Fisheries

Assessment of the South Australian Marine Scalefish Fishery in 2020

J.J. Smart, J. Earl, R. McGarvey, J. Feenstra, M.J. Drew, F. Bailleul, A.J. Fowler, D. Matthews, G. Chaplin, J.M. Matthews, B. Freeling, T.A Rogers, C.L. Beckmann and A. Tsolos

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November 2022

Report to PIRSA Fisheries and Aquaculture

Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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The South Australian Research and Development Institute respects Aboriginal people as the state's first people and nations. We recognise Aboriginal people as traditional owners and occupants of South Australian land and waters. We pay our respects to Aboriginal cultures and to Elders past, present and emerging.

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EXECUTIVE SUMMARY

This report is the fifth in the annual reporting series for South Australia's Commercial Marine Scalefish Fishery (MSF). Data considered in this report extend for 37 years from 01 January 1984 to 31 December 2020. The report provides a description of the dynamics of the multi-species, multi-gear fleet and assigns stock status to 30 stocks of 20 species or taxa that are harvested in the fishery, using the National Fishery Status Reporting Framework (Piddocke et al. 2021). It builds on previous assessment reports by Drew et al. (2021) and Steer et al. (2018a, 2018b, 2020), and includes a summary of the taxon-specific information relating to: population biology; fishing access; management arrangements; recreational catches from three State-wide surveys; trends in commercial fishery statistics at the State-wide, biological stock or regional management unit scales; and an assessment of fishery performance using performance indicators prescribed in the fishery's management plan (PIRSA 2013).

Since the last assessment (Drew et al. 2021), the MSF has undergone a structural reform that included the formation of four new management zones. In this report, these new zone boundaries have been applied to align the assessments to the spatial scale of management.

<u>Fleet Dynamics</u>

Many of the changes in the operation of the MSF fleet over the past four decades have occurred in response to changes to fisheries management arrangements. These have included reductions in fishing effort resulting from the rationalisation of the fleet through the licence amalgamation scheme implemented in 1994, reductions in the number of B-class licences, and two voluntary net buy-back initiatives in 2005 and 2014.

Declines in the availability of the primary target species have contributed to the diversification of the fishing fleet over the last six years, with many fishers switching their effort from Snapper, King George Whiting and Garfish to Southern Calamari. As a consequence, Calamari has recently surpassed Snapper and King George Whiting as the most valuable species in the MSF.

Many of the species considered in this report are taken by the hauling net sector of the fishery, and some are caught when more valuable species are targeted. Of these, Yellowfin Whiting, Australian Herring, Snook, Leatherjackets and Yelloweye Mullet are of medium wholesale value. These species share similar commercial catch and effort trends, whereby effort and catch within the hauling net sector has been sequentially reduced over the recent decades. Despite the long-term declining trend in hauling net effort across the fishery, Snook and

Leatherjackets have been increasingly targeted by hauling net fishers over recent years. There has also been an increase in catches of Ocean Jackets using fish traps over recent years.

Stock Status

This report assessed the fishery performance of 20 species (or species groups) comprising 30 stocks. Of these, 23 (77%) were classified as sustainable, two (7%) were classified as depleted and two (7%) were classified as recovering (Table E-1). The remaining three (10%) were classified as undefined as there was insufficient information to assign stock status.

The focus of this report was the Southern Garfish stock assessment. Stock statuses were assigned to six Southern Garfish Stocks: northern Spencer Gulf (NSG), southern Spencer Gulf (SSG), northern Gulf St Vincent (NGSV), southern Gulf St Vincent (SGSV), West Coast (WC) and South East (SE). The majority of Southern Garfish catches were taken in NSG and NGSV where the majority of hauling net effort occurs. NSG was previously classified as 'recovering' in 2017 (Table E-1) and this status was maintained in this assessment as recruitment remained impaired. However, several positive signs exist for this stock as the fishery age structure for 2019 contained a slightly higher proportion of fish > 3 years of age, biomass was stable and harvest fractions continued to decrease. A 'sustainable' status was maintained for the SSG, SGSV, WC and SE stocks, many of which had increased dab net CPUE in 2020, demonstrating strong fishery performance and strong stock health. Lastly, status of the NGSV stock was changed from 'depleted' to 'recovering', with evidence that the management arrangements that were put in place to recover the stock are taking effect. While the stock assessment model (GarEst) outputs indicated that recruitment remained impaired in NGSV, the increase in modelled adult biomass, increasing haul net and dab net targeted CPUE, and stable exploitation rate consistent with target levels provided evidence that recovery was occurring in 2020.

Future Directions

The most important research needs for the fishery and its management include: (1) delivery of the 2021/22 Snapper stock assessment, and the continuation of research to support the monitoring and recovery of the Spencer Gulf–West Coast (SG–WC) and GSV Snapper stocks; (2) development of harvest strategies for key species that are tailored to the tiered management of the fishery and provide the decision-making frameworks to support TACC setting; (3) development of an innovative Southern Calamari stock assessment to enable provision of reliable scientific advice to support TACC setting; (4) evaluation of the density-dependence hypothesis for Southern Garfish that has been proposed in this assessment, potentially through the development of a fishery-independent survey; and (5) regular surveys to estimate recreational harvests. Given the MSF has undergone a structural reform, an additional focus will be adapting future versions of these assessment reports to ensure they continue to meet the needs of management.

Keywords: Marine Scalefish Fishery, fleet dynamics, stock status.

Table E-1. Status of South Australia's Marine Scalefish Fishery stocks and fishery performanace indicators assessed between 2018–2020. (+) - denotes status was assigned to the biological stock. Stocks abbreviations are: West Coast (WC), Northern Spencer Gulf (NSG), Southern Spencer Gulf (SSG), Northern Gulf St Vincent (NGSV), Southern Gulf St Vincent (SGSV), South East (SE), Spencer Gulf/West Coast (SG/WC), Gulf St Vincent/Kangaroo Island (GSV/KI), Western Victoria (WV), Western Australia/South Australis (WA/SA) and Marine Scalefish Fishery (MSF).

SPECIES	STOCK	STATUS 2018	2019	2020	INDICATORS
GARFISH	WC	Sustainable	Sustainable	Sustainable	Catch & Effort
	NSG	Recovering	Recovering	Recovering	Catch, CPUE, age structure, biomass
	SSG	Sustainable	Sustainable	Sustainable	Catch & Effort
	NGSV	Depleted	Depleted	Recovering	Catch, CPUE, age structure, biomass
	SGSV	Sustainable	Sustainable	Sustainable	Catch & Effort
	SE	Sustainable	Sustainable	Sustainable	Catch & Effort
KING GEORGE WHITING	WC	Sustainable	Sustainable	Sustainable	Catch & Effort
	SG	Sustainable	Sustainable	Sustainable	Catch & Effort
	GSV/KI	Sustainable	Sustainable	Sustainable	Catch & Effort
SNAPPER	SG/WC	Depleted	Depleted	Depleted	Catch & Effort
	GSV	Depleting	Depleted	Depleted	Catch & Effort
	WV	Sustainable[+]	Sustainable[+]	Sustainable[+]	Catch & Effort
CALAMARI	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
YELLOWFIN WHITING	NSG	Sustainable	Sustainable	Sustainable	Catch & Effort
	NGSV	Sustainable	Sustainable	Sustainable	Catch & Effort
WA SALMON	WA/SA	Sustainable	Sustainable	Sustainable	Catch & Effort
AUST. HERRING	WA/SA	Sustainable	Sustainable	Sustainable	Catch & Effort
SNOOK	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
BLUE CRABS	MSF	Sustainable	Sustainable	Sustainable	Catch & Effort
SAND CRABS	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
YELLOW-EYE MULLET	MSF	Sustainable	Sustainable	Sustainable	Catch & Effort
MULLOWAY	MSF	Sustainable	Sustainable	Sustainable	Catch & Effort
WHALER SHARKS	STATE	Undefined	Undefined	Undefined	Limited data
OCEAN JACKETS	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
BLUE-THROAT WRASSSE	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
SILVER TREVALLY	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
LEATHERJACKETS	STATE	Undefined	Undefined	Undefined	Catch & Effort
RAYS & SKATES	STATE	Undefined	Undefined	Undefined	Limited data
CUTTLEFISH	STATE	Sustainable	Sustainable	Sustainable	Catch & Effort
BLACK BREAM	MSF	Sustainable	Sustainable	Sustainable	Catch & Effort

1. INTRODUCTION

1.1. Overview

This is the fifth report in this series for the South Australian Marine Scalefish Fishery (MSF) that provides a taxon-specific summary of information on: 1) fisheries biology; 2) fishing access; 3) management arrangements; 4) trends in commercial fishery statistics at the scales of the biological stock or regional management units, and 5) assessment of fishery performance. Data included in this report were sourced from logbook returns provided to SARDI by MSF licence holders over 37 years between 01 January 1984 and 31 December 2020.

This report is partitioned into five sections. Section one provides an overall description of the MSF, its management arrangements, performance indicators, and details the indicators used to assess the status of the stocks within the fishery. Section two describes the dynamics of the commercial fleet, catch composition, and spatial and temporal trends in fishing effort, while section three contains the stock assessment for Southern Garfish.

Section four consists of a series of species-based sub-sections arranged in order of their descending priority. These are structured as 'stand-alone' updates for taxa taken in the fishery, each comprising a summary of the relevant biological information, along with a description of the fishery, associated management regulations, State-wide and/or regional fishery statistics, assessment of the fishery against the general performance indicators, and the classification of the stock status for 2020.

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

1.2. Description of the Marine Scalefish Fishery

The MSF is a multi-species, multi-gear, multi-sector fishery with > 300 active licence holders in 2020. Due to the number of licences, gear types used, the species taken, fishers' ability to switch target species and the geographical range, it is considered to be the most complex fishery in South Australian waters.

Commercial fishers in the MSF are permitted to take in excess of 60 marine species, including bony fishes, molluscs, crustaceans, annelid worms, sharks, rays and skates. Fishery production by weight of catch is mainly comprised of Southern Calamari (*Sepioteuthis australis*), Snapper (*Chyrsophrys auratus*), King George Whiting (*Sillaginodes punctatus*), Southern Garfish (*Hyporhamphus melanochir*) and Yellowfin Whiting (*Sillago schomburgkii*).

Other species such as Western Australian Salmon (*Arripis truttaceus*), Australian Herring (*Arripis georgianus*) and Sand Crabs (*Ovalipes australiensis*) also contribute significantly to the overall catch.

There are 30 types of fishing gear (or devices) endorsed in the MSF. Their uses differ depending on the location of fishing and the 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. For the commercial sector there are two types of licences, i.e., Marine Scalefish (A-class) and Restricted Marine Scalefish (B-class). Marine Scalefish licence holders are more common. A proportion of the Marine Scalefish 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, licence holders from the Miscellaneous Fishery, the Northern (NZRLF) and Southern Zone Rock Lobster (SZRLF) fisheries, the Lakes and Coorong Fishery (LCF), three Western King Prawn fisheries and the Blue Crab Fishery (BCF) all have varying levels of access to the key MSF resources. For example, the three Western King Prawn fisheries can only take certain MSF species as by-product.

The broad mixture of participants, gear types, licence conditions and regulations associated with the MSF make the task of assessing the status of the stocks challenging. This is further compounded by the highly dynamic nature of fisher behavioural responses to resource availability and seafood markets, as they can switch their target effort between species and regions throughout State waters. This complexity means there is considerable capacity for the fishery to expand through the activation 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 several gear types to target a variety of MSF species.

1.3. Management Arrangements

The MSF is managed by the South Australian State Government's Department of Primary Industries and Regions (PIRSA) Fisheries and Aquaculture Division 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 2017* and licence conditions.

The commercial MSF underwent considerable management changes prior to 2020, including a settlement with the Commonwealth Government Australian Fisheries Management Authority (AFMA) for offshore waters resources management in 1992 (Offshore Constitutional

Settlement), limitation through gear restrictions and configuration, licensing, spatial and temporal closures related to protection of spawning areas 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 MSF. The first occurred in 1977, when a freeze was imposed on the issue of new licences, which converted the commercial MSF into a limited-entry fishery. This also involved a 'show-cause provision' that prevented the re-issue of licences to fishers if a minimum level of commercial fishing had not been met. Non-transferable Restricted MSF 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 (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 was also implemented in 2014 in association with the establishment of the network of South Australian Marine Parks. A structural reform of the commercial MSF occurred in 2021 creating the most substantial management changes that have occurred for the MSF.

With the exception of recreational Southern Rock Lobster pot licenses, the recreational fishery is not licensed 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 or partial protection (e.g. Western Blue Groper) of some species.

Recent commercial MSF reform

In July 2021 the commercial MSF underwent a major fishery reform that included 'three pillars': regionalisation, rationalisation, and unitisation. Four regional zones of management were created that included Spencer Gulf, Gulf St Vincent / Kangaroo Island, the West Coast and the South East (Figure 1-1). All fish stocks are now managed according to these zones through a tiered management framework (TMF) that assigns each stock to a Tier based on its importance. Stocks in Tier 1 are managed using a total allowable commercial catch (TACC) and individual transferable quotas (ITQS). Fleet rationalisation also occurred, where 100 licences were voluntarily surrendered, resulting in approximately 65 licence holders exiting the fishery. The purpose of the reform was to improve the economic performance of the commercial MSF and increase stock sustainability. Management efforts to achieve this will be ongoing and guided by a recently established Marine Scalefish Fishery Management Advisory Committee (MSFMAC).

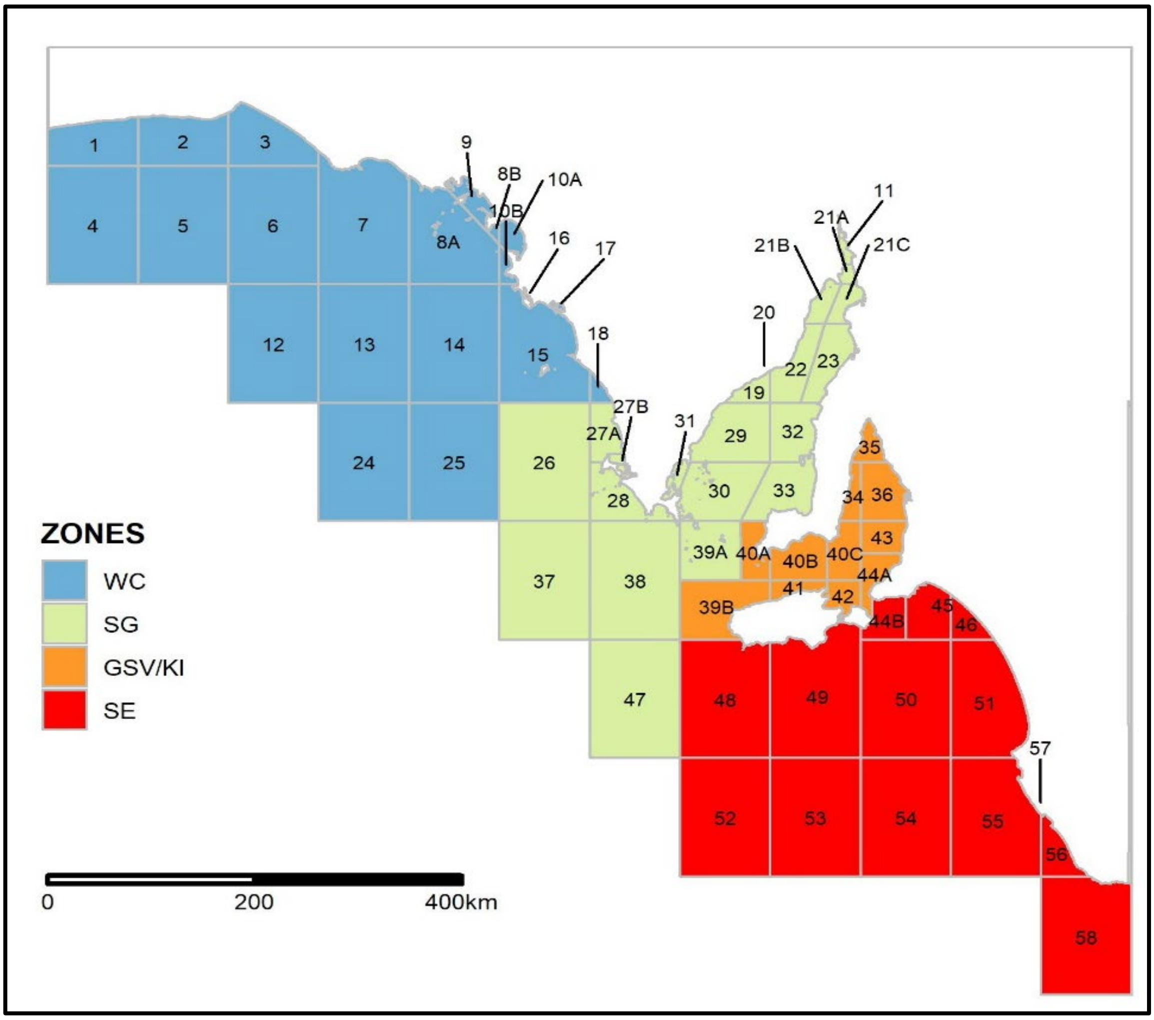

Figure 1-1. The fishing zones implemented through the commercial MSF reform in July 2021. These zones are the Spencer Gulf zone (SG), Gulf St Vincent/Kangaroo Island zone (GSV/KI), West Coast zone (WC) and South East zone (SE). The boundaries of each zone are delineated by existing MFA blocks or subblocks.

While these zones of management were implemented in July 2021, they have been applied to the regional boundaries of stocks assessed in this report. This aligns the outputs of this report to the spatial scale required by management. Further regional breakdowns for species are provided where necessary in this report. However, this has been undertaken in such a way that these are sub-regions of each zone and therefore can be amalgamated as needed into the broader fishing zones. An important example of this is for Southern Garfish (the focal species of this stock assessment) which has six regional stocks: NGSV, SGSV, NSG, SSG, WC and SE. The WC and SE stocks have been assessed using the boundaries of the new WC and SE fishing zones, respectively (Figure 1-1). Meanwhile, NGSV and SGSV constitute the respective northern and southern regions of the GSV/KI fishing zone, with the NSG and SSG regions treated similarly for the SG zone (Figure 1-2). This approach allows scientific assessments to be conducted at the appropriate biological scale, while management advice can be provided at the fishing zone spatial scale.

From 1 July 2021 the fish stocks assigned a Tier 1 status include King George Whiting (GSV/KI, SG, WC), Southern Garfish (GSV/KI, SG), Southern Calamari (GSV/KI, SG) and Snapper (GSV/KI, SG, WC, SE). All these stocks are now managed via total allowable commercial catches and every stock accept King George Whiting in the WC fishing zone has been unitised via individual transferable quotas (ITQ).

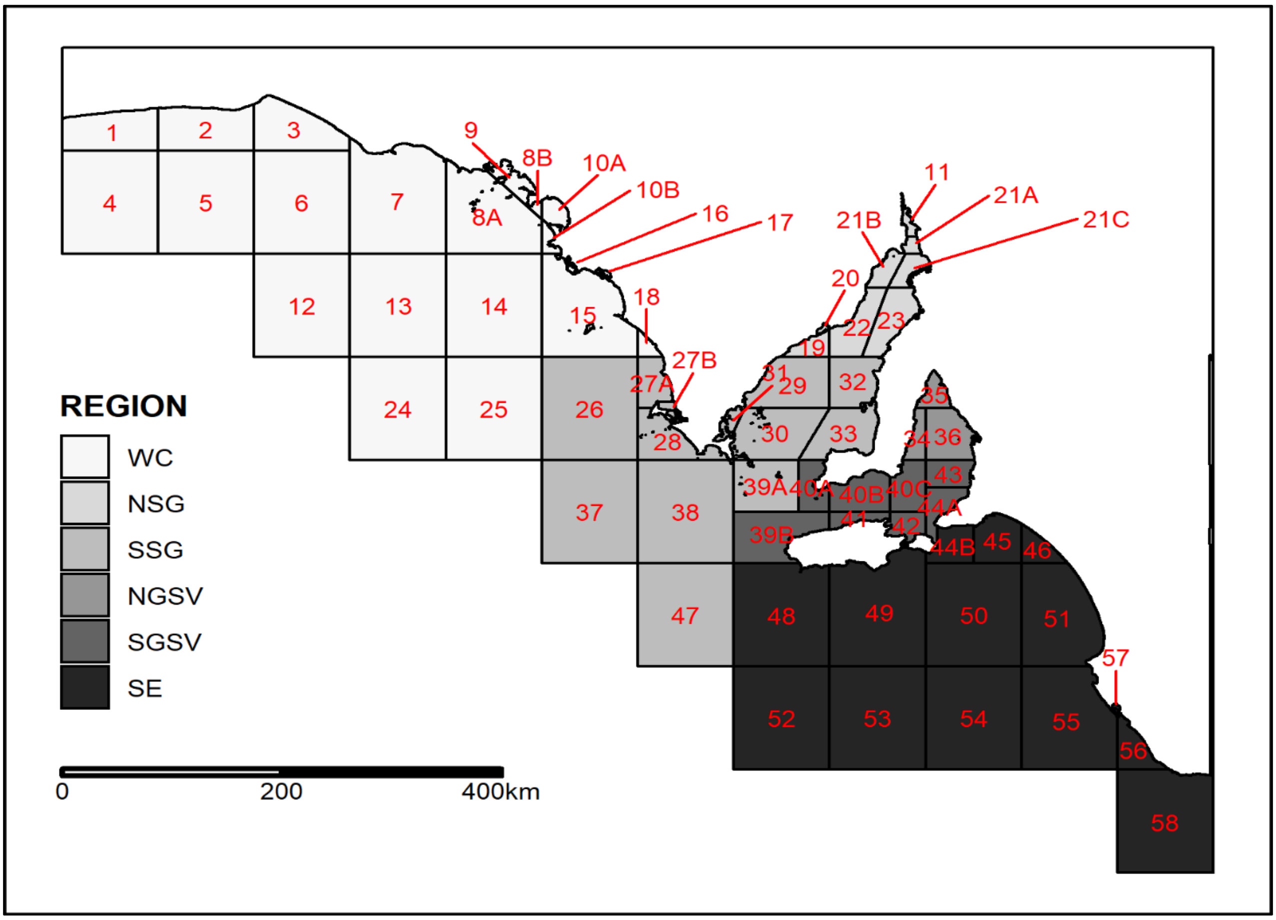

Figure 1-2. Marine Fishing Areas of South Australia's Marine Scalefish Fishery showing regional boundaries used in this assessment: West Coast (WC) which corresponds to the WC fishing zone, Northern Spencer Gulf (NSG) which corresponds to the northern region of the SG fishing zone, Southern Spencer Gulf (SSG) which corresponds to the southern region of the SG fishing zone, Northern Gulf St Vincent (NGSV) which corresponds to the northern region of the GSV/KI fishing zone, Southern Gulf St Vincent (SGSV) which corresponds to the southern region of the GSV/KI fishing zone, and South East (SE) which corresponds to the SE fishing zone.

Snapper management arrangements

As a result of a management review following the 2019 Snapper Stock Assessment (Fowler et al. 2019), fishing for Snapper was prohibited in all State waters from 1 November 2019 except for the region that now constitutes the SE fishing zone. This fishery closure remains in effect until 1 February 2023, and as such, no updated catch and effort information are available for the SG, GSV/KI and WC fishing zones in this assessment. In 2020, the Snapper fishery in the SE fishing zone was managed using a total allowable catch (TAC) that was divided into a TACC and a total allowable recreational catch (TARC). This was a recommendation by the Snapper Management Advisory Committee (SnapperMAC) that preceded the MSFMAC. The TAC in 2020 was set at 75 t and divided among sectors according to their allocations in the Management Plan (PIRSA 2013). This equated to a TACC of 60.75 t which was set as an 'Olympic Quota' and was not unitised into ITQs. The TARC was managed through a harvest tag system for both the recreational and Charter Boat sectors. The recreational component of the TARC was set at 6.0 t, which allowed 3,030 Snapper to be caught by the recreational sector. The Charter Boat Fishery component of the TARC was set at 7.5 t, which equated to 3,788 harvest tags that were divided equally among license holders (i.e., 49 tags per Charter license). The TAC also included a nominal amount (i.e., 750 kg) that was allocated for Aboriginal Traditional fishing activity. A three-month annual seasonal closure was also in place between 1 November and 31 January.

1.4. Fishery Performance Indicators

For each taxon, general performance indicators (PIs) are used to benchmark the performance of the fishery. These are derived from commercial catch, target effort and CPUE, and vary amongst the taxa. Annual time-series of these PIs were derived from commercial fishery statistics from 1984 to 2020 (reference period). Each performance indicator was benchmarked against the following trigger points:

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

1.5. Stock Status Classification

A national stock status classification system is used for the assessment of key Australian fish stocks (Piddocke et al. 2021). 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 and subsequent growth is significantly compromised (i.e. recruitment is impaired). 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: sustainable, depleting, recovering, depleted, undefined, or negligible (Table 1-1). PIRSA has adopted this classification system to determine the status of all South Australian fish stocks.

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 (Piddocke et al. 2021).

Stock status	Description	Potential implications for management of the stock
Sustainable	Biomass (or proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (recruitment is not impaired) and for which fishing mortality (or proxy) is adequately controlled to avoid the stock becoming recruitment impaired (overfishing is not occurring).	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 mortality 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 non-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

Fishing fleet dynamics reflect the decisions made by fishers that relate to when and where to fish, the most appropriate gear to use for the target species, and the economics of seafood production. These decisions are influenced by a range of factors, such as the seasonal availability, movement and migration of target stocks, seasonal changes in weather conditions, management arrangements, running costs, market access and socio-economics.

A comprehensive evaluation of the spatial and temporal characteristics of fishing activities is required before stock assessment models can be reliably developed to inform management decisions (Hilborn and Walters 1992, Mahévas et al. 2008). In most cases, this includes a detailed break-down of fishery catch patterns, fishing effort, CPUE, the spatial distribution of catches, fishing gear, location and season for each species (Hilborn and Walters 1992).

Whilst most of this report is devoted to the assessment of fishery statistics for specific taxa taken in the MSF in order to determine stock status, this section provides a holistic view of the fishery by examining and comparing trends in catches, fishing effort, gear use, regions and seasonality. This summary illustrates the dynamic nature of this fishery at different spatial and temporal scales, the changes in licence participation rates, and the relationships and trends between target 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 1-2). Licensed fishers are required to log their fishing activities by reporting specific details such as MFA fished, number of fishers on board, gear used, species targeted, species caught, weight of catch, catch in numbers of specific species, and method of capture. Prior to 2003, these details were recorded on a monthly basis but since then the fishers have been required to provide a daily log of fishing activity. These records are submitted monthly to SARDI Aquatic Sciences where they are entered into the Marine Scalefish Fisheries Information System. This database 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 1 July 1984 to the present and provides the primary source of data used for the assessments of stock status presented in this report. As such, they are based on a 37-year time-series.

The complexity of the MSF database was reduced to a smaller, more manageable dataset that allowed analysis of the major trends in 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. The other approach involved aggregating certain gear types into broader categories. Hauling 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 categorized as set nets. Similarly, handlines, troll lines and fishing rods/poles in the line sector were categorised as handlines. Longlines, drop lines and trot lines were grouped as longlines where appropriate.

2.3. Results

2.3.1. Trends in Number of Active Licences

There was a 66% (from 865 to 291) reduction in the number of licence holders actively operating in the MSF between 1984 and 2020 (Figure 2-1) The largest proportional reduction occurred for the Rock Lobster fisheries, as the number of active licence holders that accessed MSF species declined from 219 in 1987 to 22 in 2020, representing a 90% reduction. The rate of decline was accelerated from 1994 following the implementation of the licence amalgamation scheme. Two net buy-back schemes also contributed to removing active licences in 2005 and 2014. Of the 291 active licence holders in 2020, 264 were MSF, 22 were from Rock Lobster fisheries and five were from the Miscellaneous Fishery. The effects of the licence surrenders from the MSF reform will become apparent in the next assessment.

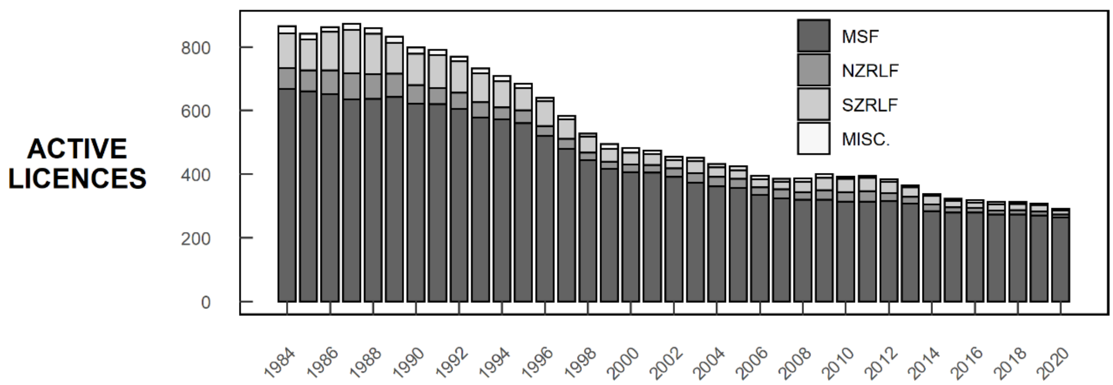

Figure 2-1. Long-term trend in the number of active licence holders that have access to the Marine Scalefish Fishery (MSF), including those from the Southern and Northern Zone Rock Lobster (SZRLF, NZRLF) and Miscellaneous (MISC.) Fisheries.

2.3.2. Trends in Commercial Catch

Since 1984, there have been considerable shifts in the composition of the commercial MSF catches which have contributed to a long-term declining trend in fishery production (Figure 2-2). Catches of the primary species have been relatively consistent, while those of secondary, tertiary and other species have declined since the 1980s. Recent annual catches in the MSF fishery are dominated by the four primary species (~43%), followed by the secondary (~28%), tertiary (~20%), and the remaining permitted species (~9%) (Figure 2-2). Appendices 1 and 2 provide summaries of annual commercial catches of permitted species taken in the Marine Scalefish Fishery between 1984 and 2020.

Total annual catches of the primary species declined from 2,089 t in 2001 to 807 t in 2020 (Figure 2-2). Prior to 1999, the composition of the primary species catch was relatively stable, where annual King George Whiting catch accounted for around 36%, followed by Southern Garfish (26%), Snapper (22%), and Southern Calamari (16%). Since then, the relative proportions of the KGW and Garfish catches have declined to 25% and 21%, respectively, whereas annual catches of Southern Calamari (46%) have increased, particularly since 2007 (Figure 2-2). The proportion of Snapper in the catches of primary species decreased significantly from 53% to 25% between 2010 and 2019, and then further to 7% in 2020 following the closure to fishing for the SG/WC and GSV Stocks.

The total annual catch of secondary species averaged 1,635 $t.yr^{-1}$ between 1984 and 2001, and peaked at 2,127 t in 1995 (Figure 2-2). The total catch of secondary species was stable at around 600–750 $t.yr^{-1}$ during the late 2000s and 2010s, and subsequently declined to a low level of 455 t in 2020. Western Australian Salmon and Australian Herring have consistently accounted for most (up to 68% collectively) of the catch of secondary species, while Blue Crabs accounted for most of the remaining catch during the 1990s (Figure 2-2). The relative contributions of the other secondary species to the total catch have remained stable since 2009, with the exception of Western Australian Salmon which had two years of increased catches of ~370 $t.yr^{-1}$ between 2016 and 2017, and then a considerable decline in catch to 75 t in 2020.

Annual catches of tertiary species peaked in 1991 at 1,102 t, when they were dominated by Ocean Jackets (88.6%). Ocean Jackets continued to contribute most of the tertiary species catch up to 2005, before targeting of this species all but ceased during 2005–2015 (Figure 2-2). Fishing for Ocean Jackets recommenced in 2016 and the highest catch since 2004 occurred in 2020 (Figure 2-2).

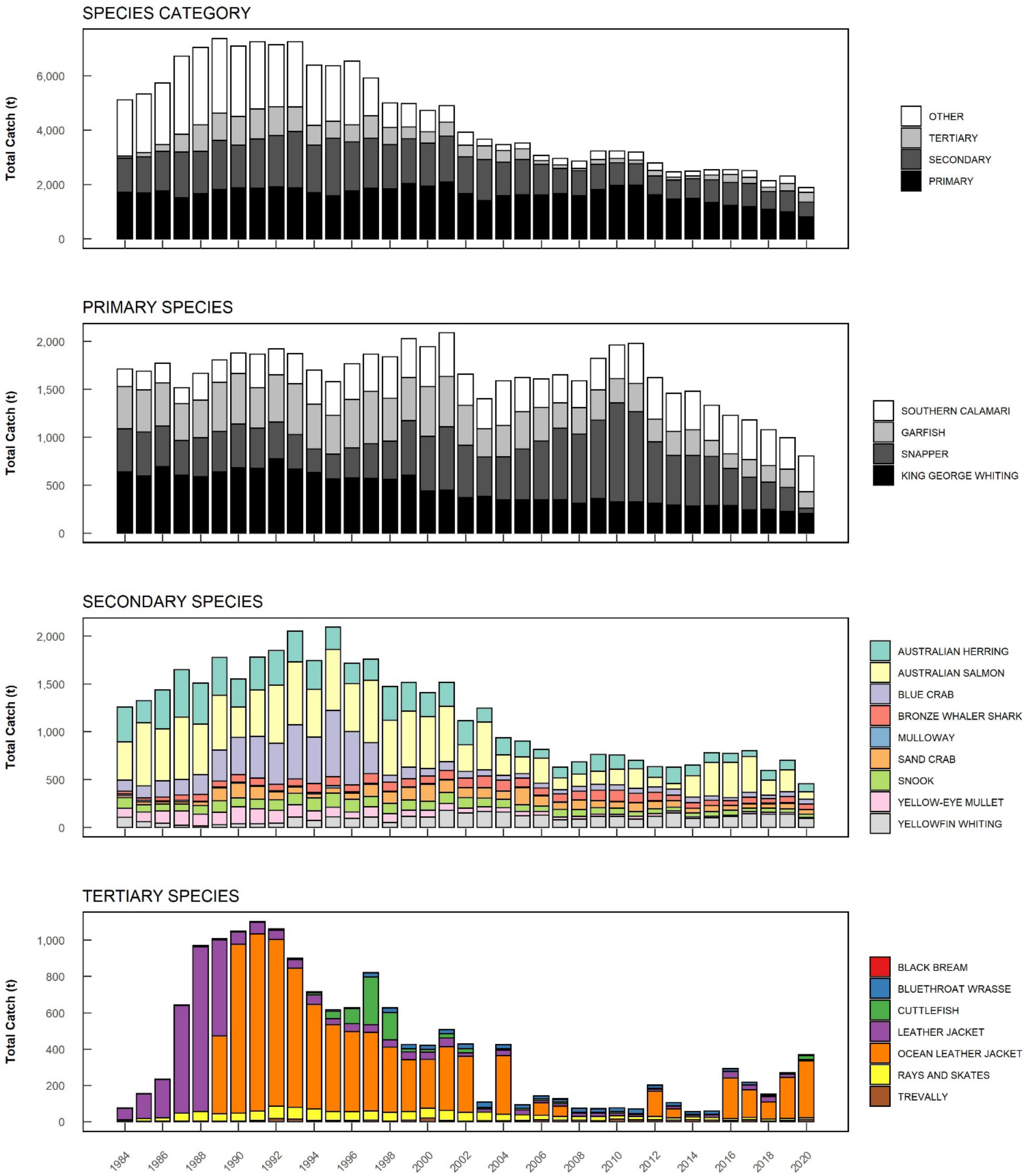

Figure 2-2. Long-term trends in total catch (t) in the commercial Marine Scalefish Fishery for primary, secondary and tertiary species between 1984 and 2020.

2.3.3. Trends in Fishing Effort

Species

Annual estimates of total fishing effort peaked at 136,550 fisher-days in 1992 (Figure 2-3). This represented an 18% increase in annual effort since 1984, after which there was a 69% reduction to 42,630 fisher-days in 2020.

Since 1984, the majority (~80%) of the fishing effort reported in fishery logbooks in most years has been 'targeted effort', whereby fishers nominated a species/taxon as their target. For the remaining (~20%) effort reported each year, fishers record 'any target' in their catch returns. This continued in 2020, with 82% of the total effort dedicated to targeting a species/taxon. Of the reported targeted effort, the four primary species have consistently accounted for the greatest proportion, of which King George Whiting has historically dominated. Since 2011, there has been a subtle shift in targeted fishing activity, as fishers have directed some targeted effort away from Snapper, King George Whiting and Garfish towards Southern Calamari. The relative proportion of effort targeted towards Southern Calamari has increased from 23% in 2010 to 42% in 2020 (Figure 2-3). Over the same period, the relative proportion of effort targeted towards Snapper declined from 24% to 4% in 2020.

The secondary species accounted for approximately 10% of the total targeted fishing effort in 2020, which is considerably lower than during the 1990s when they typically accounted for ~15% of all targeted effort (Figure 2-3). The distribution of targeted effort amongst the secondary species has also changed considerably over the past 37 years. Historically, Blue Crabs, Western Australian Salmon, Snook and Yelloweye Mullet attracted the most effort, accounting for >95% of targeted effort directed at secondary species in some years during the mid-1980s. Since 2000, the relative proportions of effort targeted towards Yelloweye Mullet, Western Australian Salmon and Blue Crab have declined, while those for Yellowfin Whiting and Whaler Sharks have increased.

During 2020, 3.4% of the State-wide fishing effort was spent targeting the six tertiary species considered in this report (Figure 2-3). There were a few periods of notable expansion for some 'niche' tertiary species across the time period, such as Leatherjackets, Ocean Jackets and Cuttlefish. Targeted effort for each of these species doubled over short (<5 years) periods but did not persist. Targeted effort for Ocean Jackets has followed an increasing trend over the last four years, reaching 609 fisher-days in 2020, which is the highest since 2005.

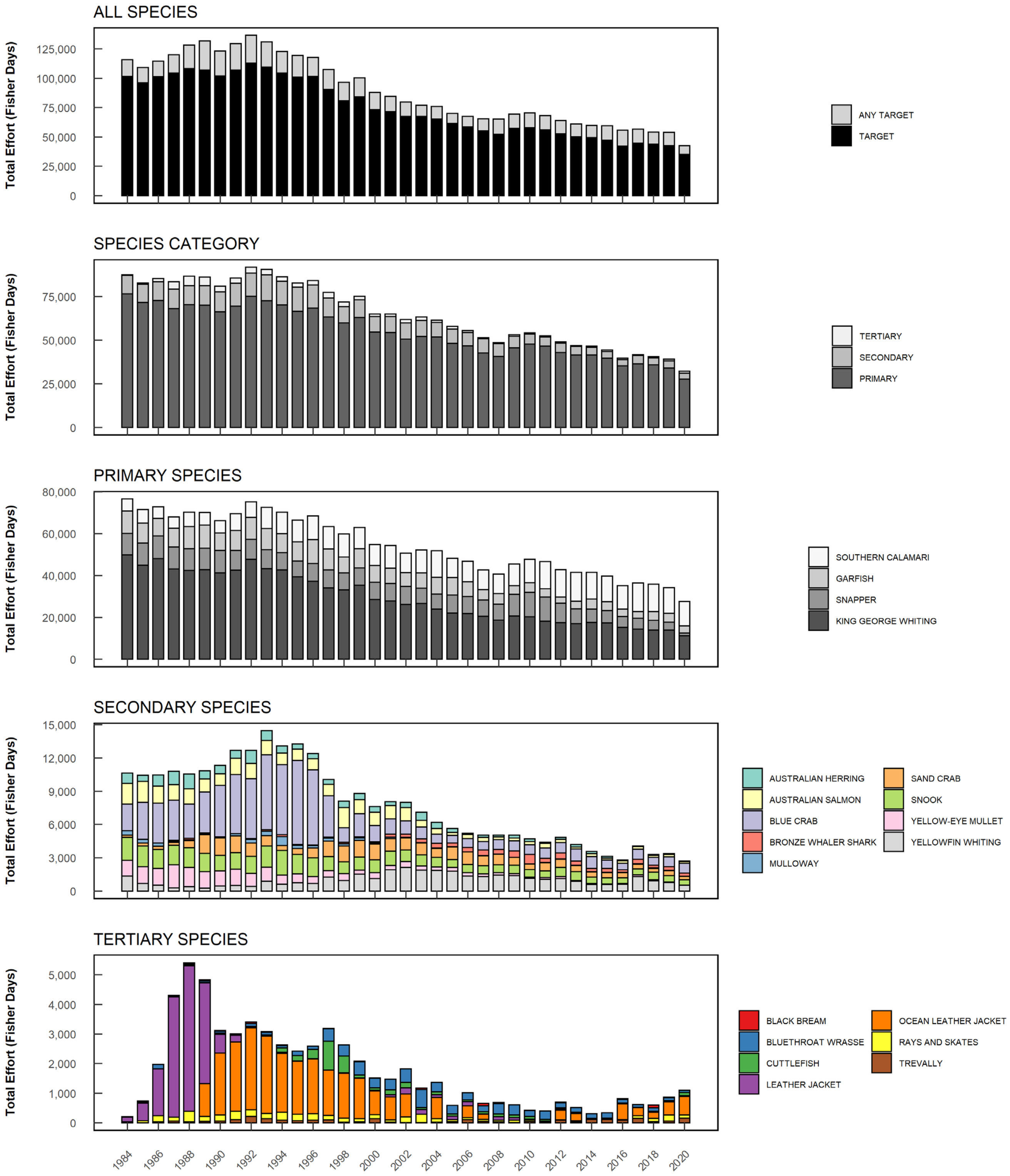

Figure 2-3. Total effort (fisher-days) in the commercial Marine Scalefish Fishery partitioned into targeted and non-targeted ('any target') effort (top graph) and into species-specific targeted effort for the period of 1984–2020.

Gear

Hauling nets and handlines have consistently been the dominant gear types used in the fishery, collectively accounting for >60% of the total fishing effort in most years since 1984 (Figure 2-4). The proportional use of set nets has declined from 16% in 1987 to <1% in 2020, with the greatest reduction occurring throughout the late 1990s and early 2000s in response to the State-wide netting review and associated restrictions. The use of squid jigs has steadily increased from 1994 as the Southern Calamari fishery evolved from a bait resource to a priority target species, and has further increased from 2011 onwards, accounting for 22.6% of the total State-wide fishing effort in 2020. The proportional use of longlines doubled from 2009 through to 2016 and but declined in 2020 and accounted for 5.5% of the total fishing effort in 2020.

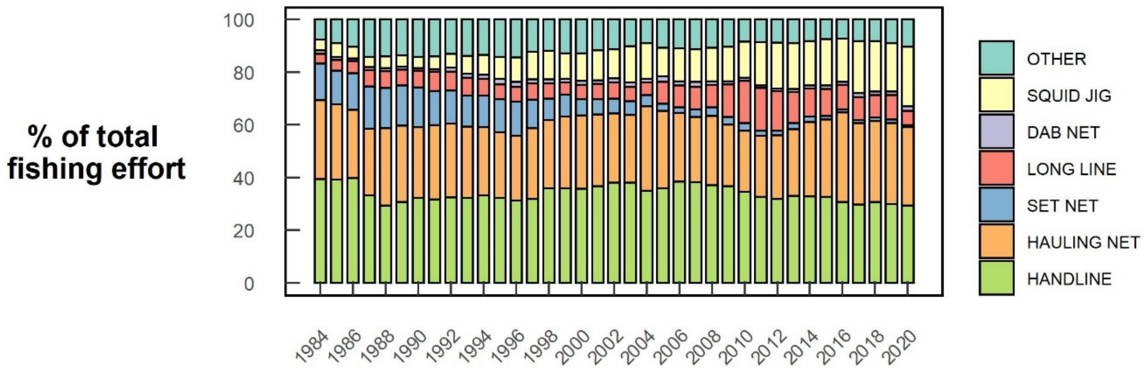

Figure 2-4. Gear usage (% of total fishing effort) within the Marine Scalefish Fishery.

Location

Historically, the spatial distribution of fishing effort was widespread with most of the State's MFAs registering some level of fishing activity (Figure 2-5). Fishing effort was most intense in the northern gulfs and near the major regional ports of 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.yr^{-1}). Of the major regional centres, only Port Lincoln and Ceduna have maintained some consistent fishing activity. The northern gulfs have continued to account for most fishing effort, but this has also declined over the past 37 years, from an average of ~ 40,000 fisher-days.yr^{-1} during the 1980s and 1990s to < 29,000 fisher-days.yr^{-1} since 2005. Average annual fishing effort within MFAs 19 and 29 in southern Spencer Gulf was below 500 fisher-days.yr^{-1} over the last four years (2017 to 2020), which is the lowest level recorded for this area (Figure 2-5).

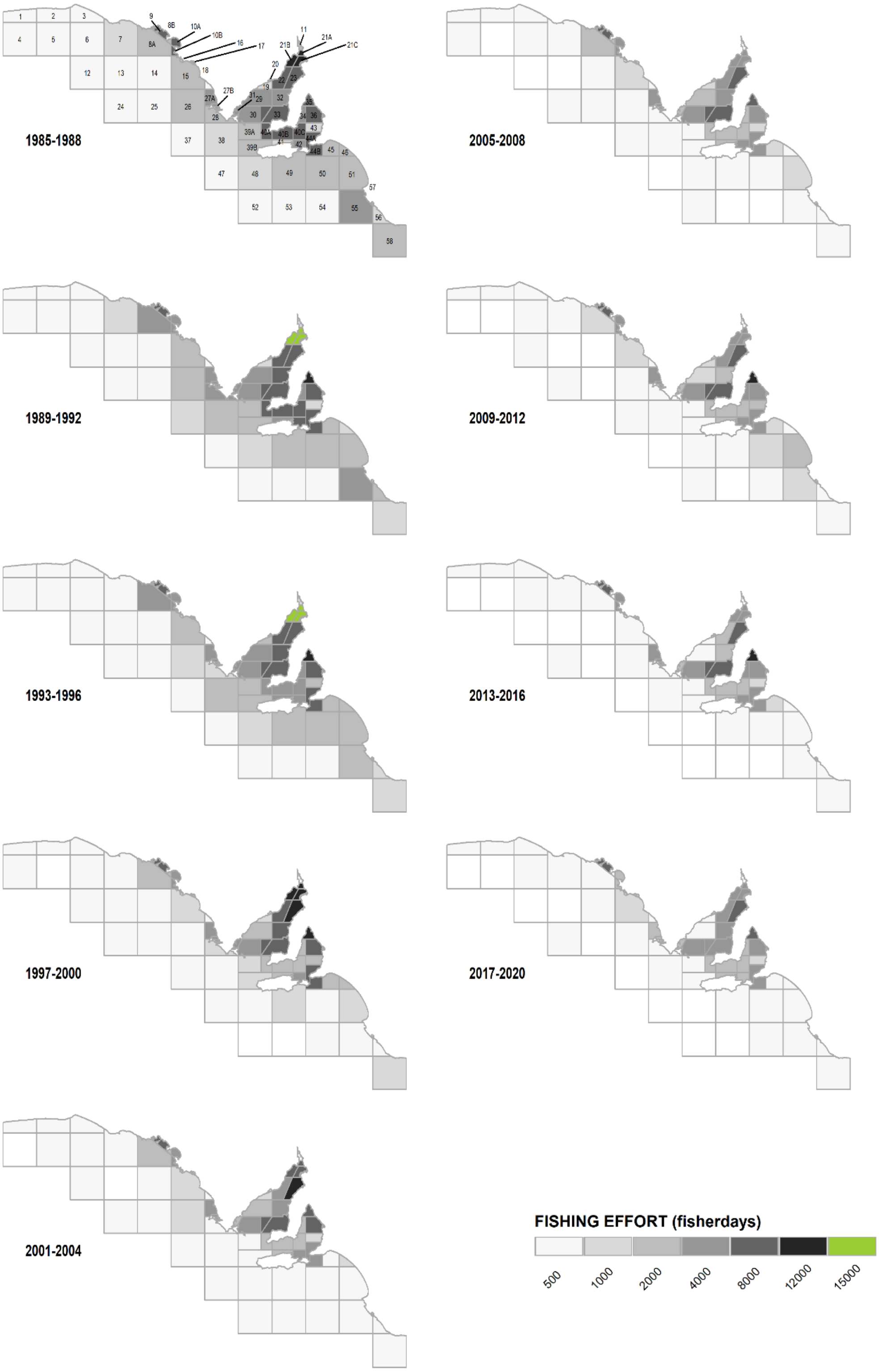

Figure 2-5. Spatial and temporal distribution of fishing effort (fisher-days) in the Marine Scalefish Fishery. Effort data by MFA were averaged over five-year periods from 1985 to 2020.

Season

The high diversity of target species within the MSF provides fishers with considerable flexibility across seasons (Figure 2-6). Among the four primary species, monthly targeted fishing effort for KGW peaked at around 1,300 fisher-days in June and July, and although this species was targeted throughout the year its fishing activity was lowest in summer. Conversely, targeted effort for Southern Garfish was highest during late summer, peaking at just over 320 fisher-days in February. Fishing effort for Southern Garfish was affected by the seasonal closures of the fishery in late winter and early spring since 2016. The seasonal pattern of fishing activity for Southern Calamari and Snapper was similar, with both maintaining relatively high levels of fishing effort throughout the year, peaking in autumn and again in late spring (Figure 2-6). Negligible effort for Snapper in November reflects the seasonal closure during this month between 2003 and 2018.

Targeted effort for most of the remaining species peaked during the spring and summer months although some level of fishing activity was maintained throughout the year. Yellowfin Whiting, Bluethroat Wrasse, Silver Trevally, Rays and Skates and, to a lesser extent, Black Bream were the only species that displayed distinct increases in fishing activity during winter and early spring (Figure 2-6).

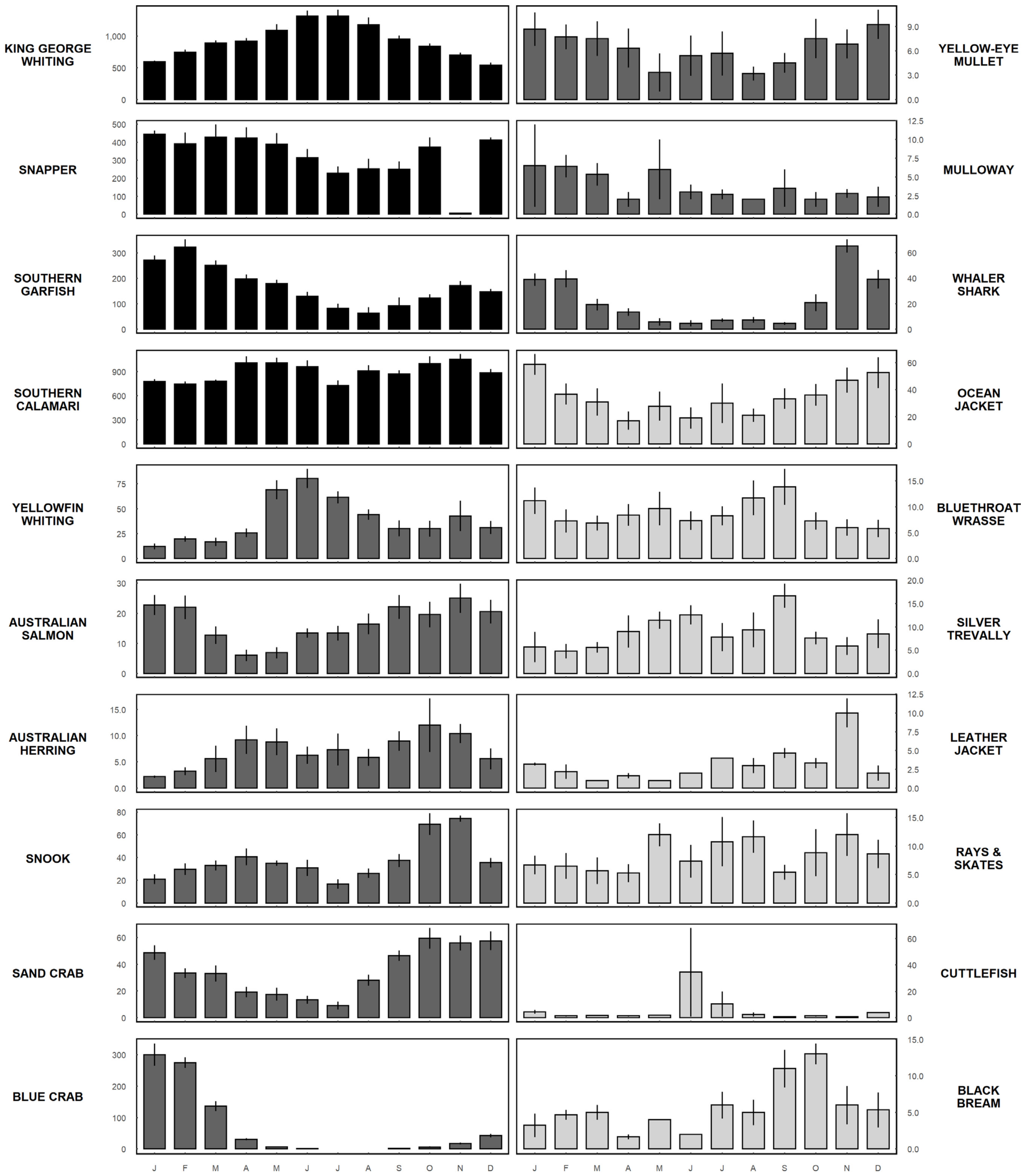

Figure 2-6. Monthly pattern of targeted fishing effort (fisher-days averaged (± se)) from 2012 to 2020 for each species/taxon assessed. The different shades denote species category; primary (black), secondary (dark grey), tertiary (light grey).

2.4. Summary

The dynamics of the MSF fleet have shifted in recent years primarily due to changes in management arrangements. The most obvious changes have been the decline in fishing effort driven by the licence amalgamation scheme in 1994, two voluntary net buy-back initiatives (2005 and 2014), and reduction in the number of B-class and Rock Lobster licences active in the fishery. Since their implementation, the major management arrangements have successfully reduced the number of active licence holders by 66%, which has led to a 68% reduction in fishing effort. This has contributed to a gradual spatial contraction of effort across the State, with the fishery becoming almost exclusively confined to gulf waters, around the major regional centres of Port Lincoln and Ceduna, and a few protected bays on the west coast of the Eyre Peninsula. Most fishing effort within the MSF has been targeted, with the remaining activities being non-specific in their target species indicating that fishers were more general in their fishing activity during that period or were not specifically recording a target species in their catch returns.

The expansion and subsequent reduction in Snapper catches, particularly following the spatial closures from 1 November 2019, a steady reduction in King George Whiting and Southern Garfish catches, and the shift in effort towards targeting Southern Calamari have also been key drivers of recent changes in fleet dynamics. Collectively, these four primary species have typically accounted for the almost two thirds of all targeted effort each year, 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 and catch limits). Reduced catch and effort in 2020 may also be in part attributed to the impact of Covid 19 and related decline in market demand and uncertainty related to the reform of the MSF. Simultaneously, targeted effort for Southern Calamari has steadily increased. This species has effectively become a year-round 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 in the fishing fleet.

The ephemeral periods of increased fishing activity for other secondary and tertiary species, such as Western Australian Salmon, Snook and Ocean Jackets 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’ or ‘lesser-known’ species and to 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 overtime.

3. SOUTHERN GARFISH STOCK ASSESSMENT

3.1. Introduction

3.1.1. Biology

The Southern Garfish (*Hyporhamphus melanochir*) is a surface-associated marine teleost species of the Hemiramphidae family. Species of this family are typically elongate in body shape and are characterised by a distinctive lower jaw that forms an extended beak which is much longer than the upper jaw. Southern Garfish is endemic to coastal waters of southern Australia. It is distributed from Shark Bay in Western Australia, along the southern coast of Australia including Tasmanian waters, and as far east as Eden in New South Wales (Kailola et al. 1993, Noell and Ye 2008). The species forms schools in sheltered bays and shallow, inshore, marine waters to depths of ~20 m, and are often associated with seagrass beds (Earl et al. 2011). They are particularly abundant throughout the gulf regions of South Australia.

Southern Garfish largely conforms to the bipartite life history that is characteristic of most marine fish species (Cowen and Sponaugle 2009). It is a multiple batch spawning species that has a protracted spawning period of six months from October to March (Fowler 2019). During the spawning period, only a small proportion (10–20%) of the population are in spawning condition at any given time (Giannoni 2013). This indicates that reproductive activity is asynchronous with small pulses of spawning activity, which is most likely a consequence of the large size of the developing oocytes (approximately 3 mm in diameter) and the time required for them to mature (Noell 2005, Fowler 2019). The estimated length-at-50%-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).

The eggs of Southern Garfish are negatively buoyant and are adapted for attachment to substrate such as seagrass blades and macroalgae (Jordan et al. 1998, Noell 2005). Although it is possible that the eggs are moved through attachment to drifting substrate, there is assumed to be greater potential for large-scale transport during the pelagic larval stage. The developing larvae remain near the surface and their movement is likely to be heavily influenced by the physical environment (i.e. tides and wind-driven currents) until the completion of fin formation at ~20 days post-hatch (Noell 2005, Fowler 2019). Thereafter, the late-stage larvae and juveniles can actively influence their dispersal. The juvenile fish develop quickly and, like the adults, are considered largely sedentary in their movement. It is possible that the limited movement of adult fish is a consequence of an obligate relationship between Southern Garfish and the intertidal seagrass *Zostera muelleri* which constitutes a significant component of the adult diet (Robertson and Klumpp 1983, Earl et al. 2011).

In 1999 and 2000, a total of 2,079 Southern Garfish from commercial catches in South Australia were aged for a study on age and growth (Ye et al. 2002). There were seven age classes (0+ to 6+ years) that contributed to the commercial catches; however, the catches were dominated (89%) by fish from 1+ and 2+ age classes. Less than 2% were from 4+ to 6+ age classes. A more recent study, which compared the size and age structures of the fishery with that of the 1950s, indicated that historically the fishery was once dominated by fish from 4+ and 5+ age classes, but over numerous years of exploitation, the age structure has become considerably truncated to consist primarily of fish from 1+ and 2+ age classes (Fowler and Ling 2010).

The population dynamics and stock structure of Southern Garfish in South Australia has been investigated using a variety of different approaches. Movement has not been investigated directly through a tagging study because of their fragile nature and susceptibility to injury and mortality as a result of capture and handling. Consequently, movement was inferred through a multi-disciplinary otolith study that involved the analysis of otolith microchemistry (trace elements and stable isotopes) (Steer et al. 2009b) and otolith morphometrics (Steer et al. 2009a, 2010, Steer and Fowler 2015), and a concurrent study that considered parasite assemblages (Hutson et al. 2011). The results of these studies suggested that the movement of adult fish was limited and that they remained associated with a particular area or bay during the first few years of their lives. This evidence of restricted movement and site-fidelity underpinned the conceptual model of stock structure for Southern Garfish in South Australia, i.e., that the State-wide distribution was divided into numerous populations that were largely discrete. These populations were: the bays along the West Coast of Eyre Peninsula (WC), Northern Spencer Gulf (NSG), Southern Spencer Gulf (SSG), Northern Gulf St Vincent (NGSV), Southern Gulf St Vincent (SGSV), and the South East (SE) (Steer et al. 2018b).

More recently, Fowler (2019) examined the demographics and population connectivity of Southern Garfish in Gulf St Vincent. The study provided fishery-independent evidence that the highest abundances of adult fish were in the northern part of the gulf and that abundance decreased moving southward. This spatial distribution of adults aligned with the distribution and abundance of the seagrass *Zostera muelleri* and is consistent with the limited movement of adult fish inferred from the previous otolith-based studies. Furthermore, Fowler (2019) also investigated the spatial distribution of Southern Garfish larvae to provide insight into the processes that replenish the two regional populations (i.e. NGSV and SGSV). The results indicated that there was local retention of larvae in each region. However, the study also identified that a large proportion of larvae produced in SGSV were transported northward and contributed to the replenishment of the population in NGSV (Fowler 2019). Consequently, the conceptual model of stock structure was updated to recognise the importance of larval supply from SGSV to the NGSV population, and the two populations were classified as a single biological stock (i.e., the Gulf St Vincent stock). Although the demographic processes of Southern Garfish in Spencer Gulf were not investigated, it is likely that the processes responsible for population replenishment are similar.

The stock structure presented in this report is more nuanced than previous assessments. The existing regional stock structure has been maintained as the limited mixing of adult populations creates a risk of localised depletion, warranting examination of catch statistics and age structures at the regional level. However, the GarEst stock assessment model has been restructured to the GSV/KI and SG fishing zone boundaries which aligns with biological stock structure. Furthermore, this allows TACCs for the SG and GSV/KI fishing zones to be informed by the model outputs which conform to these spatial scales.

3.1.2. Fishery

Southern Garfish is a significant inshore fishery species of southern Australia, with fisheries also existing in Victoria, Tasmania, and Western Australia. Historically, the national commercial catch for this species has been dominated by South Australia where the catch has often exceeded 400 t per annum, with an approximate value of $1.8 M (EconSearch 2021). This species is also a popular target amongst South Australian recreational anglers (Jones 2009, Giri and Hall 2015).

In South Australia, licence holders from three different commercial fisheries have access to Southern Garfish. These are the MSF, NZRLF and SZRLF. The Southern Garfish fishery is principally located in Spencer Gulf and Gulf St Vincent 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. The fishery in the northern gulfs is dominated by hauling net fishing while large areas in the southern gulfs are closed to haul netting. Subsequently, the dab net fisheries in the southern gulfs provide the best indicators of stock status in these regions (Fowler 2019).

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 state-wide catch of 79.2 t (Giri and Hall 2015).

3.1.3. Harvest Strategy

Two key objectives for managing the harvest of Southern Garfish within the commercial MSF considered in this assessment are to: (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 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).

3.1.4. Management Regulations

The commercial MSF has undergone considerable management changes over the past 37 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 has 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. Following the implementation of several marine parks in 2014, it was 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. 2016).

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 prior to capture (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.

Biological performance indicators (BPIs) for Southern Garfish were outlined as part of the Management Plan for the South Australian commercial MSF, which was released in October 2013 (PIRSA 2013). Although no specific management arrangements were prescribed in the Management Plan to achieve these BPI reference points (RPs), a range of tools were identified, and an adaptive management approach outlined to consider the management arrangements needed to meet the RPs 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 was subsequently increased to 38 days in 2013, 40 days in 2014, 60 days in 2016, 80 days in 2018, and 80 days in 2019 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, from 32 to 35 mm in 2017 and from 35 to 36 mm in 2019. Furthermore, the LML of Southern Garfish for commercial fishers was increased from 230 mm to 250 mm TL in 2015. In 2016, the recreational bag and boat limit of Southern Garfish was halved from 60 and 180 fish, respectively, to 30 and 90 fish. The LML, for recreational fishers, remains at 230 mm TL.

In 2014 a working group established by the former South Australian Fisheries Council was assembled to review the management structures of the MSF and recommend strategic options to improve the fishery (MSFSRWG 2016). Following this working group, the commercial MSF underwent a structural reform which concluded in July 2021. An outcome of the reform for Southern Garfish was their classification as a Tier 1 species in the GSV/KI and SG fishing zones (Smart et al. 2022). This Tier 1 status led to the introduction of a TACC implemented through individual transferable quotas (ITQs) from the 2021/22 fishing season onwards.

3.2. Methods

3.2.1. Data Sources

Commercial Fishery Statistics

For this stock assessment, the catch and effort data were aggregated across commercial fishers to provide annual totals (calendar year) and estimates of catch per unit of fishing effort (CPUE) at the State and stock levels. State waters were partitioned into six regions: (1) West Coast (WC), (2) Northern Spencer Gulf (NSG), (3) Southern Spencer Gulf (SSG), (4) Northern Gulf St Vincent (NGSV), (5) Southern Gulf St Vincent (SGSV) and the (6) South East (SE) (Figure 1-2). These data were also interrogated across the two main gear types used to target Southern Garfish – hauling nets and dab nets.

Fishing effort was reported for all six regions using fisher-days, which relates to the number of days a licenced vessel fished multiplied by the number of personnel working on board. For NSG and NGSV, where catches are dominated by the hauling net sector, a second gear-specific CPUE was calculated using catch-per-haul. 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 targeted CPUE for each gear type, which provide indices of relative abundance for Southern Garfish.

Age and length structures

On a weekly basis, SARDI researchers sampled commercial catches 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 smaller 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 fish 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). Length and age structures are presented in this report by dominant gear type for each of the stocks in NSG, SSG, NGSV and SGSV, where sufficient sample sizes were available. Age structures were estimated using age length keys that were developed from the proportional ages-at-lengths for each year. Age length keys were estimated using the 'FSA' R package (Ogle 2015, Ogle et al. 2022).

3.2.2. 'GarEst' Fishery Model for SG and GSV/KI Fishing Zones

The stock assessment of Southern Garfish is supported by an age-and-length-structured stock assessment model – 'GarEst'. This model uses the slice partition algorithm (McGarvey et al. 2007) and a quarterly model timestep to account for length selective exploitation from gear selectivity and the LML. In this assessment, the two GarEst model regions were updated to align with the new fishing zones implemented through the reform of the MSF (Figure 1-1). Specifically, the model was fitted to data from the MFAs that belong to the Spencer Gulf (SG) and Gulf St Vincent/Kangaroo Island (GSV/KI) fishing zones now defined as management units, including for quota setting, under the reform restructure. These fishing zones include both the northern and southern areas from each gulf (Figure 1-2). As most of the data on population structure, and most of the fishing activity in each gulf corresponds with the northern stocks, these model outputs are used to support the stock status classifications of the NGSV and NSG stocks, as per previous assessments (Steer et al. 2016, Steer et al. 2018b).

The principal input data for the GarEst model are (1) commercial catch and effort totals, (2) sex and age proportions in the commercial catch derived from SAFCOL market sampling, (3) length-at-age distribution properties (mean length, standard deviation, skewness and kurtosis), (4) recreational catch estimates from the National Recreational and Indigenous Fishing Survey(Henry and Lyle 2003) and South Australian Recreational Fishing Surveys (Jones 2009, Giri and Hall 2015), (5) charter boat logbook annual catch totals available since 2007, and (6) fishery-independent samples by age and sex (Fowler 2019).

The model year begins on 1 October to align with the summer spawning of Southern Garfish. Model runs were conducted in quarterly time steps (Oct-Dec, Jan-Mar, Apr-Jun, Jul-Sep) to account for seasonal variation, and extended from 1 October 1983 to 30 September 2020, as prescribed in the Management Plan (PIRSA 2013). In previous assessments, GarEst used a half-yearly time step. A quarterly time step increases the model temporal resolution, permitting: (1) the capture of seasonality in growth, which is now estimated and accounted for, (2) separation of the catch, effort and CPUE by quarter which show relatively distinct and consistent seasonal differences (see monthly trends plotted in Figure 3.7, McGarvey et al. 2009), and (3) an increase in the length-partition resolution by computing Southern Garfish number for twice as many slices spanning each cohort's length-at-age distribution.

The CPUE for the 'hauling net fishers who target Southern Garfish' category (which includes the majority of Southern Garfish catch) incorporates the refined effort type "target-plus-50% hauling net" from 2003 onwards. The "target-plus-50% hauling net" category was created to account for fishers who catch fishers can catch multiple commercial species in a single fishing event and are sometimes non-specific in their target species. Although Southern Garfish may dominate catches, hauling net fishers sometimes nominate "any species" as the fishing target in their logbook returns. If Southern Garfish constituted more than half (≥50%) of the non-specific fishers' total daily catch, then these records were included in this expanded target-plus-50% hauling net effort type.

Three surveys of South Australia's recreational fishery, undertaken in 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 total Southern Garfish catches. Recreational catch totals in the years between the three surveys were assumed to vary linearly between the estimates of 2000/01 and 2007/08, and between 2007/08 and 2013/14 (Appendix 7.4). For all preceding years, estimates of recreational catch were assumed to be constant at the 2000/01 level. Catches subsequent to the 2013/14 recreational survey were fixed at those estimates.

Given the multi-gear and multi-sector nature of the fishery, the GarEst model partitions catch and effort logbook data into five effort types: (1) target-plus-50% hauling net, (2) other hauling net catches, (3) dab net catches, (4) charter boats (for 2007 onward), and (5) recreational catches.

