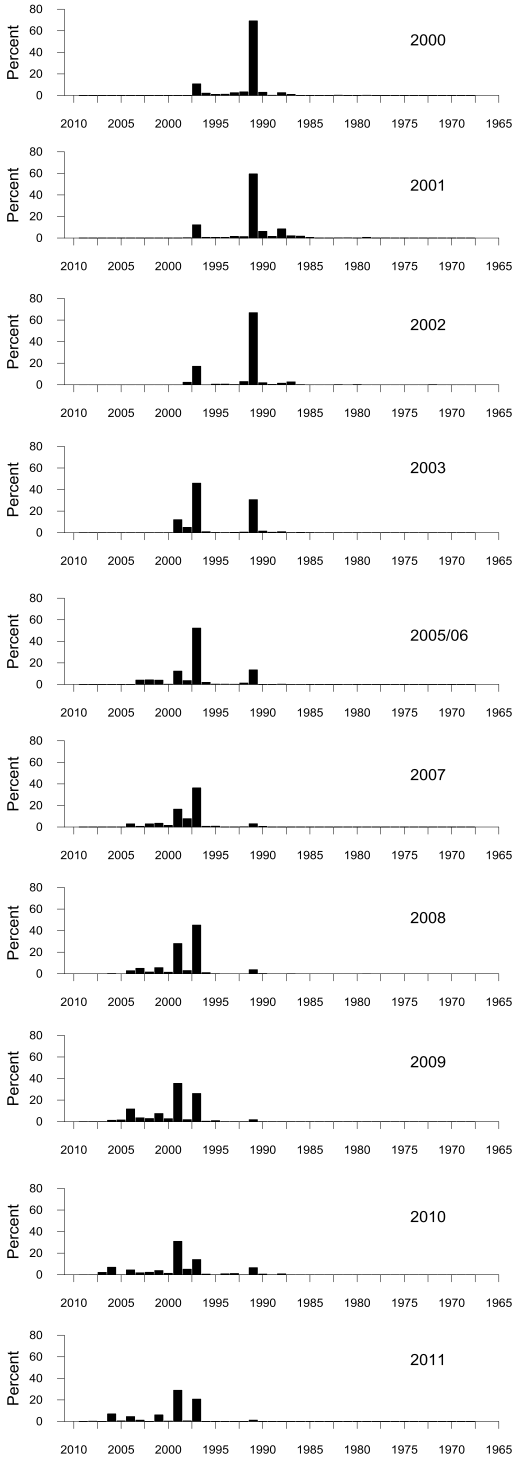

Fig. 4.4. Estimated age structures of fish caught in SSG in each of eleven years. For each year, data are presented as the relative percentage of total catch accounted for by each year class, i.e. the years in which they were spawned.

Northern Gulf St. Vincent

Prior to 2007, the numbers of fish from NGSV that were measured in the market were very low, but subsequently increased due to the increasing commercial catches. As such, annual size structures were only generated for the years from 2007 to 2012 (Fig. 4.5). All four size categories were generally well represented in the size structures in each year, although with some variation in the relative sizes of the different size categories. In 2007 and 2008, the 'small' fish were most numerous, whilst in 2009 and 2010 the 'large' and 'very large' fish were most numerous. No modal structure was evident in the size structures of 2011 and 2012, indicating that all size categories contributed to the catches. The biomass distributions were generally dominated by the 'large' and 'very large' fish, although with a considerable contribution of the 'medium fish' in 2011 and 2012.

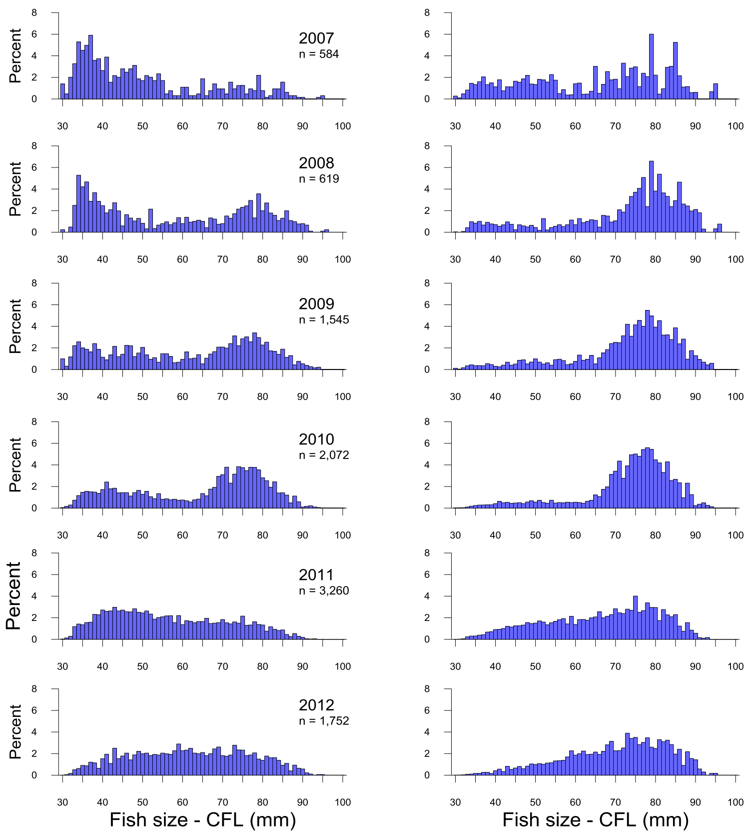

Fig. 4.5. Size and biomass distributions for snapper caught in NGSV in each year between 2007 and 2012. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catch accounted for by each size class of fish.

For NGSV, there were sufficient otoliths collected in each year from 2008 to 2012 to develop population age structures (Fig. 4.6). These were generally characterised by a broad number of year classes, relative to the other regions. Furthermore, numerous strong year classes contributed to the catches in each year that were consistent across years. These were the 1991, 1997, 1999, 2001, 2004 and 2006 year classes. The contributions of the older year classes declined between 2008 and 2012, making the 2004 and 2006 year classes the dominant contributors in the latter two years.

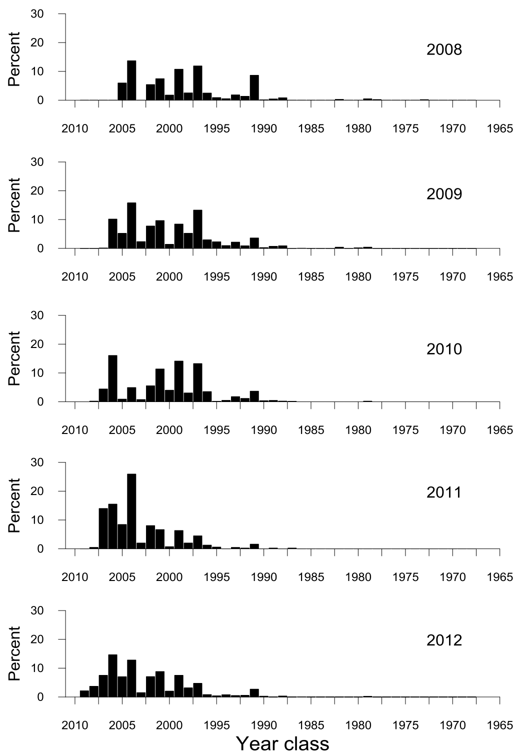

Fig. 4.6. Estimated age structures of fish caught in NGSV in each year between 2008 and 2012. For each year, data are presented as the relative percentage of total catch accounted for by each year class, i.e. the years in which they were spawned.

Southern Gulf St. Vincent

The sample sizes of fish measured from SGSV have generally been relatively low compared with those from several other regions, due to the low numbers of fish from this region available in the market. Size structures were developed for each calendar year in two periods, i.e. from 2000 to 2003 and 2007 to 2012 (Fig. 4.7). For the former period, the size structures were dominated by 'large' fish that related to strong representation of the 1991 year class in the population, which dominated catches through that period (Fig. 4.8). However, the size structures from 2007 to 2012 were very different to the earlier ones as they were dominated by strong modes in the 'small' to 'medium' size categories. In 2008 and 2009, these modes related to the dominant influence of the 2001 year class. The modes of 'small' and 'medium' fish evident from 2010 onwards reflected the influence of several strong year classes, i.e. the 2001, 2006 and later the 2007 year classes.

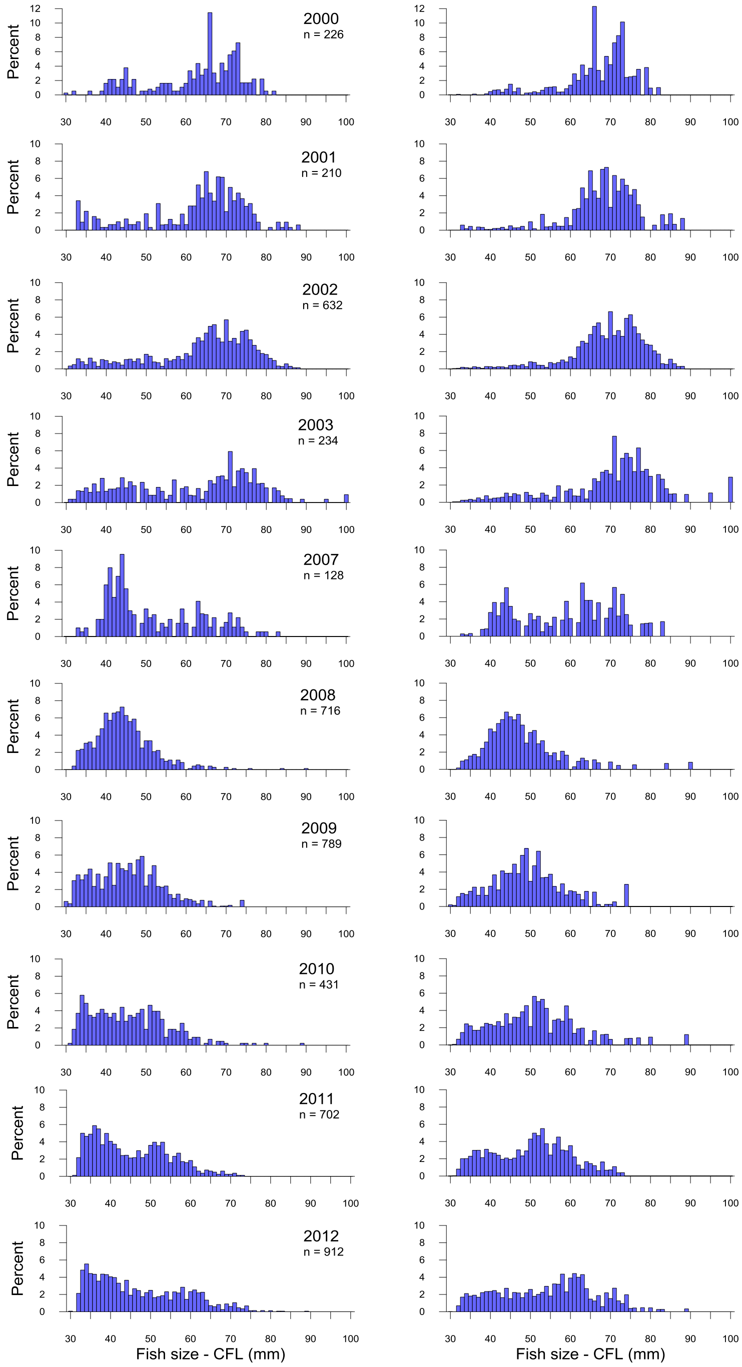

Fig. 4.7 Size and biomass distributions for snapper caught in SGSV in ten years between 2000 and 2012. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catch accounted for by each size class of fish.

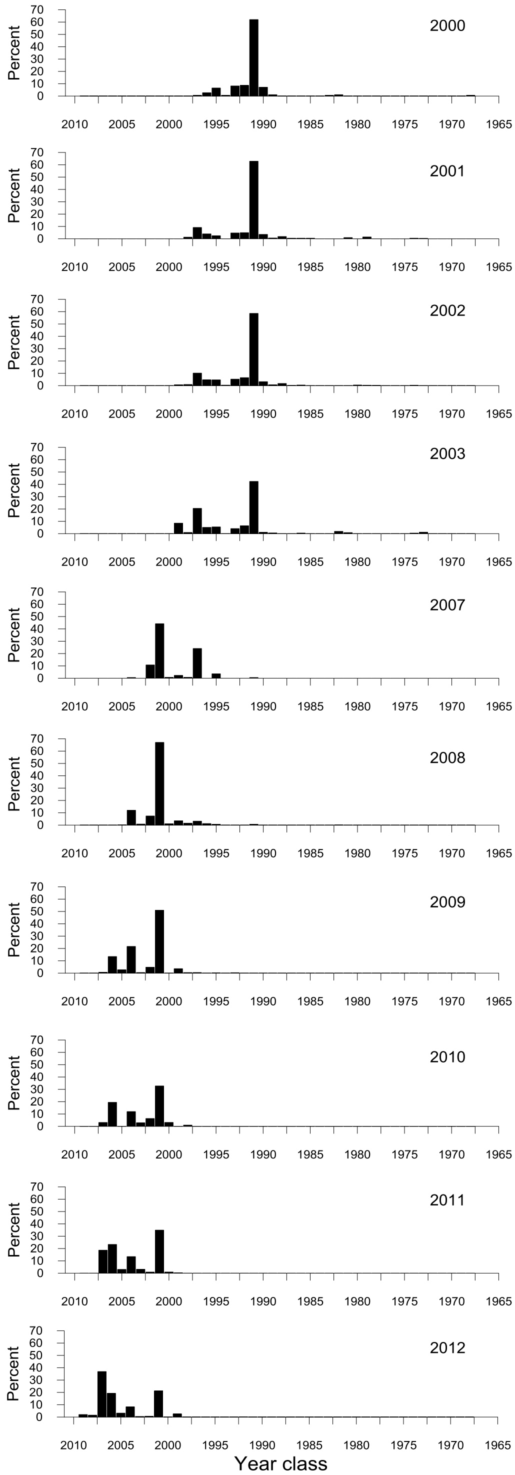

Fig. 4.8. Estimated age structures of fish caught in SGSV in each of ten years. For each year, data are presented as the relative percentage of total catch accounted for by each year class, i.e. the years in which they were spawned.

