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Snapper (*Chrysophrys auratus*) Fishery

AJ Fowler, MA Steer, R McGarvey and J Smart

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September 2019

Fishery Assessment Report to PIRSA Fisheries and Aquaculture

SOUTH AUSTRALIA

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1. EXECUTIVE SUMMARY

This stock assessment report for the South Australian Snapper fishery continues the series of annual assessment or status reports since 1997 that report the statuses of the stocks. Here, the statuses were assigned at the scale of biological stock for the Spencer Gulf / West Coast Stock (SG/WCS), the Gulf St. Vincent Stock (GSVS), and also for the regional population of the South East region (SE) of the State, which is part of the Western Victorian Stock (WVS).

Stock status was determined using the weight-of-evidence assessment following the National Fishery Status Reporting Framework (NFSRF; Stewardson *et al.* 2018).

The stock assessments were based on a combination of fishery-dependent and fishery-independent data. The former included the commercial fishery statistics that provided the 'general' fishery performance indicators as well as two specific indicators for Snapper, i.e. the proportions of daily catches that exceeded 200 kg for the hand line and longline sectors (Prop200kgHL, Prop200kgLL). The single biological performance indicator that was considered was the population age structures. For all indicators, the estimate for 2018 was assessed against trigger reference points calculated from the historical reference period of 1984 to 2018.

The fishery independent data were the results from two applications of the daily egg production method (DEPM) to estimate spawning biomass. The egg surveys and adult sampling were undertaken for Northern Spencer Gulf (NSG) in 2013 and 2018, and for Gulf St. Vincent (GSV) in 2014 and 2018.

Spencer Gulf / West Coast Stock (SG/WCS)

For the SG/WCS, the estimates of total catch and gear-specific estimates of targeted catch, effort and CPUE have been consistently low since 2012, most having declined since 2007. In 2018, several indicators were near their lowest levels, and three trigger reference points were breached. Such values point to low levels of fishable biomass. The age structures for each of NSG and Southern Spencer Gulf (SSG) throughout the 2000s, indicated the lack of strong year classes since those of the late 1990s, which indicates that recruitment for this stock has been relatively poor for at least the last 20 years.

The estimate of spawning biomass for NSG in 2018 was 192 t (129 – 255 t SE), representing a 23% reduction from the estimate for 2013. These estimates of spawning biomass are low relative to historic catches and are consistent with the low commercial fishery statistics that were recorded for 2013 and 2018. The commercial harvest fraction in 2018 was estimated at

19%. Assuming a 38% contribution to the total catch by the recreational sector (see Giri and Hall, 2015), the total harvest fraction was estimated at approximately 30% in 2013 and 2018.

For the SG/WCS, low estimates of fishery statistics from 2012 onwards suggest low levels of biomass throughout this period. This is consistent with declining biomass throughout the 2000s associated with relatively poor recruitment. The low estimates of spawning biomass from the DEPM in both 2013 and 2018 are consistent with this finding. The available evidence indicates that the overall SG/WCS harvestable biomass is likely to be depleted and that recruitment is likely to be impaired. Consequently, the SG/WCS is classified as '**depleted**' in 2018 under the NFSRF.

Gulf St. Vincent Stock (GSVS)

For the GSVS, the fishery statistics were at near-record high levels between 2010 and 2015. However, in 2016, 2017 and 2018, total catch, targeted longline catch, effort and CPUE and the numbers of fishers targeting Snapper each declined considerably. These trends are consistent with high levels of biomass between 2010 and 2015, followed by a substantial decline over the following three years. The high biomass resulted from four strong year classes that recruited to the nursery areas between 2001 and 2009. High recent catches and relatively poor recruitment since 2009 have resulted in a substantial decline in the biomass.

The estimate of spawning biomass in the area surveyed in GSV in 2018 was 343 t (213 – 473 t SE). This was an 87% reduction from the estimate of 2,590 t (1,502 – 3,678 t SE) from the same area of GSV surveyed in 2014. The primary uncertainty associated in the estimate of the spawning biomass of the GSVS in 2018 is the incomplete coverage of the potential spawning area. However, a decline in spawning biomass is consistent with the differences in the commercial fishery statistics between 2014 and 2018. Based on the spawning biomass derived from the area surveyed in 2018, the estimated commercial and recreational harvest fractions in GSV in 2018 were 46% and 24%, respectively, providing an estimated total harvest fraction of 70%.

The GSV Stock was at a record level of fishery productivity from 2010 to 2015, relating to a high level of fishable biomass. This was confirmed by the estimate of spawning biomass from the DEPM in 2014. Such high biomass reflected the strong recruitment to NGSV throughout the 2000s. Subsequent declines in fishery statistics and the estimates of biomass, from 2015, demonstrate a rapid and substantial decrease in harvestable biomass, reflective of large recent catches combined with relatively poor recruitment since 2009. Whilst the rapid declines in harvestable biomass are clear, the current stock status is difficult to determine due to uncertainty in: (1) estimates of spawning biomass from the DEPM in 2018; (2) degree to which the current fishery statistics reflect reductions in biomass given they have reduced but remain

relatively high compared to those prior to the 2000s; (3) strength of the 2014 recruitment year class; and (4) magnitude of the recreational catch. As it is not possible to determine whether the GSVS is already recruitment impaired, or at a biomass above this level, the GSVS is classified as 'depleting' in 2018 under the NFSRF. This means that fishing mortality is too high (i.e. overfishing is occurring) and moving the stock in the direction of becoming recruitment impaired and is a change in status from sustainable in 2017.

South East region (Western Victorian Stock)

The SE region is part of the WVS that is dependent on recruitment into Port Phillip Bay, Victoria. The SE region experienced relatively high levels of biomass through the mid-2000s, based on the emigration to the region of two strong year classes, i.e. 2001 and 2004. The subsequent declines in catches, effort and catch rates are consistent with the depletion of the recent, episodic high biomass level. There has been relatively high recruitment over the past seven years. The harvestable biomass in the SE region will likely be increased by emigration in the next few years. Consequently, the stock is classified as '**sustainable**'. This means that biomass is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (i.e. recruitment is not impaired) and fishing mortality is adequately controlled to avoid the stock becoming recruitment impaired.

2. GENERAL INTRODUCTION

2.1. Introduction

The Snapper (*Chrysophrys auratus*) is a species of teleost fish in the family Sparidae. It is a large, long-lived, demersal, finfish species that is broadly distributed throughout the Indo-Pacific region, where its extensive distribution includes the coastal waters of the southern two thirds of the Australian continental mainland as well as northern Tasmania (Kailola et al. 1993). Throughout this distribution, Snapper occupy a diversity of habitats from shallow bays and estuaries to the edge of the continental shelf across a depth range to at least 200 m. The stock structure for Snapper in Australian waters is complex, as there are considerable differences in the spatial scales over which populations are divisible into separate stocks (Fowler et al. 2016a; 2017). A recent study indicated that there are three stocks that occur in South Australian coastal waters (Fowler 2016, Fowler et al. 2017). The Western Victorian Stock (WVS) is a cross-jurisdictional stock that extends westward from Wilsons Promontory, Victoria into the south eastern waters of South Australia (SA) as far west as Cape Jervis. There are also two wholly South Australian stocks, i.e. the Spencer Gulf / West Coast Stock (SG/WCS) and Gulf St. Vincent Stock (GSVS) (Fowler 2016, Fowler et al. 2017).

The results of the recent study into the stock structure of Snapper were also informative about the demographic processes responsible for the replenishment of the three stocks. It indicated that each stock depends on recruitment into a primary nursery area: Port Phillip Bay (PPB), Victoria for the WVS; Northern Spencer Gulf (NSG) for the SG/WCS; and Northern Gulf St. Vincent (NGSV) for the GSVS (Fowler 2016). For the South East (SE) Region, Snapper abundance varies episodically, as fish of a few years of age migrate westwards to this region over hundreds of km from PPB (Fowler et al. 2017). This occurs when strong year classes recruit to PPB, and as such is likely to be a density dependent process related to inter-annual variation in recruitment. The populations of Snapper that occupy the two northern gulfs are independent and self-recruiting. They also experience inter-annual variation in recruitment of 0+ fish (Fowler and Jennings 2003, Fowler and McGlennon 2011), most likely as a consequence of variable larval survivorship (Hamer et al. 2010). Each is an important nursery area that acts as a source of emigration that replenishes regional populations in adjacent coastal waters (Fowler 2016). NSG is the source region for Southern Spencer Gulf (SSG) and most likely also for the West Coast of Eyre Peninsula (WC), whilst NGSV is the source for Southern Gulf St. Vincent (SGSV). As such, the dynamics in the regional populations of SA are primarily driven by temporally variable recruitment and subsequent emigration of fish from the source regions supporting the nursery areas to adjacent regional populations (Fowler 2016).

2.2. Fishery

Snapper is an iconic fishery resource in each mainland State of Australia (Kailola et al. 2003). Throughout the mid-2000s, SA was the dominant State-based contributor to the national total catches of both the commercial and recreational sectors (Fowler et al. 2016a). SA's Snapper fishery is geographically extensive and encompasses most of the State's coastal marine waters from the far west coast of Eyre Peninsula to the SE region, although the highest abundances have generally been in Spencer Gulf (SG) or Gulf St. Vincent (GSV), which have consequently produced the highest fishery catches (Fowler et al. 2016a, Steer et al. 2018).

Snapper is a primary target species of the commercial and recreational sectors of SA (PIRSA 2013). License holders from four different commercial fisheries have access to the fishery, i.e. the Marine Scalefish Fishery (MSF), the Northern Zone and Southern Zone Rock Lobster Fisheries (NZRLF, SZRLF) and the Lakes and Coorong Fishery (LCF) (PIRSA 2013). The main gear types used to target Snapper by commercial fishers are handlines and longlines, since using hauling nets to take Snapper was prohibited in 1993. For local recreational fishers and others from inter-state, Snapper has been an important species in SA's waters because of their desire to catch the large trophy fish (Fowler et al. 2016a). Such recreational fishers target Snapper using rods and lines, primarily from boats, although jetty and land-based catches do occur. Based on the most recent recreational fishing survey in 2013/14, the contributions to total catch by the commercial and recreational sectors were 62% and 38%, respectively (Giri and Hall 2015, Fowler et al. 2016a).

The spatial structure of SA's Snapper fishery underwent considerable change between 2008 and 2012 (Fowler et al. 2016a). Historically, SG supported the highest catches and catch rates, but these have declined considerably, whilst contemporaneously those in NGSV and the SE increased to unprecedented levels (Steer et al. 2018a,b). For the three different stocks these changes reflected different, independent demographic processes that related to recruitment and adult migration (Fowler 2016, Fowler et al. 2017). From 2011 onwards, the changes in the spatial structure of the fishery and stock status caused considerable concern with respect to the management of the fishery. This has resulted in several levels of action: numerous management changes were implemented to limit commercial catches and to maximise the opportunities for spawning and recruitment success; whilst several FRDC-funded research projects were undertaken to firstly identify the demographic processes responsible for the observed spatial changes (FRDC 2012/020, Fowler 2016), and also to develop a fishery independent index of fishable biomass (FRDC 2014/019, Steer et al. 2017).

2.3. Harvest Strategy

The harvest strategy for Snapper outlined in the current Management Plan (PIRSA 2013) relates to the changes and concerns about the challenges for fishery management that occurred between 2007 and 2012. The harvest strategy involved a watching brief until the two FRDC-funded projects (FRDC 2012/020, FRDC 2014/019) were completed. As such, it did not include explicit decision rules with respect to responses to fishery status. A review of the Management Plan and harvest strategy is expected to take into consideration our enhanced understanding of the biology and population dynamics of Snapper from these two projects. The future harvest strategy should follow the South Australian Fisheries Harvest Strategy Policy (PIRSA 2015) and aim to provide greater certainty for sustainable management by developing explicit decision rules about management responses to fishery status that are based on the enhanced understanding of the biology and fishery. Any review of the harvest strategy for snapper will need to take into account recent changes and proposed future changes to the management of the Snapper fishery in response to the recent status classifications (Steer et al. 2018b), as well as the overall restructure of the Marine Scalefish Fishery that is occurring subsequent to the review of the fishery (Anon 2016).

2.4. Management Regulations

Regulations for the commercial sector of South Australia's Snapper fishery involve a suite of input and output controls (PIRSA 2013, 2014). The four commercial fisheries with access to Snapper each have limited-entry, i.e. the numbers of fishers who can target Snapper have been limited for many years. In SA, there is a legal minimum length of 38 cm total length (TL), whilst there are also several gear restrictions. Snapper cannot be taken with fish traps, whilst the use of all nets, including hauling nets and large mesh gill nets for targeting Snapper has been prohibited since 1993. Commercial handline fishers are limited with respect to the numbers of handlines and hooks per line that can be legitimately used. From December 2012, for commercial fishers who operate in SG and GSV, the number of hooks that can be used on set lines was reduced from 400 to 200, but remains at 400 for other regions. Also in 2012, a daily commercial catch limit of 500 kg was introduced for all South Australian waters. In December 2016, this was further reduced due to on-going concerns about stock status for the different stocks (Fowler et al. 2016a). For the SG/WCS, it was reduced to 200 kg with a limit of two days per trip. For GSV and the SE region, the daily trip limit was reduced to 350 kg. For the former region, a trip limit of two days was set, whilst for the latter the limit of five days was set. There is also a 50 kg bycatch trip limit for the Commonwealth-managed Southern and Eastern Scalefish and Shark Fishery.

For the recreational sector, the minimum legal length of 38 cm TL as well as bag and boat limits apply. In December 2016, bag and boat limits were reduced in response to the recent changes in the spatial structure of the fishery and the classifications of stock status (Fowler 2016, Fowler et al. 2016a). Up until this time, the bag and boat limits differed geographically. However, from the review of the recreational fishery in 2016 (PIRSA 2016), the bag limit of 5 and boat limit of 15 fish for the size range of 38 - 60 cm TL, and bag limit of 2 fish and boat limit of 6 fish for fish >60 cm TL now apply for all State waters. For the Charter Boat sector, from December 2018, the individual bag limit for Snapper was reduced to three small fish (38-60 cm TL) and one large (>60 cm TL) fish. From December 2018 there was no boat limit for the Charter Boat Sector.

Since 2000, the management regime for Snapper has involved at least one seasonal closure per year for both fishing sectors. From 2003 to 2011, this was a month-long fishery closure throughout November. From 2012, the seasonal closure was extended for several weeks until 15th December for all fishing sectors. Furthermore, in 2013, five Snapper spawning spatial closures were implemented in the northern gulfs to extend the duration of protection of important spawning aggregations until the 31st January, thereby conferring protection for most of the reproductive season. The four spatial closures in NSG and one in NGSV were circular in shape with a 4-km radius from a fixed point. In December 2018, the spawning spatial closure in NGSV was removed and replaced with two new closures located in the southern part of the gulf at Tapley Shoal and Sellicks Beach. These closures were extended to the 31st March 2019. For SG, a new closure at Point Lowly was added to the existing four closures, whilst all were extended to November 2019.

2.5. Objectives of this report

This reports provides an assessment of the status of the three Snapper stocks in SA. Consequently, this report (1) analyses fishery-dependent (e.g. catch, effort, catch-per-unit effort, CPUE) and fishery-independent (i.e. spawning biomass estimates from DEPM surveys) from 1984 to 2018; (2) assesses the status of the resource; (3) identifies the uncertainty associated with the assessment; and (4) identifies future research needs.

In this report, stock status was determined using the NFSRF (Table 1-1; Stewardson *et al.* 2018), which is consistent with the South Australian fisheries harvest strategy policy (PIRSA 2015).

Table 2-1 Terminology for the status of key Australian fish stocks reports (reproduced from Stewardson *et al.* 2018).

	STOCK STATUS	DESCRIPTION	POTENTIAL IMPLICATIONS FOR MANAGEMENT OF THE STOCK
	Sustainable	Stock for which biomass (or biomass proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (i.e. recruitment is not impaired) and for which fishing mortality (or proxy) is adequately controlled to avoid the stock becoming recruitment impaired	Appropriate management is in place
	Depleting	Biomass (or proxy) is not yet depleted and recruitment is not yet impaired, but fishing mortality (or proxy) is too high (overfishing is occurring) and moving the stock in the direction of becoming recruitment impaired	Management is needed to reduce fishing pressure and ensure that the biomass does not become depleted
	Recovering	Biomass (or proxy) is depleted and recruitment is impaired, but management measures are in place to promote stock recovery, and recovery is occurring	Appropriate management is in place, and there is evidence that the biomass is recovering
	Depleted	Biomass (or proxy) has been reduced through catch and/or fishing effects, such that recruitment is impaired. Current management is not adequate to recover the stock, or adequate management measures have been put in place but have not yet resulted in measurable improvements	Management is needed to recover this stock; if adequate management measures are already in place, more time may be required for them to take effect
	Undefined	Not enough information exists to determine stock status	Data required to assess stock status are needed
	Negligible	Catches are so low as to be considered negligible and inadequate information exists to determine stock status	Assessment will not be conducted unless catches and information increase

3. METHODS

3.1. Sources of Information

Two sources of data were used in this stock assessment: fishery-dependent and fishery-independent. Fishery-dependent data were: commercial fishery statistics; recreational fishery data; and population size and age structures determined through market sampling. These data were considered at the following spatial scales, as appropriate: the State-wide scale; the scale of stocks; and also at the regional population level. Secondly, fishery-independent data were obtained as estimates of spawning biomass for two regional populations (Spencer Gulf and Gulf St. Vincent) using the daily egg production method (DEPM) that was undertaken in December 2018.

The previous stock assessment for Snapper identified a discrepancy between trends in biomass estimates of Snapper derived from fishery-dependent data and output from the fishery model SnapEst (Fowler et al. 2016a). This discrepancy was due to some of the key fishery-dependent performance indicators, such as CPUE and fishing effort, not adequately reflecting fishable biomass or recruitment. For Snapper in SA, the combination of 'hyperstability' in CPUE, technology creep on 'effective effort' and the introduction and modification of daily trip limits complicate the interpretation of the relationship between fishable biomass and CPUE, effort and Prop200kgTarHL, Prop200kgTarLL. This prompted the need for a fishery-independent estimate of biomass resulting in the development and implementation of the DEPM for Snapper (Steer et al. 2017). Consequently, for this assessment, the DEPM survey and spawning biomass estimation replaced the SnapEst model. The SnapEst model is expected to be updated in future years to integrate all fishery-dependent and -independent data sources.

3.2. Fishery-Dependent Data

Commercial fishery data for Snapper from the MSF, NZRLF and SZRLF were extracted from the commercial Marine Scalefish Fisheries Information System, and were combined with similar data from the Lakes and Coorong Fishery Information System. The data for the 35-calendar year period of 1984 to 2018 were considered in this assessment. The data on catch and effort were aggregated at the State-wide scale for the two primary gear types of handlines and longlines to provide annual estimates of total catch and effort from which were calculated estimates of catch per unit effort (CPUE). At the scale of stock, the annual estimates of targeted catch and effort by gear type were determined and used to calculate estimates of CPUE as targeted fishery statistics are considered important fishery performance indicators (PIRSA 2013). The numbers of fishers taking and targeting Snapper by gear type across the State and at the scale of stock are also presented.

Since 2000, to provide information on population structure, Snapper from regional commercial catches have been sampled at the SAFCOL fish market in Adelaide. These data have been augmented with those from occasional sampling trips to processing plants in regional areas and also on research cruises. All such sampling has conformed to a two-stage sampling protocol (Fowler et al. 2016a). In short, fishery catches were accessed at the market from which numerous fish were measured (caudal fork length, CFL) to obtain size information. The licence number and fisher are also recorded and cross-checked against the records in the commercial Marine Scalefish Fisheries Information System to determine capture location and fishing method. For a sub-sample of fish, further biological information was collected. These fish were measured for CFL, weighed, sexed and stage of reproductive maturity was determined. They were then dissected for the removal of the otoliths that were later used to determine fish age using an established ageing protocol (Fowler et al. 2016a). Annual estimates of size and age structures were developed for regional populations for which sufficient data were available, using the methods of McGlennon et al. (2000). Development of each size structure was based on all fish measured from handline and longline catches from each region, but weighted according to the size of catches of the two gear types. The proportional length data were then converted to a relative biomass distribution using a region-specific, length-weight relationship. The data are presented at the regional spatial scale from 2008 onwards. For comparison with size and age structures for the period of 2000 to 2007 refer to the figures in Section 6.1 in the appendix of Fowler et al. (2016a). Where size or age structures are not presented for a particular year and region there were insufficient data available.