Two levels of effort standardisation were undertaken for GarEst (Appendix 7.3). First, the target-plus-50% hauling net effort type was standardised by a generalised liner model (GLM) using only daily catch and effort returns. Second, catchability parameters were estimated by commercial effort type, summer or winter half-year, gulf, and sex.

Beginning in this assessment, the model also includes data from an FRDC fishery-independent sampling project (Fowler 2019). Between 2016 and 2019, in Gulf St Vincent, Southern Garfish were sampled near the surface using dab nets. Sampling was performed in 13 localities, each of which involved 15 transects divided between shallow (0-5 m), mid (5-10 m), and deep water (10-15 m) up to 20 km from shore. Sampling was undertaken twice at each location, once during spring/summer and once during autumn/winter. Sampled fish were measured for length, and a subset were aged (using the microstructure of their lapilli) and sexed. These proportions by sex and age were fitted in the present assessment model for adult Southern Garfish, specifically those ≥ 210 mm TL, whose population numbers are represented by length slice in GarEst. For full details on the fishery-independent sampling, refer to Fowler (2019).

Annual model estimates are presented for four biological performance indicators (BPIs): adult biomass, egg production, recruitment and annual harvest fraction (i.e. exploitation rate). Annual adult biomass in each model year was computed as the mean of the four quarterly biomass estimates of Southern Garfish of length 210 mm TL and above. This 210+ definition was maintained throughout the time series, despite the changes in LML in 2001 and 2015, to provide comparable biomass estimates across time. Hence this definition of adult biomass includes a component of the Southern Garfish population below the regulated LML from 2001 when the LML was raised from 210 mm to 230 mm, and from 2015 onwards when the commercial LML was raised to 250 mm (see Appendix 7.6). The annual harvest fraction was computed as the sum of the model catch in weight of the fishery in each model year divided by the annual adult biomass. Annual recruitment is defined as the number of Southern Garfish in each summer year class that survive to age one. In the recruitment time-series figures, the year shown on the x-axis is the year (the January birthdate) the cohort was spawned (Figure 3-17; Figure 3-18). The year value shown on figures for harvest fraction, egg production, and adult biomass is defined by the January of each model year. As the biomass of this stock is dominated by a single year class in any given year, estimates of biomass and other BPIs require that year class to be fully available to the fishery before those estimates can become reliable. This requires data from subsequent years where each year class is tracked through the annual age structures. As this cannot occur for the 2020-year class, this assessment presents model BPI estimates up to the 2019 model year (Oct 2018-Sep 2019).

Percent virgin egg production by region was computed as a ratio of yearly total 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 100-year projection run of GarEst with catchability (and so fishing mortality) set equal to zero, and with recruitment fixed at the estimated average from 1988 to 2000, prior to the longer-term recruitment decline that occurred around 2001.

In summary, three main improvements to the GarEst model were implemented for this assessment: (1) the model time-step was shortened from half-yearly to quarterly, (2) the model now fits to an additional fishery-independent one-off dataset of samples by age and length of the population of length 210+ (not just the catch) from the entire Gulf St Vincent, and (3) the definition of biomass was made consistent over time to include Southern Garfish ≥210 mm TL for all years. In previous assessments, the term fishable biomass was used. Now, with biomass being defined as those ≥210 mm which includes sublegal sizes after 2001, the term ‘adult biomass’ will be employed for this Southern Garfish indicator.

Further details of the GarEst Southern Garfish stock assessment model are provided in McGarvey and Feenstra (2004), McGarvey et al. (2007) and Appendices 7.3, 7.4, 7.5 and 7.6. The respective fits of the model to these data sources are presented in Appendix 7.7. Sensitivity analysis of model outputs to changes in (i) assumed natural mortality rate and (ii) the strength of weighting on the age-sex sampling data is presented in Appendix 7.8.

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: ensure the long-term sustainable harvest of Southern Garfish by rebuilding stocks during specified time frames. 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 targets of ≤30% and ≥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+) Southern Garfish within the population through each triennial stock assessment cycle and to reduce total hauling net effort by at least 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).

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 3-1. 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

Table 3-2. Commercial allocation of Southern Garfish among the sectors as prescribed in the MSF Management Plan (PIRSA 2013).

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

3.3. Results

3.3.1. State-wide

Commercial Fishery Statistics

The total commercial catch of Southern Garfish was 172 t in 2020 (*cf.* 190 t in 2019) (Figure 3-1). The 2020 season was the sixth consecutive year with total catches below 200 t. The gross value of production (GVP) of the commercial catch of Southern Garfish in 2020 was approximately $1.8 M (Figure 3-1).

The hauling net sector has accounted for ~90% of the State-wide harvest since 1984 (Figure 3-1). Annual catches in this sector varied between 325 t and 500 t from 1984 to 2002, averaging 413 $t.yr^{-1}$, before declining to 131 t in 2016. The hauling net sector caught 141 t in 2020 which accounted for 82% of the state-wide commercial catch. The dab net sector accounts for most of the remaining commercial catch (~10%). This sector yielded higher than average catches throughout the 1990s (~62 $t.yr^{-1}$) compared to the last decade when catches rarely exceeded 30 $t.yr^{-1}$ (Figure 3-1), and was 30 t in 2020.

Total fishing effort (includes targeted effort and non-targeted effort that produced catches of Garfish) for Southern Garfish for the hauling net and dab net sectors has steadily declined from a peak of 17,776 fisher-days in 1984 to a low of 4,021 fisher-days in 2020 (Figure 3-1). This represents a 78% decrease over 37 years declining at a rate of 390 fisher-$days.yr^{-1}$. This decline can largely be attributed to a consistent reduction in hauling net effort. Fishing effort has recently stabilised and maintained consistent levels of targeted effort. This trend was consistent for hauling net and dab net gear types.

Total hauling net CPUE remained relatively high from 2005 to 2014, averaging 55.5 kg.fisher-day^{-1}, which was 11.1 kg.fisher-day^{-1} above the average CPUE of the preceding decade (Figure 3-1). Since 2014, the CPUE for total hauling net effort has declined to 29 kg.fisher-day^{-1} in 2016 before increasing to 41.5 kg.fisher-day^{-1} in 2020. Dab net CPUE historically 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 3-1c). This increase was not sustained as it dropped to 31.9 kg.fisher-day^{-1} in 2007. CPUE in the dab net sector since 2014 has ranged between 37.7 and 49.5 kg.fisher-day^{-1}. In 2020, dab net CPUE was 57.0 kg.fisher-day^{-1} which was the second highest on record (*c.f.* 47.2 kg.fisher-day^{-1} in 2019) and considerably higher than the 15-year average of 40.4 kg.fisher-day^{-1}.

Two 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 significantly to the long-term decline in the number of commercial fishers who land

Southern Garfish. The second was the 2005 net buy-back. These two strategies contributed to the 57% reduction in the number of commercial fishers landing Southern Garfish from 1995 to 2011 (Figure 3-1). The relative proportion of commercial fishers that nominated Southern Garfish as their specific target has remained relatively consistent at 75% of fishers who landed Southern Garfish throughout the last 20 years.

Regional Fishery Dynamics

Most of the State-wide catch of Southern Garfish has historically been landed in NGSV and NSG (Figure 3-2). Catches from the WC, SSG and SGSV were considerably reduced from 2005 onwards as a result of the net buyback and subsequent netting closures in those regions.

From 1984 to 1999, most Southern Garfish were landed during autumn (Figure 3-2). 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 with most of the landings taken from January to August (Figure 3-2). These recent changes reflect the implementation of seasonal fishing closures in Spencer Gulf and Gulf St Vincent.

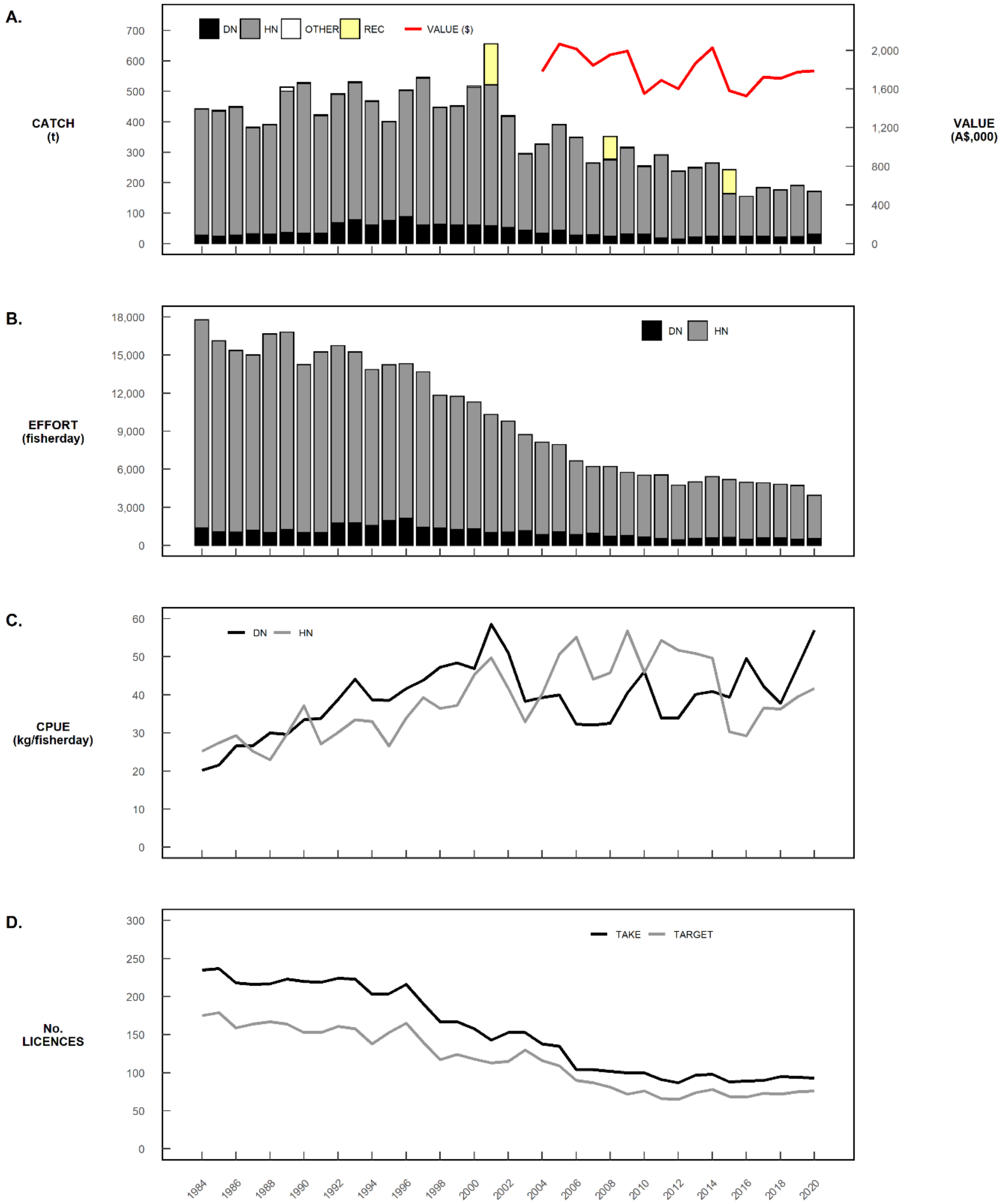

Figure 3-1. Southern Garfish. Long-term trends in State-wide estimates of: (A) total catch for the main gear types (hauling and dab nets) and gross value of production; (B) Long-term total effort for hauling and dab nets; (C) total catch per unit effort for hauling and dab nets; and (D) the number of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

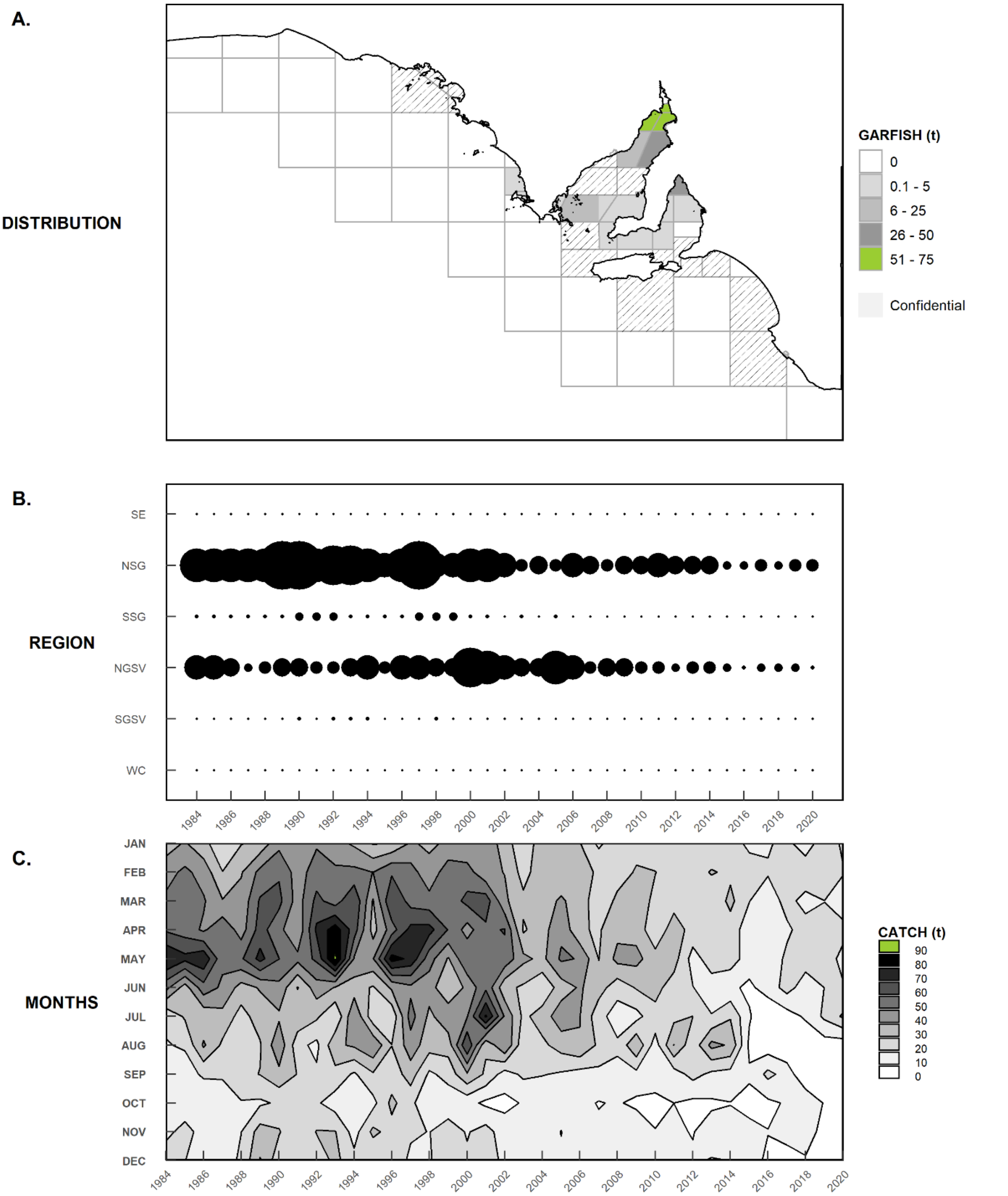

Figure 3-2. Southern Garfish. (A) The spatial distribution of catch by the commercial sector in 2020; (B) Long-term trends in the annual distribution of catch among regions; and (C) months of the year.

3.3.2. West Coast

The spatial coverage of the West Coast stock has been updated since the last assessment to reflect the WC fishing zone implemented through the MSF strutural reform (Figure 3-3). Therefore, many of the statistics provided in this report do not correspond to those of previous assessments and some catch records are now included in the SSG stock within the SG fishing zone (Figure 3-3)

From 1984 to 1999, the annual commercial catch of Southern Garfish from the West Coast accounted for < 5% of the State-wide catch. This has since progressively declined to 2.3% of the State-wide catch in 2020. This decline has been driven by a continuous reduction in hauling net effort through the implementation of commercial netting restrictions (Figure 3-3). Annual Southern Garfish catch peaked at 29.6 t in 1995, of which the hauling net sector landed 93% (Figure 3-3). Over the past nine years, catches have been below 5 t and fell to the lowest recorded level of 0.5 t in 2013. The total catch in 2020 was 3.9 t (*c. f.* 1.7 t in 2019). Dab nets emerged as the dominant gear type in 2008, although targeted catch has declined substantially since then to < 1 t in most years. In 2020, the targeted dab net catch increased to 1.6 t, which was the second highest catch since 2008 (Figure 3-3).

Targeted fishing effort across all gears has declined by 90% since 1984, with fishers expending 87 days targeting Southern Garfish in 2020, which was eleven times the effort in 2018 (Figure 3-3). Targeted CPUE in the dab net sector has ranged from 16.7 to 62.2 kg.fisher-day^{-1}. Targeted CPUE for 2020 was 61.5 kg.fisher-day^{-1} (Figure 3-3). The targeted CPUE in the hauling net sector peaked at 77.1 kg.fisher-day^{-1} in 1999. Since 2005, < 5 hauling net fishers have operated in this region per year (Figure 3-3).

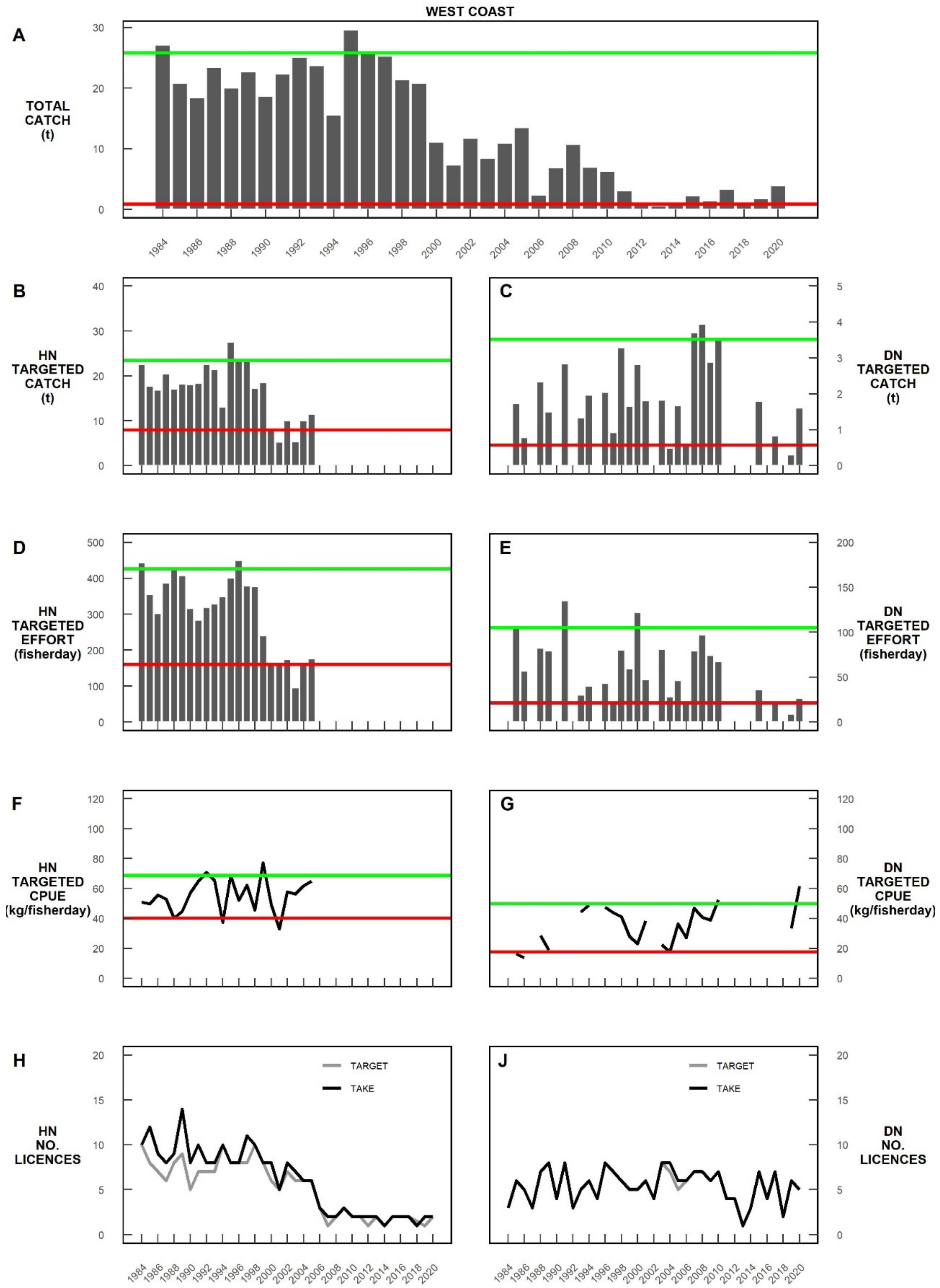

Figure 3-3. Key fishery statistics used to inform the status of the West Coast stock of Southern Garfish: Trends in total catch (A), hauling net targeted catch (B), effort (D) and CPUE (F); The number of active licence holders taking or targeting Southern Garfish with hauling nets. (H) Trends in total effort; dab net targeted catch (C), effort (E) and CPUE (G); The number of active licence holders taking or targeting Southern Garfish with dab nets (J). Green and red lines represent the upper and lower trigger reference points outlined in Table 3.1.

3.3.3. Northern Spencer Gulf

Commercial Fishery Statistics

Northern Spencer Gulf has been the most productive region for Southern Garfish in South Australia since 1984. The highest recorded catch was 271.4 t in 1990 and the lowest was 78.4 t in 2015 (Figure 3-4). Catch declined rapidly (by 61%) from 250 t in 1997 to 98 t in 2003. Annual catches exceeded 160 t twice since 2003 (2006 and 2011) and remained relatively stable between 142 and 150 t from 2012 to 2014, before decreasing to and stabilising at ~100 t from 2015 to 2020. The total catch of Southern Garfish in NSG was 92 t in 2020.

There has been a long-term trend of decreasing fishing effort in this region, from a peak of 3,417 fisher-days in 1989 to 588 fisher-days in 2012. This trend has been driven by the hauling net sector, which has consistently contributed > 95% of the fishing effort (Figure 3-4). Targeted CPUE for hauling net fishers trended upwards from 44.7 kg.fisher-day^{-1} in 2003 to 129.9 kg.fisher-day^{-1} in 2012, representing a 190% increase over nine years (Figure 3-4). CPUE subsequently fell from 101.8 kg.fisher-day^{-1} in 2014 to 51.6 kg.fisher-day^{-1} in 2018 (Figure 3-4). However, CPUE has since increased to 67.7 kg.fisher-day^{-1} in 2019 and 87.7 kg.fisher-day^{-1} in 2020. Since 2003, when units of effort have been reported in logbooks, CPUE in kg.fisher-day^{-1} and kg.haul^{-1} have followed the same trend(Figure 3-4). In 2020, the CPUE was 103.6 kg.haul^{-1} which is the highest since 2014 (105.5 kg.haul^{-1}). Few dab net fishers (< 13) have historically targeted Southern Garfish in this region each year, catching an average of 36 kg.fisher-day^{-1} (Figure 3-4). However, dab net CPUE more than doubled from 28.9 kg.fisher-day^{-1} in 2019 to 68.3 kg.fisher-day^{-1} in 2020 (Figure 3-4).

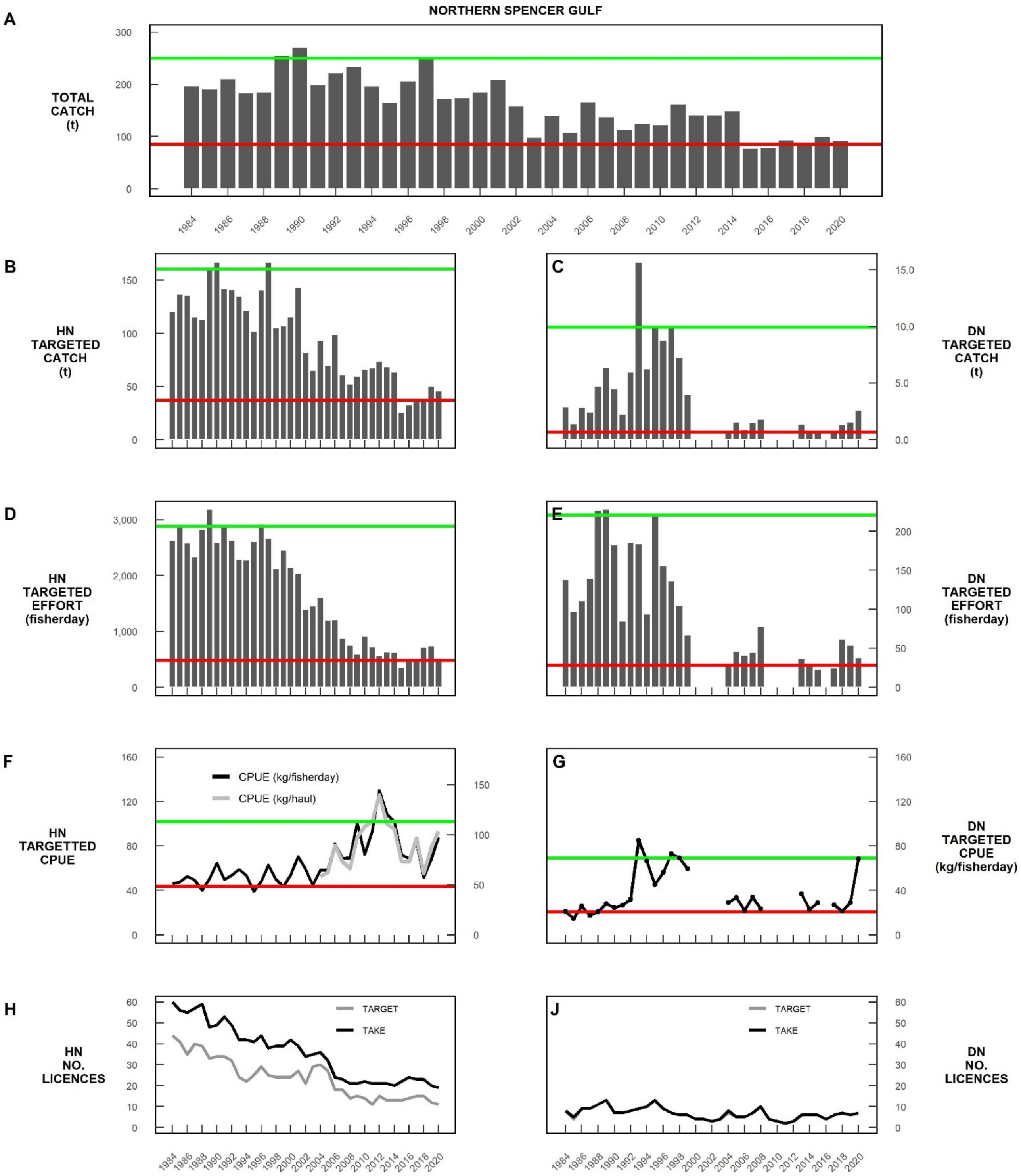

Figure 3-4. Key fishery statistics used to inform the status of the Northern Spencer Gulf stock of Southern Garfish. Trends in total catch (A), hauling net targeted catch (B), effort (D) and targetted CPUE by fisher-day (left axis) and by haul (right axis) (F); The number of active licence holders taking or targeting Southern Garfish with hauling nets. (H) Trends in total effort; dab net targeted catch (C), effort (E) and CPUE (G); The number of active licence holders taking or targeting Southern Garfish with dab nets (J). Green and red lines represent the upper and lower trigger reference points outlined in Table 3.1.

Length and Age Structures

Age samples were sourced primarily from hauling net catches as this sector constitutes most of the catch and effort in NSG. Since 2016, the age structures have been dominated by 2+ and 3+ age classes. Fish aged three years or older constituted greater than 40% of the population in three of the last four years (Figure 3-5). In 2020, the proportion of age 4+ fish was the highest in the time series, suggesting that the population age structure is becoming less truncated (Figure 3-5). The proportion of 3+ year old fish has not increased since the previous assessment which considered data up to and inclusive of 2017.

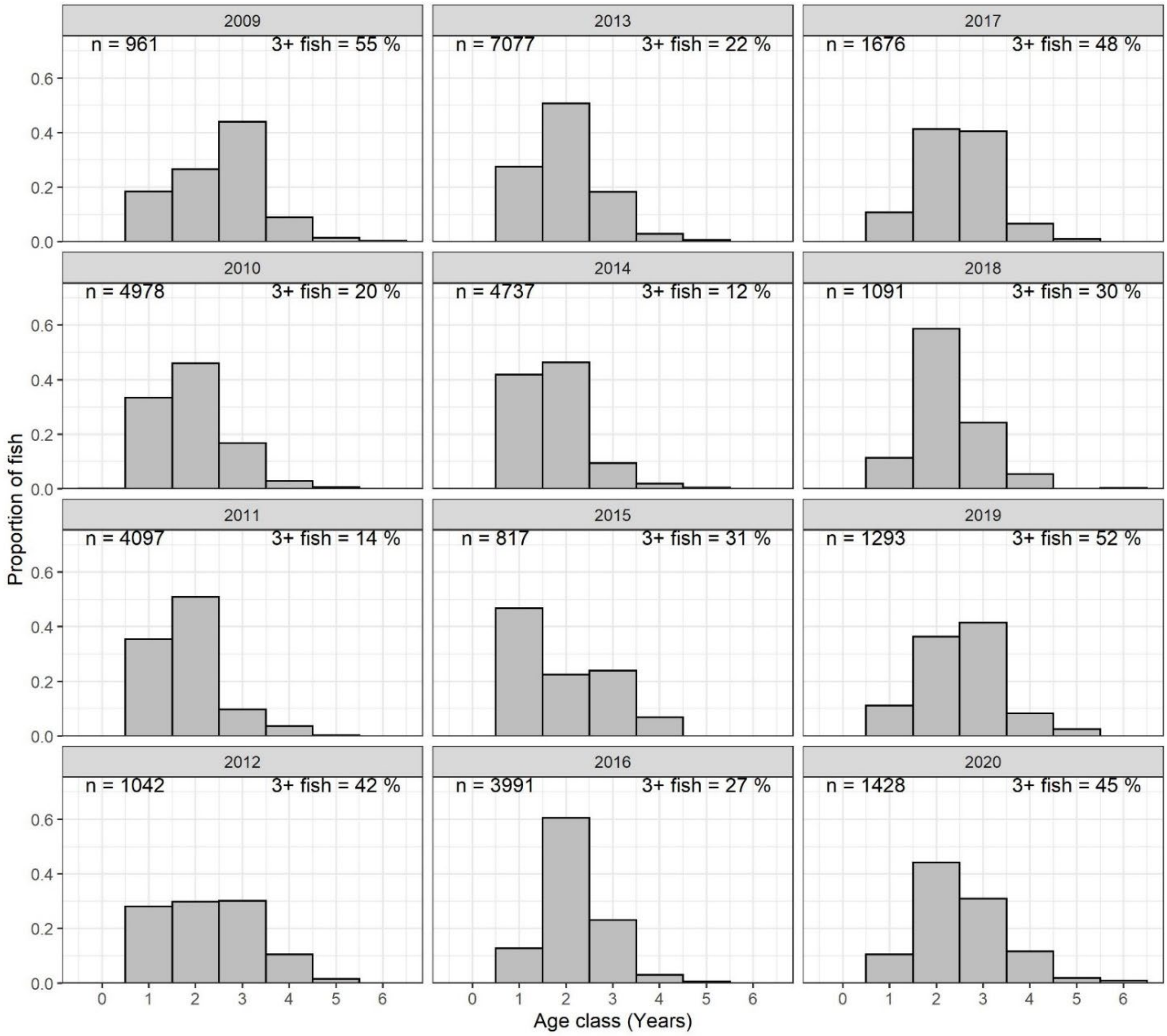

Figure 3-5. Annual age structures for Southern Garfish from Northern Spencer Gulf between 2009 and 2020 based on age-length keys calculated in each year. All fish were sourced from hauling net catches. The percentage of fish aged 3 years or more is displayed in the top right corner for each year.

The length structures of Southern Garfish in NSG show little inter-annual variation between 2009 and 2020. The length distribution across all years was right skewed with a mode between 260 and 280 mm TL, regardless of LML. The only discernible differences in length structures occurred when the LML was increased from 230 mm TL to 250 mm TL in 2015 (Figure 3-6).

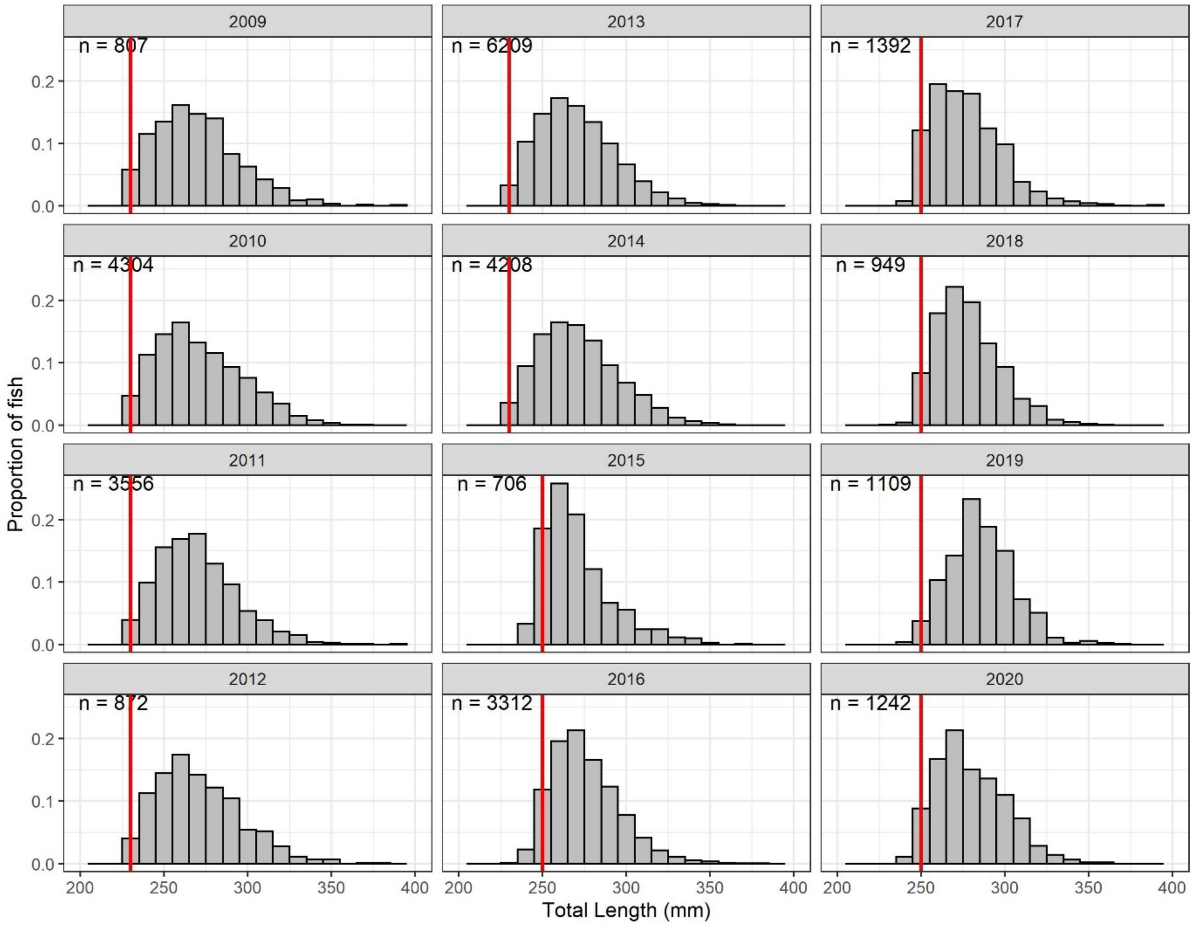

Figure 3-6. Annual length structures for Southern Garfish from Northern Spencer Gulf between 2009 and 2020. All lengths were sourced from hauling net catches. Red line indicates the legal minimum length (LML) in each calendar year.

3.3.4. Southern Spencer Gulf

Commercial Fishery Statistics

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 been < 18% in all years (Figure 3-7). Approximately half of the hauling net fishers who operated in this region specifically targeted Southern Garfish and the peak catch was 80 t in 1998. However, hauling net effort has been reduced through spatial restrictions imposed in 2005, and now this region is almost exclusively fished by the dab net sector.

Total catch of Southern Garfish in this region ranged between 10 and 17 t in the past 5 years and was) and was 11 t in 2020 (*c.f.* 11 t in 2019) (Figure 3-7). Targeted dab net effort remained relatively stable at 128–162 fisher-days from 2011 to 2014, before increasing to reach a peak of 277 fisher-days in 2015. Targeted dab net effort has progressively decreased since 2015 and was 142 fisher-days in 2020 (Figure 3-7). Targeted dab net CPUE in 2020 was the highest on record at 63.1 kg.fisher-day^{-1} which continues an increasing trend over the past four years (Figure 3-7).

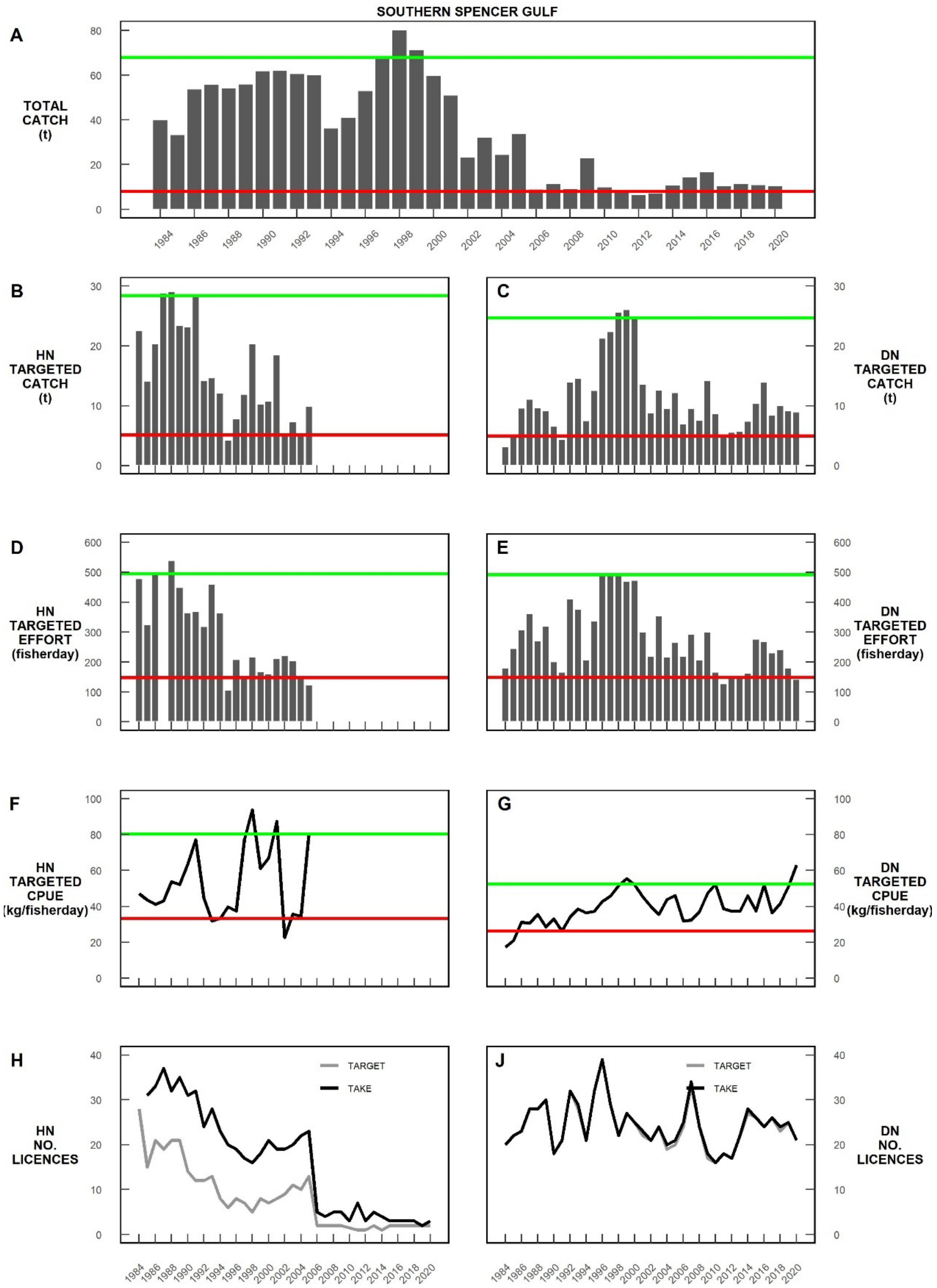

Figure 3-7. Key fishery statistics used to inform the status of the Southern Spencer Gulf stock of Southern Garfish. Trends in total catch (A), hauling net targeted catch (B), effort (D) and CPUE (F); The number of active licence holders taking or targeting Southern Garfish with hauling nets. (H) Trends in total effort; dab net targeted catch (C), effort (E) and CPUE (G); The number of active licence holders taking or targeting Southern Garfish with dab nets (J). Green and red lines represent the upper and lower trigger reference points outlined in Table 3.1.

Length and Age Structures

The age and length structures from SSG were developed from dab net catches as the majority of the catch comes from this sector. Less than 100 fish were sampled in several years as a result of lower catches from SSG compared to other regions (Figure 3-2; Figure 3-8). Years with large sample sizes were dominated by 2+ and 3+ age classes, similar to NSG (Figure 3-8). No samples were collected in 2020. Low sample sizes prevent a meaningful comparison of the proportion of 3+ year old fish between assessments.

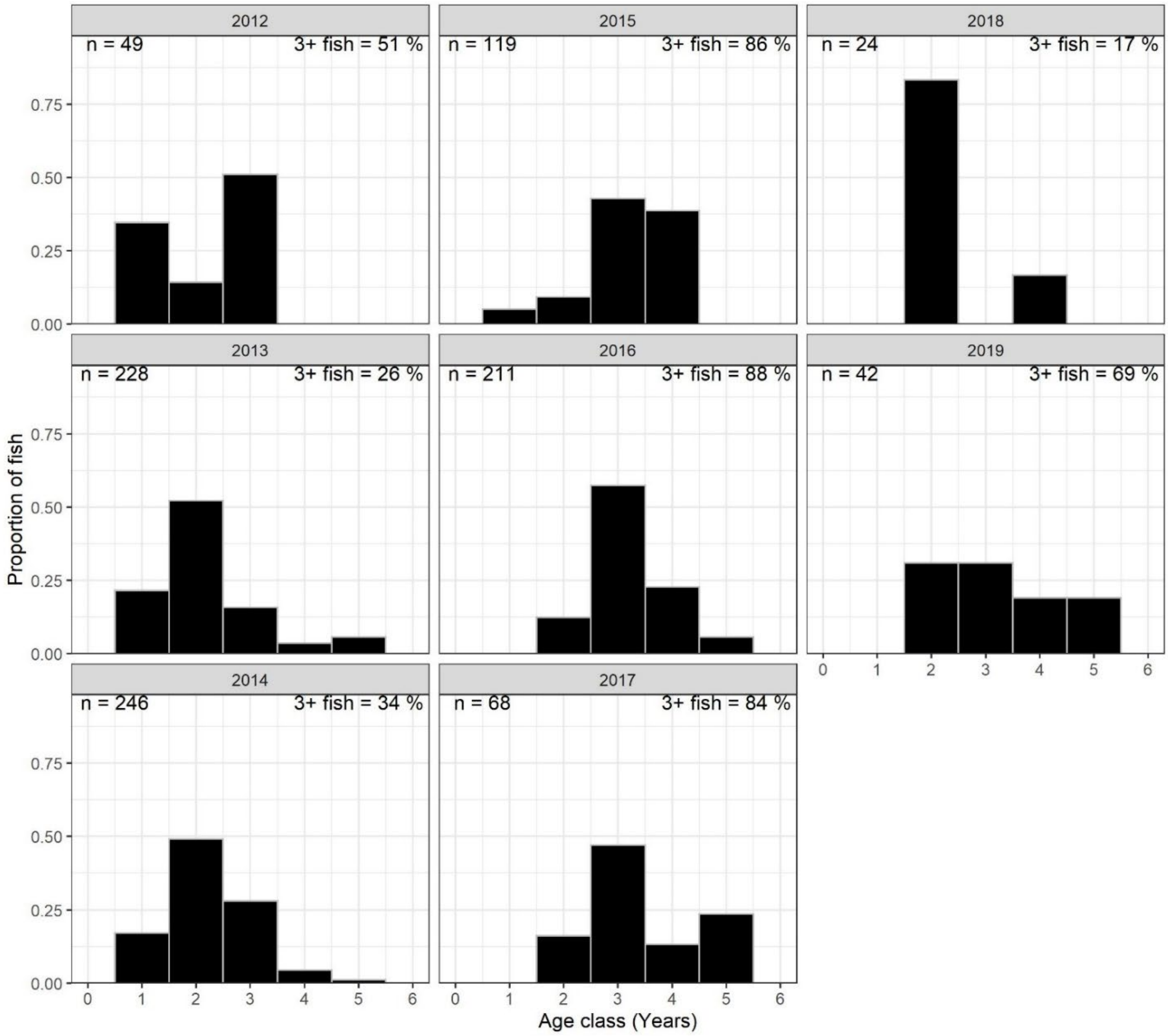

Figure 3-8. Annual age structures for Southern Garfish from Southern Spencer Gulf from 2012 to 2019 based on age-length keys calculated in each year. All fish were sourced from dab net catches. The percentage of fish aged 3 years or more is displayed in the top right corner for each year.

The length structures from SSG had larger Southern Garfish than NSG for years with sufficient sample sizes to enable comparison (i.e. 2013, 2014 and 2016) (Figure 3-9). However, the differences in fishing gear among regions makes it difficult to consistently differentiate between regional population differences versus potential differences in gear selectivity.

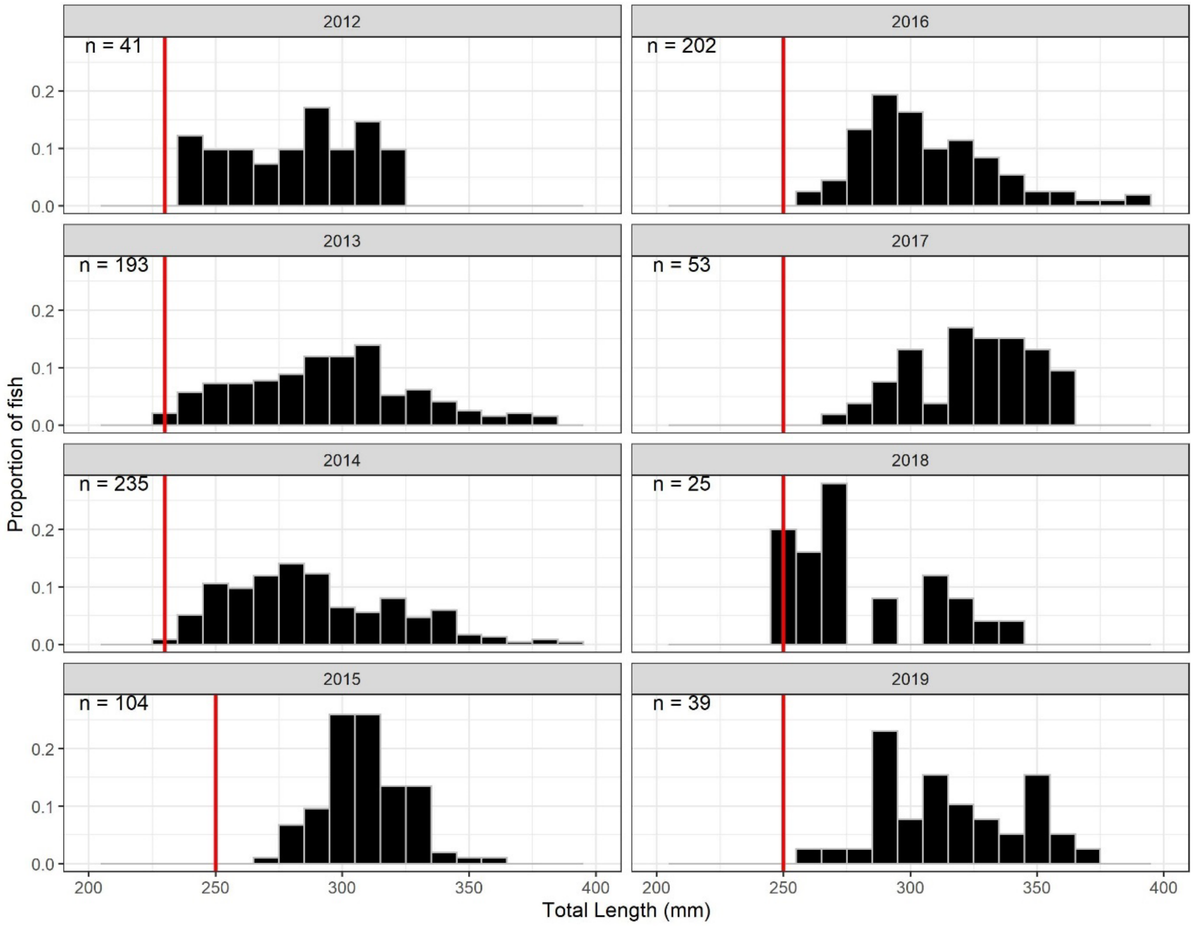

Figure 3-9. Annual length structures for Southern Garfish from Southern Spencer Gulf from 2012 to 2019. All lengths were sourced from dab net catches. Red line indicates the legal minimum length (LML) in each calendar year.

3.3.5. Northern Gulf St Vincent

Commercial Fishery Statistics

Northern Gulf St Vincent is the second-most productive commercial fishing region in South Australia for Southern Garfish and catches are dominated by the haul net sector. Annual catches were > 200 t in three of the past 37 years; 221 t in 2000, 209 t in 2001 and 210 t in 2005, before declining to a record low of 53 t in 2016. The total catch in 2020 was 58 t which was the second lowest on record (Figure 3-10). This represents a 46% decline over the past 10 years, which corresponds with decreased hauling net targeted effort, and an overall decline in targeted hauling net CPUE from its peak of 110 $kg.fisher\text{-}day^{-1}$ in 2001 to 49 $kg.fisher\text{-}day^{-1}$ in 2020 (Figure 3-10). There was a strong relationship between hauling net CPUE based on $kg.fisher\text{-}day^{-1}$ and hauling net CPUE based on $kg.haul^{-1}$ since 2003 when units of effort have been reported in logbooks (Figure 3-10). In 2020, the CPUE was 89.8 $kg.haul^{-1}$ which was the highest since 2014 (*c.f.* 92 $kg.haul^{-1}$).

Conversely, levels of annual targeted catch and effort in the dab net sector have increased and were 10 t and 185 fisher-days in 2020, respectively (Figure 3-10). This level of dab net catch has not occurred since 1997. Targeted CPUE in this sector was 34 to 45 $kg.fisher\text{-}day^{-1}$ between 2009 and 2018, and has increased to its second highest peak of 54 $kg.fisher\text{-}day^{-1}$ in 2020 (Figure 3-10).

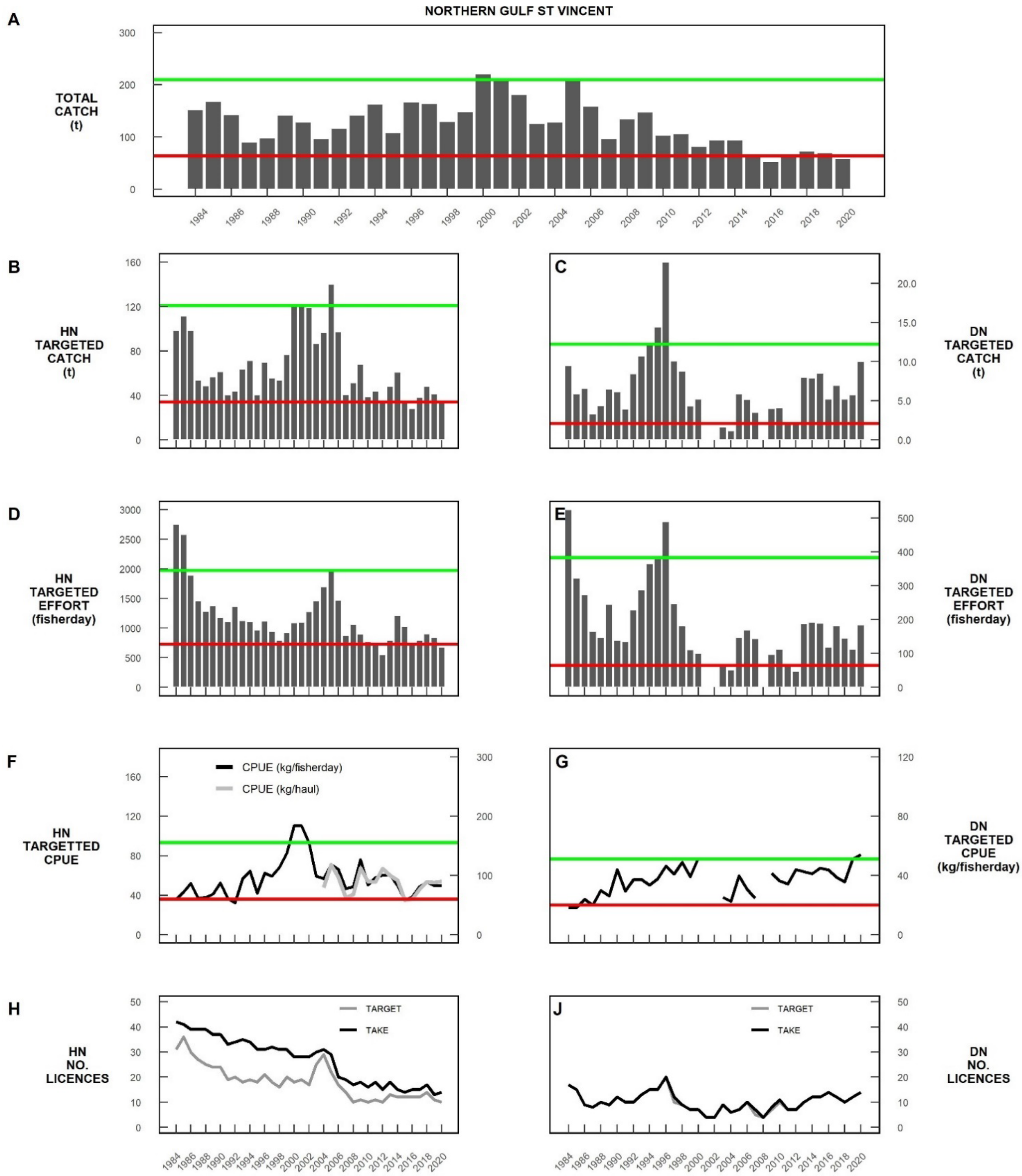

Figure 3-10. Key fishery statistics used to inform the status of the Northern Gulf St Vincent stock of Southern Garfish. Trends in total catch (A), hauling net targeted catch (B), effort (D) and targeted CPUE by fisher-day (left axis) and by hauling (right axis) (F); The number of active licence holders taking or targeting Southern Garfish with hauling nets. (H) Trends in total effort; dab net targeted catch (C), effort (E) and CPUE (G); The number of active licence holders taking or targeting Southern Garfish with dab nets (J). Green and red lines represent the upper and lower trigger reference points outlined in Table 3.1.

Length and Age Structures

Length and age structures from NGSV were sourced from the hauling net sector as dab net catches did not provide sufficient sample sizes to allow comparison across years. This corresponds to the relative catches between the two sectors. Hauling net catches in all years were dominated by age 2+ and 3+ fish, although the proportions of age 3+ fish in hauling net catches were lower than NSG. The proportions of age 3+ fish have not increased over time and were 30–33% in 2019 and 2020 (Figure 3-11). The proportion of age 4+ fish has not increased over time and remained low in 2020. Clear signs of population age truncation remain.

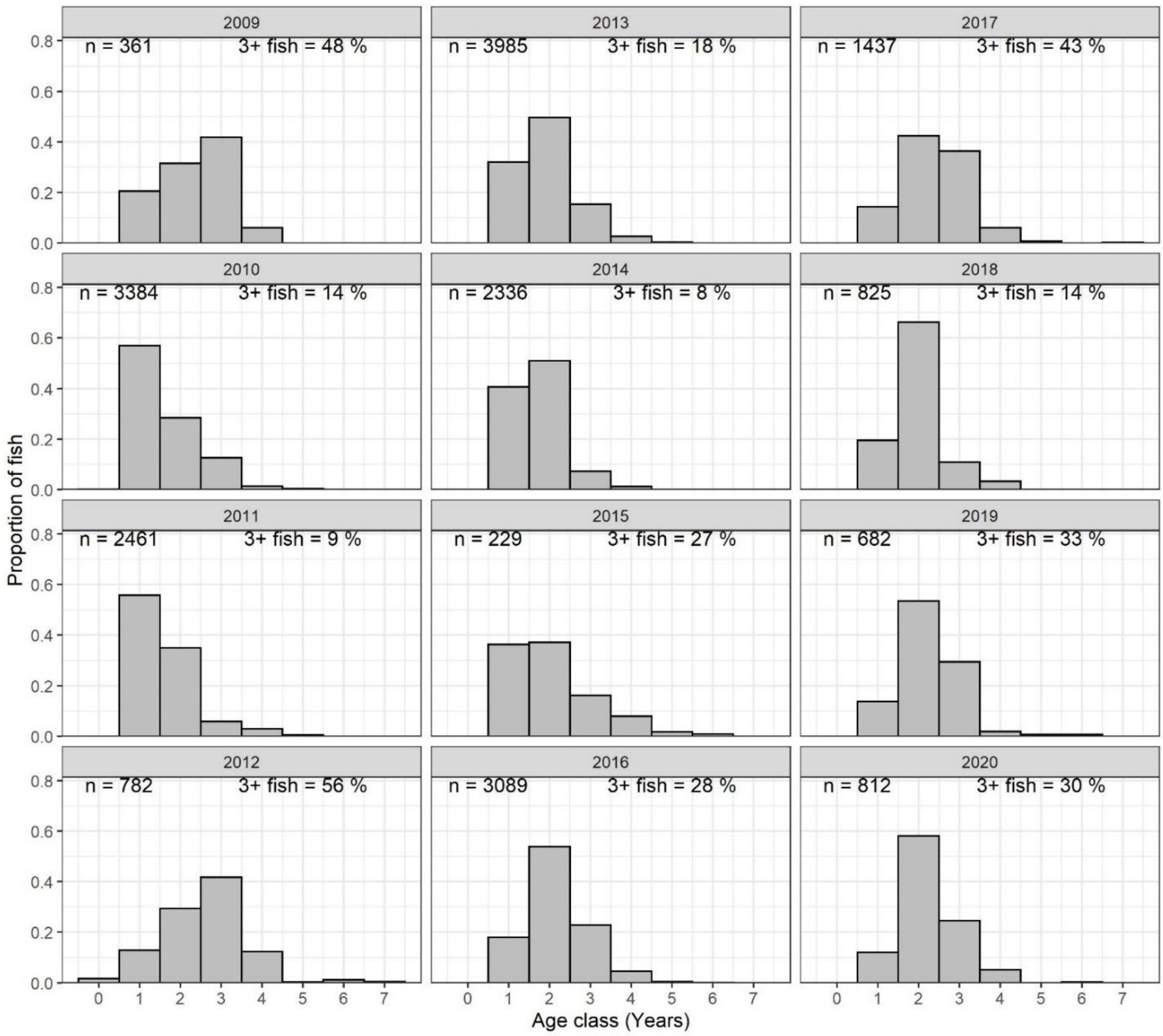

Figure 3-11. Annual age structures for Southern Garfish from Northern Gulf St Vincent from 2009 to 2020 based on age length keys estimated in each year. All fish were sourced from hauling net catches. The percentage of fish aged 3 or more is displayed in the top right corner for each year.

There was little differentiation between length structures from hauling net catches for most years in NGSV. The length distribution across all years was right skewed with a mode between 250 and 280 mm TL, regardless of LML. Similar to NSG, the only discernible changes in length structure occurred with changes in LML (Figure 3-12).

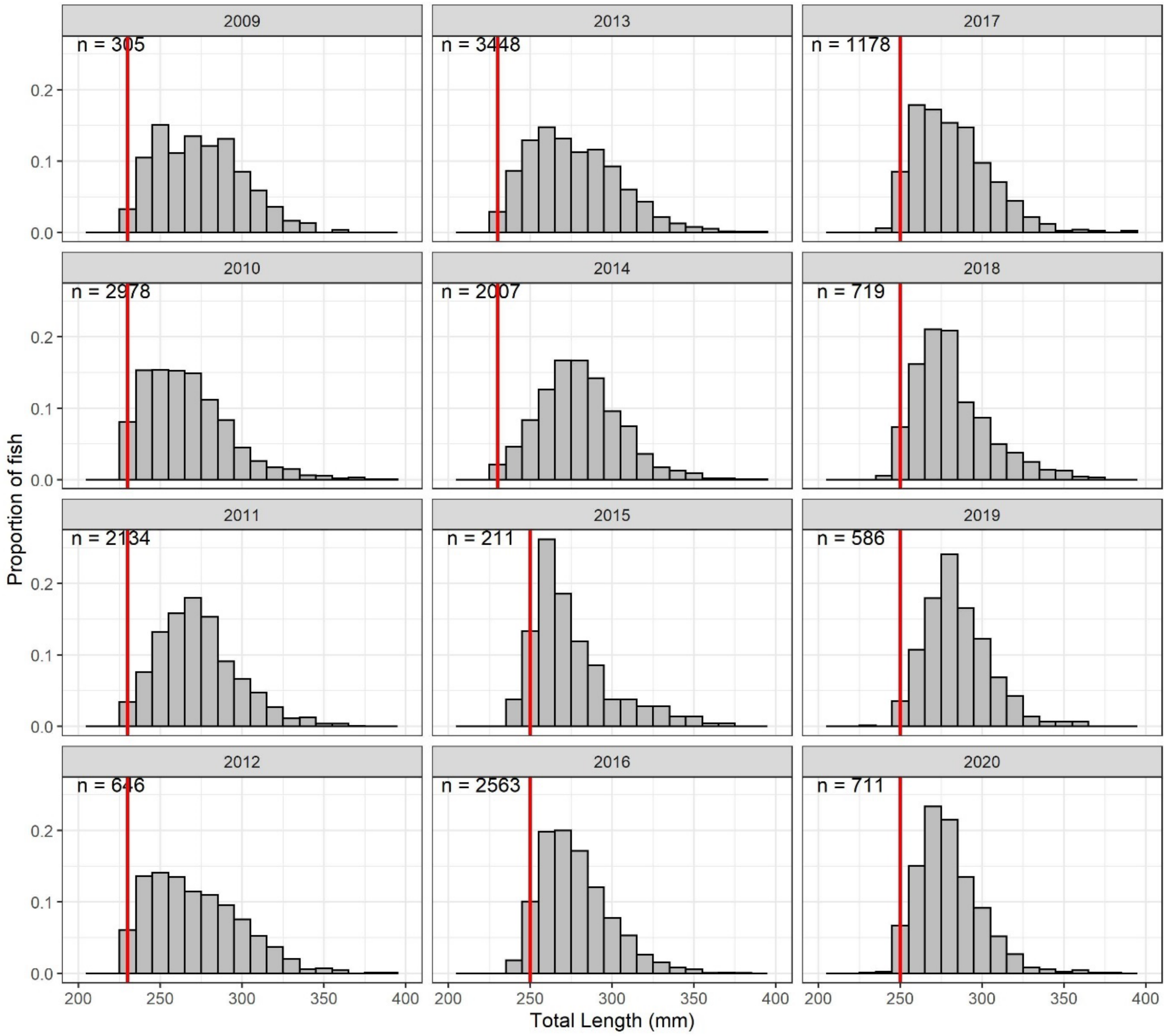

Figure 3-12. Annual length structures for Southern Garfish from Northern Gulf St Vincent from 2009 to 2020. All fish were sourced from haul net catches. Red line indicates the legal minimum length (LML) in each calendar year.

3.3.6. Southern Gulf St Vincent Stock

Commercial Fishery Statistics

The relative contribution of catches from SGSV has rarely exceeded 10% of the annual State-wide total and was only 2.4 % in 2020. Annual catches steadily increased from 24 t in 1984 to 70 t in 1993 with both the haul net and dab net sectors contributing equally (Figure 3-13). From 1993, the contribution of catch by the haul net sector declined in line with steady reductions in effort (Figure 3-13). Since 2005, the dab net sector has accounted for >75% of annual commercial fishing effort in SGSV because of netting restrictions which virtually removed all haul net activity from the region. Targeted dab net effort declined from 540 fisher-days in 2005 to a record low of 39 fisher-days in both 2015 and 2016. Targeted dab net effort was 56 fisher-days in 2020. In 2017, targeted dab net catches increased to 8.4 t, before decreasing to 4.0 t in 2020 (Figure 3-13). CPUE in the dab net sector fluctuated since 1984 between 21.0 and 72.2 kg.fisher-day^{-1}, with the overall mean target dab net CPUE for the region equalling 44.0 kg.fisher-day^{-1} (Figure 3-13). The targeted dab net CPUE for 2020 was 64.8 kg.fisher-day^{-1} which was the fourth highest CPUE on record (Figure 3-13).

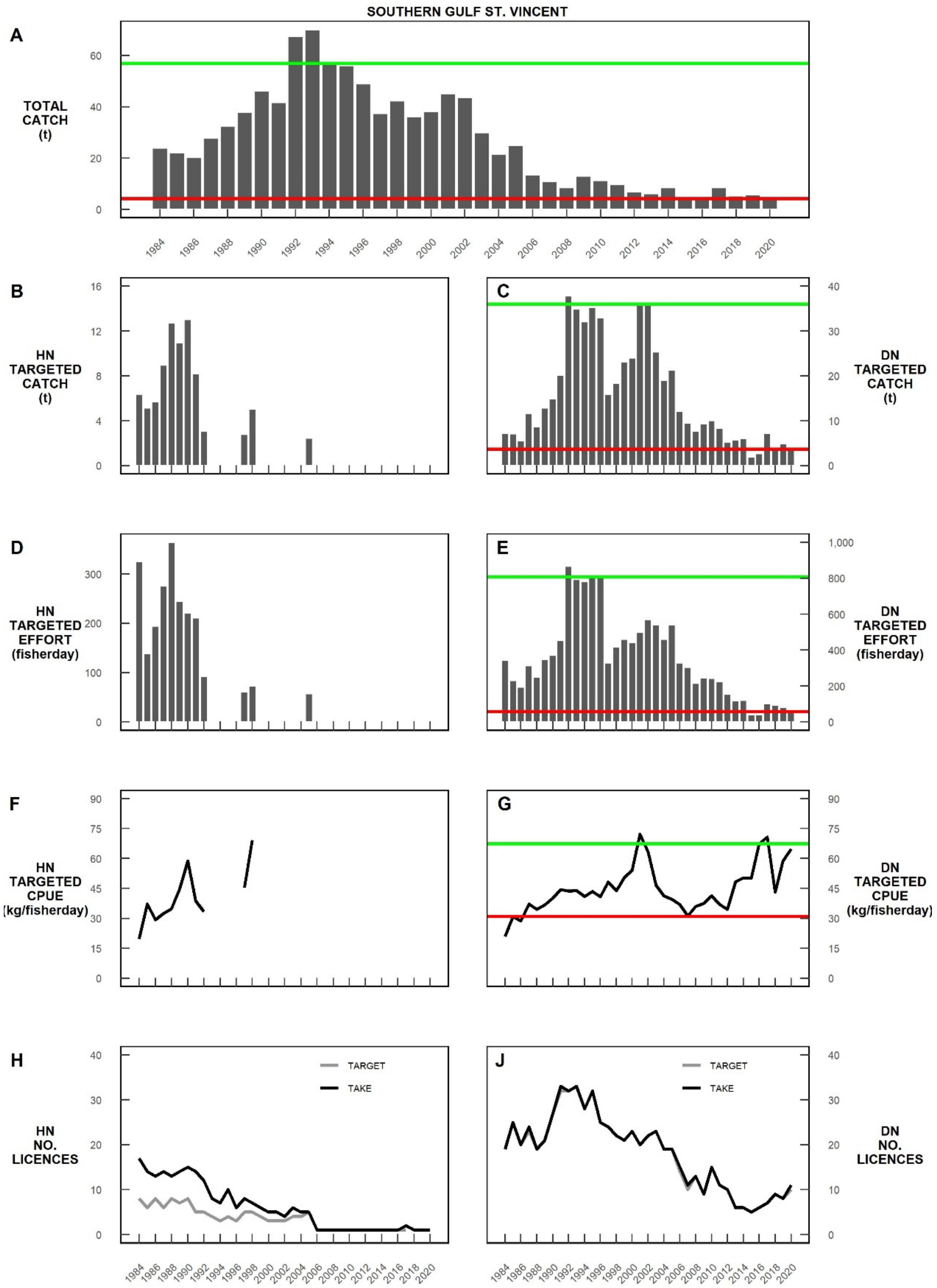

Figure 3-13. Key fishery statistics used to inform the status of the Southern Gulf St Vincent stock of Southern Garfish. Trends in total catch (A), hauling net targeted catch (B), effort (D) and CPUE (F); The number of active licence holders taking or targeting Southern Garfish with hauling nets. (H) Trends in total effort; dab net targeted catch (C), effort (E) and CPUE (G); The number of active licence holders taking or targeting Southern Garfish with dab nets (J). Green and red lines represent the upper and lower trigger reference points outlined in Table 3.1.

