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Assessment of the South Australian Marine Scalefish Fishery in 2017

MA Steer, AJ Fowler, R McGarvey, J Feenstra, J Smart, PJ Rogers, J Earl, C Beckmann, M Drew and D Matthews

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Report to PIRSA Fisheries and Aquaculture

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EXECUTIVE SUMMARY

This report is the second in the annual reporting series for the South Australian Marine Scalefish Fishery (MSF). The report provides a description of the dynamics of the multi-species, multi-gear fleet, a comprehensive assessment of South Australia's Southern Garfish stocks, and assigns a stock status to a further 20 species or taxonomic groups that are harvested within the fishery. This report includes a summary of the taxon-specific fishing information relating to population biology; fishing access; relevant management arrangements; trends in commercial fishery statistics at the State-wide scale, biological stock or regional management units; and assessment of fishery performance. The data included in this report extends over a 33-year time series from 01 Jan 1984 until 31 Dec 2017.

Fleet Dynamics

The dynamics of the MSF fishing fleet have changed in recent years and many of these changes have been influenced by diverse management arrangements. The most obvious change is the continuous decline in fishing effort, which is the result of the licence amalgamation scheme implemented in 1994 and, more recently, the two voluntary net buy-back initiatives in 2005 and 2014.

Since the implementation of the licence amalgamation scheme in 1994, 403 active MSF licences have been removed, representing an overall licence reduction of 56.3%, and translating to a 53.6% reduction in total fishing effort.

Declines in the productivity of the premium finfish species have contributed to the diversification of the MSF fishing fleet, with many fishers switching their effort over the last five years from Snapper, King George Whiting and Southern Garfish towards Southern Calamari. This recent trend indicates that Southern Calamari has been established as a target species for commercial fishers, and has surpassed Snapper and King George Whiting as the most valuable MSF species.

A number of species considered in this report constitute by-product for the hauling net sector, where they are incidentally caught when fishers target more valuable species. Of these, Yellowfin Whiting, Australian Herring, Snook, Leatherjackets and Yelloweye Mullet are of medium value, with moderate market appeal. Each of these species share similar commercial catch and effort trends, where fishing effort within the hauling net sector has been sequentially reduced.

Despite the long-term trend in declining effort, Snook and Leatherjackets have been increasingly targeted by hauling net fishers. In addition, more fishers are taking Wrasse using handlines and longlines; and there has been an increase in catches of Ocean Jackets and

Western Australian Salmon over the past four years, using fish traps and 'seine' gear, respectively.

Southern Garfish Stock Assessment

Southern Garfish is assessed in this report (2018), whilst Snapper and King George Whiting will be assessed in 2019 and 2020, respectively.

The status of the West Coast (WC), Southern Spencer Gulf (SSG), Southern Gulf St. Vincent (SGSV) and the South East (SE) biological stocks were classified as '**sustainable**'. The Northern Spencer Gulf (NSG) and Northern Gulf St. Vincent (NGSV) biological stocks were classified as '**recovering**' and '**depleted**', respectively.

The primary measure for fishing mortality is modelled estimates of harvest fraction. High exploitation rates have been evident for the NGSV stock and these peaked at 91% in 2002. Since then, the annual harvest fraction has declined by approximately 3% per year, dropping to a record low of 38.6% in 2016. The current fishing mortality is constrained by management to a level that should allow the stock to recover from its recruitment impaired state; however, measurable improvements are yet to be detected. Although adequate management may now be in place to recover the stock, more time is required to determine the relative effect of the 2017 closure. Consequently, the current status of the NGSV Southern Garfish stock remains classified as **depleted**.

Northern Spencer Gulf fishable biomass has increased since 2003, at a rate of approximately 4 $t.year^{-1}$, and was most likely driven by substantially declining exploitation rates. There was, however, little change in fishable biomass from 2014 until 2016, remaining at approximately 280 $t.year^{-1}$. Annual egg production has increased, reaching 11% of unfished levels over the last decade. There were also signs of an increase in the market-catch age structure and targeted catch rates in the hauling net sector continue to be relatively high despite strong management intervention. It appears that the appropriate management is currently in place and the stock biomass is continuing to recover. As a result, the current status of the NSG Garfish stock remains classified as a **recovering** stock.

The remaining four Southern Garfish biological stocks in South Australia (i.e. WC, SSG, SGSV and SE) were all classified as **sustainable** as they are characterised by relatively low levels of fishing activity, commercial catch and extensive netting closures. Such low level of fishing mortality is unlikely to deplete the biomass of the stocks and cause them to become recruitment impaired.

The main uncertainty in this stock assessment for Southern Garfish relates to the reliance on some of the performance indicators in determining stock status in the absence of a pre-defined reference point that determines when the stock is recruitment impaired. The confined access

of the hauling net fishery to small coastal areas further complicates the assessment, as it is unknown how reflective the status of these fished stocks are of the broader population. A further uncertainty relates to the poor understanding of temporal trends in catch and effort by the recreational sector.

Stock Status

Overall, this report assessed the fishery performance of 21 species/taxonomic groups within South Australia's Marine Scalefish Fishery (MSF). Collectively, these taxa were considered across 33 management units, at a resolution that aligned with either the biological stock, or jurisdictional level. Of these, 28 (85%) stocks were classified as 'sustainable', three (9%) were classified as 'depleted', one (3%) was classified as 'recovering', and the remaining one (3%) was classified as 'undefined' as there was insufficient information to assign a stock status (Table E-1).

Since the previous MSF assessment (Steer et al. 2018) one King George Whiting stock (Gulf St. Vincent/Kangaroo Island) improved from 'depleting' to 'sustainable' as a result of consecutive years of favourable commercial catch rates. The Spencer Gulf / West Coast Snapper stock changed from 'depleting' to 'depleted' as a result of persistent low estimates of catch, effort and catch rates, coupled with fishery independent estimates of fishable biomass that indicate that the biomass is considerably diminished (Table E-1).

Future Directions

Currently, the most significant knowledge gap in the assessment of the status of MSF fish stocks is in determining the relative contribution to the State-wide catch by the recreational fishing sector. 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 the MSF.

Determining stock status through the weight-of-evidence approach for all the MSF stocks considered in this report has relied heavily on fishery-dependent statistics. There is a need to contemporise how the data sources are treated to determine whether they need to be adjusted or weighted to adequately reflect the changes in the fishing dynamics. This may involve exploring the relative effects of nominal increases in effective effort, sensitivity analysis of various gear types, determining whether greater influence be placed on biological metrics, or if fishery-independent data streams can be used to ground-truth model-derived estimates of biomass. For the other lower value species, there is a need to revisit whether nominal estimates of CPUE are the most informative metric of relative abundance, as opposed to standardized, or averaged derivations of catch rates. New statistical and modelling methods are emerging to deal with 'data-limited' fisheries.

The MSF is currently undergoing considerable transition through the structural reform, development of new harvest strategies and pending review of the Management Plan.

Table E-1. Status of South Australia's Marine Scalefish Fishery Resources in 2018. Note, the status terminology was amended in 2017 through the Status of Australian Fish Stocks classification framework (Stewardson et al. unpublished)

SPECIES	STOCK	STATUS		INDICATORS
		2016	2017	
GARFISH	WC	Sustainable	Sustainable	Catch & Effort
	NSG	Tranistional - Recovering	Recovering	Catch, CPUE, age structure, biomass
	SSG	Sustainable	Sustainable	Catch, CPUE, age structure, biomass
	NGSV	Overfished	Depleted	Catch & Effort
	SGSV	Sustainable	Sustainable	Catch & Effort
	SE	Sustainable	Sustainable	Catch & Effort
KING GEORGE WHITING	WC	Sustainable	Sustainable	Catch & Effort
	SG	Sustainable	Sustainable	Catch & Effort
	GSV/KI	Transitional - Depleting	Sustainable	Catch & Effort
SNAPPER	SG/WC	Transitional - Depleting	Depleted	Catch & Effort
	GSV	Sustainable	Sustainable	Catch & Effort
	WV	Sustainable	Sustainable	Catch & Effort
CALAMARI	STATE	Sustainable	Sustainable	Catch & Effort
YELLOWFIN WHITING	NSG	Sustainable	Sustainable	Catch & Effort
	NGSV	Sustainable	Sustainable	Catch & Effort
WA SALMON	WA/SA	Sustainable	Sustainable	Catch & Effort
AUST. HERRING	WA/SA	Sustainable	Sustainable	Catch & Effort
VONGOLE	WCCFZ	Sustainable	Sustainable	Harvest fraction, recruitment
	CBCFZ	Sustainable	Sustainable	Harvest fraction, recruitment
	PRCFZ	Overfished	Depleted	Harvest fraction, recruitment
SNOOK	STATE	Sustainable	Sustainable	Catch & Effort
BLUE CRABS	MSF	Sustainable	Sustainable	Catch & Effort
SAND CRABS	STATE	Sustainable	Sustainable	Catch & Effort
YELLOW-EYE MULLET	MSF	Sustainable	Sustainable	Catch & Effort
MULLOWAY	MSF	Sustainable	Sustainable	Catch & Effort
WHALER SHARKS	STATE	Undefined	Undefined	Limited data
OCEAN JACKETS	STATE	Sustainable	Sustainable	Catch & Effort
BLUE-THROAT WRASSSE	STATE	Sustainable	Sustainable	Catch & Effort
SILVER TREVALLY	STATE	Sustainable	Sustainable	Catch & Effort
LEATHERJACKETS	STATE	Sustainable	Sustainable	Catch & Effort
RAYS & SKATES	STATE	Sustainable	Sustainable	Catch & Effort
CUTTLEFISH	STATE	Sustainable	Sustainable	Catch & Effort
BLACK BREAM	MSF	Sustainable	Sustainable	Catch & Effort

Keywords: Southern Garfish, fleet dynamics, stock assessment, marine scalefish, stock status.

1. INTRODUCTION

1.1. Overview

This report is the second in the new series for the MSF that will provide taxon-specific information on: population biology; fishing access; relevant management arrangements; trends in commercial fishery statistics at the State-wide scale, biological stock or regional management units; and assessment of fishery performance. Consequently, it provides a comprehensive reference document to underpin the management of this complex multi-species, multi-gear fishery. The data included in this report extends over a 33-year time series from 01 Jan 1984 until 31 Dec 2017.

This report is partitioned into five sections. The first section, following this overview, provides an overall description of South Australia's MSF, its management arrangements, and details the indicators used to assess the performance of the species within the fishery.

Section two describes the dynamics of the commercial fleet, catch composition, and spatial and temporal trends in fishing effort.

Section three provides an assessment of South Australia's Southern Garfish stocks to correspond with its triennial reporting schedule identified in the MSF Management Plan (PIRSA 2013). This assessment is based on two types of fishery performance indicators: (1) the general performance indicators that relate to the long-term trends in the commercial catch and effort statistics; and (2) the biological performance indicators that consider the population size and age structure of the stocks, including annual estimates of fishable biomass, exploitation rate and recruitment.

Section four consists of a series of species-specific sections arranged in order of their descending priority, by catch, within the MSF. Each section is structured to constitute a 'stand-alone' reference. In each section, the relevant biological information is presented, along with a description of the fishery, associated management regulations, interrogation of the State-wide and/or regional fishery statistics, assessment of the fishery against the general performance indicators, and a classification of stock status.

The final section, the General Discussion, synthesises the overall performance of the fishery, details emerging trends within the fishing fleet, and identifies key research priorities that will enhance the assessment of South Australia's MSF.

1.2. Description of the Fishery

The MSF is the most complex fishery in South Australia, based on it being a multi-species, multi-gear, multi-sector fishery. Commercial fishers are permitted to take in excess of 60

marine species that include fishes, molluscs, crustaceans, annelid worms and sharks. Fishery production is mainly comprised of traditional scalefish species, in particular King George Whiting (*Sillaginodes punctatus*), Snapper (*Chyrsophrys auratus*), Southern Garfish (*Hyporhamphus melanochir*) and Yellowfin Whiting (*Sillago schomburgkii*). Other species such as Southern Calamari (*Sepioteuthis australis*), Australian Herring (*Arripis georgianus*), Sand Crabs (*Ovalipes australiensis*) and Vongole (*Katelysia* spp.) are also important. Currently there are 30 types of fishing gear (or devices) endorsed in the fishery, but their use differs, depending on the location of fishing and the types of species being targeted. With the exception of fishing rods and handlines, all devices must be registered on a licence before they can be used to take fish for trade or business. Within the commercial sector there are two types of licences, Marine Scalefish and Restricted Marine Scalefish. Marine Scalefish licence holders are more common. They generally have full access to scalefish species and encompass a wide variety of gear endorsements. A proportion of these licence holders have specific net endorsements and are permitted to use hauling nets and set/gill nets to target certain species. Restricted Marine Scalefish licence holders have fewer gear endorsements and are prohibited from using nets. In addition to MSF licence holders, licence holders from the Miscellaneous Fishery, the Northern and Southern Zone Rock Lobster fisheries, the Lakes and Coorong Fishery, the three prawn fisheries and the Blue Crab Fishery all have some level of access.

The heterogeneous mixture of participants, fishing devices, licence conditions and regulations associated with South Australia's MSF, makes the task of assessing stock status extremely challenging. This is further compounded by the highly dynamic nature of the commercial fishers who can switch their target effort between species and fish throughout State waters. The complex nature of this fishery means that there has always been considerable capacity for it to expand through the realisation of latent effort.

The recreational fishing sector also has access to many of the MSF species. Most recreational fishing effort occurs in marine waters, including estuaries, with fishers permitted to use a variety of gear types to target a variety of MSF species.

1.3. Management Arrangements

The MSF is managed by the South Australian State Government's Primary Industries and Regions South Australia (PIRSA) Fisheries and Aquaculture in accordance with the legislative framework provided within the *Fisheries Management Act 2017*, and subordinate *Fisheries Management (General) Regulations 2017*, *Fisheries Management (Marine Scalefish Fisheries) Regulations* and *licence conditions*.

The commercial MSF has undergone considerable management changes over the past 40 years that has seen the fishery restructured and limited through gear restrictions and configuration, licensing, spatial and temporal closures, and size limits. During this time, there have been three notable changes that were primarily implemented to limit, and then reduce, the number of participants in the commercial sector. The first change occurred in 1977, when a freeze was imposed on the issue of new licences, which converted the commercial sector into a limited-entry fishery. This also involved a 'show cause provision' that prevented the reissue of licences to fishers if a minimum level of commercial fishing had not been met. Non-transferable Restricted Marine Scalefish licences were also created at this time to recognise part-time fishers. The second change was the licence amalgamation scheme which was introduced in 1994. This scheme is essentially a fractional licensing initiative which requires prospective fishers to purchase a certain number of points when buying a licence (see Steer and Besley 2016). The third change, implemented in 2005, was a voluntary buy-back of net fishing endorsements and subsequent spatial closures to net fishing. A similar, smaller licence buy-back scheme also occurred in 2014 in association with the implementation of the South Australian Marine Park network.

The recreational fishery is not licenced but subjected to a range of regulations such as size, boat, bag and possession limits, restrictions on the types of gear that may be used, temporal and spatial closures, and the complete protection of some species.

1.4. Fishery Performance Indicators

Four general performance indicators are used to assess the performance of a species within the MSF. These were derived from historical commercial fishery statistics from 1984 to 2017 (reference period), and include total commercial catch, and targeted effort and CPUE for specific gear types that vary amongst the taxa. Each performance indicator was assessed against the following trigger points:

1. the third highest and third lowest values of the reference period (1984 to 2017);
2. the greatest (%) inter-annual variation (+ and -) over the reference period;
3. the greatest rate of change (+ and -) over a five-year period; and
4. whether the data have decreased over the most recent five consecutive years.

Additional biological performance indicators are used in the assessment of stocks of Snapper, King George Whiting and Southern Garfish. These are derived from population models that assimilate commercial, recreational and biological datasets to estimate total fishable (legal) biomass, egg production, recruitment, and exploitation rates. The limit reference points associated with these biological indicators are detailed in the harvest strategies for these species (see PIRSA 2013). Stock assessments that consider both the general and biological

performance indicators are undertaken for these three species triennially. Southern Garfish is assessed in this report (2018), whilst Snapper and King George Whiting will be assessed in 2019 and 2020, respectively.

1.5. Stock Status Classification

A national stock status classification system was recently developed for the consistent assessment of key Australian fish stocks (Flood et al. 2014; Stewardson et al. unpublished). It considers whether the current level of fishing pressure is adequately controlled to ensure that the stock abundance is not reduced to a point where the production of juveniles is significantly compromised. The system combines information on both the current stock size and level of exploitation into a single classification for each stock against defined biological reference points. Each stock is then classified as either: 'sustainable', 'recovering', 'depleting', 'depleted', 'undefined, or 'negligible' (Table 1-1). These stock status classifications have been updated from the previous Status of Australia's Fish Stocks assessment (Flood et al. 2014). PIRSA has adopted this classification system to determine the status of all South Australian fish stocks (PIRSA 2015).

Table 1-1. Classification scheme used to assign fishery stock status. The description of each stock status and its potential implications for fishery management are also shown (Stewardson et al. unpublished).

	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

2. FISHING FLEET DYNAMICS

2.1. Introduction

Understanding the dynamics of fishers within a commercial fishery is as important for assessing status as are the population dynamics of the fish and the ecosystems that support them (Hilborn 1985). This is because the metrics of the fishers' catch and fishing effort are used as the basic input in assessing stocks.

The dynamics of a fishing fleet are essentially products of decisions made by the fishers that relate to when and where to fish, what gear to use and what species to target. These decisions can be influenced by a range of interconnected factors such as the seasonal movement and migration of the target species, weather conditions, management arrangements, and socio-economics. In order to reliably evaluate the impact of a fishing fleet on a resource, it has been argued that a thorough knowledge of the fishery is initially required, followed by a comprehensive evaluation of the spatial and temporal characteristics of the fishing activities before any reliable stock assessment and forecast models are developed for management purposes (Hilborn and Walters 1992, Mahévas et al. 2008). In most cases a detailed decomposition of fishing effort by species, fishing gear, location and season is considered to fundamentally characterise patterns of fishing activity (Hilborn and Walters 1992).

Whilst the bulk of this report is devoted to the assessment of fishery statistics for individual species to determine stock status, this section provides a holistic view of the fishery by examining and comparing the trends in fishing effort amongst the species, fishing gears, locations and seasons. As a consequence, it reveals the dynamic nature of this fishery in terms of the changes that have occurred at different spatial and temporal scales and the relationships in trends between species.

2.2. Methods

The MSF is divided into 58 Marine Fishing Areas (MFAs) for the purpose of statistical reporting and monitoring of commercial fishing activity (Figure 2-1). All licenced fishers are required to log their fishing activities, recording specific details such as MFA fished, number of fishers on board, species targeted, species caught, weight of catch, and method of capture. This level of detail was initially recorded on a monthly basis, but since 2003 fishers have been required to provide a daily log of fishing activity. These records must be submitted monthly to SARDI Aquatic Sciences where they are entered into a database that is routinely reviewed and cross-checked as per quality assurance protocols (Vainickis 2010). The current database is a compilation of catch and effort data collected from 1983/84 to the present and provides the primary source of data used for stock assessment of the MSF species. This assessment was

based on data up to 31 December 2017, thus providing a complete 34 calendar-year time series.

The complex MSF database was restricted to a smaller, more manageable dataset that allowed analysis of the major trends in fisher behaviour and fleet dynamics. Two main approaches were adopted to achieve this. One approach involved aggregating the data into monthly categories. This level of temporal resolution was considered appropriate, as monthly data were provided by many fishers prior to 2003 and it aligned with some of the short-term management arrangements that currently exist in this fishery (e.g. November Snapper closure). The other approach involved aggregating certain gear types into broader categories. Hauling nets, floating garfish nets, sinking and floating garfish nets, sinking mesh nets, and sinking mixed mesh nets were collectively categorised as 'hauling nets', but were differentiated from large mesh nets (>15 cm mesh size) and set gill nets (5 cm mesh size) which were considered 'set nets'. Similarly, hand lines, drop lines, troll lines and fishing rods/poles in the line sector were categorised as 'hand lines'.

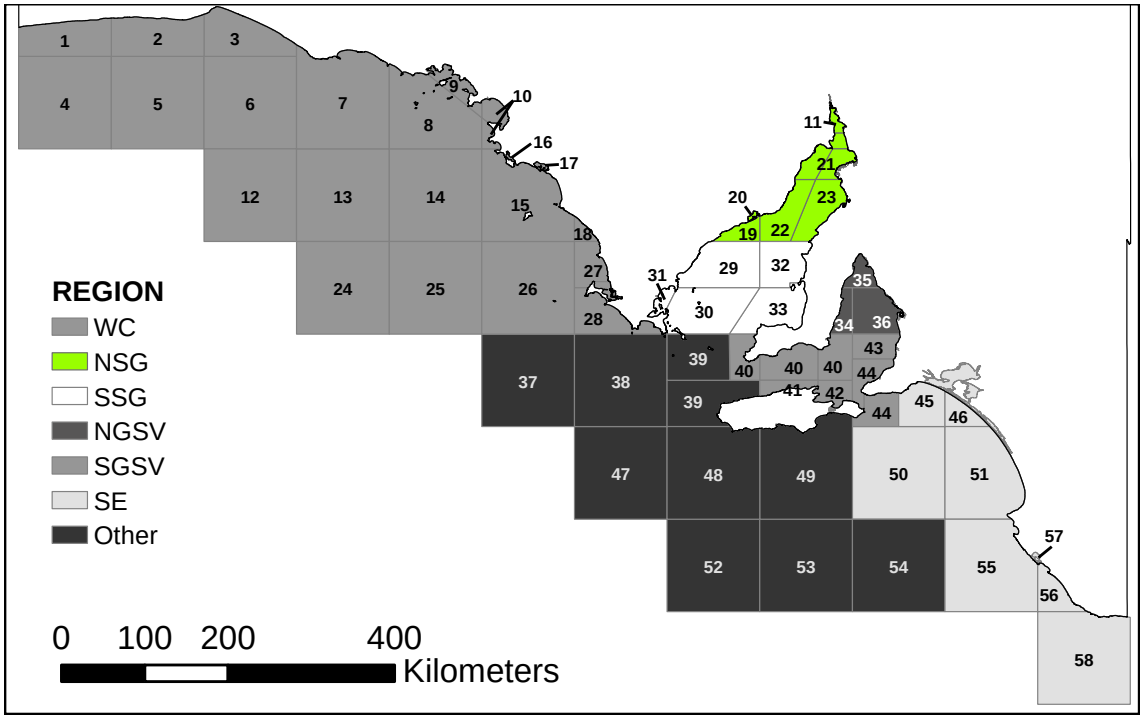

Figure 2-1. Map of the 58 Marine Fishing Areas (MFA) of South Australia's Marine Scalefish Fishery (MSF), broadly partitioned into seven regions: West Coast (WC), Northern Spencer Gulf (NSG), Southern Spencer Gulf (SSG), Northern Gulf St. Vincent (NGSV), Southern Gulf St. Vincent (SGSV), South East (SE), and Other.

2.3. Results

2.3.1. Trends in Number of Licences

Overall, there has been a 63.9% reduction in the number of active fishers licenced to harvest MSF species over the past 33 years, declining from 865 licences in 1984 to 312 in 2017 (Figure 2-2). The greatest reduction occurred within the Rock Lobster fisheries, as the number of active licence holders that accessed MSF species declined from 175 to 31 over the same period, representing an 82.3% reduction. The active MSF and Miscellaneous Fishery licence holders declined by 59.0% and 68.2%, respectively. The rate of decline was accelerated from 1994 due to the implementation of the licence amalgamation scheme. Two net buy-back schemes also contributed in removing active licences in 2005 and 2014 (Figure 2-2). Since the introduction of the licence amalgamation scheme, the number of active licence holders has reduced at a rate of approximately 15 licences.year$^{-1.}$

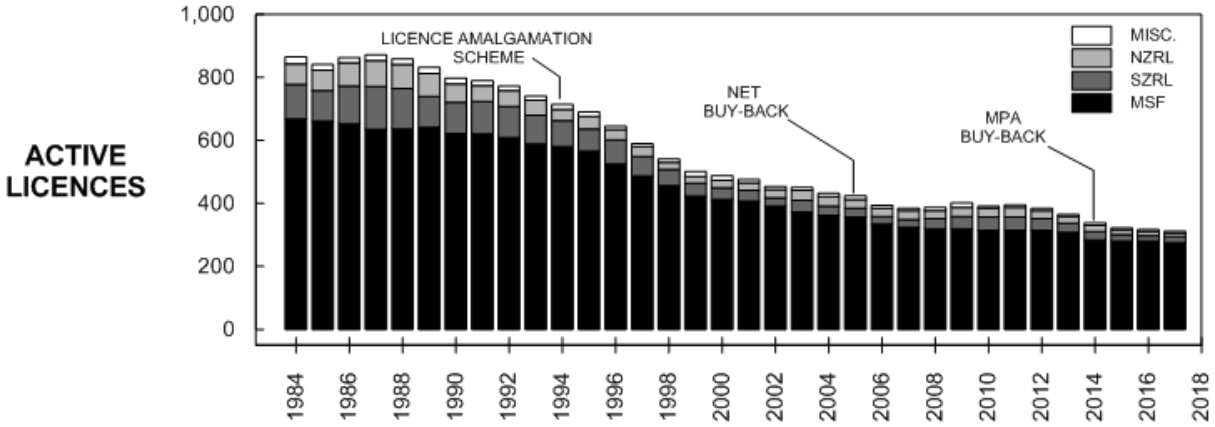

Figure 2-2. Long-term trend in the number of active licence holders that have access to the Marine Scalefish Fishery (MSF), including those from the Southern and Northern Zone Rock Lobster (SZRL, NZRL) and Miscellaneous (MISC.) Fisheries.

2.3.2. Trends in Commercial Catch

Since 1984, there has been a major shift in the composition of the commercial catch within SA's MSF. This related to the substantial removal of 'other' species catch in 2001, and was a result of the establishment of an exclusive Sardine Fishery. In the six years prior to this separation, Sardines accounted for up to 58% of the total MSF catch. Annual catches in the contemporary fishery is dominated by the four primary species (>50%), followed by the secondary (approximately 30%), tertiary (12%), and the remaining permitted species (6%) (Figure 2-3).

Total catch of primary species peaked at 2,089 t in 2001 and has since declined to a record low of 1,118 t in 2017, representing a 43.4% decline over 17 years (Figure 2-3). Prior to 1999, the composition of catch of the primary species was relatively stable, where annual King

George Whiting catch accounted for approximately 40%, followed by Southern Garfish (30%) Snapper (20%) and Southern Calamari (15%). Since then, the relative proportion of KGW and Garfish catch has declined below 25% and 15%, respectively, whereas annual catches of Snapper and Calamari have increased, particularly from 2007 onwards (Figure 2-3).

The total annual catch of secondary species remained above 1,000 t from 1984 to 2006, peaking at 2,025 t in 1995 (Figure 2-3). Western Australian Salmon and Australian Herring, collectively accounted for most (up to 74%) of the catch up to 2002. From 2002 until 2009, the annual catch of Vongole substantially increased, accounting for up to 34% of the catch of secondary species at its peak in 2007. Before separating as a dedicated fishery in 1996, Blue Crabs accounted for approximately 30% of the secondary species catch. Total annual catch has since declined to a low of 670 t in 2012 and has remained above 800 t per annum since 2015 (Figure 2-3).

Annual catches of Leatherjackets and Oceanjackets emerged during the early 1990s peaking above 900 kg in 1991; however, since 2006 annual catches have rarely exceeded 100 kgs (Figure 2-3).

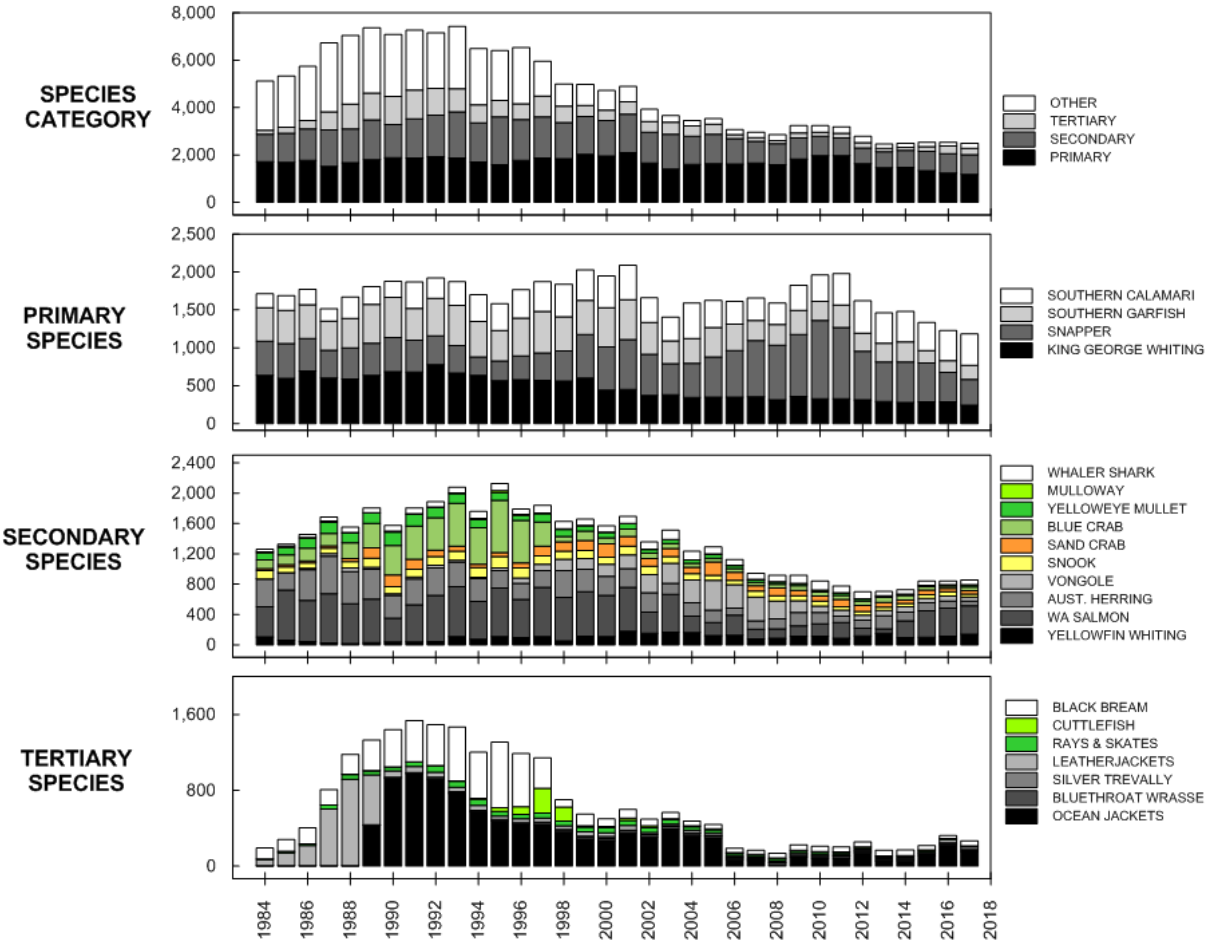

Figure 2-3. Long-term trend in total catch (t) in the commercial Marine Scalefish Fishery, presented for the species considered in this report in order of priority.

2.3.3. Trends in Fishing Effort

Species

Annual estimates of total fishing effort in the commercial MSF peaked at 136,623 fisher-days in 1992 (Figure 2-4). This peak represented an 18.2% increase in annual effort since 1984, after which, there was a 58.2% reduction in effort, which declined to 57,116 fisher-days in 2017. This decline, which occurred at a relatively consistent rate of approximately 3,036 fisher-days.year^{-1}, was influenced by the licence amalgamation scheme and subsequent net buy-back initiatives.

Up until 2015, most (>75%) of the fishing effort was targeted to a particular species. In 2017, 21.8% of the effort was non-specific, with fishers identifying 'any target' within their catch returns. This level of 'non-specific' reporting was the second highest on record, marginally improving from 2016 where 24.5% of fishers were non-specific in their fishing target. Of the reported targeted effort, the four primary species have consistently accounted for the greatest proportion (approx. 62%), of which King George Whiting (KGW) has historically dominated (approx. 40%). Since 2011, there has been a distinct shift in fishing activity, as fishers have directed targeted effort away from KGW and Snapper towards Southern Calamari. The relative proportion of effort targeted towards Southern Calamari has increased above 20%, representing a doubling in fishing effort since the late 1990s and 2000s, peaking at 23.8% in 2017 (Figure 2-4).

The secondary species attracted approximately 5% of the total fishing effort. The distribution of targeted effort amongst these species has changed over the past 33 years. Historically, Blue Crabs, Western Australian Salmon, Snook and Yelloweye Mullet attracted the most effort during the mid-1980s accounting for up to 98% of targeted effort directed at secondary species. Fishers increasingly targeted Sand Crabs from the late 1980s, and Vongole became a prominent target from 2002 onwards, accounting for up to 15% and 40% of secondary species effort, respectively. In each instance, these increases were associated with management initiatives that supported the development of the fisheries. Similarly, Whaler Sharks became targeted over the past 15 years, accounting for up to 12% of the secondary species fishing effort (Figure 2-4).

Less than 3% of the State-wide fishing effort was targeted towards the seven tertiary species considered in this report. There were a few periods of notable expansion for some 'niche' tertiary species such as Leatherjackets, Ocean Jackets and Cuttlefish. Targeted effort for each of these species doubled over short (<5 years) periods but did not persist.

The remaining 40 permitted species accounted for approximately 6% of the State-wide total targeted effort in 2017.

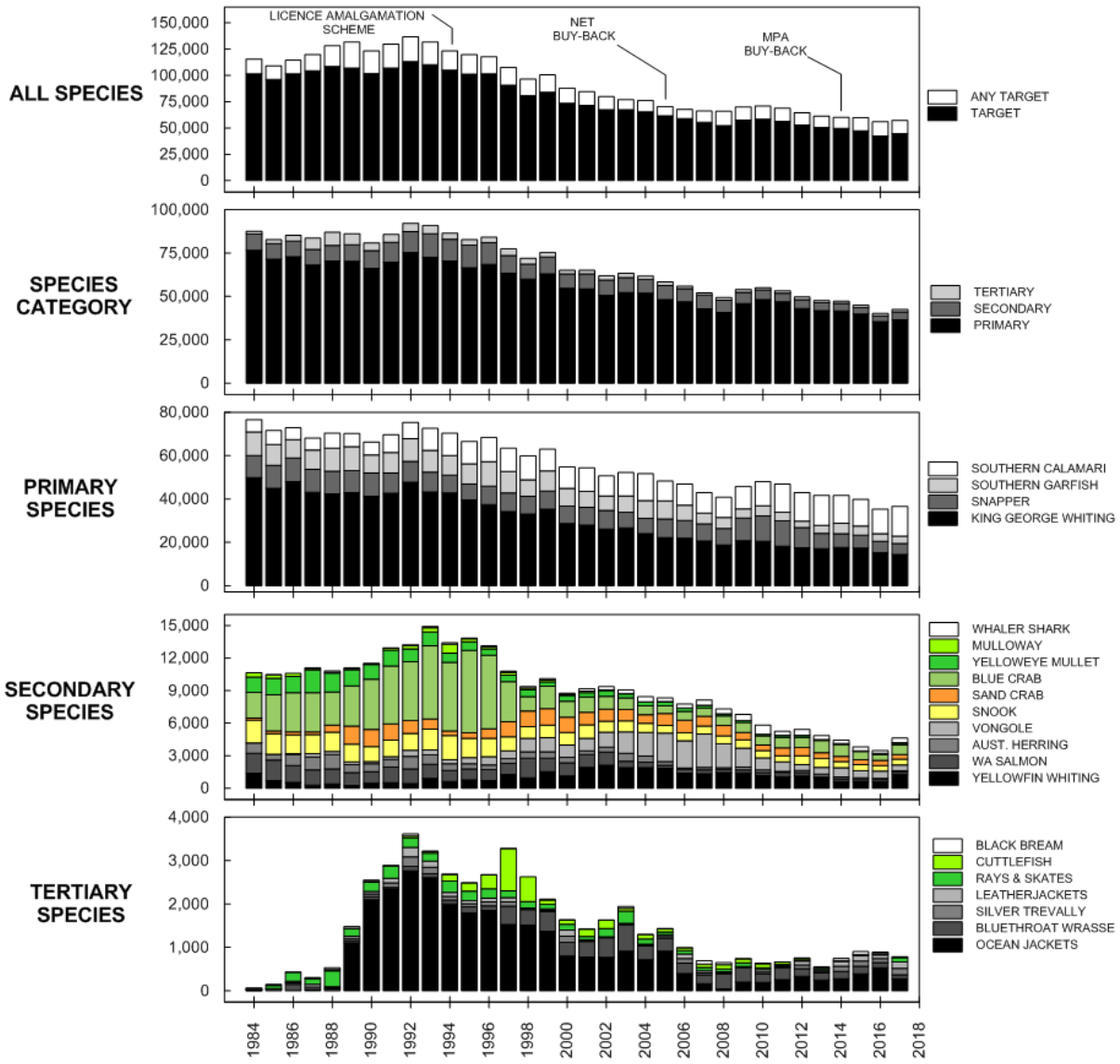

Figure 2-4. Total effort (fisher-days) in the commercial Marine Scalefish Fishery partitioned into targeted and non-targeted ('any target') effort (top graph) and into species-specific targeted effort.

Gear

Hauling nets and handlines have consistently been the dominant gear type within the fishery, collectively accounting for >60% of the total fishing effort within the fishery (Figure 2-5). The proportionate use of set nets has declined from 16% in 1987 to 1% in 2017, with the greatest reduction occurring throughout the late 1990s and early 2000s, in response to the State-wide netting review and associated restrictions. The relative use of squid jigs has steadily increased from 1994 as the Southern Calamari fishery evolved from a bait resource to a priority species within the MSF, and has further increased from 2011 onwards to account for approximately 20% of the State-wide total fishing effort. The proportionate use of longlines doubled

throughout the mid-2000s, and has since accounted for approximately 10% of the total fishing effort.

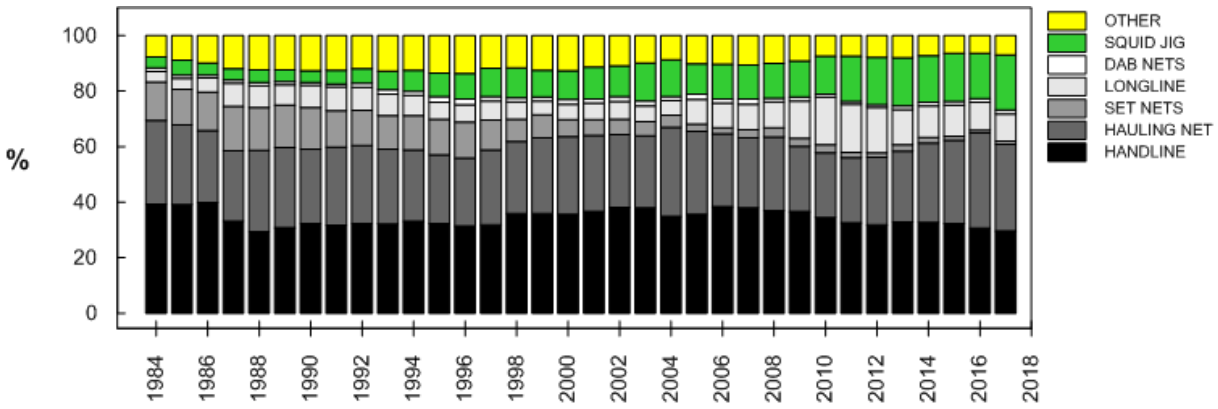

Figure 2-5. Gear usage (% of total fishing effort) within the commercial Marine Scalefish Fishery (MSF).

Location

Historically, the spatial distribution of fishing effort was widespread with most of the State MFAs registering some level of fishing activity (Figure 2-6). Fishing effort was most intense in the northern gulfs and near major regional ports such as Ceduna (MFAs 8, 9, 10), Coffin Bay (MFAs 27, 28), Port Lincoln (MFAs 30, 31) and Beachport (MFAs 55, 56, 57). Since 2000, fishing effort has largely contracted to within the gulfs, as fishing intensity around the regional centres has diminished to relatively low levels (<4,000 fisher-days.year^{-1}) (Figure 2-6). Of the regional centres, only Port Lincoln and Ceduna have maintained some consistent fishing activity. The northern gulfs have continued to account for most of the fishing effort, but this has also declined over the past 34 years, from an average of >40,000 fisher-days.year^{-1} during the 1980s and 1990s to <29,000 fisher-days.year^{-1} since 2005. Average annual fishing effort within MFAs 19 and 29 in southern Spencer Gulf was below 500 fisher-days.year^{-1} over the last three years (2015 to 2017), declining to the lowest level recorded for this area (Figure 2-6).

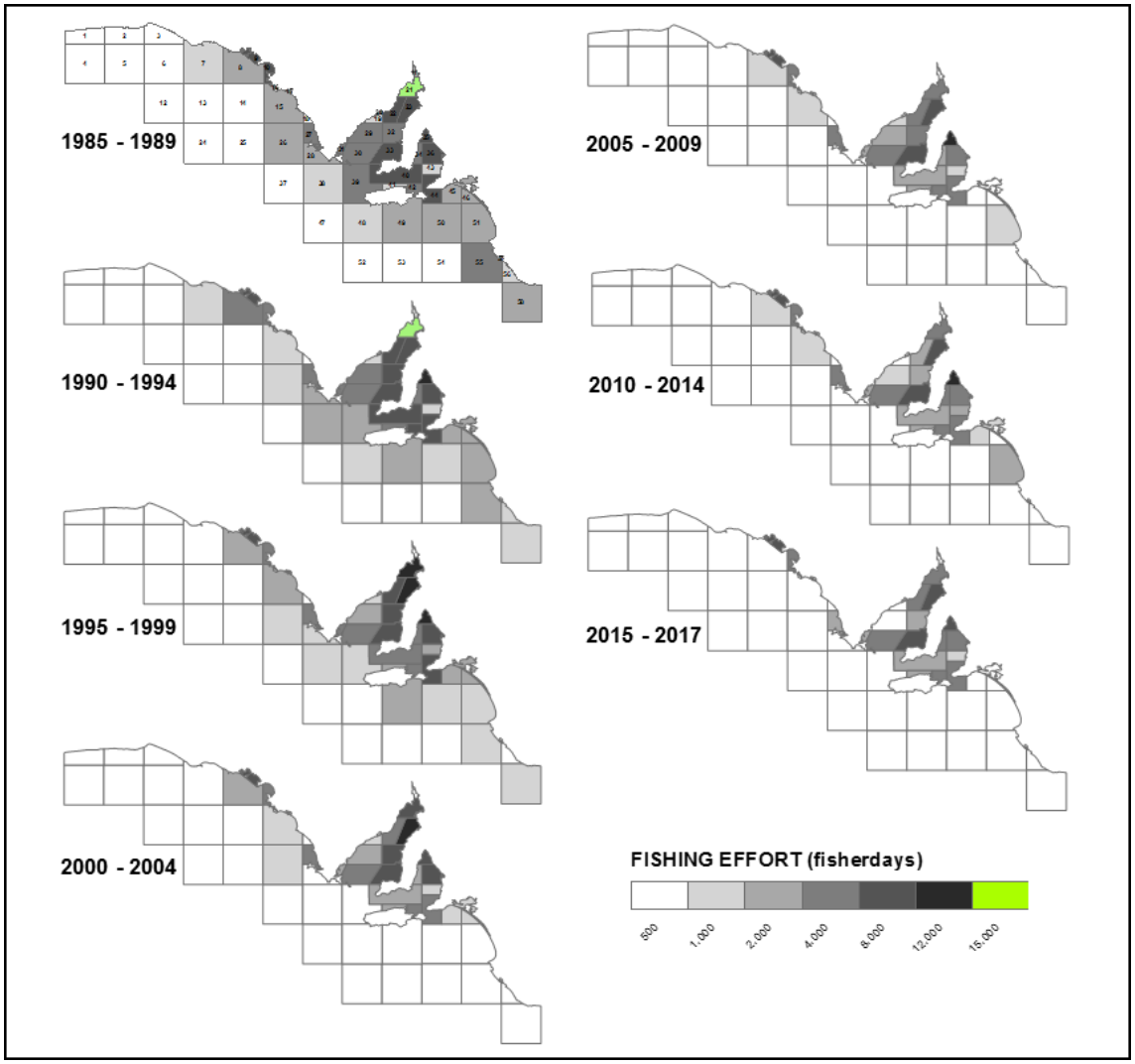

Figure 2-6. Spatial and temporal distribution of fishing effort (fisher-days) averaged over five years from 1985 to 2015, and three year average over 2015 to 2017, in the Marine Scalefish Fishery (MSF).

Season

The high diversity of target species within the MSF provides fishers with considerable flexibility (Figure 2-7). Among the four primary species, monthly targeted fishing effort for KGW peaked above 2,000 fisher-days in July, and although this species was targeted throughout the year its fishing activity remained highest during winter. Conversely, targeted effort for Southern Garfish was highest during late summer, peaking at 670 fisher-days in February. The seasonal pattern of fishing activity for Southern Calamari and Snapper was similar, where they both maintained relatively high levels of fishing effort throughout the year, peaking in autumn and again in late spring (Figure 2-7).

Targeted effort for most of the remaining species peaked during the warmer spring and summer months and maintained some level of fishing activity throughout the year. Yellowfin

Whiting, Bluethroat Wrasse, Silver Trevally and, to a lesser extent, Black Bream were the only species that displayed distinct increases in fishing activity during winter (Figure 2-7).

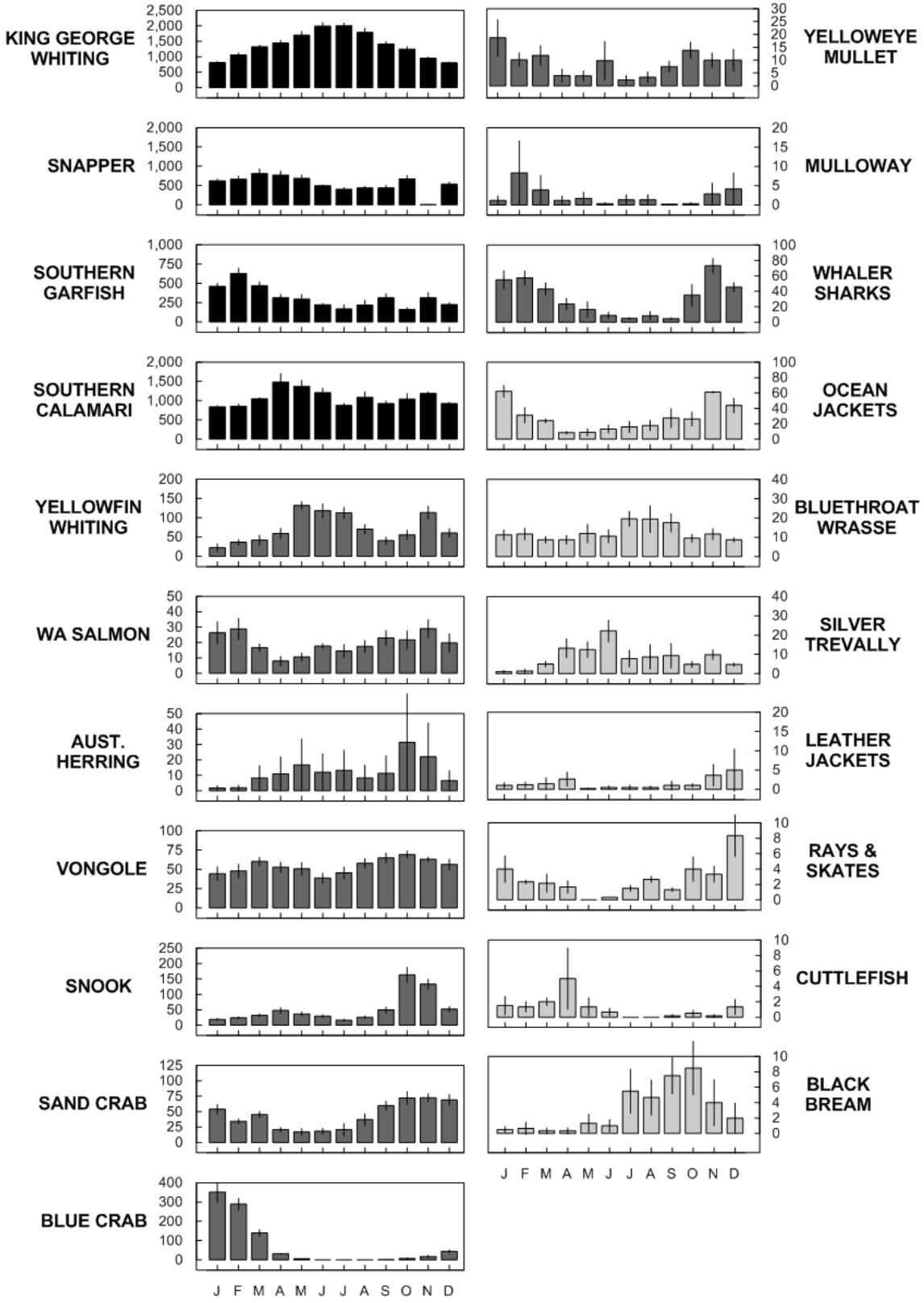

Figure 2-7. Monthly pattern of targeted fishing effort (fisher-days averaged (± se) from 2012 to 2017) for each of the 23 species/taxa assessed in this report. The different shade denote species category; primary (black), secondary (dark grey), teritary (light grey).

2.4. Discussion

The dynamics of the Marine Scalefish fishing fleet have changed in recent years and many of these changes appear to relate to management arrangements. The most obvious change has been the continuous decline in fishing effort which has been driven by the licence amalgamation scheme implemented in 1994 and, more recently, the two voluntary net buy-back initiatives in 2005 and 2014. Since their implementation, these management arrangements have successfully reduced the number of active licence holders by 63.9%, which has led to a 58.2% reduction in fishing effort. This has been manifested in a spatial contraction of effort across the State, with fishing effort virtually disappearing from most regional centres outside the gulfs and the fishery becoming almost exclusively confined to gulf waters and a few protected bays on the west coast of the Eyre Peninsula. Most of the fishing effort within the MSF was targeted, although a greater proportion of fishers in 2016 and 2017 were non-specific in their target species indicating that they are either becoming more general in their fishing activity or are not specifically recording a target species in their catch returns.

Collectively, the fishery's four primary species accounted for the greatest proportion (62%) of targeted effort, of which King George Whiting has historically dominated. Since 2011, there have been substantial declines in targeted effort for Snapper, King George Whiting and Southern Garfish as a consequence of a range of management arrangements (i.e. spatial closures, closed seasons, netting restrictions, catch limits). Conversely, targeted effort for Southern Calamari has steadily increased. This species has effectively become a year-round opportunistic target for many fishers, possibly to offset the loss of access to the other primary species. The increasing trend in the relative use of squid jigs also reflects this shift in behaviour amongst the fishing fleet.

The ephemeral periods of increased fishing activity for other secondary and tertiary species, such as Ocean Jackets, Western Australian Salmon and Snook also highlights the dynamic capacity of the MSF fishing fleet. Given the declining fishing activity observed for some of the primary species, current fishers may have greater incentive to target an increased diversity of 'under-utilised' species and synchronise their fishing activity to the species' patterns of seasonal abundance. Despite this, the diversity of secondary and tertiary species targeted by the fishing fleet has diminished in recent years.

3. SOUTHERN GARFISH STOCK ASSESSMENT

3.1. Introduction

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

Spatial and temporal analysis of gonadosomatic indices indicated that Southern Garfish have an extended spawning season that spans approximately six months (from October to March) and within this season only a small proportion (10 – 20%) of the population are in spawning condition at any given time (Giannoni 2013). This indicates that reproductive activity within the population is asynchronous; consequently, the extended spawning season is sustained by a series of small pockets of spawning activity. The estimated size at maturity ($L_{50\%}$) for female Southern Garfish in South Australia is 215 mm total length (TL), which is equivalent to the mean age of 17.5 months (Ye et al. 2002).

There have been several attempts to find Southern Garfish eggs in the field (Ling 1958, Noell 2003). In northern GSV, samples of a variety of seagrass species, including *Zostera muelleri*, *Posidonia sinuosa*, *P. angustifolia*, *Amphibolis antarctica* and *Heterozostera tasmanica* were collected and examined for adhering Southern Garfish eggs. However, no eggs were found.

During the 1990s, a total of 2,079 Southern Garfish were sampled from commercial catches in South Australia and successfully aged for a study on age and growth (Ye et al. 2002). There were seven age classes that contributed to the commercial catches (0+ to 6+ years); however, the catches were dominated (89%) by one- and two-year-old fish. Less than 2% were from 4+ to 6+ year classes. A more recent study, which compared the size and age structures of the fishery with that of the 1950s, indicated that historically the fishery was once dominated by 4+ and 5+ year old Southern Garfish, but over numerous years of exploitation, the fishery has become considerably truncated to consist of primarily one- and two-year-old Southern Garfish (Fowler and Ling 2010).

In 2009, a study adopted a combined approach to delineate potential Southern Garfish sub-populations, and determine the extent of mixing within South Australia's coastal waters, through the integration of multiple otolith-based techniques (Steer et al. 2009a). Spatial differences in otolith chemistry (trace elements and stable isotopes) and morphometrics

indicated that there were several groups of Southern Garfish that had spent significant parts of their lives in different environments and that there was some level of restriction that prevented complete mixing among the regions (Steer et al. 2009b, Steer et al. 2010; Steer and Fowler 2015). At least five regional divisions were identified. Three of these were clearly defined as they exhibited negligible levels of inter-regional mixing: The West Coast; Northern Spencer Gulf; and South-Western Spencer Gulf. The remaining two, however, were less distinct: Northern Gulf St. Vincent and Southern Gulf St. Vincent, but demonstrated a level of population structuring that would regard them as separate as a precautionary management measure. A concurrent study examining the spatial variation in parasite abundance in Southern Garfish inferred a similar population structure (Hutson et al. 2011). This level of population structuring was sufficient to suggest that the historical management framework of two discrete, gulf-specific, stocks should be restructured to align with these five smaller, semi-discrete, regional units.

3.1.1. Fishery

Southern Garfish is a significant inshore fishery species of southern Australia, with other fisheries occurring in Victoria, Tasmania, South Australia and Western Australia. Historically, the national commercial catch for this species has been dominated by that from South Australia where the catch has usually exceeded 400 t per annum, with an approximate value of $1.8 million (Econsearch 2017). This species is also a popular target amongst South Australian recreational anglers (Jones 2009).

In South Australia, licence holders from four different commercial fisheries have access to Southern Garfish within their respective fishery areas. These are the Marine Scalefish Fishery, Northern Zone Rock Lobster Fishery, Southern Zone Rock Lobster Fishery, and Lakes and Coorong Fishery. The Southern Garfish fishery is principally located in Spencer Gulf and Gulf St. Vincent (Figure 2-1) and managed as part of the multi-species, multi-gear MSF through a series of input and output controls. Commercial fishers typically target Southern Garfish using hauling nets and dab nets. Hauling net fishers account for the majority (~90%) of the commercial catch even though their fishing activities are restricted by regulation to waters <5 m deep.

Recreational fishers are permitted to use dab nets but predominantly use traditional hook and line as they fish from boats and shore-based platforms throughout the State. In 2013/14, this sector took an estimated 870,147 Southern Garfish, equating to an estimated catch of 79.2 t (Giri and Hall 2015).

3.1.2. Harvest Strategy

Two key objectives for managing the harvest of Southern Garfish within the commercial MSF will be considered in this assessment, they are: (1) ensure the long-term sustainable harvest of Southern Garfish by rebuilding stocks during specified time frames; and (2) maintain catches within agreed allocations for each sector. Achieving the long-term sustainability of the Southern Garfish fishery has been guided by the operational objectives of reducing the total harvest fraction to ≤30% by 2020, increasing egg production to ≥30% of pristine population by 2020, and increasing the proportion of age 3+ Southern Garfish between each triennial stock assessment cycle (PIRSA 2013).

3.1.3. Management Regulations

The commercial MSF has undergone considerable management changes over the past 40 years that has seen the fishery restructured and limited through gear restrictions and configuration, licensing, spatial and temporal closures, and size limits. Although most of these management changes have been generic in nature there have been a few that have largely impacted the Southern Garfish fishery. The most notable of these have been a series of net fishing spatial closures. Areas closed to netting were first implemented on the West Coast in 1958 and were subsequently followed by a depth-delimited ban in the early 1970s when net fishers were restricted to operate in coastal waters <5 m deep. Further netting closures were implemented in 1983, 1994, 1995, 1997 and 2005. In addition, deep water netting exemptions for a few commercial operators were revoked in 2006. These closures have significantly restricted the commercial Southern Garfish hauling net fishers to relatively small areas within the northern gulfs. Currently, it is estimated that net fishers in Northern Gulf St. Vincent have access to 465 km^2 of fishable area, which is approximately 55% less than the 1,028 km^2 available in Northern Spencer Gulf (Steer et. al. 2015).

In 2001, the legal minimum length (LML) for Southern Garfish was increased from 210 mm to 230 mm TL. This increase was made to ensure that at least 50% of Southern Garfish at that size would be reproductively mature and therefore had the opportunity to spawn at least once (Ye et al. 2002). Despite this increase, no corresponding changes to the mesh size regulations for hauling nets were implemented. Reductions in the recreational bag and boat limits were also implemented in 2001.

A specific harvest strategy for Southern Garfish was developed as part of the Management Plan for the South Australian Commercial Marine Scalefish Fishery which was released in October 2013 (PIRSA 2013). Although no specific management arrangements were prescribed in the Management Plan to achieve these targets, a range of tools were identified and an adaptive management approach outlined to consider the management arrangements

needed to meet the targets over time. These included gear modifications, spatial and temporal closures, and effort/catch management (PIRSA 2013). Through collaborative research and consultation amongst PIRSA, SARDI and the commercial fishing industry, it was agreed that a combination of effort and gear-based management strategies should be adopted to reach the operational targets. Furthermore, it was agreed that these strategies should be dynamic and altered in response to the status of the fishery. Initially, two 20-day seasonal closures that alternated between the gulfs were implemented in 2012. The duration of these closures were subsequently increased to 38 days in 2013, 40 days in 2014, 60 days in 2016, and 80 days in 2017 for Gulf St. Vincent. Similarly, the minimum regulated mesh size of the pocket component of the hauling nets was sequentially increased from 30 mm to 32 mm in 2013 and to 35 mm in 2017. Furthermore, the LML of Southern Garfish for commercial fishers was increased from 230 mm to 250 mm in 2015. In 2016, the recreational bag and limit of Southern Garfish was halved from 60 and 180 fish to 30 and 90 fish. The LML, for recreational fishers, remains at 230 mm.

3.2. Methods

3.2.1. Data Sources

For this stock assessment, the catch and effort data were aggregated across commercial fishers to provide annual totals (calendar year) and catch per unit of fishing effort (CPUE) at the State and stock level. State waters were partitioned into six regions; West Coast, Northern and Southern Spencer Gulf, Northern and Southern Gulf St. Vincent and the South East (Figure 2-1). These data were also interrogated across the two main gear types; hauling nets and dab nets.

Fishing effort was reported in fisher-days, which relates to the number of days a licenced vessel fished multiplied by the number of personnel working on board. There are two components to fishing effort, targeted and untargeted. Targeted effort in this fishery is a more accurate indicator of fisher behaviour than total fishing effort. It is also the metric that is used, along with targeted catch, to calculate CPUE, which provides an index of the relative abundance of Southern Garfish. Determining target effort in the hauling net sector, however, is problematic as fishers can catch multiple commercial species in a single fishing event and are sometimes non-specific in their target species. Although one species may dominate their catch, these fishers typically nominate “any species” (or record “000”) as their fishing target in their catch returns. The effort category of the non-specific hauling net fishers was then determined on the basis of what they caught. This was calculated in relation to the contribution of Southern Garfish by weight to the total catch in comparison to fishers who either targeted Southern Garfish or other species. If Southern Garfish constituted more than half (≥50%) of

the non-specific fishers' total daily catch, then these records were re-defined as targeting Garfish ("Hauling Net Target Plus"). These refined effort categories were calculated from 2004 onwards as this was when fishers began reporting their daily fishing activities.

Each week a team of SARDI researchers accessed the commercial catch of Southern Garfish at the SAFCOL market prior to the morning auction. Efforts were made to access the available catches from the northern regions of both gulfs to ensure that the information collected was representative of the fishery. Occasionally, samples from the southern gulfs were also obtained; however, these sample sizes were typically much lower than for the other two regions. The sampling methodology followed the protocol developed by Ye et al. (2002). All Southern Garfish purchased from the SAFCOL market were measured for both TL and standard length (SL) to the nearest mm, and weighed individually to the nearest 0.01 g. Each Southern Garfish was dissected to determine its sex and stage of reproductive development using the criteria of Ling (1958). The largest pair of otoliths (i.e. sagittae) were removed and subsequently used for age determination, as per the methods described in Ye et al (2002).

3.2.2. 'GarEst' Fishery Model

The principal input data for the GarEst model are (1) commercial catch and effort statistics; (2) population demographic information (i.e. sex, age and length composition) derived from the Southern Garfish market sampling program; and (3) estimated recreational catch from the National Recreational and Indigenous Fishing Survey (NRFIS) (Henry and Lyle 2003) and South Australian Recreational Fishing Surveys (Jones 2009, Giri and Hall 2015). The model partitions the time-series of data into 'biological' years to align with the recruitment schedule of Garfish, extending from 1 October 1984 to 30 September 2016. The time-series is further resolved into half-yearly (6 monthly) time steps to account for the seasonal variation in the fishery.

Given the multi-gear and multi-sectorial nature of the fishery, the model partitions the catch and effort into four categories; (1) hauling net fishers who target Garfish; (2) hauling net fishers who catch (non-target) Garfish; (3) dab net fishers; and (4) recreational fishers. Catch rates (CPUE) for the 'hauling net fishers who target Garfish' category incorporates the refined effort type "Target Plus" from October 2005 onwards, to reflect the changes in the reporting structure when commercial fishers refined the resolution of their catch returns from monthly to daily (see section 2.2).

Three surveys of South Australia's recreational fishery (2000/01 (Henry and Lyle 2003); 2007/08 (Jones 2009); and 2013/14 (Giri and Hall 2015)) were used to model the contribution of this sector to the Garfish catches. Estimates of recreational catch in the intervening years between the three surveys were assumed to vary linearly between the estimates of 2000/01

and 2013/14. For all preceding years, estimates of recreational catch and effort were assumed to be constant at the 2000/01 level.

The model estimates four biological performance indicators; fishable biomass, egg production, recruitment and harvest fraction (i.e. exploitation rate). Fishable biomasses and harvest fractions are given as yearly averages. Annual fishable biomass is computed as the mean of the half-yearly estimates in each 'biological' year. The harvest fraction is the proportion of the fishable biomass harvested by the fishery. The annual harvest fraction is calculated as the sum of the model catch in weight of the fishery in each 'biological' year divided by the annual fishable biomass. Annual recruitment is defined as the number of Garfish spawned in each summer year class that survive to age 1. In the recruitment time-series figures, the year shown on the x-axis represents the year the cohort was spawned.

Percent virgin egg production was computed as a ratio of yearly egg production divided by a measure of average 'virgin' egg production that the fishery would produce in the absence of exploitation. Virgin egg production was computed from a run of GarEst with F (and so all fishing effort) set equal to 0 as the average egg production over the years from 2000 to 2011. For this run of the virgin population, recruitment was fixed at the average from the years 1988 to 2000, prior to the longer-term recruitment decline that occurred around 2001.

Further details of the GarEst Garfish stock assessment model are provided in McGarvey and Feenstra (2004), McGarvey et al. (2007) and Appendix A, B and C. The biological performance indicators generated by the GarEst model are estimated by fitting to commercial catch totals by weight, recreational catch data by numbers in the three survey years, and to commercial catch proportions by sex, length and age. The respective fits of the model to these data sources are presented in Appendix E.

3.2.3. Assessment of Fishery Performance

Three tiers of indicators have been established to monitor the performance of the fishery over time and address the first management objective. Each performance indicator explicitly identifies a set of operational targets and trigger reference points that, if breached, elicits a management response. The nature of this response will be determined by fisheries management. Trends in model estimates of 'harvest fraction' and 'egg production' constitute the primary performance indicators within the Southern Garfish fishery, with their operational objectives set to reach $\leq$30% and $\geq$30% by 2020, respectively (Table 3-1). The secondary performance indicators relate to rebuilding Southern Garfish stocks through improving the overall age structure of the population and reducing effort within the fishery. The specific operational objectives are to display an increasing trend in the relative proportion of older (ages 3+) Garfish within the population through each triennial stock assessment cycle and to

reduce total hauling net effort by ≥13% by 2014 (Table 3-1). There are also a range of other performance indicators and trigger reference points relating to trends in commercial catch and effort statistics and biological metrics (Table 3-1). Although there is no formal management response linked to these indicators, they provide triggers for the development of further management actions to meet the objectives of the harvest strategy. In addition, the indicators provide measures for assessing the stock rebuilding strategy that can be relied on to measure the relative performance of the fishery through a 'weight-of-evidence' approach (PIRSA 2013).

Table 3-1. Performance indicators used to monitor the performance of South Australia's Southern Garfish Fishery as prescribed in the MSF Management Plan (PIRSA 2013). Biological (B) and General (G) indicators are identified.

	PERFORMANCE INDICATOR	TYPE	OPERATIONAL OBJECTIVE	TRIGGER REFERENCE POINT
PRIMARY	HARVEST FRACTION	B	≤ 60% 2014	> 60% 2014
		B	≤ 45% 2017	> 45% 2017
		B	≤ 30% 2020	> 30% 2020
	EGG PRODUCTION	B	25% 2017	< 20% 2017
		B	30% 2020	< 30% 2020
SECOND.	AGE COMPOSITION	B	↑ Prop. Age 3+	No change
	TOTAL HAULING NET EFFORT	G	↓ ≥ 13% 2014	↓ < 10% 2014
OTHER	TOTAL CATCH	G	No Target	3rd Lowest / 3rd Highest
		G	No Target	Greatest % interannual change (+/-)
		G	No Target	Greatest 5 year trend
		G	No Target	Decrease over 5 consecutive years
	TARGET HAULING NET CPUE	G	No Target	3rd Lowest / 3rd Highest
		G	No Target	Greatest % interannual change (+/-)
		G	No Target	Greatest 5 year trend
		G	No Target	Decrease over 5 consecutive years
	TARGET DAB NET CPUE	G	No Target	3rd Lowest / 3rd Highest
		G	No Target	Greatest % interannual change (+/-)
		G	No Target	Greatest 5 year trend
		G	No Target	Decrease over 5 consecutive years
	FISHABLE BIOMASS	B	No Target	3 year average is +/- 10% of previous years
	RECRUITMENT	B	No Target	+/- 10% than the average of previous 5 years

The Fisheries Management Act 2007 states that the Management Plan must specify the allocation of the resource among the various sectors within the MSF. Allocated shares were

derived from the catch data collected in 2007/08, as this year also contained the most recent recreational survey catch information (Jones 2009) at the time the allocations were decided. Three trigger limits have been determined for the primary species. The first trigger limit (Trigger 1) relates to the allocated shares of the entire fishery and is assessed at least once every five years to encompass up-dated recreational catch and effort statistics (Table 3-2). The remaining two trigger limits (Trigger 1 and 2) consider the commercial shares only and can be assessed on an annual basis. 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. Commercial allocation of Southern Garfish among the sectors as prescribed in the MSF Management Plan (PIRSA 2013).

FISHERY ALLOCATION	MSF	SZRL	NZRLF	REC.	CHARTER	ABT
	79.30%	0.13%	0.04%	19.50%	-	1.00%
TRIGGER 1	*84.00%*	*1.00%*	*1.00%*	-	-	-
COMMERCIAL ALLOCATION	**MSF**	**SZRL**	**NZRLF**	**REC.**	**CHARTER**	**ABT**
	99.79%	0.16%	0.05%	n/a	n/a	n/a
TRIGGER 2	*na*	*0.75%*	*0.75%*	-	-	-
TRIGGER 3	*na*	*1.00%*	*1.00%*	-	-	-

3.3. Results

3.3.1. Commercial Fishery Statistics

State-wide

The total commercial catch of Southern Garfish was 183.5 t in 2017, combined across all gear types, including both targeted and untargeted catch (Figure 3-1). This was the third lowest catch since 1984, and the third consecutive year where annual State-wide catches have remained below 200 t. The hauling net sector has traditionally dominated total catch, having consistently accounted for approximately 90% of the State-wide harvest since 1984 (Figure 3-1). Catches in this sector oscillated between 325 t to 500 t from 1984 to 2002, averaging 413 $t.yr^{-1}$, and have dropped to an average of 158 $t.yr^{-1}$ since 2013. The dab net sector accounts for most of the remaining catch (~10%). This sector yielded higher than average catches throughout the 1990s (~62 $t.yr^{-1}$) compared to the last decade where catches have rarely exceeded 25 $t.yr^{-1}$ (Figure 3-1).

Total fishing effort for Southern Garfish has steadily declined from a peak of 18,439 fisher-days in 1984 to a low of 4,855 fisher-days in 2012 (Figure 3-1). This represents a 73.7% decrease over 28 years, declining at a rate of 487 fisher-days per year. This decline can largely be attributed to a sequential reduction in hauling net effort. Over the past four years fishing effort has remained relatively stable, averaging approximately 5,000 fisher-days.year^{-1} (Figure 3-1). This trend was consistent for both gear types.

Annual catch rates in the hauling net sector consistently remained above 45 kg.fisher-day^{-1} from 2005 until 2014, which was approximately 12 kg.fisher-day^{-1} more than the average catch rates of the preceding decade (Figure 3-1). Catch rates in this sector peaked at 56.4 kg.fisher-day^{-1} in 2009 and remained relatively stable until 2015. They have since declined to 36 kg.fisher-day^{-1} in 2017, representing a 35% reduction over the last decade. Dab net catch rates also displayed a long-term increasing trend from 1984 to 2002, rising from 20.2 kg.fisher-day^{-1} in 1984 to a peak of 58.6 kg.fisher-day^{-1} in 2001 (Figure 3-1). This increase, however, was not sustained dropping to 31.9 kg.fisher-day^{-1} in 2007. Since then, there have been two notable peaks, where catch rates increased above 45 kg.fisher-day^{-1}, the first occurred in 2010 and again in 2016 (Figure 3-1).

Three management strategies have reduced the number of licence holders in South Australia's MSF. The first was the licence amalgamation scheme implemented in 1994, which has contributed to the long-term decline in the number of commercial fishers who land Southern Garfish, followed by net buy-backs in 2005 and 2014. These strategies have contributed to the 59% reduction in the number of commercial fishers landing Southern Garfish from 2005 until 2017 (Figure 3-1). The relative proportion of commercial fishers that nominated Southern Garfish as their specific target has remained relatively consistent at 75% throughout the last 20 years.

Most of the State-wide catch of Southern Garfish has historically been landed in the NGSV and NSG (Figure 3-2). Marine Fishing Areas 21 in SG and 35 in GSV have each consistently supported annual catches that have exceeded 40 t since 1984. During the 1980s and 1990s, the collective catch from these two MFAs accounted for approximately 45% of the State-wide commercial total. Since 2001, this relative contribution has increased to approximately 56% and has remained relatively steady, which emphasises the relative importance of these two areas to the commercial fishery. There has been a clear spatial contraction of the fishery over the past decade with catches from many regional centres in the WC (i.e. Venus Bay (MPA 17); Coffin Bay (MPA 27)) and SSG (i.e. Wallaroo (MPA 32); and Port Victoria (MPA 33)) having substantially decreased. This was primarily a result of the implementation of spatial netting closures. The contemporary fishery is now largely confined to the NSG and NGSV (Figure 3-2).

The seasonality of Southern Garfish catch is different for each of the gear types and has undergone considerable change over the past 30 years. From 1984 until 1999 most of the Garfish caught was landed during autumn. This was followed by two years during which high catches uncharacteristically peaked in mid–winter (July/August). Since then, overall monthly catches have declined considerably from the regular 40 t harvested during autumn, to more modest 10 t to 30 t monthly catches spread from January to August (Figure 3-2). Catches in the dab net sector, however, historically peaked during late spring and summer. Although dab net fishers are capable of targeting Garfish throughout the year, the temporal trends in their monthly catches have gradually diminished to < 4 t and appear to be constrained to the warmer half of the year.