South East

For the SE region, size and age distributions are only available since 2008, due to the recent increase in catch. The size structures were dominated by 'small' and 'medium' fish, and rarely involved any fish >60 cm TL (Fig. 4.9). The age structures were dominated by the 2001 and 2004 year classes, whose relative contributions changed between 2009 and 2012 (Fig. 4.10).

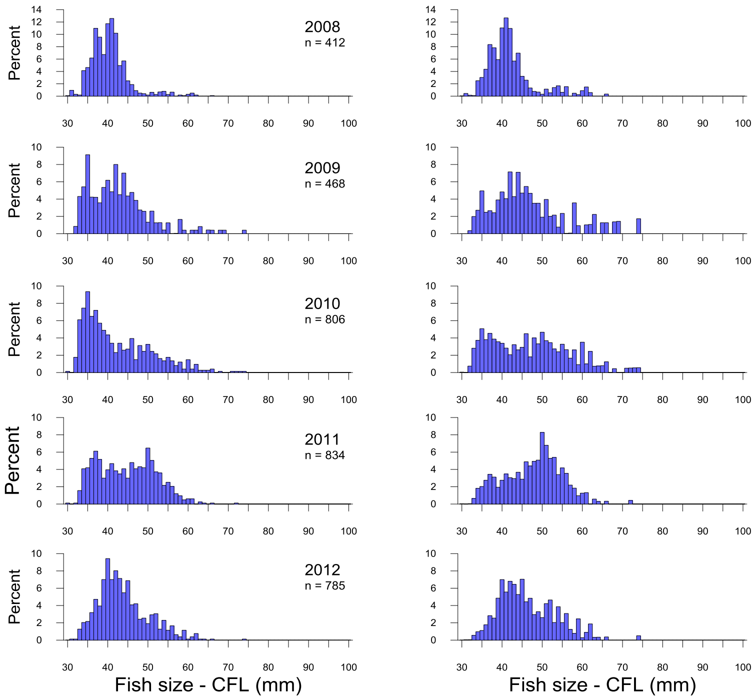

Fig. 4.9 Size and biomass distributions for snapper caught in SE in each year from 2008 to 2012. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catch accounted for by each size class of fish.

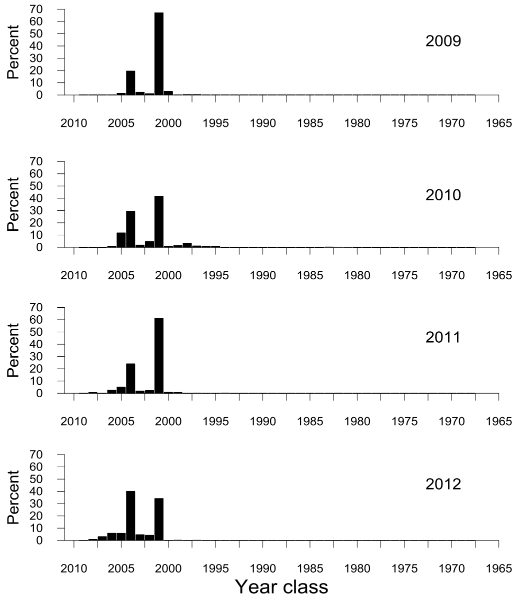

Fig. 4.10. Estimated age structures of fish caught in SE in each year from 2009 to 2012. For each year, data are presented as the relative percentage of total catch accounted for by each year class, i.e. the years in which they were spawned.

Regional recruitment histories

An average recruitment history was calculated for each region, based on catch curve analysis from annual age structures. For NSG, since there were numerous age structures generated that involved some relatively old fish, it was possible to extend the recruitment history back to 1968 (Fig. 4.11). A number of strong year classes are apparent including; 1973, 1979, 1991, 1997 and 1999. The 1970s was a period of high recruitment compared to the 1980s that was characterised by exceptionally poor recruitment. Year class strength was highly variable through the 1990s, whilst the 2000s were characterised by relatively poor recruitment. The last strong year class that recruited to this region prior to 2008 was in 1999. For SSG, the calculated recruitment history did not extend back as far as for NSG primarily because there were fewer older fish captured in this region. Again, the 1980s was a period of poor recruitment prior to the highly variable recruitment through the 1990s with strong year classes in 1991, 1997 and 1999. No strong year classes are evident for this region subsequent to 1999.

Because of the limited number of annual age structures available for NGSV, the average recruitment history for this region was limited to the period of 1986 to 2008 (Fig. 4.11). Three years, i.e. 1991, 1997 and 1999 produced the strongest year classes. However, the 2001, 2004 and 2006 year classes were also relatively stronger than for the other four regions. For SGSV, the 1980s was also a period of poor recruitment. The 1991 year class was the dominant one of the 1990s, whilst the 2001 year class was the dominant one of the 2000s. The 1997, 2004 and 2006 year classes were relatively moderate ones for this region. Because of the limited historical catches from the SE, the estimated recruitment history for this region only extended back to the mid 1990s. The recruitment history of this region is dominated by the strong 2001 and 2004 year classes.

The recruitment histories of the four gulf regions, i.e. NSG, SSG, NGSV and SGSV were compared using correlation analysis for the 21 year history of 1986 to 2006. All four time series were significantly correlated (Table 4.1), indicating some spatial consistency in the timing of the strong year classes. Nevertheless, it is clear from Fig. 4.11 that the relative sizes of the strong year classes varied considerably amongst regions. The recruitment histories of NSG and SSG were most strongly correlated, with both dominated by the strong 1991, 1997 and 1999 year classes. Whilst the recruitment histories were all significantly correlated that for SGSV was least correlated with the other three regions. This probably relates to the dramatic change in age structures in this region between the early and latter 2000s.

Table 4.1 Results of correlation analyses between recruitment histories for the four gulf regions between 1986 and 2006. Data shown are the correlation coefficients (** significant at the 0.01 level of significance).

Region	NSG	SSG	NGSV	SGSV
NSG	1			
SSG	0.8920**	1		
NGSV	0.7196**	0.6853**	1	
SGSV	0.5672**	0.5559**	0.6393**	1

<u>Analysis of growth</u>

The estimates of size-at-age and resulting von Bertalanffy growth curves differed considerably amongst the five regions (Fig. 4.12). The two northern Gulfs involved more older and larger fish than the southern regions. In contrast, for the southern regions, few fish >15 years of age were captured. Furthermore, for these regions, the estimates of size-at-age were generally distributed across a broader size range indicating the presence of many more fish that were relatively small for their ages, i.e. slower growing, than was the case for the northern gulfs. The southern regions generally had lower estimates of L_∞, but higher values of K than the northern gulfs, but also involved higher estimates of standard error around the parameter estimates (Table 4.2). The exception was for SGSV for which there was a high estimate of L_∞, probably due to the dominance in the estimates of size-at-age of the younger age classes and the under-representation of older fish, which prevented L_∞ from being well estimated. The resulting growth functions were significantly different between NSG and SSG, and between NGSV and SGSV.

Table 4.2 Estimates of von Bertalanffy growth parameters for the five regions based on estimates of size-at-age for fish sampled between 2000 and 2012. Estimates of standard error are shown in brackets.

Region	L_∞	K	t_0
NSG	97.5 (0.95)	0.11 (0.003)	-0.699 (0.079)
SSG	67.3 (1.37)	0.17 (0.01)	-0.435 (0.264)
NGSV	92.6 (0.63)	0.14 (0.003)	-0.074 (0.065)
SGSV	104.5 (3.10)	0.08 (0.005)	-0.996 (0.157)
SE	88.0 (5.91)	0.065 (0.01)	-2.735 (0.630)

4.4 Discussion

This chapter summarised the regional, annual estimates of size-at-age in terms of regional estimates of size and age structures, growth curves and recruitment histories that can be interpreted in terms of demographic processes.

NSG consistently supported broad size and age structures, demonstrated considerable variation in age class strength and a relatively tight relationship between size and age. In comparison, the population in SSG generally demonstrated a more limited range of ages, whilst age structures were consistently dominated by one or two strong year classes. Only occasionally was a 'very large' fish captured in this region. Furthermore, there was high variation in the estimates of size-at-age, resulting in a poor relationship between size and age. In recent years, NGSV has supported fish from a broad range of sizes. The population reflects numerous strong year classes, high longevity and a tight relationship between size and age. SGSV demonstrated the greatest variation in size structures between the early and later years of the 2000s. During the early 2000s, the population included many 'large' fish, whereas 'small' and 'medium' fish were sampled in the late 2000s. This difference reflected the ages of the dominant year classes at the time. In the SE region, during the late 2000s the population of snapper was dominated by numerous 'small' fish from the 2001 and 2004 year classes.

Within each region, the population size and age structures demonstrated considerable variation over time. This variation reflected the influences of inter-annual variation in recruitment. This phenomenon of variable year class strength is well documented for South Australian snapper populations, which is considered to relate to inter-annual variability in recruitment of the 0+ snapper (McGlennon et al. 2000, Fowler and Jennings 2003), and possibly related to variation in survivorship of the eggs and larvae (Hamer and Jenkins 2004). Although the recruitment histories of the different regions were correlated between years, nevertheless there was still variation amongst regions in the relative sizes of the different year classes. Of the six strong year classes of 1991, 1997, 1999, 2001, 2004 and 2006, the former two were significant in all four gulf regions, and were largely responsible for the recovery of the fishery from the mid 1990s onwards, and the record catches that were taken from the late 1990s. However, the relative significance of the 2001, 2004 and even the 2006 year classes were more significant in NGSV, SGSV and the SE than in either NSG or SSG. Since inter-annual variation in recruitment is one of the primary drivers for population dynamics and fishery productivity of snapper, there remains considerable interest in trying to understand the environmental processes that are responsible for the variation (Murphy et al. 2012, in press).

The size-at-age data also indicated that the rates of growth and estimates of longevity of snapper varied amongst regions. The differences amongst regional estimates of longevity reflect that there were older and larger fish found in the northern region of both gulfs than the two southern regions. This may relate to inter-regional movement or differential regional mortality rates and so reflects the life history of snapper. The differences in estimates of size-at-age, size and age structures of fish between the northern and southern regions of the gulfs relate, at least partly, to regional differences in the growth patterns. 'Dwarf' fish, i.e. fish that were small for their age were a feature of the southern regions but were very rare in the northern gulfs. It is assumed that such fish are residents of the southern regions and their slower growth reflects the different diets and physical environments to which they are subjected compared to the northern gulfs (Lloyd 2010). Nevertheless, not all fish removed from the southern gulfs conformed to this slower, more restricted growth pattern as many were similar in size-at-age as those from the northern regions. This begs the question about the movement of larger fish between the northern and southern regions. Whilst it is known that snapper are capable of moving over distances of several hundred kilometres (Jones 1981, 1984, McGlennon 2003), the significance of such movement on regional levels of biomass and population characteristics is not fully understood. An FRDC-funded project (FRDC 2012/020) is currently focussed on the issue of inter-regional movement and its influence on population dynamics and stock structure.