Length and Age Structures

Since 2010, only a small number of dab net catch samples have been collected from SGSV, due to low annual catches taken in this region (Figure 3-14). The age structures in both 2010 and 2013 had sample sizes above 100 fish and were dominated by 2+ fish (Figure 3-14). However, the small sample sizes across years limits the interpretation of age structures from being discussed.

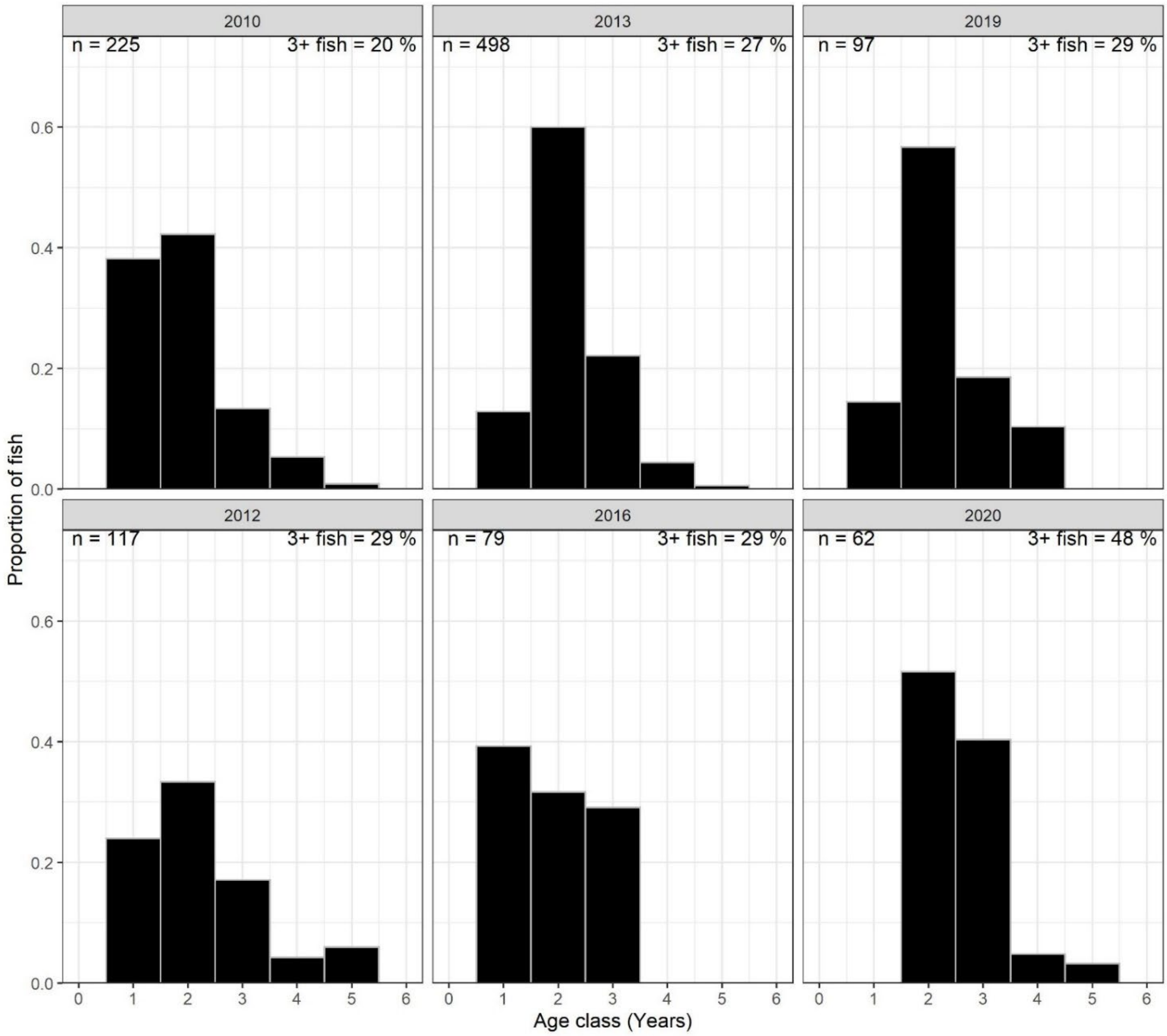

Figure 3-14. Annual age structures for Southern Garfish from southern Gulf St Vincent available from 2010 to 2020 based on age-length keys calculated in each year. All fish were sourced from dab net catches. The percentage of fish aged 3 or more is displayed in the top right corner for each year.

Similar to the age structures, fewer length samples were attained from SGSV in comparison to NGSV. The changes in LML had the greatest influence on these length structures over time. However, despite lower sample sizes there were indications that in 2019 and 2020 the length structures of Southern Garfish included a greater proportion of larger individuals in comparison to 2013 (Figure 3-15).

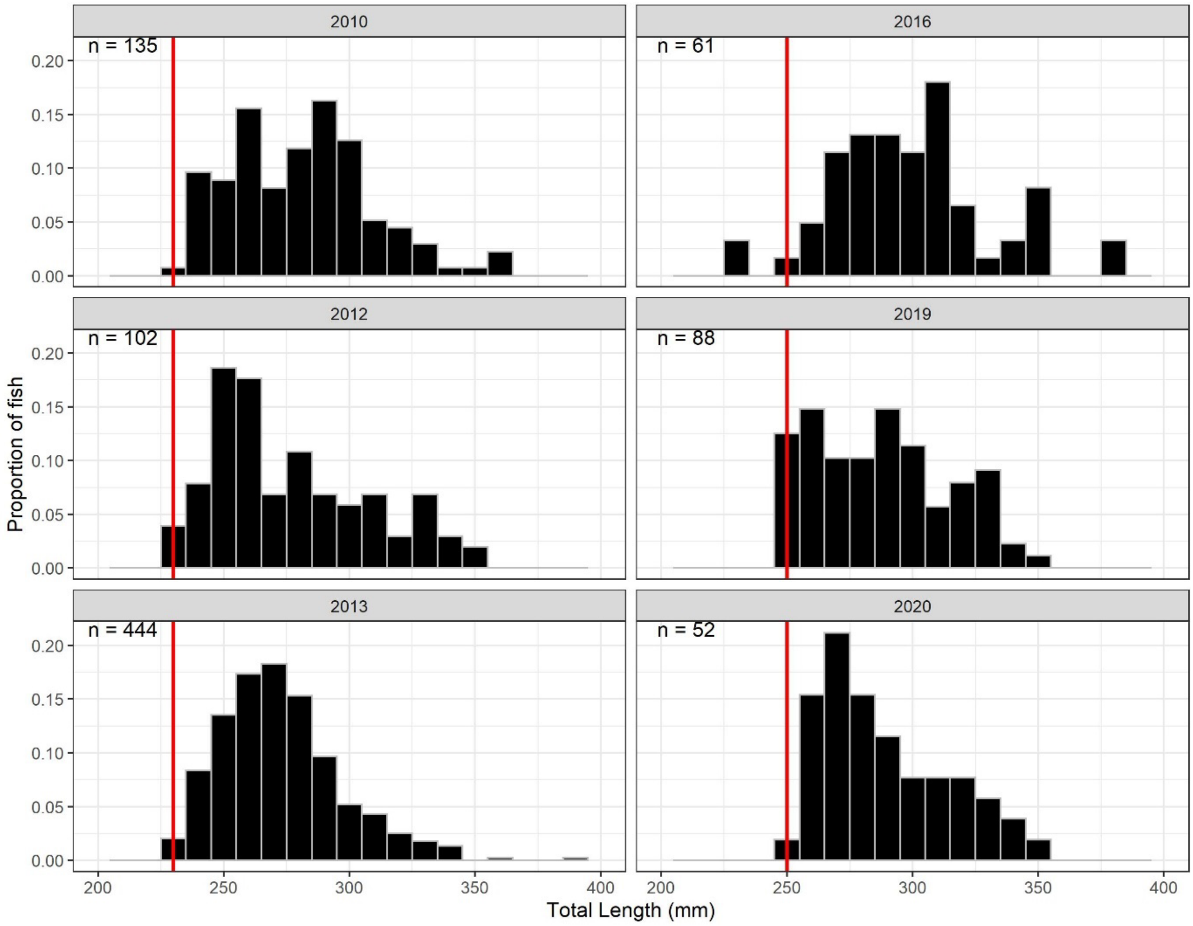

Figure 3-15. Annual length structures Southern Garfish from southern Gulf St Vincent from 2010 to 2020. All lengths were sourced from dab net catches. Red line indicates the legal minimum length (LML) in each calendar year.

3.3.7. South East

Negligible catches of Southern Garfish were landed by the commercial sector in the South East, with only 40 t landed in the region across the 37-year time-series. The total number of fishers reporting catches has been < 5 in several years, resulting in catch and effort data being confidential. However, the total catch in 2020 was the highest on record at 3.5 t (Figure 3-16).

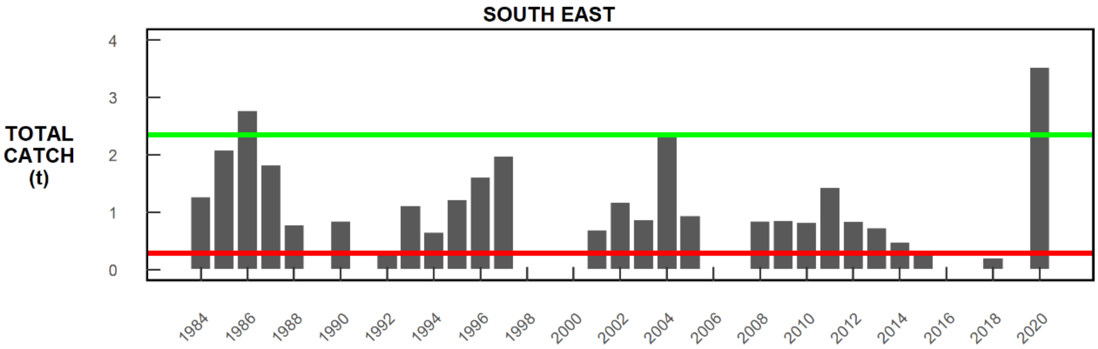

Figure 3-16. Total catch (t) for the South East stock of Southern Garfish. Green and red lines represent the upper and lower trigger reference points outlined in Table 4-5.

3.3.8. GarEst Model Results

Spencer Gulf fishing zone

The primary BPIs for the fishery are modelled estimates of harvest fraction and percent virgin egg production. Harvest fractions have reduced considerably over the history of the fishery, particularly since 2005 when a net licence buyback scheme occurred (Figure 3-17). The percentage of virgin egg production has averaged 15% over the history of the fishery with no long-term trend of rise or fall. Previous stock assessments have identified the target percentage virgin egg production of > 30% by 2020 was unlikely to be met (Steer et al. 2016; Steer et al 2018), which has been supported by this assessment (Figure 3-17).

The target harvest fraction for the fishery was to reach < 30% by 2020 which corresponds to an operational target of < 35% in 2019 (Figure 3-17). However, the harvest fraction in 2019 was 40% and has been stable since 2017 when it was 39%. Therefore, while harvest fractions have been substantially reduced since 2001, in recent years they have not met the operational targets outlined in the Management Plan.

The adult biomass increased from a historical low of 281 t in 2003 to 417 t in 2011 (Figure 3-17). Since 2011, adult biomass has been stable and ranged from 294 t to 373 t (Figure 3-17). The adult biomass was estimated as 346 t in 2019. The estimated adult biomass has been within the upper and lower trigger reference points in every year since 2005, except in 2010 and 2011 when it exceeded the upper TRP.

Recruitment in recent years has been particularly low and was 1.8 million recruits in 2019, having decreased from 3.1 million recruits in 2018. Recent recruitment was lowest in 2015 at 2.9 million recruits before increasing to > 3.4 million recruits in 2016 and 2017, suggesting that estimates up until 2018 were not negatively impacted by changes in gear restrictions. As recruitment is reliant on age structure information from subsequent years, the last year of estimated recruitment is less well informed by data than earlier years and is more uncertain than other model years.

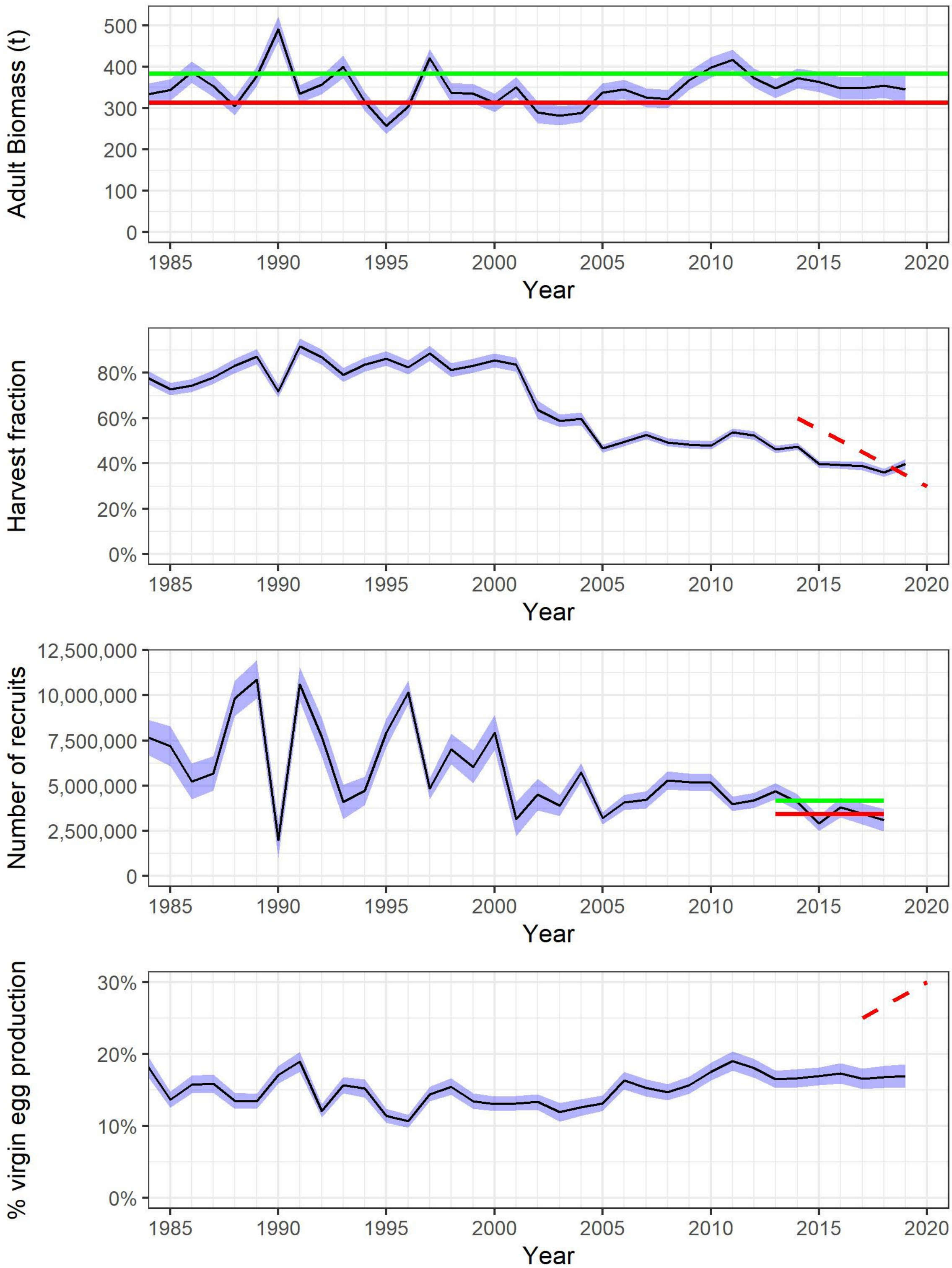

Figure 3-17. Model estimated biological performance indicators for Spencer Gulf from 1984 to 2019. The black line represents the model estimates, and the blue shading represents the standard errors estimated by the GarEst stock assessment model. The green and red lines represent upper and lower performance indicators, respectively, for adult biomass (> 210 mm) and recruitment. The year of each recruit number estimate is the cohort (January) year of spawning. Red dashed lines represent target values for a given year for harvest fraction and % virgin egg production.

Gulf St Vincent/Kangaroo Island fishing zone

Adult biomass declined rapidly between 2001 and 2007 from a peak of 380 t to a low of 218 t (Figure 3-18). In subsequent years, adult biomass stabilised at an average of 256 $t.y^{-1}$ until 2017. Modelled adult biomass has since increased to 304 t in 2019. This indicates a stock recovery of 40% since the historically low adult biomass in 2007. The adult biomass has been within the upper and lower TRPs since 2013 (Figure 3-18).

The primary BPIs for GSV/KI are modelled estimates of percentage virgin egg production and harvest fraction. Historically, the harvest fraction for GSV/KI was > 70% from 1984 to 2003. However, from 2006 harvest fraction then followed a progressively declining trend and reached a low of approximately 30% in 2016. The harvest fraction in 2019 was 31% which is within the operational target (Figure 3-18). The percentage of virgin egg production has averaged 14% since 1984 for GSV/KI, although this was higher in 2019 at 17% (Figure 3-18). However, this indicates that the target percentage of >30% by 2020 is unlikely to be achieved, as has been anticipated in previous assessments.

A declining trend in recruitment between 2007 and 2015 contributed to the stock being classified as ‘depleted’ in previous assessments (Steer et al. 2016; 2018b). Since 2015, recruitment has increased by 26% to 2.5 million recruits in 2018 (Figure 3-18). While this is still lower than the time-series average of 4.1 million recruits, it provides a positive sign of stock recovery.

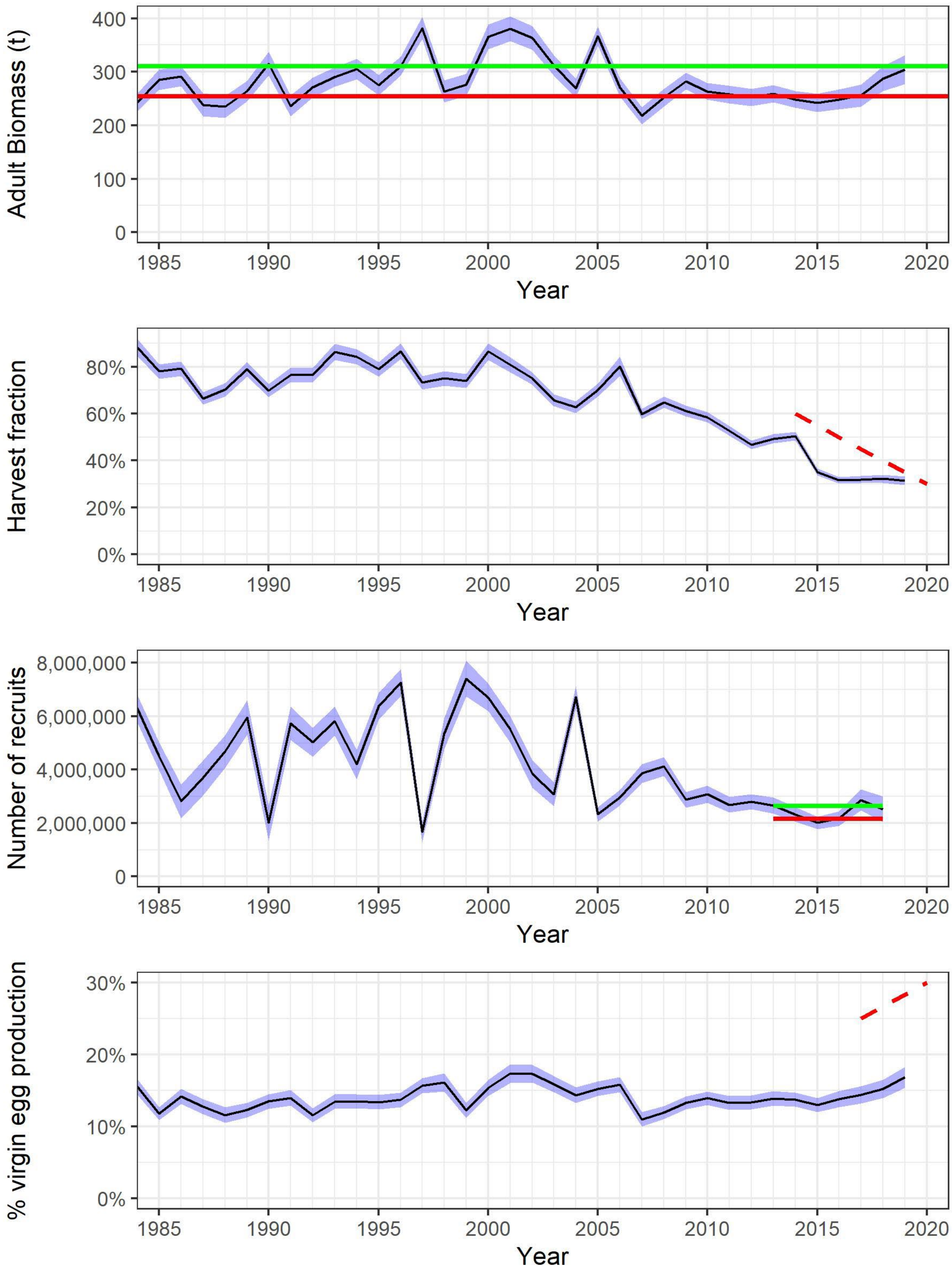

Figure 3-18. Model estimated biological performance indicators for Gulf St Vincent/Kangaroo Island from 1984 to 2019. The black line represents the model estimates, and the blue shading represents the standard errors estimated by the GarEst stock assessment model. The green and red lines represent upper and lower performance indicators, respectively, for adult biomass (> 210 mm) and recruitment. The year of each recruit number estimate is the cohort (January) year of spawning. Red dashed lines represent target values for a given year for harvest fraction and % virgin egg production.

3.3.9. Fishery Performance

The proportional contributions of the three commercial fisheries to the State-wide commercial catch have been relatively stable over the past five years (Table 3-3). No trigger limits have been exceeded by any sector since 2016 (Table 3-3).

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%
2016	99.95%	0.03%	0.02%
2017	99.81%	0.19%	0.00%
2018	99.92%	0.08%	0.01%
2019	99.91%	0.09%	0.00%
2020	99.53%	0.47%	0.00%

The general performance indicators were assessed at the regional stock level. Several trigger reference points (TRPs) were breached across each of the six stocks. The highest dab net CPUE on record occurred for WC, NGSV and SSG stocks (Table 3-4). The targeted dab net effort was the second lowest on record for SSG and SGSV stocks (Table 3-4). Targeted hauling net effort was the second lowest for NGSV. Total catch was the 2nd lowest for NGSV, 3rd lowest for SGSV and the highest on record for the SE (Table 3-4).

Modelled estimates of harvest fraction and egg production are the primary BPIs used in this assessment to determine the status of each regional component of South Australia's Southern Garfish fishery. In this assessment they have been applied at the fishing zone level (i.e. SG and GSV/KI) following the creation of these management units during the MSF reform. These zones are amalgamations of several regional stocks, notably the northern and southern stocks of each gulf, although the SG fishing zone also includes information from catch statistics on the south-west coast of the Eyre Peninsula. The operational objective of harvest fractions of < 35% in 2019 was achieved for GSV/KI (31%), but not for SG (40%) (Table 3-4). The egg production target of 28% by 2019 was not achieved and was 17% for both GSV/KI and SG. There has been no improvement in the fishery age structures for either fishing zone since 2017 (Table 3-4). The proportion of age 3+ fish in 2020 was 3% and 13% lower in 2019 than 2017 for SG and GSV/KI, respectively (Table 3-4)

Model estimates of adult biomass and recruitment constitute the remaining BPIs and contribute to the 'weight-of-evidence' approach used to determine the status of the resource in each region. Adult biomass has been stable for both SG and GSV/KI and was within their respective upper and lower TRPs. Adult biomass has had an increasing trajectory for GSV/KI since 2016, indicative of stock recovery. Estimates of recruitment for GSV/KI were above the upper TRP in 2018 and 5% higher than the average recruitment over the previous 5 years (Table 3-4). The estimate of recruitment for SG in 2018 was 18% lower than the average recruitment over the previous 5 years, triggering the lower TRP (Table 3-4).

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. Age compositions refer to age structures from haul net catches from the northern stock of each gulf.

	PERFORMANCE INDICATOR	TYPE	OPERATIONAL OBJECTIVE	TRIGGER REFERENCE POINT	WC	NSG	SSG	NGSV	SGSV	SE	GSV/KI	SG
PRIMARY	HARVEST FRACTION	B	≤ 60% 2014	> 60% 2014							47%	58%
		B	≤ 45% 2017	> 45% 2017							32%	39%
		B	≤ 35% 2019	> 35% 2019							31%	40%
			≤ 30% 2020	> 30% 2020								
	EGG PRODUCTION	B	25% 2017	< 20% 2017							15%	17%
		B	28% 2019	< 28% 2019							17%	17%
		B	30% 2020	< 30% 2020								
SECOND.	AGE COMPOSITION	B	Prop. Age 3+	No change or reduction							↓ 17% 2017	↓ 1% 2017
	TOTAL HAULING NET EFFORT	G	↓ ≥ 13% 2014	↓ < 10% since 2011								
OTHER	Harvestable Biomass	B	No Target	3 year average is +/- 10% of previous years							×	×
	Recruitment	B	No Target	+/- 10% from the average of previous 5 years							×	↓ 18%
	TOTAL CATCH	G	No Target	3rd Lowest / 3rd Highest	×	×	×	2nd LOWEST	3rd LOWEST	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 EFFORT	G	No Target	3rd Lowest / 3rd Highest		×		2nd LOWEST				
		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 EFFORT	G	No Target	3rd Lowest / 3rd Highest	×		2nd LOWEST	×	2nd LOWEST	×		
		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	HIGHEST		HIGHEST	HIGHEST	×	×		
		G	No Target	Greatest % interannual change (+/-)	×		×	×	×	×		
		G	No Target	Greatest 5 year trend	×		×	×	×	×		
		G	No Target	Decrease over 5 consecutive years	×		×	×	×	×		

3.4. Discussion

3.4.1. Context of this Assessment

A structural reform of the MSF has occurred since the previous Southern Garfish stock assessment in 2017 (Steer et al. 2018b). As part of the reform, four new fishing zones were created to facilitate regional management: (1) Spencer Gulf (SG), (2) Gulf St Vincent/Kangaroo Island (GSV/KI), (3) West Coast (WC) and (4) South East (SE) (Figure 1-1). Southern Garfish were assigned a 'Tier 1 status' for the SG and GSV/KI fishing zones and are now managed by a total allowable commercial catch (TACC) that is unitised into individual transferable quotas (ITQs). While these management arrangements commenced in July 2021, outside the time frame of this assessment, these new zones of management have been applied in GarEst modelling for this report to align with the current management arrangements for the fishery.

This assessment applied a new CPUE series with gear-specific effort units for NGSV and NSG targeted hauling net CPUE. Previously, haul net CPUE was only calculated using 'fisher-days' which is the standard effort unit for all gear types in the MSF. 'Fisher-days' is a valuable effort unit for describing the performance of the fishery as it allows comparability between fishing gears. However, as CPUE is used to infer or estimate relative abundance, there is value in determining methods to better disentangle changes in fishery dynamics or fishing efficiency from its time series. Gear-specific effort units have been reported in daily logbook records since 2003, allowing contemporary CPUE estimates to be calculated through multiple methods. The effort units reported specifically for haul nets are the length of the net (m) and the number of shots per day. This report calculated CPUE as $kg.haul^{-1}$ which provided additional information as part of the assessment for NGSV and NSG where haul net catches dominate the Southern Garfish fishery. The CPUE expressed in $kg.haul^{-1}$ and $kg.fisher\text{-}day^{-1}$ followed the same trend. The length of fishing nets did not provide value to CPUE calculations as 84% of logbook records in the fishery reported a consistent net length of 600 m and 95% reported net lengths between 500 and 600 m.

Since the last assessment (Steer et al. 2018b), an FRDC-funded project determined that commercial catches reflected stock status in GSV and provided additional information on population demographics (FRDC 2015-018; Fowler 2019). There were two main outcomes from that project that were specifically considered in this assessment: (1) it is most likely that Southern Garfish in Gulf St Vincent constitute a single biological stock, although the demographic processes that regulate the populations in NGSV and SGSV are largely discrete; and (2) the highest abundances of Southern Garfish were in NGSV and co-occurred with the availability of *Zoestera muelleri*, an intertidal seagrass that is an essential food source.

Although the demographic processes of Southern Garfish in Spencer Gulf were not investigated, it is likely that the processes responsible for population replenishment are similar.

The first outcome supports the realignment of the GarEst model to the spatial scale of the biological stock, which is consistent with the new SG and GSV/KI fishing zones. This approach provides outputs at the appropriate scale, notably for quota setting within each gulf zone. The second outcome, regarding the spatial abundances of Southern Garfish, provides insight into why modelled adult biomass in each gulf may not have significantly increased despite substantial management interventions that have been implemented since the early 2000's. This is discussed further in section 3.4.3.

The model outputs for the GSV/KI fishing zone incorporates catch and effort data, as well as age and length structures from both the NGSV and SGSV regions. However, the majority of the data informing this model originates from the NGSV stock as most of the catch and effort occurs in this region, and the biomass is higher than in SGSV (Fowler 2019). Therefore, the outputs of this model are largely representative of the NGSV stock dynamics and can be used to determine its stock status in this assessment. The SG fishing zone has been treated similarly, with the results of the GarEst model used to determine stock status for NSG.

3.4.2. Stock Status

Determination of Stock Status

The status of each of the six regional South Australian Southern Garfish stocks was classified using the national stock status classification framework (Piddocke et al. 2021) (Table 1-1). The assignment of stock status used a weight-of-evidence approach that included fishery performance indicators and associated trigger reference points prescribed 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 the population age structures and outputs from the GarEst model (Table 3-1). 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 is impaired because the adult biomass no longer has the reproductive capacity to replenish itself). Instead, the performance of the fishery is primarily assessed against modelled trends in the harvest fraction of the adult (> 210 mm TL) biomass and egg production, as required by the current harvest strategy.

West Coast Stock

A negligible amount of Southern Garfish is landed by the commercial sector in the WC zone, and its contribution to the State-wide total has rarely exceeded 2%. The implementation of commercial netting restrictions in this region has contributed to the continuous reduction in haul net effort since the late 1950s (Steer et al. 2016). In the absence of haul net fishing, the current level of exploitation of Southern Garfish off the WC is unlikely to cause the biological stock to become recruitment overfished. On this basis, the WC Southern Garfish stock is classified as **sustainable**.

Northern Spencer Gulf Stock

In 2017, the NSG stock of Southern Garfish was assigned the status of 'recovering' (Steer et al. 2018b). This status reflected favourable reductions in the harvest fraction which had continued to track toward the operational target trajectory of ≤ 30% by 2020. Egg production and fishable biomass had remained relatively stable since the previous stock assessment undertaken in 2015 (Steer et al. 2016), and there were positive signs of an increase in population age structure, with higher proportions of age 3+ fish.

Signs of stock recovery were also evident in this assessment. Notably, harvest fraction has been reduced from > 80% in 2001 to within the operational targets during 2014–2018. The long-term decline and recent stabilisation of the harvest fraction has contributed to a stabilisation in adult biomass (fish > 210 mm TL) at moderate levels since management measures were introduced in 2005. Over the past 15 years, the adult biomass has been stable at approximately 350 t and within the TRPs, except for 2010 and 2011 when it exceeded the upper TRP. Despite these positive signs, the modelled number of recruits entering the fishery remained low in 2019 compared to historical estimates from the 1990's and has trended downward in recent years indicating that recruitment remains impaired in NSG. Nevertheless, the population age structures for recent years have contained higher proportions of age 3+ fish, which indicates that the population in NSG is continuing to recover from age truncation. This is supported by recent trends in the fishery statistics. For example, in 2020 the dab net CPUE was the highest in more than 20 years, while haul net CPUE had also increased since 2018.

The above evidence indicates that appropriate management is currently in place, the stock is continuing to recover, and the current level of fishing mortality should allow the stock to recover from its recruitment impaired state. On this basis, the NSG Southern Garfish stock remains classified as **recovering**.

Southern Spencer Gulf Stock

Large areas of SSG are closed to hauling net fishing, with the most recent closure being implemented around southern Yorke Peninsula in 2005. Consequently, the haul net sector has been effectively removed from this region and, as such, become predominantly fished using dab nets. Targeted dab net effort has remained moderately high and stable (~200 fisher-days) over the past 5 years, although there was a decrease in effort in 2020. Associated CPUE was within the upper and lower TRPs until 2020 when it increased to its highest level on record and breached the upper TRP. This indicates that the biomass is at a sufficient level to ensure that future levels of recruitment are adequate (i.e., not recruitment impaired) and fishing mortality is adequately controlled to avoid the stock becoming recruitment impaired. Consequently, the SSG Southern Garfish stock is classified as **sustainable**.

Northern Gulf St Vincent Stock

In 2017, the NGSV stock of Southern Garfish was classified as 'depleted' (Steer et al. 2018b). However, the assessment identified that targeted hauling net CPUE had increased; harvest fraction had trended downwards; egg production and recruitment had remained relatively stable; older Southern Garfish had appeared in the population age structure, and that fishing mortality appeared to be constrained by management to a level that should enable the stock to recover from its recruitment impaired state. Despite these positive signs, measurable improvements in fishable biomass were not detected in that assessment (Steer et al. 2018b).

The current assessment indicates that changes in management arrangements are effectively recovering the NGSV stock. Recent increases in hauling net CPUE and dab net CPUE occurred following increases to LML and hauling net mesh size, which have led to increases in adult biomass since 2016. Percentage virgin egg production has also trended upward since 2016. Harvest fractions have reduced considerably from ~80% in 2006 to ~30% in 2019 and are within the operational targets for the fishery. The model estimate of adult biomass increased by 22% between 2016 and 2019 and is within the TRPs for this stock. This is the first increase in biomass that has occurred since 2009. Despite this, the numbers of recruits entering the fishery each year since 2005 have remained at much lower levels than the recruitment peaks of earlier years, and lower than the mean level of recruitment estimated up to 2004. Also, the proportion of older fish (i.e., age 3+) has not increased in recent age structures, which are still dominated by a few younger age classes (i.e., age 1+ and 2+). Consequently, the age structure of the NGSV population remains truncated.

Adjustments to the management arrangements for the fishery in NGSV over the past ten years, such as changes to LML, gear restrictions and the implementation of spatial closures, have reduced exploitation rates to target levels and enabled increases in adult biomass due to higher CPUE for hauling nets and dab nets. The above evidence indicates that appropriate management is currently in place, the stock is recovering, and the current level of fishing mortality should allow the stock to recover from its recruitment impaired state. On this basis, the NGSV Southern Garfish stock has been changed from depleted to **recovering**.

Southern Gulf St Vincent Stock

Prior to 1993, the commercial catch of Southern Garfish from SGSV was equally shared between the hauling net and dab net sectors. During the 1990s and early 2000s, catches from the hauling net sector declined due to a steady reduction in fishing effort, and in 2005, hauling nets were effectively removed from this region through the implementation of a voluntary net buy-back scheme and spatial netting closures. Consequently, dab nets have been the dominant gear type since 2006. Prior to these changes, the commercial catch of Southern Garfish from SGSV rarely exceeded 10% of the State-wide harvest, and after their implementation, further reduced to < 5%. The history of this regional fishery and its current stock status are very similar to SSG, which is characterised by low levels of commercial catch and effort compared to the northern gulf regions and extensive netting closures. The relatively low levels of exploitation in SGSV 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 SGSV biological stock is classified as **sustainable**.

South East Stock

Like the West Coast, a negligible amount of Southern Garfish was landed by the commercial sector in the South East, with the State-wide contribution rarely exceeding 0.3%. Even though the total catch of Southern Garfish in 2020 was the highest recorded, the current level of exploitation in the South East is unlikely to cause the biological stock to become recruitment overfished. On this basis, the South East Southern Garfish stock is classified as **sustainable**.

3.4.3. Assessment Uncertainties

As with many stock assessment models, there is uncertainty around the estimate of natural mortality (*M*) included in the GarEst model. The sensitivity analyses (Appendix 7.8) identified that the time invariant estimate for natural mortality influences the scale of modelled biomass. An estimate of *M* is available from sampling conducted in Baird Bay where netting closures have been in place since the 1950's. Therefore, this population provides an indication of unfished age structures that allowed *M* to be estimated from catch curves. This was estimated as 0.55 yr^{-1} by Jones (1990) for fish aged 4–9 years of age for both sexes combined. For females aged 4–8 years, Jones estimated an $M = 0.35$ yr^{-1}. However, the Southern Garfish sampled in Baird Bay are much older than those found in SG and GSV/KI, which are mainly 2–3 years of age. The GarEst assumed value of *M* applies for ages 1 year old and older and natural mortality is expected to be lower for the younger gulf age classes. An estimate of $M = 0.4$ yr^{-1} is used in the model for both sexes. If a value of $M = 0.5$ yr^{-1} was assumed, model biomass estimates would be higher, and likewise lower *M* values result in lower absolute biomass estimates (Appendix 7.8). This does not affect estimated depletion and therefore trends in stock recovery are unaffected. However, as Southern Garfish are now managed under TACCs in the SG and GSV/KI fishing zones, accurate estimates of absolute biomass may be required by future harvest strategies for TACC setting. The current value of *M* rerpresents a precautionary approach for recommending TACCs based on modelled biomass.

Currently, the NGSV and NSG Southern Garfish stocks are classified as 'recovering' following substantial management measures that have reduced harvest fractions and increased adult biomass. However, no recovery in modelled recruitment has occurred since management measures were introduced. Unless recruitment begins to trend upward in future assessments, it will be challenging to consider a 'sustainable' status regardless of other BPI performances, as SAFS guidelines clearly state that 'sustainable' stocks cannot be recruitment impaired. Therefore, it is important to consider why modelled recruitment has not improved in line with adult biomass and harvest fractions. There are two sources of uncertainty regarding modelled recruitment during the 1990s when estimates were substantially higher: (1) availability of age and length structure data, and (2) the possibility that recent low estimates of annual recruitment is attributed to some density-dependent mechanism.

The first source of uncertainty is that age and length data have only been available from routine market sampling done at the SAFCOL fish market since 2004 and during 1999-2000 from a FRDC-funded project (Ye et al. 2002). It would be prudent to extend the catch sampling program to other fish processing facilities, particularly those near key regional fishing ports, to provide more representative samples from across the fishery. Age structures are particularly informative of relative recruitment as they provide stock assessment models with information on year class strength as well as total mortality. Model estimated recruitment will be more certain in years where these data are available. For example, the estimates of high recruitment in the 1990s are relatively unreliable due to a lack of age and length data. Instead, the model BPIs during this period of the assessment are reliant on catch and effort statistics from commercial logbooks. These data indicate that substantial reductions in fishing effort occurred in both NSG and NGSV since 2000. The age and length data since 2004 indicates that *F* has declined in line with effort which is supported by the model fits to both datasets. Therefore, if the catchability of fishing gears remains unchanged throughout the time series (for which there is no evidence to suggest otherwise), fishing mortality during the 1990s will be far higher than that of 2000 onwards in both NSG and NGSV. In the 1990s, harvest fractions of > 80% were estimated in both regions which suggested that there must have been strong recruitment to avoid population collapse. The key uncertainty is whether modelled estimates of recruitment in the 1990s are accurate enough to evaluate whether recent estimates are truly impaired, or if they are estimated with greater accuracy and less volatility than those estimated prior to the availability of age and length data.

The second source of uncertainty is the possibility that recruitment is density dependent which may explain why recent estimates are substantially lower than those of the 1990s. Given that harvest fractions have been substantially reduced in both NSG and NGSV, a greater response in adult biomass was expected than is evident in the model outputs. This suggests that there could be additional ecological processes that are limiting biomass and preventing increased population growth, despite reduced harvest fractions. The spatial distribution and abundances of Southern Garfish in South Australia are strongly associated with Zosteracean seagrass beds, which is why the highest fishery catches come from the northern gulf regions that support extensive areas of intertidal seagrass (i.e., NGSV and NSG) (Jones et al. 2002, Earl et al. 2011, Fowler 2019). Relative abundances of Southern Garfish were recently examined by Fowler (2019) through a fishery-independent sampling program, which reiterated that adult abundances were strongly associated with this habitat. Therefore, it is possible that Southern Garfish populations could be primarily limited by habitat, and that population replenishment in the northern gulfs is limited by the health and availability of Zosteracean seagrass beds. A consequence of this possible resource limitation is that adult biomasses are hyperstable and at carrying capacity. Under this hypothesis, a reduction in harvest fraction may lead to a reduction in recruitment, rather than an increase in biomass.

The density dependence hypothesis may also explain how Southern Garfish populations withstood the high harvest fractions of the 1990s. If each adult removed by fishing is quickly replaced by a recruiting juvenile, regardless of how fast the adults are removed, biomass will remain stable. As Southern Garfish are a short-lived, early-maturing and fast-growing species, their ability to replenish the population following high levels of exploitation is greater than most other finfish species, making this hypothesis plausible. Density dependence may also contribute to the low estimates of recruitment in recent years after exploitation rates have been reduced. If biomass is held stable due to resource limitations, then lower catches remove fewer adults. With less adults being removed, the current hypothesis suggests there may be less juveniles recruiting to the population to replace them. To test this hypothesis, there is a need to better understand the biological mechanisms that regulate recruitment of Southern Garfish in South Australia, i.e., how egg production, egg and larval survival, and juvenile abundance affect the annual recruitment of age-1 fish to the population. There is not yet sufficient evidence to support this hypothesis of stable biomass and conclude that recruitment is not impaired. Such a phenomenon is rare in fisheries science and merits further exploration.

The TRPs outlined in the Management Plan (PIRSA 2013) have limitations that have been highlighted in previous assessments (Steer et al. 2018b). For example, the reference period (i.e., most recent five model years) used to assess trends in recruitment is too short and encompasses a time period that does not display the full variability of this BPI. Therefore, recent low estimates of recruitment often fall within the TRPs and this is not always appropriate given the long histories of both gulf stocks. Additionally, the operational objective of reaching 30% of virgin egg production by 2020 has not been achieved, as anticipated in previous assessments (Steer et al. 2018b). This occurs as virgin levels of biomass were determined by forecasting population recovery given the average level of estimated recruitment. As recent recruitment is far lower than the average estimated recruitment, increased percentages of virgin egg production have not sufficiently occurred over time

A further 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 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 accuracy and 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. A current recreational fishing survey is underway which is supported by an FRDC project (FRDC 2020-056) that will examine the efficacy of using smart phone applications for future surveys. The outcomes of this project may provide more accurate and timely recreational catch and effort estimates for future surveys.

3.4.4. Future Research Directions

A key uncertainty in this stock assessment for Southern Garfish relates to the proposed hypothesis of density dependence and hyperstable biomass. Currently, this hypothesis explains the outputs of the GarEst model when combined with context from Fowler (2019) that concluded that the majority of Southern Garfish biomass in GSV occurs in areas that support the highest densities of *Zoestera muelleri*. However, insufficient evidence is currently available to reliably evaluate this hypothesis as model-based outputs must be supported by additional biological evidence. Given the consequences of this hypothesis for assigning stock status and for future management decisions, a high degree of confidence must be reached before it can be supported. Therefore, dedicated research to evaluate the hypothesis of density dependence is required.

Hyperstable biomass estimates could be assessed through the development of a fishery independent survey (FIS) for Southern Garfish in NSG and NGSV. Such surveys are already implemented in several SA fisheries through industry collaborations and provide valuable inputs to harvest strategy decision rules (Beckmann and Hooper 2021, McLeay and Hooper 2021, Noell and Hooper 2021). The development of a FIS for Southern Garfish would be valuable as it would allow an independent index of abundance to be determined for biomass. This would provide further context for ongoing stock recoveries and provide more empirical evidence to test the hypothesis on density dependence in the northern gulfs. An FIS would also provide valuable information and data to inform future harvest strategies.

A model-based strategy to examine a hypothesis around density dependence would be to review how recruitment is estimated within the GarEst model. Currently, GarEst does not include a stock recruitment relationship and annual recruitment is freely estimated. For many fish stocks, the relationship between stock size and annual recruitment can be weak or poorly understood, and often strongly influenced by prevailing environmental or oceanographic conditions. However, given the significance of the model estimated recruitment, there would be value in exploring additional recruitment methods within the GarEst model. If several methods for estimating recruitment perform similarly then this would provide more certainty on the shift in annual recruitment that is currently identified by the GarEst model.

A better understanding of the ecological competition between juvenile and adult Southern Garfish would also help assess this hypothesis. For example, Southern Garfish are an obligate herbivore leading to their dependence on *Zoestera muelleri* (Earl et al. 2011). Improving the understanding of how this herbivory develops ontogenetically could determine whether competition exists between adults and juveniles, which is the basis of the density dependence hypothesis. For example, the feeding behaviour of Southern Garfish has distinct diurnal patterns where adults predominantly feed on *Zoestera muelleri* during the day and switch to hyperbenthic invertebrates at night (Earl et al. 2011). If juvenile Southern Garfish exhibit the same feeding behaviours, then it is possible that, should adult abundances decline, competition between juveniles and adults could lead to a density dependent reduction in juvenile mortality (and therefore increased recruitment).

The opportunity to improve and refine TRPs will occur through upcoming harvest strategy development. The recent reform of the MSF has led to TACC management being implemented in the SG and GSV/KI fishing zones (Smart et al. 2022). Currently, these TACCs have been set using estimates of recent average annual catches (2015 – 2019) and require refinement through harvest strategy development that establishes appropriate decision rules. Likewise, the current Management Plan (PIRSA 2013) does not outline thresholds that would support changes to stock status. Currently, a weight-of-evidence approach based on the SAFS classification system (Table 1-1) is used. However, past assessments have identified issues in determining whether positive trends in fishery statistics and population estimates have been sufficient to warrant changes to the stock status for NSG and NGSV. Stock status could be assigned with a higher level of confidence in the future if performance indicators were designed to be more indicative of stock status and aid decision making.

4. STOCK STATUS OF OTHER KEY SPECIES

4.1. Introduction

This section of the report uses a weight-of-evidence approach to determine the stock status of 19 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. Methods

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. These data span a 37-year time-series from 1984 to 2020 and were aggregated at either the biological stock, State-wide or regional scales to provide annual estimates of catch and effort for the main gear types (Table 4-1). Data on by-product of Southern Calamari by SA’s three Western King Prawn fisheries are also included.

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 general performance indicators for 2020 were benchmarked against the trigger reference points calculated from the historical data. The national stock status classification system developed for the Status of Australian Fish Stocks Report 2020 (Piddocke et al. 2021) was used to assign stock status (see Table 1-1).

Table 4-1. List of MSF categories and species/taxa considered in this report, the scale of their stock boundary, main gear types, and whether the assessment is based on targeted or total catch and effort data.

CATEGORY	SPECIES / TAXON	STOCK	GEAR	TARGETED OR TOTAL
PRIMARY	SNAPPER	Biological	Handline, Longline	Targeted
	KING GEORGE WHITING	Biological	Handline, Hauling Net, Gillnet	Total
	SOUTHERN CALAMARI	State-wide and regional	Squid Jig, Hauling Net	Targeted
	SOUTHERN GARFISH	State-wide and regional	Hauling Net, Dab Net	Targeted
SECONDARY	YELLOWFIN WHITING	Biological	Hauling Net	Targeted
	WA SALMON	State-wide	Hauling Net	Targeted
	AUST. HERRING	State-wide	Hauling Net	Targeted
	SNOOK	State-wide	Hauling Net	Targeted
	BLUE CRABS	State-wide	Crab Net	Targeted
	SAND CRABS	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
	OCEAN JACKETS	State-wide	Fish Trap	Targeted
TERTIARY	BLUETHROAT WRASSE	State-wide	Handline, Longline	Total
	SILVER TREVALLY	State-wide	Handline	Total
	LEATHERJACKETS	State-wide	Hauling Net	Total
	RAYS AND 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

Biology

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

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

Fishery

Snapper is an iconic fishery resource in each mainland State of Australia (Kailola et al. 1993). Throughout the mid-2000s, SA was the dominant State-based contributor to the national total catches of both the commercial and recreational sectors (Fowler et al. 2016). SA's Snapper fishery is geographically extensive and encompasses most of the State's coastal marine waters from the far west coast of Eyre Peninsula to the SE region, although the highest abundances have generally been in Spencer Gulf (SG) or Gulf St Vincent (GSV), which have consequently produced the highest fishery catches (Drew et al. 2022).

Snapper is a primary target species of the commercial and recreational sectors of SA (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). The main gear types used by commercial fishers to target Snapper are handlines and longlines, since using hauling nets to take Snapper was prohibited in 1993. For local recreational fishers and others from inter-state, Snapper has been an important species in SA's waters because of their desire to catch the large trophy fish (Drew et al. 2022). Recreational fishers target Snapper using rods and lines, primarily from boats, although jetty and land-based catches do occur. Based on the most recent recreational fishing survey in 2013/14, the contributions to total State-wide catch by the commercial and recreational sectors were 62% and 38%, respectively (Giri and Hall 2015, Fowler et al. 2016).

The spatial structure of SA's Snapper fishery underwent considerable change between 2008 and 2012 (Fowler et al. 2016). Historically, SG supported the highest catches and CPUE. However, these declined considerably, whilst contemporaneously those in NGSV and the SE increased to unprecedented levels. For the three different stocks these changes reflected different, independent demographic processes that related to recruitment and adult migration (Fowler 2016, Fowler et al. 2017). From 2011 onwards, the changes in the spatial structure of the fishery and deteriorating stock status' caused considerable issues for managing the fishery. This resulted in numerous management changes that were implemented to limit commercial catches and to maximise the opportunities for spawning and recruitment success, including significant spatial closures to Snapper fishing in SA's waters from 1 November 2019 to 31 January 2023. Furthermore, several FRDC-funded research projects were undertaken to firstly identify the demographic processes responsible for the observed spatial changes (FRDC 2012/020, Fowler 2016), and also to develop a fishery independent index of fishable biomass (FRDC 2014/019, Steer et al. 2017).

Management Regulations

The timeseries below describes the broad approach and historical changes to the management protocols for the commercial, recreational and charter boat sectors of the Snapper fishery. Nevertheless, since 1st November 2019, these protocols have been superseded by the following significant spatial closures and management changes:

- a total Snapper fishing closure for the waters of the west coast of Eyre Peninsula, Spencer Gulf and Gulf St Vincent until 31 January 2023;
- an annual closure in the waters of the SE Region was applied from 1st November 2020 to 31st January 2021. For the remainder of each year, this region was open to fishing, although a total allowable catch applied, to be shared amongst the commercial (81% share), indigenous (1%) and recreational/charter boat (18%) sectors.
- The TAC for the SE Region for 2020 (1 February–31 October 2020) was 75 t, of which 60.75 t was allocated to the commercial sector as a TACC. The recreational sector received a total allowable recreational catch (TARC) of 13.5 t of which 7.5 t was allocated to the Charter Boat Fishery (which equated to 3,788 fish) and 6 t was allocated to recreational fishers which equated to 3,030 fish. The TARC was implemented through a tag-based system.
- In 2020, the following fishing limits applied to the recreational sector: minimum legal size of 38 cm; personal bag limit of one Snapper; and a boat limit of three Snapper (when 3 or more people are fishing on board).

The spatial closures that were imposed in November 2019 reflect the poor statuses that were assigned to the SG/WCS and the GSVS in the stock assessment undertaken in that year (Fowler et al. 2019). Their purpose was to return these Snapper fisheries to sustainable stock levels. Particularly for the SG/WCS, the 'depleted' status was the culmination of a deterioration in stock status since 2011 (Fowler et al. 2013, 2016, 2019). From then until late 2019, the management strategy was modified numerous times, attempting to redress the deteriorating stock status. Nevertheless, the strategies adopted did not result in recovery of the stock.

Prior to the fishery closures that were imposed in November 2019, regulations for the commercial sector of SA's Snapper fishery involved a suite of input and output controls (PIRSA 2013, 2014). Since 2012, there have been numerous changes to the regulations relating to these input and output controls. 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 38 cm total length (TL), whilst there are also several gear restrictions. Snapper cannot be taken with fish traps, whilst the use of all nets, including hauling nets and large mesh gill nets for targeting Snapper has been prohibited since 1993. Commercial handline fishers are limited with respect to the numbers of lines and hooks per line that they can use. With respect to the use of longlines, from December 2012, the number of hooks that could be used was reduced from 400 to 200 in SG and GSV but remained at 400 for other regions. Also, in 2012 a daily commercial catch limit of 500 kg was introduced for all South Australian waters. In December 2016, this was further reduced due to on-going concerns about the statuses of the different stocks (Fowler et al. 2016a). For the SG/WCS, the daily catch limit was reduced to 200 kg with a limit of two days per trip. For GSV, the daily trip limit was reduced to 350 kg with a trip limit of two days. For the SE Region, the daily trip limit was also reduced to 350 kg, with a five-day trip limit, until 2020 when the TAC was introduced. There is also a 50 kg by-catch trip limit for the Commonwealth-managed Southern and Eastern Scalefish and Shark Fishery.

For the recreational sector, the minimum legal length of 38 cm TL, as well as bag and boat limits apply. In December 2016, bag and boat limits were reduced in response to the recent changes in the spatial structure of the fishery and the classifications of stock status (Fowler 2016, Fowler et al. 2016a). Until that time, the bag and boat limits had differed geographically. However, following the review of the recreational fishery in 2016 (PIRSA 2016b), the bag limit of 5 and boat limit of 15 fish for the size range of 38–60 cm TL, and bag limit of 2 fish and boat limit of 6 fish for fish >60 cm TL, applied for all State waters until the fishery was closed in November 2019. For the Charter Boat sector, from December 2018 to November 2019, the individual bag limit for Snapper was reduced to three small fish (38–60 cm TL) and one large fish (> 60 cm TL), with no boat limit.

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 for all fishing sectors was extended for several weeks until 15th 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 the 31st January, thereby conferring protection for Snapper in these areas for most of the reproductive season. The four spatial closures in NSG and one in NGSV were circular in shape with a 4-km radius from a fixed point. In December 2018, the spawning spatial closure in NGSV was removed and replaced with two new closures located in the southern gulf at Tapley Shoal and Sellicks Beach. These closures were extended to the 31st March 2019. For SG, a new closure at Point Lowly was added to the existing four closures.

Commercial Fishery Statistics

State-wide

Estimates of total State-wide commercial catch of Snapper show cyclical variation, with the cycles typically encompassing a number of years (Figure 4-1A). Since 2003, State-wide catch increased to a record level of 1,031 t in 2010, before declining by 76% to 252 t in 2019, the 2nd lowest recorded. In 2020, State-wide commercial catch was constrained by the Snapper fishing closures for the waters of the west coast of Eyre Peninsula, Spencer Gulf and Gulf St Vincent from 1 November 2019; and the TACC for the SE Region of 60.75 t.

Historically, handlines (HL) were the most significant gear type, whose catches largely accounted for the cyclical variation in total catch until 2008 (Figure 4-1). The proportional contribution of longline catches (LL) to total catch increased considerably between 2005 and 2010, becoming the dominant gear type. Both HL and LL catches declined considerably from 2010–2019. LL accounted for 99.9% of the total catch from the SE Region in 2020.

Between the mid-1980s and 2008 there was a declining trend in total commercial fishing effort that produced catches of Snapper (Figure 4-1). This was followed by a period of elevated fishing effort between 2009 and 2012 that related to an increase in LL effort. However, since 2010, LL effort has declined, complementing the on-going declining trend in HL effort since 2002. As such, the total fishing effort of 4,336 fisher-days in 2019 was the lowest recorded since at least 1984. Total fishing effort was 602 fisher-days in 2020.

State-wide HL CPUE showed cyclical variation, superimposed on a long-term increasing trend (Figure 4-1). However, since 2007 it has decreased considerably, concomitant with the emerging dominance of LL fishing. In contrast, LL CPUE increased considerably between 2004 and 2015, before declining in each year between 2016 and 2019.

The total number of fishers from across all four commercial fisheries who reported taking Snapper, declined consistently from 403 in 1984 to 244 in 2000 (Figure 4-1). It then stabilised for a number of years before declining from 260 in 2010 to 18 fishers in 2020. The numbers who targeted Snapper varied similarly and fell from 201 in 2009 and 2010 to 15 in 2020. This was due to the Snapper fishery closures in all zones except for the SE.

Regional

The relative contributions of the three stocks to total State-wide annual catches have changed considerably over time, particularly with respect to significant change in the spatial structure of the fishery that occurred between 2008 and 2012 (Figure 4-2) and the extensive spatial closures that were imposed in November 2019. The SG/WCS provided the highest annual catches up to 2009, after which they declined and fell to their lowest levels between 2012 and 2019 (Figure 4-2). The catches from the GSVS were generally very low until around 2004 after which they increased gradually for a few years before accelerating between 2007 and 2010. This stock became and subsequently remained the main contributor to the State-wide catch up to 2019. The catches from the SE region also increased dramatically between 2007 and 2010, before declining back to a low level in 2016. They increased marginally in 2018, stabilised in 2019 and then increased sharply in 2020.

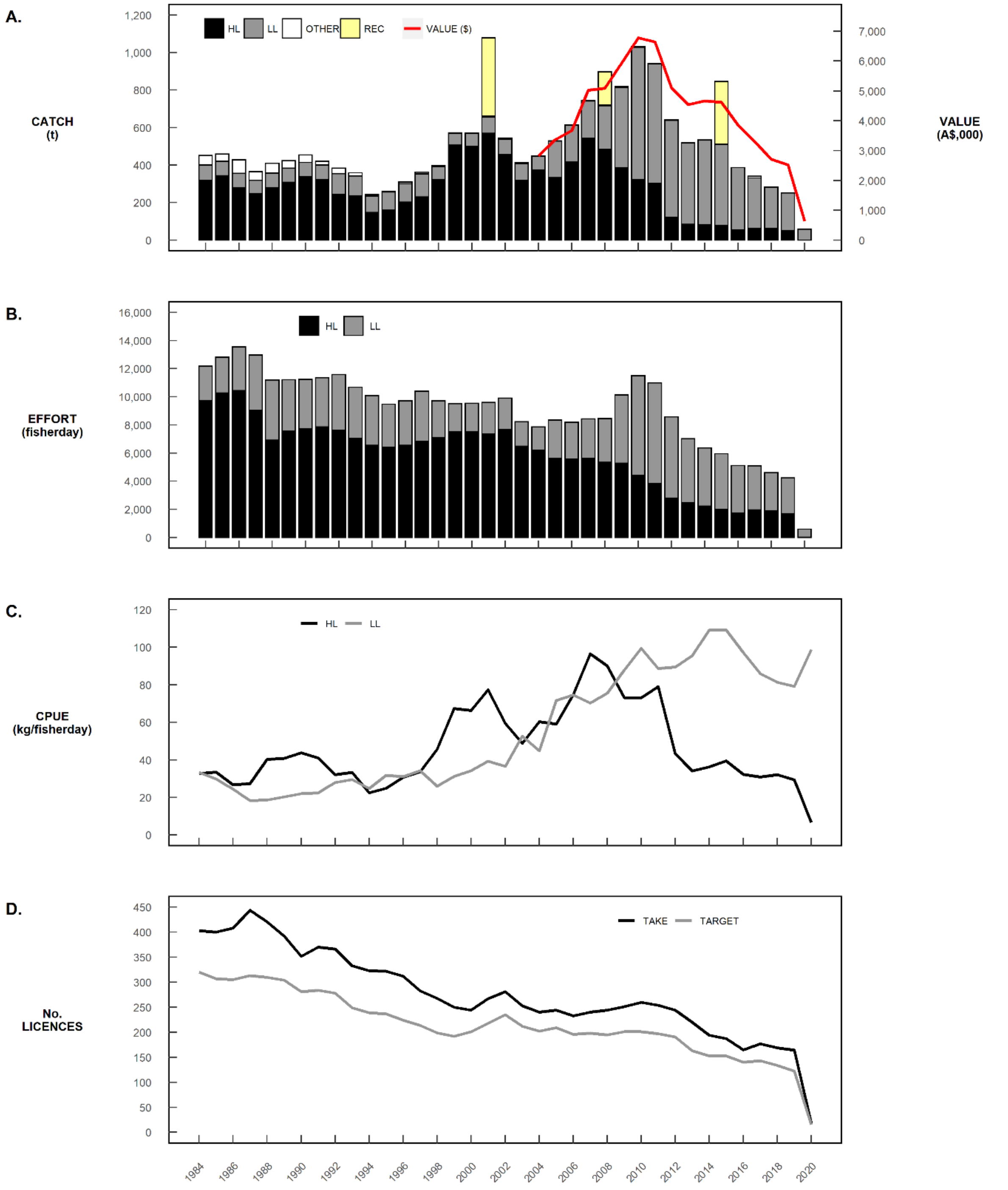

Figure 4-1. Snapper. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (handlines and longlines) and gross production value; (B) total effort for handlines and longlines; (C) total catch per unit effort (CPUE) for handlines and longlines; and (D) the number of active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

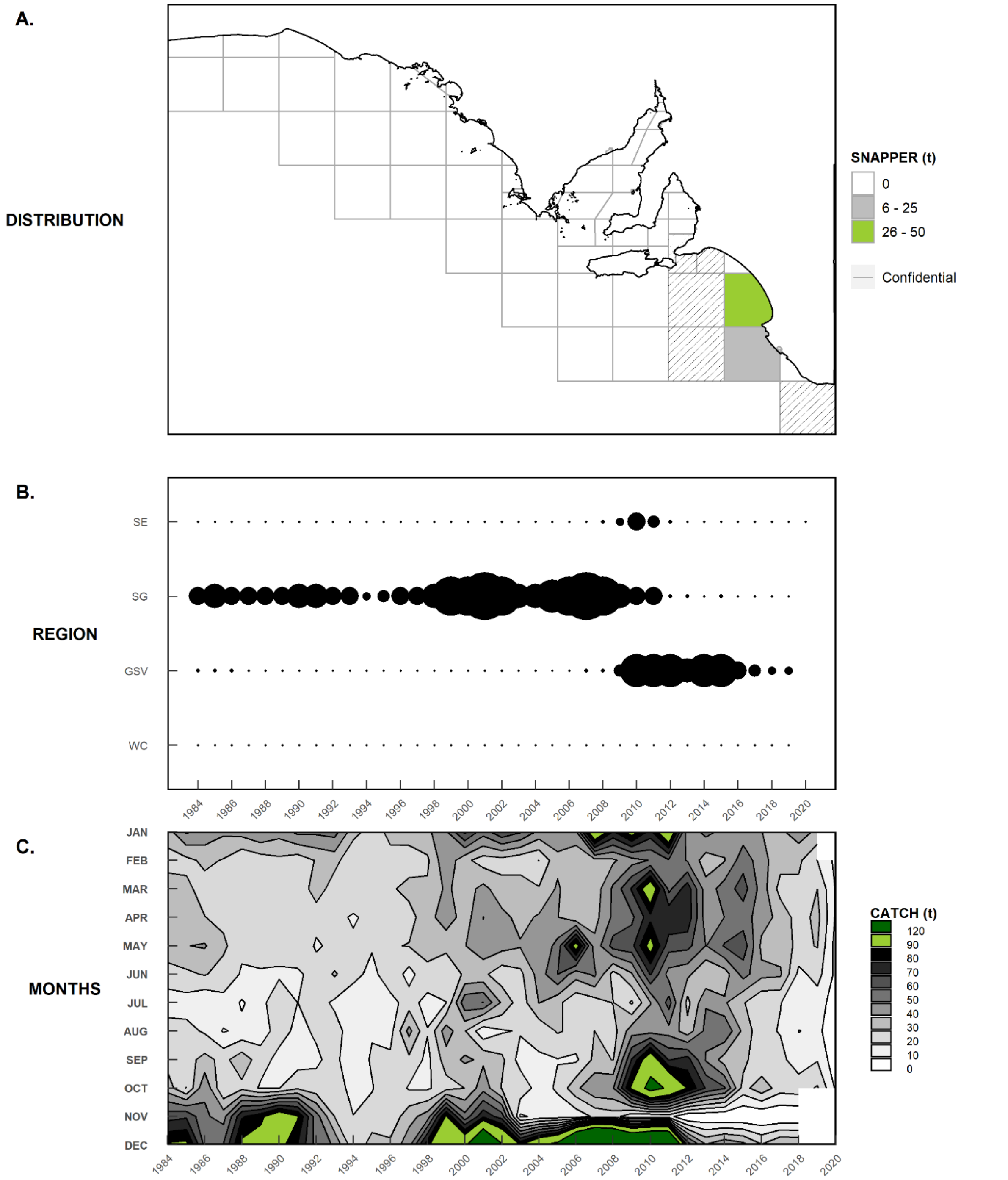

Figure 4-2. Snapper. (A) The spatial distribution of catch by the commercial sector in 2020. Long term trends in: (B) the annual distribution of catch among regional stocks, (C) months of the year.

South East Regional Population (MFAs 44B, 45, 46, 48-58)

The SE region has generally produced low catches of Snapper compared to the other regions (Figure 4.3). However, from 2006 to 2010 there was an exponential increase in catch that peaked at 271.6 t in 2010. It then fell sharply and in 2016 was only 4.8 t. Catch increased to 21.6 t in 2018 and was 23.5 t in 2019. In 2020, the TACC of 60.75 t constrained catch to 58 t.

Targeted HL catch in the SE has always been low, peaking at 12.3 t in 2007 (Figure 4-3). The low HL catches reflect low but variable fishing effort and variable CPUE. Up to 2003, targeted HL CPUE was generally <20 kg.fisher-day^{-1} (Figure 4-3). From then, it increased to its highest levels from 2006 to 2009, peaking at 60.6 kg.fisher-day^{-1} in 2008. It then declined to its lowest level in 2017 before increasing to 40.6 kg.fisher-day^{-1} in 2019. The numbers of HL fishers who targeted Snapper in the SE peaked at 18 in 1987 and was below 5 from 2013 - 2018 (Figure 4-3). The number of licences targeting Snapper in the SE was 2 in 2020 (Figure 4-3). Since 2004, the numbers of reported daily catches have been consistently low having declined from a peak of 105 catches in 2007 to only three catches in 2020. Prop200kgTarHL was highest from 2006 to 2009, peaking at 0.29 in 2008, but has been zero in most years since (Figure 4-3).

Targeted catches taken using LL have generally been the major contributor to the total catch of Snapper in the SE Region over the past 20 years (Figure 4-3). Up to 2006, annual targeted LL catches were consistently low, averaging 1.5 t and rarely exceeding 3 t. From then, there was a rapid increase to a historic peak of 250.4 t in 2010. It then declined to 3 t in 2016 before rising to 54 t in 2020. There was a considerable increase in targeted LL effort during the mid-2000s to a peak of 2,878 fisher-days in 2011 (Figure 4-3). Targeted LL effort declined to 102 fisher-days in 2016 and then increased to 568 fisher-days in 2020. Targeted LL CPUE also increased considerably between 2007 and 2010, peaking at 89.6 kg.fisher-day^{-1} (Figure 4-3). Since then it has been variable, but has increased progressively to a record high of 95.4 kg.fisher-day^{-1} in 2020.