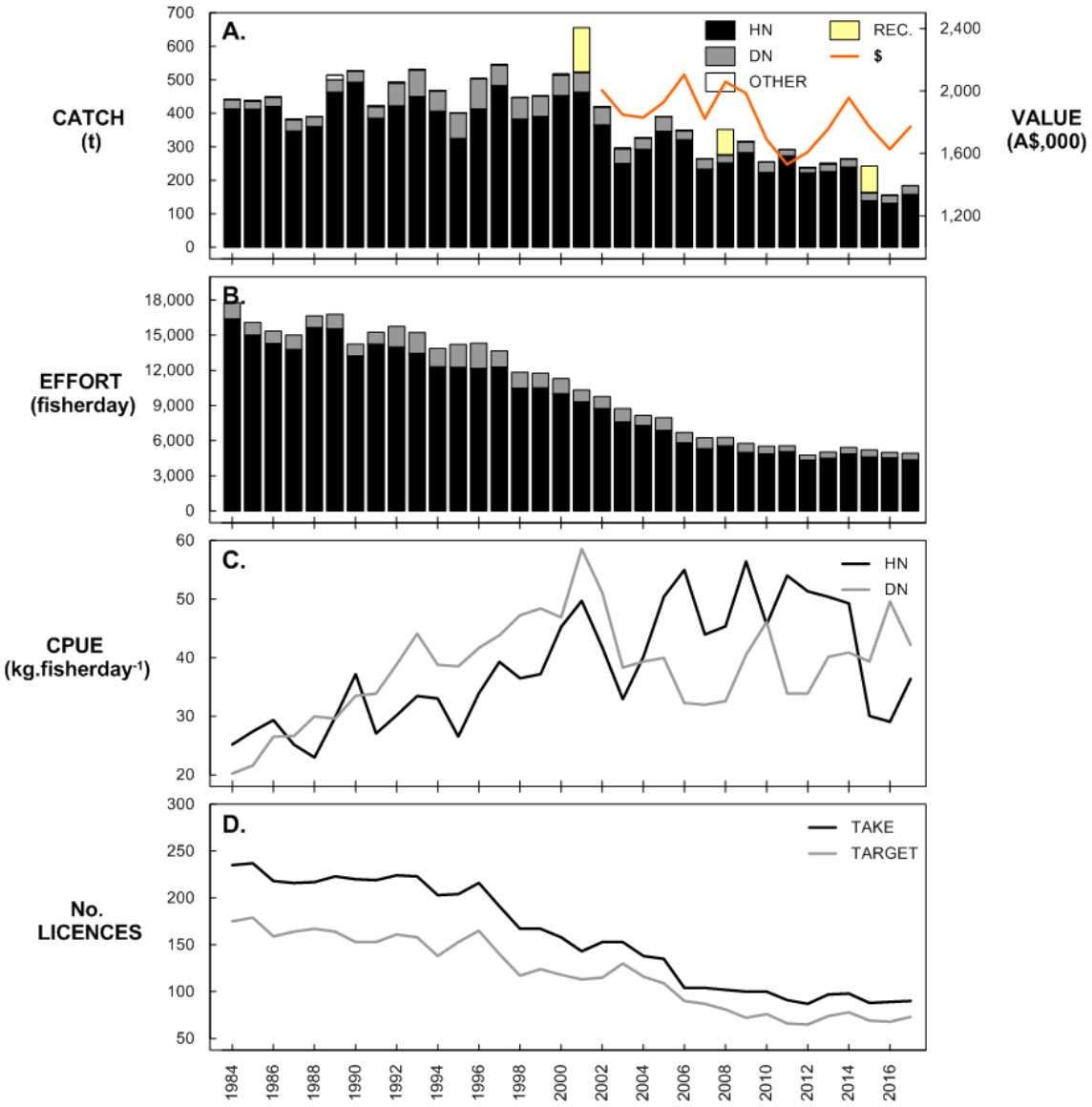

Figure 3-1. Southern Garfish. Long-term trends in: (A) total catch of the main gear types (hauling and dab nets) and gross production value; (B) total effort for hauling and dab nets; (C) total catch per unit effort (CPUE) for hauling and dab nets; and (D) the number of active licence holders taking or targeting the species.

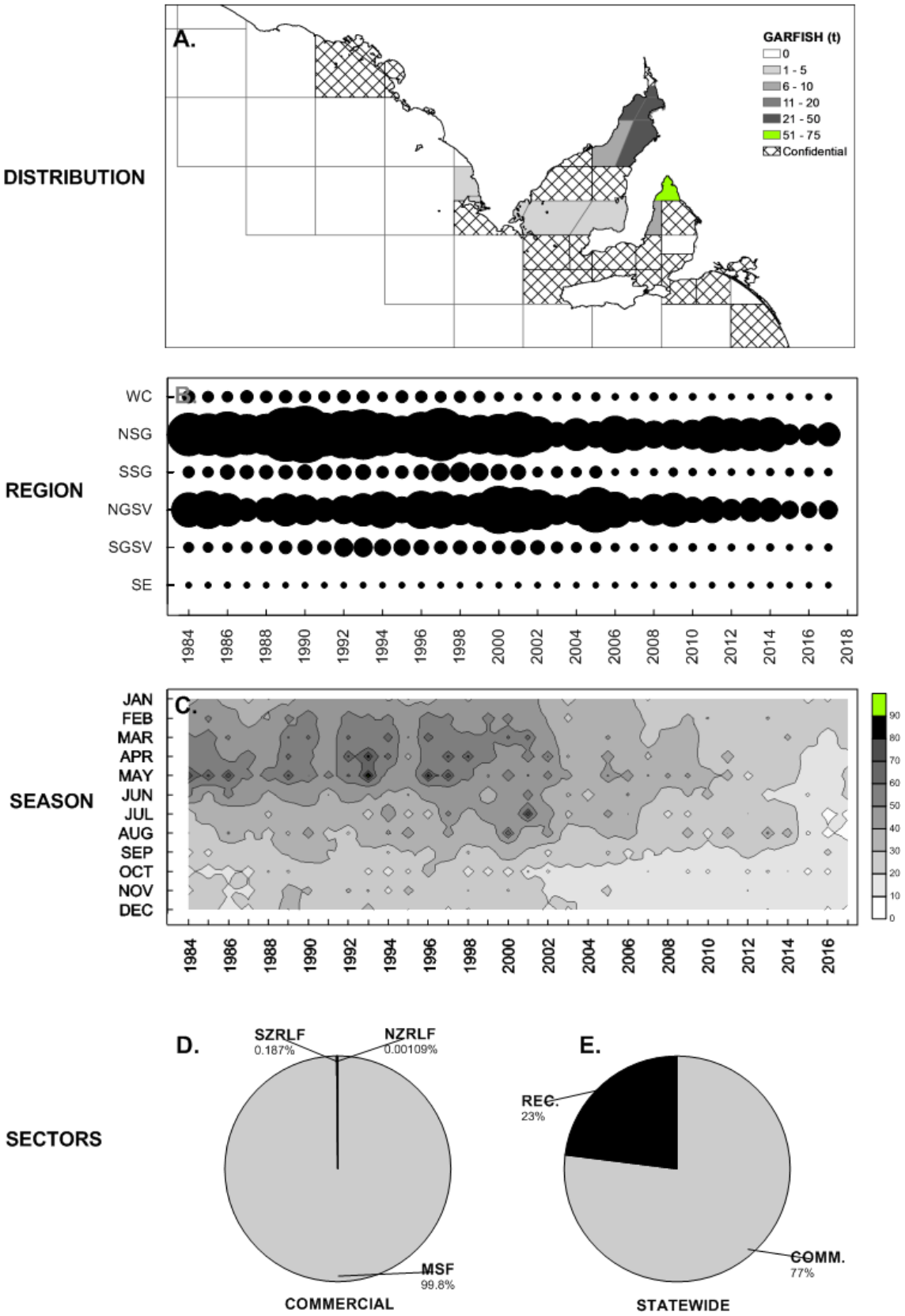

Figure 3-2. Southern Garfish. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t). The proportion of catch distributed among the commercial sector in 2017 (D); and among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

Northern Spencer Gulf Stock

Historically, NSG has been the most productive region for Southern Garfish in South Australia, and in 2017, contributed to 55% of the State-wide catch. Annual catches in this region has been low, but relatively stable over the past three years averaging approximately 85 t and were the lowest on record (Figure 3-3). Annual total hauling net effort declined to its lowest level in 2013, where fishers expended 2,226 days catching Southern Garfish. Since then, it peaked at 2,716 fisher-days in 2015 and has remained above 2,400 fisher-days (Figure 3-3). Targeted catch rates in the dominant hauling net sector had declined since the last stock assessment, dropping from a peak of 130 kg.fisher-day^{-1} in 2012 to 68 kg.fisher-day^{-1} in 2016, but have remained relatively high. It increased to 83 kg.fisher-day^{-1} in 2017 and was well within the prescribed trigger reference points (Table 3-1). The decline in hauling net effort was not unexpected given the closures were strategically implemented to reduce fishing during the peak winter season.

Modelled estimates of exploitation rate and egg production constitute the primary performance indicators in this fishery. Over the past 15 years the annual estimates of harvest fraction has trended favourably, declining at a rate of approximately 2% per year to a record low of 49.3% in 2016 (Figure 3-3). It, however, increased to 54.8% in 2017, although this value has been compromised by a lack of data resulting from the seasonal fishing closure and changing management arrangements (i.e increased mesh size). Disregarding 2017, the estimates of annual harvest fraction have remained below the trajectory that targets a harvest fraction of ≤30% by 2020. Annual egg production has remained relatively stable at approximately 11% over the last decade. It was acknowledged in the previous stock assessment that the trend in egg production was unlikely to achieve its operational target of ≥30% by 2020 (Steer et al. 2016), and this assessment has reaffirmed this improbability.

The continual increases in the minimum mesh size from 30 mm to 32 mm in 2012, to 34 mm in 2015, and to 35 mm in 2017 were specifically implemented to promote the recovery of the resource by reducing the mortality of small Garfish. It was expected that, over time, these changes would contribute to the accumulation of fishable biomass, concomitant improvement in recruitment and a population structure that consists of older, larger Garfish (Steer et al. 2011). Fishable biomass has increased since 2003, at a rate of approximately 4 t.year^{-1}, and was most likely driven by declining exploitation rates. There was little change in fishable biomass from 2014 until 2016, remaining at approximately 275 t.year^{-1} (Figure 3-3). Fishable biomass, averaged over the last three years (including the compromised 2017 estimate), was 257.4 t, 11.2% less than the average of the previous years, breaching the prescribed trigger reference point by 1.2% (Table 3-1). Recruitment declined to a historical low of 2.5 million recruits in 2015, falling 21.4% below the trigger reference point (Figure 3-3). A substantial

change in the age structure of the population was detected in this assessment, where the relative proportion of three and four year-old Garfish increased since the previous assessment by 16% and 4%, respectively (Figure 3-3). This shift is influenced by an absence of small Garfish being caught by commercial fishers as a function of increases in hauling net mesh size and extending the LML from 230 mm to 250 mm in 2015. These changes also directly influence the corresponding model outputs, as the availability of fishable biomass is inherently reduced, consequently impacting the associated harvest fraction, and extending the time period in which recruitment can be reliably detected.

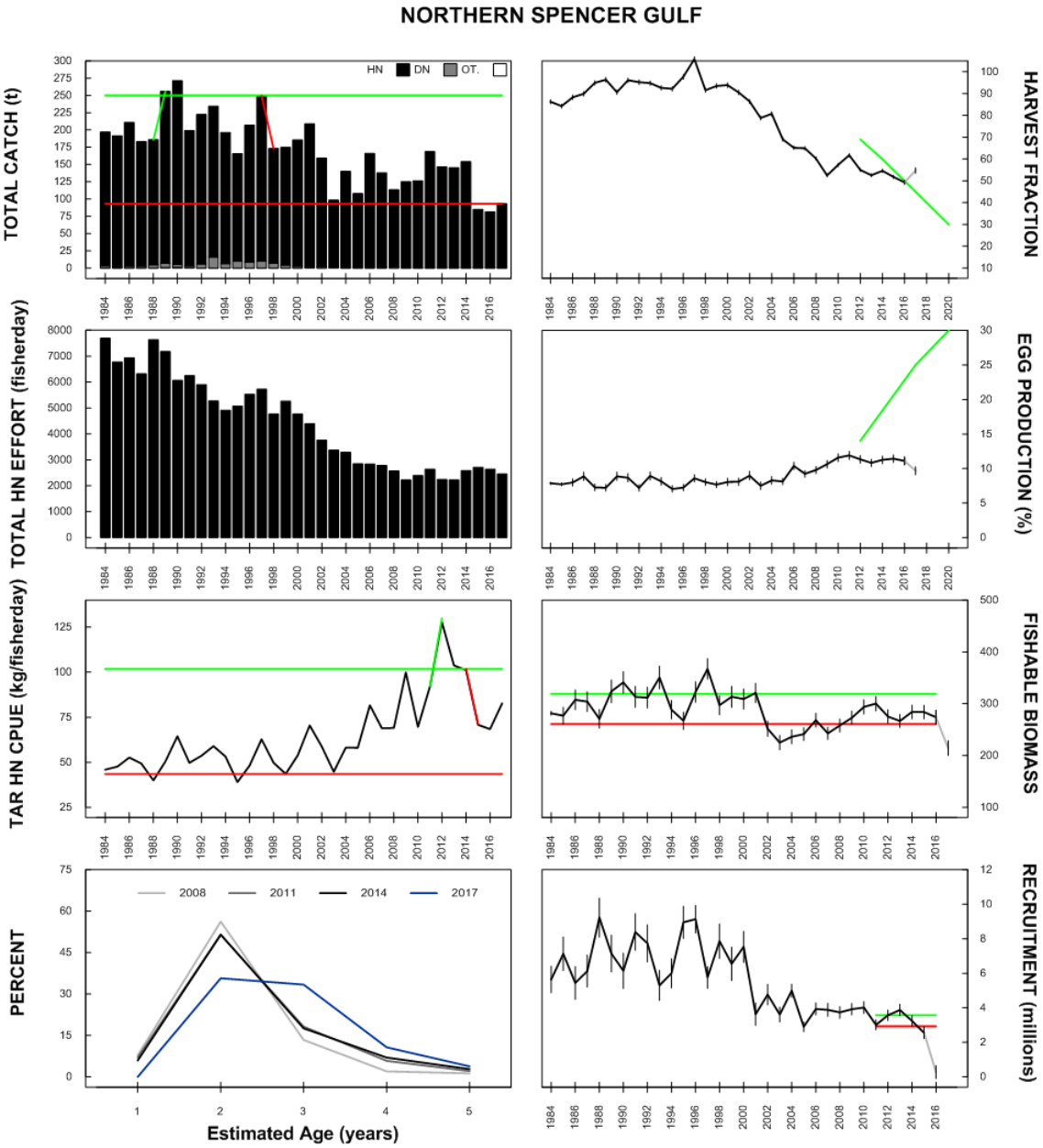

Figure 3-3. Key fishery statistics used to inform the status of the Northern Spencer Gulf stock of Southern Garfish. (Left) Trends in total catch, hauling net total effort, hauling net targeted catch rates (CPUE) and modelled age composition. (Right) Model output: harvest fraction, egg production (%), fishable biomass and average (± sd) recruitment. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Northern Gulf St. Vincent Stock

Northern Gulf St. Vincent (NGSV) is the second most productive region in the State, accounting for 35% of the commercial catch. Historically, the performance of the fishery has followed a similar pattern to NSG. This is because they share similar environments, have experienced comparable fishing pressure and were exposed to equivalent management strategies. However, a divergent trend was apparent in the last stock assessment, indicating that the concurrent level of fishing pressure in NGSV was at a point where the resilience of the Garfish stock had become compromised (Steer et al. 2016). This contributed to the stock being classified as recruitment overfished and led to increased management arrangements, with the fishing closure extending 20 days longer than NSG to span 80 days.

Like NSG, the annual total commercial catch of Southern Garfish in NGSV declined to the lowest level in 2016 to 56.8 t before increasing to 67.7 t in 2017 representing a 29% reduction since 2014 (Figure 3-4). Total hauling net effort declined to its lowest level in 2017, where fishers expended 1,768 days catching Southern Garfish, representing a 29.8% decline since 2011. Targeted catch rates within the hauling net sector have increased by 41% since 2015 to 48.7 kg.fisher-day^{-1} in 2017, returning to relatively moderate levels (Figure 3-4). The recent trend in hauling net effort was a direct reflection of the management arrangements that were strategically implemented to reduce fishing activity during the peak winter season.

High exploitation rates have also been a major concern for the NGSV stock which peaked at 91% in 2002. Since then, the annual harvest fraction has favourably declined by approximately 3% per year, reaching a record low of 38.6% in 2016 (Figure 3-4). It increased to 42.1% in 2017; however, this estimate was compromised by the timing of the extended fishing closure. Despite the uncertainty in the 2017 estimate, the trajectory of the annual harvest fraction appears on track to achieve the operational target of $\leq$30% by 2020. Like NSG, annual fishable biomass and egg production for NGSV have remained relatively stable since 2014 at approximately 200 t and 11%, respectively (Figure 3-4). However, they have trended well below their respective trigger reference points. Recruitment levels declined to 1.9 million recruits in 2015, which was 14.6% lower than the long-term average and 4.6% lower than the trigger reference point (Table 3-1). A substantial change in the population age structure was observed, with the relative proportion of three and four year-olds increasing by 13% and 4%, respectively, since the 2014 assessment (Figure 3-4). It should be reiterated, however, that like NSG, the recent increases in hauling net mesh size and the LML, were likely to have influenced the changes in the age structure, and corresponding model outputs, due

to 230 mm to 249 mm size Garfish being excluded from the commercial catch over the last two years.

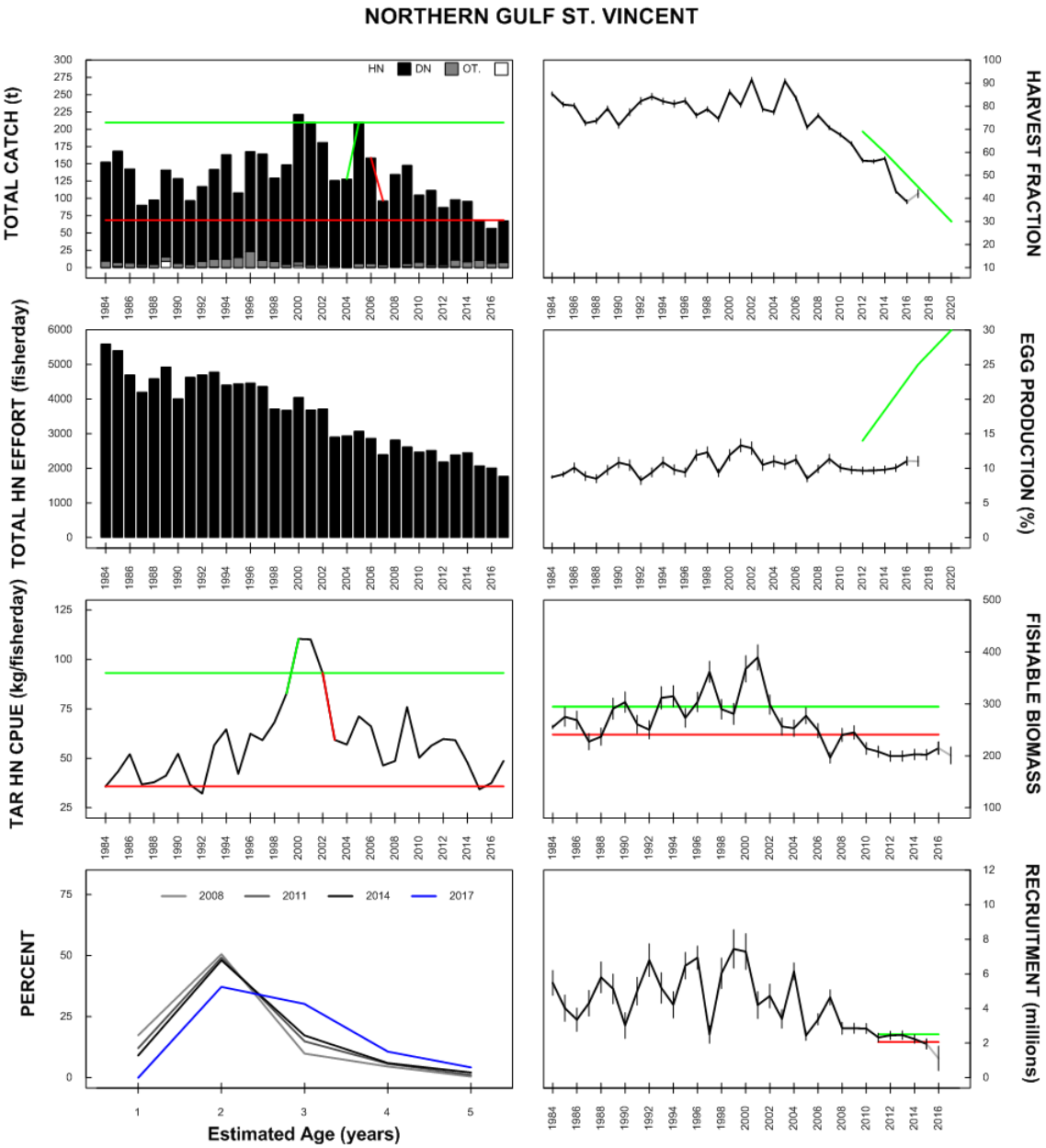

Figure 3-4. Key fishery statistics used to inform the status of the Northern Gulf St. Vincent stock of Southern Garfish. (Left) Trends in total catch, hauling net total effort, hauling net targeted catch rates (CPUE) and modelled age composition. (Right) Model output: harvest fraction, egg production (%), fishable biomass and average (± sd) recruitment. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Southern Spencer Gulf Stock

Large areas of Southern Spencer Gulf have been closed to commercial hauling net fishing since 2005, and as a result the relative contribution of this region to the State-wide catch has decreased from approximately 10% up to 2005 to 3% over the past nine years. Most hauling

net fishers (up to 90%) who operated in this region were non-specific in their target species. This sector historically accounted for approximately 30% of the total catch which peaked at 71.2 t in 1998. However, it has been considerably eroded through spatial restrictions imposed in 2005 to become almost exclusively fished by the dab net sector. Total catch of Southern Garfish in this region has not exceeded 15 t since 2009 (Figure 3-5). Targeted dab net effort remained relatively stable at approximately 120 fisher-days from 2011 to 2014, before increasing above 210 fisher-days in 2015, 2016 and 2017. Targeted dab net CPUE peaked at 55.6 kg.fisher-day^{-1} in 2010, dropping to 38.5 kg.fisher-days^{-1} in 2012 before returning to 52.4 kg.fisher-day^{-1} in 2016 (Figure 3-5). In 2017 targeted dab net CPUE was 35.6 kg.fisher-days^{-1}, representing a 32% reduction over the last year, remaining at a moderate level. Most fishers (>80%) catching Southern Garfish recorded them as their fishing target in this region.

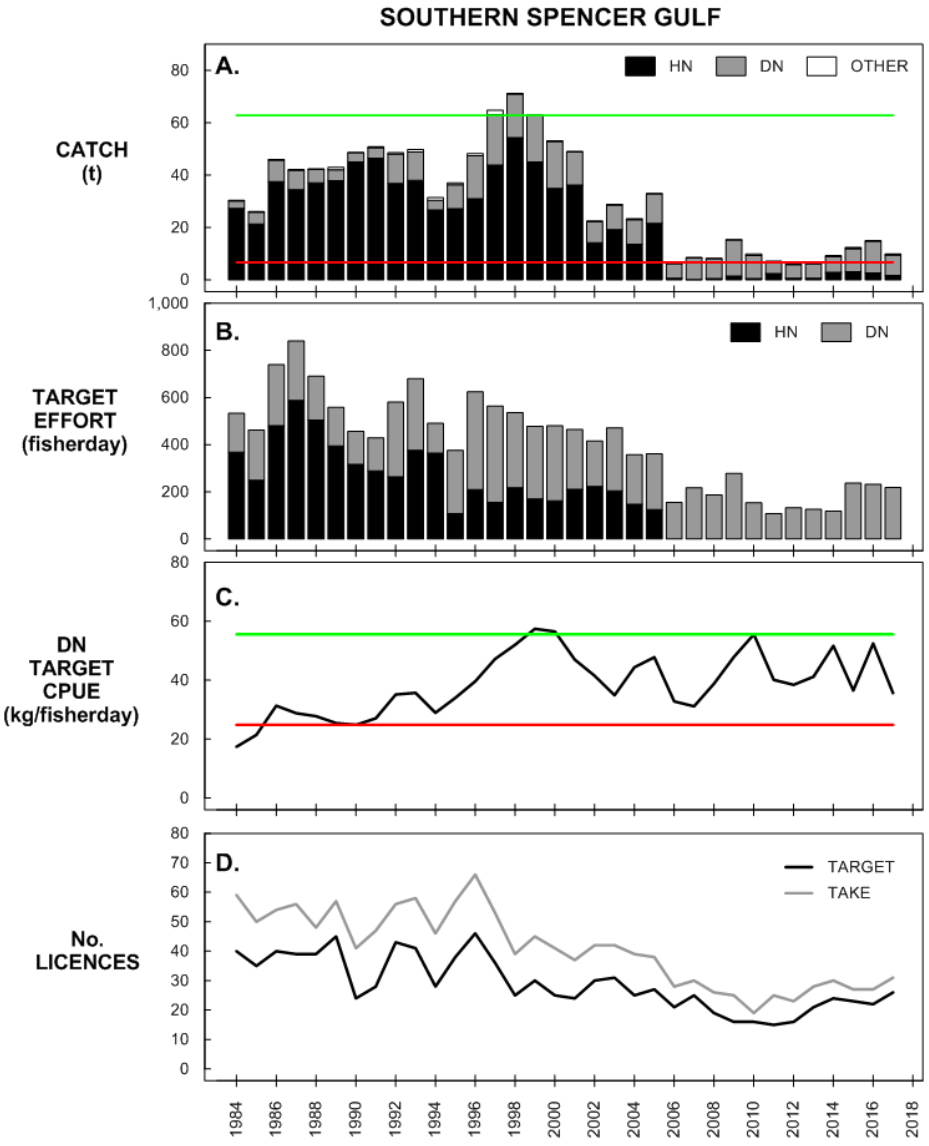

Figure 3-5. Key fishery statistics used to inform the status of the Southern Spencer Gulf stock of Southern Garfish. Long-term trends in (A) Total catch; (B) targeted effort; (C) dab net catch rates; and (D) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Southern Gulf St. Vincent Stock

The relative contribution of the commercial Southern Garfish catch from this region to the annual State-wide total has rarely exceeded 10%. Annual catches steadily increased from 24 t in 1984 to 70 t in 1993 with both the hauling net and dab net sectors contributing equally (Figure 3-6). From 1993, the contribution of Southern Garfish catch by the hauling net sector declined as a result of a steady reduction in effort (Figure 3-6). From 2005 onwards the dab net sector accounted for >75% of annual commercial fishing effort in this region as the implementation of netting restrictions virtually removed all hauling net activity from the region. Targeted dab net effort has also recently declined, dropping from 558 fisher-days in 2005 to a record low of 39 fisher-days in 2015. It has since increased to 102 fisher-days in 2017 (Figure 3-6). Consequently, total catches in this region have remained <7t over the past six years. Catch rates within the dab net sector have increased over this time period, increasing 40%, from 48 to a peak of 70 kg.fisher-day^{-1} in 2017 (Figure 3-6).

Less than 10 fishers have recorded catching Southern Garfish in this region since 2012, and the majority (>85%) actively targeted the species.

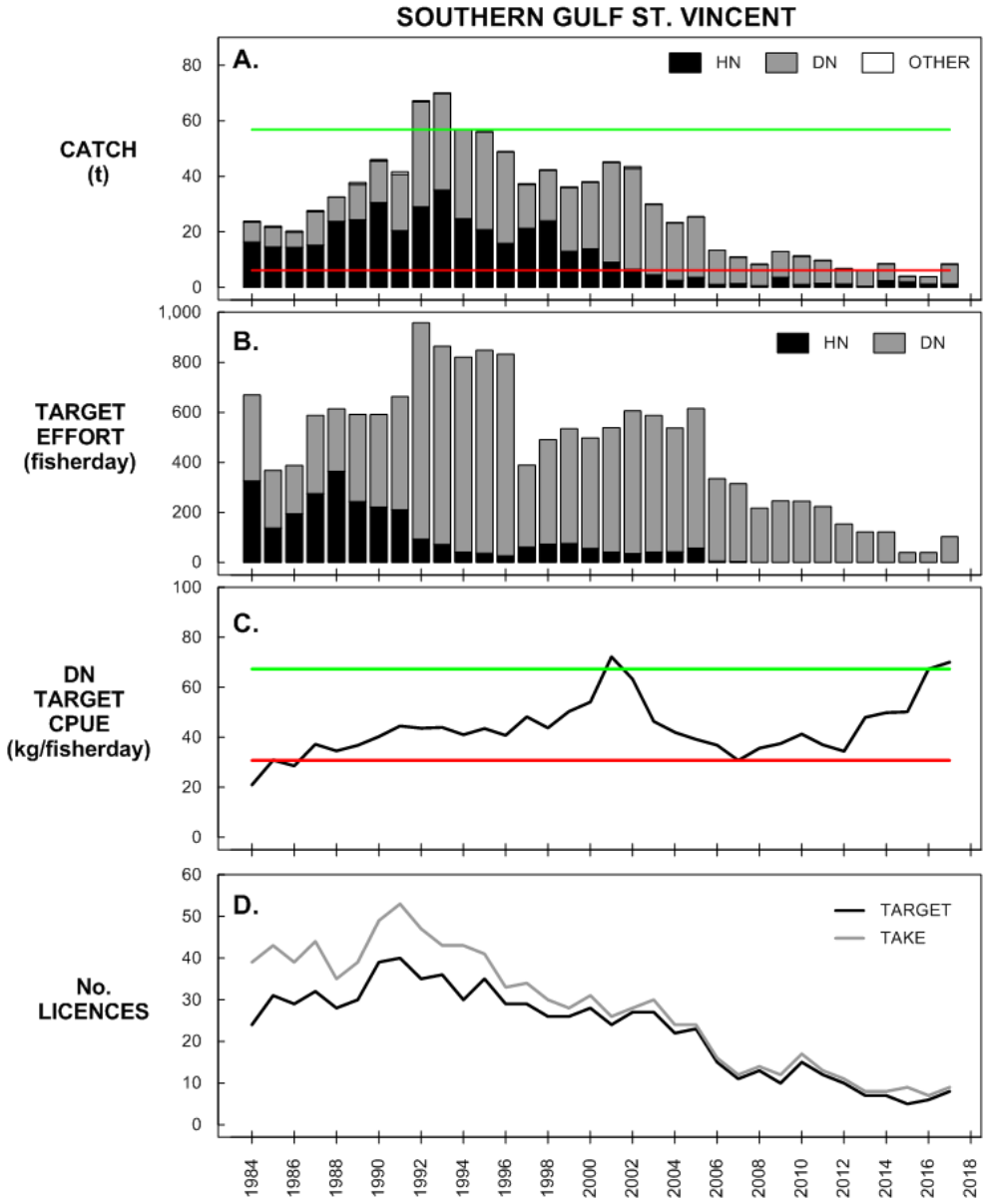

Figure 3-6. Key fishery statistics used to inform the status of the Southern Gulf St. Vincent stock of Southern Garfish. Long-term trends in (A) Total catch; (B) targeted effort; (C) dab net catch rates; and (D) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

West Coast Stock

From 1984 to 1999 the annual commercial catch of Southern Garfish from the West Coast accounted for approximately 7% of the State's catch. This has since declined to <1% in 2017 and has been driven by a continuous reduction in hauling net effort through the implementation of commercial netting restrictions (Figure 3-7). Annual Southern Garfish catch peaked at 37.2 t in 1992 of which the hauling net sector landed 86% (Figure 3-7). Annual catches declined below to the lowest recorded level of 1.3 t in 2013, before increasing by 243% in 2015 to 4.4 t and remained above 3.2 t in 2016 and 2017.

Dab nets emerged as the dominant gear type in 2006, and in 2015 this sector accounted for a record high 86% of the total regional catch (Figure 3-7). Targeted catch rates in the hauling net sector peaked at 77.1 kg.fisher-days^{-1} in 1999. Since 2005 less than five hauling net fishers have operated in this region per year. Targeted dab net effort peaked at 277 fisher-days in 2000 and declined to 27 fisher-days in 2011. Despite a small increase in 2015, where dab net fishers expended 74 days targeting Southern Garfish, effort levels have remained at approximately 35 fisher-days.year^{-1} since 2011 (Figure 3-7). Targeted catch rates by dab net fishers were the second highest on record in 2016 at 49.8 kg.fisher-days^{-1} and have since declined by 12% in 2017 (Figure 3-7). Of the 16 fishers taking Southern Garfish in this region in 2017, 11 (68.8%) actively targeted the species, predominantly with dab nets (Figure 3-7).

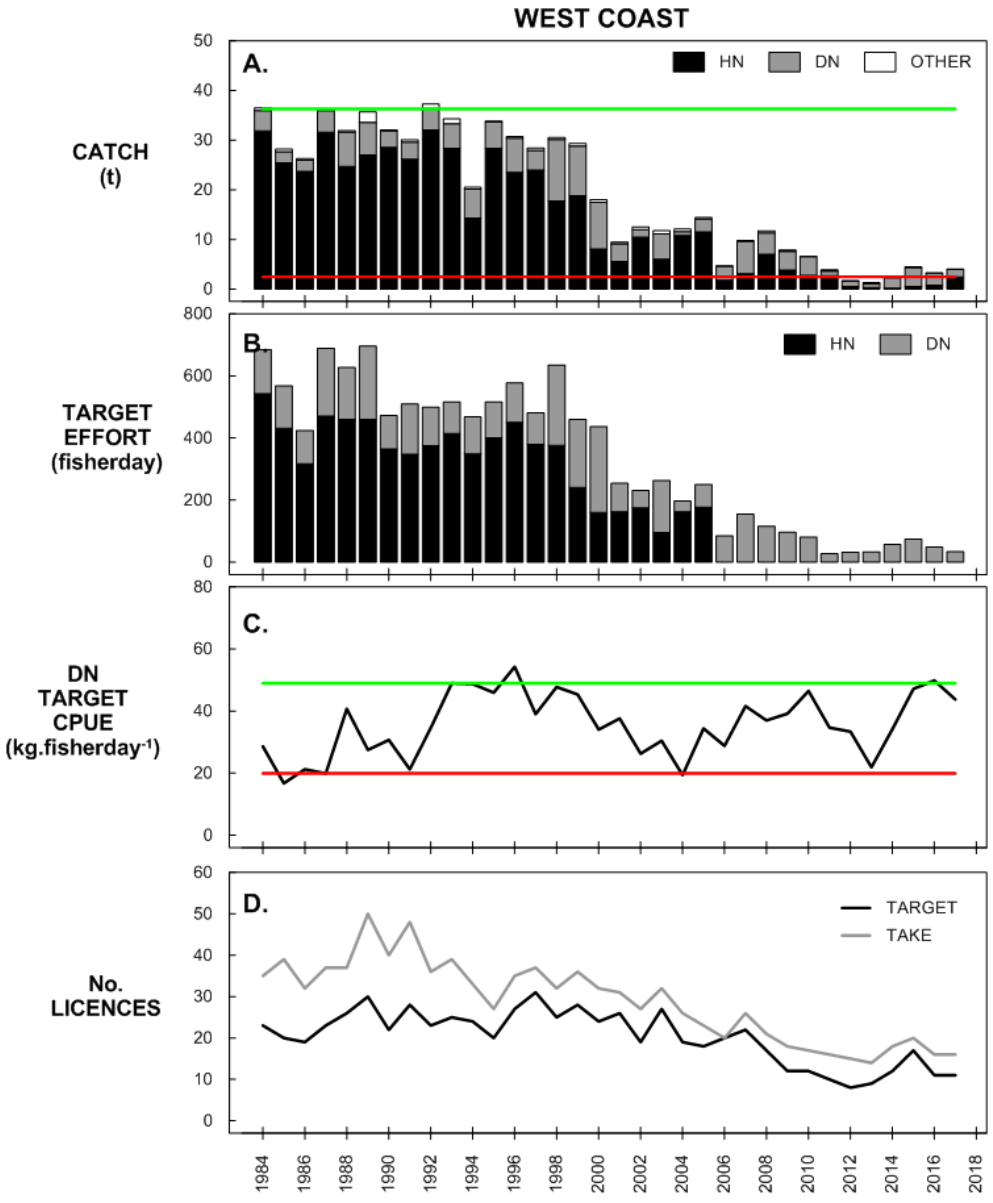

Figure 3-7. Key fishery statistics used to inform the status of the West Coast stock of Southern Garfish. Long-term trends in (A) Total catch; (B) targeted effort; (C) dab net catch rates; and (D) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

South East Stock

A negligible amount of Southern Garfish is landed by the commercial sector in the South East, with the annual State-wide contribution rarely exceeding 0.3%. Total catch and effort has remained below 1 t and 40 fisher-days per year since 2003, respectively (Figure 3-8).

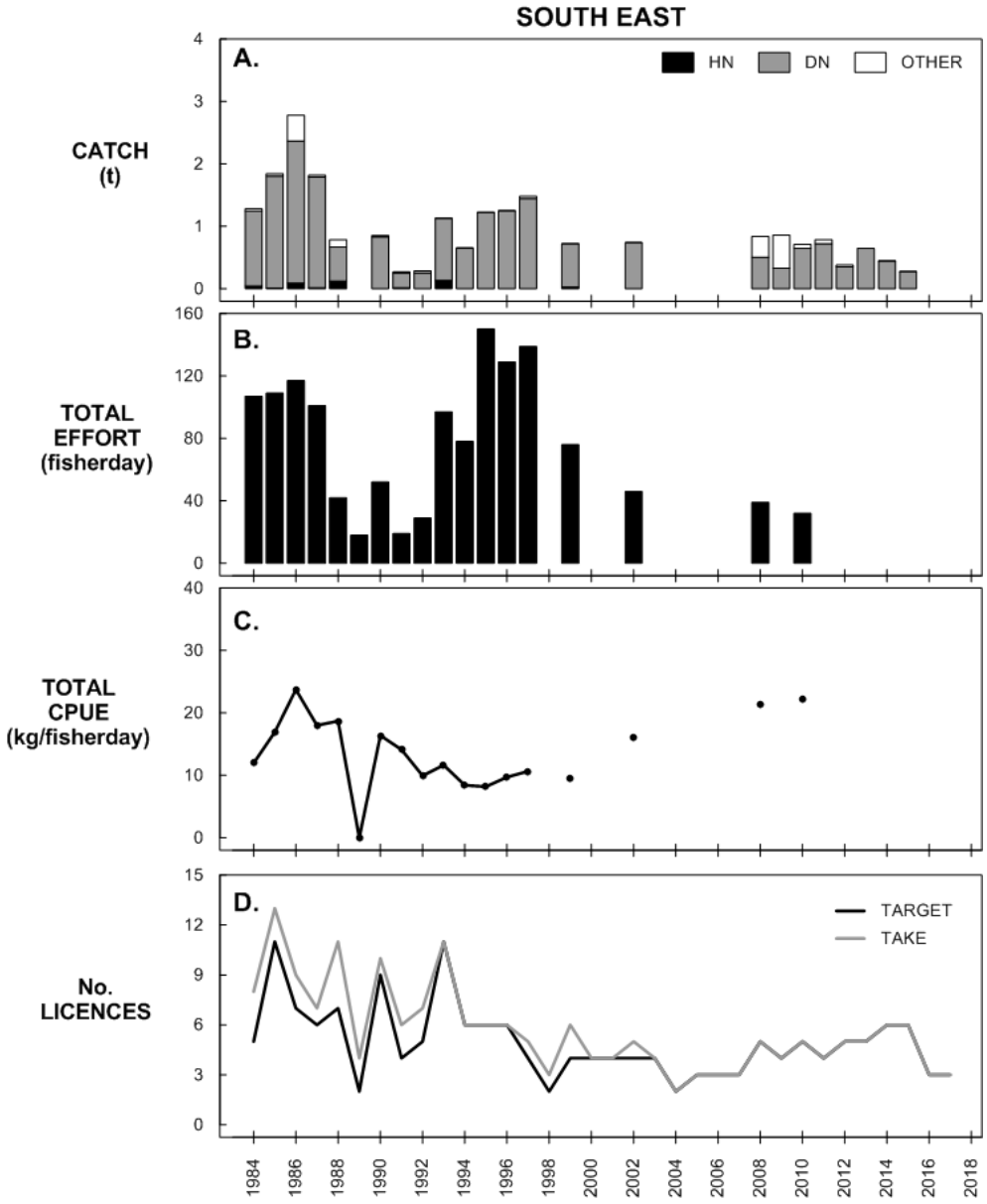

Figure 3-8. Key fishery statistics used to inform the status of the South East stock of Southern Garfish. Long-term trends in (A) Total catch; (B) targeted effort; (C) dab net catch rates; and (D) the number of active licence holders taking and targeting the species.

3.3.2. Fishery Performance

The relative contributions to the State-wide catch from the three commercial fisheries have been relatively stable over the past five years (Table 3-3). The one notable, yet minor

exception, was the Southern Zone Rock Lobster Fishery (SZRLF) which exceeded 0.2% in 2013; however, it was not large enough to breach the prescribed trigger limit.

The general performance indicators were assessed at the biological stock level. Two trigger reference points (TRPs) that related to high targeted dab net catch rates in SGSV were breached in 2017 (Table 3-4), where annual CPUE was the second highest on record, and the increasing trajectory of catch rates was the greatest over the past five years.

Modelled estimates of harvest fraction and egg production are the primary biological performance indicators used in this assessment to determine the status of South Australia's Southern Garfish fishery. The implementation of the 2017 spatial closures compromised the interpretation of the 2017 model output and the assessment of associated operational objective of achieving a harvest fraction of ≤ 45% by 2017. However, when considering the uncompromised 2016 data series, both NSG and NGSV exhibited harvest fractions below 50%, placing them on-track to meet the operational objective of achieving ≤ 30% by 2020 (Table 3-4). The egg production target of 25% in 2017 was not achieved, with estimates remaining relatively stable at approximately 11% since 2016 for both of the key fishing areas (NSG and NGSV).

Strong improvement in the age structure of the Southern Garfish population was observed in 2017 for both gulfs, with increases in the proportion of three-year-old fish by 15.8% and 12.9%, in NSG and NGSV, respectively, meeting the operational target (Table 3-4).

Estimates of fishable biomass and recruitment constitute the remaining biological performance indicators and contribute to the 'weight-of-evidence' approach in determining the status of the resource. Average fishable biomass over the past three years decreased by 23.1% in NGSV and 11.2% in NSG in comparison to the average of the preceding years, unfavourably breaching the 10% TRP (Table 3-4). Similarly, estimates of recruitment declined by 14.6% in NGSV and 21.4% in NSG, in comparison to the previous five-year average, also negatively breaching the 10% TRP (Table 3-4).

Table 3-3. Southern Garfish Commercial Fishery Allocation.

COMMERCIAL ALLOCATION	MSF 99.79%	SZRL 0.16%	NZRLF 0.05%
TRIGGER 2	n/a	0.75%	0.75%
TRIGGER 3	n/a	1.00%	1.00%
2013	99.72%	0.25%	0.03%
2014	99.89%	0.11%	0.01%
2015	99.89%	0.11%	0.00%
2016	99.95%	0.03%	0.02%
2017	99.81%	0.19%	0.00%

Table 3-4. Comparison of trends in South Australia's Southern Garfish Fishery against the performance indicators prescribed in the MSF Management Plan (PIRSA 2013). Red = negative breach, green = positive breach, grey = not applicable; arrows indicate directional shift. * denotes the interpretation of the 2016 outputs, given the impact of the fishing closures on the 2017 time series.

	PERFORMANCE INDICATOR	TYPE	OPERATIONAL OBJECTIVE	TRIGGER REFERENCE POINT	SSG	SGSV	WC	SE	NSG	NGSV
PRIMARY	HARVEST FRACTION	B	≤ 60% 2014	> 60% 2014	-	-	-	-	54.6%	57.3%
		B	≤ 45% 2017	> 45% 2017	-	-	-	-	49.3%*	38.6%*
		B	≤ 30% 2020	> 30% 2020	-	-	-	-	-	-
	EGG PRODUCTION	B	25% 2017	< 20% 2017	-	-	-	-	11.1%*	11.1%*
		B	30% 2020	< 30% 2020	-	-	-	-	-	-
SECOND	AGE COMPOSITION	B	↑ Prop. Age 3+	No change or reduction	-	-	-	-	↑15.8%	↑12.9%
	TOTAL HAULING NET EFFORT	G	↓ ≥ 13% 2014	↓ < 10% since 2011	-	-	-	-	-	-
OTHER	TOTAL CATCH	G	No Target	3rd Lowest / 3rd Highest	×	×	×	Conf.	3rd	2nd
		G	No Target	Greatest % interannual change (+/-)	×	×	×	Conf.	×	×
		G	No Target	Greatest 5 year trend	×	×	×	Conf.	×	×
		G	No Target	Decrease over 5 consecutive years	×	×	×	Conf.	×	×
	TARGET HAULING NET CPUE	G	No Target	3rd Lowest / 3rd Highest	-	-	-	-	×	×
		G	No Target	Greatest % interannual change (+/-)	-	-	-	-	×	×
		G	No Target	Greatest 5 year trend	-	-	-	-	×	×
		G	No Target	Decrease over 5 consecutive years	-	-	-	-	×	×
	TARGET DAB NET CPUE	G	No Target	3rd Lowest / 3rd Highest	×	2nd	×	Conf.	×	×
		G	No Target	Greatest % interannual change (+/-)	×	×	×	Conf.	×	×
		G	No Target	Greatest 5 year trend	×	✓	×	Conf.	×	×
		G	No Target	Decrease over 5 consecutive years	×	×	×	Conf.	×	×
	FISHABLE BIOMASS	B	No Target	3 year average is +/- 10% of previous years	-	-	-	-	↓11.2%*	↓23.1%*
	RECRUITMENT	B	No Target	+/- 10% than the average of previous 5 years	-	-	-	-	↓21.4%*	↓14.6%*

3.4. Discussion

3.4.1. Context of this Assessment

The previous Southern Garfish stock assessment, which considered commercial catch and effort statistics up to 31 December 2014, classified the two main South Australian Garfish stocks, Northern Gulf St. Vincent (NGSV) and Northern Spencer Gulf (NSG), as recruitment overfished and as transitional-recovering, respectively (Steer et al. 2016).

Over the past six years there has been variation in the timing and increasing duration of the implemented winter fishing closures. Along with these effort controls, hauling net mesh sizes of diverse types (i.e. knotted and knotless construction) have been widened and minimum size in commercial landings has been increased to further reduce exploitation level and increase the average lifespan of spawners which also brings larger more valuable garfish to market (Steer et al. 2018). The duration of the closures has increased annually from 20 days in 2012 to 80 days in 2017 and there have been various timing strategies. The initial 20-day closure in 2012 alternated between gulfs to ensure that Southern Garfish maintained a presence on the local seafood market in response to concerns regarding the increase in inferior imported product. A 30% higher price was also achieved by separate non-overlapping closures by gulf. Fishers were required to nominate which gulf they would fish, to prevent the fleet moving to the adjacent 'open' gulf (McGarvey unpublished). This strategy was not maintained, and reverted back to a single closure in 2016 and 2017. The duration of the 2017 closure was 20 days longer in GSV (80 days) than SG (60 days) in line with their respective stock statuses (Steer et al. 2018). Fishers were not required to nominate a gulf in 2017, allowing GSV hauling net fishers access to NSG during their closed period.

The current stock assessment considered data collected to the end of December 2017. Unlike previous years, the timing of the fishing closures in 2017 extended into September to coincide with the natural dispersal of Garfish schools and to strategically reduce their vulnerability to hauling net fishers upon the reopening of the fishery. Catch rates are particularly high during late winter and early spring, and the extended winter closed periods could have biased catch rate as a measure of abundance in 2017. This bias impacts both raw catch rates and the fishery assessment model which divides each year into half-yearly (6-monthly) time steps, October-March and April-September, to account for the seasonal variation in the fishery. The 2017 extended closures most strongly impacted the last winter period of the assessment. In addition, model estimates in the final year of assessment are always less well determined because the youngest year class (or two) are not fully present in the legal stock, and their final numbers are best estimated once they have passed through the fishery. Consequently, the 2017 hauling net catch rate and model outputs should be cautiously interpreted and greater

emphasis placed on the 2016 model year. The integration of subsequent commercial catch and effort and aged market sample data extending into 2018 and beyond, in combination with catch rate standardisation, should resolve much of this winter closure impact in future assessments.

3.4.2. Determination of Stock Status

The status of each of the six South Australian Southern Garfish stocks was classified using the national stock status classification framework (Stewardson et al. unpub.), of which the terminology of the classifications was recently refined and amended in 2018 (Table 1-1). The assignment of status used a weight-of-evidence approach that included fishery performance indicators and associated trigger points that are specified in the Management Plan (PIRSA 2013). These include four general performance indicators from the commercial fishery statistics and four biological indicators that are based on output from the GarEst model or on the population age structures (Table 3-1).

The overall assessment of the Southern Garfish Fishery relies heavily on the data obtained from the hauling net sector which accounts for approximately 90% of the State-wide commercial catch. Similarly, the assessment places considerable emphasis on analysing catch and effort trends in the northern gulfs since commercial hauling net fishers are restricted to these regions. The current harvest strategy for Southern Garfish (PIRSA 2013) does not provide a pre-defined limit reference point that determines when the stock is depleted (i.e., recruitment impaired because the adult biomass no longer has the reproductive capacity to replenish itself). Instead, the performance of the fishery is assessed against modelled trends in the harvest fraction of the fishable biomass and egg production.

3.4.3. Stock Status

Northern Spencer Gulf Stock

Historically, NSG has been the most productive region for southern Garfish in South Australia and, in 2017, contributed to 55% of the State-wide catch. Annual catch in this region has been low, but relatively stable over the past three years. Annual total hauling net effort declined to its lowest level in 2013. Since then, it peaked at 2,716 fisher-days in 2015 and has remained above 2,400 fisher-days despite longer winter closures. Targeted catch rates in the dominant hauling net sector declined since the last stock assessment, but have remained relatively high. The decline in hauling net effort was not unexpected given the closures were strategically implemented to reduce fishing during the peak winter season.

Modelled estimates of exploitation rate and egg production constitute the primary performance indicators in this fishery. Over the past 15 years the annual estimates of harvest fraction

(including all sectors and gears) have trended favourably, declining at a rate of approximately 2% per year to a record low of 49.3% in 2016. Disregarding the uncertain 2017 estimate, annual harvest fraction has remained below the trajectory that targets a harvest fraction of ≤30% by 2020. Annual egg production has remained relatively stable at approximately 11% of an unfished stock over the last decade. It was identified in the previous stock assessment that the trend in egg production was unlikely to achieve its operational target of ≥30% by 2020 (Steer et al. 2016), and this assessment has reaffirmed this.

The continual increases in the minimum mesh size between 2012 and 2016 were specifically implemented to promote the recovery of the resource by reducing the mortality of small Garfish. It was expected that, over time, these changes would contribute to the accumulation of fishable biomass, concomitant improvement in recruitment and a population structure that consists of older, larger Garfish (Steer et al. 2011). Fishable biomass has increased since 2003, at a rate of approximately 4 $t.year^{-1}$, and this was most likely driven by declining exploitation rates. There was, however, little change in fishable biomass from 2014 until 2016, remaining at approximately 275 $t.year^{-1}$. Recruitment declined to a historical low of 2.5 million recruits in 2015, falling 21.4% below the trigger reference point. A substantial change in the age structure of the population was detected in this assessment. This shift was influenced by an absence of small Garfish being caught by commercial fishers as a function of increases in hauling net mesh size and extending the LML from 230 mm to 250 mm in 2015. The model computes fishable biomass as Garfish above 230 mm TL, to prevent the upward shift in legal minimum length from artificially reducing that stock indicator.

Despite catch rate complications in 2017, the exploitation rates have been favourably reduced and continue to track below the operational target trajectory. Egg production and fishable biomass have remained relatively stable since the previous stock assessment. There are also signs of an increase in the market catch age structure though how these carry through to the population is difficult to infer given the effect of recent increases in LML and mesh size. Targeted catch rates in the hauling net sector continue to be relatively high despite strong management intervention, whereas recruitment levels remain low but stable since 2000. It appears that the appropriate management is currently in place and the stock biomass is continuing to recover, so on this basis, the current status of the NSG Garfish stock remains classified as a **recovering** stock.

Northern Gulf St. Vincent Stock

Northern Gulf St. Vincent is the second most productive region in the State, accounting for 35% of the commercial catch. Historically, the performance of the fishery has followed a similar pattern to NSG. This is because they share similar environments, have experienced

comparable fishing pressure and were exposed to equivalent management strategies. However, a divergent trend was apparent in the last stock assessment, indicating that the concurrent level of fishing pressure in NGSV was at a point where the resilience of the Garfish stock had become compromised (Steer et al. 2016). This contributed to the stock being classified as recruitment overfished and led to increased management arrangements, with the fishing closure extending 20 days longer than NSG to span 80 days.

Since the previous assessment, targeted catch rates in NGSV have increased in the hauling net sector; harvest fraction has trended downwards; fishable biomass, egg production and recruitment have remained relatively stable; and older Southern Garfish are appearing in the population age structure. This indicates that current fishing mortality is constrained by management to a level that should allow the stock to recover from its recruitment impaired state; however, measurable improvements are yet to be detected. Furthermore, 2017 was the first year the fishing closure extended into October, increasing the opportunity for Southern Garfish schools to disperse, reducing their vulnerability to the hauling net fishers. Although adequate management may now be in place to recover the stock, more time is required to determine the relative effect of the 2017 closure, consequently, the current status of the NGSV Garfish stock remains classified as **depleted**.

Southern Spencer Gulf Stock

The relatively low levels of exploitation in SSG indicate that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. Furthermore, the above evidence indicates that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On this basis, the Southern Spencer Gulf biological stock is classified as **sustainable**.

Southern Gulf St. Vincent Stock

Prior to 1993, the commercial catch of Southern Garfish from southern Gulf St. Vincent was equally shared between the hauling net and dab net sectors. Since then, the hauling net sector declined due to a steady reduction in fishing effort. In 2006, dab nets became the dominant gear type. Hauling nets were removed from this region by implementation of a voluntary net buy-back scheme and spatial netting closures in 2005. Prior to this management restructure, the commercial catch of Southern Garfish from this region rarely exceeded 10% of the State-wide harvest, which after its implementation was reduced to <5%. Since 2005, total catch from this region has generally been <13 $t.yr^{-1}$. The history of this regional fishery is characterised by relatively low levels of fishing activity, commercial catch and extensive netting closures. Over the last three years, targeted dab net effort has declined to the lowest levels on record; however, their associated catch rates have remained relatively strong, indicating that the

current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. The above evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. Furthermore, the above evidence indicates that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On this basis, the Southern Gulf St. Vincent biological stock is classified as **sustainable**.

West Coast Stock

A small amount of Southern Garfish is landed by the commercial sector on the West Coast. Since 2005, total catch has been <10 $t.yr^{-1}$, which equates to <2% of the State-wide total annually. The implementation of commercial netting restrictions in this region has contributed to the continuous reduction in hauling net effort since the late 1950s (Steer et al. 2018). Targeted catch rates, by approximately 11 dab net fishers have remained high (>42 $kg.fisher\text{-}day.yr^{-1}$) since 2015, reflecting a relatively high abundance of Southern Garfish in the region. The above evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. Furthermore, the above evidence indicates that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On this basis, the West Coast biological stock is classified as **sustainable**.

South East Stock

Few Southern Garfish are landed by the commercial sector in the South East. During the 2000s, total catch has generally been <1.0 $t.yr^{-1}$, rarely exceeding 0.3% of the annual catch State-wide catch. The biomass of the stock is unlikely to be depleted at this level of exploitation, nor is recruitment likely to be impaired. On this basis, the South East biological stock is classified as **sustainable**.

3.4.4. Assessment Uncertainties

Assessing the status of the Garfish fishery through multiple lines of evidence that describe fishery performance from a combination of general and biological indicators is of considerable value. Tracking the relative trends in these indicators is particularly informative, and the trigger reference points serve as ‘precautionary limits’ that indicate further management action may be required. The hard-line reliance on some of the performance indicators and reference points, however, may need to be reviewed.

The reference period used to assess trends in recruitment which compares the latest estimate against the average of the previous five years appears too short. This is clearly evident for Northern Spencer Gulf where recruitment historically oscillated around 8 million recruits and was halved in 2000 and has since remained relatively stable. The contemporary five-year reference period does not adequately capture these early years and consequently constrains

the trigger reference points (±10%) to a narrow, impracticable range. Extending the reference period to account for all previous years, similar to that used to assess fishable biomass may provide more informative trigger reference points.

Tracking the mean proportion of three-year-old Garfish in the population over successive stock assessment cycles is misleading. Ideally, this metric was developed to assess the flow-on benefits of the imposed increases in hauling net mesh size which reduces the mortality of small (young) Garfish. The lack of young Garfish in the population due to poor recruitment, however, masks the interpretation of this performance indicator, as the proportion of older fish will be artificially inflated. So although it would appear that the population is responding well to the gear-based changes, the age structure may be altered by unfavourable recruitment of young fish into the population. It would be more informative to compare the model derived number of Garfish in each of the age classes over the successive assessment cycles, rather than their relative proportions.

A further significant uncertainty relates to the poor understanding of the temporal trends in catch and effort by the recreational sector. This sector's total harvest has 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 implications in the assessment of Southern Garfish and other MSF species. It also has implications for determining resource shares against prescribed allocations, which can ultimately lead to changes in the management of the resource among the fishing sectors. 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 the MSF.

3.4.5. Future Work

The current assessment of the Southern Garfish Fishery is entirely based on fishery-dependent data. The relative abundances and age structures of Garfish in areas not accessed by commercial fishers are unknown. Consequently, it is not known whether recruitment from outside key fishing areas may help explain the remarkable resilience of Garfish to prolonged and intense fishing pressure. A jointly funded (FRDC, PIRSA and industry) Southern Garfish project (FRDC Project 2015/018) began in July 2015, that aims to determine the relative abundance and population structure of Garfish outside of the spatially limited fishing areas to establish whether the commercial fishery data used to assess the resource accurately reflects the status of the broader resource.

South Australia's MSF is currently undergoing a strategic review with the principal aim to restructure the fishery in order to ensure its long-term sustainability and economic viability. Central to this reform will be a rationalisation of the fleet, establishment of management zones, and the introduction of quota-based fisheries management strategies. Given Southern Garfish is a primary species within the MSF, there is a requirement to consider new harvest strategies that integrate economic metrics to align with the overall reform of the multi-species, multi-gear, multi-sectorial fishery.

4. STOCK STATUS OF KEY MARINE SCALEFISH SPECIES

4.1. Introduction

Assessing the status of fish stocks can be challenging, particularly for lower value stocks that have limited data to inform quantitative assessments. In these situations, a weight-of-evidence approach is required to support stock determination (Flood et al. 2014, Stewardson et al. unpub.). With the exception of three primary MSF species (King George Whiting, Snapper and Southern Garfish) that have supporting sophisticated computer models capable of integrating fishery-dependent and -independent information to inform stock status, determining the status of the remaining species relies on the interpretation of fishery-dependent catch and effort data. Additional information about the species' stock structure, biology and management arrangements can contribute to the decision-making process.

This section of the report uses a weight-of-evidence approach to determine the stock status of 20 MSF species or taxonomic groups that are distributed across the 'Primary', 'Secondary' and 'Tertiary' species categories, as defined in the Management Plan (PIRSA 2013). For each species or taxon, the relevant biological information is presented, along with a description of the fishery; associated management regulations; interrogation of the fishery statistics at either the biological stock, State-wide or regional scale; assessment of the fishery against the general performance indicators; and a classification of stock status.

4.2. Method

Commercial catch and effort data are the primary data considered in this section. The appropriate data for each taxon were extracted from the SARDI Aquatic Sciences' commercial Marine Scalefish Fisheries Information System which includes data from the Marine Scalefish, Northern and Southern Zone Rock Lobster Fisheries. Data on Snapper catches by the Lakes and Coorong Fishery (LCF) and by-product of Southern Calamari by SA's prawn fisheries are also included. The data span a 33-year time series from 1984 to 2017 and were aggregated at either the biological stock, State-wide or regional scale to provide annual estimates of catch and effort for the main gear types (Table 4-1). The presentation of data was limited by constraints of confidentiality, i.e. data could only be presented for years when summarised from five or more fishers. Estimates of recreational catch obtained from three telephone/diary surveys (Henry and Lyle 2003, Jones 2009, Giri and Hall 2015) were also presented.

The performance of each stock was assessed by comparing the general performance indicators for 2016, against the trigger reference points calculated from the historical data (see Section 1.5).

Table 4-1. List of MSF categories and species/taxa considered in this section, the scale of their stock boundary, main gear types, and the resolution of catch and effort data (whether its targeted or total).

CATEGORY	SPECIES/TAXON	STOCK	GEAR	TARGETED OR TOTAL
PRIMARY	SNAPPER	Biological	Handline, Longline	Targeted
	KING GEORGE WHITING	Biological	Handline, Hauling Net, Gll Net	Total
	SOUTHERN CALAMARI	State-wide & Regional	Squid Jig, Hauling Net	Targeted
SECONDARY	YELLOWFIN WHITING	Biological	Hauling Net	Targeted
	WA SALMON	State-wide	Hauling Net	Targeted
	AUST. HERRING	State-wide	Hauling Net	Targeted
	VONGOLE	Biological	Cockle Rake	Total
	SNOOK	State-wide	Hauling Net	Targeted
	BLUE CRABS	State-wide	Crab Net	Targeted
	SAND CRAB	State-wide	Crab Net	Targeted
	YELLOWEYE MULLET	State-wide	Hauling Net	Total
	MULLOWAY	State-wide	Handline, Set Net	Total
	WHALER SHARKS	State-wide	Longline	Targeted
TERTIARY	OCEAN JACKETS	State-wide	Fish Trap	Targeted
	BLUETHROAT WRASSE	State-wide	Handline, Longline	Total
	SILVER TREVALLY	State-wide	Handline	Total
	LEATHERJACKETS	State-wide	Hauling Net	Total
	GUMMY SHARK	State-wide	Longline	Targeted
	SCHOOL SHARK	State-wide	Longline	Total
	RAYS & SKATES	State-wide	Hauling Net, Longline	Total
	CUTTLEFISH	State-wide	Squid Jig	Total
	BLACK BREAM	State-wide	All	Total

4.3. Results

4.3.1. SNAPPER (*Chrysophrys auratus*)

Biology

Snapper is a large, long-lived, demersal, finfish species that is a member of the family Sparidae. It is broadly distributed throughout the Indo-Pacific region including Australia, where its extensive distribution includes the coastal waters of the southern two-thirds of the 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 of at least 200 m. The stock structure for Snapper in Australian waters is complex, as there is considerable variation in the spatial scales over which populations are divisible into separate stocks (Fowler et al. 2016a; 2017). A recent otolith chemistry study has indicated that the South Australian population involves three stocks (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 (SE). The remaining waters of South Australia are divisible into the Spencer Gulf / West Coast Stock (SG/WCS) and Gulf St. Vincent Stock (GSVS) (Fowler 2016a, Fowler et al. 2017).

The recent otolith chemistry study provided information on the demographic processes responsible for the replenishment of the three South Australian 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 SE region, Snapper abundance varies episodically, as fish of a few years of age move westwards over hundreds of kilometers from PPB (Fowler et al. 2017). This relates to strong year classes in 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, as a consequence of variable larval survivorship (Fowler and Jennings 2003). Each is an important nursery area that acts as a source of emigration that replenishes regional populations in adjacent coastal waters. 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 SGSV. As such, regional population dynamics for South Australia's populations are primarily driven by temporally variable recruitment and subsequent emigration of fish from source to adjacent regional populations.

Fishery

Snapper is an iconic fishery resource in each mainland state of Australia (Kailola et al. 2003). In recent years, South Australia has been the dominant state-based contributor to the national total catches of both the commercial and recreational sectors (Fowler et al. 2016a, b). South Australia's Snapper fishery is geographically extensive and encompasses most of the State's coastal marine waters from the far west coast of the Eyre Peninsula to the SE, although the highest abundances and fishery catches have generally been in Spencer Gulf (SG) or Gulf St. Vincent (GSV).

Snapper is a primary target species of the commercial and recreational sectors of South Australia (PIRSA 2013). Licence 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). Their main fishing gear types for targeting Snapper are handlines and longlines, since using hauling nets to take Snapper was prohibited in 1993. Snapper is a favourite species of local and inter-state recreational fishers, many of whom target the large trophy fish that can be abundant in South Australia's coastal waters. 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 fishery survey, the relative contributions to total catch by the commercial and recreational sectors were 62% and 38%, respectively (Giri and Hall 2015, Fowler et al. 2016b).

The spatial structure of South Australia's Snapper fishery has experienced considerable change since 2007 (Fowler et al. 2016a). Historically, the highest catches and catch rates were made in SG, but these have declined considerably, whilst contemporaneously those in NGSV and the SE increased to unprecedented levels (Fowler et al. 2016a). These changes reflected independent demographic processes relating to recruitment and adult migration that occurred for each of the three SA stocks (Fowler 2016, Fowler et al. 2017). From about 2011 onwards, the changes caused considerable concern for managing the fishery that ultimately resulted in several levels of action. Numerous management changes were implemented to limit commercial catches whilst several FRDC-funded research projects were undertaken to identify the demographic processes responsible for the observed spatial changes (FRDC 2012/020, Fowler 2016), and to develop a fishery independent index of fishable biomass (FRDC 2014/019, Steer et al. 2017).

The harvest strategy for Snapper outlined in the current management plan (PIRSA 2013) reflects the changes and concerns about the challenges for fishery management since 2007. The harvest strategy involved a watching brief until 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. It proposed that the review of the management plan and harvest strategy that is scheduled for 2018 take into consideration, what should be, our enhanced understanding of the biology and population dynamics of Snapper that will result from these two projects. Then, the aim should be to provide greater certainty for sustainable management by developing a harvest strategy that involves explicit decision rules about management responses to fishery status that are based on the enhanced understanding of the biology and fishery.

Management Regulations

Regulations for the commercial sector of South Australia's Snapper fishery involve a suite of input and output controls (PIRSA 2013). The four commercial fisheries with access to Snapper each have limited-entry, i.e. the numbers of fishers who can target Snapper have been limited for many years. There is a legal minimum length of 380 mm 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. From December 2012, the number of hooks on set lines was reduced from 400 to 200 for fishers that operate within SG and GSV, but remains at 400 for other regions. There is also a 50 kg bycatch trip limit for the Commonwealth-managed Southern and Eastern Scalefish and Shark Fishery. Commercial handline fishers are limited with respect to the numbers of handlines and hooks per line that can be legitimately used. Also, a daily commercial catch limit of 500 kg was introduced for all South Australian waters. In December 2016, this catch limit was further reduced due to on-going concerns about stock status for the three South Australian Snapper stocks (Fowler et al. 2016a). For the SG/WC Stock, it was reduced to 200 kg with a limit of two days per trip. For the waters of GSV and also the SE region, the 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.

For the recreational sector, the minimum legal length of 380 mm 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 spatial structure and stock status (Fowler 2016, Fowler et al. 2016a). Up until this time, the bag and boat limits differed geographically. However, based on 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 380 - 600 mm TL, and bag limit of 2 fish and boat limit of 6 fish for fish >600 mm TL now apply for all state waters. For the Charter Boat sector, the bag and boat limits are currently similar to those of the general recreational sector, with a further complication that relates to numbers of passengers on board. When the number exceeds six passengers, the

catches are limited to 1 fish per day for those >600 mm TL, and either 3 or 5 for the 380 – 600 mm TL, depending on location.

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 15 December. 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 31 January, thereby conferring protection for the duration of most of the reproductive season. The four spatial closures in NSG and one in NGSV are circular with a 4-km radius from a fixed point.

Commercial Fishery Statistics

State-wide

Estimates of total State-wide commercial catch of Snapper show cyclical variation, with the cycles typically encompassing several years (Figure 4-1). Since 2003, i.e. the year that produced the lowest catch at the start of the most recent cycle, State-wide catch increased to a record level of 1,035 t in 2010, before declining by 67.2% to 339 t in 2017. Historically, handlines were the most significant gear type, and their catches largely accounted for the cyclical variation in total catch until 2008. However, longline catch increased marginally between 2005 and 2008, before increasing considerably until 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 2011, longline effort has declined, complementing the on-going, long-term declining trend for handline effort. As such, in 2016 and 2017, targeted fishing effort was the lowest yet recorded. State-wide handline CPUE showed cyclical variation, superimposed on a long-term increasing trend. However, since 2007 it has decreased considerably, concomitant with the decline in handline effort and the emerging dominance of longline fishing. Longline CPUE increased considerably between 2004 and 2015, before declining marginally in 2016 and then again in 2017.

The number of fishers from across all four commercial fisheries who reported taking Snapper, declined consistently from 403 in 1984 to 244 in 2000. It then stabilised for a number of years before again declining from 260 in 2010 to 177 fishers in 2017. The number who targeted Snapper varied similarly and fell from 201 in 2010 to only 143 in 2017.

In 2017, the commercial catch was dominated by the MSF which contributed 99% of the reported catch (Figure 4-2). Small catches were reported by the NZRLF and SZRLF, with none reported by the LCF.

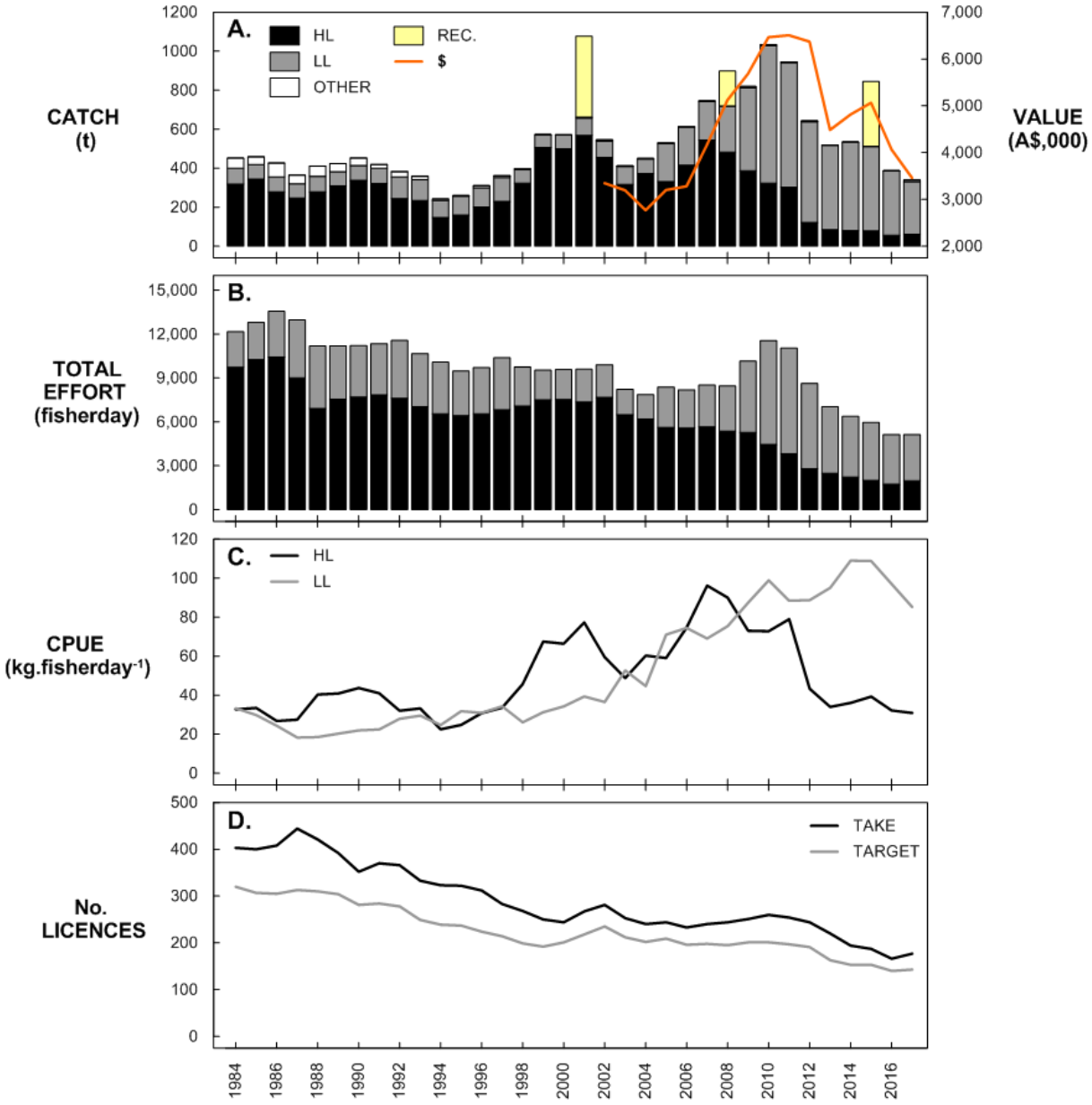

Figure 4-1. Snapper. Long-term trends in: (A) total catch of the main gear types (handline and longline), estimate of recreational catch and gross production value; (B) total effort for handline and longline; (C) total catch per unit effort (CPUE) for handline and longline; and (D) the number of active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

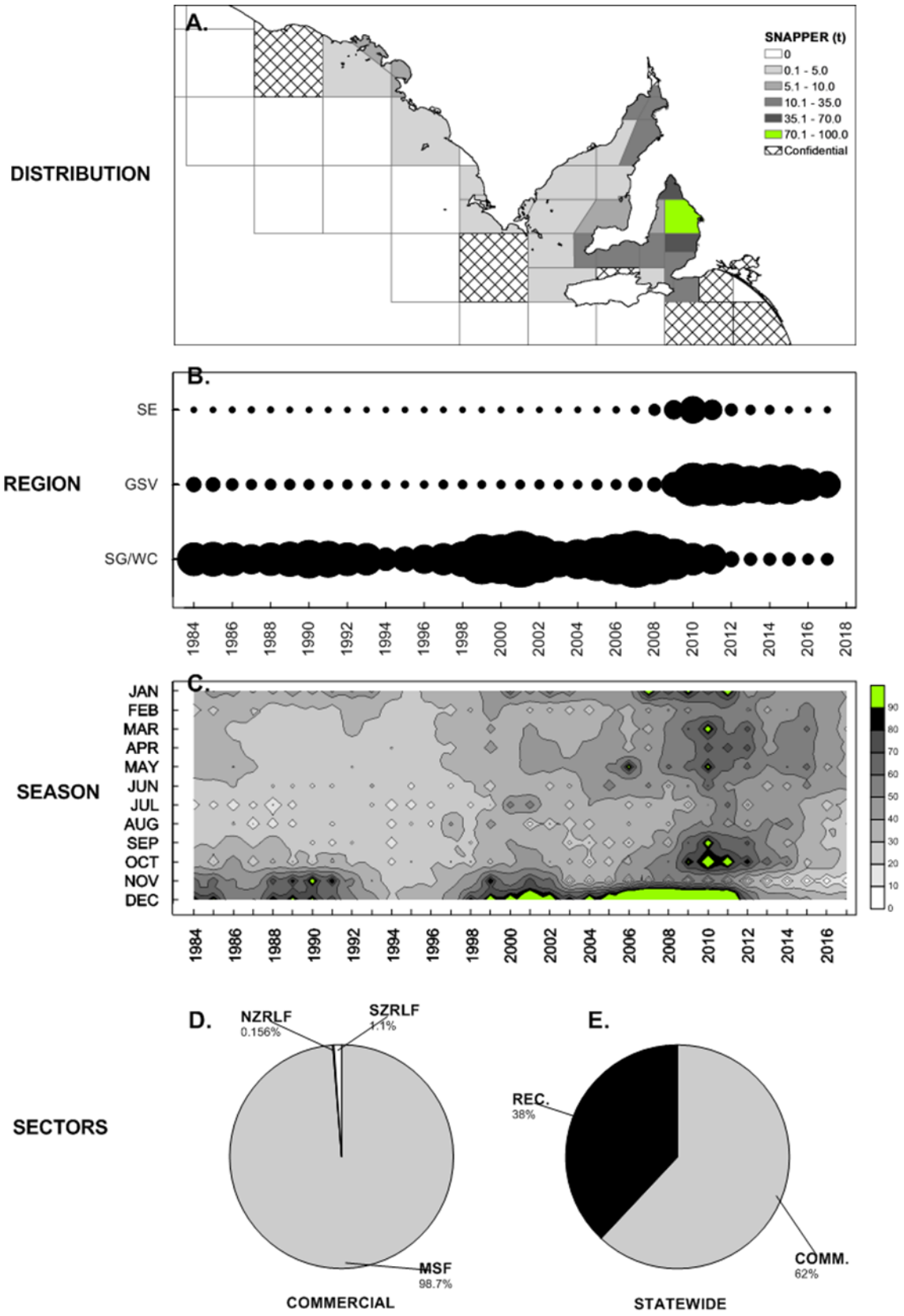

Figure 4-2. Snapper. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among biological stocks, (C) months of the year (t); (D) the proportion of catch distributed among the commercial sector in 2017; and (E) among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall 2015).

