

Snapper (*Chrysophrys auratus*) Fishery

Fishery Assessment Report to PIRSA

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

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1. EXECUTIVE SUMMARY '

1. This is the 9th stock assessment report for the South Australian snapper fishery since 1997 and comes three years after the last assessment that was undertaken in 2007. It provides a comprehensive summary of: commercial catch and effort data from 1983/84 to 2008/09; results from three State-wide recreational surveys; data on population structure primarily from 2000 onwards; and results from a recruitment survey. These results are interpreted in terms of stock status.
2. 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 taken in 2008/09 of 786 t was the highest ever recorded. Although SG remained the primary regional contributor, the relative contributions from both NSG and SSG declined, whilst those from GSV, WC and the SE all increased to record levels. Furthermore, there were increases in longline fishing effort, which accounted for more boatdays than handlines for the first time. Catch rates were high or at record levels for both these gear types in all regions.
3. The commercial fishery statistics for 2008/09 provided estimates of general fishery performance indicators that were assessed against limit reference points at the State-wide and regional scales. Many of the limit reference points were breached, relating to the high catches, high longline effort and record catch rates for both handline and longline gear types.
4. The data for State-wide snapper catches from the 2007/08 South Australian Recreational Fishery Survey indicated that the recreational catch in terms of weight had declined considerably since 2000/01, and now accounted for 19.3% of the total catch. Also, the catch from NSG had declined considerably whilst that from GSV had increased. This spatial change is consistent with results from the commercial sector.
5. The annual size and age structures, as determined from market sampling throughout the 2000s, indicated a number of strong year classes, as related to recruitment in 1997, 1999, 2001 and 2004. In 2009, fish from these strong year classes were not distributed evenly throughout all regions. The 1997 and 1999 year classes were strongest in SG, the 2001 year class was strongest in SGSV and the SE, whilst the 2004 year class was strongest in SGSV and SGSV. The demographic processes leading to this uneven distribution of fish are not fully understood.

6. The fishery model SnapEst provided estimates of the output parameters of recruitment, fishable biomass, exploitation rate and egg production for the three regions of NSG, SSG and GSV over the time period of 1984 to 2009. These output parameters demonstrated different trends in the three regions. NSG demonstrated trends of increasing biomass and egg production through the 2000s due to high recruitment in recent years and a low exploitation rate. For SSG, biomass declined from the mid 2000s due to poor recent recruitment and relatively high exploitation rate since 2005. GSV showed trends of increasing biomass and egg production reflecting good recruitment in 2001 and 2004, although exploitation rate did increase considerably from the mid 2000s.
7. Several biological fishery indicators exceeded their limit reference points. For each of NSG, SSG and GSV fishable biomass was >10% above the previous 5-year average, which is indicative of the high biomass of snapper that was generally available in 2009. Also, for each region, recruitment in 2005 was low relative to the previous 5-year average. The latter is not cause for concern because of the variable nature of recruitment for this species.
8. The results from this assessment consistently indicate a high biomass of snapper across all regions of South Australia's coastal waters, despite a likely recent decrease in biomass from a high level in SSG. The high levels of biomass reflect numerous good recruitment years since 1997. This successful recruitment may be the consequence of natural biological processes and/or the benefits of a number of management interventions over the past 20 years or so.
9. In 2008/09, South Australia's snapper stocks were healthy and did not present any immediate stock sustainability issues. Nevertheless, the fishery in SG, particularly SSG, would benefit considerably from the recruitment of a new strong year class to the population.

2. BACKGROUND

2.1 Introduction

Stock assessments for the South Australian snapper fishery have been done regularly since 1997, with this being the ninth in the series (McGlennon and Jones 1997, McGlennon 1999, McGlennon and Jones 1999, Fowler 2000, Fowler 2002, Fowler et al. 2003, Fowler et al. 2005, Fowler et al. 2007). The central focus of each report has been to provide a current assessment of the status of the snapper stocks. The assessment presented here is based on the commercial catch and effort data up to June 2009, results from the recent South Australian Recreational Fishery Survey 2007/08 (Jones 2009), and the biological data that were collected up to March 2010. These data were integrated using the computer fishery model ‘SnapEst’ that was developed through the early 2000s (McGarvey and Feenstra 2004). This model was used to produce time-series of several fishery performance indicators, i.e. annual recruitment rates, fishable biomass and exploitation rate. The time-series of regional catch and effort data and fishery performance indicators were then used to generate limit reference points. The most recent catch and effort data for 2008/09, as well as output from the computer fishery model, were then compared against these limit reference points and interpreted in terms of the status of the stocks.

This stock assessment report includes a number of sections that report fishery statistics, the new biological information, the output from the computer fishery model and the results of comparisons between fishery performance indicators and limit reference points. The remainder of this chapter provides an introduction to the South Australian snapper fishery. It summarises the management regulations and 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. (2007). Chapter 4 summarises the information available on catches of snapper by recreational fishers, i.e. the results from the recreational boat creel survey that was undertaken in 1994/96 (McGlennon and Kinloch 1997), the National Recreational and Indigenous Fishing Survey (NRIFS) done in 2000/01 (Henry and Lyle 2003, Jones and Doonan 2005) and the South Australian Recreational Fishing Survey that was done in 2007/08 (Jones 2009). The regional recreational catches were compared between surveys and with the commercial catches for the same time periods.

Chapters 5 and 6 present the results from the long-term monitoring programs for snapper in South Australia (SA). In the first, a summary of all data collected on population structure, primarily since 2000, is presented. Chapter 6 presents the findings of the trawl survey for 0+ snapper that has been done annually in northern Spencer Gulf since 2000. This work has been aimed at quantifying and providing understanding of the high inter-annual variation in recruitment that underlies the population dynamics of snapper in South Australia. Here the data collected up to April 2010 are reported.

Chapter 7 summarises the output of the ‘SnapEst’ computer fishery model. This model integrates all data available up to September 2009, including: regional estimates of catch and effort from the commercial fishery; the data on the recreational catch obtained from both the NRIFS (Henry and Lyle 2003) and the 2007/08 state survey (Jones 2009); and the regional size and age structure data collected from 2000. The model generated time-series of estimates for the three critical fishery indicators of recruitment, fishable biomass and exploitation rate for the period of 1984 to 2009.

In Chapter 8, the General Fishery Performance Indicators and Biological Performance Indicators for 2008/09 were compared against the Limit Reference Points calculated for the time series of data for the period of 1983/84 to 2005/06. This was done at the State-wide and the 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. This synthesis provides an assessment of the status of the different regional stocks in the context of a discussion on the population dynamics for each region.

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). Over the past few years the national catch has approximated 1,700 to 1,800 tonnes per year (Table 2.1) (Anon 2009). The rise in catch in SA through the 2000s suggests that there has been an increase in biomass. The catches in NSW and Victoria also increased through the mid 2000s, but catches have decreased markedly in both Western Australia and Queensland (Table 2.1). The South Australian snapper catch is now the highest State-based commercial catch, having exceeded that of Western Australia for the first time in 2006/07. In the following year, SA accounted for 41.3% of the national commercial production.

The snapper fishery of SA is geographically extensive and encompasses most of the State’s inshore marine waters. For the purposes of stock assessment these waters have normally been divided into five geographic regions; Northern Spencer Gulf, Southern Spencer Gulf, Northern Gulf St. Vincent, Southern Gulf St. Vincent and the West Coast (Fig. 2.1). However, for the first time, this report also considers the estimates of catch and effort for the south eastern region of the State (South East), due to anecdotal reports about recent high catches from this region. Each region consists of a combination of MFAs that are indicated in Table 2.2 and shown on Fig. 2.1. Historically, the combined catch from Northern and Southern Spencer Gulf has accounted for approximately 80% of the State-wide total catch.

Snapper is an icon species for local and inter-state recreational fishers, who are particularly interested in the large ‘trophy’ fish that remain abundant in the coastal waters of SA. There have been three broad-scale recreational fishery surveys that have provided data on the catch and effort on snapper: a creel survey done in 1994-96 (McGlennon and Kinloch 1997); the NRIFS in 2000/01 (Henry and Lyle 2003) and the state-based recreational survey of 2007/08 (Jones 2009). These surveys indicate that hundreds of thousands of snapper are captured per year in the waters of SA by recreational fishers, of which many are discarded, primarily for being undersized. A further recent study established that there is considerable concern about the fate of such discarded fish (Fowler et al. 2009). The results from the three surveys also indicated that the relative significance of different regions to the total recreational catch was variable. Clearly, the recreational catch is significant enough for it to be taken into consideration in the stock assessment process. The three recreational surveys are considered in Chapter 4.0.

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

State	2005-06	2006-07	2007-08
NSW	236	238	294
Vic	92	108	113
Qld	228	186	155
WA	693	586	492
SA	529	644	741
Total	1,778	1,762	1,795

Table 2.2 Fishery regions considered for the snapper fishery of South Australia, and the Marine Fishing Areas that comprise them.

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)	50, 51, 54, 55, 56, 57, 58
Others	all remaining MFAs

The commercial sector accounts for the highest share of the snapper catch in SA. License holders from three different commercial fisheries have access to the snapper stocks, i.e. the Marine Scalefish Fishery, the Rock Lobster Fishery and the Lakes and Coorong Fishery. The main fishing gear types that are used to target snapper are handlines and longlines since the use of haulnets for taking snapper was prohibited in 1993. Commercial fishing vessels are generally 5-8 m in length and equipped with GPS systems for fine-scale navigation and echo sounders to find specific fishing drops. Handlines have been the dominant gear type whilst historically the most significant longline fishery was in northern Spencer Gulf between Whyalla and Port Pirie, and north of Point Lowly.

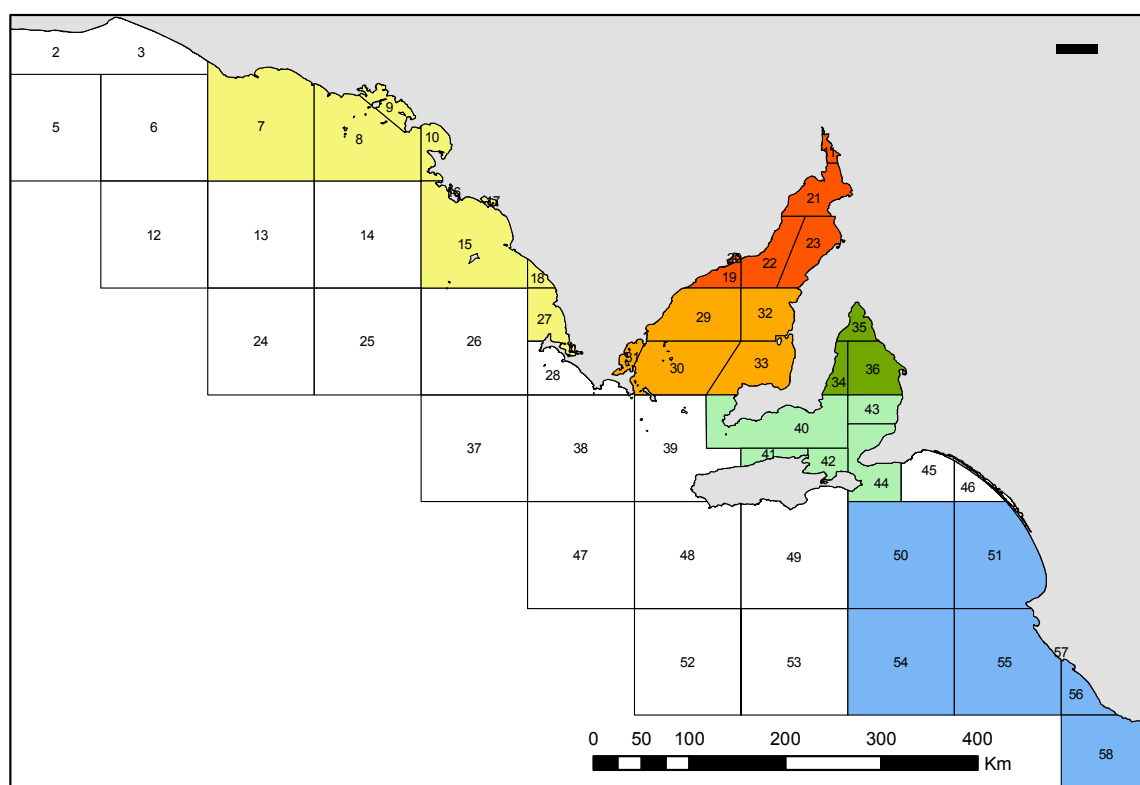


Fig. 2.1 Map of South Australia showing the Marine Fishing Areas that are recognised in the administration of the Marine Scalefish Fishery. The six regions that are considered in this stock assessment of the snapper fishery are indicated, i.e. Northern Spencer Gulf (red), Southern Spencer Gulf (orange),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

Snapper catches in SA have demonstrated considerable inter-annual variation. Typically they have increased and decreased in cycles over periods of a few years that strongly suggest that the biomass varies cyclically. Such variation in biomass reflects the consequence of natural demographic processes. The age structures of fishery catches have revealed 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). The total catch and CPUE of the fishery tend to vary according to the numbers of strong year classes and their ages in the population at that time (McGlennon and Jones 1997). For example, poor recruitment between 1979 and 1986 caused a decline in the handline catch in Northern Spencer Gulf between 1990/91 and 1994/95, as earlier strong year classes became less available. Furthermore, there was a significant decline in the longline catch in 1998/99, which dropped to 40% of that of the previous year, causing a significant drop in CPUE. This drop most likely reflected the decline in abundance of the 1979 year class that had sustained this sector for numerous years (McGlennon and Jones 1999). Alternatively, the recovery of the snapper fishery through the mid to late 1990s and early

2000s seems to be largely attributable to the particularly strong year class that recruited as 0+ fish in 1991 (Fowler 2000, 2002, Fowler et al. 2003, 2005, 2007).

The sizes of fish captured in the fishery relate, at least partly, to the selectivity of the two major gear types. Snapper first recruit to the handline fishery from the age of 3 years and are likely to be fully recruited by 5 years of age. Vulnerability to handlines decreases from the age of about 12 years and size of around 80 cm CFL, which means that few fish older than 15 years are taken with this gear (McGlennon and Jones 1997). However, such older fish are still targeted in the longline fishery and are vulnerable at ages greater than 12 years, and continue to be fished even until greater than 30 years of age (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).

There is also substantial seasonal variation in the handline fishery. Effort is higher between November and January when spawning aggregations are targeted. The sizes of fish at this time may indicate the arrival of non-resident fish from non-Gulf waters (McGlennon and Jones 1997, Fowler 2000). The proportion of fish involved in this migration appears to increase dramatically at about 9 years of age. It has been proposed that some fish migrate back to the continental shelf each year, and that the proportion that remain in Gulf waters increases from about 12 years of age and appears complete by about 15 years of age (McGlennon and Jones 1997). Thus, this life history model involves complex, age-related migration.

2.3 Management Regulations

Current regulations for taking snapper by the commercial sector involve both input and output controls. The three commercial fisheries with access to snapper are limited-entry fisheries, which limits the number of commercial operators who can target them. There are also several gear restrictions. Snapper cannot be taken in fish traps, whilst the use of all nets, including haulnets and large mesh gill nets, to target snapper was prohibited in 1993. Commercial fishermen who use longlines are restricted to using a maximum of 400 hooks per day, whilst handline fishers are also restricted with respect to the numbers of handlines and number of hooks per line that can legitimately be used. There is a minimum legal length of 38 cm total length (TL). There is also legislation which imposes a 50 kg trip limit on the Southern and Eastern Scalefish and Shark Fishery.

The recreational snapper fishery is regulated by a combination of size, bag and boat limits. The minimum legal length of 38 cm TL also applies to this sector. The bag and boat limits vary geographically and with fish size. 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 complete seasonal closure per year. This resulted from significant management concern and action that was taken in the late 1990s. In 1998/99 there was a substantial decline in the longline catch in Northern Spencer Gulf, to 40% of that of the previous year and to the lowest level since 1981/82. This decline 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 (summarised by 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 then 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 between the dates of 1st to 20th August and the second between the 6th and 25th November. Similar regimes of seasonal closures were also used in both 2001 and 2002. However, in 2003, the August closure was discontinued and the November closure was extended for the entire month. This protocol of a single, month-long closure throughout November was maintained in both 2004 and 2005. The effectiveness of the closures was then assessed in mid 2006. It was concluded from consideration of commercial catch and effort data at several time 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 (Fowler and McGarvey 2006). As such, the month-long fishery closure has also been implemented in each November since 2006.

2.4 Biology

Genetic Stocks

The snapper is a member of the family Sparidae. It is widely distributed throughout the 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 18°S 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 from 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, with the division occurring in the waters located west of the River Murray mouth (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 numerous 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. 1989, 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 do 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).

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 initial life history model for this species, which involves significant age-related fish migration (McGlennon and Jones 1997). It 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 during which they are highly 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 derives from age-related migration from numerous different regions. This 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, Fowler et al. 2005b). That study provided some provocative data from which a new life history model was developed. 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 the State waters. Once this happens their subsequent movement appears to be limited.

The otolith chemistry study suggests that most fish, regardless of where they were captured, had a common origin. This would indicate why there is no 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).

Growth, Longevity and Age Structures

Transverse sections of the sagittae of adult snapper from SA generally display clear incremental patterns of opaque and translucent zones, which form annually and so can be used to 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 2000-2007. 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.

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 the 0+ fish (McGlennon and Jones 1997; Fowler 2000, 2002; Fowler et al. 2003, 2005). 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. The second strong year class that recruited in 1997 has contributed significantly to all the regional fisheries since 2000 (Fowler 2002; Fowler et al. 2003, 2005, 2007).

Reproductive Biology

Analysis of gonads indicates that South Australian snapper are multiple batch spawners that have indeterminate fecundity and asynchronous oocyte development (Fowler unpublished data, Saunders 2009). 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 Northern Spencer Gulf through the years of 2005-2008 (Saunders 2009). Intensive sampling of adult fish throughout this period has suggested that gonad development commences in October but spawning does not start until late November. Spawning activity peaked throughout December and then declined in January and was finished by early February. It is likely that gonad development and spawning varied to some extent amongst the other geographic regions. The timing appears to be approximately one month later in Southern Spencer Gulf (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. 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 Northern Spencer Gulf ranged from 12,750 to >1,000,000 and up to

551,000 oocytes in Southern Spencer Gulf. In both regions batch fecundity increased with fish size, weight and ovary size.

In South Australia, fish of size >80 cm caudal fork length (CFL) and 15 years or older can be quite numerous in the two northern gulfs (Fowler 2002, Fowler et al. 2003). However, there is some ambiguity about their reproductive viability and contribution to egg production. Some sources in the aquaculture industry have suggested that older 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 of the reproductive contribution of the older fish has been considered to some extent for South Australian fish. The results clearly suggested the likelihood that such older fish do continue to be involved in spawning activity. Ovaries with advanced yolked oocytes and post-ovulatory follicles were obtained from fish that were up to 25 years old, while some fish with hydrated oocytes were up to 22 years of age. 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 2mm 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 SL when they are capable of settlement and becoming demersal juveniles (Fukuhara 1985, Tanaka 1985, Fowler and Jennings 2003). The spatial distribution of snapper eggs has only been explored for northern Spencer Gulf (i.e. north of 34°S). This was done on two occasions as part of attempts to estimate spawning biomass using the daily egg production method (McGlennon and Jones 1999, Fowler 2002). The distribution pattern on both occasions was patchy, and suggested distinct spawning hotspots. Some of these were consistent between sampling occasions such as near Franklin Harbor, whilst there were considerable differences between years. From the hydrodynamics in Northern Spencer Gulf (Tronson 1974, Bullock 1975), larvae are most likely to be retained in that region than to be advected southwards.

The patterns of distribution and abundance of the 0+ fish throughout Northern Spencer Gulf, based on an annual recruitment survey, have now been documented for the period of 2000 to 2010 (Fowler and Jennings 2003, Fowler et al. 2005, Fowler et al. 2007). Recruitment is highly variable and until recently was thought to be related to sea surface temperature (Fowler and Jennings 2003, Fowler et al. 2007). This is examined further in this report in Chapter 6. The new recruits were distributed consistently between 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 the small fish on a planktonic diet, particularly

copepods, which aggregate in such benign conditions. In Japan, the 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).

Aspects of the early life history of the 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 have clear increments that form daily from the third day after hatching, as well as a clear settlement mark. Therefore, age and pre-settlement duration could be 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 that take snapper in SA have been required to submit, on a monthly basis, a catch return that relates their catch and effort data for the preceding month. Such data now provide a data time series that constitutes the most fundamental dataset available as an indicator of fishery status in this fishery. These commercial fishery statistics are examined here at three spatial scales; State-wide, regional and Marine Fishing Area (MFA). In this chapter the data were examined qualitatively whereas in Chapter 8 they were used to calculate general fishery performance indicators and compared against limit reference points. Furthermore, the catch and effort data reported here were also used in the fishery assessment model, SnapEst, to calculate time-series of output parameters that relate to population processes and to fishery status (Chapter 7). These output parameters are assessed against limit reference points to indicate the status of the fishery (Chapter 8).

3.2 Methods

For this stock assessment, data from fishers' catch returns were accumulated across fishers to provide regional, annual totals of catch and effort by gear type, which were then accumulated into State-wide totals for each financial year until 2008/09. The data presented below at the State-wide level are 'total catch' and 'targeted effort'. '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 rather than the five regions considered previously, with the South East region considered for the first time. The regions and their component MFAs are identified in Fig. 2.1 and Table 2.2. For each region, the estimates of targeted catch, effort and CPUE for handlines and longlines are presented, which are considered to be the most meaningful indicators of stock biomass.

3.3 Results

Trends in State-wide estimates of catch and effort

The estimates of State-wide 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). The previous cycle to the current one was from 1994/95 to 2003/04 during which catch increased from 223 t to 648 t, before decreasing again to 411 t (Fig. 3.1a). Since 2003/04, State-wide catch has increased to record high levels, reaching 643 t in 2006/07, 743 t in 2007/08 and 786 t in 2008/09. Handline catch has always been the dominant component of total catch (Fig. 3.1a). They have been highly cyclical and have largely driven the trends in total catch. Longline catch has generally been more consistent but since 2003/04 has increased considerably, sometimes contrary to the trend in handline catch. The contribution to total

catch of gear types other than handlines and longlines is now minimal since the use of haul nets for targeting snapper was banned in 1993. In 2008/09, fishers from the Marine Scalefish Fishery dominated the snapper catch, whilst there was a much lower reported catch from the Rock Lobster Fishery and no reported catch from the Lakes and Coorong Fishery (Table 3.1).

Targeted commercial effort decreased considerably between the early-mid 1980s and 1994/95, but has since become more stable (Fig. 3.1b). Between 1983/84 and 2007/08, handlines were the dominant gear type. However, longline effort increased by 34.2% in 2008/09, making longlines the dominant gear type for the first time in the history of the fishery. Fishers from the Marine Scalefish Fishery accounted for the majority of targeted fishing effort (Table 3.1).

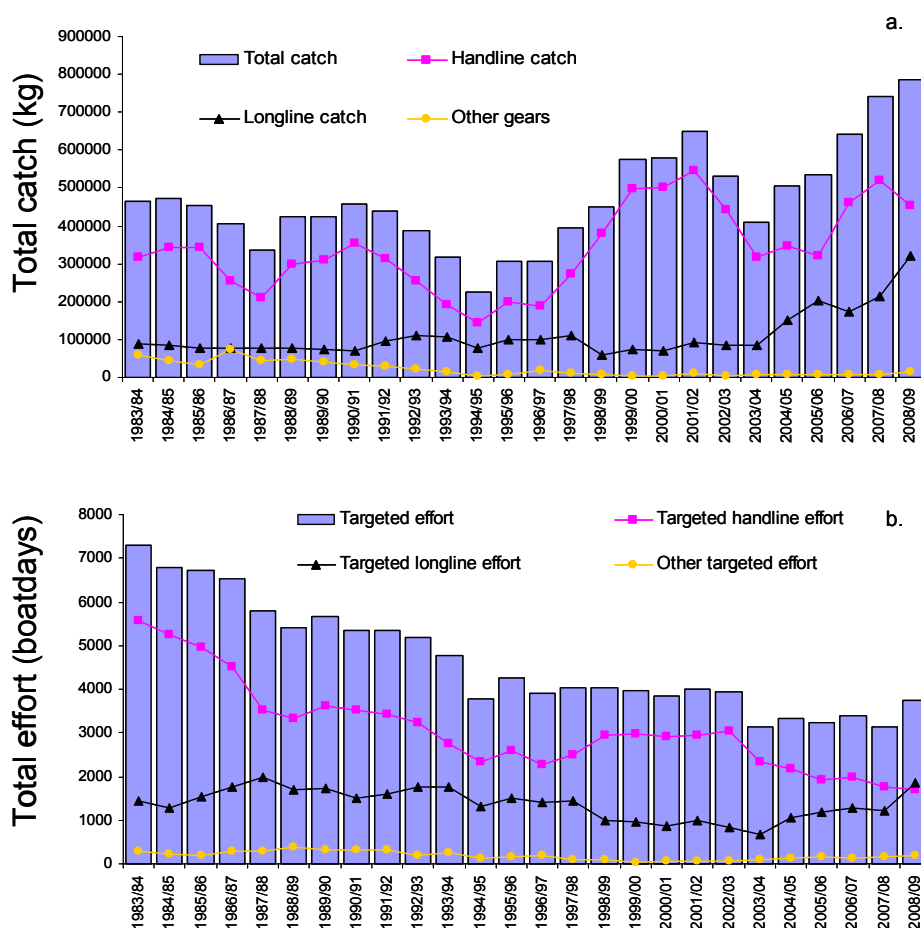


Fig. 3.1 a. Total commercial catch of snapper by gear type from 1983/84 to 2008/09; b. annual estimates of targeted fishing effort by gear type for the same time period.

Regional Analysis of Catch and Effort Statistics (1983/84 – 2008/09)

The division of the total, annual, State-wide commercial catch of snapper into its regional components is presented in Fig. 3.2. These data show that the variation in total catch differed amongst regions. NSG

was the most significant region in the fishery from 1983/84 to 2003/04, but has since dropped considerably. Alternatively, since 2004/05, SSG has been the dominant regional contributor to total catch. Also, in 2007/08 and 2008/09 catch has increased dramatically in NGSV whilst in the latter year the WC has recorded its highest ever catch. The most dramatic recent changes have been in the SE where catch has increased dramatically to >100 t.yr⁻¹. Only in SGSV has catch been relatively stable for the past 15 years or so. The following section provides a regional analysis of targeted catch, effort and CPUE.

Table 3.1 Contributions in 2008/09 of the three commercial fisheries with access to the snapper stocks, i.e. the Marine Scalefish Fishery (MSF), the Rock Lobster Fishery (RL) and the Lakes and Coorong Fishery (L & C) to the total reported catch and targeted effort.

Fishery	Number of fishers reporting snapper catch	Total catch (t) of snapper (% of total)	Targeted effort (boatdays) (% of total)
MSF	201	745.5 (96.0)	3,562 (94.7)
RL	33	31.2 (4.0)	199 (5.3)
L & C	0	0	0
Total	234	785.7	3,761

Northern Spencer Gulf

Handline Fishery

The targeted handline catch of snapper was at record high levels between 1998/99 and 2002/03 with the highest annual catch of 301.4 t taken in 1999/00 (Fig. 3.3a). However, it has decreased considerably since then, dropping to only 88.1 t in 2005/06, i.e. a drop of 70.8% in six years to the lowest handline catch in this region since 1983/84. Since then there has been a marginal increase back to 129 t in 2008/09. Targeted handline fishing effort has also decreased since 1998/99, particularly since 2002/03 when it fell from 1,748 to 592 boatdays, i.e. a drop of 66% (Fig. 3.3b). The targeted catch per unit effort (CPUE) increased from a local minimum in 1994/95 to a peak in 1999/00, before gradually declining to a second minimum in 2005/06. Since then there has been a large increase in CPUE, during which the consecutive years of 2006/07, 2007/08 and 2008/09 provided the three highest estimates of handline CPUE ever recorded for this region.

Longline fishery

Targeted longline catch of snapper varied between 39.4 and 80 t until 1997/98, but has subsequently fallen to historically low levels with only 12.2 t taken in 2008/09 (Fig. 3.3c). Longline fishing effort decreased dramatically between 1997/98 and 2006/07 from 1,123 to only 69 boatdays, i.e. a reduction of 94% in nine years, but has marginally increased since then (Fig. 3.3d). Targeted longline CPUE increased gradually from the low of 45.5 kgs.boatday⁻¹ recorded in 1998/99 and attained a peak of 117.1 kg.boatday⁻¹ in 2003/04. By 2005/06, it had subsequently dropped again to 52.2 kg.boatday⁻¹, i.e. the

lowest since 2000/01 (Fig. 3.3d). It then increased dramatically, attaining the record level of 177 kg.boatday⁻¹ in 2007/08.

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 2003/04, but then decreased considerably. The catches in MFAs 22 and 23 have been more variable but attained their maxima during the late 1990s and early 2000s. They decreased again to 2005/06 and have only increased marginally since then.

The number of fishers who targeted snapper in MFA 21 declined relatively consistently from 1991/92 to 2004/05, followed by an accelerated reduction (Fig. 3.4). However, in the other two MFAs the number of fishers who targeted snapper in the period of 2003/04 to 2008/09, were marginally lower than through the peak fishing years of the early 2000s.

Southern Spencer Gulf

Handline fishery

The targeted handline catch in SSG has shown considerable variation, particularly since 1994/95 (Fig. 3.5a). It peaked at 222.3 t in 2001/02 before decreasing to 90.0 t in 2003/04. It increased to 146 t in 2006/07 before decreasing considerably again. Targeted handline fishing effort has also demonstrated considerable cyclical variation. It increased from 1994/95, peaked at 821 boatdays in 2001/02 then decreased by 25.2% in 2005/06 (Fig. 3.5b). Targeted CPUE increased dramatically from 41.8 kgs.boatday⁻¹ in 1994/95 to 270.9 kg.boatday⁻¹ in 2001/02 (Fig. 3.5b), but then dropped precipitously in the following year by 49.3% to only 137.3 kg.boatday⁻¹. Since 2002/03, it has increased rapidly to record levels of approximately 350 kg.boatday⁻¹.

Longline fishery

The targeted longline catch in SSG remained a fraction of the handline catch until 2003/04 after which it increased dramatically to 82.7 t in 2004/05 and to 131.9 t in 2005/06 (Fig. 3.5c). Since then, longline catch has been more stable. The relatively higher catches over the past five years are attributable to a substantial increase in fishing effort from 111 boatdays in 2003/04 to 275 boatdays in 2004/05 and to 445 boatdays in 2005/06 (Fig. 3.5d). Thus, longline effort increased by 300% within only two years, before declining marginally in 2007/08 and 2008/09. Targeted CPUE increased gradually through the late 1990s and early 2000s to levels of around 150 kg.boatday⁻¹, but then subsequently increased substantially to approximately 300 kg.boatday⁻¹ in both 2004/05 and 2005/06 (Fig. 3.5d). In recent years it has decreased to 200-250 kgs.boatday⁻¹.

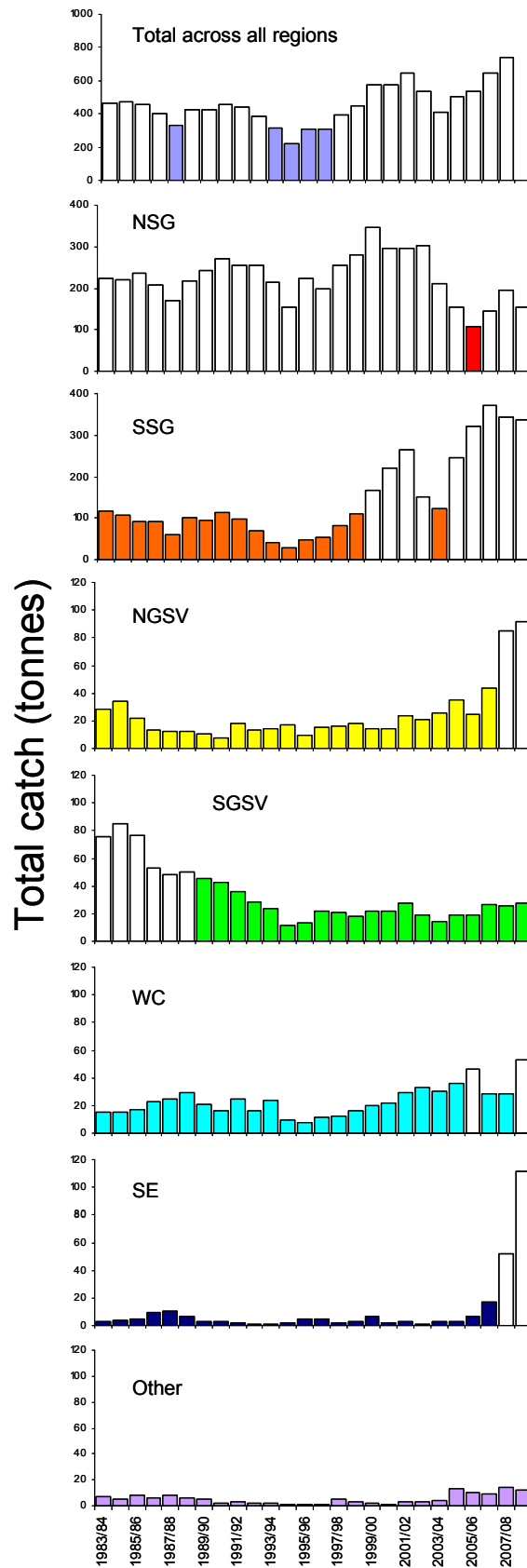


Fig. 3.2 . Total commercial catch of snapper for each of the six main regions and for the 'other' category, for the period from 1983/84 to 2008/09.

Contributions of MFAs

Across the five MFAs that comprise 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 that are located on the eastern side of the gulf (Fig. 3.6), which reached their maxima in 2001/02. Alternatively, the catches from MFAs 29 and 30 were historically very low, but increased through the late 1990s and then peaked in 2006/07 and 2005/06, respectively. Subsequently the catch from MFA 30 has declined. As such, the spatial distribution of catch and effort in SSG has changed over the past five years.

The numbers of fishers who targeted snapper partly reflect the trends in targeted catch. MFAs 32 and 33 have usually supported the highest number of participants, which have either been consistent or declined since the early 2000s (Fig. 3.6). Alternatively, the number of fishers who targeted snapper in MFAs 29 and 30 were low until the late 1990s when they increased considerably, peaking in 2006/07.