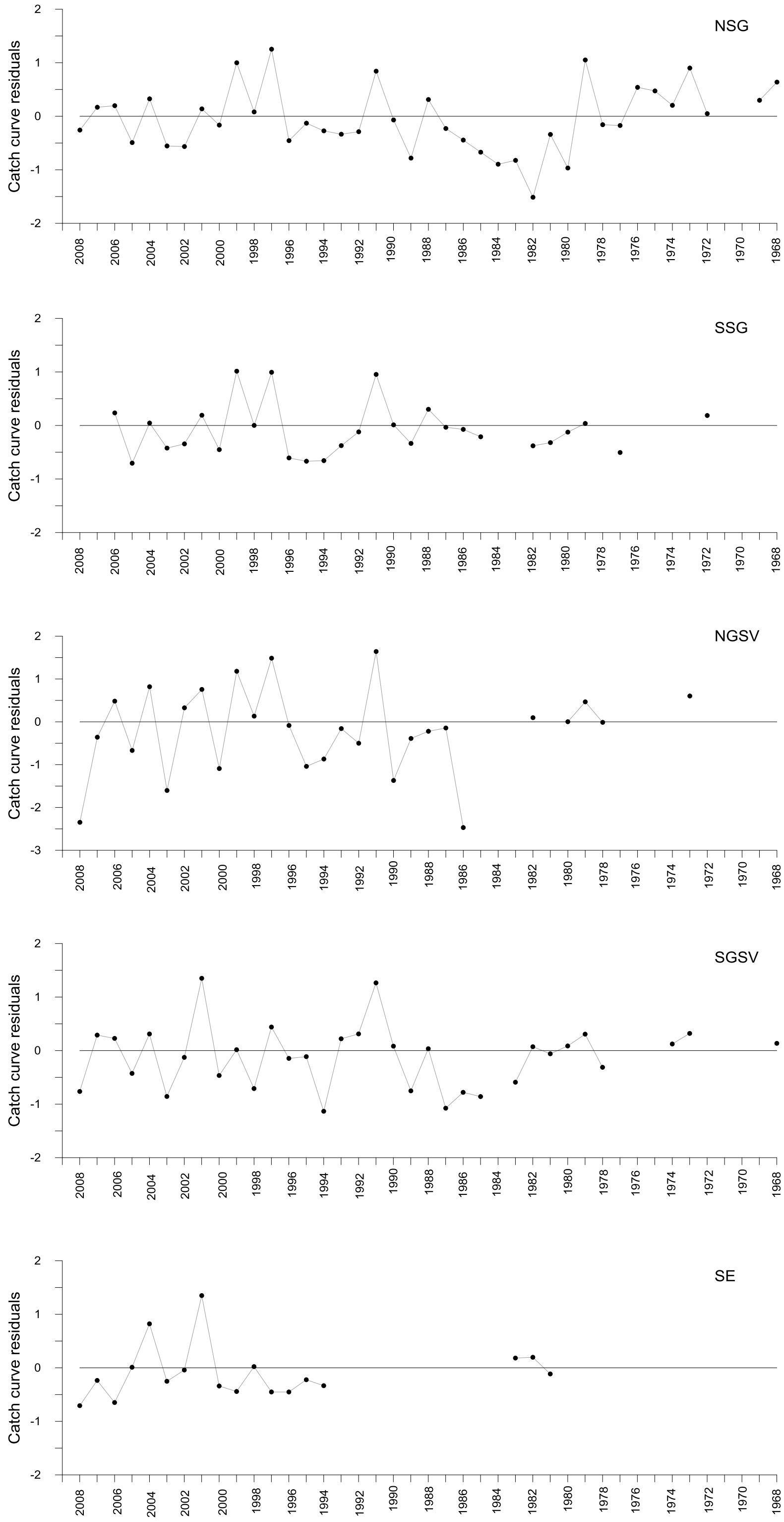

Fig. 4.11. Estimated recruitment histories for five regions, showing relative year class strength estimated as the average of residuals calculated from catch curve analysis from annual age structures.

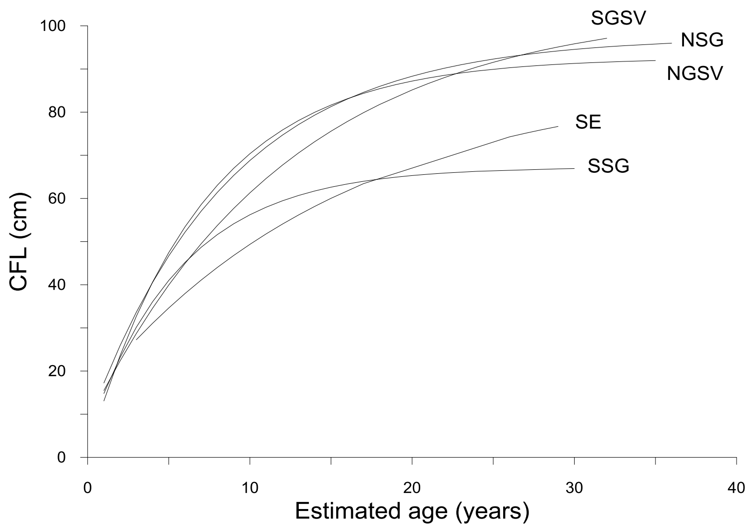

Fig. 4.12. Von Bertalanffy growth curves for each of five regions of South Australia's snapper fishery.

5. ASSESSMENT MODEL FOR SOUTH AUSTRALIA'S SNAPPER FISHERY

5.1 Introduction

The status of snapper stocks are monitored by assessing general and biological performance indicators on an annual basis. Four of five biological yearly performance indicators are estimated by analysing all available data using a spatial, dynamic fishery model ('SnapEst') developed under FRDC Project No. 1999/145, "Stock assessment models with graphical user interfaces for key South Australian marine finfish stocks" (McGarvey and Feenstra 2004). In this chapter we present the model-estimated time series outputs for the key model-based biological performance indicators for the three main fishery regions in the two gulfs. In Chapter 6, these yearly model estimates of snapper biomass, recruitment, harvest fraction and egg production are compared against the trigger reference points for these biological indicators as specified by the Management Plan (PIRSA 2013).

Five data sets are used as input to the South Australian snapper stock assessment model. They are:

1. commercial catch and effort data (Chapter 3);
2. recreational catch and effort data from the two telephone and diary surveys, 2000/01 and 2007/08;
3. charter boat catch and effort data;
4. commercial length-frequency samples (Chapter 4);
5. commercial catch-at-age samples (Chapter 4).

The model input data set was updated to September 2012. Commercial catches of South Australian snapper (fish lengths and a sub-sample of ages read from otoliths) were research-sampled in three separate programs since the early 1990s, i.e. in 1990-91, 1994-95, and 2000 to September 2012. All catch samples in the first two programs were from NSG only. The 2000-2012 samples were larger, more comprehensive, covered both gulfs, and spanned the entire year. The model inferences are most strongly drawn from these more recent and complete catch length and age samples. The absence of sampling prior to 1991 for NSG means that model outputs for the years prior to then are less well informed by data, and for SSG and GSV prior to 2000. Recreational catch and effort data are now available from two data sources, logbook catch and effort reporting by charter boat operators, and two recreational surveys using the telephone and diary method carried out in 2000/01 and 2007/08 (Jones and Doonan 2005, Jones 2009).

5.2 Materials and Methods

The snapper stock assessment model runs on a half-yearly time step, fitting to data from each summer (Oct-Mar) and winter (Apr-Sep) time step since October 1983.

Spatially, the snapper model covers only the two gulfs. There were three model regions analysed; NSG, SSG and GSV (north and south combined). The WC and SE have not been included in the modelling because the market-measuring program accessed very few samples from these regions, and they continue to constitute a minority of the total South Australian catch, though that percentage has risen and subsequently fallen in recent years in the SE (Chapter 3). Because data to quantify migration are not yet available, there is no movement assumed in the model. Thus, the results from each region are effectively independent.

The 'SnapEst' model integrates the five input data sets, to carry out maximum likelihood estimation of four critical stock assessment indicators: yearly recruitment (quantified by the recruiting number of 3 year olds), semi-yearly fishable biomass, semi-yearly harvest fraction, and yearly egg production. Yearly recruit numbers (Fig. 5.1) are designated by the year class, the January date for the summer when those fish were spawned and thus when they settled at age 0+. They reach fishable sizes at ages 3-5 years, depending on how fast they grow. The snapper model employs the slice-partition method developed in South Australia to describe fish population numbers by both age and length (McGarvey et al. 2007). The model considers the catches and associated effort divided into (now) 6 categories (handline, longline, hauling net, all other commercial gears combined, charter boats, and other recreational). Target type is not differentiated, and non-target catches of snapper were, for the most part, low. Further details of this model are included in the FRDC final report (McGarvey and Feenstra 2004). The snapper model is similar in structure to another model, i.e. GarEst, which was reviewed by Dr. André Punt, as described in the FRDC final report (McGarvey and Feenstra 2004).

Charter boats, since July 2007, report the catches, in number of each species, and the person hours of anglers aboard each charter trip. In prior stock assessment model runs, when charter boat data were unavailable or not yet sufficient, charter catch was not differentiated from other recreational catch, and charter catch was accounted for by its inclusion in the recreational surveys which recorded charter trips by telephone and diary interviewees. However, because charter catches are now fully reported, the charter logbooks provide a more precise and accurate measure of the catch and effort of this sector than do the recreational surveys. In this year's run of the model, charter boat records were therefore removed from the 2007/08 survey, leaving only survey non-charter recreational catches from that year onward. A new charter effort type, adding to the four existing commercial effort types, was then created for the model starting in the October 2007 time step to input and model charter boat catches and effort.

Estimates of (non-charter) recreational catch and effort totals from both telephone and diary recreational surveys covered one full year for each of the three model regions. For years prior to the 2000/01 survey, catches were estimated for each half-yearly model time step by extrapolating backward, as in previous assessments, assuming recreational effort and catch varied yearly in proportion to the South Australian census count of human population. For years between the two available recreational surveys, half-yearly catch and effort were linearly interpolated between the estimates of each survey. Model time steps subsequent to 2007/08 used the results of the 2007/08 recreational survey directly, with no extrapolation applied, as they were thought to provide more accurate estimates of recreational catch.

The fecundity relationship employed to calculate yearly egg production is based on more recent work on snapper reproduction in NSG (Saunders 2009), including the timing of peak spawning in December and the fecundity relationship derived from Saunders' batch counts of eggs released per spawning event by female snapper of varying length. Saunders' data were fitted by maximum likelihood in the snapper management strategy evaluation study (McGarvey et al. 2010; 2011), yielding the relationship $(Batch\ fecundity) = 7.2x10^{-4} \cdot TL^3$, where TL = total length.

Because overall exploitation rates of South Australian snapper are relatively low, shown by the presence in catch samples of fish that are 20 years of age and older, the influence of uncertainty in the rate of natural mortality (M) has a greater impact on model-estimated levels of absolute biomass than with other marine scale (and other South Australian) species. Models of New Zealand snapper have been under development for several decades (Gilbert et al. 2006). New Zealand snapper models assume a value of M = 0.051-0.054, estimated from age samples of their West Coast stocks in the 1970s prior to significant exploitation (D. Gilbert, pers. comm.). Accepting these as direct measurements of snapper natural mortality rate, we assumed a value of M = 0.05.

Around 2005, new snapper longliners fishing in SSG introduced a new lighter-weight monofilament gear, which is known to have permitted an increased capture efficiency. This inflated longline catch rates, first where it was introduced in SSG, and later throughout the longline sector as this new gear became more widely adopted. To account for a higher longline catchability, a separate catchability parameter was estimated in the model for SSG and GSV from 2005 onward. This yielded a measurably higher longline catchability post-2005 in these regions, lowering model estimates of biomass relative to those implied by raw catch rates.

5.3. Results

The biological performance indicators of recruitment, biomass, harvest fraction and egg production estimated by the 'SnapEst' model are presented for the three regions in Figs. 5.1-5.4 and discussed below.

<u>Recruitment</u>

The high yearly variation of snapper recruitment is evident, with a few year classes dominating (Fig. 5.1). This is consistent with (and is inferred from) the age-structure catch samples of Chapter 4, in which those same year classes are evident.

Yearly recruitment estimates in the two SG regions (Fig. 5.1) were highly correlated (r = 0.93). The model estimates by region are independently estimated. Thus, yearly environmental factors, egg production, and/or successful fertilisation being common to both northern and southern waters of SG must act synchronously on recruitment to both regions. Peak cohorts of recruitment were those identified directly from the age structures (Figs. 4.2 and 4.4): 1991, 1997, 1999, 2001, 2004 and 2006. In absolute terms, the model inferred higher levels of recruitment to SSG than NSG in 1991 and similar levels in 1997 and 1999. But recruit numbers have been much lower in the 2000s compared to the 1990s, particularly in SSG. Average 1990s (1990-1999) yearly recruitment was 363,000 age 2 snapper in SSG and 308,000 in NSG. In the 2000s (2000-2008) these average yearly recruitment numbers declined to 51,000 and 118,000 snapper in SSG and NSG, declines of recruitment to 14% and 38% of 1990s levels, respectively. Thus, model estimates of recruitment to the Spencer Gulf are much lower on average since 2000.

GSV recruitment was correlated with NSG (r = 0.49) and SSG (r = 0.45). Estimated GSV recruitment numbers were much stronger in the 2000s, rising from a 1990s average of 102,000 snapper per year to a 2000s average of 183,000.

Biomass

Model-estimated biomass in all three regions had been increasing since about 1994 (Fig. 5.2). The rate of increase in biomass accelerated in GSV and NSG in the early 2000s, around the time that the temporal closures were implemented. Biomass peaked in SSG in 2005. In GSV, estimated biomass doubled from 2000 to its peak in 2010, reflecting higher and more consistent yearly recruitment to this gulf in 2000s.

A large increase in biomass since 2000 was also estimated for NSG. NSG catch rates were variable but trended upward since about 2002 for both gear types (Fig. 3.3), notably for handlines, the dominant gear in this region, which the model interprets as increased biomass. This large rise in CPUE to 2011, was difficult to interpret since it coincided with strongly declining commercial fishing effort; longlining all but ceasing in NSG (Section 3.3). The large one-year drop observed in 2012 NSG catch rate (both handline and longline) would not be possible for the model to replicate as correspondingly reduced biomass, notably because effort levels, and thus total fishing mortalities have been low in recent years, and so changes in biomass over one year would imply much bigger removals by fishing (or some other cause) than were reported for this region. Model biomass for South Australian snapper can generally change only slowly with time due to both the low exploitation levels associated with low commercial effort and low natural mortality (M = 0.05). This one-year CPUE decline from 2011 to 2012 is consistent with the hypothesis of hyperstability in catch rates as handlines target highly aggregated snapper spawning aggregations (see Section 7.2).

Harvest Fraction

Harvest fraction (Fig. 5.3) quantifies the exploitation rate as the proportion of the fishable biomass which is harvested in each six-monthly model time step (Fig. 5.3a-c) or in each year (Fig. 5.3d). Snapper exploitation levels vary seasonally, being higher in summer (Fig. 5.3a-c) when handline fishers target snapper aggregated at well-defined spawning locations.