Regional

The relative contributions of the three stocks to total State-wide annual catches have changed considerably over time, relating to the change in spatial structure of the fishery. The SG/WC Stock provided the highest annual catches up to 2009, after which they declined and fell to their lowest levels between 2012 and 2017 (Figure 4-2). The catches from the GSV Stock were very low until around 2004. 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 2017. The catches from the South East region also increased considerably between 2007 and 2010, but have declined back to a low level in 2017.

Spencer Gulf / West Coast Stock

Annual catches from the SG/WC Stock 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 remained stable at a low level for the past five years. The lowest catch was 66.3 t taken in 2016, which increased marginally to 77.9 t in 2017.

Targeted handline catches have also varied cyclically over time. The highest of 516.1 t was taken in 2001, which fell to the lowest of only 28.4 t in 2017 (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 560 fisher days in 2017. Targeted handline CPUE has varied cyclically, but also shown a long-term increasing trend. Nevertheless, it peaked in 2007 at 138.2 kg.fisher-day^{-1}, but then declined steeply in 2012 to 64.6 kg.fisher-day^{-1}, before decreasing even further to 50.7 kg.fisher-day^{-1} by 2017. The number of licence holders who took and targeted Snapper declined slowly through the 1980s and 1990s but the rates of decline increased through the 2000s. Those taking Snapper with handlines fell from 206 to 100 between 1984 and 2017, and those targeting fell from 170 to 73.

Targeted longline catch for the SG/WC Stock was relatively flat from 1984 to 2004. It then increased and peaked at 154.1 t in 2006 before declining again. By 2017, it had fallen to only 38.2 t. Since targeted LL effort peaked at 2,578 fisher days 1997, it has also declined considerably. By 2016 it had fallen to 610 fisher days, before increasing marginally to 817 fisher days in 2017. Targeted LL CPUE peaked between 2004 and 2011, with the highest at 99.4 kg.fisher-day^{-1} in 2006. By 2017, it had dropped to 46.7 kg.fisher-day^{-1}. The numbers of fishers taking and targeting Snapper with longlines have declined steadily from 1988 to 2017. Those taking Snapper fell from 116 to 42 and those targeting it fell from 99 to 37 (Figure 4-3).

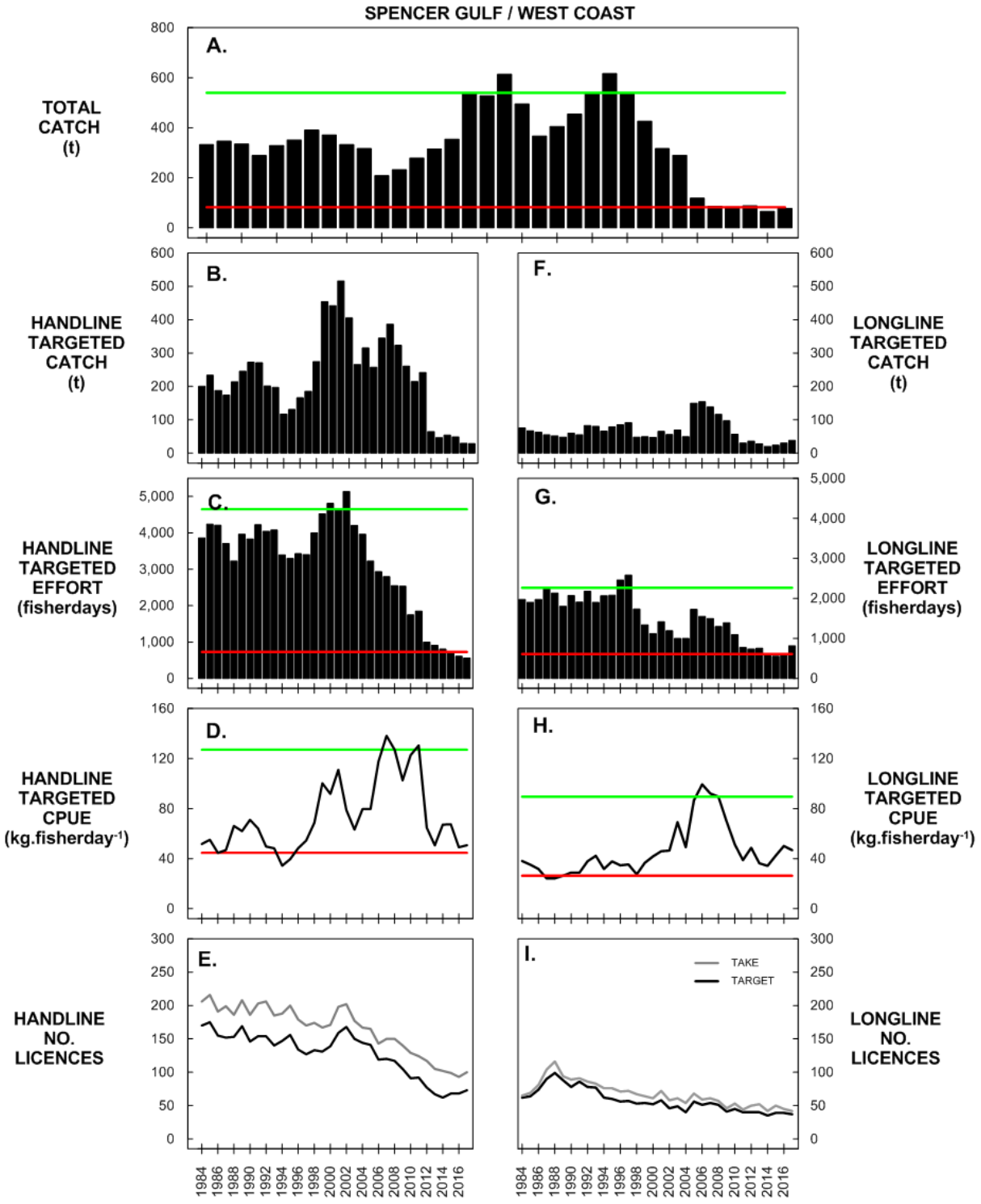

Figure 4-3. Key fishery statistics used to inform the status of the Spencer Gulf / West Coast stock of Snapper. Long-term trends in (A) total catch. (Left) trends in handline (B) catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. (Right)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

Gulf St. Vincent Stock

Historically, the GSV Stock produced relatively low catches from 1984 to 2006. However, from 2006 to 2010 total catch increased exponentially culminating in the record catch of 454.1 t (Figure 4-4). Catch has subsequently declined to 251.4 t in 2017.

Targeted HL catch has generally remained relatively low for this stock despite the high effort levels during the early 1980s. Targeted HL CPUE remained moderate even between 2006 and 2016, when effort was highest.

The LL fishery for the GSV Stock has largely accounted for the recent rapid increase in catches. Between 2008 and 2015, targeted LL catch increased from 46.7 t to 388.2 t. This increase was associated with a 334.1% increase in longline fishing effort from 657 to 2,852 fisher days. This has dropped back to 1,957 fisher days in 2017. Longline CPUE demonstrated a long-term increase primarily between 2000 and 2010, when it peaked at 145.7 kg.fisher-day^{-1}. It has subsequently declined to 109.7 kg.fisher-day^{-1} in 2017. The numbers of LL fishers who took and targeted Snapper peaked in 2012 at 66 and 64, respectively. These numbers have declined considerably to 40 and 37, in 2017. (Figure 4-4).

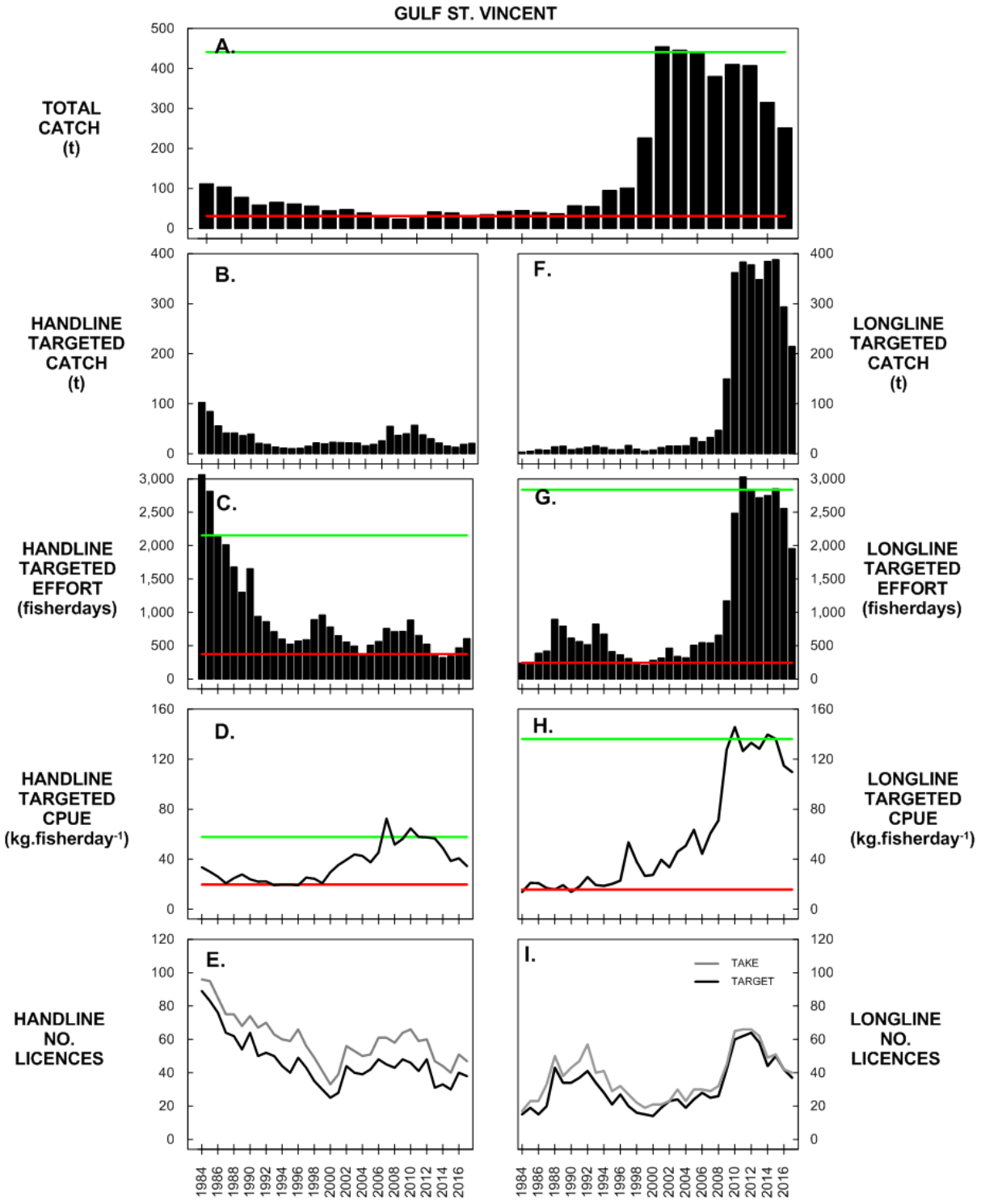

Figure 4-4. Key fishery statistics used to inform the status of the Gulf St. Vincent stock of Snapper. Long-term trends in (A) total catch. (Left) trends in handline (B) catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. (Right) trends in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

South East

The SE region has generally produced only marginal catches of Snapper (Figure 4-5). However, from 2006 to 2010 there was an exponential increase that culminated in a record catch of 258 t in 2010. Since then, it has fallen consistently and in 2017 total catch was 9.2 t.

Targeted HL catch in the SE has always been low. There was a minor increase between 2006 and 2009, which has subsequently declined. Such catches reflect low but variable fishing effort, which peaked at 300 fisher days in 2007. Targeted HL CPUE was generally <20 kg.fisher-day^{-1}, but increased from 2003 onwards, and was highest from 2006 to 2009. It peaked at 68.6 kg.fisher-day^{-1} in 2008. The numbers of HL fishers who took and targeted Snapper peaked in 2009, and have subsequently declined to just a few.

Targeted LL catches were always less than several tonnes.yr^{-1} up to 2007 after which there was a rapid increase to the maximum level of 239 t in 2010 (Figure 4-5). Subsequently it has declined to only 9.0 t in 2017. There was a considerable increase in targeted longline effort that peaked in 2010 at 2,608 fisher days, but which has subsequently declined to only 162 fisher days in 2017. Targeted CPUE also increased considerably between 2007 and 2010, peaking at 91.6 kg.fisher-day^{-1} before declining to 55.3 kg.fisher-day^{-1} in 2017. The numbers of LL fishers who took and targeted Snapper increased dramatically from 2005 and peaked in 2010 at 32 and 25, respectively. They declined to 8 and 6 in 2017.

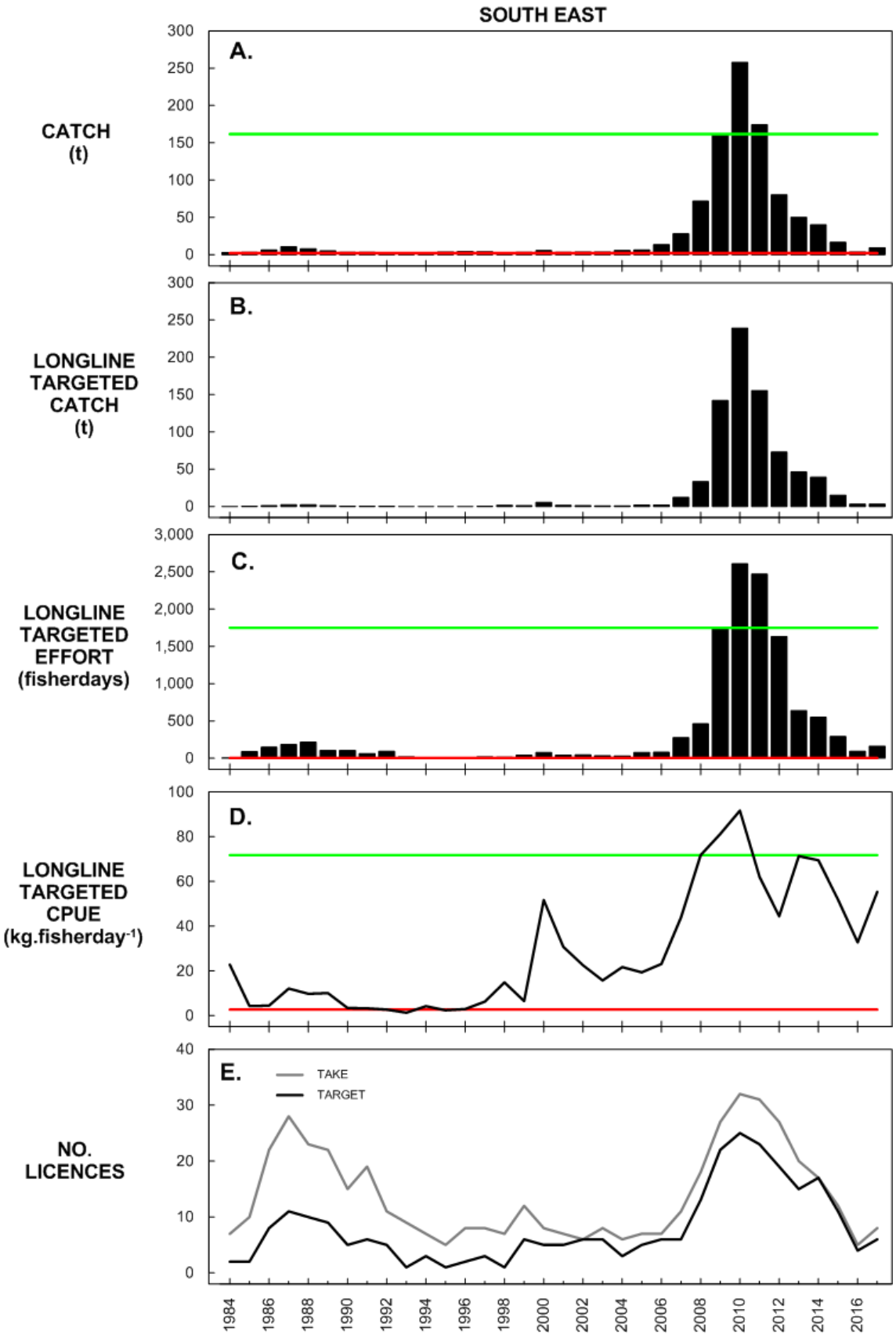

Figure 4-5. Key fishery statistics used to inform the status of the South East region of Snapper. Long-term trends in (A) total catch; (B) targeted longline catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Fishery Performance

The catch data from the four commercial fisheries from 2017 were compared against their allocations using Triggers 2 & 3 as reference points (Table 4-2). No trigger reference points were exceeded. The general fishery performance indicators were assessed for the SG/WC Stock, GSV Stock and the SE regional population. There were four breaches of trigger reference points, three of which were for the SG/WC Stock (Table 4-3). In 2017, total catch was the 2nd lowest yet recorded, whilst there had been five years of declining handline effort to the lowest recorded level. There were no breaches for the GSV Stock. For the SE in 2017, targeted handline effort was the lowest yet recorded.

Table 4-2. Comparisons of percentages of commercial catch of Snapper taken by the fisheries, with their allocations and trigger limits specified in the Management Plan (PIRSA 2013). MSF – Marine Scalefish, SZRL – Southern Zone Rock Lobster, NZRL – Northern Zone Rock Lobster, LCF – Lakes and Coorong. Green colour – allocation not exceeded, red colour – allocation trigger activated.

COMMERCIAL ALLOCATION	MSF 97.50%	SZRL 1.78%	NZRLF 0.68%	LCF 0.04%
TRIGGER 2	n/a	2.68%	1.30%	0.75%
TRIGGER 3	n/a	3.58%	2.00%	1.00%
2013	96.50%	3.10%	0.40%	0.10%
2014	98.90%	0.70%	0.10%	0.20%
2015	99.40%	0.50%	0.20%	-
2016	99.90%	0.10%	0.10%	-
2017	98.70%	1.10%	0.20%	-

Table 4-3. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the biological stock level for Snapper in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	SG/WCS	GSVS	SE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	2nd LOWEST	×	×
	G	Greatest % interannual change (+/-)	×	×	×
	G	Greatest 5 year trend	×	×	×
	G	Decrease over 5 consecutive years	×	×	×
TARGET HANDLINE EFFORT	G	3rd Lowest / 3rd Highest	LOWEST	×	2nd LOWEST
	G	Greatest % interannual change (+/-)	×	×	×
	G	Greatest 5 year trend	×	×	×
	G	Decrease over 5 consecutive years	✓	×	×
TARGET HANDLINE CPUE	G	3rd Lowest / 3rd Highest	×	×	×
	G	Greatest % interannual change (+/-)	×	×	×
	G	Greatest 5 year trend	×	×	×
	G	Decrease over 5 consecutive years	×	×	×
TARGET LONGLINE EFFORT	G	3rd Lowest / 3rd Highest	×	×	×
	G	Greatest % interannual change (+/-)	×	×	×
	G	Greatest 5 year trend	×	×	×
	G	Decrease over 5 consecutive years	×	×	×
TARGET LONGLINE CPUE	G	3rd Lowest / 3rd Highest	×	×	×
	G	Greatest % interannual change (+/-)	×	×	×
	G	Greatest 5 year trend	×	×	×
	G	Decrease over 5 consecutive years	×	×	×

Stock Status

Spencer Gulf / West Coast Stock

The last stock assessment for Snapper considered commercial fishery statistics up to 2015, when the SG/WC Stock was assigned the status of transitional-depleting (Fowler et al.

2016a,b). This reflected that the biomass in the three component regions of NSG, SSG and the WC were declining, based on decreasing trends in commercial catches, effort and CPUE. This broad-scale decline in biomass was thought to reflect poor recruitment since 1999 into the main nursery area in NSG (Fowler et al. 2016a, 2017). This poor recruitment to NSG meant that emigration to and the replenishment of populations of SSG and the WC have been relatively low throughout the 2000s (Fowler et al. 2016b). In 2016, despite the below-average recruitment to the SG/WC Stock, there remained some uncertainty about whether the stock was recruitment overfished. This was because regional exploitation rates had fallen considerably due to reductions in commercial fishing effort, whilst management changes had been implemented between 2012 and 2016 to reduce the exploitation rate and to facilitate reproductive output and recruitment.

In the assessment of stock status that considered fishery data for the SG/WC Stock up to December 2016 (Steer et al. 2018), there was little evidence for change in the stock biomass and so the status of transitional depleting was retained. Now, considering the commercial fishery statistics up to December 2017, again there is no indication of improvement, with all estimates of catch and gear-specific effort and CPUE remaining close to historically low levels. Furthermore, in 2013, the daily egg production method was used to provide a fishery-independent estimate of the spawning biomass for a region of SG that encompassed NSG and part of SSG (Steer et al. 2017). The estimated biomass of 280 t is very low. It is considerably lower than the catches that were recorded during the early 2000s, and an order of magnitude less than the estimate of biomass for the GSV Stock. In 2015, a further estimate of spawning biomass using the daily egg production method was 592 t. Although, in the latter year, the methodology was less reliable than for 2013. Nevertheless, the estimate was still considerably lower than that for the GSV Stock in the same year.

Overall, for the SG/WC Stock, the low estimates of catch, effort and CPUE and fishery independent estimates of fishable biomass indicate that the biomass is considerably depleted. Furthermore, the age structures through the 2000s indicate the likelihood that recruitment has been impaired. As such the status for this stock is changed to **depleted**.

Gulf St. Vincent Stock

The GSV Stock involves the two regions of NGSV and SGSV. In 2016, in the last stock assessment, this stock was assigned the status of ‘sustainable’ (Fowler et al. 2016a, b). This reflected the strong performance of the fishery in NGSV from about 2008 onwards that indicated a substantial increase in biomass. For example, in 2014, an estimate of spawning biomass using the daily egg production method was 2,780 t, i.e. ten times that for the SG/WC Stock (Steer et al. 2017). This high biomass related to the recruitment of several strong year

classes to NGSV throughout the 2000s, which augmented several strong year classes from the late 1990s (Fowler et al. 2016a). The high biomass in NGSV sustained the highest catches ever recorded for any SA region throughout the history of the fishery. SGSV supported a much lower biomass through this time, but also showed evidence of an increase in biomass up to 2012.

By December 2016, the fishery statistics were showing some declines, suggesting that the high biomass had started to decrease. Nevertheless, the indicators remained very high compared to historical values. As such, the stock status of sustainable was retained (Steer et al. 2018). By December 2017, the fishery statistics had decreased even further, consistent with further decline in the biomass. Nevertheless, the estimates of the performance indicators in 2017 still remained high compared with historical values. Furthermore, between 2012 and 2016, management changes were implemented to restrict the fishing pressure on the standing stock and to maximize the opportunity for reproduction and recruitment. The above evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. As such, the biological stock is classified as **sustainable**.

Western Victorian Stock

The SE population of Snapper is part of the larger Western Victorian Stock. This regional population is sustained through emigration of adult fish from the main nursery area located approximately 600 km to the east in Port Phillip Bay, Victoria (Fowler et al. 2017). In 2016, the stock was assigned the status of 'sustainable', reflecting strong fishery performance in PPB and recent above-average recruitment of Snapper to that nursery area (Hamer et al. 2016). These results suggest that the stock is not overfished nor is the current level of fishery performance likely to cause it to become overfished. Despite the very low recent catches, effort and CPUE recorded for the fishery in the SE, it is part of the larger **sustainable** stock.

4.3.2. KING GEORGE WHITING (*Sillaginodes punctatus*)

Biology

King George Whiting (*Sillaginodes punctatus*) is one of the most valuable, coastal marine finfish species of southern Australia. It occurs in coastal and shelf waters, distributed from Sydney (NSW), around the southern coastline, and to Perth in Western Australia (WA) (Kailola et al. 1993). The species is particularly significant in South Australia (SA), the geographic centre of its distribution, where abundances and fishery productivity are highest.

King George Whiting has a complex life history that involves ontogenetic changes in habitats that are linked by movement at different life history stages (Fowler and Jones 2008). In SA, spawning occurs during autumn and early winter at off-shore reefs, shoals and mounds in relatively deep water in exposed localities that experience medium/high wave energy (Fowler et al. 2000a,b, 2002). The eggs and larvae are advected throughout a prolonged pre-settlement duration to nursery areas in shallow, protected bays located in the northern gulfs or those on the west coast and Kangaroo Island (Fowler and Short 1996, Fowler et al. 2000b). Juvenile fish grow and develop in the vicinity of these nursery areas. When they reach approximately three-years of age, those in the northern gulfs undertake significant movement southwards, whilst those in other bays move off-shore. Such movement ultimately replenishes the populations of older fish on the spawning grounds (Fowler et al. 2000b, 2002). The movement results in a significant ontogenetic shift from relatively protected shallow waters that support extensive meadows of seagrass to more exposed, deeper water and reef habitat. As a consequence, population size and age structures of King George Whiting vary geographically (Fowler et al. 2000a). The northern gulfs and inshore bays support populations with only a few age classes, whereas in the south the populations involve multiple age classes with fish up to around 20 years of age. The spawning grounds and nursery areas for King George Whiting can be separated by up to several hundred kilometres. As such, the processes of larval advection and adult movement are significant obligate steps that link the different life history stages and the habitats they occupy (Fowler et al. 2002).

The stock structure for King George Whiting throughout its range in southern Australia remains unresolved due to uncertainty about the connectivity amongst regional populations and the lack of clear phylogeographic genetic structure (Haigh and Donnellan 2000). A recent genetic study indicated that the SA and Victorian populations were genetically similar, but were distinct from those in Western Australia and also in Tasmania (Jenkins et al. 2016). The similar genotypes between the SA and Victorian populations are consistent with the results from hydrodynamic modelling and otolith chemistry analyses which indicate that the Victorian populations may be replenished from spawning grounds located in SA, through the eastward

advection of eggs and larvae (Jenkins et al. 2000, 2016). The genetic homogeneity of the SA regional populations indicate that there must be at least a small degree of mixing between them. Nevertheless, for stock assessment and management purposes three stocks are recognised based largely on the locations of and connectivity between nursery areas and spawning grounds (Fowler et al. 1999, 2000b). These stocks are: west coast of Eyre Peninsula (WC); Spencer Gulf (SG); and Gulf St. Vincent / Kangaroo Island (GSV/KI) (Fowler and McGarvey 2000, Fowler et al. 2014).

Fishery

King George Whiting is a 'primary' species of SA's Marine Scalefish Fishery (PIRSA 2013), that is heavily targeted by both the commercial and recreational sectors (Steer et al. 2018). Several life history stages are targeted: young, immature adults in the northern gulfs; the immature fish as they travel southwards; and mature adults on the spawning grounds. As such, during their ontogenetic development, the fish run the gauntlet of fishing lines and nets that are used to target them in different habitats. Because of this, SA's King George Whiting fishery is described as a 'gauntlet' fishery.

Three different commercial fisheries have access to SA's King George Whiting stocks, i.e. the Marine Scalefish Fishery (MSF), and the Northern Zone and Southern Zone Rock Lobster Fisheries (NZRLF, SZRLF) (PIRSA 2013). Historically, this species was the most valuable for the commercial sector, but since 2007/08 its total value fell below that of Snapper and more recently below that of Southern Calamari. Nevertheless, King George Whiting remains the highest value species by weight. The main gear types used in the commercial fishery to target it are hand lines, hauling nets and gill nets. For the recreational sector, this is an iconic species that is heavily targeted with hook and line, principally from boats.

When the commercial Management Plan was developed (PIRSA 2013), the three King George Whiting stocks were classified as 'sustainably fished' (Fowler et al. 2011). As such, the primary objective of the harvest strategy at that time was to maintain this positive status and fishery performance. Nevertheless, in the subsequent stock assessment (Fowler et al. 2014), the statuses of the two gulf stocks, i.e. SG and GSV/KI were changed to 'transitional-depleting'. In response, the recent focus has been to recover the status of both stocks, whilst maintaining the sustainable status of the West Coast Stock. To this end, significant management changes were implemented in December 2016.

Management Regulations

Regulations for managing South Australia's King George Whiting fishery involve a complex suite of input and output controls (PIRSA 2013). For the commercial sector, the principal means of effort control is 'limited entry', and the number of licence holders who operate in the

MSF has declined considerably over time. Furthermore, there is a complexity of regulations that apply to the gear that are used to take King George Whiting. These restrict the numbers of hand lines and hooks that can be legitimately used, and for hauling nets and gill nets involve gear specifications and spatial and temporal restrictions. The take of the recreational sector is managed through size, bag and boat limits and spatial restrictions.

The management regulations for King George Whiting were recently enhanced following the transitional depleting status that was assigned to the two stocks in the South Australian gulfs (Fowler et al. 2014), and the ensuing extensive review of management arrangements that took place throughout 2016. The considerable changes that were implemented in December 2016 were: (1) an increase in legal minimum length (LML) from 31 to 32 cm TL for all waters east of longitude 136°E, whilst the LML remains at 30 cm TL in West Coast waters; (2) a State-wide reduction in the recreational bag limit from 12 to 10 legal-sized fish per person, with the boat limit reduced from 36 to 30 fish per boat; (3) a possession limit of either 72 fish or 10 kg of fillets or 36 fish and up to 5 kg of fillets; (4) and, introduction of a spatial spawning closure in Investigator Strait and southern Spencer Gulf from 1st to 31st May that was first implemented in 2017.

Commercial Fishery Statistics

State-wide

There has been a long-term declining trend in total commercial catch of King George Whiting. This involved a 68.4% reduction from the highest catch of 776 t recorded in 1992 to the lowest of 245 t recorded in 2017 (Figure 3-1). In comparison, the annual estimates of catch from the recreational sector of 382 t in 2000/01, 324 t in 2007/08 and 367 t in 2013/14 have been relatively consistent (Fowler et al. 2014, Giri and Hall 2015).

Hand lines have always been the dominant gear used to target King George Whiting by commercial fishers. Between 1984 and 1999, hand line catches were around 400 t.yr^{-1} (Figure 4-6). Subsequently, hand line catch fell by 49.0% from 431 t in 1999 to 220 t in 2017. The catch by hauling nets has fallen by 93.2% from the record of 266 t in 1992 to only 35 t in 2017. The total State-wide gillnet catch has always been less than 50 t.year^{-1}, and fell to 6 t in 2017. The value of the annual commercial catch of King George Whiting has varied considerably over time (Figure 4-6). It fell from $5.5 million in 2003 to $3.6 million in 2005, and was $4.4 million in 2017.

Hand line effort on King George Whiting declined from 30,732 fisher days in 1992 to 10,900 fisher days in 2017, i.e. a reduction of 64.5% over 25 years (Figure 4-6). This declining trend relates, at least partly, to the reduction in number of licence holders in the commercial fishery. Between 1984 and 2017, the number who reported taking KGW fell from 646 to 226, and those

targeting KGW from 592 to 198 (Figure 4-6). The rate of decline accelerated after 1994 when the licence amalgamation scheme was introduced and again in 2005 through the net buyback.

The estimates of State-wide hand line CPUE have been variable, but have trended upward over time, although divisible into several time periods (Figure 4-6). It increased from 1984 to 1991, but then declined over several years to 1995. It then increased considerably until 1999, after which there was a noticeable decline to 2002. Subsequently, hand line CPUE gradually increased to the highest recorded level in 2016, before decreasing marginally in 2017.

The State-wide commercial catches are divisible into those from the three component stocks, which have all declined over time (Figure 4-7). Through the 1980s and 1990s, the SG Stock provided the highest catches. Through the 2000s, they fell below those of the WC Stock, which has continued to produce the highest catches. Those from the GSV/KI Stock have always been the lowest of the three stocks.

Seasonal variation in catches of King George Whiting have been a consistent feature (Figure 4-7). They have generally been higher through the cooler months and lower during summer. In 2017, the commercial catch was dominated by that from the MSF Fishery, with a relatively small contribution from the NZRLF (Figure 4-7). In 2013/14, the recreational sector accounted for 56.6% of the total catch, i.e. a considerably higher percentage than that of the commercial fishery.

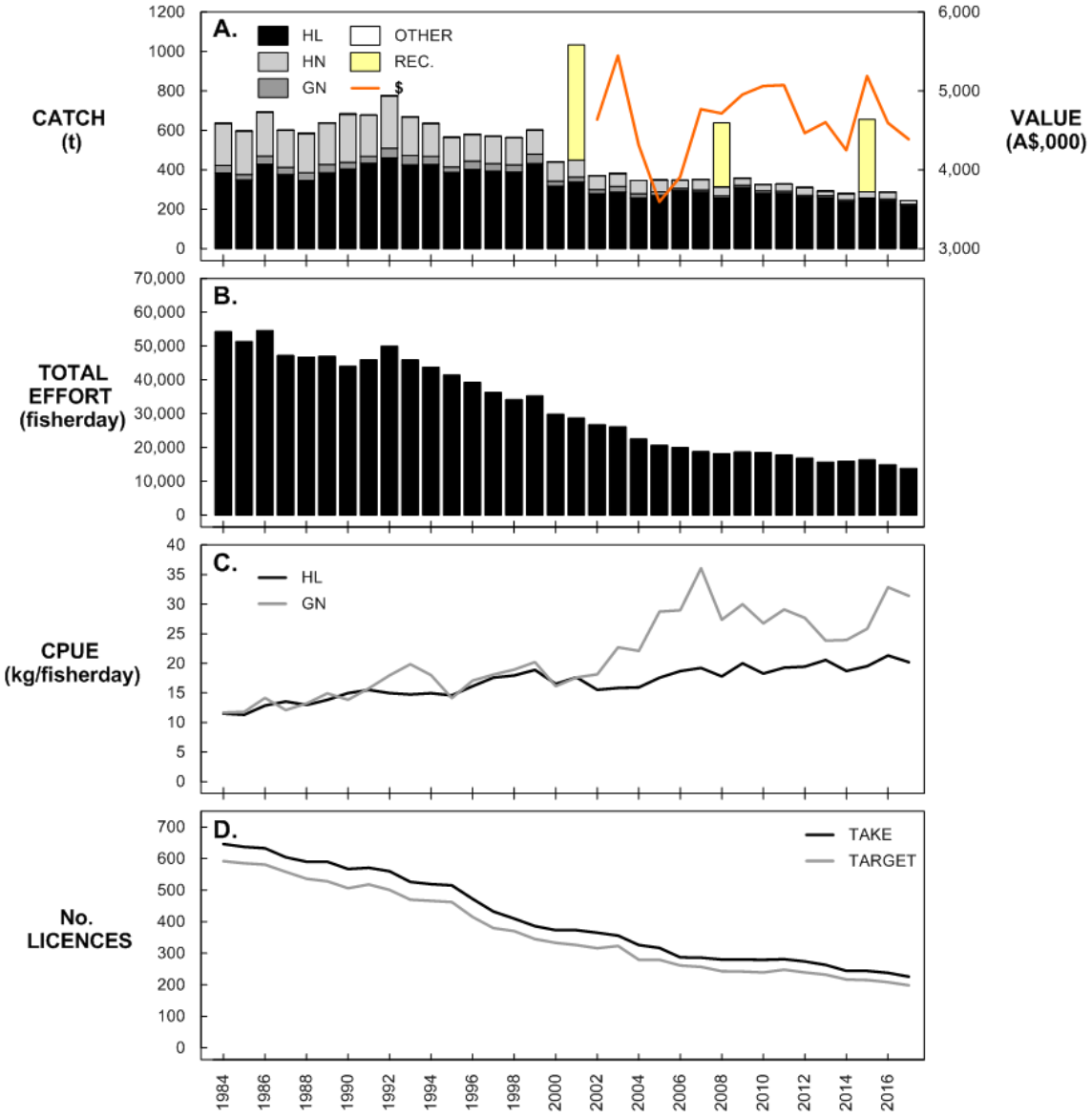

Figure 4-6. King Geroge Whiting. Long-term trends in: (A) total catch of the main gear types (handline, hauling net and gill net), estimate of recreational catch and gross production value; (B) total effort; (C) total catch per unit effort (CPUE) for handline and longline; and (D) the number of active licence holders taking or targeting the species.

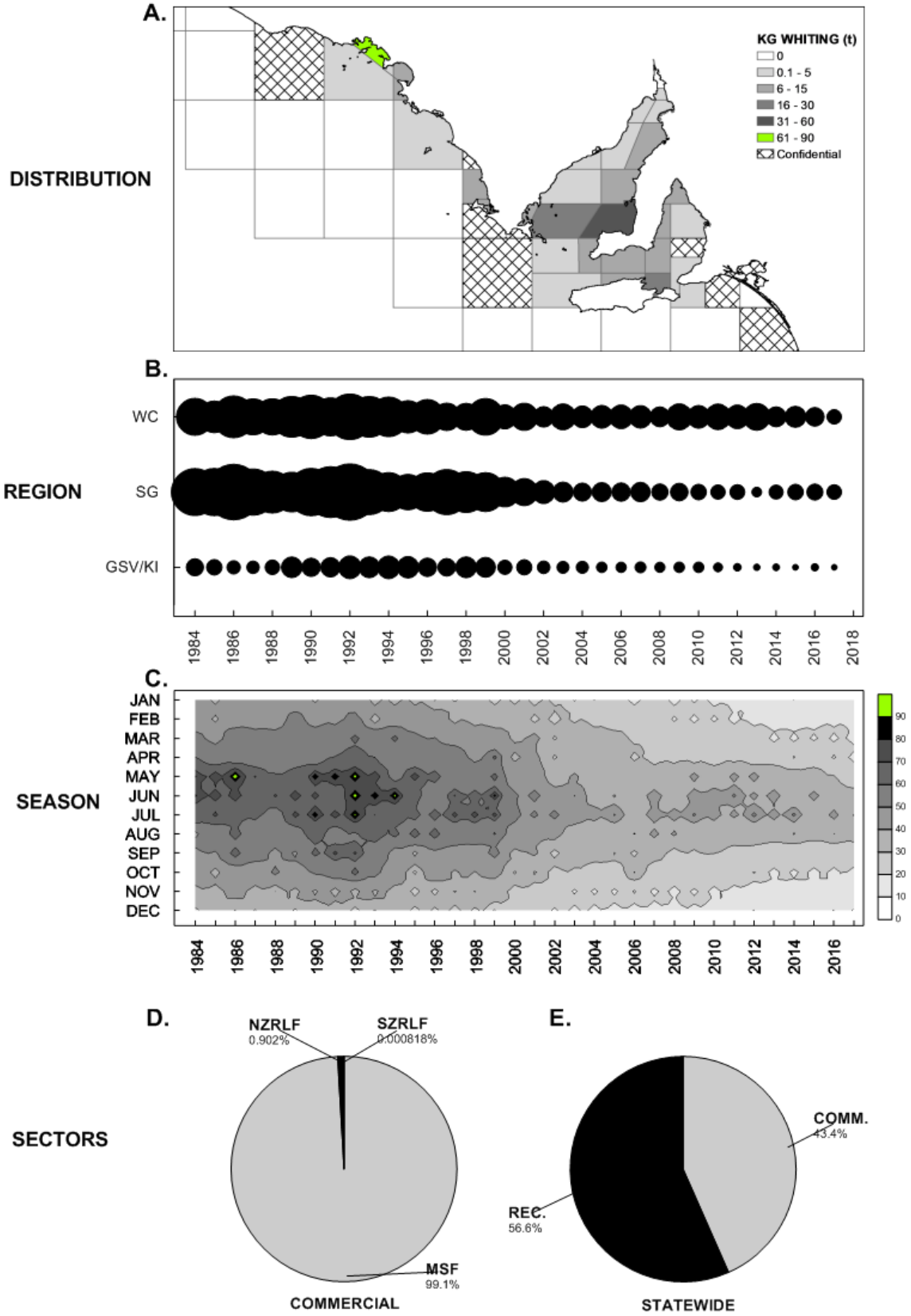

Figure 4-7. King George Whiting. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among biological stocks, (C) months of the year (t); (D) the proportion of catch distributed among the commercial sector in 2017; and (E) among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

Regional

West Coast Stock (WCS)

Annual commercial catches for this stock increased between 1984 and 1992 when the maximum of 283 t was taken (Figure 4-8). From then, total catch gradually declined by 53% to only 134 t in 2002. Subsequently, it increased to 171 t in 2013, before falling to 99 t in 2017, which was the lowest ever recorded.

In all years, handlines were the dominant gear. Handline catches dropped from the high of 218 t in 1999 to 98.2 t in 2017 (Figure 4-8). Handline effort has declined relatively consistently from the maximum of 15,738 fisher-days in 1984 to the lowest of 4,391 fisher-days in 2017. In contrast, handline CPUE has increased considerably in several multi-year steps. It increased between 1987 and 1992 before declining considerably to 1995. It increased again to 1999 before falling from 20.8 to 15.6 kg.fisher-day^{-1} in 2002. Subsequently, CPUE increased to the record value of 25.1 kg.fisher-day^{-1} in 2013. Although it dropped considerably in 2014, it recovered to the second highest level of 24.4 kg.fisher-day^{-1} in 2016, before declining to 22.4 kg.fisher-day^{-1} in 2017. The number of fishers taking and targeting King George Whiting from the WC Stock with handlines have both declined considerably between 1984 and 2017 (Figure 4-8). The former fell from 194 to 84, whilst the latter declined from 193 to 82.

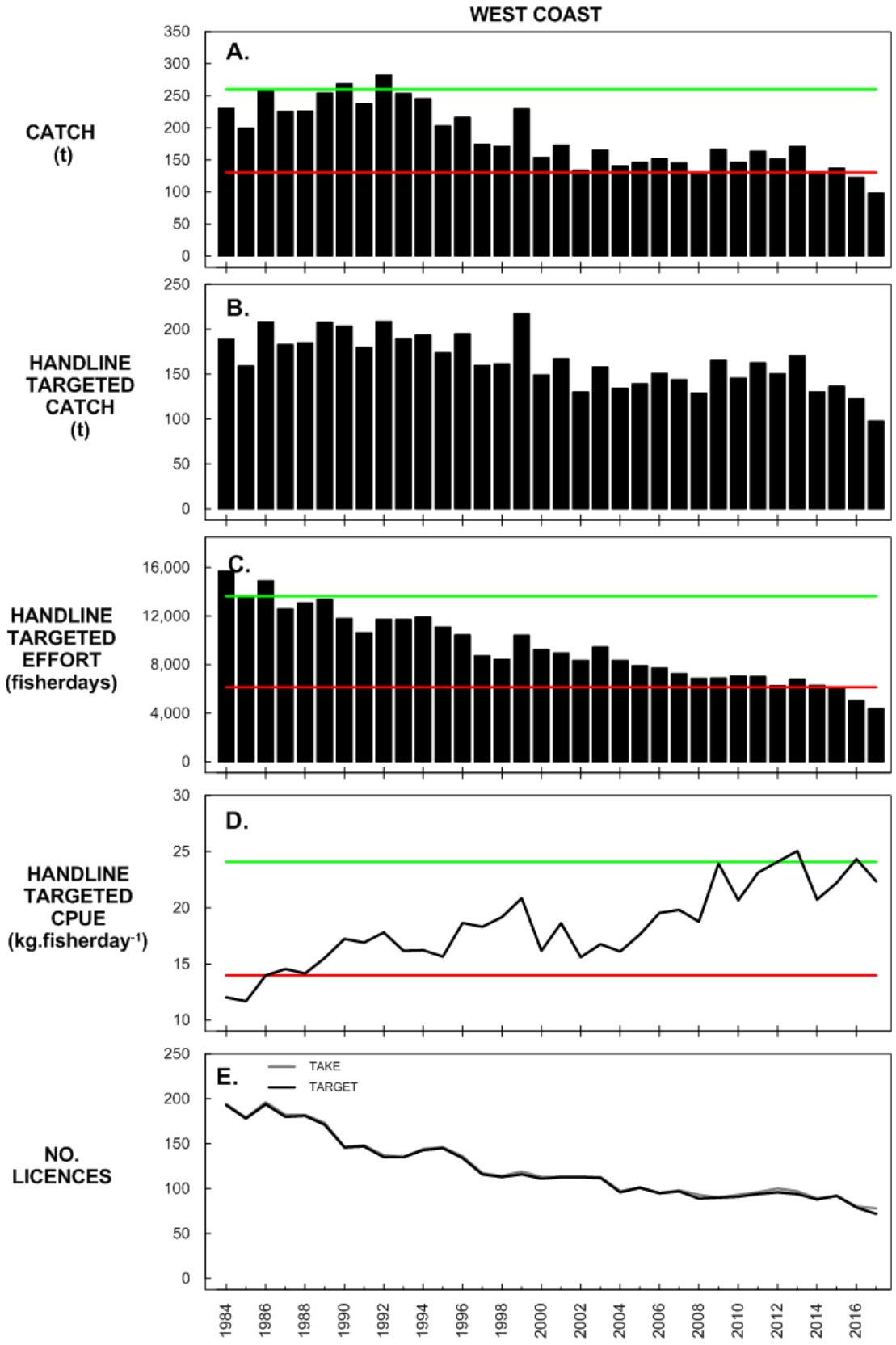

Figure 4-8. Key fishery statistics used to inform the status of the West Coast stock of King George Whiting. Long-term trends in (A) total catch; (B) targeted hand line catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Spencer Gulf Stock (SGS)

Total commercial catch of King George Whiting from Spencer Gulf varied cyclically between 1984 and 1997 (Figure 4-9). From the latter year until 2004, it declined by 57.1% and then to 2013 declined by a further 44.8% to the lowest recorded amount of 70.6 t. From 2013 to 2017, total catch increased to 99.5 t.

Total handline catch has been considerably lower through the 2000s then through the 1980s and 1990s (Figure 4-9). It was lowest at 57 t in 2013 before increasing by 54% to 88 t in 2017. Handline fishing effort was variable between 1984 and 1992, before declining by 57.8% in 2004. It was then relatively stable for several years, until declining in 2013 to the lowest level of 3,414 fisher-days, but has since increased by 27.6% to 4,359 fisher-days in 2017. Handline CPUE showed a long-term increase although with clear cyclical variation for which the cycles typically involved several years when catch rates increased quickly, followed by a number of years when they declined. From 2003 to 2007, catch rate increased by 33.1% from 15.4 to 20.5 kg.fisher-day^{-1}. However, from 2007 to 2013, there was the longest period of decline during which it dropped by 18.0% to 16.8 kg.fisher-day^{-1}. Nevertheless, between 2013 and 2016, it increased again, attaining the highest recorded level of 21.0 kg.fisheryday^{-1}, before declining marginally to 20.2 kg.fisher-day^{-1} in 2017. The number of licence holders who took King George Whiting with handlines fell from 237 in 1984 to 110 in 2017 (Figure 4-9), whilst those targeting it fell from 233 to 109.

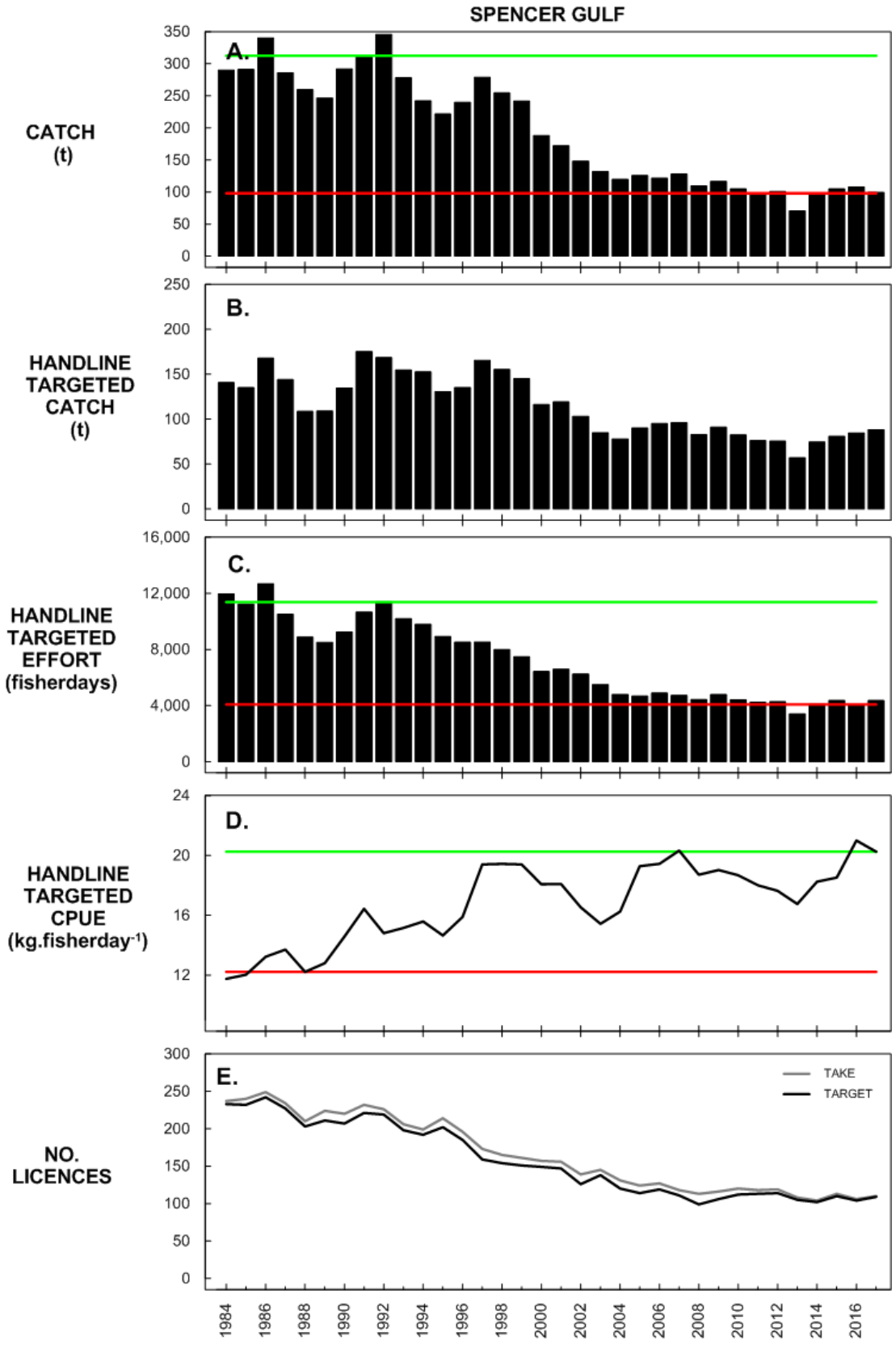

Figure 4-9. Key fishery statistics used to inform the status of the Spencer Gulf stock of King George Whiting. Long-term trends in (A) total catch; (B) targeted hand line catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Gulf St. Vincent/Kangaroo Island Stock (GSV/KIS)

Total commercial catch from this stock has been consistently lower than for the other two stocks and has varied through several different periods (Figure 4-10). After declining between 1984 and 1988, it increased to the record level of 147.3 t in 1992. Subsequently, it declined to the lowest annual catch of 46.2 t in 2017.

Handline catch largely accounted for the variation in total catch, being highest between 1992 and 1995 before declining to the lowest level of 32 t in 2013. It subsequently increased by 19% to 38 t in 2016, but has fallen to 33 t in 2017. Handline fishing effort reached its highest level of 7,655 fisher days in 1992 (Figure 4-10). It subsequently declined by 54.5% to 3,484 fisher-days in 2000 and then remained relatively flat to 2009, after which there was further decline to 2,137 fisher days in 2017. Between 1984 and 2007, handline CPUE was variable but nevertheless increased by 65.8% (Figure 4-10). Over the following five years, it declined by 20% to the low value of 12.7 kg.fisher-day^{-1} in 2012. It has subsequently increased by 22% over several years to 15.6 kg.fisher-day^{-1} in 2017. The numbers of licence holders who captured or targeted King George Whiting with handlines have declined considerably. In 1984, a total of 135 fishers took King George Whiting, which fell to 50 in 2017 (Figure 4-10). The numbers who targeted this species with handlines fell from 131 to 47 over the same period.

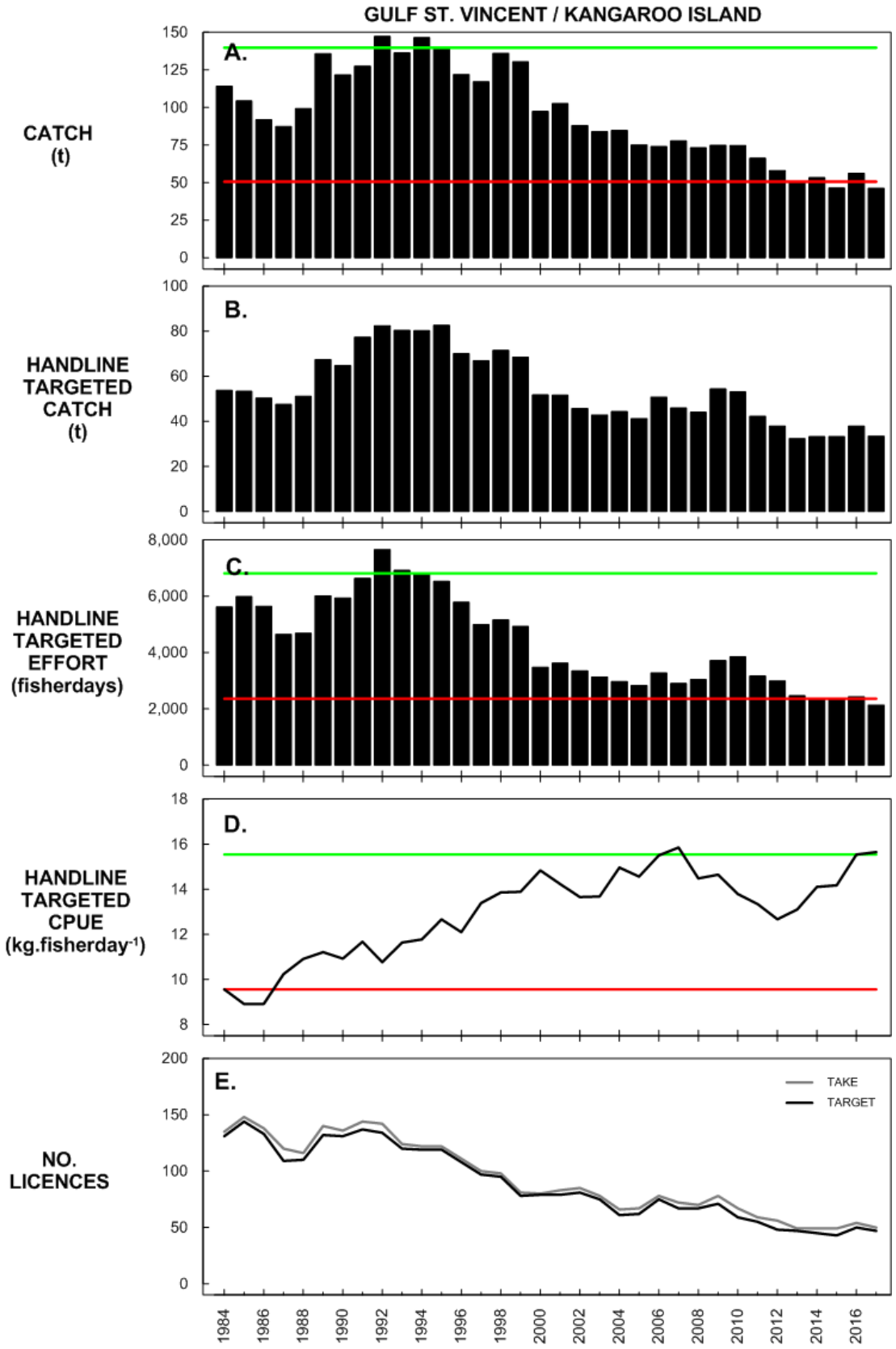

Figure 4-10. Key fishery statistics used to inform the status of the GSV/KI stock of King George Whiting. Long-term trends in (A) total catch; (B) targeted hand line catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Fishery Performance

The catch data from the four commercial fisheries from 2017 were compared against their allocations using Triggers 2 & 3 as reference points. No trigger reference points were exceeded (Table 4-4). The general fishery performance indicators were assessed at the State-level and for each of three stocks. There were nine breaches of trigger reference points that were quite consistent at the two spatial scales (Table 4-5). At the State-wide scale and for both the WCS and GSV/KIS the lowest catches and lowest levels of handline effort were recorded for 2017. At the same time, the 2nd and 3rd highest levels of handline CPUE were recorded at the State-wide scale and for both the SGS and the GSV/KIS.

Table 4-4. Comparisons of percentages of commercial catch of King George Whiting taken by the fisheries, with their allocations and trigger limits specified in the Management Plan (PIRSA 2013). MSF – Marine Scalefish, SZRL – Southern Zone Rock Lobster, NZRL – Northern Zone Rock Lobster. Green colour – allocation not exceeded, red colour – allocation trigger activated.

COMMERCIAL ALLOCATION	MSF 98.10%	SZRL n/a	NZRLF 1.90%
TRIGGER 2	n/a	0.50%	2.97%
TRIGGER 3	n/a	0.75%	3.96%
2013	97.20%	0.10%	2.80%
2014	98.90%	0.00%	1.10%
2015	98.80%	0.00%	1.20%
2016	99.40%	0.00%	0.60%
2017	9.10%	0.00%	0.90%

Table 4-5. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the biological stock level for King George Whiting.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE	WC	SG	GSV/KI
TOTAL CATCH	G	3rd Lowest / 3rd Highest	LOWEST	LOWEST	×	LOWEST
	G	Greatest % interannual change (+/-)	×	×	×	×
	G	Greatest 5 year trend	×	×	×	×
	G	Decrease over 5 consecutive years	×	×	×	×
TARGET HANDLINE EFFORT	G	3rd Lowest / 3rd Highest	LOWEST	LOWEST	×	LOWEST
	G	Greatest % interannual change (+/-)	×	×	×	×
	G	Greatest 5 year trend	×	×	×	×
	G	Decrease over 5 consecutive years	×	×	×	×
TARGET HANDLINE CPUE	G	3rd Lowest / 3rd Highest	2nd HIGHEST	×	3rd HIGHEST	2nd HIGHEST
	G	Greatest % interannual change (+/-)	×	×	×	×
	G	Greatest 5 year trend	×	×	×	×
	G	Decrease over 5 consecutive years	×	×	×	×

Stock Status

West Coast Stock

This stock includes the populations of King George Whiting that inhabit all the bays and offshore areas of the Eyre Peninsula. In recent years it has been consistently classified as sustainable (Fowler et al. 2014, Steer et al. 2018). Between 2002 and 2013, total catch from

this stock gradually increased by 27.6%. Nevertheless, between 2013 and 2017 it dropped by 42.5%. Handline effort shows a long-term decreasing trend, consistent with a declining number of fishers. However, between 2013 and 2017, the rate of decline increased considerably during which it fell by 35.5%. CPUE increased by 53% between 2002 and 2009 and has subsequently remained around this high level despite the recent declines in catch and effort. Estimates of fishable biomass from the stock assessment model have gradually increased over time, particularly through the two periods of 1984 to 1999 and 2008 to 2016 (Steer et al. 2018). This general increasing trend in biomass reflects a long-term increasing trend in recruitment and long-term declining exploitation rate associated with the declining fishing effort associated with declining numbers of commercial fishers (Steer et al. 2018).

The levels of catch and effort for this stock have declined since 2013, particularly in 2016 and 2017. Nevertheless, there is no indication in the estimates of handline CPUE up to 2017 and estimates of fishable biomass, recruitment and exploitation rate up to 2016 (Steer et al. 2018), to suggest that the biomass has been depleted and that recruitment is likely to be impaired. As such, the classification of **sustainable** for this stock is retained.

Spencer Gulf Stock

This stock extends throughout the entire northern and southern regions of Spencer Gulf. Throughout the 2000s, total catch and effort have been low relative to the high levels recorded through the 1980s and 1990s (Fowler et al. 2014, Steer et al. 2018). Also, handline CPUE has varied cyclically over time, but nevertheless demonstrated a long-term increasing trend. However, between 2007 and 2014, catch effort and CPUE all declined contemporaneously (Fowler et al. 2014). The estimated biomass from the stock assessment model also declined through this period reflecting a significant decline in recruitment. As such, on the basis of these negative fishery performance indicators, this stock was classified as transitional depleting (Fowler et al. 2014). This prompted a review of the fishery management arrangements that resulted in changes that were implemented in December 2016.

Between 2013 and 2017, there have been notable increases in the commercial fishery statistics. Over this period, total catch increased by 41%, handline effort by 28% and handline CPUE by 21%. Furthermore, the output from the stock assessment model indicated that from 2013 to 2016, there was an upward trend in recruitment that resulted in an 11.3% increase in fishable biomass (Steer et al. 2018). Such variable biomass appears typical for this stock, which is evident in the cyclical variation in temporal trends in fishery statistics. These indicators suggest that the population is subject to recruitment variation that impacts on population biomass and fishery productivity over cycles that last for a number of years. This result is not consistent with the biomass being depleted and moving the stock in the direction of being recruitment impaired. Rather, it suggests that the biomass is at a level sufficient to

ensure that future recruitment is adequate. As such, the classification of this stock is retained as **sustainable**.

Gulf St. Vincent/Kangaroo Island Stock

The Gulf St. Vincent/Kangaroo Island Stock occurs throughout Gulf St. Vincent, Investigator Strait and the waters surrounding Kangaroo Island. The recent stock assessments completed in 2014 and 2017 showed that commercial catch and effort for this stock were considerably higher during the 1990s compared to the 2000s, consistent with a long-term decline in the number of fishers participating in the fishery (Fowler et al. 2014, Steer et al. 2018). In particular, between 2009 and 2013, there were considerable declines in commercial catch and effort (Steer et al. 2018). Whilst CPUE had shown a long-term increasing trend between 1984 and 2007, this was followed by a period of consistent decline between 2007 and 2012, during which it fell by 25.1%. Consequently, the estimates of biomass for the period of 2007 to 2012 from the stock assessment model showed a considerable decline of 11.7%. This related to a period of declining recruitment. Based on these fishery performance indicators, the fishery was classified as transitional depleting (Fowler et al. 2014). This prompted a review of fishery management arrangements that were implemented in December 2016.

Since 2012, total catch and handline effort for this stock have been relatively stable. However, by 2016 and 2017, handline CPUE had increased by over 20% from the low level in 2012. The estimates in those years were the 2nd and 3rd highest ever recorded. Recent estimates of biomass from the stock assessment model have also stabilized in recent years, reflecting an increasing trend in recruitment (Steer et al. 2018). These recent estimates of fishery performance indicators indicate that the biomass of this stock is now unlikely to be depleted and that recruitment is unlikely to be impaired. As such, the status of the stock is now changed to **sustainable**.

4.3.3. SOUTHERN CALAMARI (*Sepioteuthis australis*)

Biology

Southern Calamari is endemic to southern Australian and northern New Zealand waters. In southern Australia, it ranges from Dampier in Western Australia to Moreton Bay in Queensland, including Tasmania. It inhabits coastal waters and bays, usually in depths of less than 70 m (Winstanley et al. 1983).

The life-history of Southern Calamari is typical of most squid species where they 'live-fast and die-young', exhibiting rapid growth and a sub-annual life-span (Jackson 2004). In South Australia, adults and juvenile Southern Calamari are predominantly found in shallow, inshore waters, whereas the deeper, offshore waters are occupied by sub-adults. Such spatial segregation is common in squid species, as is having offshore nursery and inshore spawning grounds (Sauer 1995). The distribution and abundance patterns of adult Southern Calamari in South Australia's gulfs tend to conform to a seasonal, systematic pattern consistent amongst years (Triantafillos 2001). Adult abundance typically increases for six months to a peak and declines for the remainder of the year. The timing of these peaks vary among regions and tend to follow an anti-clockwise progression around the gulfs, starting in the south-east during late spring and concluding along the western coasts during late winter. Seasonal patterns in water clarity, associated with the prevailing winds, appear to drive this progression as Calamari seek the relatively protected leeward shores to spawn (Triantafillos 2001; Steer et al. 2007). Spawning occurs throughout the year, consequently supplying a continuous 'conveyor-belt' of recruits to the population.

The biological stock structure across the distribution of Southern Calamari is complex and potentially dynamic. One study used allozyme markers to identify three genetic types with overlapping distributions and possible stocks off Western Australia, South Australia, New South Wales and Tasmania (data are not available for Victoria) (Triantafillos 2004). In contrast, another study using microsatellite markers found little genetic differentiation between seven study sites in Western Australia, South Australia, Victoria and Tasmania (Smith et al. 2015). It also identified Tasmania as a possible important site for gene flow. Life history dynamics, and studies of movement and statolith microchemistry in Tasmania also suggest some localised biological stock structuring (Pecl et al. 2011). For the purpose of this assessment South Australia's Southern Calamari is considered to comprise a single stock; however, the catch and effort data will be interrogated at the regional scale to explore the dynamics of this fishery at a greater resolution.

Fishery

In South Australia, the Calamari resource is shared by three sectors. Adults are targeted by commercial licence holders and recreational fishers on the inshore spawning grounds, while juveniles and sub-adults are incidentally caught by commercial prawn trawlers operating in the deeper (>10 m), offshore, gulf waters. The commercial prawn trawling fleet are permitted to retain and sell Southern Calamari as by-product.

Recreational fishers also fish from jetties, breakwaters and other shore-based platforms. Most of the catch is landed by hand jigs; however, commercial fishers are also licenced to use hauling nets, gill nets and dab nets. Daily boat and bag limits apply to the recreational sector. In 2013/14, this sector took an estimated 473,803 Southern Calamari, equating to an estimated catch of 154.9 t (Giri and Hall 2015).

Management Regulations

As far back as 1992, there were fishery management concerns about the increasing popularity of Southern Calamari fishing by both recreational and commercial fishers and the potential vulnerability of the spawning stocks (Marine Scalefish White Paper 1992). There were also reports of the illegal sale of Southern Calamari. These concerns resulted in the implementation of recreational bag and boat limits in 1995 (i.e. 15 per bag/45 per boat per day) and have remained unchanged. Currently, input controls such as spatial and temporal closures and gear restrictions (minimum mesh size 30 mm and lengths 600 m) apply to the net sector, however these are generic measures rather than being specific to Southern Calamari. Restrictions currently prevent netting in all metropolitan waters and in waters >5m deep, as well as in numerous bays and marine protected areas. The jigging sector dominates the Southern Calamari fishery and is permitted in most State waters, with the exception of several aquatic reserves. In 2004, a full-time cephalopod fishing closure was implemented in False Bay, northern Spencer Gulf, to protect the annual spawning aggregation of the Giant Australian Cuttlefish, *Sepia apama*. It is not known whether this spatial closure inadvertently provides some regional protection for spawning Southern Calamari.

Commercial Fishery Statistics

State-wide

The total reported commercial catch of Southern Calamari, combined across all fisheries, in 2017 was 466.22 t and has remained relatively stable (>350 t) over the last six years (Figure 4-11). Of this, Southern Calamari by-product pooled across all three prawn fisheries has consistently accounted for <10 % since it was first reported in 2004; however, it increased to 10.5% and 11.3% in 2016 and 2017, respectively. The estimated production value of this

fishery has increased from approximately AUD$1.9 million in 2001/02 to a peak of A$5.1 million in 2011/12. Since then it has remained above AUD$3.6 million per year, and in 2017 was the most valuable MSF species at AUD$5.1 million (Figure 4-11).

Prior to 1992, the jig and hauling net sectors of the MSF contributed equally to annual catches. Since then, jigs have become the preferred gear type and have generally accounted for approximately 70% of the annual catch. Total fishing effort combined for both jig and hauling net fishers had remained relatively stable from 2005 until 2016 ranging between 11,461 fisher-days in 2008 to 14,487 fisher-days in 2011. In 2017, 15,156 fisher-days were expended catching Southern Calamari within the MSF. Catch rates have gradually increased over the past 33 years for both gear types, at a rate of approximately 0.5 kg.fisher-day.year^{-1}. Since the implementation of the licence amalgamation scheme in 1994, the number of licence holders taking Southern Calamari has declined from 355 to 208, representing a 41% reduction over 23 years. The number of licence holders specifically targeting Southern Calamari has remained relatively stable, averaging approximately 215 licences per year (Figure 4-11).

Regional

Southern Calamari is caught throughout the State with the majority landed within the gulfs (Figure 4-12). Catches have notably increased in NSG, SSG and NGSV since 2008, with all three regions accounting for similar proportions of the State-wide commercial total. Although, Calamari can be caught throughout the year, they tend to peak during late spring and late autumn. In 2017, the commercial catch of Southern Calamari was dominated by the Marine Scalefish fishers (88.6%), whilst the Prawn fishery accounted for 11.3%, and Southern and Northern Zone Rock Lobster fishers accounted for the remaining <1% (Figure 4-12). In 2013/14 the recreational sector accounted for 30.2% of the State-wide catch of Southern Calamari.

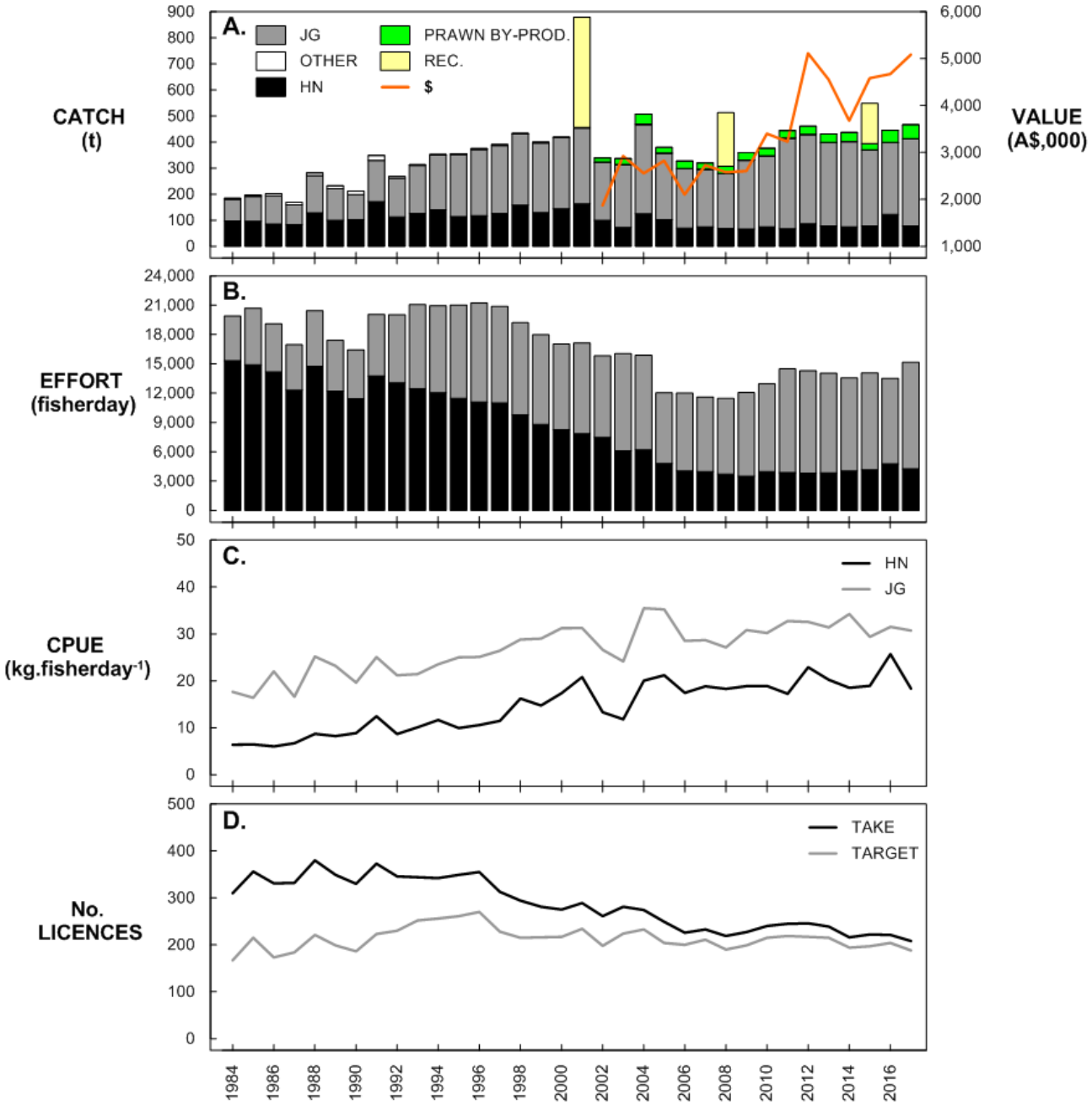

Figure 4-11. Southern Calamari (A) Catch distribution for 2017; Long-term trends in: (B) total catch for the main gear types (squid jig, hauling net, prawn bycatch), estimated recreational catch and gross production value; (C) Long-term total effort for squid jigs and hauling nets; (D) total catch per unit effort for squid jigs and hauling nets; and (E) the number of active licence holders taking or targeting the species.