The numbers of fishers who targeted Snapper using LL increased dramatically from 2005 and peaked in 2010 at 30, before declining to 5 in 2016 (Figure 4-3). They increased to 13 in 2020. The reported numbers of daily LL catches increased from 2006, peaked in 2010 at 807 catches and subsequently declined to a minimum of 48 in 2016, before gradually increasing to 255 catches in 2020. Prop200kgTarLL also increased to a secondary peak in 2010 at 0.55 and declined to 0.02 in 2016 (Figure 4-3). It has risen again to a record high of 0.57 in 2020.

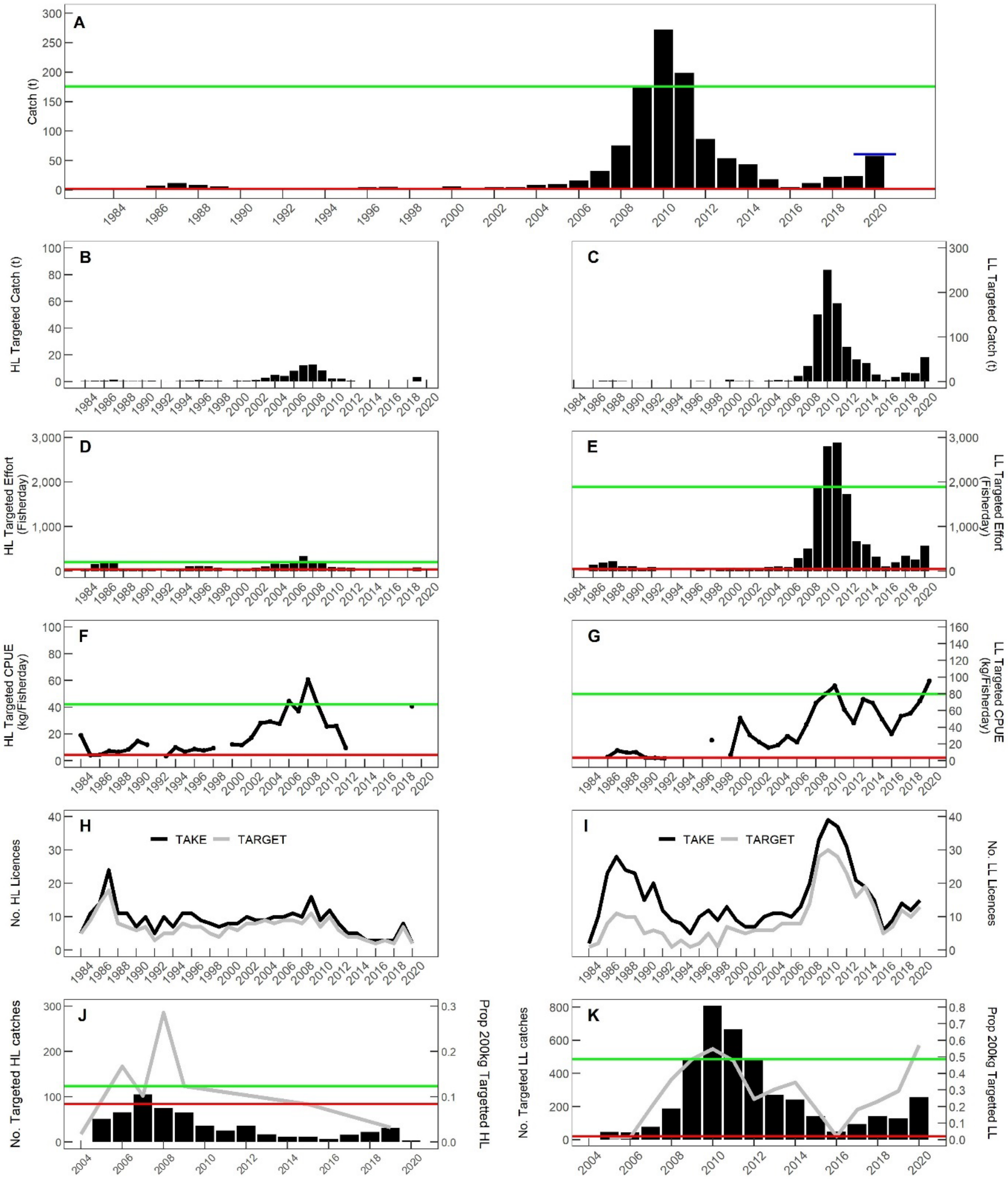

Figure 4-3. Key fishery statistics used to inform the status of the South East regional population of Snapper. Long-term trends in (A) total catch – blue line represents the annual total allowable commercial catch (TACC) of 60.75 t for 2020. (Left) trends in targeted handline (B) catch; (D), effort, and (F) CPUE; (H) numbers of active licences taking and targeting the species; and (J) numbers of targeted catches and Prop200kgTarHL. (Right) trends in targeted longline (C) catch; (E), effort, and (G) CPUE; and (I) the number of active licences taking and targeting the species; (K) number of targeted catches and Prop200kgTarLL. Green and red lines represent the upper and lower reference points identified in Table 4-3.

Fishery Performance Indicators

The proportions of the total commercial catches taken by the different commercial fisheries are presented for each year from 2016 to 2020 in Table 4-2. For 2020, the relative catches from the four fisheries in 2020 were compared against their allocations using Triggers 2 & 3 as reference points (Table 4-2). There was one breach of a trigger reference point in 2020, with the SZRLF breaching Trigger 3. However, this has occurred due to the closure of the Snapper fishery in waters outside of the South East region which has resulted in reduced State-wide catches (Figure 4-1). Therefore, the decrease in MSF catches has caused the Trigger 3 breach, rather than increased catches by the SZRLF (Table 4-2). Historically, the SZRLF has accounted for approximately 20% of Snapper catches in the SE.

The general fishery performance indicators were assessed for the SE Regional Population, based on the estimates for 2020. Overall, there were four breaches of trigger reference points (Table 4-3), although all are considered positive breaches associated with the increases in total catch over recent years and high targeted LL CPUE in 2020.

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. Green colour – allocation not exceeded. Trigger 2 is breached if the respective sector allocation is breached for three consecutive years. Trigger 3 is breached if the respective sector allocation is breached in any one year.

COMMERCIAL ALLOCATION	MSF 97.50%	SZRLF 1.78%	NZRLF 0.68%	LCF 0.04%
TRIGGER 2	na	2.68%	1.30%	0.75%
TRIGGER 3	na	3.58%	2.00%	1.00%
2016	99.90%	0.05%	0.06%	0%
2017	98.75%	1.10%	0.16%	0%
2018	96.35%	3.59%	0.06%	0%
2019	97.67%	2.11%	0.12%	0.11%
2020	82.22%	17.78%	0.00%	0.00%

Table 4-3. Results of the assessment general (G) fishery performance indicators against their trigger reference points for the SE regional population for Snapper in 2020. Confidential data (CONF) is not provided.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	SE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×
	G	Greatest % interannual change (+/-)	✓
	G	Greatest 5 year trend	×
	G	Decrease over 5 consecutive years	×
TARGET HANDLINE EFFORT	G	3rd Lowest / 3rd Highest	CONF
	G	Greatest % interannual change (+/-)	CONF
	G	Greatest 5 year trend	CONF
	G	Decrease over 5 consecutive years	CONF
TARGET HANDLINE 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
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	HIGHEST
	G	Greatest % interannual change (+/-)	×
	G	Greatest 5 year trend	×
	G	Decrease over 5 consecutive years	×
PROP200KGTARHL		3rd Lowest / 3rd Highest	CONF
		Greatest % interannual change (+/-)	CONF
		Greatest 5 year trend	CONF
		Decrease over 5 consecutive years	CONF
PROP200KGTARLL		3rd Lowest / 3rd Highest	HIGHEST
		Greatest % interannual change (+/-)	×
		Greatest 5 year trend	✓
		Decrease over 5 consecutive years	×

Stock Status

The most recent full stock assessment for Snapper, where the statuses of SA's stocks were determined using a combination of fishery-dependent and fishery-independent data sources, was undertaken in 2022 (Drew et al. 2022). It included updated fishery size and age structures, as well as commercial fishery statistics up to the end of 2019 for the SG/WCS and GSVS, and up to July 2022 for the SE region. Furthermore, it reported on results of all DEPM surveys undertaken since 2013. The SG/WCS and GSVS were both classified as 'depleted' in 2020 and 2022 (Fowler et al. 2020b, Drew et al. 2022).

South East Regional Population

The SE Regional population of Snapper in SA is the western extremity of the cross-jurisdictional Western Victorian Stock (Fowler 2016, Fowler et al. 2017, 2021b). This population is sustained through emigration of fish from the main nursery area, which is located in PPB, Victoria, i.e., approximately 600 km to the east. This SE region remained open to fishing (1st February–31st October) in 2020 with a TAC of 75 t, of which 60.75 t was allocated to the commercial sector.

For this regional population, substantial increases in annual fishery catches, effort and CPUE occurred primarily between 2008 and 2012, but these have subsequently declined. Outputs from the Snapper stock assessment model (SnapEst) indicated that this reflected a substantial increase in fishable biomass following recruitment of two strong year classes in PPB in 2001 and 2004 and their subsequent emigration from PPB to the SE Region (Fowler et al. 2017). However, fishable biomass has subsequently declined, due to reduced recruitment into PPB since 2004 (Fowler et al. 2020b). Model-estimated fishable biomass increased slightly between 2018 and 2022, reflecting recruitment of the strong 2014 year (Fowler et al. 2020b, Drew et al. 2022)., and likely contributed to the substantial increase in total catch and high targeted LL CPUE in 2020.

In 2016 (Hamer and Conron 2016), 2018 (Stewardson *et al.* 2018) and 2020 (Fowler et al. 2021b) the WVS was classified as a '**sustainable**' stock. The annual 0+ recruitment survey undertaken in PPB showed that over the 12 years preceding 2016, there had been six years for which recruitment was at, or above, the long-term average. Furthermore, the 2018-year class in PPB was the largest yet recorded and it is expected that these fish will enter the fishable biomass from 2023. This evidence shows that the adult biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment overfished.

4.3.2. King George Whiting

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 around the southern coastline from Sydney, NSW, to Perth, WA (Kailola et al. 1993). The species is particularly significant in 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 offshore reefs, shoals and mounds in relatively deep water in exposed localities that experience medium/high wave energy (Fowler et al. 2000a, 2000b, 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 indicates 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. 2000b, Drew et al. 2021). 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 (Drew et al. 2021). 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.

Three different commercial fisheries have access to SA’s King George Whiting stocks - the MSF, NZRLF and 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 gillnets. 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 SA’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 operating in the MSF has declined considerably over time. Furthermore, there is a complexity of regulations that apply to the gears that are used to take King George Whiting. These restrict the numbers of handlines and hooks that can be 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, boat, possession limits and spatial restrictions.

The management regulations for King George Whiting were recently enhanced following the status of "transitional depleting" 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 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 of 30 cm TL was retained in the waters of the west coast of Eyre Peninsula; (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; and (4) an introduction of a spatial spawning closure in Investigator Strait and southern Spencer Gulf from 1st to 31st May that was first implemented in 2017. This spatial closure was removed in 2020 when fisheries for all three stocks were reclassified as sustainable.

Commercial Fishery Statistics

State-wide

There has been a long-term declining trend in total commercial catch of King George Whiting. This included a 74% reduction from the highest catch of 776 t in 1992 to the lowest recorded value of 202 t in 2020 (Figure 4-4). 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 (Jones 2009, Giri and Hall 2015). The economic value of the annual commercial catch of King George Whiting varied considerably over time (Figure 4-4), falling from \$5.2 M in 2009 to \$3.4 M in 2020 (*c.f.* \$4.1 M in 2019) (Figure 4-4).

Handline catches accounted for 85–90% of annual catches over the past decade, with most of the remaining catches taken using hauling nets (7–12%) and gillnets (1–3%). Between 1984 and 1999, handline catches were approximately 400 $t.yr^{-1}$ (Figure 4-4), before they fell to 179 t in 2020. The catch from hauling nets fell by 93% from an historical record of 266 t in 1992 to 16 t in 2020. The State-wide gillnet catch was < 50 $t.year^{-1}$ in all years and has been <10 $t.yr^{-1}$ since 2012.

The annual estimates of total fishing effort across gear types used to harvest King George Whiting declined from 54,254 fisher-days in 1984 to 10,511 fisher-days in 2020, i.e. a reduction of 81% over 37 years (Figure 4-4). This declining trend relates, at least partly, to the reduction in number of licence holders in the fishery. Between 1984 and 2020, the number of fishers who reported taking King George Whiting fell from 646 to 216 licence holders, and those targeting King George Whiting from 592 to 186 (Figure 4-4). The rate of decline accelerated after 1994 when the licence amalgamation scheme was introduced and again in 2005 as a result of the net buyback. Total effort for gillnets peaked at around 2,700 fisher-days in 1992 and then progressively declined to an historical low of 116 fisher-days in 2020.

The estimates of State-wide handline CPUE have been variable, but have trended upward over time, although divisible into several time periods (Figure 4-4). Handline CPUE increased from 1984 to 1991, declined over several years to 1995, then increased considerably until 1999 before declining to 2002. Subsequently, handline CPUE gradually increased to the highest recorded level in 2016 and remained at this level during 2017–2020 (Figure 4-4). A sharp increase in gillnet CPUE occurred in 2020, with an increase from 22.8 kg.fisher-day^{-1} in 2019 to 52.3 kg.fisher-day^{-1} (Figure 4-4). This occurred as the fleetwide total gillnet effort for King George Whiting halved in 2020 (decreasing from 253 to 116 fisher-days from 2019) while the licence holder that had the highest gillnet CPUE in the fishery fished more regularly than in previous years. Therefore, the higher CPUE of this fisher was not suppressed by a larger number of less efficient fisher-days, as had occurred in previous years.

The State-wide commercial catches are divisible into those from the three component stocks, which have all declined over time (Figure 4-5). Through the 1980s and 1990s, the SGS provided the highest catches. Through the 2000s, catches from the SGS fell below those of the WCS, which continued to produce the highest catches since then. Catches from the GSV/KIS have always been the lowest of the three stocks.

Seasonality has been a consistent feature of the King George Whiting fishery (Figure 4-5). Catches were generally higher through the cooler months and lower during summer. In 2019, the commercial catch was dominated by that from the MSF Fishery, with a relatively small contribution of 0.79% from the NZRLF.

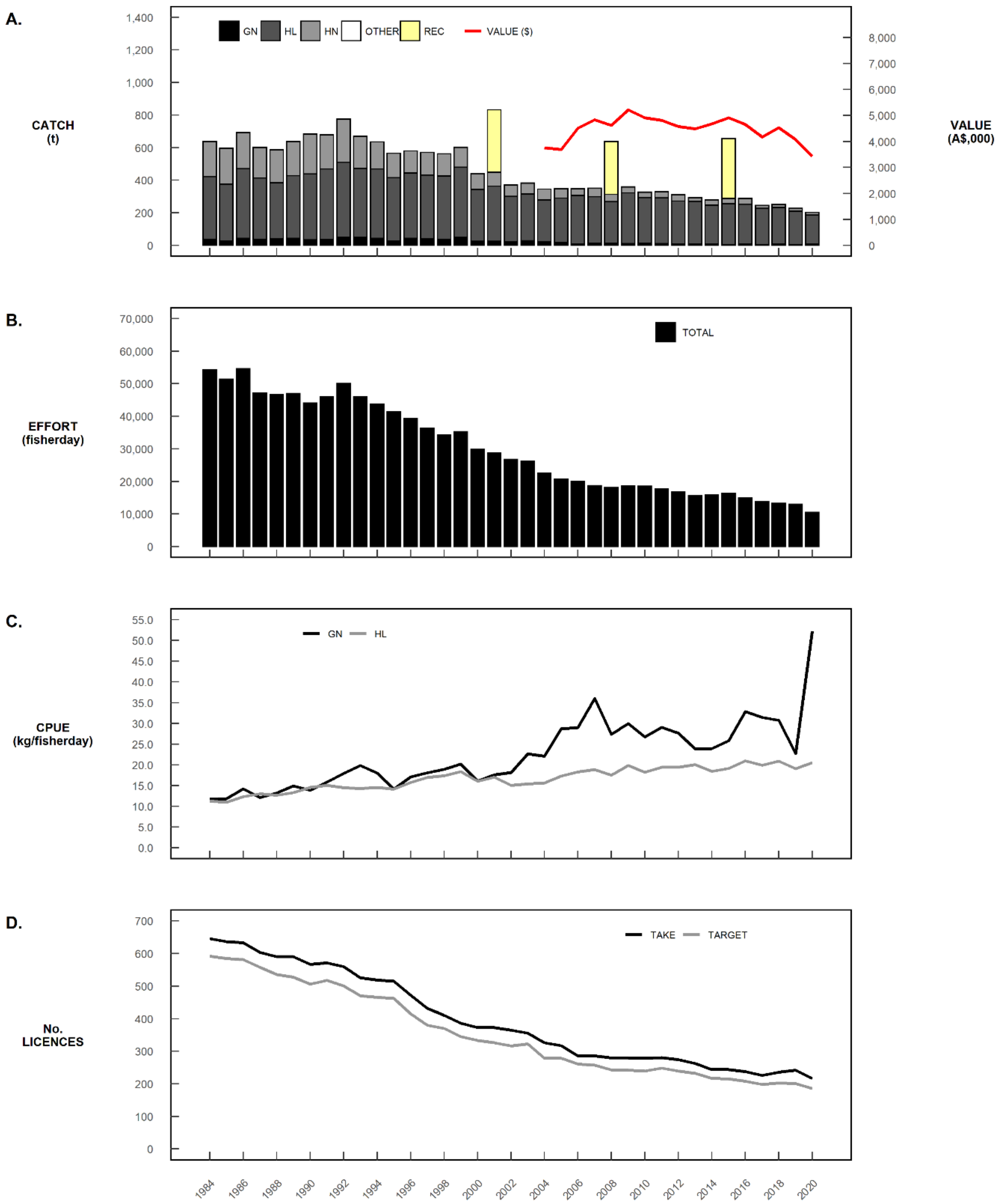

Figure 4-4. King George Whiting. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (handline, hauling net and gill net), estimate of recreational catch and gross production value; (B) total effort; (C) total catch per unit effort (CPUE) for handline and longline; and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

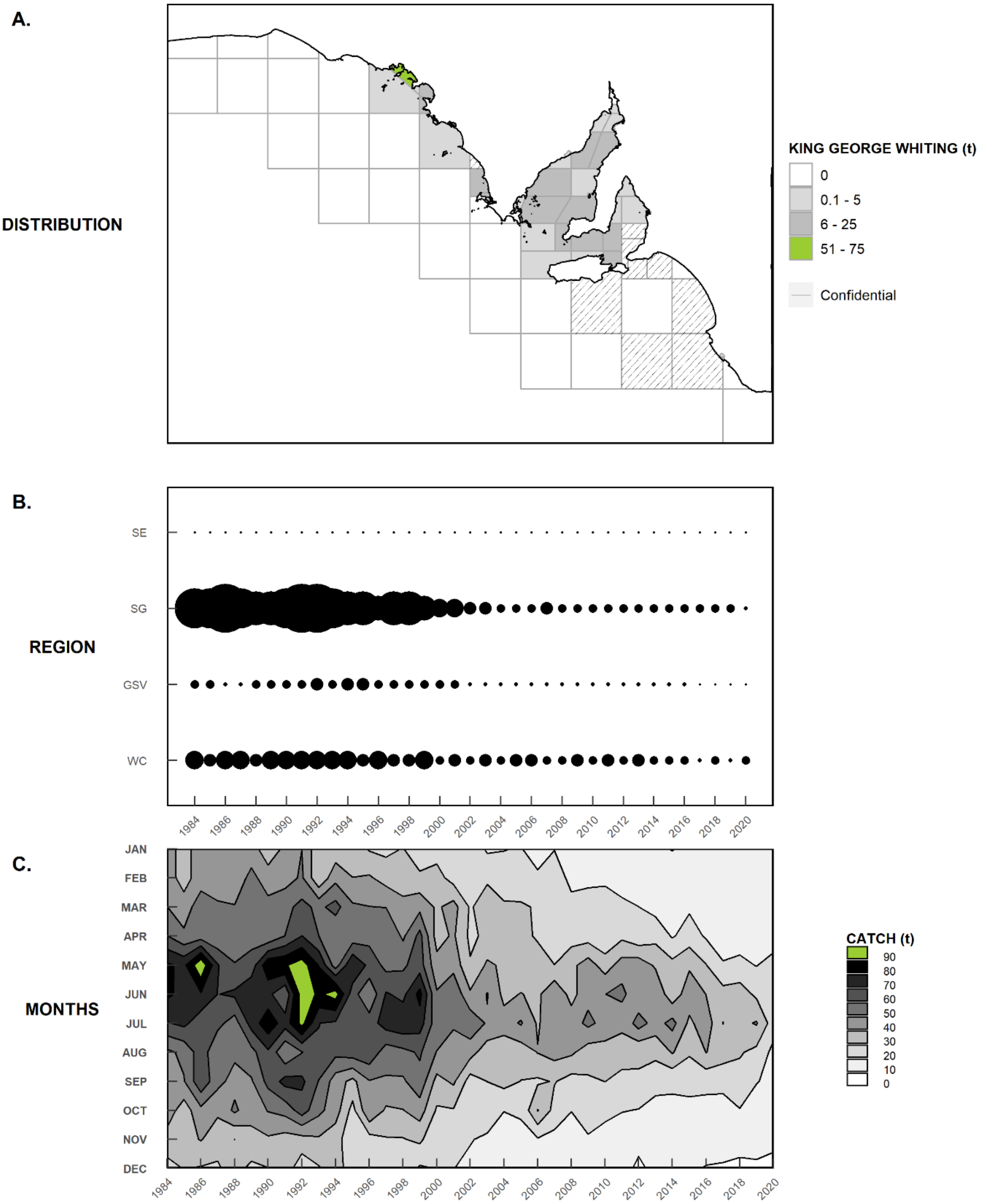

Figure 4-5. King George Whiting. (A) The spatial distribution of catch by the commercial sector in 2020. Long term trends in: (B) the annual distribution of catch among stocks, (C) months of the year (t).

Regional

West Coast Stock

The recently established WC fishing zone encompasses all MFA's west of Elliston. Annual commercial catches from this region increased between 1984 and 1992 when the highest annual catch of 222 t was taken (Figure 4-6). From then, total catch gradually declined by 46% to 120 t in 2002. Subsequently, it increased to 153 t in 2013, before falling to the lowest ever recorded catch of 92 t in 2020.

In all years, handlines were the dominant gear. Targeted handline catches dropped from the high of 196 t in 1999 to 88 t in 2019 (Figure 4-6). Targeted handline catch was 90 t in 2020. Targeted handline effort declined relatively consistently from the maximum of 13,993 fisher-days in 1984 to the lowest of 3,524 fisher-days in 2020 (Figure 4-6). In contrast, handline CPUE increased considerably over several multi-year steps. Handline CPUE increased between 1987 and 1992 before declining considerably to 1995 (Figure 4-6). Handline CPUE increased again to 1999 before falling from 20.8 to 15.5 kg.fisher-day^{-1} in 2002. Subsequently, CPUE increased to 24.5 kg.fisher-day^{-1} in 2013. Although CPUE dropped considerably in 2014, it recovered and peaked at 25.4 kg.fisher-day^{-1} in 2018. The CPUE of 25.67 kg.fisher-day^{-1} in 2020 was the highest on record.

The numbers of fishers catching King George Whiting with handlines from the WCS have both declined considerably between 1984 and 2019 (Figure 4-6). The former fell from 197 to 71 fishers, whilst the latter declined from 196 to 70 fishers.

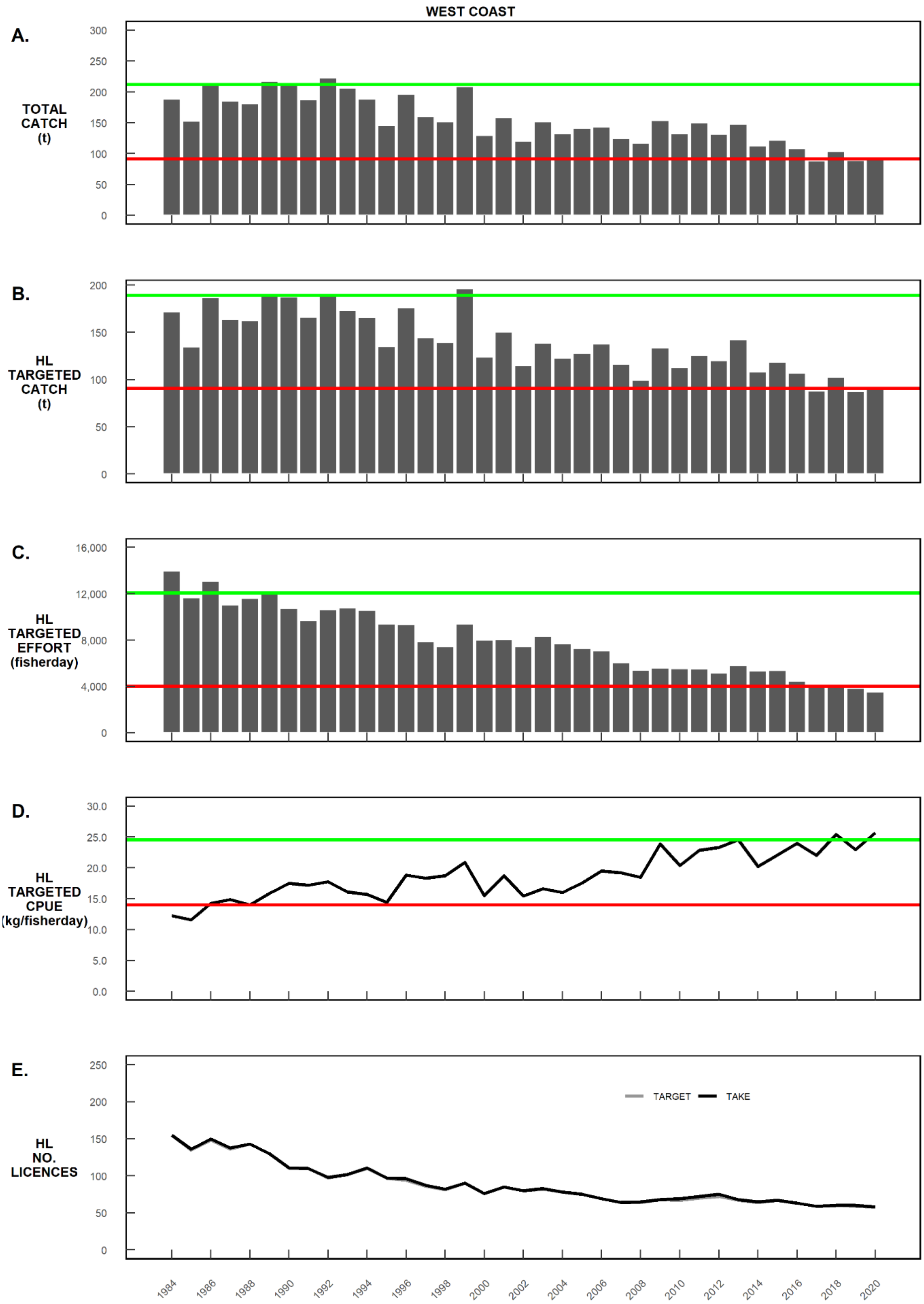

Figure 4-6. Key fishery statistics used to inform the status of King George Whiting in the West Coast. Long-term trends in (A) total catch; (B) targeted handline catch; (C) targeted handline effort; (D) targeted handline CPUE; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-5.

Spencer Gulf Stock

Total annual commercial catch of King George Whiting from Spencer Gulf was relatively high and varied cyclically between 1984 and 1997 (Figure 4-7). The highest catch of 409 t was recorded in 1992. From 1997 until 2004, total catch declined by 56% and then further declined by 41% to 94 t in 2013. From 2014 to 2018, total catch increased again and varied at around 115 $t.yr^{-1}$ before declining to 96 t in 2019. Total catch declined by 20% to 76.5 t in 2020, which was the lowest recorded for Spencer Gulf.

Throughout the 2000s, targeted handline catch was considerably lower than it was throughout the 1980s and 1990s (Figure 4-7). It was lowest at 77 t in 2013 before increasing to 83 t in 2019 and then declining to a low of 60.5 t in 2020. Handline fishing effort was variable between 1984 and 1992. Between 1992 and 2004, it declined by 58% from 11,962 to 5,049 fisher-days, respectively. It was then relatively stable for several years, until it declined further to 4,070 fisher-days in 2013. It remained at around 4,500 fisher-days through to 2019 before declining to a historical low of 3,121 fisher-days in 2020 (Figure 4-7).

Handline CPUE has shown a long-term increase, although with clear cyclical variation (Figure 4-7). The cycles typically spanned several years during which CPUE increased quickly, followed by several years of decline. From 2003 to 2007, CPUE increased from 15.8 to 21.2 $kg.fisher\text{-}day^{-1}$. However, the longest period of decline occurred from 2007 to 2013, when CPUE declined to a low value of 19.2 $kg.fisher\text{-}day^{-1}$. From 2013 and 2016, CPUE increased again, attaining the highest recorded level of 22 $kg.fisher\text{-}day^{-1}$. Handline CPUE subsequently declined over three years to 18.8 $kg.fisher\text{-}day^{-1}$ in 2019. In 2020, handline CPUE was similar at 19.4 $kg.fisher\text{-}day^{-1}$. The number of licence holders who took King George Whiting with handlines fell from 237 in 1984 to 102 in 2020, whilst those targeting it fell from 233 in 1984 to 99 in 2020 (Figure 4-7).

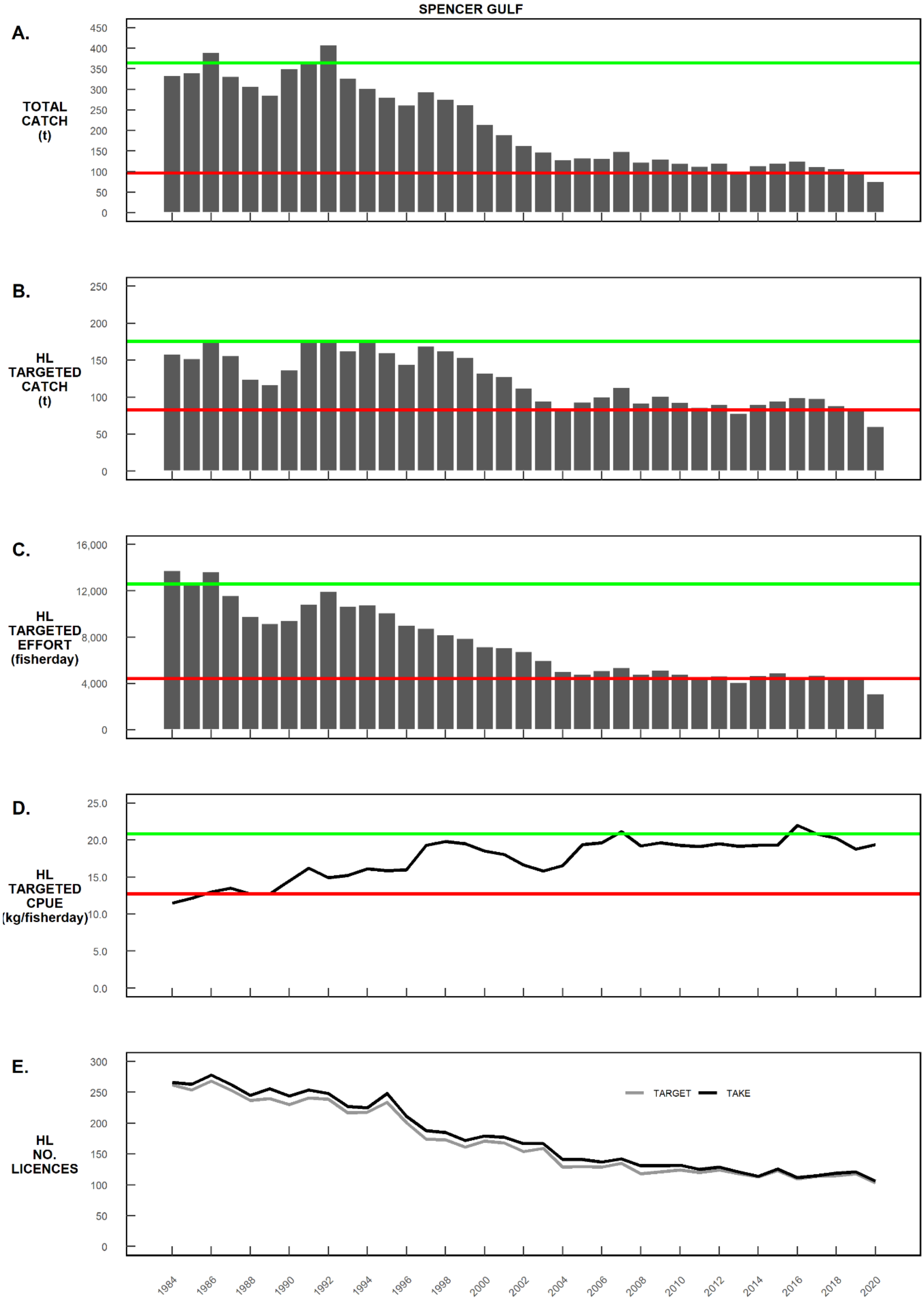

Figure 4-7. Key fishery statistics used to inform the status of King George Whiting in Spencer Gulf. Long-term trends in (A) total catch; (B) targeted handline catch; (C) targeted handline effort; (D) targeted handline CPUE; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-5.

Gulf St Vincent / Kangaroo Island Stock

Total annual commercial catch from this region has been consistently lower than for the other two regions and has varied through several different periods. After declining between 1984 and 1988, catches increased to the record level of 145 t in 1994 (Figure 4-8). Subsequently, catches have shown a long-term decline to the lowest annual catch of 33.9 t in 2020.

Targeted handline catch largely accounted for the variation in total catch, being highest between 1992 and 1995 before declining to 38 t in 2005 (Figure 4-8). Targeted handline catch increased again to 51 t in 2009 and 2010, but has subsequently declined to the lowest level of 25 t in 2020. Fishing effort for handlines was highest in 1992 when it reached 7,038 fisher-days (Figure 4-8). Since then, effort progressively declined to an historic low of 1,747 fisher-days in 2020.

Between 1984 and 2007, handline CPUE was variable but nevertheless increased from 8.9 to 15.4 kg.fisher-day^{-1} (Figure 4-8). Over the following five years, it declined to the 12.7 kg.fisher-day^{-1} before it increased to 15.3 kg.fisher-day^{-1} in 2018. In 2020, handline CPUE was 14.5 kg.fisher-day^{-1}. The number of licence holders who captured or targeted King George Whiting with handlines has declined considerably. In 1984, a total of 128 fishers caught King George Whiting, with this falling to 38 fishers in 2020 (Figure 4-8). The numbers of licence holders who targeted this species with handlines fell from 126 to 32 fishers over the same period.

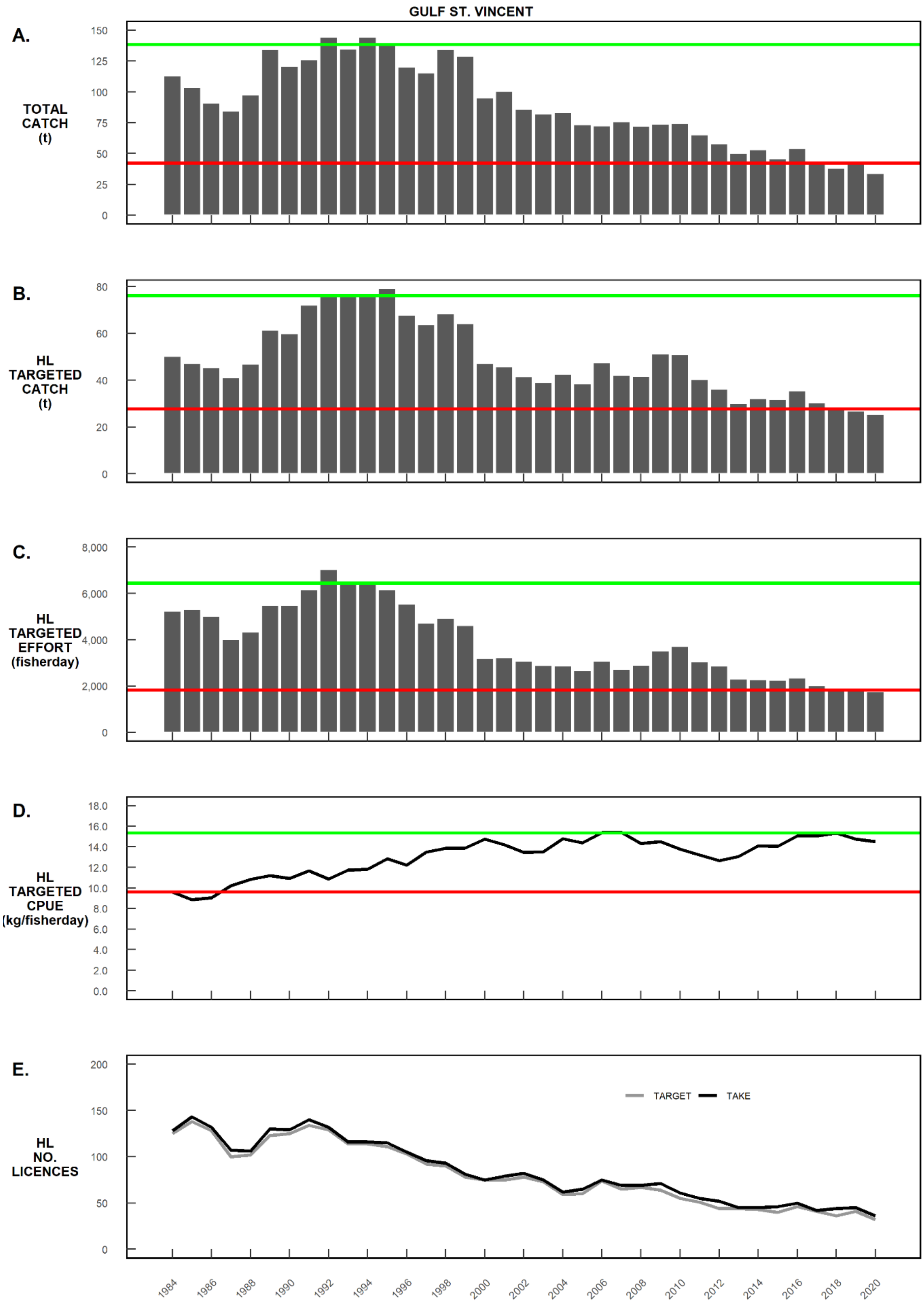

Figure 4-8. Key fishery statistics used to inform the status of King George Whiting in Gulf St Vincent. Long-term trends in (A) total catch; (B) targeted handline catch; (C) targeted handline effort; (D) targeted handline CPUE; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-5.

Fishery Performance

The catch data from the three commercial fisheries from 2020 were compared against their allocations using Triggers 2 and 3 as reference points. No negative trigger reference points were breached (Table 4-4).

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. Trigger 2 is breached if the respective sector allocation is breached for three consecutive years. Trigger 3 is breached if the respective sector allocation is breached in any one year.

COMMERCIAL ALLOCATION	MSF 98.10%	SZRL n/a	NZRL 1.90%
TRIGGER 2	n/a	0.50%	2.97%
TRIGGER 3	n/a	0.75%	3.96%
2015	98.78%	0.00%	1.22%
2016	99.36%	0.00%	0.64%
2017	99.10%	0.00%	0.90%
2018	98.60%	0.00%	1.39%
2019	99.20%	0.01%	0.79%
2020	99.53%	0.02%	0.44%

The general fishery performance indicators were assessed at the State-level and for each of three stocks. There were 14 breaches of trigger reference points that were generally consistent at the two spatial scales (Table 4-5). At the State-wide scale and for each of the three stocks, the lowest (State, WC and GSV/KI) or second lowest (SG) catches and lowest levels of handline effort were recorded for 2020. At the same time, CPUE for GSV/KI was the highest on record, whilst the 3rd and 2nd highest levels of handline CPUE were recorded at the State-wide scale and the WC, respectively.

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	2nd 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	LOWEST
	G	Greatest % interannual change (+/-)	×	×	✓	×
	G	Greatest 5 year trend	×	×	×	×
	G	Decrease over 5 consecutive years	✓	×	×	×
TARGET HANDLINE CPUE	G	3rd Lowest / 3rd Highest	3rd HIGHEST	HIGHEST	×	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 the bays and offshore areas along the west coast of Eyre Peninsula. In the current assessment, fishery statistics were examined according to the new fishing zone boundaries. In recent years this stock has been consistently classified as sustainable (Steer et al. 2018a, Steer et al. 2018b, Steer et al. 2020, Fowler et al. 2021a), including in the 2019 stock assessment (Drew et al. 2021), which considered modelled estimates of fishable biomass, recruitment and harvest fraction, and fishery statistics for the commercial sector up until the end of 2019. Nevertheless, over the past eight years total catch has declined. Targeted handline effort also declined at a similar rate over the same period, consistent with a declining number of fishers taking and targeting this species.

Since 2014, targeted handline CPUE has progressively increased, reaching a historic peak in 2018 and remaining at a near record-high level in 2020. Modelled estimates of fishable biomass for the WCS have also gradually increased over time and were at near record-high levels from 2017 to 2019 (Drew et al. 2021). This increasing trend in biomass reflected a long-term increasing trend in recruitment and declining exploitation rate. The low harvest fraction of ~10% in 2019 was the result of increased biomass and declining fishing effort relating to the declining numbers of commercial fishers in the sector. The above evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired, and the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, the West Coast Stock is classified as **sustainable**.

Spencer Gulf Stock

This stock extends throughout the entire northern and southern regions of Spencer Gulf, although the fishery statistics were examined according to the new fishing zone boundaries. Throughout the 2000s, total catch and effort have been low relative to the high levels recorded through the 1980s and 1990s. Also, targeted handline CPUE has varied cyclically over time, but nevertheless has demonstrated a long-term increasing trend. However, between 2007 and 2013, catch, effort and handline CPUE all declined. The estimates of 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 to the management regime that were implemented in December 2016.

Between 2013 and 2017, there were notable increases in several key commercial fishery statistics. Over this period, total catch, handline effort and targeted handline CPUE increased. Furthermore, the outputs from the stock assessment model indicated that from 2013 to 2016, there was an upward trend in recruitment that resulted in an 11% increase in fishable biomass (Steer et al. 2018a). Such variable biomass appears typical for this stock, which is evident as cyclical variation in the fishery statistics. It suggests that the population is subject to inter-annual variation in recruitment that impacts on population biomass and fishery productivity over cycles that last a number of years. The fishery statistics to 2017 and outputs from the fishery assessment model to 2016 were not consistent with the biomass at that time being depleted and moving the stock in the direction of being recruitment impaired (Steer et al. 2018b). Rather, they suggested that the biomass had recovered to a level sufficient to ensure that future recruitment was adequate. As such, in that year the stock was classified as 'sustainable' (Steer et al. 2018a).

Between 2017 and 2019, there were marginal declines in catch, targeted handline effort and targeted CPUE in SG. Outputs from the fishery assessment model indicated that the declines in the fishery performance indicators were associated with a recent decline in recruitment. However, the lower recruitment during that period was not reflected in lower fishable biomass, with low exploitation rates in recent years enabling the highest estimated biomass levels in recent years to be retained. As such, in that year the stock classification of 'sustainable' was retained (Drew et al. 2021).

For 2020, catch and targeted handline effort declined. Despite these reductions, targeted CPUE increased and was high in 2020, suggesting that the relative abundance of King George Whiting was also high. The above evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired, and the current low level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, the Spencer Gulf Stock classification remains at **sustainable**.

Gulf St Vincent/Kangaroo Island Stock

The GSV/KIS occurs throughout Gulf St Vincent, Investigator Strait and the waters surrounding Kangaroo Island. The recent stock assessments completed in 2014, 2017 and 2019 showed that commercial catch and effort for this stock were considerably lower during the 2000s compared to the 1990s, consistent with a long-term decline in the number of fishers participating in the fishery (Fowler et al. 2014, Steer et al. 2018a, Drew et al. 2021). In particular, between 2009 and 2013, there were considerable declines in commercial catch and effort (Steer et al. 2018a). 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 18%. Consequently, estimates of biomass for the period of 2007 to 2012 from the stock assessment model showed a considerable decline of 12% (Steer et al. 2018a). 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, in association with the stock status assigned to the SG stock, prompted a review of fishery management arrangements that resulted in the changes that were implemented in December 2016.

From 2013 and 2019, the estimates of commercial catch and effort stopped declining and targeted handline CPUE increased by 20%. The years of 2016, 2017 and 2018 produced estimates of handline CPUE that were among the highest recorded for this stock since 1984. In the several years leading up to 2019, estimates of biomass from the stock assessment model had stabilised, reflecting a period of increasing recruitment, and as with the other two stocks, a trend of on-going long-term reductions in exploitation rate that is closely linked to similar long-term reductions in numbers of fishers targeting this species. Estimated biomass from the stock assessment model increased to 664 t in 2019, considerably higher than the lowest value of ~500 t, estimated for 1986 (Drew et al. 2021). The fishery statistics and outputs from the fishery assessment model to 2019 were not consistent with the biomass at that time being 'transitional depleting' and moving the stock in the direction of being recruitment impaired (Drew et al. 2021). Rather, they provided evidence that the biomass had recovered to a level sufficient to ensure that future recruitment was adequate. As such, in that year the stock was classified as 'sustainable' (Drew et al. 2021).

In 2020 there were marginal declines in targeted handline catch, effort and CPUE, nevertheless, CPUE remained at a near-record high level. The above evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired, and the current low level of fishing mortality is unlikely to cause the stock to become recruitment impaired. As such, the GSV/KI stock classification remains at **sustainable**.

4.3.3. Southern Calamari

Biology

Southern Calamari (*Sepioteuthis australis*) 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.

The life-history of Southern Calamari is characterised by rapid growth and a sub-annual life-span (Jackson 2004). In South Australia, adults and juveniles are predominantly found in shallow, inshore waters. Offshore waters to depths <70 m tend to be occupied by sub-adults (Winstanley et al. 1983). The patterns of distribution and abundance of adult Southern Calamari in South Australia's gulfs tends to be seasonal and consistent amongst years (Triantafillos 2001). Adult abundance typically increases for six months to a peak and declines for the remainder of the year. Timing of these peaks varies among regions and follows an anti-clockwise progression around the gulfs. This cycle starts in the south-east during late spring and concludes along the western coasts during late winter. Seasonal patterns in water clarity, associated with the prevailing cross-offshore winds, appear to drive this progression as Southern Calamari spawn in shallow seagrass habitats found along protected leeward shores (Triantafillos 2001, Steer et al. 2007). Spawning occurs throughout the year and recruitment to the fishery is continuous.

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 are assessed at the regional scale to match the spatial dynamics of the fishery.

Fishery

In South Australia, the Southern Calamari resource is shared by three sectors. Adult Southern Calamari are targeted by commercial MSF fishers, charter fishery clients, 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 target Southern Calamari from jetties, breakwaters and rocky shorelines. Most of the catch is landed by handlines and rods and reels using squid jigs that are shaped like a prawn. Commercial fishers also mostly use these jigs, but are also licensed 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 (Department of Fisheries 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 and a maximum of 45 per boat per day with 3 people onboard) 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 also provides some regional protection for spawning Southern Calamari.

Commercial Fishery Statistics

State-wide

The total reported commercial catch of Southern Calamari remained relatively stable (> 350 t) over the last six years (Figure 4-9). The economic value of the commercial catch of Southern Calamari in 2020 was approximately $6 M (*c.f.* $5.4 M in 2019) (Figure 4-9). Therefore, Southern Calamari continues to have the highest economic value in the fishery. Southern Calamari is taken as by-product in all three South Australian commercial prawn fisheries and has consistently accounted for <10% of total state-wide catches since it was first reported in 2004; however, it increased to 10.5% and 11.3% in 2016 and 2017, respectively.

In 2020, the prawn fisheries by-product component of the Calamary catch equated to 9.2% of the total State-wide commercial catch, noting, however, that the size structure of the catch of Southern Calamari differs in the MSF and prawn fleets, with the latter mostly taking sub-adults in deeper water.

Total State-wide catch of Southern Calamari inclusive of the prawn fisheries was 408 t in 2020, and 374 t in the MSF (*c.f.* 327 t in the MSF in 2019). In the past 5 years, fishers using hauling nets have taken 18.8–26.1% of the MSF Southern Calamari catch (26.4% in 2020). Fishers using jigs have taken 69.2–81.0% of the total catch in the MSF (73.8% in 2020). 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 70–80% 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 2020, 13,149 fisher-days (*c.f.* 13,642 fisher-days in 2019) were spent catching Southern Calamari within the MSF (Figure 4-9). CPUE has gradually increased for both gear types, at a rate of 0.51 kg.fisher-day.year^{-1} (Figure 4-9). Since the implementation of the licence amalgamation scheme in 1994, the number of licence holders taking Southern Calamari has declined from 355 to 209 in 2017, with 218 licence holders taking the species in 2020. The number of licence holders specifically targeting Southern Calamari has remained relatively stable, averaging approximately 200 licences per year (Figure 4-9). In 2020, 199 licence holders targeted Southern Calamari.

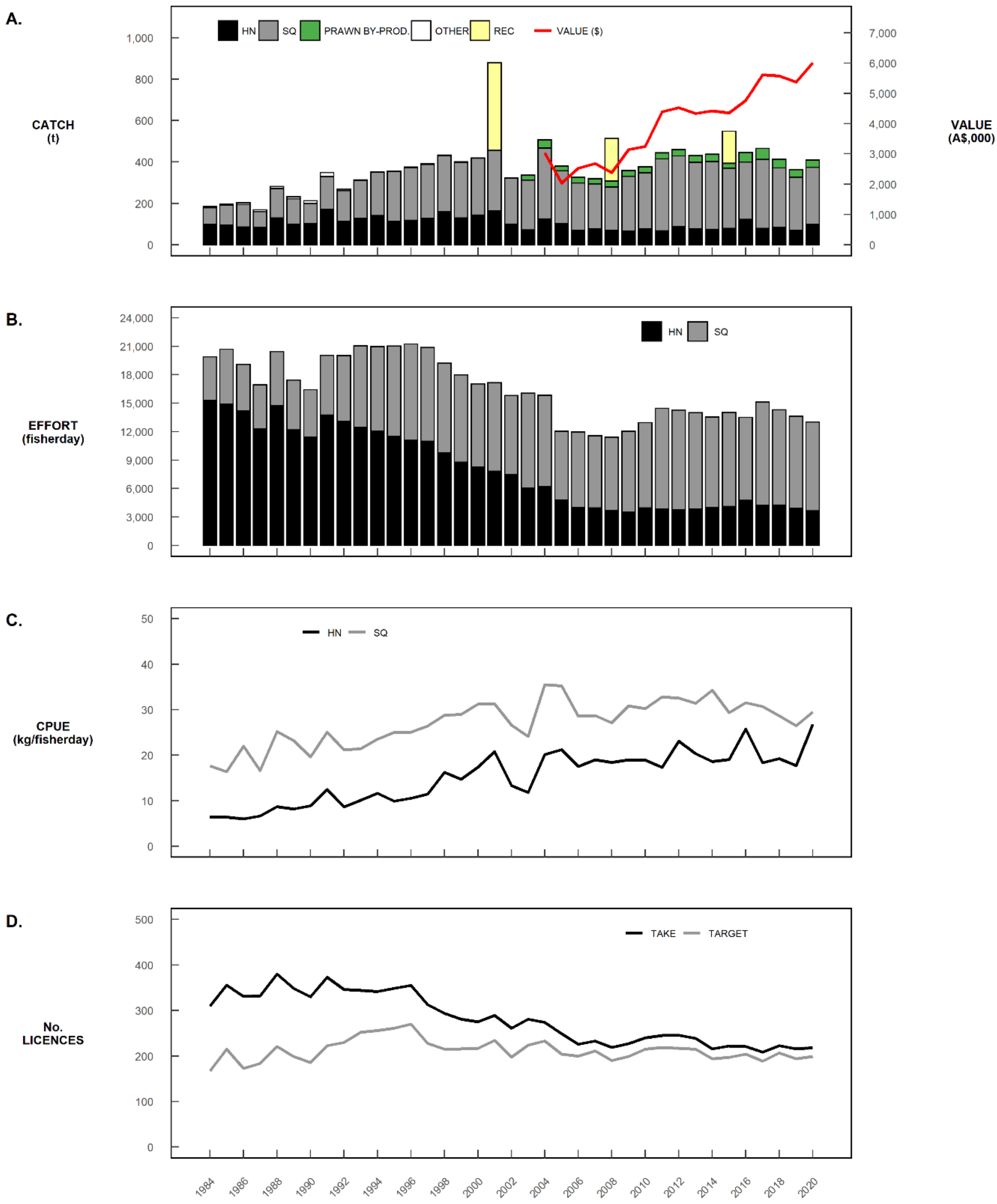

Figure 4-9. Southern Calamari. Long-term trends in State-wide estimates of (A) total catch for the main gear types (squid jig, hauling net, prawn by-product), estimated recreational catch and gross production value; (B) Long-term total effort for squid jigs and hauling nets; (C) total catch per unit effort for squid jigs and hauling nets; and (D) the number of active licence holders taking or targeting the species.

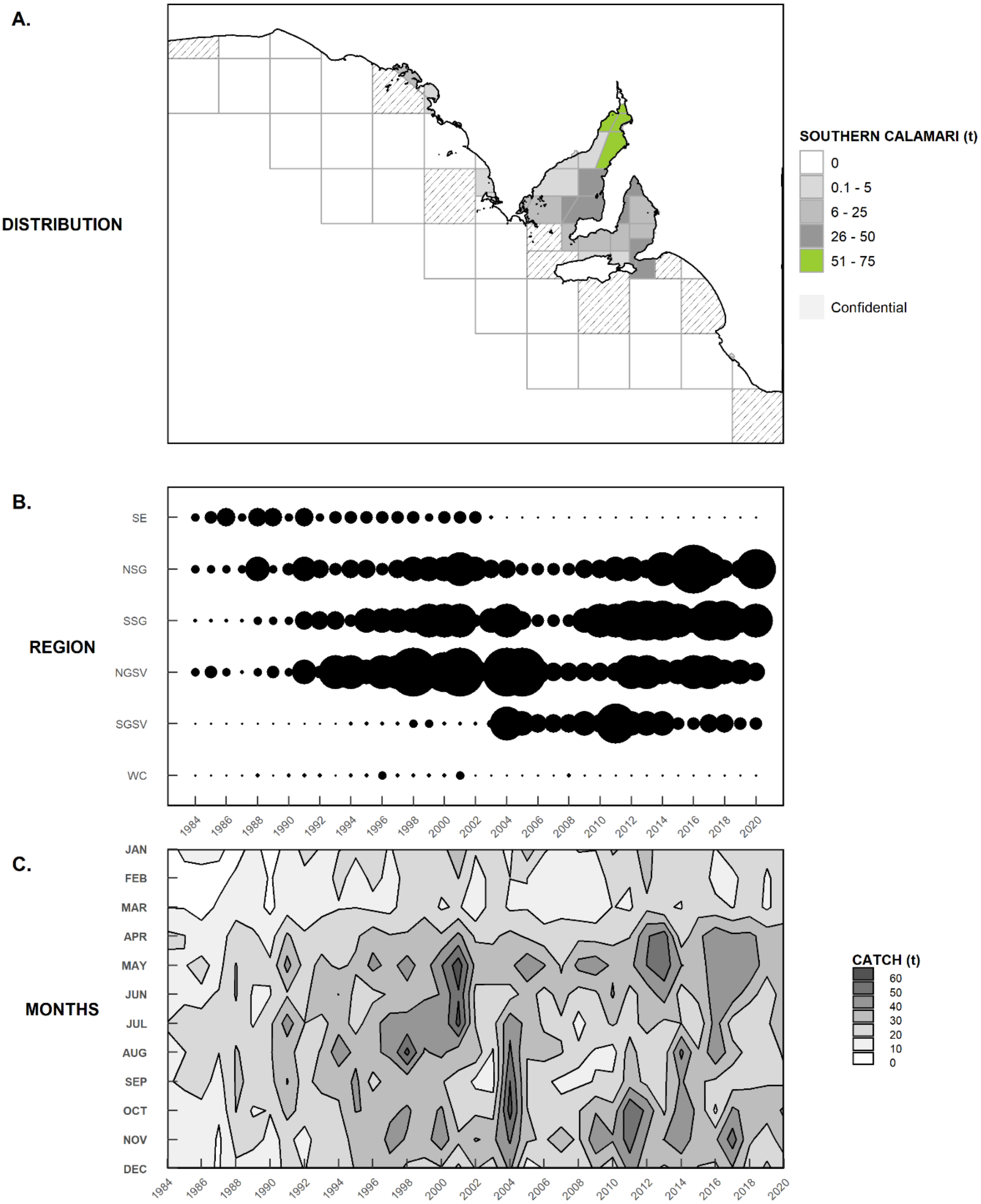

Figure 4-10. Southern Calamari. (A) The spatial distribution of catch by the commercial sector in 2020. Long-term trends in: (B) the annual distribution of catch among regions, (C) months of the year.

Regional

Southern Calamari is caught throughout the State with the majority landed within the gulfs (Figure 4-10). Catches have increased in NSG, SSG and NGSV since 2008, with all three regions accounting for similar proportions of the State-wide commercial total (Figure 4-10). Although, Southern Calamari can be caught throughout the year, catches tend to peak during late spring and late autumn (Figure 4-10). In 2020, the commercial catch of Southern Calamari was dominated by the MSF fishers (~90%), prawn fleets (9.2%) and Northern Zone Rock Lobster fishers accounted for <1%.

West Coast

The annual commercial catch of Southern Calamari from the WC has rarely exceeded 10% of the State's catch. Total catches declined from a peak of 36.5 t in 1996 to its lowest catch of 3.6 t in 2014 (Figure 4-11). Annual catch of Southern Calamari in the WC fluctuated between 8.2–10.3 t during 2015–2019. In 2020, the total catch was 9.6 t. Targeted jig effort in this region declined from a historic peak of 1,235 fisher-days in 2001 to 189 fisher-days in 2014 (Figure 4-11). Targeted jig effort fluctuated between 333-412 fisher-days since 2016 and was 410 fisher-days in 2020. Targeted jig CPUE has fluctuated between 23.1–27.8 kg.fisher-day^{-1} since 2015 and was 23.3 kg.fisher-day^{-1} in 2020 (Figure 4-11). Most of the fishing for Southern Calamari in this region has been targeted using jigs. The number of licence holders targeting Southern Calamari using jigs ranged from 21–38 over the past decade and was 32 licence holders in 2020 (Figure 4-11).

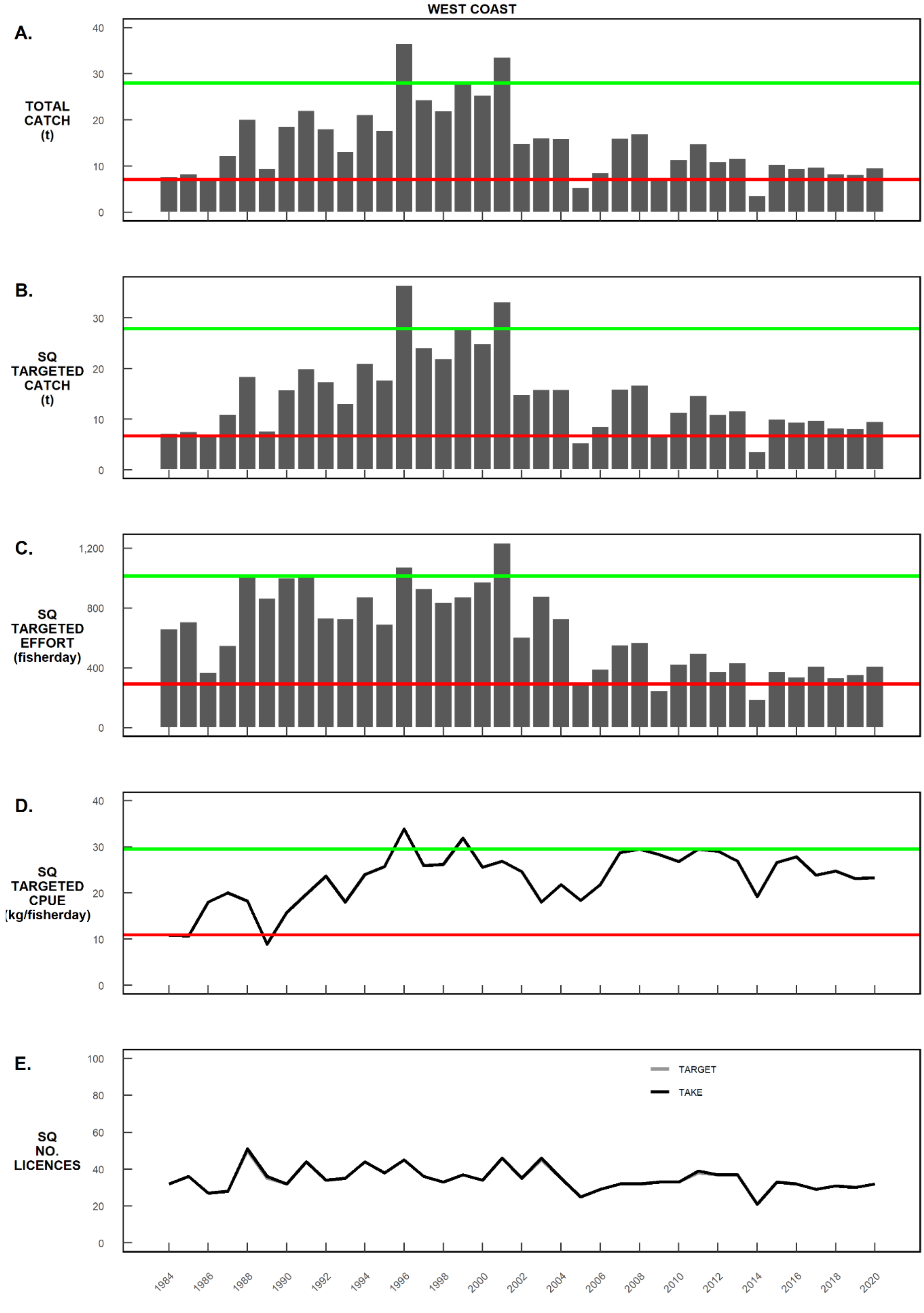

Figure 4-11. Key fishery statistics used to inform the status of Southern Calamari in the West Coast. Long-term trends in (A) total catch; (B) targeted squid jig catch; (C) effort; (D) CPUE; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-7.

Northern Spencer Gulf

Total catch of Southern Calamari in NSG has typically accounted for 25% of the State's catch. The annual total catch for NSG increased by 49 t from 2019 to 121 t in 2020 (Figure 4-12). This is the second highest catch for the NSG region. In line with increased total catch, the targeted hauling net catch increased from 5.8 t in 2019 to 24 t in 2020 (Figure 4-12). Targeted jig catch also increased to 52 t in 2020 (*c.f.* 39 t in 2019). Targeted jig effort in NSG similar in 2019 (1,532 fisher-days) and 2020 (1,549 fisher-days) (Figure 4-12). Targeted jig CPUE in 2020 increased from 24.9 kg fisher-day^{-1} in 2019 to 33.3 kg fisher-day^{-1}, which was the fourth highest CPUE recorded (Figure 4-12). The number of licence holders targeting Southern Calamari using jigs has declined from a peak of 45 fishers in 2011 to 34 in 2020 but has been stable for the past five years (Figure 4-12).

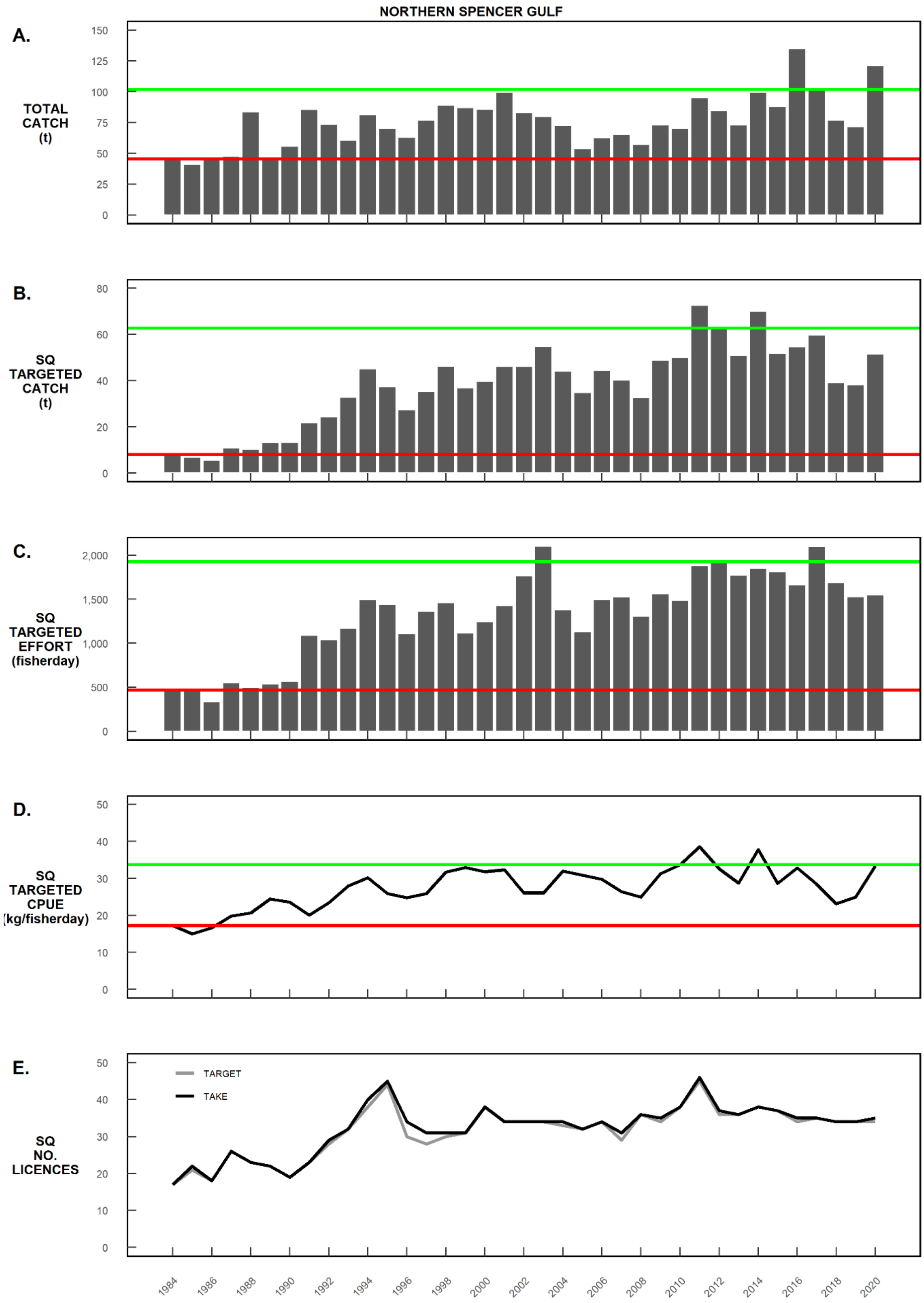

Figure 4-12. Key fishery statistics used to inform the status of Southern Calamari in Northern Spencer Gulf. Long-term trends in (A) total catch; (B) targeted squid jig catch; (C) effort; (D) CPUE; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-7.

Southern Spencer Gulf

Total catch of Southern Calamari in the MSF in SSG has accounted for 30% of the State-wide MSF catch. Total catches reached a record high of 123.7 t in 2017, before stabilising at 121 t in 2018 (Figure 4-13). The total catch has since declined by 14% to 104 t in 2020. Effort levels followed a similar trend, with targeted jig effort rising to a peak of 3,763 fisher-days in 2012 (Figure 4-13). Targeted jig effort then decreased to 2,806 fisher-days in 2016 before peaking at the highest effort recorded of 4,108 fisher-days in 2018. Targeted jig effort decreased to 3,386 fisher-days in 2020. Almost all fishing of Southern Calamari in SSG consisted of jigs, as area available for hauling netting is limited. Targeted jig CPUE peaked at 35.1 kg.fisher-day^{-1} in 2013 but declined over the next seven years to 24.8 kg.fisher-day^{-1}.year^{-1} in 2019 (Figure 4-13). In 2020, targeted jig CPUE increased for the first time since 2013 to 30.3 kg.fisher-day^{-1}.The number of licence holders using jigs to target Southern Calamari in this region remained relatively stable since 2010, ranging from 96–103 fishers per year (Figure 4-13).