Northern Gulf St. Vincent

Handline Fishery

The handline catch in this region dropped to a minimum of only 2.8 t in 1993/94 before increasing to 12.5 t in 2004/05 (Fig. 3.7a). From 2006/07 to 2008/09 the catches were higher than for more than 20 years, attaining a maximum of 47.8 t in 2007/08. These high catches were associated with a considerable increase in effort which peaked in 2007/08 at 276 boatdays (Fig. 3.7b). CPUE was relatively stable until 1995/96, after which it has been more variable (Fig. 3.7b). It increased to 108 kg.boatday⁻¹ in 1998/99, stabilised for a number of years, and then fell to a local minimum of 55.8 kg.boatday⁻¹ in 2005/06. CPUE then increased to the highest ever recorded level of 173.3 kg.boatday⁻¹ in 2007/08. Subsequently, the catch rate has fallen to 96.1 kg.boatday⁻¹.

Longline Fishery

Longline catch has increased since 1999/00, culminating in a maximum of 55.1 t in 2008/09 (Fig. 3.7c). Associated effort increased after 1997/98 reaching a record level of 303 boatdays in 2008/09 (Fig. 3.7d). Longline CPUE has also been highly variable, but nevertheless demonstrated a longterm increasing trend. In 2008/09 it increased to the highest recorded level of 182 kg.boatday⁻¹ in 2008/09.

Contributions of MFAs

The northern reaches of GSV, i.e. MFA 35, has always produced the highest snapper catch and attracted the highest number of fishers targeting snapper (Fig. 3.8). Nevertheless, the catches in all three MFAs that constitute this region have increased considerably in the past few 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 catch of 3.8 t in 1994/95 (Fig. 3.9a). Since then catch increased systematically to a peak of 17.4 t in 2001/02, before declining by 75% to 4.3 t in 2008/09. Targeted handline effort also declined systematically between 1983/84 and 1994/95, before increasing marginally from 1998/99 to 2001/02 (Fig. 3.9b). It has subsequently decreased and for the past seven years has been less than 200 boatdays.yr⁻¹. The handline effort of 83 boatdays in 2008/09 was the lowest yet recorded (Fig. 3.9b). Targeted CPUE increased consistently between 1994/95 and 2001/02, and reached a local maximum of 68.8 kg.boatday⁻¹ in 2002/03 (Fig. 3.9b). From 2005/06 it has been highly variable and in 2007/08 reached the maximum of 98.8 kg.boatday⁻¹. It declined significantly again in 2008/09.

Longline Fishery

Targeted longline catch has consistently been <10 t.yr⁻¹ but since 2004/05 has increased and peaked at 15.0 t in 2008/09 (Fig. 3.9c). Effort was relatively stable at <100 boatdays.yr⁻¹ between 1996/97 and 2003/04, but increased to be considerably higher than 100 boatdays.yr⁻¹ in each year from 2004/05 onwards (Fig. 3.9). Targeted longline CPUE has been highly variable but nevertheless demonstrated a general increasing trend between 1995/96 and 2008/09 (Fig. 3.9). The past three years have produced the three highest annual catch rates yet recorded for this region.

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 considerable increases in catch since 2003/04 have been taken from MFA 44.

West Coast

Handline Fishery

Targeted handline catch increased consistently from a minimum in 1995/96 until 1999/00 and was then quite variable until 2007/08 (Fig. 3.11a). Between 2007/08 and 2008/09 it increased from 5.8 to 21.4 t, i.e. the highest targeted catch ever recorded for the WC. Handline effort has also been quite variable (Fig. 3.11b). It increased between 1995/96 and 1999/00, remained relatively consistent at 150 - 200 boatdays.yr⁻¹ before dropping again in 2007/08. After increasing between 1995/96 and 1999/00, targeted CPUE was quite consistent until 2008/09 when it increased dramatically to 134 kg.boatday⁻¹ (Fig. 3.11b).

Longline fishery

Longline catch was variable until the early 2000s when it increased dramatically to between 14.0 and 27.4 t.yr⁻¹ (Fig. 3.11c). Targeted effort displayed similar variation with high effort through the early 1990s, which dropped through the late 1990s, before increasing again to record levels in the 2000s. It reached the maximum of 472 boatdays in 2008/09 (Fig. 3.11d). Targeted CPUE increased after 1996/97 reaching a maximum of 112.0 kg.boatday⁻¹ in 2003/04 before decreasing considerably over the subsequent five years (Fig. 3.11d).

Contributions of MFAs

Most of the snapper catch has historically come from MFAs 9 and 10, i.e. the two small coastal MFAs that include Denial Bay and Murat Bay (Fig. 2.1). Snapper catch has been most variable in MFA 10, which recorded its highest ever catch in 2008/09 (Fig. 3.12). MFA 27, i.e. Coffin Bay, also demonstrated a significant increase in catch in this year. The number of fishers who targeted snapper in these MFAs has been relatively consistent since the late 1980s.

South East

Handline Fishery

Targeted handline catch in the South East has always been low, before increasing to nearly 10 t in 2006/07 and 2007/08 (Fig. 3.13a). The low catches reflect a low and variable fishing effort level (Fig. 3.13b). CPUE has always been less than 50 kg.boatday⁻¹, but in 2005/06 increased dramatically to 220.2 kg.boatday⁻¹ (Fig. 3.13b). Since then, it has remained above 120 kg.boatday⁻¹.

Longline fishery

Longline catches were always less than several tonnes.yr⁻¹ but in 2007/08, increased to 24.2 t, and then to 88.9 t in 2008/09 (Fig. 3.13c). Longline effort also increased considerably in the past two years to 164 and then to 448 boatdays in 2007/08, respectively (Fig. 3.13d). CPUE has increased rapidly since 2005/06 to 198.4 kg.boatday⁻¹ in 2008/09 (Fig. 3.13d).

Contributions of MFAs

There are eight MFAs that constitute the SE region (Fig. 2.1). However, MFA 51, i.e. the one adjacent to the southern Coorong has produced the most catch, particularly over the past three years (Fig. 3.14). As such, there was a substantial increase in the number of fishers who targeted snapper in this MFA in 2008/09.

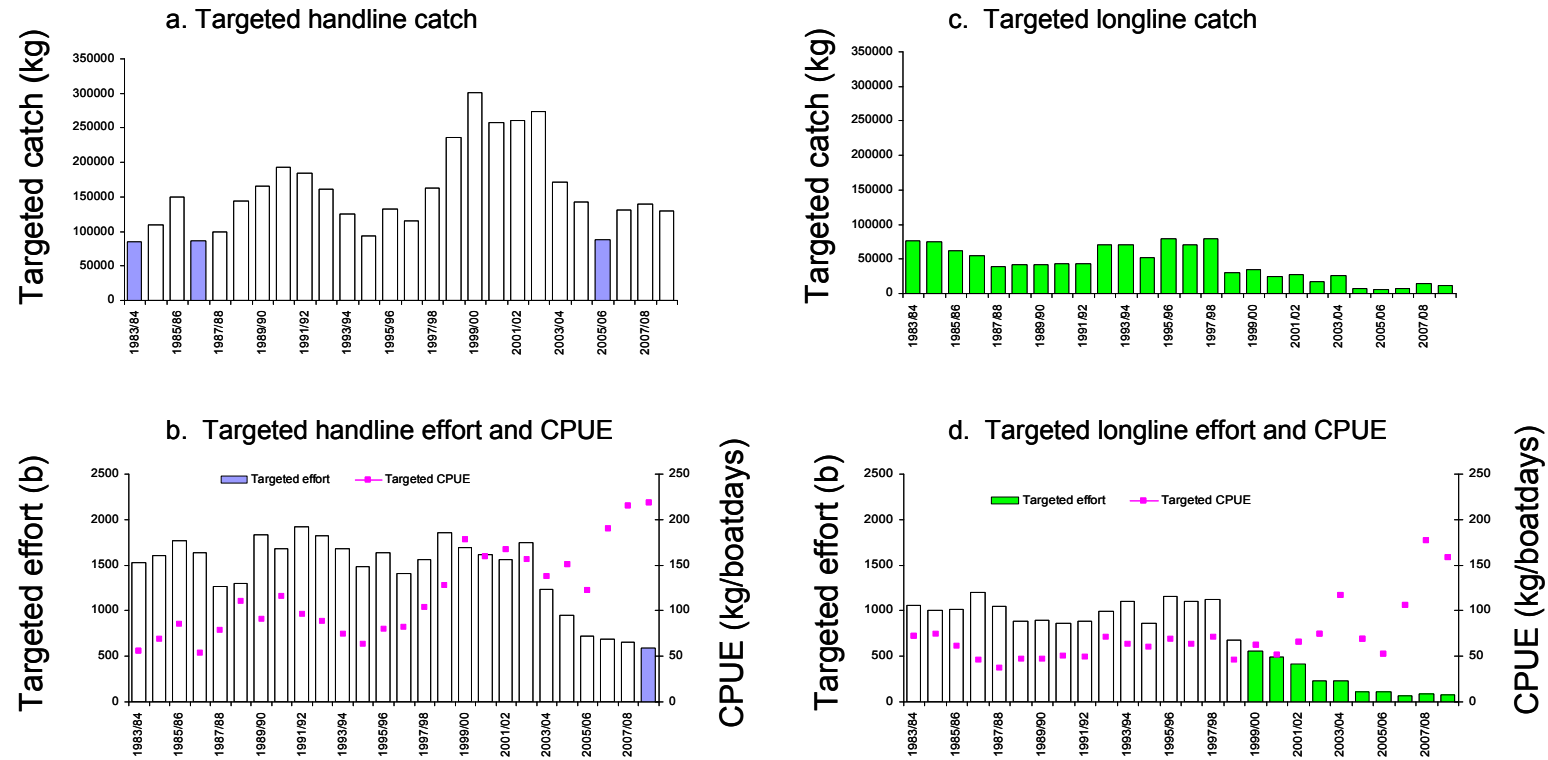


Fig. 3.3 Northern Spencer Gulf. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted effort and CPUE in the commercial longline sector.

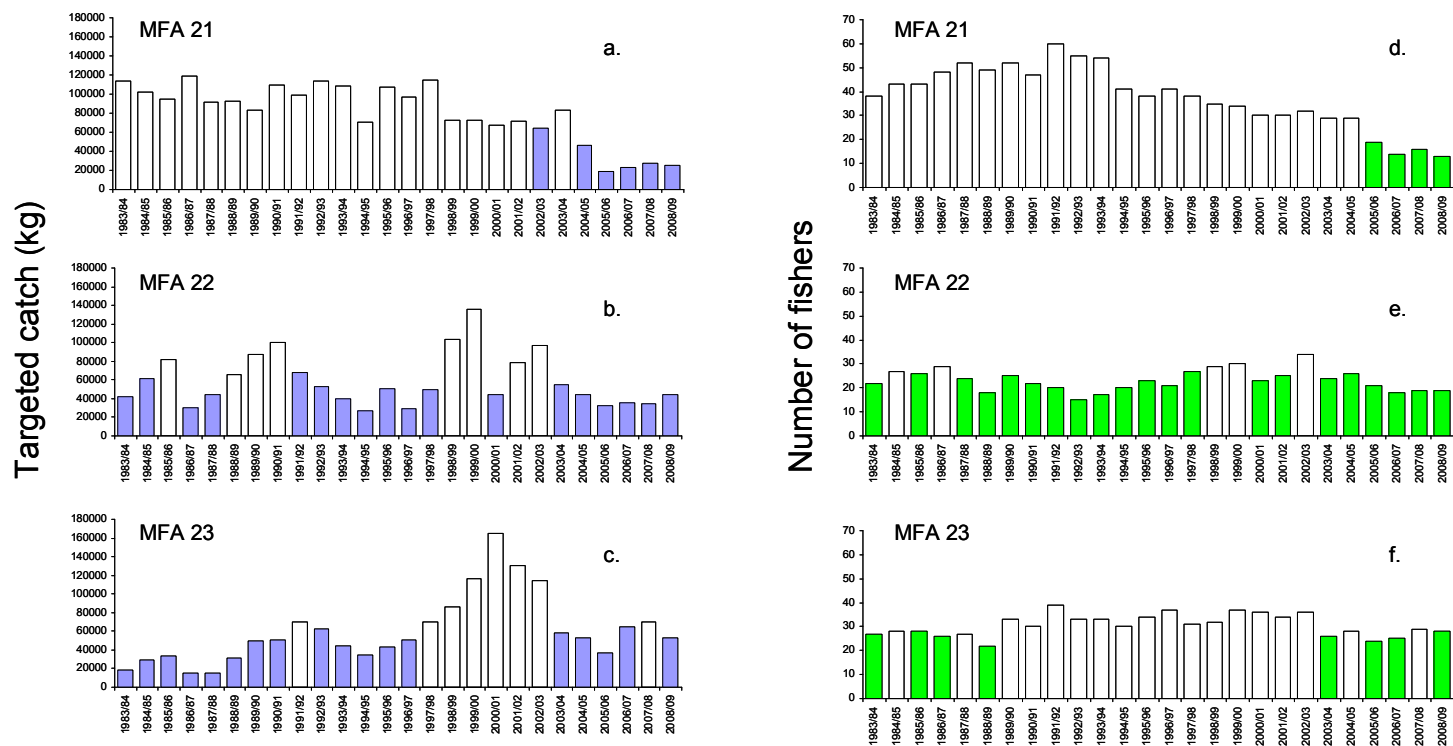


Fig. 3.4 Northern Spencer Gulf. a-c. Historical record of combined targeted handline and longline catch for MFAs 21, 22 and 23; d-f. Historical record for the number of fishers who targeted snapper in MFAs 21, 22 and 23.

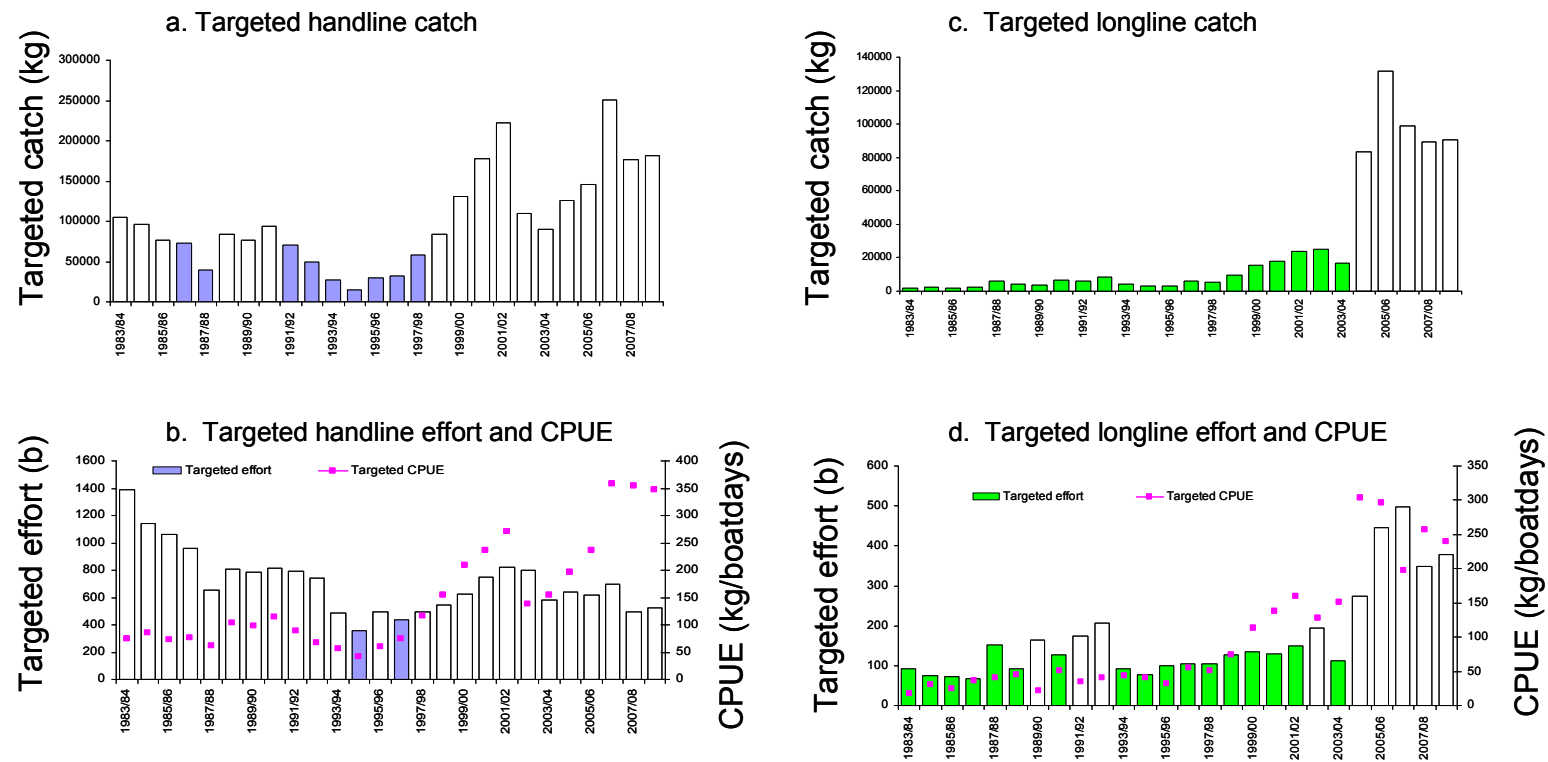


Fig. 3.5 Southern Spencer Gulf. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of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

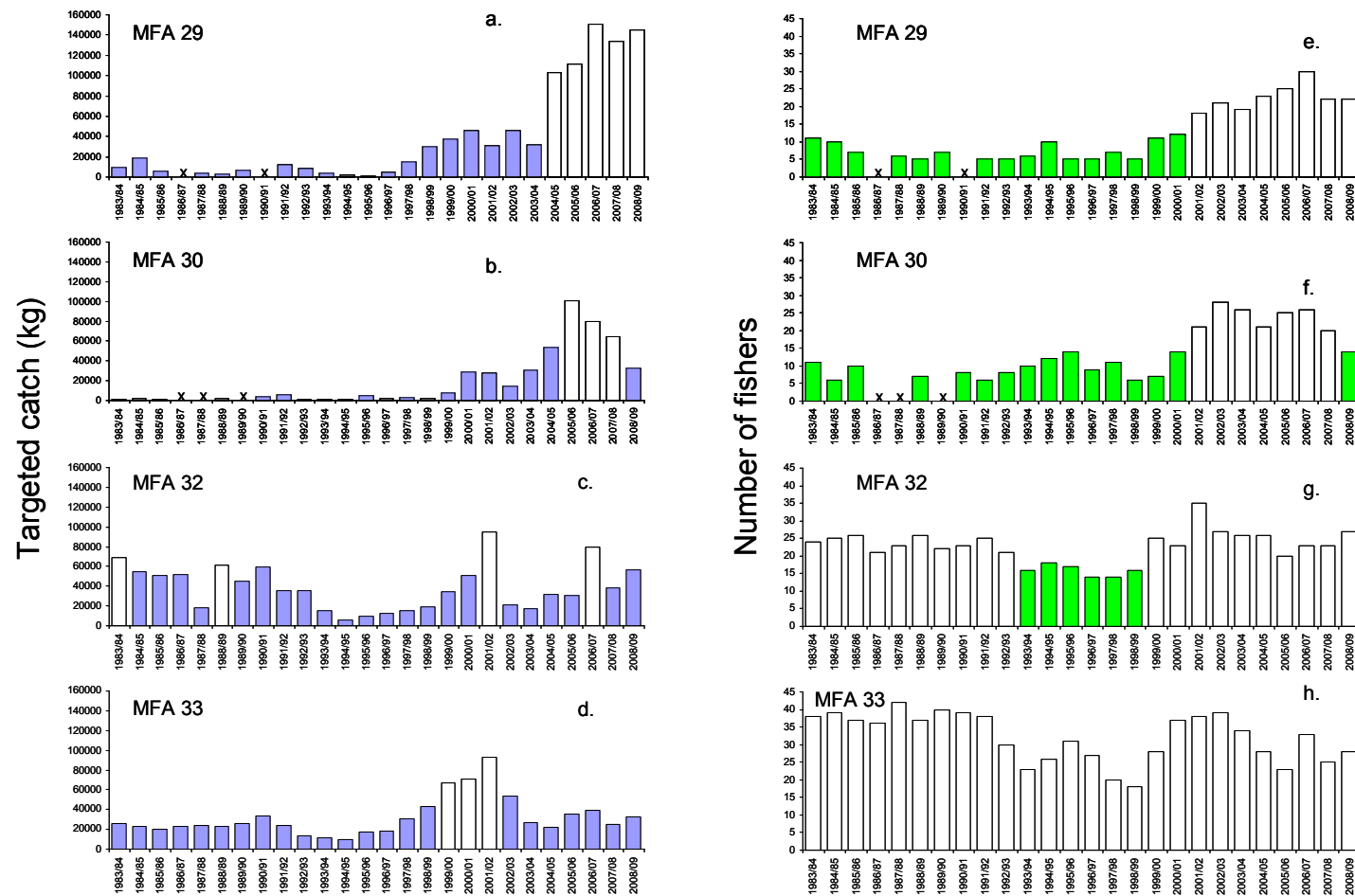


Fig. 3.6 Southern Spencer Gulf. a-d. Historical record of combined targeted handline and longline catch for MFAs 29, 30, 32 and 33; e-h. Historical record for the number of fishers who targeted snapper in MFAs 29, 30, 32 and 33. Crosses indicate confidential data, i.e. <5 fishers).

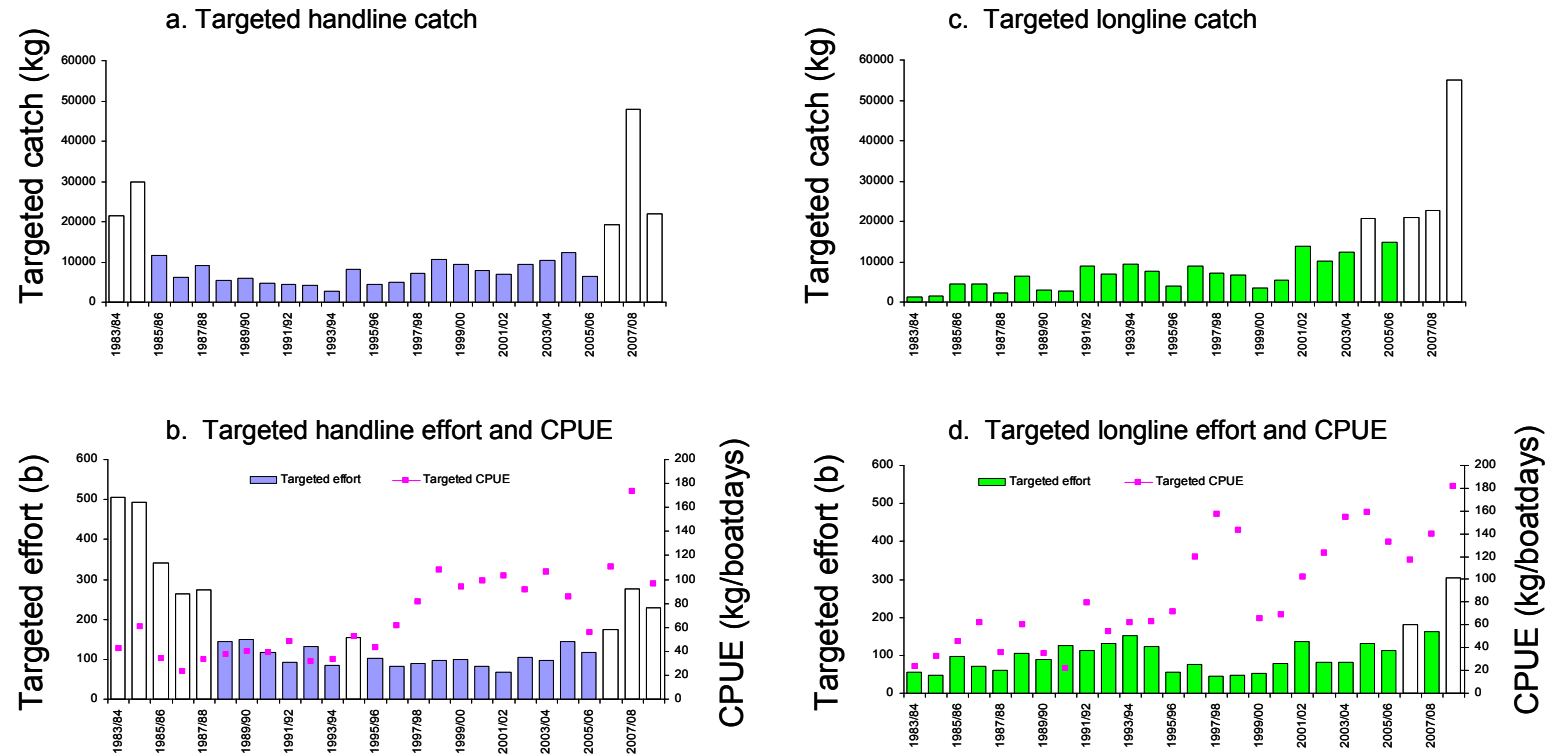


Fig. 3.7 Northern Gulf St. Vincent. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record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

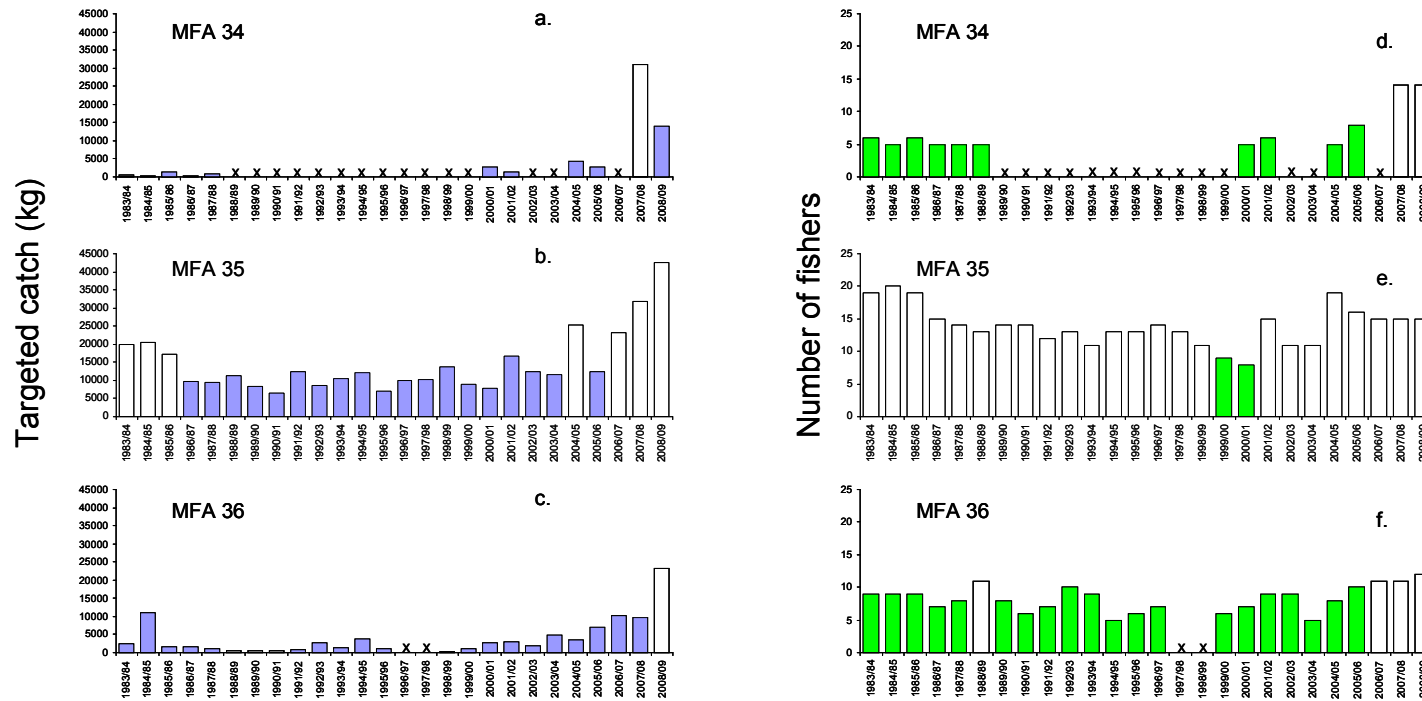


Fig. 3.8 Northern Gulf St. Vincent. a-c. Historical record of combined targeted handline and longline catch for MFAs 34, 35, and 36; d-f. Historical record for the number of fishers who targeted snapper in MFAs 34, 35 and 36. Crosses indicate confidential data, i.e. <5 fishers).

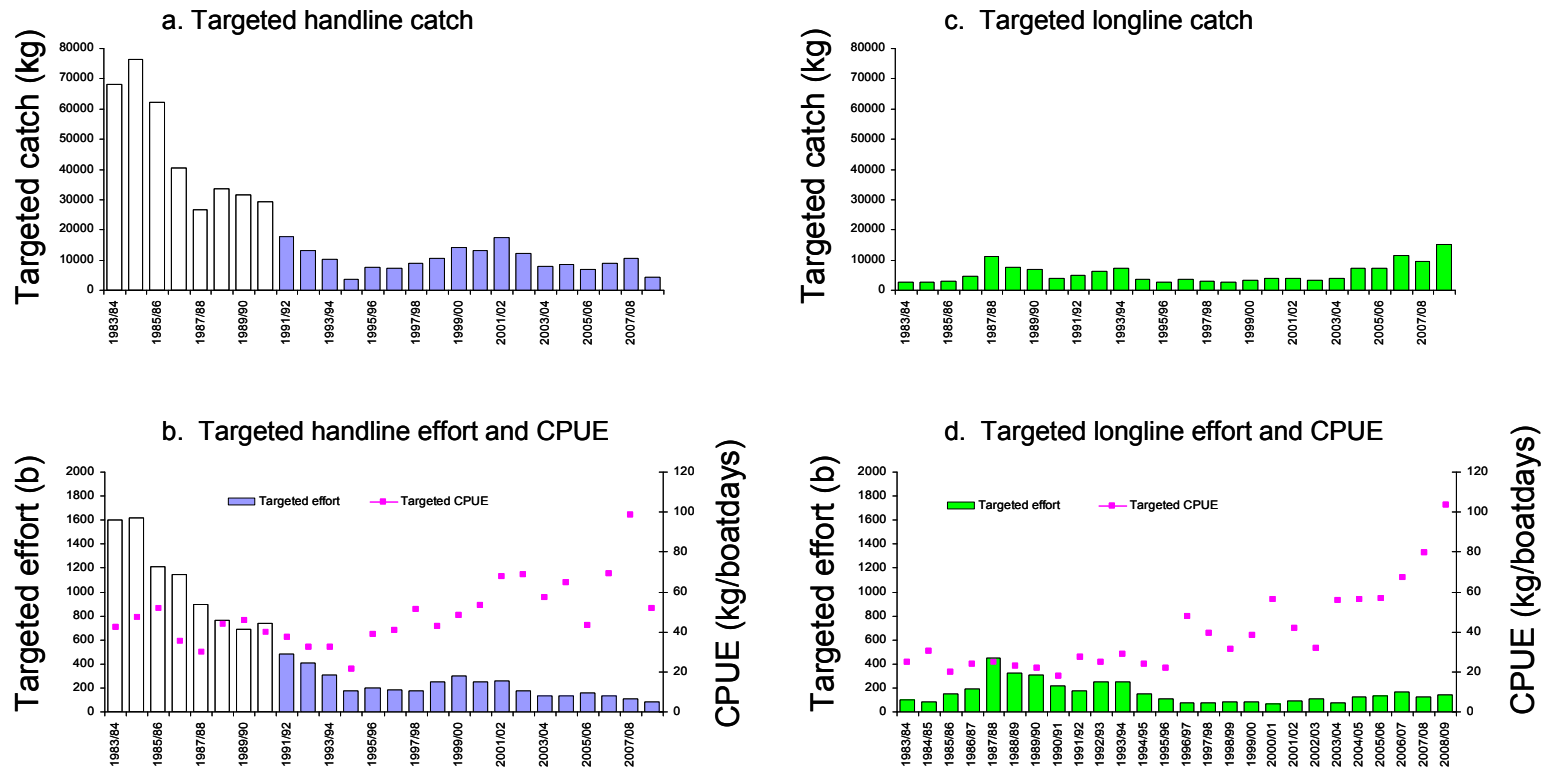


Fig. 3.9 Southern Gulf St. Vincent. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record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

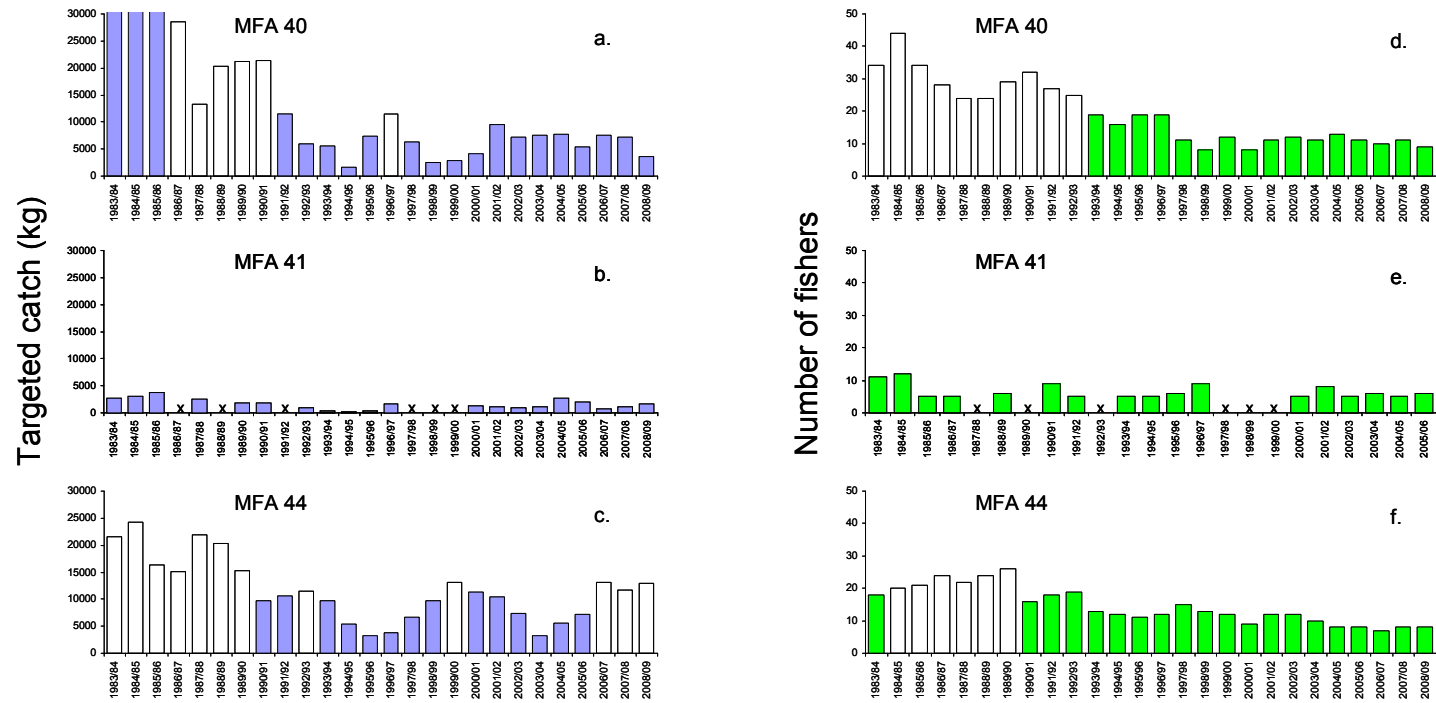


Fig. 3.10 Southern Gulf St. Vincent. a-c. Historical record of combined targeted handline and longline catch for MFAs 40, 41 and 42; e-h. Historical record for the number of fishers who targeted snapper in MFAs 40, 41 and 42. Crosses indicate confidential data, i.e. <5 fishers).