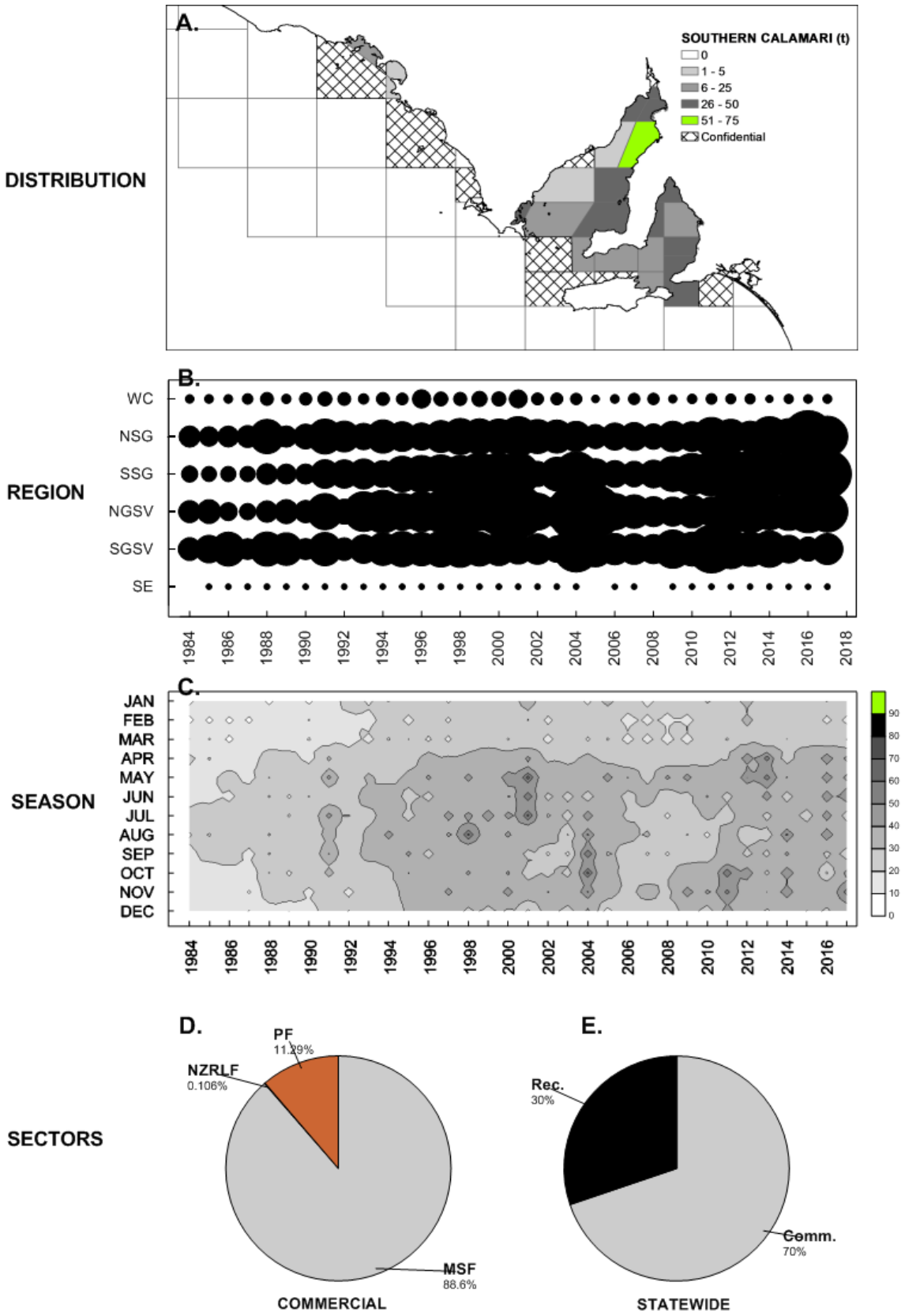

Figure 4-12. Southern Calamari. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t); (D) The proportion of catch distributed among the commercial sector in 2017; and (E) among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

West Coast

The annual commercial catch of Southern Calamari from the West Coast has rarely exceeded 10% of the State's catch (Figure 4-13). Total catches have declined from a peak of 37.2 t in 1996 to 5.2 t in 2014. Annual catch has remained around 10 t over the past three years. Targeted jig effort in this region has also declined from a historic peak of 1,343 fisher-days in 2001 to 277 fisher-days in 2009, decreasing at rate of 94 fisher-days.year-1 over eight years. Targeted jig effort levels have remained below 430 fisher-days.year-1 since 2014. With the exception of a notable decline in 2014, targeted jig catch rates have remained relatively stable over the past 12 years, averaging approximately 25 kgs.fisher-days.year-1. Almost all (>98%) of the fishing for Southern Calamari in this region has been targeted by the jig sector as there are negligible areas that are available for hauling net fishers. The number of fishers targeting Southern Calamari has ranged from 33 to 55 over the past decade (Figure 4-13).

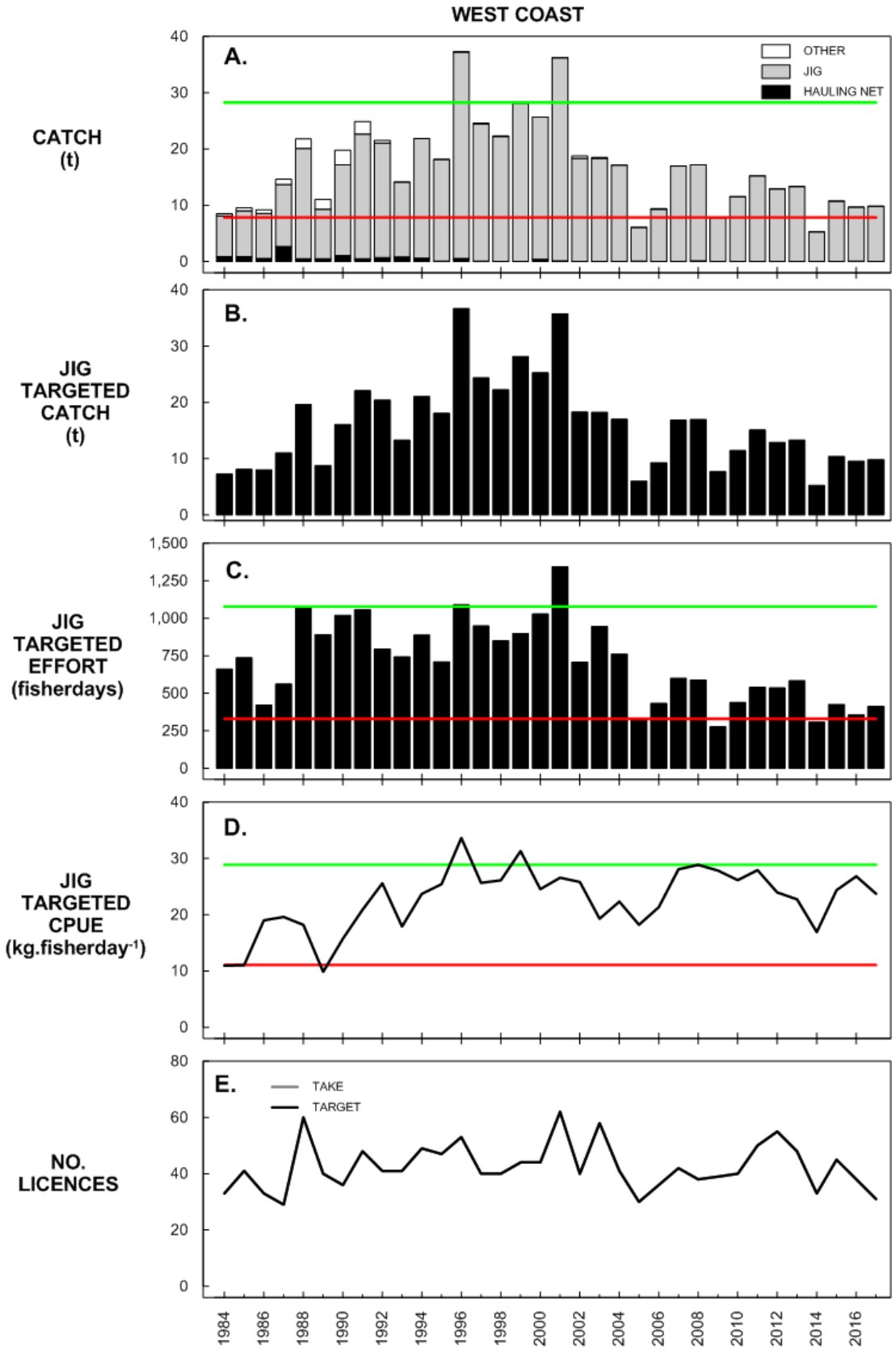

Figure 4-13. Key fishery statistics used to inform the status of Southern Calamari in the West Coast. Long-term trends in (A) total catch; (B) targeted squid jig catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Northern Spencer Gulf

Total catch of Southern Calamari in Northern Spencer Gulf has typically accounted for approximately 25% of the State's catch. The 2017 annual catch of 102 t was the second highest on record, decreasing from the previous year by 24.1% (Figure 4-14). Of this, targeted jig catch accounted for 59.1%. The targeted hauling net catch for this year was 6.5 t, where historically catches in this sector have rarely exceeded 3 t per year. Targeted jig effort in 2017 was the second highest on record, registering 2,101 fisher-days. Targeted jig catch rates have peaked above 37 kg.fisher-day^{-1} twice over the last seven years, with 2017 yielding a lower catch rate of 28.8 kg.fisher-day^{-1}. The number of licence holders targeting Southern Calamari using jigs has declined from a recent peak of 45 fishers in 2011 to 35 in 2017 (Figure 4-14).

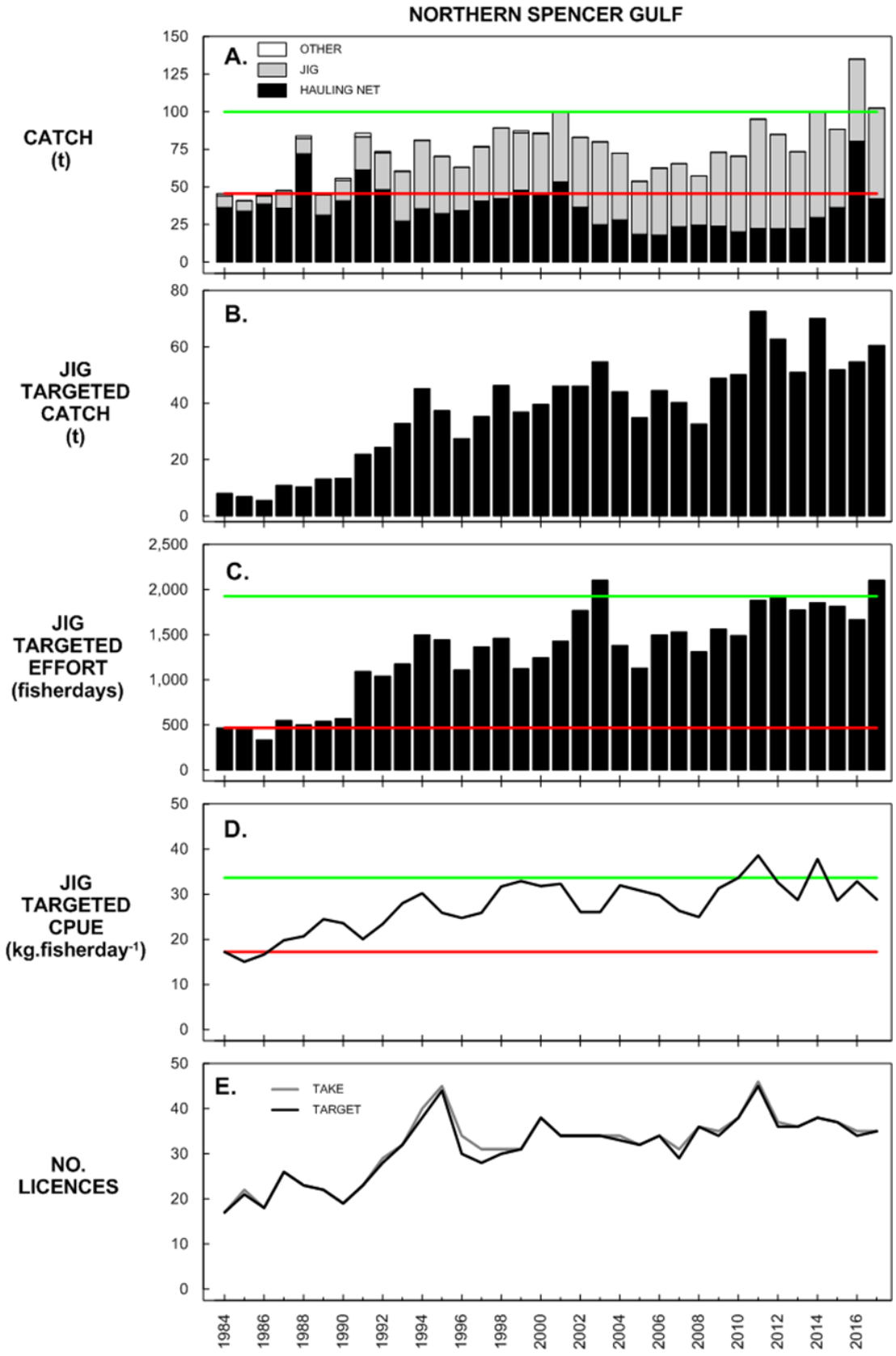

Figure 4-14. Key fishery statistics used to inform the status of Southern Calamari in Northern Spencer Gulf. Long-term trends in (A) total catch; (B) targeted squid jig catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Southern Spencer Gulf

Total catch of Southern Calamari in Southern Spencer Gulf has accounted for approximately 30% of the State's catch. It peaked at 122 t in 2012 and declined to 93 t in 2016, dropping below 100 t for the first time in eight years, and returned to a record high of 123.7 t in 2017 (Figure 4-15). Total effort levels followed a similar trend, rising to a peak of 3,749 fisher-days in 2012 before subsiding to 2,917 fisher-days in 2016, and attaining a record level of 3,761 fisher-days in 2017. Like the WC, almost all (>98%) of the fishing for Southern Calamari in this region has been targeted by the jig sector as there are negligible areas that are available for hauling net fishers. Catch rates in this sector peaked at 36.3 kg.fisher-day-1 in 2013 and has since remained above 32 kg.fisher-day-1.year-1 (Figure 4-15). The number of licence holders using jigs to target Southern Calamari in this region has remained relatively stable since 1992, averaging approximately 87 licences per year (Figure 4-15).

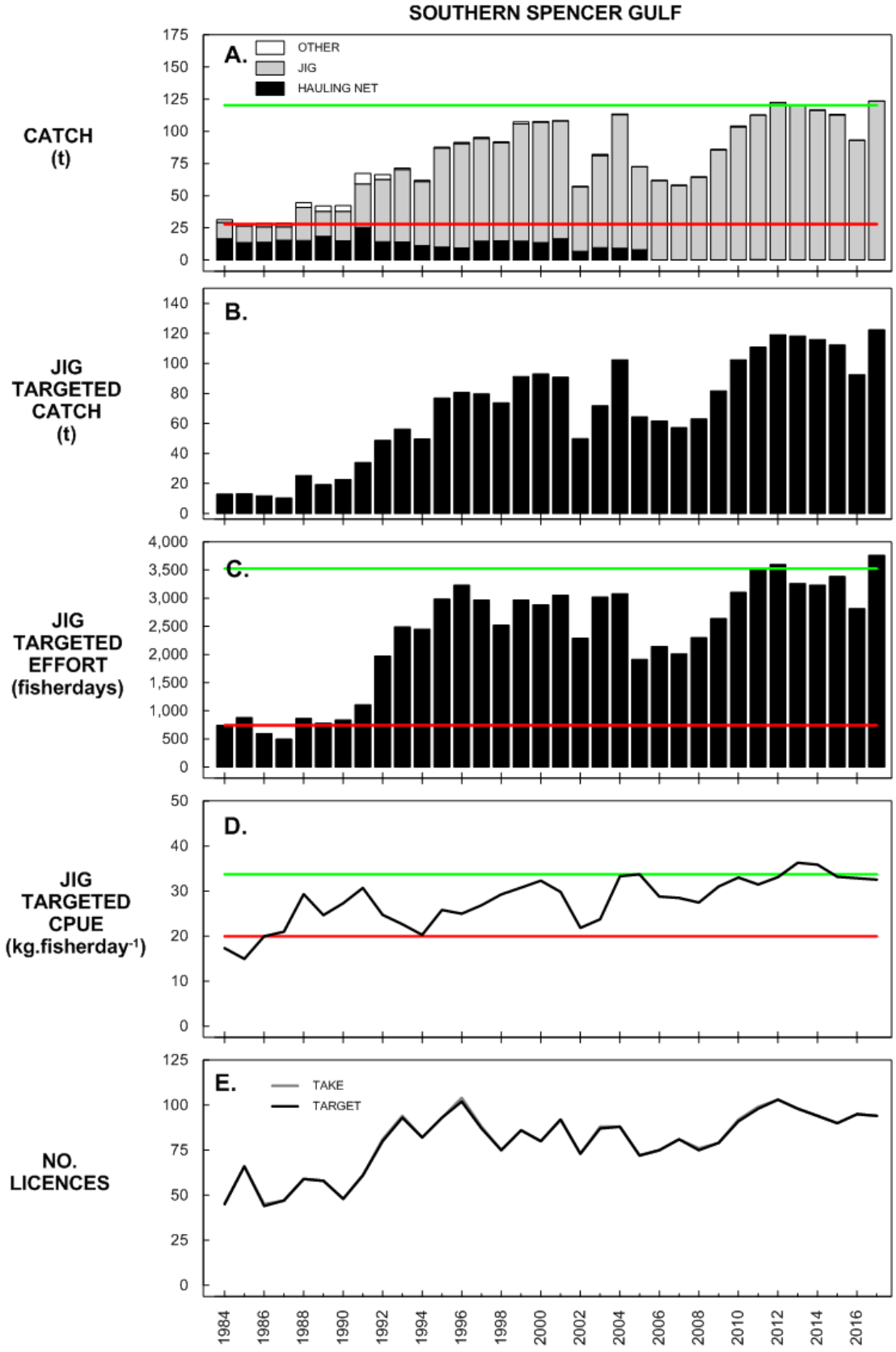

Figure 4-15. Key fishery statistics used to inform the status of Southern Calamari in Southern Spencer Gulf. Long-term trends in (A) total catch; (B) targeted squid jig catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Northern Gulf St. Vincent

The relative contribution of the commercial Southern Calamari catch from this region to the annual State-wide total is approximately 25%. Annual catches have decreased from a peak of 148 t in 2004 to the most recent low of 68 t in 2009 (Figure 4-16). Since then, annual total catch has remained relatively stable at approximately 100 t per year. Approximately 85% of the catch is targeted, of which 25% is by the hauling net sector and 60% by the jig sector. Targeted jig effort ranged from 500 to 1,500 fisher-days.year^{-1} from 1984 until 2012. Since then it has increased at a rate of approximately 186 fisher-days.year^{-1}, to a record level of 2,207 fisher-days in 2017 (Figure 4-16). The associated catch rates during this period, have ranged from 28.5 to 33.5 kg.fisher-day.year^{-1}. The number of licence holders using jigs to target Southern Calamari in this region has remained relatively stable since 1992, averaging approximately 42 licences per year (Figure 4-16).

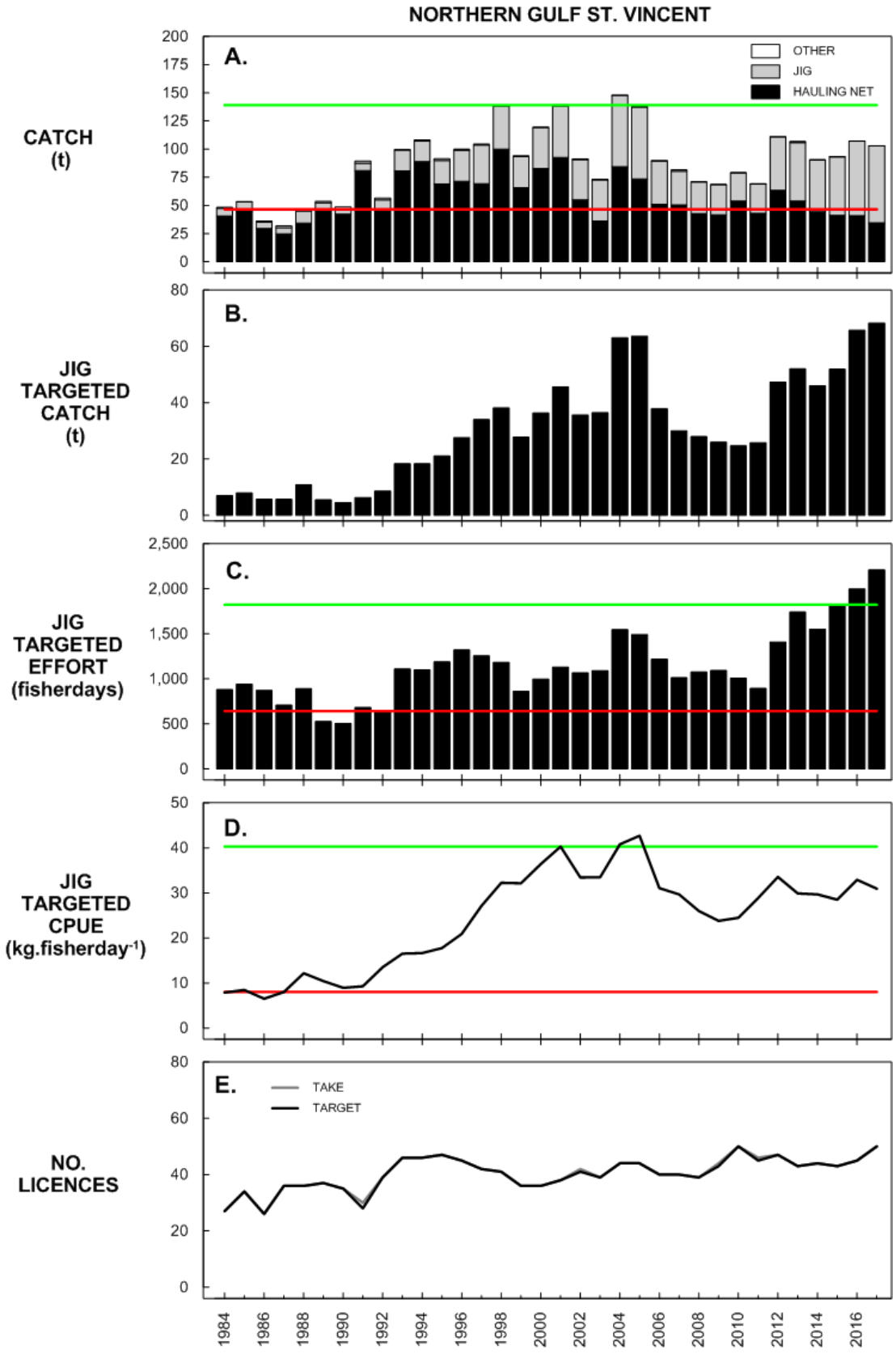

Figure 4-16. Key fishery statistics used to inform the status of Southern Calamari in Northern Gulf St. Vincent. Long-term trends in (A) total catch; (B) targeted squid jig catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Southern Gulf St. Vincent

Southern Gulf St. Vincent accounts for approximately 20% of the State-wide catch of Southern Calamari, with almost all (>98%) of it targeted by jig fishers. Total catch has declined from a peak of 122.7 t in 2011 to 52.4 t in 2016, representing a 57.3% decrease (Figure 4-17). Total catch increase by 38.0% in 2017 to 74.4 t (Figure 4-17). This decreasing trend has been driven by a concomitant decrease in targeted jig effort, declining from 3,870 fisher-days in 2011 to a record low of 1,857 fisher-days in 2016. Targeted jig effort levels increased to 2,367 fisher-days in 2017. Targeted jig CPUE has been moderate and relatively consistent since 1984, averaging 28 kg.fisher-day.year-1 (Figure 4-17). Like Northern Gulf St. Vincent, the number of licence holders using jigs to target Southern Calamari in this region has remained relatively stable, averaging approximately 53 licences per year since 1992 (Figure 4-17).

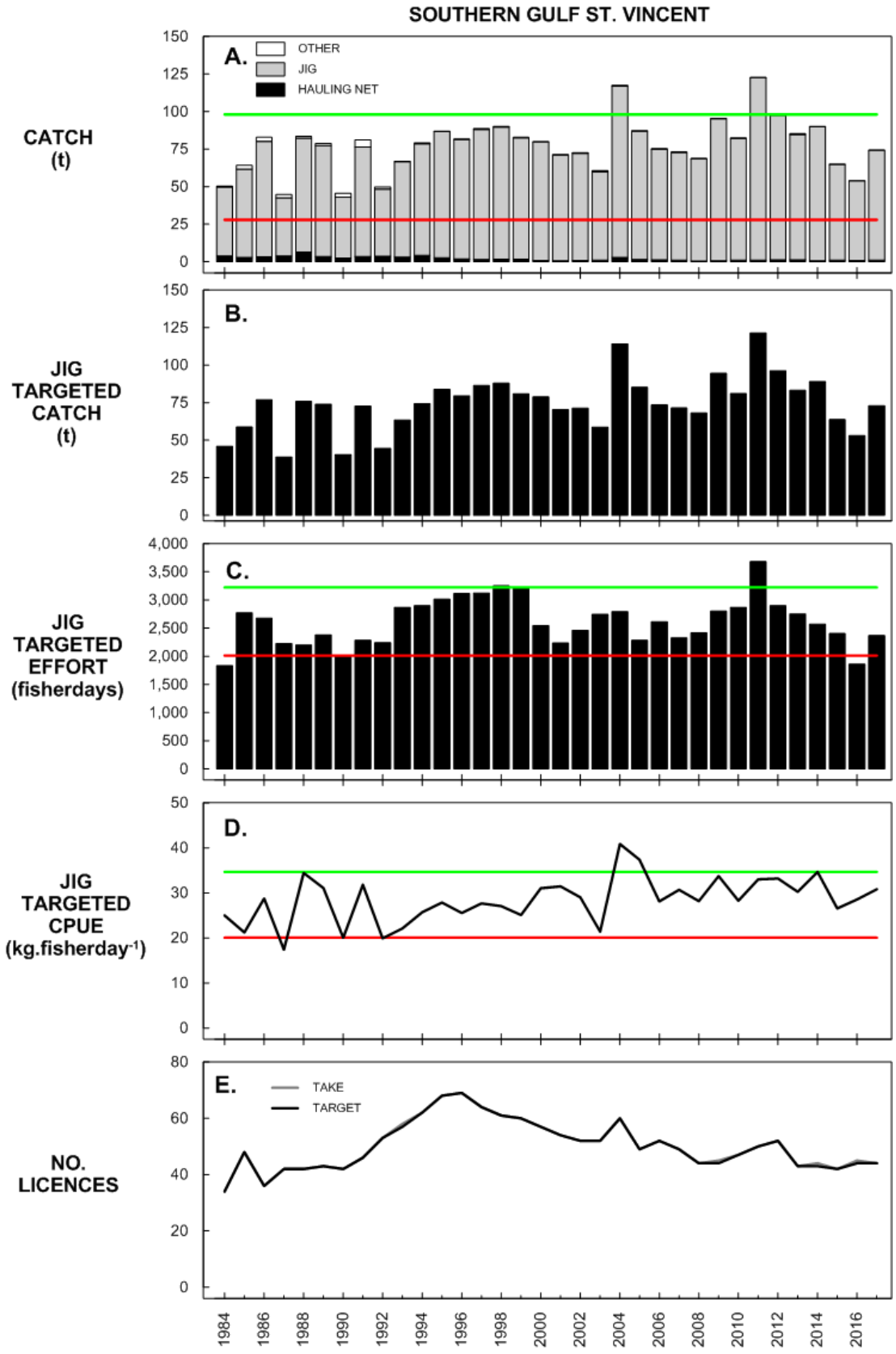

Figure 4-17. Key fishery statistics used to inform the status of Southern Calamari in Southern Gulf St. Vincent. Long-term trends in (A) total catch; (B) targeted squid jig catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

South East

A negligible proportion of the State wide catch of Southern Calamari is landed in the South East.

Fishery Performance

No trigger limits associated with the relative proportion of commercial catch shares were breached (Table 4-6). The general performance indicators were assessed at the regional scale for 2017. There were six breaches of trigger reference points across the seven regions (Table 4-7). Three of these related to SSG, which yielded record total catch in 2017, as well as the greatest inter-annual change in targeted jig effort, culminating into the highest level on record. Targeted jig effort for Southern Calamari was the highest in NGSV and contributed to the greatest five-year increasing trend. The second highest total catch and targeted jig effort level was recorded in NSG.

Table 4-6. Results from consideration of commercial catches of Southern Calamari by fishery against their allocation percentages and trigger reference points. MSF = Marine Scalefish, NZRL = Northern Zone Rock Lobster, GSVP = Gulf St. Vincent Prawn Fishery; SGP = Spencer Gulf Prawn Fishery; WCP = West Coast Prawn Fishery. Green colour – allocation not exceeded, red colour – allocation trigger activated.

COMMERCIAL ALLOCATION	MSF 90.91%	SZRL n/a	NZRLF 0.73%	GSVP 0.73%	SGP 7.47%	WCP 0.16%
TRIGGER 2	92.70%	-	1.46%	1.46%	8.20%	0.75%
TRIGGER 3	95.40%	-	2.19%	2.19%	11.20%	1.00%
2013	91.98%	-	0.66%	0.00%	7.23%	0.13%
2014	91.89%	-	0.34%	0.04%	7.60%	0.12%
2015	93.98%	-	0.21%	0.51%	5.22%	0.07%
2016	89.14%	-	0.34%	0.77%	9.69%	0.06%
2017	88.60%	-	0.11%	0.88%	10.33%	0.08%

Table 4-7. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the regional spatial scales for Southern Calamari in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	WC	NSG	SSG	NGSV	SGSV	SE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×	2nd HIGHEST	HIGHEST	×	×	conf.
	G	Greatest % interannual change (+/-)	×	×	×	×	×	conf.
	G	Greatest 5 year trend	×	×	×	×	×	conf.
	G	Decrease over 5 consecutive years	×	×	×	×	×	conf.
TARGET JIG EFFORT	G	3rd Lowest / 3rd Highest	×	2nd HIGHEST	HIGHEST	HIGHEST	×	conf.
	G	Greatest % interannual change (+/-)	×	×	✓	×	×	conf.
	G	Greatest 5 year trend	×	×	×	✓	×	conf.
	G	Decrease over 5 consecutive years	×	×	×	×	×	conf.
TARGET JIG CPUE	G	3rd Lowest / 3rd Highest	×	×	×	×	×	conf.
	G	Greatest % interannual change (+/-)	×	×	×	×	×	conf.
	G	Greatest 5 year trend	×	×	×	×	×	conf.
	G	Decrease over 5 consecutive years	×	×	×	×	×	conf.

Stock Status

In the absence of conclusive evidence on the biological stock boundaries of Southern Calamari throughout its geographical range the assessment of its stock status is ascertained at the State-wide level. The primary measure for biomass and fishing mortality is targeted CPUE from jig and hauling-net fishers. The total reported commercial catch of Southern

Calamari in 2017, combined across all fisheries, was 466 t and has remained relatively stable (>370 t) over the last seven years. Commercial CPUE has remained relatively high in both the jig and the hauling net sectors of the fishery.

Trends in targeted catch and catch rates in northern and southern Spencer Gulf and northern GSV have remained relatively high over the past seven years. Despite notable declines in targeted jig catch in SGSV and the WC, their respective catch rates have also remained relatively high. Although it is clear that many MSF licence holders have shifted their effort away from other primary species to target Southern Calamari (Figure 2-4), there appears to be little impact on the sustainability of the resource. This is most likely buffered by the high-paced life history of the species, which is capable of supplying a continual supply of recruits into the population (Jackson and Pecl, 2003). The above evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. On this basis, South Australia's Southern Calamari Fishery is classified as **sustainable**.

4.3.4. YELLOWFIN WHITING (*Sillago schomburgkii*)

Biology

Yellowfin Whiting is the second most valuable finfish species of the family Sillaginidae that occurs in South Australian waters (Kailola et al. 1993). The species is endemic to Australia, being found in the coastal waters from Dampier to Albany in Western Australia and in the gulf waters of South Australia (Kailola et al. 1993). There is some uncertainty about the continuity of distribution through the remote coastal waters of Western Australia and South Australia (Kailola et al. 1993).

Fishery catches indicate that in South Australia, Yellowfin Whiting occur in highest abundances in the two northern gulfs, with lower abundances in the southern gulfs and the west coast of Eyre Peninsula. Its life history appears particularly adapted to habitation of relatively protected, shallow, near-shore waters. Adults are generally associated with shallow, tidal creeks and coastal sand flats, and so are commonly found in waters of 1 – 10 m depth (Jones 1981). Spawning occurs during the summer months, and then between February and April, post-larvae are found along the shallow, protected, sandy beaches of the northern gulfs. Subsequently, juvenile fish occupy similar habitats as well as tidal creeks (Kailola et al. 1993, Ferguson 1999). Yellowfin Whiting demonstrate different growth patterns between the sexes that culminates in females reaching larger sizes-at-age than males (Ferguson 1999). Furthermore, market sampling of commercial catches has demonstrated considerable bias in sex ratios towards females. Ageing of fish from otoliths has indicated a longevity of approximately 12 years, although most fish taken in the commercial fishery were in the 2 to 4 year age classes (Ferguson 1999).

Based on the possible discontinuous distribution between South Australian and Western Australian populations, there is the possibility of separate stocks as well as genetic differentiation. However, even within South Australia, the oceanographic separation of the two gulfs during the spawning season in summer must considerably reduce the opportunity for mixing by egg and larval advection. As such, the populations in the two gulfs may constitute separate stocks. This remains to be resolved.

Fishery

Yellowfin Whiting is one of the more valuable ‘secondary’ species of South Australia’s MSF (PIRSA 2013). The ‘secondary’ classification might reflect that its catches have been variable, reflecting that in the past it was targeted when demand for, or availability of, primary species was low (Jones 1981, Ferguson 1999). Because Yellowfin Whiting is a schooling species that occupies sandy, shallow habitats predominantly in the northern gulfs, it is particularly vulnerable to net fishers of the MSF. As such, historically the commercial catches have been

dominated by the net sector, with hauling nets the predominant gear followed by bottom-set gillnets. Over many years, the Northern and Southern Zone Rock Lobster Fisheries (NZRLF, SZRLF) have reported only incidental catches. Yellowfin Whiting is a popular target species of boat and shore-based recreational fishers who target them using hook and line. In 2013/14, this sector took an estimated 174,264 Yellowfin Whiting, equating to an estimated catch of 45.3 t (Giri and Hall 2015).

Management Regulations

For Yellowfin Whiting, there is a minimum size limit of 240 mm TL that applies to both sectors. Furthermore, for the commercial sector, the many regulations that are input controls for the different netting gears contribute to minimising the fishing effort directed at Yellowfin Whiting. These include restrictions to net lengths and mesh sizes as well as the extensive spatial closures and temporal restrictions that limit where and when net fishing can be legitimately undertaken. For the recreational sector, a bag limit of 20 fish and boat limit of 60 fish is well established for the species.

Commercial Fishery Statistics

State-wide

Estimates of annual, State-wide commercial catches of Yellowfin Whiting show considerable variation, ranging from 14.5 t in 1988 to 179 t in 2001 (Figure 4-18). The 141.6 t reported in 2017 was an intermediate level of catch. Hauling nets have always accounted for considerably higher proportions of annual catches than gillnets. The hauling net and gillnet effort that accounted for the annual total catches have declined considerably since 2002. State-wide estimates of CPUE for hauling nets and gillnets have been variable over the years, but nevertheless both show long-term increasing trends. From 1984 to 2017, the numbers of fishers who reported taking Yellowfin Whiting showed a long-term decreasing trend falling from the maximum of 129 to 49. The number of licence holders who targeted Yellowfin Whiting has been variable but not shown a long-term trend (Figure 4-18).

Regional

Although the annual catches of Yellowfin Whiting in NSG have been variable since 1984, they have always been higher than those from the other SA regions (Figure 4-19). Since the early 1990s, NGSV has been the second most productive region, whilst lower catches have come from the southern gulfs, and only incidental catches from the SE and WC.

Northern Spencer Gulf continues to be the area where most of the State's commercial catch of Yellowfin Whiting is caught in 2017, and it has principally been a winter-based fishery since the early 1990s (Figure 4-19). In 2017, MSF fishers accounted for the entire commercial

catch. In 2013/14, the recreational sector accounted for approximately 31.5% of the State-wide catch (Figure 4-19).

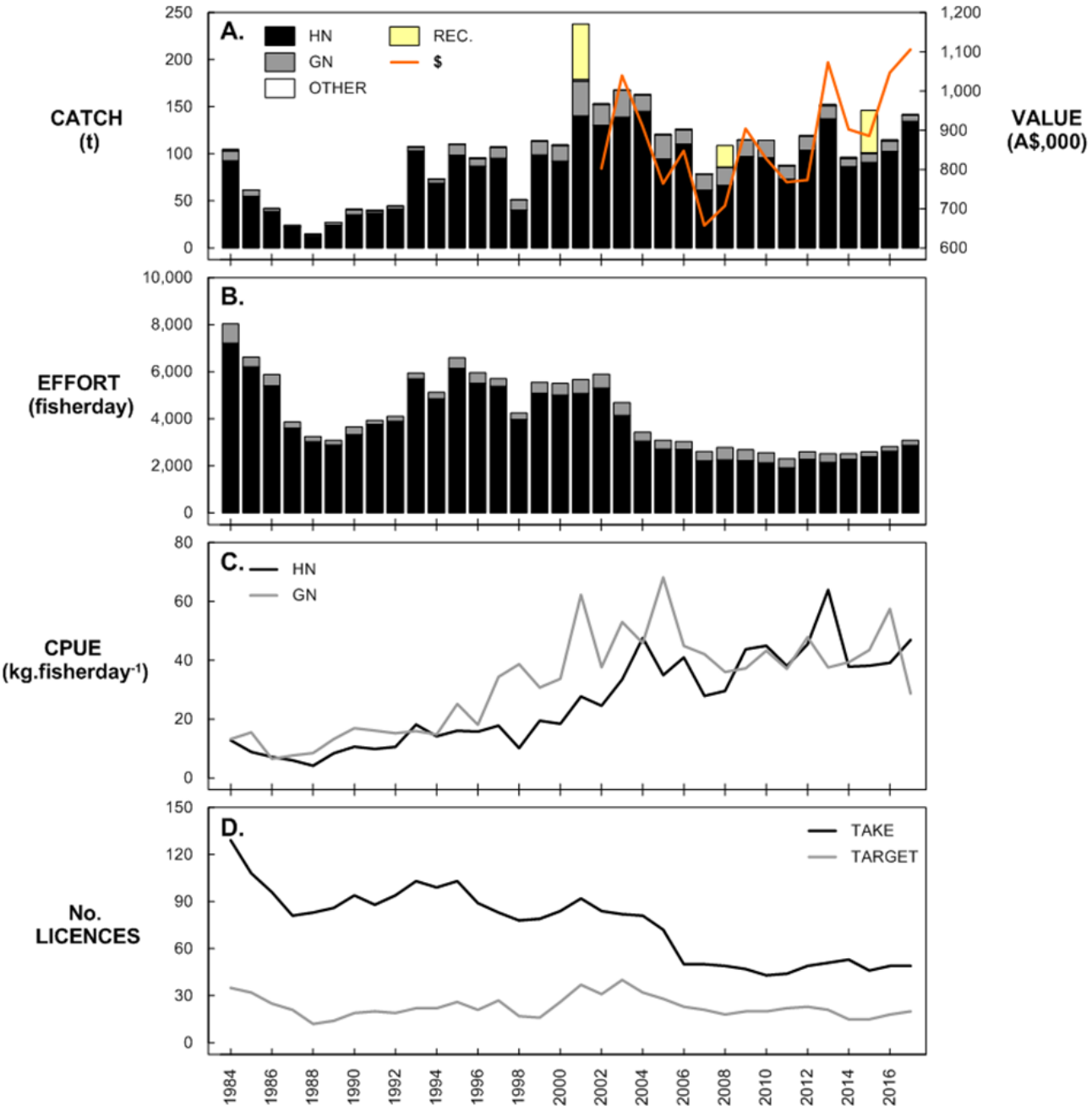

Figure 4-18. Yellowfin Whiting. Long-term trends in: (A) total catch of the main gear types (hauling and gilnets), estimates of recreational catch and gross production value; (B) total effort for hauling and set nets; (C) total catch per unit effort (CPUE) for hauling and dab nets; and (D) the number of active licence holders taking or targeting the species.

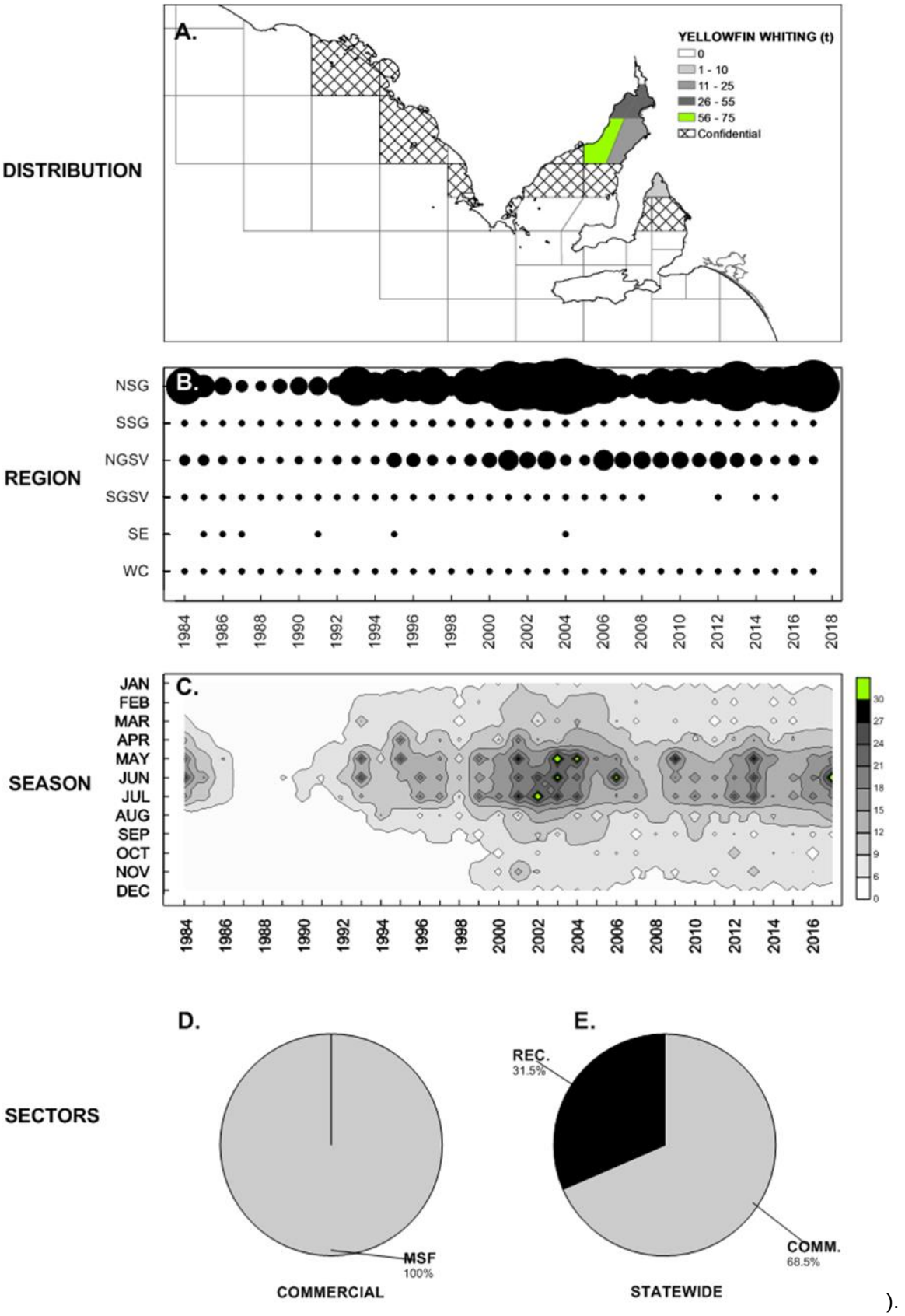

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Figure 4-19. Yellowfin Whiting. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t). The proportion of catch distributed among the commercial sector in 2017 (D); and among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

Northern Spencer Gulf Stock

Total catch of Yellowfin Whiting from NSG has varied considerably over the years. The lowest catch of 13.4 t was taken in 1988 and the highest of 148 t was taken in 2004. The total catch of 134.1 t in 2017 was the third highest on record (Figure 4-20).

Targeted hauling net catches have been highly variable, with the highest catches taken between 2001 and 2004 (Figure 4-20). Targeted hauling net effort also peaked through this period, but has subsequently dropped to a much lower level. Targeted hauling net CPUE has varied considerably, with no obvious long-term trend, peaking in 2013 and 2014, before subsequently dropping to intermediate levels in 2016 and 2017. The number of licence holders who took Yellowfin Whiting with hauling nets was highest at 59 in 1984, and has subsequently fallen to 23 in 2017. The number of fishers who targeted this species with hauling nets has also declined, particularly since 2001, falling to 12 fishers in 2017 (Figure 4-20).

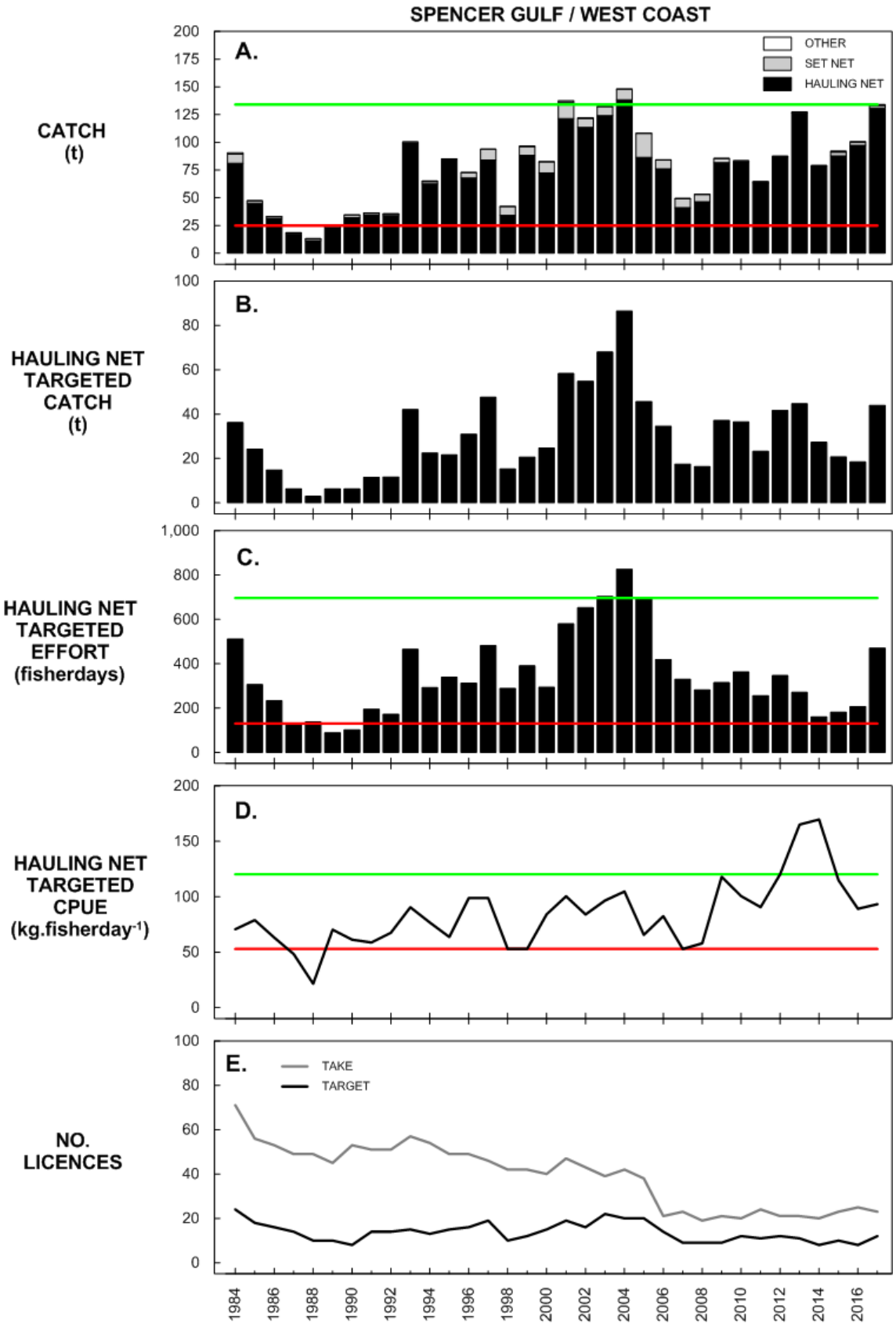

Figure 4-20. Key fishery statistics used to inform the status of Yellowfin Whiting in Spencer Gulf / West Coast. Long-term trends in (A) total catch; (B) targeted hauling net catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Gulf St Vincent Stock

In Northern Gulf St. Vincent, total annual catches of Yellowfin Whiting were highest between 2002 and 2012, ranging between 20 and 40 $t.yr^{-1}$ (Figure 4-21). They have subsequently declined to 7.5 t in 2017. The effort levels associated with these catches were higher during the 1980s and 1990s, and have declined considerably through the 2000s.

Targeted hauling net catches have generally been <5 $t.yr^{-1}$, associated with low levels of targeted effort (Figure 4-21). Such low levels of targeted catch and effort led to variable estimates of targeted CPUE for which there was no long-term trend. Relatively few fishers that took Yellowfin Whiting with hauling nets in NGSV targeted this species, suggesting that it is largely a by-product species for hauling net fishers. Confidentiality issues associated with the <5 fisher rule prevents presenting the full time series of commercial catch and effort data.

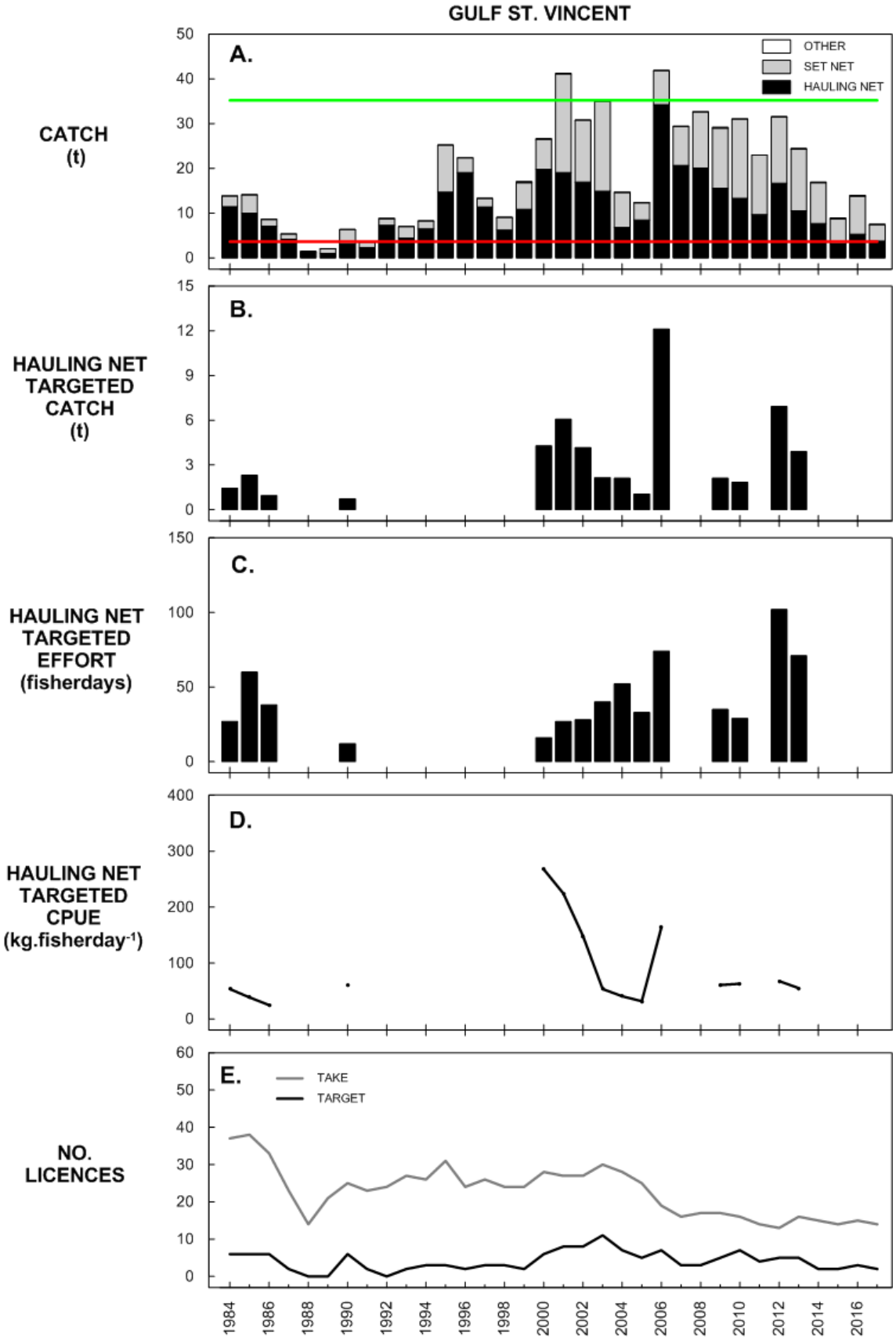

Figure 4-21. Key fishery statistics used to inform the status of Yellowfin Whiting in Gulf St. Vincent. Long-term trends in (A) total catch; (B) targeted hauling net catch; (C) effort; (D) catch rate; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Fishery Performance

The general fishery performance indicators for Yellowfin Whiting were assessed for 2017 for both NSG and NGSV. The total catch of Yellowfin Whiting in NSG for 2017 was the second highest on record, representing the only breach of a trigger reference point (Table 4-8). The resolution of the targeted effort and associated catch rates for hauling net fisher in GSV were confidential due to the <5 fisher rule.

Table 4-8. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the regional spatial scales for Yellowfin Whiting in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	SG/WC	GSV
TOTAL CATCH	G	3rd Lowest / 3rd Highest	2nd HIGHEST	×
	G	Greatest % interannual change (+/-)	×	×
	G	Greatest 3 year trend	×	×
	G	Decrease over 5 consecutive years	×	×
TARGET HAULING NET EFFORT	G	3rd Lowest / 3rd Highest	×	CONF.
	G	Greatest % interannual change (+/-)	×	CONF.
	G	Greatest 3 year trend	×	CONF.
	G	Decrease over 5 consecutive years	×	CONF.
TARGET HAULING NET CPUE	G	3rd Lowest / 3rd Highest	×	CONF.
	G	Greatest % interannual change (+/-)	×	CONF.
	G	Greatest 3 year trend	×	CONF.
	G	Decrease over 5 consecutive years	×	CONF.

Stock Status

The South Australian catches of Yellowfin Whiting were dominated by those from Spencer Gulf, although the fishery performance indicators for this region are characterised by high levels of variability. This may reflect the transient nature of targeted fishing effort, with fishers either opportunistically targeting Yellowfin Whiting due to market demands, or when the availability of higher value species is low. There has been a long-term declining trend in fishing effort for Yellowfin Whiting. However, this decline has not been reflected in total catch, targeted catch or targeted CPUE. The above evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. Furthermore, the above evidence indicates that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On this basis, the Spencer Gulf population is classified as a **sustainable** stock.

The Gulf St. Vincent population has produced considerably lower annual catches than those from Spencer Gulf. The targeted catches from the netting sector in this region have declined in recent years, but these reflect lower effort levels rather than declining estimates of CPUE. The above evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. Furthermore, the above evidence indicates that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On the basis of the evidence provided above, the Gulf St. Vincent stock is classified as a **sustainable** stock.

4.3.5. WESTERN AUSTRALIAN SALMON (*Arripis truttaceus*)

Biology

The Western Australian Salmon (hereafter referred to as 'Salmon') biological stock extends from southern Western Australia to the east coast of Tasmania, with each State jurisdiction harvesting different life-history stages. The species intermixes with Eastern Australian Salmon (*Arripis trutta*) in eastern Victorian waters and around Tasmania. The Western Australian fishery typically targets mature spawning fish that aggregate around the south-western tip of the State, whereas the South Australian, Victorian and Tasmanian fisheries predominantly harvest juveniles and sub-adults in coastal waters as they migrate along the southern coast of Australia (Cappo 1987; Jones and Westlake 2003).

Spawning typically occurs in large schools in the coastal waters between Cape Leeuwin and Busselton, Western Australia, during late autumn and early winter when the eastward flow of the Leeuwin current is strongest. The developing larvae settle along the entire southern coastline of Australia, with the main nursery grounds located along the south-eastern coast. Juvenile fish remain in coastal nursery areas for approximately three years where they feed on epibenthic crustaceans and small fish associated with seagrass beds (Hoedt and Dimmlich 1995). As they mature and begin to migrate back to the spawning grounds their diet shifts to small pelagic fish, predominantly Australian Sardines. Salmon attain a maximum age of approximately 12 years and can reach a size of up to 850 mm FL (Cappo 1987).

Fishery

Historically, the harvest of Salmon in South Australia has been confined to gulf and coastal waters and targeted by hauling net fishers and a few dedicated seine net fishers within the MSF. The Southern and Northern Zone Rock Lobster fisheries and Miscellaneous Fishery have reported negligible catches of Salmon over many years.

Salmon is an iconic recreational fishery species in South Australia and is targeted with rod and line. The State-wide recreational survey in 2013/14 estimated that 220,332 Salmon were captured, of which 148,361 fish were harvested (Giri and Hall 2015). The estimated total harvest weight was 56.2 t, which was approximately 48% of the State's total catch in 2013/14.

Management Regulations

Since 1984, the commercial harvest of Salmon in South Australia has been managed through the implementation of a 1,100 t catch limit with varying entitlements allocated to individual licence holders on the basis of their net endorsements. Despite this capacity, the annual State-wide commercial catch has rarely exceeded 600 t (Fowler et al. 2016b). Other regulations that

are in place for this sector include temporal and spatial netting closures, and restrictions to net lengths and mesh sizes, and a minimum legal size of 210 mm TL (PIRSA 2016).

There are multiple management regulations in place for Salmon in the recreational sector. Input and output controls ensure the total catch is maintained within sustainable limits and that access is distributed equitably among fishers. The minimum legal length of 210 mm (TL) applies for recreational fishers. In 1995, bag and boat limits were implemented for the recreational sector that were size related. For fish from 210 to 350 mm TL, the bag and boat limits are 20 and 60 fish, respectively. For fish >350 mm TL, the limits are 10 and 30 fish.

Commercial Fishery Statistics

State-wide

Historically, the commercial MSF for Salmon has involved a general hauling net component and a specialist purse seine (i.e. Salmon net) component. From 1984 to 2003, the annual commercial catches fluctuated around 600 t per year, with most taken by a small number of purse seiners operating throughout the West Coast and Kangaroo Island/Investigator Strait of Southern Gulf St. Vincent (SGSV) (Figure 4-22). From 2004 to 2013, catch was considerably lower, ranging from 59–262 t.yr^{-1}, as a number of key purse seiners exited the fishery. During that period, hauling net fishers accounted for most (up to 90%) of the annual catch. Since 2013, catch has progressively increased in response to a developing market. The total catch of 374 t in 2017 was the highest catch since 2003.

Targeted effort levels in the hauling net sector have remained relatively stable at approximately 58 fisher-days.yr^{-1} since 2008 (Figure 4-22). Prior to this, fishing activity has steadily declined from a peak of 807 fisher-days in 1992. Associated catch rates peaked at 1,721 kg.fisher-day.year^{-1} in 2009. This peak was uncharacteristically high as catch rates have rarely exceeded 450 kg.fisher-day.yr^{-1}, and have typically ranged between 100 and 500 kg.fisher-day.year^{-1}. The hauling net catch rate of 194 kg.fisher-day^{-1} in 2017 was similar to that of the previous year. Approximately 45% of fishers that take Salmon actively target the species, and this proportion has remained relatively consistent over time.

Regional

Up to the early 2000s, the highest catches were recorded from the West Coast or SGSV, with intermediate contributions from Southern Spencer Gulf (SSG) (Figure 4-23). From 2004 to 2013, the highest catches were taken in SSG. However, since 2013, the contributions from the West Coast and SGSV have increased, with catches from SSG remaining relatively stable. Most of the catch taken in each year has been landed throughout spring and summer.

In 2017, catches taken by MSF fishers accounted for 99% of the State-wide commercial catch. In 2013/14, the recreational sector accounted for approximately 48% of the State-wide catch (Figure 4-23).

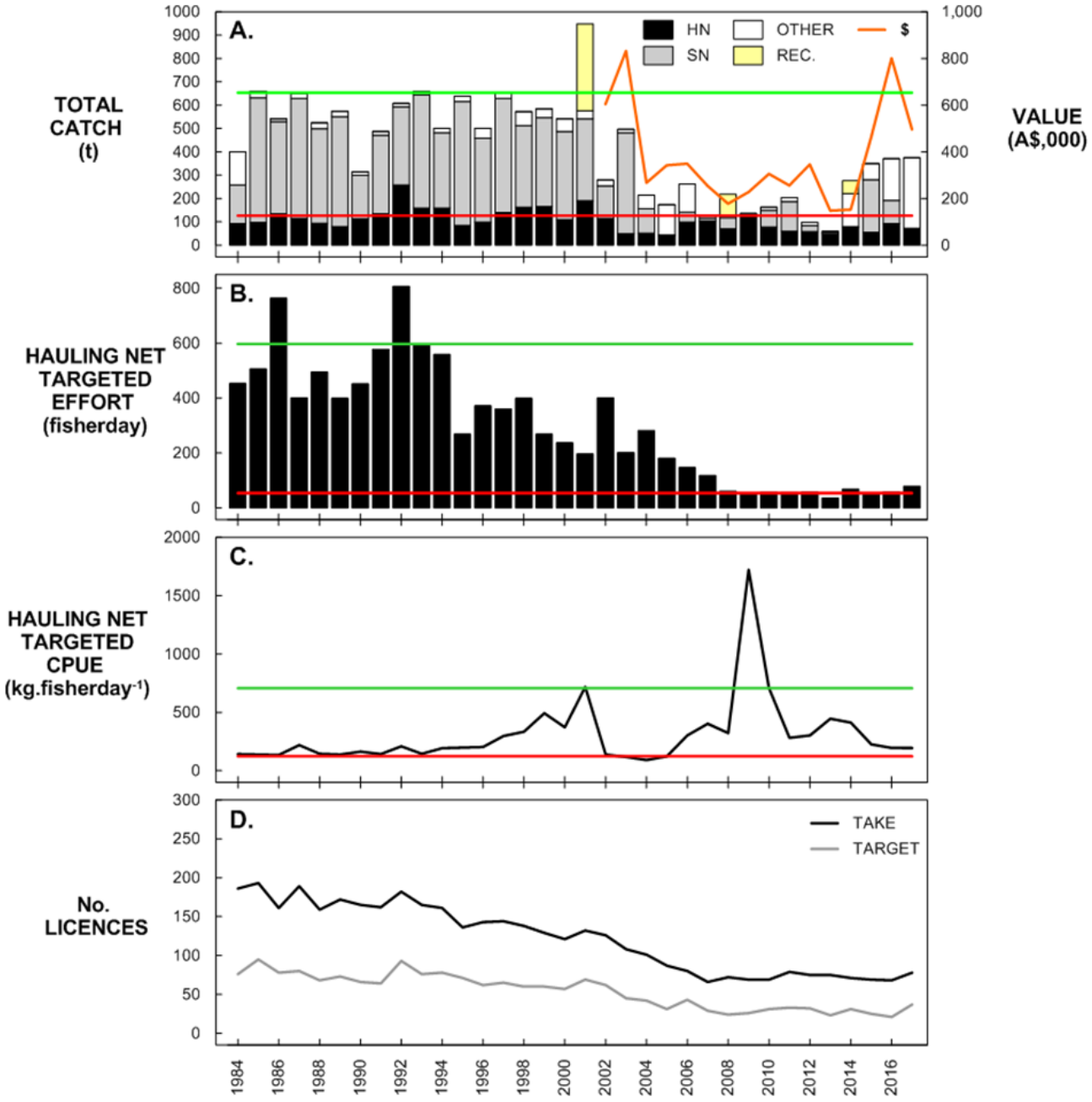

Figure 4-22.Western Australian Salmon. Long-term trends in: (A) total catch of the main gear types (hauling and set nets), estimates of recreational catch, and gross production value; (B) targted effort for hauling nets; (C) total catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

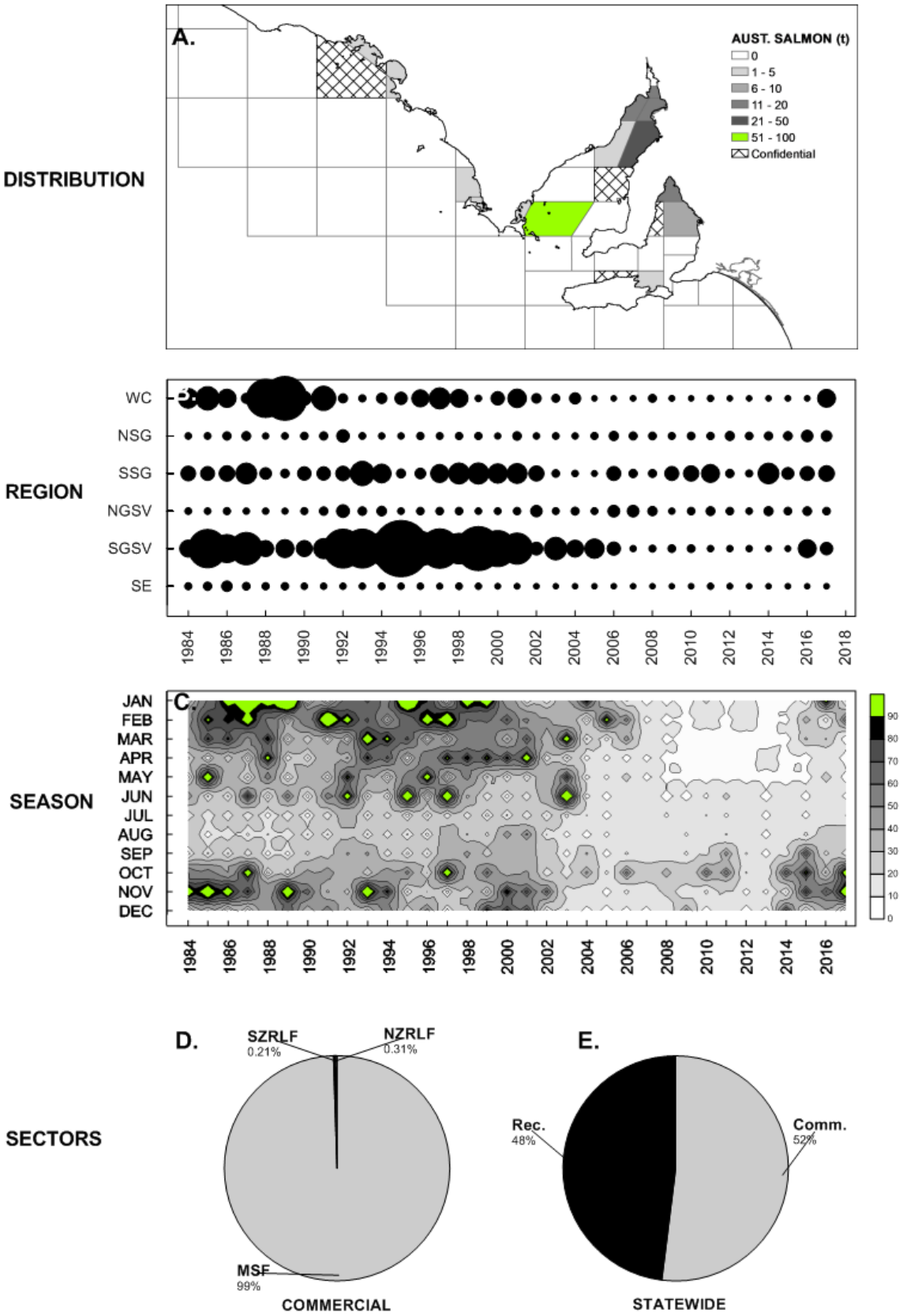

Figure 4-23 Western Australian Salmon. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t), (D) the proportion of catch distributed among the commercial sector in 2017; and (E) among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

Fishery Performance

The general performance indicators for Salmon were assessed for 2017 at the State-wide scale. No trigger reference points were activated (Table 4-9).

Table 4-9.Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Western Australian Salmon in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGET HAULING NET EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGET HAULING NET CPUE	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

Given the shared nature of the Salmon biological stock across southern Australia it is important that each jurisdiction has adequate management in place to ensure that their respective fisheries do not compromise the overall sustainability of the resource. Currently the stock is considered to be 'sustainable' as the fishery has been relatively inactive due to weak market demand and low wholesale prices (Stewart et al. 2016). Trends in catch and effort within South Australia's Salmon Fishery also reflect this inactivity and have been further restricted as a consequence of a series of netting closures that were implemented in 2005. Similarly, the relative inactivity of key purse seiners is indicative of a weak market, however, the increase in annual catches over the past four years and escalating value suggest new, emerging markets for this species. There were no trigger references points breached in 2017. The recent medium-level catches and associated catch rates indicate that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. On this basis, the Salmon fishery is classified as **sustainable**.

4.3.6. AUSTRALIAN HERRING (*Arripis georgiana*)

Biology

Australian Herring (hereafter referred to as 'Herring') is an abundant pelagic fish species that occurs along the west and south coasts of Australia. They are distributed in coastal marine and estuarine waters between Shark Bay, Western Australia, and Port Phillip Bay, Victoria, and are considered to constitute a single biological stock (Ayvazian et al. 2000). Herring share a similar life-history to Western Australian Salmon where they spawn around reefs off the lower west coast of Australia from late May to early June and the developing eggs and larvae are advected eastwards. The extent of their distribution depends on the relative strength of the Leeuwin Current which transports warm tropical water along Australia's southern coastline. Juveniles settle in inshore waters throughout this eastward distribution, some in close proximity to the spawning grounds, whereas others extend as far as Victoria. Juveniles prey upon small epibenthic crustaceans associated with shallow seagrass beds and as they mature switch their diet to include small fish (i.e. juvenile Australian Sardines), larger crustaceans and surface insects. Herring attain sexual maturity at two to three years of age and approximately 200 mm in length and typically return to southwestern Australia where they contribute to the spawning population (Smith et al. 2013).

Fishery

The schooling nature of Herring have made them a particularly important secondary species within the hauling net sector of the MSF, whereas they constitute a minor catch for the line sector. The majority of Herring caught in South Australia has been for human consumption, and given its relatively low value they are typically caught as a by-product when hauling net fishers target more valuable species, such as King George Whiting or Southern Garfish. Set and gill nets are also used to catch Herring for bait for either commercial longlining or Rock Lobster fishing operations. The Northern and Southern Zone Rock Lobster licence holders and Miscellaneous Fishery licence holders have reported negligible catches of Herring over many years. The species is a popular target within the State's recreational fishing sector. These fishers capture Herring using rod and line from boat and shore-based platforms. The latest estimate of catch from the recreational sector was 157.2 t (Giri and Hall 2015).