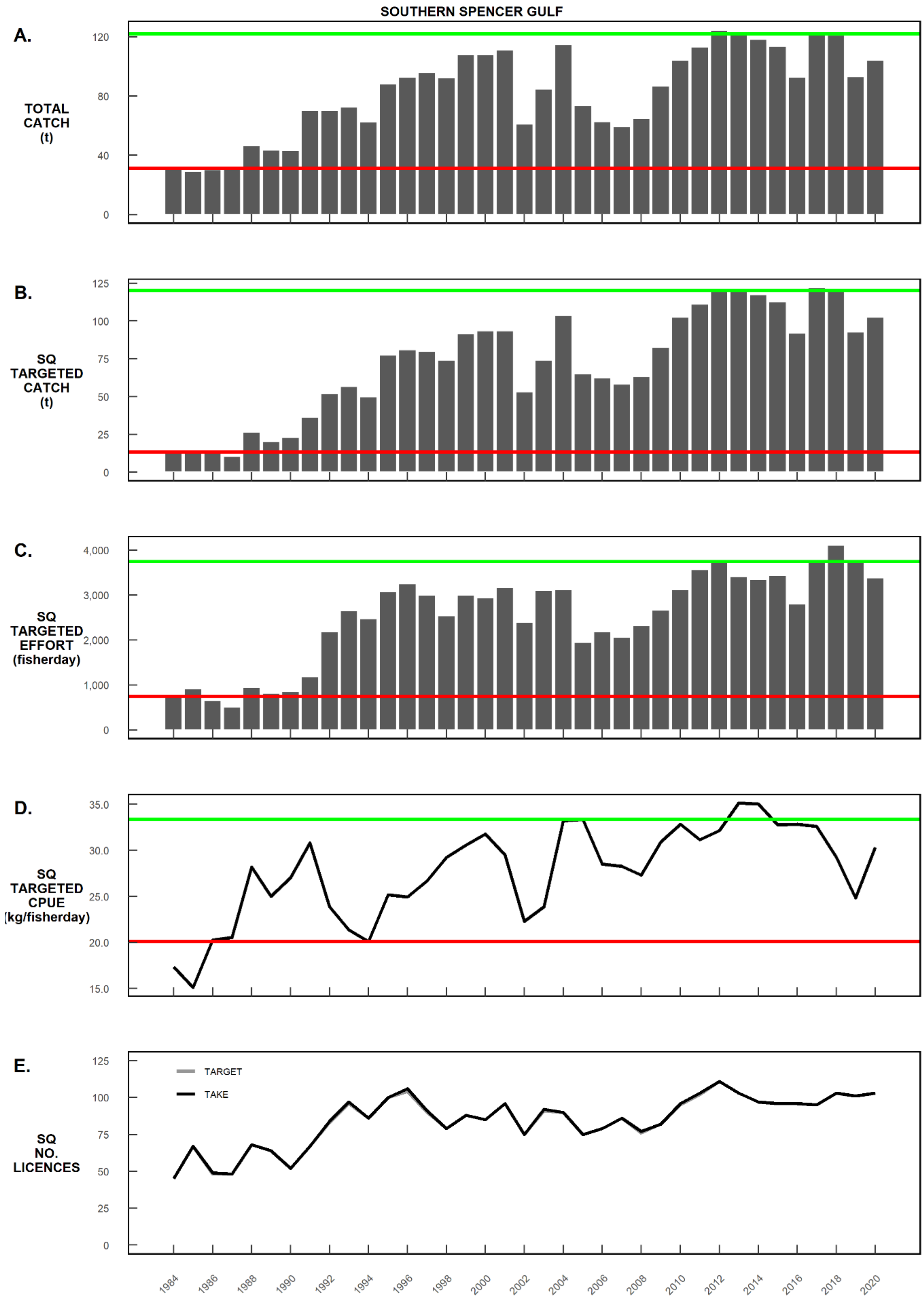

Figure 4-13. Key fishery statistics used to inform the status of Southern Calamari in Southern Spencer Gulf. Long-term trends in (A) total catch; (B) targeted squid jig catch; (C) effort; (D) CPUE; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-7.

Northern Gulf St Vincent

The relative contribution of the commercial Southern Calamari catch from NGSV to the annual State-wide total is ~25%. Annual catches have decreased from a peak of 148 t in 2004 to the most recent low of 69 t in 2009 (Figure 4-14A). Since then, annual total catch has remained relatively stable, averaging ~94 t per year. A total of 92% of the catch was targeted in 2020, of which 32% and 68% were taken using hauling nets and jigs, respectively (Figure 4-14B). Targeted jig effort fluctuated annually following an increasing trend that ranged from 503 to 1,546 fisher-days.yr^{-1} from 1984 to 2012 (Figure 4-14C). Target effort then increased sharply, ranging between 1,409 and 2,207 fisher-days.yr^{-1} between 2012 and 2017. Targeted jig effort was 1,731 fisher-days in 2020. CPUE has been relatively stable between 2011 and 2019, ranging from 28.5 to 33.5 kg.fisher-day.yr^{-1} (Figure 4-14D). In 2020, the CPUE was 27.5 kg.fisher-day^{-1}. The number of licence holders using jigs to target Southern Calamari in NGSV was stable with a slightly upward trend since 1992, averaging 43 per year (Figure 4-14E). However, in 2020 this number decreased to 37 licences which was the lowest number since 2000.

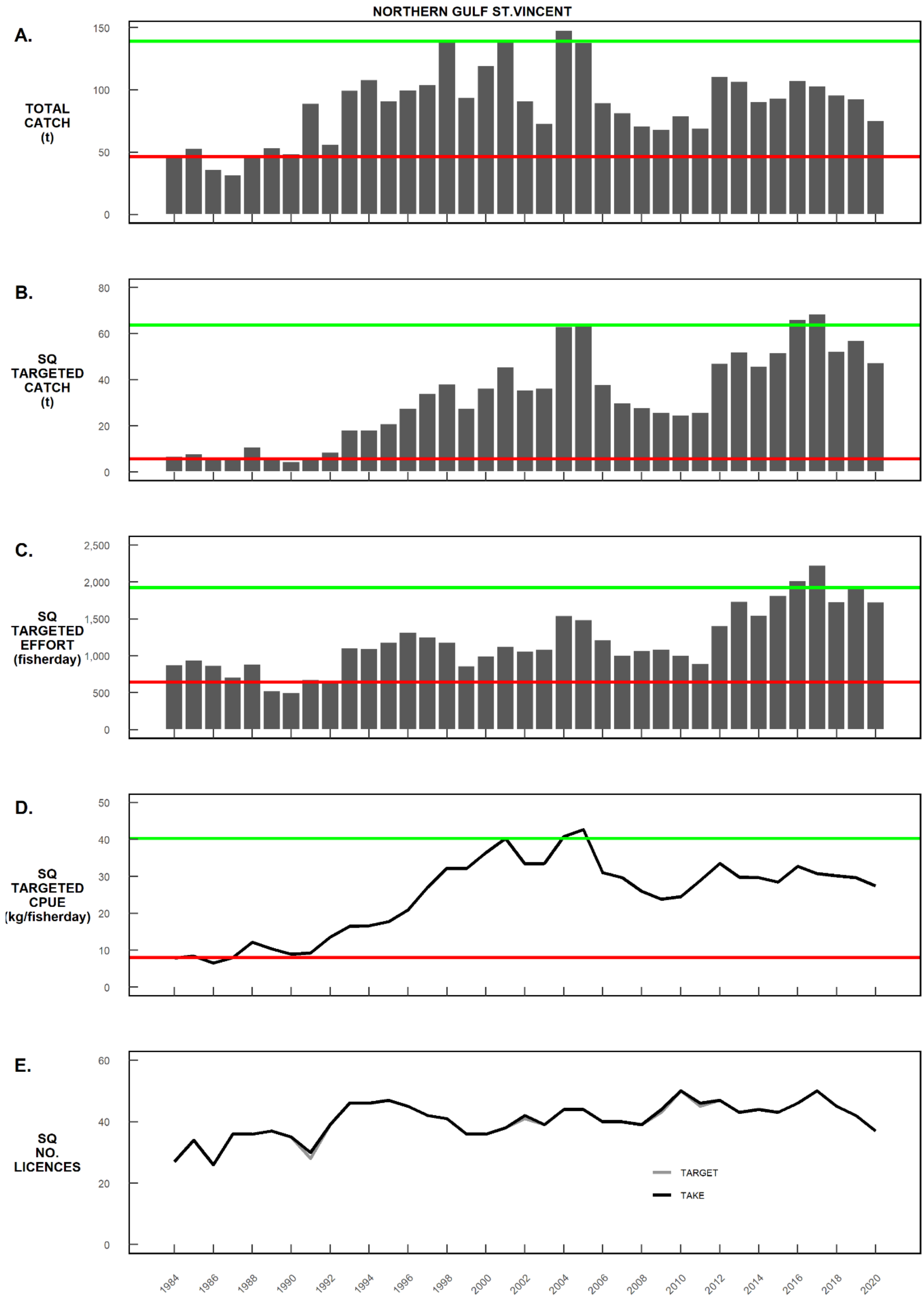

Figure 4-14. Key fishery statistics used to inform the status of Southern Calamari in Northern Gulf St Vincent. Long-term trends in (A) total catch; (B) targeted squid jig catch; (C) effort; (D) CPUE; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-7.

Southern Gulf St Vincent

Southern Gulf St Vincent accounts for ~20% of the State-wide catch of Southern Calamari, in the MSF with almost all (>98%) of it targeted by jig fishers. Total catch peaked at 120.9 t in 2011 (Figure 4-15). Total catch of Southern Calamari in SGSV was 62 t in 2020, representing a decrease in total catch of ~50% in the last 10 years. This decreasing trend has been driven by a concomitant decrease in targeted jig effort, declining from 3,645 fisher-days in 2011 to a record low of 1,830 fisher-days in 2016 (Figure 4-15). Targeted jig effort was 2,140 fisher-days in 2020. Targeted jig CPUE has been moderate and relatively consistent since 1984, averaging 28.5 kg.fisher-day.year^{-1} (Figure 4-15). The number of licence holders using jigs to target Southern Calamari in this region peaked at 69 in 1996, and remained stable, ranging between 42 and 47 during the past 8 years (Figure 4-15).

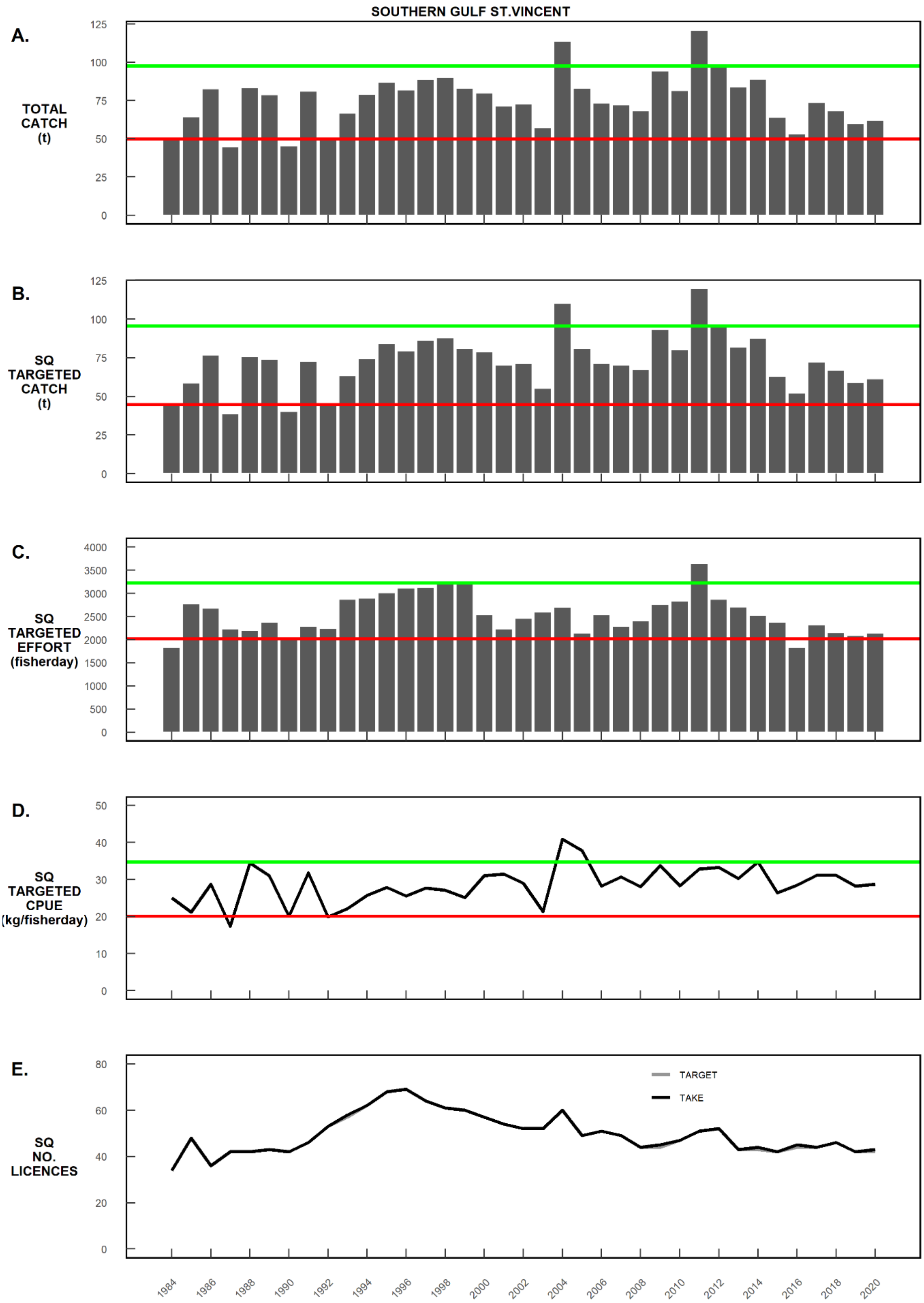

Figure 4-15. Key fishery statistics used to inform the status of Southern Calamari in Southern Gulf St Vincent. Long-term trends in (A) total catch; (B) targeted squid jig catch; (C) effort; (D) CPUE; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-7.

South East

A negligible proportion of the catch (<1%) of Southern Calamari in the MSF was landed in the SE.

Fishery Performance

No trigger limits associated with the relative proportion of commercial catch shares were breached in 2020 (Table 4-6). There were two positive breaches of the general performance indicators for NSG in 2020 (Table 4-7).

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. Trigger 2 is breached if the respective sector allocation is breached for three consecutive years. Trigger 3 is breached if the respective sector allocation is breached in any one year.

COMMERCIAL ALLOCATION	MSF	SZRL	NZRLF	GSVP	SGP	WCP
	90.91%	n/a	0.73%	0.73%	7.47%	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%
2014	91.87%	-	0.34%	0.04%	7.62%	conf.
2015	93.97%	-	0.21%	0.51%	5.23%	conf.
2016	89.18%	-	0.34%	0.77%	9.65%	conf.
2017	88.65%	-	0.11%	0.77%	10.35%	conf.
2018	89.81%	-	0.14%	1.01%	8.85%	conf.
2019	90.15%	-	0.05%	0.70%	8.94%	conf.
2020	91.42%	-	0.06%	0.51%	7.81%	conf.

Table 4-7. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the regional spatial scales for Southern Calamari in 2020.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	WC	NSG	SSG	NGSV	SGSV	SE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	×	2nd HIGHEST	×	×	×	conf.
	G	Greatest % interannual change (+/-)	×	2nd HIGHEST	×	×	×	conf.
	G	Greatest 5 year trend	×	×	×	×	×	conf.
	G	Decrease over 5 consecutive years	×	×	×	×	×	conf.
TARGET JIG EFFORT	G	3rd Lowest / 3rd 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 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 2020, combined across all fisheries was 408 t, with 374 t taken in the MSF (*c.f.* 372 t in 2019). Commercial CPUE has remained relatively high in both the jig and the hauling net sectors of the fishery.

Southern Calamari has become an alternate target species as fishers have shifted their effort away from other primary species (Figure 2-4). Although the biological stock of Southern Calamari encompasses the State, there has been evidence of regional depletion. This was particularly evident in SSG where targeted jig CPUE had declined by 31% between 2012 and 2019. This decline in targeted jig CPUE breached the associated trigger point in the 2019 fishery assessment (Drew et al. 2021). Similar declines in targeted jig CPUE had also been occurring in NSG but with less severity. However, in 2020 targeted jig CPUE increased in both regions of Spencer Gulf, indicating that stock health has improved. While this is a positive result for the fishery, the previous decline in CPUE highlights the potential for regionalised depletion to occur for Southern Calamari. Along with recent declines in CPUE there has also been concerns within industry regarding local productivity with anecdotal reports suggesting that some areas are displaying signs of localised depletion. These inferences have been based on Southern Calamari being 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, the species' high paced life-history, dynamic spawning behaviour, and movement potential, favours population replenishment at the broader biological stock level (Pecl et al. 2006). This may have occurred in Spencer Gulf, leading to these increases in CPUE. While the recovery of targeted jig CPUE in both regions of Spencer Gulf is a positive result, the occurrence of these previous declines indicates that Southern Calamari should be monitored carefully for future signs of regional depletion.

The above evidence indicates that the biomass of Southern Calamari at the State level is unlikely to be depleted and that recruitment is unlikely to be impaired at the biological stock level. However, there are concerns regarding levels of fishing activity on regional populations, particularly within Spencer Gulf. Nevertheless, the current level of fishing mortality is unlikely to cause the biological stock to become recruitment impaired. On this basis, South Australia's Southern Calamari stock is classified as **sustainable**.

4.3.4. Yellowfin Whiting

Biology

The Yellowfin Whiting (*Sillago schomburgkii*) is endemic to Australian coastal waters from Dampier to Albany in Western Australia and in South Australia’s gulf waters (Kailola et al. 1993). Uncertainty exists about the continuity of the species' distribution through the remote coastal waters between Western Australia and South Australia (Ferguson and Duffy 2021).

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. The life history of this species appears particularly adapted to habitation of relatively protected, shallow, near-shore gulf and coastal waters. Adults are generally associated with shallow, tidal creeks and coastal sand flats 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 (Ferguson 2000). Yellowfin Whiting demonstrate different growth patterns between the sexes that culminates in females reaching larger sizes-at-age than males (Ferguson 2000). Furthermore, market sampling of commercial catches has demonstrated considerable bias in sex ratios towards females. Age estimation of Yellowfin Whiting using otoliths has indicated a longevity of ~12 years, although most fish taken in the commercial fishery were 2 to 4 years old.

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 (Ferguson and Duffy 2021). 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 reflect that its catches have been variable as in the past it was targeted when demand for, or availability of, primary species was low. As the Yellowfin Whiting is a schooling species that occupies sandy, shallow habitats predominantly in the northern gulfs, it is particularly vulnerable to net gear types used in 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. 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

There is a minimum size limit of 240 mm TL for Yellowfin Whiting that applies to the commercial and recreational sectors. A bag limit of 20 fish and boat limit of 60 fish is in place for the recreational sector. Furthermore, for the commercial sector, the many regulations that are input controls for the net gear types contribute to minimising fishing effort directed at Yellowfin Whiting. These include restrictions to net lengths and mesh sizes, extensive spatial closures and temporal restrictions that limit net fishing activities.

Commercial Fishery Statistics

State-wide

Estimates of total annual State-wide commercial catches of Yellowfin Whiting have ranged from 14.5 t in 1988 to 179 t in 2001 (Figure 4-16). During the last decade, catch increased from 88 t in 2011 to 151 t in 2013 and averaged 122 $t.yr^{-1}$ (range: 96–141 $t.yr^{-1}$) from 2014–2019. In 2020, total catch declined to 95.7 t. The economic value of the commercial catch of Yellowfin Whiting in 2020 was approximately $886 K (*c.f.* $1.1 M in 2019) (Figure 4-16).

Combined hauling net and gillnet effort declined between 2002 and 2007 and has been relatively flat since then (Figure 4-16). Hauling nets account for most of the fishing effort that produces catches of this species. State-wide annual estimates of CPUE for hauling nets (targeted and non-targeted effort) have been highly variable, with an increasing trend from 1984 to 2020, with the estimate in the latter year being 52.9 $kg.fisher\text{-}day^{-1}$ (Figure 4-16). Also, from 1984 to 2020, the total number of licence holders who reported taking Yellowfin Whiting declined from 129 to 43, with 40–50% of these licences targeting the species in each year since 2005 (Figure 4-16).

Regional

Although the annual catches of Yellowfin Whiting in NSG have been variable since 1984, they have always been higher than in the other SA regions (Figure 4-17). Since the early 1990s, NGSV has been the second most productive region, whilst lower catches have come from the southern gulfs. Only incidental catches have been recorded from the SE and WC.

Northern Spencer Gulf continues to be the region where most of the State's commercial catch of Yellowfin Whiting is taken (Figure 4-17).

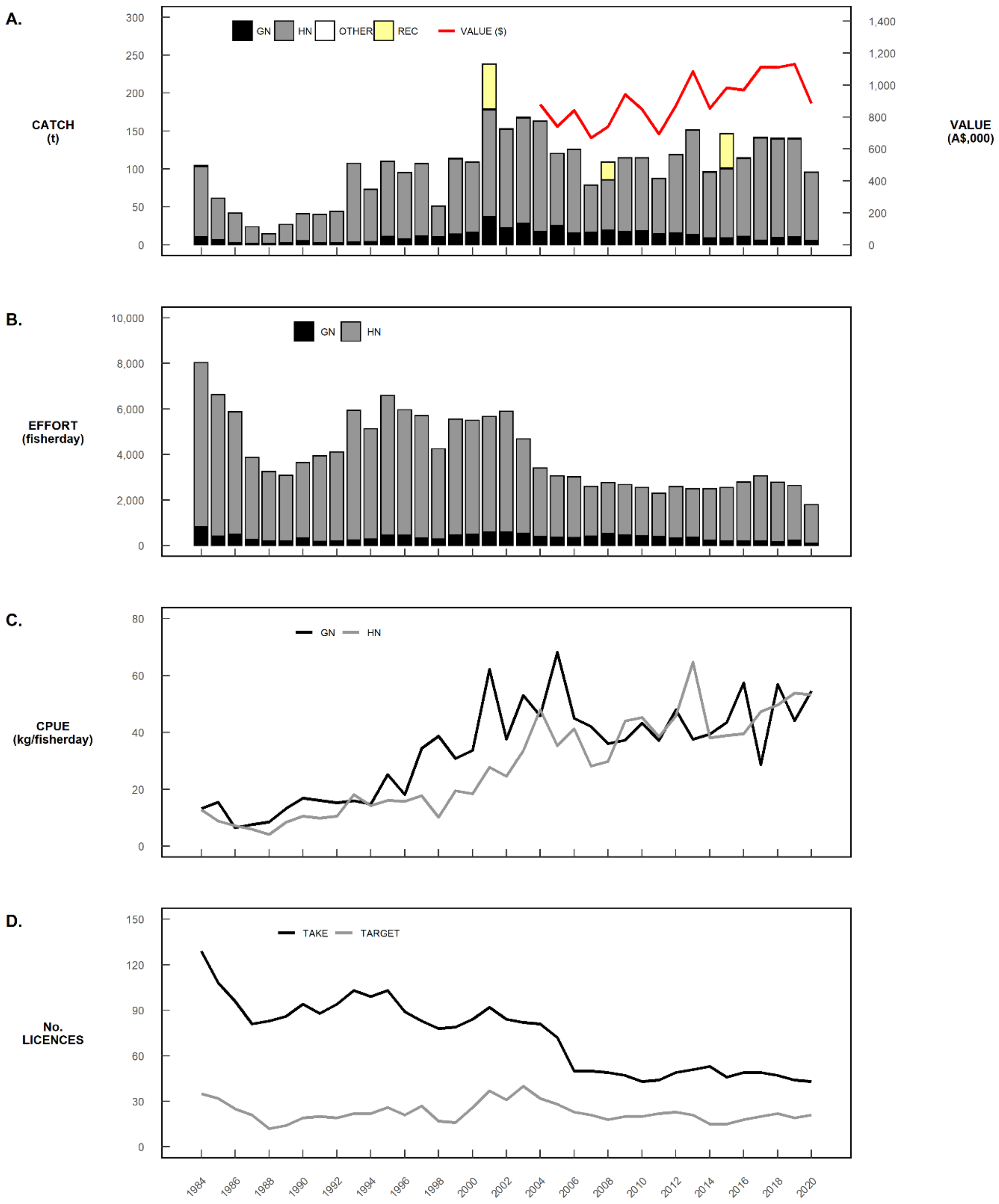

Figure 4-16. Yellowfin Whiting. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (hauling and gillnets), estimates of recreational catch and gross production value; (B) total effort for hauling and set nets; (C) total catch per unit effort (CPUE) for hauling and dab nets; and (D) the number of active licence holders taking or targeting the species.

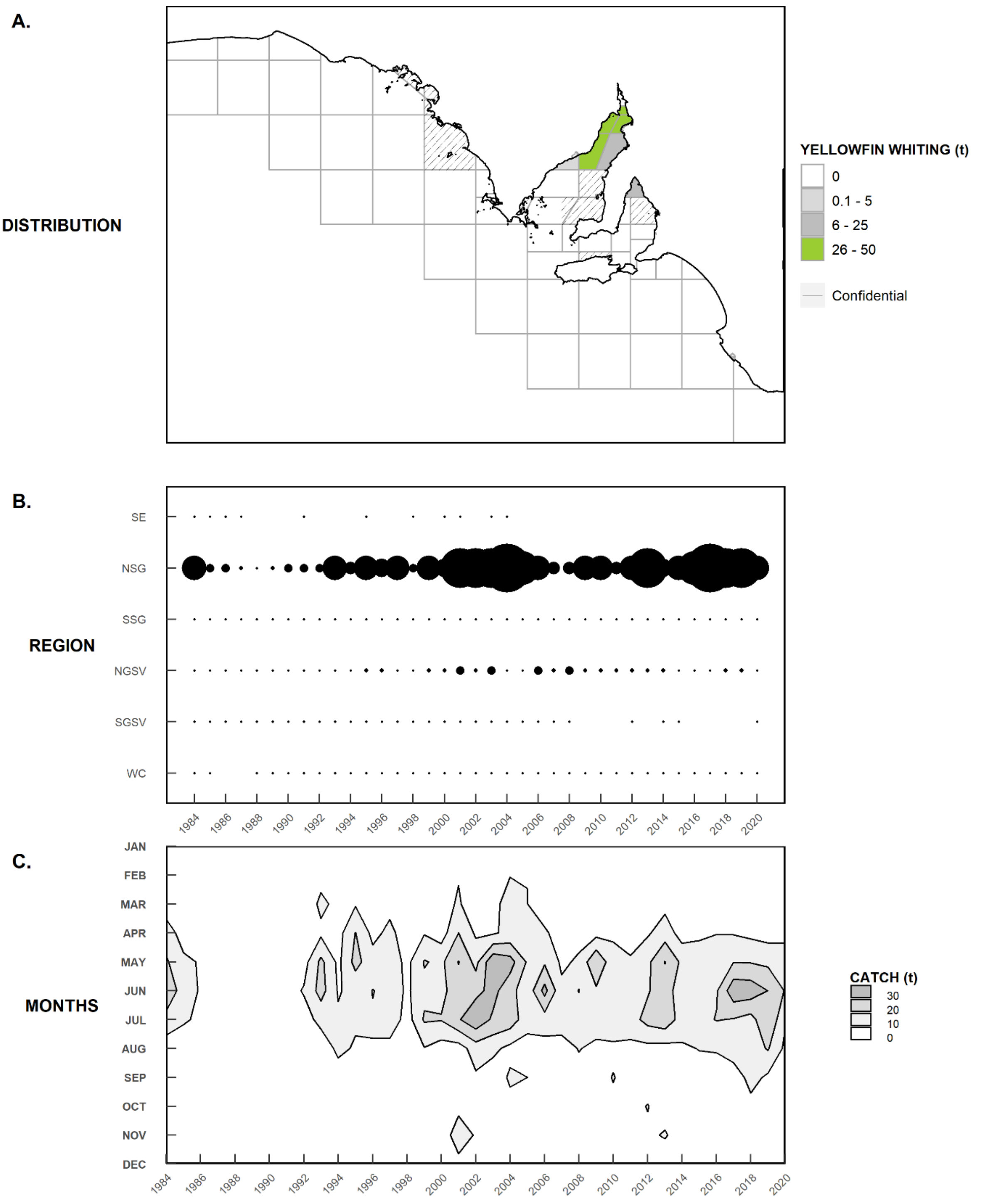

Figure 4-17. Yellowfin Whiting. (A) The spatial distribution of catch by the commercial sector in 2020. Long-term trends in: (B) the annual distribution of catch among regions, (C) months of the year.

Spencer Gulf / West Coast Stock

Total catch of Yellowfin Whiting from WC/SGS has varied considerably over the years (Figure 4-18). The lowest catch of 13.1 t was taken in 1988 and the highest of 148 t was taken in 2004. The total catch of 85 t in 2020 was the lowest since 2015 and approximately equal to the average annual catch taken during 2005–2015.

Targeted hauling net catches have been highly variable, with the highest catches of 54–86 t taken between 2001 and 2004 (Figure 4-18). Targeted hauling net effort peaked at 826 fisher-days in 2004, but subsequently decreased to 161 fisher-days in 2014, prior to increasing again to 295 fisher-days in 2019 (Figure 4-18). Targeted hauling net effort was 176 fisher-days in 2020.

Targeted hauling net CPUE in SG has been variable but showed no long-term trend from 1984 to 2008, but has increased considerably since then, peaking at 169.6 kg.fisher-day^{-1} in 2014 (Figure 4-18). In 2020, the targeted hauling net CPUE of 147 kg.fisher-day^{-1} was the fourth highest on record. The number of licence holders who took Yellowfin Whiting with hauling nets has been stable at around 21–29 since 2006. The number of fishers who targeted this species with hauling nets has also been relatively stable and typically around 40–50% of the total number of fishers that landed the species (Figure 4-18).

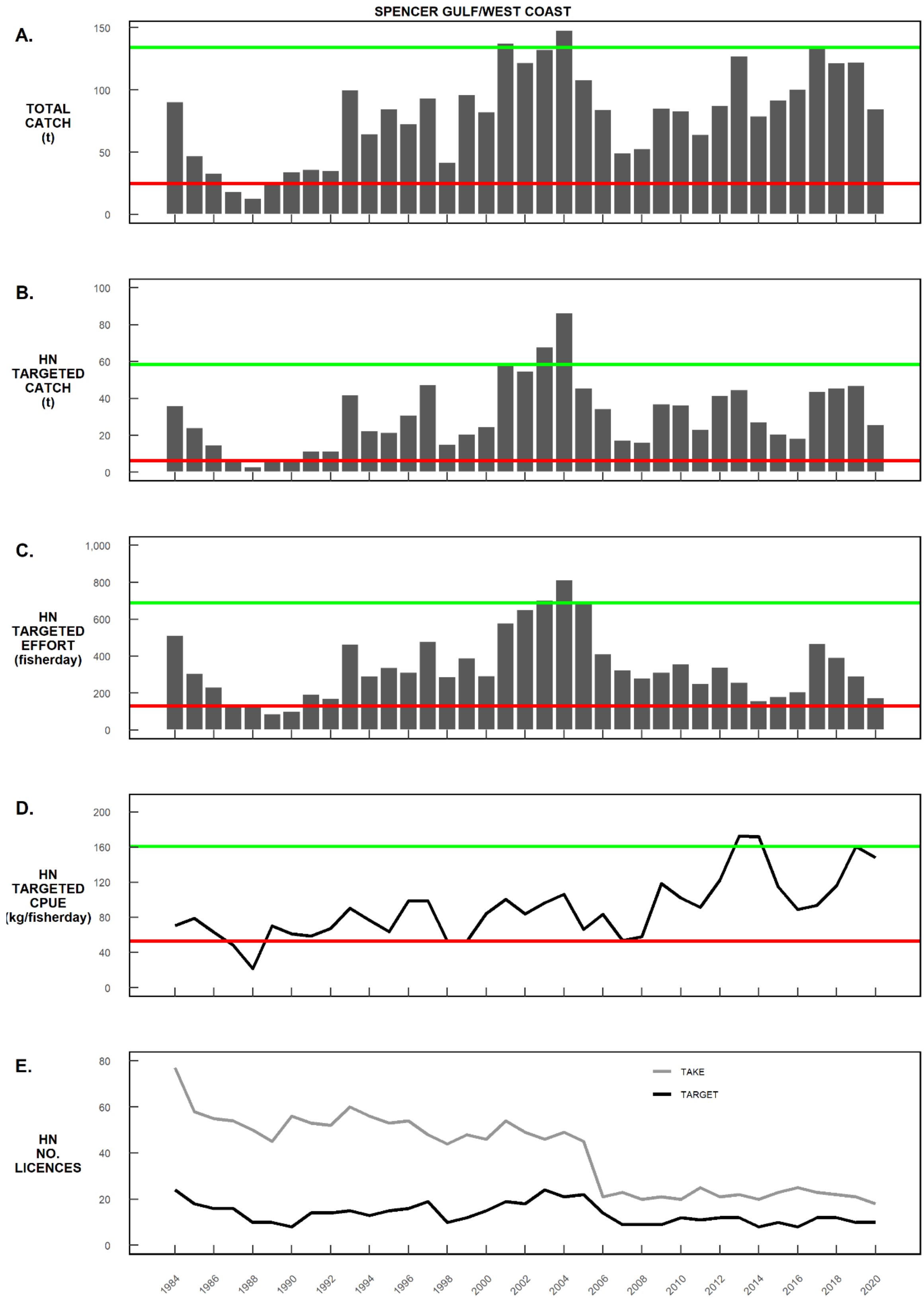

Figure 4-18. Key fishery statistics used to inform the status of Yellowfin Whiting in Spencer Gulf / West Coast. Long-term trends in (A) total catch; (B) targeted hauling net catch; (C) effort; (D) CPUE; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-8.

Gulf St Vincent Stock

In GSV, total annual catches of Yellowfin Whiting were highest in 2001 and 2006, when they peaked at 41 $t.yr^{-1}$ (Figure 4-19). Catch declined to 7.5 t in 2017 and was 10.9 t in 2020. Targeted hauling net catches have been <5 $t.yr^{-1}$ in most of the past 13 years (Figure 4-19). These low levels of targeted catch were associated with low levels of targeted hauling net effort, which in 2019 was at 44 fisher-days (Figure 4-19). Estimates of targeted catch, effort and CPUE using hauling nets in 2020 were confidential (i.e. data reported by fewer than five licences). In 2018, targeted hauling net CPUE was 79 $kg.fisher\text{-}day^{-1}$, which was similar to the average CPUE from 2001–2020 (Figure 4-19). In 2020, 15 fishers landed Yellowfin Whiting in GSV with six of those having targeted the species. Confidentiality issues prevent presenting the full time-series of commercial catch and effort data (Figure 4-19).

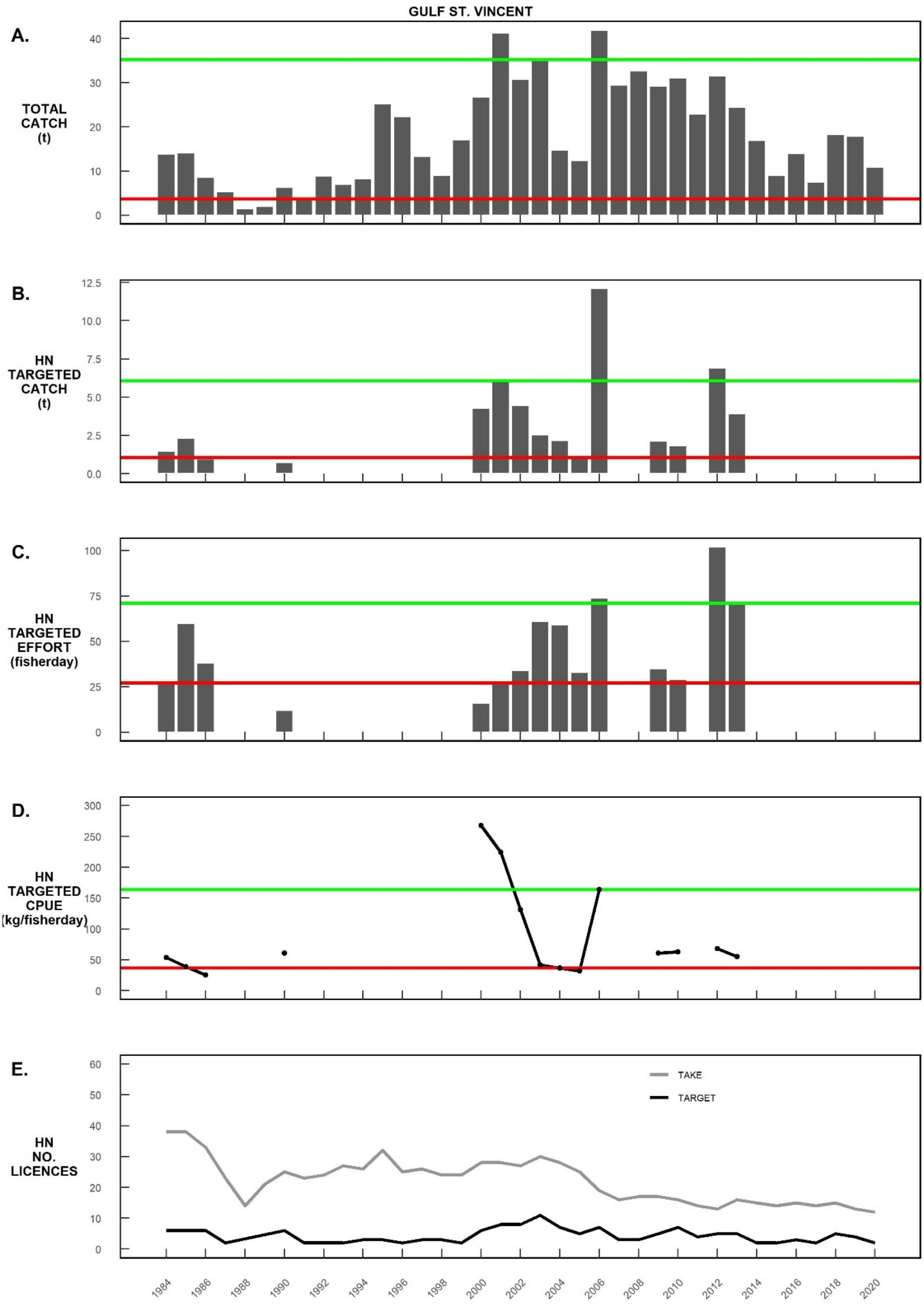

Figure 4-19. Key fishery statistics used to inform the status of Yellowfin Whiting in Gulf St Vincent. Long-term trends in (A) total catch; (B) targeted hauling net catch; (C) effort; (D) CPUE; and (E) the number of active licence holders taking and targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-8.

Fishery Performance

The general fishery performance indicators for Yellowfin Whiting were assessed for 2020 for both the SG and GSV stocks. No trigger reference points were breached (Table 4-8).

Table 4-8. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the regional spatial scales for Yellowfin Whiting in 2020.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	SG	GSV
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	×	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

Spencer Gulf Stock

State-wide commercial catches of Yellowfin Whiting have been dominated by those from Spencer Gulf, although the fishery performance indicators for this region are characterised by high levels of variability. This reflects the variable nature of targeted fishing effort, with fishers either opportunistically targeting the species due to market demands, or when the availability of higher value species is low. There was a declining trend in targeted effort for Yellowfin Whiting between 2005 and 2016. This decline, however, was not reflected in the trends in total catch, targeted catch or targeted CPUE. Then, targeted effort increased again from 2017–2019 and this culminated in increases in total catch, targeted catch and CPUE. Catch declined in 2020 reflecting a decline in targeted effort, while targeted CPUE was high. Such evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current catch level is unlikely to cause the stock to become recruitment impaired. On this basis, Yellowfin Whiting in Spencer Gulf is classified as a **sustainable** stock.

Gulf St Vincent Stock

The Gulf St Vincent stock has produced considerably lower annual catches than those from Spencer Gulf. The targeted catches from the hauling net sector in this region have been variable over time reflecting variable effort. Recent estimates of total catch have been low–moderate and within the lower and upper trigger reference points. The evidence above indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On this basis, Yellowfin Whiting in Gulf St Vincent stock is classified as a **sustainable** stock.

4.3.5. Western Australian Salmon

Biology

The Western Australian Salmon (*Arripis truttaceus*) (hereafter referred to as ‘Salmon’) comprises a single biological stock that extends from south-eastern Western Australia to the western coasts of Tasmania and Victoria, with each State jurisdiction across this distribution harvesting different life-history stages (Earl et al. 2021). The Western Australian fishery typically targets adult fish that aggregate around the south-western coastline near Albany, whereas the fisheries in South Australia, Victoria and Tasmania harvest juveniles and sub-adults in coastal waters as they migrate west along the southern coast of the continent to join the adult biomass in WA (Cappo 1987, Jones and Westlake 2003).

Salmon form large schools in 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. Eggs and larvae settle along the entire southern coastline of Australia, with the main nursery grounds located in South Australia, and to a lesser extent, northern Tasmania and western Victoria (Earl et al. 2021). Juveniles remain in coastal nursery areas (e.g. gulf waters in SA) for approximately up to three years where they feed on epibenthic crustaceans and small–medium bodied fish (Hoedt and Dimmlich 1995). During their second and third years of life, they move from nursery areas to exposed coastal waters where they form large schools and begin to migrate westward to join the spawning biomass as 5-6 year olds, where they can attain a maximum age of ~12 years and reach a maximum size of 850 mm FL (Cappo 1987). As a result of these demographic processes which operate across a large spatial scale of ~3,000 km, the fishery in SA harvests mainly juvenile and sub-adult Salmon.

Fishery

Historically, the commercial harvest of Salmon in South Australia has been confined to gulf and coastal waters and targeted by hauling net fishers and 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. The product is typically used for lobster bait with a small but increasing proportion of the catch used for human consumption.

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 recreational harvest weight was 56.2 t, which was ~48% of the State’s total catch in 2013/14.

Management Regulations

Since 1984, the commercial harvest of Salmon in SA 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 not exceeded 650 t since at least 1984. 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 2016b).

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. Daily size, bag and boat limits were implemented for the recreational sector in 1995. 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 hauling net component and a specialist purse seine (i.e. Salmon net) component. From 1984 to 2003, the commercial catches fluctuated around 450–600 t per year, with most of the catch taken by a small number of purse seiners operating throughout the lower West Coast and Southern Gulf St Vincent (SGSV) (Figure 4-20). From 2004 to 2013, catch was considerably lower and averaged 156 $t.yr^{-1}$ (range 59–262 $t.yr^{-1}$), as purse seiners exited the fishery. During that 10-year period, hauling net fishers landed most (up to 90%) of the annual catch. Catch increased to ~370 t in 2016 and 2017 and then fell to 156 t in 2018. Total catch declined to 75 t in 2020, which was the second lowest recorded for the fishery. The decline in catch related to a decline in total catch by fishers using purse seine, as catch taken using hauling net was stable (Figure 4-20). The economic value of the commercial catch of Salmon in 2020 was approximately $179 K (*c.f.* $304 K in 2019) (Figure 4-20).

Targeted fishing effort using hauling nets was highest during 1980s and early 1990s with peaks of 764 and 807 fisher-days in 1986 and 1992, respectively (Figure 4-20). From 1993 it gradually declined to 61 fisher-days in 2008 and since then has not exceeded 95 fisher-$days.yr^{-1}$. Targeted CPUE using hauling nets peaked at 1,721 $kg.fisher\text{-}day^{-1}$ in 2009 (Figure 4-20). This peak was uncharacteristically high as annual CPUE has rarely exceeded 450 $kg.fisher\text{-}day^{-1}$ since 1984 and has typically ranged between 100–500 $kg.fisher\text{-}day^{-1}$. CPUE decreased to 230 $kg.fisher\text{-}day^{-1}$ in 2020 (*c.f.* 275 $kg.fisher\text{-}day^{-1}$ in 2019) which is slightly below the average CPUE for 2010–2020.

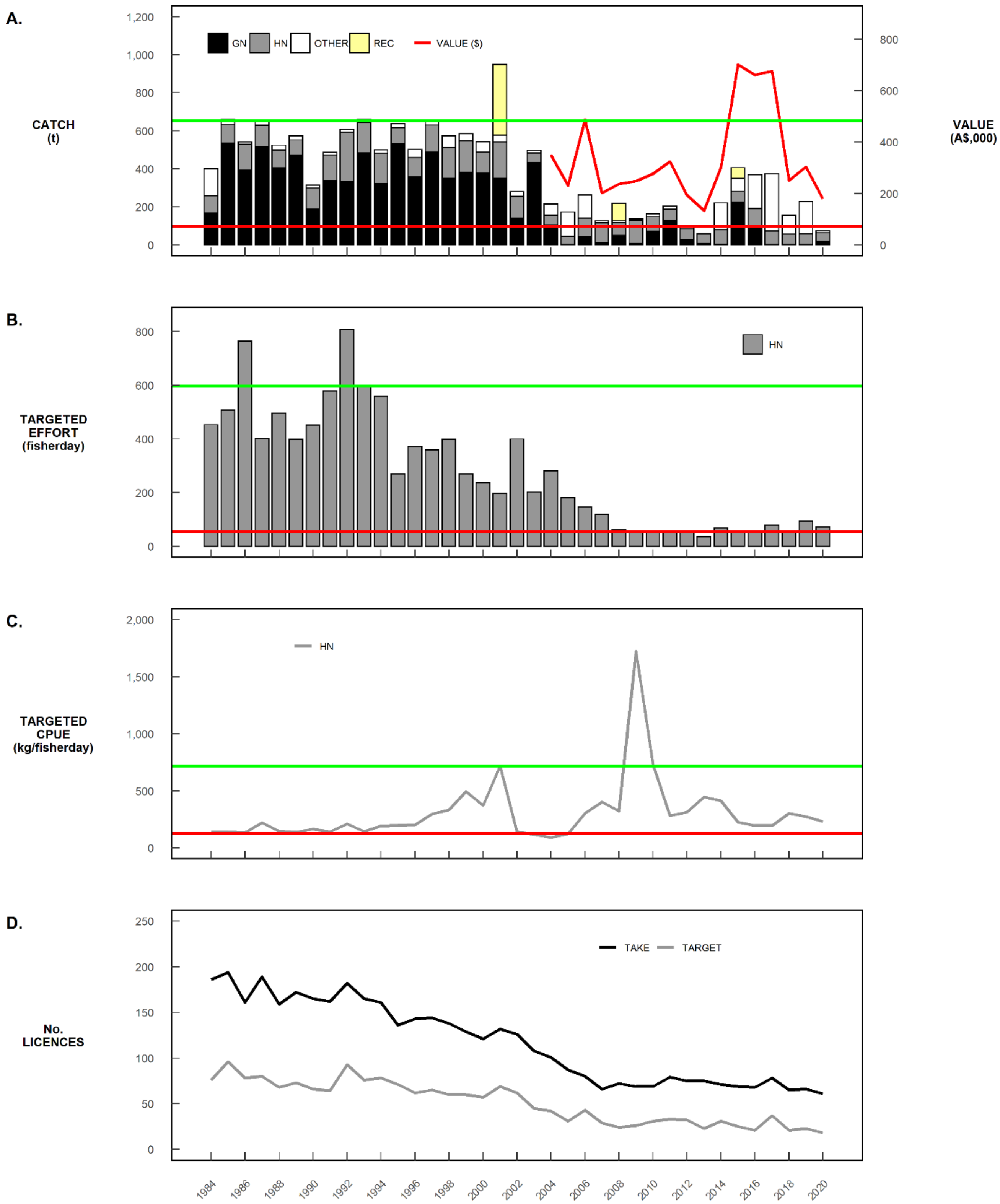

Figure 4-20. Western Australian Salmon. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (hauling and set nets), estimates of recreational catch, and gross production value; (B) targeted effort for hauling nets; (C) total catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-9.

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 4-21). From 2004 to 2013, the highest catches were taken in SSG. However, since 2013, the relative 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 (Figure 4-21).

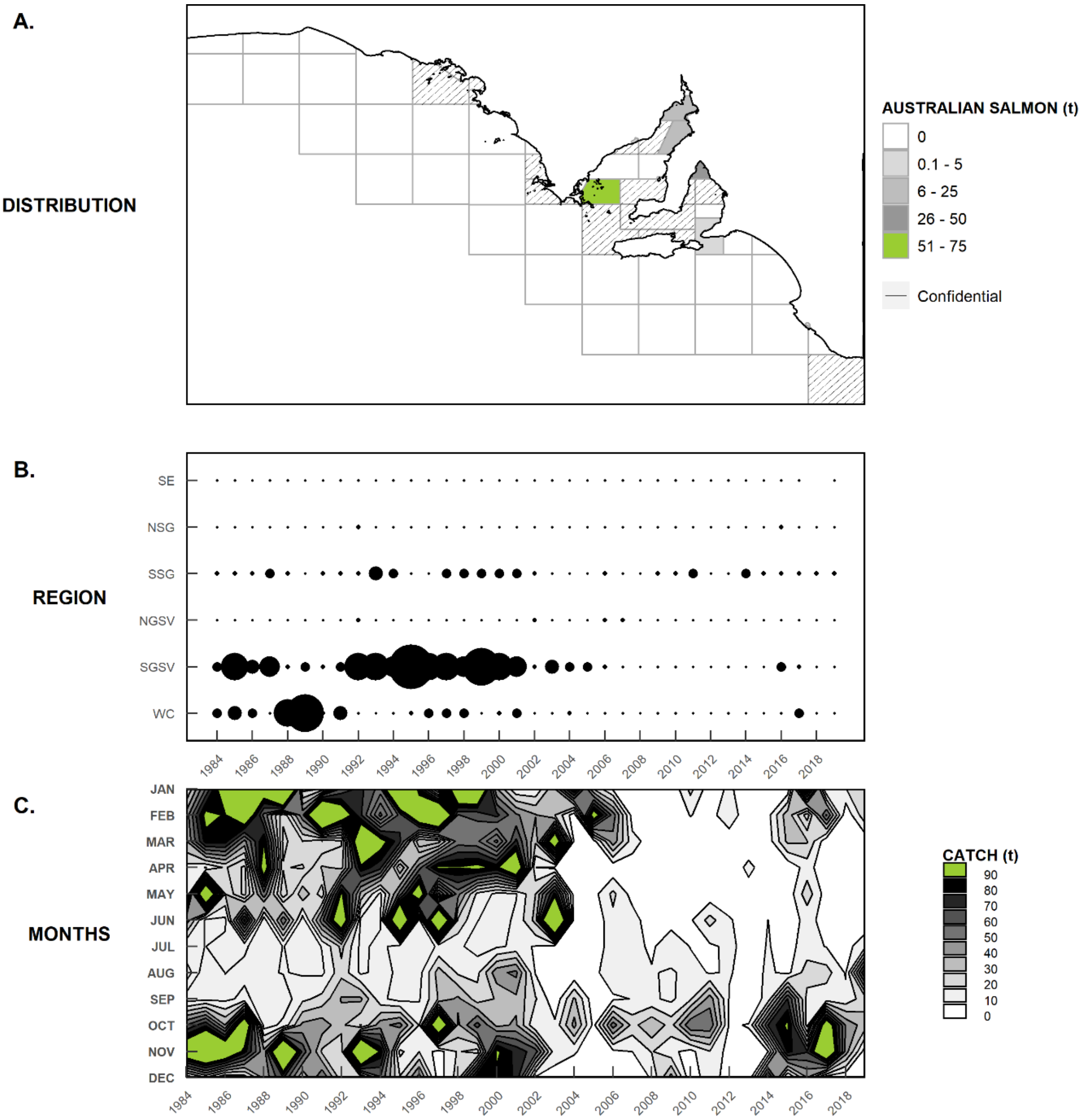

Figure 4-21 Western Australian Salmon. (A) The spatial distribution of catch by the commercial sector in 2020. Long-term trends in: (B) the annual distribution of catch among regions, (C) months of the year.

Fishery Performance

The general performance indicators for Salmon were assessed for 2020 at the State-wide scale. Two trigger reference points relating to total catch were breached. One breach related to the low total catch of 75 t in 2020, which was the second lowest catch recorded in the fishery, while the other was related to the 133% decline in total catch from 2019 (Table 4-9).

Table 4-9. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Salmon in 2020.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	2nd 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 cross-jurisdictional biological stock of Salmon has components in Western Australia, South Australia, Victoria and Tasmania. Given the shared biological stock of Salmon 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. In 2018/19, the biological stock was considered to be 'sustainable' as the fisheries in each State had been relatively inactive due to weak market demand and low wholesale prices (Earl et al. 2021).

In South Australia, the MSF is the main commercial fishery for Salmon and has predominantly used hauling nets with some fishers using purse seine nets. In recent years a high proportion of the catch has been taken using purse seine nets. Recent trends in catch and targeted effort in the MSF indicate that the current levels of fishing mortality in South Australia have been relatively low in most years since the mid-2000s, partly because of a series of netting closures that were implemented in 2005. However, the relative inactivity of key purse seiners in the fishery is indicative of a weak market. The slightly higher catches taken from 2015 to 2017 and subsequent higher economic value of the fishery suggested emerging markets for this species. However, since then catches have dropped considerably with the total catch 75 t in 2020 the second lowest catch recorded in the fishery. The low catch in 2020 was due to considerable decline in catch taken by the purse seine component of the fishery, while catch taken using hauling nets was stable. The recent low catches and relatively stable low–moderate levels of CPUE indicate that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment overfished. On this basis, the MSF for Salmon is classified as **sustainable**.

4.3.6. Australian Herring

Biology

Australian Herring (*Arripis georgiana*) (hereafter referred to as ‘Herring’) is distributed in coastal marine and estuarine waters between Shark Bay, Western Australia, and Forster in New South Wales, although is uncommon east of Bass Strait (Duffy et al. 2021). It constitutes a single biological stock across this range (Ayvazian et al. 2000, Ayvazian et al. 2004).

Herring 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 (Smith et al. 2013). The extent of their distribution relates to the relative strength of the Leeuwin Current which transports warm tropical water southward in the Indian Ocean and eastward along Australia’s southern coastline during autumn and winter. Juveniles settle in inshore waters throughout this eastward distribution, some in close proximity to the spawning grounds, whereas others extend as far as Victoria. Fish grow and mature at two to three years of age and ~200 mm TL in each jurisdiction before migrating back to the spawning area where they remain as adults. There are no records of spawning by this species along the east coast (Smith et al. 2013).

Fishery

The schooling behaviours of Herring have made them an 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. 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 gillnets are also used to catch Herring for bait for either commercial longlining or Rock Lobster fishing. 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. Recreational fishers capture Herring using rod and line from boat and shore-based platforms. The 2013/14 estimate of catch for the recreational sector was 157.2 t (Giri and Hall 2015).

Management Regulations

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 annual State-wide commercial catch of Herring increased to a historical peak of 493.8 t in 1987. Since then, catch gradually declined to a low of 61.2 t in 2017 and was 83.1 t in 2020 (*c.f.* 99.8 t in 2019) (Figure 4-22). The economic value of the commercial catch of Australian Herring in 2020 was approximately $348 K (*c.f.* $322 K in 2019) (Figure 4-22).

Netting closures have contributed to a long-term reduction in total hauling net effort in the MSF (Figure 4-22). This reduction is reflected in long-term trends in targeted hauling net effort for Herring, which peaked at ~700 fisher.days.yr^{-1} in the late 1980s and early 1990s and has gradually declined to historically low levels during the past five years. The targeted hauling net effort for Herring of 32 fisher-days in 2020 was the second lowest recorded in the fishery since 1984.

Target CPUE of Herring in the hauling net sector has been highly variable since 1984 ranging from 53.4 kg.fisher-day^{-1} in 2003 to 216.5 kg.fisher-day^{-1} in 1999 (Figure 4-22). Targeted hauling net CPUE for Herring in 2020 was 85.3 kg.fisher-day^{-1}. Approximately 10–20% of fishers that take Herring actively target the species, and this has remained relatively consistent since 2005 (Figure 4-22). In 2020, 78 fishers landed Herring, of which 11 fishers actively targeted the species.

Regional

Prior to the implementation of the netting closures in 2005, the highest catches for Herring were shared amongst NSG, SSG, and NGSV (Figure 4-23). Since then, the catches from SSG and NSGV have reduced while the relative proportion of catch from NSG has remained relatively unchanged. Historically, most of the Herring catch in each year has been landed throughout spring and autumn (Figure 4-23).

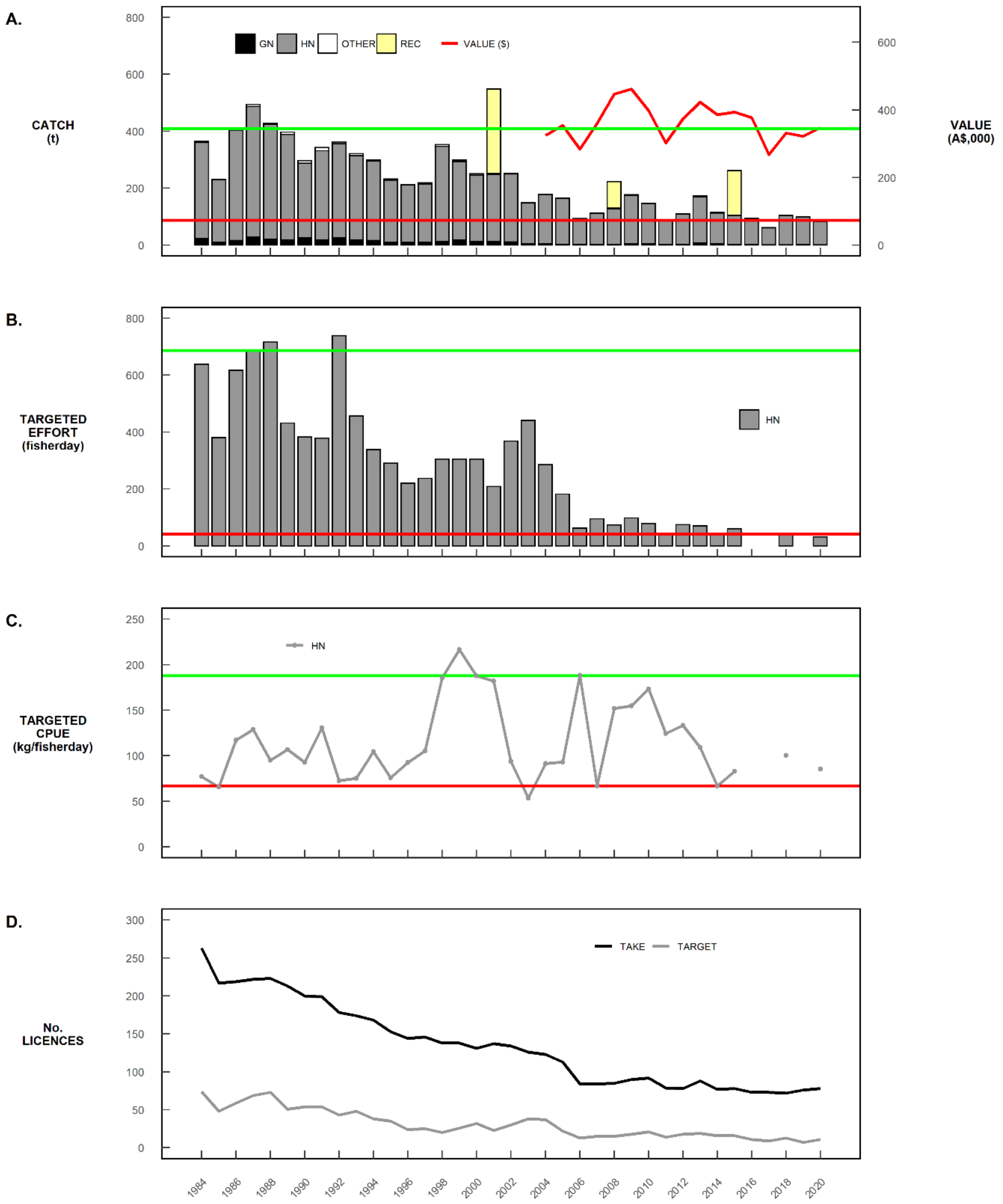

Figure 4-22. Australian Herring. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (hauling and set nets), estimates of recreational catch, and gross production value; (B) targeted effort for hauling nets; (C) total catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-10.

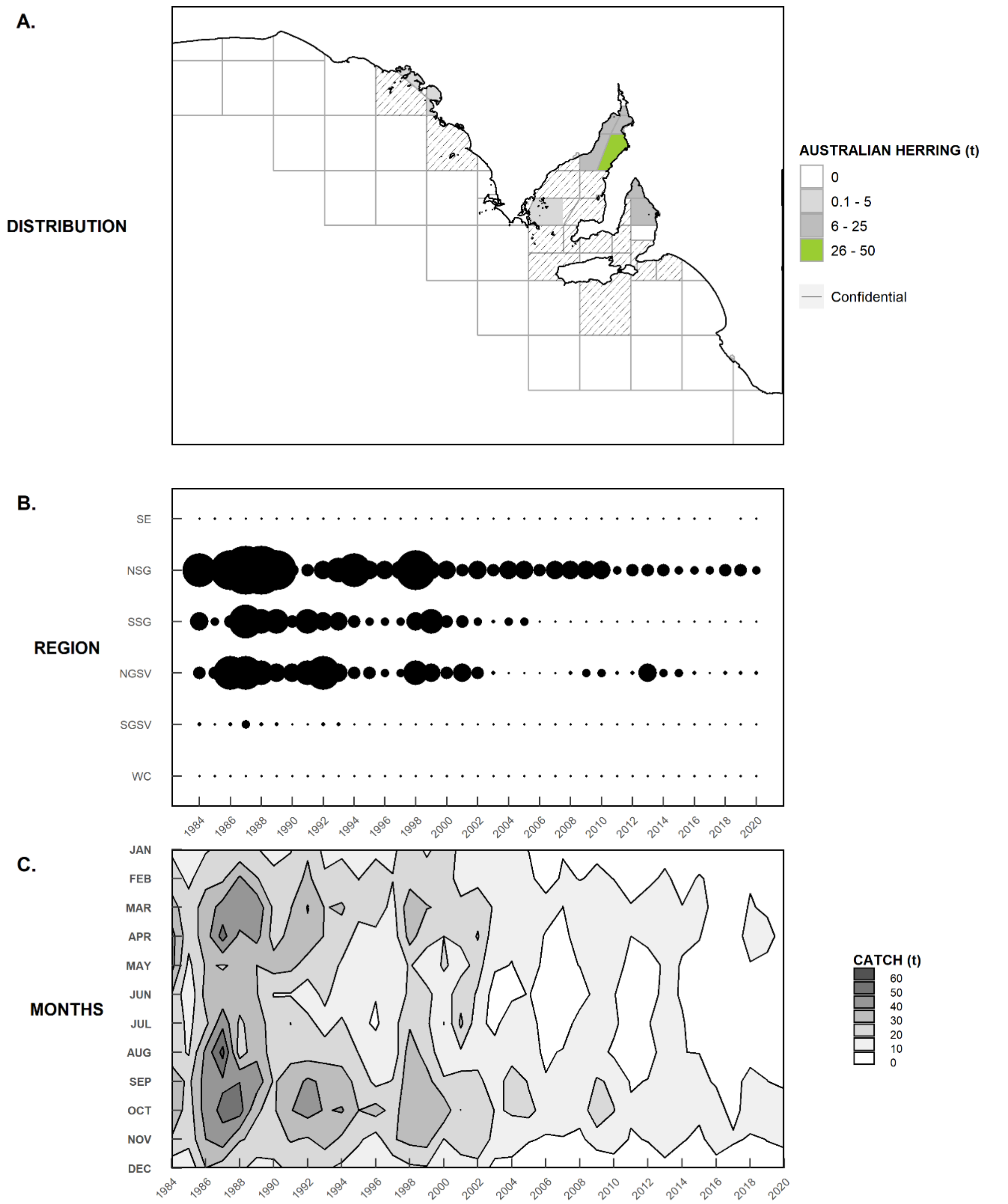

Figure 4-23. Australian Herring. (A) The spatial distribution of catch by the commercial sector in 2020. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t).

Fishery Performance

The general performance indicators for Herring were assessed for 2020 at the State-wide scale, using the reference period 1984–2020. Two trigger reference points were activated for 2020, with the second lowest total catch and third lowest targeted hauling net effort recorded (Table 4-10).

Table 4-10. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State scale for Australian Herring in 2020.

PERFORMANCE INDICATOR	TYPE	TRIGGER REFERENCE POINT	STATE
TOTAL CATCH	G	3rd Lowest / 3rd Highest	2nd 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	3rd LOWEST
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×
TARGETED 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 biological stock of Herring across southern Australia is accessed by fisheries in Western Australia (WA), South Australia, Victoria and New South Wales (NSW). Historically, WA has been the main contributor to annual catches of Herring with smaller contributions from SA and minor contributions from Victoria and NSW. The most recent assessment for Herring in WA indicated that the spawning biomass of the biological stock was above the limit reference level (20 per cent of the unfished level) and has increased since 2016 (Wise and Molony 2018). This increase in stock biomass likely reflects the high productivity of the species and the introduction of management arrangements in WA in 2015 which have significantly reduced commercial landings. The stock was classified as 'sustainable' in the 2020 Status of Australian Fish Stocks Report (Duffy et al. 2021)

In the MSF, levels of targeted hauling net effort and total catch have been consistently low since the implementation of a series of netting closures in 2005. This continued in 2020 with the second lowest total catch and third lowest targeted effort recorded since 1984. Over the past six years, targeted CPUE for the hauling net sector has been relatively stable at moderate levels with small numbers of fishers actively targeting the species due to weak market demand. The recent low levels of targeted fishing effort and subsequent catches and stable CPUE indicate that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On this basis, the MSF for Herring is classified as **sustainable.**

4.3.7. Snook

Biology

Snook (*Sphyraena novaehollandiae*) are elongate predators that occur over seagrass beds and reefs in inshore and offshore waters (Emery et al. 2016). They prey on pelagic and demersal teleost fishes, crustaceans and cephalopods (Bertoni 1994). The species is distributed across southern Australia from Perth to Sydney, including around Tasmania as well as New Zealand (Gomon et al. 2008). There is little information available on the stock structure of Snook throughout its broad Australasian distribution (Emery et al. 2016).

A study in Gulf St Vincent and Spencer Gulf during 2002 (O'Sullivan and Jones 2003) found that the largest fish was 820 mm TL, although most fish measured were in the size range of 300 to 500 mm TL. The modal age was 2+ years and the oldest fish were 12 years old. Males and females have similar growth patterns, with a strong bias in the sex ratio towards females. Snook were reproductively active during late spring-summer (Bertoni 1994). They are multiple batch spawners with indeterminate fecundity. The length-at-50%-maturity (L_{50}) is 391 mm and 403 mm TL for males and females, respectively, at two years of age.

Fishery

Snook are taken by both the commercial and recreational sectors of the MSF. In the commercial sector, they are generally taken with hauling nets and gillnets when fishers target higher value species such as King George Whiting, Southern Garfish, Southern Calamari and Yellowfin Whiting. Snook are also targeted by commercial fishers using troll lines. Recreational fishers target Snook with rods and lines. The State-wide recreational survey done in 2013/14 estimated that 187,165 Snook were captured, of which 12,941 were released, leaving 174,224 fish that were retained (Giri and Hall 2015). The retained catch provided an estimated State-wide recreational harvest of 126.3 t.

Management Regulations

For the commercial sector, input controls are in place for the netting gear types to limit fishing effort. The minimum size limit for Snook was increased from 360 to 450 mm TL in July 2001. However, a reduction in size limit to 410 mm TL came into effect in 2017 to align with the estimated length-at-maturity (Bertoni 1994). For 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 remained the same after the recent review of the recreational fishery (PIRSA 2016b).