3.3. Fishery-Independent Data

In December 2018, SARDI undertook a DEPM survey to estimate the spawning biomass for the regional populations of Snapper in GSV and NSG. The methodology to achieve this for Snapper in SA were established in an earlier study (Steer et al. 2017). This method relies on the premise that the biomass of spawning adults (*B*) can be calculated by dividing the mean number of eggs produced per unit mass of adult fish (Lasker 1985). Spawning Biomass (*B*) is calculated according to the following equation:

$$B = \left(\frac{P_0 \cdot A}{S \cdot R \cdot \sum_{w=1}^{\omega} F_w \cdot p_w^{\mathrm{N}}} \right) \cdot \sum_{w=1}^{\omega} p_w^{\mathrm{N}} \cdot \breve{w}_w \qquad \text{[Equation 1]}$$

Where P_0 is mean egg density, A is spawning area, S is spawning fraction, R is sex ratio in weight, w is weight class number, ω is the number of weight classes, $\breve{w}_w$ is each weight-class

midpoint, F_w is the fecundity at $\breve{w}_w$ and p_w^{N} is the proportion of females in weight class w (Steer et al. 2017, McGarvey et al. 2018).

These data are based on quantifying the number of Snapper eggs throughout the regions of interest. The multi-step process to achieve this included: a plankton survey in SG and GSV; sorting of plankton samples to extract the fish eggs; and identifying the Snapper eggs. The plankton sampling was undertaken throughout both regions from 10th to 19th December 2018. The total survey area, however, was reduced in 2018 compared with the previous 2013 and 2014 surveys as a result of 48 hrs of inclement weather. Due to the resulting time constraints, survey stations along the southern boundary of SG, the southwestern corner of GSV, and along the Adelaide metropolitan coastline were not able to be sampled (Figure 3-1). Stations that were not be sampled when the time available to complete the survey was reduced were selected on the basis they did not yield high densities of eggs or exhibit strong evidence of spawning activity in 2014.

Plankton samples were collected at 329 stations using paired bongo nets, towed obliquely throughout the water column. All fish eggs were sorted from each of the samples at SARDI's Aquatic Sciences Centre. A specifically designed molecular probe was used to identify Snapper eggs from the mixed fish egg samples through the use of a blue pigment (Oxley et al. 2017). Adult Snapper were sampled from targeted fishing during the plankton sampling cruises and via SARDI's ongoing fishery-dependent market sampling program.

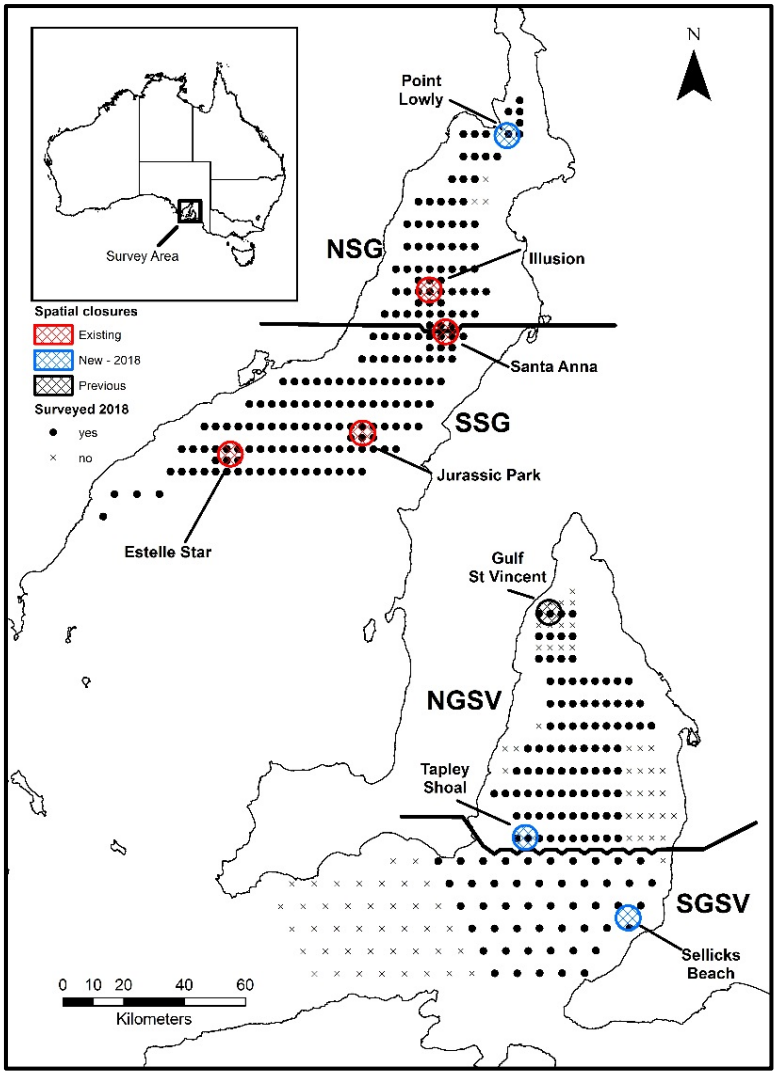

Figure 3-1. DEPM Survey area. Locations of sampling stations (throughout South Australia's Spencer Gulf (partitioned into northern (NSG) and southern regions (SSG)) and Gulf St. Vincent (northern (NGSV) and southern (SGSV) regions). Black dots represents the reduced sampling program undertaken in 2018 compared with previous 2013 (SG) and 2014 (GSV) surveys denoted by crosses.

Daily egg production methods are known to have large imprecision which results from the combination of several parameters, that are themselves imprecise. While it is acknowledged that DEPM estimates are considered unbiased and demonstrably capable of detecting changes in biomass, this imprecision requires sensitivity analyses to determine uncertainty in which parameters are likely to have most influence on estimates of biomass. A sensitivity analysis was performed using the 2018 surveys for the three most influential parameters in the DEPM analysis: egg density (P_0), spawning area (A) and spawning fraction (S).

The sensitivity analysis for spawning area was performed by maintaining all other parameters (P_0, S, R, F_w, $\breve{w}_w$ and p_w^{N}) at their mean values and altering the value of A in the equation

(Equation 1). This same process was followed for P_0 and S. The values included in the sensitivity analysis were determined differently for each parameter. Egg density (P_0) was analysed using the different values of egg mortality (Z) tested in its estimation (Figure 4-21). Spawning area (A) was analysed using the regional areas estimated in 2013/14 to examine the effects of the under-sampling in 2018. Three percentiles (25%, 50% and 75%) between the 2018 and previous spawning areas were also examined. The sensitivity of alternate values of S on the spawning biomass estimate were examined using values of 25%, 50% and 75% above the lower of the regional value estimated for 2013/14 or 2018, as well as the values estimated from limited data collected in 2018 that ranged from 0.34 to 0.94 and the value of 0.72 that was used in 2018 to estimate spawning biomass (from Saunders 2009).

3.4. Assessment of Fishery Performance

The fishery performance indicators and associated reference points that were used here to consider stock status primarily relate to the fishery-dependent data (PIRSA 2013). These were considered for each of the two main gear types of handlines and longlines at the scale of stock for the SG/WCS and GSVS and at the regional population level for the SE region. The specific performance indicators considered in each case were: total catch; targeted handline effort; targeted handline CPUE; targeted longline effort; targeted longline CPUE.

As further fishery performance indicators for each stock, the proportions of daily fishing trips for which the handline or longline catches were equal to or greater than 200 kg were also considered (Prop200kgTarHL, Prop200kgTarLL). Note here, the change from the total of 250 kg prescribed in the Management Plan (PIRSA 2013), reflects the reduction in the daily trip limit for the SG/WCS that was implemented in December 2016. The calculation of the annual estimates of the two performance indicators (Prop200kgTarHL, Prop200kgTarLL) used daily catch data from the commercial sector that are available by calendar year from 2004 to 2018. For each year, only the targeted catch data from February to October were included in the calculations, so as to remove the influence of the seasonal closure on the data (PIRSA 2013). The estimates of Prop200kgTarHL and Prop200kgTarLL for 2018 were compared against those from 2004 to 2017, using the same trigger reference points that are used for the general performance indicators (Table 3-1).

The population age structures were also considered as fishery performance indicators for which the operational objective is to maintain the proportion of fish older than 10 years of age above 20% of the fished population. The trigger reference point is structured around this operational objective (PIRSA 2013).

Estimates of spawning biomass do not constitute part of the current harvest strategy for Snapper since the process of undertaking DEPMs was established after development of the

current Management Plan (PIRSA 2013). As there are no formal reference points against which to assess the 2018 estimates of spawning biomass, the estimates of spawning biomass for 2018 were compared against those obtained in 2013 for NSG and 2014 for GSV. Direct comparison was complicated by the numbers of stations that were sampled in both gulfs in 2018 being lower than those sampled in 2013 for NSG and 2014 for GSV (Figure 3-1) (Steer et al. 2017). This meant that the areas of the gulfs that were sampled in 2018 were smaller than those sampled in the previous years. This affected the comparability of the new estimates of spawning biomass with those reported previously. To address this, the estimates of biomass for 2013 and 2014 were re-estimated to match the reduced area sampled in 2018, providing a direct comparison of change in relative spawning biomass between 2013/2014 and 2018. Consequently, the estimates of biomass presented here for SG in 2013 and GSV for 2014 are marginally lower than those originally reported in Steer et al. (2017).

Table 3-1. Performance indicators used to monitor the performance of South Australia's Snapper fisheries as prescribed in the MSF Management Plan (PIRSA 2013). Biological (B) and General (G) indicators and whether a primary (P) or secondary (S) indicator are identified.

Performance	Type	P or S	Trigger Reference Point
Total catch	G	S	3rd lowest/3rd highest
			Greatest interannual change (±)
			Greatest 3-year trend (±)
			Decrease over 5 consecutive years?
Targeted handline effort	G	P	3rd lowest/3rd highest
			Greatest interannual change (±)
			Greatest 3-year trend (±)
			Decrease over 5 consecutive years?
Targeted handline CPUE	G	P	3rd lowest/3rd highest
			Greatest interannual change (±)
			Greatest 3-year trend (±)
			Decrease over 5 consecutive years?
Targeted longline effort	G	P	3rd lowest/3rd highest
			Greatest interannual change (±)
			Greatest 3-year trend (±)
			Decrease over 5 consecutive years?
Targeted longline CPUE	G	S	3rd lowest/3rd highest
			Greatest interannual change (±)
			Greatest 3-year trend (±)
			Decrease over 5 consecutive years?
Prop200kgTarHL		P	3rd lowest/3rd highest
			Greatest interannual change (±)
			Greatest 3-year trend (±)
			Decrease over 5 consecutive years?
Prop200kgTarLL		S	3rd lowest/3rd highest
			Greatest interannual change (±)
			Greatest 3-year trend (±)
			Decrease over 5 consecutive years?
Age composition	B	P	Prop >10yrs <20% of fished population

Allocation

The Fisheries Management Act 2007 states that the Management Plan must specify the allocation of the resource among the various sectors, taking into account the shares that exist at the time the Minister calls for a Management Plan to be prepared. Allocated shares were derived for the MSF from the catch data collected in 2007/08, when a State-wide recreational fishery survey was done (Jones 2009). The resource allocation for Snapper is 81% Commercial, 18% Recreational, and 1% Aboriginal traditional. For Snapper, there are three trigger limits for the assessment of all allocations amongst fisheries and sectors (Table 3-2) (PIRSA 2013). The first trigger limit (Trigger 1) relates to the allocated shares amongst the commercial fisheries, recreational fishery and charter boat sector (PIRSA 2013). Since there is no new recreational fishery data, this assessment was not done here (see Fowler et al. 2016). The remaining two trigger limits (Triggers 2 and 3) relate specifically to the allocation of shares amongst the different commercial fisheries, and so can be assessed on an annual basis (Table 3-2). The trigger limits have been set at levels that are commensurate with the initial allocation and allows for variability in catches. Trigger 2 relates to exceeding the commercial sector allocation by the relevant percentage in three consecutive years or in four of the previous five years. Trigger 3 relates to exceeding the commercial sector allocation by the relevant percentage in any one year.

Table 3-2. Allocation of Snapper catch shares among the sectors as prescribed in the MSF Management Plan (PIRSA 2013).

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

4. RESULTS

4.1. Commercial Fishery Statistics

State-wide

Estimates of total State-wide commercial catch of Snapper show cyclical variation (Figure 4-1). Since 2003, i.e. the year that produced the minimum catch at the start of the most recent cycle, State-wide catch increased to a record level of 1,032 t in 2010, before declining by more than 72.8% to 281 t in 2018. Historically, handlines were the most significant gear type, and these catches largely accounted for the cyclical variation in total catch until 2008. However, the proportional contribution of longlines to total catch increased considerably between 2005 and 2010, when it became the dominant gear type. Both longline and handline catches have declined since 2010.

There was a long-term, gradual declining trend in targeted commercial fishing effort between the mid-1980s and 2008 (Figure 4-1). This was followed by a period of elevated fishing effort between 2009 and 2012 that related to the increase in longline effort. However, since 2010, longline effort has declined, complementing the on-going, long-term declining trend in handline effort. As such, the total fishing effort of 4,691 fisher-days in 2018 was the lowest recorded since 1984. State-wide handline CPUE showed cyclical variation, superimposed on a long-term increasing trend. However, since 2007 it has decreased considerably, concomitant with the emerging dominance of longline fishing. In contrast, longline CPUE increased considerably between 2004 and 2015, before declining in each of 2016, 2017 and 2018.

The numbers of fishers from across all four commercial fisheries who reported taking Snapper, declined consistently from 403 in 1984 to 245 in 2000. It then stabilised for a number of years before declining from 260 in 2010 to 168 fishers in 2018. The numbers who targeted Snapper varied similarly and fell from 201 in 2009 to 133 in 2018.

In 2018, the commercial catch was dominated by the MSF which contributed 96.3% of the reported catch (Figure 4-2). The SZRLF accounted for most of the remaining catch.

Regional

The relative contributions of the three stocks to total State-wide annual catches have changed considerably over time particularly with respect to significant change in the spatial structure of the fishery that occurred between 2008 and 2012 (Figure 4-2). The SG/WCS provided the highest annual catches up to 2009, after which they declined and fell to their lowest levels between 2012 and 2018 (Figure 4-2). The catches from the GSVS were generally very low until around 2004 after which they increased gradually for a few years before accelerating between 2007 and 2010. This stock became and has subsequently remained the main

contributor to the State-wide catch up to 2018. The catches from the South East region also increased dramatically between 2007 and 2010, before declining back to a low level in 2017. They increased marginally in 2018.

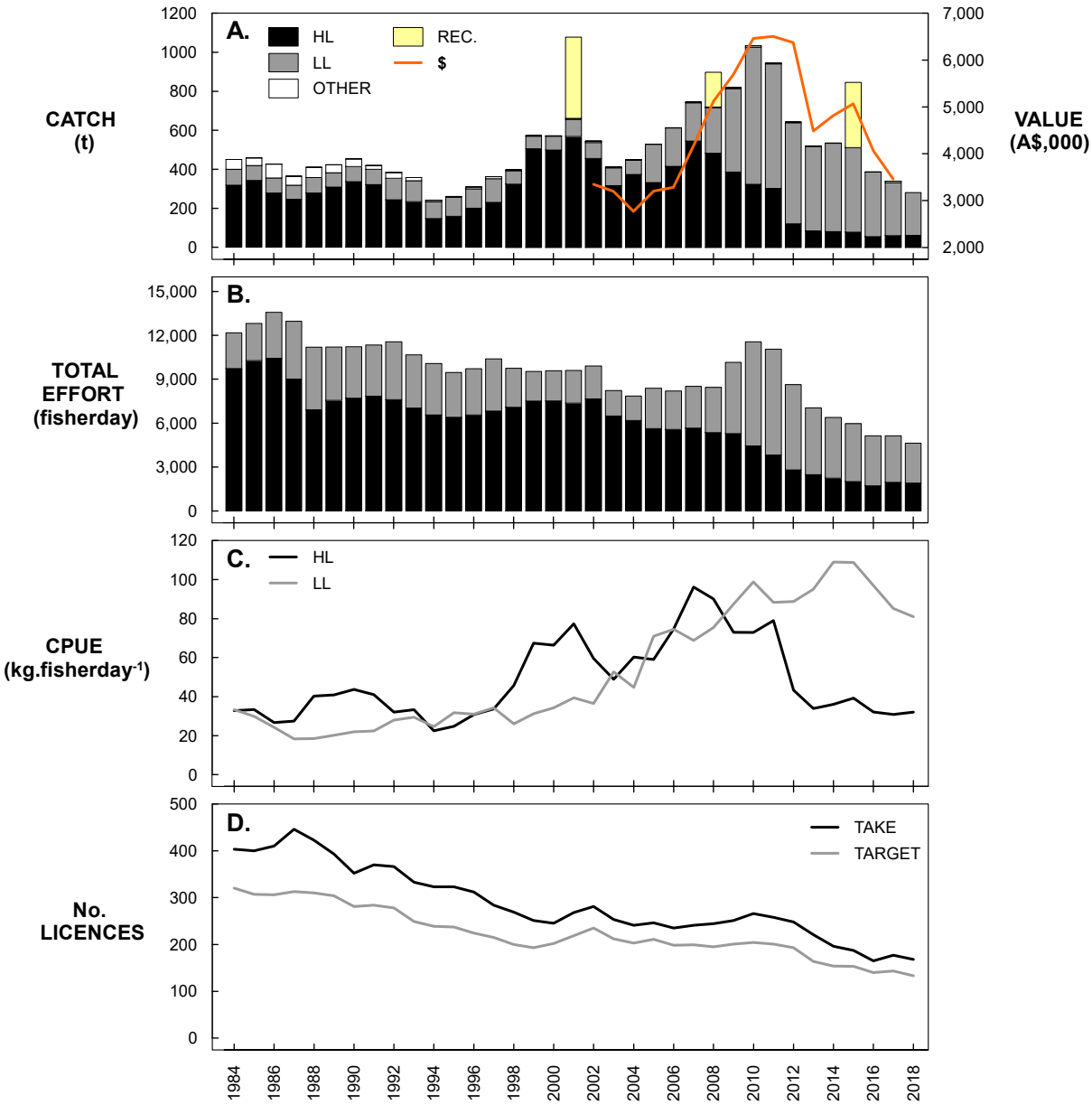

Figure 4-1. Snapper. Long-term trends in: (A) total catch of the main gear types (handlines and longlines) and gross production value; (B) total effort for handlines and longlines; (C) total catch per unit effort (CPUE) for handlines and longlines; and (D) the number of active licence holders taking or targeting the species.