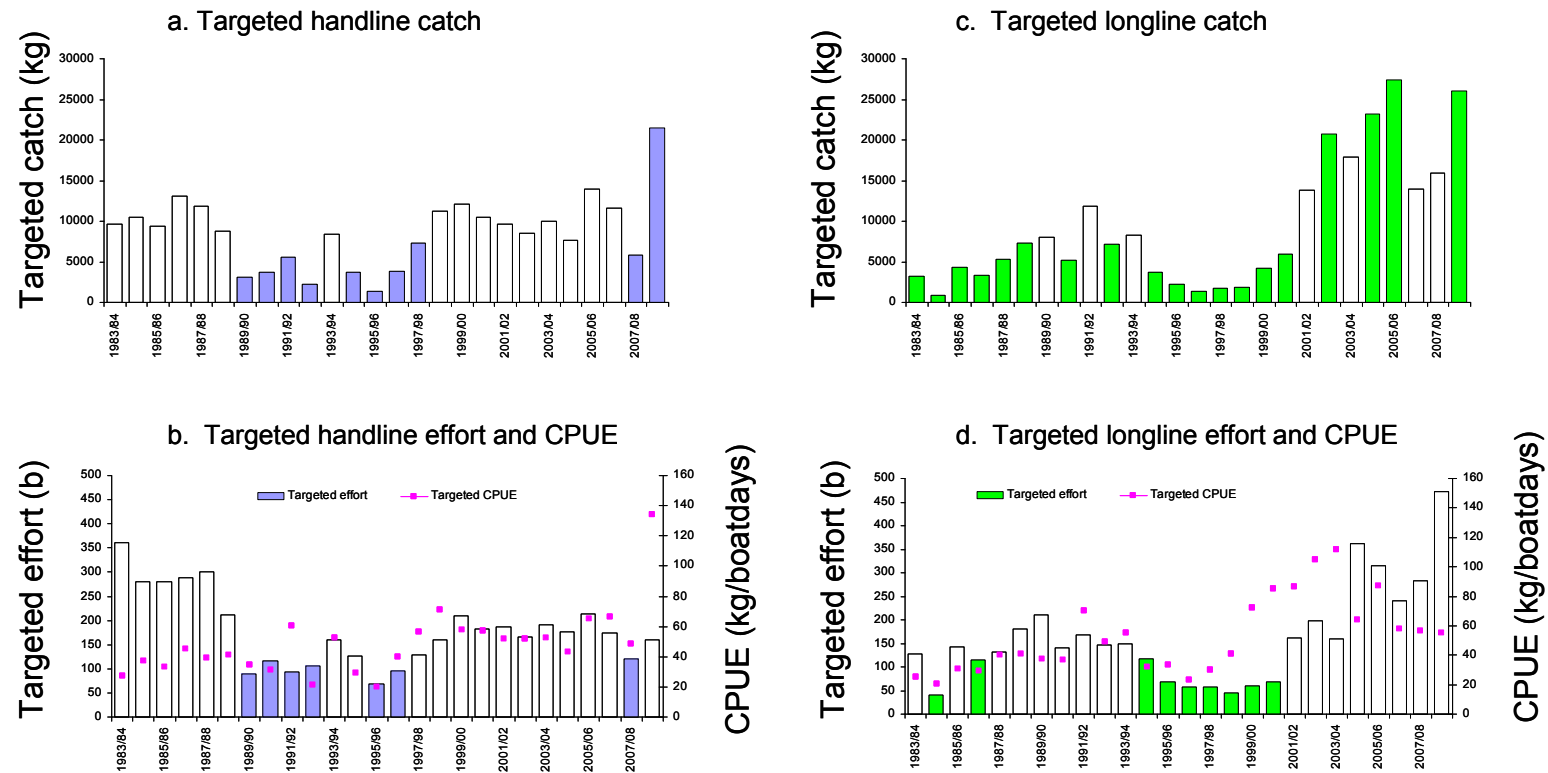


Fig. 3.11 West Coast. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted effort and CPUE in the commercial longline sector.

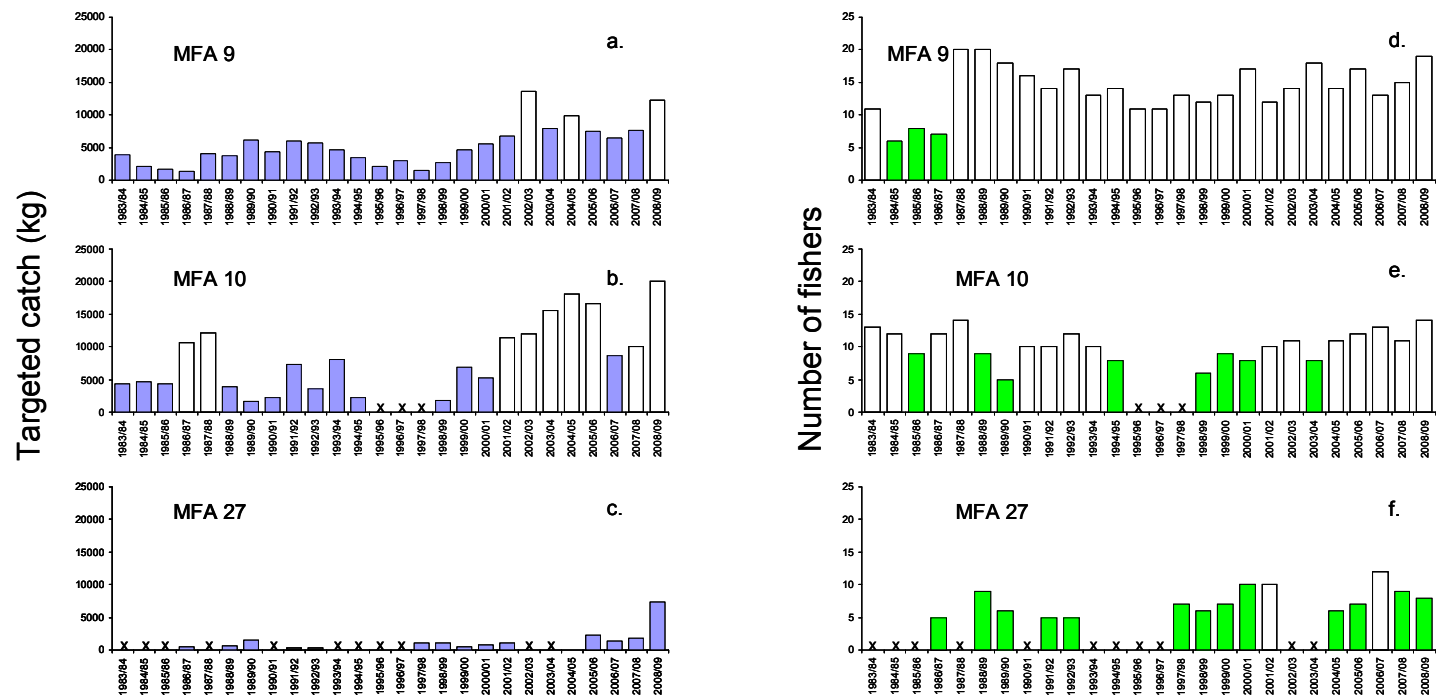


Fig. 3.12 West Coast. a-c Historical record of combined targeted handline and longline catch for MFAs 9, 10, and 27; d-f. Historical record for the number of fishers who targeted snapper in MFAs 9, 10, and 27. Crosses indicate confidential data, i.e. <5 fishers).

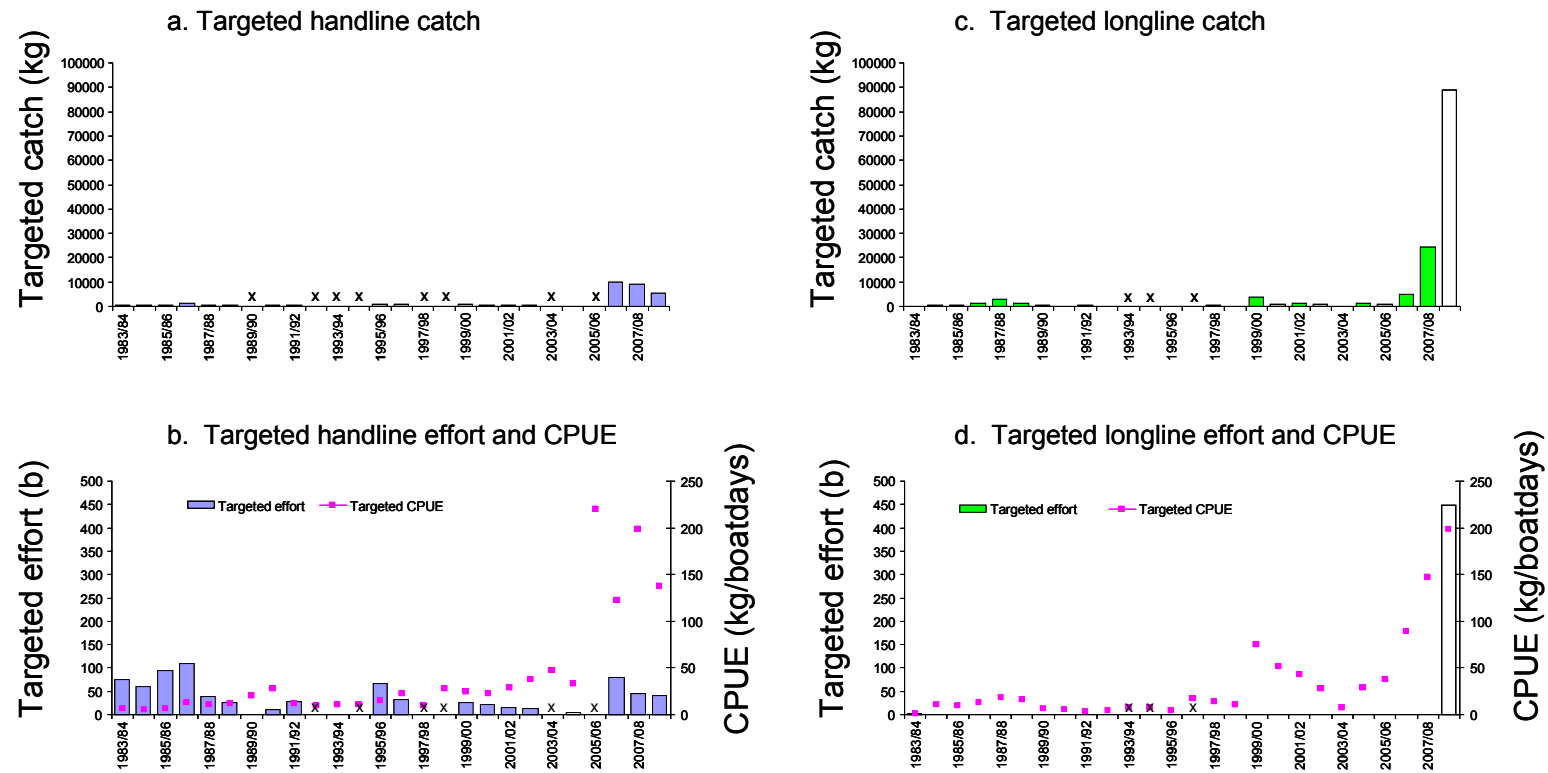


Fig. 3.13 South East. a. Historical record of targeted catch of snapper by the commercial handline sector; b. historical record of the targeted effort and CPUE of the handline sector; c. historical record of targeted catch of snapper by the commercial longline sector; d. historical record of targeted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

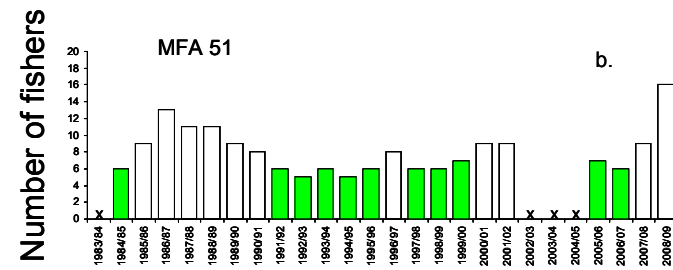
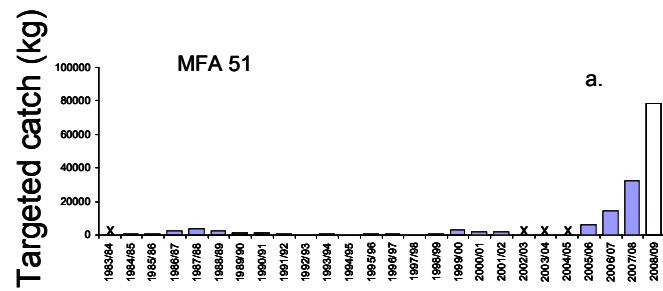


Fig. 3.14 South East. a. Historical record of combined targeted handline and longline catch for MFA 51. b. Historical record for the number of fishers who targeted snapper in MFA 51. Crosses indicate confidential data, i.e. <5 fishers).

Regional Analysis of Catch and Effort Statistics (July –December 2009)

The catch and effort statistics for snapper have normally been considered by financial year (Fig. 3.3 – 3.14). This means that there is a considerable gap between the completion of the last financial year (2008/09), and the delivery of the stock assessment report. As such, it was considered important here to also report on the commercial fishery data from July to December 2009 because of the dynamics in the structure of the snapper fishery. To place the data from 2009 in context, the six monthly regional totals of catch and effort from that year were compared against those from each year from 2005 to 2008.

For NSG, the targeted catch and effort by handline from July – December 2009 were marginally higher than those from the previous three years, although CPUE was marginally lower (Fig. 3.15). The data on catch and effort in the longline sector in 2009 were confidential since less than five fishers had used this gear through the six months of July – December 2009. As such, it is likely that the catch and effort were lower than in the four previous years.

In SSG, the estimates for all of handline catch, effort and CPUE and longline catch, effort and CPUE in 2009 were considerably lower than the estimates for the previous few years (Fig. 3.16).

In 2009, the six-monthly catch and effort estimates for handlines in NGSV were not particularly different from those of the past few years (Fig. 3.17). Alternatively, longline catch, effort and CPUE were all substantially higher in 2009 than the previous few years. Similarly, in SGSV the only obvious differences between 2009 and the previous few years were the higher catch, effort and CPUE for longlines in 2009 (Fig. 3.18).

For the WC, the catch, effort and CPUE from July to December 2009 for both handlines and longlines were not exceptionally different to the previous few years (Fig. 3.19). In contrast, in the SE there were substantial differences between gear types. For handlines, the data were confidential for each of the five years as there were few fishers who worked with this gear. However, for longlines there were substantial increases in targeted catch, effort and CPUE in 2008 and 2009 compared to previous years (Fig. 3.20).

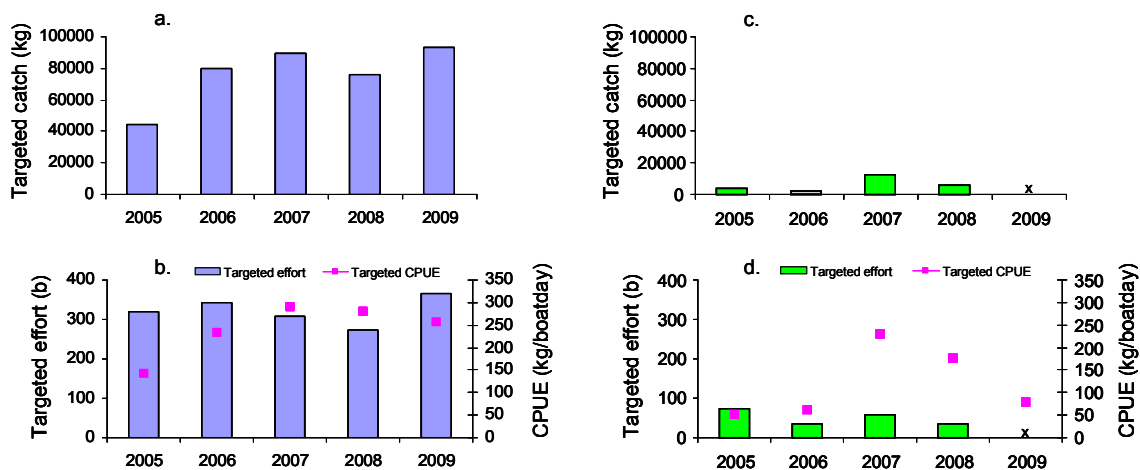


Fig. 3.15 Northern Spencer Gulf. a. Targeted commercial catch of snapper by handlines through the six-month period of July-Dec for each nominated year. b. Targeted commercial effort and CPUE by handlines for July-Dec for each nominated year. c. Targeted commercial catch of snapper by longlines through the six-month period of July-Dec for each nominated year. d. Targeted commercial effort and CPUE by longlines for July-Dec for each nominated year. Crosses indicate confidential data (i.e. <5 fishers).

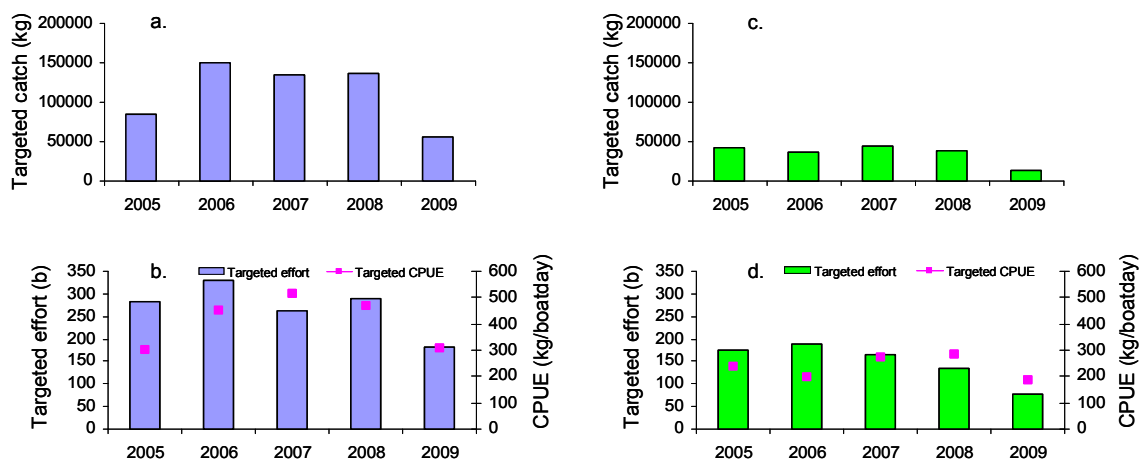


Fig. 3.16 Southern Spencer Gulf. a. Targeted commercial catch of snapper by handlines through the six-month period of July-Dec for each nominated year. b. Targeted commercial effort and CPUE by handlines for July-Dec for each nominated year. c. Targeted commercial catch of snapper by longlines through the six-month period of July-Dec for each nominated year. d. Targeted commercial effort and CPUE by longlines for July-Dec for each nominated year.

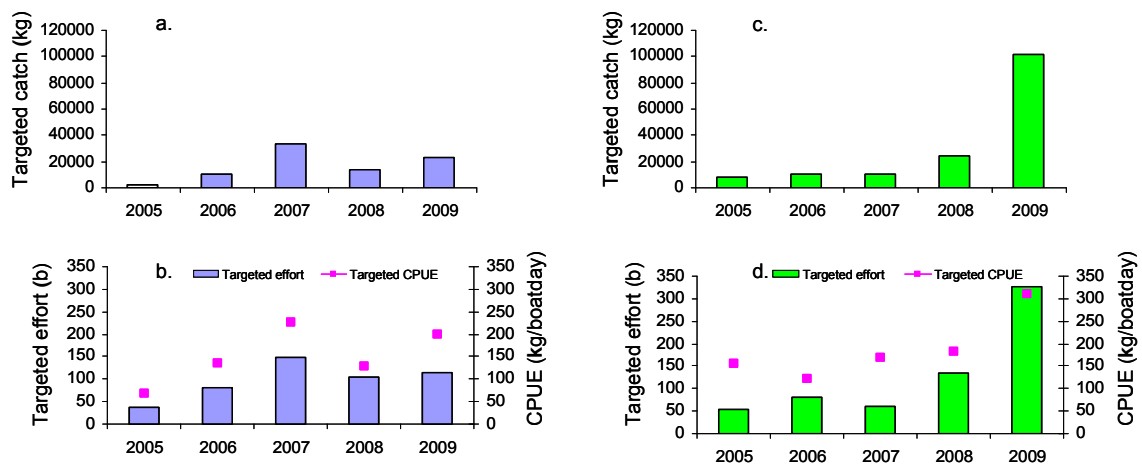


Fig. 3.17 Northern Gulf St. Vincent. a. Targeted commercial catch of snapper by handlines through the six-month period of July-Dec for each nominated year. b. Targeted commercial effort and CPUE by handlines for July-Dec for each nominated year. c. Targeted commercial catch of snapper by longlines through the six-month period of July-Dec for each nominated year. d. Targeted commercial effort and CPUE by longlines for July-Dec for each nominated year.

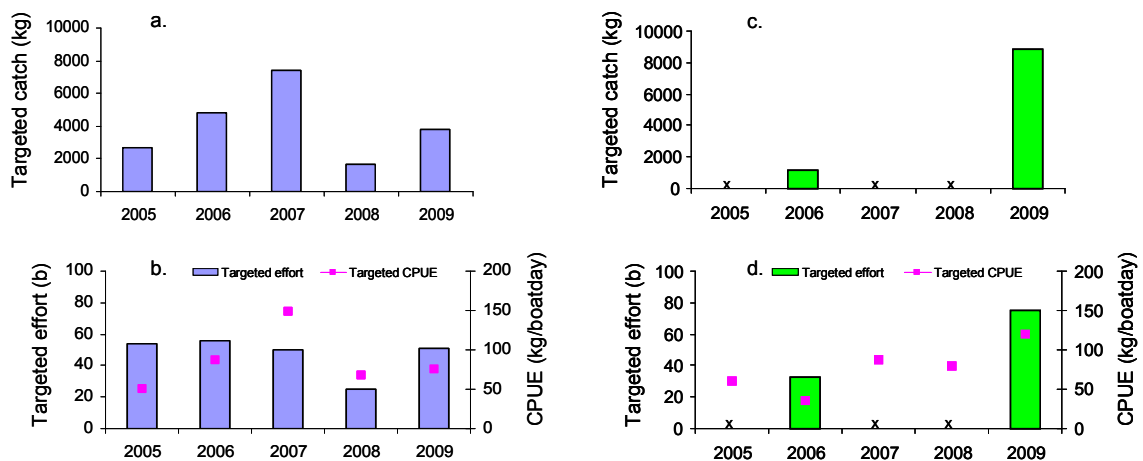


Fig. 3.18 Southern Gulf St. Vincent. a. Targeted commercial catch of snapper by handlines through the six-month period of July-Dec for each nominated year. b. Targeted commercial effort and CPUE by handlines for July-Dec for each nominated year. c. Targeted commercial catch of snapper by longlines through the six-month period of July-Dec for each nominated year. d. Targeted commercial effort and CPUE by longlines for July-Dec for each nominated year. Crosses indicate confidential data (i.e. <5 fishers).

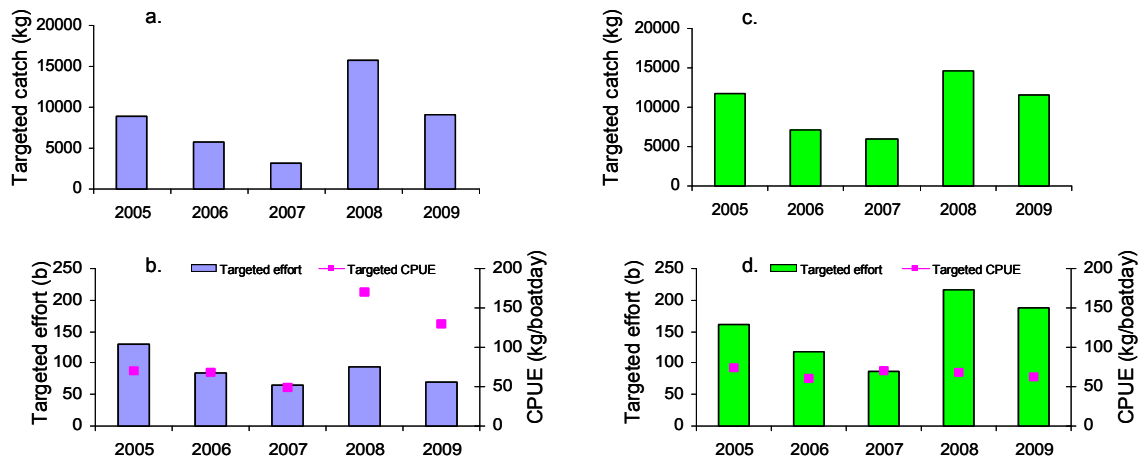


Fig. 3.19 West Coast. a. Targeted commercial catch of snapper by handlines through the six-month period of July-Dec for each nominated year. b. Targeted commercial effort and CPUE by handlines for July-Dec for each nominated year. c. Targeted commercial catch of snapper by longlines through the six-month period of July-Dec for each nominated year. d. Targeted commercial effort and CPUE by longlines for July-Dec for each nominated year.

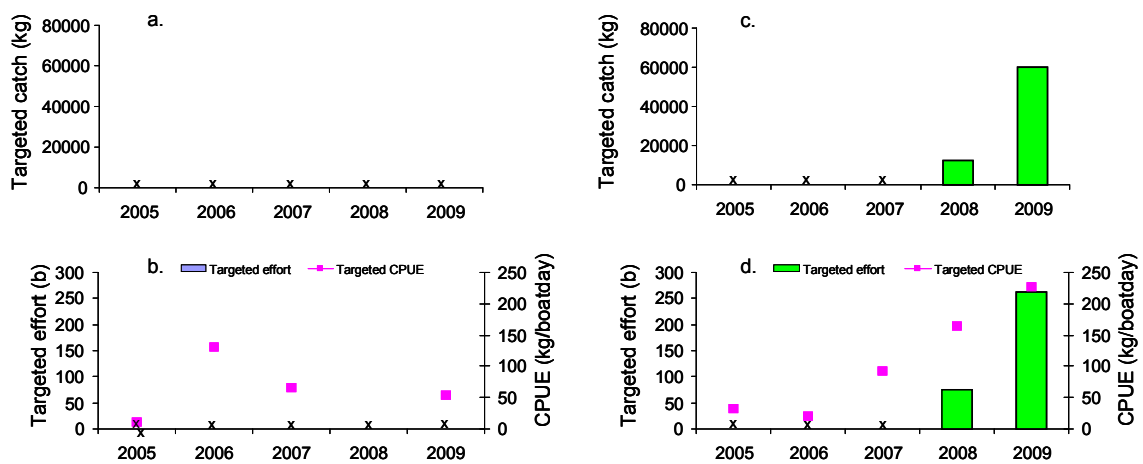


Fig. 3.20 South East. a. Targeted commercial catch of snapper by handlines through the six-month period of July-Dec for each nominated year. b. Targeted commercial effort and CPUE by handlines for July-Dec for each nominated year. c. Targeted commercial catch of snapper by longlines through the six-month period of July-Dec for each nominated year. d. Targeted commercial effort and CPUE by longlines for July-Dec for each nominated year. Crosses indicate confidential data (i.e. <5 fishers).

3.4 Discussion

In 2008/09, the highest-ever commercial catch of snapper of 786 t was reported. This corresponded to the highest recorded level of longline fishing effort from across the State, which was higher than the reported handline catch for the first time. Nevertheless, these record State-wide values were the culmination of different trends in the different regions.

Historically NSG has been the most significant region in the South Australian snapper fishery. Over the 20 years to the early 2000s it contributed 106 to 346 t.yr⁻¹, which was an annual average of 58% of the State's commercial catch. However, since 2003/04, its relative contribution has declined considerably to the lowest level ever recorded. In the early 2000s, this decline was due to the expanding fishery in SSG. However, after 2002/03, the regional catch and effort in NSG also declined. This decline, however, does not appear to have related to declining biomass as, over the past three years, the estimates of catch rate for both gear types have been the highest ever recorded.

The fishery statistics for SSG contrast with those from the NSG. This region now accounts for the highest regional catches of the State having first surpassed NSG in 2004/05. Since then, both handline and longline catches and catch rates have increased to record levels. These record catches in the mid-late 2000s primarily reflect a significant increase in longline fishing effort particularly in MFA 29, an area that had previously attracted little attention from fishers. As such, it appears that the significance of SSG during the 2000s relates to the development of a new fishing area. Nevertheless, the fishery statistics for July – December 2009 indicate surprising reductions in catch, effort and catch rate relative to the same six month period in the previous few years. Furthermore, such reductions were not observed in any of the other regions.

Historically, GSV has produced much lower snapper catches than has SG. The annual catches from NGSV and SGSV declined to very low levels in the mid 1990s and then remained low even during the late 1990s when catches in SG recovered and ultimately increased to record levels. However, in the late 2000s there has been a recovery in NGSV. Catches increased slowly from 2000, but in 2007/08 and 2008/09 increased considerably, reflecting increases in both handline and longline fishing effort and dramatic increases in CPUE. Such data are indicators of a substantial increase in the biomass of snapper available to fishers. Smaller increases in longline catch and CPUE for SGSV suggest at least some marginal increase in biomass in that region as well. The recovery in the GSV fishery in the late 2000s has occurred contemporaneously with the decline in the fishery of NSG.

The WC snapper fishery demonstrated the same decline that occurred in the gulfs during the early 1990s. From then, the catches and catch rates have demonstrated a long, protracted recovery that has ultimately culminated in 2008/09 producing the highest catch that was ever recorded for this region. The relatively

slow changes in catch and catch rates suggest that biomass was very low through the early 1990s but has subsequently recovered to relatively high levels through the 2000s.

Whilst the WC has always attracted considerable fishing effort, the SE region has generally not attracted concerted commercial fishing effort. However, since 2005/06 there has been an exponential increase in longline effort that has resulted in fishing catches in recent years of up to 100 t.yr⁻¹. There are insufficient fishery data available to determine whether this recent increase reflects the opening up of a fishery ground that has supported a considerable abundance of snapper or whether there has been a considerable increase in the biomass available in MFA 51 that produces the bulk of the catch of this region.

4. ANALYSIS OF THE RECREATIONAL FISHERY '

4.1. Introduction

It is now apparent that recreational fishery catches contribute significantly to the total catches and fishing effort for particular types of marine fish species (Henry and Lyle 2003, Coleman et al. 2004), and must be taken into consideration when determining fish stock status and for resolving resource allocation issues. To achieve this requires obtaining robust estimates of recreational catch that can be compared over time, and compared with estimates for the commercial sector. To obtain such statistical estimates of recreational catch and effort requires sampling methods other than the comprehensive logbook system that is generally used by the commercial fishing sector (Jones 2009). As such, different survey methods are used for recreational fisheries that include creel and telephone/diary survey methods.

In South Australia there have been three, broad-scale, recreational fishery surveys. The first was a creel survey that was done through the period of 1994-96 (McGlennon and Kinloch 1997). The two subsequent surveys were State-wide telephone/diary surveys that were done in 2000/01 (Henry and Lyle 2003) and 2007/08 (Jones 2009). South Australia also supports a successful charter boat fishing sector that constitutes a component of the recreational sector. This sector involves a number of licensed charter boat operators whose commercial enterprises are based on taking recreational fishers fishing. Because of the limited number of these operators it is possible to track their fishing activity through logbooks (Knight 2010). Since September 2005 the charter boat operators have been required to submit a monthly log that details their fishing activity throughout the previous month, including information on the spatial distribution of their catch and effort.

The primary objective of this chapter is to provide a summary of the data available on the recreational catch and effort for snapper in South Australian coastal waters, as provided by the three broad-scale, general recreational surveys. Furthermore, this chapter provides a summary of logbook data from the charter boat sector for the period from September 2005 to June 2009.

4.2 Materials and Methods

Creel Survey (1994-96)

This was a large-scale two-year project that provided annual estimates of the catches of recreational boat-fishers in the main fishery areas of SA (McGlennon and Kinloch 1997). The geographic range of the survey covered the three geographic regions of Gulf St. Vincent, Spencer Gulf and the West Coast. Each of these was divided into a number of circuits of boat ramps that were surveyed using the “bus-route” method. This involved researchers travelling around a set of boat ramps and waiting at each ramp for a prescribed period. At each ramp, the number of boat trailers was counted to estimate fishing effort, whilst fishers returning to shore were interviewed to obtain estimates of their catches. These data on catch and effort were used to derive estimates of State-wide total catch and effort (McGlennon and Kinloch 1997). The survey was done for Gulf St. Vincent from April 1994 to March 1995 and for Spencer Gulf and the West Coast from April 1995 to March 1996. The creel survey was confined to major public boat ramps during daylight hours. It largely excluded Kangaroo Island due to the time and cost of travelling there. As such, the estimates of recreational catch and effort represented selected subsets of the overall recreational totals.

National Recreational and Indigenous Fishing Survey (NRIFS) (2000/01)

This was a national recreational survey that was undertaken in 2000 and 2001 for which the methods and results are described comprehensively by Henry and Lyle (2003) and Jones and Doonan (2005). For each state, including SA, there were two primary components to the survey. The first was a telephone interview screening survey that was done through March and April 2000 during which 4,422, randomly-chosen South Australian households were interviewed to determine participation rates in recreational fishing and to provide demographic information about recreational fishers and details of boat ownership. The second component was a diary/telephone survey of numerous households (2,428 diarists) from across the State to record accurate information on recreational effort and catch. The data from both components were expanded to population-wide estimates for the State. Since the diarists involved in the second part of the survey were randomly selected from across the state, the survey represented a more comprehensive census of the total recreational and indigenous catch than the creel survey of 1994-96. Also, the telephone and diary survey included catches from charter boats, which accounted for 1.7% of the recreational fishing effort recorded. Furthermore, because this was a national survey, the estimates of catch and effort included the data from inter-state visitors who had fished in South Australia during the survey period.

The survey structure was based on 26 marine fishing blocks (Fig. 4.1). Unfortunately not all of these blocks aligned perfectly with the South Australian Marine Fishing Areas, but in general there was reasonable similarity to compare with the geographic regions normally considered for snapper in SA (Fig.