Management Regulations

Generic netting restrictions that have been implemented since the 1950s have affected many species within the MSF, including Herring. In 1983, the legal minimum length of 150 mm (TL) that applied to the recreational fishing sector was abolished. A recreational bag limit of 60 fish per person and a boat limit of 180 fish per vessel was introduced in July 2001. This was reduced to 40 and 120 fish, respectively, in December 2016.

Commercial Fishery Statistics

State-wide

The total State-wide commercial catch of Herring in 2017 was 61.1 t, which was the lowest on record (Figure 4-24). This represented an 87.6% decrease from the peak annual catch of 493.8 t in 1987. Annual catches have remained below 200 t since 2003. Rock lobster licence holders accounted for less than 0.1% of the 2017 commercial catch. The gross production value of this fishery has ranged from AUD$292,000 to AUD$453,000 during this time, and in 2017 was valued at AUD$337,000. Netting closures have contributed to the erosion of fishing effort, where hauling net fishers have rarely exceeded 80 fisher-days.year^{-1} targeting Herring since 2005. Prior to this, total targeted effort for the hauling net sector declined from a peak of 738 fisher-days in 1992 to 182 fisher-days in 2005 (Figure 4-24).

Target catch rates of Herring in the hauling net sector have been highly variable over the past 33 years ranging from 53.4 kg.fisher-day in 2003 to 2016.5 kg.fisher-days in 2009 (Figure 4-24). Targeted hauling net catch rate of Herring in 2017 is confidential due to the <5 fisher rule. Despite such high variability, the long term trend has been relatively stable. Approximately 20% of fishers that take Herring actively target the species, and this proportion has remained relatively consistent over the last 33 years.

Regional

Prior to the implementation of the netting closures in 2005, the highest catches for Herring were shared amongst NSG, SSG, and NGSV (Figure 4-25). Since then, most of the catch from SSG has reduced. Similar reductions were evident in NGSV but only lasted approximately six years before returning back to moderate levels. The relative proportion of catch from NSG has remained relatively unchanged (Figure 4-25). Most of this catch has been historically landed throughout spring and autumn. In 2017, MSF fishers dominated the catches accounting for >99.9% of the commercial catch. The remainder was shared amongst the fishers of the NZRLF and SZRLF. In 2013/14, the recreational sector accounted for approximately 52% of the State-wide catch (Figure 4-25).

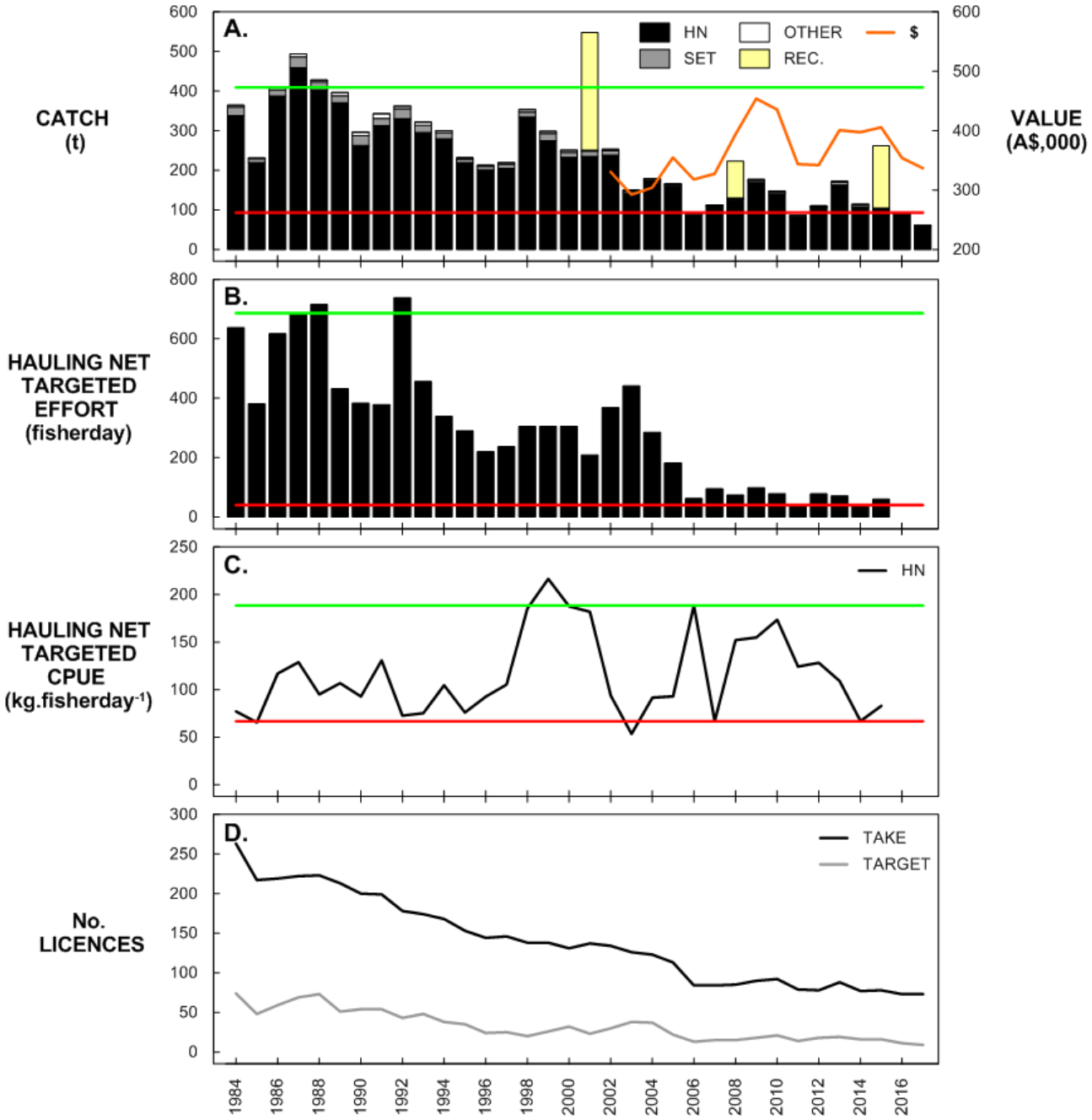

Figure 4-24. Australian Herring. Long-term trends in: (A) total catch of the main gear types (hauling and set nets), estimates of recreational catch, and gross production value; (B) targted effort for hauling nets; (C) total catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

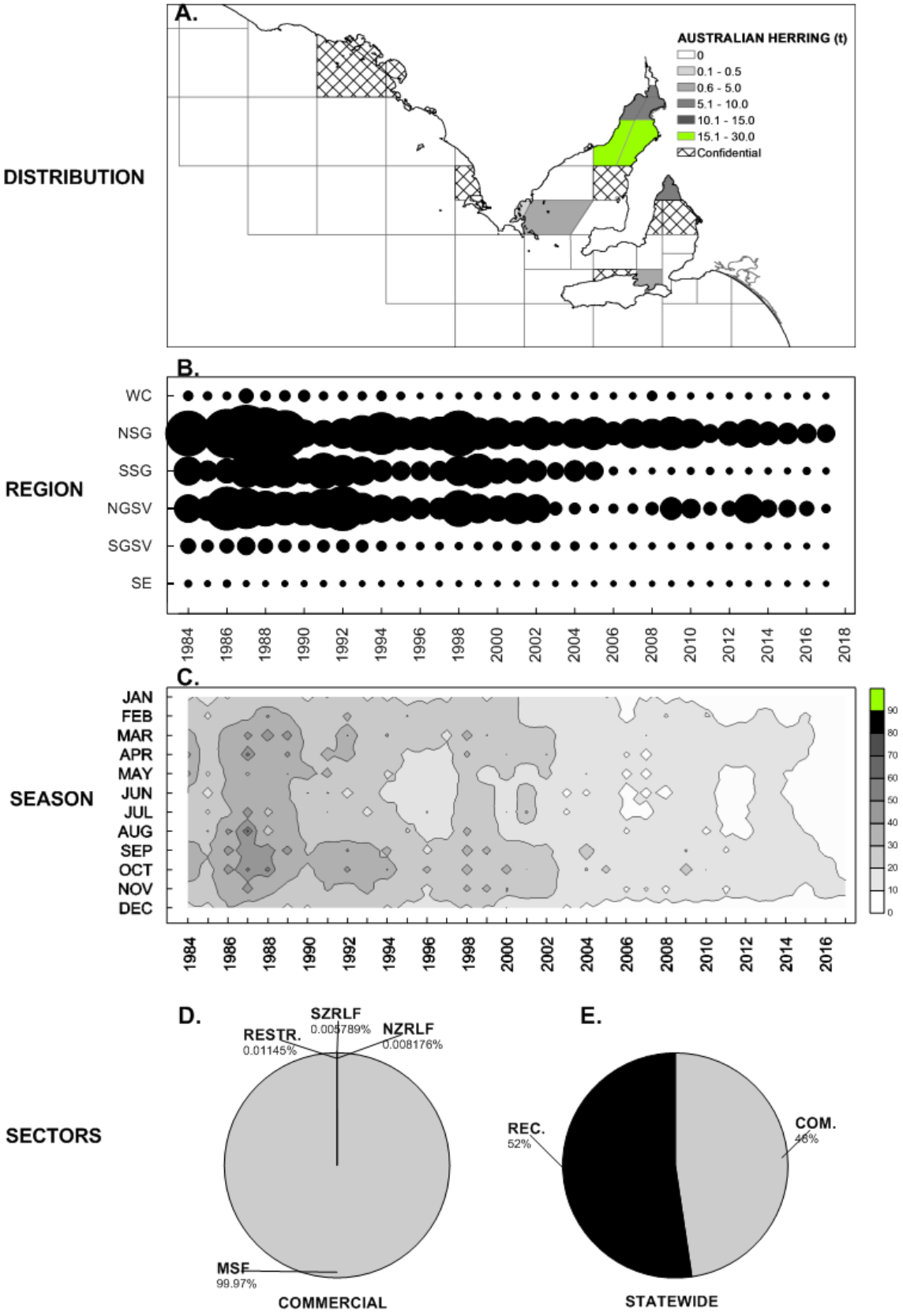

Figure 4-25. Australian Herring. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t), (D) the proportion of catch distributed among the commercial sector in 2017; and (E) among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall 2015).

Fishery Performance

The general performance indicators for Herring were assessed for 2017 at the State-wide scale, using the reference period 1984 to 2017. The resolution of the targeted effort and associated catch rates for hauling net fishers were confidential due to the <5 fisher rule. The 2017 catch of Herring was the lowest on record, breaching this single trigger reference point (Table 4-10).

Table 4-10. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State scale for Australian Herring in 2017. CONF. denotes confidential data, <5 fishers.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	LOWEST
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGETED HAULING NET EFFORT	G	3rd Lowest / 3rd Highest	CONF.
	G	Greatest % interannual change (+/-)	CONF.
	G	Greatest 3 year trend	CONF.
	G	Decrease over 5 consecutive years	CONF.
TARGETED HAULING NET CPUE	G	3rd Lowest / 3rd Highest	CONF.
	G	Greatest % interannual change (+/-)	CONF.
	G	Greatest 3 year trend	CONF.
	G	Decrease over 5 consecutive years	CONF.

Stock Status

Given the shared nature of the stock it is important that each jurisdiction has adequate management in place to ensure that their respective fisheries do not compromise the overall sustainability of the resource. A recent assessment of Australian Herring in southwestern Australia indicated that the sustainability of the resource was at a high risk (Smith et al. 2013). This was ascertained through a weight-of-evidence approach and justified the assessment on the basis of high fishing mortality rates, truncated age and size structures, a high proportion of immature fish in the commercial catch; and inferred low recruitment. The fishery-dependent indicators of the status predominantly related to the spawning stock, whereas other fishery-independent indicators (i.e. recruitment indices) of overall stock status were based on data collected at a broader regional scale (Smith et al. 2013). It was suggested that the fishery warranted a reduction in fishing effort and/or catch to promote its recovery. In 2015, management arrangements were introduced in Western Australia to curtail the capture of Herring which included the closure of the South Coast Trap Net Fishery that specifically targets Herring, and reduction in the recreational bag limit.

The levels of fishing effort and subsequent catch of Herring in South Australia have substantially declined over the past 33 years and were particularly eroded by the implementation of a series of netting closures in 2005. Total catch of Herring in 2017 was

61.2 t, the lowest on record, reflecting historically low effort levels. Despite this erosion, catch rates within the hauling net sector have remained highly variable with no clear, long-term trend. This is most likely due to this species being infrequently targeted by the commercial sector as a result of Herring having a relatively low market value. The species is a popular target within the state's recreational fishing sector.

A dedicated research program that assessed the status of Herring at the biological stock level identified a strong relationship between a pre-recruit index in Gulf St. Vincent and sea level heights for Albany, Western Australia (Ayvazian et al. 2000; Jones and Westlake 2003). This indicated that the variation in annual recruitment within the South Australian nursery grounds and subsequently to the fishery is dependent on the Western Australian spawning stock. The high productivity of the species and the management arrangements introduced in WA in 2015, has contributed to the recovery of the resource (DPIRP 2017). Consequently the status of the South Australian Herring Fishery should reflect the Western Australian assessment.

The current level of fishing mortality of Herring in South Australia is unlikely to cause the stock to become recruitment impaired. On the basis of the evidence provided above, the Australian Herring biological stock is classified as a **sustainable** stock.

4.3.7. VONGOLE (*Katelysia* spp.)

Biology

South Australia has three Vongole species (commonly known as Mud Cockles) that are commercially harvested; 'Greys' (*Katelysia scalarina*), 'Yellows' (*K. rhytiphora*) and 'Whites' (*K. peronei*) (Dent et al. 2016a). All three species inhabit shallow estuarine and marine embayments and are broadly distributed along the temperate coastline from Augusta, Western Australia to Port Jackson, New South Wales (Roberts 1984). The stock structures of the three species are unknown, but given their species short larval periods (Gluis and Li 2014), it is expected that Vongole in individual bays would constitute separate stocks (Dent et al. 2015). In South Australia, three putative biological stocks have been identified as separate management zones: West Coast, Coffin Bay, and Port River Cockle Fishing Zones. Vongole reach a maximum age of 29 years and attain sizes of 55 mm shell length (SL). Size and age at maturity have been estimated at 23-31 mm SL and 4 years, respectively (Riley et al. 2005).

Fishery

Vongole have been commercially harvested in South Australia since the early 1960s with the majority of catch taken from the Port River and Kangaroo Island and sold as bait. Since the mid-1980s there has been an increasing demand for this species for human consumption, particularly driven by Melbourne-based markets. Despite this demand, South Australia's Vongole fishery remained lightly exploited (Dent et al. 2016a, b). Commercial MSF licence holders typically use hand-held cockle rakes to target Vongole in shallow, sand/mud substrates, although there are some records where they have been harvested by hand. These rakes can only be used if they are specifically endorsed on the commercial licence.

In 2013/14, an estimated 12,805 Vongoles, weighing approximately 0.14 t, were harvested by the recreational sector (Giri and Hall 2015).

Management Regulations

The Vongole fishery is managed separately from other MSF species. In October 2008 the fishery transitioned to an individual transferable quota (ITQ) management system. A total allowable commercial catch (TACC) was established as the principal output control for South Australia's commercial Vongole Fishery in 2008/09. This was initially set at 195 t for all zones on the basis of catch history, partitioned amongst the three zones: 100 t Port River, 70 t Coffin Bay, and 25 t West Coast. A fishery-independent program that estimated the harvestable biomass was developed in 2010 (Gorman et al. 2010). This research program provides survey-based estimates of biomass and size-at-maturity in each of the three fishing zones. The subsequent estimates of harvestable biomass provide the key performance indicator for

determining the TACC. The TACC is determined as a fraction of the biomass estimate (at 80% confidence), up to a maximum of 7.5%. All licence MSF fishers that do not own quota can harvest 10 kg per day of Vongole for bait.

A size limit of 35 mm maximum shell width is current for Vongole (Whites and Yellows) within the Coffin Bay Cockle Fishing Zone, outside of this zone the size limit is lower at 30 mm for all three species. Recreational size limits for Vongole are 38 mm within Coffin Bay, and 30 mm outside of the bay. They are further restricted to a personal bag limit of 300 cockles. The Port River Cockle Fishing Zone was closed in 2011, and continues to be closed, due to sustainability concerns. SARDI is currently undertaking a research project to inform a potential re-stocking program.

Commercial Fishery Statistics

The total State-wide commercial catch of Vongole in 2017 was 54.8 t with an estimated gross production value of AUD$881,000 (Figure 4-26). Given the majority of this fishery has been managed under a TACC since 2008/09, annual catches have been relatively stable. The difference between the TACC for fishers with ITQ and the total annual catches was negligible, indicating that there is only a minor amount of Vongole harvested by other MSF fishers for bait. From 2005 until 2007, this fishery peaked above 300 t, and the gross value was approximately AUD$1 million per annum. Vongole are almost exclusively harvested using cockle rakes, with the majority of the catch taken from Coffin Bay on the West Coast. Given the highly selective nature of the gear, the long term trend in effort often reflects the catch. Cockle rake effort levels have declined below 700 fisher-days.year^{-1} in 2015, 2016 and 2017. These low levels of effort have not been observed since 1997. Catch rates of Vongole declined from a peak of 205.1 kg.fisher-day^{-1} in 2002 to a low of 62.0 kg.fisher-day^{-1} in 2011. They have since increased to 101.7 kg.fisher-day^{-1} in 2017 (Figure 4-26). Those fishers that have recorded catches of Vongole have generally actively targeted them. The number of licence holders has declined from 45 in 2007 to 14 in 2017, representing a 68.9% reduction over ten years.

Regional

The West Coast and NGSV regions have historically accounted for most of the State-wide catch, supporting the establishment of the three management zones (Figure 4-27). The closure of the Port River Cockle Fishing Zone in 2011 was responsible for removing the catch from NGSV. During the peak of the fishery in the late 1990s and 2000s most of the catch was harvested in late winter and spring. Marine Scalefish licence holders have accounted for almost 100% of the commercial catch in 2016. The recreational sector accounted for <0.2% of the State-wide catch in 2013/14 (Figure 4-27).

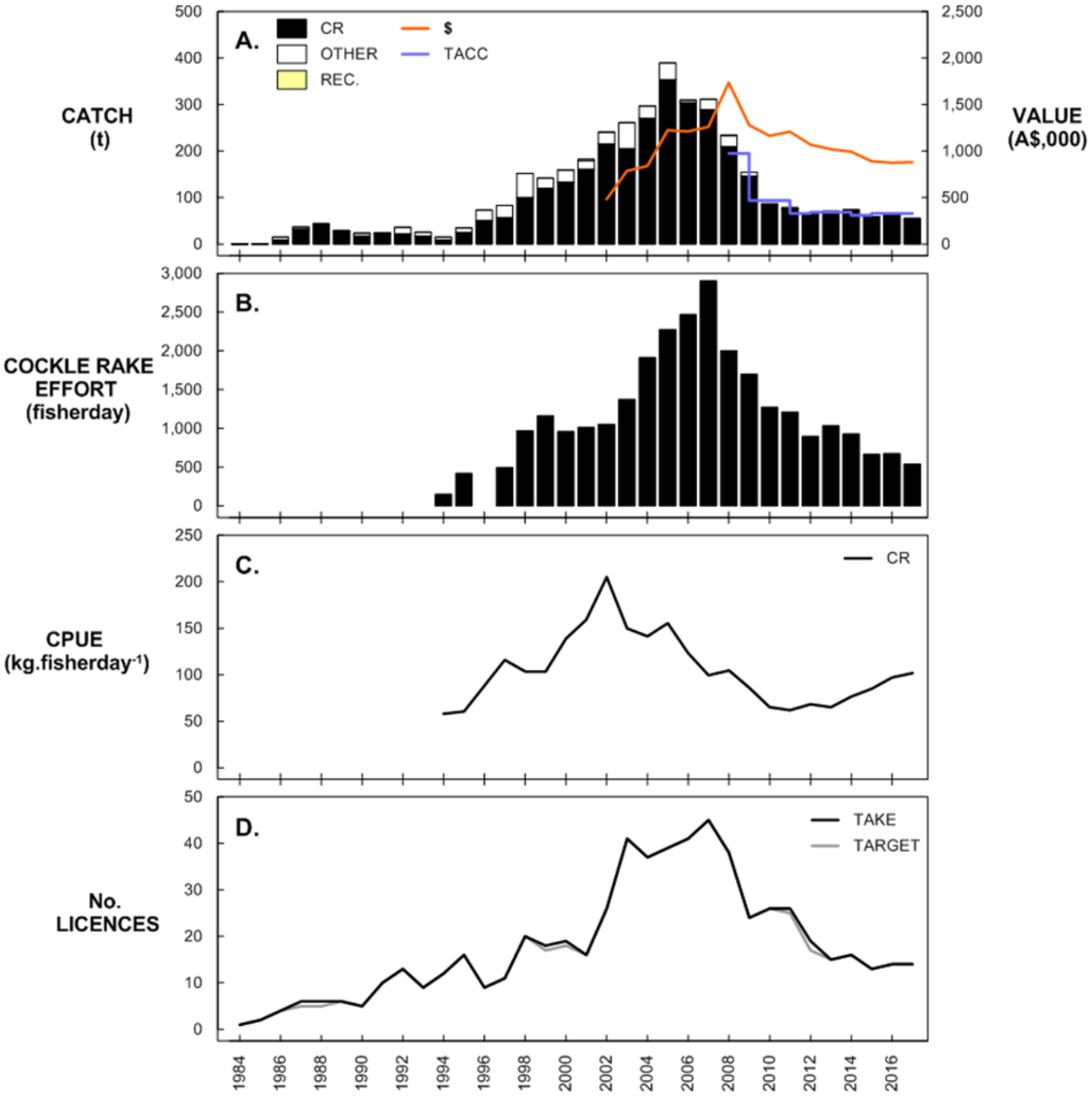

Figure 4-26. Vongole. Long-term trends in: (A) total catch of the main gear types (cockle rake and other), estimates of recreational catch, gross production value, and total allowable commercial catch (TACC); (B) total effort for cockle rakes; (C) total catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species.

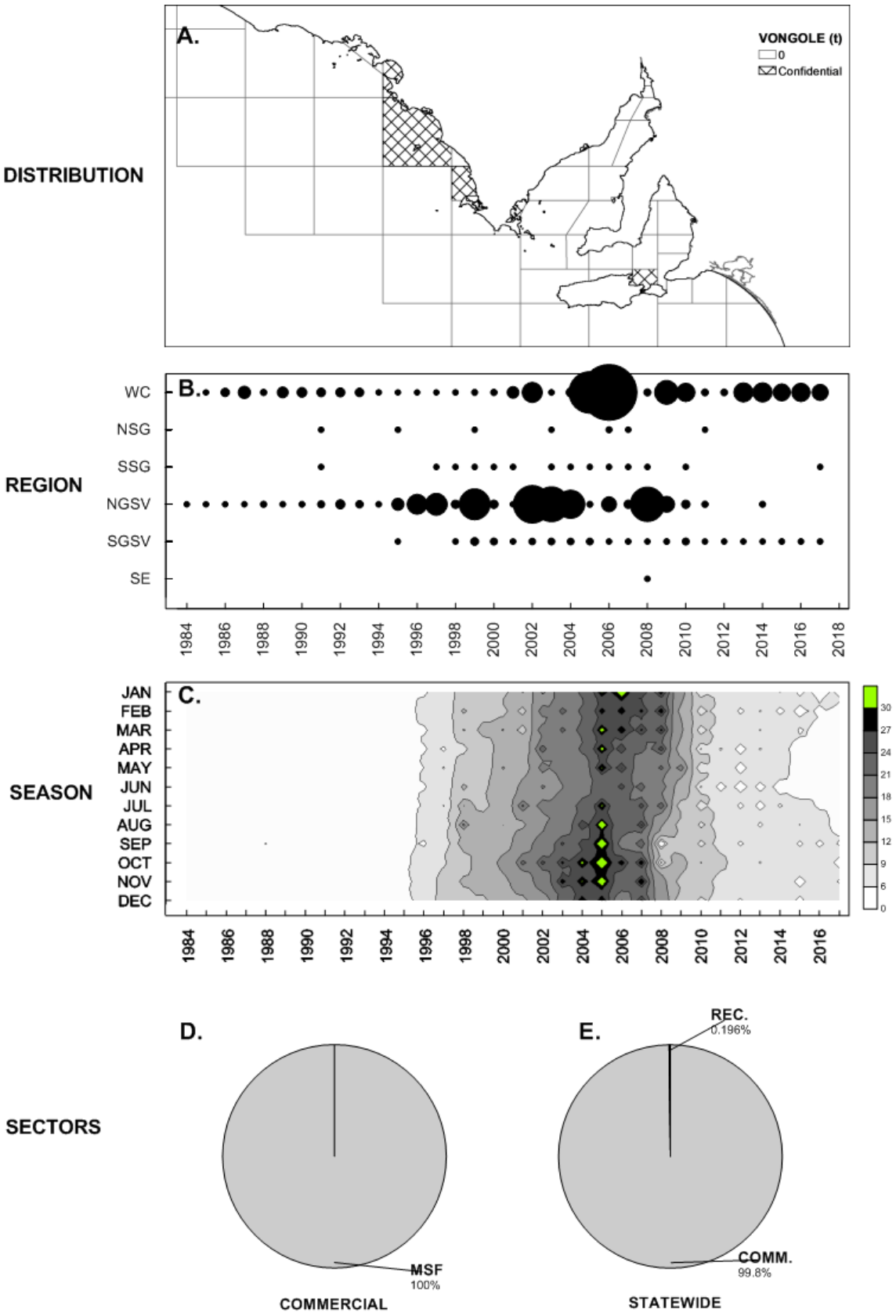

Figure 4-27. Vongole. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t), (D) the proportion of catch distributed among the commercial sector in 2017; and (E) among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

Fishery Performance

The general MSF performance indicators and associated reference limits do not apply for Vongole fishery, as it is managed by a TACC (PIRSA 2013).

Stock Status

The status of South Australia's Vongole Fishery is determined from a routine fishery-independent research program that undertakes structured surveys to determine the relative density and size structure of Vongole populations within the three management zones; West Coast, Coffin Bay and Port River Cockle Fishing Zones (Gorman et al. 2010, Dent et al. 2016a). The overall objective of these surveys is to estimate the harvestable biomass to provide the key performance indicator to determine the TACC.

The latest assessment indicated that, based on collective evidence of high harvestable biomass, low exploitation rates and strong recruitment, the Coffin Bay and West Coast Cockle Fishing Zones were unlikely to be recruitment overfished and consequently classified as **sustainable** (Dent et al. 2016 a, b).

The first survey conducted for the Port River Cockle Fishing Zone in 2009 indicated that the biomass was low. Given this zone has historically produced significant catches, its low biomass raised sustainability concerns, and consequently it was closed to the taking of Vongole by all fishing sectors in 2011/12. A biomass survey conducted in 2016 showed that the stock had not yet recovered and remains in a depleted state. The status of this fishing zone is classified as **depleted**.

4.3.8. SNOOK (*Sphyraena novaehollandiae*)

Biology

Snook is a member of the Sphyraenidae family, i.e. the Barracudas (Gomon et al. 2008). The species is broadly distributed across southern Australia from Perth to Sydney, including Tasmania as well as New Zealand (Gomon et al. 2008). There is little information available on stock structure throughout this broad Australasian distribution (Emery et al. 2016). Snook are usually found over seagrass beds and kelp reefs near the surface both in inshore and offshore waters of up to 20 m depth (Emery et al. 2016). They are elongate, slender fish with a pointed head and projecting jaw that facilitates their feeding mode. They are powerful swimmers and voracious predators that take a variety of prey including pelagic and demersal teleost fishes, crustaceans and cephalopods (Bertoni 1994).

Biological studies on this species have been limited, reflecting its status as a 'secondary' species for the MSF. In 2002, a South Australian study considered several hundred specimens collected from northern Gulf St. Vincent and Spencer Gulf from which population structure and reproductive biology were considered (O'Sullivan and Jones 2003). The largest specimen was 820 mm TL, although most were from 300 to 500 mm TL. The modal age was 2+ years, with the oldest up to 12 years of age. The males and females demonstrated similar growth relationships, whilst in both gulfs there were strong biases in the sex ratio towards females. The fish are reproductively active during summer between late November and early February (Bertoni 1994). They are multiple batch spawners and have indeterminate fecundity. The size at first maturity (L_{50}) is 391 mm and 403 mm for males and females, respectively, with the associated ages for both sexes being two years of age.

Fishery

In South Australia, Snook are taken by both the commercial and recreational sectors of the MSF. In the former sector, they are generally taken with hauling nets and gill nets when commercial net fishers target higher value species such as King George Whiting, Southern Garfish, Southern Calamari and Yellowfin Whiting. Snook are also targeted by commercial troll line fishers.

Recreational fishers target Snook with rods and lines. The State-wide recreational survey in 2013/14 estimated that 187,165 Snook were captured, of which 12,941 were released, leaving 174,224 fish retained (Giri and Hall 2015). The latter provided a total estimated State-wide harvest of 126.3 t.

Management Regulations

For the commercial sector, the many regulations that constitute input controls for the different netting gears contribute to minimising fishing effort on Snook, as well as a minimum size limit. This was increased from 360 to 450 mm TL in July 2001. A reduction in size limit to 410 mm TL came into effect in 2017, to align with size at maturity information (Bertoni 1994). At the request of the recreational sector, the size limit remains at 450 mm TL, with a bag limit of 20 fish and a boat limit of 60 fish. These regulations were not changed in the recent review of the recreational fishery (PIRSA 2016).

Commercial Fishery Statistics

State-wide

Estimates of annual, State-wide commercial catches of Snook increased to the highest recorded level in 1995, before declining over the long-term to the lowest level of 38.9 t in 2017 (Figure 4-28). Hauling nets have generally accounted for at least half of the annual catches, with troll lines generally the second most significant gear type. Whilst Snook have been reported being taken with several other gears types, gillnets account for the majority of the 'other' catch. Targeted hauling net fishing effort has declined since 1995 to the lowest recorded level in 2010, followed by marginal increases in 2016 and 2017 (Figure 4-28). Targeted hauling net CPUE has been highly variable, often fluctuating by >30 kg.fisher-day^{-1} in a single year. During the 1980s and 1990s annual targeted catch rates within the hauling net sector fluctuated around 25 kg.fisher-day^{-1}. Since the late 1990s onwards these catch rates have increased to approximately 50 kg.fisher-day^{-1}. Targeted hauling net CPUE in 2017 was relatively high at 51.9 kg.fisher-day^{-1} (Figure 4-28). The number of fishers that reported taking Snook has declined over the long-term at a faster rate than the lower number who targeted this species. Since 2006, approximately 60% of fishers who reported catching Snook actively targeted them (Figure 4-28).

Regional

Catches of Snook have been reported from the six geographic regions of South Australia's marine waters (Figure 4-29). The highest regional catches were taken during the 1990s, mainly from NSG and NGSV, with intermediate catches from SSG and the WC. Catches from all regions were lower during the 2000s. The fishery is seasonal with highest catches generally taken between July and November. Marine Scalefish Fishery licence holders accounted for all of the State-wide commercial catch in 2017, and in 2013/2014 landed 24.9% of the total State-wide catch with the recreational sector accounting for the remaining 75.1% (Figure 4-29).

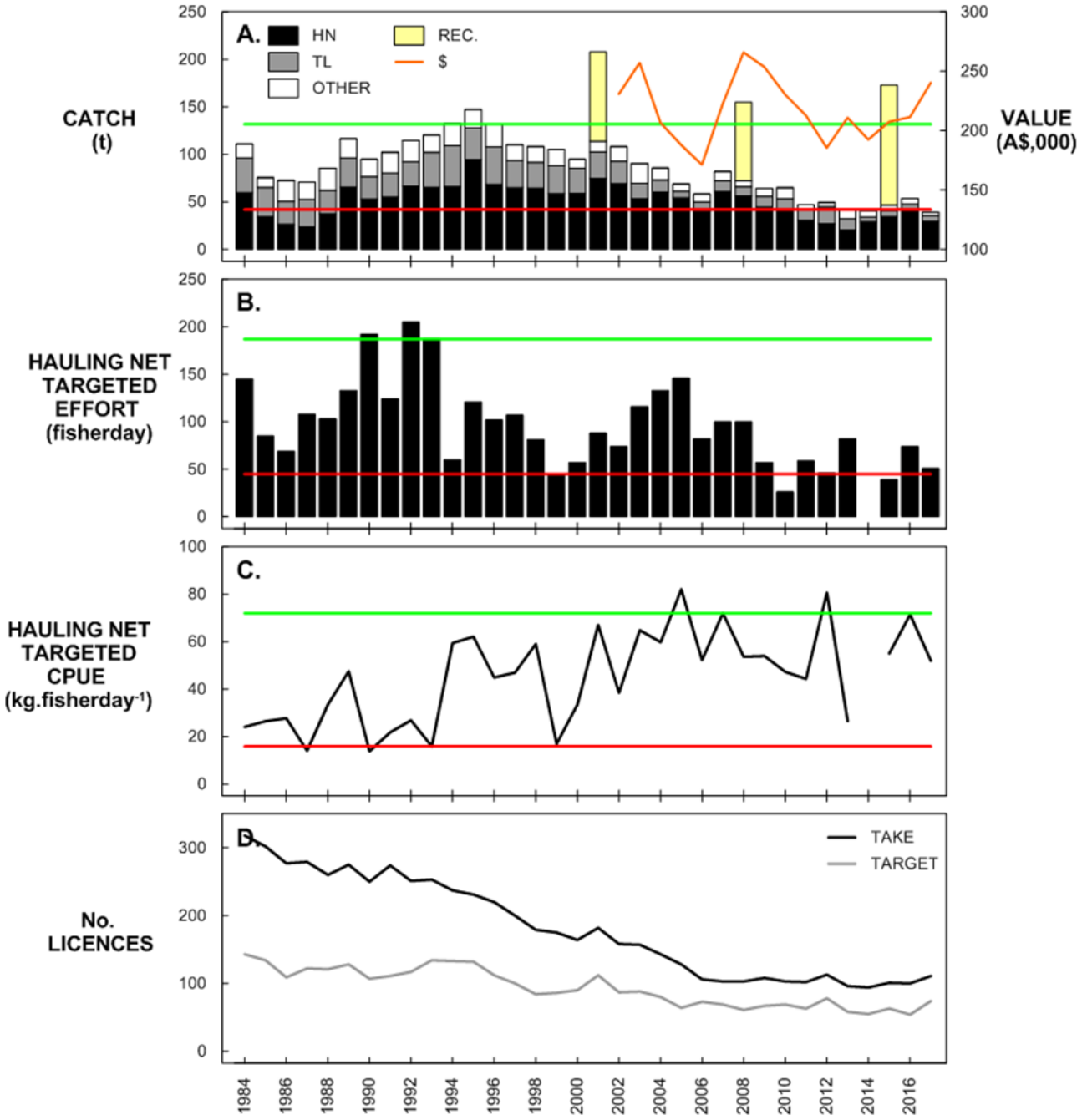

Figure 4-28. Snook. Long-term trends in: (A) total catch of the main gear types (hauling net and troll line), estimates of recreational catch, and gross production value; (B) targeted effort for hauling nets; (C) total catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

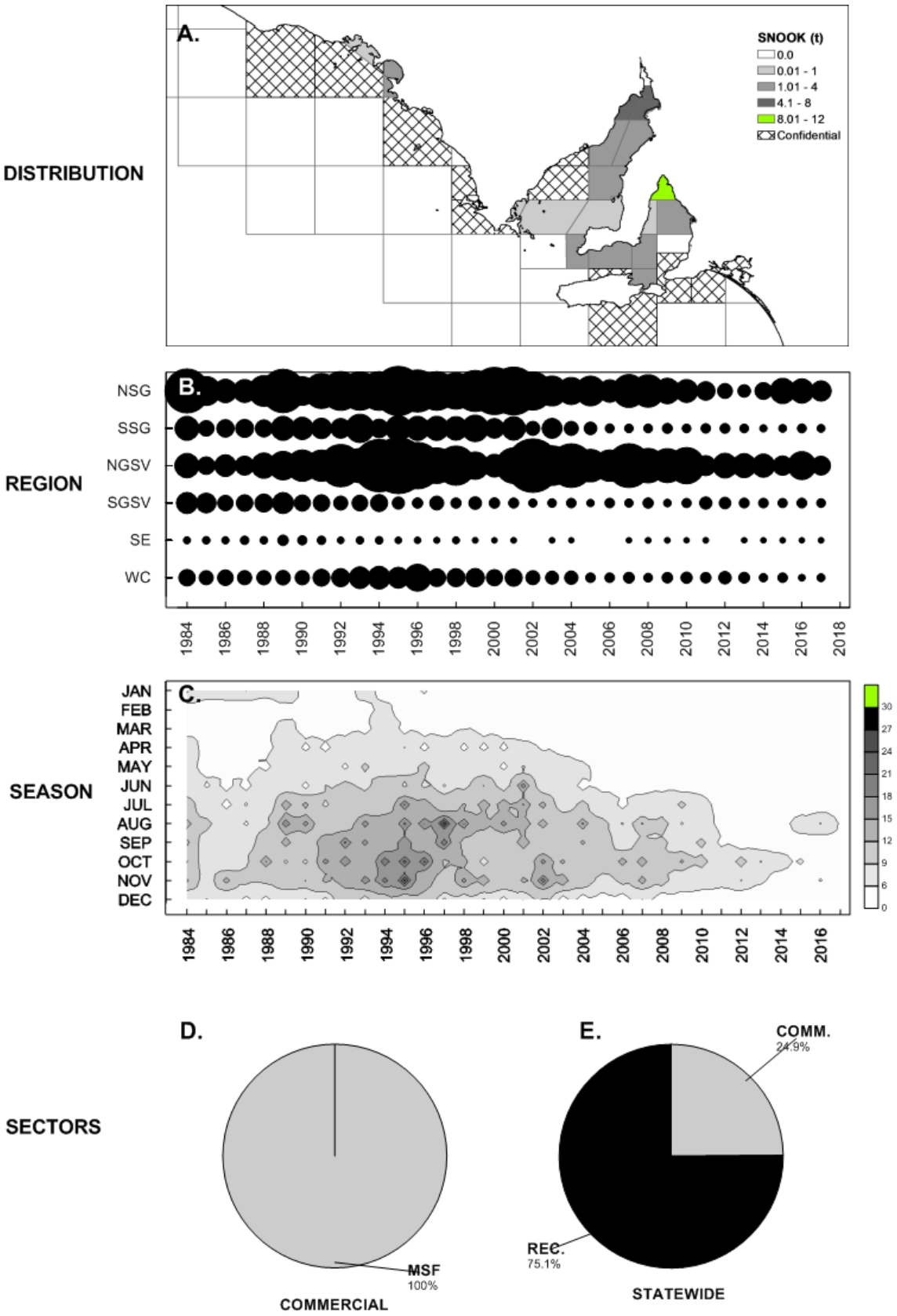

Figure 4-29. Snook. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t), (D) the proportion of catch distributed among the commercial sector in 2017; and (E) among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

Fishery Performance

The general fishery performance indicators for Snook were assessed for 2017 at the State-wide scale. The commercial catch of 38.8 t in 2017 was the lowest on record and breached the associated trigger reference point (Table 4-11).

Table 4-11. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State-wide scale for Snook in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	LOWEST
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGET HAULING NET EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGET HAULING NET CPUE	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

The primary measures for biomass and fishing mortality are targeted catch rates using troll lines and hauling nets. Approximately 25 per cent of the annual catch is targeted using troll lines and hauling nets, with the remaining 75 per cent landed as by-product when fishers target other, higher-value species. Targeted catch rates for both gear types are typically variable, ranging between 15–30 kg.fisherday^{-1} and 20–80 kg.fisherday^{-1} for troll lines and hauling nets, respectively. Total annual commercial catches have declined from a peak of 147 t in 1995 to 39 t in 2017, driven by an 80 per cent reduction in fishing effort. This reduction largely reflects the removal of hauling net fishers through the implementation of a voluntary buy-back scheme and spatial netting closures in 2005. During this time, catch rates have been highly variable, but have not shown any long-term decline. The recent medium-level catches and associated catch rates indicate that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. On this basis, Snook in South Australia is classified as a **sustainable** stock.

4.3.9. BLUE CRAB (*Portunus armatus*)

Biology

Blue Crabs are distributed within near-shore, marine bays and estuarine systems in Australia and New Caledonia (Lai et al. 2010). They occur in a wide range of algal and seagrass habitats, and on sandy and muddy substrata, from the intertidal zone to a depth of at least 50 m (Williams 1982; Edgar 1990). Smaller crabs are generally found in shallow waters <1 m, while adults are found in deeper waters.

Blue Crabs generally reach sexual maturity at carapace widths of between 70 and 90 mm (Smith 1982). The spawning season lasts for three to four months over the summer/autumn period (Kumar et al. 2000). In South Australian waters, Blue Crabs close to the Minimum Legal Size (MLS = 110 mm carapace width) are ~14 to 18 months old and sexually mature. Females have produced at least two batches of eggs within a single season. Fecundity of female Blue Crabs is size-dependent, increasing up to a carapace width of 134 mm and decreasing thereafter, with females producing between 650,000 and 1,760,000 eggs per spawning event (Kumar et al. 2000; 2003). From 105 mm to 125 mm, fecundity was shown to increase by 84%, indicating that a single large female can produce as many eggs as two small females (Kumar et al. 2003).

Using allozyme markers, Bryars and Adams (1999) determined that the populations of *P. armatus* within Spencer Gulf, Gulf St Vincent and West Coast regions of South Australia represented separate sub-populations with limited gene flow.

Fishery

Blue Crabs were first harvested as by-product in South Australian Prawn and Marine Scalefish Fisheries in the 1970s. In 1981, an experimental trawl fishery with four licensed fishers was established in northern Spencer Gulf. This approach was later abandoned, and in 1983, six experimental pot fishing permits were offered to licence holders in the MSF. In 1985/86 the number of experimental licences was increased to 12, i.e. four on the West Coast, six in Spencer Gulf, and two in Gulf St Vincent. In 1986, the West Coast fishery declined and the four licence holders surrendered their entitlements. Also during 1986, the sale of Blue Crabs as by-product from the prawn fishery was prohibited.

In June 1996, management arrangements for a separate commercial Blue Crab Fishery (BCF) in South Australia was established. The BCF is based on the capture of a single species (*P. armatus*), although other crab species may also be landed. The BCF comprises two fishing zones, i.e. the Spencer Gulf and Gulf St Vincent fishing zone. An annual total allowable commercial catch (TACC) or 'quota' is determined for the BCF for the 12-month period from 1

July to 30 June, with separate quota units allocated for each fishing zone. Almost all of the TACC (99%) is allocated among the BCF licence holders (also referred to as 'pot fishers'), with the remainder allocated to some MSF licence holders. Fishery-independent surveys are conducted to inform stock assessment of the BCF with the most recent report classifying the Gulf St Vincent and Spencer Gulf biological stocks as sustainable (Beckmann and Hooper 2018).

The *Fisheries Management (General) Regulations 2007* state that Blue Crabs may also be taken from State waters within three nautical miles of the coast west of longitude 135°E, although this 'West Coast' region of South Australia is not subject to quota management arrangements. Commercial pot fishers generally haul their gear once or twice every 24 hours using specifically designed crab pots covered with mesh. MSF fishers use either hoop or drop nets hauled every 20-30 minutes. Recreational fishers target Blue Crabs mostly using hoop/drop nets or hand held rakes. The most recent estimate of recreational catch was 376 t between December 2013 and November 2014 (Giri and Hall 2015).

Management Regulations

Current output controls for Blue Crabs caught in South Australia include restrictions on the total commercial catch through a quota system (BCF), spatial and temporal commercial closures, bag and boat limits for recreational fishers, a minimum legal size limit (MLS) of 110 mm carapace width measured from the anterior base of the first spine, and restrictions on taking berried females.

Formalised management arrangements for the BCF include pot dimension restrictions, pot to quota unit ratios, delineation of two fishing zones in SG and GSV, and a single TACC with quota units allocated separately for each zone. Quota is transferable between the pot fishers of the BCF and eligible MSF licence holders, but only within the same zone.

The State-wide TACC for the BCF was initially set at 520 t for the 1996/97 fishing season (325 t in SG and 194 t GSV). Over the following four quota years the TACC was gradually increased to 627 t (382 t in SG and 245 t in GSV) in 2000/01, where it remained until 2012/13. In 2013/14 and 2014/15, the TACC for the GSV zone was reduced to 196 t due to stock sustainability concerns. A voluntary commercial closure in GSV was also implemented from 1 July 2013 to 15 January 2014. From 2015/16, the TACC for the GSV zone was increased to 245 t, resulting in an overall TACC of 627 t (382 t in SG and 245 t in GSV).

Since December 2016, recreational fishers have been restricted to a bag limit of 20 crabs (Blue Crabs and/or Sand Crabs combined) per person per day and a boat limit of 60 crabs per day (where 3 or more people are on board).

Commercial Fishery Statistics

State-wide

Estimates of annual, State-wide commercial catches of Blue Crabs have been variable since the fishery commenced in 1984 (Figure 4-30). Annual catches were comparatively low until 1988. They then increased considerably between 1989 and 1995 reaching a peak of 692.9 t, before dropping to a low of 74.3 t in 1998. Since then, total catch increased to the 123.9 t in 1999, but has since declined over the long-term reaching a minimum value of 31.2 $t.yr^{-1}$ in 2016 before increasing to 51.6 t in 2017. During the early years the fishery was primarily based on the use of specialised crab pots. However, from 1998, crab pots were no longer used by the MSF as effort was transferred to the pot fishing sector of the BCF. In the following years, the use of crab nets became the predominant gear type in the MSF. Targeted crab net effort peaked at 5,000 – 7,000 fisher-days during the 90s. Since 1998, there has been a gradual decline in targeted effort to 556 fisher-days in 2016, before increasing to 849 fisher-days in 2017 (Figure 4-30).

Targeted crab net CPUE has increased from approximately 40 $kg.fisher\text{-}day^{-1}$ in 1985 to 94.8 $kg.fisher\text{-}day^{-1}$ in 1995, before declining to 51.8 $kg.fisher\text{-}day^{-1}$ in 2000 (Figure 4-30). Since then, CPUE has remained relatively stable with 56.8 $kg.fisher\text{-}day^{-1}$ recorded in 2017. Since 1989, the numbers of fishers taking and targeting Blue Crabs have been closely linked, which indicates that this species is specifically targeted rather than being a by-product species. The number of fishers targeting Blue Crabs peaked at 79 in 1988, and has declined to 21 in 2017.

Regional

From 1985 to 2005, Blue Crabs were primarily harvested from NSG and NGSV (Figure 4-31). Catch in NSG was highest from 1985–1997, while NGSV was highest from 1998–1997. Outside of this region, the highest catches have been taken from the WC and from 2006 onwards, a majority of the catch was harvested from this region. Lower annual catches occurred in SSG and SGSV, while no catch has been recorded the SE. From 1984–1996, the Blue Crabs were harvested all year round, with highest catches during February and March. Since 1997 Blue Crabs harvests have been seasonal with highest catches taken between January and March.

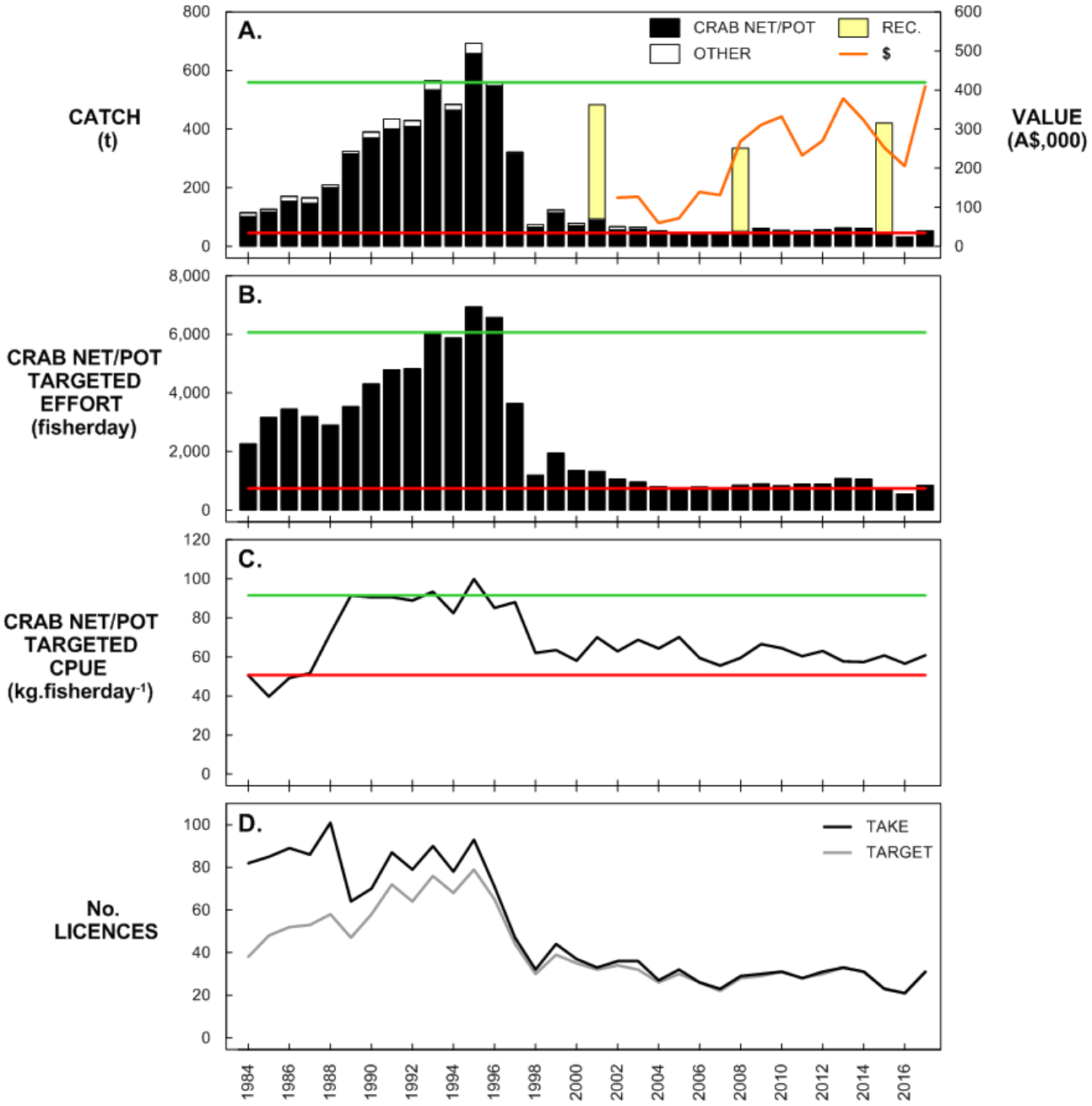

Figure 4-30. Blue Crabs. Long-term trends in: (A) total catch of the main gear types (crab net/pot and other), estimates of recreational catch, and gross production value; (B) targeted effort crab net/pots; (C) total catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified Table 3-1.

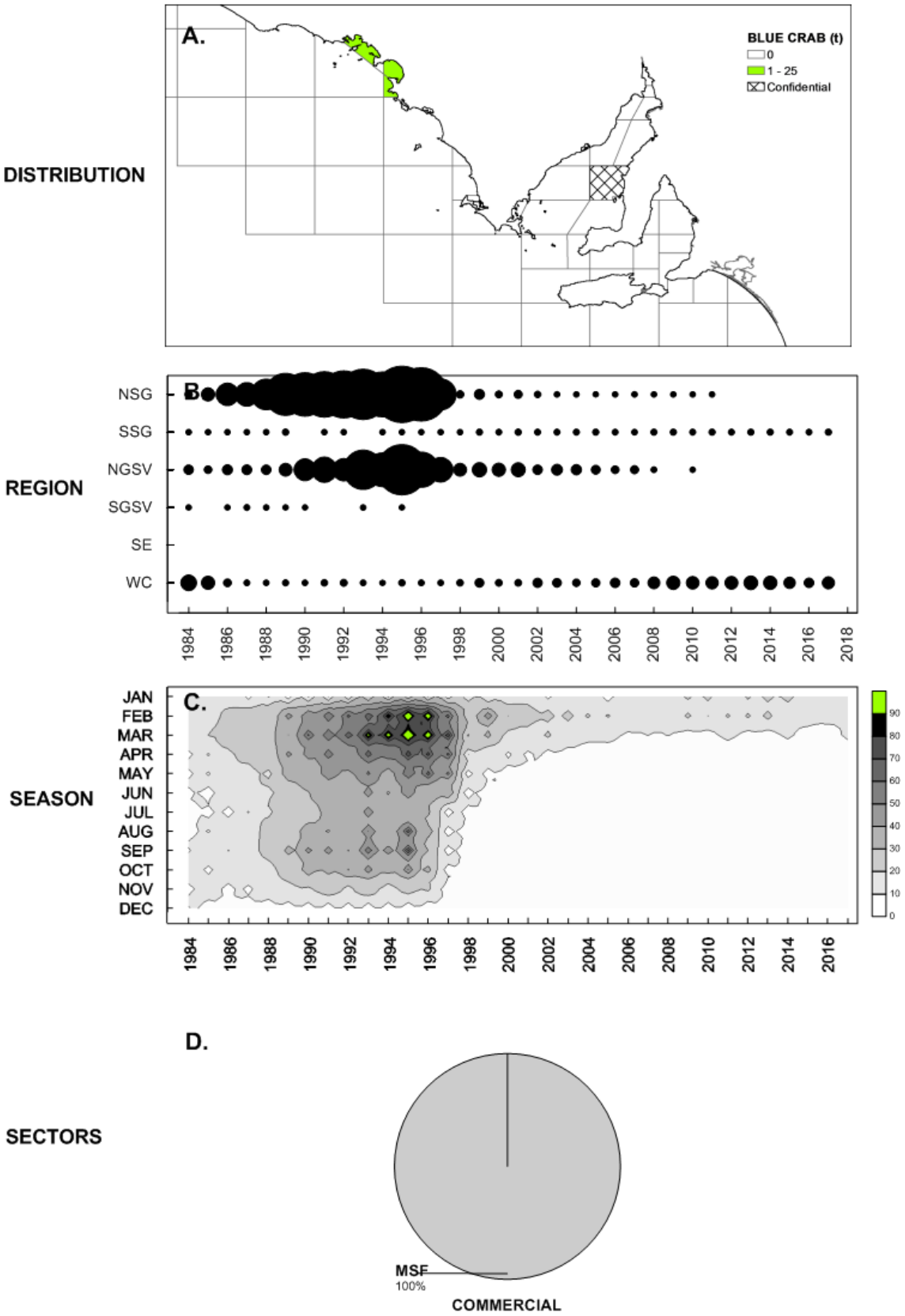

Figure 4-31. Blue Crabs. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t); and (D) the proportion of catch distributed among the commercial sector in 2017.

Fishery Performance

The general fishery performance indicators for Blue Crabs were assessed for 2017 at the State-wide scale. No trigger reference points were breached (Table 4-12).

Table 4-12. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State-wide scale for Blue Crab in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGET CRAB NET EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGET CRAB NET CPUE	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

The Blue Crab resource is accessed by specialist fishers that require endorsed net or pot types on their licences to target the species, consequently the fishery statistics considered here at State-wide scale related to targeted fishing effort. Nevertheless, the interpretation of such data is complicated by the transfer of MSF effort to the pot fishing sector in the gulfs. This is reflected by low catches (<7 t) from the Spencer Gulf and Gulf St Vincent since 2008. For the WC zone, recent catches and targeted crab net effort levels are relatively high compared to those in the past. Relatively stable CPUE and consistent catches over the past decade indicate that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. On this basis, the stock is classified as '**sustainable**'.

4.3.10. SAND CRAB (*Ovalipes australiensis*)

Biology

The Sand Crab is a medium-sized crab species of the family Portunidae. It has a broad distribution across southern Australia from Wide Bay in Queensland, to Rottnest Island in Western Australia, including Tasmanian waters (Kailola et al. 1993). They occur on surf beaches, sandy bays and inlets, and in off-shore waters to approximately 100 m depth. In South Australia, they occur in most inshore waters except the northern gulfs and west coast bays (Jones 1995), where Blue Crabs (*Portunus pelagicus*) are most abundant. The stock structure for Sand Crabs is unknown across the broad Australian distribution.

A study on the reproductive biology in Coffin Bay determined that Sand Crabs are winter spawners with reproductive activity peaking in July and berried females present until late August (Deakin 1996). Female Sand Crabs attain sexual maturity at a smaller size compared to males. A measuring program undertaken in Coffin Bay throughout the late 1990s determined that all sampled females were below the minimum legal size or 100 mm, indicating the regional Sand Crab fishery was essentially based on males (Jones and Deakin 1997, Jones 2000).

Fishery

In South Australia, the commercial fishery for Sand Crabs initially developed in Coffin Bay in 1982 and subsequently extended to southern coastal areas. It started as an experimental trap or pot fishery. The fishery expanded outside of Coffin Bay as fishers began using more efficient hoop and drop nets, actively targeted Sand Crabs during the night, and implemented mechanical net haulers (Jones 1995, Jones and Deakin 1997).

Recreational fishers target Sand Crabs using hoop or drop nets from jetties along the southern metropolitan Adelaide coast, and from small vessel in southern coastal waters. Approximate 55,557 Sand Crabs were captured by the recreational sector in 2013/14, of which 48.1% were released, resulting in a harvest of 27,277 animals, with an estimated total weight of 9.9 t (Giri and Hall 2015).

Management Regulations

A minimum legal size of 100 mm carapace width (measured across the widest point) was introduced in 1992 for market purposes (Jones 1995). Commercial fishers require a specific licence endorsement to target Sand Crabs and are restricted to a nominated quantity of crab net/pots. Within the MSF there a four dedicated Sand Crab licence holders with combined access to 400 crab net/pots. Recreational fishers have a combined Sand/Blue Crab bag and boat limit of 20 and 60 crabs, respectively (PIRSA 2016b).

Commercial Fishery Statistics

State-wide

Estimates of annual, State-wide commercial catches of Sand Crabs have been variable since the fishery commenced in 1984 (Figure 4-32). Annual catches were comparatively low until 1988. They then increased considerably between 1989 and 1990 reaching a peak of 152 t, before dropping to a minimum of 40.1 t in 1994. Since then, total catch increased again to the highest recorded level of 177 t in 2005, but has since declined over the long-term to 42.8 $t.yr^{-1}$ in 2017. During the early years the fishery was based on the use of crab pots. However, in 1989, crab nets (hoop and drop nets) were more prevalent. In the following years, the use of crab nets gradually increased, and since 1991 have dominated the fishery. There were two peaks of targeted crab net effort of approximately 800 – 1,000 fisher-days during 1997–2000 and 2005–2008. Since 2006, there has been a gradual decline in targeted effort to 422 fisher-days in 2017.

Targeted crab net CPUE has demonstrated a long-term increase from 89.2 $kg.fisher\text{-}day^{-1}$ in 1988 to 141.8 $kg.fisher\text{-}day^{-1}$ in 2015, before dropping back to 101.4 $kg.fisherday^{-1}$ in 2017 (Figure 4-32). The numbers of fishers taking and targeting Sand Crabs are closely linked, which indicates that this species is specifically targeted rather than being a by-product species. The numbers of fishers increased up to 45 in 1997, but have since declined to 14 in 2017.

Regional

The fishery has been heavily concentrated on the West Coast, primarily in Coffin Bay (Figure 4-33). Outside of this region, the highest catches have been taken from SSG. Lower annual catches have occurred in SGSV and NGSV, with only incidental catches ever recorded from NSG and the SE. The Sand Crab fishery has been seasonal with highest catches taken between October and March.

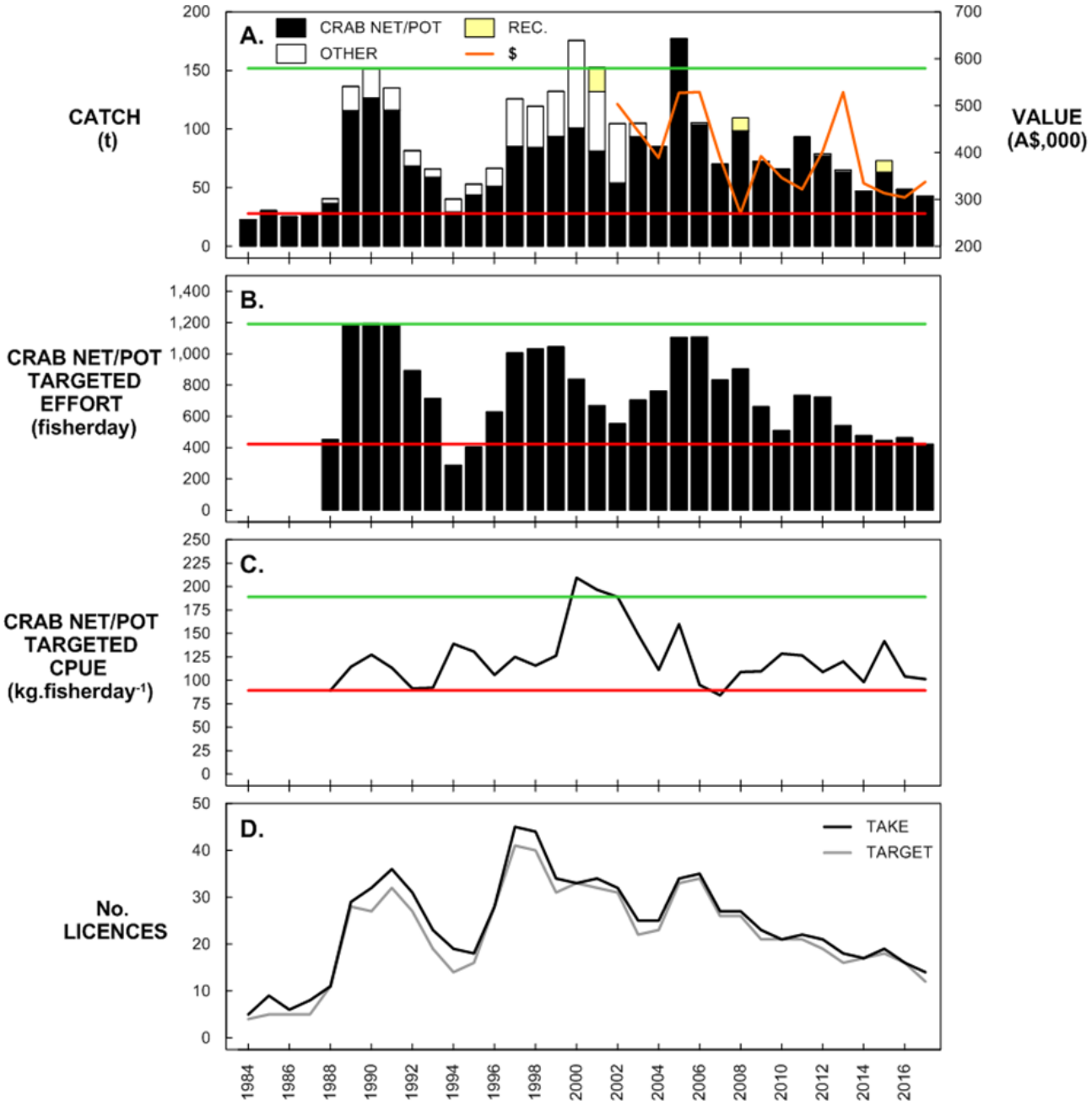

Figure 4-32. Sand Crab. Long-term trends in: (A) total catch of the main gear types (crab net/pot and other), estimates of recreational catch, and gross production value; (B) targeted effort crab net/pots; (C) total catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

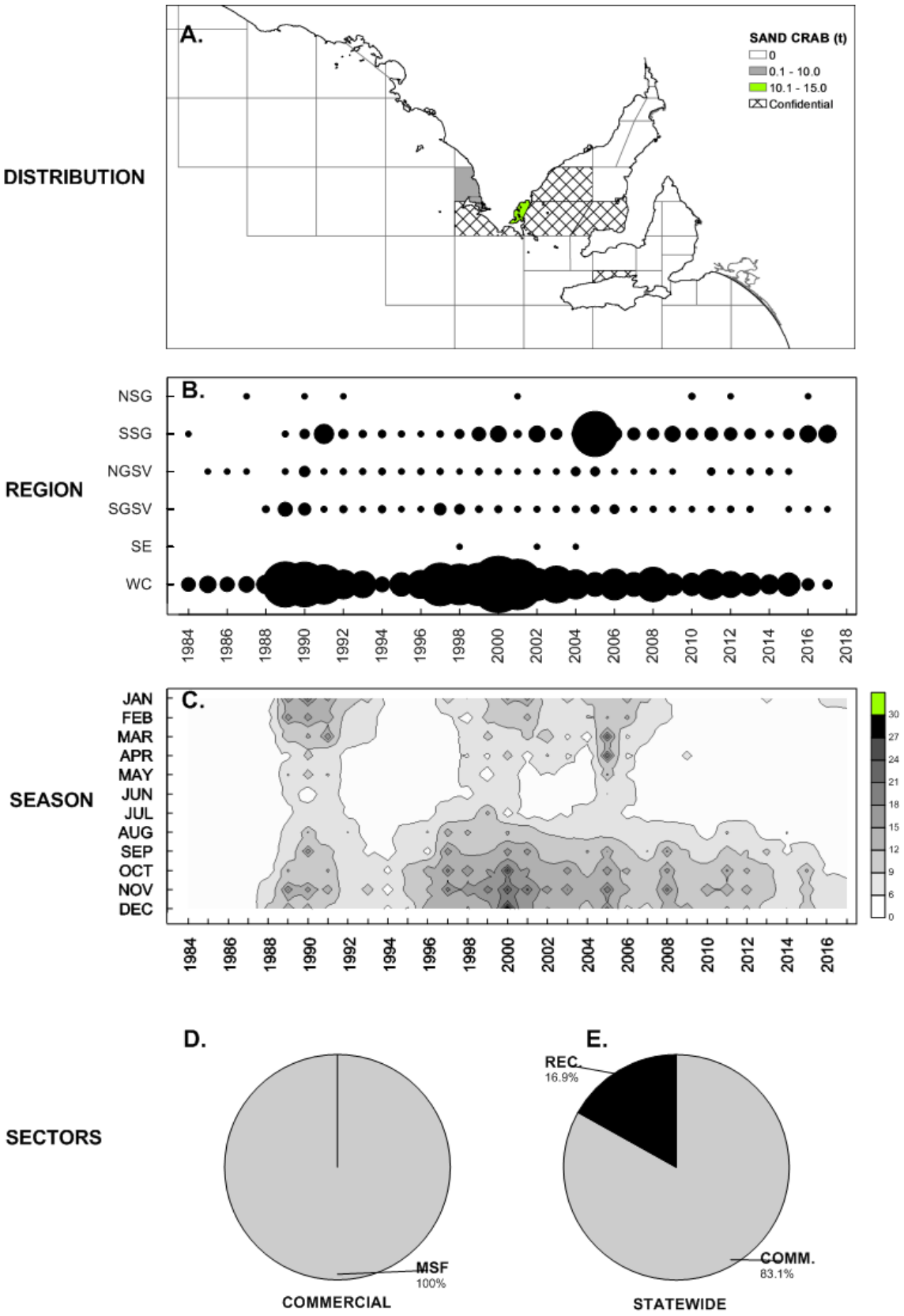

Figure 4-33. Sand Crab. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t), (D) the proportion of catch distributed among the commercial sector in 2017; and (E) among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

Fishery Performance

The general fishery performance indicators for Sand Crabs were assessed for 2017 at the State-wide scale. No trigger reference points were activated (Table 4-13).

Table 4-13. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State-wide scale for Sand Crab in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGET CRAB NET EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGET CRAB NET CPUE	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

The Sand Crabs fishery consists of specialist fishers that require endorsed net or pot types on their licences to target the species. Consequently, the fishery statistics considered here at State-wide scale related to targeted fishing effort. Nevertheless, the interpretation of such data is complicated by the development of the fishery since 1982/83 that resulted in improvements in fishing efficiencies (Jones 1995, Jones and Deakin 1997, Jones 2000). The early fishery involved a few fishers that primarily used crab pots. Then, as the number of operators increased they began using hoop nets, which were later replaced with more effective drop nets. Furthermore, fishers started to work at night when the crabs were more active, and to use portable, mechanical net haulers, which allowed further modifications to net design.

The commercial fishery statistics for Sand Crabs are characterised by significant inter-annual variability, although with long-term trends apparent. The trends in State-wide catch statistics are largely driven by those from the West Coast, which was dominated by the Coffin Bay fishery. The recent catches and targeted crab net effort levels are relatively low compared to those in the past, whilst targeted catch rates have generally increased over time. As such, these data show evidence of the increases in efficiencies in the fishery but no indication that it is becoming recruitment limited. On the basis of these data, South Australia's Sand Crab fishery is classified as **sustainable**.

4.3.11. YELLOWEYE MULLET (*Aldrichetta forsteri*)

Biology

Yelloweye Mullet is a member of the Mugilidae family, i.e. the Mullets (Gomon et al. 2008). This species inhabits estuaries and nearshore coastal waters along Australia's southern coast from Kalbarri in Western Australia to the Hunter River in New South Wales, and around Tasmania (Earl et al. 2016a). Yelloweye Mullet typically form dense schools over sandy and muddy substrates to depths of 20 m and are often highly abundant in estuaries (Kailola et al. 1993). Characterised by a silvery, slender, cigar-shaped form, this species is considered a marine estuarine-opportunist, i.e. spawns at sea; regularly enters estuaries, particularly as juveniles, but use, to varying degrees, coastal marine waters as alternative nursery areas (Potter et al. 2015).

The biological stock structure of Yelloweye Mullet throughout southern Australia is not well understood. It has been suggested that the populations of this geographic region form two discrete stocks, i.e. the Western and Eastern Stocks. The South Australian populations on the Far West Coast are thought to contribute to the Western Stock (Smith et al. 2008), while populations in Spencer Gulf, Gulf St Vincent and the South East are thought to be part of the Eastern Stock (Thomson 1954; Pellizzari 2001). In South Australia, Yelloweye Mullet are a fast growing, short-lived species that attains a maximum length of 440 mm and maximum age of 10 years. Females mature at around 240 mm TL, while males mature at around 250 mm TL (Earl and Ferguson 2013). They have a protracted spawning season from winter to early autumn, with spawning most frequent during December–February.

Fishery

Yelloweye Mullet are taken by both the commercial and recreational sectors of the MSF. In the commercial sector, they are targeted and taken as by-product with hauling nets and set nets. However, most (80–90%) of the annual State-wide commercial catches over the past decade have been taken by the Lakes and Coorong Fishery, and is not considered in this report (Earl 2018).

Recreational fishers target Yelloweye Mullet with rod and line. The State-wide recreational survey in 2013/14 estimated that 100,876 Yelloweye Mullet were captured, of which 29,598 fish were released, leaving 71,278 fish retained (Giri and Hall 2015). This provided a total estimated State-wide recreational harvest of 19.4 t.

Management Regulations

Mullet spp. are considered a secondary taxa of the commercial MSF, being of medium value and making a relatively small contribution to the total production value of the fishery (PIRSA

2013). For the commercial sector, regulations are in place to manage fishing effort and limit the take of Mullet spp. These include temporal and spatial netting closures, restrictions to net lengths and mesh sizes, and a minimum legal size of 210 mm TL (PIRSA 2016).

There are multiple management regulations in place for Mullet spp. in the recreational sector. Input and output controls ensure the total catch is maintained within sustainable limits and that access is distributed equitably among fishers. These include a daily bag limit of 60 fish and boat limit of 180 fish, and gear restrictions. The minimum size limit of 210 mm TL also applies to this sector.

Commercial Fishery Statistics

State-wide

The total commercial catch of Yelloweye Mullet peaked at 175 t in 1990, before progressively declining to an historic low of 12.5 t in 2016 (Figure 4-34). Catch increased to 22.1 t in 2017, which was the highest catch since 2012. In recent years, most catch has been taken using hauling nets, with set nets making the second largest contribution. Annual estimates of total fishing effort that produced catches of Yelloweye Mullet have been dominated by hauling nets. Total haul net fishing effort declined from a peak of almost 6,000 fisher-days in 1984 to < 500 fisher-days in 2009. Between 2009 and 2016, effort has been relatively stable.

Hauling net catch per unit effort (CPUE) was relatively stable in the 1980s and 1990s, before it increased substantially between 2003 and 2005 (Figure 4-34). It remained high during the late 2000s and early 2010s, before increasing to the highest value on record (55 kg.fisherday^{-1}) in 2011. The hauling net CPUE of 28.4 kg.fisher-day^{-1} in 2017 was approximately equal to the long-term average.

The numbers of fishers who reported taking and targeting Yelloweye Mullet have been quite different over time, suggesting the catch is largely by-product when other species are targeted.

Regional

Historically, catches of Yelloweye Mullet have been reported from each of the six geographic regions of South Australia's marine waters (Figure 4-35). Between 1984 and 1992, the highest catches were taken in Northern and Southern Gulf St Vincent, the former remaining the major contributor since 2003. Catches in the other five regions have been low over the past decade.

Prior to 2005, the fishery was seasonal, with most catches taken between January and April of each year. There has been no clear seasonality of Yelloweye Mullet catches by the MSF during the past decade. In 2017, the MSF licence holders accounted for approximately 96% of the MSF commercial catch, with the SZRLF accounting for the remaining 4% (Figure 4-35).