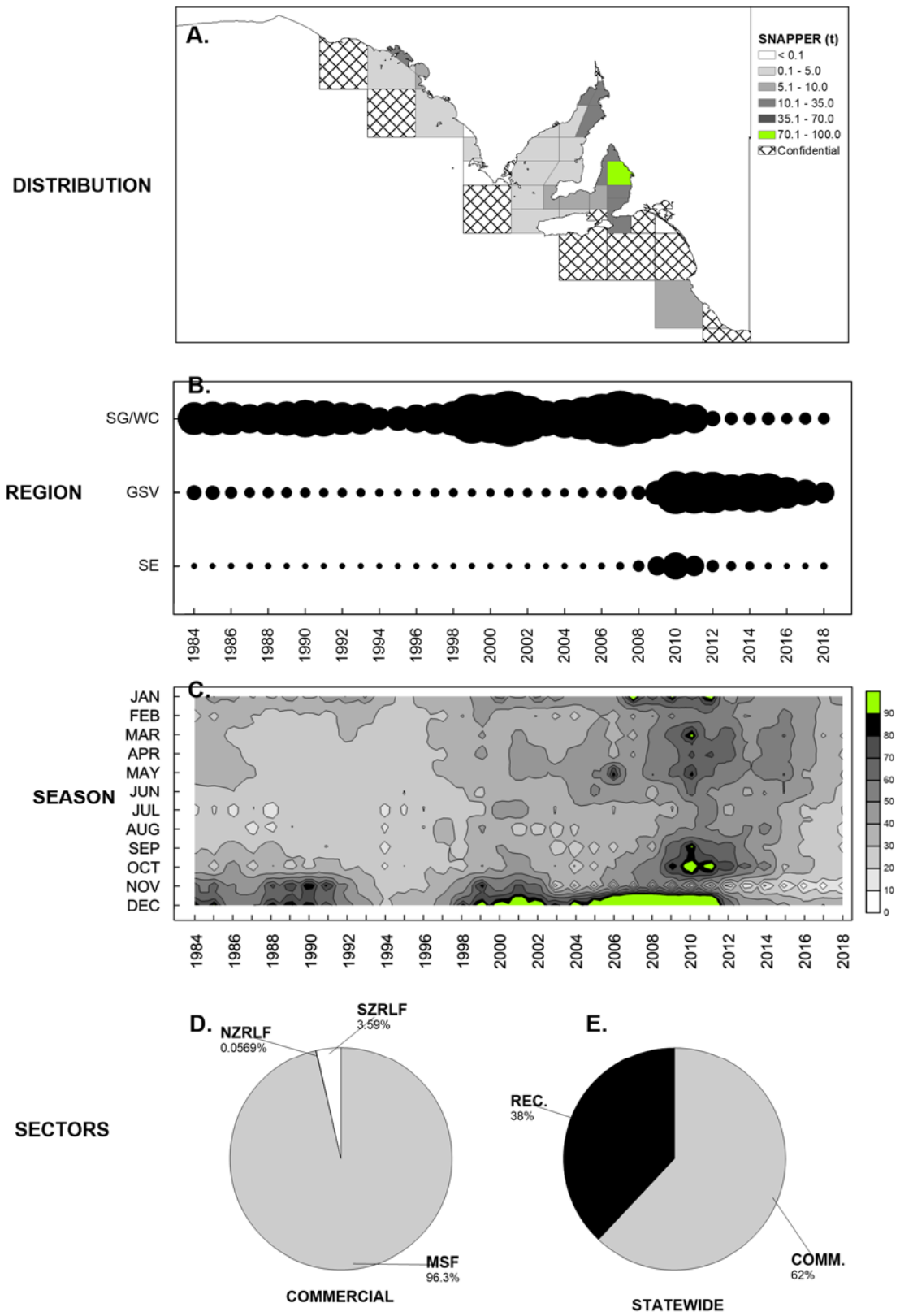

Figure 4-2. Snapper. (A) Catch distribution for 2018. Long term trends in: (B) the annual distribution of catch among biological stocks, (C) months of the year t); the proportion of catch distributed among the commercial sector in 2018 (D); and among the state-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

Spencer Gulf/ West Coast Stock

Annual catches from the SG/WCS have varied cyclically with peaks in 1990, 2001 and 2007. The latter year produced the highest catch of 616.6 t (Figure 4-3). From 2007 to 2013, annual catches fell considerably, and have subsequently remained relatively stable at a low level. The lowest catch of 66.3 t was taken in 2016, which increased marginally to 77.9 t in 2017 before dropping back to 73.5 t in 2018.

Targeted handline catches have also varied over time. The highest of 516.1 t was taken in 2001, which has since fallen to the lowest of only 28.2 t in 2018 (Figure 4-3). Targeted handline effort increased between 1984 and 2002 to the highest level of 5,138 fisher-days. Since then, it has declined to the lowest of 563 fisher-days in 2017 before increasing marginally to 587 fisher-days in 2018. Targeted handline CPUE has varied cyclically, but has also shown a long-term increasing trend to 2011, which peaked in 2007 at 138.2 kg.fisher-day^{-1}, but in 2012 declined steeply to 64.6 kg.fisher-day^{-1}, before dropping to 48.1 kg.fisher-day^{-1} by 2018. The number of licence holders who took and targeted Snapper with handlines declined slowly through the 1980s and 1990s but the rates of decline increased through the 2000s. Those taking Snapper with handlines fell from a high of 216 in 1985 to 97 in 2018, and those targeting fell from 175 to 65 over the same period. The number of reported daily handline catches (between February and October) declined considerably from 2004 to 2018. The estimates of Prop200kgHLTar were variable, declining from the maximum in 2010, to low levels in 2012 and 2013. They increased again in 2014 and 2015 before declining to 2018.

Targeted longline catch for the SG/WCS was relatively flat from 1984 to 2004. It then increased and peaked at 154.1 t in 2006 before declining again. By 2018, it had fallen to 35.8 t. Since targeted LL effort peaked at 2,578 fisher-days in 1997, it has declined considerably. By 2014 it had fallen to 591 fisher-days, before it increased to 679 fisher-days in 2018. Targeted LL CPUE peaked between 2005 and 2008, with the highest at 99.4 kg.fisher-day^{-1} in 2006. From 2008, it has fallen considerably and by 2014 had dropped to 34.2 kg.fisher-day^{-1}. Subsequently it has increased to 52.8 kg.fisher-day^{-1} in 2018. The numbers of fishers taking and targeting Snapper with longlines have declined steadily from 1988 to 2018. Those taking Snapper fell from 116 to 41 and those targeting it fell from 99 to 40 (Figure 4-3). The numbers of reported daily longline catches fell between 2006 and 2011 and have subsequently remained relatively low. The annual estimates of Prop200kgLLTar declined to approximately 0.1 in 2011 and have since remained at this low level.

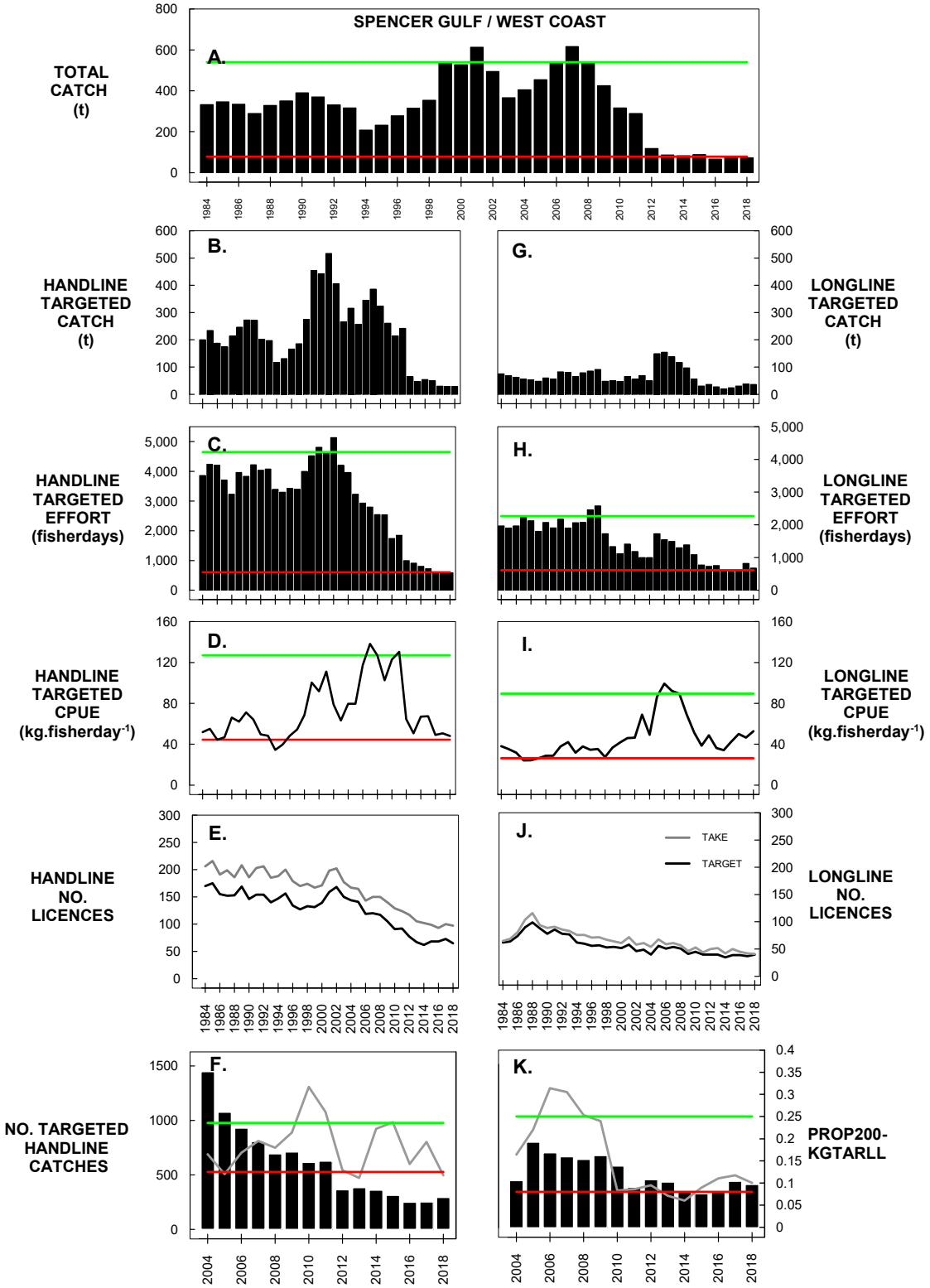

Figure 4-3. Key fishery statistics used to inform the status of the Spencer Gulf/ West Coast Stock of Snapper. Long-term trends in (A) total catch. (Left) trends in (B) targeted handline catch; (C), effort , (D) catch rate; and (E) the number of active licence holders taking and targeting the species; (F) number of targeted daily catches (bars) and Prop200kgTarHL (line). (Right) trends in (G) targeted longline catch; (H), effort , (I) catch rate; and (J) the number of active licence holders taking and targeting the species; (K) number of targeted daily catches (bars) and Prop200kgTarLL (line). Green and red lines represent the upper and lower reference points identified in Table 3-1.

Gulf St. Vincent Stock

Between 1984 and 2006, the GSVS produced relatively low catches. However, from 2006 to 2010, total catch increased exponentially culminating in the record catch of 454.1 t (Figure 4-4). Total catch declined marginally between 2010 and 2015 after which the rate of decline increased. Total catch in 2018 was 188.3 t, i.e. 41.5% of the record level.

Targeted HL catch has generally been low for this stock despite the high effort levels during the early 1980s (Figure 4-4). Targeted effort declined to a low level in 1995 and has since remained low but varied cyclically. Estimates of annual targeted HL CPUE were low until 2006, before they increased to the highest levels between 2007 and 2013. It has subsequently decreased to moderate levels, with 42.4 kg.fisher-day^{-1} recorded in 2018. The numbers of handline fishers fell considerably through the 1980s and 1990s. Throughout the 2000s the numbers have been variable but shown no long-term trends. The numbers of reported daily handline catches have remained relatively low since 2004. The estimates of Prop200kgTarHL were relatively high between 2007 and 2012. From then, they declined to <0.1 in 2015 and have since remained low.

The LL fishery for the GSVS largely accounted for the recent rapid increase in total catches. Between 2008 and 2015, targeted LL catch increased from 46.7 t to 388.2 t (Figure 4-4). This increase was associated with a 334.1% increase in targeted longline fishing effort from 657 to 2,852 fisher-days. Targeted fishing effort has declined in each of 2016, 2017 and 2018 dropping to 1,551 fisher-days in the latter year. Longline CPUE demonstrated a long-term increase primarily between 2000 and 2010, when it peaked at 145.7 kg.fisher-day^{-1}. Since 2015, it has declined consistently to 103.8 kg.fisher-day^{-1} in 2018. The numbers of LL fishers who took and targeted Snapper peaked in 2012 at 66 and 64, respectively. They have declined considerably to 33 and 32 respectively, in 2018. The numbers of daily longline catches increased from 2007, peaked in 2012 and have subsequently declined from then until 2018. Prop200kgTarLL was relatively high from 2011 to 2015, but has declined considerably in 2016, 2017 and 2018.

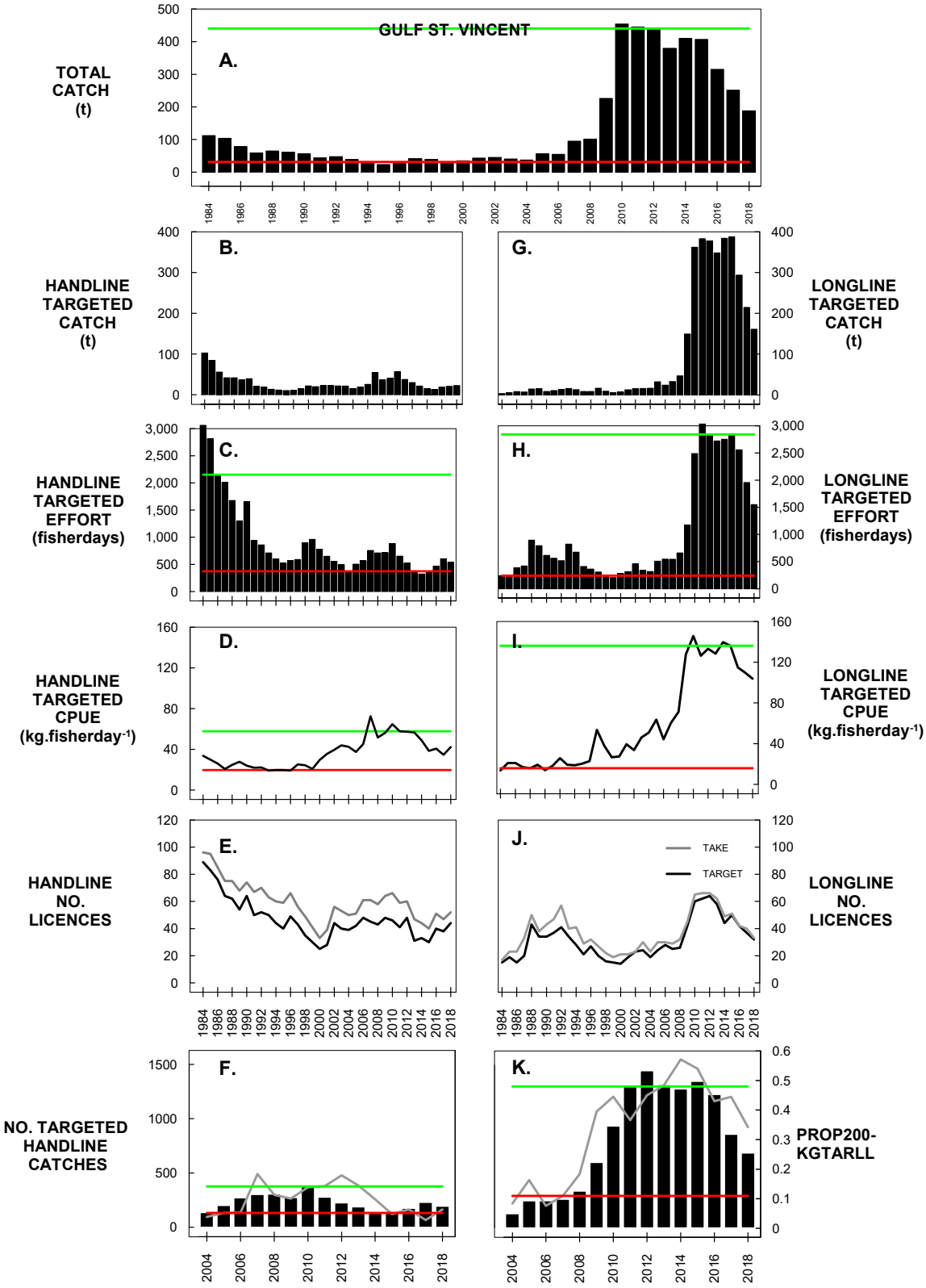

Figure 4-4. Key fishery statistics used to inform the status of the Gulf St. Vincent Stock of Snapper. Long-term trends in (A) total catch. (Left) trends in (B) targeted handline catch; (C), effort , (D) catch rate; and (E) the number of active licence holders taking and targeting the species; (F) number of targeted catches (bars) and Prop200kgTarHL (line). (Right) trends in (G) targeted longline catch; (H), effort, (I) catch rate; and (J) the number of active licence holders taking and targeting the species; (K) number of targeted catches (bars) and Prop200kgTarLL (line. Green and red lines represent the upper and lower reference points identified in Table 3-1.

South East Regional Population

The SE region has generally produced only small catches of Snapper (Figure 4-5). However, from 2006 to 2010 there was an exponential increase in catch that peaked in 2010 at 257.9 t. It then fell consistently and in 2017 total catch was 9.4 t, before increasing to 19.1 t in 2018.

Targeted HL catch in the SE has always been low. There was a minor increase between 2006 and 2009, which peaked in 2007 at 12.4 t, but which has subsequently declined. Such catches reflect low but variable fishing effort, which peaked at 316 fisher-days in 2007. Up to 2003, targeted HL CPUE was generally <20 kg.fisher-day^{-1}. It then increased to its highest levels from 2006 to 2009, peaking at 68.6 kg.fisher-day^{-1} in 2008. The numbers of HL fishers who took and targeted Snapper recently peaked in 2009, at 16 and 13, respectively. They have subsequently declined to three fishers each in 2018. The numbers of reported daily catches have remained low since 2004. Prop200kgTarHL was highest from 2006 to 2009, but has subsequently been very low.

Up to 2007, targeted LL catches were less than several tonnes.yr^{-1}. After this, there was a rapid increase to the maximum level of 239.2 t in 2010 (Figure 4-5). It then declined to 9.0 t in 2017 before increasing to 18.6 t in 2018. There was a considerable increase in targeted longline effort that peaked in 2010 at 2,614 fisher-days, which subsequently declined to only 162 fisher-days in 2017 before increasing to 308 fisher-days in 2018. Targeted CPUE also increased considerably between 2007 and 2010, peaking at 91.5 kg.fisher-day^{-1} before declining to 60.2 kg.fisher-day^{-1} in 2018. The numbers of LL fishers who took and targeted Snapper increased dramatically from 2005 and peaked in 2010 at 34 and 27, respectively. They declined to 11 and 9 in 2018. The reported numbers of daily catches increased from 2007, peaked in 2010 and subsequently declined to a minimum in 2016, before increasing marginally in 2017 and 2018. Prop200kgTarLL also peaked in 2010 and declined to 2016. It has risen again to >0.2 in 2018.