Commercial Fishery Statistics

State-wide

Estimates of annual, State-wide commercial catches of Snook increased to the highest recorded level of 147.3 t in 1995, before steadily declining to 40.3 t in 2014 (Figure 4-24). From then, catch remained low and ranged between 38.9 t in 2017 to 53.5 t in 2016. In 2020, the annual commercial catch declined to a historical low of 33.1 t. The economic value of the low commercial catch of Snook in 2020 was ~ $203 K (*c.f.* $233 K in 2019) (Figure 4-24).

Hauling nets have generally accounted for at least half of the annual catches, whilst troll lines and gillnets have been the second and third most important gear types (Figure 4-24). Targeted hauling net fishing effort has declined since 2005, falling to the lowest recorded level of 26 fisher-days in 2010, after which it has been variable but increased to 70 fisher-days in 2020 (Figure 4-24).

Targeted hauling net CPUE has been highly variable, often fluctuating by >20 kg.fisher-day^{-1} between years. During the 1980s and 1990s, annual targeted hauling net CPUE ranged from 14 to 62.1 kg.fisher-day^{-1} (Figure 4-24). Through the 2000s, CPUE was >50 kg.fisher-day^{-1} in most years. The CPUE of 60.4 kg.fisher-day^{-1} in 2020 was considerably higher than the long-term average CPUE of 46 kg.fisher-day^{-1} for this species. The number of MSF fishers taking Snook decreased from 318 in 1984 to 127 in 2005, and then fell further to 91 in 2020 (Figure 4-24). The number of fishers targeting Snook each year has fallen from 143 in 1984 to 55 in 2020.

Regional

Catches of Snook were reported from all six geographic regions of South Australia's marine waters in 2020, consistent with previous years (Figure 4-25). The highest regional catches were mainly taken from NSG and NGSV during the 1990s, with intermediate catches from SSG and the WC (Figure 4-25). Catches from all regions have been lower during the 2000s. The fishery is typically seasonal with highest catches generally taken between July and November (Figure 4-25).

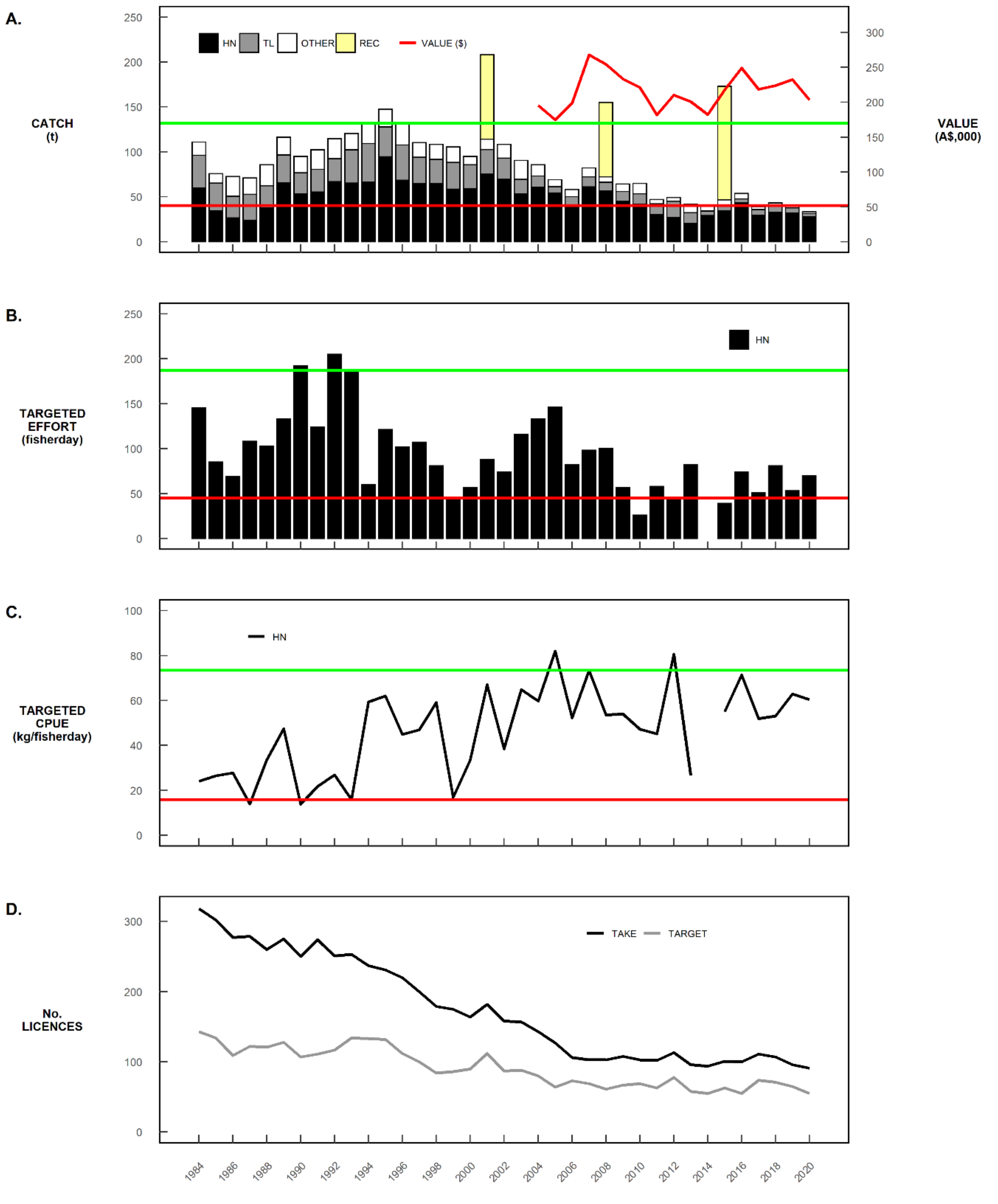

Figure 4-24. Snook. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (hauling net and troll line), estimates of recreational catch, and gross production value; (B) targeted effort for hauling nets; (C) total catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-11.

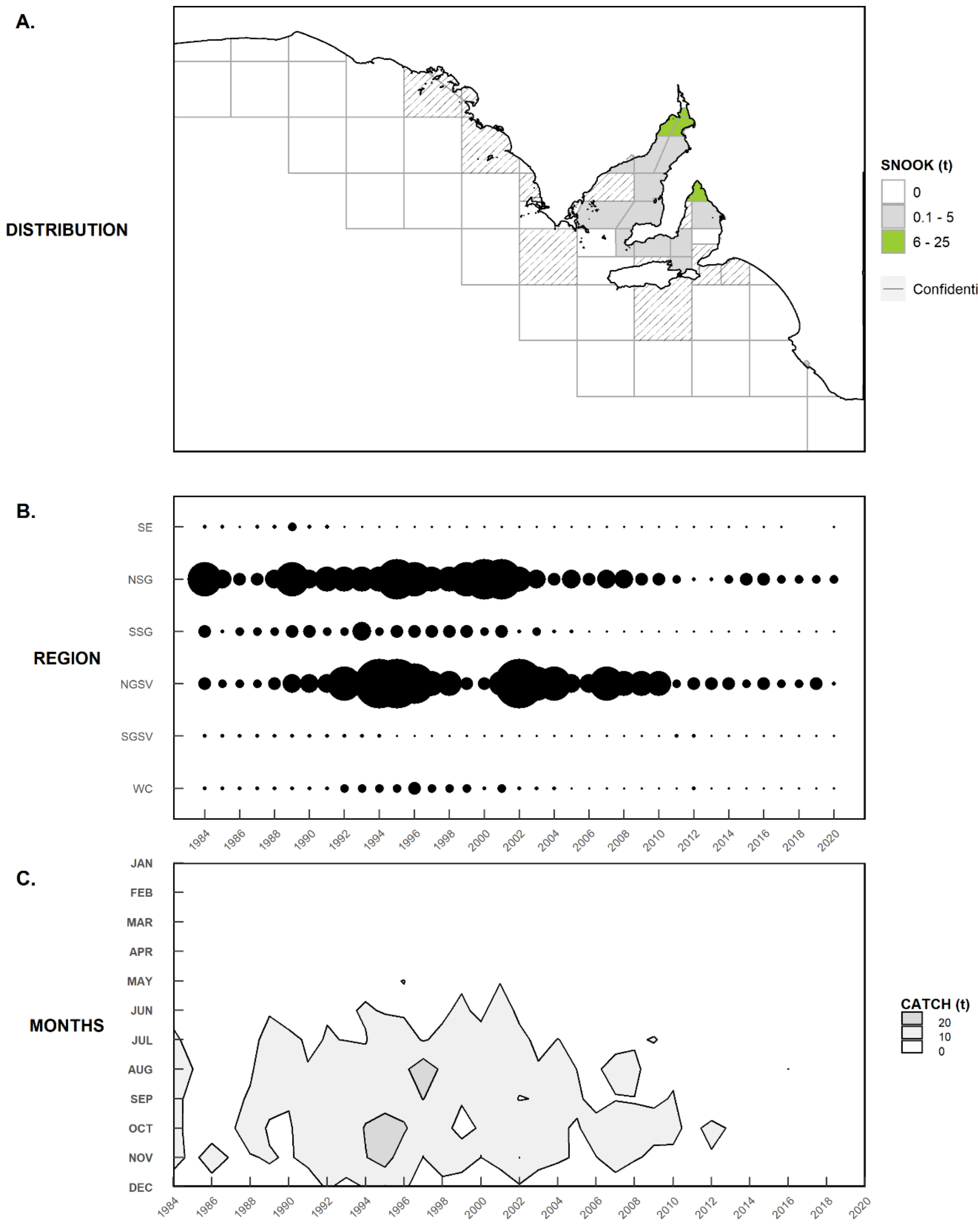

Figure 4-25. Snook. (A) The spatial distribution of catch by the commercial sector in 2020. Long-term trends in: (B) the annual distribution of catch among regions, (C) months of the year.

Fishery Performance

The general fishery performance indicators for Snook were assessed for 2020 at the State-wide scale. There was a breach of one trigger reference point, with the lowest total catch of Snook being recorded (Table 4-11).

Table 4-11. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State-wide scale for Snook in 2020.

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

Snook is a secondary species for the commercial sector of the MSF (PIRSA 2013). This reflects the relatively low catches taken compared to the primary species. The majority of the catch is taken either as by-product by the hauling net fishers or as targeted catch by trolling line fishers. This is reflected by the relatively high numbers of fishers who report taking Snook, but the considerably fewer fishers who report targeting it.

Total catches of Snook at the State-wide and regional scales have declined considerably since the mid-1990s. For the regional fisheries in the two northern gulfs, this largely reflects the declines in hauling net effort that have occurred over this period. Nevertheless, from 1984 to the early 2000s, despite that targeted hauling net CPUE was variable they showed an increasing trend. This continued in 2020 with targeted hauling net CPUE well above the long-term average for the fishery and slightly higher than the previous year. Since then, the annual CPUE has continued to be variable with no long-term trend. The recent stable catches and moderate–high estimates of CPUE indicate that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. Furthermore, the recent low catches and low targeted effort indicate that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On this basis, the LCF for Snook is classified as **sustainable.**

4.3.8. Blue Crab

Biology

The Blue Crab (*Portunus armatus*) is distributed within near-shore, marine bays and estuarine systems in Australia and New Caledonia (Lai et al. 2010). The species occurs in a wide range of inshore habitats to a depth of at least 50 m (Williams 1982, Edgar 2000). Blue Crabs generally reach sexual maturity at carapace widths of between 70 and 90 mm (Kumar et al. 2003).

The spawning season lasts for three to four months over the summer/autumn period (Kumar et al. 2000). In South Australian waters, Blue Crabs near the Minimum Legal Size (MLS = 110 mm carapace width) have reached sexual maturity and are ~14 to 18 months old. Females produce at least two batches of eggs within a single season. Fecundity of females is size-dependent, increasing up to a carapace width of 134 mm and decreasing thereafter. Between 650,000 and 1,760,000 eggs are produced per spawning event (Kumar et al. 2000, 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.

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 Blue Crab Fishery (BCF).

In June 1996, management arrangements for a separate commercial BCF in South Australia were 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. Following this, crab nets (also referred to as 'lift nets' became the predominant gear type used in the MSF. 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 et al. 2020). The statistics in this report refer to the MSF component of the Blue Crab catch and exclude the BCF catches from 1996 onwards.

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.

Unless endorsed with Blue Swimmer Crab quota, MSF licence holders have been restricted from fishing in the BCF zones. Since 1998 the commercial take of Blue Swimmer Crab has been restricted to waters west of longitude 135°E (near Elliston) unless Blue Crab quota was held, in which case Blue Swimmer Crabs could only be taken from the waters of the BCF zones. This has meant that commercial quantities in the MSF have predominantly been taken from Streaky Bay, Smoky Bay and Ceduna over the last 24 years.

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).

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). From 2017/18–2019/20, the annual State-wide TACCs were 626.8 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 in the MSF have been variable since the fishery commenced in 1984 (Figure 4-26). Catches progressively increased from 114 t in 1984 to a peak of 692.9 t in 1995, before falling to 74.3 t in 1998 due to the formation of the Blue Crab Fishery. Catches continued to decline during the 2000s and early 2010s, dropping to a low of 31.2 t in 2016, and have since increased to 54.5 t in 2020 (*c.f.* 53.5 t in 2019). The economic value of the commercial catch of Blue Crabs in the MSF in 2020 was unchanged from 2019 at approximately $467 K (Fig. 4-26).

Targeted crab net effort peaked at 5,000–7,000 fisher-days during the 1990s. In the past decade, targeted effort ranged between 556 fisher-days in 2016 and 1,106 in 2013. In 2020, target effort for Blue Crabs was 853 fisher-days (*c.f.* 849 in 2019) (Figure 4-26).

Since 1998 (i.e. establishment of the BCF), targeted crab net CPUE in the MSF has been relatively stable at 50–60 kg.fisher-day^{-1} in most years (Figure 4-26). In 2020, CPUE increased to 63.9 kg.fisher-day^{-1}, which was the highest since 2010 (*c.f.* 60.7 kg.fisher-day^{-1} in 2019). Since 1998, 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.

Regional

Prior to 1998, Blue Crabs were primarily harvested from NSG and NGSV (Figure 4-27). Since then, the WC region has been the main contributor to the total catch, with small contributions from SSG and SGSV. Typically, the majority of the Blue Crab catch is taken between January and April (Figure 4-27).

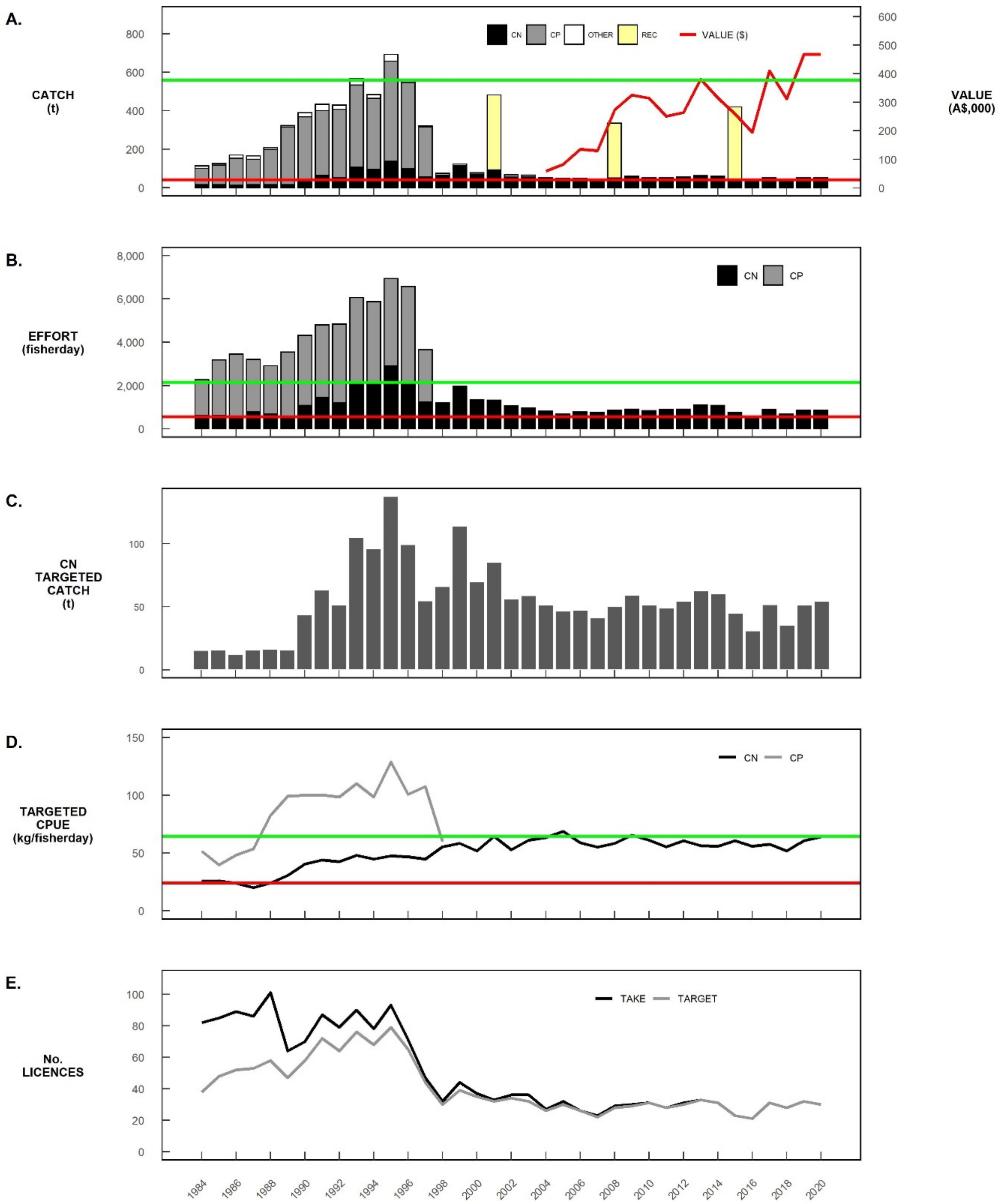

Figure 4-26. Blue Crab catch within the MSF. Long-term trends in State-wide estimates of: (A) total catch of the MSF for the main gear types (crab net/pot and other), estimates of recreational catch, and gross production value for the MSF component; (B) MSF targeted effort crab net/pots; (C) MSF crab net targeted catch; (D) MSF targeted catch per unit effort (CPUE); and (E) the number of active licence holders in the MSF taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-12.

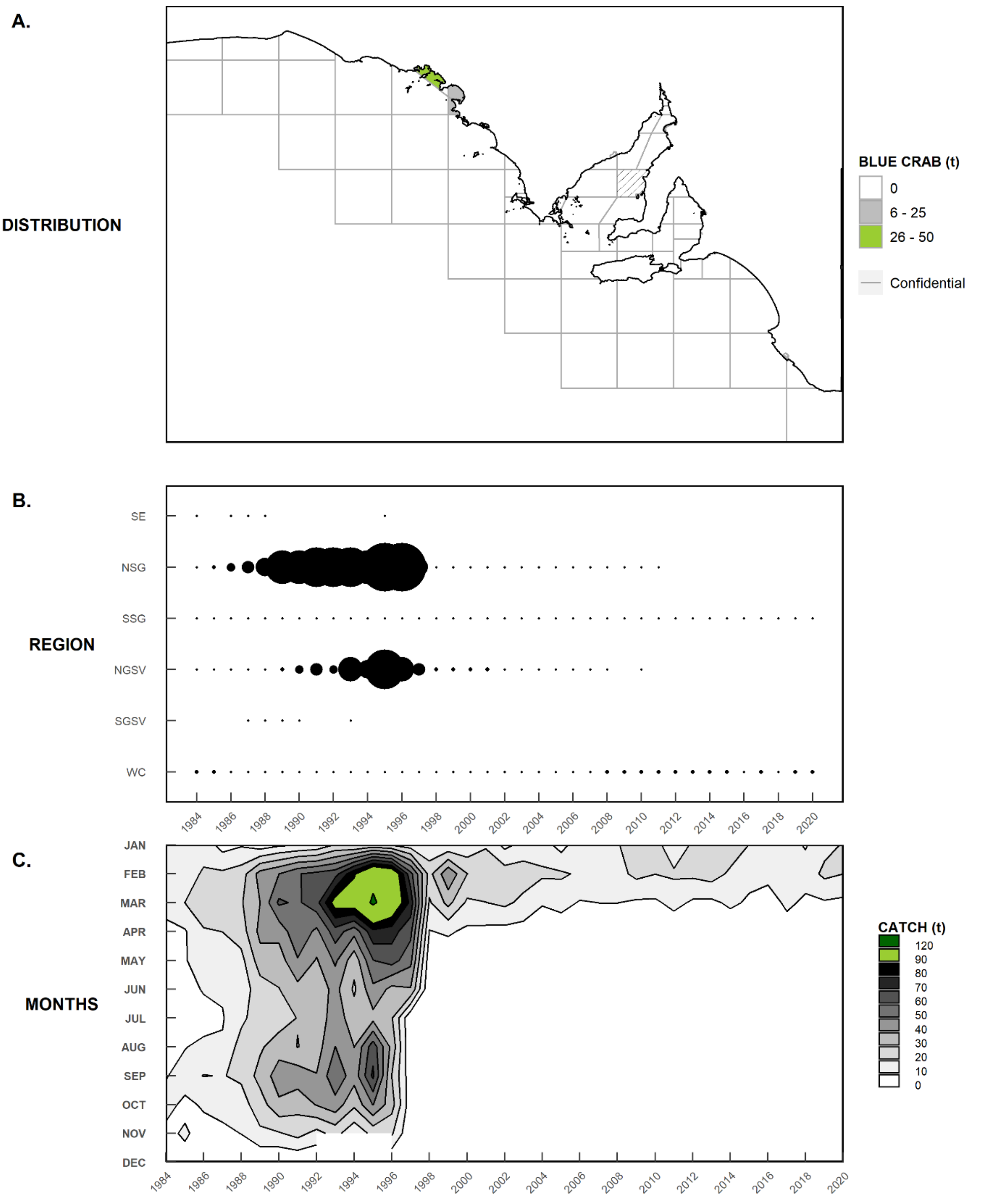

Figure 4-27. Blue Crabs catch within the MSF. (A) The spatial distribution of catch by the commercial sector in 2020. Long term trends in: (B) the annual distribution of MSF catch among regions, (C) months of the year.

Fishery Performance

The general fishery performance indicators for Blue Crabs were assessed for 2020 at the State-wide scale. No trigger reference points were activated for 2020 (Table 4-12).

Table 4-12. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State-wide scale for Blue Crab in 2020.

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 MSF licences to target the species. Consequently, the fishery statistics considered here at State-wide scale related to targeted fishing effort for these gears. Nevertheless, the interpretation of such data is complicated by the transfer of MSF effort to the Blue Crab Fishery in the gulfs. This is reflected by low catches from the Spencer Gulf and Gulf St Vincent since 2008. The most recent Blue Crab Fishery assessment classified both the SG and GSV stocks as sustainable (Beckmann and Hooper 2021). 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 management unit (stock) is unlikely to be depleted and that recruitment is unlikely to be impaired. On this basis, the Blue Crab stock available to the MSF is classified as **sustainable**.

4.3.9. Sand Crab

Biology

The Sand Crab (*Ovalipes australiensis*) is a medium-sized crab species with a broad distribution across southern Australia from Wide Bay in Queensland to Rottnest Island in Western Australia, including the waters of Tasmania (Kailola et al. 1993). They occur along surf beaches, in sandy bays and inlets, and in offshore waters to ~100 m depth. In South Australia, they are found in most inshore waters except the northern gulfs and west coast bays (Jones 1995), where Blue Crabs are more abundant. The stock structure of Sand Crabs is unknown.

A study into the reproductive biology of Sand Crabs in Coffin Bay determined that they are winter spawners for which reproductive activity peaks in July, with berried females present until late August (Deakin 1996). Female Sand Crabs attain sexual maturity at a smaller size than males. A measuring program undertaken in Coffin Bay during the late 1990s determined that all sampled females were below the minimum legal size of 100 mm, indicating that 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 targeting Sand Crabs during the night; and implementing 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 vessels in southern coastal waters. Approximately 52,557 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 are four dedicated Sand Crab licence holders who have a combined access to 400 crab 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 1984 (Figure 4-28). Annual catches were between 22.8–40.5 t from 1984 to 1988. They then increased to a peak of 152 t in 1990, before declining to 40.1 t in 1994. Catch increased to peaks of 175 t and 177 t in 2000 and 2005, respectively. From then, catch progressively declined to 44 t in 2017 and 2018 and remained low at 49.5 t in 2020. The economic value of the commercial catch of Sand Crabs in the MSF in 2020 was approximately $420.96 K (*c.f.* $451.99 K in 2019) (Figure 4-28).

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 been the dominant gear used in the fishery.

There have been three peaks in targeted fishing effort on Sand Crabs during which the effort level exceeded 1,000 fisher-days.yr^{-1} (Figure 4-28). These were in 1989–1991, 1997–2000, and in 2005 and 2006. Since 2006, there has been a gradual decline in targeted effort, which dropped to 323 fisher-days in 2020.

Targeted crab net and pot CPUE has been variable but nevertheless demonstrated a gradual, long-term increase from 76.5 kg.fisher-day^{-1} in 1992 to 159.8 kg.fisher-day^{-1} in 2005 before declining to 79.5 kg.fisher-day^{-1} in 2004 (Figure 4-28). Since then, CPUE has remained relatively stable at higher levels, increasing to 151 kg.fisher-day^{-1} in 2020, which was the second highest CPUE recorded in the fishery.

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 (Figure 4-28). The numbers of commercial fishers who reported taking sand crabs increased up to 45 in 1997 but have since declined to 16 in 2020. A total of 14 fishers reported targeting this species in 2020.

Regional

The fishery has been heavily concentrated in and around Coffin Bay on the West Coast (Figure 4-29). Outside of this region, the highest catches have been taken from SSG and was where most of the catch was taken in 2020 (Figure 4-29). 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 4-29).

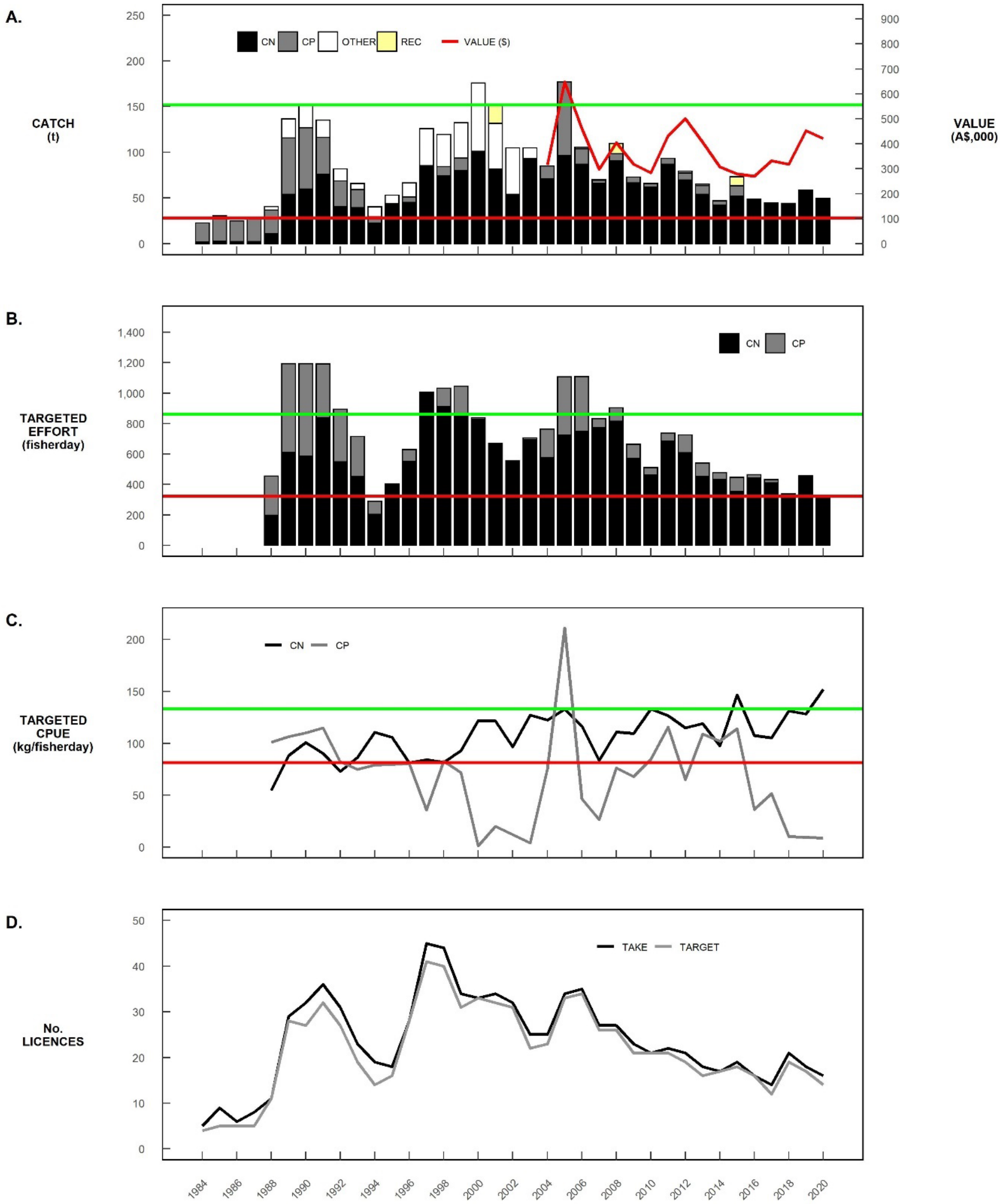

Figure 4-28. Sand Crab. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (crab net/pot and other), estimates of recreational catch, and gross production value; (B) targeted effort crab net/pots; (C) targeted catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-13.

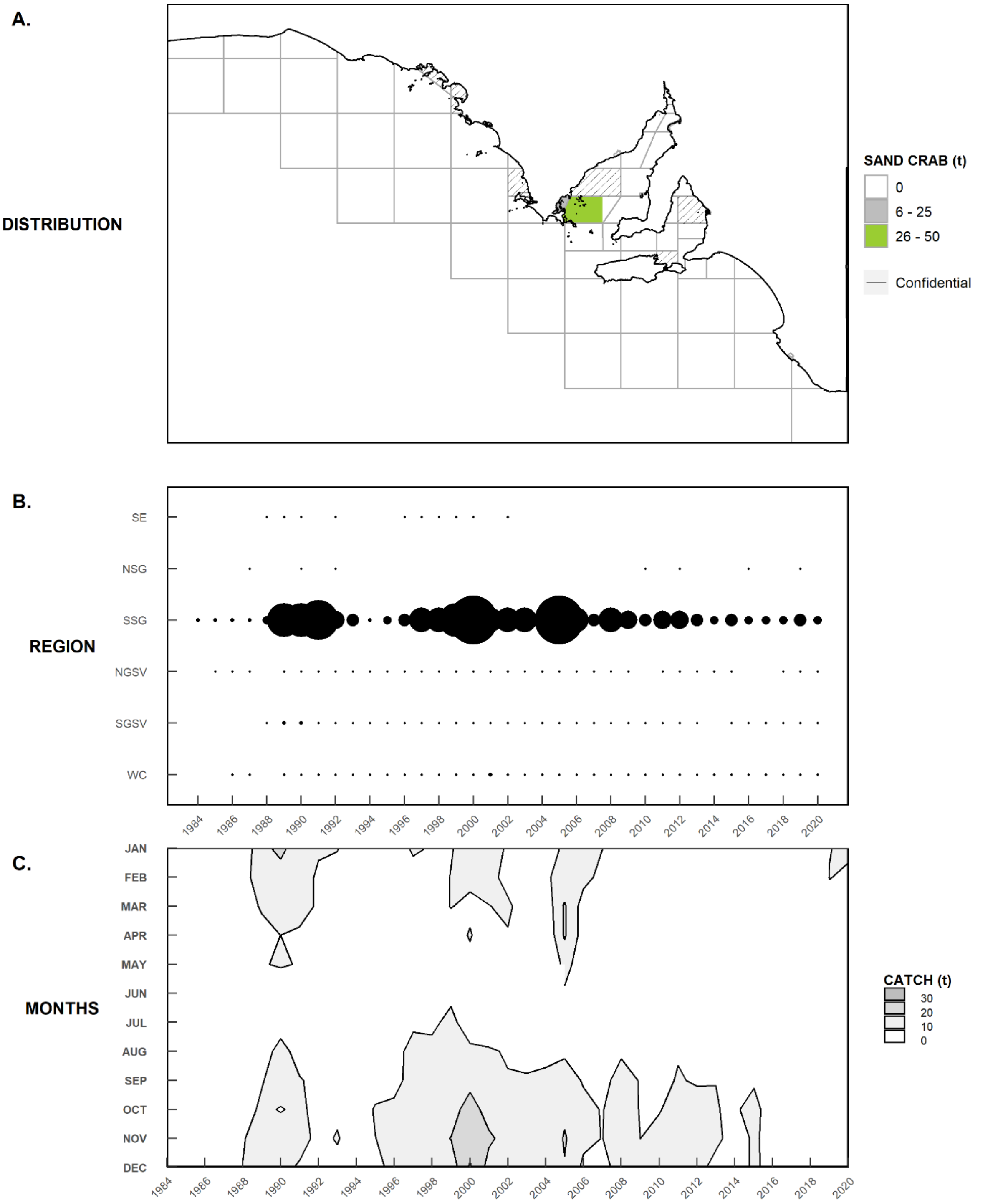

Figure 4-29. Sand Crab. (A) The spatial distribution of catch by the commercial sector in 2020. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year.

Fishery Performance

The general fishery performance indicators for Sand Crabs were assessed for 2020 at the State-wide scale (Table 4-13). The reference period was from 1989 onwards, when the fishers starting to target Sand Crabs with crab nets. One trigger reference point was activated for 2020, with the second highest targeted hauling net CPUE recorded.

Table 4-13. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State-wide scale for Sand Crab in 2020.

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	2nd HIGHEST
	G	Greatest % interannual change (+/-)	×
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

The commercial Sand Crab fishery involves specialist fishers that require endorsed crab net or pot types on their licences to target the species. Consequently, the fishery statistics considered here at the 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). The early fishery involved a small number of fishers who primarily used crab pots. Then, as the number of operators increased, they began to use 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 began to use portable, mechanical net haulers, allowing further modifications to net design. The commercial fishery statistics for Sand Crabs are characterised by significant inter-annual variation, although long-term trends are apparent. The trends in State-wide catch statistics are largely driven by those from the West Coast, 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 CPUE has increased over the past six years to the second lowest level recorded in the fishery in 2020. The recent stable low catches and high CPUE indicate that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current low level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On this basis, the MSF for Sand Crab is classified as **sustainable**.

4.3.10. Yelloweye Mullet

Biology

The Yelloweye Mullet (*Aldrichetta forsteri*) is a small, schooling species that 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 (Gomon et al. 2008, Earl et al. 2016a). Yelloweye Mullet occur over sandy and muddy substrates to depths of 20 m, and are often abundant in estuaries (Kailola et al. 1993). This species is considered a marine estuarine-opportunist, i.e. spawns at sea; regularly enters estuaries, particularly as juveniles, but also uses coastal marine waters as alternative nursery areas (Potter et al. 2015).

The biological stock structure of Yelloweye Mullet throughout southern Australia is poorly understood. Available data suggest the populations in this geographic region form two discrete biological 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 1957, Pellizzari 2001).

In South Australia, the Yelloweye Mullet is a fast growing, short-lived species that attains a maximum length of 440 mm TL 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, 80–90% of annual State-wide commercial catches over the past decade have been taken by the Lakes and Coorong Fishery, which is not considered in this report (Earl and Bailleul 2021).

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 2016a).

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 recreational 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 (Figure 4-30). From then, catch progressively declined to an historical low of 9.8 t in 2020 (*c.f.* 13.9 t in 2019). The economic value of the commercial catch of Yelloweye Mullet in 2020 was approximately $75.2 K (*c.f.* $80.3 K in 2018) (Figure 4-30). In recent years, around 85% of the catch has been taken using hauling nets, with set nets accounting for most of the remaining catch.

Annual estimates of total fishing effort that produced catches of Yelloweye Mullet have been dominated by hauling nets (Figure 4-30). Total hauling net effort declined from a peak of ~5,800 fisher-days in 1984 to ~470 fisher-days in 2009. Since 2009, hauling net effort has been stable at relatively low levels, ranging between 401–694 fisher-days, with 468 fisher-days recorded in 2020 (*c.f.* 567 in 2019).

Hauling net CPUE was relatively stable at low–moderate levels (range: 12–28 kg.fisher-day^{-1}) in the 1980s, 1990s and early 2000s before it increased to 50 kg.fisher-day^{-1} in 2005 and peaked at 55 kg.fisher-day^{-1} in 2011 (Figure 4-30). Since then, hauling net CPUE has decreased and was 19.5 kg.fisher-day^{-1} in 2020 (*c.f.* 20.4 kg.fisher-day^{-1} in 2019). The numbers of fishers who reported taking (25 in 2020) and targeting (9 in 2020) Yelloweye Mullet have both decreased over the time-series (Figure 4-30).

Regional

Historically, catches of Mullet have been reported from each of the six regions of South Australia's marine waters (Figure 4-31). During the 1980s and 1990s (i.e. when catches were highest), most of the catch was taken in Northern Gulf St Vincent. Catches in all regions have been low over the past decade, with the highest catches taken in Northern Spencer Gulf.

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 15 years (Figure 4-31).

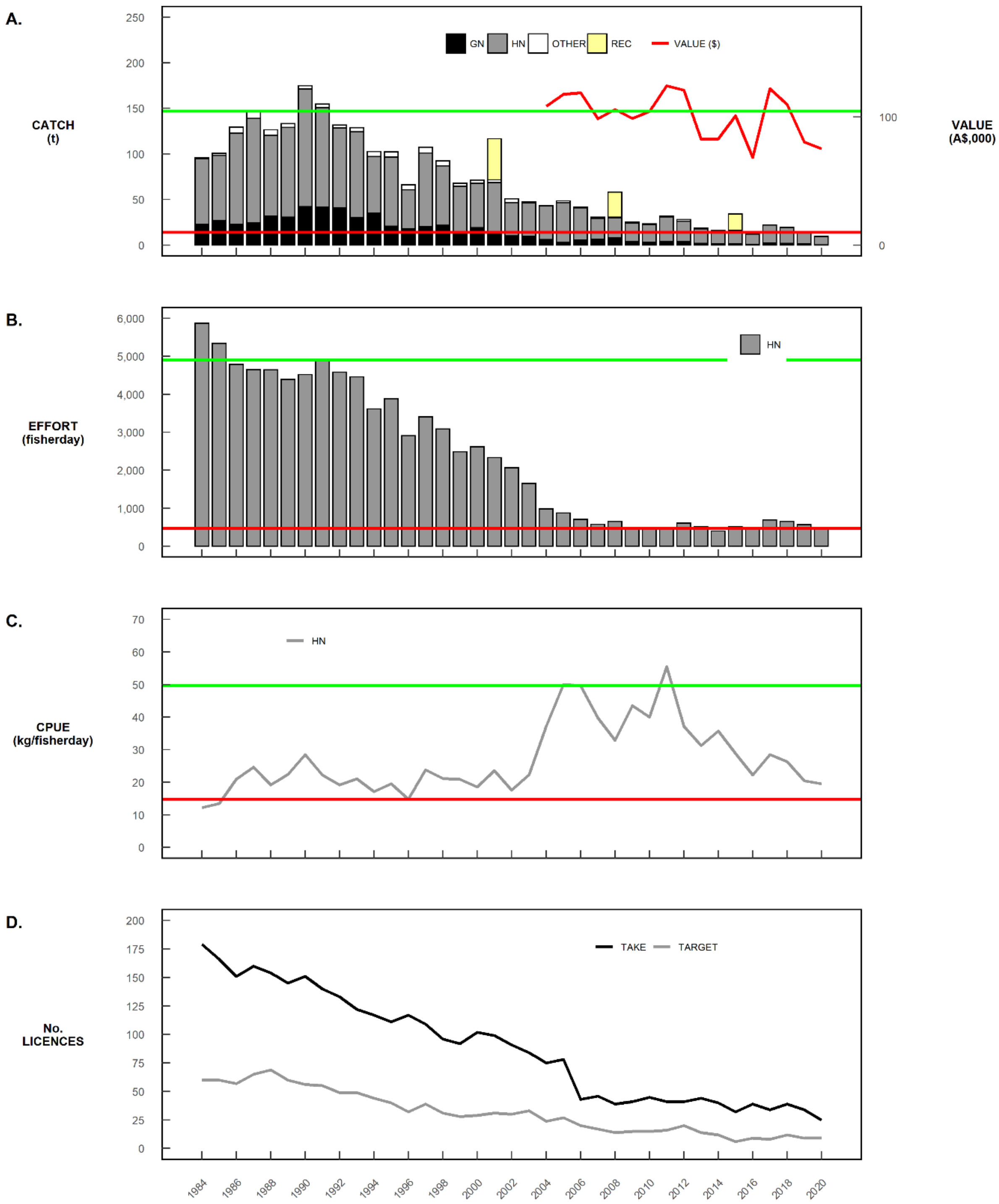

Figure 4-30. Yelloweye Mullet. Long-term trends in State-wide estimates of: (A) total catch in the MSF for the main gear types (hauling net and set net), estimates of recreational catch, and gross production value for the MSF; (B) MSF total effort hauling net; (C) MSF total catch per unit effort (CPUE); and (D) the number of active MSF licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-14.

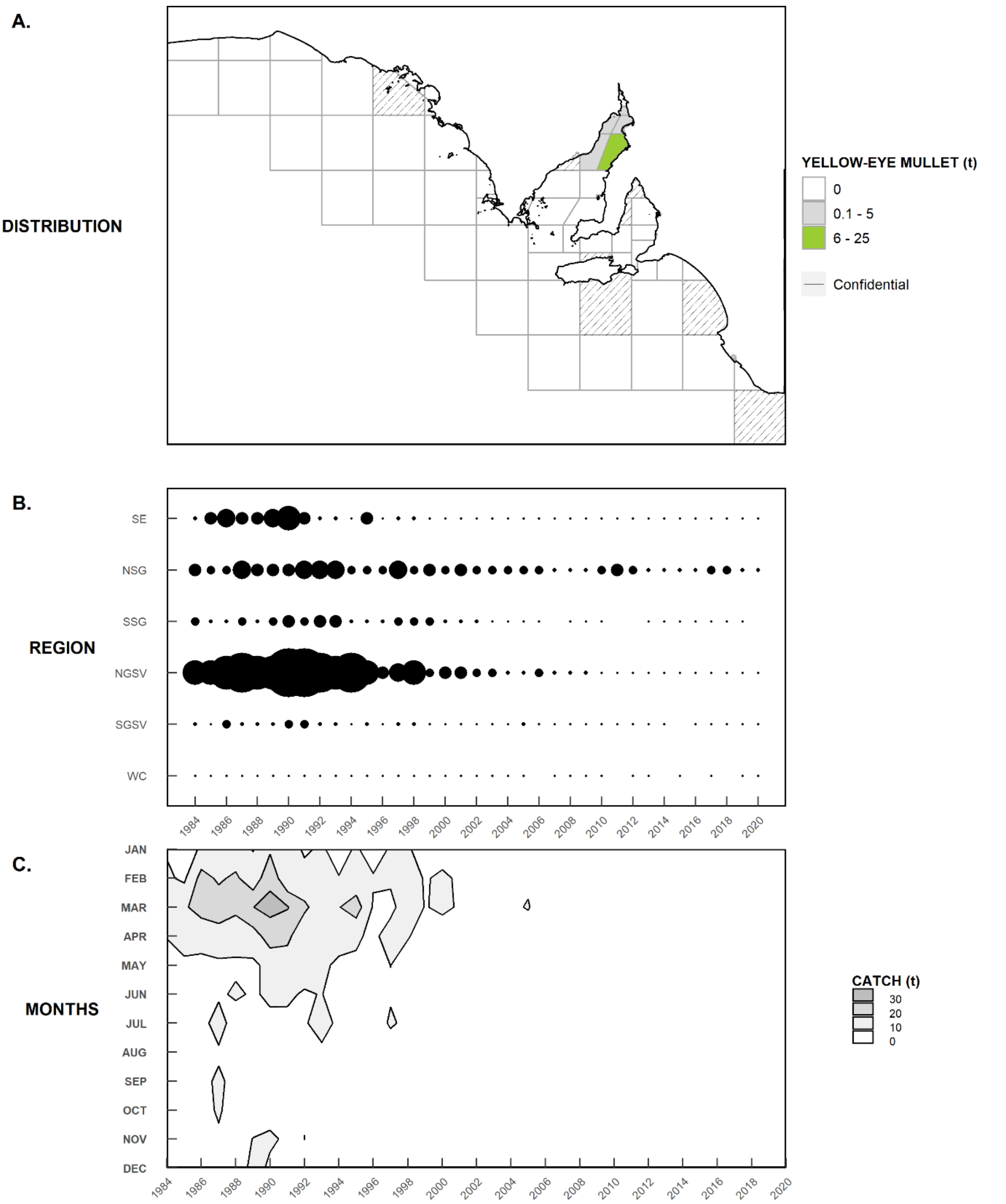

Figure 4-31. Yelloweye Mullet catches in the MSF. (A) The spatial distribution of catch by the commercial sector in 2020. Long-term trends in: (B) the annual MSF distribution of catch among regions, (C) months of the year.

Fishery Performance

The general fishery performance indicators for Yelloweye Mullet were assessed for 2020 at the State-wide scale. Two trigger reference points were activated with the lowest total catch and second lowest total hauling net effort recorded (Table 4-14).

Table 4-14. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Yelloweye Mullet in 2020.

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	×
TOTAL HAULING NET EFFORT	G	3rd Lowest / 3rd Highest	2ND LOWEST
	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	×

Stock Status

Yelloweye Mullet is predominantly taken as by-product within the hauling net sector of the MSF when other species are targeted. Annual catches of Yelloweye Mullet have been stable at low levels for a considerable period, which reflects the 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 similar to the long-term average for the fishery. Yelloweye Mullet is predominantly caught in the Lakes and Coorong Fishery where it was recent classified as sustainable (Earl and Bailleul 2021). The above evidence indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current low level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On this basis, the MSF for Yelloweye Mullet is classified as **sustainable**.

4.3.11. Mulloway

Biology

Mulloway (*Argyrosomus japonicus*) is a large, schooling species that inhabits estuaries and nearshore coastal waters in subtropical to temperate regions of the Atlantic, Pacific and Indian Oceans including around southern Australia, Africa and India (Gomon et al. 2008, 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 often 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 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 ~780 mm TL and five years of age for males and 850 mm TL and six years of age for females (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). This assessment of stock status is undertaken at the management unit level – the MSF.

Fishery

In South Australia, most of the commercial catch of Mulloway is taken by the Lakes and Coorong Fishery (Earl and Ward 2014, Earl and Bailleul 2021), which is not considered in this report. However, this species is also taken by the commercial and recreational sectors of the MSF. In the commercial sector, Mulloway are taken with multiple gear types that include set nets, fishing rods and handlines. For the recreational sector, Mulloway is an iconic species that 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 annual catches of the commercial MSF sector.

Management Regulations

Mulloway can be taken by the commercial MSF fishers in all coastal waters of South Australia, except those accessible to the commercial Lakes and Coorong Fishery (PIRSA 2016a). While no specific harvest strategy exists for Mulloway in the MSF (PIRSA 2013), 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 two fish and boat limit of six fish applies in marine waters.

Commercial Fishery Statistics

State-wide

During the mid-1980s and early 1990s, total annual commercial catch of Mulloway fluctuated between 7–15 $t.yr^{-1}$ with a peak of 24.2 t in 1995 (Figure 4-32). Catches declined during the late 1990s, remained low during the 2000s, and then declined to a low of 1.1 t in 2016. The total commercial catch of Mulloway in 2020 was 2.6 t. The economic value of the commercial catch of Mulloway in 2020 was approximately $25.56 K (*c.f.* $45.61 K in 2019) (Figure 4-32).

From 1984 to 2001, total catch was dominated by set nets (i.e. mesh gillnets) and handlines. Since then, hauling nets have accounted for proportionally higher catches (Figure 4-32). CPUE for set nets was relatively stable between 2000 and 2009, but became highly variable between 2010 and 2018 (Figure 4-32). CPUE for handlines has shown no long-term trend from 1984 to 2018. In 2019 and 2020, the CPUE for handlines and set nets were confidential.

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 (Figure 4-32). The higher numbers of fishers taking (7 in 2020) Mulloway compared to those targeting the species (3 in 2020), suggests it is largely a by-product when fishing 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 having been taken in the South East (Figure 4-33). In recent years, larger proportions of the catches have been reported from NGSV. Historically and overall, there is no clear seasonality for Mulloway catches by the MSF (Figure 4-33).

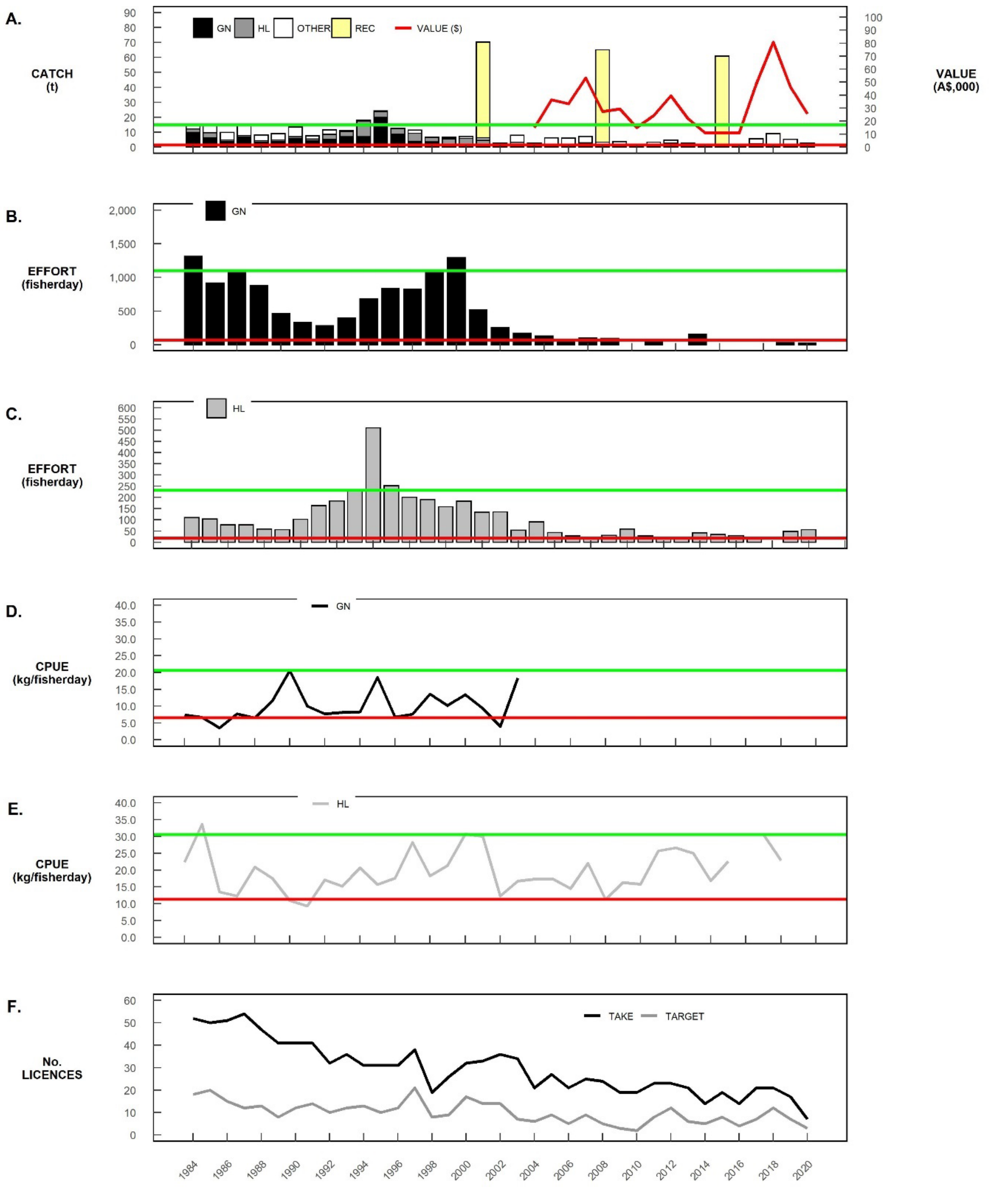

Figure 4-32. Mulloway. Long-term trends in State-wide estimates of: (A) total catch for the main gear types (handline and set net), recreational sector for 2007/08 and 2013/14 and gross production value for MSF; (B) total gill net effort; (C) total handline effort (D) total gill net catch per unit effort (CPUE); (E) total handline catch per unit effort (CPUE); and (F) 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 4-15 where data is not confidential.

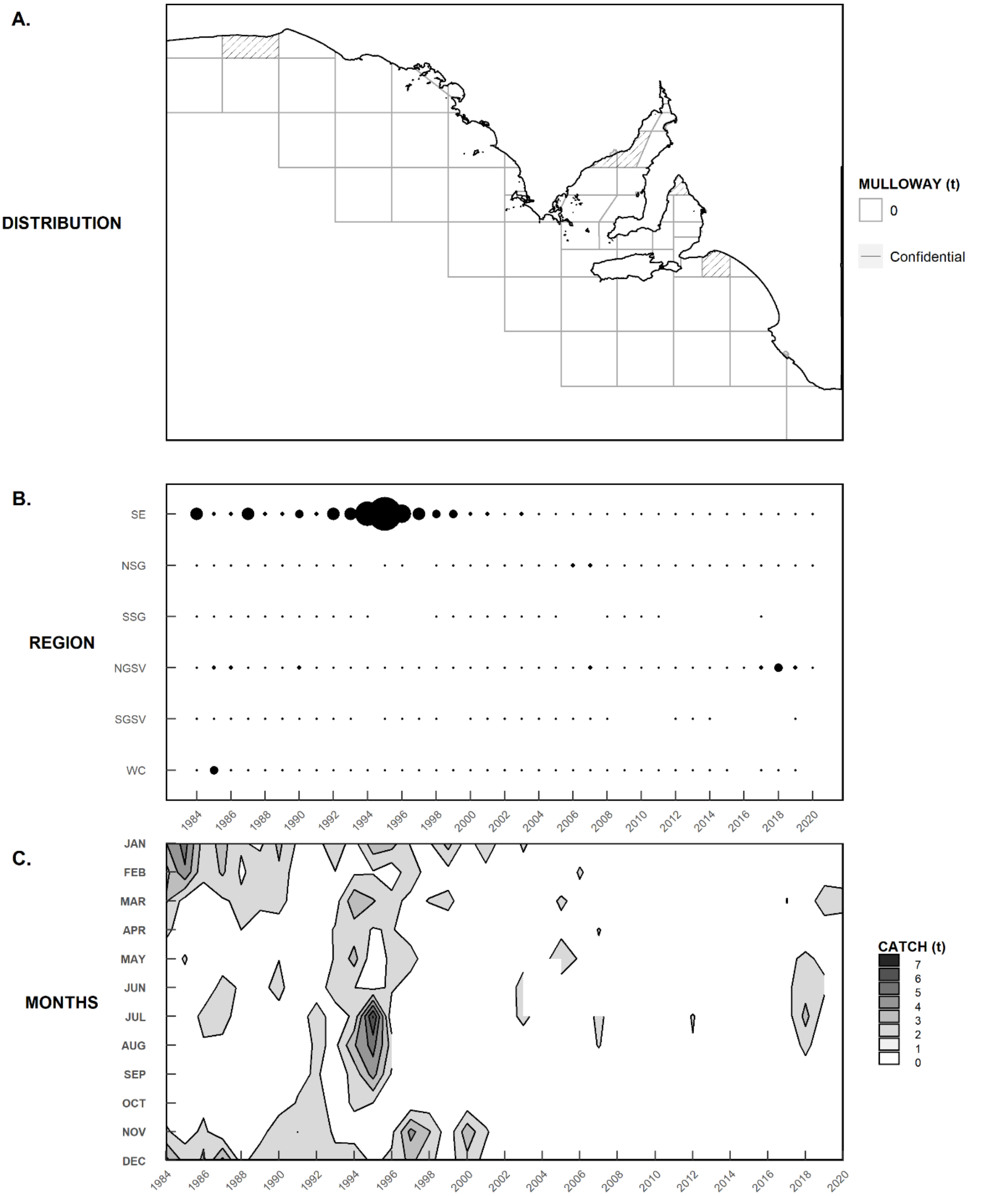

Figure 4-33. Mulloway. (A) The spatial distribution of catch by the commercial sector in 2020. Long-term trends in: (B) the annual MSF distribution of catch among regions and (C) months of the year.

Fishery Performance

The general fishery performance indicators for Mulloway were assessed for 2020 at the State-wide scale. No trigger reference points were breached (Table 4-15).

Table 4-15. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State-wide spatial scale for Mulloway in 2020.

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	CONF.
	G	Greatest % interannual change (+/-)	CONF.
	G	Greatest 3 year trend	CONF.
	G	Decrease over 5 consecutive years	CONF.
TOTAL HAND LINE 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.
TOTAL SET 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.
TOTAL SET 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

Mulloway is of medium-high value but makes a relatively minor contribution to the commercial MSF total production value because of the low volume taken. 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. Mulloway is predominantly caught in the Lakes and Coorong Fishery where it was recent classified as sustainable (Earl and Bailleul 2021). Total commercial catch of Mulloway in the MSF 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 CPUE has generally remained consistent over the same period. The recent high CPUE indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment overfished. On this basis, the MSF for Mulloway is classified as **sustainable**.

4.3.12. Whaler Sharks

Biology

Two species of 'Whaler Sharks' including the Bronze Whaler (*Carcharhinus brachyurus*) and the Dusky Shark (*C. obscurus*) are taken in the MSF. These species can be differentiated by their physical characteristics. Bronze Whalers are copper coloured, have non-serrated teeth and lack an inter-dorsal ridge, whereas Dusky Sharks are dark brown in colour, have serrated teeth and an inter-dorsal ridge located between the first and second dorsal fin.

Female Bronze Whalers live up to 31 years and males have similar lifespans of up to 25 years (Drew et al. 2016). Males and females both reach sexual maturity at 16 years of age at lengths of 2.2 and 2.7 m TL, respectively (Drew et al. 2016). Bronze Whalers produce 16–24 pups per litter but the breeding frequency is poorly understood in Australian waters.

Dusky Sharks are long-lived (max ~50 years), slow growing, have a 3-year breeding frequency and only produce 3–12 pups per litter (McAuley et al. 2007, Romine et al. 2009). Large juveniles (>2.0 m) migrate between Western Australia and South Australian waters (Rogers et al. 2013b). Similarly, there is preliminary evidence of eastward and westward movements of Bronze Whalers between state jurisdictions (Rogers et al. 2013a, 2013b, Drew et al. 2019).

Fishery

Catches of Whaler Sharks in the MSF are not currently resolved to the species level and so those of Bronze Whalers and Dusky Sharks are combined in the logbooks. The MSF mostly uses longlines to target Whaler Sharks and in the last decade 70–90% of the total annual catches were taken using that gear type. During the years prior to the Offshore Constitutional Settlement with AFMA (pre-1999), a larger proportion (45–92%) of the catch of Whaler Sharks was taken using demersal-set gillnets.

Preliminary data suggest catch contributions of the two Whaler Shark species are spatially and temporally variable, and MSF longline catches are mostly (>90%) comprised of juvenile Bronze Whalers. The MSF predominantly targets Whaler Sharks during spring–autumn using floating and demersal set longlines in Spencer Gulf, Gulf St Vincent and along the West Coast.

Recreational fishers target Whaler Sharks during spring and summer from boats, jetties and the shore in South Australia (Jones 2008). A small number (<40 per annum) are also taken by recreational fishers in the South Australian Charter Boat Fishery (Rogers et al. 2017), and by fishers targeting Mulloway from the shore on the West Coast (Rogers et al. 2014).

Recreational fishers target Whaler Sharks with rod and line. The State-wide recreational survey in 2013/14 did not quantify the retained catch weight of Whaler Sharks. The 2007/08 recreational fishing survey provided an estimated recreational harvest of 6.3 t (Jones 2009).

Given the Dusky Shark stock (early juveniles and adults) is mostly distributed off Western Australia, the status of the biological stock is determined from assessments during the National Status of Australian Fish Stocks (SAFS) process for the Western Australia jurisdiction. For the first time in SAFS 2020, Bronze Whalers were assessed at the single-species level (Rogers et al. 2021). The Southern Australia biological stock was classified as undefined because there was insufficient information available to confidently determine its status. The stock has been previously assessed at the state level in the MSF based on the combined Whaler Shark catch statistics (Steer et al. 2020, Drew et al. 2021).

Management Regulations

Whaler Sharks in the MSF are managed under input controls on longlines, set nets, drop lines and handlines. There is no minimum legal size. Management measures 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. South Australian recreational fishery regulations for Whaler Sharks (both species) 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.

Regulations are in place which prohibit the finning of sharks at sea with the exceptions of pelvic fins and claspers, and the removal of the tail at the sub-terminal notch, leaving the caudal lobe attached to the body.

Commercial Fishery Statistics

State-wide

Annual patterns in catches of Whaler Sharks have been highly variable since 1984. Annual catch progressively increased from 27 t in 1985 to a peak of 121 t in 2010 and then declined to 45–62 t.yr^{-1} during 2013–2018 (Figure 4-34). The annual total commercial catch was 52.1 t in 2020 (*c.f.* 62.7 t in 2019). The economic value of the commercial catch of Whaler Sharks in 2020 decreased to approximately $245 K (*c.f.* $255 K in 2019) (Figure 4-34).

Longlines have been the dominant gear type for taking Whaler Sharks since 2000 and comprised ~ 90% (40–56 t) of annual catches between 2014 and 2020. Catches taken using the net gear types have been < 3.1 t in the past 6 years.

Annual targeted longline effort was highly variable and increased from 25 fisher-days in 1995 to a peak of 571 fisher-days in 2010 (Figure 4-34). Since 2014, targeted effort has stablised and averaged ~255 fisher-days.yr^{-1}, and was 243 fisher-days in 2020. Targeted longline CPUE has maintained a stable trend since 1997, ranging from 104 to 215 kg.fisher-day^{-1} (Figure 4-34). The targeted longline CPUE of 167.5 kg.fisher-day^{-1} in 2020 was the fourth highest on record. The number of licences taking and targeting Whaler Sharks have each remained relatively stable since 2002 and have followed the same trajectories (Figure 4-34).

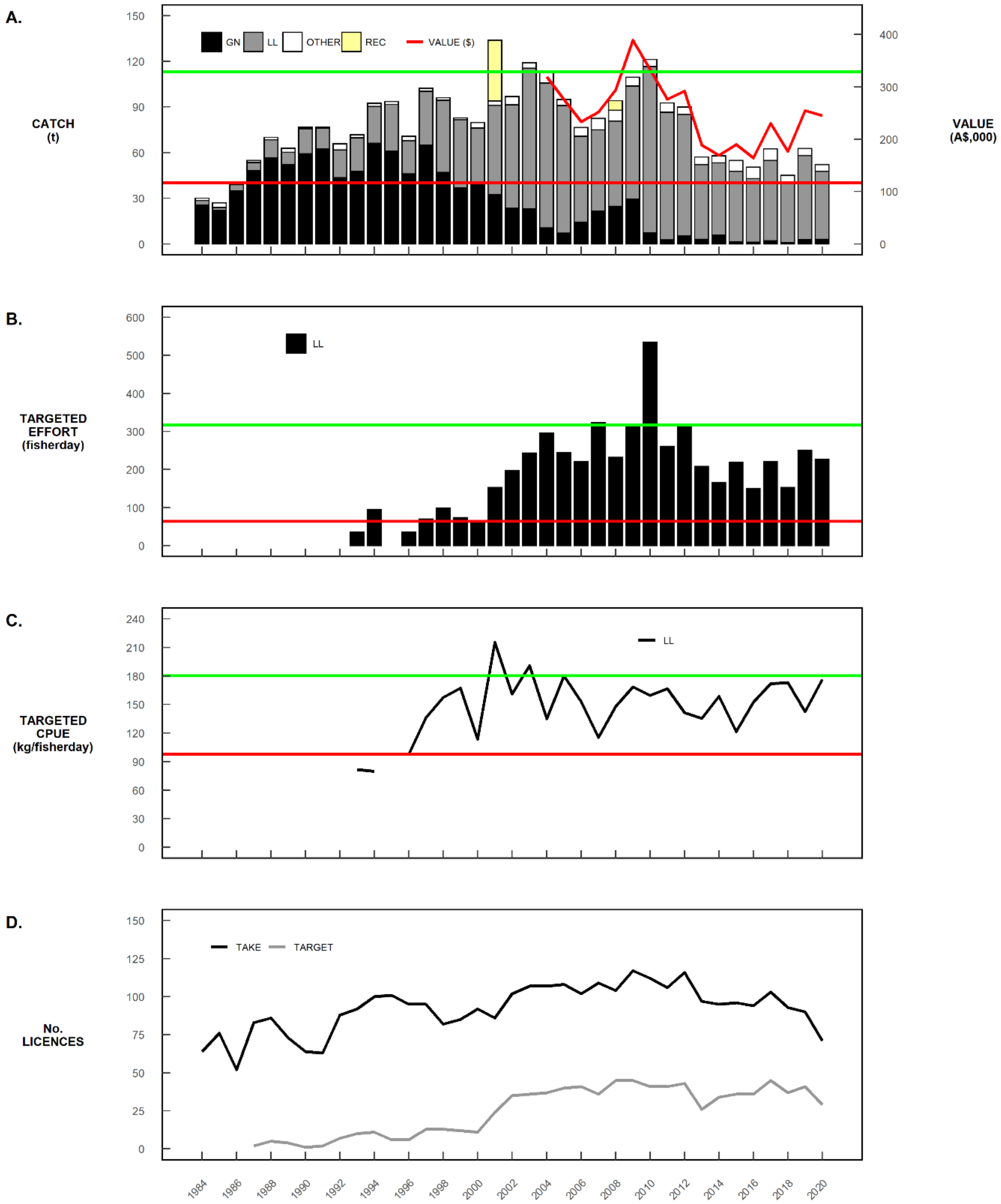

Figure 4-34. Whaler Sharks. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (longline and set net), estimates of recreational catch, and gross production value; (B) total effort longline; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-16.

Regional

The commercial catch of Whalers Sharks was mostly distributed in southern Spencer Gulf, southern Gulf St Vincent, including Investigator Strait, and the West Coast (Figure 4-35). A high proportion of the catch was landed on the West Coast in the 1980s, 1990s, 2000s and more recently in 2017 (Figure 4-35). Marine Fishing Areas (MFAs) in southern and central Spencer Gulf, supported either a greater or similar proportion of the catch between 2003 and 2012 (Figure 4-35), with a notable peak in Spencer Gulf occurring in 2010. Catches mostly occurred between spring and autumn with only sporadic catches during the winter months in three years since 1984 (Figure 4-35).