Estimated levels of harvest fraction on South Australian stocks are relatively low (Fig. 5.3). Yearly snapper harvest fractions in the two Spencer Gulf regions are currently estimated to be 4% in both Spencer Gulf regions. These are much lower than for other South Australian species whose harvest fraction has been estimated such as southern garfish and King George whiting. However, they are not far below what would be considered optimal if the rule of thumb were applied where the fishery seeks to set fishing mortality about equal to natural mortality. *M* in this fishery model is 5% based on estimates from New Zealand as noted in Section 5.2. Moreover, these Spencer Gulf estimated harvest fractions are now at all-time lows. In both Spencer Gulf regions, average harvest fraction levels have declined from about 9% during the more active years (2000 to 2009 in SSG; 1984 to 2002 in NSG).

The model estimates low South Australian snapper harvest fractions because average yearly survival must be high in order for there to be measurable, sometimes even predominant numbers of snapper aged above 10 years old, and measurable proportions of snapper above age 20 years. It is not known if this high average survival rate is possibly due to complex movements of snapper, which could provide inadvertant refuge if South Australian snapper during part of their lives swam away from areas of stronger fishery exploitation.

The decline in estimated Spencer Gulf exploitation rates was inferred principally from the extent of decline in commercial fishing effort in these two regions. Overall effort has shown large declines in both Spencer Gulf regions. As observed in effort data (Section 3.3), longlining has virtually ceased in NSG, and handline fishing levels are very low in SSG.

In GSV, exploitation rates more than tripled (Fig. 5.3), to 18% in the last two years (2011 and 2012), from about 5% (1995-2004). This was due to a large and rapid increase in fishing effort into this region attracted by the appearance of biomass levels (2007-2012, Fig. 5.2) that are nearly 3 times higher than pre-1995 level. The value of 18% constitutes the highest snapper harvest fraction estimated for any year in any of the three regions.

<u>Egg production</u>

The yearly production of eggs by snapper in all three regions (Fig. 5.4) was estimated to have risen substantially since the mid-1990s in all three model regions. It peaked in 2005 in SSG and 2010 in GSV and has declined in these two regions since. This is consistent with, and inferred from the same processes that have caused model biomass to rise since 1994, which potentially include exclusion of netting in 1993 and seasonal closures starting in 2000, and of declining stock biomass in these two regions subsequently.

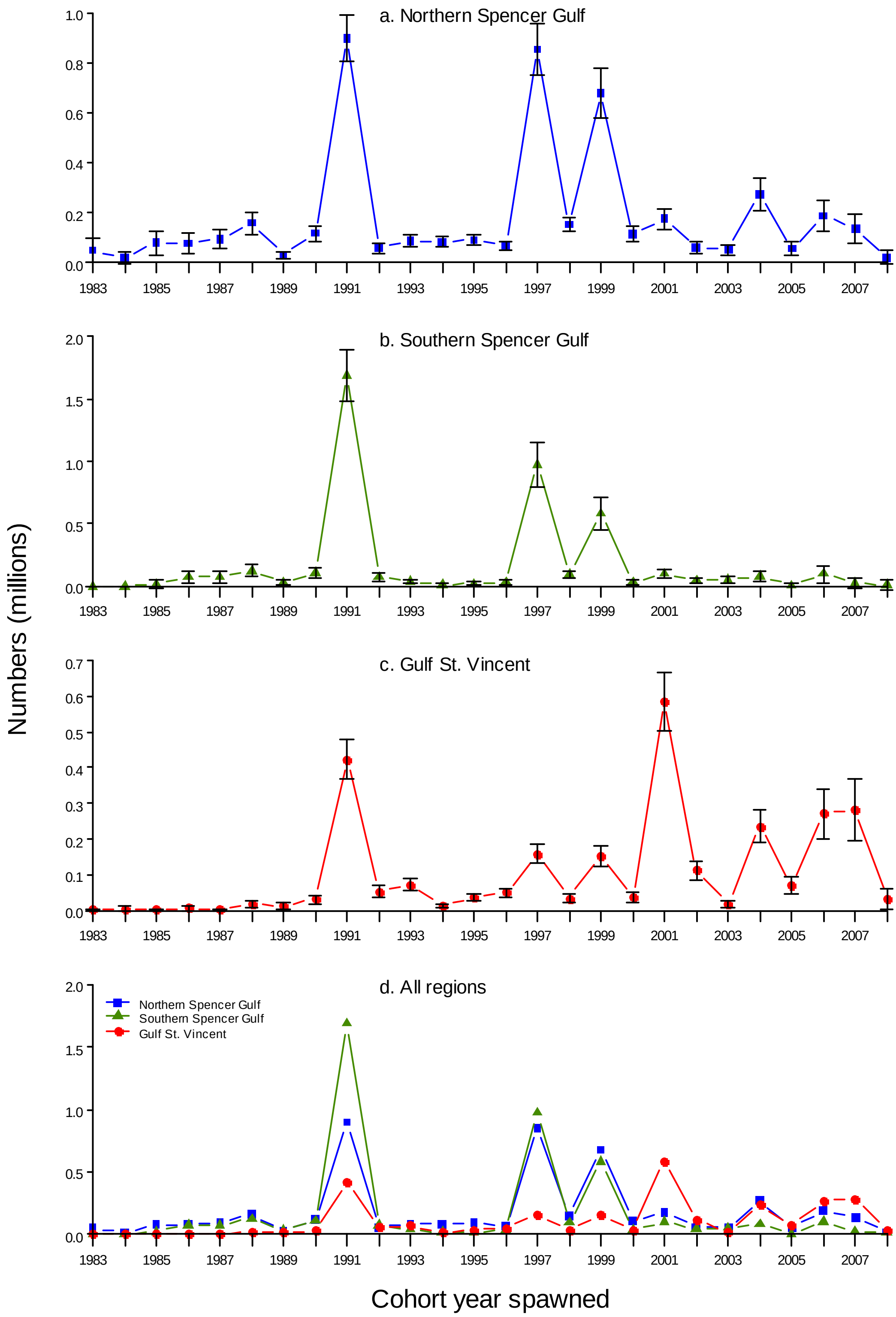

Fig. 5.1 Yearly recruitment estimates for the South Australian snapper stock, by region. The model defines recruitment of a year class as the number of snapper spawned in any given summer spawning season (e.g. 1991) that reach fishable size at age 3 years. Error bars quantify the 95% confidence intervals in this and subsequent model output, Figs. 5.1-5.4.

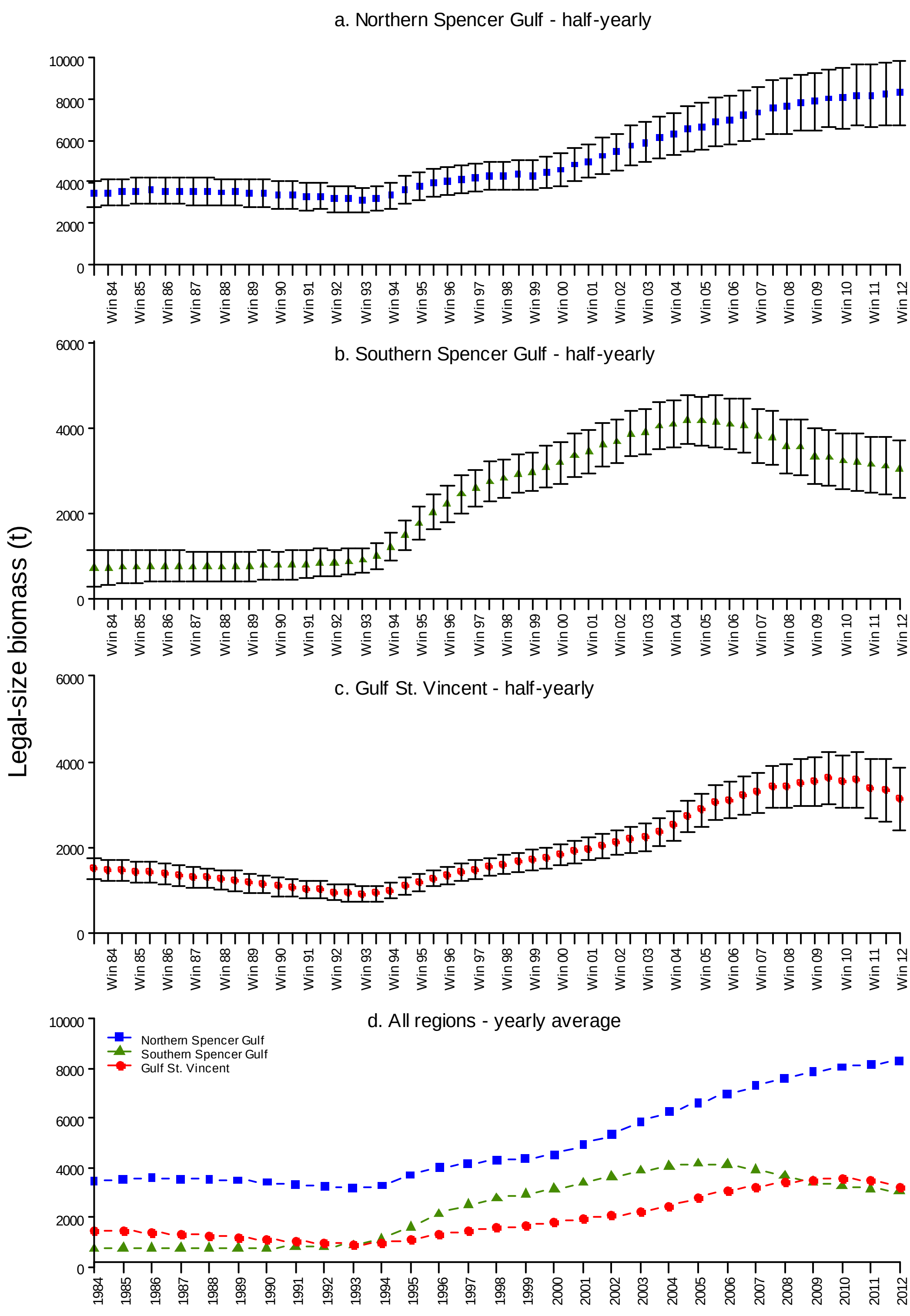

Fig. 5.2 Model estimates of snapper legal-size (i.e. fishable) biomass. These are shown (a-c) by region, as half-yearly model estimates with 95% confidence intervals, and (d) as yearly averages of model biomass (the average of winter and summer) from all three regions plot on the same graph, for visual comparison between regions and assessment of yearly trends.

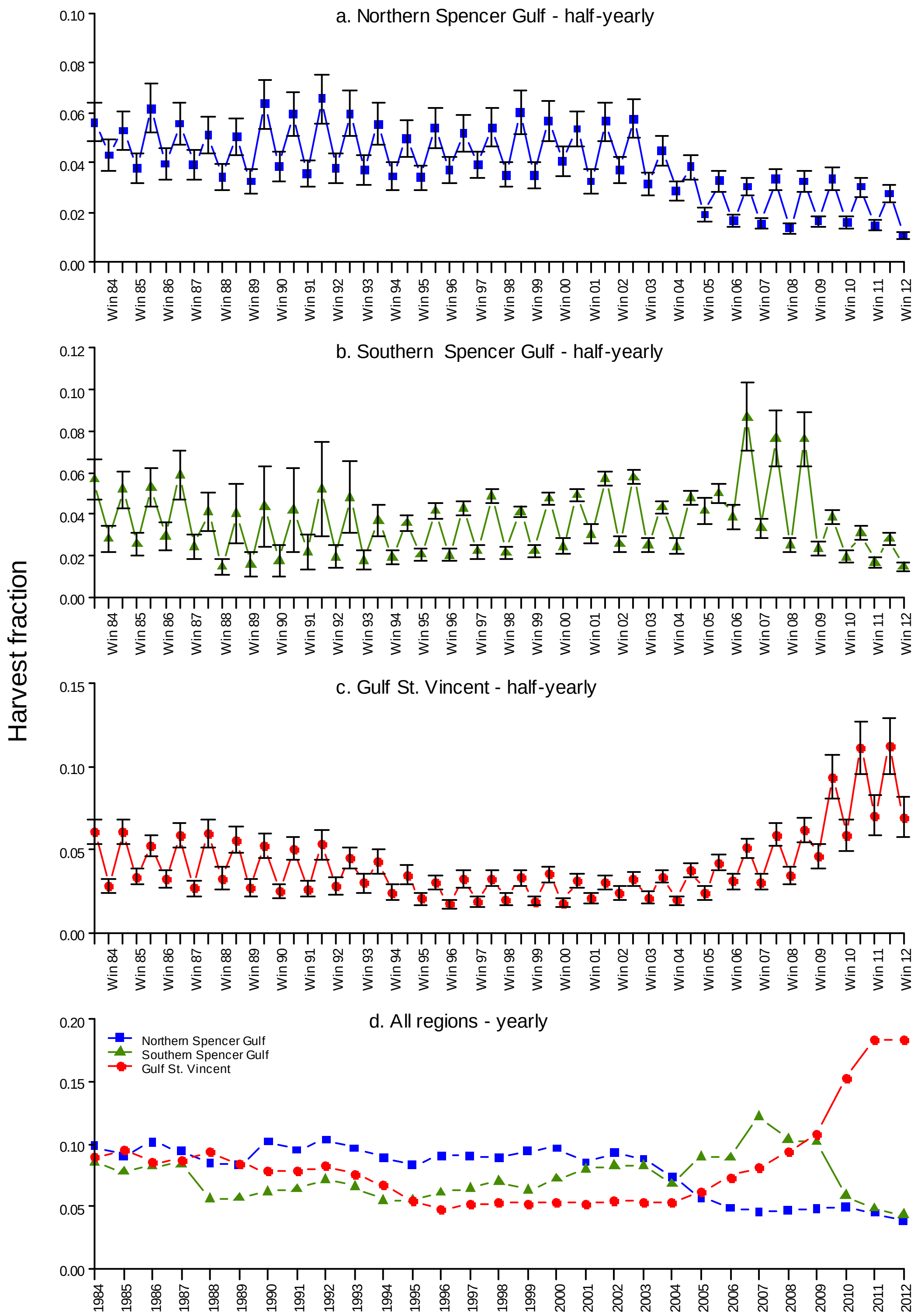

Fig. 5.3 Model estimates of snapper harvest fraction (i.e. exploitation rate). Regional estimates (a-c) by half year, with 95% confidence intervals, define harvest fraction as model-estimated catch divided by start of half-year model biomass. In graph (d) each yearly harvest fraction is calculated as the total yearly model catch divided by the yearly average of model biomass, for all three regions.