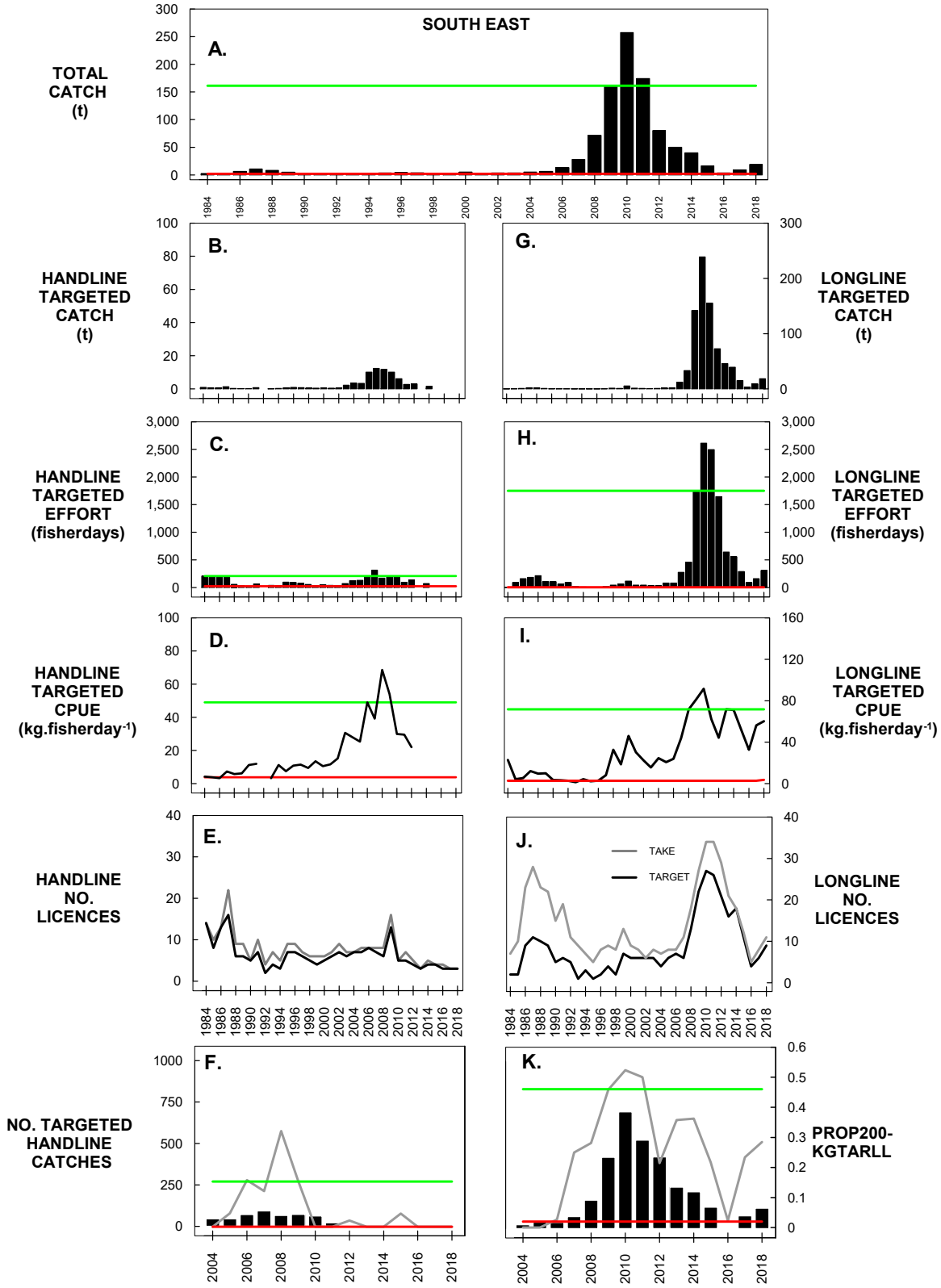

Figure 4-5. Key fishery statistics used to inform the status of the South East regional population of Snapper. Long-term trends in (A) total catch. (Left) trends in (B) targeted handline catch; (C), effort , (D) catch rate; and (E) the number of active licence holders taking and targeting the species; (F) number of targeted catches (bars) and Prop200kgTarHL (line). (Right) trends in (G) targeted longline catch; (H), effort, (I) catch rate; and (J) the number of active licence holders taking and targeting the species; (K) number of targeted catches (bars) and Prop200kgTarLL (line). Green and red lines represent the upper and lower reference points identified in Table 3-1.

4.2. Regional Estimates of Size and Age Structures

Northern Spencer Gulf

The annual size structures essentially reflect modes of fish in four size categories, i.e. 'small' fish in the 30 – 40 cm CFL range, 'medium' fish that were 40 – 60 cm CFL, 'large' fish that were 60 – 80 cm CFL and 'very large' fish that were >80 cm CFL. Throughout the mid- 2000s, the sample sizes were large due to the high catches from this region. Through those years the size structures were dominated by 'small' and 'large' fish (Figure 4-6). However, from 2012, the sample sizes fell considerably as there were far fewer fish available at the SAFCOL market. In 2016, 2017 and 2018, the relatively low numbers of measured fish were primarily in the 'small' size class with fewer 'medium' ones and very few 'large' ones.

In each year, there were particular year classes that contributed more to the catches than others (Figure 4-7). From 2008 to 2012 and also in 2015, the catches were dominated by the strong 1997 and 1999 year classes. Nevertheless, in each of 2017 and 2018, the age structures of the measured fish were dominated by fish that had recruited between 2012 and 2015. As such, there was an obvious lack of older fish indicating that the age structures were considerably truncated.

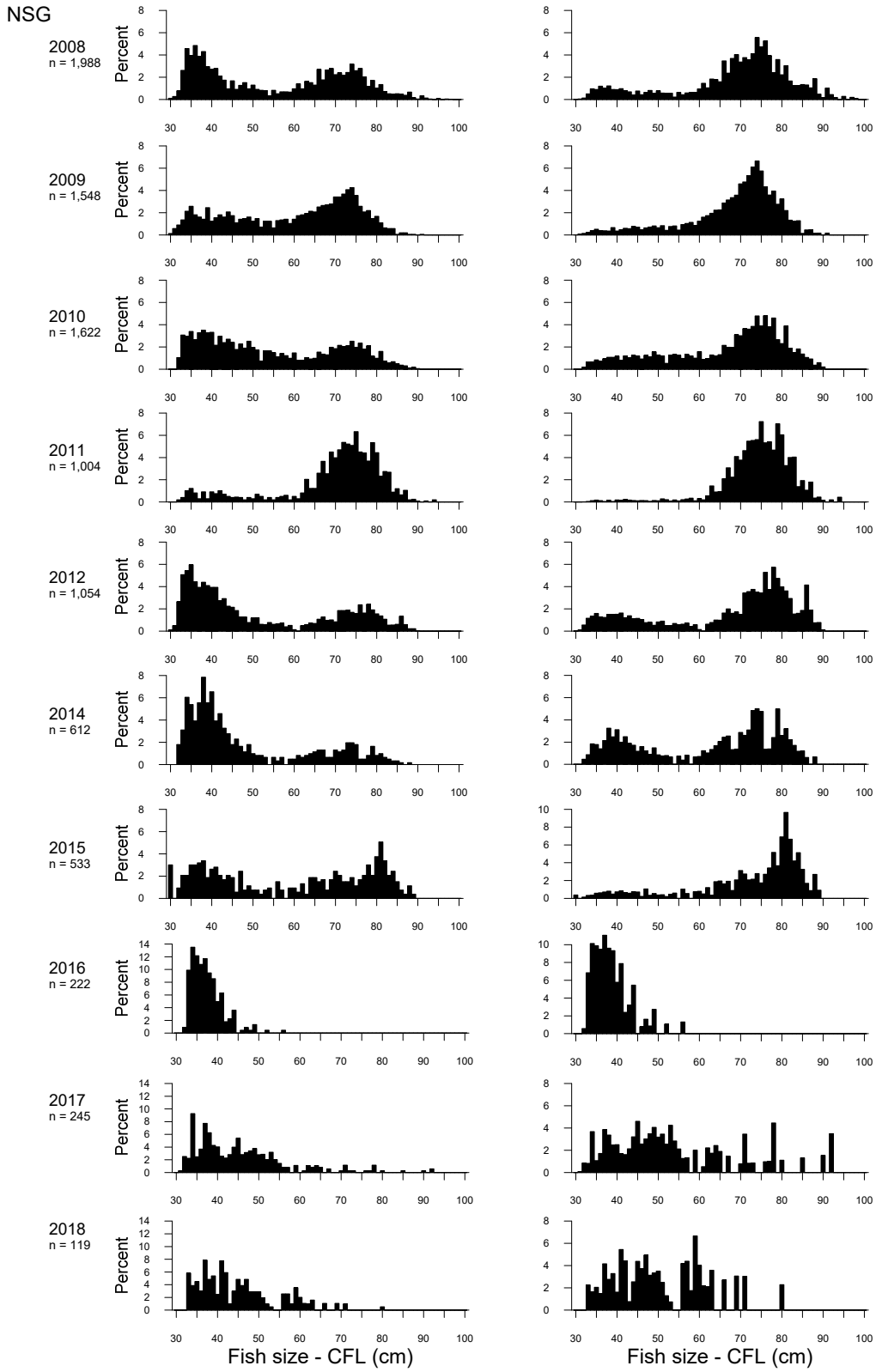

Figure 4-6. Size and biomass distributions for Snapper caught in NSG from 2008 to 2018. Left hand graphs show the size structures. Right hand graphs show the percentage of relative biomass accounted for by each size class.

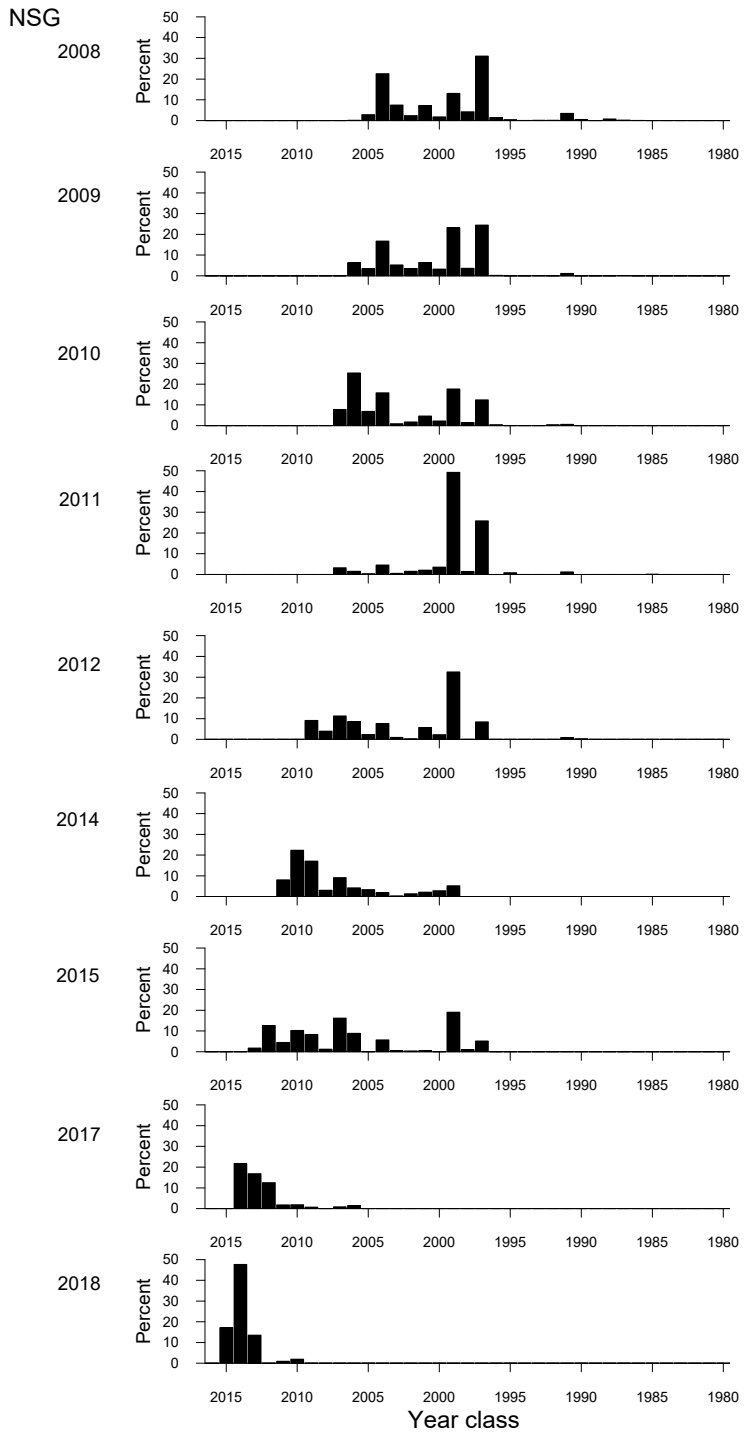

Figure 4-7. Estimated annual age structures for fish caught in NSG between 2008 and 2018. For each year, data are presented as the relative percentage of total catch accounted for by each year class, i.e. the years in which they were spawned.

Southern Spencer Gulf

Population size structures for SSG are available for most years from 2008 to 2018 (Figure 4-8). Sample sizes were quite variable amongst years, but generally declined over time. The annual size structures usually involved modes of ‘small’ and ‘large’ fish, whose relative sizes varied between years. The ‘large’ fish always dominated the biomass distributions in this region.

Age structures could not be generated for 2016, 2017 and 2018 as too few fish were aged. The age structures from 2008 to 2014 were dominated by the 1997 and 1999 year classes, indicating that the more recent year classes were relatively weak (Figure 4-9). In 2015, the 1997 and 1999 year classes were poorly represented, suggesting that these strong year classes had become depleted.

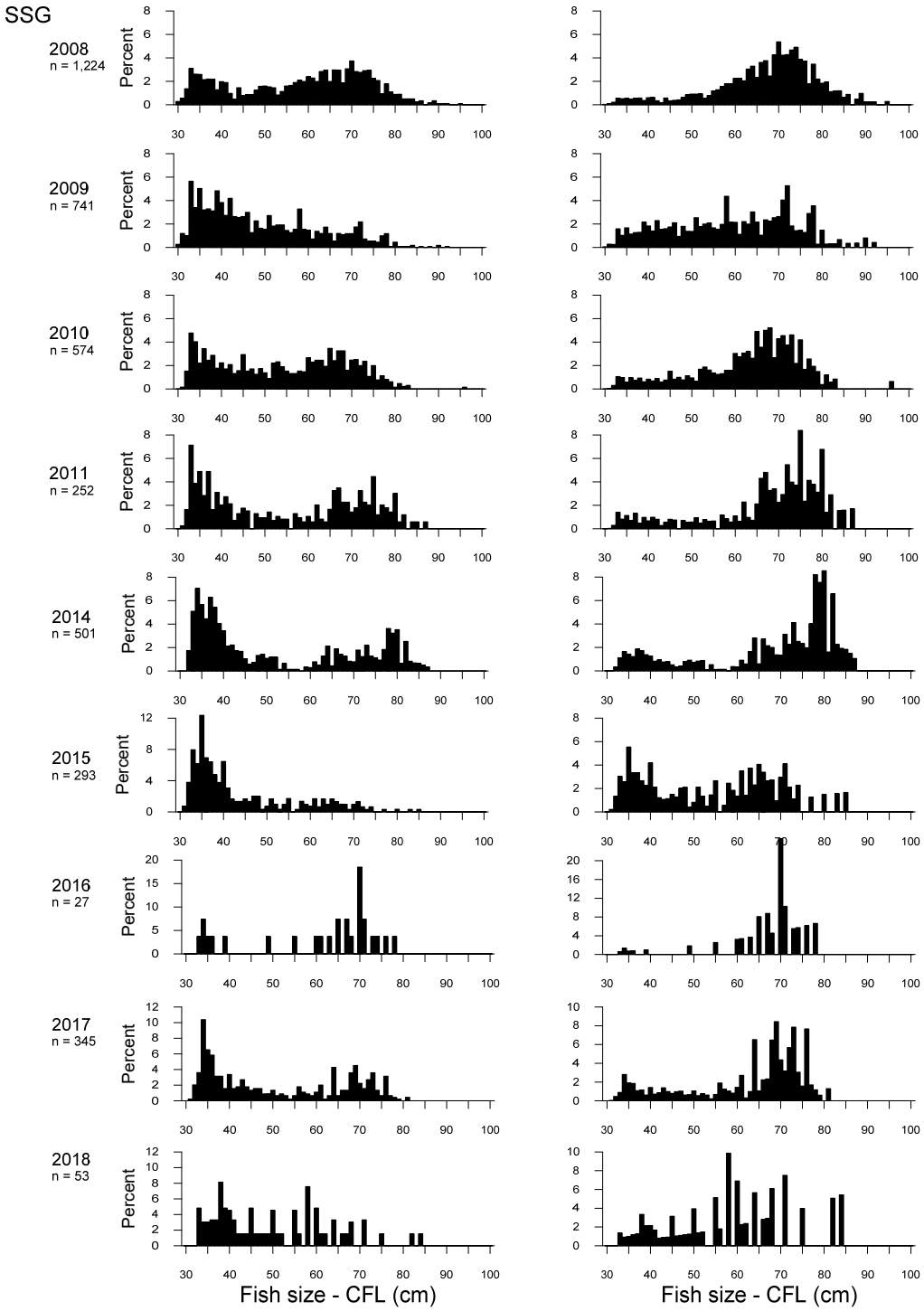

Figure 4-8. Size and biomass distributions for Snapper caught in SSG from 2008 to 2018. Left hand graphs show the size structures. Right hand graphs show the percentage of relative biomass accounted for by each size class.

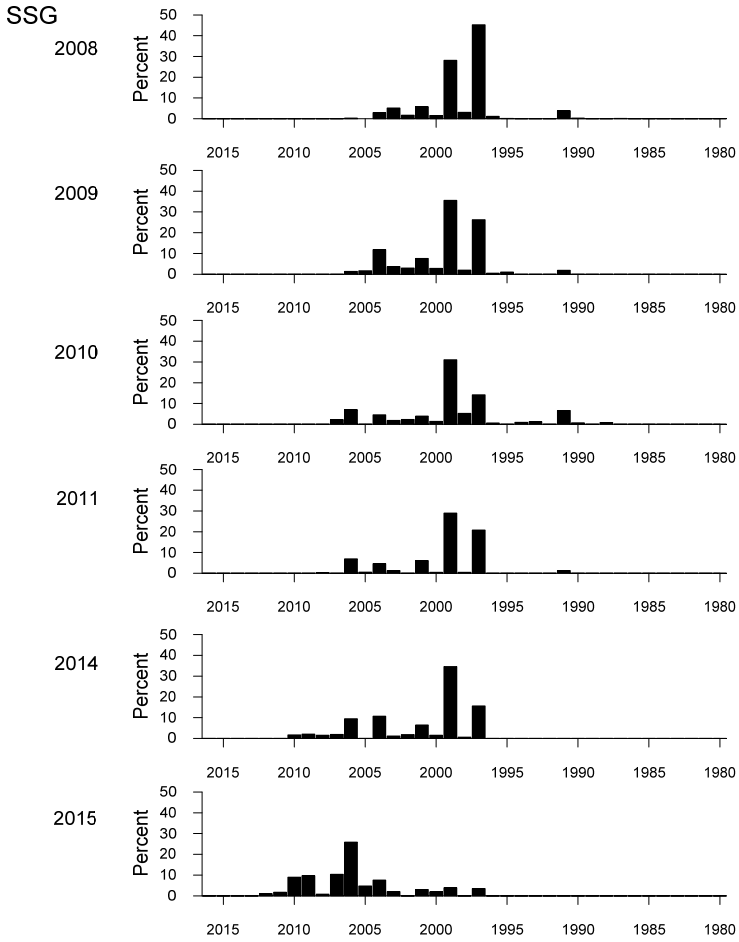

Figure 4-9. Estimated annual age structures for fish caught in SSG between 2008 and 2018. For each year, data are presented as the relative percentage of total catch accounted for by each year class, i.e. the years in which they were spawned.

Northern Gulf St. Vincent

Relatively high numbers of fish from this region were measured annually, particularly prior to 2016. All four size categories were generally well represented in the size structures in each year, although with some variation in the relative sizes of the different size categories (Figure 4-10). In 2008, the ‘small’ fish were most numerous, whilst in 2009 and 2010 the ‘large’ and ‘very large’ fish were most numerous. No modal structure was evident in the size structures of 2011 and 2012, indicating that all size categories contributed to the catches. The size structures in 2016, 2017 and 2018 were dominated by ‘large’ fish. Besides there being relatively fewer ‘small’ fish in these size structures, there were also fewer ‘very large’ fish compared to the previous years. This suggests that there was some recent contraction in the size structures.