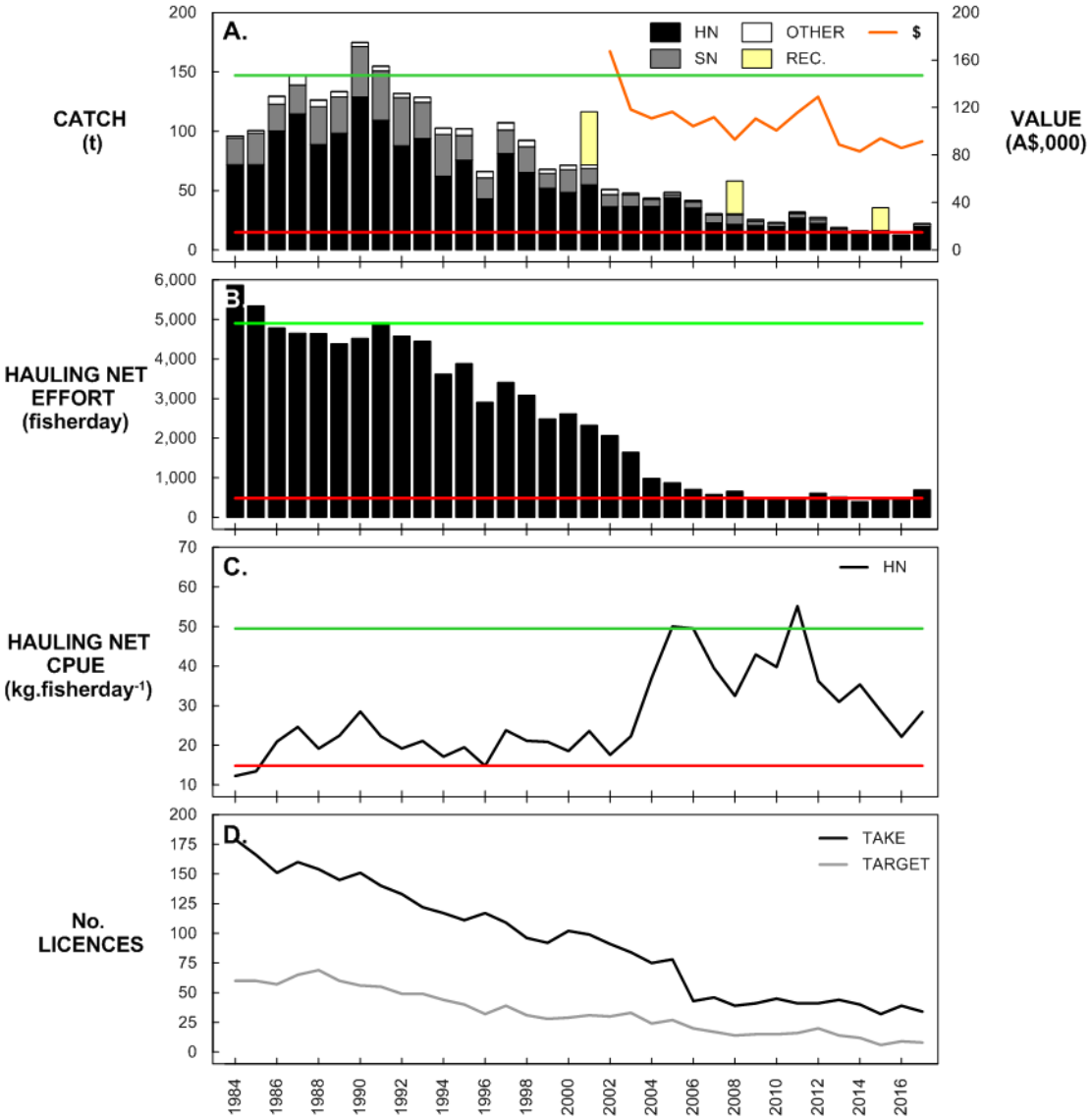

Figure 4-34. Yelloweye Mullet. Long-term trends in: (A) total catch of the main gear types (hauling net and set net), estimates of recreational catch, and gross production value; (B) total effort hauling net; (C) total catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

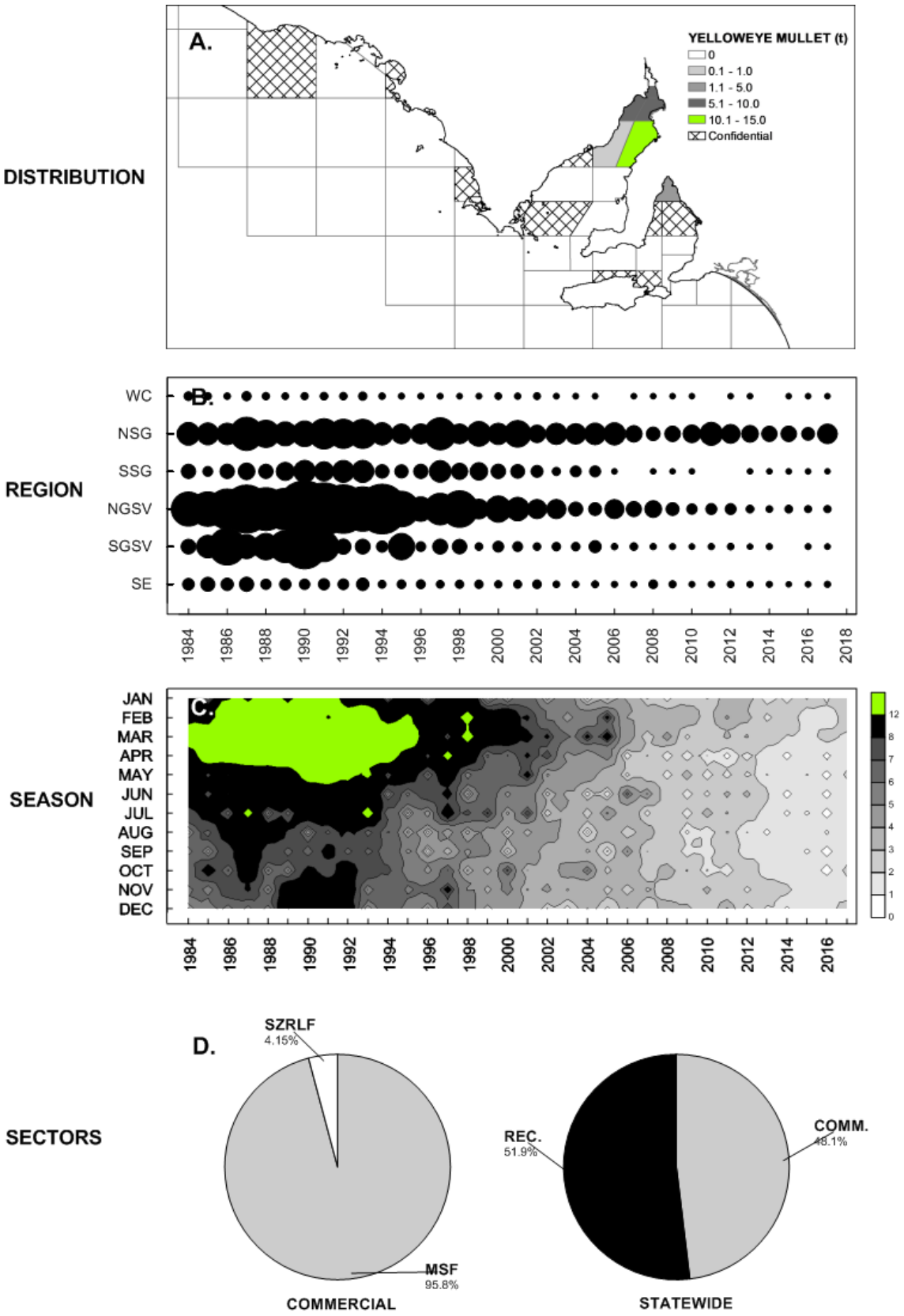

Figure 4-35. Yelloweye Mullet. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t); (D) the proportion of catch distributed among the commercial sector in 2017, and (E) among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

Fishery Performance

The general fishery performance indicators for Yelloweye Mullet were assessed for 2017 at the State-wide scale. No trigger reference points were breached (Table 4-14).

Table 4-14. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Yelloweye Mullet in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	✖
TOTAL HAULING NET EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTALHAULING NET CPUE	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

Yelloweye Mullet is predominantly taken as by-product within the hauling net sector of the MSF when other species are targeted. The overwhelming trend for Yelloweye Mullet has been one of declining annual catches. This largely reflects the significant declines in fishing effort in the hauling net sector of the fishery. The long-term decline in fishing effort likely relates to the relatively low value of Yelloweye Mullet on the domestic market, rather than a declining biomass, as hauling net CPUE over recent years has been above the long-term average for the fishery. The above evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. On this basis, the Yelloweye Mullet fishery is classified as **sustainable**.

4.3.12. MULLOWAY (*Argyrosomus japonicus*)

Biology

Mulloway is a member of the Sciaenidae family, i.e. Croakers and Drums (Gomon et al. 2008). It is a large, schooling species that inhabits estuaries and nearshore coastal waters (to depths of 100 m) in subtropical to temperate regions of the Atlantic, Pacific and Indian Oceans including around southern Australia, Africa and India (Silberschneider and Gray 2008). In Australia, Mulloway occur from North West Cape, Western Australia, to the Burnett River, Queensland, excluding Tasmania (Kailola et al. 1993). Juveniles are most abundant in estuaries, while adults are predominantly found in nearshore coastal waters, including the surf zone and around the mouths of rivers (Griffiths 1997).

Mulloway is a long-lived, late-maturing species that can attain a maximum age of 42 years and maximum length of 2000 mm TL. In South Australia, Mulloway mature at around 780 mm TL for males and 850 mm TL for females, and 5 years and 6 years of age, respectively (Ferguson et al. 2014). Spawning occurs from October to January each year (Ferguson et al. 2014). Regional differences in otolith morphology and chemistry, and genetic characteristics suggest distinct populations of Mulloway along the eastern and western coasts of South Australia (Ferguson et al. 2014; Barnes et al. 2015).

Fishery

Mulloway is taken by both the commercial and recreational sectors of the Marine Scalefish Fishery (MSF). In the commercial sector, this species is taken with multiple gear types, including set nets, fishing rods and hand lines. Most of the commercial catch in South Australia has been taken by the Lakes and Coorong Fishery and not considered in this report (Earl and Ward 2014).

Mulloway is an iconic recreational fishery species in South Australia and is targeted with rod and line. The State-wide recreational survey in 2013/14 estimated that 47,238 Mulloway were captured by the recreational sector of which 37,354 fish were released, leaving 9,833 fish harvested (Giri and Hall 2015). The estimated total harvest weight was 59.5 t, which was considerably higher than the estimated annual catch of 1.1 t taken by the commercial MSF.

Management Regulations

Mulloway is permitted to be taken by the commercial MSF in all coastal waters of South Australia, except those accessible to the commercial Lakes and Coorong Fishery (PIRSA 2014). No specific harvest strategy exists for Mulloway in the MSF (PIRSA 2013). However, multiple management regulations are used to ensure the sustainable harvest of the species. For the commercial sector, temporal and spatial netting closures are used to manage fishing

activity and effort. Restrictions to gear including net lengths and mesh sizes, and a minimum size limit of 820 mm TL applies for both sectors. For the recreational sector, a bag limit of 2 fish and boat limit of 6 fish applies in marine waters.

Commercial Fishery Statistics

State-wide

During the mid-1980s and early 1990s, total annual commercial catch of Mulloway by the MSF fluctuated between 7–15 t.yr^{-1}, before increasing to 24.2 t in 1995 (Figure 4-36). Catch declined during the late 1990s, remained relatively low during the 2000s, and then declined to a low of 1.3 t in 2015. The total catch of 5.6 t in 2017 was the highest catch since 2007. The variation in total catch reflects total fishing effort that produced catches of Mulloway, i.e. effort peaked in the mid-1990s and has been low in most years since 1997.

Historically, total catch and effort has been dominated by set nets and handlines. Catch rates for both gear types have been relatively stable over the long term (Figure 4-36). In 2017, catch rates for set net and handlines were among the highest recorded in the fishery.

The number of licence holders who reported taking Mulloway has declined over the long-term at a faster rate than the lower number of fishers who reported targeting the species. While the former decreased from >50 fishers.yr^{-1} in the 1980s to 14 in 2016, the latter declined from 20 in 1985 to 4 licences in 2016 (Figure 4-36). The higher numbers of fishers taking Mulloway compared to those targeting it suggests that for many fishers this species was taken as by-product when they fished for more valuable species.

Regional

Historically, catches of Mulloway have been reported from each of the six geographic regions of South Australia's marine waters, with most coming from the South East (Figure 4-37). There is no clear seasonality of Mulloway catches by the MSF. In 2017, all commercial catches of Mulloway in marine waters were taken by Marine Scalefish fishers (Figure 4-37).

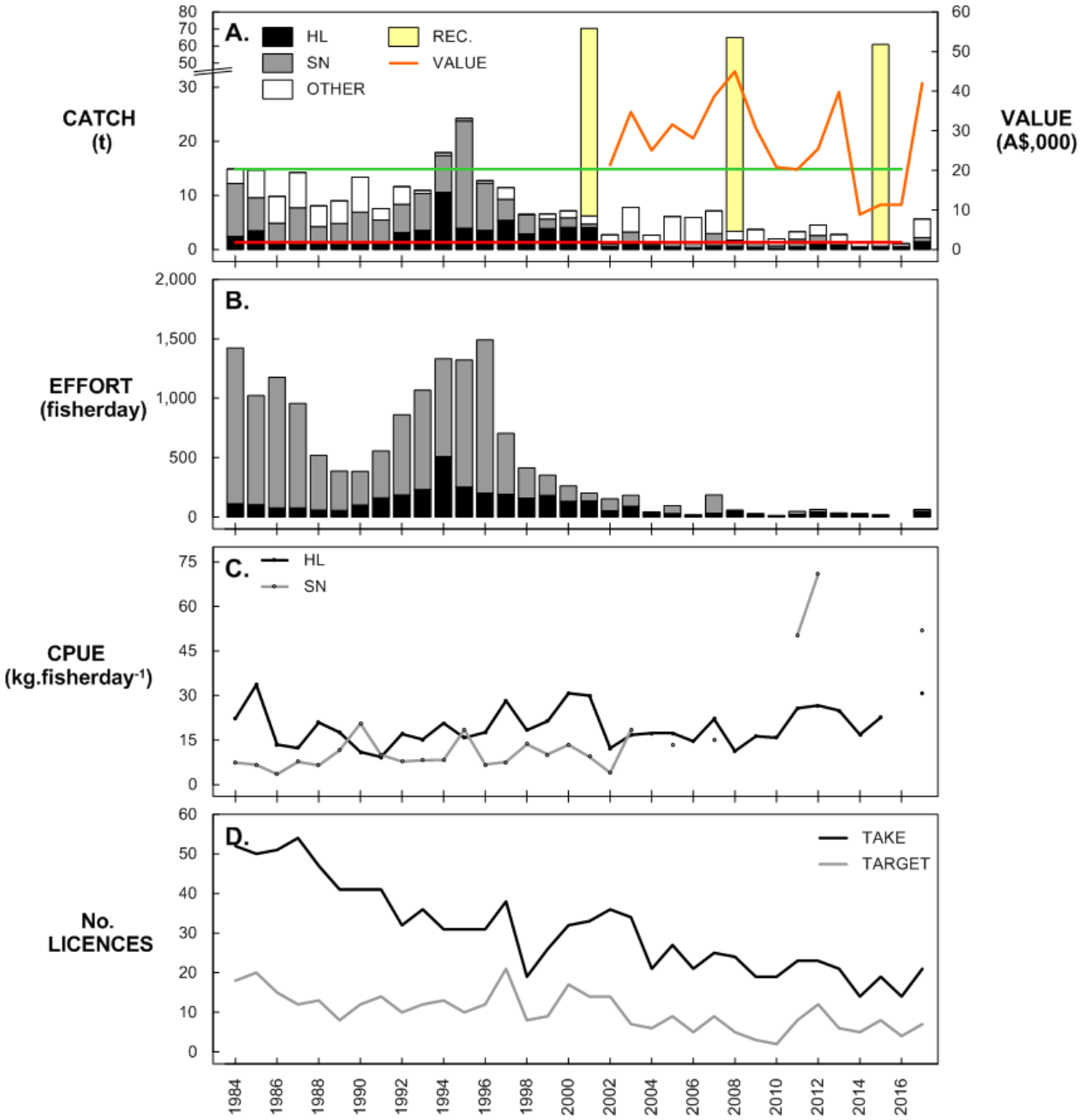

Figure 4-36. Mulloway. Long-term trends in: (A) total catch of the main gear types (handline and set net), estimates of recreational catch, and gross production value; (B) total effort; (C) total catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

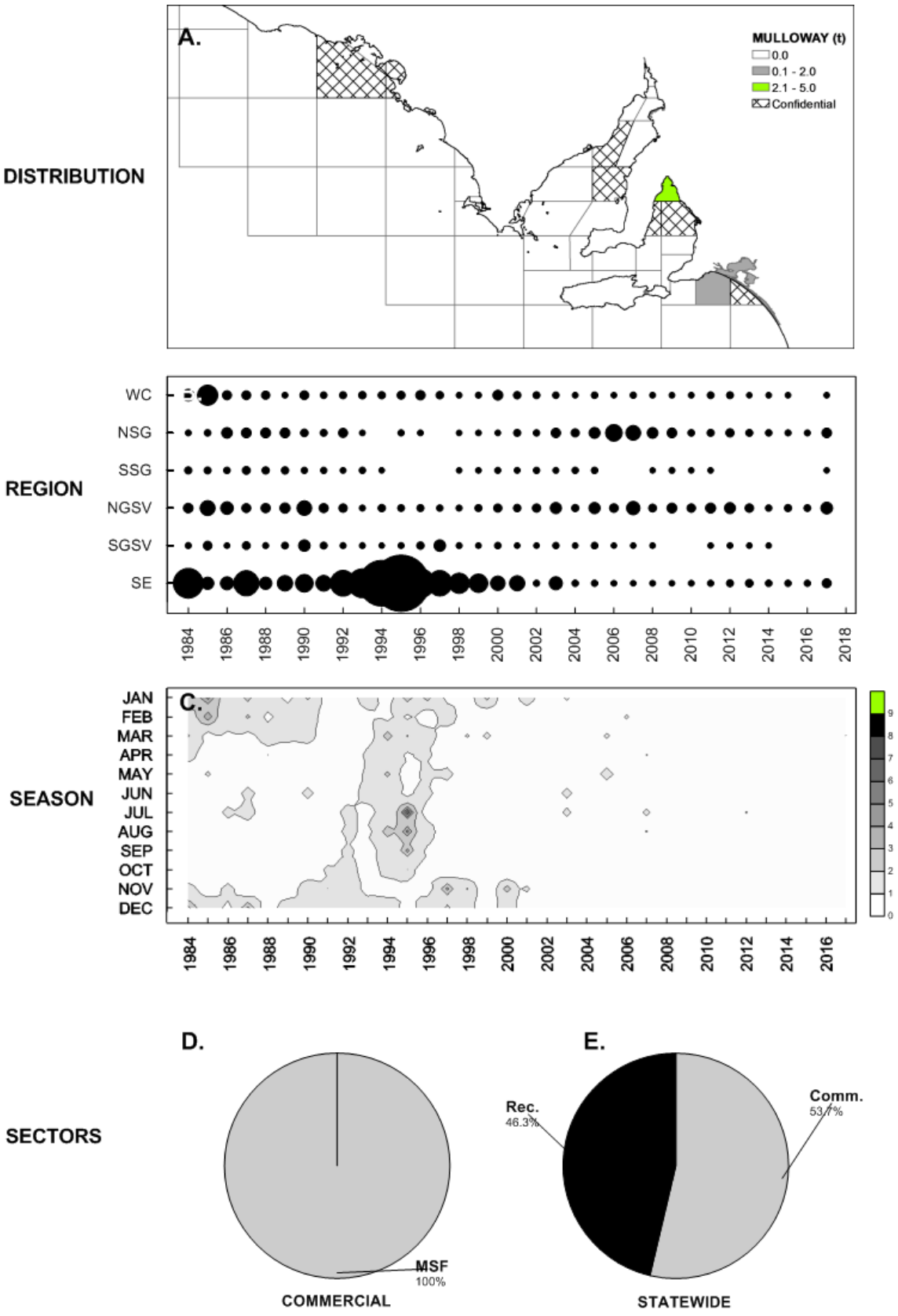

Figure 4-37. Mulloway. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t), (D) the proportion of catch distributed among the commercial sector in 2017; and (E) among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

Fishery Performance

The general fishery performance indicators for Mulloway were assessed for 2017 at the State-wide scale. Three trigger reference points were breached (Table 4-15). In 2017, total handline CPUE was the 3rd highest on record (since 1984); total set net effort was the lowest on record; and total set net CPUE was the 2nd highest on record.

Table 4-15. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State-wide spatial scale for Mulloway in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL HAND LINE EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL HAND LINE CPUE	G	3rd Lowest / 3rd Highest	3rd HIGHEST
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL SET NET EFFORT	G	3rd Lowest / 3rd Highest	LOWEST
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL SET NET CPUE	G	3rd Lowest / 3rd Highest	2nd HIGHEST
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

Mulloway is of medium-high value but makes a relatively minor contribution to the commercial fishery's total production value. Whilst the species is taken as targeted catch, the higher numbers of fishers who reported taking Mulloway suggest it is taken predominantly as by-product. Total commercial catch of Mulloway has shown a long-term decline since the peak in the mid-1990s. This likely reflects the long-term reduction in fishing effort, rather than a decline in fishable biomass, as catch rates have generally remained consistent over the same period. The recent high CPUE indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. On this basis, the Mulloway fishery is classified as **sustainable**.

4.3.13. WHALER SHARKS (*Carcharhinus brachyurus* & *C. obscurus*)

Biology

The term 'Whaler Sharks' is used to describe two sympatric species, the Bronze Whaler (*Carcharhinus brachyurus*) and the Dusky Shark (*C. obscurus*) in South Australia. Dusky Sharks are dark brown in colour, have triangular serrated teeth and a defined central inter-dorsal ridge located between the first and second dorsal fin. Bronze Whalers are copper coloured, have narrow non-serrated teeth and lack an inter-dorsal ridge. Dusky Sharks favor warm water temperatures during mid-late summer and Bronze Whalers are mostly present in commercial and recreational fishery catches between spring and autumn. Female Bronze Whalers live for 31 years and males have similar lifespans of 25 years. Both sexes reach sexual maturity at 16 years of age (Drew et al. 2016). Males and females reach sexual maturity at 2240 and 2700 mm TL, respectively (Drew et al. 2016).

Dusky Sharks are long-lived (max~50 years), slow growing and have low productivity (3 year breeding frequency, 3–12 pups per litter) (Romine et al. 2009; McAuley et al. 2007). These and other demographic data have been used to assess the impacts of fishing on population dynamics in Western Australian waters (McAuley et al. 2007; Kinney and Simpfendorfer 2009). Satellite tagging of large juvenile Dusky Sharks (>2000 mm) indicated there was migratory-mediated connectivity during autumn between the coastal and shelf waters off southern and central Western Australia and Spencer Gulf, South Australia (Rogers et al 2012). Genetic analyses indicated that Australian populations are genetically isolated from those inhabiting other southern hemisphere ocean-basins (Benavides et al. 2011), which suggests that stock structures for management purposes are likely to reflect panmixia, and/or SW region based and eastern Australian (EAC) separation. The latter structure underpins the Status of Australian Fish Stocks process for the species (Stewardson et al. 2016).

Fishery

The fishery for 'Whaler Sharks' in South Australia is reliant on access to two seasonally mobile and/or highly migratory stocks (Rogers et al. 2012; 2013). Bronze Whalers are targeted by commercial and recreational fisheries throughout their Australasian range (Francis 1998; Rogers et al. 2013). Carcharhinid species compositions are not currently resolved in 'Whaler Shark' catches in the South Australian State-managed Marine Scalefish Fishery in commercial log-books. Based on preliminary data, juvenile Dusky Sharks are assumed to represent <10% of the annual commercial catch in South Australian waters (Stewardson et al. 2016). Preliminary catch commercial data suggest species contributions are considered to be spatially and temporally variable, yet are mostly comprised of juvenile Bronze Whalers (>90%).

The commercial fishery predominantly targets the species using floating (pelagic set) longlines in Spencer Gulf, Gulf St Vincent and the West Coast in spring–autumn. Given that the stock of Dusky Shark is mostly distributed off Western Australia, and catches have historically been several times higher than those in the other jurisdictions, its stock status is determined from stock assessments in the Western Australian management jurisdiction.

Whaler Sharks are a target game fishing species by recreational anglers. These species are targeted from vessels, metropolitan and regional jetties, rock shore-lines and beaches. A small number (<40 per annum) are captured by recreational fishers participating in the South Australian Charter Fishery (Rogers et al. 2017). Recreational tag-recapture data collected by the NSW Game-Fish Tagging Program suggests that the recreational fishery is responsive to seasonal availability (Jones 2008; Rogers et al. 2013).

Management Regulations

The catch of Whaler Sharks in the MSF is subject to management input controls on longlines, set nets, droplines and handlines. Management controls aimed at limiting fishing effort and mortality of larger mature individuals include, limits on the daily number of hooks that can be set (n = 200), limits on hook leader diameter (2 mm) for longlines, and mesh size restrictions (150 mm) for demersal gill nets. There is currently no TACC, trip limit restrictions, or minimum legal lengths implemented for Whaler Sharks. Recreational fishery regulations for Whaler Sharks (combined) include a daily bag limit of one shark per fisher and a daily boat limit of three sharks, when there are three or more fishers on-board.

Commercial Fishery Statistics

State-wide

The State-wide annual total commercial catch of combined Whaler Shark species was 61.8 t in 2017 (*c.f.* 50.4 t in 2016). Catch trajectories were relatively stable in the five-year period between 2013 and 2017 (inclusive) (Figure 4-38). In 2017, the commercial catch of Whaler Sharks was predominantly (90%) taken using longlines, with 65% taken using this gear type on trips whilst specifically targeting these species. Longlines have been the dominant gear type since 2001. Set nets were infrequently used by 2010, and the remaining 10% of the commercial catch was predominantly landed using droplines and hand lines. Target longline fishing effort for Whaler Sharks increased from 35 fisher-days in 1993 to 571 fisher-days in 2010 (Figure 4-38). Some of this increasing pattern in the latter part of the time-series may be explained by the inception of the OCS with the Commonwealth in 2000. This was closely followed by displacement of effort from Snapper and Gummy Shark and was driven by a suite of management measures (seasonal closures, day and trip limits) aimed at reducing longline effort away from those species.

Since that period, there was a decline in catch and effort targeting Whaler Sharks followed by a stabilisation to 296 fisher-days in 2017 (c.f. 207 fisher-days in 2016; 5-year mean to 2017 = 245 fisher-days). Longline targeted catch rates of Whaler Sharks remained relatively stable at ~135.5 kg.fisher-day^{-1} in 2017 (c.f. 121 kg.fisher-day^{-1} in 2016; 5-year mean to 2017 = 125.6 kg.fisher-day^{-1}). Approximately 40% of fishers that take Whaler Sharks have actively targeted them over the past 15 years (Figure 4-38).

Regional

A high proportion of the commercial catch of Whaler Sharks was landed off the West Coast of Eyre Peninsula in the 1980s and 1990s. Marine Fishing Areas (MFAs) in Southern Spencer Gulf supported either a greater or similar proportion of the catch to that taken off the West Coast between 2003 and 2012 (Figure 4-39). The spatial distribution of the catch was spread between the West Coast, Southern Spencer Gulf and southern Gulf St. Vincent between 2013 and 2017. Catches of Whaler Sharks mostly occurred between spring and autumn, with only sporadic catches during winter in three years since 1984. The MSF licence holders accounted for 95.7% of the catch. Of the remaining catch, 3.86% and 0.41%, respectively, were landed by NZRLF and SZRLF licence holders in 2017 (Figure 4-39).

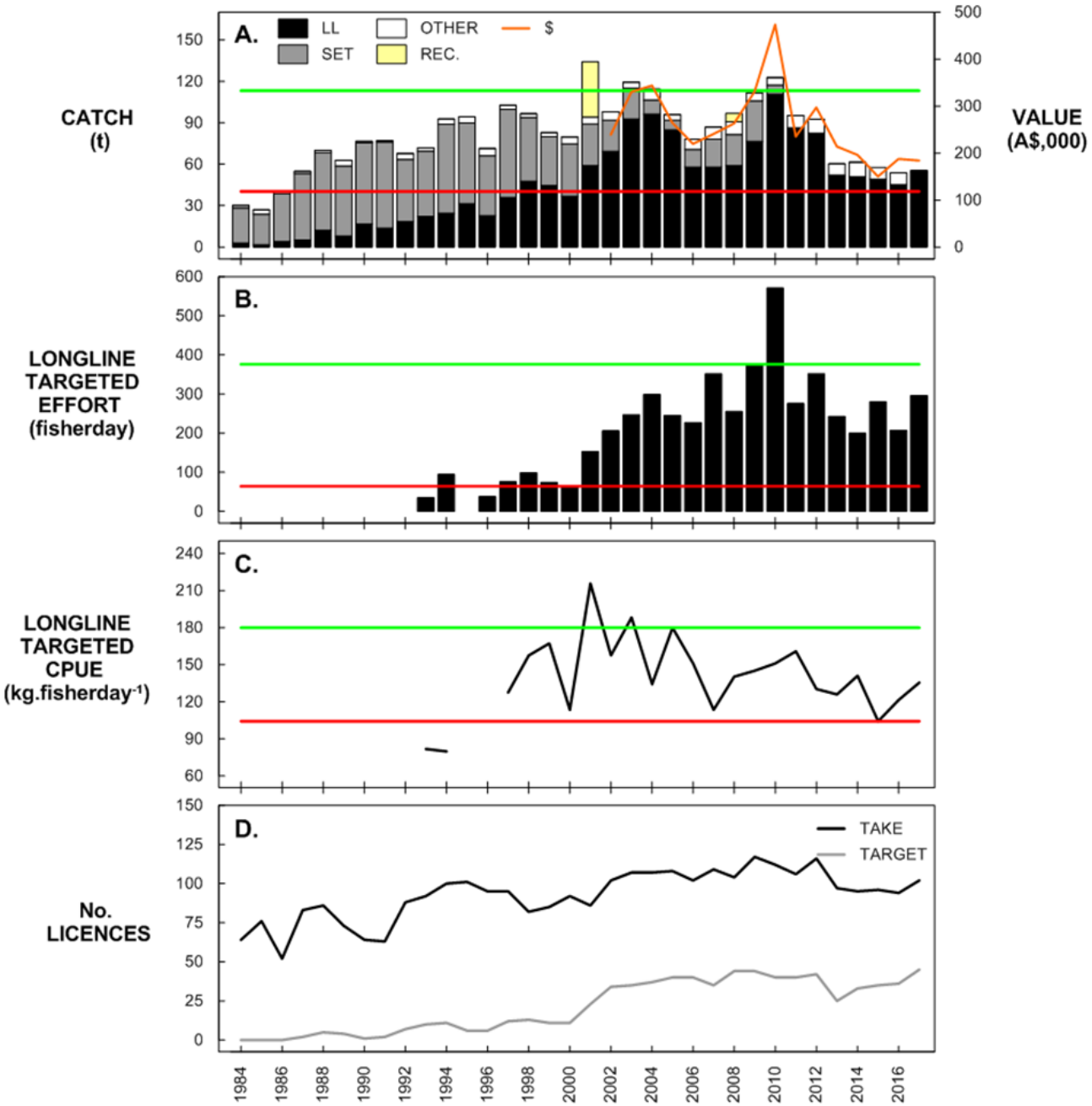

Figure 4-38. Whaler Shark. Long-term trends in: (A) total catch of the main gear types (longline and set net), estimates of recreational catch, and gross production value; (B) total effort longline; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

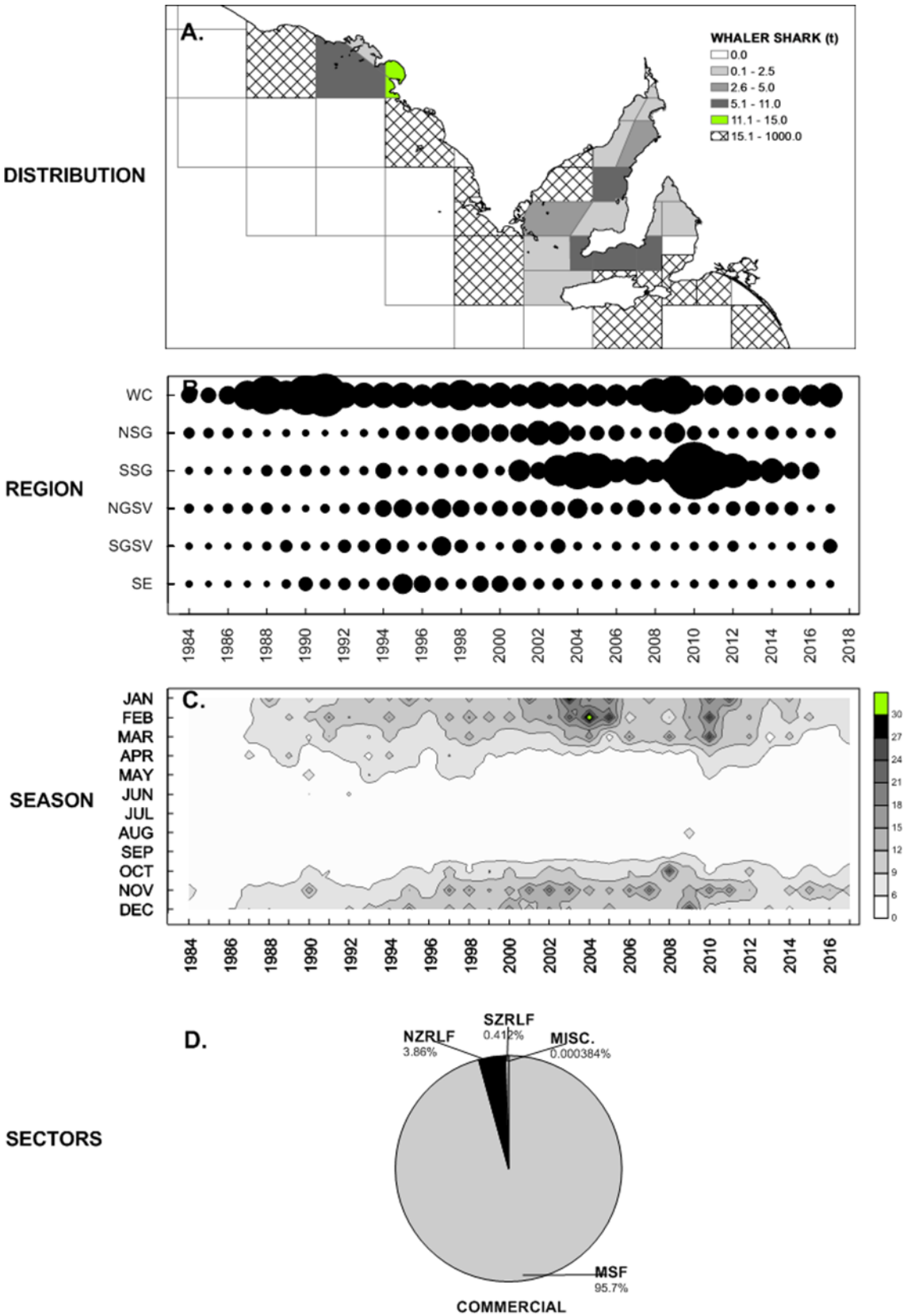

Figure 4-39. Whaler Shark. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t); and (D) the proportion of catch distributed among the commercial sector in 2017.

Fishery Performance

The general fishery performance indicators for Whaler Sharks were assessed for 2017 at the State-wide scale. No trigger reference points were breached (Table 4-16).

Table 4-16. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Whaler Shark in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGETED LONGLINE EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGETED LONGLINE CPUE	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

The mixed reporting of the two Whaler Shark species within the MSF catch returns complicates the assessment of the stocks; however, the commercial catch composition is weighted towards Bronze Whalers. Recent demographic models developed for the Bronze Whaler stock, suggested current catch rates are likely to be sustainable.

The western Australian Dusky Shark biological stock is part of a migratory population (Rogers et al. 2012; Braccini et al. 2017). Components of the population travel across fishery management jurisdictions, including those of Western Australia, South Australia and several Commonwealth fisheries on the continental shelf. In 2016, the western stock was classified as transitional-recovering (Stewardson et al. 2016; Braccini et al. 2015), and in the most recent SAFS in 2017 was classified as ‘recovering’ (Braccini et al. 2018). These classifications are informed by demographic modelling, fishing mortality estimation and analyses of catch and effort trends. The most recent SAFS assessment is based on evidence that catches of juvenile Dusky Sharks in targeted fisheries have stabilised in Western Australian State fishery jurisdictions (Stewardson et al. 2016).

Relatively stable annual trends in longline targeted catch rates for Whaler Sharks, stabilising effort and CPUE, suggest this mixed-species fishery is likely to be sustainable at a low level within the 50–75 t per year range. However, the fundamental need to differentiate the two species within fishery log-books remains as the key uncertainty in estimating fishing mortality, and hence, the status of the fishery is classified as **undefined**.

4.3.14. OCEAN JACKETS (*Nelusetta ayraudi*)

Biology

The Ocean Jacket is the largest species of leatherjacket of southern Australia that can reach 700 mm in length (Gomon et al. 2008). It is a demersal, schooling species that is distributed from central Queensland southwards, along the southern coastline and continental shelf and then up to the central coast of Western Australia (Kailola et al. 1993, Gomon et al. 2008). The species occurs across a broad depth range from very shallow to >350 m, due to off-shore movement associated with ontogenetic development. The juveniles occur in shallow, coastal bays whilst the adults are located over flat, sandy bottom in off-shore, continental shelf waters >60 m in depth (Grove-Jones and Burnell 1991). Stock structure throughout the broad distribution is unknown, but must be influenced by off-shore, ontogenetic migration, and capacity of adults for significant long-distance movement (Grove-Jones and Burnell 1991).

This is a dichromatic species of leatherjacket that is fast-growing and short-lived, as determined from ageing work based on rings in vertebrae (Grove-Jones and Burnell 1991). Most fish aged from the commercial fishery were 3 – 6 years of age, whilst the oldest male was seven years and oldest female was nine years old (Grove-Jones and Burnell 1991). Reproductive maturity was attained from 2 – 4 years of age, associated with size-at-first-maturity of 310 mm, and corresponded with the timing of off-shore migration. In South Australia, spawning occurs in April and early May in waters >85 m depth in off-shore waters.

Fishery

Because adult Ocean Jackets occur in deep, off-shore waters, the fishery is essentially a commercial one, although juveniles are likely to be taken incidentally by recreational fishers in shallow, near-shore coastal waters (Grove-Jones and Burnell 1991). The commercial fishery commenced in 1984/85 in continental shelf waters off Streaky and Venus Bays on Eyre Peninsula. It commenced as, and has remained a targeted, baited fish trap fishery. The catches rose very quickly until 1988/89, as new entrants came into the fishery and the geographic range of fishing activity spread throughout the Great Australian Bight (Grove-Jones and Burnell 1991). At that time, discussions commenced about regulating the fishery to control this expansion and to prevent catches from exceeding the long-term sustainable yield. As a result, regulations were introduced to: restrict access to Ocean Jackets to a limited number of MSF fishers; reduce the numbers of fish traps per licence; and regulate the dimensions of the fish traps (Grove-Jones and Burnell 1991). These regulations largely curtailed the expansion of the fishery.

Management Regulations

There are defined regulations for Ocean Jacket traps that differ from those for fish traps, as specified on the fishery licences. Currently there are four MSF licences with Ocean Jacket trap endorsements. Each licence holder has access to 20 traps, equating to a total of 80 Ocean Jacket traps that can be used by South Australia's MSF. Such traps can only be used in depths >60 m, and to target Ocean Jackets. Other fish traps can only be used in waters <60 m depth to target any species.

Commercial Fishery Statistics

State-wide

The reported catch for Ocean Jackets in 1990 was 930 t (Figure 4-40). This related to a total fishing effort of 2,095 fisher days by 11 licence holders, and a relatively high fish trap CPUE of 444 kg.fisher-day^{-1}. In the following few years, catch and effort increased to their maxima. Total catch was highest in 1991 at 977 t, whilst effort was highest in the following year at 3,103 fisher days, of which most related to fish traps. Total catch and effort declined between 1991 and 2000 before stabilising for several years. Catch and effort have subsequently declined to and remained at low levels. There were noticeable increases in catch and effort in 2016, but these declined again in 2017. Since 2008, the numbers of fishers who took and targeted Ocean Jackets in each year have generally been less than five. CPUE for fish traps has been variable, shown a number of modes, ranged between 196 and 554 kg.fisher-day^{-1}, but nevertheless showed no long-term trend. There was a considerable increase in fish trap CPUE between 2013 and 2017 from 199 to 554 kg.fisher-day^{-1} (Figure 4-40).

Regional

Two regions have contributed the most to catches of Ocean Jackets in South Australia. High catches reported from the 'Other' region between 1989 and 1998 came from MFAs 37, 38, and 39, located off-shore from southern Eyre Peninsula (Figure 4-41). Subsequently, these declined to moderate to low levels. Very high catches were reported from the WC MFAs 24, 25, and 26 between 1989 and 1993. Catches declined before increasing to high levels again between 1998 and 2007. After this, they declined back to moderate levels before increasing again in 2016 and 2017. There have only ever been incidental catches of Ocean Jackets reported from the gulf regions and the SE.

Throughout the higher catch years of 1989 to 2006, commercial catches of Ocean Jackets were distributed throughout the year, although the highest catches were taken between September and March.

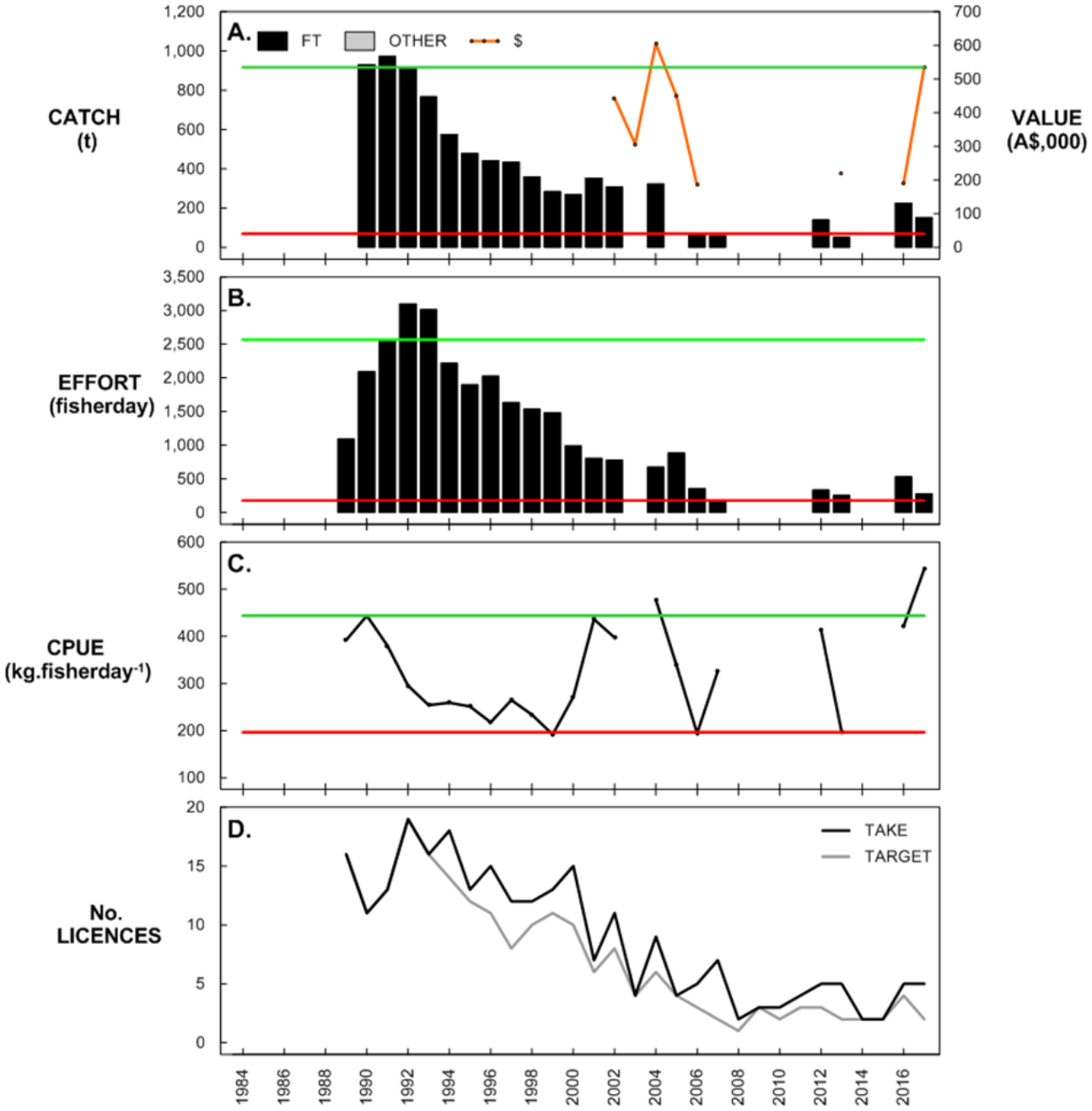

Figure 4-40. Ocean Jacket. Long-term trends in: (A) total catch of the main gear types (fish trap and other), and gross production value; (B) total effort; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

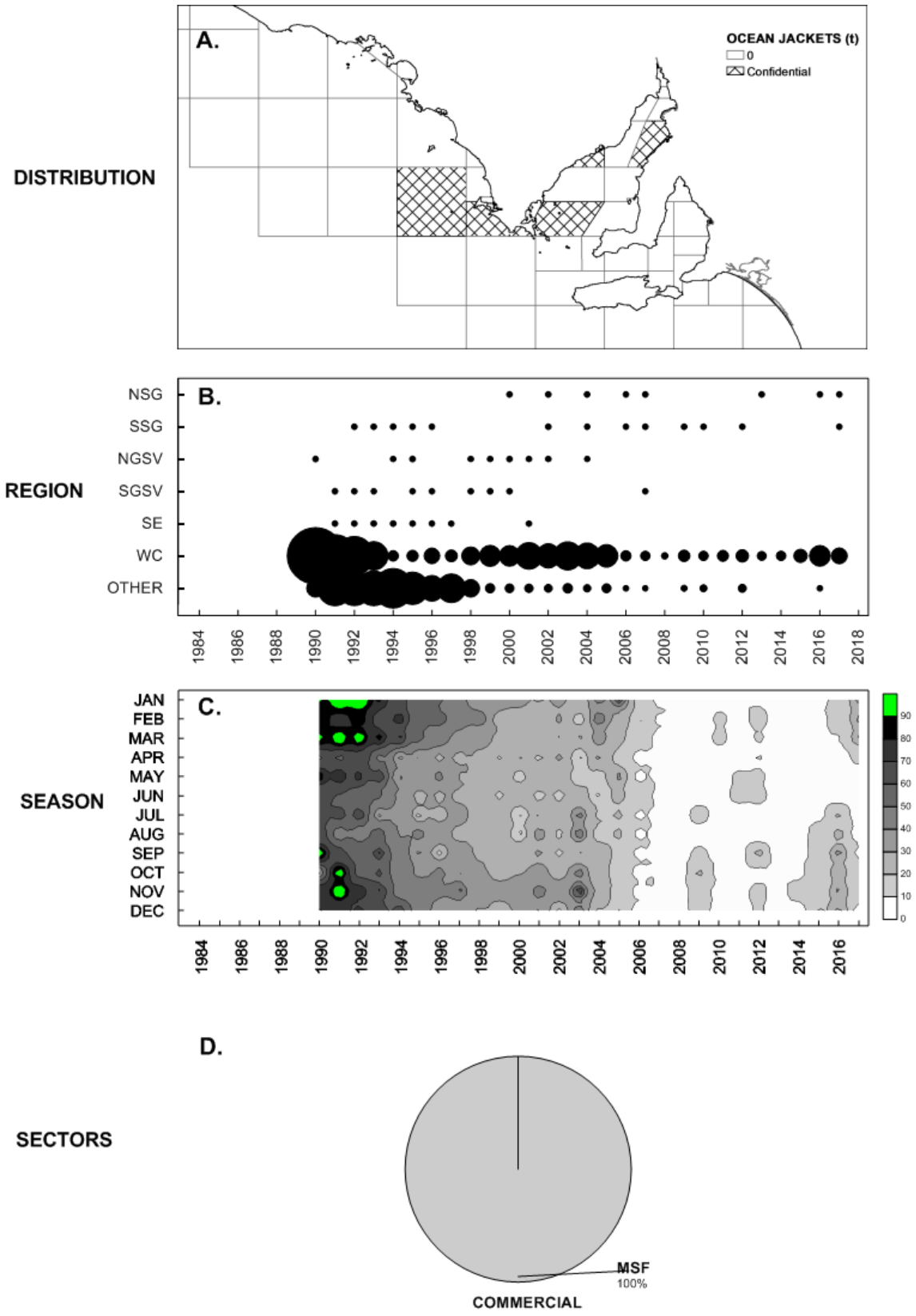

Figure 4-41. Ocean Jacket. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t); and (D) the proportion of catch distributed among the commercial sector in 2017.

Fishery Performance

The general fishery performance indicators for Ocean Jackets were assessed for 2017 at the State-wide scale. A single trigger reference point was activated (Table 4-17). In 2017, fish trap CPUE was the highest ever recorded.

Table 4-17. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Ocean Jacket in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGET FISH TRAP EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGET FISH TRAP CPUE	G	3rd Lowest / 3rd Highest	HIGHEST
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

The Ocean Jacket fishery developed very quickly between 1984 and 1988 resulting in an exponential increase in total annual catch that reflected an increase in effort as new entrants came into the fishery as well as geographic expansion (Grove-Jones and Burnell 1991). The fast rate of fishery development caused concerns about sustainability, which soon led to the introduction of regulations to limit the numbers of fishers and fishing effort. As a result, the fishery attained its highest productivity in the early 1990s. Since then, the fishery statistics have been dominated by declining levels of catch, effort, and numbers of specialist fishers. These declines are also likely to relate to the perception that developed early amongst some fishers that the Ocean Jacket fishery was not worthwhile due to the marginal economics associated with high fishing costs relative to low price in return (Grove-Jones and Burnell 1991).

In 2017, the highest catch rate yet recorded for the fishery was attained. The relatively low fishery catches, low level of targeted fishing effort and the recent high catch rates are unlikely to cause the stock to become recruitment impaired. As such, South Australia's Ocean Jacket fishery is classified as **sustainable**.

4.3.15. BLUETHROAT WRASSE (*Notolabrus tetricus*)

Biology

There are several species of temperate wrasse (family: Labridae) that occur in South Australian waters (Gomon et al. 2008, Shepherd and Baker 2008). They are generally colourful species that are associated with shallow, near-shore reef habitats, making them particularly vulnerable to fishing activity. Only one of these species, i.e. the Bluethroat Wrasse (*Notolabrus tetricus*) is recognised as a legitimate commercial species for the MSF (PIRSA 2013). Nevertheless, historically some or all of the other species have been taken by commercial fishers and collectively have been reported as Bluethroat Wrasse. Consequently, it is not possible to differentiate the fishery statistics amongst species, although it is likely that since the Bluethroat Wrasse is the most abundant species, it has historically dominated the fishery catches (Saunders et al. 2010).

Bluethroat Wrasse is the largest of the labrids, reaching a maximum size of 420 mm TL (Gomon et al. 2008). Its distribution includes the coastal waters of New South Wales, Victoria, Tasmania and extends as far west as central South Australia (Gomon et al. 2008, PIRSA 2016). It occupies algal beds and reefs through the depth range of 0 – 50 m, with fish size increasing with depth. It is a significant predator of benthic invertebrates that include crustaceans and molluscs (Shepherd and Baker 2008).

Bluethroat Wrasse are highly territorial and display long-term residency of their home-ranges (Barrett 1995, Shepherd and Baker 2008). Their strong site attachment is associated with their complex social structure and reproductive biology. The species is a monandric, sequential, protogynous hermaphrodite, i.e. the adult males only originate through sex change from a female fish (Smith et al. 2003). The social structure is based around the male that defends a territory which includes a harem of numerous females that have overlapping home ranges. This social structure is size-dependent, i.e. if the male is removed, its hierarchical position is quickly replaced by the largest female which transitions into the territorial male over a period of a few weeks. This complex social and reproductive strategy complicates managing the fishery because of concerns about localised depletion and the need to maintain sufficient males in the population to ensure reproductive output (Shepherd et al. 2010).

Fishery

Because Bluethroat Wrasse and the other temperate wrasse species inhabit nearshore, shallow waters, they are particularly vulnerable to line fishing by both the commercial and recreational sectors of the MSF. For the commercial sector there is a relatively small targeted fishery for which the captured fish are sold either as fresh, ice-slurried product or as ‘live fish’ to the Sydney Fish Market. Alternatively, they are captured as by-product when other more

valuable species are targeted. As such, there are considerable discrepancies between the numbers of fishers who report taking Bluethroat Wrasse, and those who actually target it.

For the recreational sector, Bluethroat Wrasse is not a prized target species. Rather, they are often taken as by-catch when more desirable species are targeted, which can result in a high discard rate. In 2013/14, there was an estimated 22,073 Bluethroat Wrasse captured by the recreational sector, of which 68.7% were released (Giri and Hall 2015). No estimated harvest weight was provided.

Management Regulations

Prior to 01 December 2016 there was no size limit nor were there recreational bag and boat limits for the Bluethroat Wrasse. In the review of the recreational sector undertaken in 2016, there was concern about size-selective harvesting that related to its hermaphroditic reproductive mode (PIRSA 2016). In response, a slot limit of 250 – 350 mm TL was introduced in order to maintain some males in the population to ensure the reproductive output. Given the complexity in identifying Bluethroat Wrasse, there regulations apply to all wrasse species with the exception of Blue Groper. Also, a bag limit of 5 fish and boat limit of 15 fish was introduced for the recreational sector.

Commercial Fishery Statistics

State-wide

Between 1984 and 1996, the reported commercial catch of Bluethroat Wrasse was relatively low at <10 $t.yr^{-1}$ (Figure 4-42). In 1997 it increased considerably after which it remained at >20 $t.yr^{-1}$ until 2004. Since then it has fallen and generally been <20 $t.yr^{-1}$, with considerable decline between 2012 and 2017. The total catch of 13.4 t in 2017 was close to the lowest since 1996. Up to 2004, the catch was dominated by that taken on handlines. Subsequently, the proportion taken on longlines increased considerably. In 2017, longlines accounted for 39% of the total commercial catch.

Between 1984 and 1991, total line effort was low, before it increased considerably up to 1997. Since then it has been highly variable (Figure 4-42). From 2005, the proportion of total line effort accounted for by longlines has increased considerably. In 2010, the highest level of effort and the highest proportional contribution from longlines were recorded. Since 2012, effort has declined, as has the proportional contribution from longlines. Between 1984 and 1996, total line CPUE was low, before it increased considerably up to 2000. Over the following nine years there was a gradual decline in CPUE before it stabilised between 2009 and 2017.

Since 1984, there has been a considerable disparity between the high numbers of fishers who reported taking Bluethroat Wrasse and those who targeted it (Figure 4-42). The former

increased up to 2013, after which there has been considerable decline. The numbers who targeted this species have been relatively constant since 1997.

Regional

Since 1997, the WC has provided the highest catches of Bluethroat Wrasse with SSG as the next most significant region. Only incidental catches have been reported from the other four regions (Figure 4-43). Furthermore, catches have not been concentrated in any season but have been distributed throughout the year. In 2017, the MSF fishers accounted for 93.4% of the commercial catch, with Rock Lobster fishers accounting for the remainder (Figure 4-43). There was no estimate of the total weight of the recreational catch from 2013/14 to compare against that from the commercial sector (Giri and Hall 2013).

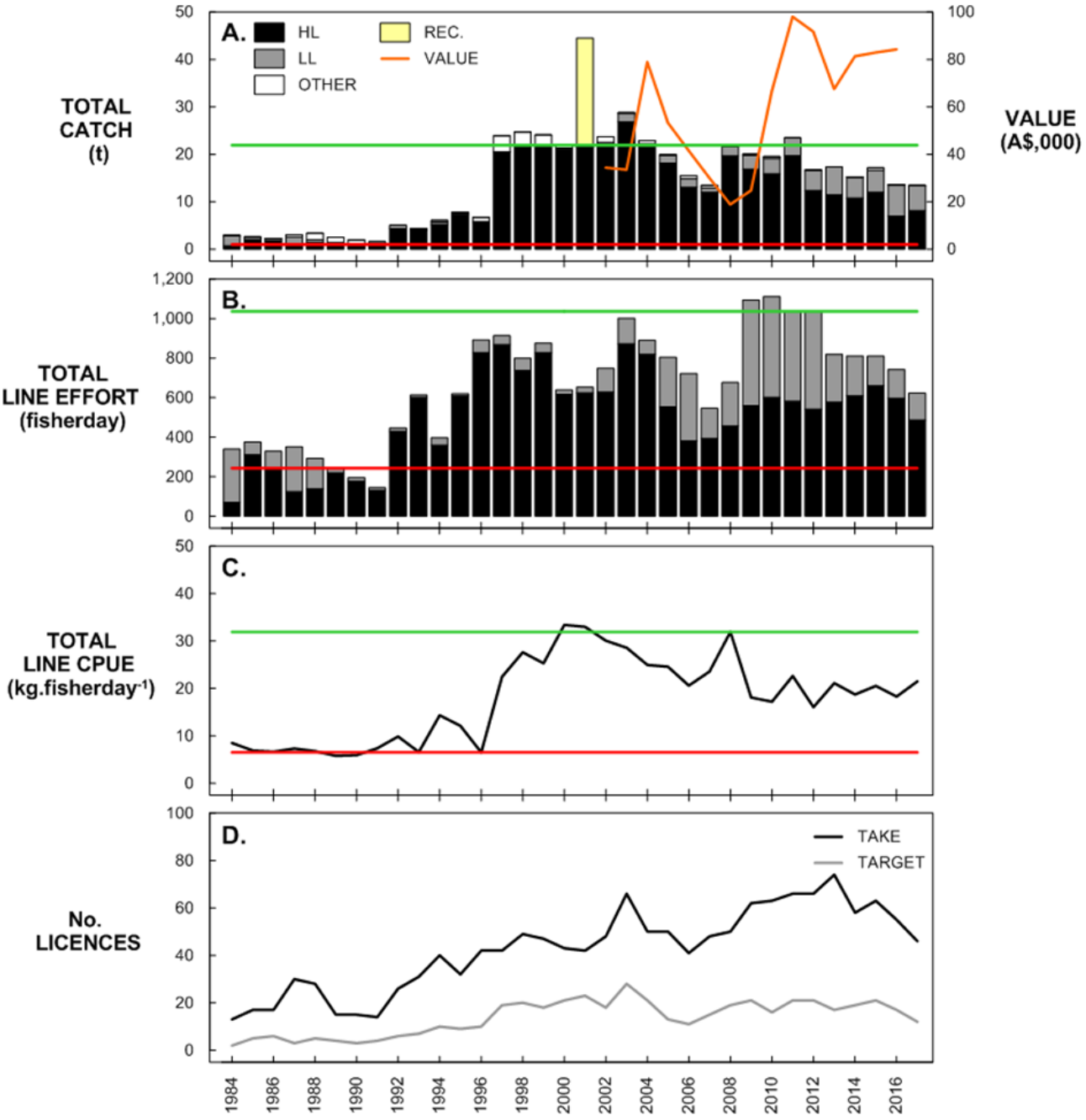

Figure 4-42. Bluethroat Wrasse. Long-term trends in: (A) total catch of the main gear types (handline and longline), eatimate of recreational catch, and gross production value; (B) total line effort; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

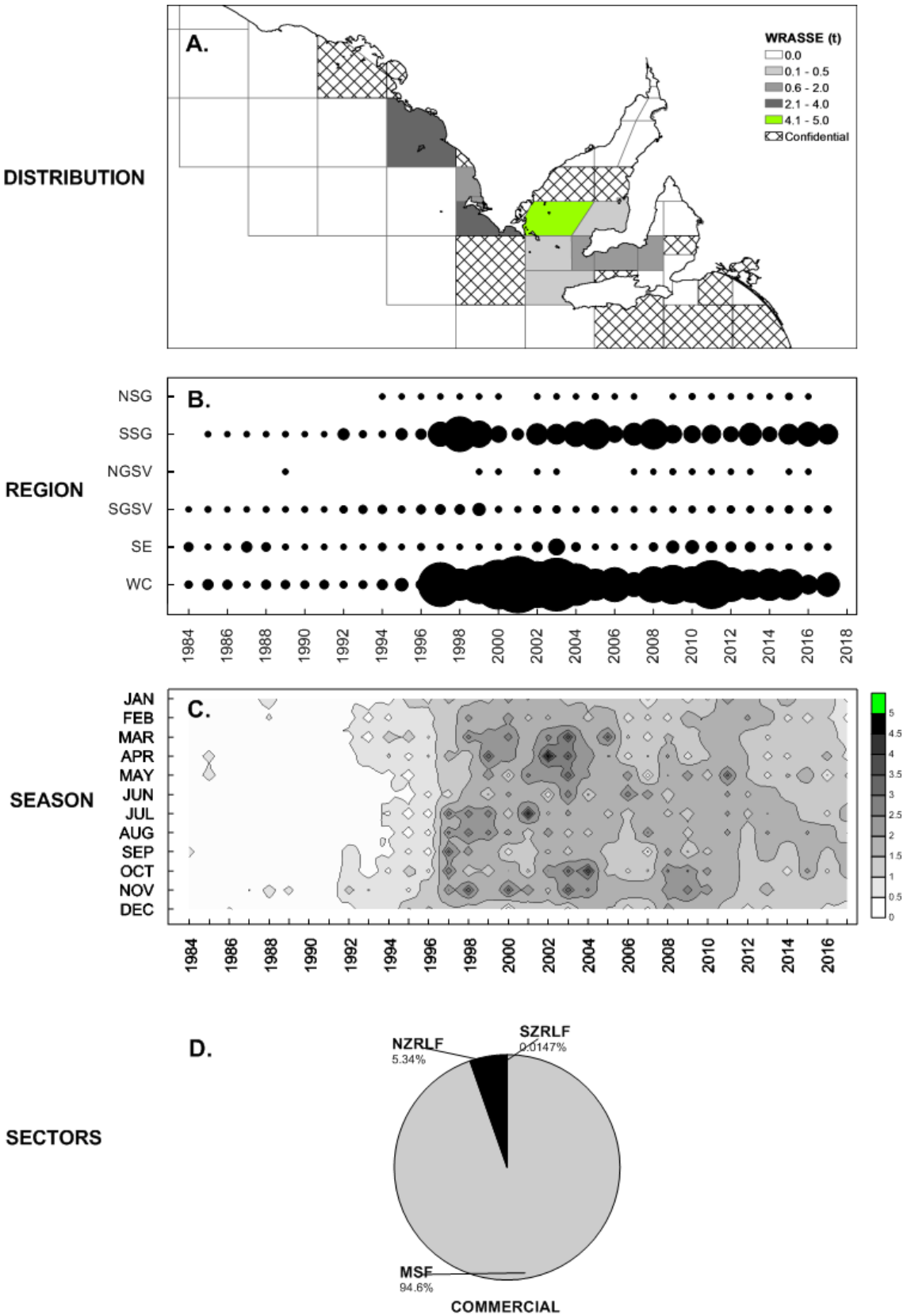

Figure 4-43. Bluethroat Wrasse. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t); and (D) the proportion of catch distributed among the commercial sector in 2017.

Fishery Performance

The general fishery performance indicators for Bluethroat Wrasse were assessed for 2017 at the State-wide scale. Total effort combined across hand line and longline fishing methods consistently declined over five consecutive years, breaching the associated trigger reference point (Table 4-18).

Table 4-18. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Bluethroat Wrasse in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL LINE EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	✓
TOTAL LINE CPUE	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

There is a small targeted fishery for the Bluethroat Wrasse with the product directed towards the live fish trade, which accounts for considerable proportions of the total annual catches. The remaining catch is taken as by-product when other more valuable species are targeted. The tendency towards higher longline catches after 2004, might reflect the development of the longline fishery for Snapper in Southern Spencer Gulf. The later decline in longline effort that produced catches of Bluethroat Wrasse may well correspond with the decline in the Snapper fishery that occurred in that region.

Total catch of Bluethroat Wrasse has declined since 2009, corresponding with declining longline effort. During this time, annual catch rates have been relatively stable at medium levels. They are considerably lower than the high catch rates recorded through the peak period of the early 2000s, but nevertheless much higher than the low levels of the 1980s and 1990s. There were no trigger reference points breached for 2016. The recent medium-level catches and stable catch rates indicate that the biomass of this species is unlikely to be depleted and that recruitment is unlikely to be impaired. On this basis, South Australia's Bluethroat Wrasse fishery is currently classified as **sustainable**.

4.3.16. SILVER TREVALLY (*Pseudocaranx georgianus*)

Biology

There has been confusion around the taxonomy of the species of the Carangidae family that inhabit southern Australia. Historically, *Pseudocaranx georgianus* was regarded as part of the widely distributed, anti-tropical species *Pseudocaranx dentex*, but it is now considered a separate species (Gomon et al. 2008). Silver Trevally (*P. georgianus*) is distributed across southern Australia from Coffs Harbour in New South Wales (NSW) to Perth in Western Australia (Stewart 2015). It is a schooling species that is common over sandy substrata in estuaries and nearshore coastal waters, where it feeds on benthic and pelagic invertebrates.

The population biology of Silver Trevally in South Australian waters is poorly understood. It is thought to be a relatively slow-growing species that can live up to 25 years in NSW waters (Stewart 2015), and 33 years in New Zealand waters (Langley 2004). Spawning occurs between spring and autumn, with the larvae occurring in coastal waters, which may enter estuaries before settling out as juveniles.

Fishery

Silver Trevally are taken by both the commercial and recreational sectors of the Marine Scalefish Fishery (MSF). Commercial catches in South Australia have been dominated by MSF fishers, with only incidental catches reported by the Northern Zone Rock Lobster Fishery. Hand line catches account for the majority of commercial catches, with smaller contributions taken using netting gears.

The recreational catch is taken by rods and lines and is substantial relative to the commercial catch. The State-wide recreational survey in 2013/14 estimated that 73,924 Silver Trevally were captured by the recreational sector, of which 57,140 were harvested. The estimated total harvest weight was 14.6 t (Giri and Hall 2015).

Management Regulations

Silver Trevally is considered a tertiary species of the commercial MSF, being of low-medium value and making a minor contribution to the total production value of the fishery (PIRSA 2013). For the commercial sector, regulations are in place to manage fishing effort and limit the take of this species. These include temporal and spatial netting closures, restrictions to net lengths and mesh sizes, and a minimum legal size of 240 mm TL (PIRSA 2016).

There are multiple management regulations in place for Silver Trevally in the recreational sector. Input and output controls ensure the total catch is maintained within sustainable limits and that access is distributed equitably among fishers. These include a daily bag limit of 20 fish

and boat limit of 60 fish, and gear restrictions. The minimum size limit of 240 mm TL also applies to the recreational sector.

Commercial Fishery Statistics

State-wide

Total annual commercial catch of Silver Trevally has been highly variable, ranging from 2.1 t in 1985 to 21 t in 2000 (Figure 4-44). From 1984 to 1991, catches were low and rarely exceeded 4.5 t.yr^{-1}. Since then, they have ranged from 5 – 15 t.yr^{-1}, except for the peak catch of 21 t taken in 2000. Recent catches have been at moderate levels. The total catch of 10.5 t in 2017 was above the long-term average catch for the sector. Since 1992, handline catches have contributed most to annual catches, with the remaining catch taken using various net gears.

Hand line fishing effort that produced catches of Silver Trevally has varied cyclically since the mid-1980s (Figure 4-44). It was 129–395 fisher-days.yr^{-1} during the 1980s, increased to a peak of 1167 fisher-days in 1993, and then dropped to 261 fisher-days in 2001. It increased to a secondary peak of 833 fisher-days in 2015, before declining to 632 fisher-days in 2017. Hand line catch per unit effort (CPUE) has progressively increased over the long-term. The high catch in 2000 was associated with uncharacteristically high CPUE. Catch rate declined the following year and has remained at round the long-term average for the sector since 2004. The hand line CPUE of 15.1 kg.fisher-day^{-1} in 2017 was the highest catch rate since 2010.

Historically, there has been a considerable difference between the numbers of licence holders who take Silver Trevally compared with those who target this species. The former has often been >50 fishers.yr^{-1}, whilst the latter have generally been <10 fishers.yr^{-1} (Figure 4-44). This suggests that for many fishers Silver Trevally was taken as by-product when they fished for more valuable species.

Regional

Catches of Silver Trevally have been reported from each of the six regions in most years since 1984 (Figure 4-45). Since 2000, the majority of catches have been taken from Southern Spencer Gulf during May, June and July. In 2017, the commercial catch was dominated by Marine Scalefish fishers (Figure 4-45). In 2013/14, the recreational sector accounted for around 57% of the total State-wide catch of Silver Trevally.

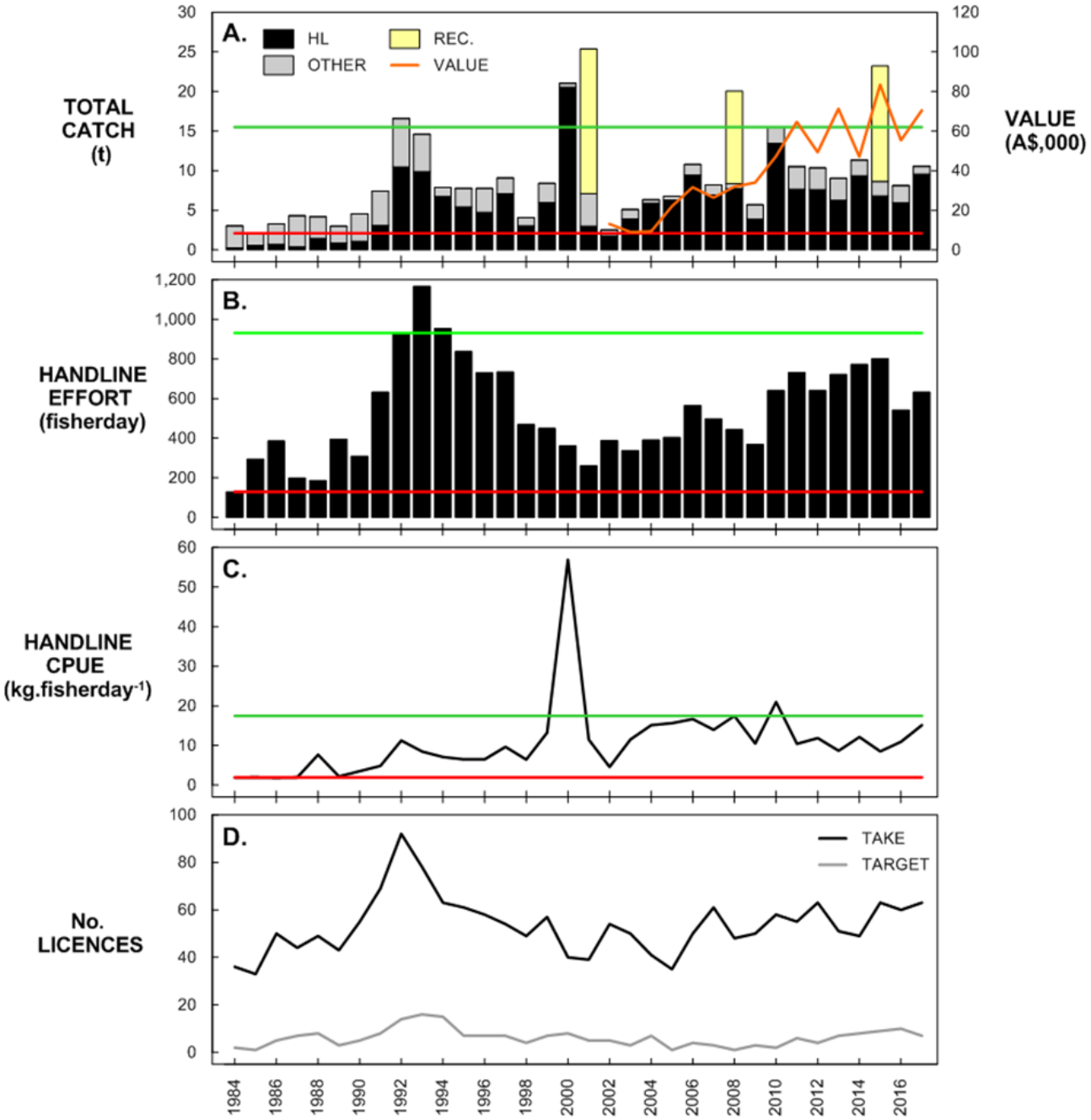

Figure 4-44. Silver Trevally. Long-term trends in: (A) total catch of the main gear types (handline and other), estimates of recreational catch, and gross production value; (B) total handline effort; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

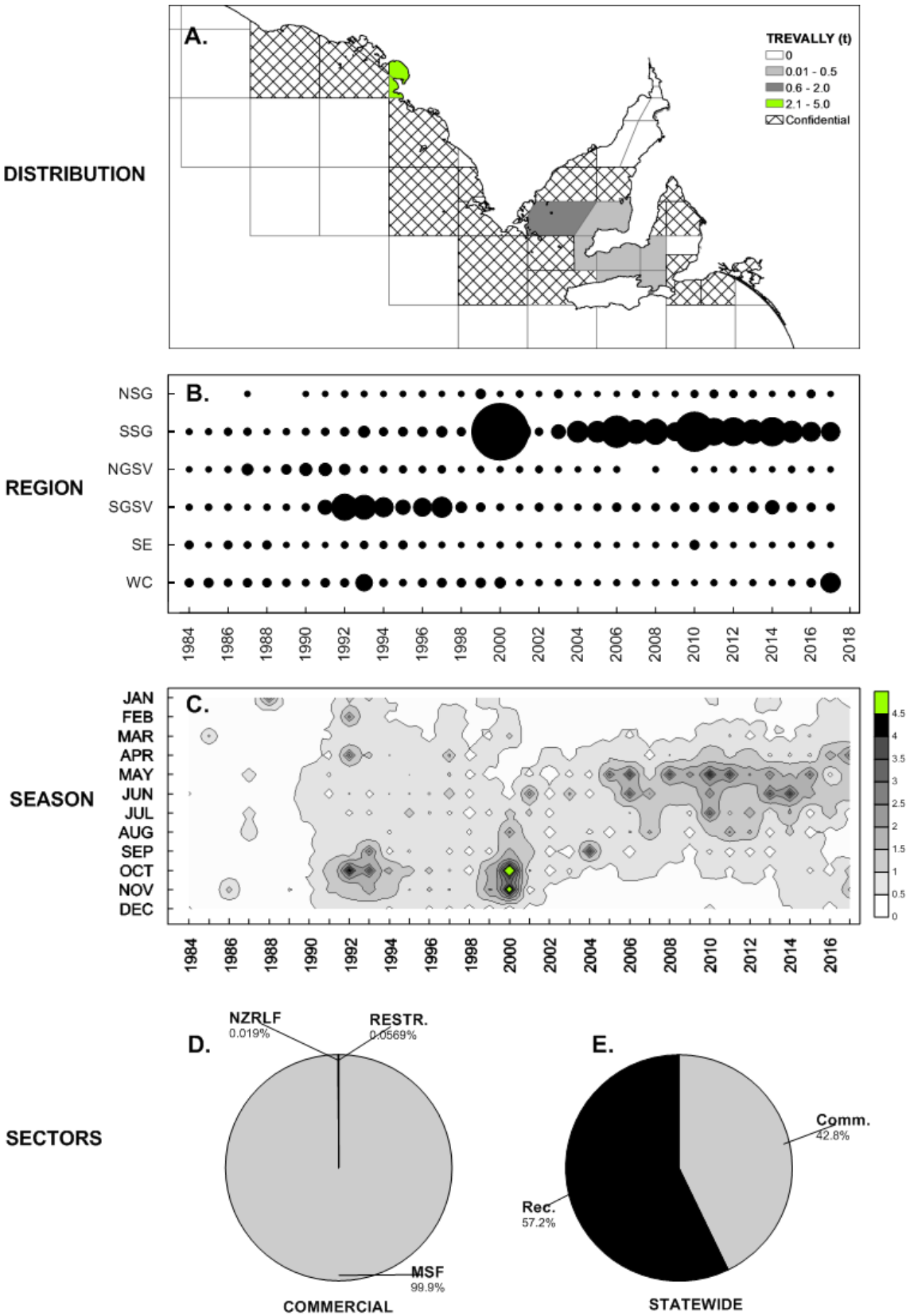

Figure 4-45. Silver Trevally. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t), (D) the proportion of catch distributed among the commercial sector in 2017; and (E) among the State-wide MSF in 2013/14 ascertained from the latest recreational fishing survey (Giri and Hall, 2015).