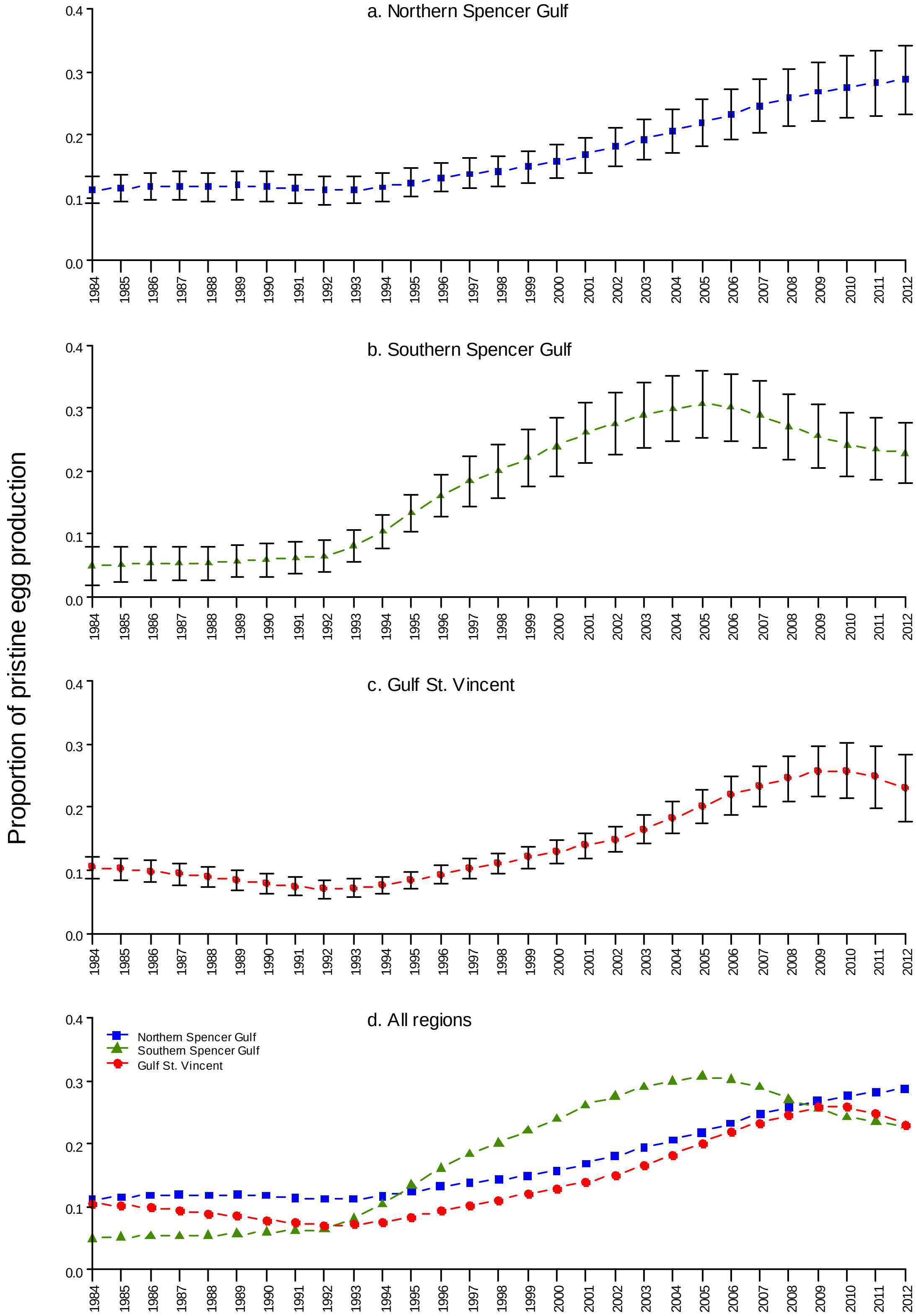

Fig. 5.4 Yearly egg production estimates for the South Australian snapper stock, by region. Egg production is scaled as a proportion of the model-estimated level that would be obtained, on average, in an unfished (pristine) population, obtained by setting model fishing mortality equal to 0.

6. ASSESSMENT OF FISHERY PERFORMANCE INDICATORS

6.1 Introduction

The new Management Plan for the Marine Scalefish Fishery of South Australia includes a harvest strategy for snapper, of which one objective is to ensure long-term sustainability of the fishery. To achieve this, the strategy outlines the process of monitoring the effectiveness of the management arrangements using two sets of fishery performance indicators, 'general' and 'biological', and appropriate trigger reference points (Appendix 4, PIRSA 2013). The former are based entirely on commercial fishery statistics, whilst the latter are largely based on output from the computer fishery model 'SnapEst', but also include population age structures. In the snapper harvest strategy, the 'general' and 'biological' performance indicators are divided into primary and secondary indicators (Table 6.1), with the former selected as the key determinants of fishery performance, and the latter providing supporting information in a weight of evidence approach about fishery performance.

The new management measures that were implemented in October 2012 will reduce the catchability of snapper by the commercial sector. These measures will limit catches and thereby reduce the nominal estimates of daily CPUE. As such, this will disrupt the integrity of CPUE as a relative measure of stock abundance because from 2013 onwards the annual estimates of CPUE will no longer be comparable to those from 1984 to 2012. To accommodate the loss of the value of CPUE as a fishery indicator, two new fishery performance indicators have been proposed and incorporated into the new harvest strategy, i.e. the proportion of daily fishing trips that used either handlines or longlines where the catches reached 250 kg (PIRSA 2013). These indicators were shown to track historical trends in handline and longline CPUE, and because they are not affected by the new management arrangements, they could provide useful replacements for CPUE as measures of abundance that are continuous with historical data. So, for the first time these two new fishery performance indicators are considered in this assessment.

A second objective of the harvest strategy is to maintain catches within allocations for each sector. The share allocated to a particular sector is that to which it had access at the time the Minister requested the Fisheries Council prepare the Management Plan, based on the most recent information available (PIRSA 2013). For the Marine Scalefish Fishery, the most recent data were those from 2007/08, i.e. the year when the last recreational survey was done (Jones 2009). In this assessment, for the first time, the recent catches of the different fisheries that comprise the commercial sector were compared against their allocations that are specified in the Management Plan (PIRSA 2013).

Table 6.1 Division of fishery performance indicators into primary and secondary categories, based on snapper harvest strategy (PIRSA 2013).

Category	Performance Indicator
Primary	Handline and longline fishing effort Handline CPUE Yearly proportion of handline trips reaching 250 kg Age composition Fishable biomass Exploitation rate
Secondary	Total catch Longline CPUE Yearly proportion of longline trips reaching 250 kg Recruitment index Yearly egg production

6.2 Materials and Methods

Fishery Performance Indicators

Both the 'general' and 'biological' performance indicators were assessed at two spatial scales. For the former the scales were; State-wide, as well as for the regions specified in Fig. 2.1, for which the fishery statistics were summarised in Chapter 3. The general fishery performance indicators considered were; total catch, targeted handline effort, targeted longline effort, targeted handline CPUE and targeted longline CPUE. For each region and at the State-wide scale, the time series of data from 1984 to 2012 for each indicator was prepared. Then, the value for 2012, was compared against a number of trigger reference points calculated for the 'reference period', i.e. the historical data time series back to 1984 (Appendix 4, PIRSA 2013). This comparison was done by addressing four questions:

- was the value of the indicator in 2012 among either the top three or bottom three values over the reference period of 1984 to 2012?;
- was the change in the indicator between 2011 and 2012, i.e. the two most recent years, the greatest inter-annual increase or decrease over the reference period?;
- was the slope of the linear trend over the last five years to 2012, the greatest rate of increase or decrease over five-year periods throughout the reference period?
- and did the indicator decrease over the last five consecutive years?

For the State-wide statistics and each region, a 'results' table was prepared that showed the outcomes of these comparisons, indicating whether or not the target reference points were breached.

Here, for the first time, the proportions of handline and longline fishing trips for which catches reached 250 kg are considered as fishery performance indicators. The calculation of the two new performance indicators was based on daily catch data from the commercial sector. Since such data are only available from July 2003, when the daily reporting of commercial logbook became mandatory, for this assessment their calculation was restricted to the calendar years of 2004 to 2012. The targeted catch data from

November to January in each summer were excluded, to remove the influence of the seasonal closure on the data (PIRSA 2013). The annual estimates of both indicators were calculated for each fishery region by determining the proportion of daily catches from all fishers that produced catches of 250 kg or greater. The two parameters are henceforth called 'Prop250kgTarHL' and 'Prop250kgTarLL', for handlines and longlines, respectively. The regional estimates of Prop250kgTarHL and Prop250kgTarLL for 2012 were then compared against those from 2004 to 2012, using the same trigger reference points that are used for the general performance indicators.

For snapper, there are five biological performance indicators: fishable biomass; egg production; harvest fraction; recruitment; and age structure (PIRSA 2013). The first four are time-series of output parameters from the SnapEst model (Chapter 5), whilst the age structures are catch proportions by age from market sampling, as summarised in Chapter 4. The estimates of output parameters were considered for each of the three regions considered in SnapEst, i.e. NSG, SSG and GSV, as well as combined amongst these regions. For the first two indicators, recruitment and biomass, the value considered to best represent the status of the fishery is the average value of the three most recent annual estimates of the output time-series from SnapEst. This value was calculated and compared against specific target reference points that are specified in Tables 17 and 18 of PIRSA (2013). For harvest fraction and egg production, the estimated value from the last year was chosen for consideration as it would be expected to not differ meaningfully from the average of the last three years since such indicators change slowly over time. In each case, this estimated value was compared against internationally accepted levels (Tables 17 and 18 of PIRSA 2013). The trigger reference point for the last indicator, i.e. the most recent annual age structure, is that the proportion of fish older than 10 years was less than 20% of the fished population (Table 17 of PIRSA 2013).

<u>Comparison with allocations for commercial sectors</u>

The comparisons between reported catches and allocations for the different commercial fisheries were done using the fishery statistics from 2012. For the comparisons, trigger limits are specified in the Management Plan that provide for some variability in the proportional contributions to total catch between years, allowing limited ability for sectors to exceed allocations without triggering a review. The assessment was done by addressing the following questions about relative contributions to the total commercial catch:

- did a fishery's contribution to total commercial catch at the State-wide scale exceed its allocation by the percentage nominated as Trigger 2 in Table 6.2, (from Table 8 in PIRSA 2013), in three consecutive years or in four of the five previous years up to 2012?;
- did the fishery's contribution in 2012 exceed its allocation by the amount nominated as Trigger 3 in Table 6.2?

The total annual catches for each commercial fishery were determined for each year from 2008 to 2012. From these, their percentage contributions in these years were calculated. These were then assessed against the trigger limits specified below in Table 6.2, according to the criteria specified above.

Table 6.2 Allocation triggers for commercial fisheries. The table shows the percentage of the commercial allocation to each commercial fishery, and their trigger reference points for each of Triggers 2 and 3. Note that for the MSF fishery, no trigger limits are set as allocation is >95%. Fisheries are identified as MSF = Marine Scalefish Fishery; SZRL = Southern Zone Rock Lobster Fishery; NZRL = Northern Zone Rock Lobster Fishery; LCF = Lakes and Coorong Fishery.

Fishery	MSF	SZRL	NZRL	LCF
Commercial allocation (%)	97.5	1.78	0.68	0.04
Trigger 2	na	2.68	1.3	0.75
Trigger 3	na	3.58	2.0	1.0

6.3 Results

General Performance Indicators

For the State-wide fishery statistics, a total of seven out of 20 general performance indicators exceeded the trigger reference points (Table 6.3). These related to the data from 2012 showing the greatest decrease in catch ever recorded, declines in handline effort and CPUE, but high levels of longline effort and CPUE related to the longline expansion since 2008.

Table 6.3 Results of comparisons between general performance indicators and trigger reference points for snapper based on State-wide fishery statistics.