For NGSV, there were sufficient otoliths collected in most years from 2008 to 2018 to develop population age structures (Figure 4-11). These were generally characterised by a broad number of year classes, relative to the other regions. Furthermore, numerous strong year classes contributed to the catches in each year that were consistent across years. These were the 1991, 1997, 1999, 2001, 2004, 2006, 2007 and 2009 year classes. Whilst in the recent age structures, there was no consistent evidence of any strong year classes since 2009, the age structure in 2018 suggests the possible emergence of the 2014 year class as a strong one.

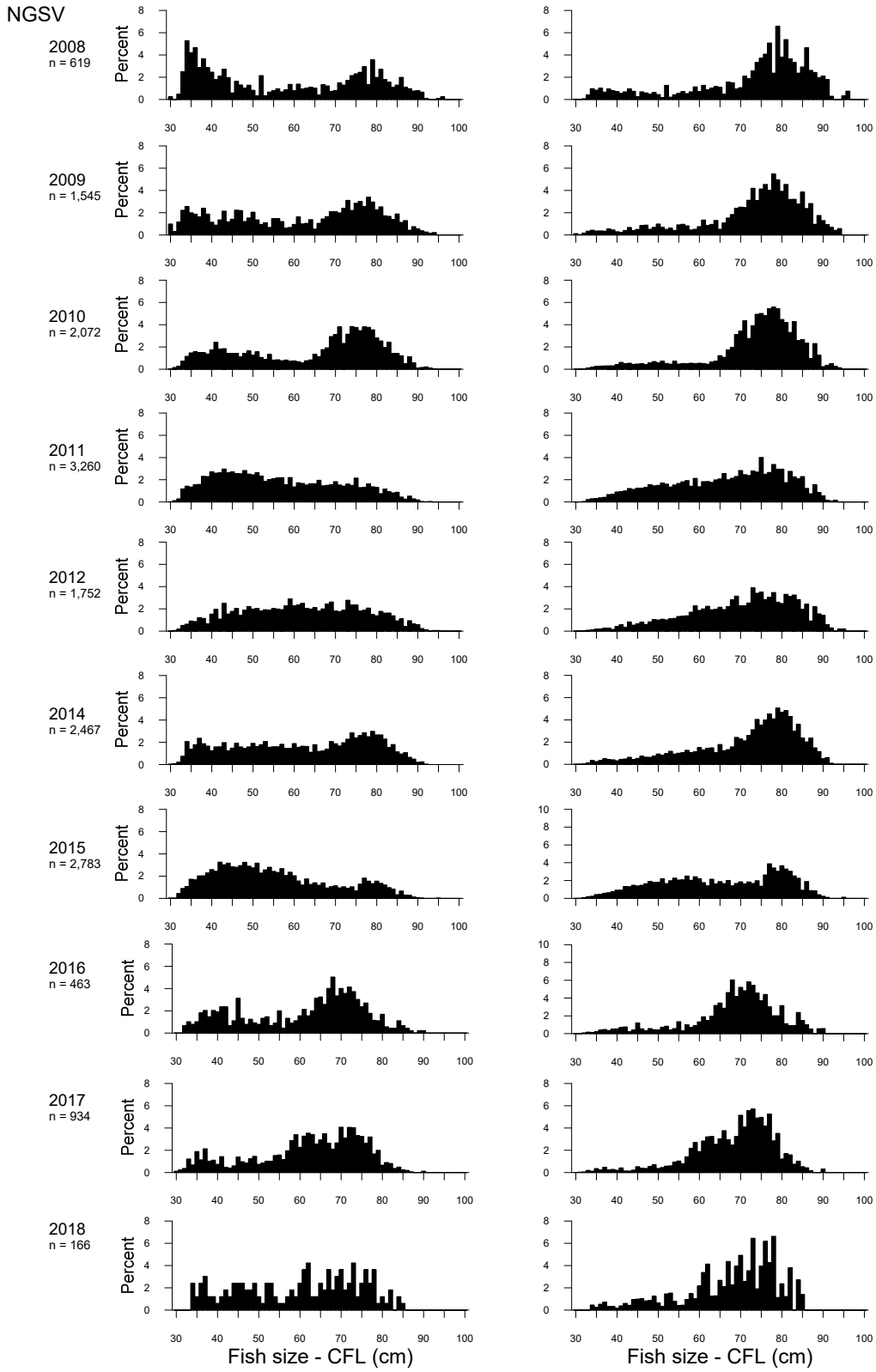

Figure 4-10. Size and biomass distributions for Snapper caught in NGSV from 2008 to 2018. Left hand graphs show the size structures. Right hand graphs show the percentage of relative biomass accounted for by each size class.

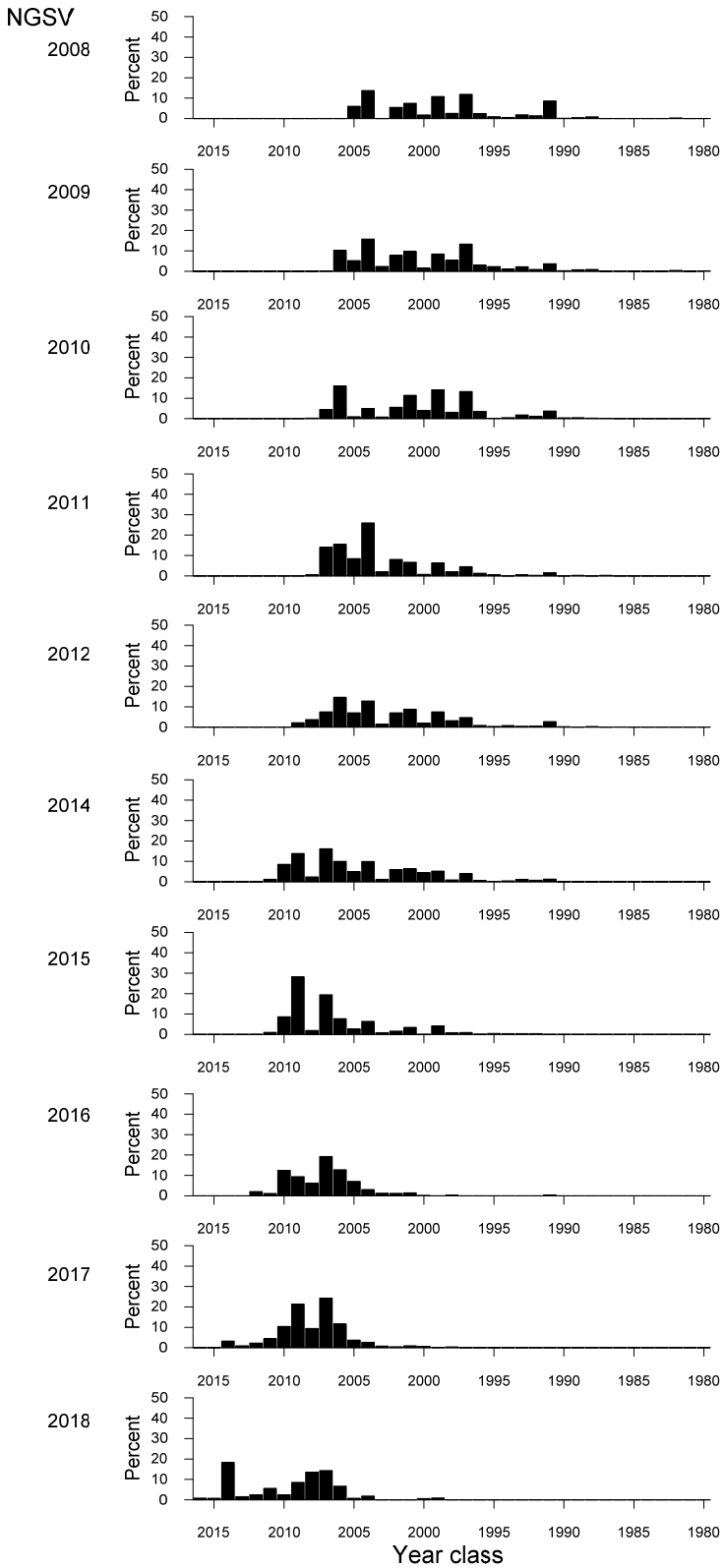

Figure 4-11. Estimated annual age structures for fish caught in NGSV between 2008 and 2018. For each year, data are presented as the relative percentage of total catch accounted for by each year class, i.e. the years in which they were spawned.

Southern Gulf St. Vincent

The sample sizes of fish measured from SGSV were relatively high until 2015 after which they have declined considerably. The size structures from 2008 to 2015 have been dominated by ‘small’ and ‘medium’ sized fish (Figure 4-12). Nevertheless, the size structures in 2017 and 2018 included proportionally more ‘large’ fish than the earlier years.

The age structures from 2008 onwards have included very few fish from the year classes of the 1990s (Figure 4-13). Those for the years of 2008 to 2015 were dominated by the 2001, 2004, 2006, 2007 and 2009 year classes. These were the same strong year classes that were evident for NGSV. The age structures developed in 2016, 2017 and 2018 do not display consistent evidence of any strong year classes.

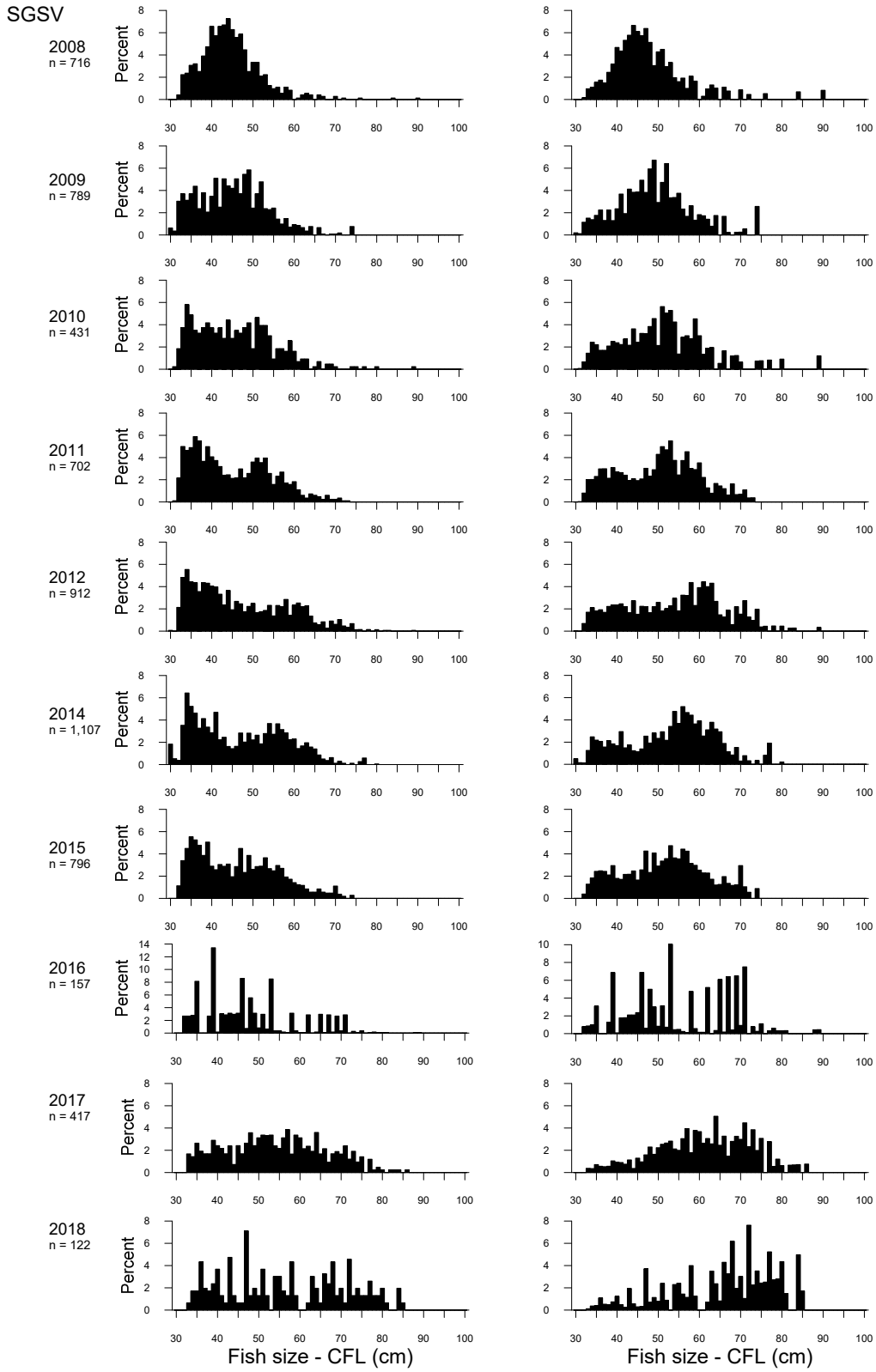

Figure 4-12. Size and biomass distributions for Snapper caught in SGSV from 2008 to 2018. Left hand graphs show the size structures. Right hand graphs show the percentage of relative biomass accounted for by each size class.

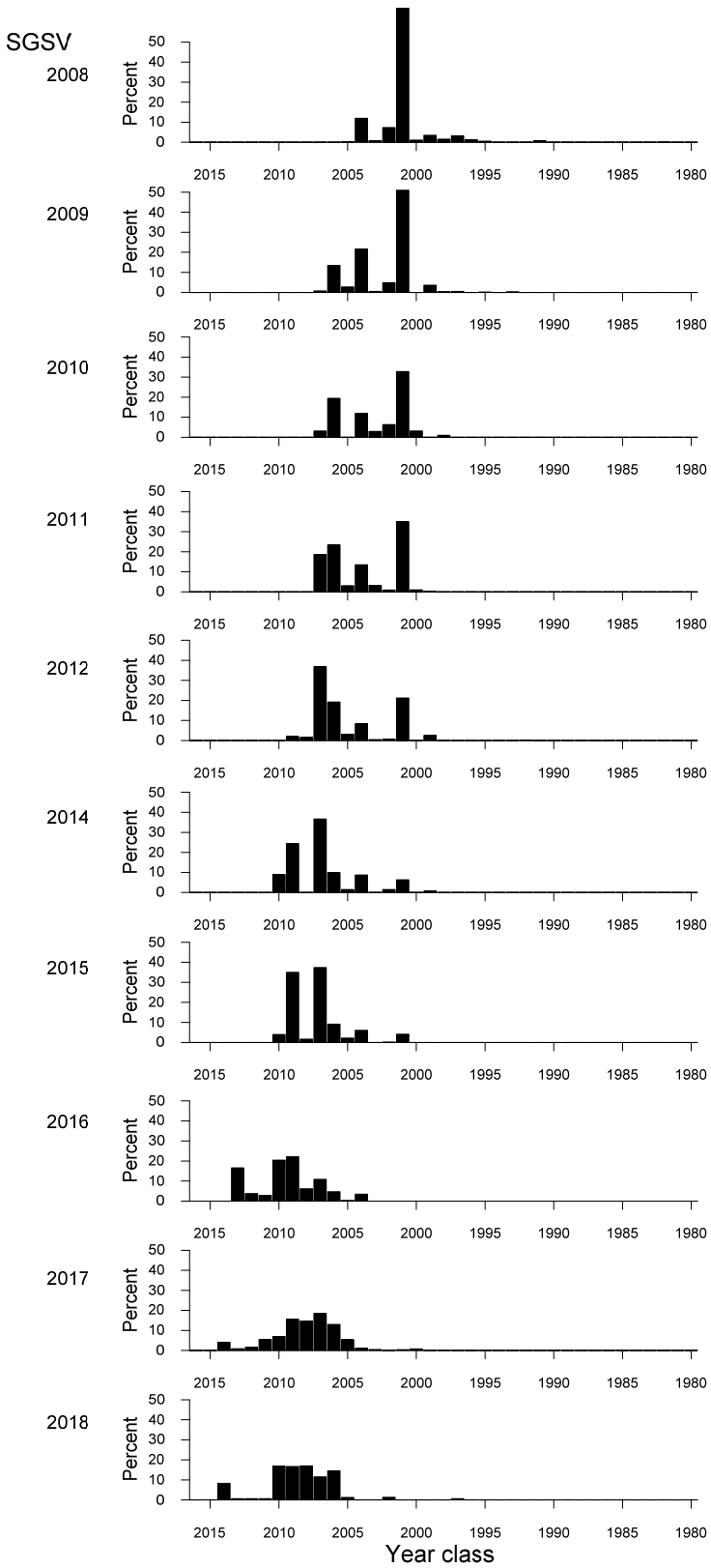

Figure 4-13. Estimated annual age structures for fish caught in SGSV between 2008 and 2018. For each year, data are presented as the relative percentage of total catch accounted for by each year class, i.e. the years in which they were spawned.

South East

For the SE region, size distributions are available for a number of years from 2008 to 2017 (Figure 4-14). Up to 2012, the size structures were dominated by ‘small’ and ‘medium’ fish and rarely involved fish >60 cm TL. Subsequently, there was a proportional increase in the representation of these ‘large’ fish. The age structures up to 2014 were dominated by the 2001 and 2004 year classes, whose relative contributions changed between 2009 and 2012 (Figure 4-15). By 2015, the representation of these year classes was considerably reduced, with catches dominated by the 2007 and 2009 year classes.

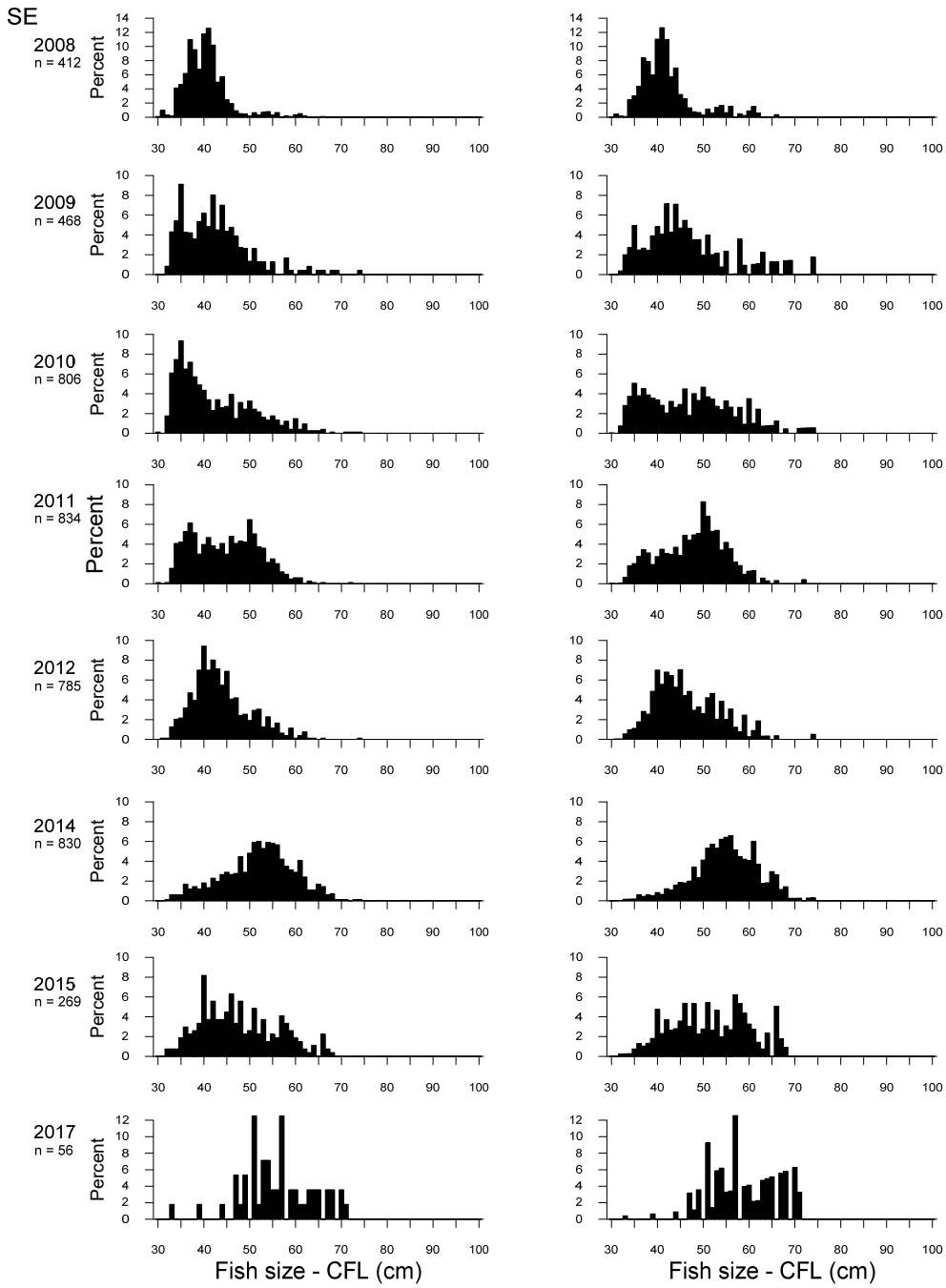

Figure 4-14. Size and biomass distributions for Snapper caught in SE from 2008 to 2018. Left hand graphs show the size structures. Right hand graphs show the percentage of relative biomass accounted for by each size class.