2.1). Therefore, it was possible to do an approximate regional comparison between the recreational data collected in 2000/01 with the commercial data collected at the same time and with the recreational data collected in 1994/96 and 2007/08.



Fig. 4.1 Map of South Australia showing the boundaries of the different geographic blocks used in the National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003).

An estimate of the total weight of fish taken from each region was determined to compare with the commercial catch over the same period and with the recreational catch from 1994-95. The conversion from numbers to weight taken was possible because of the biological sampling and market measuring that was done for snapper by SARDI researchers at the same time that the NRIFS was done. It was assumed that the size structure of fish taken by recreational fishers was the same as that taken by commercial handline fishers in the same region for the period of May 2000 to April 2001 (Fowler et al. 2005). The size distributions were then converted to weight using region-specific length/weight relationships, which were used to calculate the average weight of fish taken per region. This average weight was multiplied by the estimated number of fish to give the total recreational catch by weight per region.

South Australian Recreational Fishing Survey (2007/08)

This study essentially used the same survey-based approach that was used in the NRIFS of 2000/01. The specific description of methods and the comprehensive results are presented in Jones (2009). The study involved a telephone interview screening survey of 7140 randomly-chosen households aimed at

determining participation rates and identifying the demographics of recreational fishers. After this, a 12-month telephone survey of 1310 households was undertaken to monitor their catches and fishing effort between November 2007 and October 2008. The estimates of catch and effort from the survey were then multiplied up to population level. The same regions and fishing blocks that were used for the NRIFS were used here (Fig. 4.1). This survey was designed to provide up-to-date annual estimates of the participation rates of South Australian residents in recreational fishing, their fishing effort and their catches of key species, such as snapper. Since this was a state-based survey rather than part of a national one, it was restricted to South Australian residents, and so regional estimates of catch and effort did not include contributions from inter-state visitors.

4.3 Results

Creel Survey (1994-96)

Over the 2 years of the recreational boat survey a total of 631 sample days were surveyed during which 3,514 interviews were done. Total annual fishing effort was estimated at 988,980 boat hours distributed across 196,900 boat days. A total of 5.7%, i.e. 11,232 of these boat days were identified as targeted fishing for snapper (Table 4.1). NSG and SSG attracted the highest rate and number of targeted fishing days for snapper. Both NGSV and the WC had the lowest effort of any of the five main regions of the proportion of fishing effort targeted at snapper (Table 4.1).

The estimated State-wide recreational harvest of snapper in 1994-96 was 23,544 fish with a total weight of 48 tonnes (Table 4.2). Approximately half these fish and 57% of their weight were taken in NSG. SSG accounted for 37% of the number of fish and 18.5% of the weight taken. Thus, in total, Spencer Gulf accounted for 86.5% of the number and 75% of the weight of fish taken by the recreational boat sector. Gulf St. Vincent accounted for the bulk of the remaining catch, i.e. 13.1% of the numbers of fish and 22.5% of the total weight. The contribution of the West Coast to recreational snapper catch was minimal.

Table 4.1 Regional breakdown of characteristics of fishing effort by the recreational boat sector as determined by the creel survey done through 1994-96 (McGlennon and Kinloch 1997).

Region	Estimated total boat days	Estimated number of boat days targeted at snapper	% of boat days targeted at snapper
NSG	36,318	5,412	14.9
SSG	36,480	2,238	6.13
NGSV	72,932	1,676	2.3
SGSV	26,854	1,447	5.39
WC	24,316	459	3.78
Total	196,900	11,232	5.7

The estimated annual harvest of the commercial sector for the same period of time was 282.0 tonnes (Table 4.2). A total of 87.1% of this was taken in Spencer Gulf, particularly in NSG, whilst only 10.4% of the commercial snapper catch was taken in Gulf St. Vincent and 2.5% on the West Coast. The total estimated catch across both sectors was 330 tonnes, which was clearly dominated by NSG. The relative proportion of the total catch taken by recreational fishers differed amongst regions, being highest in NGSV, but lowest in NSG.

Table 4.2 Regional breakdown of catch of snapper by the recreational boat sector, as determined by the creel survey done through 1994-96, compared with the annual commercial catch. Estimates provided show the regional number or weight of snapper, with the respective percentage of total in brackets.

Region	Estimated recreational catch (numbers)	Estimated recreational catch (tonnes)	Estimated commercial catch (tonnes)	Total catch (tonnes)	Recreational % of total
NSG	11,655 (49.5)	27.3 (56.9)	207.0 (73.4)	234.3 (71.0)	11.7
SSG	8,717 (37.0)	8.9 (18.5)	38.6 (13.7)	47.5 (14.4)	18.7
NGSV	1,615 (6.9)	8.3 (17.3)	16.9 (6.0)	25.2 (7.6)	32.9
SGSV	1,457 (6.2)	2.5 (5.2)	12.5 (4.4)	15.0 (4.5)	16.7
WC	100 (0.4)	1.0 (2.1)	7.0 (2.5)	8.0 (2.4)	12.5
Total	23,544	48.0	282.0	330	14.5

National Recreational and Indigenous Fishing Survey (NRIFS) (2000/01)

An estimated 441,586 snapper were captured by recreational fishers throughout the 12 month period of the NRIFS (Table 4.3). Of these, 73.8% i.e. 325,785 fish were released, leaving 115,801 snapper retained by the fishers. The rate of release varied among regions with the highest release rate obtained in NGSV and SGSV. The release rate was intermediate in Spencer Gulf, but was lowest on the West Coast and the South East. The region with the highest number of retained fish was NSG, followed by SSG with the combined harvest from both regions accounting for 83.9% of the State-wide total number harvested. The remainder was distributed between the other four regions. In total, there were 43,249 hours of targeted fishing effort directed by recreational fishers at snapper. These were divided amongst the main regions, except NGSV for which there was no recorded targeted effort. There was also significant untargeted effort across the regions, i.e. effort targeted at other species that lead to the capture of snapper.

Table 4.3 Summary of results from the NRIFS for catch and effort for snapper. The totals presented were accumulated across the geographic blocks that are indicated for each region and are shown on Fig. 4.1.

Region	Fishing Block	Targeted effort (hrs)	Non-targeted effort (hrs)	Harvest numbers	Released numbers	Total catch numbers	% released
NSG	8-10	10,606	150,750	74,900	213,221	288,121	74.0
SSG	7, 11, 12	6,927	60,594	22,203	48,054	70,257	68.4
NGSV	16-18	0	15,851	3,127	26,947	30,074	89.6
SGSV	13-15,19,20	15,572	21,692	5,346	30,088	35,434	84.9
WC	1-6	2,044	5,954	4,303	4,477	8,780	51.0
SE	22-25	8,100	61,092	5,922	2,998	8,920	33.6
Total		43,249	315,933	115,801	325,785	441,586	

The total estimated recreational harvest by weight was 416.0 tonnes (Table 4.4). Of this, 67% was taken in NSG and a further 18% in SSG, giving a total of 85% of the State-wide total being taken from throughout Spencer Gulf. Of the remaining 15%, SGSV contributed more than NSGV, the WC or SE. From May 2000 – April 2001 the reported catch from the commercial sector was 567.5 t. In combination with the 416.0 t from the recreational sector this gave a total catch of 983.5 t. As such, the recreational component was 42% of the total South Australian snapper catch. In two regions there was a considerable difference between the catches of the two sectors. In SSG, catch was dominated by the commercial sector, and in the SE 86% of the catch was taken by the recreational sector (Table 4.4).

Table 4.4 Summary of information used to calculate the total weight per region of the catch of the recreational sector and the comparative estimates of catches for the commercial sector for the period of May 2000-April 2001.

Region	Harvest numbers	Sample size (n)	Ave. wt per fish	Estimated recreational catch (tonnes)	Estimated commercial catch (tonnes)	Total catch (tonnes)	Recreational % of total
NSG	74,900	4,739	3.70	277.1	300.6	577.7	48.0
SSG	22,203	1,659	3.30	73.3	202.6	275.9	26.6
NGSV	3,127	73	3.38	10.6	17.7	28.3	37.5
SGSV	5,346	166	4.68	25.0	19.9	44.9	55.7
WC	4,303	33	3.31	14.2	24.2	38.4	37.0
SE	8,100	44	2.67	15.8	2.5	18.3	86.3
Total	115,801	6,714	3.61	416.0	567.5	983.5	42.3

South Australian Recreational Fishing Survey (2007/08)

From November 2007 to October 2008 the estimated number of snapper captured by South Australian residents was 384,077 (Table 4.5). Of these, 97010 were retained whilst 287,067 were released. Snapper were taken from throughout all inshore coastal waters of the State, but GSV accounted for the majority i.e. 47.4% of all snapper caught. Of these, however, 77% were released. Spencer Gulf (SSG + NSG) accounted for the next highest number of fish captured and harvested, followed by the SE and WC.

Table 4.5 Summary of results from the 2007/08 South Australian Recreational Fishing Survey. The totals presented were accumulated across the geographic blocks that are indicated for each region and are shown on Fig. 4.1.

Region	Fishing Block	Harvest numbers	Released numbers	Total catch numbers	% released
NSG	8-10	17,998	54,107	72,105	75.0
SSG	7, 11, 12	24,048	80,322	104,370	77.0
GSV	13-15,16-18,19,20	41,805	140,087	181,893	77.0
WC	1-6	2,692	1,849	4,542	40.7
SE	22-25	10,467	10,701	21,169	50.6
Total		97,010	287,067	384,077	74.7

The estimated total weight of snapper harvested by South Australian residents in the recreational sector was 177.7 t (Table 4.6). The regional contributions from the recreational sector in order from highest to lowest were from GSV, SSG, NSG, SE and the WC. In comparison, the commercial catch through the period of July 2007 to June 2008 was 742.7 t. Overall, the total catch was 920.4 t, of which the contribution by recreational fishers that were residents of South Australia was 19.3%. Nevertheless, there was considerable variation amongst the regional contributions of the recreational sector that ranged from 13.4% to 38.0% of the total catch (Table 4.6).

Table 4.6 Summary of information used to calculate the total weight per region of the catch of the recreational sector and the comparative estimates of catches for the commercial sector. The estimates of recreational catch were for the period of November 2007 to October 2008. The estimates of commercial catch were for the financial year of 2007/08 (i.e. July 2007 to June 2008).

Region	Harvest numbers	Sample size (n)	Ave. wt per fish	Estimated recreational catch (tonnes)	Estimated commercial catch (tonnes)	Total catch	Recreational % of total
NSG	17,998	739	2.125	38.3	195.9	234.2	16.4
SSG	24,048	222	2.20	52.9	342.3	395.2	13.4
GSV	41,805	554	1.616	67.6	110.4	178.0	38.0
WC	2,692	94	2.248	6.1	28.0	34.1	17.9
SE	10,467	133	1.222	12.8	51.7	64.5	19.8
Other					14.4	14.4	
Total	97,010	1742		177.7	742.7	920.4	19.3

Comparison amongst survey estimates of recreational catch

From the results of the National Recreational and Indigenous Fishing Survey of 2000/01, the component of total recreational catch that was taken by only the South Australian residents in each fishery region were calculated, for comparison with data collected in 1994/96 and 2007/08. The data from all three surveys are presented for five of the South Australian regions in Fig. 4.2. The estimated regional catches by weight in 1994-96 were generally lower than those from the 2000s, particularly for NSG in 2000/01, which produced an estimated catch of 198 t. This catch far exceeded any other regional total including that for NSG in 2007/08. The extraordinary total in 2000/01 reflected an annual

estimated harvest of 53,596 fish, which also far exceeded any other regional catch in terms of numbers. This drop in catch in NSG, contributed significantly to the overall drop in the contribution of the recreational sector to total catch from 42% in 2000/01 to 19.3% in 2007/08.

There was a considerable change over time in the relative contributions of the different regions to total recreational catch. Whilst Spencer Gulf dominated the recreational catches in both 1994-96 and 2000/01, Gulf St. Vincent produced the highest recreational catch by weight in 2007/08, reflecting a substantial increase in the number of snapper harvested in this region between years.

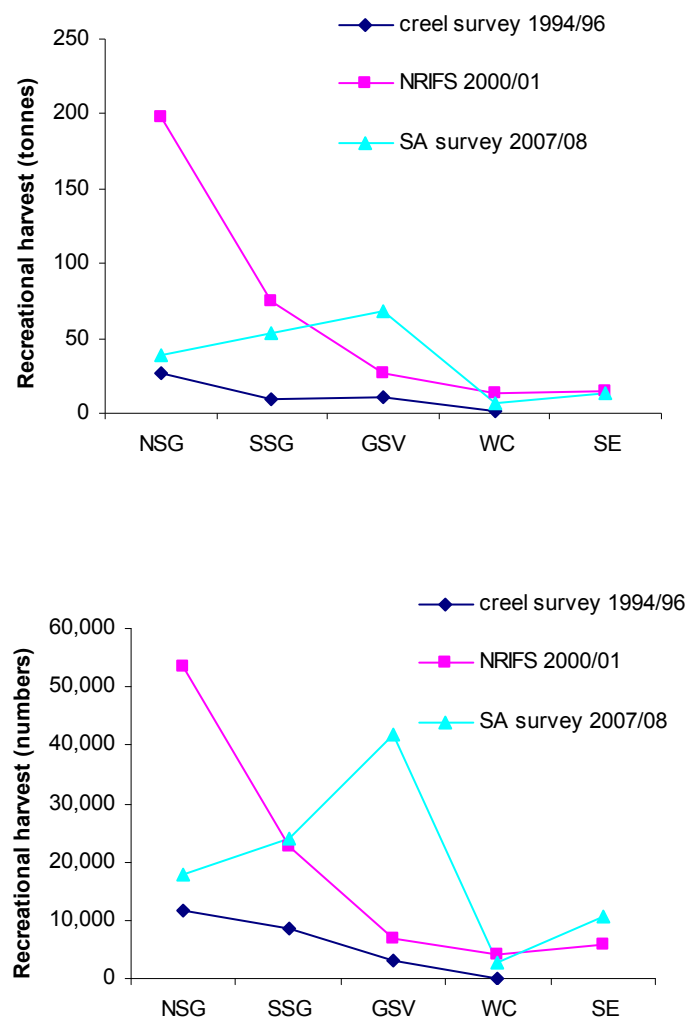


Fig. 4.2 Comparison of the regional estimates of recreational harvest by South Australian residents between the creel survey of 1994/96, the NRIFS of 2000/01 and the South Australian survey of 2007/08. Top graph shows regional harvest in tonnes, bottom graph shows regional harvest in numbers. Refer to text for the limitations of each survey.

Recreational Charter Boat Sector !

The charter boat sector makes a significant contribution to the total estimated catch of snapper by recreational fishers. The estimated annual catch of snapper of this sector ranged between 61.4 and 94.1 t over the four-year period of 2005/06 to 2008/09, representing an increase in the number of snapper retained from 23,329 to 34,447 (Table 4.7). SG has consistently produced the highest charter boat catches, followed by GSV (including Kangaroo Island), with relatively minor catches from the WC and the SE (Fig. 4.3). The total weight and number of snapper taken in SG were highest in 2007/08. Alternatively, for GSV, the highest total weight and numbers of snapper were taken in 2008/09. The snapper catches of both SG and GSV demonstrated considerable seasonality (Fig. 4.4). They were always highest in December, regardless of region or year. They then decreased consistently until the low catches that were taken through winter. The catches remained relatively low before increasing considerably in October. They were very low in November due to the seasonal closure, but then increased dramatically in December each year.

Table 4.7 Estimates of snapper harvested numbers and weight by the recreational charter boat sector between 2005/05 and 2008/09. Note that estimates for data for 2005/06 were for the period of September 2005 to June 2006.

Year	Harvest numbers	Estimated charter boat catch (tonnes)
2005/06	30,673	65.9
2006/07	23,329	61.4
2007/08	34,447	94.1
2008/09	30,830	92.3

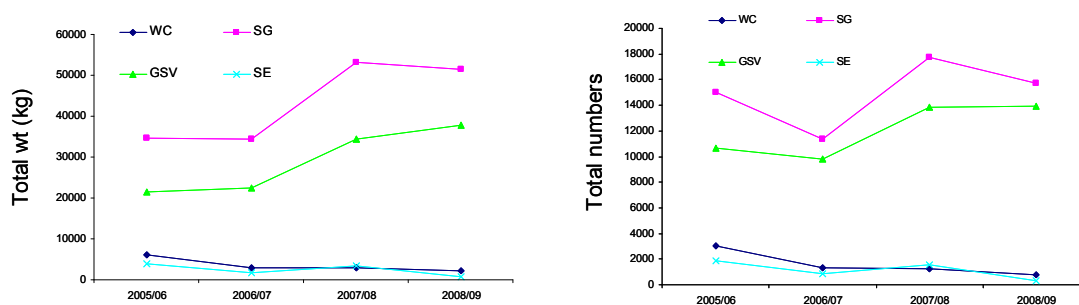


Fig. 4.3 Comparison of the regional catches by the charter boat sector by weight and number of fish harvested for the years of 2005/06, 2006/07, 2008/09 and 2009/10. Note that data collection in 2005 commenced in September, as such data for 2005/06 were for 10 months rather than 12 months.

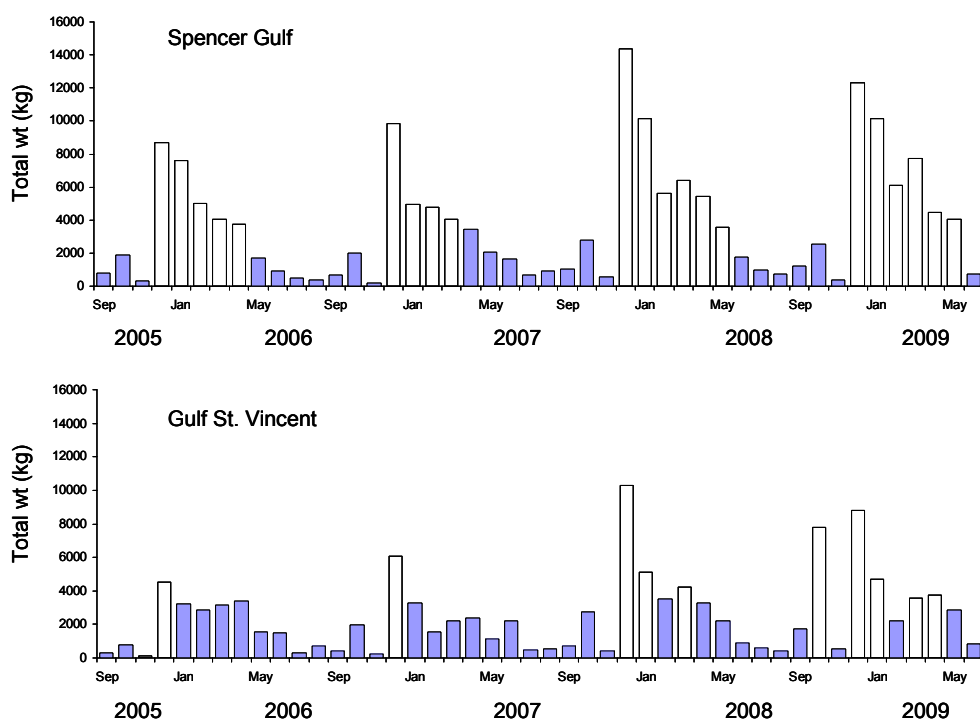


Fig. 4.4 Comparison of monthly charter boat catches of snapper from September 2005 to June 2009, for each of Spencer Gulf and Gulf St. Vincent (including Kangaroo Island).

4.4 Discussion

The results from the three recreational fishery surveys were not directly comparable. The creel survey provided only relative regional estimates of fishery catches since only selected boat ramps were surveyed during daylight hours. The two later telephone/ diary surveys were more inclusive but nevertheless the second one in 2007/08 only considered South Australian residents whereas the first one in 2000/01 included the data from inter-state fishers who had fished in South Australia. Despite these differences there were some useful comparisons between surveys.

The creel survey identified the significance of the snapper fishery in SG to the recreational sector in the mid-1990s accounting for a high proportion of the numbers of fish and biomass taken. This was even more evident in 2000/01 when very high numbers and biomass of snapper were estimated to have been taken from NSG. Furthermore, the estimates of catch from SSG were the second highest despite being considerably lower than for NSG. The significance of snapper catches from SG is consistent with the record catches that were taken by the commercial sector at the same time. Nevertheless by 2007/08, GSV had become the dominant region for recreational catches of snapper. This result is also consistent with the high commercial catch and catch rate in NGSV in that year. As such, it appears that the

regional trends in the data for snapper may well reflect the regional changes in biomass that were suggested by the commercial fishing statistics (Chapter 3).

One primary aim for undertaking recreational fishing surveys is to determine the trends in catch by this sector over time. In this regard the comparison of data between 2000/01 and 2007/08 was somewhat contradictory. It is estimated that between these years there was a reduction by 25.7% in the number of South Australian residents (> 5 years old) who undertook recreational fishing activity (Jones 2009). Despite this, it is estimated that the number of snapper caught and harvested in SA increased from 332,978 and 85,951, respectively to 384,077 and 97,010 in 2007/08. Nevertheless, the estimated biomass captured in the latter survey was 177.7 t, considerably less than half of the estimate from 2000/01. The lower biomass but higher numbers in 2007/08 reflects the considerably lower average weights of fish taken at this time compared to 2000/01.

5. POPULATION STRUCTURE

5.1 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 length and age frequencies that provide information on recruitment, growth and mortality, i.e. rates of demographic processes. Age-based demographic information is particularly significant in this context because it provides the temporal scale at which the rates that such demographic processes can be measured (Campana 1999). The determination of the age of fish is generally done by interpreting the structure of their hard anatomical structures such as their otoliths.

For snapper in South Australia, a market measuring and biological research program has been underway since 2000, whose aim has been to produce estimates of the size and age of fish caught from each population. In this study, fish catches were accessed from various sources from which the individual fish were measured, and some were aged from their otoliths, to develop population age structures (McGlennon et al. 2000, Fowler et al. 2005). Such size and age structures have been developed on a regional basis for a number of years between 2000 and 2010. Furthermore, for NSG some size and age structures were available from earlier market sampling done through the 1990s (McGlennon et al. 2000). The aim of this chapter was to analyse the regional size and age structures from the 2000s (and also the 1990s for NSG), to be compared with the temporal catch and catch rate data (Chapter 3), and interpreted in terms of the demographic processes that take place in each regional population. These results were then compared between regions. Furthermore, the recent size and age data were also used to update the SnapEst computer fishery model, to simulate the natural population dynamics and demographics, and to output biological fishery indicators (Chapter 7).

5.2 Materials and Methods

For the calendar years of 2000, 2001, 2002 and 2003, the financial years of 2005/06, 2007/08 and 2008/09 as well as the period from July 2009 to March 2010, 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 other 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 caudal fork

length (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 lab, 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 to provide an estimate of fish 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. For each of NSG and SSG the age/length key was applied independently to each of the handline and longline length frequency distributions to generate gear-specific estimates of annual age structures. For NGSV and SGSV there was no differentiation between gear types because of the lower sample sizes. In order to ensure that otoliths were interpreted consistently between sampling occasions and between readers, each otolith reader was tested against a random selection of otoliths from a reference collection every three months.

Data processing

The analytical procedures that were used here to develop the annual size and age structures were the same as those used by McGlennon et al. (2000) that were 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. These were developed independently for catches by handline and longline for each of NSG and SSG, but were not differentiated by gear type for the other regions. First, for each season (January - March, April - June, July - September, October - December) the proportion of fish per one cm length class (30 – 100 cm CFL) were determined. These proportional length data were then converted to a biomass distribution using a region-specific, length – weight relationship. The biomass distribution was then used to determine the average weight of fish caught per season. Then, the total reported catch weight for each season, accumulated from the catch returns, was divided by the average fish weight, to estimate the total number of fish captured. The seasonal length frequencies were then combined to an annual length frequency by weighting the seasonal proportions at length by the estimated number of snapper landed per season. An age/length key was developed for each region and 12-month period based on the sizes and ages of fish that were aged during that year, regardless of season or gear type. The age/length key for that year was then applied to the length frequency distributions to generate gear-specific estimates of annual age structures.

5.3 Results

Population size and age structures

Northern Spencer Gulf

Handline sector

Size structures are available for NSG for numerous calendar and financial years between 1991 and 2010. These annual size structures essentially reflected 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' that were >80 cm CFL. There were some consistencies but also some considerable differences in the size distributions among years. In each year the size distributions of the fishery catches reflected at least two modes of fish that varied between years (Fig. 5.1). In 1991, the catches largely consisted of 'small' and 'large' fish, whereas in 1994/95 the 'small' fish dominated. Throughout the 2000s, there were usually modes of 'small' and 'large' fish, with occasional modes of 'medium' sized fish. There were few 'very large' fish in the handline catches. In 1991, 2000-2003, 2007/08 and 2008/09 the 'large' fish dominated the biomass distribution graphs. However, in 1994/95, the 'small' fish dominated the biomass distribution and in 2005/06 the 'very large' fish dominated the biomass distribution.

The age structures of the catches taken in the handline fishery in NSG demonstrated several characteristics. Firstly, most fish taken on handlines were about 12 years of age or younger, but there were rare occasions when a fish of up to 27 years of age was captured (Fig. 5.2). Furthermore, within any year there were particular age classes that contributed more to catch than did others. For example, the strong age classes in 2000 were the 3+ and 9+'s, whereas in 2001 they were the 4+ and 10+'s. This variation in age class strength ultimately related to strong and weak recruitment years, which then persisted in the population for numerous subsequent years and even decades. The strong 1991 and 1997 year classes persisted in the fishery catches until 2010, although their relative contributions varied amongst years. The 1991-year class contributed the highest number of fish caught in both 1994/95 and 2000, but was displaced from 2001 onwards. The 1997 year class was the most significant contributor to handline catches in 2001, 2002 and again in 2007/08, and was also a significant contributor in 2008/09 and 2009/10. The 1999 year class was also a significant one that contributed most fish in 2003 and 2009/10. Also, the 2004 year class emerged as a significant one in 2007/08, and was the most significant contributor to numbers of fish taken in 2008/09.

Longline sector

In both 1991 and 1994/95 the size distributions of the longline catches were essentially unimodal and mainly involved 'large' and 'very large' fish (Fig. 5.3). However, during the 2000s the size distributions

changed, as each of the 'small', 'medium', 'large' and 'very large' size categories were well-represented in the longline catches. Nevertheless, the larger size classes still dominated the biomass distributions, due to the heavier weights of these larger fish. After 2003, there were few fish measured due to the low catches taken on longlines in this region.

The age structures of the longline catches demonstrated some similarities and differences from the handline catches (Fig. 5.4). Generally, there were more age classes included in the longline catches with fish up to 33 years of age recorded. For each year there was considerable variation in the contributions of the different age classes. For example, in 1991 the longline catch was dominated by the 12 year old fish, whereas in 2000 the longline catches were dominated by the three and nine year old fish. The variation in age class representation for the longline catches related to strong and weak year classes, with strong recruitment years evident for 1979, 1991, 1997 and 1999. As such, consideration of the ages of fish from the longline catches extended our understanding of the sequence of strong and weak recruitment years back to the 1970s.

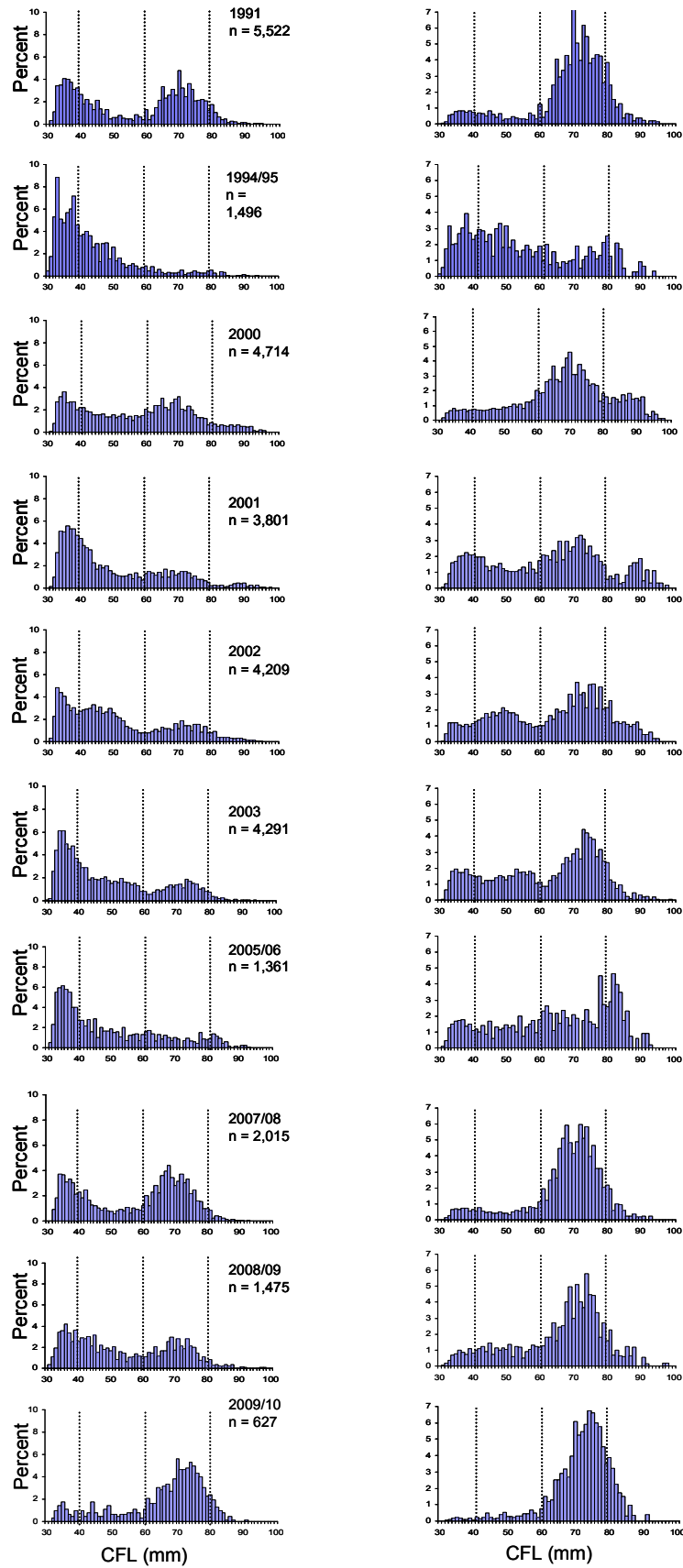


Fig. 5.1 Size and biomass distributions for snapper caught in NSG on handlines in each of ten different years. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catch accounted for by each size class of fish. Vertical lines on graphs delineate the four size categories of small, medium, large and very large fish.

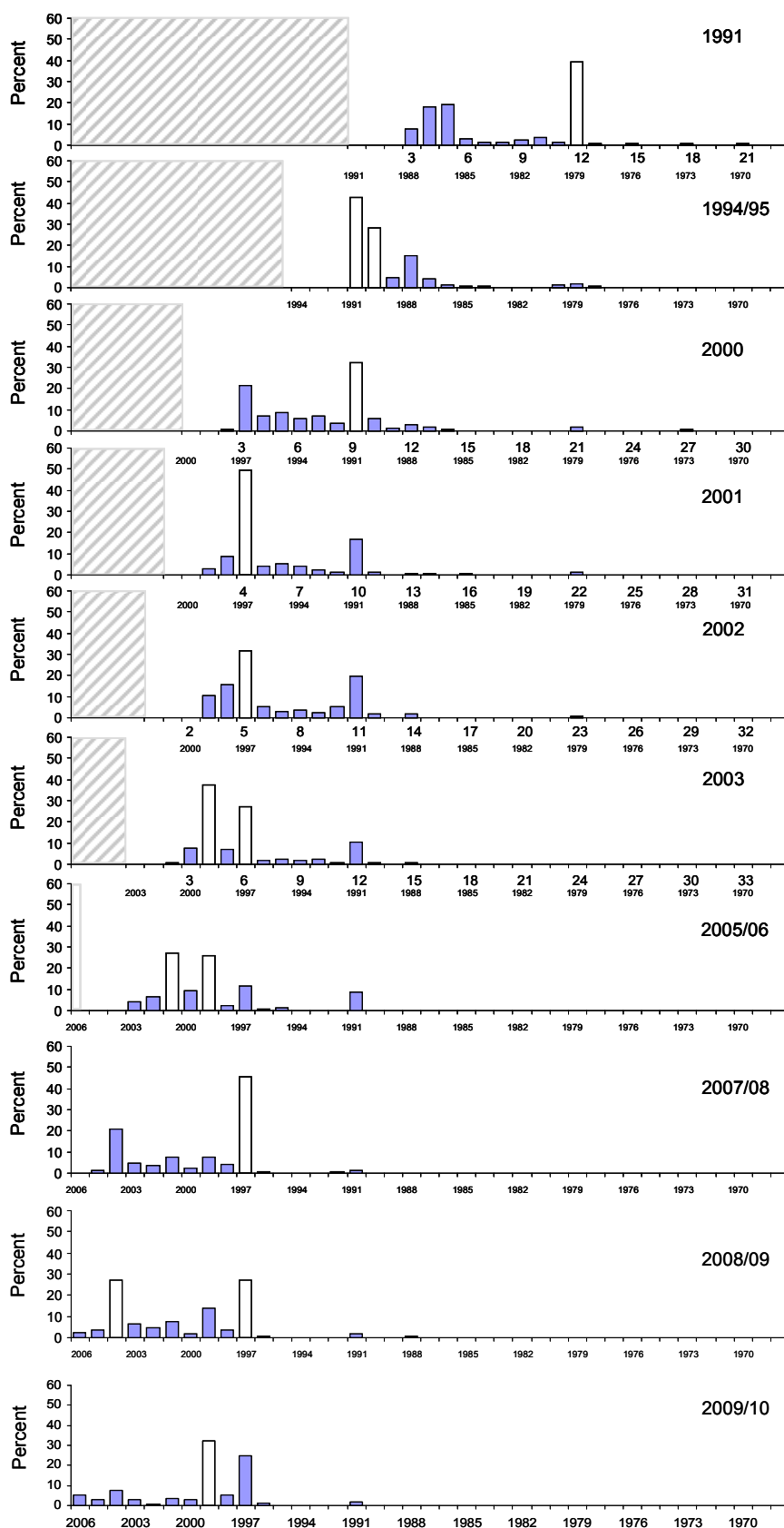


Fig. 5.2. Estimated age structures of fish caught on handlines in NSG in each of ten calendar or financial years. For calendar years, both the age classes and the recruitment year classes are shown on the X-axis. For the financial years only the recruitment year classes are shown on the X-axis.