Fishery Performance

The general fishery performance indicators for Silver Trevally were assessed for 2017 at the State-wide scale. No trigger reference points were breached (Table 4-19).

Table 4-19. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State-wide spatial scale for Silver Trevally in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL HAND LINE EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL HAND LINE CPUE	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

Silver Trevally make a minor contribution to the total production value of the commercial sector of the MSF. Relatively few fishers actively target this species. Nevertheless, the targeted catch accounts for a considerable proportion of the total line catch. The remaining catch is taken as by-product by a considerably larger number of fishers when they target more valuable species such as King George Whiting and Snapper. Over the past decade, estimates of total catch, effort and line CPUE for Silver Trevally have been stable at moderate levels. No trigger reference points were breached for the data from 2017. The medium-level catches and stable catch rates indicate that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. On this basis, the Silver Trevally fishery is classified as **sustainable**.

4.3.17. LEATHERJACKETS (family Monacanthidae)

Biology

There are 19 species of Leatherjackets (family: Monacanthidae) that occur in the waters of southern Australia, between WA and NSW (Gomon et al. 2008). These species are characterised by a compressed, deep body, prominent dorsal spine above the eyes and leathery skin (Gomon et al. 2008). Most are sexually dimorphic in body shape and colouration. For South Australia's MSF, anecdotal evidence suggests that the Horseshoe Leatherjacket (*Meuschenia hippocrepis*) and the Sixspine Leatherjacket (*M. freycineti*) are the dominant commercial species. These are two of six species that occur on nearshore coastal reefs. They are omnivores that feed on small invertebrates, algal turfs and seagrass (Shepherd and Baker 2008).

In the MSF, historically some or all of the suite of species of leatherjackets may have been taken by commercial fishers. Collectively they have been reported as Leatherjackets and recorded in the Marine Scalefish Fishery Information System as such. Consequently, it is not possible to differentiate the fishery statistics amongst species.

Fishery

In South Australia, Leatherjackets are taken by both the commercial and recreational sectors of the Marine Scalefish Fishery. In the commercial sector, Leatherjackets are predominantly taken as by-product when more valuable species are targeted; however, a small number of fishers target these species. Leatherjackets are caught in the commercial MSF predominantly using hauling nets or handlines.

Recreationally, Leatherjackets are taken with rod and line. In 2013/14, an estimated 121,962 Leatherjackets were captured by the recreational sector, of which 75,787 fish were released, leaving 46,175 fish retained (Giri and Hall 2015). No estimate of total State-wide harvest weight is available for the recreational sector.

Management Regulations

All species of Leatherjackets are legitimate species of the commercial sector of the MSF (PIRSA 2014). They are classified as tertiary taxa in the commercial MSF Management Plan as they have low-medium value and make a minor contribution to the total production value of the commercial fishery (PIRSA 2013). There is no size limit nor bag or boat limit for either the commercial or recreational fishing sectors.

Commercial Fishery Statistics

State-wide

The State-wide, annual commercial catch for Leatherjackets was highest between 1995 and 2000. It declined regularly over the long-term to the lowest recorded catch of 10.5 t in 2014 (Figure 4-46). It subsequently increased to 34 t in 2016, but declined again to 27 t in 2017. Since 1990, the catch has been dominated by that taken with hauling nets. The second major gear type was handlines for which the annual catch peaked at 5.5 t in 1997. Annual estimates of total fishing effort that produced catches of Leatherjackets have always been dominated by hauling nets. Hauling net effort has consistently declined from its peak of almost 5,000 fisher days in 1991 to 678 fisher days in 2014, before increasing to 1,314 fisher days.yr^{-1} in 2017 (Figure 4-46).

Between 1990 and 2001, hauling net CPUE was relatively consistent until it declined in 2002 to its lowest recorded level of 6 kg.fisher-day^{-1}. Nevertheless, it increased dramatically in 2004 and since then has remained relatively high, peaking at 19.3 kg.fisher-day^{-1} in 2017. The number of fishers who reported taking Leatherjackets has declined from 142 fishers.yr^{-1} in 1990 to 75 fishers.yr^{-1} in 2014, before increasing again to 86 in 2017. Since 2010, the number who targeted this taxon has consistently remained at ≤5 fishers.yr^{-1}. The higher numbers of fishers who took Leatherjackets compared to those who targeted it suggests that this taxon has largely been taken as a by-product when more valuable species have been targeted (Figure 4-46).

Regional

Between 1990 and 2017, NSG and NGSV provided the highest catches of Leatherjackets. Incidental catches were taken from the other four regions (Figure 4-47). Historically, catches have been highest between March and October. In 2017, the MSF fishers accounted for 99.1% of the commercial catch, whilst the Northern and Southern Zone Rock Lobster fishers accounted for the remaining 0.9% (Figure 4-47).

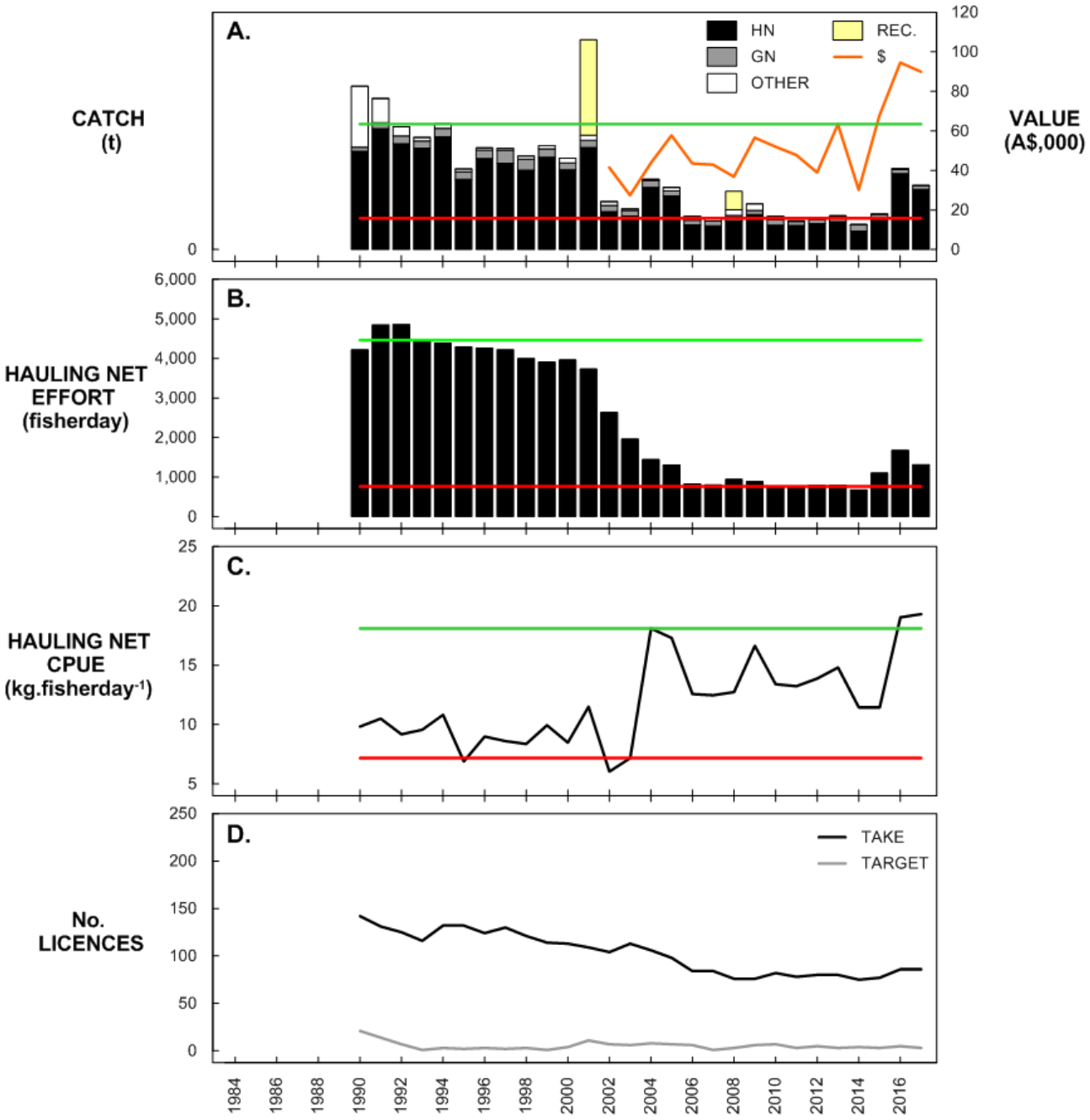

Figure 4-46. Leatherjackets. Long-term trends in: (A) total catch of the main gear types (hauling net and gilnets), estimates of recreational catch, and gross production value; (B) total hauling net effort; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

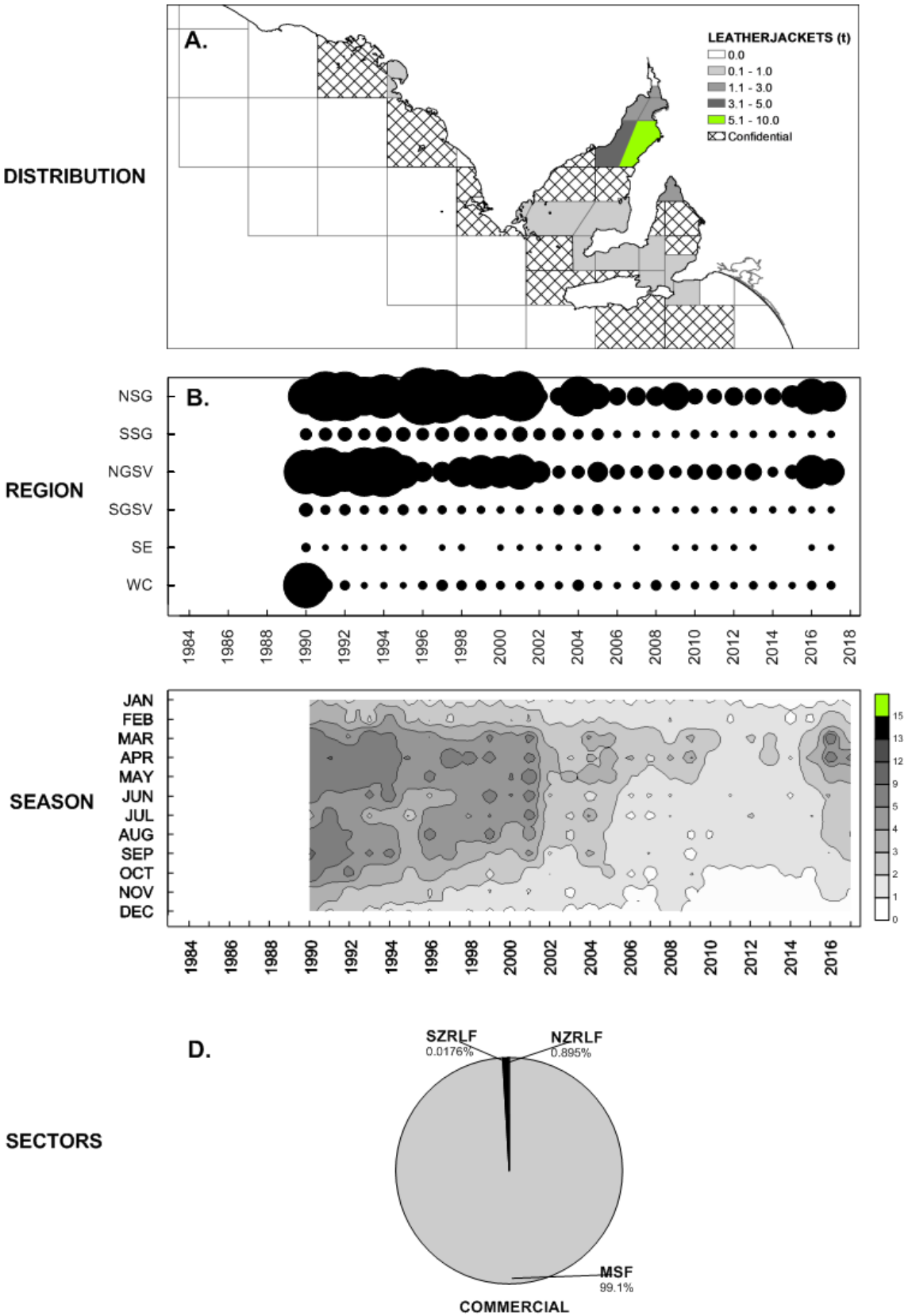

Figure 4-47. Leatherjacket. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t), and (D) the proportion of catch distributed among the commercial sector in 2017.

Fishery Performance

The general fishery performance indicators for Leatherjackets were assessed for 2017 at the State-wide scale, using the reference period of 1990 to 2017. One trigger reference point was activated (Table 4-20). Targeted hauling net CPUE in 2017 was the highest recorded.

Table 4-20. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Leatherjacket in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL HAULING NET EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL HAULING NET CPUE	G	3rd Lowest / 3rd Highest	HIGHEST
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

Although some catch is targeted, Leatherjackets are predominantly taken as by-product when more valuable species are targeted. As such, there have been consistently higher numbers of fishers who reported taking Leatherjackets than those that targeted it. Until 2015, the overwhelming trend was one of declining annual catches for Leatherjackets. This largely reflected the significant declines in effort in the net sector of the Marine Scalefish Fishery. However, targeted hauling net CPUE increased in 2017 resulting in a breach of this trigger reference point. This reflected increases in both hauling net catch and effort, although they remained lower than those up to the early 2000s. The low catches, low effort levels and medium levels of CPUE provide no indication that the Leatherjackets are heading towards being recruitment impaired. On this basis, South Australia's Leatherjacket fishery is currently classified as **sustainable**.

4.3.18. RAYS AND SKATES

Biology

Undifferentiated species of Rays and Skates are reported in catch and effort logbooks by the commercial Marine Scalefish Fishery (MSF). Products from the Southern Eagle Ray including (*Myliobatis tenuicaudatus*) is regularly identified during market sampling of commercial catches from the MSF. This species is distributed from Jurien Bay in Western Australia to Moreton Bay in Queensland, including, South Australia, Victoria, Tasmania and New Zealand (Last and Stevens 2009), and is commonly found along beaches, seagrass beds and sand-flats from 0–130 m. Southern Eagle Rays are born at body sizes of 200–300 mm disc width (DW), and individuals reach a maximum size of up to 1600 mm DW (> 3000 mm TL) (Last and Stevens 2009). Age and growth studies in New Zealand suggest the species reaches a maximum age of >15 years for males and >26 years for females (Hartill 1989).

Fishery

Rays and Skates are mostly taken as bycatch using large-mesh hauling nets whilst targeting higher value Marine Scalefish species in South Australia (Fowler et al. 2009). During the most recent recreational fishing survey, it was estimated that 9,489 Southern Eagle Rays were captured and all were released (Giri and Hall 2015).

Management Regulations

Rays and Skates of all species are permitted to be taken by the MSF (PIRSA 2014). No commercial harvest strategy has been developed (PIRSA 2013). There is currently no size, daily bag or boat limits for Ray and Skate species taken in the commercial or recreational fishing sectors in South Australian State-managed waters.

Commercial Fishery Statistics

State-wide

The total State-wide catch of Sharks and Rays was 13.0 t in 2017 (*c.f.* 9.6 t in 2016). Catch was relatively stable in the five-year period between 2013 and 2017 (inclusive) (Figure 4-48). Longlines are the dominant gear type since 1985 (56–88% of total annual catch), and the remainder of the catch mostly landed using hauling nets and handlines.

Annual trends in longline effort in the MSF have shown a relatively steady decline since 1992 from 1,305 fisher days to 183 days in 2016. Longline effort increased moderately to 250 fisher-days in 2017 (Figure 4-48). In the previous 5-year-period, long line effort has been stable at a low level ranging from 183–292 fisher-days. Longline CPUE has been stable at a low level of 32.5 to 40. 3 kg.fisher-day^{-1} since 2006 (Figure 4-48).

Regional

The largest annual catches of Sharks and Rays occurred off the West Coast between 1988 and 2005. Southern GSV was the second most significant region until 2003, with NSG and the SE also supporting significant annual catches in some years (Figure 4-49). In the past five years, catches have been homogeneously distributed, albeit at low levels, with the WC retaining the highest catches. Catches of Sharks and Rays are generally more frequent in the warmer months between spring and autumn. In 2017, the MSF fishers accounted for ~94.4% of the commercial catch, with the Southern Zone Rock Lobster (SZRLF) and Northern Zone Rock Lobster (SZRLF) fisheries taking 3.91% and 1.69% of the total catch, respectively (Figure 4-49).

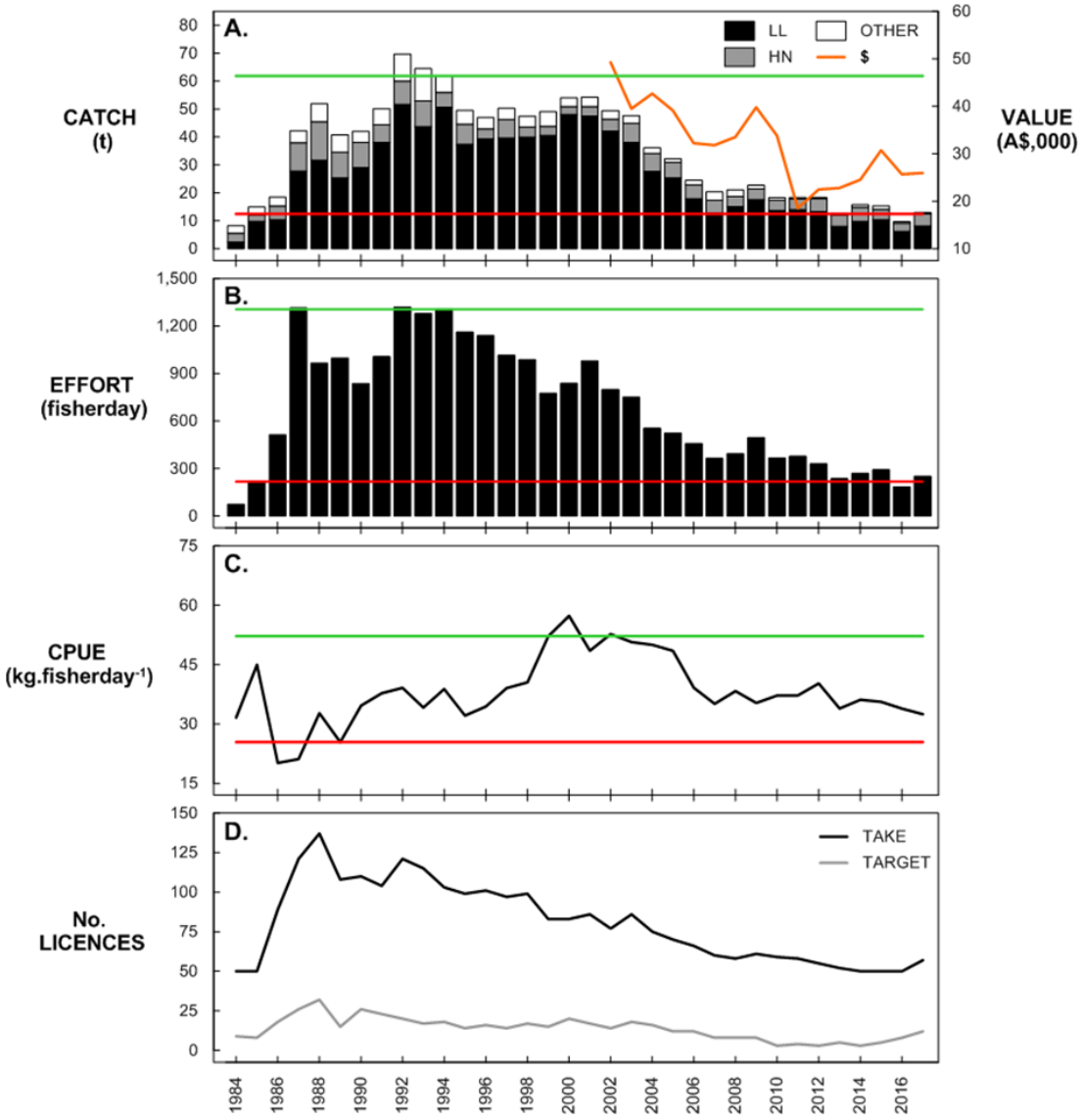

Figure 4-48. Rays and Skates. Long-term trends in: (A) total catch of the main gear types (longline and hauling net), and gross production value; (B) total effort; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

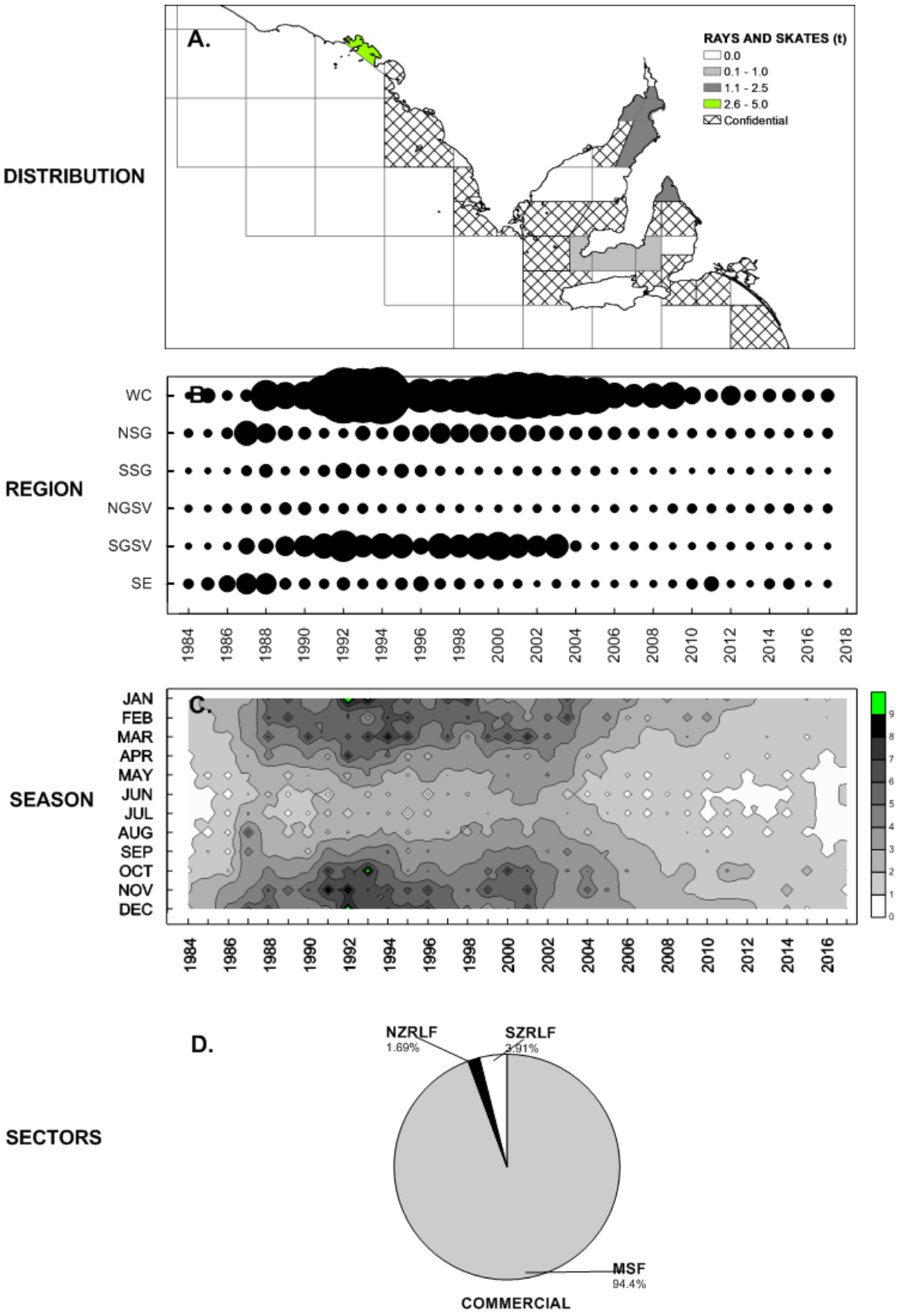

Figure 4-49. Rays and Skates. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t), and (D) the proportion of catch distributed among the commercial sector in 2017.

Fishery Performance

The general fishery performance indicators for Rays and Skates were assessed for 2017 at the State-wide scale. No trigger reference points were breached (Table 4-21).

Table 4-21. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Rays and Skates in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL HAULING NET EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL HAULING NET CPUE	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL LONGLINE EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TOTAL LONGLINE CPUE	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

The low recent catches and stable catch rates provide no evidence that the fishery is recruitment overfished. The Ray and Skate catch in the MSF is currently classified as **sustainable** due to the low level of annual production. Uncertainties remain regarding the species composition of commercial catches.

4.3.19. CUTTLEFISH (*Sepia* spp.)

Biology

Two cuttlefish species, Giant Australian Cuttlefish (*Sepia apama*) and Nova's Cuttlefish (*S. novaehollandiae*), are commercially harvested in the MSF. Of these, Giant Australian Cuttlefish is the largest and most abundant local cuttlefish species (Edgar 2000) reaching a maximum size of 500 mm mantle length and weighing up to 10.5 kg (Jereb and Roper 2005). This species is endemic to Australia, broadly distributed around the southern coastline from Point Cloates, Western Australia to Moreton Bay, Queensland, including Tasmania (Edgar 2000). Giant Australian Cuttlefish are generally found over seagrass beds and rocky reef habitats in waters of up to 100 m depth (Jereb and Roper 2005).

Within South Australia, two genetically distinct populations of Giant Australian Cuttlefish have been identified (Gillanders et al. 2016). While the southern Spencer Gulf cluster extends into Gulf St. Vincent, the northern cluster is restricted to northern Spencer Gulf (NSG) and shows a clear pattern of philopatry, i.e. individuals return to the site of hatching to breed at either one or two years of age. This population forms a mass breeding aggregation at Point Lowly (Steer et al. 2013, Steer 2015, Gillanders et al. 2016) during late autumn and early winter each year. Water temperature conditions and suitable substrate are thought to drive the inshore migration (Hall and Fowler 2003). The species shows sexual dimorphism with males reaching larger mantle sizes with longer arms that are used in courtship. The species is semelparous, dying soon after spawning (Hall and Fowler 2003).

Fishery

In South Australia, Cuttlefish are taken by both the commercial and recreational sectors of the Marine Scalefish Fishery. In the commercial sector, they are generally taken with handlines and jigs and are either targeted or taken as by-product when Southern Calamari are targeted. Historically, cuttlefish were retained by commercial fishers as bait for Snapper.

Cuttlefish are rarely targeted by recreational fishers and incidentally caught when fishers target Southern Calamari with squid jigs. In 2013/14, the State-wide recreational survey estimated that 2,648 Cuttlefish were captured, of which 1,217 were released, leaving 1,431 fish retained (Giri and Hall 2015). This provided a total estimated catch of 0.34 t, which was considerably lower than the estimated commercial catch of 2 t.

Management Regulations

Cuttlefish of all species are permitted to be taken commercially by the MSF (PIRSA 2014). There is no size limit for either the commercial or recreational fishing sectors. However, for the recreational sector there is a combined cuttlefish/squid bag limit of 15 fish and boat limit

of 45 fish. A cephalopod fishing closure, that aimed to protect the iconic Giant Australian Cuttlefish spawning population in False Bay, Northern Spencer Gulf was implemented in 1998. This area was extended in 2012 to offer greater protection to the spawning population. An additional temporary closure was implemented in 2013 that prohibited the targeting and retention of Giant Australian Cuttlefish north of Wallaroo, Spencer Gulf, and remains current.

Commercial Fishery Statistics

State-wide

Between 1994 and 1997, the reported commercial catch of Cuttlefish increased from 12.3 $t.yr^{-1}$ to its peak at 262 $t.yr^{-1}$ (Figure 4-50) corresponding with a dramatic increase in both targeted and untargeted effort. In the following two years catches fell to <16 $t.yr^{-1}$ and have continued to decline until 2017. Since 1999 annual catches have generally been <20 $t.yr^{-1}$. The total catch of 0.9 t in 2017 was the lowest since 1987.

Until 1994, total jig effort was <350 $fisher\text{-}days.year^{-1}$, before peaking at 1,477 fisher-days in 1997 (Figure 4-50). Since then, it has fluctuated between 600 and 900 $fisher\text{-}days.yr^{-1}$ before dropping to 358 fisher-days in 2017. Jig CPUE followed a similar trend increasing from >50 $kg.fisher\text{-}day^{-1}.year^{-1}$ to 173 $kg.fisher\text{-}day^{-1}$ in 1997, and subsequently declining to <15 $kg.fisher\text{-}day^{-1}.year^{-1}$ since 2007. The short-term expansion of the fishery between 1994 and 1997 reflects the fleet's concentrated of fishing effort on the spawning aggregation in northern Spencer Gulf. The fishery was effectively arrested by the False Bay spawning closure, which accounted for >90% of the State-wide catch.

During the late 1990s and early 2000s up to 56% of the fishers catching Cuttlefish were actively targeting them. The number of fishers actively targeting Cuttlefish has rarely exceeded 20% since 2010, indicating that the majority of Cuttlefish landed are incidentally caught (Figure 4-50).

Regional

Between 1994 and 2002, NSG has provided the highest catches of Cuttlefish with only incidental catches from the other regions (Figure 4-51). During these years, catch was concentrated at the time of the spawning aggregation between April and August. In 2017, the MSF fishers accounted for 100% of the commercial catch, and the majority of this was landed in the south eastern corner of Spencer Gulf (Figure 4-51).

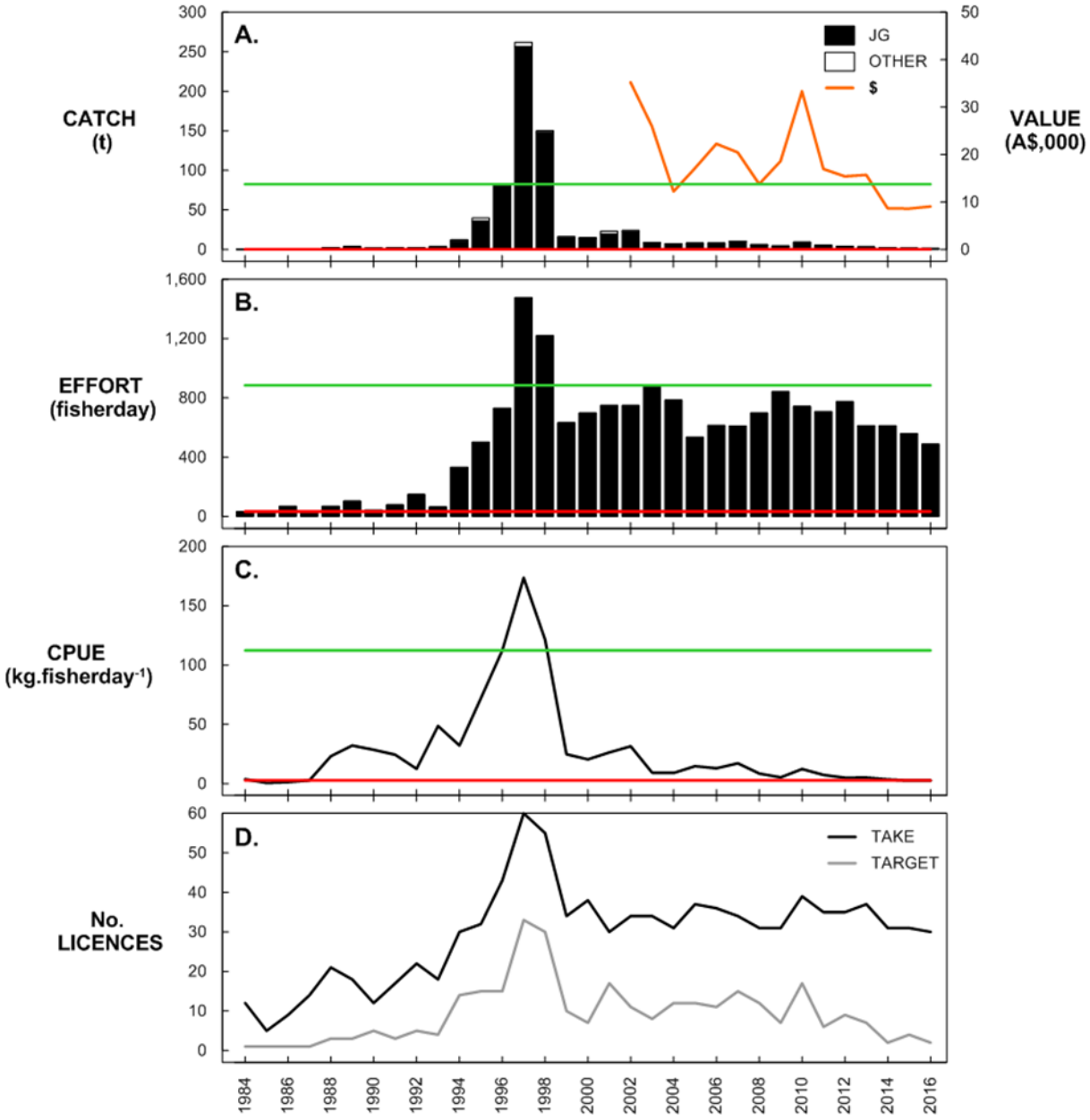

Figure 4-50. Cuttlefish. Long-term trends in: (A) total catch of the main gear types (squid jig and other), and gross production value; (B) total effort; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

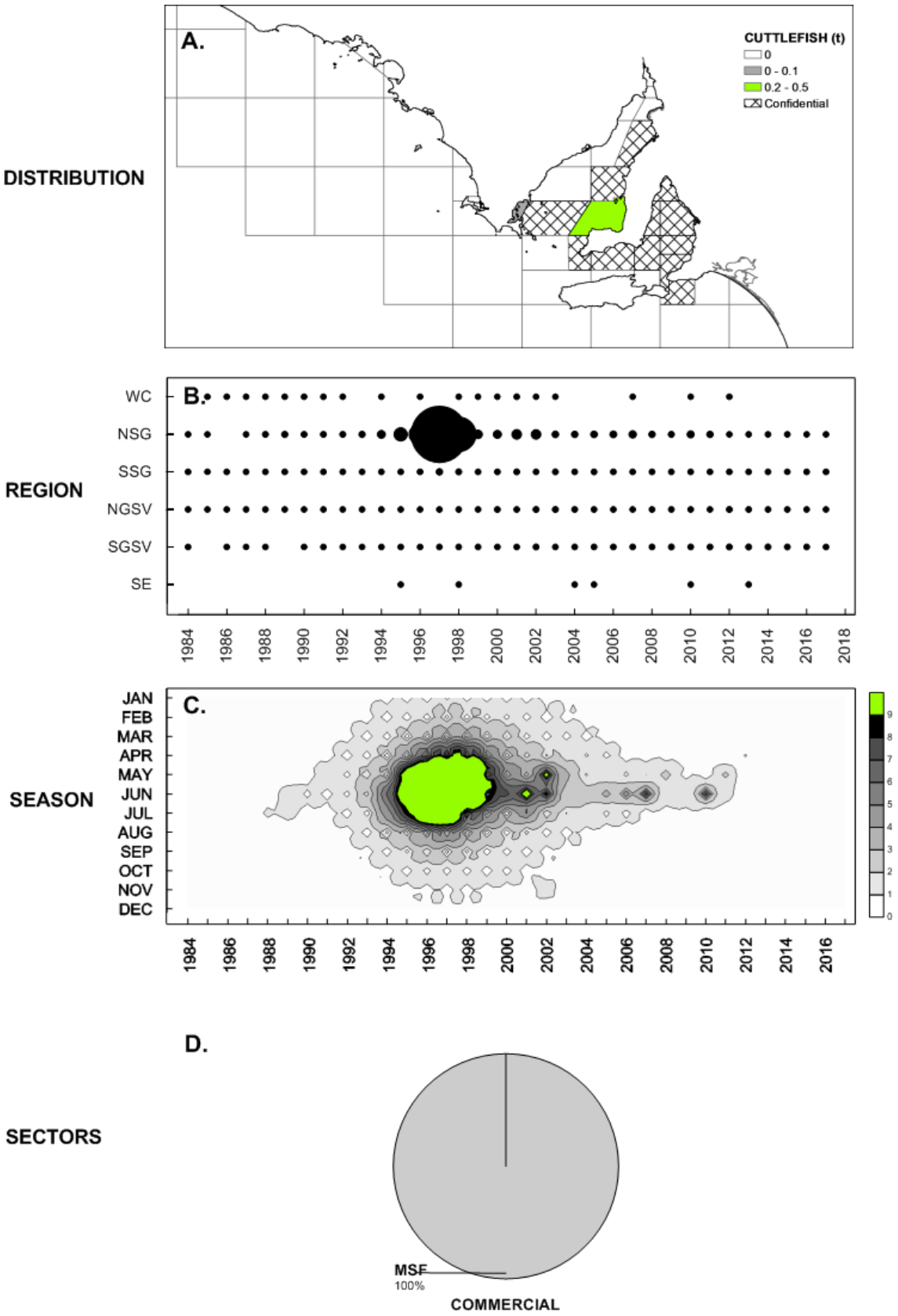

Figure 4-51. Cuttlefish. (A) Catch distribution for 2017. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t), and (D) the proportion of catch distributed among the commercial sector in 2017.

Fishery Performance

The general fishery performance indicators for Cuttlefish were assessed for 2017 at the State-wide scale. Four trigger reference points were activated in 2017 (Table 4-22). Total catch, jig effort and jig CPUE declined over 5 consecutive years, while total jig CPUE was the third lowest recorded since 1984.

Table 4-22. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Cuttlefish in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	✓
TOTAL JIG EFFORT	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	✓
TOTAL JIG CPUE	G	3rd Lowest / 3rd Highest	3rd LOWEST
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	✓

Stock Status

There is a minor targeted fishery for this species although it is primarily taken as by-product when other more valuable species, such as Southern Calamari, are targeted. As such, there were a large number of fishers who reported taking Cuttlefish compared to those who reported targeting it. Total catch of Cuttlefish has generally declined since 1997, corresponding with the implementation of spatial and temporal closures (Steer 2015). In 2017, the catch rate was the third lowest level recorded since 1984. This was considerably lower than the high catch rates recorded through the peak period of the mid to late 1990s, and only slightly higher than the lowest level recorded in 1985. There were four trigger reference points breached for the data from 2017 reflecting low targeted jig CPUE and a declining total catch over 5 consecutive years. However, fishery independent surveys of abundance in the Point Lowly closure area showed consecutive annual increases from 2014 and 2015, and relatively high abundance in 2017 (Steer, unpublished data). This, in addition to the low recent catches and decrease in effort, suggests that the fishery is unlikely to become recruitment overfished at the current level of fishing pressure. On this basis, South Australia's Cuttlefish fishery is currently classified as **sustainable**.

4.3.20. BLACK BREAM (*Acanthopagrus butcheri*)

Biology

Black Bream is a member of the Sparidae family, i.e. the Seabreams (Gomon et al. 2008). It occurs in estuaries and nearshore coastal waters across southern Australia from the Murchison River in Western Australia (WA), to Myall Lake in New South Wales, including Tasmania (Norriss et al. 2002). Unlike most Sparids, Black Bream complete their life cycle within estuaries (Partridge and Jenkins 2002). Genetic studies of Black Bream in Victoria and Western Australia have suggested that while there is gene flow occurring between adjacent estuaries (Chaplin et al. 1998) there is evidence of isolation by distance among populations. Furthermore, results of tagging studies conducted in southern WA (Norriss et al. 2002), and the Coorong estuary (Hall 1984) indicated limited or no evidence of emigration between estuaries and coastal movements.

Black Bream is considered a periodic strategist (Winemiller and Rose 1992), i.e. a large-bodied fish with slow growth, late maturation, long life-span, high fecundity and low juvenile survivorship. In South Australia, the species attains a maximum age of 32 years, maximum length of 550 mm TL, and matures at 289–340 mm TL and 1.9–4.3 years old (Ye et al. 2015).

Fishery

Black Bream are taken by both the commercial and recreational sectors of the MSF. In the commercial sector, the species is targeted and taken as by-product using hauling nets and set nets.

Recreational fishers target the species using rod and line in nearshore coastal waters, estuaries and lower reaches of rivers (Kailola et al. 1993). The State-wide recreational survey in 2013/14 estimated that 197,848 Black Bream were captured, of which 180,869 were released, leaving 16,979 fish retained (Giri and Hall 2015). The latter provided a total estimated State-wide recreational harvest of 4.97 t, which was higher than the estimated State-wide commercial MSF catch of 1.4 t.

Management Regulations

Black Bream is considered a tertiary species of the commercial MSF, being of low-medium value and making a minor contribution to the total production value of the fishery (PIRSA 2013). For the commercial sector, regulations are in place to manage fishing effort and limit the take of Black Bream. These include temporal and spatial netting closures, restrictions to net lengths and mesh sizes, and a minimum legal size of 300 mm TL (PIRSA 2016).

There are multiple management regulations in place for Black Bream in the recreational sector. Input and output controls ensure the total catch is maintained within sustainable limits

and that access is distributed equitably among fishers. These include a daily bag limit of 10 fish and boat limit of 30 fish, and gear restrictions. The minimum size limit of 300 mm TL also applies to the recreational sector. A temporal closure prohibits the take of Black Bream from 1 September to 30 November in the Onkaparinga River upstream of the Main South Road Bridge at Noarlunga.

Commercial Fishery Statistics

State-wide

Historically, total annual commercial catch of Black Bream by the MSF has rarely exceeded 1 t.yr^{-1}. It increased to a peak of 3.9 t in 2007, was low during the early 2010s, and then increased to 2.3 t in 2016. Catch data for 2017 are confidential, i.e. they were reported by fewer than five fishers (Figure 4-52). Estimates of total annual fishing effort that produced catches of Black Bream have been highly variable since 1984. Effort declined to 8 fisher-days.yr^{-1} in 1996, before increasing to an historic peak of 253 fisher-days in 2003. Since then effort has been considerably lower ranging from 11–84 fisher-days.yr^{-1}.

Total catch per unit effort (CPUE) fluctuated between 3–21 kg.fisher-day^{-1} until 2007 when it increased to a peak of 47 kg.fisher-day^{-1}. Since then, total CPUE has fluctuated considerably but remained above 20 kg.fisher-day^{-1} in most years. The numbers of fishers who reported taking and targeting Black Bream have been quite different over time, suggesting the catch is largely by-product when other species are targeted (Figure 4-52).

Regional

Confidentiality constraints (<5 fisher rule) prevented an interrogation of the commercial catch and effort data at the regional scale (Figure 4-52).

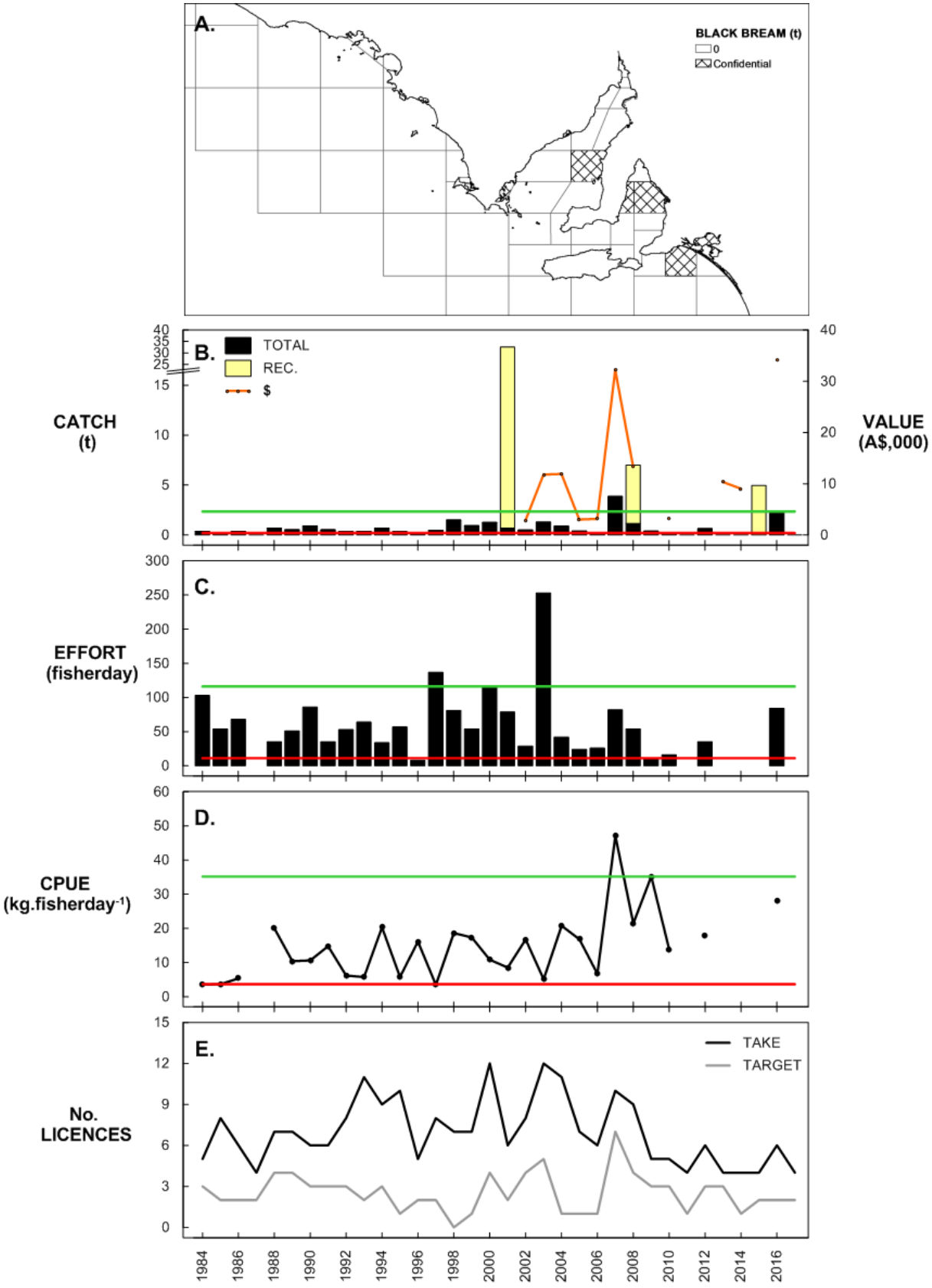

Figure 4-52. Black Bream: (A) Catch distribution for 2017. Long-term trends in (B) total catch, and estimates of recreational catch; (C) total effort; (D) catch per unit effort (CPUE); and (E) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 3-1.

Fishery Performance

Confidentiality constraints prevented the assessment of the 2017 catch and effort data against the general performance indicators (Table 4-23).

Table 4-23. Results from the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Black Bream in 2017.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	CONF.
	G	Greatest % interannual change (+/-)	CONF.
	G	Greatest 3 year trend	CONF.
	G	Decrease over 5 consecutive years	CONF.
TOTAL EFFORT	G	3rd Lowest / 3rd Highest	CONF.
	G	Greatest % interannual change (+/-)	CONF.
	G	Greatest 3 year trend	CONF.
	G	Decrease over 5 consecutive years	CONF.
TOTAL CPUE	G	3rd Lowest / 3rd Highest	CONF.
	G	Greatest % interannual change (+/-)	CONF.
	G	Greatest 3 year trend	CONF.
	G	Decrease over 5 consecutive years	CONF.

Stock Status

Black Bream is a tertiary species for the commercial sector of the MSF (PIRSA 2013). This reflects low annual catches and its minor contribution to the total production value of the sector. Catches were historically low from 1984 to 2006, as a result of low targeted effort and low CPUE. Between 2013 and 2017, catches increased slightly and estimates of CPUE were > 80% higher than the long-term average catch rate. The recent increases in total catch and CPUE indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. On this basis, the Black Bream fishery is classified as **sustainable**.

4.3.21. Catch Statistics of Permitted Species

Table 4-24. Summary table showing the total annual commercial catches in tonnes for the main Marine Scalefish Fishery permitted species contained in this report. Crosses indicate confidential data (<5 fishers).

YEAR	GARFISH	KGW	SNAPPER	CALAMARI	YFW	WA SALMON	AUST HERRING	VONGOLE	SNOOK	BLUE CRAB	SAND CRAB	YE MULLET	MULLOWAY	WHALERS	OCEAN JACKETS	BT WRASSE	TREVALLY	LEATHER JACKET	GUMMY SHARK	SCHOOL SHARK	RAYS & SKATE	CUTTLEFISH	BREAM
1984	441.9	636.0	451.1	183.9	104.5	400.2	364.2	0.2	110.9	114.7	22.8	96.0	14.8	30.1	X	2.9	3.0	X	651.1	881.3	8.2	0.3	0.4
1985	438.4	597.0	457.9	196.2	61.4	659.6	231.2	0.3	75.6	126.1	30.4	100.5	14.7	27.0	X	2.6	2.1	X	647.1	999.7	14.9	0.1	0.2
1986	449.1	693.2	427.2	201.7	41.7	541.7	409.2	15.2	72.5	170.1	25.0	129.4	9.8	40.2	X	2.3	3.3	X	699.9	1130.1	18.4	0.3	0.4
1987	382.4	602.5	364.5	168.2	23.8	650.6	493.8	37.0	70.8	165.2	28.0	147.0	14.2	54.8	X	3.0	4.3	X	835.0	1259.7	42.3	0.2	X
1988	391.0	586.6	409.8	281.3	14.5	524.9	427.7	43.9	85.5	209.4	40.5	126.3	8.1	70.0	X	3.4	4.2	X	930.4	1237.7	51.9	2.3	0.7
1989	513.7	638.0	423.3	231.6	26.9	573.3	396.2	28.6	116.4	323.6	136.5	133.3	9.0	62.8	X	2.5	3.0	X	1074.8	1212.5	40.8	3.5	0.5
1990	527.7	683.8	453.1	212.1	40.8	313.6	296.0	23.4	94.8	390.5	151.9	174.7	13.4	76.6	930.0	1.9	4.6	68.9	889.7	1003.1	42.0	2.0	0.9
1991	422.5	678.0	419.5	348.5	39.9	486.5	342.8	24.4	102.3	434.6	135.2	154.8	7.6	76.9	977.3	1.6	7.4	63.7	707.1	799.1	50.1	2.1	0.5
1992	492.8	776.3	383.1	268.3	44.4	607.2	362.1	36.2	114.7	429.1	81.6	131.8	11.6	67.7	916.8	5.0	16.6	51.6	670.2	576.5	69.6	2.1	0.3
1993	531.5	668.8	358.2	312.9	107.4	658.7	321.2	25.5	120.5	566.3	65.9	128.6	10.9	71.6	766.3	4.4	14.6	47.3	704.3	774.5	64.4	3.3	0.4
1994	469.0	635.0	242.1	352.5	73.3	500.1	299.9	15.1	132.6	484.3	40.1	102.5	17.9	92.4	575.3	6.1	7.9	52.9	755.3	621.9	61.8	12.3	0.7
1995	401.9	565.0	260.3	355.2	110.3	638.0	231.5	34.9	147.3	692.9	53.0	102.1	24.2	93.6	477.0	7.8	7.8	33.9	631.9	626.2	49.5	39.8	0.3
1996	503.9	579.1	310.2	374.5	95.4	500.9	212.9	73.1	131.8	559.6	66.5	66.0	12.7	70.7	441.7	6.7	7.8	42.8	824.0	660.4	46.9	82.5	0.1
1997	546.4	570.6	362.4	390.7	107.0	653.5	219.1	83.1	110.1	320.9	125.9	107.3	11.4	102.2	433.0	23.9	9.1	42.5	482.9	275.1	50.3	262.0	0.5
1998	447.2	562.3	398.2	433.2	51.2	572.7	353.1	151.8	108.3	74.3	119.5	92.2	6.5	96.1	359.6	24.7	4.1	39.4	223.9	74.3	47.4	150.1	1.5
1999	452.2	602.1	572.9	400.4	113.7	584.7	298.3	142.4	105.4	123.9	132.1	67.8	6.6	82.8	284.1	24.1	8.4	43.7	243.8	48.8	49.0	16.3	0.9
2000	517.4	440.7	571.5	419.3	109.3	542.1	250.7	159.2	94.9	78.5	175.7	71.3	7.1	79.7	269.2	21.9	21.0	38.4	194.9	22.5	54.0	15.0	1.3
2001	522.8	449.1	661.5	455.6	178.9	576.4	250.9	179.7	113.9	92.9	131.7	71.6	6.2	93.9	352.1	21.9	7.1	48.1	49.1	3.8	54.2	23.3	0.7
2002	419.9	370.7	545.0	323.3	152.9	279.7	252.9	240.7	108.4	66.7	104.7	50.8	2.7	96.9	308.0	23.7	2.5	20.2	38.6	4.6	49.4	23.8	0.5
2003	295.7	381.8	412.0	314.5	167.7	496.3	149.4	261.0	90.4	66.2	104.9	47.7	7.8	119.1	X	28.8	5.1	17.1	45.4	5.9	47.6	8.9	1.3
2004	327.3	345.7	449.9	468.8	162.9	213.8	178.8	296.7	85.6	51.9	84.9	43.4	2.6	113.2	322.7	22.9	6.3	29.5	54.0	3.8	36.1	7.1	0.9
2005	390.6	348.0	529.6	357.9	120.5	173.5	165.4	389.5	69.0	47.8	177.0	48.5	6.1	94.8	X	19.9	6.8	26.1	52.9	3.3	32.2	7.9	0.4
2006	350.0	348.0	613.6	299.3	126.1	262.5	93.2	309.5	58.1	47.6	105.5	41.6	5.9	76.5	69.2	15.5	10.8	14.0	58.2	4.3	24.5	8.0	0.2
2007	264.5	351.7	745.4	295.9	78.8	126.3	112.6	311.5	82.0	41.8	70.2	30.5	7.2	82.4	57.7	13.4	8.2	13.3	84.4	8.1	20.3	10.5	3.9
2008	277.1	313.3	719.7	279.1	85.7	126.7	130.0	233.6	72.1	51.0	98.5	30.5	3.3	87.9	X	21.7	8.4	16.8	106.6	9.9	21.0	6.0	1.2
2009	316.7	358.5	818.5	331.0	114.7	136.1	176.7	154.5	64.3	60.4	72.7	25.6	3.7	109.5	X	20.0	5.7	19.2	148.5	13.8	22.7	4.5	0.4
2010	254.9	326.7	1034.5	347.9	114.4	163.5	147.1	86.6	64.9	54.2	65.7	23.3	2.0	121.1	X	19.5	15.5	14.0	149.8	10.5	18.3	9.1	0.2
2011	291.7	328.2	945.0	415.4	87.5	204.0	86.4	78.5	46.8	53.6	93.2	31.8	3.3	92.6	X	23.5	10.5	12.1	144.2	16.4	18.3	5.2	X
2012	238.9	310.9	642.7	429.4	119.0	98.0	109.7	64.1	49.2	56.6	79.0	27.5	4.5	90.0	138.6	16.7	10.3	13.2	161.2	15.2	18.3	3.8	0.6
2013	250.4	292.5	519.4	399.0	152.0	59.4	172.1	70.7	41.9	62.5	65.0	18.9	2.8	57.2	50.2	17.3	9.1	14.2	103.7	12.0	12.4	3.1	X
2014	264.0	280.6	534.4	402.5	96.2	220.1	114.5	73.6	40.3	60.9	46.9	16.0	1.3	58.3	X	15.2	11.3	10.5	88.6	14.7	15.7	2.2	X
2015	163.3	288.5	512.4	370.3	101.0	349.5	104.3	59.1	46.7	45.0	63.2	16.1	1.3	54.8	X	17.2	8.7	15.0	85.7	17.2	15.4	1.5	X
2016	155.2	287.3	386.8	398.8	114.6	370.1	93.5	66.1	53.5	31.2	48.4	12.5	1.1	50.4	224.2	13.6	8.1	34.1	76.8	17.7	9.6	1.3	2.4
2017	183.5	244.5	339.4	413.6	141.6	374.1	61.2	54.9	38.9	51.6	42.8	22.1	5.6	61.8	151.2	13.4	10.5	27.0	73.3	17.8	13.0	0.9	X

Table 4-25. Summary table showing the total annual commercial catches in tonnes for the remaining Marine Scalefish Fishery permitted species that were not considered in detail in this report. Crosses indicate confidential data (<5 fishers).

YEAR	ANNELIDS	GOOLWA COCKLE	MUSSEL	OCTOPUS	OYSTER	SCALLOP	GOULD'S SQUID	ANCHOVY	BARRACOUTA	COD	DORY	FLATHEAD	FLOUNDER	GOATFISH	YELLOWTAIL KINGFISH	PINK LING	BLUE MACKEREL	JACK MACKEREL	MORWONG	OTHER MULLET	BIGHT REDFISH	SWEEP	SWALLOWTAIL	BLUE EYE TREVALLA	SCHOOL WHITING	OTHER SHARK
1984	13.9	X	X	X	X	X	X	X	76.1	0.4	X	4.6	0.3	2.5	0.7	X	X	2.1	10.8	X	5.1	3.5	X	X	X	21.1
1985	14.6	X	X	0.2	X	X	X	X	24.0	X	X	3.2	1.0	2.6	X	X	X	X	13.4	X	8.9	3.1	X	3.6	X	25.8
1986	15.2	X	X	0.1	X	X	X	X	7.6	X	X	3.4	1.2	3.7	X	0.1	X	3.0	19.5	X	16.3	1.7	X	24.6	X	27.7
1987	11.8	X	X	1.4	X	X	X	X	5.8	X	X	3.3	0.5	3.3	X	1.1	3.7	X	24.4	X	13.8	1.8	X	153.4	X	80.7
1988	11.3	X	X	3.1	X	X	X	X	12.2	0.4	X	5.1	0.3	4.0	X	0.4	0.8	37.4	22.7	X	14.7	2.7	X	81.8	X	83.6
1989	13.7	X	X	2.6	X	X	X	X	9.1	0.2	X	4.0	0.3	4.7	X	0.2	1.3	X	28.7	X	22.0	9.6	0.2	54.9	X	72.5
1990	15.9	X	X	3.9	X	X	X	X	12.9	X	X	5.6	X	6.3	X	0.2	0.6	X	28.3	X	15.6	10.5	0.3	84.3	0.1	73.5
1991	15.8	X	X	6.2	X	X	X	X	5.2	X	X	6.9	0.2	3.9	0.4	0.1	1.4	0.3	20.5	X	9.4	7.0	0.4	70.6	X	102.8
1992	17.0	366.1	X	9.7	X	X	X	X	2.5	X	X	5.9	0.2	4.8	2.5	0.4	0.7	0.4	16.3	X	10.4	3.2	0.3	49.0	X	260.2
1993	13.7	X	X	6.5	X	X	X	X	2.0	X	X	4.5	0.1	4.6	1.7	2.1	0.5	0.4	13.6	X	13.5	4.8	0.4	54.5	0.1	352.0
1994	13.7	X	X	5.3	X	X	X	X	0.5	X	X	3.9	0.1	4.9	0.7	0.7	6.7	0.0	20.1	X	13.7	8.9	0.5	35.8	0.1	135.5
1995	13.9	X	X	6.8	X	X	X	X	X	X	X	2.8	0.5	4.1	0.5	0.6	5.0	0.3	25.8	X	18.2	5.8	0.1	17.9	0.0	114.6
1996	14.1	436.1	X	11.4	X	X	X	X	0.9	X	X	2.3	0.2	4.9	X	1.3	5.7	X	29.8	X	11.9	5.9	0.4	6.6	0.1	135.4
1997	11.6	362.6	X	5.9	X	X	X	X	X	X	X	2.2	0.1	3.5	X	1.6	4.0	X	14.1	X	9.3	8.7	0.1	4.5	X	78.5
1998	11.3	X	X	X	X	X	X	X	0.3	X	X	2.5	X	4.6	X	X	4.6	X	8.6	X	4.6	5.9	0.1	X	X	61.1
1999	11.5	340.7	X	7.4	X	X	X	X	X	X	X	2.8	0.2	4.7	X	X	2.4	X	3.7	X	5.5	2.6	X	X	X	54.9
2000	14.5	332.0	X	7.5	X	X	X	X	X	X	X	2.1	0.0	3.7	X	X	3.6	X	1.6	X	3.0	1.4	X	X	X	56.0
2001	10.8	338.7	X	X	X	X	X	X	X	X	X	2.1	X	4.8	X	X	0.4	X	0.5	X	1.6	1.8	X	X	X	75.6
2002	8.3	273.5	X	5.5	X	X	X	X	2.0	X	X	2.1	X	3.6	0.2	X	5.1	X	1.5	X	3.6	2.0	X	X	X	46.8
2003	7.1	X	X	5.1	X	X	X	X	2.4	0.0	X	2.2	X	3.4	0.4	X	1.5	X	2.6	X	3.4	2.0	X	X	0.1	36.2
2004	7.3	X	X	X	X	X	X	X	5.5	X	X	2.1	X	3.8	0.1	0.1	3.6	X	3.0	X	4.7	1.7	X	X	X	31.3
2005	7.5	34.3	X	X	X	X	X	X	4.3	X	X	2.2	X	3.7	0.4	X	0.8	X	3.8	0.2	7.5	1.4	X	X	X	24.8
2006	7.5	2.2	X	8.1	X	X	X	X	0.9	X	X	1.7	X	4.6	X	X	2.3	X	2.0	X	3.9	1.4	0.0	X	X	25.3
2007	6.6	X	X	18.9	X	X	X	X	X	X	X	2.1	X	5.8	X	X	3.6	X	2.3	X	4.6	0.8	0.1	X	X	19.5
2008	7.6	X	X	23.3	X	X	X	X	X	X	X	2.4	X	4.5	0.5	X	3.5	X	1.8	X	3.3	1.2	0.1	X	0.1	12.1
2009	6.1	X	X	X	X	X	X	X	2.2	0.4	X	3.3	X	4.9	0.1	X	2.1	X	2.6	2.4	6.8	2.5	0.4	X	X	16.4
2010	5.8	X	X	X	X	X	X	X	X	X	X	4.2	X	4.3	0.3	X	1.9	X	3.4	0.2	8.9	2.2	0.5	X	X	19.4
2011	5.9	X	X	14.6	X	X	X	X	X	X	X	5.7	X	3.3	X	X	X	X	2.9	X	14.2	3.1	0.2	X	X	23.0
2012	6.5	X	X	X	X	X	X	X	X	X	X	2.6	X	3.3	0.2	X	0.3	X	1.2	X	10.7	3.1	0.3	X	X	12.9
2013	5.4	X	X	7.6	X	X	X	X	X	X	X	1.6	X	5.2	X	X	X	X	1.0	X	10.0	2.4	0.2	X	0.0	8.4
2014	5.0	X	X	11.4	X	X	X	X	X	X	X	2.0	X	4.3	2.8	X	X	X	0.6	X	8.3	2.0	0.1	X	0.2	7.5
2015	5.2	X	X	10.6	X	X	X	X	X	X	X	2.0	X	3.5	1.3	X	X	X	0.9	X	12.6	1.1	0.1	X	X	7.1
2016	4.3	X	X	X	X	X	X	X	X	X	X	0.8	X	3.5	2.0	X	X	X	0.9	X	12.2	0.9	0.1	X	X	4.4
2017	4.7	X	X	14.4	X	X	X	X	X	X	X	1.1	X	3.3	2.1	X	X	X	1.2	X	19.8	0.7	0.2	X	X	6.1

5. GENERAL DISCUSSION

5.1. Synthesis

This report assessed the fishery performance of 23 species/taxonomic groups within South Australia's Marine Scalefish Fishery (MSF). Collectively, these taxa were considered across 35 management units, at a resolution that aligned with either the biological stock, or the State-wide or regional level. Of these, 29 (83%) stocks were classified as 'sustainable', four (9%) were classified as 'depleted, one (3%) was classified as 'recovering', and the remaining one (3%) was classified as 'undefined' as there was insufficient information to assign a stock status.

The four primary species (King George Whiting, Snapper, Southern Garfish, and Southern Calamari) have consistently accounted for more than half of the State-wide total commercial catch over the last decade, emphasising their importance to the MSF. Previous stock assessments for King George Whiting (Steer et al. 2018), Southern Garfish (Steer et al. 2016) and Snapper (Fowler et al. 2016a) have identified different levels of concern regarding the sustainability of some stocks. The Gulf St. Vincent/Kangaroo Island (GSV/KI) King George Whiting stock was classified as 'depleting' on the basis of declining trends in commercial catch rates, estimates of biomass and high exploitation rates (Steer et al. 2018). Similarly, the Spencer Gulf/West Coast (SG/WC) Snapper stock was assessed as 'transitional-depleting', as a result of below average recruitment and declining biomass (Fowler et al. 2016a). Persisting low rates of egg production, relatively high exploitation rates and declining catch rates lead to the Northern GSV Garfish stock being classified as 'depleted' (Steer et al. 2016). In each case, these assessments supported the development and implementation of specific management arrangements to recover these stocks.

With the exception of one Southern Garfish stock (NGSV), whose status has remained 'depleted' (previously termed 'overfished'), the status of the one Snapper and one King George Whiting stock have changed in this assessment. The GSV/KI King George Whiting stock has improved from 'depleting' to a 'sustainable' classification on the basis of increasing catch rates, relatively stable catch and effort trends, and consistent recruitment over the past three years. Conversely, the SG/WC Snapper stock has deteriorated from 'depleting' to a 'depleted' classification, as a result of persisting declines in targeted catch, effort and catch rates, and a relatively low fishery-independent estimate of spawning biomass (Steer et al. 2017).

The improved status of the King George Whiting Gulf St. Vincent / Kangaroo Island stock appears to be unrelated to the management arrangements implemented in December 2016, which included a spatial closure to protect known spawning grounds and an increase in the

legal minimum length, as it occurred within a year of its implementation. Nevertheless, the new spatial spawning closure is likely to provide additional benefit, particularly as the advancement of fishing technologies, such as increased vessel power, affordable electronic fish-finding equipment, improved fishing gear, and rapid communication through social media, has increased the fishing fleet's capacity to extend their effort into offshore areas that have been difficult to access in the past. A project is currently underway to determine key King George Whiting spawning areas throughout the southern gulfs and to understand their role in replenishing local stocks (FRDC 2016/003). It is anticipated that the results of that study will improve the assessment and management of this important resource.

The performance of the SG/WC Snapper stock has deteriorated despite considerable management arrangements implemented over the last five years to reduce exploitation and enhance reproductive output and recruitment. From at least 2012 onwards, fishery performance indicators show that the biomass of the SG/WC stock has declined considerably (Fowler et al. 2013, 2016, Steer et al. 2018). In response, significant fishery management changes were implemented between 2012 and 2016 to reduce the commercial catch and to increase reproductive output, thereby providing the opportunity for enhanced recruitment (Fowler et al. 2016). These changes included: introduction of daily commercial catch limits; a further restriction to the number of hooks that could be used on set lines; an extension of two weeks to the State-wide, seasonal closure for taking Snapper (until mid-December); and implementation of four spatial spawning closures throughout Spencer Gulf to protect the key spawning aggregations throughout the entire reproductive season (Fowler et al. 2016). Furthermore, recreational bag and boat limits have also been reduced. Despite these changes, commercial fishery statistics up to 2017 showed no improvements, with all estimates of catch and gear-specific effort and CPUE remaining at or around historically low levels. Furthermore, the application of the daily egg production method in 2013 provided an estimate of biomass of 280 t across all of NSG and part of SSG (Steer et al. 2017). This biomass is considerably lower than the catches that were recorded during the early 2000s, and is an order of magnitude less than the estimated biomass for the adjacent Gulf St. Vincent stock. The population age structures also suggest that recruitment has been relatively low throughout the 2000s (Fowler et al. 2016). The above evidence indicates that the biomass of this stock is likely to be depleted and that recruitment is likely to be impaired. Furthermore, the current fishing mortality is constrained by management to a level that should allow the stock to recover from its recruitment impaired state; however, measureable improvements are yet to be detected, consequently the SG/WC stock is classified as 'depleted'. The manifestation of any benefit within the population is likely to extend over a longer timeframe. This is because Snapper are a long-lived species and this stock has historically been replenished by highly

irregular recruitment events of varying strengths. The last notable recruitment events in SG/WC occurred in 1997 and 1999 (Fowler et al. 2016a).

Conversely, the short lifespan and rapid generation turnover of Southern Garfish increases the populations' capacity to respond rapidly to effective management arrangements. This was indeed the case for the NSG Southern Garfish stock which has displayed promising signs of improvement in biomass, exploitation rates, egg production, and population age structure, and was subsequently classified as 'recovering'. Targeted catch rates in NGSV have increased in the hauling net sector; however, harvest fraction has trended downwards; and fishable biomass, egg production and recruitment have remained relatively stable. This indicates that current fishing mortality is constrained by management to a level that should allow the stock to recover from its recruitment impaired state; however, measurable improvements are yet to be detected. Although adequate management may now be in place to recover the stock, more time is required to determine the relative effect of the 2017 management arrangements, which included an extended closure and increased hauling net mesh sizes. Furthermore, a dedicated research project (FRDC Project 2015/018) is approaching completion and aims to determine whether the commercial fishery data used to assess the regional stock accurately reflects the status of the broader resource.

Declines in the productivity of the premium finfish species have contributed to the diversification of the MSF fishing fleet, with many fishers switching their effort from Snapper, King George Whiting and Southern Garfish towards Southern Calamari. This change has most likely been economically driven, where it has become more cost-effective to target Southern Calamari based on their relative abundance, catchability, low set-up costs and high market value. Targeted jig effort for Southern Calamari has continued to increase in 2017, exceeding the associated trigger limits in NSG, SSG, and NGSV. This recent trend indicates that Southern Calamari has been established as an opportunistic target species for commercial fishers, and has surpassed Snapper and King George Whiting as the most valuable MSF species. Although the resource is considered 'sustainable' at the biological stock level there are concerns within industry about local productivity, with anecdotal reports suggesting some areas are displaying signs of localised depletion. These inferences have been based on Southern Calamari becoming increasingly difficult to catch in areas that were previously highly productive, a lack of eggs in known spawning areas, and a notable absence of large animals. Although localised depletion can occur through intense fishing pressure on spawning aggregations, their high-paced life history, dynamic spawning behaviour, and movement potential, favours population replenishment at the broader biological stock level (Pecl et al. 2006).