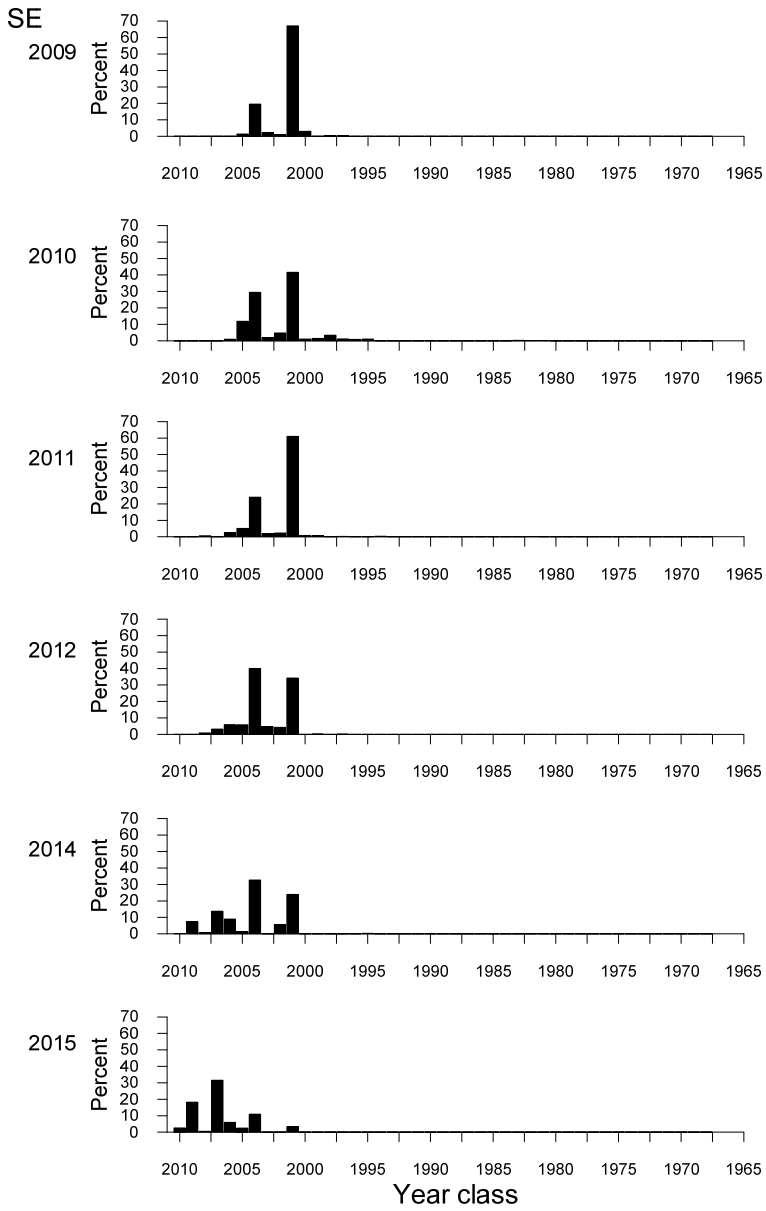

Figure 4-15. Estimated annual age structures for fish caught in SE between 2008 and 2018. For each year, data are presented as the relative percentage of total catch accounted for by each year class, i.e. the years in which they were spawned.

4.3. Regional Estimates of Spawning Biomass

Distribution and Abundance of Eggs

In December 2013, Snapper eggs were patchily distributed throughout NSG, and the densities were generally <5 eggs.m^{-2} (Figure 4-16). Nevertheless, there were a number of hotspots where the densities were in the range of 5 – 15 eggs.m^{-2}. These were generally in the vicinity of the four spatial spawning closures at the Illusion, the Santa Anna, the Estelle Star and Jurassic Park, as well as at a location near Point Lowly. In contrast, in 2018, the Snapper eggs were more evenly distributed throughout both the northern and southern areas. There were generally lower densities near the five high density sites evident in 2013 and it was only near the Santa Anna, that the density exceeded 5 eggs.m^{-2}.

For GSV, in 2014, the Snapper eggs were also unevenly distributed. In the southern area, the densities were generally <1 egg.m^{-2}. They were generally higher in the northern area, particularly around Tapley Shoal where they were >25 eggs.m^{-2}. In 2018, the eggs were again more concentrated in the northern area, particularly at several hotspots located across the gulf between Port Adelaide and Black Point.

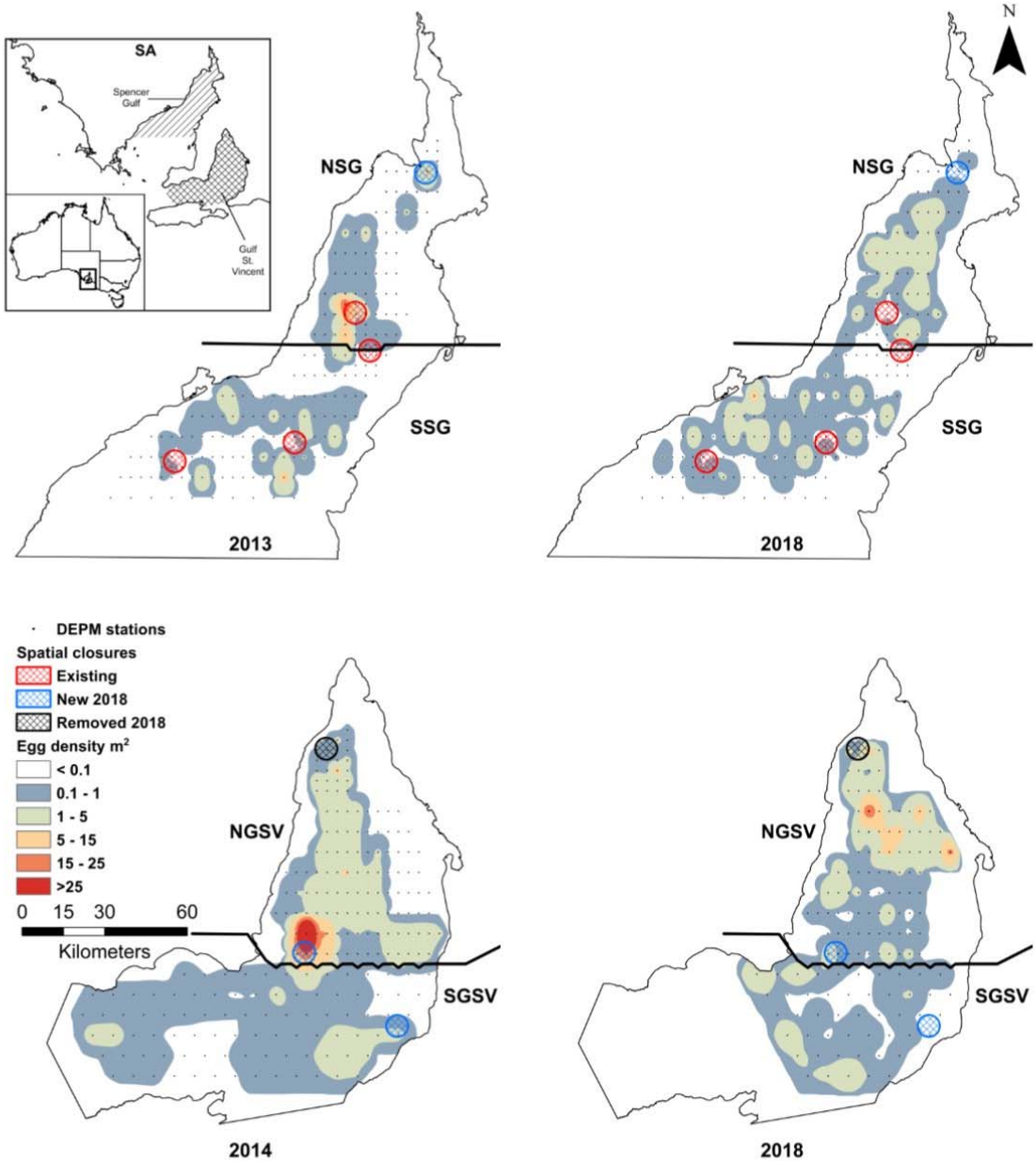

Figure 4-16. Estimates of the densities of Snapper eggs in Northern Spencer Gulf in 2013 and 2018 and in Gulf St. Vincent in 2014 and 2018. The estimates are based on extensive plankton surveys. The sample stations in each region and year are indicated as dots.

Spawning Area (*A*)

The spawning areas for the 2013 SG and 2014 GSV surveys were recalculated to conform to the reduced area sampled in 2018 for comparative purposes. With the exception of SSG, where the spawning area increased by 0.2%, the recalculation reduced the spawning area by 6.2% for NGSV, 11.6% for NSG, and 38.9% for SGSV (Table 4-1). The recalculated spawning area for SG in 2018 of 3,979 km^2 was 42.1% larger than the previous 2013 estimate. The

spawning area in GSV was 3,126 km^2, representing a 34% reduction compared with recalculated 2014 estimate (Table 4-1).

Table 4-1. Regional estimates of Snapper spawning area (*A*), including the original 2013 SG and 2014 GSV estimates and subsequent recalculation to align with the reduced sampling area in 2018.

YEAR	GULF	REGION	SPAWNING AREA (km^2)	SPAWNING AREA (Adj)	% CHANGE
2013	SPENCER GULF*	NSG	1188.28	1050.82	-11.57
		SSG	1611.71	1615.50	0.24
		TOTAL	***2799.99***	***2666.32***	***-4.77***
2014	GULF ST. VINCENT*	NGSV	2563.17	2404.19	-6.20
		SGSV	3871.30	2365.80	-38.89
		TOTAL	***6434.47***	***4769.99***	***-25.87***
2018	SPENCER GULF	NSG	-	1622.22	-
		SSG	-	2357.06	-
		TOTAL	***-***	***3979.29***	***-***
2018	GULF ST. VINCENT	NGSV	-	1997.50	-
		SGSV	-	1128.28	-
		TOTAL	***-***	***3125.78***	***-***

Daily Egg Production (P_0)

Re-estimation of mean daily egg production (P_0) was required for the 2013 and 2014 surveys in order to provide comparable estimates to the most recent 2018 survey. This was performed by removing sites from the 2013/14 surveys that were not sampled in 2018 and re-estimating egg densities as if these sites had not been sampled. These re-estimates are similar across three of the surveys with mean differences of less than 0.1 eggs.m^2 (Table 4-2). The largest difference in egg density resulting from this re-estimation (1.73 eggs.m^2) was for SGSV, which was the region where the difference in survey area between 2014 and 2018 was greatest (Figure 4-17). However, the re-vised estimate of P_0 increased for this region as the portion of the survey area that was not sampled in 2018 had the lowest egg densities in 2014.

Differences between the 2018 P_0 estimates and the corresponding re-estimates for 2014 show a large decline in egg production across all four regions. While uncertainty around the P_0 estimates are large, the scale of these differences are sufficient to conclude that egg production in the areas surveyed in both years has declined over time (Figure 4-17). However, the level of spawning (egg production) that occurred outside the survey area in GSV in 2018 is unknown and a source of uncertainty for this assessment.

Table 4-2. Estimates of mean daily egg production (P_0) for Snapper in northern and southern Spencer Gulf and Gulf St Vincent across the eight surveys. The original P_0 estimates from 2013/14 are presented alongside their re-estimates using a consistent survey area between years. All estimates of P_0 were determined using an egg mortality rate (Z) of 0.4 day^{-1}.

GULF	REGION	EGG PRODUCTION (P_0) 2013/14	P_0 RE-ESTIMATED (± SE) 2013/14	P_0 (± SE) 2018	% REDUCTION
SPENCER GULF	NSG	3.23	3.53 (1.08)	0.95 (0.21)	73%
	SSG	1.54	1.57 (0.23)	0.73 (0.08)	54%
GULF ST. VINCENT	NGSV	20.67	20.57 (9.04)	2.03 (0.39)	90%
	SGSV	4.73	6.44 (1.48)	0.53 (0.13)	92%

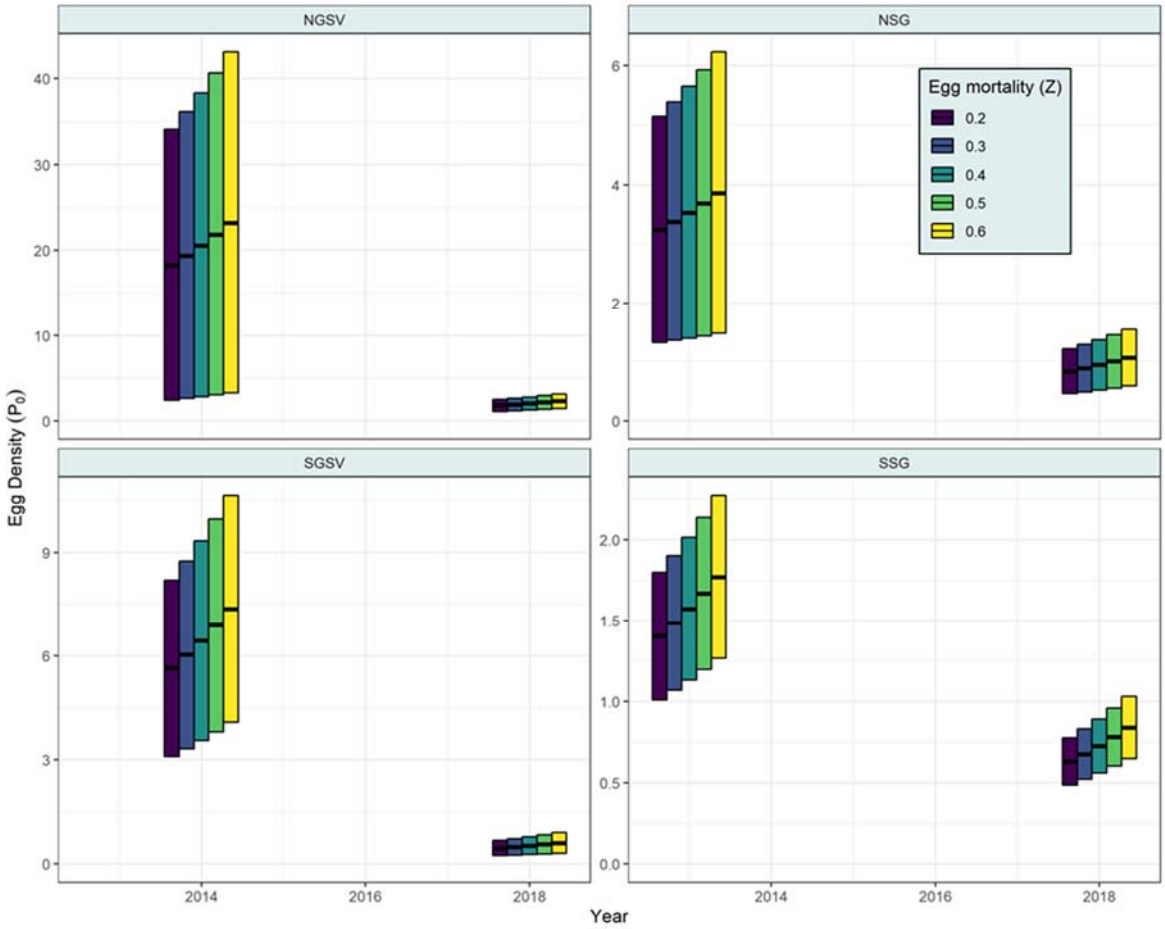

Figure 4-17. Estimates of egg density (P_0) for all four regions in 2013/14 and 2018. Black lines represent the mean P_0 values and the extent of the coloured bars shows the mean ± standard error. Five sensitivity scenarios are presented (coloured bars) for egg mortality (Z). A Z of 0.4 is used as standard in all further analyses. Note that scales on the y-axis are inconsistent across panels so as to shows differences between years rather than across regions.

Female Weight (*W*)

Weight frequency histograms for the northern and southern regions of each gulf were reconstructed from length data using an allometric length-weight relationship (Steer et al. 2017). Small Snapper weighing <2 kgs dominated the SG, accounting for 80.4% and 69.4% of the sample for NSG and SSG, respectively (Figure 4-18). Similar size fish were also evident in GSV, however, there were significantly more large fish (>4 kg) in the population, accounting for 37.3% and 40.0% of the population for NGSV and SGSV, respectively (Figure 4-18).

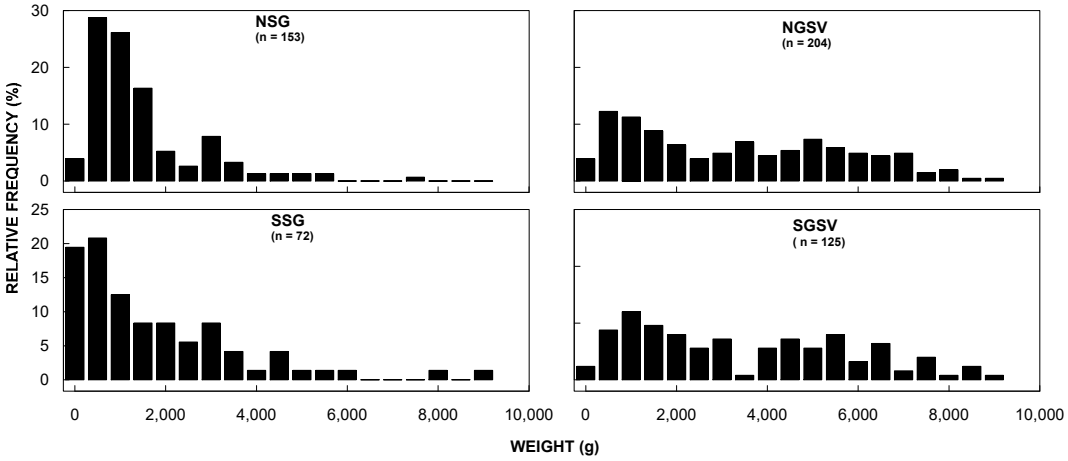

Figure 4-18. Weight frequencies of South Australian Snapper combined from the fishery-dependent sampling program and fishery-independent adult sampling for each of the four survey regions.

Sex Ratio (*R*)

The Snapper population was biased towards females in the northern gulfs in 2013 and 2014, accounting for 63% and 57% of the sampled population by weight in GSV and SG, respectively Table 4-3. The lowest proportions of females was observed during the 2018 survey, particularly in GSV and NSG. Gulf-wide sex ratios by weight varied by <25%.

Table 4-3. Population sex ratio (R) by weight for each survey region and year.