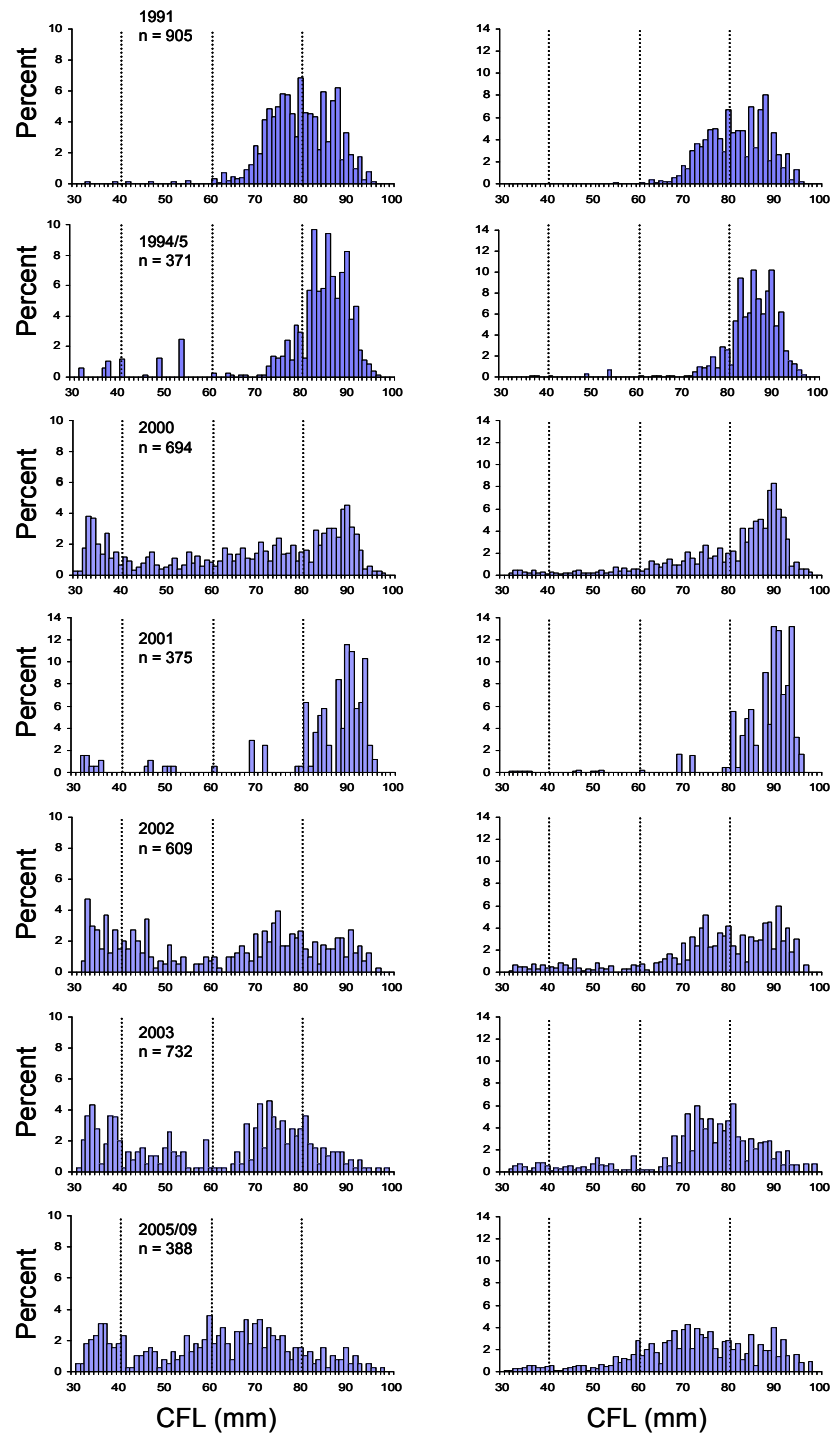


Fig. 5.3 Size and biomass distributions for snapper caught in NSG on longlines in each of six different years, as well as combined across the period of 2005-09. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catch accounted for by each size class of fish. Vertical lines on graphs delineate the four size categories of small, medium, large and very large fish.

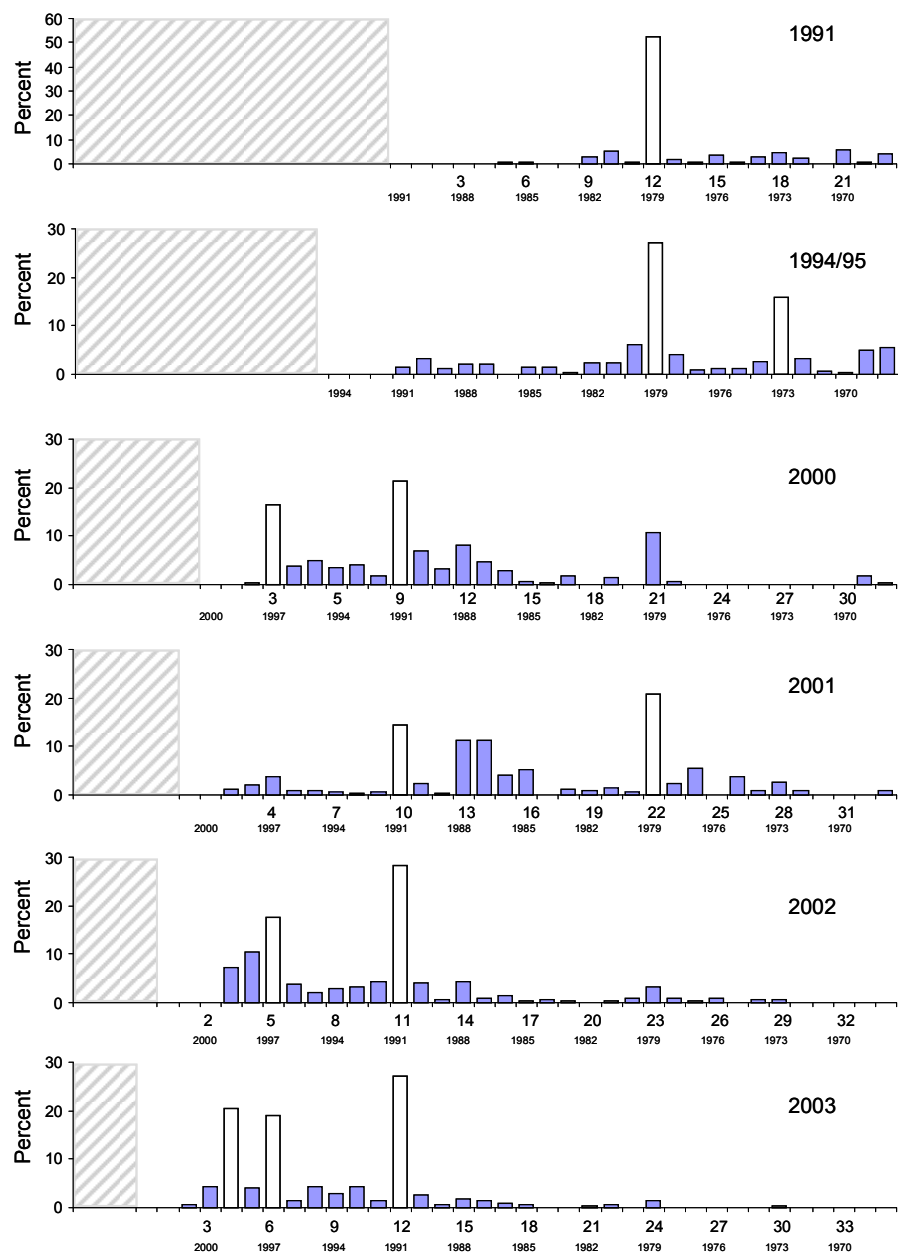


Fig. 5.4. Estimated age structures of fish caught on longlines in NSG in each of six calendar and financial years. For calendar years, both the age classes and the recruitment year classes are shown on the X-axis. For the financial years only the recruitment year classes are shown on the X-axis.

Southern Spencer Gulf

Handline sector

Population size and age structures for SSG are available since 2000. Since that time the annual size structures from handline catches have been quite similar amongst years (Fig. 5.5). Fish >80 cm CFL were always extremely rare, whilst there were usually modes of 'small' and 'large' fish, with troughs in the 40 – 50 cm CFL size range. The relative sizes of the peaks and troughs did vary between years. The 'large' fish generally dominated the biomass distributions. These distributions were remarkably similar between 2000, 2001, 2002, 2007/08 and 2008/09. Alternatively, the 'small' and 'medium' sized fish made considerable contributions to the biomass in both 2003 and 2005/06.

Each of the annual age distributions for the handline catches were dominated by up to three age classes (Fig. 5.6). In 2000, these were the 3+ and 9+ fish, which related to strong recruitment years in 1991 and 1997. The former dominated the fishery catches until 2002 but remained evident in the catches until 2009/10. The 1997 year class was the most numerous contributor in 2003 and remained so until 2008/09. In 2003, the 1999 year class began to emerge as another strong year class and by 2008/09 it contributed >35% of the numbers of fish captured, and in 2009/10 had become the dominant year class.

Longline sector

The longline catches generally included 'small', 'medium' and 'large' fish but very few 'very large' individuals (Fig. 5.7). During most years there was little modal structure in the size frequency distributions, indicating that relatively similar numbers of fish were taken in the different size categories. Consequently, the biomass distributions were dominated by the 'large' fish, by virtue of their greater individual weights.

In each year the age structures of the longline catches were dominated by two age classes (Fig. 5.8). These related to the 1991 and 1997 year classes until 2005/06. By 2007/08, the significance of the 1991 year class had diminished considerably and the catches had become dominated by the 1997 year class. Furthermore, the 1999 year class has gradually emerged as a significant year class.

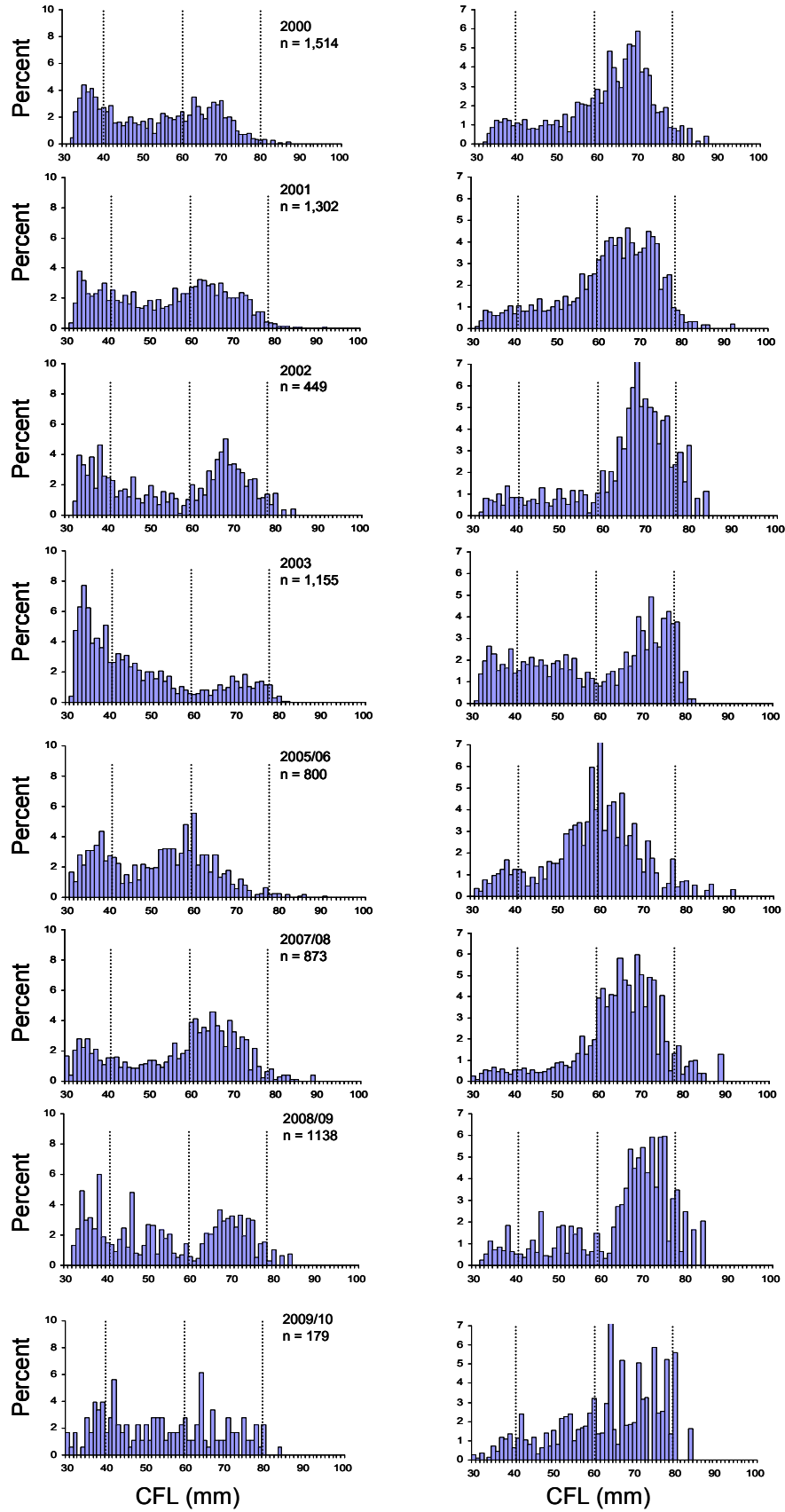


Fig. 5.5 Size and biomass distributions for snapper caught in SSG on handlines in each of ten different years. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catch accounted for by each size class of fish. Vertical lines on graphs delineate the four size categories of small, medium, large and very large fish.

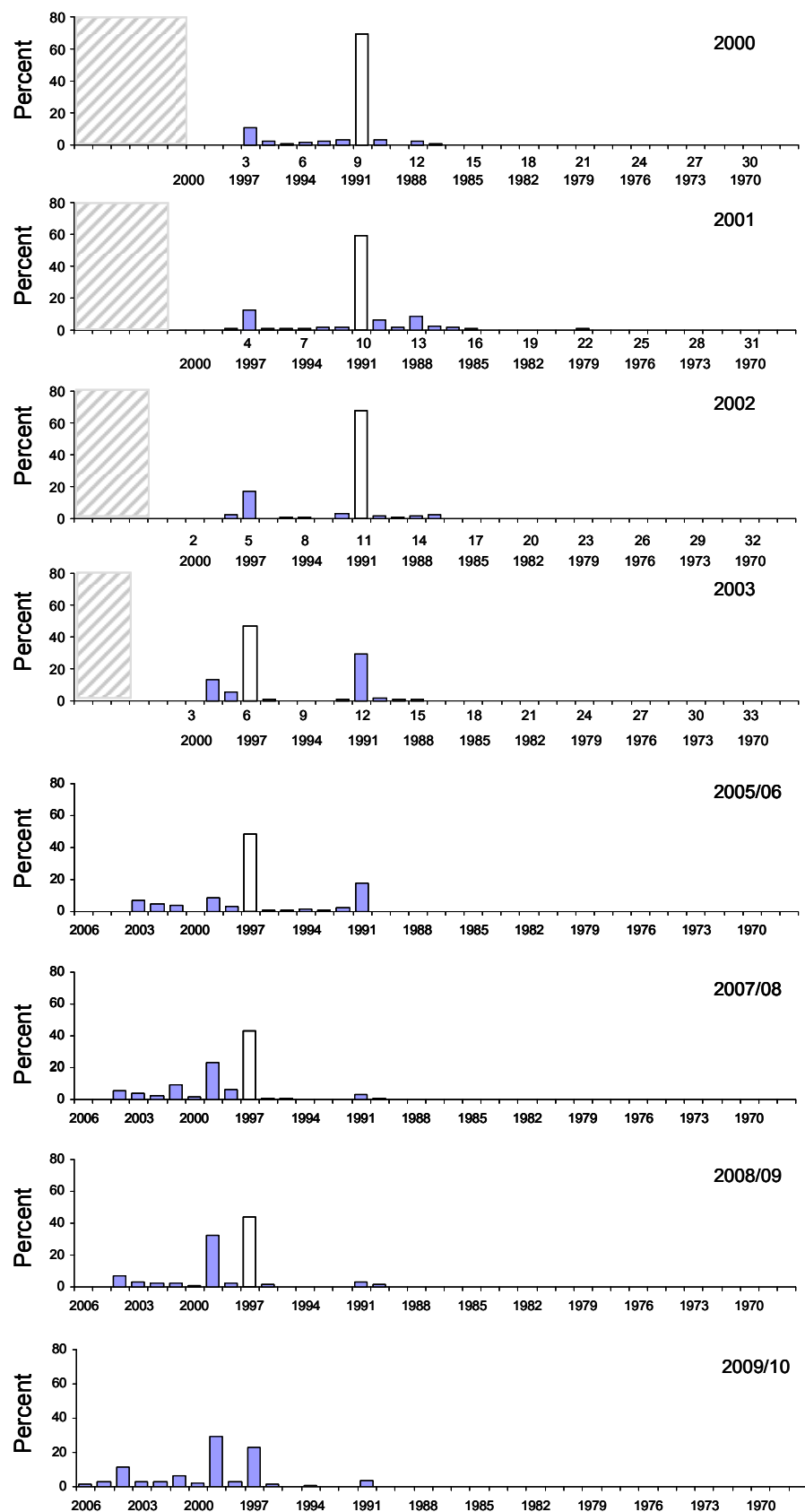


Fig. 5.6. Estimated age structures of fish caught on handlines in SSG in each of eight years. For calendar years, both the age classes and the recruitment year classes are shown on the X-axis. For the financial years only the recruitment year classes are shown on the X-axis.

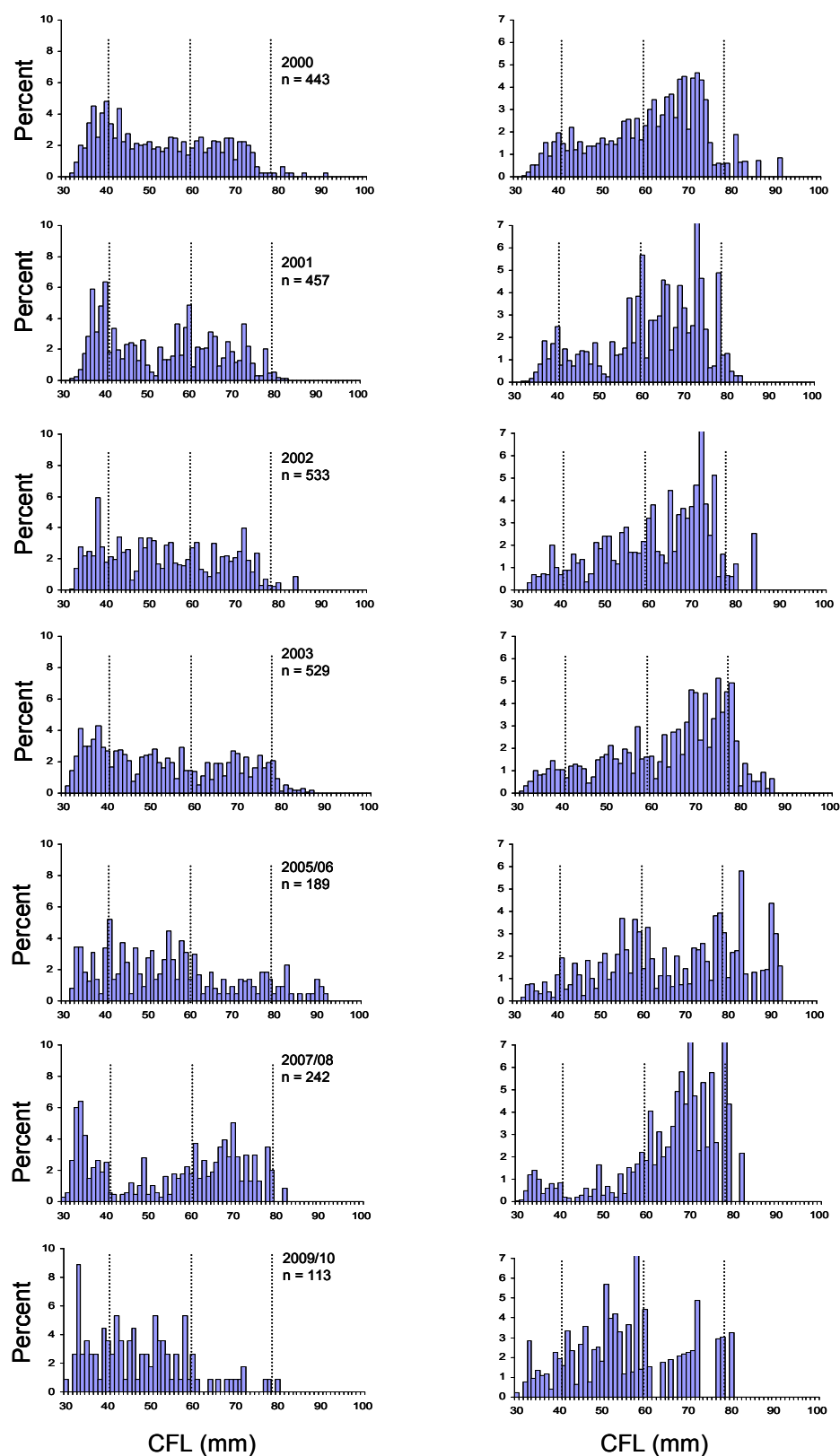


Fig. 5.7 Size and biomass distributions for snapper caught in SSG on longlines in each of seven different years. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catch accounted for by each size class of fish. Vertical lines on graphs delineate the four size categories of small, medium, large and very large fish.

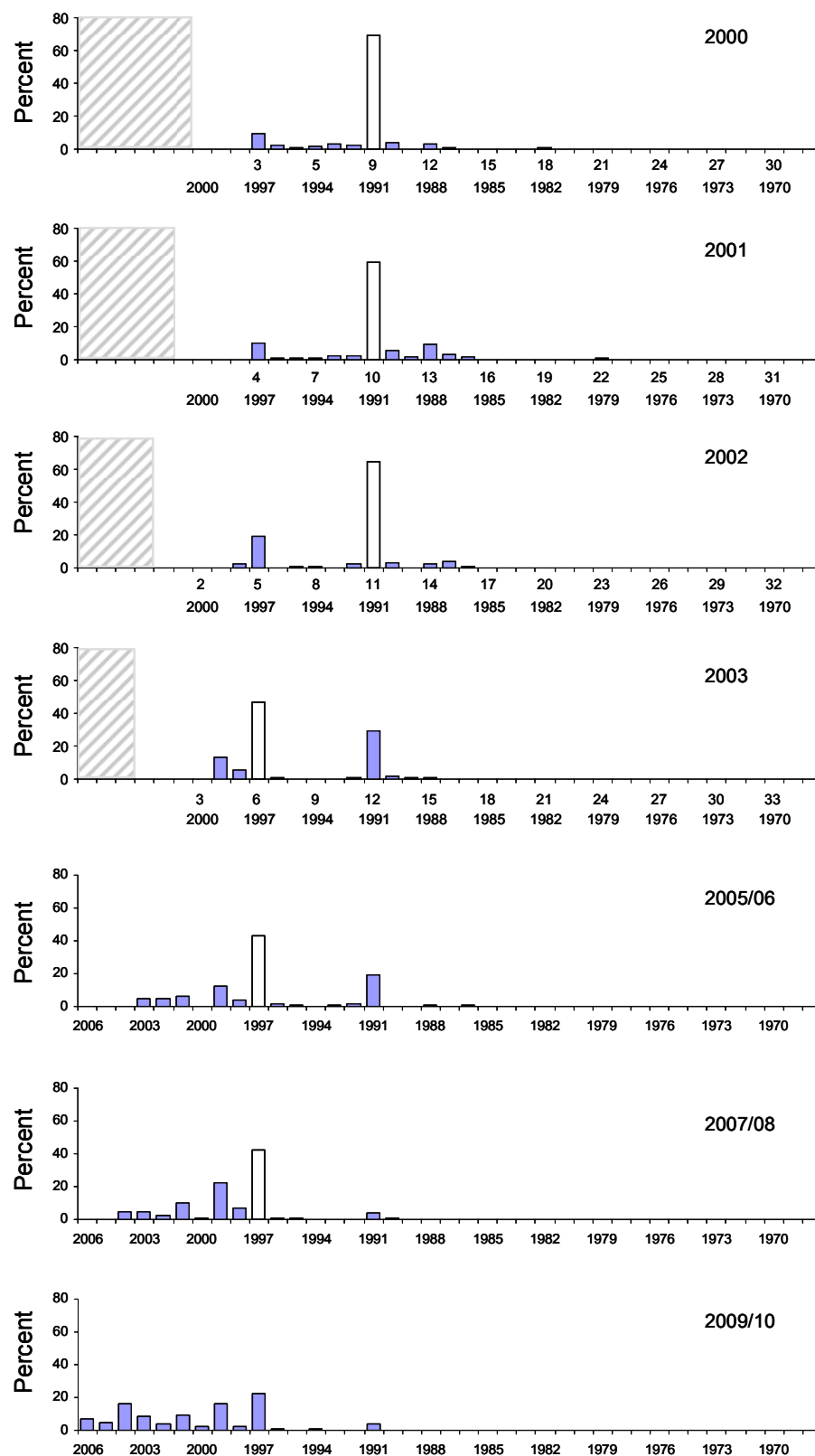


Fig. 5.8. Estimated age structures of fish caught on longlines in SSG in each of seven years. For calendar years, both the age classes and the recruitment year classes are shown on the X-axis. For the financial years only the recruitment year classes are shown on the X-axis.

Northern Gulf St. Vincent

Estimates of size and age structures for NGSV are divisible into two groups based on sample sizes. Those developed for the years of 2000 to 2003 were based on small sample sizes because of the low catches and low numbers of fish that passed through the fish markets at that time. Those catches were dominated by 'large' fish (Fig. 5.9). Furthermore, most fish related back to the exceptionally strong 1991 year class that dominated catches in all regions throughout the early 2000s (Fig. 5.10).

The second group of size and age structures for NGSV are those developed for the late 2000s. During this period the catches and catch rates in NGSV were much higher than earlier, which led to larger numbers of fish being sampled. The size structures in 2007/08, 2008/09 and those up to March 2009/10 were similar, being dominated by 'small' and 'large' fish, but with considerable representation of the 'very large' size class. Numerous age classes contributed to these size distributions with the most significant being the 1991, 1997, 1999, 2001 and 2004 year classes (Fig. 5.10). These are the same year classes that were significant for NSG, whilst it also appears that 2006 might be emerging as another significant year class.

Southern Gulf St. Vincent

Throughout the 2000s the catches from SGSV were more consistent than those from NGSV providing reasonable sample sizes during both the early and late 2000s. From 2000 to 2002, the catches were dominated in numbers and biomass by 'large' fish (Fig. 5.11). However, in 2003, there were higher numbers of small fish captured. The catches throughout this period were dominated by the 1991 year class with progressively increasing contributions from the 1997 and 1999 year classes in 2002 and 2003 (Fig. 5.12). By the late 2000s, the size structures of fish captured in SGSV were considerably different than earlier in the decade. These later catches were dominated in numbers and biomass by 'small' and 'medium' fish, with few 'large' and very few 'very large' fish processed. The age distributions for these years were dominated by the 2001 year class that provided >60% of the fish captured in 2008/09 and 2009/10. The proportional contribution of the 2004 year class increased with consecutive years, whilst the 2006 year class also began to emerge as a significant year class in 2009/10.

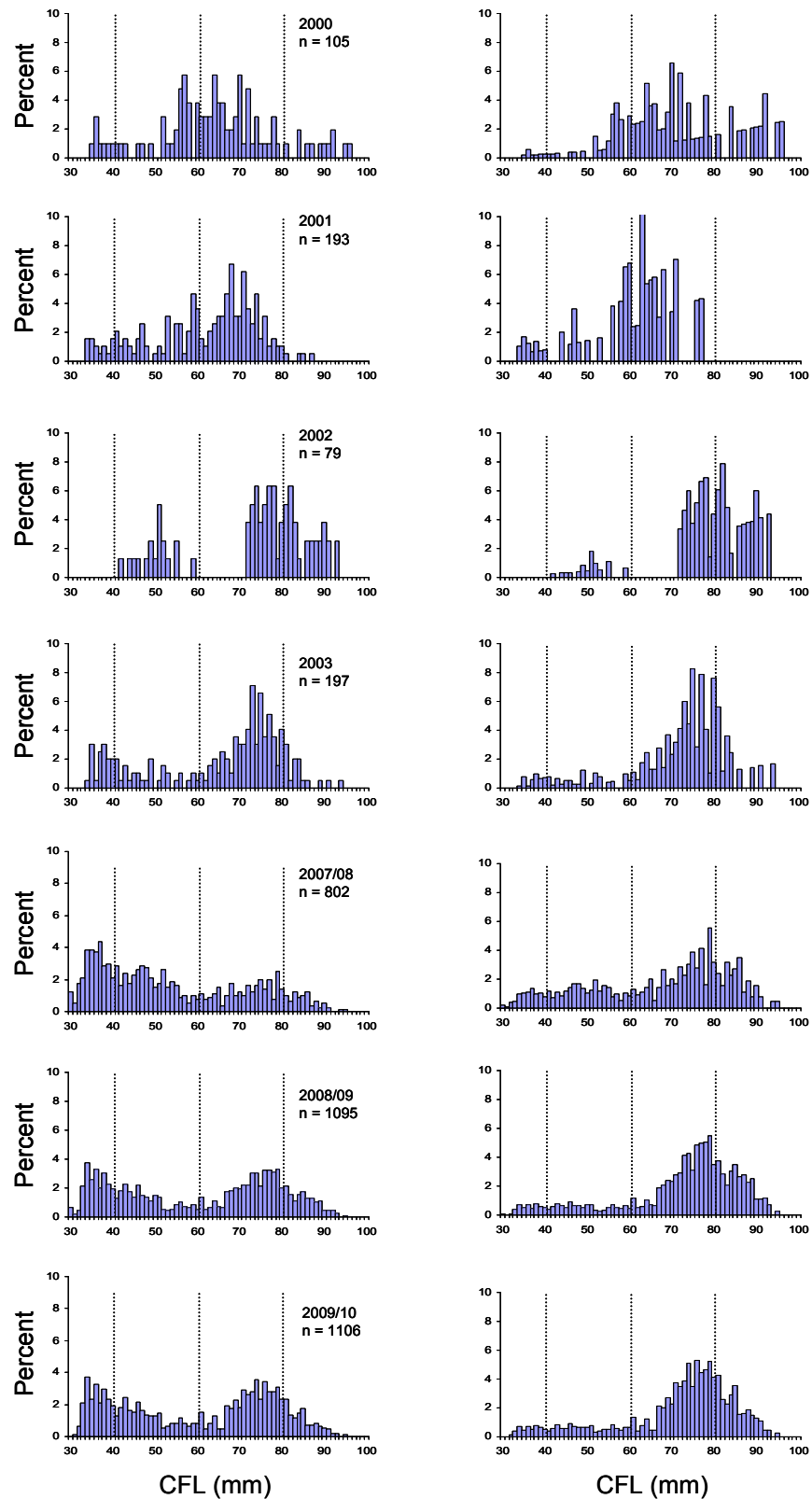


Fig. 5.9 Size and biomass distributions for snapper caught in NGSV on handlines and longlines in each of seven different years. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catch accounted for by each size class of fish. Vertical lines on graphs delineate the four size categories of small, medium, large and very large fish.

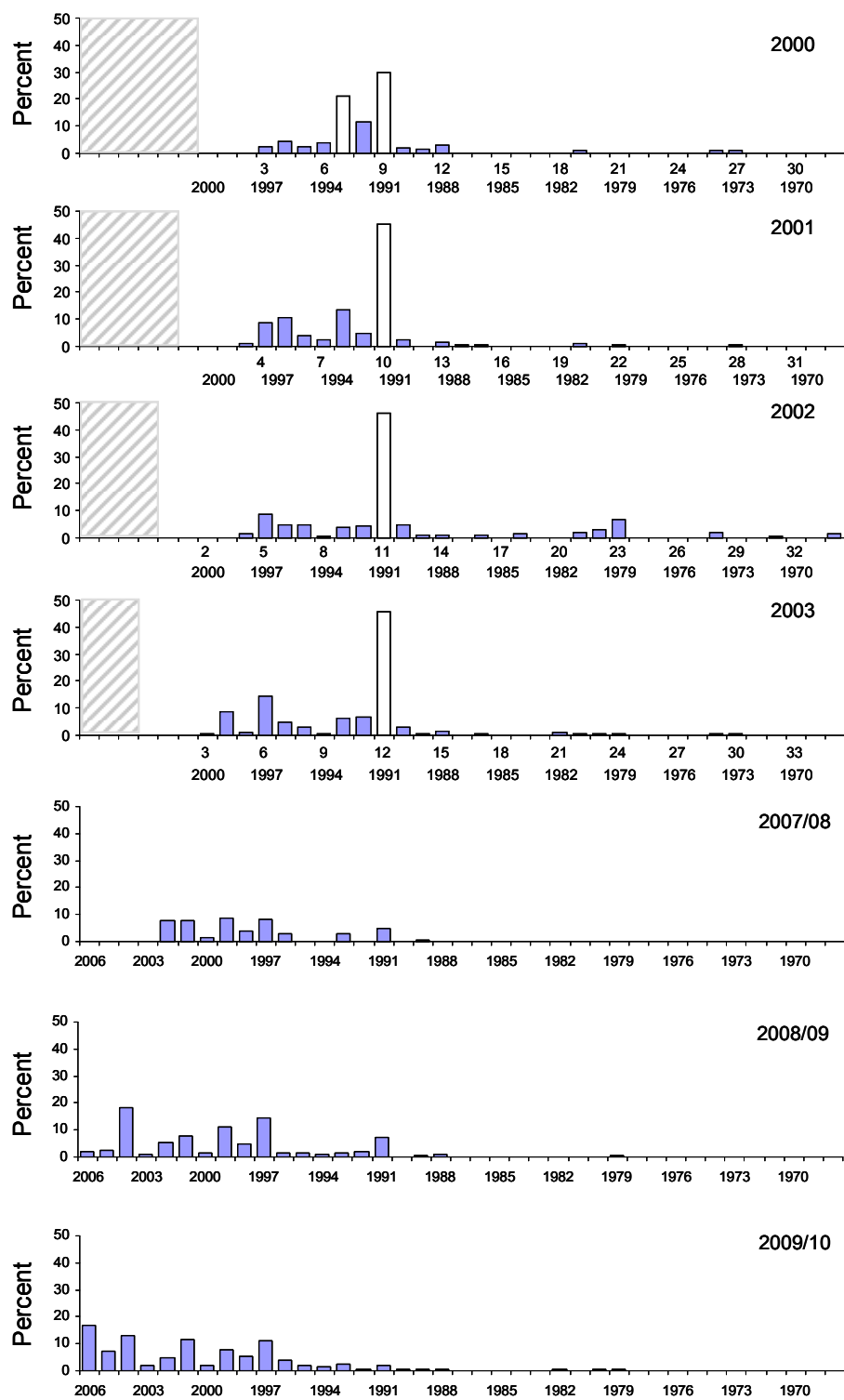


Fig. 5.10. Estimated age structures of fish caught on handlines and longlines in NGSV in each of seven years. For calendar years, both the age classes and the recruitment year classes are shown on the X-axis. For the financial years only the recruitment year classes are shown on the X-axis.