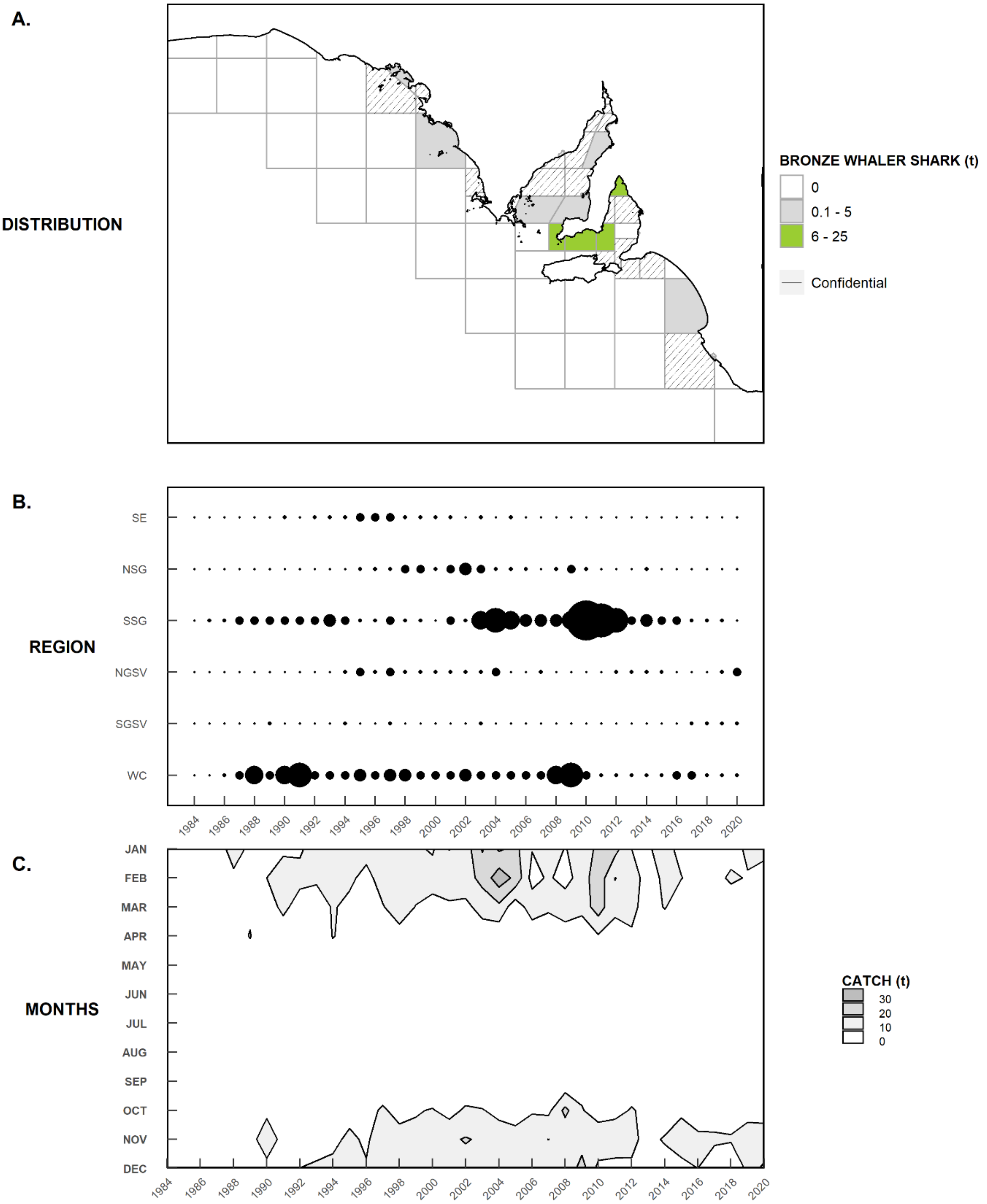

Figure 4-35. Whaler Shark catch in the MSF. (A) The spatial distribution of catch by the commercial sector in 2020. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year.

Fishery Performance

The general fishery performance indicators for Whaler Shark species combined were assessed for 2020 at the State-wide scale. No trigger reference points were breached (Table 4-16).

Table 4-16. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Whaler Sharks in 2020.

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

There is limited information for determining stock status, and the information available is compounded by a paucity of information on the catch composition (species) of Whaler Sharks harvested. The limited data prevents assessment of current stock size or fishing pressure. Consequently, there is insufficient information available to confidently classify the status of this stock.

On the basis of the evidence provided above, the Southern Australia biological stock is classified as an **undefined** stock.

4.3.13. Ocean Jacket

Biology

The Ocean Jacket (*Nelusetta ayraudi*) is the largest species of Leatherjacket of southern Australia and 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 wide depth range from very shallow to >350 m, due to offshore movement associated with ontogenetic development. Juvenile Ocean Jackets occur in shallow, coastal bays whilst the adults are located over flat, sandy bottom in offshore, 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 the capacity of adults for significant long-distance movement (Grove-Jones and Burnell 1991).

The Ocean Jacket is a sexually dichromatic species that is fast-growing and short-lived, as determined from ageing work from rings in vertebrae (Grove-Jones and Burnell 1991). Most fish 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 length-at-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 offshore waters.

Fishery

As adult Ocean Jackets occur in deep, offshore waters, the fishery is essentially commercial only, 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. 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. Prior to 1990, catches of Leatherjacket species in the MSF were not resolved to the species level and so those of Ocean Jackets and all other Leatherjacket species were combined in the logbooks. As such, this assessment for Ocean Jacket considered data from 1990 to 2020.

Management Regulations

There are separate limits to the numbers of fish traps that may be used at the one time in the two Gulfs and Greater Coffin Bay (in most cases 5), and all other waters (in most cases 15). There are defined regulations for Ocean Jacket traps that differ from those for fish traps.. 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 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 4-36). This related to a total fishing effort with fish traps 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 (Figure 4-36). Total catch peaked at 977 t in 1991, whilst effort was highest in the following year at 3,105 fisher-days using fish traps. Total catch and effort declined between 1991 and 2000 before stabilising for several years. From 2006–2015, catch and effort further declined and averaged 74 t.yr^{-1}. There were noticeable increases in catch and effort in 2016, 2019 and 2020, with the average annual catch from 2016–2020 increasing to 201 t.yr^{-1} (range: 94–312 t). The fishery data for 2020 are confidential because they relate to < 5 fishers (Figure 4-36). Fish trap CPUE has been variable, ranging from 196–543 kg.fisher-day^{-1}, but nevertheless has showed no long-term trend. Estimates of annual fish trap CPUE for several recent years have been amongst the highest on record (Figure 4-36). The economic value of the commercial catch of Ocean Jackets in 2020 was approximately $1.14 M (*c.f.* $1 M in 2019) (Figure 4-36).

Regional

Most of the catches of Ocean Jackets have been taken in SSG, and to a lesser extent, the west coast of Eyre Peninsula of South Australia (Figure 4-37). There have only ever been incidental catches of Ocean Jackets reported from the gulf regions and the SE (Figure 4-37). Throughout the higher catch years of 1989 to 2006, commercial catches of Ocean Jackets were taken throughout the year, although the highest catches were taken between September and March (Figure 4-37).

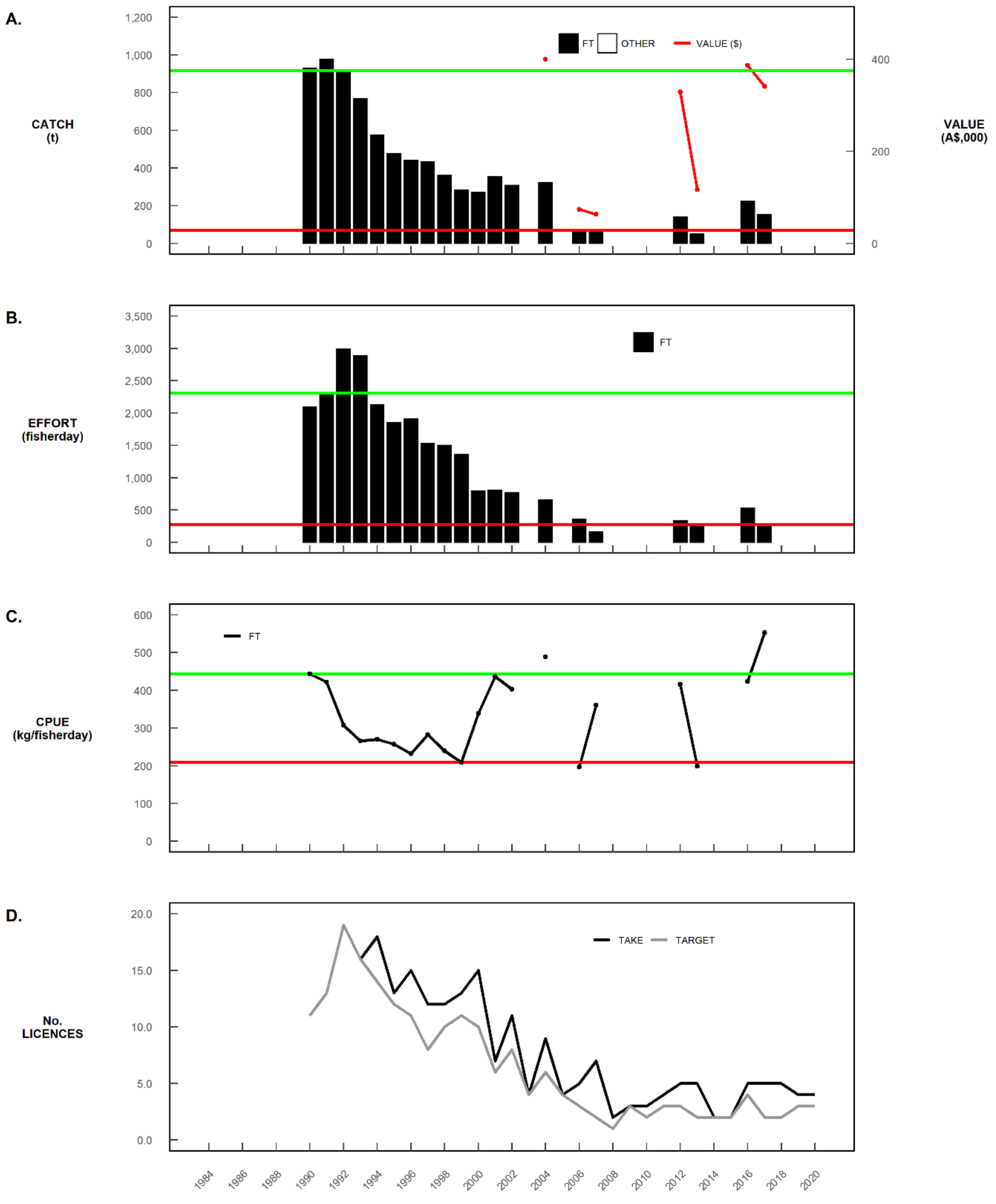

Figure 4-36. Ocean Jacket. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (fish trap and other), and gross production value; (B) total effort; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-17.

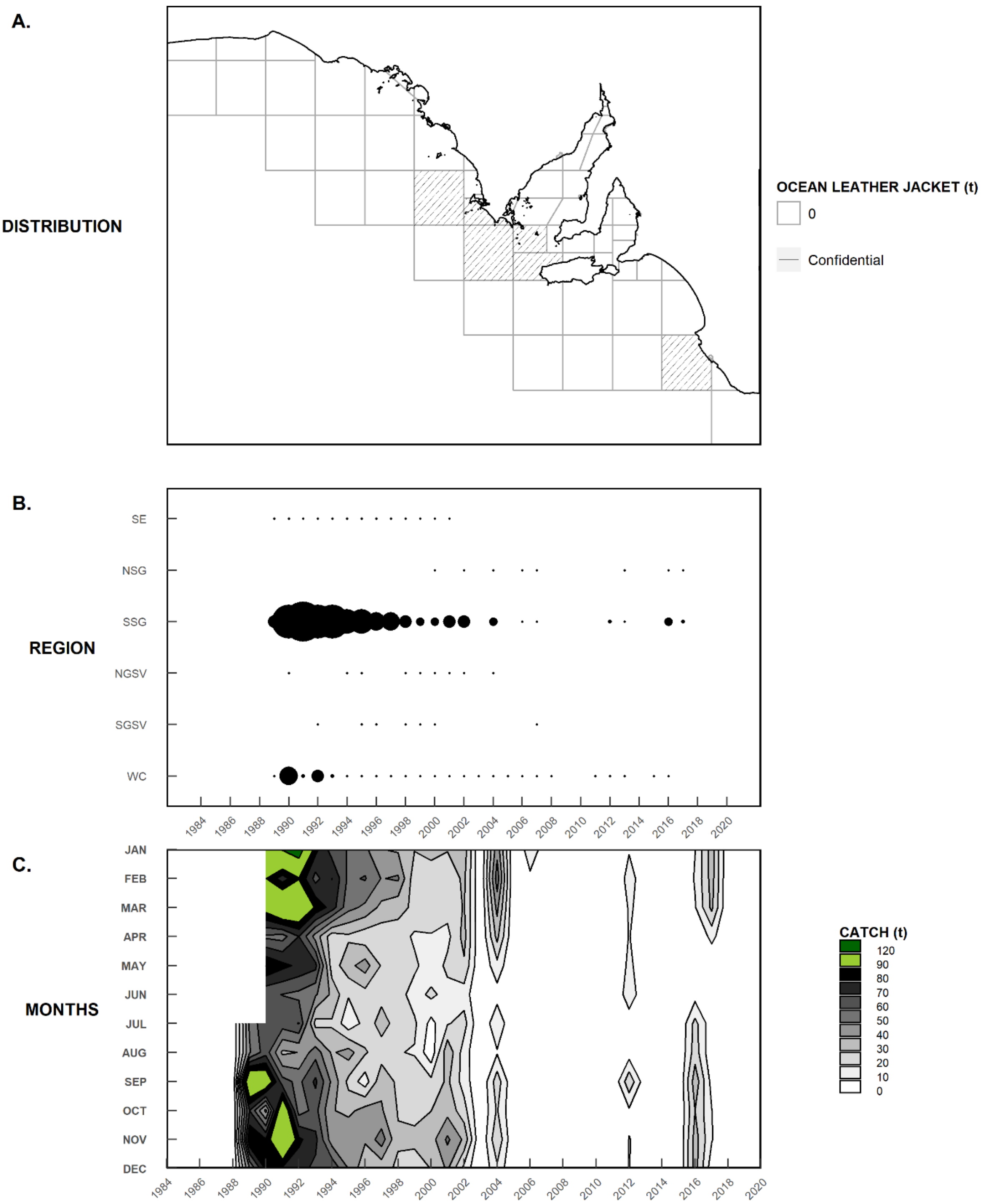

Figure 4-37. Ocean Jacket. (A) The spatial distribution of catch by the commercial sector in 2020. Long-term trends in: (B) the annual distribution of catch among regions, and (C) months of the year.

Fishery Performance

The general fishery performance indicators for Ocean Jackets were assessed for 2020 at the State-wide scale. One trigger reference points was activated, reflecting the relatively high targeted fish trap CPUE in 2020 (Table 4-17).

Table 4-17. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Ocean Jacket in 2020.

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
TARGET FISH TRAP 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 FISH TRAP 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 Ocean Jacket fishery developed rapidly during the mid-1980s resulting in an exponential increase in total annual catch that reflected both an increase in effort as new entrants came into the fishery and the geographic expansion of the fishery (Grove-Jones and Burnell 1991). The rapid expansion of this fishery caused concerns about sustainability, which led to the introduction of regulations to limit the numbers of fishers and fishing effort. The fishery attained its highest productivity in the early 1990s, and the underwent a period of declining levels of catch effort, and numbers of specialist fishers through to around 2008. 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 the low wholesale price of the product (Grove-Jones and Burnell 1991).

In 2020, there was a moderate increase in total catch that reflected a moderate increase in targeted effort and relatively high CPUE. The high CPUE in several recent years indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment overfished. On this basis, South Australia's Ocean Jacket fishery is classified as **sustainable**.

4.3.14. Bluethroat Wrasse

Biology

There are several temperate Wrasse species (Family Labridae) that occur in South Australian waters (Gomon et al. 2008, Shepherd and Baker 2008). They are all associated with shallow, near-shore reef habitats, rendering them vulnerable to line fishing. Only the Bluethroat Wrasse (*Notolabrus tetricus*) is recognised as a legitimate commercial species for the MSF (PIRSA 2013). 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. The Bluethroat Wrasse occupies algal beds and reefs through the depth range of 0–50 m. 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 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 within 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

The Bluethroat Wrasse has historically been used as bait to target Southern Rock Lobster, but is also a commercially targeted species in the MSF (PIRSA 2013). Other labrid species are also taken in lower numbers and are reported as Parrotfish in the MSF logbooks. Consequently, it is not possible to differentiate the fishery statistics amongst the wrasse 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). For the commercial sector there is a relatively small, targeted fishery for which the captured fish are sold as live product by the Sydney Fish Market. Alternatively, they are captured as by-product when other more valuable species are targeted. As such, there are considerable differences between the numbers of fishers who report taking Bluethroat Wrasse, and those who 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 1 December 2016 there were no size limits or 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 2016b). In response, a harvest 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, these 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. Under Ministerial exemption in 2018 and 2019, commercial licence holders were permitted to take Wrasse above the maximum 350 mm TL. A condition of this exemption was mandatory collection of additional data to inform consideration of future size limits for the species.

Commercial Fishery Statistics

State-wide

Between 1984 and 1996, the reported commercial catch of Bluethroat Wrasse was relatively low at <8 $t.yr^{-1}$ (Figure 4-38). It increased to 23.9 t in 1997 and remained at 21.9–28.7 $t.yr^{-1}$ until 2004. From then it progressively declined to ~7 $t.yr^{-1}$ in 2018 and 2019. The total catch of 5 t in 2020 was the lowest since 1994. The economic value of the commercial catch of Bluethroat Wrasse in 2020 was approximately $37.6 K (c.f. $43.5 K in 2019) (Figure 4-38). Up to 2004, most of the catch was taken using handlines. Subsequently, the proportion of the catch taken using longlines increased considerably largely due to a decline in catch taken using handlines. In 2020, 51% of the catch was taken using handlines with the remaining 49% taken using longlines.

Between 1984 and 1991, total line effort (handline and longline combined) was low, before it increased considerably up to 1997. Since then, it has been highly variable (Figure 4-38). In most years, handlines accounted for most of the effort with smaller contribution from longlines, except from 2005 to 2012, when the proportion of total line effort accounted for by longlines increased considerably. In 2020, handlines accounted for 83% of the total line effort that produced catches of Bluethroat Wrasse.

The long-term trends in total line CPUE have been similar to those for total catch and effort (i.e. low during the 1980s, increased during the late 1990s (peak of 33.7 $kg.fisher\text{-}day^{-1}$ in

2000) and then progressively declined to 2020 (Figure 4-38). Over recent years, CPUE has declined from 21.7 kg.fisher-day^{-1} in 2017 to 11.4 kg.fisher-day^{-1} in 2020.

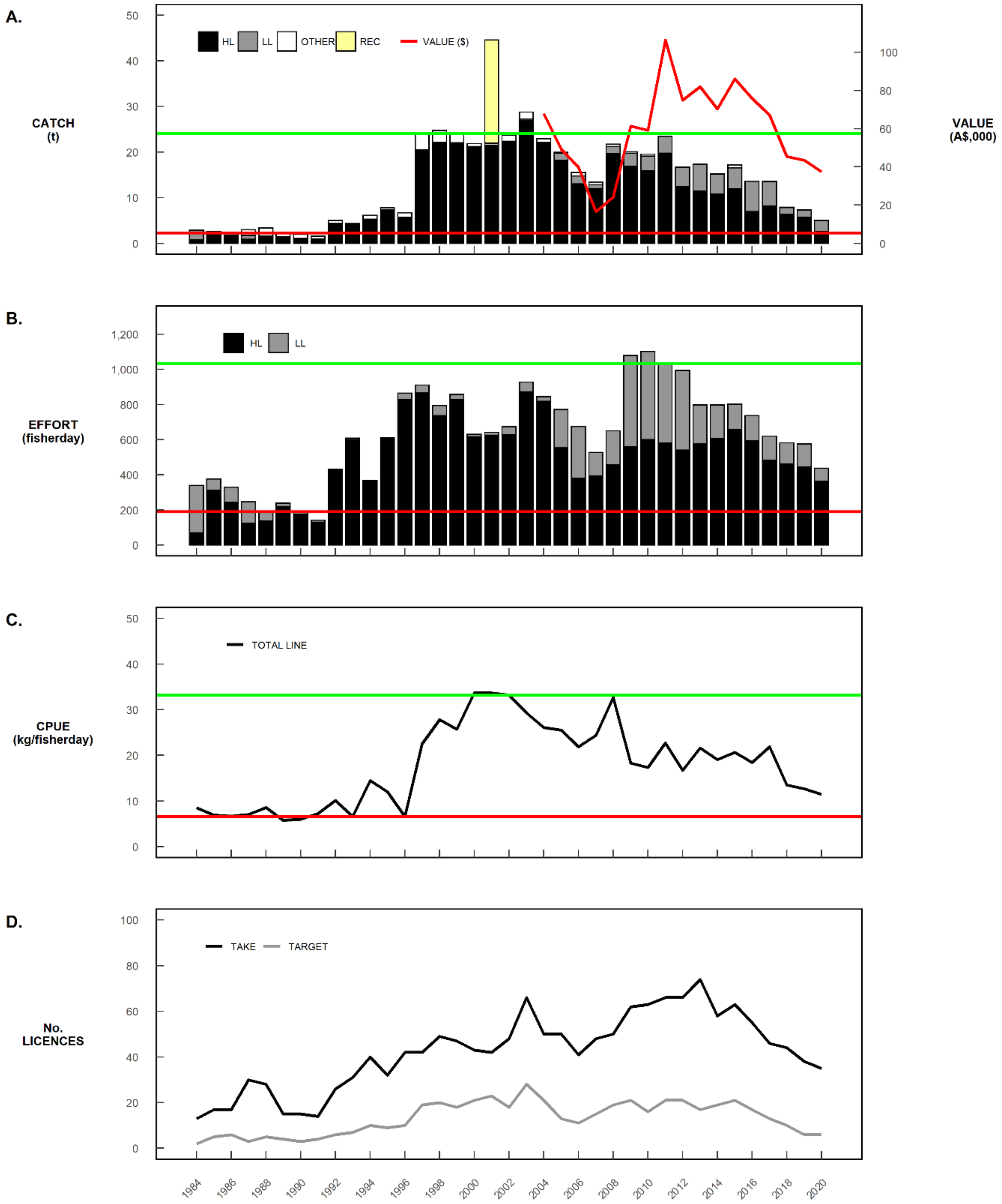

Figure 4-38. Bluethroat Wrasse. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (handline and longline), estimate of recreational catch, and gross production value; (B) total line effort; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-18.

Since 1984, there has been a disparity between the high numbers of fishers who reported taking Bluethroat Wrasse and those who targeted it (Figure 4-38D). The former increased up to 74 in 2013 and then declined to 35 fishers in 2020, while the latter increased up to 28 in 2003 and then declined to 6 fishers in 2019 and 2020.

Regional

Since Bluethroat Wrasse catch increased in the late 1990s, the WC and SSG regions have been the major contributors to the total catch, although catches from the WC have been relatively low since 2012. Only incidental catches have been reported from the other four regions (Figure 4-39). In 2020, most of the catch was taken in SSG with minor landings in all other regions except NSG. Catches have been distributed throughout the year (Figure 4-39).

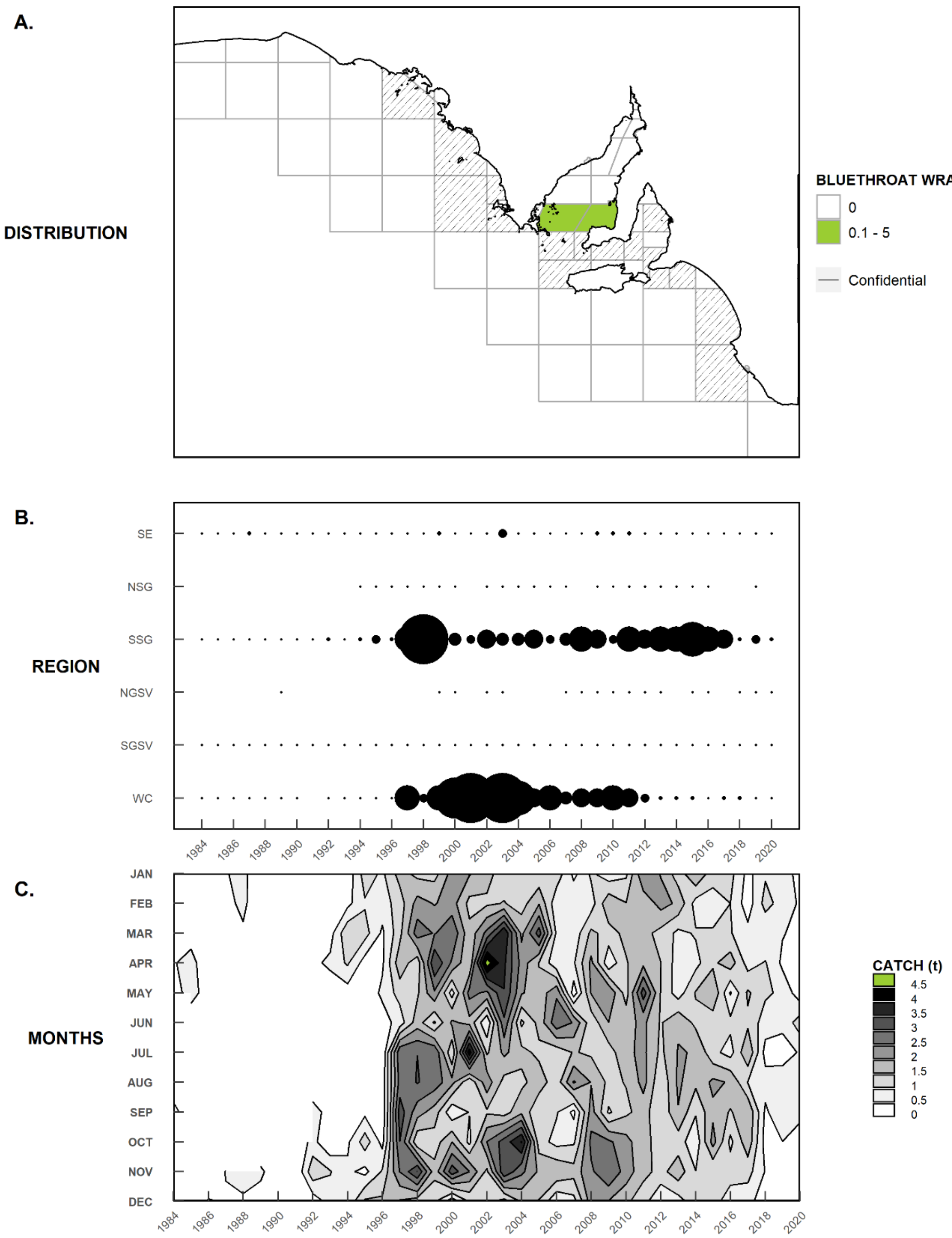

Figure 4-39. Bluethroat Wrasse. (A) The spatial distribution of catch by the commercial sector in 2020. Long-term trends in: (B) the annual distribution of catch among regions, (C) months of the year.

Fishery Performance

The general fishery performance indicators for Bluethroat Wrasse were assessed for 2020 at the State-wide scale. Estimates of total catch and total line effort (combined across handline and longline fishing methods) have declined over five consecutive years since 2016, breaching the associated trigger reference points (Table 4-18).

Table 4-18. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State-wide spatial scale for Bluethroat Wrasse in 2020.

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 a large proportion of the catch in each year directed towards the live fish trade. Most of the remaining catch is taken as by-product when other species are targeted. A cyclical trend in State-wide catch occurred through a reduction in catches from the WC zone in the mid 2000's prior to an increase in catches from SSG following 2008. Following the shift in catch to SSG, the higher longline catch and effort from 2004 to the mid-2010s, might reflect the development of the longline fishery for Snapper in this region. The later decline in longline effort that produced catches of Bluethroat Wrasse may well correspond with the decline and subsequent closure of the Snapper fishery that occurred in that region in the late 2010s.

Total catch of Bluethroat Wrasse has declined since 2011, corresponding with a general decline in line fishing effort. This decline in effort continued in 2020 and resulted in a breach of the associated trigger reference point. From 2011 to 2017, annual CPUE was relatively stable around a moderate level. However, in 2018, there were notable declines in both total catch and CPUE, which continued into 2019 and 2020. As such, the recent estimates of catch and CPUE are considerably lower than the high values recorded through the peak period of the early 2000s, but nevertheless remain higher than the low levels of the 1980s and 1990s. The recent declines in commercial catch and CPUE are not yet sufficient to indicate that a change in stock status is warranted. As a result, the Bluethroat Wrasse stock is classified as **sustainable**.

4.3.15. Silver Trevally

Biology

The Silver Trevally (*Pseudocaranx georgianus*) is distributed from Coffs Harbour in New South Wales (NSW) across southern Australia to Perth in Western Australia (Stewart 2015). It forms schools over sandy bottom in estuaries, as well as gulf, nearshore coastal and shelf waters, where it feeds on small fish, benthic and pelagic invertebrates.

The population biology of Silver Trevally in South Australian waters is poorly understood. They are slow-growing and live up to 25 years in NSW waters (Stewart 2015), and 33 years in New Zealand waters (Langley 2001). 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). In South Australia, the commercial catches have been dominated by MSF fishers, with only incidental catches reported by the Northern Zone Rock Lobster Fishery (NZRLF). Handline catches account for most commercial catches, with smaller contributions taken using net gear types.

The recreational catch is taken using 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 recreational 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 that 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 2016b).

For the recreational sector, there are multiple management regulations in place for Silver Trevally. Input and output controls ensure that 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, as well as 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 since 1984. It was consistently low and did not exceed 5 $t.yr^{-1}$ during the 1980s, before increasing to a small peak of 16.6 t in 1992 (Figure 4-40). Since then, catch has been at moderate levels (average ~9 $t.yr^{-1}$), except for the historic high of 21 t in 2000 and the historic low of 2.5 t in 2002. The total catch of 11.98 t in 2020 was 74% higher than the 2019 catch of 6.9 t and slightly higher than the average catch taken over the last decade. The economic value of the commercial catch of Silver Trevally in 2020 was approximately $102 K, which was twice that of the previous year (*c.f.* $50.9 K in 2019) (Figure 4-40).

Since 1992, handline catches have contributed most to annual catches, with the remainder taken using various net types. Handline fishing effort that produced catches of Silver Trevally has varied cyclically since the mid-1980s (Figure 4-40). It was 129–395 $fisher\text{-}days.yr^{-1}$ during the 1980s, increased to a peak of 1,167 fisher-days in 1993, and then declined to 261 fisher-days in 2001. It increased to a smaller peak of 802 fisher-days in 2015 and was 899 fisher-days in 2020.

Handline CPUE has increased slowly over the long-term. The high catch in 2000 was associated with an uncharacteristically high CPUE of 56.9 $kg.fisher\text{-}day^{-1}$ which declined the following year to a level that was consistent with the long-term average CPUE. Since then CPUE has been more stable and averaged ~12.3 $kg.fisher\text{-}day^{-1}$. In 2020, handline CPUE was 12.67 $kg.fisher\text{-}day^{-1}$, which was 55% higher than the previous year (Figure 4-40).

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 4-40). This suggests that for many fishers, Silver Trevally has been taken as by-product when they fished for more valuable species. This continued in 2020 when 66 fishers landed Silver Trevally and 16 fishers targeted the species.

Regional

Catches of Silver Trevally have been reported from each of the six regions in most years since 1984 (Figure 4-41). Since 2000, the majority of catches have been taken from Southern Spencer Gulf during May, June and July (Figure 4-41). In 2018 and 2020, catch contributions from the west coast have been slightly higher than in previous years.

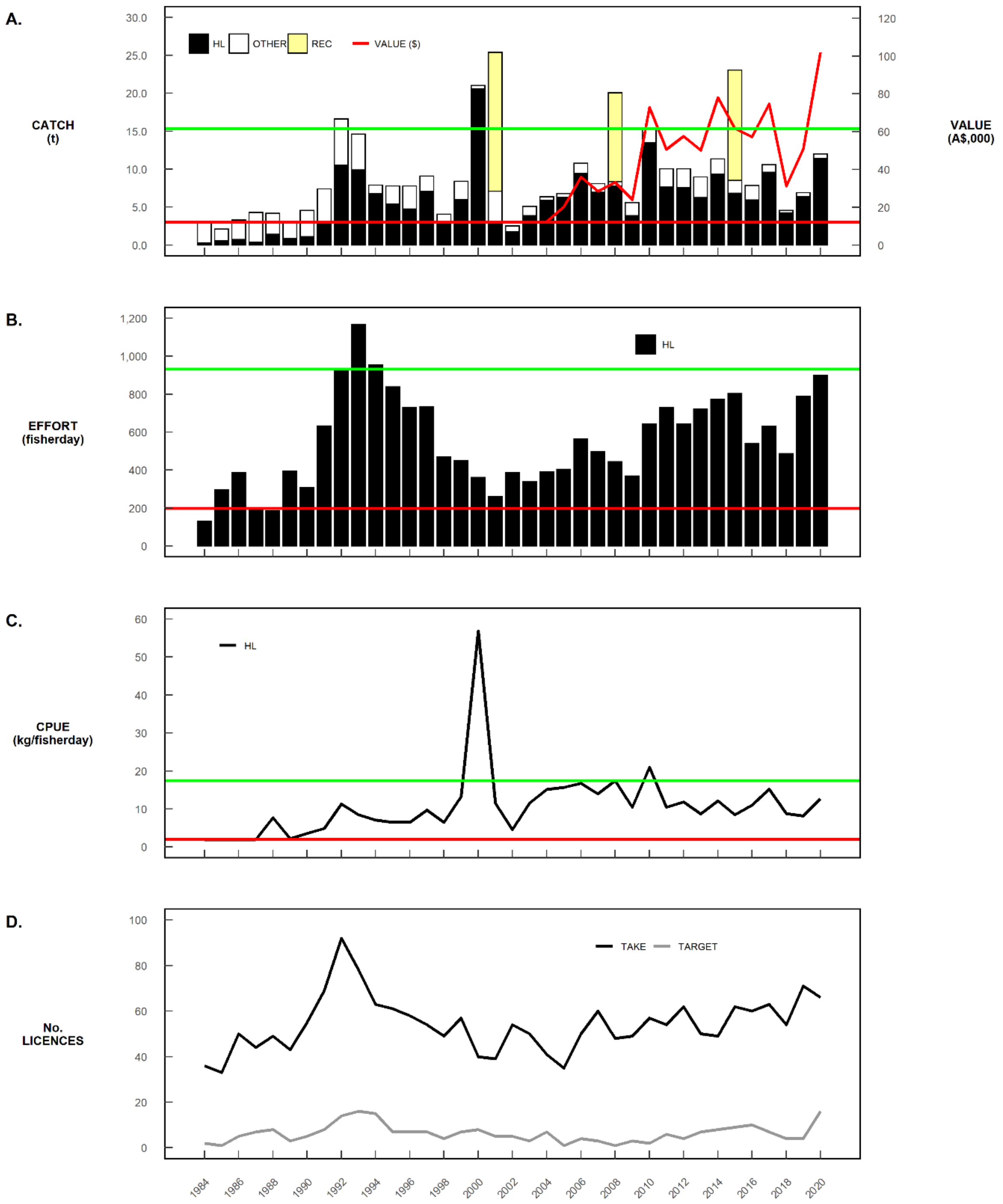

Figure 4-40. Silver Trevally. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (handline and other), estimates of recreational catch, and gross production value; (B) total handline effort; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-19.

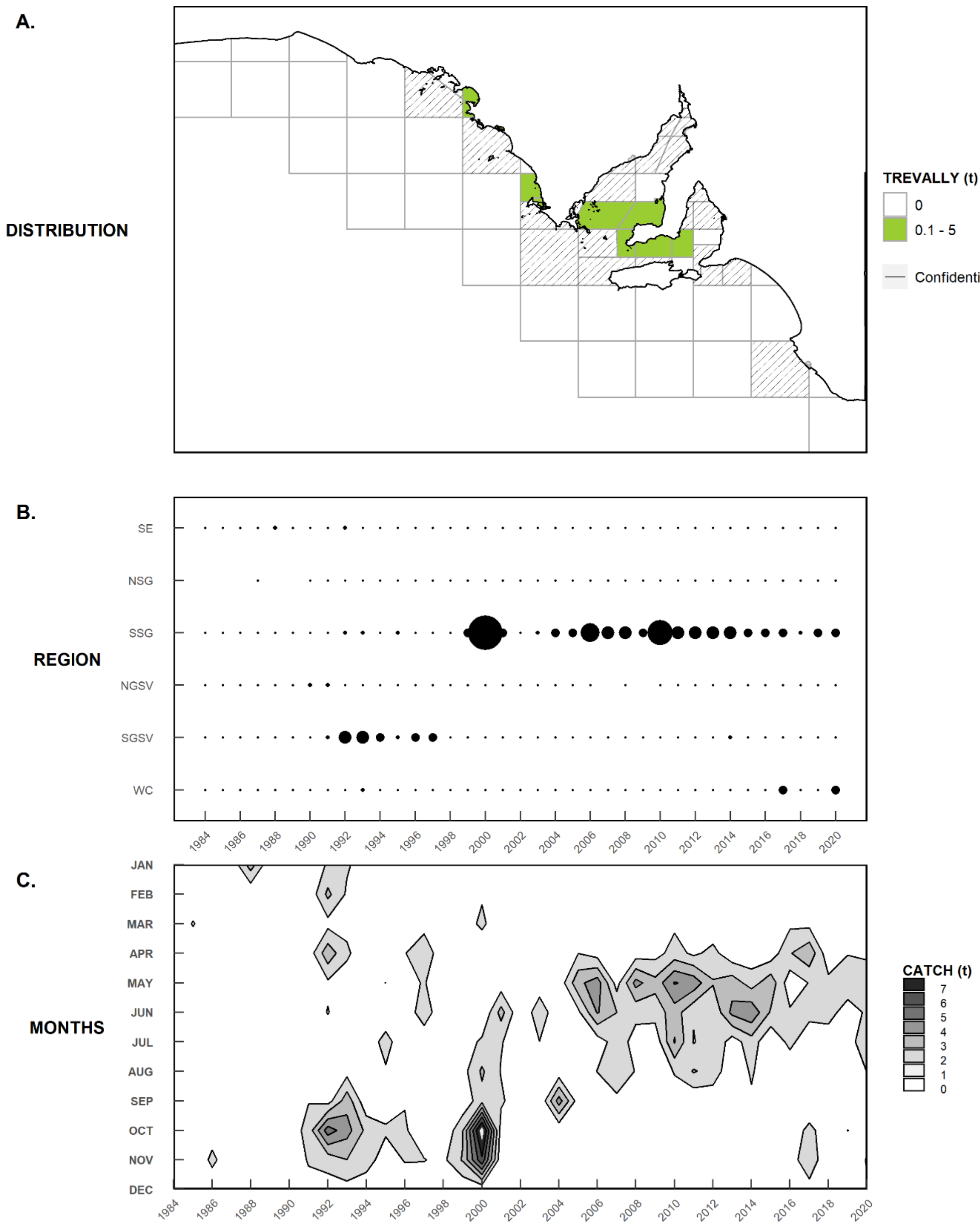

Figure 4-41. Silver Trevally. (A) The spatial distribution of catch by the commercial sector in 2020. Long-term trends in: (B) the annual distribution of catch among regions, (C) months of the year.

Fishery Performance

The general fishery performance indicators for Silver Trevally were assessed for 2020 at the State-wide scale. No trigger reference points were breached (Table 4-19).

Table 4-19. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State-wide spatial scale for Silver Trevally in 2020.

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 decade prior to 2018, estimates of total catch, handline effort and handline CPUE for Silver Trevally were stable at moderate levels. In 2018, each of these performance indicators showed a downturn, but no trigger reference points were breached. In 2019, there was some recovery in catch and effort and this continued in 2020 with considerable increases in catch, effort and CPUE whilst no trigger reference points were breached. On this basis, the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired, and the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On this basis, the MSF for Silver Trevally is classified as a **sustainable** stock.

4.3.16. Leatherjackets

Biology

Of 19 species of Leatherjackets (Monacanthidae) that occur in the waters of southern Australia, at least six species inhabit coastal reef habitats in South Australia. Leatherjacket species are characterised by having 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. They are omnivores that feed on small invertebrates, algal turfs and seagrass (Shepherd and Baker 2008). The Ocean Jacket (*Nelusetta ayraudi*) is the predominant species of Leatherjacket caught in the MSF by a large margin. Therefore, this species is assessed independently. The current chapter assesses the remaining species of Leatherjackets caught in the MSF as a species complex.

For South Australia's MSF, anecdotal evidence suggests that the Horseshoe Leatherjacket (*Meuschenia hippocrepis*) and the Sixspine Leatherjacket (*M. freycineti*) are the dominant species taken, following Ocean Jackets. Nevertheless, mixed species catches are reported collectively 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, Leatherjacket species are taken in the commercial and recreational sectors of the MSF. For the commercial sector, Leatherjackets are predominantly taken as by-product when more valuable species are targeted; however, a small number of fishers also target these species. Leatherjackets are mostly caught using hauling nets or handlines but are also susceptible to capture using fish traps. Prior to 1990, catches of Leatherjackets in the MSF were not resolved to the species level and so those of Ocean Jackets and all other Leatherjacket spp. were combined in the logbooks. As such, this assessment for Leatherjacket considered data from 1990 to 2020.

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

Management Regulations

All species of Leatherjackets are permitted in 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 catches for Leatherjackets were highest during the early 1990s when they varied between 50–70 t (Figure 4-42). Total catch declined regularly over the long-term to the lowest recorded level of 10.5 t in 2014. Since 2014, catches peaked at 34.1 t in 2016, and have decreased to 7.6 t in 2020. The economic value of the commercial catch of Leatherjackets in 2020 was approximately $52.6 K (*c.f.* $81.7 K in 2019).

Since 1990, generally >50% of the annual catches were taken with hauling nets. The second major gear type that contributed to catches of Leatherjackets was handlines, for which the annual catches 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 (Figure 4-42B). Hauling net effort has progressively declined from its peak of 4,860 fisher-days in 1992 to 678 fisher-days in 2014 before increasing to 1,681 fisher-days in 2016. Hauling net effort declined to an historic low of 610 fisher-days in 2020.

Between 1990 and 2001, hauling net CPUE was relatively consistent at between 8.4–11.5 kg.fisher-day^{-1} before it declined to a low of 6 kg.fisher-day^{-1} in 2002 (Figure 4-42). It increased to 18.1 kg.fisher-day^{-1} in 2004 and then remained relatively high, i.e. between 12–19 kg.fisher-day^{-1} until 2017. Hauling net CPUE peaked at 22.2 kg.fisher-day^{-1} in 2018 and then declined to 9.62 kg.fisher-day^{-1} in 2020.

The number of fishers who reported taking Leatherjackets has declined from 142 in 1990 to 68 fishers in 2020 (Figure 4-42). An average of around 5 fishers.yr^{-1} reported that they actively targeted these species since 1984, with eight fishers targeting Leatherjackets in 2020. The higher numbers of fishers who took Leatherjackets compared to those who targeted it suggests that this taxon has largely been a by-product when more valuable species were targeted).

Regional

Between 1990 and 2018, NSG and NGSV contributed the highest catches of Leatherjackets. Incidental catches were taken from the other four regions (Figure 4-43). Historically, catches have been highest between March and October (Figure 4-43).

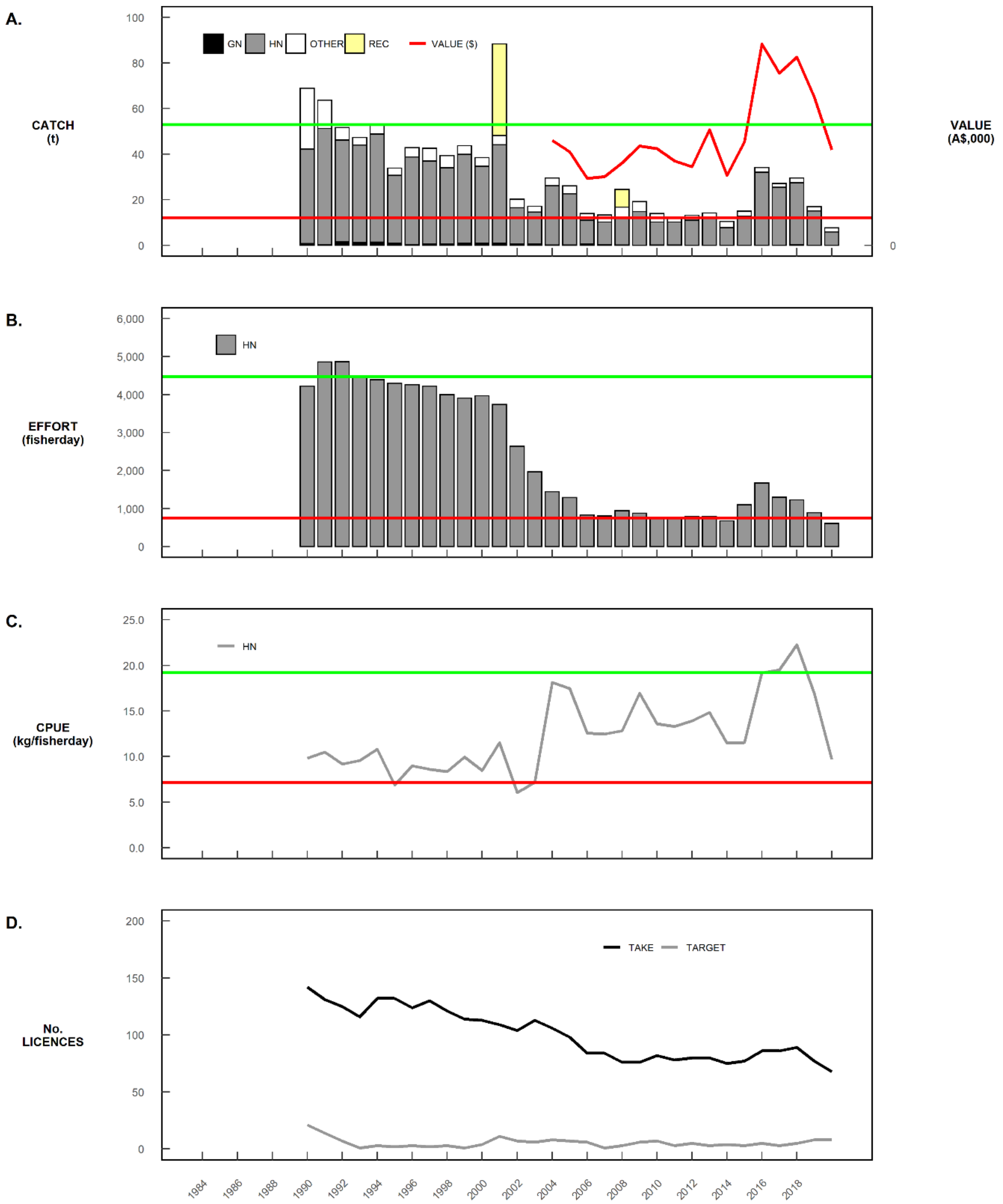

Figure 4-42. Leatherjackets. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (hauling net and gillnets), estimates of recreational catch, and gross production value; (B) total hauling net effort; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-20.

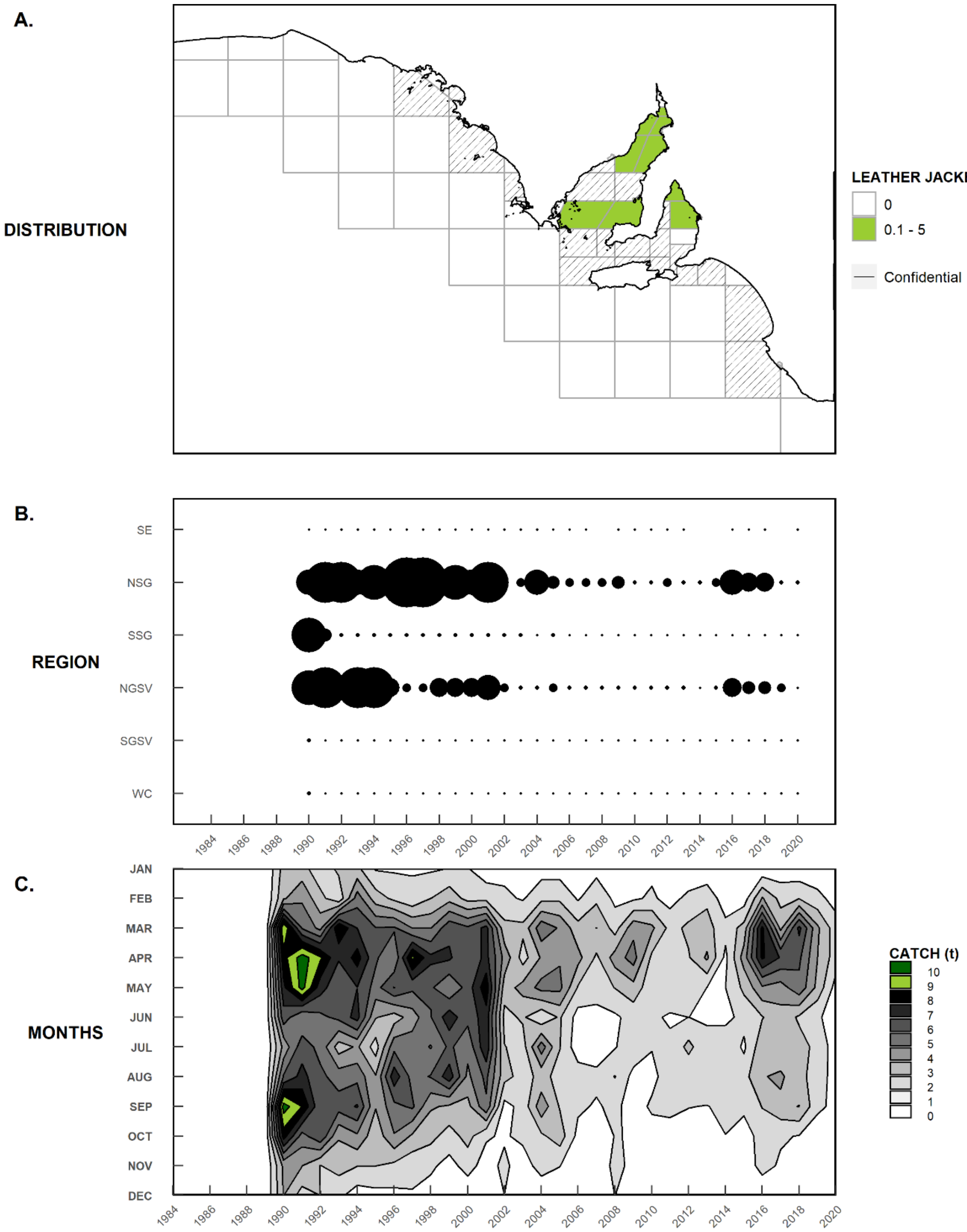

Figure 4-43. Leatherjacket. (A) The spatial distribution of catch by the commercial sector in 2020. Long-term trends in: (B) the annual distribution of catch among regions, (C) months of the year (t).

Fishery Performance

The general fishery performance indicators for Leatherjackets were assessed for 2020 at the State-wide scale, using the reference period of 1990 to 2020. Three trigger reference points were breached for 2020 with the lowest total catch and lowest total hauling net effort recorded

(Table 4-20). Total hauling net effort has decreased over five consecutive years which has resulted in a breach of the associated trigger reference point.

Table 4-20. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Leatherjacket in 2020.

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	×
TOTAL HAULING NET EFFORT	G	3rd Lowest / 3rd Highest	LOWEST
	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	×

Stock Status

There is limited information for determining stock status, and the information available is compounded by a paucity of information on the catch composition (species) of Leatherjackets harvested. The limited data prevents assessment of current stock size or fishing pressure. Consequently, there is insufficient information available to confidently classify the status of this stock.

On the basis of the evidence provided above, the Southern Australia Leatherjacket stock is classified as an **undefined** stock.

4.3.17. Rays and Skates

Biology

Rays and Skates that are common in South Australian waters belong to several Families, including the Myliobatiae (e.g. Southern Eagle Ray), Dasyatidae (e.g. Smooth Stingray) and Rajidae (e.g. Bight Skate). The catch of Rays and Skates in the MSF is not differentiated by species in the fishery logbooks. Products from Southern Eagle Rays (*Myliobatis tenuicaudatus*) are regularly identified during market sampling, and hence, it is likely this species comprises a prominent proportion of the Ray and Skate landings in the MSF.

The Southern Eagle Ray is distributed from Jurien Bay in Western Australia to Moreton Bay in Queensland. The species is also found in South Australia, Victoria, Tasmania and New Zealand (Last and Stevens 2009). Southern Eagle Rays reach a maximum size of up to 1.6 m disc width (>3 m TL) (Last and Stevens 2009). Age and growth studies suggest the species reaches a maximum age of >15 years for males and >26 years for females in New Zealand (Hartill 1989).

Fishery

Rays and Skates are mostly taken as bycatch in the MSF when fishers use hauling nets and longlines to target higher value species (Fowler et al. 2009). The most recent recreational fishing survey estimated that 9,489 Southern Eagle Rays were captured by recreational fishers in South Australia, 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 for this species group (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 Rays and Skates was 10.2 t in 2020 (*c.f.* 11.8 t in 2019). Total annual catches were relatively stable between 2014 and 2020 and averaged 12.2 t per year (Figure 4-44). The economic value of the commercial catch of Rays and Skates in 2019 was approximately $40 K (*c.f.* $26 K in 2020).

Rays and Skates have been predominantly taken using longlines and hauling nets. In 2020, the total annual catches using longlines and hauling nets were 7.5 t and 2.5 t, respectively. Annual trends in longline effort that produced catches of Skates and Rays showed a steady decline from ~1,300 in the early 1990s to an historical low of 162 fisher-days in 2020. Hauling net effort that produced catches of Rays and Skates has also declined over the past three decades from a peak of 1,990 fisher-days in 1988 to an historic low of 163 fisher-days in 2020 (Figure 4-44).

Longline CPUE for Rays and Skates in 2020 was 46.54 kg.fisher-day^{-1}, which was the highest annual CPUE recorded since 2005 (Figure 4-44). Hauling net CPUE has been stable and ranged between 14–17 kg.fisher-day^{-1} over the past 5 years and was 15.4 kg.fisher-day^{-1} in 2020. The number of licences taking (~55) and targeting (~6) Rays and Skates has been stable over the past decade (Figure 4-44).

Regional

The largest annual catches of Rays and Skates occurred off the West Coast between 1988 and 2005 (Figure 4-45). Southern GSV was the second most significant region until 2003, with NSG and the SE also supporting significant annual catches in some years. In the past five years, catches have been homogeneously distributed, albeit at low levels, with fishers from the WC and NSG maintaining the highest catches. Catches of Rays and Skates are generally more frequent between spring through autumn (Figure 4-45).

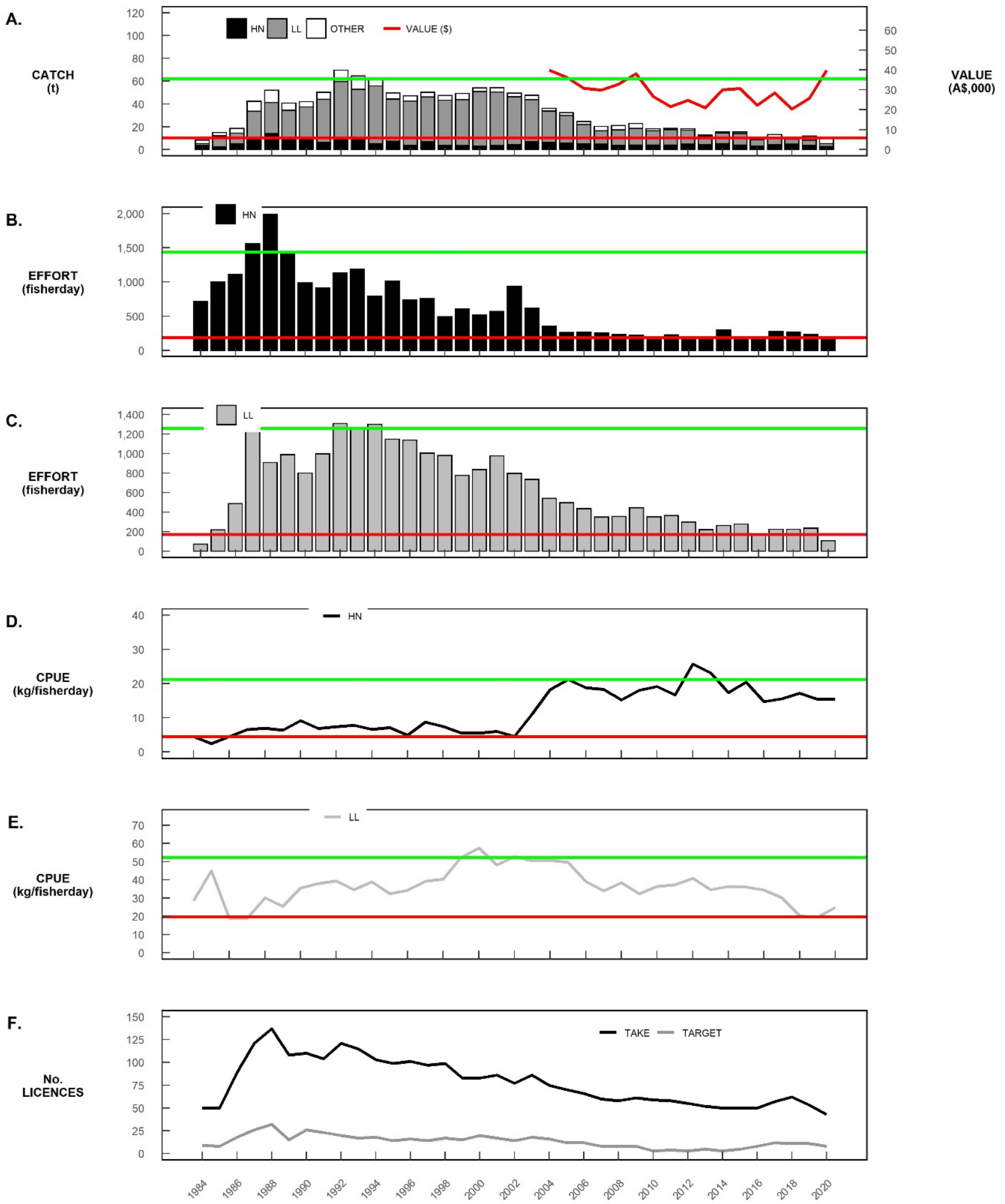

Figure 4-44. Rays and Skates. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (longline and hauling net), and gross production value; (B) total longline effort; (C) total haul net effort (D) total long line catch per unit effort (CPUE); (E) total haul net catch per unit effort (CPUE); and (F) 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 4-21.

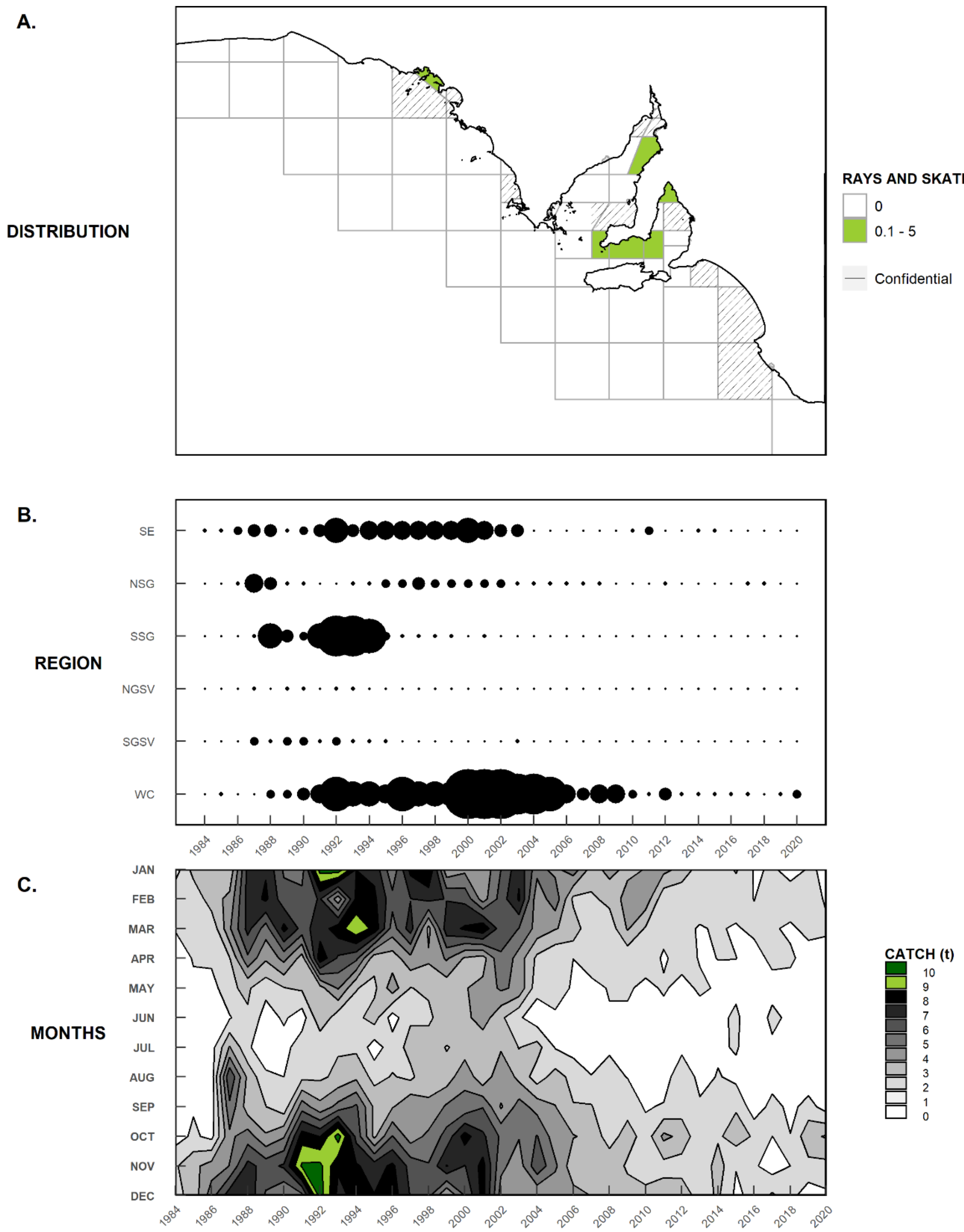

Figure 4-45. Rays and Skates. (A) The spatial distribution of catch by the commercial sector in 2020. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year.

Fishery Performance

The general fishery performance indicators for Rays and Skates were assessed for 2020 at the State-wide scale. Five trigger reference points were breached in 2020 (Table 4-21), most of which related to the low levels of hauling net and longline effort that produced catches of

Rays and Skates and the high CPUE for longlines over recent years. Total hauling net effort that produced catches of Rays and Skates for 2020 was the lowest on record, while that for longlines was the second lowest on record. The decline in longline effort from 2019 to 2020 represented the greatest (%) interannual decline since 1984.

Table 4-21. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Rays and Skates in 2020.

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	LOWEST
	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	2nd LOWEST
	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

There is limited information for determining stock status, and the information available is compounded by a paucity of information on the catch composition (species) of Rays and Skates harvested. The limited data prevents assessment of current stock size or fishing pressure. Consequently, there is insufficient information available to confidently classify the status of these stocks.

On the basis of the evidence provided above, the Southern Australia Rays and Skates stock (i.e., management unit) is classified as an **undefined** stock.

4.3.18. Cuttlefish

Biology

Giant Australian Cuttlefish (*Sepia apama*) and Nova's Cuttlefish (*S. novaehollandiae*) are commercially harvested in the MSF. The 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).

Two populations of Giant Australian Cuttlefish have been identified in South Australia (Gillanders et al. 2016). While the Cuttlefish stock in southern Spencer Gulf extends into Gulf St Vincent, the northern stock is restricted to northern Spencer Gulf (NSG) with individuals returning to the site of hatching to breed at either one or two years of age (Hall et al. 2007). The NSG population forms a breeding aggregation at Point Lowly (Steer et al. 2013, Steer 2015, Gillanders et al. 2016) during late autumn and early winter each year. The species is semelparous, dying soon after spawning (Hall 2003).

Fishery

Cuttlefish species are taken in the commercial and recreational sectors of the MSF. Handlines and jigs are used in the commercial sector where they are either targeted or taken as by-product by fishers whilst fishing for Southern Calamari. Historically, Cuttlefish were retained by commercial fishers as bait for Snapper.

Recreational fishers mostly take Cuttlefish using jigs when they are targeting Southern Calamari. In 2013/14, the State-wide recreational survey estimated that 2,648 Cuttlefish were captured, of which 1,217 were released, leaving 1,431 retained (Giri and Hall 2015). This provided a total estimated recreational catch of 0.34 t, which was considerably lower than the estimated commercial catch of 2 t during the survey period.

Management Regulations

Cuttlefish species are permitted to be taken by the commercial sector of 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. A cephalopod fishing closure, that aimed to protect the 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 to prohibit the targeting and retention of Giant Australian Cuttlefish to the north of Wallaroo, Spencer Gulf. In 2020, the northern Spencer Gulf Cuttlefish closure was revised, and some previously closed areas were reopened to commercial cephalopod fishing.

Commercial Fishery Statistics

State-wide

Between 1994 and 1997, the commercial catch of Cuttlefish increased from 12.3 $t.yr^{-1}$ to a peak at 262 $t.yr^{-1}$ (Figure 4-46) corresponding with an increase in both targeted and untargeted effort (Figure 4-46). Total catch declined but remained high in 1998 at 150 t, and then averaged ~19.6 t over the four-year period between 1999 and 2002. Between 2003 and 2016 the total catches of Cuttlefish decreased further and ranged from 10.5 t in 2007 to 1.3 t in 2016. The total catch of 0.9 t in 2017 was the lowest since 1987 and had only increased marginally to 1.1 t in 2019. In 2020, total catch increased substantially to 23 t – the highest catch since 2003. The economic value of the catch in 2020 was approximately $146.6 K (*c.f.* $ 10 K in 2018) (Figure 4-46).

Until 1994, total jig effort was <350 fisher-days.yr^{-1}, before increasing to a peak of 1,477 fisher-days in 1997 (Figure 4-46). From 1998 to 2016 it fluctuated between 600 and 900 fisher-days.yr^{-1} before dropping to 326 fisher-days in 2019 and remaining relatively low at 351 fisher-days in 2020. Jig CPUE followed a similar trend and increased from historically low levels during the 1980s to a high of 173 kg.fisher-day^{-1} in 1997, subsequently declining to near historical low levels of <10 kg.fisher-day^{-1} during the 2010s (Figure 4-46). The increase in total catch in 2020 was associated with an increase in CPUE to 65 kg.fisher-day^{-1} – the highest CPUE since 1998.

The short-term expansion of the fishery between 1994 and 1997 reflects the fleet's concentration of fishing effort on the spawning aggregation in north-western Spencer Gulf. The fishery's take of Cuttlefish was reduced considerably by the False Bay spawning closure in 1998, which accounted for >90% of the State-wide catch.

During the late 1990s and early 2000s up to 56% of the fishers that landed Cuttlefish actively targeted them. This trend has changed since 2010 with the number of fishers actively targeting Cuttlefish relative to those taking them has rarely exceeded 20%, indicating that the majority of Cuttlefish landed are incidentally caught, most likely by fishers targeting Southern Calamari (Figure 4-46).