Performance Indicator	Trigger reference Point	Breached ?	Details
Total commercial catch	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	**Yes**	**Greatest decrease**
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted handline effort	3rd highest/3rd lowest	**Yes**	**Lowest**
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	**Yes**	
Targeted longline effort	3rd highest/3rd lowest	**Yes**	**3rd highest**
	Greatest interannual change (±)	No	
	Greatest 5-year trend	**Yes**	**Greatest increase**
	Decrease over five consecutive years ?	No	
Targeted handline CPUE	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	**Yes**	**Greatest decrease**
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted longline CPUE	3rd lowest/3rd highest	**Yes**	**2nd highest**
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	

For the 20 comparisons for NSG, there were six breaches of trigger reference points that related to significant decreases in total catch, handline and longline CPUE to 2012, as well as the lowest levels of handline and longline effort (Table 6.4). For SSG, five comparisons exceeded trigger reference points that related to low levels of catch, declining handline effort, and a significant reduction in handline CPUE (Table 6.5).

Table 6.4 Results of comparisons between general performance indicators and trigger reference points for NSG.

Performance Indicator	Trigger reference Point	Breached ?	Details
Total commercial catch	3rd lowest/3rd highest	**Yes**	**Lowest**
	Greatest interannual change (±)	**Yes**	**Greatest decrease**
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted handline effort	3rd lowest/3rd highest	**Yes**	**Lowest**
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted longline effort	3rd lowest/3rd highest	**Yes**	**Lowest**
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted handline CPUE	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	**Yes**	**Greatest decrease**
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted longline CPUE	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	No	
	Greatest 5-year trend	**Yes**	**Greatest decrease**
	Decrease over five consecutive years ?	No	

Table 6.5 Results of comparisons between general performance indicators and trigger reference points for SSG.

Performance Indicator	Trigger reference Point	Breached ?	Details
Total commercial catch	3rd lowest/3rd highest	**Yes**	**3rd lowest**
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	**Yes**	
Targeted handline effort	3rd lowest/3rd highest	**Yes**	**Lowest**
	Greatest interannual change (±)	No	
	Greatest 5-year trend	**Yes**	**Greatest decrease**
	Decrease over five consecutive years ?	No	
Targeted longline effort	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted handline CPUE	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	**Yes**	**Greatest decrease**
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted longline CPUE	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	

For NGSV there were seven breaches of trigger reference points. These related to the substantial increase in total catch in the past few years and the recent increases in longline effort, as well as handline and longline CPUE (Table 6.6). In contrast, there was only a single breach of a trigger reference point for SGSV, which related to the greatest annual decrease in longline CPUE yet recorded (Table 6.7).

Table 6.6 Results of comparisons between general performance indicators and trigger reference points for NGSV.

Performance Indicator	Trigger reference Point	Breached ?	Details
Total commercial catch	3rd lowest/3rd highest	**Yes**	**3rd highest**
	Greatest interannual change (±)	No	
	Greatest 5-year trend	**Yes**	**Greatest increase**
	Decrease over five consecutive years ?	No	
Targeted handline effort	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted longline effort	3rd lowest/3rd highest	**Yes**	**2nd highest**
	Greatest interannual change (±)	No	
	Greatest 5-year trend	**Yes**	**Greatest increase**
	Decrease over five consecutive years ?	No	
Targeted handline CPUE	3rd lowest/3rd highest	**Yes**	**Highest**
	Greatest interannual change (±)	No	
	Greatest 5-year trend	**Yes**	**Greatest increase**
	Decrease over five consecutive years ?	No	
Targeted longline CPUE	3rd lowest/3rd highest	**Yes**	**3rd highest**
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	

Table 6.7 Results of comparisons between general performance indicators and trigger reference points for SGSV.

Performance Indicator	Trigger reference Point	Breached ?	Details
Total commercial catch	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted handline effort	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted longline effort	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted handline CPUE	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted longline CPUE	3rd lowest/3rd highest	No	
	Greatest interannual change (±)	**Yes**	**Greatest decrease**
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	

For the SE region, there were two breaches of trigger reference points (Table 6.8). Both targeted handline effort and CPUE showed their greatest five-year declines between 2008 and 2012. Furthermore, the greatest decrease in handline CPUE was recorded between 2008 and 2012. There were three breaches of trigger reference points for the WC region that related to a declining trend in total commercial catch, as well as a low handline effort and a declining trend in handline CPUE (Table 6.9).

Table 6.8 Results of comparisons between general performance indicators and trigger reference points for the SE.

Performance Indicator	Trigger reference Point	Breached ?	Details
Total commercial catch	3rd lowest/3rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted handline effort	3rd lowest/3rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	**Yes**	**Greatest decrease**
	Decrease over five consecutive years ?	No	
Targeted longline effort	3rd lowest/3rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted handline CPUE	3rd lowest/3rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	**Yes**	**Greatest decrease**
	Decrease over five consecutive years ?	No	
Targeted longline CPUE	3rd lowest/3rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	

Table 6.9 Results of comparisons between general performance indicators and trigger reference points for the WC.

Performance Indicator	Trigger reference Point	Breached ?	Details
Total commercial catch	3rd lowest/3rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	Yes	**Greatest decrease**
	Decrease over five consecutive years ?	No	
Targeted handline effort	3rd lowest/3rd highest	**Yes**	**2nd lowest**
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted longline effort	3rd lowest/3rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	
Targeted handline CPUE	3rd lowest/3rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	**Yes**	**Greatest decrease**
	Decrease over five consecutive years ?	No	
Targeted longline CPUE	3rd lowest/3rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
	Decrease over five consecutive years ?	No	

Prop250kgTarHL and Prop250kgTarLL

The daily catch data of snapper from 2004 to 2012 (excluding Nov-Jan) were used to generate new fishery performance indicators, i.e. Prop250kgTarHL and Prop250kgTarLL, at the regional scale. The values for 2012 were then assessed against trigger reference points calculated from the whole period (Table 6.10, Fig. 6.1). For NSG, one trigger reference point was activated that related to the greatest annual decrease in 2012 of Prop250kgTarHL. For SSG, Prop250kgTarHL was the 3rd lowest value yet recorded. Alternatively, for NGSV there were three trigger reference points activated for Prop250kgTarHL that related to the highest value and greatest increase to 2012 yet recorded. Furthermore, for NGSV, the value of Prop250kgTarLL in 2012 was the 2nd highest value yet recorded. For both SGSV and the SE, there were no handline catches in 2012 that reached 250 kg, and so Prop250kgTarHL was the lowest estimate yet recorded and also experienced their greatest 5-year declines. Furthermore, for the SE, Prop250kgTarLL experienced its greatest decline in 2012. For WC, in 2012 there were also no daily handline catches that reached 250 kg and had its greatest 5-year decline, whilst Prop250kgTarLL was at its 2nd lowest recorded level. Overall, the activation of trigger reference points relate to significant downturns in all regional fisheries except for that of NGSV, for which they relate to the fishery being at its highest recorded level.

Table 6.10 Results of comparisons between regional estimates of 'Prop250kgTarHL' and 'Prop250kgTarLL' for 2012 and trigger reference points.

Region	Performance Indicator	Trigger Reference Point	Breached ?	Details
NSG	Prop250kgTarHL	3rd lowest/3rd highest	No	
		Greatest interannual change (±)	**Yes**	**Greatest decrease**
		Greatest 5-year trend	No	
		Decrease over five consecutive years ?	No	
	Prop250kgTarLL	3rd lowest/3rd highest	No	
		Greatest interannual change (±)	No	
		Greatest 5-year trend	No	
		Decrease over five consecutive years ?	No	
SSG	Prop250kgTarHL	3rd lowest/3rd highest	**Yes**	**3rd lowest**
		Greatest interannual change (±)	No	
		Greatest 5-year trend	No	
		Decrease over five consecutive years ?	No	
	Prop250kgTarLL	3rd lowest/3rd highest	No	
		Greatest interannual change (±)	No	
		Greatest 5-year trend	**Yes**	**Greatest decrease**
		Decrease over five consecutive years ?	No	
NGSV	Prop250kgTarHL	3rd lowest/3rd highest	**Yes**	**Highest**
		Greatest interannual change (±)	**Yes**	**Greatest increase**
		Greatest 5-year trend	**Yes**	**Greatest increase**
		Decrease over five consecutive years ?	No	
	Prop250kgTarLL	3rd lowest/3rd highest	**Yes**	**2nd highest**
		Greatest interannual change (±)	No	
		Greatest 5-year trend	No	
		Decrease over five consecutive years ?	No	
SGSV	Prop250kgTarHL	3rd lowest/3rd highest	**Yes**	**Zero**
		Greatest interannual change (±)	No	
		Greatest 5-year trend	**Yes**	**Greatest decrease**
		Decrease over five consecutive years ?	No	
	Prop250kgTarLL	3rd lowest/3rd highest	No	
		Greatest interannual change (±)	No	
		Greatest 5-year trend	No	
		Decrease over five consecutive years ?	No	
SE	Prop250kgTarHL	3rd lowest/3rd highest	**Yes**	**Zero**
		Greatest interannual change (±)	No	
		Greatest 5-year trend	**Yes**	**Greatest decrease**
		Decrease over five consecutive years ?	No	
	Prop250kgTarLL	3rd lowest/3rd highest	No	
		Greatest interannual change (±)	No	
		Greatest 5-year trend	No	
		Decrease over five consecutive years ?	No	
WC	Prop250kgTarHL	3rd lowest/3rd highest	**Yes**	**Zero**
		Greatest interannual change (±)	No	
		Greatest 5-year trend	**Yes**	**Greatest decrease**
		Decrease over five consecutive years ?	No	
	Prop250kgTarLL	3rd lowest/3rd highest	**Yes**	**2nd lowest**
		Greatest interannual change (±)	No	
		Greatest 5-year trend	No	
		Decrease over five consecutive years ?	No	

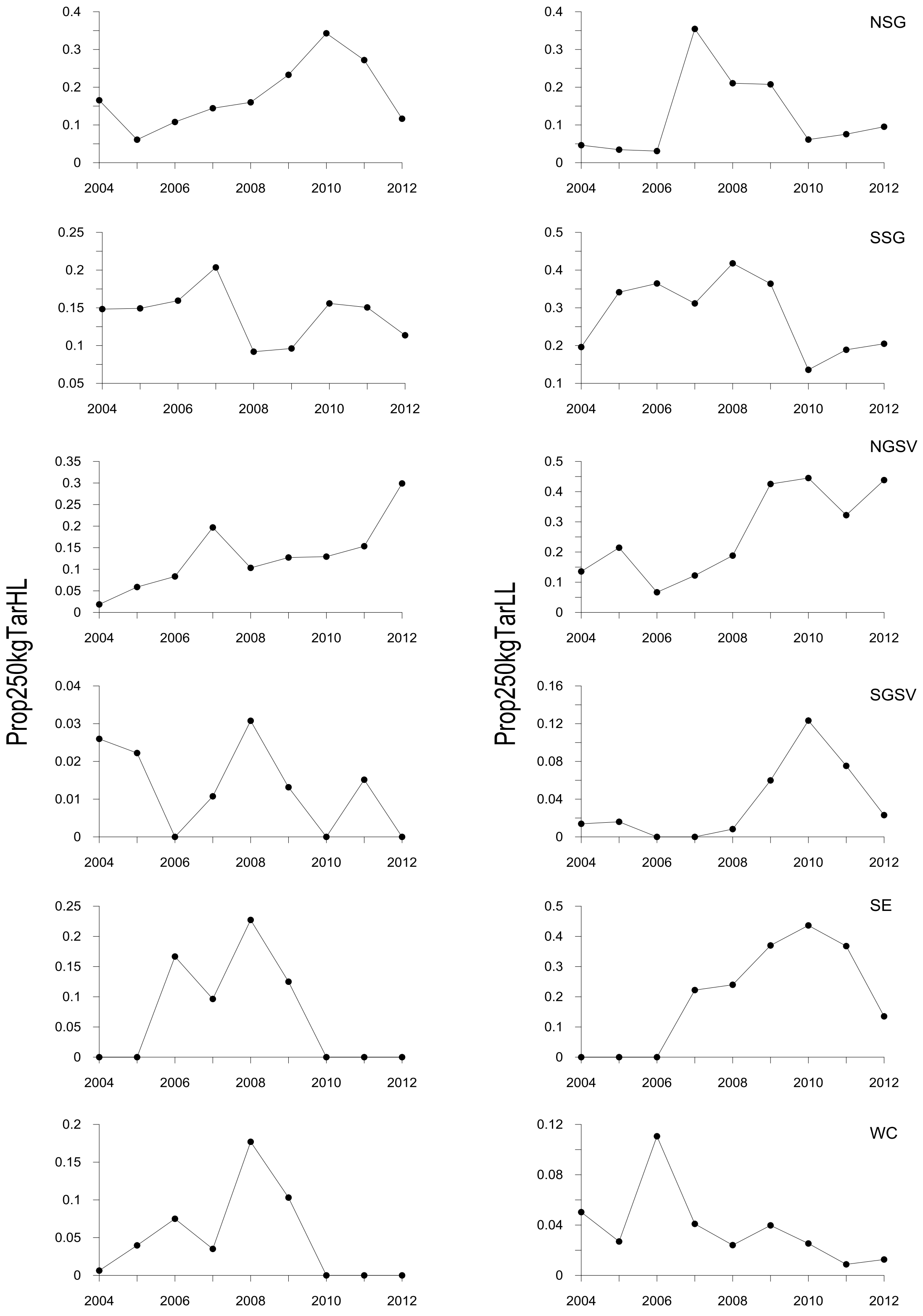

Fig. 6.1 Left hand graphs show the annual estimates of 'Prop250kgTarHL' for the indicated regions. Right hand graphs show the estimates of 'Prop250kgTarLL' for the same regions.