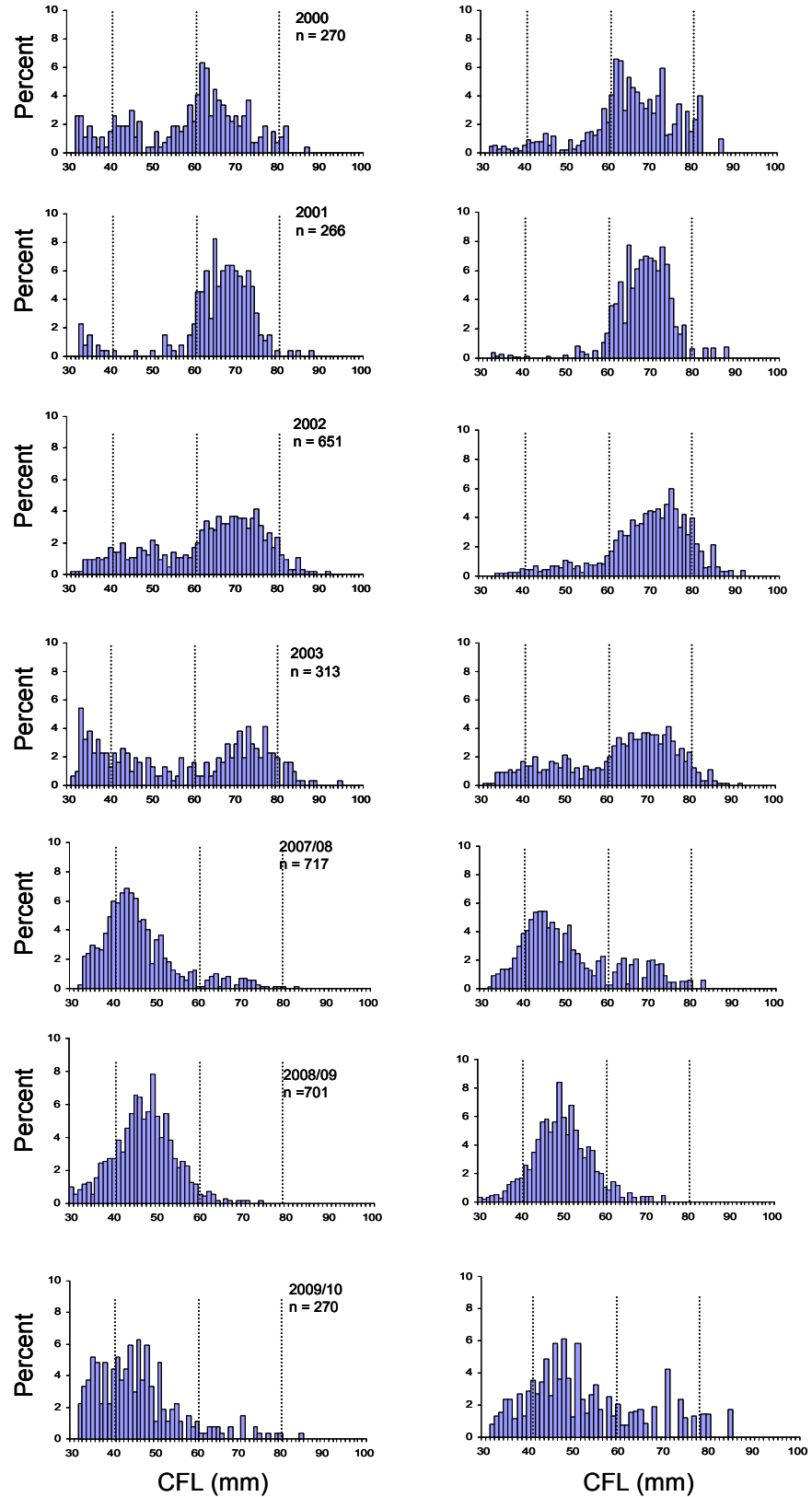


Fig. 5.11 Size and biomass distributions for snapper caught in SGSV on handlines and longlines in each of seven different years. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catch accounted for by each size class of fish. Vertical lines on graphs delineate the four size categories of small, medium, large and very large fish.

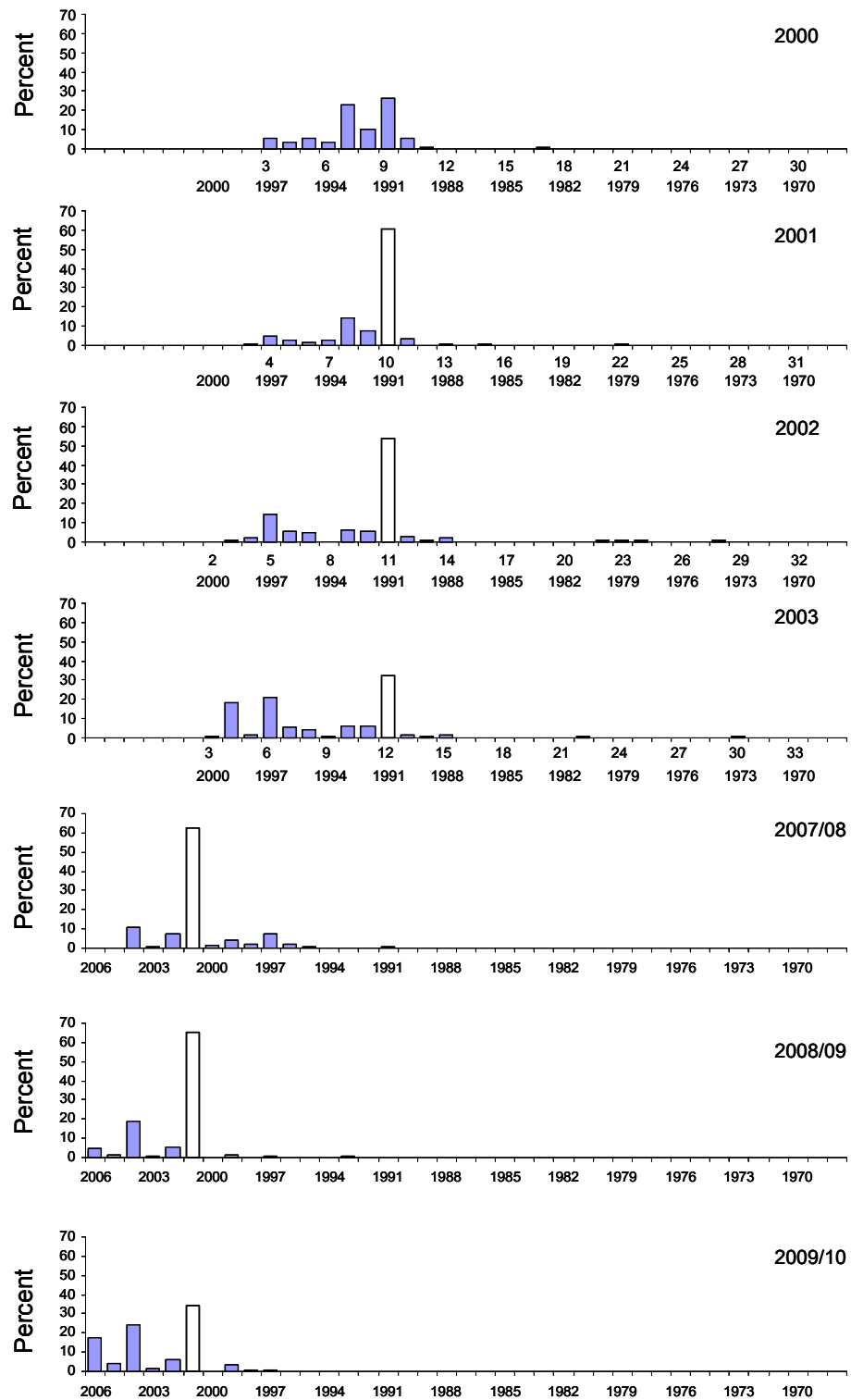


Fig. 5.12. Estimated age structures of fish caught on handlines and longlines in SGSV in each of seven years. For calendar years, both the age classes and the recruitment year classes are shown on the X-axis. For the financial years only the recruitment year classes are shown on the X-axis.

South-East

Data on population size structures for the South-East are only available for the three years of 2007/08, 2008/09 and 2009/10 (Fig. 5.13). Throughout these years the catches were dominated by 'small' and 'medium' fish. In 2007/08, there were two modes, one each of 'small' and 'medium' fish. In 2008/09, the catches were unimodal with a marginally larger mode than for the previous year. Fish were marginally larger again in 2009/10.

There were too few fish aged to generate age frequency distributions using the age/length key method. However, the frequencies of fish aged, indicated that throughout this three-year period, the population was dominated by the 2001 year class, as was the case for SGSV (Fig. 5.14).

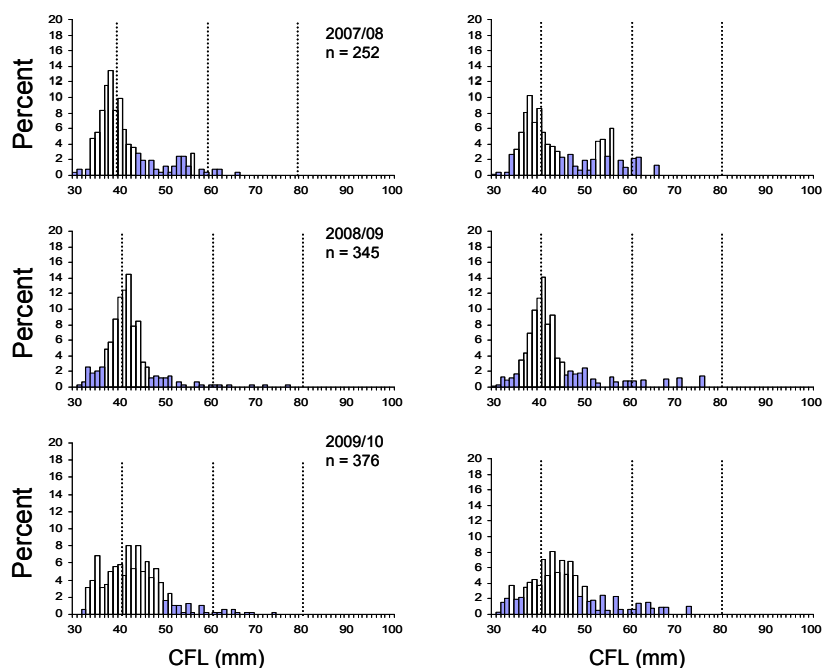


Fig. 5.13 Size and biomass distributions for snapper caught in SE on handlines and longlines in each of three different years. Left hand graphs show the size structures. Right hand graphs show the biomass of the fishery catch accounted for by each size class of fish. Vertical lines on graphs delineate the four size categories of small, medium, large and very large fish.

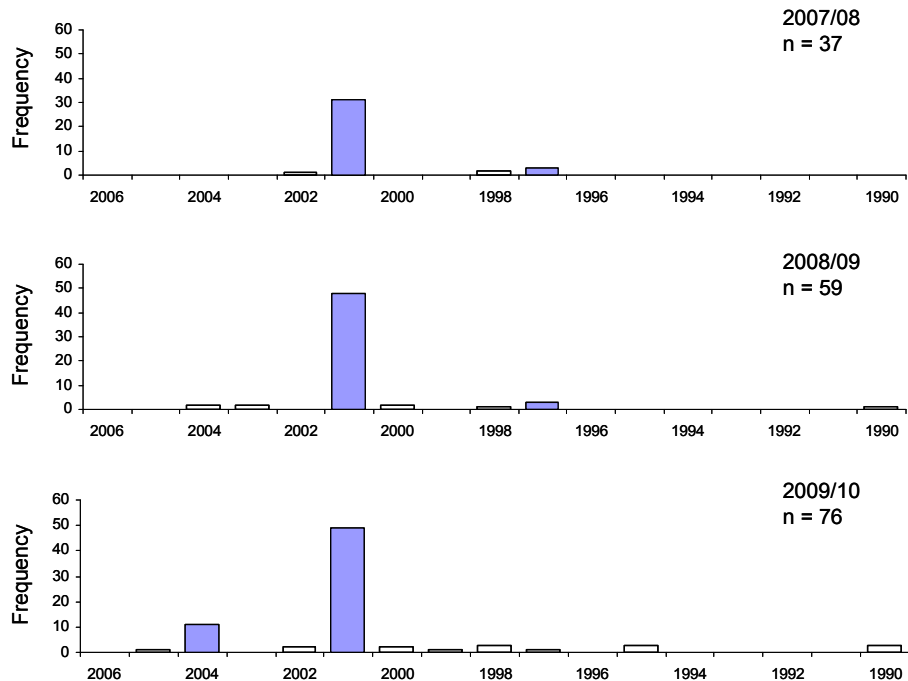


Fig. 5.14. Estimated age structures of fish caught on handlines and longlines in SE in each of three years.

Spatial comparisons of size at age

The regional size structures presented in Figs. 5.1 – 5.13 demonstrated considerable differences between regions. This reflected, to some extent, the different age structures of the populations amongst regions. However, it also reflected different regional growth characteristics. Fish from the 1991 year class that were captured in NSG during the early 2000s generally belonged to either the 'large' or 'very large' size categories although a few fish from MFAs 22 and 23 were in the 'medium' size category (Fig. 5.15). In contrast, the 1991 fish captured between 2000 and 2003 from SSG were generally smaller than in NSG, and covered a much broader size range which even included some 'small' and numerous 'medium' sized fish. The fish captured in MFA 33 largely conformed to a bimodal size structure with a significant number of 'small' to 'medium' fish and a second mode of 'large' fish. The 'large' fish were similar in size to those from NSG, but the many smaller fish were not evident in northern region. Overall, the results indicated a latitudinal effect on size at age with many fish from SSG having grown more slowly than was the case for NSG. This suggests that the southern region has a lower level of productivity compared to the northern region.

A further spatial difference in growth was evident between NGSV, SGSV and the SE. Those from the 2001 year class that were captured in NGSV in the late 2000s were mostly in the size range of 60 – 70 cm

CFL, with some even in the ‘very large’ size category. Alternatively, most of the 6-8 year old snapper captured in SGSV between 2007 and 2009 were in the size range of 40 – 50 cm CFL, with some even in the 30 – 40 cm CFL size range. Furthermore, the fish from the SE were even smaller than those from SGSV, with many 7 – 8 year old fish even less than 40 cm CFL. Such data indicate very different regional growth characteristics, and therefore different levels of productivity between the three geographic regions.

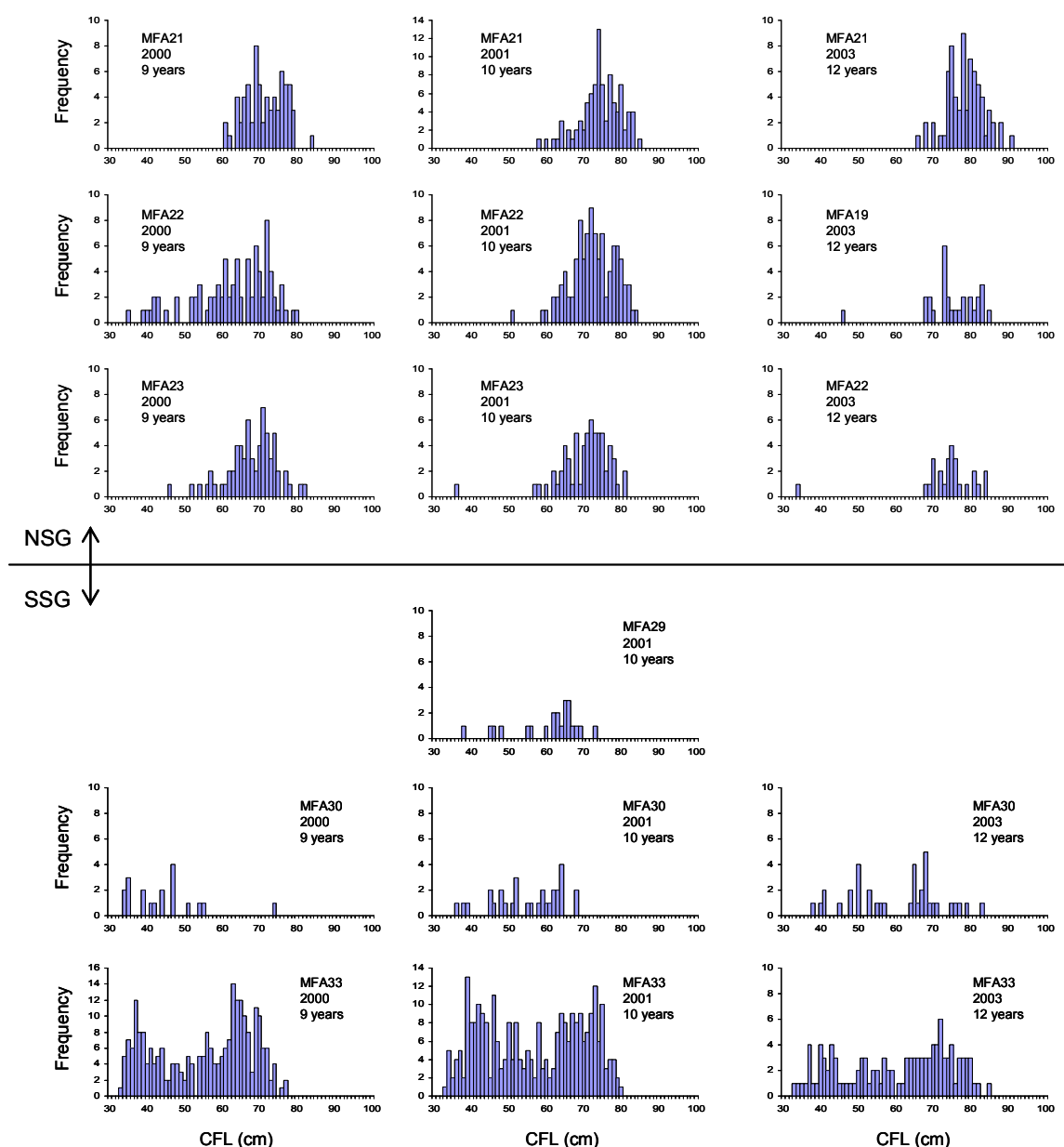


Fig. 5.15. Comparison of size structures of snapper from the 1991 year class that were captured in the nominated MFAs in NSG and SSG in the years of 2000, 2001 and 2003. Note that graphs are arranged vertically according to latitude of MFAs (north at top, south at bottom).

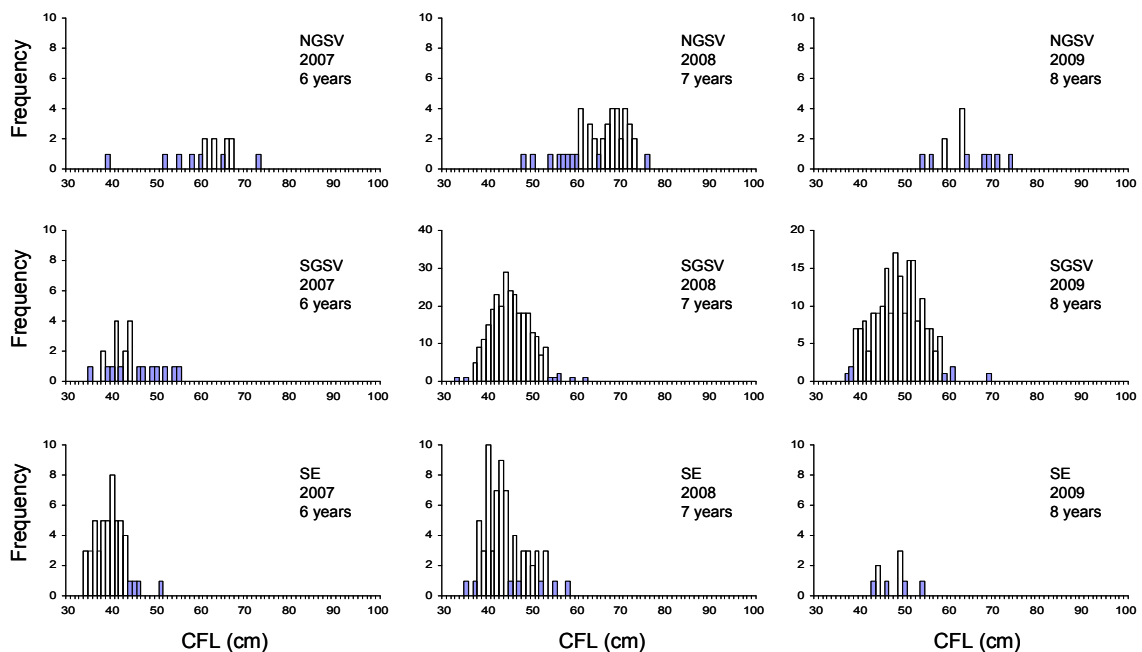


Fig. 5.16. Comparison of size structures of snapper from the 2001 year class that were captured in NGSV, SGSV and the SE in the years of 2000, 2001 and 2003.

5.4 Discussion

Population size and age structures were successfully generated for each of NSG, SSG, NGSV, SGSV and the SE region. There were a number of similarities in the results from different regions, but also some important differences that must reflect different processes occurring in different regions.

NSG has consistently supported broad size and age structures, and demonstrated considerable variation in age class strength. Also, there is a relatively tight relationship between size and age. In comparison, the population in SSG has generally demonstrated a more restricted range of ages, whilst age structures have consistently been dominated by one or two strong year classes. Only occasionally is a ‘very large’ fish captured in this region. There is high variation in the estimates of size at age, resulting in a poor relationship between size and age. In fact, some individual age classes, such as the nine year old fish in 2000 and the 10 year olds in 2001 had bimodal size distributions, suggesting differential growth patterns amongst fish captured in the same places. NGSV appears to be the most eclectic with respect to supporting fish from different size and age classes, although differences in age class strength are apparent in the age structures. SGSV has supported more restricted size and age structures, particularly in the late 2000s, during which time this regional population was dominated by the 2001 year class. During the late

2000s the population of snapper occupying the SE region was dominated by numerous small fish from the 2001 year class, similar to SGSV.

Overall, the data on population structure are indicative of processes that ultimately influence the biomass, numbers and structure of the various regional populations. Differences in age class strength were evident for all regions. This phenomenon is well-documented for South Australian snapper, and is commonly related to inter-annual variability in recruitment of the 0+ snapper (McGlennon et al. 2000, Fowler and Jennings 2003). Strong year classes are, to some extent, consistent between regions and include those that recruited as 0+ fish in 1991, 1997, 1999, 2001 and 2004. Nevertheless, there are considerable differences amongst years in the relative significance of these different year classes. The 1991 and 1997 year classes were significant in each of the four gulf regions, and are largely responsible for the recovery of the fishery from the mid 1990s onwards, and the record catches that have been taken from the late 1990s onwards. However, the relative significance of the 1999, 2001, 2004 and even the 2006 year classes have differed between regions. Whilst the 2001 year class now dominates catches in SGSV and the SE, it has made only relatively minor contributions to the catches in both NSG and SSG. Also, the 2006 year class has begun to make reasonable contributions to catches in GSV in 2009, but the contributions to catches in SG have been only minor, and non-existent for the SE region. The differences in spatial and temporal patterns in year class strength manifested in the age structures between regions, suggest the influence of a combination of large and small-scale processes on regional recruitment that are not fully understood. Perhaps the biggest concern from the age structures is the lack of evidence of recent strong year classes in SG.

The differences in sizes and ages of fish between the northern and southern parts of the gulfs also imply several differences in population processes. Firstly, 'dwarf' fish, i.e. those that are 10 – 12 years old and still in the 'small' size category small, are a feature of the southern regions but are very rare in the northern parts of the gulfs. This strongly suggests significant differences in growth between regions since some fish from the southern regions grow more slowly than all fish in the north. Nevertheless, not all fish removed from the southern gulfs conform to this slower, more restricted growth pattern. Many are of a similar size at age as those collected from the northern regions. This begs the question as to the origins of these larger southern fish. Did they develop and grow in the northern regions and recently move and join one of the southern populations? Alternatively, have these fish always lived in the southern region but for some reason have experienced higher growth rates than the slower-growing southern fish? At present it is not possible to differentiate between these alternative hypotheses. This indicates that we continue to have a poor understanding of movement of snapper among regions and its significance as a demographic process that influences regional biomass and fish numbers.

6. RECRUITMENT INDEX

6.1 Introduction

The population dynamics and fishery productivity of snapper in SA are fundamentally driven by high inter-annual variation in recruitment (McGlennon and Jones 1997, Fowler 2000, 2002, Fowler and Jennings 2003, Fowler et al. 2005, 2007). It was demonstrated in the previous chapter that there are distinct strong and weak age classes in the population that are consistent between years, which are likely to relate to inter-annual variation in recruitment of 0+ snapper (McGlennon et al. 2000, Fowler and Jennings 2003). It appears that the occasional strong year class sustains the fishery through periods that are characterised by poor to average recruitment. For example, the increases in catches and catch rates in Spencer Gulf throughout the late 1990s and record catches around 1999 and 2000 were largely related to a single, exceptionally-strong year class that recruited as 0+ fish in 1991 (Fowler et al. 2005, Chapter 5). Since the productivity of this fishery is largely determined by variable recruitment, having an accurate annual index of recruitment could be a good indicator of future fishery catches. Consequently, one aim of SARDI's research program for snapper since 2000 has been to develop such understanding. This general aim has involved addressing two objectives: to describe the spatial and temporal patterns in recruitment of 0+ fish in NSG; and to elucidate aspects of the early life history and larval and juvenile ecology, towards understanding the processes that regulate recruitment. This chapter provides an update to this project, including: annual estimates of recruitment to NSG from 2000 to 2010; data on the dispersion of recruits throughout the study area; data on the biological characteristics of the recruits; and some discussion on the qualitative comparison between recruitment rates and year class strength in the catches in the fishery. As such, this chapter provides estimates of recruitment for a further three years, i.e. 2008 to 2010 over those provided in earlier summaries by Fowler and Jennings (2003), and Fowler et al. (2005, 2007). Note also that the recruitment rates for the three years of 2006-2008 were considered in detail by Saunders (2009).

6.2 Materials and methods

The basis of this study is an annual survey for 0+ snapper in NSG that was done in April of each year from 2000 to 2010. The survey has involved sampling with an otter trawl from the research vessel the RV Ngerin at numerous places throughout NSG (i.e. north of 34°S in Spencer Gulf), as described in detail by Fowler and Jennings (2003). For the first six years, more than 100 trawl stations were sampled per year throughout five latitude zones between 34° 00'S and 32° 30'S (Fig. 6.1). However, in 2006 the sampling effort was reduced to approximately 70 stations by excluding the two southern zones that had not produced any 0+ fish to that time. As such, from this year onwards, only the Central, Northern and Far Northern Zones (i.e. between 33° 30'S and 32° 30'S) were sampled. The sampling stations were generally distributed throughout the channel that runs down through the western part of the gulf. At

each station a 10-minute shot with an otter trawl was done, after which the trawl catch was sorted for 0+ snapper (Fowler and Jennings 2003). These small fish were measured, weighed altogether and then preserved by freezing for future ageing work.

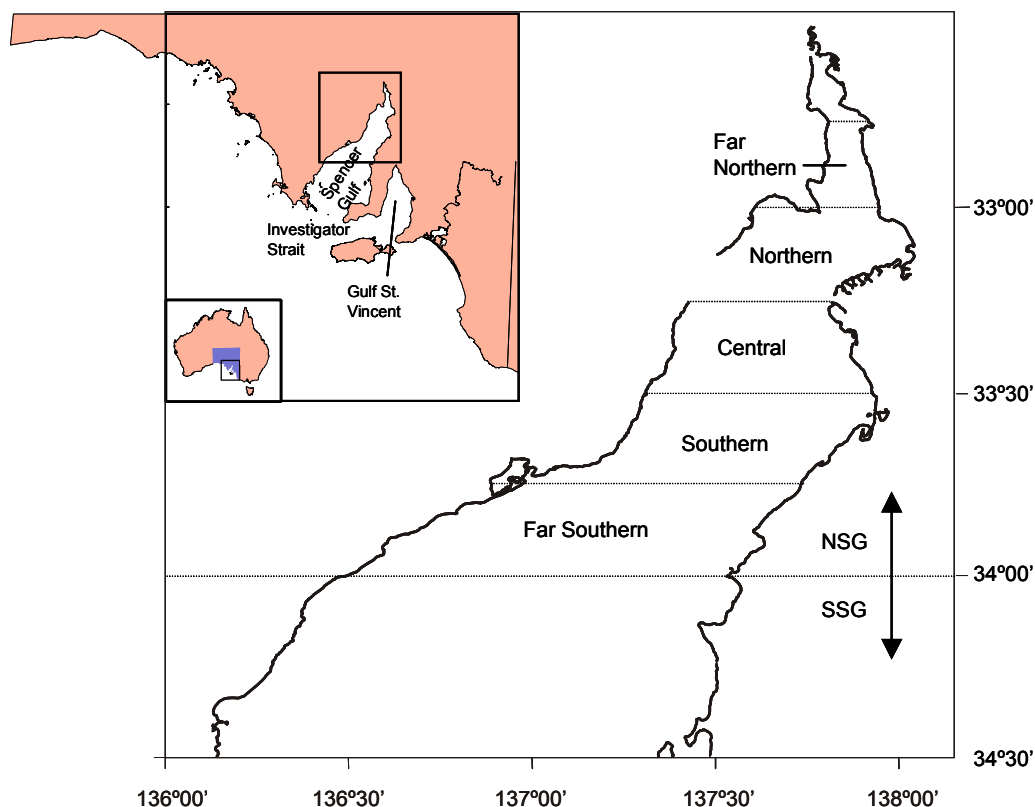


Fig. 6.1. Map of Northern Spencer Gulf (NSG) showing the five latitude zones of Far Northern Zone (FNZ), Northern Zone (NZ), Central Zone (CZ), Southern Zone (SZ) and the Far Southern Zone (FSZ) that were sampled for 0+ snapper using the otter trawl. The inset shows part of the South Australian coastline with northern Spencer Gulf highlighted, along with the area of South Australia relative to the national coastline.

Later in the laboratory, each specimen was dissected for removal of its otoliths. One sagitta from each fish was sectioned in the transverse plane, and the microstructure was interpreted to provide a total count of all daily increments that were differentiated into those from the pre-settlement and post-settlement parts of the otolith, based on the location of the settlement mark (Fowler and Jennings 2003). With data on fish age and collection dates, the birth dates of the 0+ fish were calculated. Frequency distributions of fish size, age and birth dates were generated and compared among years. The number of recruits and the timing of when they were spawned were considered in the context of the water temperature regime for that year. The sea surface temperature data (SST) were purchased from CSIRO having been originally derived from satellite images.

In 2000, the substratum at each trawl station was sampled using a benthic grab. These benthic samples were processed by particle size analysis that divided the sample by weight into three component fractions: coarse (particle size > 2mm); sand ($63\ \mu\text{m} < \text{particle size} < 2\ \text{mm}$); and clay/silt (particle size < $63\ \mu\text{m}$). The relationship between the distribution and abundance of snapper and substratum type was then determined by comparing the different distribution maps.

6.3 Results

Region-wide estimates of catch rates of 0+ fish

The recruitment survey produced annual estimates of the 0+ fish in NSG for the 11 year period from 2000 to 2010, which demonstrated considerable inter-annual variation (Fig. 6.2, Table 6.1). The highest capture rate of 3.6 snapper per trawl was recorded in 2006. Lower rates of 2.1 – 2.2 recruits per trawl were recorded in 2001 and 2010. In each of 2000 and 2007 the capture rate was approximately 1.0 fish per trawl, whilst in the remaining six years less than 1.0 fish per trawl was captured. The lowest capture rates were recorded in 2005 and 2008 when there were totals of only two and three fish captured respectively, from the minimum of 69 trawls that were sampled (Table 6.1). The longest period of poor catches was from 2002 to 2005, during which the capture rates ranged from 0.02 to 0.52 fish per trawl. Correlation analysis was used to assess the relationship between recruitment rate and average water temperature. Whilst the patterns of variation in recruitment and water temperature mirrored each other quite closely for the first six years of the survey, subsequently the relationship fell apart and ultimately there was no significant correlation up to 2009 ($r = 0.5194$, $n = 10$, $df = 8$, $p = 0.1239$) (Fig. 6.2).

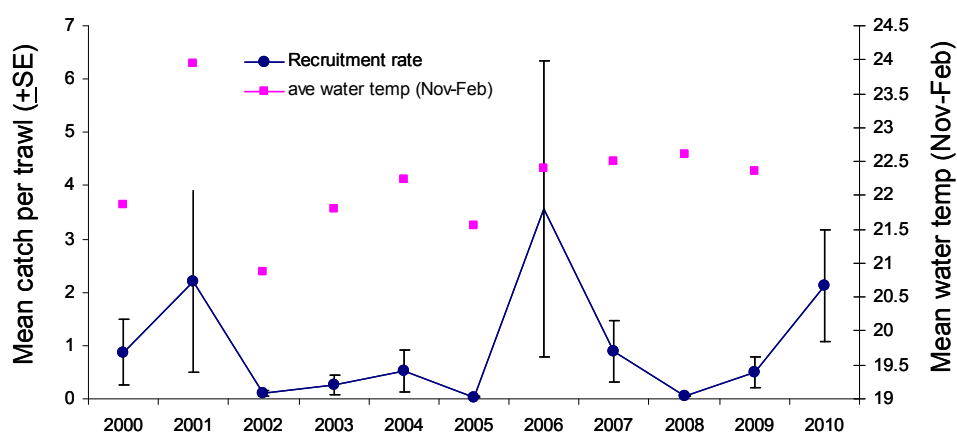


Fig. 6.2 Comparison of mean catch rates of the 0+snapper between years from the trawl survey done annually in Northern Spencer Gulf, compared with the average water temperature between November and February.

Particle size analysis and dispersion of fish

The particle size analysis for samples collected in 2000 indicated substantial differences amongst stations both within and between the five latitude zones (Fowler 2002, Fowler and Jennings 2003). In the FSZ and SZ the substratum was dominated by either sand or gravel (Fig. 6.3). In comparison, the three northern zones were dominated by sand except at four places where there was a high clay/silt fraction, which gave the substratum a real muddy texture. These four places were: in the mid-gulf around the border of the SZ and CZ; at the western border between the CZ and NZ; in the north-western part of the NZ; and in the middle of the FNZ.