YEAR	GULF	REGION	*n*	SEX RATIO (*R*)
2013	SPENCER GULF	NSG	116	0.63
		SSG	103	0.45
2014	GULF ST. VINCENT	NGSV	94	0.57
		SGSV	18	0.45
2018	SPENCER GULF	NSG	23	0.34
		SSG	24	0.57
2018	GULF ST. VINCENT	NGSV	32	0.45
		SGSV	289	0.39

Batch Fecundity (*F*)

The relationship between batch fecundity (F) and total female weight (W) was best described by allometric linear regression. No statistical differences were detected between the relative slopes (analysis of covariance, year*weight interaction: $F_{2, 109} = 0.07$, $p = 0.94$) nor intercepts (year: $F_{2, 109} = 0.23$, $p = 0.53$) of the linear relationships between years. Consequently all data were combined into a single analysis and fitted using maximum likelihood (Figure 4-19). This overall relationship was similar to previous studies which examined reproduction and spawning dynamics of Snapper in South Australia over the past 16 years (Figure 4-19).

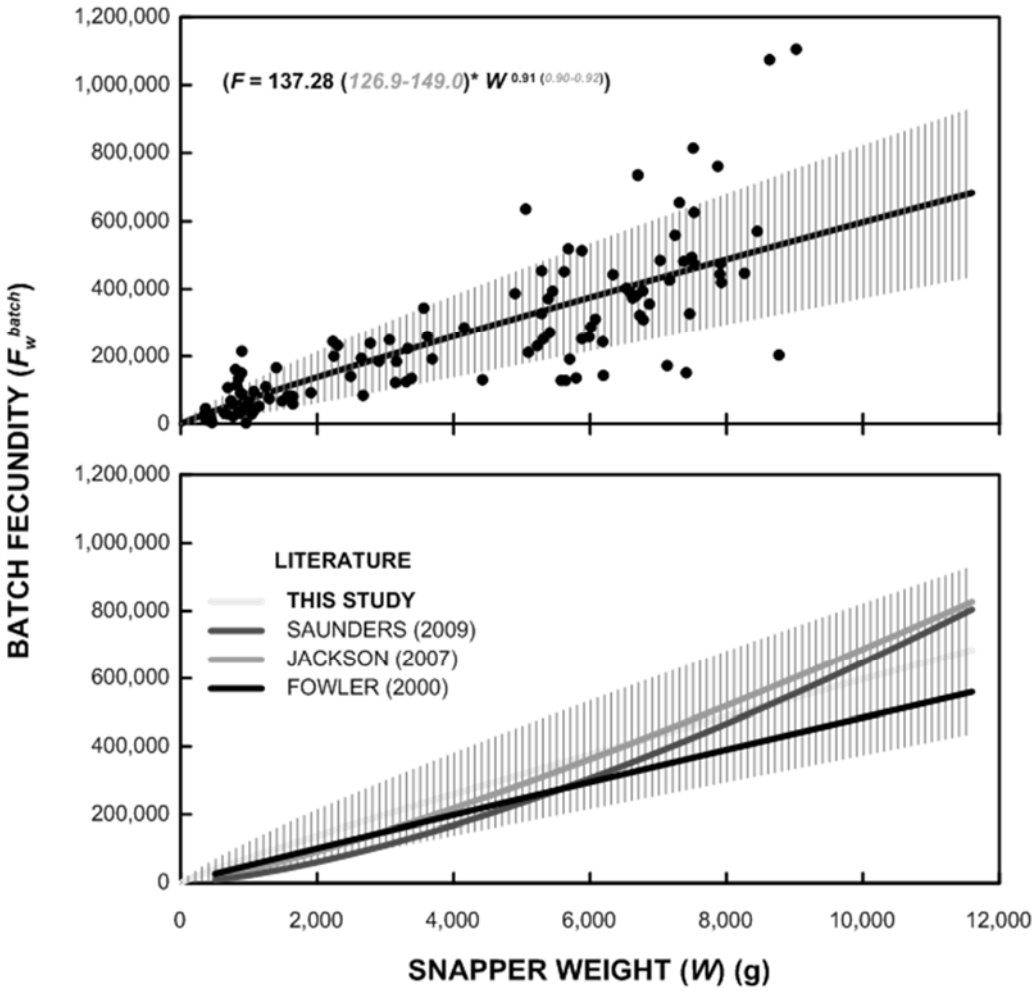

Figure 4-19. Batch fecundity versus body weight for South Australian Snapper. *Upper panel*: Fit of measured batch fecundity using maximum likelihood. The error bars indicate estimated 95% confidence intervals (shown as grey error bars in both panels). *Lower panel*: Comparison of the batch fecundity by weight relationship for Snapper derived in this study with previous published studies.

Spawning Fraction (*S*)

Low numbers of adult Snapper were sampled during the 2018 plankton survey and there was greater reliance on collecting biological information from the fishery-dependent market sampling program throughout December 2018 (Table 4-3). Consequently, there was insufficient biological information from female Snapper to confidently determine a regional spawning fraction. To overcome this, an established average spawning fraction of 72% was used in the spawning biomass calculation (Saunders 2009). This value was also within the range of the regional estimates used in the 2013 SG and 2014 GSV surveys (Steer et al. 2017).

Spawning Biomass (*B*)

The recalculated estimates of spawning biomass, to account for the reduced survey area in 2018, resulted in a 31 t (11.1%) reduction in SG and a 190 t (6.8%) reduction in GSV from the original 2013/14 estimates.

In 2013, for NSG, the total re-estimated spawning biomass was 249 t that consisted of 127 t in the northern area and 122 t in the southern area (Table 4-4). In comparison, the estimates for 2018, were considerably lower, i.e. 107 t for NSG and 85 t for SSG giving a total of 192 t, which was a reduction of 22.9 The total corresponding commercial catches taken from the SG survey area in 2013 and 2018 were 46.4 t and 37.3 t, respectively. This represents an estimated commercial harvest fraction of 18.6% in 2013 and 19.4% in 2018 (Figure 4-20). Assuming a 38% contribution to the total catch by the recreational sector (see Giri and Hall, 2015), the total harvest fraction was estimated at approximately 30% in 2013 and 2018.

For GSV, there was a considerable reduction in the estimates of spawning biomass for the same surveyed area between 2014 and 2018 (Table 4-4). For the former year, the total re-estimate was 2,590 t, consisting of 1,890 t in the northern area and 700 t in the southern area. The overall reduction was by 86.8% to 343 t in 2018, i.e. 277 t in the northern area and 66 t in the southern area. The total estimated commercial catches from GSV from the 2018 surveyed area were 388.6 t in 2014 and 157.2 t in 2018. This represents an estimated commercial harvest fraction, in the 2018 surveyed area, of 15.0% in 2014 and 45.8% in 2018 (Figure 4-20). Assuming a 38% contribution to the total catch by the recreational sector (see Giri and Hall, 2015), the total harvest fraction was estimated at 45.8% in 2013 and 73.4% in 2018.

Table 4-4. Comparison of the estimates of spawning biomass between DEPM surveys undertaken in 2013 and 2018 for Spencer Gulf, 2014 and 2018 for Gulf St. Vincent. Comparable sample areas were considered in the calculations for the two DEPMs undertaken in each gulf.

GULF	REGION	SPAWNING BIOMASS (*SB*) t (± SE) 2013/14	RECALCULATED SB t (± SE) 2013/14	SPAWNING BIOMASS 2018	% REDUCTION
SPENCER GULF	NSG	132 (78)	127 (53)	107 (58)	15.7%
	SSG	148 (74)	122 (40)	85 (25)	30.3%
	TOTAL	***280 (152)***	***249 (67)***	***192 (63)***	***22.9%***
GULF ST. VINCENT	NGSV	1,933 (1020)	1,890 (1040)	277 (125)	85.3%
	SGSV	847 (423)	700 (322)	66 (33)	90.6%
	TOTAL	***2,780 (1,444)***	***2,590 (1,088)***	***343 (130)***	***86.8%***

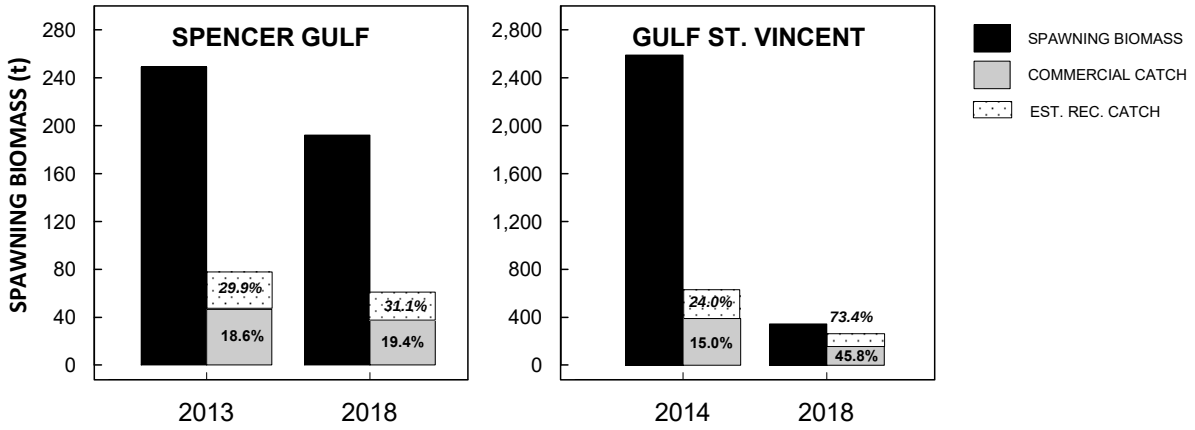

Figure 4-20. Comparisons of estimates of spawning biomass for Snapper from the two DEPM surveys and estimates of commercial and recreational catch. Commercial catches for SG were extracted from MFAs 11, 19, 20, 21, 22, and 23 and for GSV were from MFAs 34, 35, 36 and 43.

Sensitivity Analysis

Spawning area had the greatest influence when biomass was low. In SGSV (the region most under-sampled in 2018), using the estimate of *A* from 2014 lead to an increase of 46 t of spawning biomass. Proportionally, this was the greatest change of any of the four regions.

Mean egg density (P_0) produced a maximum difference between biomasses of 25% based on varying egg mortalities (*Z*) (Figure 4-21). These biomass differences varied by 22 – 25% across regions.

Spawning fraction is one of the more influential DEPM parameters (Figure 4-21). However, it's influence increases exponentially at lower values (>0.4) which is less problematic for Snapper than for other species (e.g. Sardine, Ward et al. 2017) as spawning fractions are typically high and are relatively stable during the spawning season. A more comprehensive dataset demonstrated that a value of 0.72 is appropriate for Snapper and was therefore

applied across years. The limited data collected in 2018 appeared biased, especially in GSV and NSG, due to low samples of female Snapper. Estimates of *S* from GSV were up to 0.9 while conversely NSG had low spawning fraction of 0.36. The GSV estimates appeared to be over-estimated and biased biomass downwards while the SG estimate was an underestimate that greatly biases the biomass upwards. A plausible range of *S* (0.7 – 0.8) for Snapper has little influence on estimated biomass (Figure 4-21).

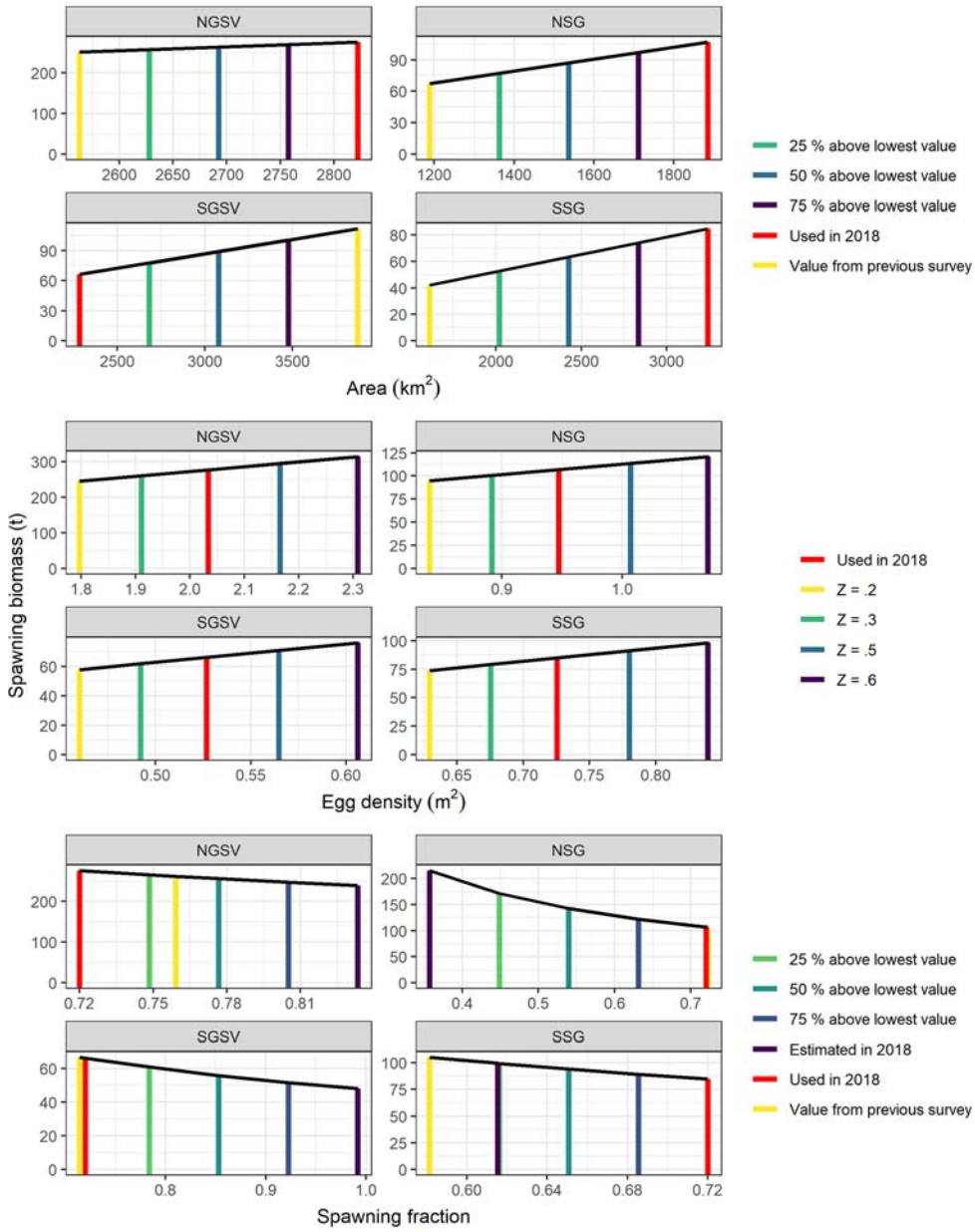

Figure 4-21. Sensitivity analysis of the three most influential DEPM parameters on Snapper biomass for all four regions. The red line marks the value used in the 2018 DEPM assessment. The point at which it intersects with the horizontal black line is the biomass estimate produced by it. Remaining coloured lines represent other parameter values included in the analysis.

4.4. Fishery Performance

The catch data from the four commercial fisheries in 2018 were compared against their allocations using Triggers 2 and 3 as reference points (Table 4-5). One trigger reference point was exceeded. For the SZRLF, Trigger 3 was activated, indicating that the catch from this fishery taken in 2018 exceeded its allocation.

Table 4-5. Snapper Commercial Fishery Allocation.

	MSF	SZRLF	NZRLF	LCF
Commercial allocation	*97.5*	*1.78*	*0.68*	*0.04*
Trigger 2 (%)	*na*	*2.68*	*1.3*	*0.75*
Trigger 3 (%)	*na*	*3.58*	*2.0*	*1.0*
% total 2014	98.91	0.70	0.14	0.25
% total 2015	99.37	0.46	0.18	0
% total 2016	99.90	0.05	0.06	0
% total 2017	98.75	1.10	0.16	0
% total 2018	96.35	3.59	0.06	0

The general fishery performance indicators were assessed for the SG/WCS, GSVS and the SE regional population. In total, there were five breaches of trigger reference points (Table 4-6). In 2018, for the SG/WCS, total catch was the 2nd lowest recorded, whilst targeted handline effort was also the 2nd lowest. The lowest value for Prop200kgTarHL was recorded. There were no breaches for the GSVS. For the SE in 2018, targeted handline effort was the lowest yet recorded, whilst for Prop200kgTarHL the lowest value was also recorded.

For 2018, age structures could only be generated for NSG, NGSV and SGSV as for the other regions there were either no or too few fish aged to generate an age length key. For each of the latter age structures the percentage of fish that were older than 10 years was estimated and compared against the trigger reference point of 20%. For NGSV and SGSV, the reference point was not activated (Table 4-7). However, for NSG, there were no fish >10 years of age and so the trigger reference point was activated.

Table 4-6. Comparison of trends in South Australia's Snapper Fishery against the performance indicators prescribed in the MSF Management Plan (PIRSA 2013).

Performance Indicator	Type	Trigger Reference Point	SG/WC	GSV	SE
Total catch	G	3rd lowest/3rd highest	2nd Lowest	n	n
		Greatest interannual change (±)	n	n	n
		Greatest 5-year trend (±)	n	n	n
		Decrease over 5 consecutive years?	n	n	n
Targeted handline effort	G	3rd lowest/3rd highest	2nd Lowest	n	Lowest
		Greatest interannual change (±)	n	n	n
		Greatest 5-year trend (±)	n	n	n
		Decrease over 5 consecutive years?	n	n	n
Targeted longline effort	G	3rd lowest/3rd highest	n	n	n
		Greatest interannual change (±)	n	n	n
		Greatest 5-year trend (±)	n	n	n
		Decrease over 5 consecutive years?	n	n	n
Targeted handline CPUE	G	3rd lowest/3rd highest	n	n	n
		Greatest interannual change (±)	n	n	n
		Greatest 5-year trend (±)	n	n	n
		Decrease over 5 consecutive years?	n	n	n
Targeted longline CPUE	G	3rd lowest/3rd highest	n	n	n
		Greatest interannual change (±)	n	n	n
		Greatest 5-year trend (±)	n	n	n
		Decrease over 5 consecutive years?	n	n	n
Prop200kgTarHL		3rd lowest/3rd highest	Lowest	n	Lowest
		Greatest interannual change (±)	n	n	n
		Greatest 5-year trend (±)	n	n	n
		Decrease over 5 consecutive years?	n	n	n
Prop200kgTarLL		3rd lowest/3rd highest	n	n	n
		Greatest interannual change (±)	n	n	n
		Greatest 5-year trend (±)	n	n	n
		Decrease over 5 consecutive years?	n	n	n

Table 4-7. Sample sizes of Snapper measured and aged by market sampling in 2018. Also, shown is the result from assessment of the trigger reference point for age structure.

Region	No measured	No aged	Prop >10yrs
NSG	119	46	0
SSG	53	27	n.a.
NGSV	165	79	25.1
SGSV	122	69	29.3
SE	0	0	n.a
WC	0	0	n.a

5. DISCUSSION

5.1. Context of this Assessment

During the 1980s, 1990s and early 2000s, SA's Snapper fishery was concentrated in SG, particularly NSG (Fowler et al. 2016a). From around 1999, changes started to occur in the spatial structure of the fishery. The catches from NSG began to decline and those from SSG dominated the State-wide catches from 2005 to 2009, before they also declined considerably. From 2007, the catches from the GSVS, particularly from NGSV, increased exponentially from a low level (Fowler et al. 2016a). By 2010, this region had become the dominant contributor to the State's catch, and has remained so since. Also, from 2008 to 2012, the catches from the SE regional population were substantially higher than previously, but have once again declined to a low level.