Biological Performance Indicators

Biological performance indicators (BPIs) were compared with trigger reference points for the three regions of NSG, SSG and GSV and for the three regions combined (Table 6.11). Harvest fraction (a primary indicator) and percent of pristine egg production (a secondary indicator) were compared to accepted trigger reference levels for sustainable exploitation (Table 6.11) as in previous years. Trigger reference points for the snapper biomass BPI (a primary indicator) and recruitment (a secondary indicator) have been modifed under the new MSF Management Plan (PIRSA 2013).

The biomass BPI over the last three modelled years (October 2009 – September 2012) did not trigger for NSG or GSV being 8% above (NSG) and 1% above (GSV) compared with the average of the previous 3 years (Table 6.11). Biomass in SSG for these last three years did trigger, with 14% lower stock biomass over the last 3 years compared with the previous three years. At the State-wide level, fishable biomass averaged over these last 3 years was 1% above the previous 3-year average, which was well within the boundaries of the +/- 10% trigger reference point.

Estimates of annual harvest fraction were low for the regions and State-wide compared with the recommended 32% trigger reference point (Table 6.11). The estimated regional egg production levels ranged from 23 to 29% of the pristine populations (Table 6.11). As such, none were lower than the trigger reference point of 20% of pristine population level.

The BPI of recruitment is quantified by model-estimated recruit numbers for the last three cohorts that have largely recruited to date, here namely 2006-2008. The estimates of recruitment for the two Spencer Gulf regions were far below the historical means prior to 2006, by 39% for NSG and 78% for SSG (Table 6.11). Recruitment to GSV over the last three years was more than double (112%) that of the mean from previous historical years. The larger trigger breaches for recruitment against the previous historical mean (-39%, -78%, and +112%) suggest that recruitment has changed more dramatically (for the worse in SG and for the better in GSV) over the past decade, rather than over the past nine years (Fig. 5.1). For the second trigger reference point applied to this yearly recruitment BPI, namely comparing the last three years with the six years that preceded them, the extremes of variation are much reduced, and only SSG (16% below) and GSV (11% above) triggered.

For the latest age structures that were presented for NSG, SSG, NGSV and SGSV (Figs. 4.2, 4.4, 4.6, 4.8), i.e. those for either 2011 or 2012, the trigger reference point was 'the proportion of fish older than 10 years was less than 20% of the fished population'. In all cases these values exceeded 20%, which meant that no trigger reference points were activated (Table 6.11).

Table 6.11. Results from assessment of the biological performance indicators against trigger reference points for the three regions individually and combined . The first four biological performance indicators were estimated by the SnapEst model and were summarised by year (or half-year) in Section 5.3. Age composition was summarised in Chapter 4. Trigger reference points that were breached in this assessment are highlighted in yellow. For fishable biomass, the current performance years are the last three years estimated by the model, October 2009 – September 2012, and for recruitment the performance years are the last three cohorts reliably estimated, 2006-2008. For percent pristine egg production and harvest fraction, the last year (October 2011 – September 2012) is the reference year.

Biological Performance Indicator	NSG	SSG	GSV	Combined across regions (NSG + SSG + GSV)	Trigger Reference Point
Fishable biomass	8% above average of previous 3 years	14% below average of previous 3 years	1% above average of previous 3 years	1% above average of previous 3 years	Most recent 3-yr average is +/- 10% of previous 3-yr average
Harvest fraction	2012: 4%	2012: 4%	2012: 18%	2012 : 7%	Exceeds international standard (above 32%)
Egg production (% of pristine population)	2012: 29%	2012: 23%	2012: 23%	2012: 26%	Lower than 20% of pristine population
Recruitment	2006-08 cohorts were 39% below historical mean	2006-08 cohorts were 78% below historical mean	2006-08 cohorts were 112% above historical mean	2006-08 cohorts were 24% below historical mean	Most recent 3-yr average is +/- 10% of the previous historical mean
	2006-08 cohorts were 6% below previous 6-yr average	2006-08 cohorts were 16% below previous 6-yr average	2006-08 cohorts were 11% above previous 6-yr average	2006-08 cohorts were 1% above previous 6-yr average	Most recent 3-yr average is +/- 10% of the previous 6-yr average
Age composition	50% >10 yrs old	52.1% >10 yrs old	NGSV - 33.0% >10 yrs old SGSV - 24.0% >10 yrs old		Proportion of fish older than 10 years less than 20% of the fished population

Comparison with allocations for commercial sectors

The reported catches by the four commercial fisheries and their relative contributions to the total commercial catch in each year from 2008 to 2012 are shown in Table 6.12. The Marine Scalefish fishers dominated the catches in each year generally accounting for >95% of the reported catch. The reported catches from the Southern Zone Rock Lobster fishers generally accounted for <4% of the total, whilst those of the Northern Zone Rock Lobster fishers were generally <1%. There was no reported catch of snapper from the Lakes and Coorong Fishery between 2008 and 2012. These contributions of the various commercial fisheries to total catch did not vary significantly from their allocations (Table 6.13).

Table 6.12 Comparison of catches of snapper (tonnes) and relative contribution to total commercial catch (percentage) by the different commercial fisheries that reported taking snapper in each year between 2008 and 2012. Fisheries are identified as MSF = Marine Scalefish Fishery; SZRL = Southern Zone Rock Lobster Fishery; NZRL = Northern Zone Rock Lobster Fishery; LCF = Lakes and Coorong Fishery.

Year	MSF	NZRL	SZRL	LCF	Total	%MSF	%NZRL	%SZRL	LCF
2008	700.7	5.1	14.4	0	719.7	97.3	0.7	2.0	0
2009	772.1	10.7	35.7	0	818.5	94.3	1.3	4.4	0
2010	986.7	8.9	35.9	0	1,031.5	95.7	0.9	3.5	0
2011	913.8	6.8	22.1	0	942.7	96.9	0.7	2.3	0
2012	625.1	1.6	15.0	0	641.7	97.4	0.3	2.3	0

Table 6.13 Comparisons between the catches of snapper by the different commercial sectors in 2012 with allocation trigger limits specified in the Management Plan (PIRSA 2013). Fisheries are identified as MSF = Marine Scalefish Fishery; SZRL = Southern Zone Rock Lobster Fishery; NZRL = Northern Zone Rock Lobster Fishery; LCF = Lakes and Coorong Fishery.

Commercial sector	Draft Trigger Limit	Breached?
MSF	Trigger 2 – no trigger limit set as allocation >95%	n.a.
	Trigger 3 – no trigger limit set as allocation >95%	n.a.
NZRL fishery	Trigger 2 – exceeds allocation of 1.3% in multiple years	No
	Trigger 3 – exceeds allocation of 2.0% in 2012	No
SZRL fishery	Trigger 2 – exceeds allocation of 2.68% in multiple years	No
	Trigger 3 – exceeds allocation of 3.58% in 2012	No
LCF	Trigger 2 – exceeds allocation of 0.75% in multiple years	No
	Trigger 3 – exceeds allocation of 1.0% in 2012	No

6.4 Discussion

General fishery performance indicators were assessed at both the State-wide and regional spatial scales, which resulted in many breaches of trigger reference points at both spatial scales. The breaches were generally consistent amongst regions NSG, SSG, SGSV, SE and WC, relating to decreases in catch, effort or CPUE. Whilst the management changes in 2012 will have caused some reduction in fishery catches and effort for 2012, the results highlight the extent to which there have been downturns in these regional fisheries in the past few years, as is evident in the fishery statistics presented in Chapter 3. Furthermore, the results from the new fishery performance indicators, i.e. Prop250kgTarHL and Prop250kgTarLL for these regions are also indicative of recent downturns. In contrast, the fishery performance indicators and estimates of Prop250kgTarHL and Prop250kgTarLL for NGSV all highlight the recent increases in this regional fishery, particularly the longline sector, and that it continues to produce record levels of catch, based on high effort and high levels of CPUE. Such results are consistent with a high biomass level remaining in this region.

The four biological performance indicators of fishable biomass, harvest fraction, egg production and recruitment show results consistent with the catch and effort data and age and length structures on which the general performance indicators and SnapEst model is based. Generally low exploitation levels on South Australian snapper mean harvest fraction and egg production indicators did not trigger. However, exploitation rates in GSV have more than tripled to 18% from about 5% (1995-2004). The trigger reference point of 32%, currently applied to all three main Marine Scalefish species, may be high for a species such as South Australian snapper. Biomass changes slowly for a species subject to relatively low fishing and natural mortality, so the biomass trigger reference points which compare the last 3 years with the 3 years before did not trigger. Recruitment has been found to vary on two time scales, yearly and decadal. The recruitment trigger reference point which compares the last 3 years with the 6 years prior showed relatively modest change. But comparing the last 3 years with the historical mean showed very large change, this reference point being exceeded by a large margin in all three regions, indicating large declines in more recent recruitment in the two Spencer Gulf regions, and a large increase in recruitment in Gulf St. Vincent. The poor recent recruitment to Spencer Gulf during the 2000s is apparent in the age structure with 50% of these populations comprised of fish greater than 10 years of age. The values were less for the two Gulf St. Vincent regions that have been the beneficiaries of significant recruitment through the 2000s.

7. GENERAL DISCUSSION

7.1 Information for stock assessment

This report presented the results from several long-term monitoring programs in order to determine the current status of the stocks of snapper in South Australia. These datasets were: the commercial catch and effort data from 1984 to 2012; and the data on population size and age structures that were collected throughout the 2000s up to 2012. These data were integrated in the SnapEst computer fishery model, along with recreational fishery data, to produce time series of significant biological performance indicators. Stock status was determined through the assessment of numerous fishery performance indicators for 2012 that were compared against trigger reference points calculated from the historical time series from 1984 to 2012. Stock status is determined using the classification system that was used in the recent national stock status report (Flood et al. 2012) and South Australia's up-coming stock status report, which includes five different levels of stock status, i.e. 'sustainable', 'transitional-recovering', 'transitional-depleting', 'overfished' and 'undefined'.

7.2 Status of snapper stocks

From the assessment of fishery performance indicators there has been considerable change in the status of South Australia's snapper fishery compared to when the last stock assessment was completed in 2010, which reported statistics up to 2008/09 (Fowler et al. 2010). At that time, the regional fisheries were generally characterised by high catches, high fishing effort and record catch rates that resulted in the status of most stocks being described as extremely healthy. The current assessment considered commercial and biological data up to the end of 2012. It documented that, in general, the fishery statistics continued to increase after 2008/09, but then peaked and declined considerably to 2012. Such results are consistent with significant declines in some regional fisheries over the most recent two to three years. The extent of the declines varied regionally, and so the regional trends are considered independently below, and stock status is assigned at this regional level.

<u>Northern Spencer Gulf</u>

NSG has historically been the most significant region in South Australia's snapper fishery. During the 1990s, it consistently contributed greater than 60% of the State's commercial catch. Since then, the region's catch has declined to its lowest recorded level, whilst its relative contribution to the State's total fell to around 50% in the early 2000s, to 21% by 2009, and to 9% in 2012. These recent drops in annual catch and relative contribution reflect considerable declines in both handline and longline fishing effort. In fact, there is now only minimal longline fishing effort in this region. In 2012, there were also dramatic declines in handline and longline CPUE. These low levels of catch, effort and CPUE resulted in the activation of numerous trigger reference points.

Up until 2012, the decline in the commercial fishery in NSG was perplexing as fishing catch and effort declined even though record catch rates were being produced. It was suggested that the fishery statistics were consistent with hyperstability, with CPUE estimates remaining high despite declining levels of biomass because of the aggregative behaviour of the fish and the efficiency of remaining fishers (Fowler and McGlennon 2011). The fact that in 2012 the annual catch and catch rate declined so significantly is consistent with this hyperstability hypothesis, and that the biomass in this region has now decreased significantly. The population age structures, particularly in 2011 and 2012, suggest that there have been no persistent strong year classes in this population since the 1999 year class, suggesting that the biomass may have declined due to low annual recruitment through the 2000s. Although the 2004 and 2006 year classes made some contributions to fishery catches in particular years, these contributions have not been consistent across years. The demographic processes behind such inter-annual variation in relative year class strength are not yet understood but most likely involve some processes other than inter-annual variation in recruitment of the 0+ fish.

Estimates from the SnapEst model were consistent to above. No strong recruitment year classes were evident after 1999. Average yearly snapper recruit numbers to this region from cohorts spawned in the summers from 2000 to 2008 were much lower than in the 1990s, averaging 38% of the 1990s (1990-1999 cohort) level. However, the model inferred a steadily increasing biomass from both; (1) increasing catch rates until 2011, and (2) much lower rates of exploitation. Commercial catch rates, especially for the dominant gear in NSG of handlines, rose considerably from 2005 to 2011, although with high yearly variability. Commercial exploitation rates were most likely much lower, due to lower fishing effort by both gears, especially longlines. Nevertheless, large declines in catch rates in 2012, for both gears, signal a problem with this stock which the model cannot replicate in the yearly model biomass indicator, as this changes slowly.

Overall, recruitment to NSG through the 2000s has been relatively poor resulting in the lack of evidence for any recent strong year class that would assist the population to recover. As such, the fishable biomass is likely to continue to decline in the near future through fishing and natural mortality. On the basis of this, the stock is defined as **transitional depleting**.