There was considerable consistency in the dispersion patterns of the 0+ fish amongst years with several places where fish were consistently captured (Fig. 6.4). The most significant was near Western Shoal on the western side of the gulf near the border of the Central and Northern Zones. There were also several places further north in the Northern Zone, whilst generally a few fish were captured in one area in the Far Northern Zone (Fig. 6.4). The places that consistently produced the best catches of 0+ fish were those that supported the muddy substratum, as identified in Fig. 6.3. As such, there were a number of areas that were consistently used as nursery areas by the 0+ snapper, of which Western Shoal was the most significant. It is notable that during the years of lowest recruitment, i.e. 2005 and 2008, there were no recruits captured at or near Western Shoal.

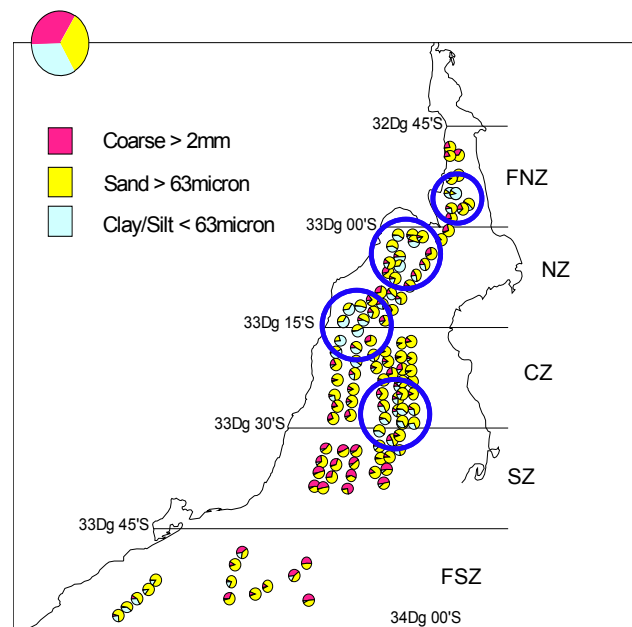


Fig. 6.3 Map of Northern Spencer Gulf showing the results from the particle size analysis of the substratum samples that were collected in 2000. The four areas of high silt/clay content, i.e. particularly muddy areas are identified with blue circles.

Table 6.1. Estimation of recruitment rates to the latitudinal zones in Northern Spencer Gulf in each year from 2000 to 2010. The mean numbers per trawl for the three northern zones (i.e. FNZ, NZ and CZ) were converted to weighted estimates based on the areas of these zones. The annual means for the region are plotted in Fig. 6.2. Note that the SZ and FSZ were not sampled from 2006 to 2010.

Year	Zone	No. stations sampled	No. 0+ snapper	Mean no. per trawl	Area of zone (km ²)	Mean per trawl weighted by area of zone	Regional weighted mean per trawl (SE)
2000	FNZ	11	5	0.45	407	0.19	0.87 (0.62)
	NZ	28	48	1.71	1186	2.11	
	CZ	60	14	0.23	1301	0.32	
	SZ	28	0	0	1763	-	
	FSZ	16	0	0	2452	-	
2001	FNZ	11	6	0.55	407	0.23	2.21 (1.70)
	NZ	29	132	4.55	1186	5.60	
	CZ	42	25	0.60	1301	0.80	
	SZ	24	1	0.04	1763	-	
	FSZ	16	0	0	2452	-	
2002	FNZ	11	1	0.09	407	0.04	0.11 (0.06)
	NZ	28	5	0.18	1186	0.22	
	CZ	42	2	0.05	1301	0.06	
	SZ	24	0	0	1763	-	
	FSZ	20	0	0	2452	-	
2003	FNZ	11	3	0.27	407	0.12	0.26 (0.18)
	NZ	28	14	0.5	1186	0.61	
	CZ	32	1	0.03	1301	0.04	
	SZ	24	0	0	1763	-	
	FSZ	19	0	0	2452	-	
2004	FNZ	11	4	0.37	407	0.15	0.52 (0.40)
	NZ	28	30	1.07	1186	1.32	
	CZ	28	2	0.07	1301	0.10	
	SZ	24	0	0	1763	-	
	FSZ	19	0	0	2452	-	
2005	FNZ	11	1	0.09	407	0.01	0.02 (0.01)
	NZ	28	1	0.04	1186	0.04	
	CZ	28	0	0	1301	0	
	SZ	24	0	0	1763	-	
	FSZ	19	0	0	2452	-	
2006	FNZ	11	14	1.27	407	0.54	3.56 (2.78)
	NZ	29	215	7.41	1186	9.12	
	CZ	30	23	0.77	1301	1.03	
	SZ	0	-	-	-	-	
	FSZ	0	-	-	-	-	
2007	FNZ	11	1	0.09	407	0.04	0.89 (0.58)
	NZ	29	47	1.62	1186	1.99	
	CZ	30	14	0.47	1301	0.63	
	SZ	0	-	-	-	-	
	FSZ	0	-	-	-	-	
2008	FNZ	11	1	0.09	407	0.04	0.04 (0.01)
	NZ	28	1	0.04	1186	0.04	
	CZ	30	1	0.03	1301	0.04	
	SZ	0	-	-	-	-	
	FSZ	0	-	-	-	-	
2009	FNZ	11	7	0.64	407	0.27	0.5 (0.3)
	NZ	27	24	0.89	1186	1.09	
	CZ	30	3	0.1	1301	0.13	
	SZ	0	-	-	-	-	
	FSZ	0	-	-	-	-	
2010	FNZ	11	1	0.09	407	0.04	2.13 (1.05)
	NZ	28	68	2.43	1186	2.99	
	CZ	30	75	2.5	1301	3.37	
	SZ	0	-	-	-	-	
	FSZ	0	-	-	-	-	

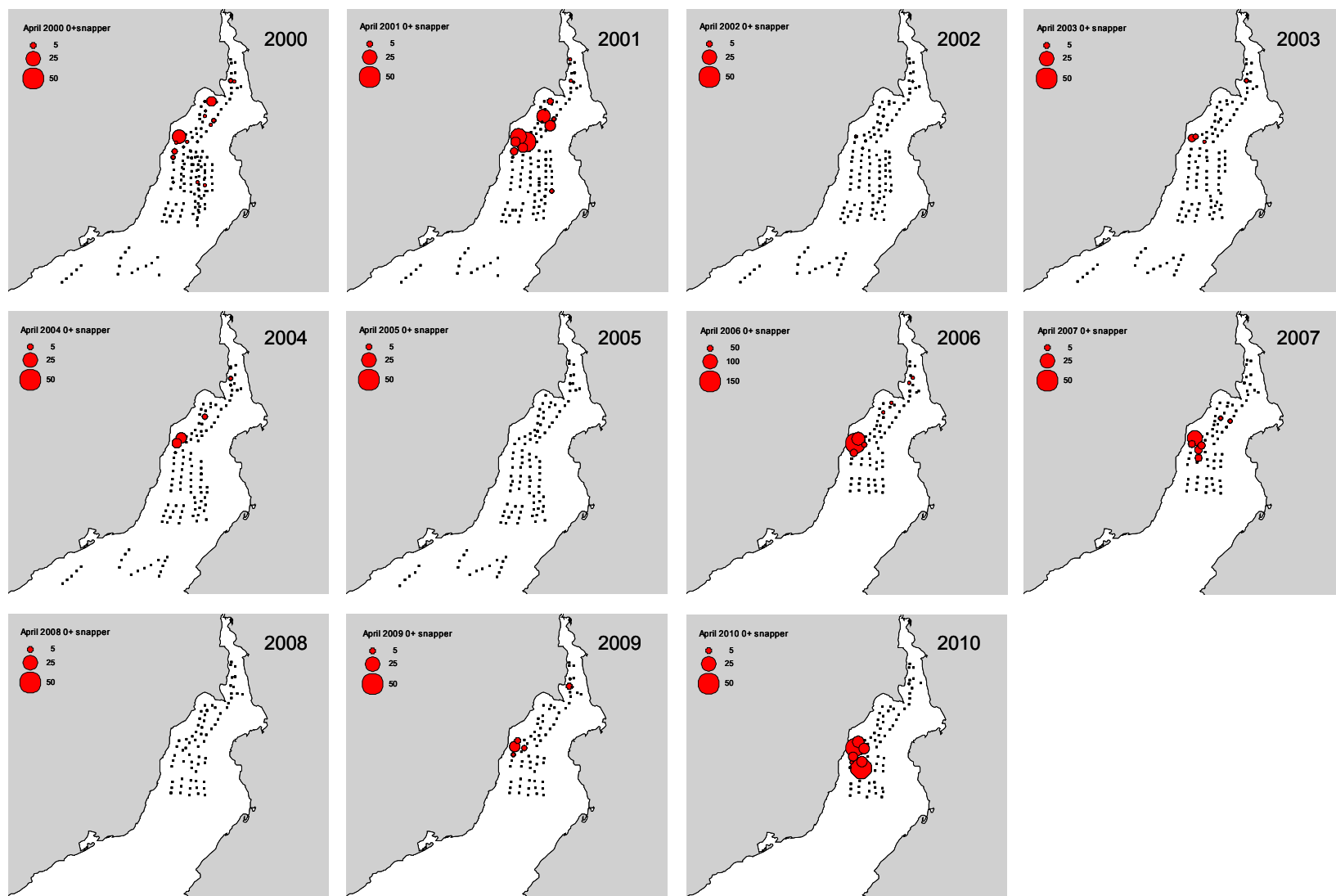


Fig. 6.4 Results from sampling 0+ snapper in Northern Spencer Gulf in each year between 2000 and 2010, showing the location and number of fish per trawl. Trawls stations where no 0+ snapper were captured are indicated with a dot. Note the different scale used for 2006.

Biological characteristics of 0+ snapper

There were considerable differences in the biological characteristics of the 0+ fish captured amongst years. A total of 779 0+ snapper were measured from the 11 years of sampling. Whilst in 2001, 2005, 2007, 2008 and 2010 the average size was >70 mm CFL, the smallest fish were captured in 2004, when the mean size was only 47.1 mm CFL (Fig. 6.5a). The consecutive years of 2002, 2003 and 2004 produced fish that were consistently small, with average sizes of <56 mm CFL. The average ages also varied amongst years. In 2007, the average age was 113.4 days, compared with only 75 days in 2008 (Fig. 6.5b). In each of 2001, 2002, 2003 and 2007 the average ages of the 0+ snapper exceeded 100 days, whereas in 2000, 2004, 2006 and 2008 the average ages were <95 days of age. There were also differences in growth rates, which were highest in 2000, 2001, 2007 and 2009 and relatively low from 2002 to 2006 (Fig. 6.5c). These biological data indicate the likely influence and response to different environmental conditions in different years.

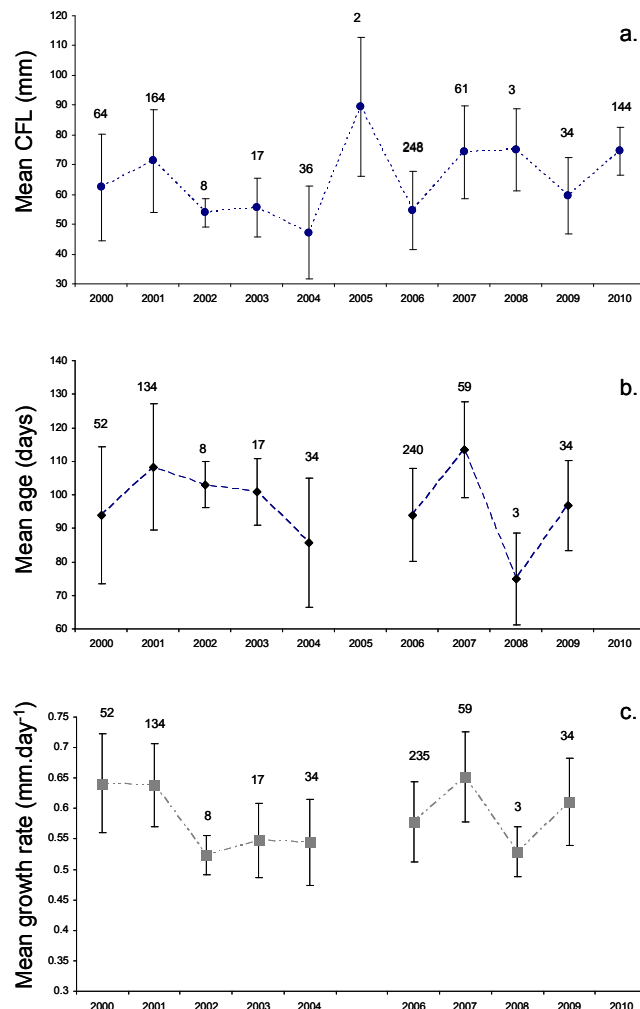


Fig. 6.5 Comparison of the biological characteristics of the 0+ snapper amongst years. a. average sizes (+ sd). b. average ages (+ SD). c. average growth rates (+ sd).

With estimates available for total age and date of collection for each successful recruit it was possible to determine the date on which each was spawned. In all years most 0+ snapper were spawned between early December and early February, although in 2001 some were spawned in mid-late November (Fig. 6.6). In all years, the successful spawn dates were not distributed evenly or consistently throughout the December-February period but were grouped at particular times. Furthermore, the duration and timing of these periods varied between years. For example, in 2001 most recruits originated between late November and mid January, whereas in 2002 and 2003, the few successful recruits originated in late December and early January. The distribution of spawn dates in each year was compared with the water temperature regime in that year. Comparison across years indicated that most successful birth dates corresponded to the water temperature range of 21 to 25°C. However, for those years that produced few recruits there were numerous days in the optimal temperature range that did not produce recruits.

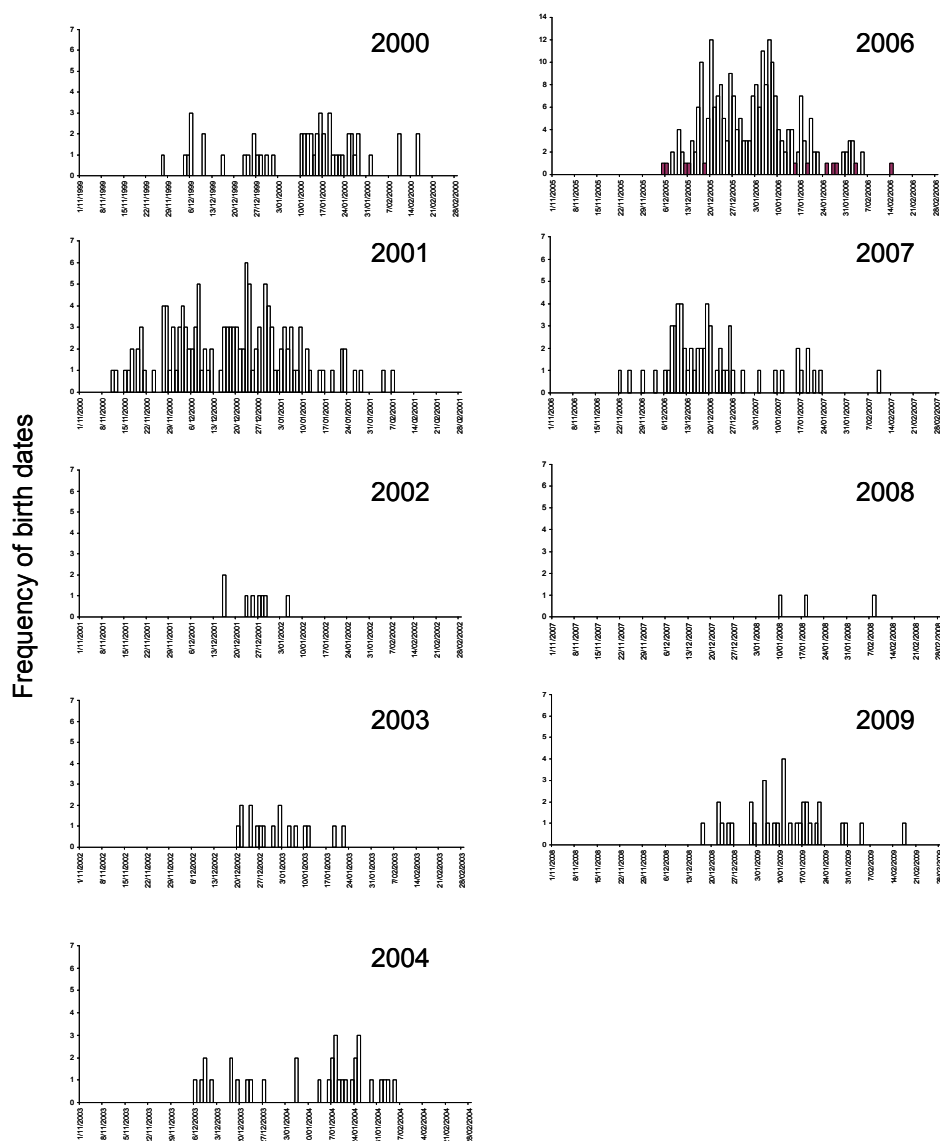


Fig. 6.6 Frequency distributions of the estimated birth dates for the 0+ snapper captured at the end of each summer from 1999-2000 to 2008/09. Note that there are no estimates available for 2005 and 2010.

6.4 Discussion

The annual sampling in NSG has provided some compelling results regarding the spatial and temporal patterns in distribution and abundance of 0+ snapper. Despite the inter-annual variation in catch rates, the dispersion of 0+ fish was generally consistent across years. Furthermore, their spatial distribution strongly corresponded with the areas with a muddy substratum, rather than sand or gravel. This finding is consistent with habitat selection at the time of settlement by the post-larvae or soon after settlement, involving post-settlement movement by the juvenile fish.

In contrast to the spatial consistency, there was considerable inter-annual variation in recruitment rates. In fact, there was at least a 100 times difference amongst the recruitment rates across the eleven years. Furthermore, the biological characteristics of the 0+ fish also varied considerably between years. This variation was evident in the sizes, ages and the dates when successful recruits were spawned. The dates on which successful recruits were spawned varied considerably among years, which ultimately led to the differences in ages and sizes of 0+ fish between years. As such, there are periods during each spawning season, i.e. 'windows of opportunity' when the conditions are appropriate for survivorship of eggs and larvae that ultimately lead to successful recruitment. However, as yet, the basis of this relationship remains poorly understood. Such an environmental influence may affect the spawning of the adult fish, the survivorship of the eggs and larvae or a combination of both. Water temperature is likely to be involved since successful recruitment most often ensued from spawning that occurred in the range of 20 - 25°C (Saunders 2009), presumably related to physiological tolerance ranges. Nevertheless, there were many periods through numerous summers when the temperature was in this range and spawning did occur, but successful recruitment did not ensue (Fowler and Jennings 2003, Saunders 2009). As such, water temperature cannot be the sole environmental influence over successful recruitment.

One reason why recruitment was monitored for eleven years in NSG was to determine if an annual recruitment index was an indicator of subsequent year class strength that would predict future catches. This is now possible by comparing the relative recruitment indices presented in Fig. 6.1 against the regional age structures presented in Chapter 5. The recruitment indices for NSG indicate that the highest numbers of 0+ fish were in NSG in 2001, 2006 and 2010. It is too early, as yet, for the latter year class to be represented in the fishery catches. However, neither the 2001 or 2006 year classes have yet become apparent as strong year classes in catches from either NSG or SSG (Figs. 5.2, 5.4, 5.6 and 5.8). Furthermore, the recruitment rate recorded in 2004 was low, yet the age structures of the handline catches in NSG in 2007/08 and 2008/09 indicate that this was a relatively significant year class in the population. Clearly, the temporal signal in the measured recruitment rates is not currently a good indicator of year class strength in the fishery catches of NSG and SSG. However, the recruitment index in NSG might have broader significance as an indicator of year class strength. The 2001 year class is very strong in the fishery catches of both SGSV and the SE (Figs. 5.12 and 5.14), whilst the 2006 year class

may well be emerging as a significant year class in both NGSV and SGSV (Figs. 5.10, 5.12). As such, the recruitment rates in NSG might be useful indicators of year class strength for regions outside of SG. Such a relationship would implicate fish movement, an aspect of the biology of snapper that is only poorly understood. Nevertheless, there remains considerable ambiguity about the value of measured recruitment rates in NSG, for predicting long-term changes in population biomass and fishery catches, as related to year class strength. Consequently, it is planned, at this stage, to discontinue this sampling program until the value of the data collected to date can be better evaluated.

7. MODEL-ESTIMATED TIME SERIES OF BIOLOGICAL PERFORMANCE INDICATORS

7.1 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 8, these yearly model estimates of snapper biomass, recruitment, harvest fraction and egg production are compared against the limit reference points for these biological indicators as specified by the management plan.

Four 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 (Chapter 4);
3. ! commercial length-frequency samples (Chapter 5);
4. ! commercial catch-at-age samples (Chapter 5).

The model input data set was updated to September 2009. 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 1990's, i.e. in 1990-91, 1994-95, and 2000 to September 2009. All catch samples in the first two programs were from Northern Spencer Gulf only. The 2000-2009 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 (Chapter 5). 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.

The methods for extrapolating recreational catches in years following the 2000/01 telephone and diary survey have been changed to incorporate information about the trend of change in recreational catch and effort made available from the second telephone and diary survey run in 2008/09 (Chapter 4). The estimates from 2000/01 were also revised to account for the improved 2-stage survey weighting allocations developed for the 2007/08 survey data analysis, making both survey estimates self-consistent. Estimates of recreational catch and effort totals from both surveys covered one full year for each of the three model regions. Prior to 2000, we extrapolated backward, as in previous snapper reports, by

assuming recreational effort and catch varied yearly in proportion to South Australian census count of human population. For years between the two available recreational surveys, we linearly interpolated catches and efforts from the estimates of each survey. The last two model years used the results of the 2007/08 survey directly, with no extrapolation applied.

7.2 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; Northern Spencer Gulf, Southern Spencer Gulf and Gulf St. Vincent. The West Coast and South East have not been included in 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 increased in recent years, notably in the South East (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 four data sources described in Section 7.1, 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 exploitation rate, and yearly egg production. Yearly recruit numbers (Fig. 7.1) 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 5 categories (handline, longline, hauling net, all other commercial gears combined, and 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).

Several modifications to the model have been made since 2007. The fecundity relationship used to calculate yearly egg production now accounts for recent work on snapper reproduction in Northern Spencer Gulf (Saunders 2009), including the timing of peak spawning in December and the fecundity relationship derived in the recent snapper management strategy evaluation study (McGarvey et al. 2010) from Saunders' batch counts of eggs released per spawning event by female snapper of varying length - $\text{Batch fecundity} = (7.2 \times 10^{-4}) \text{TL}^3$, 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, 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). Currently, New Zealand snapper models assume a value of $M = 0.051-0.054$, estimated from age samples of their West Coast stocks in the 1970's prior to significant exploitation (D. Gilbert, pers. comm.). Accepting these as direct measurements of snapper natural mortality rate, this year, we reduced the assumed value from $M = 0.075$ to $M = 0.05$.

7.3. Results

The biological performance indicators of recruitment, biomass, exploitation rate and egg production estimated by the 'SnapEst' model are presented for the three regions in Figs. 7.1-7.4. Principal outcomes for these snapper population indicators are summarised in this section:

1. ! The high yearly variation of snapper recruitment is evident, with a few year classes dominating (Fig. 7.1). This is consistent with (and is inferred from) the age-structure catch samples of Chapter 5, in which those same year classes are evident.
2. ! As reported above, based on direct examination of the catch-at-age samples (Chapter 4), the historically strong 1991 year class which had sustained the South Australian snapper fishery for over a decade has now largely passed through. The model estimates of recruitment show that 1991 produced the highest recruitment overall for the period of 1983-2005 (Fig. 7.1) and was very strong in all three model regions, highest on record in NSG and SSG and second highest in GSV.
3. ! More recent model estimates of recruitment show several year classes since 1991 which are strong in NSG, notably 1997, 1999, 2001 and 2004 (Fig. 7.1a), as inferred from the age samples reported in Chapter 5. As a percentage of the 1991 year class, estimated NSG recruit numbers for these four year classes were estimated to be 87%, 58%, 22% and 36% respectively.
4. ! Recruitment numbers of snapper have been noticeably higher on average, since the mid 1990s (Fig. 7.1). The model estimated a 60% rise in mean recruitment since 1996. The earlier period was marked by a strong, single year class in 1991, which dominated catches for 10 or so years subsequently, while lately there has been relatively strong recruitment in NSG every few years.
5. ! The higher levels of recruitment for years since 1996 are coincident with decreasing exploitation levels resulting in increasing egg production (Fig. 7.4). Higher snapper egg production in NSG, and in South Australian waters overall, was roughly coincident in time with rising mean levels of recruitment. This may suggest that recent all-time high levels of biomass and catch are, at least in

part, due to higher snapper egg production, notably in NSG (and northern parts of SSG).

6. ! NSG model biomass for 2007, 2008 and 2009 has continued rising to new highs as fishing effort by both commercial (Chapter 3) and recreational (Chapter 5) sectors have declined. SSG biomass peaked around the middle of the 2000s, and has been trending downward in later years, as fishing effort by longlines and catchability by handlines, has risen in recent years. The rising biomass trend for GSV has increased in steepness, reaching levels higher than any previously estimated. This reflects higher catch rates in GSV in recent years, reflecting recruitment of the strong 2001 year class, and high catches of large snapper in NGSV.
7. ! Exploitation rates (Fig. 7.3) quantify the fraction of the fishable biomass which is harvested in each six-monthly model time step (Fig. 7.3a-c) or in each year (Fig. 7.3d). Exploitation levels vary seasonally, being higher in summer (Fig. 7.3a-c) when handline fishers target snapper aggregated at well-defined spawning locations. Overall, estimated levels of exploitation on South Australian stocks are relatively low with yearly levels in 2009 of approximately 10% in SSG and GSV (Fig 7.3d) and about 5% in NSG.
8. ! In recent years, two clear trends for exploitation rate in the two regions of SG are evident: (1) In SSG, exploitation rates have risen strongly in the last 3 years, particularly in the summers. This reflects higher levels of effort in SSG by longlines over the last 5 years (Fig. 3.5), as well as higher catch rates with both gears. To obtain good fits to catches by handlines in the last 3 years, it was necessary to estimate a level of catchability in SSG by handlines which was three times higher in the last three summers. (2) In NSG, the opposite trend was observed: exploitation rates were much lower in the last 4-5 years, reflecting lower levels of commercial and recreational effort (despite rising biomass and catch rates).
9. ! Changing the assumed natural mortality level from $M = 0.075$ to $M = 0.05$ had the expected effect on SnapEst estimates of decreasing biomass, increasing exploitation rate, and decreasing egg production compared with overall levels reported in 2007.

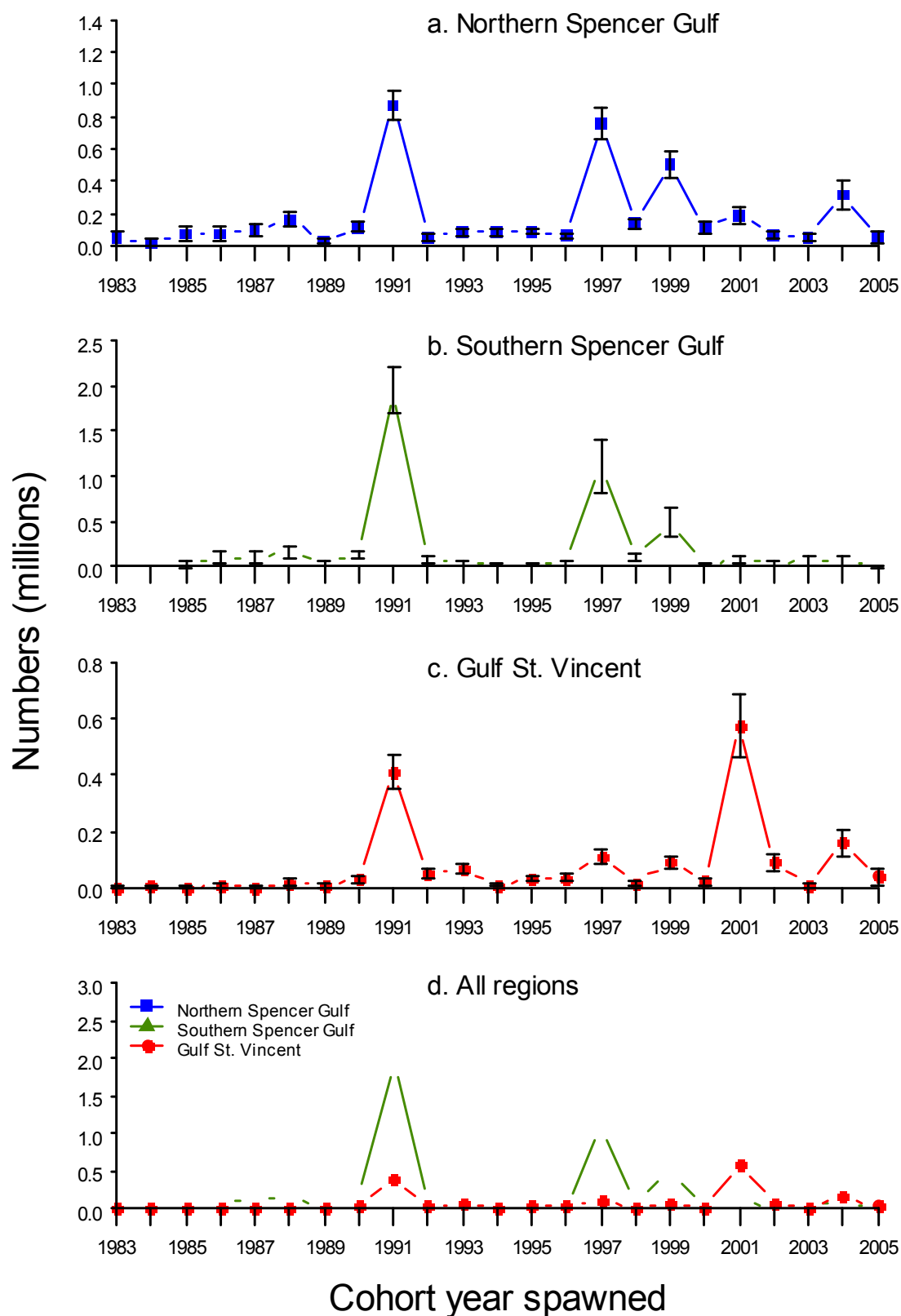


Fig. 7.1 Yearly recruitment estimates for the South Australian snapper stock, by region. The model defines recruitment of a year class as the number of snapper spawned in any given summer spawning season (e.g. 1991) that reach fishable size at age 3 years. Error bars quantify the 95% confidence intervals in this and subsequent model output, Figs. 7.1-7.4.

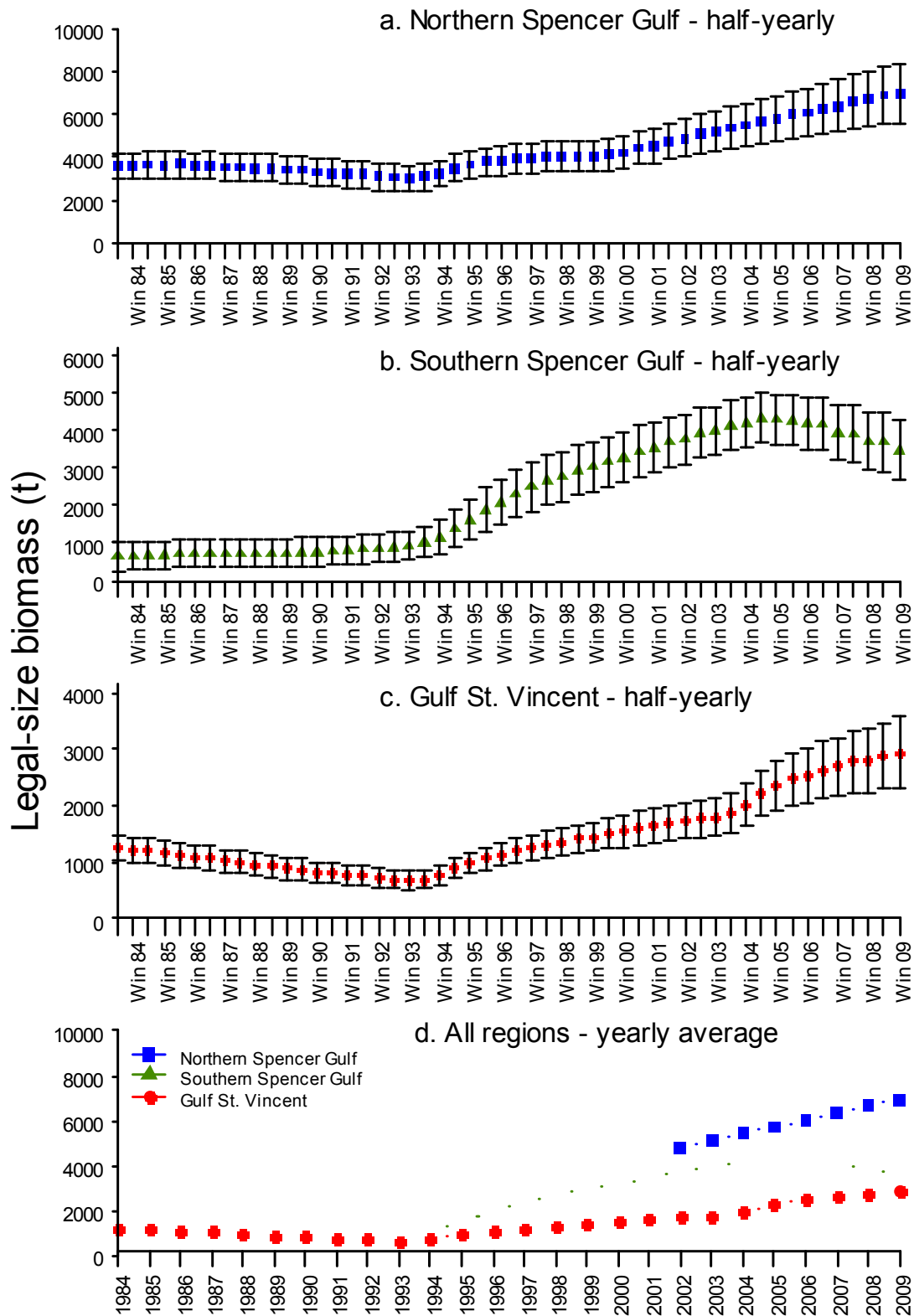


Fig. 7.2 Model estimates of snapper legal-size (i.e. fishable) biomass. These are shown (a-c) by region, as half-yearly model estimates with 95% confidence intervals, and (d) as yearly averages of model biomass (the average of winter and summer) from all three regions plot on the same graph, for visual comparison between regions and assessment of yearly trends.