The long-term erosion of fishing effort through licence reduction is a distinct feature of the MSF. Since 1994, 403 MSF licences have been removed, representing an overall reduction of 56.4%, and translating to a 53.6% reduction in total fishing effort. With the exception of NGSV, where the number of active licences has remained relatively stable and annual effort levels have slightly increased over the last decade, the long-term erosion of licence numbers is clearly evident in all other regions considered in this report. Industry and government have recently committed to a structural reform of the fishery, to ensure its long-term sustainability and economic viability. This reform aims to address the inherent complexities of the fishery through reviewing its overall structure and function, refine its future management, and develop a mechanism to further rationalise the fleet. Aspects of this reform will be informed by a dedicated research project that aims to firstly disentangle and understand the fleet dynamics of this complex multi-species, multi-gear fishery, then explore the implications of strategic management options (e.g. regionalisation, unitisation) on the future structure and viability of the MSF, from resource sustainability, economic and social perspectives (FRDC 2017/014).

The multi-species nature of the MSF can be considered a strength of the fishery, as it provides considerable flexibility in the fishing dynamics of the fleet. As seen with the recent increase in effort targeted towards Southern Calamari, there is also evidence of other, relatively low value, secondary and tertiary species becoming more prominent within the fishery. Snook and Leatherjackets have been increasingly targeted by hauling net fishers, more fishers are taking Wrasse using handlines and longlines; and there has been a resurgence in catches of Ocean Jackets and Western Australian Salmon over the past four years. For some of these species, increased effort has presumably been in response to developing markets, whereas others have arisen out of the need for fishers to counteract diminishing access to more valuable species as a consequence of management arrangements, sustainability concerns or competitive interactions. Reducing the MSF's reliance on the four primary species through the development of under-utilised species has been identified by industry and government as a means of redirecting effort away from compromised stocks to facilitate their recovery, and to increase the overall productivity and profitability of the fishery. A study has recently been funded to explore the MSF's potential to diversify by increasing production of these lower value, under-utilised species, whilst conforming to the principles of ecologically sustainable development (FRDC 2017/023).

A number of species considered in this report constitute by-product for the hauling net sector, where they are incidentally caught when fishers target more valuable species. Of these, Yellowfin Whiting, Australian Herring, Snook, Leatherjackets and Yelloweye Mullet are of medium value, with moderate market appeal. Each of these species, share similar commercial catch and effort trends, where fishing effort within the hauling net sector has been sequentially

reduced as a function of the licence amalgamation scheme implemented in 1994, and two net buy-backs associated with increased netting closures introduced in 2005 and 2014. These management arrangements, have effectively constrained the fishing capacity of the hauling net sector to predominantly target premium MSF species (i.e. Southern Garfish, King George Whiting, Southern Calamari). Nominal catch rates for the by-product species have trended upwards, suggesting that they are relatively abundant and being harvested at sustainable levels.

The South Australian Marine Scalefish Fishery continues to demonstrate its capacity to respond to productivity levels and market demands. The effectiveness of the current management strategies implemented to ensure the sustainable utilisation of the premium species (i.e. Snapper, Southern Garfish, and King George Whiting) is largely governed by the rate of the species life-history. The rapid growth of Southern Calamari, coupled with its high market value, has effectively counteracted the decline in Snapper productivity. Similar opportunities exist for some under-utilised species, such as Western Australian Salmon, Ocean Jackets and Snook, which may contribute to distributing fishing pressure more widely throughout the fishery and reduce target effort on key species.

5.2. Research Priorities

Currently, the most significant gap in our knowledge in the assessment of the status of MSF fish stocks is in 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 primary MSF species, for which the recreational contribution is considered significant (i.e. King George Whiting and Snapper). It also has implications for determining resource shares against prescribed allocations, which can ultimately lead to changes in the management of the resources amongst the fishing sectors. 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 the MSF. Assessing new technologies and techniques that could improve the cost-effectiveness and robustness of recreational fishing surveys was the central focus at a FRDC-funded (Project 2017/198) national recreational fisheries science workshop hosted by SARDI (Aquatic Sciences) in July 2018. It is anticipated that outcomes of this workshop will be integrated into future recreational fishing surveys and contribute in the development of cross-jurisdictional research

collaborations that aim to improve our understanding of Australia's recreational fishing dynamics.

Determining stock status through the weight-of-evidence approach for all the MSF stocks considered in this report has relied heavily on fishery-dependent statistics. Given the diverse structure and function of the fishery, these data sources will continue to form the basis of both quantitative and qualitative assessments. This is particularly relevant for the secondary and tertiary species that have fewer data available and limited resources to develop more sophisticated fishery-independent assessment programs. In recent years, it has become increasingly evident that the fishing dynamics of the MSF fleet has changed, and, in some cases, these changes have compromised the reliance on fishery-dependent information to determine stock status. For example, changes in fishing efficiency combined with new management arrangements for Snapper have compromised the use of CPUE as a suitable index of stock biomass, and lead the development of an alternate fishery-independent estimate (Steer et al. 2017). Similarly, the issue of advancing fishing technologies and improved efficiency was identified as a key concern for King George Whiting. The WhitEst model does not assume long-term changes in 'effective' effort, and estimating this rate is challenging without reliable fisher-dependent measures. This evolution of the fishery was acknowledged in the previous King George Whiting stock assessments (Fowler et al. 2014, Steer et al. 2018) which also led to a project to explore fishery-independent alternatives (FRDC 2016/003). For the primary species, that have dedicated quantitative stock assessment models, there is a need to explore the relative effects of nominal increases in effective effort, and to determining whether greater influence be placed on biological metrics, or if fishery-independent data streams can be used to 'ground-truth' model-derived estimates of biomass. For the other lower-value species, there may be a need to revisit whether nominal estimates of targeted CPUE are the most informative metric of relative abundance, as opposed to standardised catch rates. New statistical and modelling methods are beginning to be used to deal with 'data-limited' fisheries. The aim is to deliver the most robust, transparent and defensible fishery assessments possible to support sustainable resource management. The MSF is currently undergoing considerable transition through the structural reform, development of new harvest strategies and pending review of the Management Plan. An FRDC project that will provide statistical support to this structural reform will review current fishery assessment methods and consider the implementation of data-limited approaches to optimise its sustainable utilisation of the resource.

The re-activation of a number of key fishers that have targeted Western Australian Salmon in recent years may be indicative of a resurging fishery. Industry have indicated the potential for this fishery to expand by altering fishing practices to efficiently target large, offshore schools

and to embrace new processing technologies to maximise the product quality for human consumption. The current level of biological information that exists for Western Australian Salmon in South Australia is dated (Malcolm 1960, Cappo 1987) and largely focused on the coastal component of the shared stock. The potential expansion of the fishery into offshore waters represents access to an unknown component of the resource. There is a fundamental need to update our understanding of the population structure of Western Australian Salmon throughout State and southern Australian waters including both the inshore and offshore components of the stock. There is also a need to update key biological metrics for this species (e.g. size/age structure, size at maturity, reproductive condition, growth rates) to underpin the development of a species-specific harvest strategy to ensure the sustainability of the resource.

The inability to differentiate between the two species of Whaler Sharks caught within the MSF precludes an accurate assessment of their respective statuses. Although it is understood that Bronze Whalers tend to dominate the catch, this needs to be accurately reconciled by discriminating the species at the time of capture and subsequent documentation. Fishers will need to become familiar with the slight, yet distinguishable characteristics that separate Bronze Whaler and Dusky Sharks, which may be achieved through the development of an identification guide. Although, a lesser priority, similar guides may also be of value in the discrimination of Bight Redfish, Wrasse, Leatherjacket, and other Shark species that are retained within the MSF.

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7. APPENDICES

7.1. Appendix A: Effort Standardisation

In previous assessments, 2012 and earlier, effort data were not standardised. Two changes in the fishery have increased the benefit of an external GLM-based standardisation procedure: (1) some Garfish hauling net operators have changed the target species reported, in some cases reporting 'Any' when the proportions of Garfish taken are high, and (2) in the management restructure of 2005, more than half of the hauling net endorsements were removed, introducing a break in the CPUE time trend. A GLM-based standardisation procedure where the effect of individual licences is explicit was implemented this year (2018) and in the last assessment (2015) to account for the removal of those licences.

Because GarEst is an effort-conditioned model, a standardised effort time series is required. The method (Maunder and Punt 2004) is to estimate a half-yearly standardised CPUE using conventional GLM methods, and obtain the standardised effort by dividing data catches by the standardised CPUE. We standardised effort for only the target-plus hauling net (EType=1) effort type, but not for non-target hauling nets, dab nets, or recreational effort types.

The procedure followed to generate a half-yearly time series of standardised target-plus hauling net effort, separately for each gulf, is as follows:

1. For EType=1, include all hauling net records where Garfish was the reported target species and also any hauling net records where Garfish constituted 50% or more of the landed catch.

2. In R, fitting to all EType=1 records, run the GLM fit to these catch records. The model that predicts the catch rate of each record was

$$\text{CPUE} \sim 0 + \text{HalfYear} + \text{ModelMonth} + \text{LicenceNo} + \text{MFABlock}$$

with a Gamma residual error structure and an inverse (canonical) link function. The "0" indicates that no overall intercept was fitted. All four data covariates are treated as factors, meaning an intercept is estimated for each level of each factor. So for each LicenceNo, the relative catching power was a freely estimated intercept. The standardised CPUE value taken for use in the assessment is the back-transformed HalfYear intercept for each half-yearly model time step and region.

3. To compute the standardised effort value for EType=1 in each half-yearly time step, divide each half-yearly catch (of EType=1) by the standardised CPUE value (the estimated HalfYear intercept).

7.2. Appendix B. Recreational and Charter Boat Catch and Effort Data in 'GarEst'

Recreational data constitute a large proportion of the catch of Southern Garfish in South Australian waters. But the data available to inform the catch from that sector is relatively limited and imprecise, provided predominantly from three telephone and diary survey surveys conducted in 2000/01 (Henry and Lyle, 2003), 2007/08 (Jones and Doonan, 2009), and 2013/14 (Giri and Hall, 2014). Since 2007, charter boats have reported their catch totals in logbooks and as of this assessment are now included as a fifth effort type. In this Appendix we summarise the handling of these data for use as input to the GarEst stock assessment model.

The most recent recreational fishing survey (Giri and Hall, 2014), covering 2013/14, did not provide the estimated Garfish catch number broken down by month, as the two previous surveys had done, and included no effort data specific to Garfish. As GarEst uses a semi-annual time step, we introduced several additional steps of data pre-processing to obtain the required data inputs for recreational catch by region and half year. We give details of this pre-processing in first subsection below. In the second subsection, we outline modifications to the GarEst model fitting procedure undertaken in the absence of recreational effort data for 2013/14. Surveys report all catches in numbers rather than weight landed. Accordingly, the model fits to recreational and (from 2007 onward separately) to charter boat catches in numbers landed. In the third subsection we outline the inclusion of catch and effort data from the South Australian charter boat fishery.

Giri and Hall (2015, Table 8) reported a single total number of Southern Garfish harvested (870,147) by recreational fishers (including charter boats and onshore) for the 12-month period covered by the telephone and diary survey from December 2013 to November 2014. They also reported percentages by region (Giri and Hall 2015, p. 36, Figure 13) that we applied to the total yearly harvest number, giving estimates of total yearly Garfish recreation harvest by region for the year.

Pre-processing to obtain catches by half-year time step for the 2013/14 recreational survey

To obtain seasonal numbers harvested by recreational fishers, from the yearly totals $\left\{N_r;\ r=1,n_{Region}\right\}$ by region, we inferred seasonal proportions harvested by fitting to the seasonal recreational catch total estimates available from the two previous recreational surveys of 2000/01 and 2007/08.

Specifically, we fitted the following statistical model in R,

RecHarvestNos ~ 0 + Region + Season,

using a Gaussian GLM with an identity link, to the data of Garfish catches by factors of Season (Summer and Winter) and GarEst model *Region* (Spencer Gulf and Gulf St. Vincent) for the two previous surveys. The proportion of catch taken in each season for both regions was calculated from these predictions and used to distribute the total annual catch of the 2013/14 survey results into region-specific seasonal catches. Seasonal catch estimates for non-survey years were estimated by interpolating linearly between survey periods. Beyond the 2013/14 survey, the catch estimates are carried forward up until the current model time step (Figure 7.1).

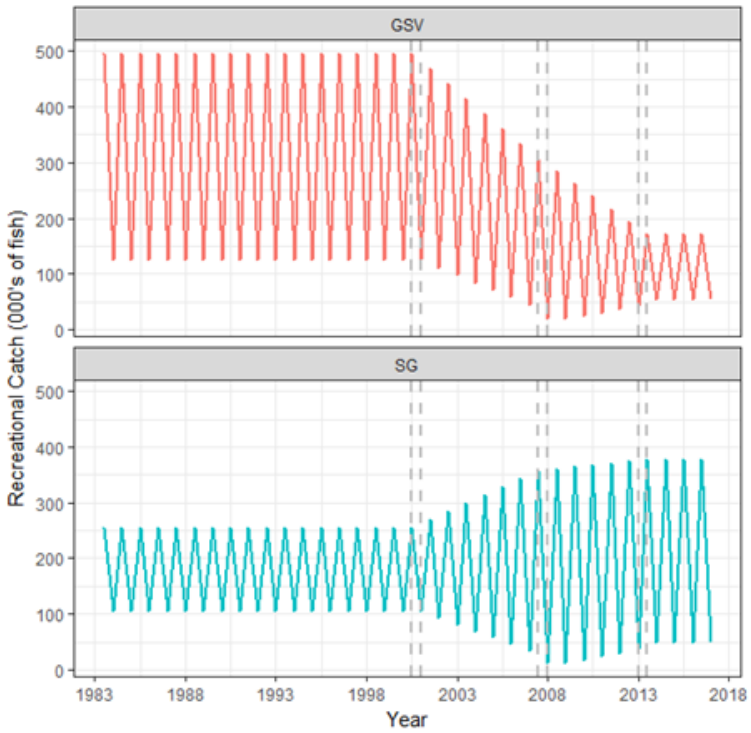

Figure. 7.1. Estimated recreational Garfish catches from three surveys (2000/01, 2007/08 and 2013/14) for Gulf St. Vincent and Spencer Gulf. Catches between survey years are interpolated linearly. The catch estimates from the last survey are carried forward until the current model time step. Vertical grey dashed bars indicate survey periods.

Fitting GarEst to recreational catches in the absence of effort data from the 2013/14 survey

The recreational data were obtained from telephone and diary surveys run in 2001/02, 2007/08 and 2013/14. Between those survey years, recreational catch and effort totals, by region and season, were assumed to vary linearly between the survey-estimated values, and to retain the values of 2001/02 prior to that first survey, and retain the values of 2013/14 subsequently. Only catch number data for the full year by region were available from the 2013/14 survey

recently completed, for which we assumed (1) survey catches by year were broken down into two half-years using proportions taken in winter of 15% for Spencer Gulf and 20% for Gulf St. Vincent, and (2) effort varied relative to 2007/08 values with the same slopes by gulf and season observed for catches. The recreational data from the 2013/14 survey were carried forward to the current time step as no further surveys have been conducted since the 2015 assessment.

Incorporating charter boat catch and effort data into GarEst

Since 2007, the South Australian charter boat fishery has recorded catch and effort information in daily logbooks permitting the inclusion of charters as a fifth effort type in GarEst. With separate much higher quality information available from charter boats, charter catches were modelled separately from other recreational catch from October 2007 onward. Because charter boat catches were included in the totals estimated by the recreational fishing surveys (Henry and Lyle, 2003; Jones and Doonan, 2009; Giri and Hall, 2015), from 2007 onward, these charter catch totals were subtracted from the survey totals to obtain the (non-charter) recreational catches for each regional and seasonal time step.

Because charter boats targeting Garfish had substantially higher catch rates than those not targeting Garfish, a total charter effort measure was constructed that accounted for this difference. This was performed by downward weighting non-target effort by a scaling factor (0.21 for Gulf St Vincent and 0.24 for Spencer Gulf) determined from the relative difference between target and non-target CPUE (converting non-target effort into units of catching power equivalent to target effort) and adding it to the target effort to get total charter fishing effort:

$$TotalCharterEffort_{itHY,RG} = TargetEffort_{itHY,RG} + NonTargetEffort_{itHY,RG} * CScalingFactor_{RG},$$

The scaling factor was computed as a ratio, dividing the catch rate of non-target by the catch rate of target averaged over all available time steps (since 2007). This was performed for each region (RG) and season (itHY),

$$CScalingFactor_{RG} = \frac{\sum_{itHY} NonTargetCatch_{itHY,RG} \Big/ \sum_{itHY} NonTargetEffort_{itHY,RG}}{\sum_{itHY} TargetCatch_{itHY,RG} \Big/ \sum_{itHY} TargetEffort_{itHY,RG}}$$

where *TargetEffort* and *TargetCatch* include days where charter boat operations targeted garfish and *NonTargetEffort* and *NonTargetCatch* include days when charters targeted other species (or did not explicitly target garfish) but caught garfish. $TotalCharterEffort_{itHY,RG}$ (Figure 7.2) was used as the charter effort data input in the GarEst model.

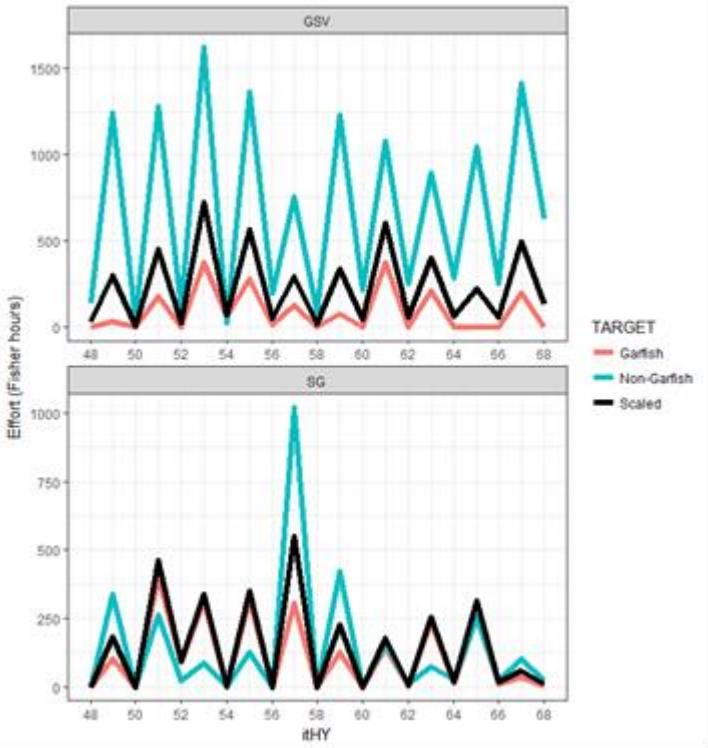

Figure. 7.2. Total, target, and unscaled non-target garfish effort (number of fisher hours), by half-yearly time step since October 2007, for the South Australian charter boat fishery. Total effort was used in the GarEst stock assessment model. The total effort (Black line) included the target (red line) and scaled non-target (not shown) CPUE.

7.3. Appendix C: Age-length 'slice' partitioning method

The GarEst model is based on a method for representing the population structure of Garfish numbers, for each region, gulf and time step, broken down by age, and also by the lengths of fish within each age group, each recruited cohort. Representing population structure by both age and length improves model accuracy in a stock such as Garfish, where legal minimum length separates fish of very high fishing mortality from those incurring only natural mortality. As shown in Figure 7.2, faster growing Garfish, because they reach legal size sooner, incur 60-70% exploitation rates one or two years sooner than the slower growing fish in each cohort. The slice-partition stock assessment model formalism was developed (McGarvey and Feenstra 2004; McGarvey et al. 2007) to account for this length-asymmetric mortality explicitly, in a dynamic fashion, with a method that is computationally efficient. In addition, the three principal data sources, catch totals in weight, age proportions, and length proportions, are from the catch, and so include only Garfish above legal size. Cleanly separating sublegal from legal fish in the slice partition method thus permits a much more accurate prediction of these data quantities to be fitted.

The programming steps for calculating the three slice partition quantities used by GarEst are outlined in this appendix, summarizing the coding algorithm for implementing a slice partition in an age-based model. The main difference of this approach is that fish are not moved between fixed length bins. Rather it is the length bins themselves that grow. The Garfish within each bin, once assigned to it as they reach legal size, incur only mortality. This greatly improves model computational efficiency.

Additional computational efficiency was achieved by (1) employing the normal score for each slice partition point (fish lengths separating each slice), and (2) making midpoint approximations in place of more exact integrals under the pdf (for mean weights). (1) As the cohort of lengths grows to the right with each model time step, a standardized normal variate (the *z*-score or normal score) is assigned to each slice in the time step when it is first created, as that segment of the length-at-age pdf grows in the legal size range, each *z* given by the position of legal minimum length (LML) along the standardized normal length-at-age pdf, designating the left boundary of that new slice. This normal score value for each slice is unchanged thereafter as the mean and standard deviation of the cohort length pdf's grow with age. Thus, given the mean and standard deviation for all subsequent cohort ages, the fish lengths specifying slice left-hand partition points are calculated from the *z*-scores. The use of the normal score obviates the need for solving integral equations for lower limits of integration. However, this short-cut requires an assumption of normally distributed fish lengths. A fixed P_{slice} probability under the pdf curve for each slice, which remains unchanged for all subsequent ages underlies the definition of slices, and also explains why the *z*-scores uniquely specify the slice partition for any chosen model age. (2) The fish mean weight in each slice is approximated by the weight-length function evaluated at the midpoint length of each slice (or, for the upper tail slice, the median probability length) rather than numerically integrating weight versus length across each slice subinterval.

The slice partition algorithm has 6 basic steps, coded by 6 iteration loops in ADMB. In each loop, calculations iterate over cohort age (for each region and sex, that is, for each distinct set of length-at-age growth parameters):

Step 1. Calculate the (1.1) mean length, $\bar{l}(a)$, and (1.2) standard deviation, $\sigma(a)$, and thus, also, the (1.3) *z*-score, $z(a) = (LML - \bar{l}(a))/\sigma(a)$, for every age (a) of growth. This step requires the input of growth submodel parameters specifying $\bar{l}$ and σ, given *a*. In this loop, calculate also (1.4) $P_{sublegal}(a) = \int_{-\infty}^{LML} p(l \mid \theta; a)\, dl$, and (1.5) $P_{legal}(a) = 1 - P_{sublegal}(a)$. For calculating the $P_{sublegal}(a)$ normal cumulative probabilities, we used the AD Model Builder

cumd_norm function, which encapsulates the Abramowitz and Stegan (1965, formula 26.2.17) polynomial approximation and takes the standardized *z*-score as input.

Step 2. Calculate slice probabilities, $P_{slice}(a)$, the proportions of the cohort reaching legal size in each model age, $P_{slice}(a) = P_{legal}(a) - P_{legal}(a-1)$, $a = a_b+1, \ldots, a_{max}$, where, for GarEst, the birth age of cohort creation, $a_b = 3$, at the start of the third half-year (1 October in the summer following the summer of spawning) for all cohorts.

Step 3. Calculate the first of 3 output quantities, the fish transfer coefficients, $f_{transfer}(a) = P_{slice}(a) / P_{sublegal}(a-1)$, $a = a_b+1, \ldots, a_{max}$. No transfer coefficient is needed for birth age a_b cohorts, the population number for their one legal (upper-tail) slice given by $P_{slice}(a_b)$ (= $P_{legal}(a_b)$) times the total recruit number estimated for that cohort.

Step 4. Calculate the slice partition points, specifically the left-hand sides of each slice subinterval, specified as a triangular matrix by age and slice number, $l_{lhs}(a, s)$. The number of slices, for each legal cohort age, is given by $n_s(a) = a - a_b + 1$, $a = a_b, \ldots, a_{max}$. (4.1.) For newly created slices, whose slice subscript number equals the total number of legal slices, $n_s(a)$, the left-hand-side partition point is, by definition, the legal minimum length (LML): $l_{lhs}(a, s = n_s(a))$ = LML, $a = a_b, \ldots, a_{max}$. (4.2) Looping over all other slices in each cohort age group, s = 1 to $n_s(a)-1$, the slice left-hand-sides are derived using the *z*-scores: $l_{lhs}(a,s) = \bar{l}(a) + \sigma(a) \cdot z(s-1+a_b)$.

Step 5. Calculate the second slice partition output quantity, the triangular matrix of central lengths for each slice, $l(a,s)$. (5.1) For all slices except upper-tail slices, the midpoints were used: $l(a,s) = (l_{lhs}(a,s) + l_{lhs}(a, s-1))/2$. (5.2) For the upper tail slices, the central length was chosen to be the median probability value of the upper tail, whose *z*-score was calculated by $z_{median}(a, s=1) = \text{inv_cumd_norm}(1 - P_{legal}(a_b)/2)$. The inv_cumd_norm function in AD Model Builder (Abramowitz and Stegan 1965, formula 26.2.23) gives a standardized normal *z*-value for any given probability.

Step 6. Calculate the mean weights, evaluating the weight-length formula at each slice central length: $w(a, s) = \alpha (l(a,s))^{\beta}$.

A graphical description of how these slice partition length bins are constructed is given in Figures 7.3 and 7.4.

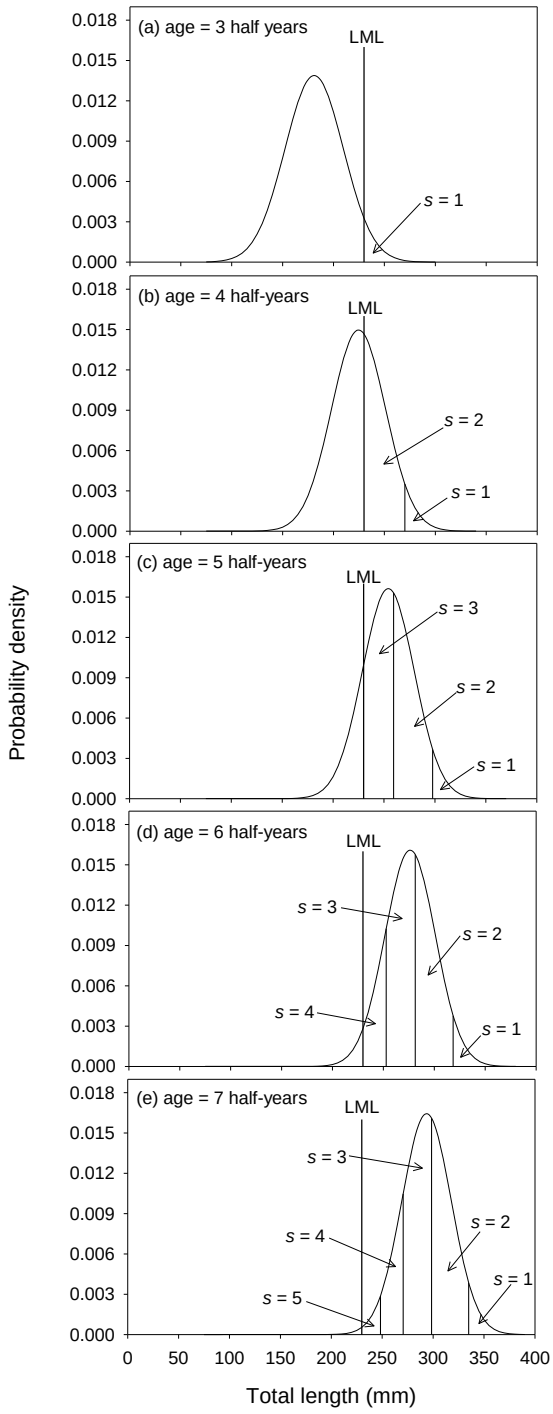

Figure. 7.3. The growth of a normal length-at-age Garfish cohort is shown in successive panels. With each time step, a new slice, as the fish of length newly grown above LML, numbered *s*=1, 2, etc., is created as shown. See Steps 1 and 2 above.

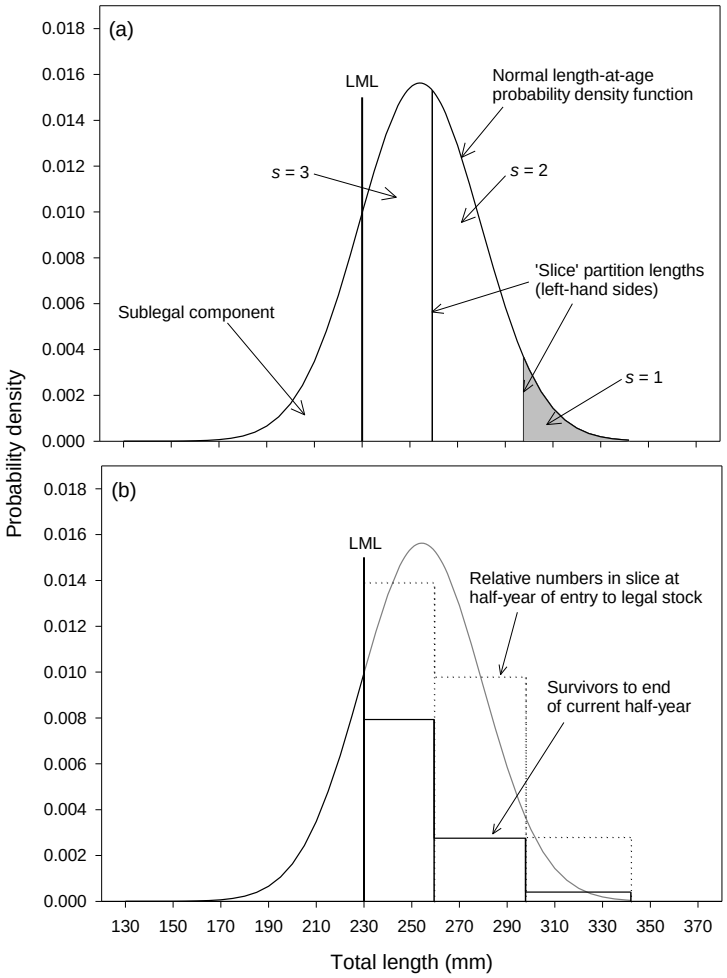

Figure. 7.4. (a) The transfer of Garfish from sublegal sizes (left of LML) to each newly created slice, is done using Step 3. (b) Subsequently, the proportional reductions in the population number in each slice differ depending on how long it has been exposed to fishing mortality, and on the length selectivity applying to each slice, in each model time step. In this Garfish stock, high fishing mortality causes population numbers the faster growing slice (*s* = 1, farthest slice to the right) to be greatly reduced compared to the more slowly growing members of their cohort.

7.4. Appendix D. Garfish Stock Assessment Model

The starting point and basis of the slice method for partitioning fish cohorts by length is the length-at-age growth submodel. A statistical growth submodel is needed which fully specifies the probability density function (pdf) of fish lengths for each model age. This represents the (normal) distribution of fish by length in each cohort age that would be observed in the absence of length-asymmetric mortality, because length-selective capture mortality will subsequently be imposed on these model cohorts, after they are partitioned into slices. To model mean fish length $\bar{l}$, the mean of the normal length-at-age pdf, for any half-yearly cohort age, a, we employed a 4-parameter exponent-generalized von Bertalanffy mean length-at-age curve: $\bar{l}(a) = L_\infty \left\{1 - \exp\left[-K\left(\frac{a-t_0}{2}\right)\right]\right\}^r$ (McGarvey and Fowler 2002). Using two additional parameters, the dependence of the length-at-age standard deviation $\sigma(a)$ is modelled as an allometric function of mean length: $\sigma(a) = \sigma_0 \cdot \left(\bar{l}(a)\right)^{\sigma_1}$.

The growth parameters can be estimated by fitting to length-at-age samples (1) previous to, or (2) by integrating growth estimation into, the stock assessment likelihood. We undertook both in that order. First we fitted the growth submodel directly to catch lengths-at-age to obtain approximate growth parameter estimates. A likelihood probability of observation truncated at LML was assumed to make explicit the absence of sublegal Garfish in these catch samples (McGarvey and Fowler 2002). A second growth estimation was integrated into the stock assessment likelihood, re-estimating the two parameters that most directly determine the mean rate of growth and spread of lengths at each age, von Bertalanffy K and the normal length-at-age standard deviation coefficient σ_0.

Starting from this growth submodel, an algorithm (described in Appendix C) was devised to effectively 'slice off' the length subintervals of fish which have grown past legal minimum length (LML) in each model time step. Once this population number is assigned to each newly created slice bin by transferring these fish from the sublegal component, there is no subsequent further exchange of fish between length bins. Fish within slices incur only mortality. The simplification of neglecting growth diffusion among length bins affords the slice approach large reductions in computation time compared with, for example, a length-transition approach, which requires $(n_L)^2$ growth-transition multiplications in each model time step and for each cohort, where n_L is the number of length bins. In a slice partition model, growth is quantified as the increasing length range with age of each slice subinterval, and no computation is needed to shift fish among bins.

Recruitment

Recruitment is defined as the creation of the (normal) length-at-age cohort at age a_b = 3 half-years (at age 1 year) when the fastest growing fish first reach legal size. The number of fish in each cohort at the birth age, a_b, is the model estimate of yearly recruitment. Each yearly recruit number is a freely estimated model parameter, which is multiplied by an estimated proportion per sex. The numbers of Garfish above legal minimum length at age a_b (in the upper tail of the length at age pdf) are computed (Appendix C) and defined as the first newly created slice. In subsequent model time steps, new slices are created as the calculated proportion of sublegal fish in each cohort that have grown into legal size since the previous time step, thereby modelling the gradual recruitment of each cohort to fishable sizes over the number of model time steps required, as determined by the growth submodel (Appendix C).

Model Population Array

The model Garfish population array $N(t,r,x,c,s)$ is 5-dimensional, fish numbers broken down by (1) half-yearly model time step, t, (2) spatial region, r, (3) sex, x, (4) cohort (i.e. year-class, given by year of spawning), c, and (5) slice, s.

Variable subscripts for winter or summer half-year (t_{season}), and cohort age in half-years (a), were calculated as functions of model time step, t, and cohort year, c. Ages ran from 3 to 12+ half-years, the oldest age being a 'plus' group. Garfish catch and effort, for data and model, were divided into five effort types, i_E: (i) hauling nets targeting Garfish, (ii) hauling nets not targeting Garfish, (iii) dab nets and minor gears, (iv) charter boats, and (v) recreationals. The two commercial gears, g, each with separate length selectivity, are hauling net and dab net. Data quantities, such as reported effort $\tilde{E}$, are denoted by a tilde.

Mortality

Mortality is differentiated for legal and sublegal fish. Legal-size fish, partitioned into length slices, are subject to both fishing and natural mortality. Length-dependent gear selectivity, and any other length-dependent mortality processes, are applied to the length-partitioned fish numbers, specifically in the legal size range. In addition to the knife-edge cut-off below legal minimum length, gear-specific length selectivity is modelled for legal size Garfish. Sublegal population numbers (fish below the legal size limit) incur only natural mortality.

The catch equations were effort conditioned. Thus, fishing mortality was written as a linear proportion of reported fishing effort for each component of catch:

(B.1) $$F(t,r,x,c,s,i_E) = q(r,\ t_{season},\ x,\ i_E)\ \cdot \tilde{E}(t,r,i_E)\ \cdot s_{len}(g(i_E),s)\,.$$

The catchability, q, was assumed to vary with region, season, sex, and effort type. Length selectivity, s_{len}, by gear type, followed a logistic function of fish length, the latter specified by the midpoint of each slice.

(B.2) $$s_{len}(g(i_E), s) = 1 \Big/ \left\{1 + \exp\left[-r_{sel}\left(g(i_E)\right) \cdot \left(\bar{l}(s) - l_{50}\left(g(i_E)\right)\right)\right]\right\}.$$

Logistic length selectivity is varied in time to model recent regulated increases in hauling net pocket mesh size from 30 mm to 32 mm implemented in winter 2013 to reduce capture rates of undersize Garfish. Prior to winter 2013, hauling nets were assumed to retain all legal size Garfish. With the mesh size increase in winter 2013, the $l_{50}\left(g(i_E = 1 \,\&\, 2)\right)$ for hauling net gear (first two effort types) is given by regressions relating mesh size to l_{50} derived from a series of mesh selectivity experiments undertaken by SARDI and industry:

(B.3) $$l_{50}\left(g(i_E = 1 \,\&\, 2)\right) = \begin{cases} 7.9684 \cdot meshsize - 29.203 & \text{in summer} \\ 6.4785 \cdot meshsize + 32.246 & \text{in winter} \end{cases}.$$

On 1 April 2015 the mesh size was increase to 34 mm, and to 35 mm on 1 April 2016.

For commercial effort, the catchability was written:

(B.4) $$q(r, t_{season}, x, i_E) = q_{CSE}(r, t_{season}, i_E) \cdot s_{SS}(t_{season}, x) \cdot \left(1 + q' \cdot (t - t_{mid})\right)$$

with q_{CSE} being the absolute catchability given as function of region, season, and effort type, a relative selectivity coefficient $s_{SS}(t_{season}, x)$ describing the specifically sex-dependent seasonality of catchability, notably strong differences in sex ratios in the catch between summer and winter. A linear time trend in catchability (changing effective effort) from the model start in 1983 to winter of 2001 was estimated as q', the rate of catchability increase relative to the time step t_{mid} = 22 half-years; q' = 0.01356 or 1.35% increase per half year. For some regions and commercial effort types $q_{CSE}(r, t_{season}, i_E)$ was replaced for limited time periods with an alternative catchability parameter (separate and specific to each time period).

Changes in legal minimum length can impact the estimate of fishable biomass which is normally computed by summing over length size slices. For SA Garfish, legal minimum length rose from 230 to 250 mm in 2015, but only for the commercial sector, not for recreational landings. To account for this increase in minimum legal length, but not have this change artificially reduce the fishable biomass by excluding fish between 23 and 25 mm from 2015 onward, the slice partition retains 230 as the length at which slices are created, but a zero selectivity is imposed on slices between 230 and (approximately) 250 to account for the

absence of these Garfish in commercial landings. Retaining 230 is also suitable for the recreational sector which is still regulated by that legal size limit. In this way, the difference in the size limit between two sectors is modelled, and the increase in commercial sector legal size does not artificially reduce the indicator of fishable biomass.

The instantaneous fishing mortality rate for each element of the population array is given by a sum of fishing mortalities over all fishing effort types:

(B.5) $$F(t,r,x,c,s) = \sum_{i_E=1}^{n_E} F(t,r,x,c,s,i_E) \, .$$

The Baranov depletion equation for each element of the population array was written:

(B.6) $$N(t+1,r,x,c,s) = N(t,r,x,c,s) \cdot \exp\left[-\left(M + F(t,r,x,c,s)\right) \cdot p_{yr}(t)\right]$$

where $p_{yr}(t)$ quantifies the proportion of a year spanned by the days in each half-yearly time step. Instantaneous natural mortality rate was taken as constant, M = 0.4 yr^{-1} (Jones 1990).

Estimation: Parameters and Model Likelihood

The model likelihood (Fournier and Archibald 1982) is fitted to (1) half-yearly catch totals by weight, (2) market sample catch proportions by age and sex, and (3) market sample catch moment properties of fish length for each age and sex. The negative log-likelihood components for the fitting to age and length data respectively were downweighted by factors of 0.2 and 0.025.

Parameters

Estimated parameters for the model fall into seven categories: (1) yearly recruit numbers by region, (2) recruitment sex proportion (of females) by region, (3) catchabilities, (4) relative selectivities by sex and season, (5) logistic length selectivity, (6) growth, and (7) likelihood standard deviations of fits to half-yearly catch totals. The following parameters were fixed at the values that were estimated in the assessment run of 2015: initial steady-state recruitments parameters, dab net length selectivity parameters, and all the absolute catchability parameters (except charter boat),

Likelihood for Catch Totals by Weight

Model commercial catch totals by weight (kg) are fitted to data using a lognormal likelihood. The catch by weight is calculated using the standard Baranov formula as:

$$\hat{C}(t,r,x,c,s,i_E) = N(t,r,x,c,s)\cdot w(a(t,c),s)\cdot \frac{F(t,r,x,c,s,i_E)}{M+F(t,r,x,c,s)}\cdot\left\{1-\exp\left[-\left(M+F(t,r,x,c,s)\right)\cdot p_{yr}(t)\right]\right\} \quad \text{(B.7)}$$

where the weights by age and slice $w(a(t,c),s)$ are derived in Appendix C.

The likelihood factor for each combination of region, *r*, and commercial effort type (i_E up to n_E-1), is written:

(B.8)

$$L_C = \prod_{t=1}^{n_t}\prod_{i_E=1}^{n_E-1}\prod_{r=1}^{n_r}\frac{1}{\sqrt{2\pi}\cdot\sigma_C(t_{season},r,g(i_E))\cdot\tilde{C}(t,r,i_E)}\exp\left[-\frac{1}{2}\left(\frac{\ln\left(\hat{C}(t,r,i_E)\right)-\ln\left(\tilde{C}(t,r,i_E)\right)}{\sigma_C(t_{season},r,g(i_E))}\right)^2\right]$$

where

$\sigma_C(t_{season},r,g(i_E))$ = an estimated catch-likelihood standard deviation parameter, one per gear, season, and (for recreational data) region;

$\tilde{C}(t,r,i_E)$ = reported catch by weight for each time step, *t*, region, *r*, and effort type, i_E;

$\hat{C}(t,r,i_E)$ = model-predicted catch by weight for each *t*, *r*, and i_E.

Charter boat data is fittted ($i_E = n_E - 1$) from Apr-Sep-07 onwards as an additional gear type that was not included in previous assessments. Full details of these data can be found in section 1.8.3.

This lognormal likelihood form is also fitted to recreational ($i_E = n_E$) catch survey numbers, and involves fixed sigma values of 0.21 and 0.27 for Spencer Gulf and Gulf St. Vincent respectively.

Likelihood for Catch Samples by Age and Sex

A two-dimensional multinomial likelihood is used to fit to catch-sample proportions by sex and age, since both are attributes of a single catch sample data set. The fitted data, from the principal gear, hauling nets, in the two time steps and regions where catch was monitored, consists of the counts of sampled fish falling into each possible combination of sex and half-yearly age, $\tilde{n}(a,\ x;\ t,r)$. But the data fitted consisted of the observed counts multiplied by a factor that depends on the relative discrepancy ratio of each age sampled length value compared to that length in the full market samples of lengths (including fish not aged), the

latter samples taken as being more length-representative of the population than the aged samples (see the FRDC report, McGarvey and Feenstra (2004)). Finally, each such corrected count at age-length was multiplied by a scaling factor so that the total raw sample size is preserved at the level of region, time step, and gear. The multinomial likelihood factor is written:

(B.9) $$L_{AX} = \prod_{i_{AX}=1}^{n_{AX}} \prod_{a=a_b}^{12+} \prod_{x=0}^{1} \hat{p}(a, x; i_{AX})^{\tilde{n}(a, x; i_{AX})}$$

where

i_{AX} = index over the set of n_{AX} catch samples of fish age and sex;

$\hat{p}(a, x; i_{AX})$ = two-dimensional array of model-predicted fish proportions captured by age and sex, for each sampled half-year and region, indexed by i_{AX} ;

$\tilde{n}(a, x; i_{AX})$ = fish numbers for each age and sex, observed in the catch-at-age sample i_{AX} .

Likelihood for Catch Samples by Length

A normal likelihood is applied to fit the model to data moment ‘properties’, mean length, standard deviation of length, skewness, and kurtosis. Fournier and Doonan (1987) first proposed fitting to length moments and also fitted a normal likelihood, but to the central moments rather than moment properties. The likelihood for the length moments fit is written:

(B.10)

$$L_{mp} = \prod_{i_{AX}=1}^{n_{AX}(i_{mp})} \prod_{i_{mp}=1}^{4} \prod_{sex=0}^{1} \prod_{a=a_b}^{12+} \prod_{g=1}^{2} \left\{ \frac{\exp\left[-\frac{1}{2} \left(\frac{\left\{ \tilde{b}(i_{mp}, x, a, g; i_{AX}) - \right\}}{\sigma_{mp}(g)} \right)^2 \right]}{\sqrt{2\pi} \cdot \sigma_{mp}(g)} \right\}^{\tilde{n}_a(x,a,g;i_{AX})} .$$

where

σ_{mp} = is the estimated moment-likelihood standard deviation parameter, separately per the two gears.

$\tilde{b}(i_{mp},...)$ = observed moment, indexed by i_{mp}, per sample and half-yearly age-sex.

$\hat{b}(i_{mp}...)$ = model-predicted counterpart to $\tilde{b}(i_{mp},...)$.

The observed moments were not calculated using the raw counts of fish per age and length category, but instead were based on length counts from the aged fish that were corrected for representative length sampling as noted further above (see the FRDC report, McGarvey and Feenstra (2004)). We weighted each factor in the log-likelihood by the uncorrected sample size ($\tilde{n}_a(x,a,g;\ i_{AX})$), that is by the actual number of aged fish. Higher moment properties require more data to be informative. We therefore set criteria for exclusion of smaller catch sample data sets, i_{AX}, from the L_{mp} likelihood, depending on the moment property fitted. Thus the number of qualifying data sets, $n_{AX}(i_{mp})$, decreased with increasing moment property i_{mp}. We required at least 8 aged fish for kurtosis, 4 for skewness, 2 for standard deviation, and 1 for fitting to mean length. Similarly we required 4 model slices for kurtosis, 3 for skewness, 2 for standard deviation, and 1 for fitting mean length.

7.5. Appendix E. Model Fits to Data

Parameters and thus stock performance indicators in the GarEst model are estimated by fitting to data for commercial catch totals by weight, interpolated recreational catches by number (see Appendix D), charter boat catches by number (see Appendix C), and to commercial catch proportions by age and sex, in each half-yearly time step when sampling occurred. In this Appendix, graphs comparing fitted model and data indices are presented (Figure 7.5 to 7.12).

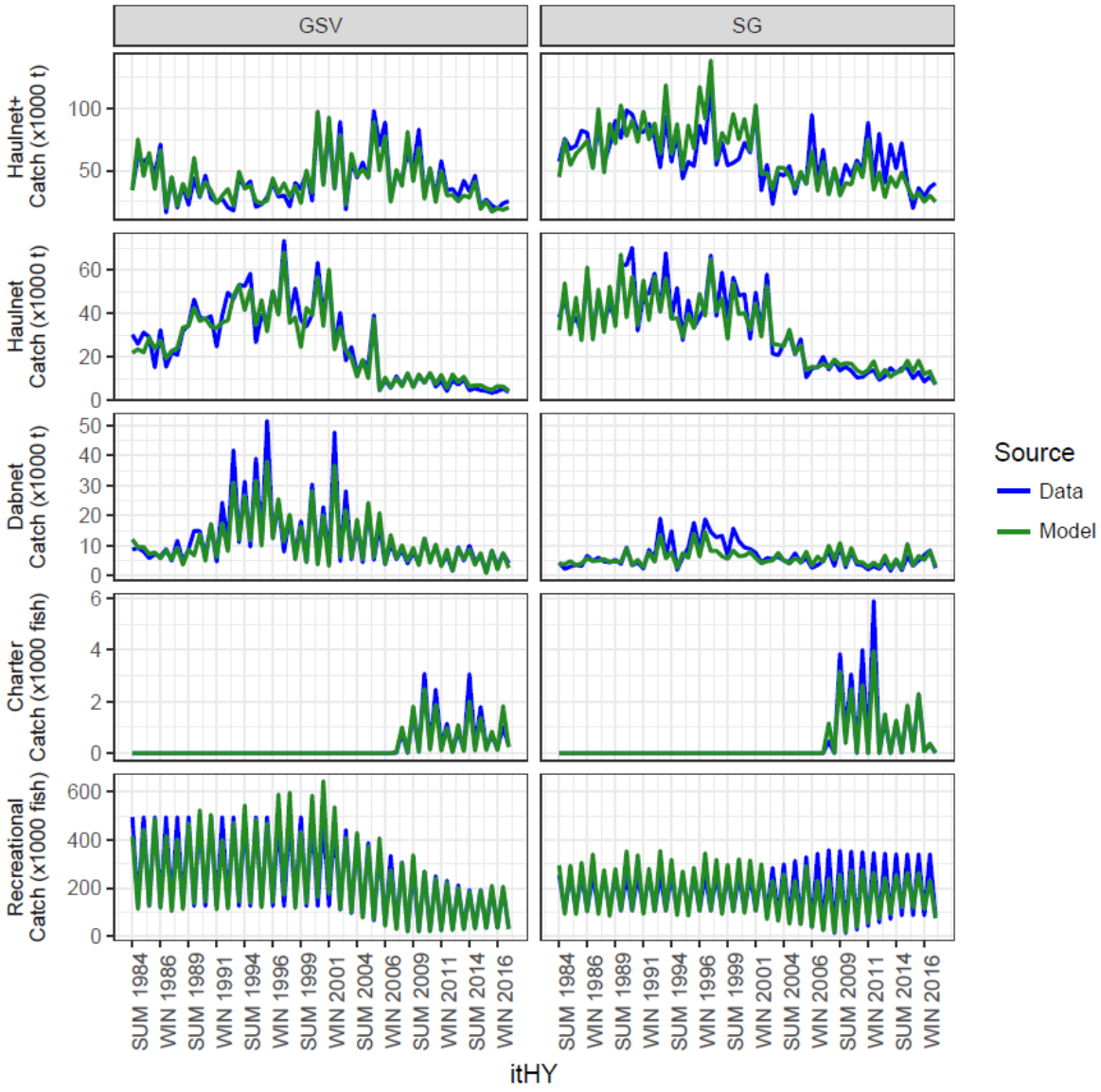

Figure 7.5. Fits of Spencer Gulf and Gulf St Vincent models to data half-yearly catch totals for the 5 effort types.

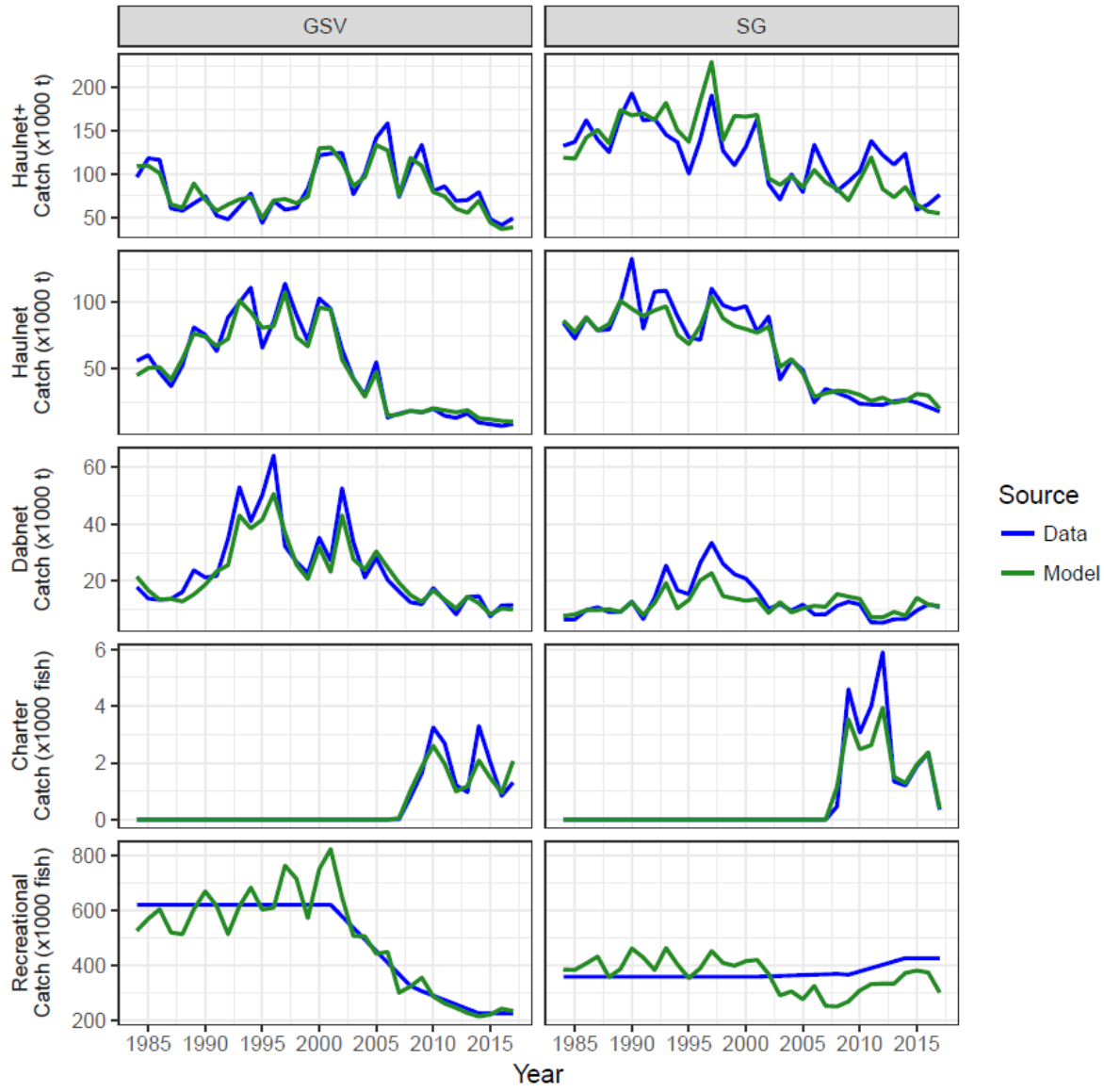

Figure 7.6. Fits of Spencer Gulf and Gulf St Vincent models to data annual catch totals for the 5 effort types.

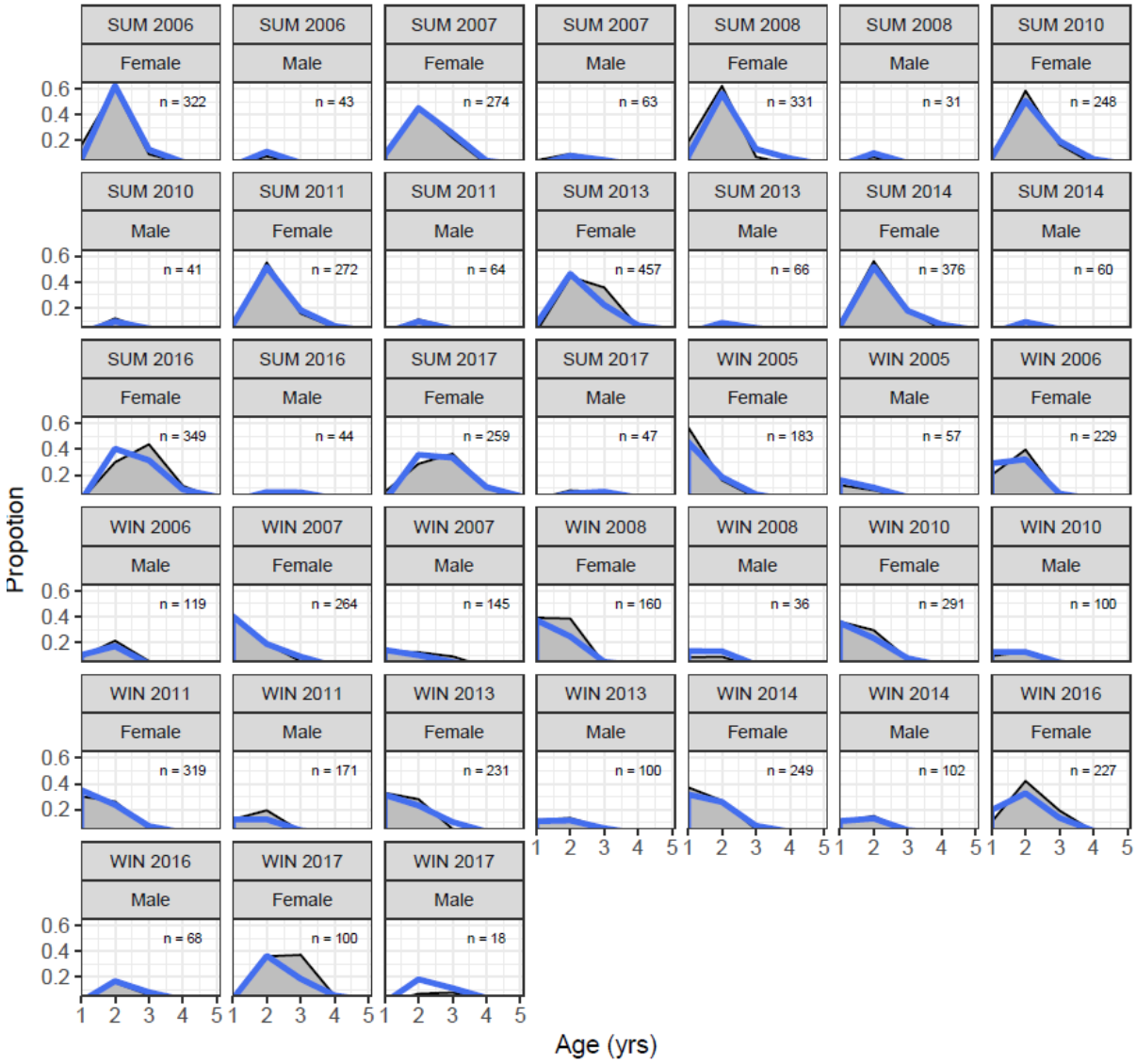

Figure 7.7. Model fits to age proportions from catch samples. The 38 most recent Spencer Gulf data sets are shown by sex and half-yearly model time step.

Figure 7.8. Model fits to age proportions from catch samples. The 38 most recent Gulf St. Vincent data sets are shown by sex and half-yearly model time step.

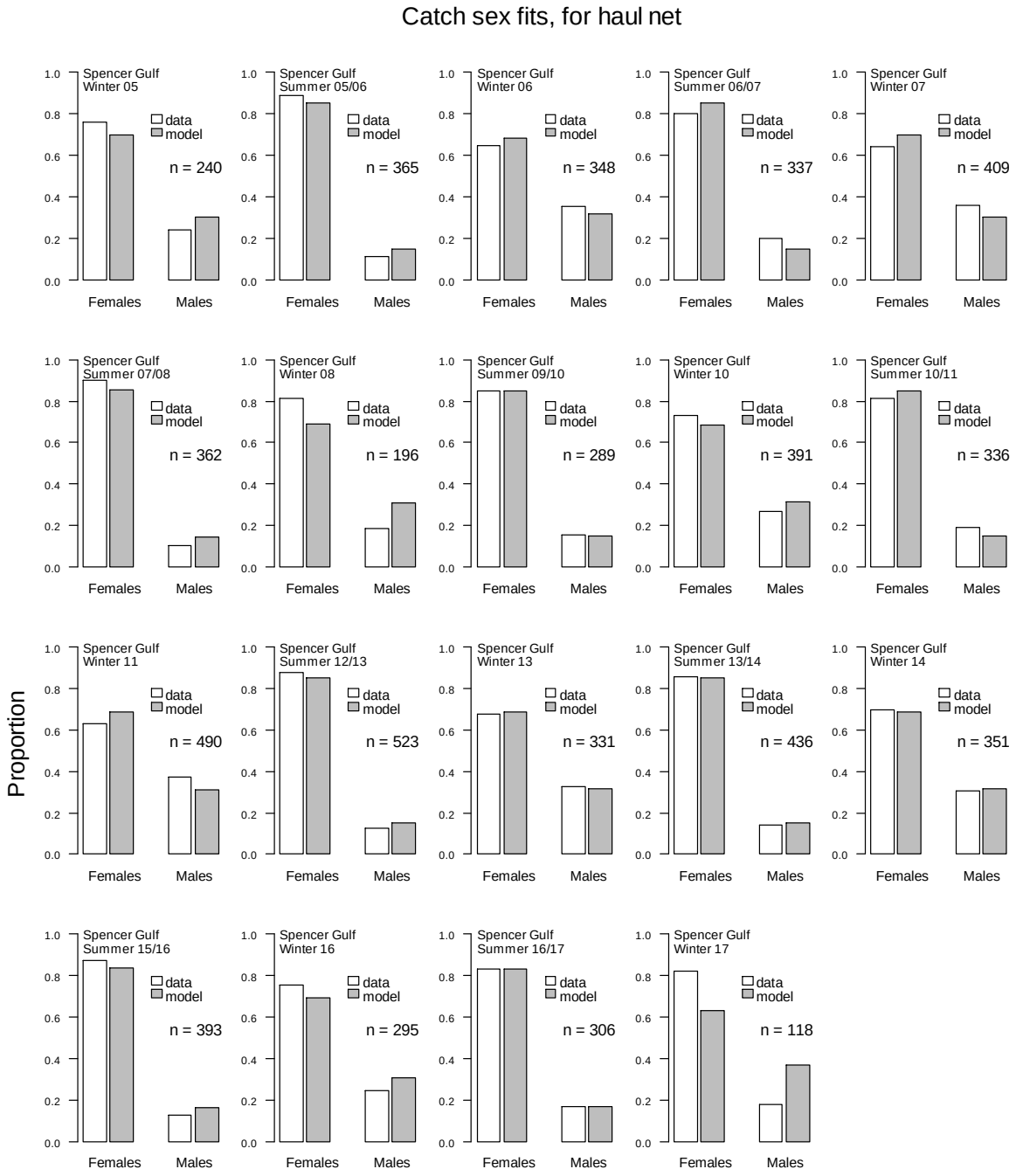

Figure 7.9. Model fits to sex ratios from SAFCOL market samples. The 19 most recent for Spencer Gulf are shown by gulf and half-yearly model time step.

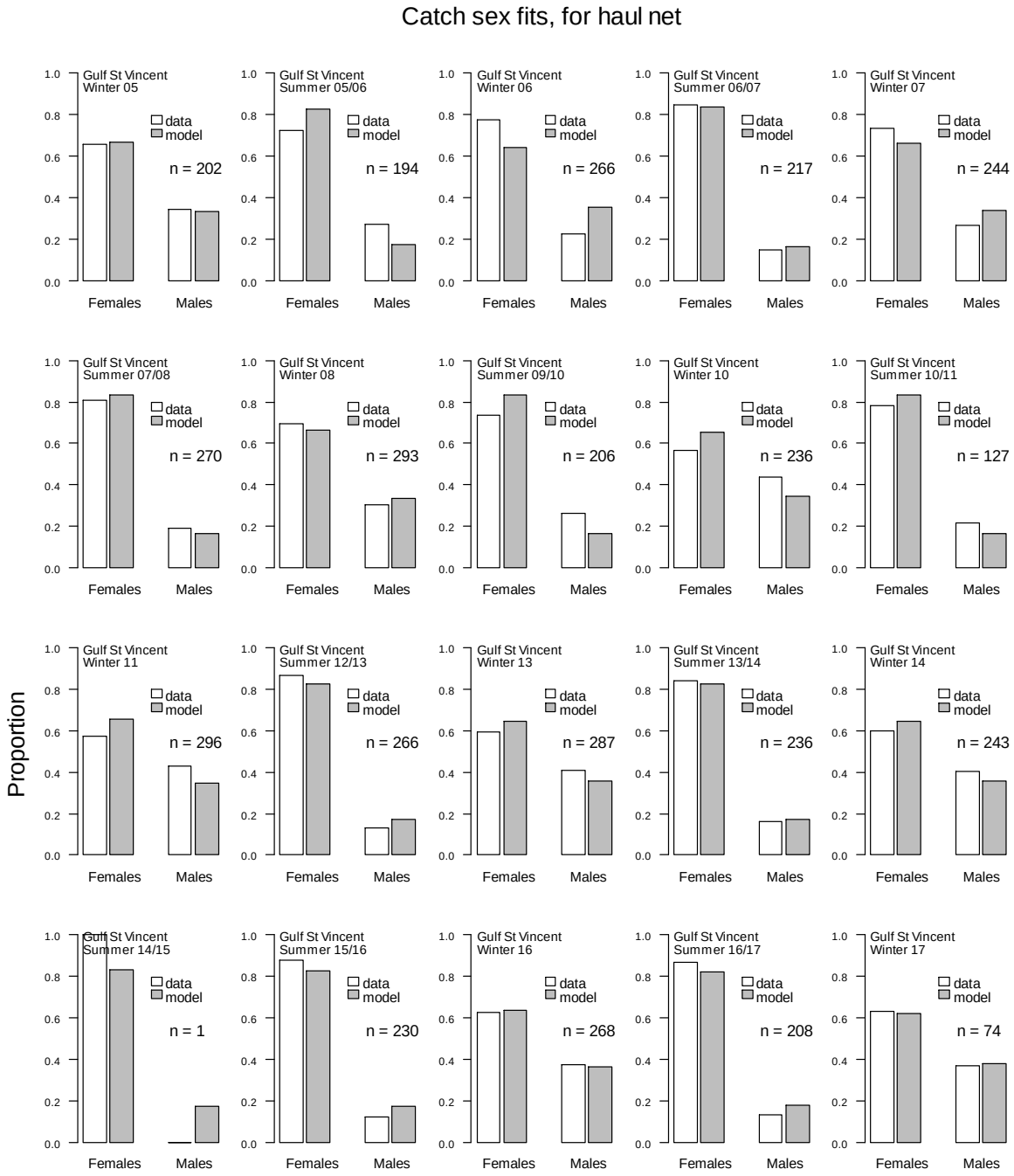

Figure 7.10. Model fits to sex ratios from SAFCOL market samples. The 20 most recent for Gulf St Vincent are shown by gulf and half-yearly model time step.

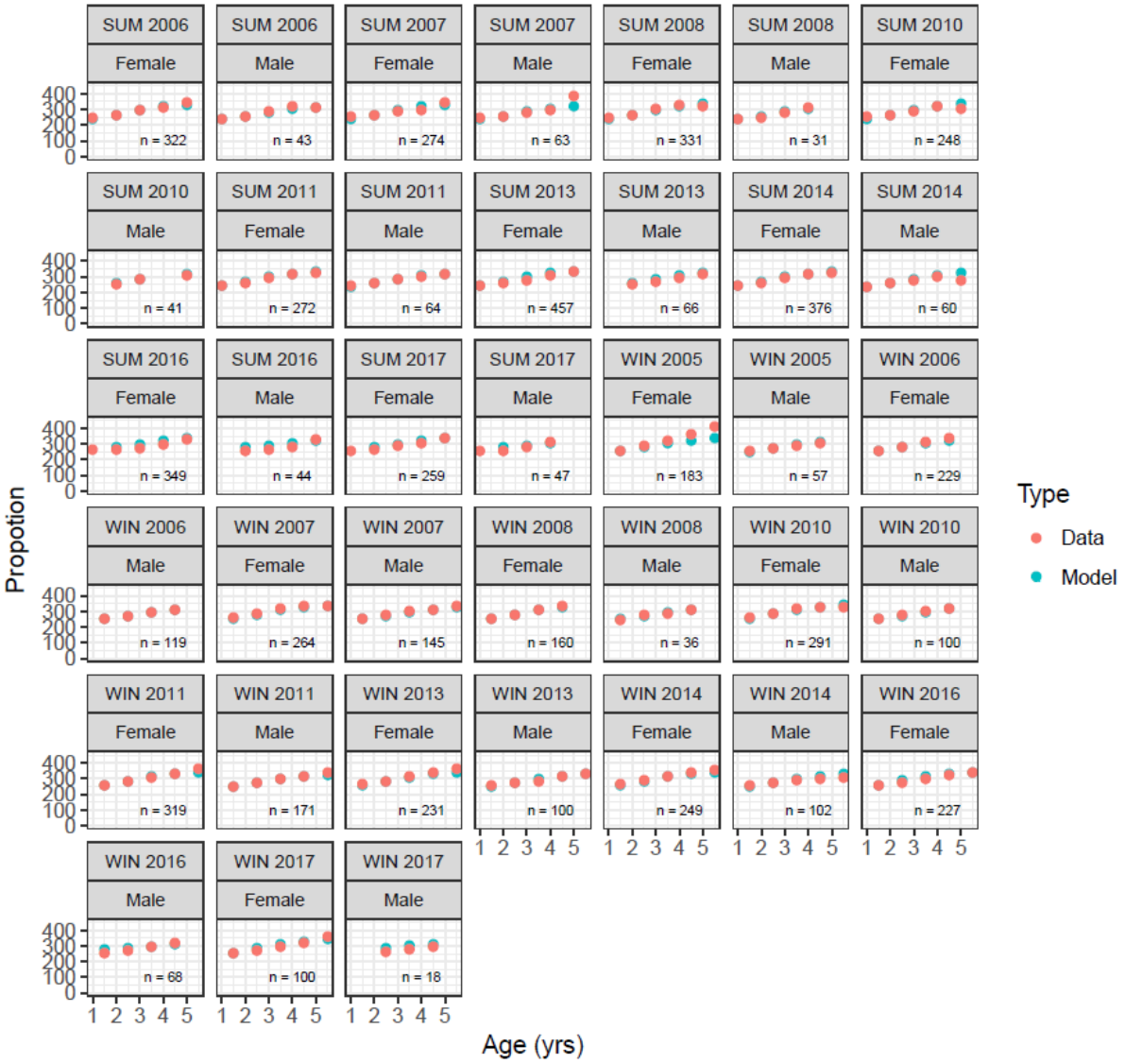

Figure 7.11. Model fits to catch mean lengths of modelled cohorts from catch samples. The 38 most recent Spencer Gulf data sets are shown by sex and half-yearly model time step.

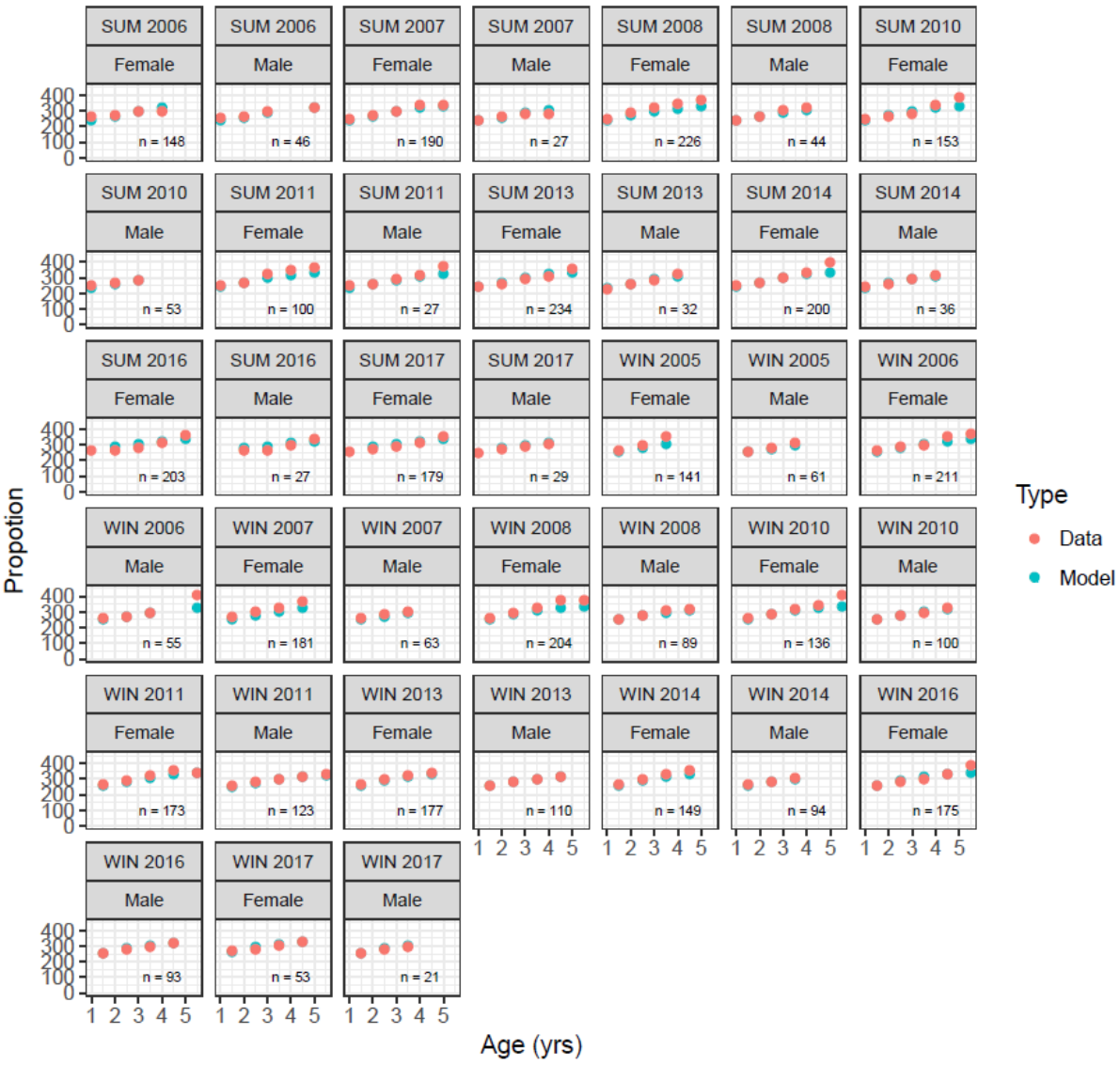

Figure 7.12. Model fits to catch mean lengths of modelled cohorts from catch samples. The 38 most recent Gulf St. Vincent data sets are shown by sex and half-yearly model time step.