<u>Southern Spencer Gulf</u>

Since 2008/09, the status of the fishery in SSG has changed dramatically. At that time, handline and longline catches and CPUE had all begun to decline from near record levels attained between 2006 and 2008. In 2008, this region contributed 46.1% of the State's total catch of snapper, which was the dominant regional contribution. Since then, the handline and longline catches and effort have declined whilst estimates of CPUE have also declined markedly. By 2012, the region contributed only 6% of the State's total catch. The low catches, effort and declining CPUE have resulted in numerous target reference points being activated.

Model estimates of recruitment to SSG show more significant declines in recruitment in the 2000s compared to the 1990s than was the case in NSG. Average recruitment numbers to SSG for the 2000-2008 year classes were about 14% of those of 1990-1999. Model biomass peaked in 2005 and has declined by about 26% to 2012.

The results described above are consistent with a significant decline in fishable biomass subsequent to the period of record catches and catch rates from 2006 to 2008. Since 2000, the population structure and fishery catches from this region have generally reflected the influence of several strong year classes. Between 2000 and 2003 they were the 1991 and 1997 year classes. Through the period of record catches in the mid-late 2000s, the population was dominated by the strong 1997 and 1999 year classes. However, since then no further strong year classes have recruited to the population. This has culminated in the decline in the fishable biomass.

The data for this region were consistent with a substantial decline in fishable biomass subsequent to the increase in exploitation rate through the mid 2000s and poor recruitment throughout the 2000s. As such, the SSG stock is classified as **transitional depleting**.

<u>Northern Gulf St. Vincent</u>

For NGSV in 2008/09, there had been a recent increase in the annual catch and catch rate of snapper with longlines. In the following years, longline catch, effort and CPUE continued to increase causing this region's contributions to the total State-wide catch to increase from 9% in 2007 to 24% in 2009, 43% in 2011 and 65% in 2012. As such, this region became the dominant contributor to the State's snapper catches. This reflects a substantial increase in fishing effort that was associated with the switch to longlines, as well as an influx of fishers to the region. These data were consistent with a substantial increase in fishable biomass between 2005 and 2012, relative to the earlier years. The recruitment history for this region is informative about this increase. The same strong year classes were apparent in the recruitment history for NGSV as for the other regions, i.e. 1991, 1997, 1999, 2001, 2004 and 2006, but the relative significance of each of the latter three year classes were stronger in this region than was the case elsewhere. As such, the biomass in NGSV reflects strong recruitment through the 2000s, thereby contrasting considerably with the stocks in Spencer Gulf over the same period.

Although the GSV spatial cell in SnapEst combines northern and southern GSV, since about 95% of the catch comes from the northern region, model estimates relate primarily to NGSV. SnapEst model recruitment estimates showed the same year classes as strong, based on the age structure samples, but with commercial catch rates also incorporated bringing information on trends in snapper abundance. Fishable biomass is estimated to have risen by 81% from 2000 to 2012. Over longer time scales the rise is even greater, increasing by 175% from its lowest level in 1992-1994 to the current period of 2010-2012. This reflects increases in GSV recruit numbers, with recruitment averaging about 80% higher in

GSV for the 2000-2008 year classes, compared to the 1990-1999 year classes. The model also identified an even greater rise in levels of fishery exploitation. The snapper harvest fraction for GSV rose from a steady 5% over the more recent years of low abundance (1995-2004) to 18% in 2011 and 2012.

The data for this region were consistent with a substantial increase in biomass as a consequence of strong recruitment over recent years. In 2012, this was the only South Australian region for which the activation of trigger reference points related to the recent up-turn in the fishery, rather than to a down-turn. On this basis, this stock is classified as **sustainably fished**.

<u>Southern Gulf St. Vincent</u>

SGSV has never produced the substantial catches that each of the other gulf regions have at different times. From 2008/09, longline catches and catch rates were starting to increase relative to the low catches taken during the early 2000s, thereby increasing at a similar time to the increase in NGSV. After this, they continued to increase, but plateauxed in 2010 and 2011. They were nevertheless still at a fraction of the high levels that were attained in NGSV. From 2009 to 2012, this population produced about 4.0% of the State's annual catches. In 2012, the declines in longline statistics were sufficient to activate a trigger reference point. Overall, these recent statistics were consistent with a considerable decline in fishable biomass.

The characteristics of the population in this region changed dramatically between the early and late 2000s. In the former period, the population was dominated by relatively large, old fish from the 1991 year class. Subsequently, in the late 2000s, the population was dominated by relatively small, slow-growing fish from the 2001 and 2004 year classes. No large fish from these or older year classes were apparent. Such fish contrast with the larger, faster growing fish from NGSV, which suggests that the simultaneous increases in biomass in the two regions did not involve fish that moved between the two regions. This suggests that the increases occurred independently of each other. On the basis of this apparent separation from the large stock in NGSV, and the declining levels of catch and CPUE, this stock is classified as **transitional depleting**.

<u>South East</u>

In 2008/09 in the SE, longline catches, effort and CPUE had increased dramatically. They then continued to increase and reached their maxima in 2010. In that year, 25% of the State's total catch came from this region having increased from <1% in 2003, 4% in 2007 and 20% in 2009. Subsequently, the fishery statistics have declined and in 2012 the region produced 12.5% of the State's total catch. The high catches were predominantly taken from MFA 51, which were augmented with those from the other MFAs adjacent to the Coorong and further south. Historically, few fishers have fished in MFAs 45, 46 and 50, suggesting that the higher catches at least partly relate to the opening up of new fishing grounds. However, MFAs 51 and 55 have attracted considerable numbers of fishers in the past, which have produced relatively low catches and catch rates, suggesting the likelihood that fishable biomass has recently increased in these MFAs. The catches from this region involved small-medium fish of the 2001 and 2004 year classes, similar to those being taken at the same time from SGSV. These observations suggest the likelihood of a significant population of fish located in continental shelf waters offshore from the Coorong coast. The declining levels of catch and CPUE between 2010 and 2012 are consistent with declining biomass in this region. Despite the unknown origins of this population of fish, and therefore the lack of understanding about how the population is replenished, the recent declining levels of catch and catch rate strongly suggest that the stock status is **transitional depleting**.

West Coast

Due to the lack of biological information the only fishery performance indicators that can be considered for this stock are the commercial fishery statistics. The region has historically produced small catches relative to those from the gulfs. In 2008/09, the WC fishery supported relatively high levels of handline and longline catch and effort. Handline CPUE was at a record high level, whereas longline CPUE had been declining for several years. As such, there were ambiguous signals from the fishery performance indicators. Since then, whilst the handline fishery has declined and longline effort has been maintained, catch and CPUE have declined considerably. Whilst this region produced 7% of the State's catch in 2008, this was halved by 2012. These decreases were sufficient to result in the activation of three trigger reference points in 2012. The results are consistent with a declining level of biomass in MFAs 8, 9 and 10.

Given the lack of biological understanding for the WC stock, and lack of fishery indicators other than the commercial fishery statistics, there is insufficient information available to classify the status of this stock. As such, the stock status is classified as **undefined**.

7.3 Conclusions

There have been significant changes in stock status, as well as the structure and management of South Australia's snapper fishery since the last stock assessment (Fowler et al. 2010). That assessment indicated that up to 2008/09, there were generally high if not record levels of catch and CPUE of snapper by the commercial sector across most regions of the State. Those data were consistent with high levels of fishable biomass, except in SSG. That situation corresponded with a change in the spatial structure of the fishery which involved a decline in the significance of the Spencer Gulf fishery and increases elsewhere particularly NGSV and the SE. There was also a change from a handline to a longline fishery. In the following few years, these trends continued, culminating in the State producing its highest ever commercial catch of >1,000 t in 2010, with major contributions from NGSV and SE. However, in 2011 and 2012, there were significant declines in catches and catch rates in most regional fisheries, particularly in both SG regions. Such results are consistent with falling levels of fishable biomass, essentially across the whole State. NGSV continued to be the dominant regional fishery despite that annual catches plateauxed and SnapEst biomass and catch rates declined in 2011 and 2012. This region clearly supported the highest levels of fishable biomass between 2010 and 2012 and attracted a considerable increase in fishing effort. The increase in biomass in this region relates to there being numerous strong year classes represented in the age structures that recruited through the 1990s and 2000s. In contrast, the declining levels of fishable biomass in Spencer Gulf reflect relatively poor recruitment through the 2000s, whilst those of the SE and SGSV reflect the depletion of the strong 2001 and 2004 year classes that have sustained these regional populations for several years.

Significant management changes were introduced in October 2012 after a considerable process of review, concerns about declining levels of biomass in some regions and high levels of catch and effort in others. These included a number of management changes to reduce commercial catches. Furthermore, a two-week extension to the seasonal closure, as well as spatial closures of several significant spawning aggregation sites in the northern gulfs to commence in 2013 will enhance the opportunities for undisturbed spawning and recruitment of snapper spatial closures. The next stock assessment scheduled for 2016 will provide an opportunity to assess the effectiveness of these changes on the regional populations of snapper and their fishery productivity.

7.4 Future research needs

The new management arrangements that were put in place for snapper in October 2012 impose limits on commercial fishers that restrict their catches and potentially cause them to modify their behaviour. As such, this will alter their fishery statistics and impact on the usefulness of CPUE as an indicator of fishable biomass. This has been addressed, to some extent, by the addition in the harvest strategy of two new fishery performance indicators, i.e. Prop250kgTarHL and Prop250kgTarLL (PIRSA 2013). However, all of the performance indicators that are used for assessing this fishery depend on the commercial sector to some extent. Consequently, PIRSA Fisheries and Aquaculture has identified the need for a 'fishery independent' indicator of stock biomass. SARDI Aquatic Sciences has considered the methodological options for this requirement, and proposed that the Daily Egg Production Method (DEPM) would be the most logistically tractable method that would likely produce useful results. This concept and a proposal for its application were presented to industry representatives and PIRSA Fisheries and Aquaculture at a workshop in February 2013. The outcome of this was an 'in principal' agreement for a multi-year project to develop the methodology for applying the DEPM for snapper in South Australia. This will be funded as part of the Service Level Agreement with PIRSA in 2013/14, with further funding for the project to be sought from FRDC. A national strategic planning workshop for snapper research was undertaken in March 2013 that involved FRDC and was aimed at determining research priorities for the different jurisdictions and how to address them. The proposal to develop a method for applying the DEPM in South Australia was discussed and it was agreed that FRDC funding would be sought for a three-year project commencing in 2014.

In the text above it was indicated that there has been significant change in the spatial structure of South Australia's snapper fishery through the 2000s. Until around 2004, NSG retained its status as the most significant region after which it was replaced by SSG. However, after 2009 the two Spencer Gulf regional fisheries declined considerably, particularly in 2012. Simultaneously, there were dramatic increases in both the NGSV and SE up to about 2010. It would be highly beneficial to understand the demographic processes responsible for these spatial changes. Above, it was suggested that relatively poor recruitment to Spencer Gulf since 1999 has contributed to the declining biomass in both NSG and SSG. Furthermore, it was also suggested that relatively strong recruitment to NGSV and SE in at least 2001 and 2004 contributed to the higher levels of biomass in those regions. However, there remains the possibility that there has been some large-scale movement of fish into the latter two regions, possibly from Spencer Gulf that has led to their supplementation. Some support for this hypothesis comes from the variable nature of the 2004 and 2006 year classes in the annual age structures of NSG between 2007 and 2012. Therefore, the issues to be resolved for each of NGSV and SE are – did the recent strong year classes recruit as 0+ individuals or did juveniles and sub-adult fish move into these regions from elsewhere? The demographic significance of snapper movement remains poorly understood with respect to the extent to which inter-regional movement can affect regional levels of biomass. This issue is currently being addressed through FRDC Project 2012/020. By the end of 2014, that project should provide a better understanding of snapper movement through an acoustic telemetry study and the analysis of regional characteristics of otoliths, including their chemistry. The project will help understand the stock structure of snapper in south eastern Australia and develop a better spatial management strategy for the snapper fisheries of this region.

Although the demographic processes for snapper are not completely understood, the size and age structures developed from market sampling provide invaluable insights into how their populations work. In the future, such monitoring will continue. Snapper will be targeted in market sampling from October 2013 until September 2015, which will provide a further two years of data on population structure from which to follow the fate of the strong year classes that currently sustain the regional catches and to help identify any new strong year classes that recruit to any regions.

The 0+ recruitment survey that was done in NSG from 2000 was suspended after the survey in 2010 due to uncertainty about the value of the data as a recruitment index. However, it is now apparent from the recruitment history based on age structures for NSG that the 2000s was a period of relatively poor recruitment to this region during which no exceptional year classes recruited to the population. It is possible that had one of the exceptional year classes, such as those for 1991, 1997 or 1999, recruited through the survey period it could have produced an exceptional catch rate of 0+ fish in our survey. As such, in the future, the recruitment survey could produce a useful recruitment index for this region. Therefore, it is worth considering re-establishing the annual recruitment trawl survey. It would be possible to develop a more refined survey protocol given our understanding of where important nursery areas are located in NSG (Fowler and Jennings 2003, Fowler et al. 2010). Another option for developing a yearly index of snapper pre-recruit abundance, which could, in turn, potentially inform understanding of snapper movement, would be to add a means of recording undersize snapper numbers on handline catch and effort logbooks. In some years, handline fishers targeting King George whiting have reported very high catches of undersized snapper (aged 0 or 1) taking their bait and being brought up and thrown back. If the recording of discarded undersized snapper was implemented, this could provide a low-cost method for forecasting yearly snapper recruitment.

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