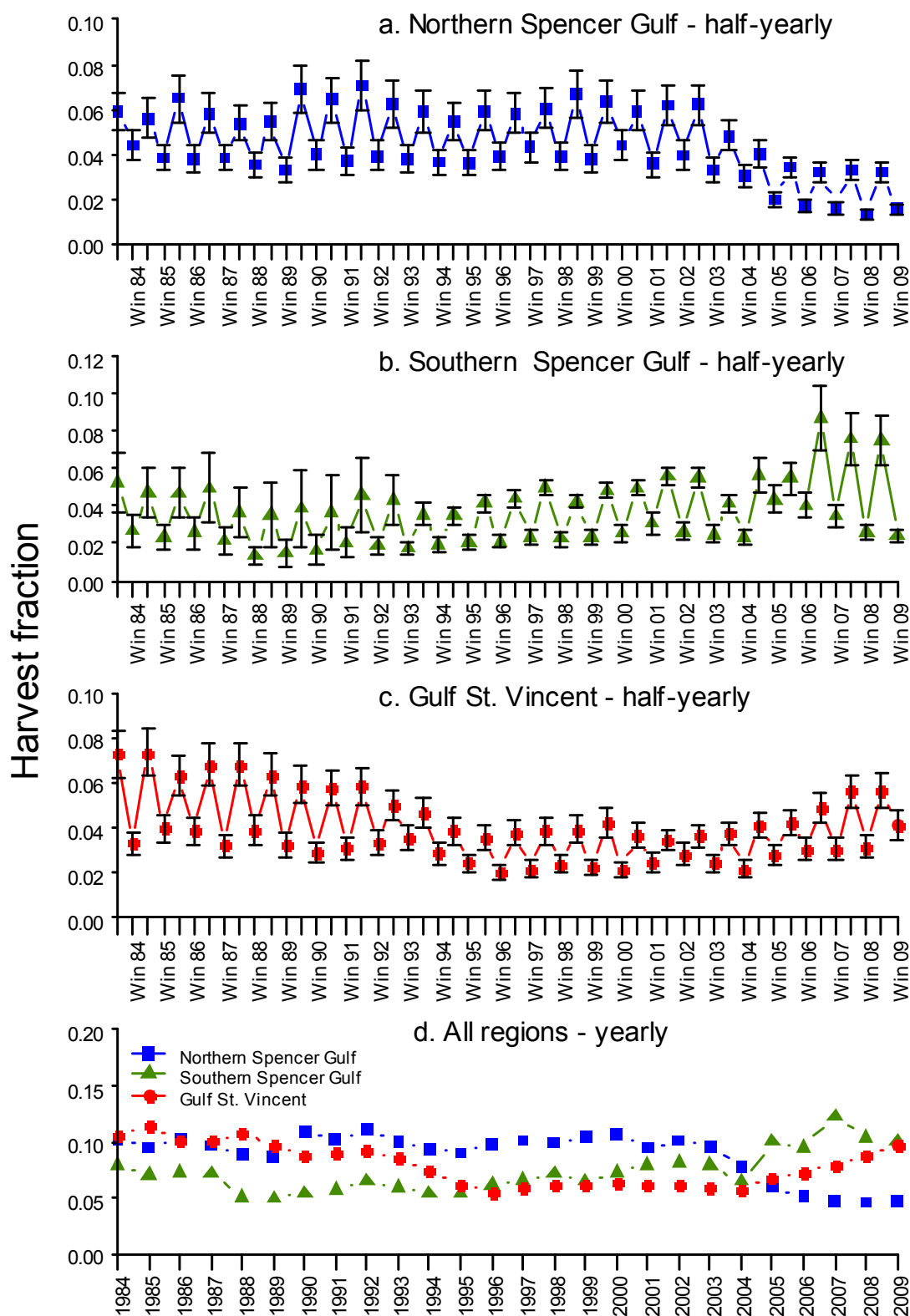


Fig. 7.3 Model estimates of snapper exploitation rate (i.e. harvest fraction). Regional estimates (a-c) by half year, with 95% confidence intervals, define harvest fraction as model-estimated catch divided by start of half-year model biomass. In graph (d) each yearly harvest fraction is calculated as the total yearly model catch divided by the yearly average of model biomass, for all three regions.

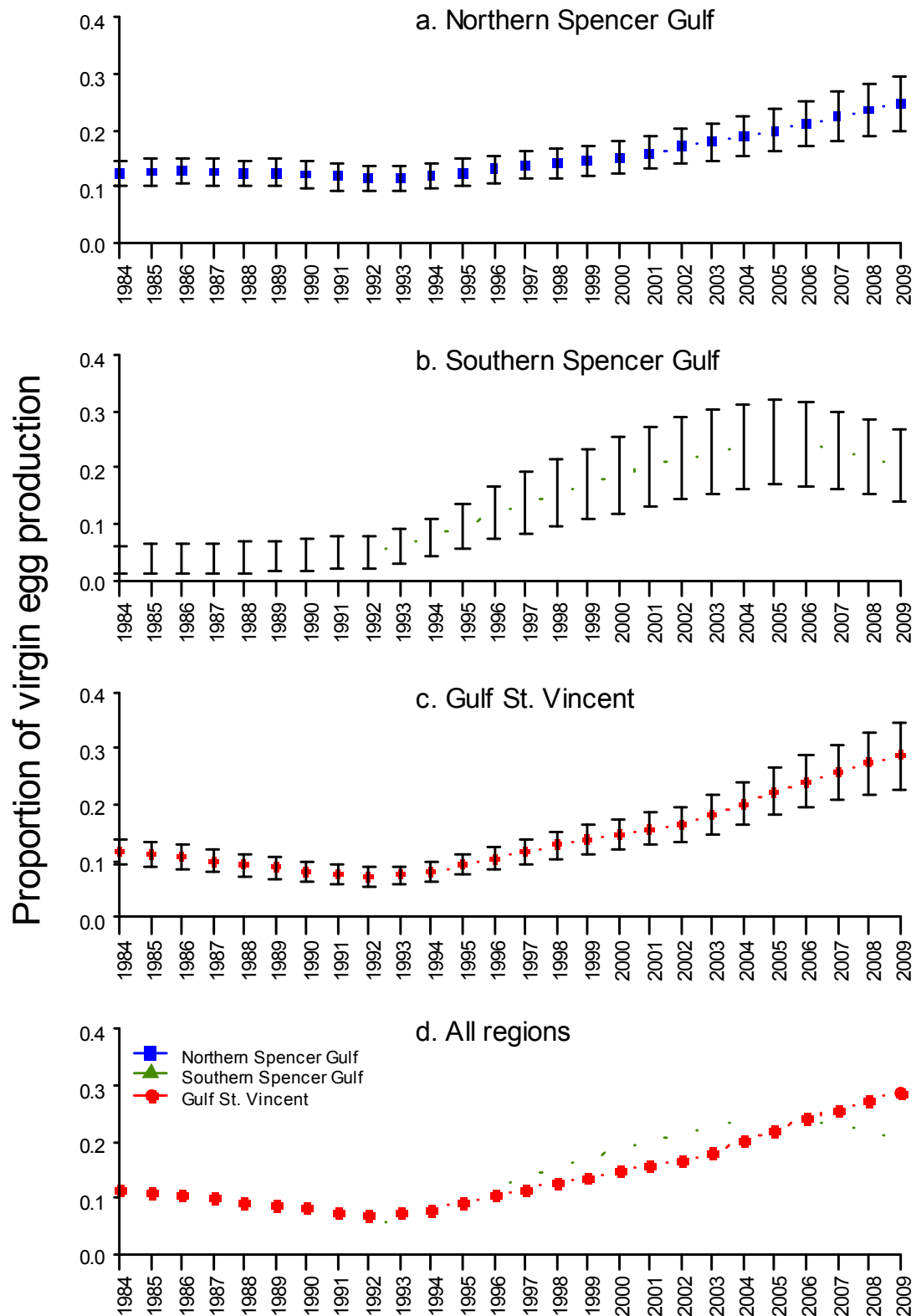


Fig. 7.4 Yearly egg production estimates for the South Australian snapper stock, by region. Egg production is scaled as a proportion of the model-estimated level that would be obtained, on average, in an unfished (virgin) population, obtained by setting model fishing mortality equal to 0.

8. ASSESSMENT OF FISHERY PERFORMANCE INDICATORS

8.1 Introduction

The Management Plan for the Marine Scalefish Fishery of South Australia provides a strategic framework to guide fishery management decisions (Noell et al. 2006). This framework links the management goals with the stock assessment process and identifies appropriate responses to the potential outcomes of the assessment. Essential to this process are fishery performance indicators that relate to the status of the fishery, with respect to the management objectives. For this fishery there are two sets of fishery performance indicators that are assessed against particular limit reference points, i.e. the 'general performance indicators' that relate to the commercial catch and effort data and 'biological performance indicators' that relate to estimates of biological parameters that primarily come from the 'SnapEst' model. For the former, the indicators and reference points that are specified in the Management Plan (Noell et al. 2006) were not used in this assessment. At a meeting of the Marine Scalefish Fishery Management Committee that was held on the 17th February 2006, it was agreed that new sets of general performance indicators and limit reference points should be adopted (Minutes of meeting No. 98 of MSFMC), which are outlined below. The biological performance indicators remain as specified in the Management Plan (Noell et al. 2006).

8.2 Materials and Methods

General Performance Indicators

Three general fishery performance indicators are now used in the Marine Scalefish Fishery: total commercial catch; targeted effort and targeted CPUE. For snapper, the targeted effort types that are considered are handlines and longlines. The limit reference points used to assess the general indicators are:

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

For this study, time series of estimates of general performance indicators were calculated from the commercial catch and effort data for the State-wide fishing statistics, and regional data from 1983/84 to 2008/09. The appropriate limit reference points, as defined above, were then derived from these different time-series of data. The estimates of indicators for 2008/09 were then compared with the limit reference points. For the State-wide statistics and each region a 'results' table was prepared that showed

the outcomes of the comparisons, with respect to whether the limit reference points were breached or not.

Biological Performance Indicators

For snapper, there were five biological performance indicators assessed: fishable biomass; exploitation rate of the fishable biomass; egg production; abundance of pre-recruits, and age structure (Noell et al. 2006). The first four of these were outputs from the SnapEst model (Chapter 7), whilst the fifth relates to the analysis of population structure that was presented in Chapter 5. The estimates of output parameters from the SnapEst model were compared against prescribed limit reference points for each of the three regions considered in SnapEst, i.e. NSG, SSG and GSV. Furthermore, the estimates for these three regions were combined to provide approximate estimates for the State-wide geographic scale that were also compared against limit reference points. There was one further biological performance indicator considered that was not derived from the SnapEst model, i.e. 'age composition' for which the limit reference point is – significant change over the past five years. Here, the new age structures presented in Chapter 5, were compared against the earlier estimates for age structures.

8.3 Results

General Performance Indicators

For the State-wide fishery statistics, a total of seven of 15 comparisons of general performance indicators exceeded the limit reference points (Table 8.1). These related to 2008/09 producing the highest total catch ever recorded, the highest and most substantial increase in longline effort, as well as high estimates of handline and longline catch rates.

For the 15 comparisons for NSG, there were three breaches of limit reference points that related to high estimates of CPUE for both handlines and longlines (Table 8.2). For SSG, four comparisons exceeded the limit reference points that related to the high total catch, high longline effort and high estimates of handline CPUE (Table 8.3).

For NGSV there were six breaches of limit reference points that related to the substantial increase in total catch in the past few years and the recent increases in longline effort and CPUE (Table 8.4). There were several breaches of limit reference points for SGSV that were for handline and longline CPUE. Whilst handline CPUE dropped considerably from a record high in 2007/08, longline CPUE maintained a six year increasing sequence to attain its highest ever recorded level (Table 8.5).

There were five breaches of limit reference points for the WC region (Table 8.6). These related to a record high total catch, record high longline effort as well as a significant increase in handline CPUE.

For the SE region, a considerable proportion of the limit reference points were breached (Table 8.7). These related to the substantial increase in catch over the past few years that culminated in a record catch in 2008/09, as a consequence of substantial increases and record levels in longline effort and catch rates. There were also high, recent handline catch rates, of which the highest was recorded in 2008/09.

Table 8.1 Results of comparisons between general performance indicators and limit reference points for State-wide fishery statistics.

Performance Indicator	Limit Reference Point	Breached ?	Details
Total commercial catch	3 rd lowest/3 rd highest	Yes	Highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted handline effort	3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted longline effort	3 rd highest	Yes	2 nd highest
	Greatest interannual change (+)	Yes	
	Greatest 5-year trend	Yes	
Targeted handline CPUE	3 rd lowest/3 rd highest	Yes	2 nd highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	Yes	
Targeted longline CPUE	3 rd lowest/3 rd highest	Yes	2 nd highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	

Table 8.2 Results of comparisons between general performance indicators and limit reference points for NSG.

Performance Indicator	Limit Reference Point	Breached ?	Details
Total commercial catch	3 rd lowest/3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted handline effort	3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted longline effort	3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted handline CPUE	3 rd lowest/3 rd highest	Yes	Highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted longline CPUE	3 rd lowest/3 rd highest	Yes	2 nd Highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	Yes	

Table 8.3 Results of comparisons between general performance indicators and limit reference points for SSG.

Performance Indicator	Limit Reference Point	Breached ?	Details
Total commercial catch	3 rd lowest/3 rd highest	Yes	3 rd highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted handline effort	3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted longline effort	3 rd highest	Yes	3 rd highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted handline CPUE	3 rd lowest/3 rd highest	Yes	3 rd highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	Yes	
Targeted longline CPUE	3 rd lowest/3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	

Table 8.4 Results of comparisons between general performance indicators and limit reference points for NGSV.

Performance Indicator	Limit Reference Point	Breached ?	Details
Total commercial catch	3 rd lowest/3 rd highest	Yes	Highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	Yes	
Targeted handline effort	3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted longline effort	3 rd highest	Yes	Highest
	Greatest interannual change (+)	Yes	
	Greatest 5-year trend	Yes	
Targeted handline CPUE	3 rd lowest/3 rd highest	No	
	Greatest interannual change (+)	Yes	
	Greatest 5-year trend	No	
Targeted longline CPUE	3 rd lowest/3 rd highest	Yes	Highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	

Table 8.5 Results of comparisons between general performance indicators and limit reference points for SGSV.

Performance Indicator	Limit Reference Point	Breached ?	Details
Total commercial catch	3 rd lowest/3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted handline effort	3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted longline effort	3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted handline CPUE	3 rd lowest/3 rd highest	No	
	Greatest interannual change (+)	Yes	
	Greatest 5-year trend	No	
Targeted longline CPUE	3 rd lowest/3 rd highest	Yes	Highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	Yes	

Table 8.6 Results of comparisons between general performance indicators and limit reference points for the WC.

Performance Indicator	Limit Reference Point	Breached ?	Details
Total commercial catch	3 rd lowest/3 rd highest	Yes	Highest
	Greatest interannual change (+)	Yes	
	Greatest 5-year trend	No	
Targeted handline effort	3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted longline effort	3 rd highest	Yes	Highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted handline CPUE	3 rd lowest/3 rd highest	Yes	Highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	Yes	
Targeted longline CPUE	3 rd lowest/3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	

Table 8.7 Results of comparisons between general performance indicators and limit reference points for the SE.

Performance Indicator	Limit Reference Point	Breached ?	Details
Total commercial catch	3 rd lowest/3 rd highest	Yes	Highest
	Greatest interannual change (+)	Yes	
	Greatest 5-year trend	Yes	
Targeted handline effort	3 rd highest	No	
	Greatest interannual change (+)	No	
	Greatest 5-year trend	No	
Targeted longline effort	3 rd highest	Yes	Highest
	Greatest interannual change (+)	Yes	
	Greatest 5-year trend	Yes	
Targeted handline CPUE	3 rd lowest/3 rd highest	Yes	Highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	Yes	
Targeted longline CPUE	3 rd lowest/3 rd highest	Yes	Highest
	Greatest interannual change (+)	No	
	Greatest 5-year trend	Yes	

Biological Performance Indicators

Biological performance indicators were compared with limit reference points for the three regions of NSG, SSG and GSV and for the three regions combined (Table 8.8). Since the estimates of biomass for NSG and GSV for 2008/09 were 14% and 20% above the mean of the previous 5 years, whilst it was lower in SSG by 13%, all three regional biomass reference points were activated. At the State-wide level, fishable biomass was 6% above the previous 5-year average, which was within the boundaries of the 10% limit reference point. Estimates of annual harvest fraction were relatively low at the regional and State-wide levels compared with the recommended international standard and so no limit reference points were activated. These low annual harvest fractions contributed to egg production being at acceptable levels, which also means that these limit reference points also were not activated.

The biological performance indicator of pre-recruit abundance is quantified by SnapEst-estimated recruitment levels of the 2005 year class for the three regions individually and combined. The regional estimates of pre-recruit abundance (i.e. model recruitment) for the 2005 spawning year class were compared with the mean from the previous five-year period of 2000-2004. For each region and for the combined data, the estimates of recruitment for 2005 fell well short of the previous five-year averages, and so the limit reference points were all activated.

The estimated age structures that were presented in Figs. 5.2 – 5.14 (Chapter 5), were considered qualitatively here for any significant changes over the past five years. For NSG and SSG, there were no changes other than those that would be expected through normal demographic processes. For Gulf St. Vincent there were insufficient data for the past 5 years to make an appropriate assessment.

8.4 Discussion

General fishery performance indicators were assessed for State-wide and for regional fishing statistics. There were many performance indicators that were breached that reflected a consistent stock status at both spatial scales. The breaches consistently related to high catches, high effort levels and generally the highest catch rates ever recorded across the whole State. In general, they present an extremely positive view of the status of the stocks.

Several biological performance indicators were also breached. For both NSG and GSV these included that fishable biomass in 2009 was more than 10% above the average of the previous five years. Alternatively, the results were less positive for SSG for which there had been a 13% decline in the estimated biomass. The estimates of pre-recruit abundance for 2005 were considerably lower than the previous 5-year average and so activated the limit reference point. This result, however, is not particularly surprising or concerning for this species because such variable recruitment is a characteristic of the population biology of snapper.

Table 8.8. Results from assessment of the biological performance indicators against limit reference points for the three regions combined and individually. The first four biological performance indicators were estimated by the SnapEst model and were summarised by year (or half-year) in Sec. 7.3. Age composition was summarised in Chapter 5. Limit reference points that were breached are highlighted in yellow. The current performance year covers the period October 2008 – September 2009, except for pre-recruit abundance (see text).

Biological Performance Indicator	Northern Spencer Gulf	Southern Spencer Gulf	Gulf St. Vincent	Combined across regions (NSG + SSG + GSV)	Biological Limit Reference Point (BLRP)
Fishable biomass	14% above average of previous 5 years	13% below average of previous 5 years	20% above average of previous 5 years	6% above average of previous 5 years	+/- 10% of previous 5-yr average
Harvest fraction	Yearly: 4%	Yearly: 10%	Yearly: 10%	Yearly: 7%	Exceeds international standards (32% yearly)
Egg production (% of pristine population)	25%	20.5%	29%	24%	20%
Pre-recruit abundance	2005 cohort is 64% below average of previous 5 years	2005 cohort is 91% below average of previous 5 years	2005 cohort is 77% below average of previous 5 years	2005 cohort is 74% below average of previous 5 years	+/- 10% of previous 5-yr average
Age composition	Conformed to expected shifts to older ages	Conformed to expected shifts to older ages	No new data available		Significant change over previous 5 years

9. GENERAL DISCUSSION

9.1 Information for stock assessment

This report presented the results from several long-term monitoring programs to assist in determining the current status of the stocks of snapper in South Australia. These datasets included: the commercial catch and effort data from 1983/84 to 2008/09; the recreational fishery statistics from several broad-scale surveys that were done over a 15-year period; data on population size and age structures that were primarily collected throughout the 2000s; and the results from a 0+ recruitment survey in NSG. The data from the first three of these were integrated in the SnapEst computer fishery model to produce time series of significant biological performance indicators. Stock status was determined through the assessment of numerous fishery performance indicators for 2008/09, as compared against limit reference points calculated from the historical time series from 1983/84 to 2008/09.

9.2 Fishery assessment at State-wide and regional scales

There was an overwhelming result from the consideration of fishery performance indicators. Numerous indicators that were assessed at both the State-wide and regional scales exceeded the limit reference points. These generally reflected high catches, high fishing effort and record catch rates across most of the State. The year 2008/09 produced the highest ever commercial catch of snapper of 786 t that resulted from high catches across most regions of the State. This catch had an estimated value of \$5.6 million, which made snapper the most valuable of the Marine Scalefish species in SA (Knight and Tsolos 2010). Furthermore, 2008/09 also produced the second highest catch rates for both the handline and longline sectors. In the recreational sector there was a marginal increase in the number of snapper captured between 2000/01 and 2007/08, contrasting with most other fish species for which there were considerable drops in catch (Jones 2009). Also, the catches of snapper by the charter boat sector have increased considerably since record-taking commenced in 2005/06.

Overall, the high catches and catch rates across most regions of SA's coastal waters present an extremely healthy assessment of the current status of snapper stocks. Nevertheless, there were different regional trends in the commercial catch and effort data, the recreational catch data, the data for population structure and the output from the SnapEst model. This indicates that different processes affected catches and catch rates in the different regional waters. Consequently, it is important to consider these regional trends independently to determine the status of the local stocks.

Northern Spencer Gulf

NSG has historically been the most significant region in SA's snapper fishery. During the 1990s it consistently contributed greater than 60% of the total State-wide commercial catch. However, in

2003/04 its contribution began to decline, and by 2008/09 it contributed only 19.8% of the State's total commercial catch. This drop in relative significance resulted from a considerable decline in both handline and longline fishing effort. In fact, there is now only extremely low longline fishing effort in this region. Furthermore, there has been a substantial decline in the total weight of snapper harvested by the recreational sector in this region.

The decline in the commercial fishery in this region is perplexing as it appears to not be related to a down-turn in the fishable biomass of snapper as the fishery has recently produced the highest ever catch rates for both gear types. The SnapEst model integrated these high catch rates, along with the data on population structure, to determine that the biomass of snapper in this region increased through the mid to late 2000s. This was largely due to the strong year classes of 1991, 1997, 1999, and 2004. In 2008/09, most of the strong year classes were relatively old, and given that fish in NSG are generally large for their age, indicates that the population consisted of relatively high numbers of large fish. Since longline fishing is particularly selective for such large to very large fish, the continuing decline of the longline fishing sector is particularly perplexing. Perhaps the decline in the longline sector relates, at least partly, to PIRSA Fisheries having stopped issuing exemptions for non-attendance of longlines in this region. Nevertheless, given the high estimated biomass, high recruitment rates over the past 15 years and low exploitation rates, there is currently no evidence to suggest that the declining catches in this region are a consequence of over-exploitation.

Southern Spencer Gulf

The status of the snapper fishery in SSG differs from that in NSG. This region surpassed NSG as the dominant contributor to SA's snapper catch in 2004/05, when it contributed 48.4% of the State's commercial catch. The development of this regional fishery through the mid 2000s was driven largely by a substantial increase in longline fishing effort that produced record catches and catch rates. This was associated with an areal expansion of the fishery into MFA's 29 and 30 that had previously attracted only minimal effort from few fishers. The relative contribution of SSG peaked in 2005/06 and has since declined to 43% in 2008/09, reflecting both declining effort and catch rate. The data from July to December 2009 indicated a considerable decline in catch and catch rate relative to the same period in the previous few years.

The biological characteristics of the snapper population in this region also differ from those of NSG. As the fishery expanded through the mid 2000s there were two main year classes that sustained the catches, i.e. the 1991 and 1997 year classes. Towards the end of the 2000s, the 1991 year class declined and was largely replaced by the 1999 year class. On the basis of the poor year class strength for all years since 1999 and the observed declining catch rates, the SnapEst model has indicated relatively poor recruitment since 1999. Furthermore, it has indicated that the fishable biomass started to decline from the mid 2000s, whilst the exploitation rate continued to increase over the past three years. For SSG, the recent

declining catches and catch rates, the lack of recent recruitment, the relatively high rates of exploitation and the model-estimated declining biomass determine that this regional fishery is that of highest concern with respect to the status of the stocks. Clearly, this regional fishery would benefit considerably from the arrival of a new strong year class into the population.

Gulf St. Vincent

NGSV and SGSV demonstrated different recent trends to each other in terms of fishery statistics and population structure. In NSGV, fishery catches increased relatively consistently from the early 2000s culminating in dramatic increases in 2007/08 and 2008/09. In these two years, this region contributed >11% of the State's total catch, a considerable increase over the contribution in previous years. In 2007/08, there were high levels of handline catch, effort and catch rate. In 2008/09, the record longline catch, effort and catch rate favourably exceeded numerous limit reference points. These record values continued through to the end of 2009. The high recent catches in NSGV involved fish from a broad range of sizes and ages that included many old fish even back to the 1979 year class.

The fishery in SGSV has involved a gradual replacement of handline fishing effort with longline effort. The last three years have produced record longline catches and catch rates, although the scale of these increases were lower than in NSGV. The recent catches in SGSV were dominated by a high proportion of fish from the 2001 year class. Although these fish were seven and eight years old in 2008 and 2009 respectively, many were very small for their age, suggesting relatively slow growth rates throughout significant parts of their lives. These fish were similar in size and age to those taken from the South East. This suggests the existence of a large population of snapper, largely consisting of a single year class, that was located in continental shelf waters off-shore from the Coorong coast, which was accessible to fishers working in MFAs 44 and 51.

The SnapEst model integrated data from NSGV and SGSV to produce output for the whole GSV region. This model-output for GSV indicated that biomass increased through the 1990s and early 2000s before increasing dramatically in the mid 2000s. The latter increase largely reflected the substantial recruitment of the 2001 year class to SGSV, and further augmentation to both the northern and southern parts by the 2004 year class. Although the exploitation rate has increased as a consequence of the higher recent fishing activity, it has nevertheless remained below 10% of the adult biomass. Overall, the high catches and catch rates, and high recent recruitment are indicative of a recent recovery in the GSV population that was entirely unexpected just a few years ago. This, in association with the low exploitation rate, suggests a positive status for this regional fishery.

West Coast and South East regional fisheries

The West Coast snapper fishery has demonstrated a number of characteristics that are similar to the fisheries in the two gulfs. Firstly, through the 2000s there was a substantial increase in longline fishing

effort while handline fishing effort remained relatively stable. This longline effort culminated in record longline catches with 2008/09 producing the highest ever commercial catch for this region. There were several fishery indicators that exceeded the limit reference points in this year. However, the longline catch rate dropped in the mid to late 2000s, whereas handline catch and catch rate increased rapidly in 2008/09. These results provide ambiguous signals about the level of fishing effort that can be sustained in the region. Nevertheless, the high recent catches and catch rates indicate the likelihood of a relatively high biomass of snapper in this region.

In the South East, particularly MFA 51, there have been rapid rises to unprecedented levels in longline effort, catch and catch rate in 2007/08 and 2008/09. The harvested population involves large numbers of fish from the 2001 year class. As mentioned above, there appears to be a significant population of such fish located on continental shelf waters offshore from the Coorong coast. Given the lack of evidence for large numbers of snapper in this region previously, it is unknown whether these fish will persist here into the future or whether they will move elsewhere such as into the gulfs. As such, despite the current positive status of this regional fishery, its future remains uncertain.

9.3 Synthesis of biological processes

The above text has highlighted a number of changes to the snapper fishery throughout the 2000s, particularly in the most recent years. There has been a considerable change in the spatial configuration of the fishery with respect to the relative contributions of the different regions to the total State catch. SG continues to make the greatest contribution despite a considerable drop in its proportional contribution. In NSG, this decrease in catch appears to be unrelated to declining biomass, whereas the drop in catch from SSG does appear to be related to declining biomass. In contrast, the catches and catch rates from GSV, WC and the SE are all currently at record levels, thus increasing their proportional contributions to the State's total snapper catch. All regional changes have co-occurred with the expansion of longline fishing effort. The significance of the relative effort levels of the two gear types remains unknown.

The regional catch rates indicate that there were high levels of snapper biomass throughout virtually all of the State's waters in the late 2000s. The obvious question from this is – why has biomass apparently increased so much, particularly in the less traditional areas for snapper? This increase has likely been driven by a substantial increase in recruitment in recent years. In fact, based on output from SnapEst, recruitment has risen by approximately 60% since the mid 1990s. Data on population structure, shows that the 1991 year class was the first major recruitment event to the snapper stocks after 1979. Because of that exceptional year class all regional stocks recovered throughout the mid-late 1990s. Since 1991 there have been a number of strong year classes recruit to the population and subsequently enter the fishery, including the 1997, 1999, 2001 and most recently the 2004 year classes. Overall, it appears that the increase in the frequency of strong year classes has led to higher biomass throughout most coastal waters. Recruitment for this species is highly variable and is thought to reflect the influence of inter-

annual environmental variation on the replenishment processes of the populations, notably survivorship of the eggs and larvae (Fowler and Jennings 2002, Saunders 2009). Perhaps, the last 15 years have provided the appropriate environmental conditions to facilitate recruitment. The stocks may also be manifesting the effects of the significant management interventions that have been implemented over the past 20 years or so. These include: the increase in minimum legal length from 28 to 38 cm TL prior to 1990; the implementation of the netting ban for snapper in 1993; and the seasonal closures that have been implemented every year since 2000. These management measures may have led to lower fishing mortality resulting in higher stock biomass, higher egg production and ultimately higher recruitment. Favourable environmental conditions and the changes to the management regime may have had a synergistic effect on stock biomass.

One new feature of the recent strong year classes is that their relative strength differed among regions. The 1997 and 1999 year classes were strongest in SG, the 2001 year class was strongest in SGSV and the SE, whilst the 2004 year class was most apparent in NGSV and SGSV. This situation contrasts to the similarity in regional age structures that was documented in the early 2000s (Fowler et al. 2005). Of particular interest here is the origin of fish that have recently been fished on the continental shelf of the South East region that have primarily consisted of small representatives of the 2001 year class. This year class is currently poorly represented in NSG, SSG and NGSV. It is unlikely that the 2001 year class in the South East recruited as 0+ fish to this region in sufficient numbers to account for the large population since 0+ snapper normally settle in coastal bays that are relatively shallow, protected and support a muddy substratum (Fowler and Jennings 2003, Hamer and Jenkins 2004). Such a habitat is the antithesis of that presented along South Australia's south east coast. As such, it is more likely that these fish moved to the SE from elsewhere when they were several years old. There are two likely sources from where they may have moved. In 2005/06, the 2001 year class made a significant contribution to the commercial catch in NSG. However, subsequently their relative contribution to the catches from this region declined considerably. Perhaps many individuals of the 2001 year class left the gulf and eventually took up residence in the continental shelf waters of the South East. The alternative source for the 2001 year class to the South East region is Port Phillip Bay, Victoria. This bay received a high level of recruitment of 0+ fish in 2001 (Hamer and Jenkins 2004). Some fish may have left Port Phillip Bay and eventually moved westwards along the Victorian coastline, ending up in the waters of south eastern SA. Despite the mechanism, this large population has contributed to the accelerated rate of development of the fishery in this region. Furthermore, this phenomenon is the result of a demographic process that has not previously been described and so has contributed to the diversity of population processes that snapper display in the waters of SA.

9.4 Considerations for the future

The datasets on commercial fishery statistics and population structure from market sampling were invaluable for documenting the likely trends in fishable biomass and for determining the underlying demographic processes that influenced these trends. Clearly, the continuation of such monitoring in the future is mandatory. Snapper will be targeted in market sampling from October 2010 until September 2012, 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. Furthermore, this sampling will help to identify any further strong year classes that recruit to any regions.

The 0+ recruitment survey that has been done in NSG since 2000 indicated that in 2006 the capture rate of the juvenile fish was the highest on record. However, despite that this year class of fish are now in their 5th year they have not been strongly represented in any fishery catches. This result may suggest that the 0+ surveys have been of limited value as indicators of year class strength and future fishery catches. This has led to the suspension of the 0+ survey for 2011. Nevertheless, in recent weeks there have been some signs that the 2006 year class may, in fact, be quite strong in some regions. Some four year old fish from NSG were recently detected in the SAFCOL fish market. Furthermore, there have been several recent anecdotal reports about large numbers of undersized snapper in both NGSV and SGSV that may relate to the 2006 year class. The uncertainty as to whether the 2006 year class will contribute significantly to fishery catches in the next few years will be resolved through the market sampling program. As such, this will determine whether there is any value in re-establishing the 0+ recruitment surveys in the future.

Snapper are now an extremely significant coastal resource of SA that is exploited by many fishers from the Marine Scalefish Fishery, the Rock Lobster Fishery and the Lakes and Coorong Fishery. Given this higher significance, it is timely to consider whether the fishery should be subjected to a higher level of scrutiny and monitoring. It would be beneficial to introduce some fishery independent sampling to provide direct measures of population abundance. This could involve application of the Daily Egg Production Method (DEPM) for estimating biomass. This method was applied during the 1990s to estimate snapper biomass in NSG (McGlennon and Jones 1999), and has also successfully been used in Shark Bay, Western Australia (Jackson and Cheng 2000). In the South Australian application, the identification of snapper eggs can be problematical (Fowler unpublished data), which would likely affect the integrity of the method. However, new DNA-based molecular techniques could possibly circumvent such problems, making the application of the DEPM approach a tractable prospect. Other fishery independent methods for consideration include acoustic surveys or sampling juvenile fish at the ages of 1+ to 3+ years as a measure of year class strength.

Our analysis of population structure in the different regions indicated that we still do not have a complete understanding of the demographic processes for snapper. This was evident in the above discussion that considered the origin of the population that has recently occupied the South East region. Whilst it is likely that fish migrated to this region, the fact that this process has not been documented previously is indicative of our general poor understanding of fish movement patterns and the processes of regional population replenishment. Acoustic technologies and electronic tags have developed considerably in recent years, and are now being used in many fish movement studies in different parts of the world, and various places around Australia. The use of such technological approaches appears to offer the best opportunity for resolving the issues of movement for snapper throughout South Australian waters.

9.5 Conclusions

In 2008/09, there were high if not record catches and catch rates of snapper by the commercial sector in different regions across the State, that contributed to the highest catch of 786 t yet taken for this species from South Australian waters. This is likely to have been the highest State-based catch of snapper across the country and also ensured that snapper was the most valuable species in SA's Marine Scalefish Fishery. For the recreational sector, the catches taken in recent years were the highest in terms of fish numbers yet recorded. In both sectors there has been a recent spatial redistribution of catch, which suggests a considerable geographic expansion of the stocks. The data on population structure indicate the presence of a number of strong year classes in the populations, the consequence of good recruitment over the past 15 years. The SnapEst model has integrated the fishery and biological data to indicate high and increasing levels of biomass throughout the main fishery regions, with the exception of SSG. The high levels of biomass are a consequence of the recent successful recruitment, which may result from good environmental conditions and/or successful fishery management decisions over the past 20 years. At present, South Australia's snapper stocks are healthy and do not present any immediate stock sustainability issues.

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