The significant changes in the spatial structure of SA's Snapper fishery, particularly during the mid-2000s, resulted in considerable fishery management concerns. These were associated with the declines in catches from the SG/WCS and the substantial increases in commercial fishing effort on the GSVS, particularly by the longline sector in NGSV. In response, since 2012, there have been a number of fishery management interventions. These have included: (1) the introduction and subsequent reductions in daily commercial trip limits; (2) the tightening of restrictions on commercial fishing gear; (3) changes to recreational bag and boat limits; (4) extension of the duration of the State-wide annual, seasonal closure of the Snapper fishery; and (5) the introduction of spatial spawning closures in both gulfs. Nevertheless, despite these interventions, the statuses of the stocks have not improved. In 2013, when status was still assigned at the regional level, each of NSG, SSG, SGSV and the SE were classified as 'transitional depleting' (Fowler et al. 2013). In contrast, NGSV was classified as 'sustainable', due to high catches, catch rates and numerous strong year classes. In 2016, status was assigned at the scale of biological stock, using the stock structure that had recently been recognised (Fowler 2016, Fowler et al. 2017). The SG/WCS was classified as 'transitional depleting' as commercial catch, effort and CPUE data declined to 2015, reflecting poor recruitment throughout the 2000s. Again in contrast, to 2015, the GSVS continued to produce high catches and catch rates reflecting the recruitment of several strong year classes throughout the 2000s and was classified as 'sustainable'. The WVS, the cross-jurisdictional stock that spans the SE Region, was also classified as 'sustainable' based on relatively high recruitment throughout the 2000s (Hamer and Conlon 2016).

In the assessment undertaken in the following year, based on commercial fishery data up to 2016, the classifications of 'transitional depleting' for the SG/WCS and 'sustainable' for the GSV and WVS were retained (Steer et al. 2018a). However, in the most recent assessment

completed in late 2018 (Steer et al. 2018b), the status of the SG/WC was downgraded to 'depleted'. This reflected that the commercial fishery statistics to December 2017 remained around historically low levels. These low fishery statistics continued to reflect poor recruitment throughout the 2000s, indicating that recruitment had become impaired (Fowler et al. 2016a). Furthermore, in 2013, the estimate of spawning biomass for NSG based on the DEPM, was extremely low (Steer et al. 2017). In 2018, for the GSVS, declines in fishery performance indicators also suggested recent declines in biomass. Nevertheless, because recent estimates of performance indicators still remained high compared to the historical values from before 2008, the status of the GSVS was retained as 'sustainable'. Similarly, the WVS also continued to be classified as 'sustainable'.

In late 2018, in response to the apparent deterioration in status for both the SG/WCS and GSVS, PIRSA Fisheries and Aquaculture initiated a process to review the management arrangements for SA's Snapper fishery. This ongoing, consultative process involved the fishery managers, fishery scientists from SARDI and representatives of the commercial, recreational and charter boat sectors of the Marine Scalefish Fishery (MSF). To ensure that this process of management review was appropriately informed, PIRSA Fisheries and Aquaculture requested that SARDI provide an assessment of Snapper stock status for 2018, that included current estimates of spawning biomass based on a DEPM survey in December 2018 for NSG and GSV.

5.2. Stock Status

Spencer Gulf / West Coast Stock

From the mid-2000s, the commercial fishery statistics for the SG/WCS showed substantial declines, particularly from 2012. Since then, there has been no indication of substantial improvement or recovery. The declines are apparent for each general performance indicator, i.e. total catch, targeted handline effort and CPUE and targeted longline effort and CPUE, as well as for both gear types the proportion of daily catches that achieved 200 kg. Furthermore, targeted catches by gear type and the numbers of fishers who took and targeted Snapper also declined. In 2018, most parameters remained around historically low levels which resulted in several associated trigger reference points being activated.

The consistently low commercial fishery statistics for the SG/WCS from 2012 to 2018 strongly suggest that this stock had a low biomass throughout this period. However, the value of these statistics as fishery performance indicators was compromised, to some extent, by the introduction in 2012 of a daily trip limit of 500 kg, which was further decreased to 200 kg in December 2016. The potential financial consequences of these restrictions may have influenced the willingness of fishers to fish for Snapper, thereby resulting in a decline in

targeted fishing effort. The fishery-independent method of estimating spawning biomass using the DEPM has the ability to reduce potential ambiguity from the commercial fishery statistics (Steer et al. 2017). Application of the DEPM in NSG on two occasions, i.e. in December 2013 and December 2018, both produced low estimates of spawning biomass, with a 23% decline between them. These estimates are lower than the commercial catches that were recorded during the early 2000s and are also an order of magnitude lower than the estimated biomass for the GSVS in 2014 (Steer et al. 2017). The results from the DEPM confirm the inference from the commercial fishery statistics that the spawning biomass of Snapper in NSG remains low and has been at this level for a number of years.

The decline in biomass of the SG/WCS occurred over a number of years and has been apparent at the regional and biological stock levels since 2013 (Fowler et al. 2013). It has been attributed to poor recruitment since 1999 into the primary nursery area in NSG, based on the lack of strong year classes evident in the annual age structures since 1999 (Fowler et al. 2016a). The new age structures presented in this report, i.e. for 2017 and 2018, indicate that during these latter years the population in NSG effectively consisted of small, young fish up to five years of age, with minimal representation of older fish. Furthermore, these age structures for NSG no longer included any representatives of the strong year classes that had recruited in 1997 and 1999. Such observations suggest that the recent size and age structures are severely truncated.

Overall, there are several independent sets of data that demonstrate that the fishable biomass of the SG/WCS is low. The estimates of commercial catch, effort and CPUE remain at historically low values. The age structures from commercial market sampling suggest that the regional population in NSG is severely truncated and provide no evidence of the recent recruitment of any new strong year classes. These observations are consistent with this population being recruitment-impaired. The results from the DEPM undertaken in 2018 suggest that the spawning biomass declined further from the low level in 2013, for which it is now apparent that the spawning biomass was already compromised. The estimated commercial harvest fraction has remained >18% over the past two surveys. Assuming a 38% contribution to the total catch by the recreational sector (see Giri and Hall, 2015), the total harvest fraction was estimated at approximately 30% in 2013 and 2018. The available evidence indicates that the SG/WCS harvestable biomass is likely to be depleted and that recruitment is likely to be impaired. Consequently, the SG/WCS is classified as '**depleted**' in 2018 under the NFSRF (Stewardson *et al.* 2018). This status is unchanged from that in 2017.

Gulf St. Vincent Stock

The commercial fishery statistics for the GSVS, particularly for the longline sector, increased considerably between 2007 and 2010 to unprecedented levels, and then remained near these

levels until 2015. Nevertheless, since then, there have been substantial declines in total catch, targeted longline catch, effort, CPUE, the number of longline fishers targeting and taking Snapper, the number of their reported daily catches, and the proportion of the latter that were 200 kg or greater. Overall, since 2015, the trends in these indicators are consistent with a substantial decline in the biomass of the GSVS. This was substantiated by comparison of the fishery-independent estimates of biomass that were obtained from application of the DEPM in 2014 and 2018. The decline in the estimates of spawning biomass in the areas surveyed in both 2014 and 2018 was from 2,590 to 343 t; this represents a reduction of 87%. The primary uncertainty associated in the estimate of the spawning biomass of the GSVS in 2018 is the incomplete coverage of the potential spawning area. Sensitivity testing demonstrated that if the spawning area from 2014 was applied to other data obtained in 2018, the estimate of spawning biomass would have increased by 46 t. This sensitivity analysis accounts for the possibility that P_0 was underestimated in 2018 because sampling did not occur in potentially important spawning areas, such as off the Adelaide metropolitan coastline, where recreational and commercial fishers reported high Snapper abundance in summer 2018. High commercial catches from this region in 2018 substantiate these reports (see Figure 4-2). It is, however, not possible to estimate the degree to which the 2018 estimates of mean egg density and spawning biomass may have been influenced by the reduced sampling area.

The 87% reduction in spawning biomass, from the same spatial area sampled in GSV, between December 2014 and December 2018 equates to a reduction of 2,247 t of Snapper. Over this four-year period, 1,043 t of Snapper was reported as having been harvested from Northern Gulf St. Vincent by the commercial sector and is documented in the catch returns. The catch harvested by the recreational sector during the same period is unknown. However, if a state-wide resource share of 38% – estimated from the last recreational fishing survey (Giri and Hall 2015) – is applied, then the catch from the recreational sector would be 628 t over the same time period. The reported commercial catch and estimated recreational catch sum to 1,672 t and equate to 74% of the reduction in spawning biomass. Whilst these estimates need to be cautiously interpreted, because they do not consider recruitment, natural mortality, changes in regional catches by the recreational sector, and movement of Snapper, they demonstrate that the 87% reduction in spawning biomass between comparable surveys is feasible.

The population age structures for NGSV provide some insight into the large changes over the past decade or so. They indicate that strong year classes recruited to this stock in 2001, 2004, 2007 and 2009 that supplemented the already strong 1997 and 1999 year classes. In response, the fishable biomass increased substantially, resulting in the record fishery catches. Whilst in the recent age structures there has not been any consistent evidence of any strong

year classes since 2009, the age structure in 2018 suggests the emerging 2014 year class may be relatively strong. Fishable biomass and fishery productivity have declined since 2015, as a consequence of this relatively low recent recruitment.

The assignment of stock status for the GSVS in 2018 is difficult because of conflicting inferences from the available data. There is clear evidence the GSVS was at a high level of fishery productivity from 2010 to 2015, reflecting a substantial fishable biomass. This was confirmed by the high estimate of spawning biomass from the DEPM in 2014 and reflected the strong recruitment to NGSV throughout the 2000s with low catches prior to 2005. Subsequent declines in fishery statistics and the estimate of relative spawning biomass since 2015, demonstrate a rapid and substantial decrease in stock status driven by large recent catches and relatively poor recruitment since 2009. This is emphasized in the estimated harvest fraction for the commercial sector of 46% of the Snapper biomass in 2018, and would more likely exceed 70% when considering the recreational catch share (38%). Whilst the rapid decline in harvestable biomass is clearly demonstrated, the current stock status is difficult to determine due to uncertainty in the (1) estimate of spawning biomass from the DEPM in 2018 due to incomplete coverage of the potential spawning area; (2) the implications of the recent declines in fishery statistics, which although substantial remain relatively high compared to those prior to the 2000s; (3) potential strength of the 2014 recruitment year class; and (4) magnitude of the recreational catch. Despite this uncertainty, it is clear that the abundance of Snapper in GSV is declining. However, it is not possible to determine whether the GSVS is already recruitment impaired. Given this uncertainty, the GSVS is classified as ‘depleting’ in 2018 under the NFSRF. This means that fishing mortality is too high (i.e. overfishing is occurring) and moving the stock in the direction of becoming recruitment impaired. The classification of ‘depleting’ for 2018 is a change in status from ‘sustainable’ in 2017.

South East Regional Population

The SE population of Snapper is part of the WVS (Fowler 2016, Fowler et al. 2017). The regional population is sustained through emigration of adult fish from the main nursery area located 600 km to the east in Port Phillip Bay (PPB), Victoria. From 2007 to 2014, this regional population sustained unprecedented longline catches on the back of two exceptionally strong year classes that had recruited to PPB in 2001 and 2004 (Hamer and Conron 2016). The annual catches have subsequently declined to a low level, presumably as these strong year classes have declined through natural and fishing mortality. Nevertheless, total catch and the performance indicators relating to the longline sector have shown some increases in 2017 and 2018. This may relate to recent emigration to this region from PPB, which experienced relatively strong recruitment in 2009, 2013, 2014 and the strongest year class was recorded

in 2018 (Hamer and Conron 2016, Hamer pers. comm.). As such, in the coming years, the outlook for Snapper catches in this region is positive, on the basis of these strong year classes.

In 2016, the WVS was classified as sustainable. This was largely on the basis of the results from the annual 0+ recruitment survey, which showed that over the 12 years to 2016, there had been six years for which recruitment was at or above the long-term average (Hamer and Conron 2016). The 2013 and 2014 year classes were two of the largest yet recorded. The evidence above means that biomass is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (i.e. recruitment is not impaired) and fishing mortality is adequately controlled to avoid the stock becoming recruitment impaired. Consequently, the WVS is classified as '**sustainable**'.

5.3. Current Performance Indicators and Reference Points

The combination of fishery-independent spawning biomass estimates and the interpretation of patterns in year class strength from the biological sampling program have now become the most compelling sources of information to assess South Australia's Snapper stocks. This is because the relative value of the fishery-dependent commercial catch and effort statistics have been diminished through diverse and changing management arrangements, advancing fishing technologies, and 'hyperstability' in CPUE. The introduction of daily catch restrictions, the unknown influence of technology creep on 'effective' effort, and the ability of fishers to efficiently target schools of Snapper, compromise the link between catch rates and biomass. For schooling species such as Snapper, catch rates can remain high despite declines in abundance as fishers continue to target known remnant, but diminishing schools. Thus, reductions in CPUE likely underestimate declines in fishable biomass, and a rapid reduction in CPUE may only occur once the stocks have become depleted. Given these issues, the current general performance indicators and reference points prescribed in the Management Plan (PIRSA 2013) that rely on fishery-dependent catch and effort data may no longer be suitable. Considering trends in catch and catch rates in association with other sources of fishery-independent information through a weight-of-evidence approach is likely a more appropriate use of the fishery-dependent information.

5.4. Research Priorities

There are six key research priorities for Snapper in SA. The most important of these, and reflective of the success of the application of the DEPM to date, is the development of a protocol for undertaking regular DEPMs in SG and GSV. Recommendations regarding the management of SA's Snapper fishery are currently being considered. This is occurring against the backdrop of the overall, large-scale restructure of the MSF. In the long-term, the intention is that SA's Snapper Fishery will be managed by quota, designed around a process and

harvest strategy that are yet to be developed. Whilst that process has not concluded, it is likely that biomass estimates from the DEPM will be needed to support future management arrangements for Snapper.

The second most important research priority for the assessment of the status of Snapper is determining the relative contribution of the state-wide catch by the recreational fishing sector. This sector's total harvest has traditionally been determined through telephone/diary surveys that are undertaken on a five-year cycle (Henry and Lyle 2003, Jones 2009, Giri and Hall 2015). Although these surveys adopt a standard methodology that allows the results to be compared through time, their estimates of catch and effort are typically imprecise. This imprecision has flow-on ramifications in the assessment of Snapper, and other MSF species, for which the recreational contribution is significant. Improving the precision of the recreational catch estimates, either through more frequent surveys or increased participation rates, will broadly benefit the assessment and subsequent management of Snapper and the MSF.

Thirdly, re-commencement of annual recruitment surveys in the nursery areas in NSG and their establishment in NGSV would provide an early indication of year class strength in each year, particularly of a strong year class that would underpin stock recovery. Since recruitment is the fundamental driver of the variability in populations in SA, a new research project (FRDC 2019/046) is currently focussed on enhancing our understanding of such variability. This project also aims to develop a sampling methodology that would provide a relative recruitment index for Snapper. Such an index would provide an indicator of the likely future variation in fishable biomass and would be built into the stock assessment process, as occurs in Victoria (Hamer and Conron 2016).

The fourth research priority is to update South Australia's Snapper stock assessment model, 'SnapEst', to re-establish its ability to deliver robust and defensible stock assessments. The model needs to be contemporised to integrate all new sources of information including: diverse fishery-independent data (i.e. spawning biomass estimates, pre-recruit surveys, post-release mortality estimates); recreational catch and effort estimates; population age and size structure information; and the time-series of fishery-dependent commercial catch and effort data. The model would need to have the capacity to routinely undertake data standardisation and sensitivity testing; set TACCs within established harvest strategies at appropriate regional scales; and have the ability to extrapolate forecasts to inform management.

The fifth research priority is to increase the sample sizes of Snapper obtained from the SAFCOL market, or elsewhere. Recent sample sizes have reduced as there were far fewer fish available for sampling. As the smaller sample sizes are notable, and provide a source of uncertainty in the interpretation, the current sampling methodology needs to be modified to

raise sample size despite lower catches. This could partly be achieved by engaging other relevant stakeholders (commercial, recreational, charter) to participate in a biological sampling program.

Finally, given release rates of line-caught Snapper are relatively high, estimated at 75% in the recreational sector (Giri and Hall 2015) and up to 43% in the Charter Boat sector (Steer and Tsolos 2016), an estimate of post-release survival – likely to be considerable (Fowler et al. 2009) – is required such that all sources of mortality on Snapper can be accounted for. A project proposal that aims to quantify post-release mortality rates across all sectors of South Australia's community-shared Snapper fishery is currently being considered by the Fisheries Research and Development Corporation.

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7. REVIEW OF THE DRAFT SNAPPER FISHERY ASSESSMENT REPORT 2019

Tony Smith AM

4 September 2019

Terms of Reference for the review

- Undertake a review of the draft 2019 Snapper Fishery Assessment Report, consistent with the actions from the 17 July 2019 meeting which discussed the Snapper and stock assessment research program.

- Liaise with SARDI Aquatics Sciences through the direct provision of feedback on the draft Snapper Fishery Assessment report

- Provide a brief summary report to PIRSA to document the outcomes of the review process, including highlighting any issues and identifying improvements or refinements to the stock assessment process and/or methodology.

Process for the review

This review was undertaken at the request of the Executive Director, Fisheries and Aquaculture, PIRSA. This followed my attendance, as an independent scientist, at a Meeting to Discuss the Snapper Research Program, chaired by the Executive Director and held at SARDI on 17 July 2019, at which my involvement in the present review was foreshadowed.

Following the first term of reference outlined above, I undertook a preliminary review of the draft Snapper assessment, which was provided to me on 31 August 2019. Following the second term of reference, I provided my written comments to SARDI on 3 September, followed by a discussion with several SARDI scientists on the same day (Drs Michael Steer, Rick McGarvey, Jonathan Smart and Stephen Mayfield), at which their initial response to my comments was discussed. The Executive Director, PIRSA, provided SARDI's written responses to my initial review on 4 September 2019, together with a revised draft of the Snapper assessment report, indicating the changes made to the initial report subsequent to my review.

This final brief summary report addresses the third term of reference for the review.

Summary Report

My preliminary report of 3 September supported the general conclusions of the draft assessment, including the status determination for the three stocks in SA – Spencer Gulf / West Coast Stock (depleted), Gulf St. Vincent Stock (depleting), and South East Region (Western Victoria Stock) (sustainable). My report also included 20 specific suggestions for clarification or improvement to the assessment report. My preliminary report, and SARDI's written responses to it, are at Attachment 1 below.

Having considered SARDI's responses, and the revised draft of the Snapper Assessment Report, I am satisfied that my suggestions have been addressed appropriately, and that the assessment report provides an appropriate basis for the status categories assigned.

Focusing only on the most important issues I raised, the following points are noted:

- Harvest fraction: The inclusion of estimates of harvest fraction for the SG and GSV stocks is important as it provides additional perspective on the status of these stocks and the urgency of the management responses that are required. Harvest fraction is estimated as the ratio of current removals (catch) to estimated biomass (from the DEPM surveys). This has been estimated both for commercial catches and total catches, including recreational and charter fishing. **The estimates of harvest fraction for both gulfs are high (above sustainable levels) and in the case of Gulf St. Vincent alarmingly high, supporting the "depleting" category for this stock. Taken at face value, the estimates of harvest fraction for GSV suggest that rapid depletion is occurring and that, if catches are not curtailed, the stock is very likely to become depleted (recruitment impaired) very soon, if it is not already so.**

- Current performance indicators: The performance indicators used to assess fishery status are built into the (2013) Management Plan and continue to be reported. I have pointed to several problems with these PIs which are now fully acknowledged in the revised assessment report. Until a new Management Plan and harvest strategy are adopted, these PIs will have to continue to be reported, but my advice is that they are not serving a useful function in assessing stock status. **The most important information underpinning the weight of evidence approach adopted in this assessment is the combination of DEPM biomass estimates and catch structure (size and age) data. Without this information, the current PIs would not be providing a robust basis for assessing the current status of these resources.**

- Future research: Following from the previous point, the ongoing collection of DEPM and biological data are vital for the future management of the fishery. **I would also recommend enhancing the modelling capability for this fishery, as a matter of some urgency.** This would allow the proper integration of all the data available for the fishery, including the fishery independent survey data, and should allow a number of the uncertainties in the current weight of evidence approach to be addressed more explicitly. It will provide an important basis for exploring alternative management arrangements and harvest strategies, as these matters are considered in the near future. It is good to see this point addressed in the revised report. **I also endorse the call for much better data on recreational fishing, as this remains an important uncertainty in all current assessments.**