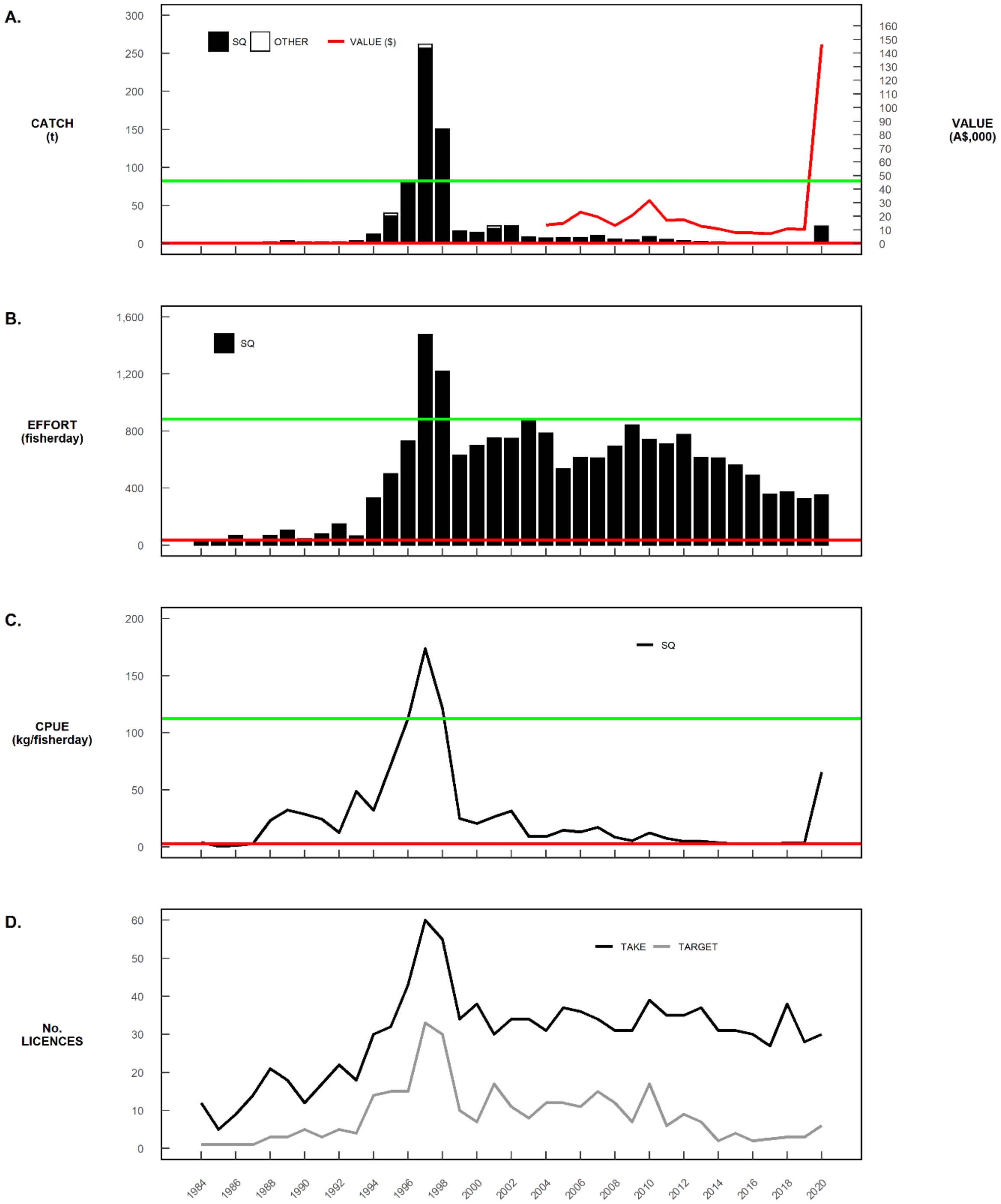

Figure 4-46. Cuttlefish. Long-term trends in State-wide estimates of: (A) total catch of the main gear types (squid jig and other), and gross production value; (B) total effort; (C) catch per unit effort (CPUE); and (D) the number of active licence holders taking or targeting the species. Green and red lines represent the upper and lower reference points identified in Table 4-22.

Regional

Between 1994 and 2002, NSG provided the highest catches of Cuttlefish with only incidental catches from the other regions (Figure 4-47). This was also the case in 2020, with most of the annual catch taken in NSG and smaller contributions from SSG, NGSV, SGSV and the upper SE (Figure 4-47). During the high catch years, the seasonality of catches aligned with the timing of the spawning aggregation between April and August (Figure 4-47).

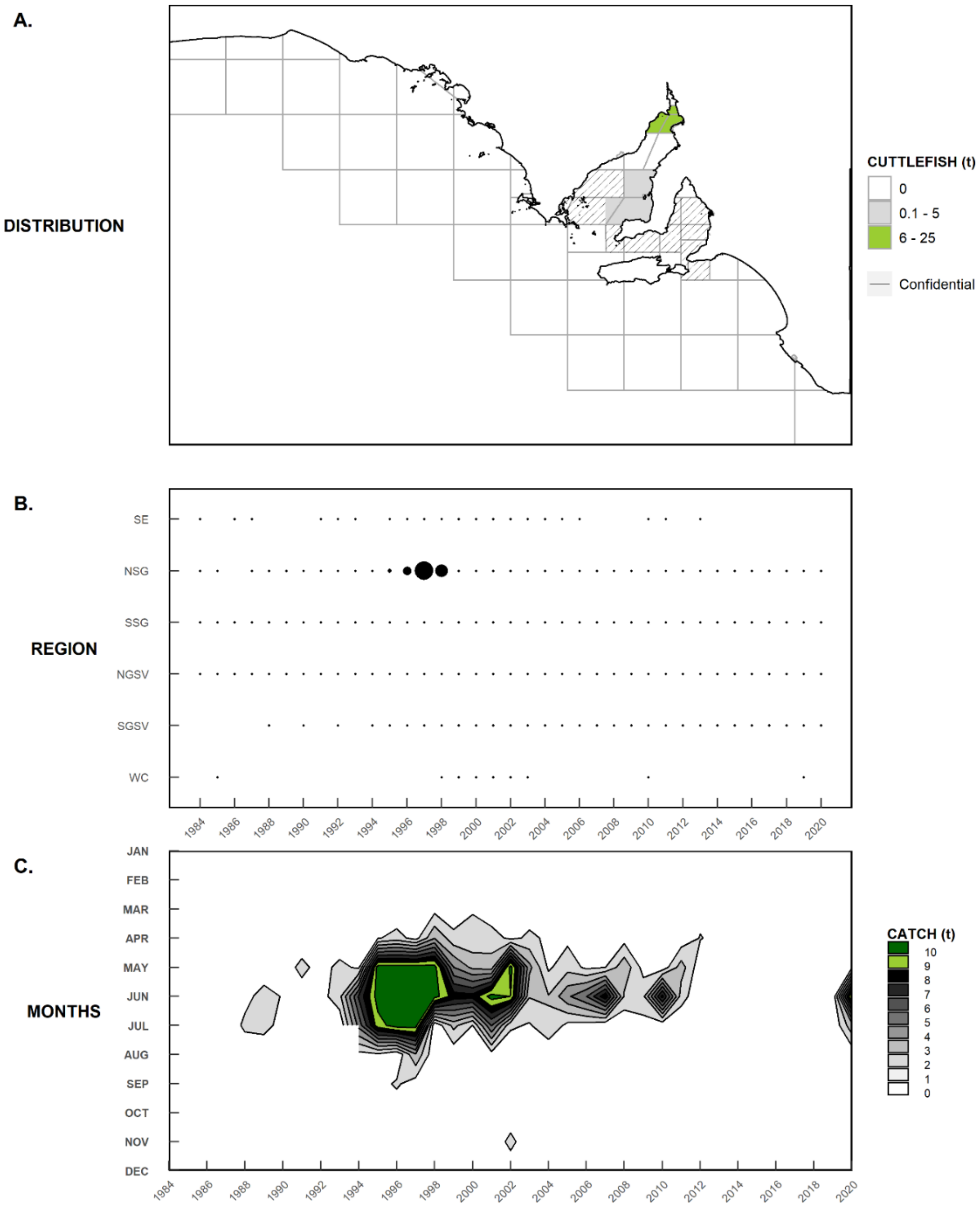

Figure 4-47. Cuttlefish. (A) The spatial distribution of catch by the commercial sector in 2020. Long term trends in: (B) the annual distribution of catch among regions, (C) months of the year.

Fishery Performance

The general fishery performance indicators for Cuttlefish were assessed for 2020 at the State-wide scale (Table 4-22). Two trigger reference points were activated in 2020 with the annual increases in total catch (from 1.1 t in 2019 to 23 t in 2020) and CPUE (from 3.4 kg.fisher-day^{-1} in 2019 to 65 kg.fisher-day^{-1} in 2020) representing the greatest % inter-annual changes in their respective time series' since 1984.

Table 4-22. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Cuttlefish in 2020.

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	×
	G	Greatest % interannual change (+/-)	✓
	G	Greatest 3 year trend	×
	G	Decrease over 5 consecutive years	×

Stock Status

There is a small, targeted fishery for Cuttlefish in South Australia, although it is primarily taken as by-product by fishers when Southern Calamari are targeted. This is reflected in the considerably higher numbers of fishers that take Cuttlefish each year compared to the number of fishers that actively target the species. Total catch of Cuttlefish declined sharply in the late 1990s, corresponding with the implementation of spatial and temporal closures to limit the take of the species (Steer 2015). During 2004–2019, total catch, total jig effort and jig CPUE were at historically low levels. In 2020, total catch and total jig CPUE both increased sharply to levels not reached since the early 2000s. These increases in catch and CPUE resulted in breaches of their respective trigger reference points for the greatest (%) interannual changes (+/-) and likely reflected improved access to the Cuttlefish resource in northern occurred where some previously closed areas were reopened to commercial cephalopod fishing in 2020.

Fishery independent surveys of Cuttlefish abundance in the Point Lowly closure area in NSG have been done annually since 2008 (Steer et al. 2013). Annual estimates of abundance were relatively high from 2015-2019 and then increased 116% from 2019 to 2020, to an unprecedented record high level (Heldt 2020). The abrupt increase in commercial fishery catch and CPUE and high fishery-independent estimates of relative abundance in NSG in 2020 suggests that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired and the current level of fishing mortality is unlikely to cause the stock to become recruitment overfished. On this basis, South Australia’s Cuttlefish fishery is currently classified as **sustainable**.

4.3.19. Black Bream

Biology

Black Bream (*Acanthopagrus butcheri*) occurs in estuaries and nearshore coastal waters across southern Australia from the Murchison River in Western Australia to Myall Lake in New South Wales, including Tasmania (Norriss et al. 2002, Gomon et al. 2008). It is a medium-bodied, slow-growing species that can reach 600 mm TL and live to 32 years of age. In South Australia, Black Bream mature at 289–340 mm TL (Ye et al. 2013).

Unlike most Sparids, Black Bream is an estuarine-dependent species, completing its life-cycle within a single estuary (Chaplin et al. 1998). Tagging studies in estuaries in South Australia (Hall 1984), Western Australia (Norriss et al. 2002) and Victoria (Butcher and Ling 1962, Hindell et al. 2008) found limited or no evidence of migration among estuaries. Spawning occurs in estuaries from August to January each year. This assessment of stock status is undertaken at the management unit level – the MSF.

Fishery

Black Bream are taken by 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. However, in most years during the past decade around 70% of annual State-wide commercial catches have been taken by the Lakes and Coorong Fishery, which is not considered in this report (Earl and Bailleul 2021).

Recreational fishers target the species using rod and line in coastal waters and estuaries (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 (Giri and Hall 2015). A total of 16,979 fish were retained and contributed to an estimated harvest weight of 4.97 t.

Management Regulations

Black Bream is a tertiary species of the 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 closures, restrictions to net lengths and mesh sizes, and a minimum legal size of 300 mm TL (PIRSA 2013, 2016a).

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 gear restrictions and a daily bag limit of 10 fish and boat limit of 30 fish. The minimum size limit of 300 mm TL also applies to the recreational sector. A spatial and temporal closure prohibits the take of Black

Bream from 1 September to 30 November in the area upstream of the Main South Road Bridge in the Onkaparinga River at Noarlunga.

Commercial Fishery Statistics

State-wide

Total annual commercial catch has been negligible in most years since 1984. Total catch peaked at ~3.8 t in 2007 and 2018 and has been < 1 t in most other years (Figure 4-48). The total catch of 0.38 t in 2019 was among the lowest recorded in the fishery. Catch, effort and CPUE data for Black Bream are confidential for several years during the last decade, including 2020, hence, substantially reducing the timeframe of this assessment. The economic value of the commercial catch of Black Bream during 2019 was \$6,900 (*c.f.* \$71 K in 2018) (Figure 4-48).

Estimates of total annual fishing effort for Black Bream have been highly variable since 1984 (Figure 4-48). Effort declined from 103 fisher-days in 1984 to 8 fisher-days in 1996, before increasing to an historic peak of 253 fisher-days in 2003. Since then, effort has ranged between 11 and 101 fisher-days, including 27 fisher-days in 2019.

Total CPUE was highly variable from 1984–2006 and ranged between 3–21 kg.fisher-day^{-1}. It increased to a peak of 47 kg.fisher-day^{-1} (Figure 4-48). In the past decade, for the reportable years CPUE has ranged between 13.8 and 38.1 kg.fisher-day^{-1} and was 14.26 kg.fisher-day^{-1} for 2019. The numbers of fishers who reported taking and targeting Black Bream were variable over time, suggesting the catch is largely by-product when other species are targeted (Figure 4-48).

Regional

Confidentiality constraints (<5 fisher rule) prevented an interrogation of the commercial catch and effort data at regional scales.

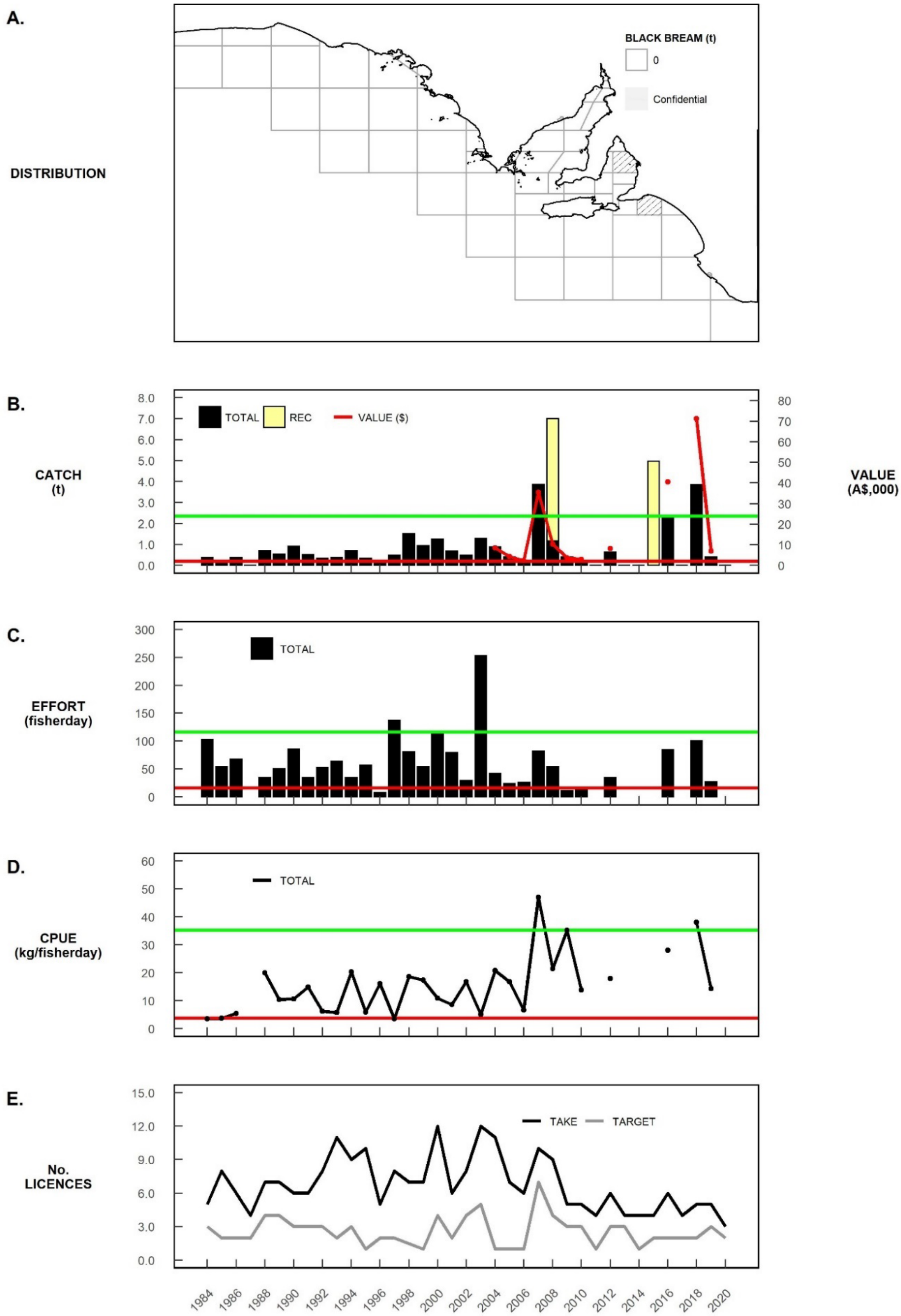

Figure 4-48. Black Bream. (A) The spatial distribution of catch by the commercial sector in 2020. Long-term trends in State-wide estimates of: (B) total catch for all gear types, the recreational sector for 2007/08 and 2013/14 and gross production value for MSF; (C) total effort; (D) catch per unit effort (CPUE); 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 4-23.

Fishery Performance

Confidentiality constraints prevented the assessment of 2020 catch and effort data against the performance indicators (Table 4-23).

Table 4-23. Results of the assessment of the general (G) fishery performance indicators against their trigger reference points at the State spatial scale for Black Bream in 2020.

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 and targeted effort for Black Bream was low from 1984 to 2006, which resulted in low CPUE. Between 2014 and 2018, catches increased slightly and estimates of CPUE were > 80% higher than the long-term average CPUE. In 2019, catches reduced by ~90% compared to the previous year. Catch and effort data for Black Bream in 2020 are confidential.

In South Australia, Black Bream is currently assessed at the management unit level where it is has been classified as 'depleted' for the Lakes and Coorong Fishery since 2014/15 (Earl et al. 2016b, Earl and Bailleul 2021). There is currently no evidence of population linkage between Black Bream taken by the MSF to those taken in Lakes and Coorong Fishery. Therefore, the two fisheries are assessed independently. The consistent long-term trend of minor total catches for the MSF indicates that the biomass of this stock is unlikely to be depleted, recruitment is unlikely to be impaired, and the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On this basis, the MSF for Black Bream stock is classified as **sustainable**.

5. DISCUSSION

This report assessed the fishery performance of 20 species/taxonomic groups taken in the MSF based on data available until the end of 2020. Collectively, these taxa were considered across 30 management units, at a resolution that aligned at the State-wide or regional level. Of these, 23 (~77%) stocks were classified as sustainable, two (~7%) were classified as depleted, two (~7%) were classified as recovering, and the remaining three (~10%) were 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 in the MSF over the last decade, which emphasises their collective importance to the regions and the State's economy. Previous stock assessments for King George Whiting (Steer et al. 2018a), Southern Garfish (Steer et al. 2018b) and Snapper (Drew et al. 2022) have identified different levels of concern regarding stock sustainability. The previous King George Whiting assessment classified all three stocks as sustainable based upon model outputs (Drew et al. 2021). This classification was maintained in the current assessment due to stable fishery performance. For Snapper, the SG/WC Stock and the GSV Stock were both determined to be depleted in the most recent stock assessment (Drew et al. 2022). This reflects a significant reduction in the spawning biomass, as well as declining catches and CPUE, and recent poor recruitment in both gulf stocks (Drew et al. 2022). In each case, the stock status classifications have supported the development and implementation of specific management arrangements to recover each stock. In this assessment, only the SE Regional population of Snapper (i.e., the western extremity of the cross-jurisdictional Western Victorian Stock) could be assessed as there were no catch and effort data available for 2020 from the SG/WCS and GSVS.

There have been concerns about the status of Southern Garfish in the northern regions of both gulfs for more than a decade (McGarvey et al. 2009). As a result, numerous management measures have been implemented since 2012, which included changes to LML, increases in the mesh size in hauling net pockets and seasonal fishery closures within each gulf. The short lifespan and rapid generation turnover of Southern Garfish increases the capacity of their populations to respond to effective management intervention. The impacts of these management changes implemented in the northern areas of both gulfs since 2009 are now evident and have led to recovering status assigned to both NSG and NGSV.

The NSG stock of Southern Garfish was first classified as recovering in the 2015 stock assessment (Steer et al. 2016) due to favourable trends in annual harvest fractions and the stabilisation of adult biomass. However, the population age structures remained truncated in

2020 when compared to those from the 1950s (Fowler and Ling 2010), despite increases in the proportion of age 3+ fish in the population in recent years. Hauling net fishers in NSG have recently commented that they are catching larger Southern Garfish and that stock health seems to have improved. A greater proportion of fish from the 4+ age class were present in 2020, lending some support to this anecdotal information. However, reports of larger fish being landed in 2021 could not be substantiated in the current assessment because the required catch sampling concluded in September 2020. The current harvest strategy for Southern Garfish in the Management Plan (PIRSA 2013) does not provide a pre-defined target reference point that determines when a recovering Southern Garfish stock is sustainable, and therefore lacks an index that explicitly defines stock status. However, if the age structure of the stock continues to rebuild, annual recruitment increases and recent trends in harvest fraction and adult biomass continue, then a 'sustainable' status could be considered.

The NGSV stock of Southern Garfish was classified as 'depleted' in the 2015 stock assessment (Steer et al. 2016) and this classification was retained in the 2017 stock assessment (Steer et al. 2018b). However, the 2017 assessment identified that harvest fractions were declining, and age structures were becoming less truncated. While this evidence was positive, it was not sufficient at the time to warrant a change in stock status. The results of the current assessment indicate that the NSGV stock is recovering, which is supported through increased adult biomass in recent years. The age structures have not had sustained improvement and are dominated by age 2+ fish in most years. Low levels of annual recruitment, truncated age structures and a low percentage of virgin egg production indicate this population remains depleted and recruitment impaired. However, extensive management arrangements imposed since 2012 have effectively reduced harvest fractions, increased adult biomass and as a result, hauling net CPUE and dab net CPUE have improved. Therefore, while the stock remains depleted, there is evidence of recovery following management intervention. Therefore, the NGSV Southern Garfish stock was classified as 'recovering' in this assessment.

A key source of uncertainty in the Southern Garfish stock assessment relates to the hypothesis that recruitment to the adult biomass in both gulfs is density dependent, which may explain why recent estimates are substantially lower than those of the 1990s. Essentially, the high harvest fractions of the 1990s were supported by commensurate increases in recruitment which readily replenished the stocks. While harvest fractions have declined significantly since the mid-2000s, model-estimated biomass for both gulfs have remained stable or have not increased at the expected rate. Instead, recruitment in both gulfs has decreased, and it cannot yet be determined if this is due to recruitment impairment or density-dependent processes. Consideration of this hypothesis will be ongoing and potential research projects to evaluate it will be pursued. However, as of this assessment, the hypothesis of density-dependent responses in Southern Garfish recruitment must remain academic. Instead focus should be placed on developing appropriate TRPs as part of upcoming harvest strategy development.

Southern Calamari has recently become the most profitable species in the commercial MSF and has the highest GVP ($5.7 M in 2019/20) in the fishery (EconSearch 2021). This has occurred through the relatively low costs of squid jig fishing and continually increasing market prices. Southern Calamari is a highly productive species with a short life span (< 1 year), allowing it to sustain higher harvest fractions than most other MSF species. However, a 7-year decline in CPUE was previously documented in the SSG region, indicating that regional depletion may be occurring (Drew et al. 2021). Concerns regarding localised declines in productivity have also been raised by industry, who reported that Southern Calamari have become increasingly difficult to catch in areas that were previously highly productive. Anecdotally, there is currently a lack of eggs in known spawning areas and there has been a notable absence of large animals in fisher catches. However, targeted squid jig CPUE in SSG increased substantially in 2020, arresting the 7-year decline. This suggests that some stock recovery may have occurred in this region, possibly through a period of stronger recruitment. However, the reliance of the Southern Calamari assessment on commercial fishery data is problematic for several reasons: (1) the spatial coverage of the Southern Calamari fishery can only be examined at the MFA level which may be too broad to detect regional or more localised depletion; (2) a potentially weak correlation between abundance and CPUE prevents the effects of fishing on the population from being determined; and (3) the impact of recreational fishing on Southern Calamari stocks has not been regularly determined but may be a substantial source of fishing mortality. From the information available in this assessment, Southern Calamari at the State-wide level have been classified as 'sustainable'. However, the importance of this species to MSF warrants future research to determine an appropriate stock assessment program that befits the fishery's highest value species.

The multi-species and multi-method nature of the MSF can be considered a strength of this 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 and there has been a resurgence in catches of Ocean Jackets over the past five years. For some species, increases in effort have 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 'lesser-known' (or '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 recent study of 'lesser-known' species (FRDC 2017-023) identified 13 taxa currently within the MSF that could support increased exploitation, the scale of increased harvest is dependent on the individual species life history and varied on scales of tens to hundreds of tonnes (Fowler et al. 2020a).

The MSF reform in 2021 comprised three pillars to enhance sustainability and profitability: (1) Regionalisation, where four management zones enable the MSF to be assessed and managed at local levels, rather than at the State level; (2) Unitisation, where Tier 1 stocks will be managed using output controls to increase fishery sustainability and maximise production; and (3) Rationalisation, where a voluntary licence surrender program reduced the number of operators in the fishery, with the aim of increasing the economic returns of those who remain. The reform was informed by work undertaken as part of a recent research project (FRDC 2017-014) that disentangled the complexity of this multi-sector, multi-species and multi-gear fishery.

New management arrangements of the MSF reform came into effect in July 2021 and will be described in the next MSF assessment report. These will have implications for future assessments and will be considered when developing harvest strategies for priority species. For example, several current PIs for MSF species are based on catch and effort statistics with the entire time series of the fishery as a reference period. This has proven to be problematic for some species, including Blue Crab where total catch has substantially reduced since the creation of the Blue Crab Fishery in 1996. As a result, the remaining Blue Crab fishing in the MSF is unlikely to ever trigger the upper TRP which is set from these high catches. Following the reform, TRPs based on catch will also be ineffective for Tier 1 stocks as TACCs will be applied, effectively capping the catches at a prescribed level. Therefore, the ability to exceed the three highest or lowest years on record is no longer of relevance for these stocks. Similarly, 100 licences have been removed from the fishery which will reduce effort across the fishery. This will cause several species to breach the TRPs related to effort as a reduction in fleet size means that a comparison to pre-reform effort levels provides little useful information. Fortunately, research supporting the reform has identified that the CPUE time-series for most Tier 1 stocks will not be substantially affected by changing fleet size (Smart et al. 2022). This has occurred as many of the surrendered licences contributed very little fishing effort for the Tier 1 species and did not diverge from the fleetwide average CPUE for many species. Therefore, CPUE will likely provide useful TRPs for most species in the years immediately following the reform.

A tiered management framework (TMF) was designed as part of the MSF reform research project (Smart et al. 2022) which assigned each species to a tier of management in each of the four fishing zones. Tier 1 stocks will be managed via a TACC that may be further unitised into ITQs, Tier 2 stocks will be assessed according to a recommended biological catch (RBC) that demonstrates fishing levels are within sustainable limits, and Tier 3 stocks will be assessed using fishery statistics in a similar manner to what was done in this report. Each stock was assigned to a tier based on six diverse indicators that include stock status, commercial importance, recreational importance, Aboriginal/Traditional importance, level of targeting, and management need. The final recommendation of which Tier each species in a zone should be assigned to will be provided by the MSFMAC.

Currently, MSF species are categorised as Primary, Secondary or Tertiary species in the Management Plan (PIRSA 2013). However, this Management Plan is due to be updated and it is possible that these categories will be replaced with the classifications from the TMF. Therefore, the structure of this report may need to be adjusted to match the specifications of the new management plan.

5.1. Challenges and Uncertainties in the Assessment

Determining stock status through the weight-of-evidence approach for 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 for which fewer data are available and there are limited resources for developing more sophisticated fishery-independent assessment programs. But for such species considered in this report, the primary measure of population abundance is CPUE from the dominant gear type and reliance solely on these data can be problematic. Catch per unit effort standardisation may help improve the usefulness of CPUE as an index of relative abundance, including by accounting for differences in the relative contributions of targeted and non-targeted catches to the total catch. Improving the reliability of CPUE as an indicator of biomass would improve the confidence in assessments of stock status.

One significant gap in our knowledge for assessing the status of the stocks that support the MSF is determining the relative contribution of the State-wide catch of the recreational fishing sector. This sector's total harvest has traditionally been determined through infrequent 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 have been infrequent and typically imprecise. This imprecision has key implications for the assessments of King George Whiting, for which recreational contribution to overall State-wide catch has been significant. Improving the precision of the estimates of the recreational catches, either through more frequent surveys or increased participation rates, will improve assessments of stock status. Challenges around the collection of recreational fishing data were highlighted at a workshop in 2018 (Beckmann et al. 2019). Alternative survey methods such as app-based data collection are currently being investigated as part of the 2021/22 Recreational Fishing Survey and its associated research project (FRDC 2020-056).

In recent years, it has become increasingly evident that the fishing behaviour 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 and management arrangements for Snapper reduced the reliability of CPUE as a suitable index of biomass. Therefore, an alternate fishery-independent indicator, the DEPM, was developed to underpin the Snapper stock assessments (Steer et al. 2017, Fowler et al. 2019). Similarly, the issue of advancing fishing technologies and improved efficiency was identified as a key concern for offshore populations of King George Whiting (Drew et al. 2021).

The current effort unit applied to all MSF species is ‘fisher-day’ which is the number of boat days (i.e., fishing events) multiplied by the number of fishers. Fisher-day is an appropriate unit for gauging fishery performance in terms of overall activity and the profitability of each fishing event. It also provides a consistent unit between gears and stocks that facilitates comparability. However, it is likely that fisher-days from different fishing events differ to one another such that a unit of effort is not equivalent. For example, fisher-days could differ in length (i.e., number of hours) or in the amount of gear used, neither of which are captured by these units of effort. Since daily logbooks commenced in 2003, effort units and gear units have also been reported. While using these data may be ideal, they are complicated to include as these logbook fields are subject to erroneous or inaccurate reporting at different rates across the fishery. Therefore, a substantial data cleaning exercise must be undertaken to determine suitability of the new effort units for a given stock and gear. Nevertheless, these gear specific effort units provide an opportunity to refine the effort units used to describe the fishing activity and CPUE for a stock. For example, targeted haul net CPUE for Southern Garfish was calculated in this assessment using both fisher-days and number of hauls. This was feasible as preliminary analyses identified that very little data cleaning was required and these gear units could be readily incorporated into assessments. However, these preliminary analyses also identified other gear types such as lift nets and handlines require substantial data cleaning and could not be included in this assessment. Consideration of these data and how they could be included in assessments will be an ongoing exercise to provide the best information possible for supporting stock assessments.

Another challenge is the complication of having a multi-species complex in three of the stocks assessed in this report. Currently, there are uncertainties and limited data around the proportion of species in the catches of Whaler shark, Rays and Skates, and Leatherjackets. As a result of these uncertainties and limited data, these stocks have been assessed as undefined. A greater level of detail in species identification is required to be able to untangle the relative stock composition, and this will be potentially resolved as the MSF catch reporting moves to an electronic reporting system. Currently, the stocks which have been assessed as undefined as a result of the unknown species composition are predominately one main species in each stock (i.e., Southern Eagle Ray in Rays and Skates). Improving species identification in catch reporting will allow us to potentially remove these species from the multi-species complex and assess them individually or appropriately weight the fishery statistics to the known contribution of each species in a stock. This may become a priority for Whaler Sharks which have been assigned a Tier 2 status in several fishing zones following the MSF reform (Smart et al. 2022). Therefore, research may be required to separate these species as part of an ongoing assessment program.

Perhaps the greatest challenge for continued assessments of the MSF is growing research need following the fishery's recent reform. The current GVP of the fishery in 2019/20 was $19.9 M and has decreased by 17% since 2016/17 (*c.f.* $23.9 M) (EconSearch 2021). As the fishery requires regular assessment of 20 species across 30 management units (which will increase due to the fishery's reform), it is likely that the research needs of the fishery will grow at a rapid pace. Therefore, the cost effectiveness of ongoing assessments must be a primary consideration when developing the science program for the reformed fishery. The MSF is a community resource and there is a need to consider not only biological sustainability, but also the economic and regional benefits to the community which includes commercial fishers, recreational fishers, Aboriginal traditional fishers and the wider seafood consuming public. Costs of the research program for recreational fishing are contributed by Government on behalf of the recreational sector and additional funds are sourced from recreational Rock Lobster pot licences and recreational net licences (PIRSA 2020). Research projects are occasionally developed to improve or review knowledge of recreational species, and recreational fishing surveys are generally conducted at five-year intervals to estimate state-wide participation, catch and effort. However, the infrequent consideration of the community use of the stocks underpinning the MSF is problematic. Several previous reports have highlighted that insufficient recreational data is a key source of uncertainty for several MSF stock assessments (Steer et al. 2018a, Steer et al. 2018b, Steer et al. 2020, Drew et al. 2021). These data limitations are likely to persist as there is no existing database that can be used to target recreational fishers using a probability-based off-site survey and general population surveys are required to generate State-wide estimates of catch and effort with varying levels of precision.

5.2. Research Priorities

Following the MSF reform, 11 stocks of King George Whiting, Snapper, Southern Garfish and Southern Calamari, have been assigned a Tier 1 status and require a TACC. The current assessment programs for King George Whiting, Snapper, and Southern Garfish are appropriate for providing these TACC recommendations and can form the foundation of upcoming harvest strategy development, if required. However, no such assessment program exists for Southern Calamari which is only assessed through fishery dependent information. Therefore, the current assessment program does not match the importance of this species to the fishery and cannot provide sufficient management advice for setting TACCs. A priority of MSF research must now include the development of such an assessment program which will provide appropriate advice for TACC setting. Cephalopods such as Southern Calamari have well known assessment difficulties as most species have biological characteristics and life histories that are markedly different from fish or crustaceans, for which standard fisheries modelling techniques have been developed. Therefore, many cephalopod fisheries have struggled to develop appropriate assessments (Arkhipkin et al. 2021). As Southern Calamari are short-lived and highly productive, it was thought that their populations were resilient to fishing. However, this has recently been challenged as the Tasmanian stock is currently classified as 'depleting' (Fraser et al. 2021), and fishers have expressed concerns about stock health in SA. This suggests that Southern Calamari may not be as tolerant to high levels of fishing as previously thought and that methods to assess their population status need development. Furthermore, cephalopod population dynamics are influenced by prevailing environmental conditions, obfuscating the impact of fishing, and causing management complications. Therefore, there are numerous assessment difficulties that must be overcome in order to provide a science program that can support this fishery.

While Tier 1 stocks will be managed via TACCs, Tier 2 stocks will require recommended biological catches (RBCs) to inform appropriate management. Currently, only the primary finfish species in the MSF have sufficient assessments to determine RBCs, although data-limited approaches such as catch MSY models (Martell and Froese 2013) have been previously applied to some stocks (Fowler et al. 2020a, Smart et al. 2022). Additional stock assessment approaches may need to be considered to support management of Tier 2 stocks. A current FRDC project "Fisheries biology of Western Australian Salmon: improving our understanding of population dynamics in South Australia to enable quantitative stock assessments and improved fisheries management" (FRDC 2018-035) will provide further information for Western Australian Salmon that could be used in a Tier 2 assessment for this species. However, remaining stocks assigned to Tier 2 may not have the same level of information available. Recently, there has been a proliferation of data-limited approaches that could be applied to various populations, which have limited available data in comparison to the primary finfish species in the MSF. A recent database has been established of available ‘off the shelf’ stock assessment packages that could be used for stocks with varying degrees of data availabilities (http://toolbox.frdc.com.au/; Dichmont et al. 2021). This database of available stock assessment packages could be used to determine potential candidate models that may be applied for different stocks as the need arises. Potential models could include surplus production models which do not require data on population structure (Haddon 2001) or Bayesian models, where auxiliary information can be provided as ‘priors’ to help inform the models (Winker et al. 2018). The application of data-limited models may also be improved by the successful implementation of CPUE standardisation and use of gear specific effort units, which would provide more appropriate indices of abundance.

Lastly, a better understanding of the importance of MSF fish stocks to Aboriginal/Traditional fishers and communities is required. The recent development of the TMF highlighted the paucity of information on Aboriginal/Traditional fishing that is available. Subsequently, it was not possible to appropriately determine which stocks would be of most importance to different Aboriginal/Traditional fishers and communities as a part of this framework. This has highlighted that a greater research focus is required to better understand the significance of the MSF to the Aboriginal/Traditional sector and to incorporate this in decision making. Although Aboriginal/Traditional fishers are defined as one sector under the Fisheries Management Act 2007, they encapsulate multiple groups with different languages, values, and cultures. The value to Indigenous peoples of Sea Country’s marine, intertidal and estuarine resources is more than just for subsistence; it has value both culturally or spiritually, and includes all living things, beliefs, values, creation spirits and cultural obligations connected to that area. Recognising which stocks are most important to Aboriginal/Traditional fishers and their communities is therefore important and needs to be determined.

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7. APPENDICES

7.1. Appendix 1. Annual commercial catches (in tonnes) of assessed species and taken in the Marine Scalefish Fishery between 1984 and 2020.

	Primary				Secondary									Tertiary						Other	
	Garfish	KGW	Snapper	Calamari	Yellowfin Whiting	Aust. Salmon	Aust. Herring	Snook	Blue Crab	Sand Crab	Yelloweye Mullet	Mulloway	Whaler Sharks	Ocean Jacket	Wrasse spp.	Silver Trevally	Leather-jackets	Black Bream	Rays & Skates	Cuttlefish
1984	441.9	636.0	451.1	183.9	104.5	400.2	364.2	110.9	114.7	22.8	96.0	14.8	30.1		2.9	3.0	x	0.4	8.2	0.3
1985	438.4	597.0	457.9	196.2	61.4	659.6	231.2	75.6	126.1	30.4	100.5	14.7	27.0		2.6	2.1	x	0.2	14.9	0.1
1986	449.1	693.2	426.9	201.7	41.7	541.7	409.2	72.5	170.1	25.0	129.4	9.8	40.2		2.3	3.3	x	0.4	18.4	0.3
1987	382.4	602.1	364.3	168.2	23.8	650.6	493.8	70.8	165.6	28.0	147.0	14.2	54.8		3.0	4.3	x	x	42.3	0.2
1988	391.0	586.6	409.7	281.3	14.5	524.9	427.7	85.5	209.4	40.5	126.3	8.1	70.0		3.4	4.2	x	0.7	51.9	2.3
1989	513.7	638.0	423.3	231.6	26.9	573.3	396.2	116.4	323.6	136.5	133.3	9.0	62.8	429.4	2.5	3.0	c	0.5	40.8	3.5
1990	527.7	683.8	453.1	212.1	40.8	313.6	296.0	94.8	390.5	151.9	174.7	13.4	76.6	930.0	1.9	4.6	68.9	0.9	42.0	2.0
1991	422.5	678.0	419.5	348.5	39.9	486.5	342.8	102.3	434.6	135.2	154.8	7.6	76.9	977.3	1.6	7.4	63.7	0.5	50.1	2.1
1992	492.8	776.3	383.1	268.3	44.4	607.2	362.1	114.7	429.1	81.6	131.8	11.6	67.7	916.8	5.0	16.6	51.6	0.3	69.6	2.1
1993	531.5	668.8	358.2	312.9	107.4	658.7	321.2	120.5	566.3	65.9	128.6	10.9	71.6	766.3	4.4	14.6	47.3	0.4	64.4	3.3
1994	469.0	635.0	242.1	352.5	73.3	500.1	299.9	132.6	484.3	40.1	102.5	17.9	92.4	575.3	6.1	7.9	52.9	0.7	61.8	12.3
1995	401.9	565.0	260.2	355.2	110.3	638.0	231.5	147.3	692.9	53.0	102.1	24.2	93.6	477.0	7.8	7.8	33.9	0.3	49.5	39.8
1996	503.9	579.1	310.2	374.5	95.4	500.9	212.9	131.8	559.6	66.5	66.0	12.7	70.7	441.7	6.7	7.8	42.8	0.1	46.9	82.5
1997	546.4	570.6	362.4	390.7	107.0	653.5	219.1	110.1	320.9	125.9	107.3	11.4	102.2	433.0	23.9	9.1	42.5	0.5	50.3	262.0
1998	447.2	562.3	396.7	433.2	51.2	572.7	353.1	108.3	74.3	119.5	92.2	6.5	96.1	359.6	24.7	4.1	39.4	1.5	47.4	150.1
1999	452.2	602.1	572.0	400.4	113.7	584.7	298.3	105.4	123.9	132.1	67.8	6.6	82.8	284.1	24.1	8.4	43.7	0.9	49.0	16.3
2000	517.4	440.7	570.0	419.3	109.3	542.1	250.7	94.9	78.5	175.7	71.3	7.1	79.7	269.2	21.9	21.0	38.4	1.3	54.0	15.0
2001	522.8	449.1	661.4	455.6	178.9	576.4	250.9	113.9	92.9	131.7	71.6	6.2	93.9	352.1	21.9	7.1	48.1	0.7	54.2	23.3
2002	419.9	370.7	545.0	323.3	152.9	279.7	252.9	108.4	66.7	104.7	50.8	2.7	96.9	308.0	23.7	2.5	20.2	0.5	49.4	23.8
2003	295.7	381.8	412.0	314.5	167.7	496.3	149.4	90.4	66.2	104.9	47.7	7.8	119.1	391.5	28.8	5.1	17.1	1.3	47.6	8.9
2004	327.3	345.7	449.8	468.8	162.9	213.8	178.8	85.6	51.9	84.9	43.4	2.6	113.2	322.7	22.9	6.3	29.5	0.9	36.1	7.1
2005	390.8	348.0	529.2	357.9	120.5	173.5	165.5	69.0	47.8	177.0	48.5	6.1	94.8	299.5	19.9	6.8	26.1	0.4	32.2	7.9
2006	350.0	347.9	613.5	299.3	126.1	262.5	93.2	58.1	47.6	105.5	41.6	5.9	76.5	69.2	15.5	10.8	14.0	0.2	24.5	8.0
2007	264.5	350.3	743.8	295.9	78.8	126.3	112.6	82.0	41.8	70.2	30.5	7.2	82.4	57.7	13.4	8.1	13.3	3.9	20.3	10.5
2008	277.1	313.3	719.7	279.1	85.7	126.7	130.0	72.1	51.0	98.5	30.5	3.3	87.9	x	21.7	8.4	16.8	1.2	21.0	6.0
2009	316.7	358.5	818.5	331.0	114.7	136.1	176.7	64.3	60.4	72.7	25.6	3.7	109.5	x	20.0	5.6	19.2	0.4	22.7	4.5
2010	254.9	326.7	1031.5	347.9	114.4	163.5	147.1	64.9	54.2	65.7	23.4	2.0	121.1	x	19.5	15.3	14.0	0.2	18.3	9.1
2011	291.7	328.2	941.9	415.4	87.5	204.0	86.4	46.8	53.6	93.2	31.8	3.3	92.6	x	23.5	10.0	12.1	x	18.3	5.2
2012	238.9	310.9	642.2	429.4	119.0	98.0	109.7	49.2	56.6	79.0	27.9	4.5	90.0	138.6	16.7	10.1	13.2	0.6	18.3	3.8
2013	250.4	292.5	518.8	399.0	152.0	59.4	172.1	41.9	62.5	65.0	18.9	2.8	57.2	50.2	17.3	9.0	14.2	x	12.4	3.1
2014	264.0	280.6	533.0	402.5	96.2	220.1	114.5	40.3	60.9	46.9	16.0	1.3	58.3	x	15.2	11.3	10.5	x	15.7	2.2
2015	163.3	288.5	512.4	370.3	101.0	349.5	104.3	46.7	45.0	63.2	16.1	1.3	54.8	x	17.2	8.5	15.0	x	15.4	1.5
2016	155.2	287.3	386.8	398.8	114.6	370.1	93.5	53.5	31.2	48.4	12.5	1.1	50.4	224.2	13.6	7.9	34.1	2.4	9.6	1.3
2017	183.5	244.8	339.7	412.9	141.6	374.1	61.2	38.9	51.7	44.7	22.1	5.6	62.5	151.2	13.6	10.6	27.0	x	13.1	0.9
2018	176.2	250.2	281.3	371.1	140.2	156.3	104.5	43.2	35.6	44.2	19.7	9.0	45.1	94.8	7.9	4.6	29.5	3.8	10.2	1.3
2019	190.2	227.1	251.8	327.0	140.2	228.7	99.8	40.5	53.4	58.8	13.9	5.2	62.7	x	7.3	6.9	16.9	0.4	11.8	1.1
2020	172.4	202.1	58	374.5	95.8	75	83.1	33.1	54.5	49.5	9.8	2.7	52.1	x	5	12	7.6	x	10.2	23

7.2. Appendix 2. Annual commercial catches (t) of remaining permitted species and species groups taken in the Marine Scalefish Fishery between 1984 and 2020. The 'Other Shark' category contains all reported shark species except Whaler Sharks, Gummy Sharks and School Sharks. These species were not considered in detail in this report. Crosses indicate confidential data (<5 fishers).

	Annelids	Pipi	Mussel	Octopus	Oyster	Scallop	Gould's squid	Anchovy	Barra-couta	Cod	Dories	Flathead	Flounder	Goatfish	YT Kingfish	Pink Ling	Blue Mack.	Jack Mack.	Morwong	Other Mullet	Bight Redfish	Sweep	Swallow-tail	Blueeye Trevalla	School Whiting	Gummy Shark	School Shark	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	10.5	x	5.1	3.5	x	3.2	x	651.1	881.3	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	13.0	x	8.9	3.1	x	3.6	x	647.1	999.7	25.8
1986	15.2	x	x	x	x	x	x	x	7.6	x	x	3.4	1.2	3.7	x	0.1	x	3.0	19.3	x	16.3	1.7	x	24.6	x	699.9	1130.1	27.7
1987	11.1	x	x	1.4	x	x	x	x	5.8	x	x	3.3	0.5	3.3	x	1.1	3.7	x	23.6	x	13.8	1.8	x	153.4	x	835.0	1259.7	80.7
1988	11.2	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	21.2	x	14.7	2.7	x	81.8	x	930.4	1237.7	83.6
1989	13.5	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	26.4	x	22.0	9.6	0.2	54.9	x	1074.8	1212.5	72.5
1990	15.7	x	x	3.9	x	x	x	x	12.9	x	x	5.6	x	6.3	x	0.2	0.6	x	26.8	x	15.6	10.5	0.3	84.3	0.1	889.7	1003.1	73.5
1991	15.6	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	20.1	x	9.4	7.0	0.4	70.6	x	707.1	799.1	102.8
1992	16.8	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	16.1	x	10.4	3.2	0.3	49.0	x	662.1	572.3	259.3
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	13.5	x	13.5	4.8	0.4	54.5	0.1	686.3	674.0	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	732.0	617.3	132.1
1995	13.7	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	598.1	624.1	108.4
1996	14.0	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	29.6	x	11.9	5.9	0.4	6.6	0.1	821.1	660.3	135.4
1997	11.5	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	470.7	258.7	75.1
1998	11.2	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	223.9	74.3	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	243.8	48.8	54.9
2000	14.3	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	194.9	22.5	56.0
2001	10.8	338.7	x	x	x	x	x	x	x	x	x	2.1	x	4.8	x	x	0.5	x	0.5	x	1.6	1.8	x	x	x	49.1	3.8	75.6
2002	8.2	273.5	x	5.5	x	x	x	x	2.0	x	x	2.1	x	3.6	0.2	x	5.2	x	1.5	x	3.6	2.0	x	x	x	38.6	4.6	46.8
2003	7.0	x	x	5.1	x	x	x	x	2.4	0.0	x	2.2	x	3.4	0.4	x	1.5	x	2.5	x	3.4	2.0	x	x	0.1	45.4	5.9	36.2
2004	7.2	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	54.0	3.8	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	52.9	3.3	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	2.6	x	2.0	x	3.9	1.4	0.0	x	x	58.6	4.3	25.3
2007	6.6	x	x	18.9	x	x	x	x	x	x	x	2.1	x	5.7	x	x	3.7	x	2.3	x	4.6	0.8	0.1	x	x	84.4	8.1	19.8
2008	7.6	x	x	23.3	x	x	x	x	x	x	x	2.4	x	4.5	0.5	x	4.1	x	1.8	x	3.3	1.2	0.1	x	0.1	106.6	9.9	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	2.2	x	2.6	2.4	6.8	2.5	0.4	x	x	148.5	13.8	16.4
2010	5.8	x	x	x	x	x	x	x	x	x	x	4.2	x	4.3	0.3	x	2.6	x	3.4	0.2	8.9	2.2	0.5	x	x	149.8	10.5	19.4
2011	5.9	x	x	14.6	x	x	x	x	x	x	x	5.7	x	3.3	x	x	1.5	x	2.9	x	14.2	3.1	0.2	x	x	144.2	16.4	23.0
2012	6.5	x	x	x	x	x	x	x	x	x	x	2.6	x	2.9	0.2	x	1.8	x	1.2	x	10.7	3.1	0.3	x	x	161.0	15.2	12.9
2013	5.4	x	x	7.6	x	x	x	x	x	x	x	1.6	x	5.2	x	x	1.6	x	1.0	x	10.0	2.4	0.2	x	0.0	103.7	12.0	8.4
2014	5.0	x	x	11.4	x	x	x	x	x	x	x	2.0	x	4.3	2.8	x	2.4	x	0.6	x	8.3	2.0	0.1	x	0.2	88.6	14.7	7.5
2015	5.2	x	x	10.6	x	x	x	x	x	x	x	2.0	x	3.5	1.3	x	2.6	x	0.9	x	12.6	1.1	0.1	x	x	85.7	17.2	7.1
2016	4.3	x	x	x	x	x	x	x	x	x	x	0.8	x	3.5	2.0	x	2.8	x	0.9	x	12.2	0.9	0.1	x	x	76.8	17.7	4.4
2017	4.7	x	x	14.4	x	x	x	x	x	x	x	1.1	x	3.3	2.1	x	4.4	x	1.2	x	19.8	0.7	0.2	x	x	74.5	17.9	6.4
2018	3.8	x	x	x	x	x	x	x	x	x	x	1.1	x	4.0	1.9	x	3.8	x	1.1	3.1	20.7	1.6	0.2	x	x	74.4	20.5	4.1
2019	2.9	x	x	x	x	x	x	x	x	x	x	1.0	x	3.4	4.2	x	3.7	x	1.3	x	19.2	0.9	0.2	x	x	84.2	24.8	20.3
2020	3.7	x	x	14.2	x	x	x	x	x	x	x	1.1	0.1	3.1	4.9	x	5.7	x	0.8	1.8	24.9	0.8	x	x	x	42.4	12.4	7.3

7.3. Appendix 3: Effort Standardisation

There are two stages of effort standardisation, which we detail in this Appendix. The first stage applies the conventional method of a GLM using data fields available from daily catch and effort returns. This GLM is run only for the first model effort type. The second stage is integrated within the overall GarEst model fit, wherein a separate catchability parameter is estimated for every combination of the three commercial effort types, summer and winter half-years, and the two gulfs, and where a second multiplicative array of catchabilities are estimated by half-year and Garfish sex.

7.3.1. Stage 1 standardisation: GLM for target-plus-50% hauling net effort type

In previous assessments, 2012 and earlier, effort data were not standardised. Two changes in the fishery have increased the usefulness 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. To account for the removal of those licences, a GLM-based standardisation procedure where the effect of individual licences is explicit has been implemented since 2015. This year (2021), the procedure for effort data standardisation has been updated.

As GarEst is an effort-conditioned model, a standardised effort time series (rather than a standardised CPUE time series) is required. The method (Maunder and Punt 2004) was to estimate a quarterly 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 primary effort type, target-plus-50% hauling net (EType=1).

The procedure followed to generate a quarterly time series of standardised target-plus-50% hauling net effort, separately for each gulf, is as follows:

1. For EType=1, include all hauling net records from logbooks (reported monthly or daily) 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 CPUE records. The model predicts the CPUE for each record as

$$CPUE \sim 0 + QuarterYear + ModelMonth + LicenceNo\_and\_Master + MFABlock$$

with a Gamma residual error structure and an inverse (canonical) link function. The "0" indicates that no overall intercept was estimated. All four data covariates are treated as factors, meaning a real intercept is estimated for each level of each factor. The standardised CPUE value taken for use in the assessment is the back-transformed *QuarterYear* intercept for each region and quarterly model time step across all years back to the start of data in 1983.

The above model differs from the previous assessment (2018) in two key ways. First, the term QuarterYear replaces what was previously HalfYear, since the model now uses quarterly time steps. Secondly, the input factor of *LicenceNo_and_Master* replaces what was previously LicenceNo. The term *LicenceNo_and_Master* is a variable that designates a separate level for every combination of licence number and registered master, thus accounting for variation in both licence number and registered master. Master is the skipper of the vessel fishing under each licence as recorded in the PIRSA licencing (PIMS) database. Because data on registered master is only available since PIMS started in 2008; for data points before 2008, this variable is equivalent to LicenceNo.

Four different alternatives to *LicenceNo_and_Master* as a single factor variable were also tried. These include: (1) using only LicenceNo, as in previous GarEst assessments; (2) using a variable that corresponds to LicenceNo up to 2007, and only Master thereafter; (3) using two variables, one of which corresponds to LicenceNo and one of which corresponds to Master; and (4) not standardising effort (i.e., using nominal effort). The standardisation method that was used (*LicenceNo_and_Master*) was selected based on the fact that the total catch fits of Spencer Gulf for all effort types were reasonably improved, relative to the four alternative standardisation methods, without reducing fits to other data inputs.

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

7.3.2. Stage 2 standardisation: Separate catchability estimates by effort type, summer or winter, gulf, and sex

A second stage of standardisation is expressed in the wide array of catchability parameters estimated as part of the overall GarEst model fit. A separate catchability is estimated for each combination of the three commercial effort types (ETypes 1-3, target-plus-50% hauling net, other hauling net, and dab net), each half-year (Oct-Mar, Apr-Sep), and each gulf. Catchability is the coefficient that relates data-reported fishing effort to model-estimated fishing mortality for every combination of effort type, season and region. In this role, these catchability parameters reflect the relative fishing power of each unit of effort (Eq. 7.1) since they determine the catch of Garfish, given each respective level of Garfish abundance, and the reported fishing effort.

The implementation of this highly detailed catchability array permits GarEst to use all the available data in estimating catchability. For the main EType = 1, this supplements the daily logbook variations of CPUE used in a standard GLM of stage 1 above. For the other two commercial effort types, this provides a form of standardisation that uses all the available data informing the assessment. In addition, the model estimates a biological variation in catchability by Garfish sex and summer/winter (Eq. 7.4).

The estimated annual levels of fishing mortality *F* by effort type and gulf are shown in Figure 7-1. These are denoted maximum *F* ($q(r,\ t_{season},\ x,\ i_E)\ \cdot\tilde{E}(t,r,i_E)$ in Eq. 7.1) because they are multiplied by a logistic length selectivity ogive which scales from 0 to 1 to give the length-specific fishing mortality in each model slice. These same fishing mortality estimates are plotted along with effort in Figure 7-2 to show that they vary closely with reported fishing effort, as assumed in the Baranov-mortality effort-conditioned GarEst model.

From these figures, we see that two effort types, namely other hauling nets and dab nets were primarily responsible for the overall decline in harvest fraction in both gulfs shown in Figures 3-17 and 3-18. In addition, recreational fishing mortality also declined substantially in GSV/KI. By the levels of *F* plotted for these effort types prior to around 2000, we see that these contributed substantial fishing mortality in those early years, each with estimated values of *F* around 0.4, substantially less for dab nets and recreational in SG.

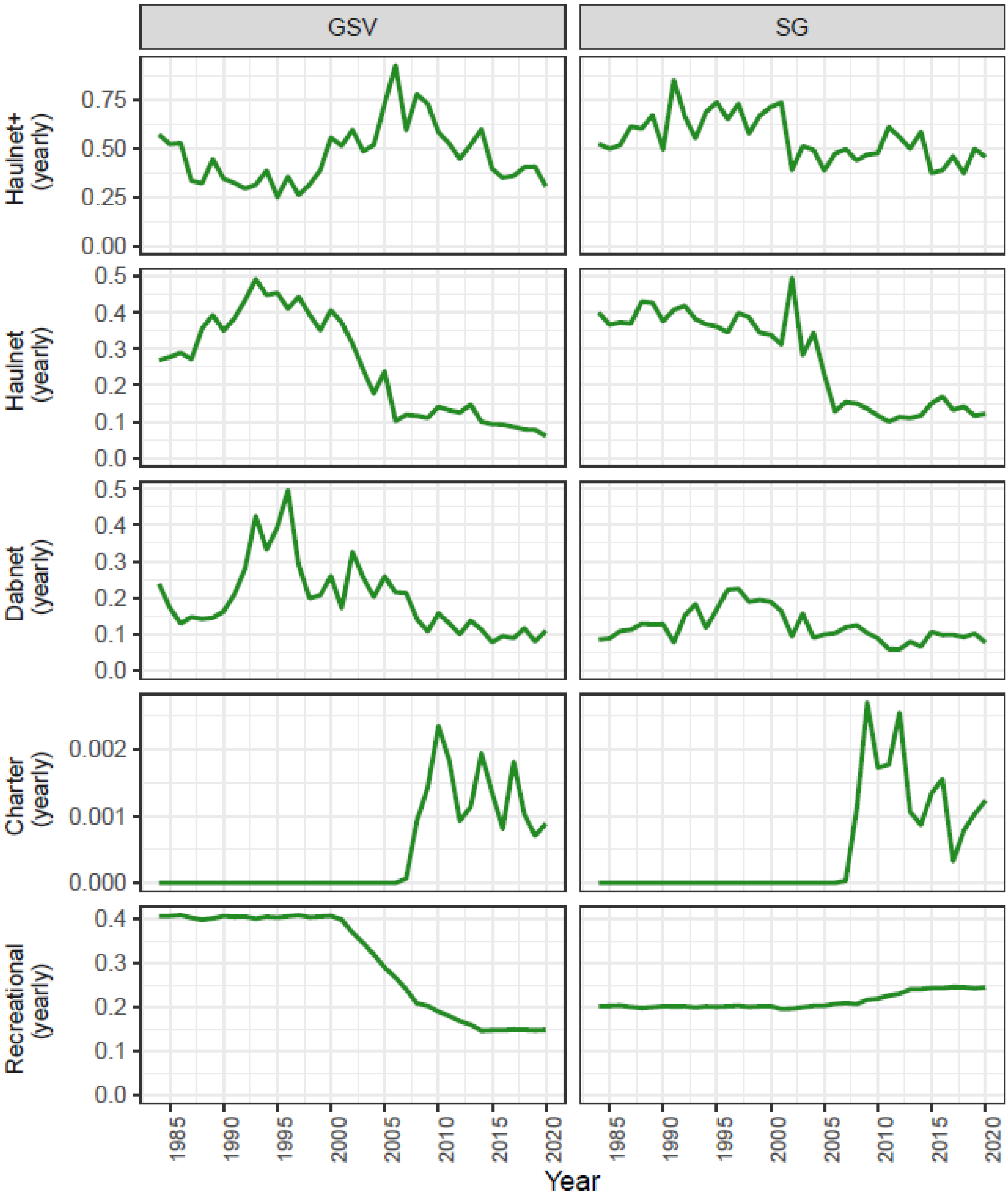

Figure 7-1. GarEst estimates of annual average maximum fishing mortality (*F*) by effort type for Gulf St Vincent and Spencer Gulf.

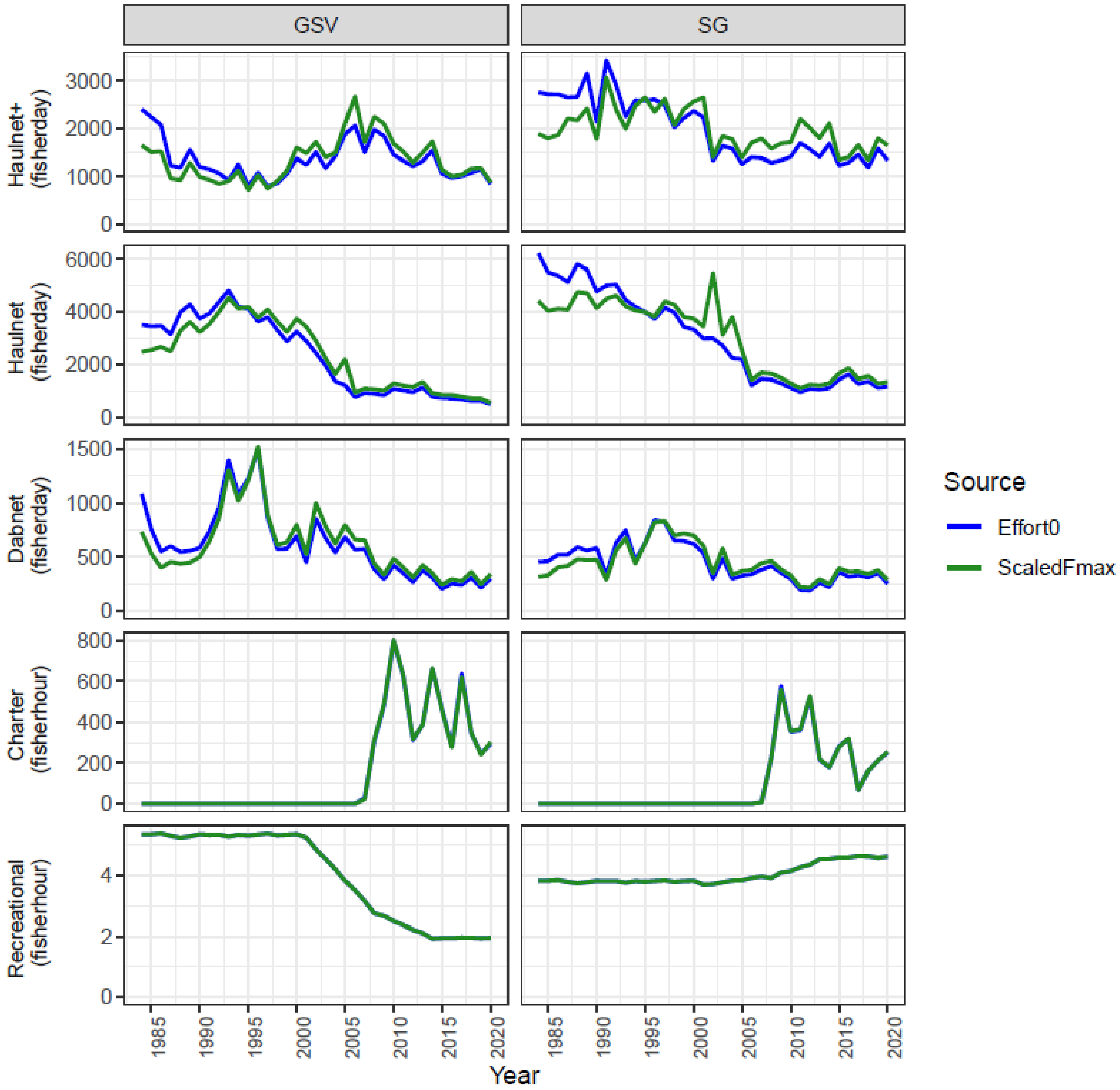

Figure 7-2. Annual effort data by effort type for Gulf St Vincent and Spencer Gulf, for comparison with the same estimates of maximum *F* shown in Figure 7-1.

7.4. Appendix 4. 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 surveys conducted in 2000/01 (Henry and Lyle, 2003), 2007/08 (Jones, 2009), and 2013/14 (Giri and Hall, 2015). Since 2007, charter boats have reported their catch totals in logbooks and since the 2018 assessment charter boats have been included as a fifth model effort type in GarEst. 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, 2015), 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 recreational effort data specific to Garfish. As GarEst uses a quarterly time step, we introduced several additional steps of data pre-processing to obtain the required data inputs for recreational catch by region and quarter 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 the last (2013/14) survey. Surveys and charter boats report all catches in number 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 (870147) 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 recreational harvest by region for the year, namely 49% for Spencer Gulf & KI, 26% for Gulf St Vincent. The 19% for West Coast and 6% for South East of Garfish harvested in South Australia were not included in the model.

7.4.1. Pre-processing to obtain catches by quarterly time step for the 2013/14 recreational survey

To obtain quarterly numbers harvested by recreational fishers, from the yearly totals $\left\{N_r;\ r=1,n_{Region}\right\}$ by region, we inferred quarterly proportions harvested by fitting to the quarterly recreational catch total estimates available from the two previous recreational surveys of 2000/01 and 2007/08 from which monthly estimates were reported. Once estimated, these four estimates of quarter-year recreational catch proportions are applied for all model years.

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 quarterly *Season* (October-December, January-March, April-June, and July-September) and GarEst model *Region* (Spencer Gulf and Gulf St Vincent) for the two previous surveys. The proportion of catch taken in each quarter for both regions was calculated from these estimates and used to distribute the total annual catch of the 2013/14 survey results into region- and quarter-specific catches.

For non-survey years, quarterly catch estimates were estimated by interpolating linearly between survey periods. Prior to the first survey in 2001/02 the four quarterly values of 2001/02 were retained unchanged. Beyond the last survey, these quarterly 2013/14 catch estimates are carried forward up to the current model time step (Figure 7-3).

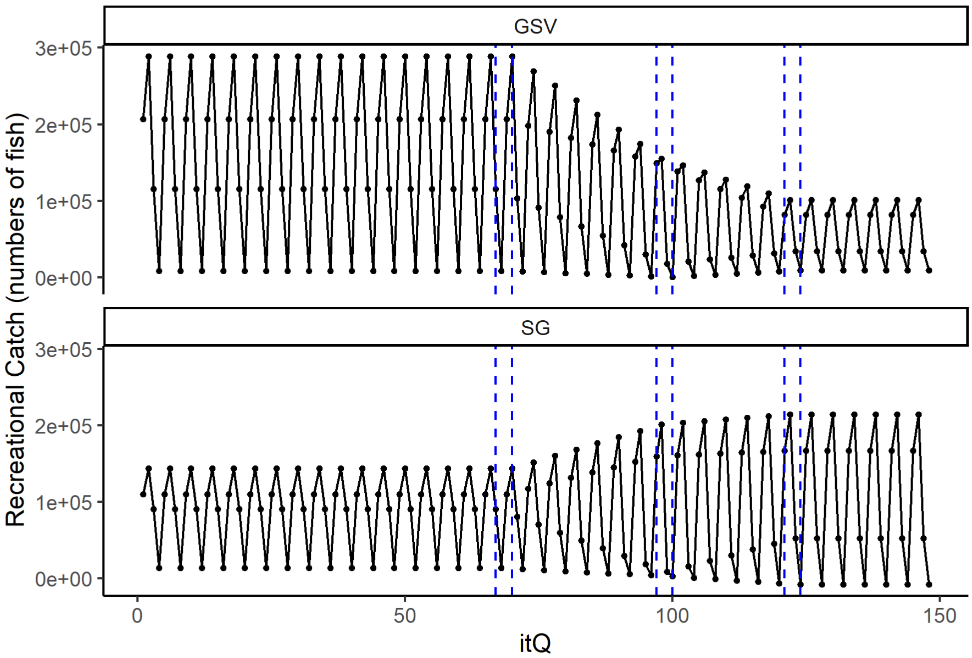

Figure 7-3. Recreational Garfish catch totals estimated from three surveys (2000/01, 2007/08 and 2013/14) for Gulf St Vincent and Spencer Gulf. Catches between survey years are interpolated linearly. The catch estimates from the last survey are carried forward to the current model time step. Vertical blue dashed bars indicate telephone and diary survey periods. itQ = quarterly GarEst model time step.

7.4.2. Recreational effort inputs

For recreational effort as in input to this effort-conditioned model, the current stock assessment uses an updated approach. It is important to account for the removal of recreational catch from the garfish stock. However, recreational catch data have relatively high uncertainty, and recreational effort (and catch-per-unit-effort) data do not appear to contain any information about garfish stock abundance. Therefore, it is desirable for GarEst to remove the recreational catch from the model population while ignoring recreational effort data when estimating garfish abundance. To achieve this, for each region, a time-series of recreational effort values was generated in each quarter as the recreational catch in that quarter-year divided by the mean recreational catch. (A very small amount of random noise was added to this effort time series to prevent issues during numerical convergence.) This way, the recreational effort varies in direct proportion to survey recreational catch. A single recreational catchability value was estimated. The recreational component of the model likelihood was given a low weighting, which means its CPUE has negligible impact on estimates of garfish abundance. This enables the model to remove the recreational catch of garfish in each quarterly time step while removing any influence of recreational effort in model assessment.

7.4.3. 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. This permitted the inclusion of charter boats as a fifth effort type in GarEst. With this separate much higher quality information, 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, 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 quarterly time step.

Because charter boats targeting Garfish had substantially higher CPUE 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 (0.22 for Gulf St Vincent and 0.19 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:

$$TotalCharterEffort_{itQ,RG} = TargetEffort_{itQ,RG} + NonTargetEffort_{itQ,RG} * CScalingFactor_{RG} \text{ ,}$$

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

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

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. $TotalCharterEffort_{itQ,RG}$ (Figure 7-4) was used as the charter effort data input in the GarEst model.

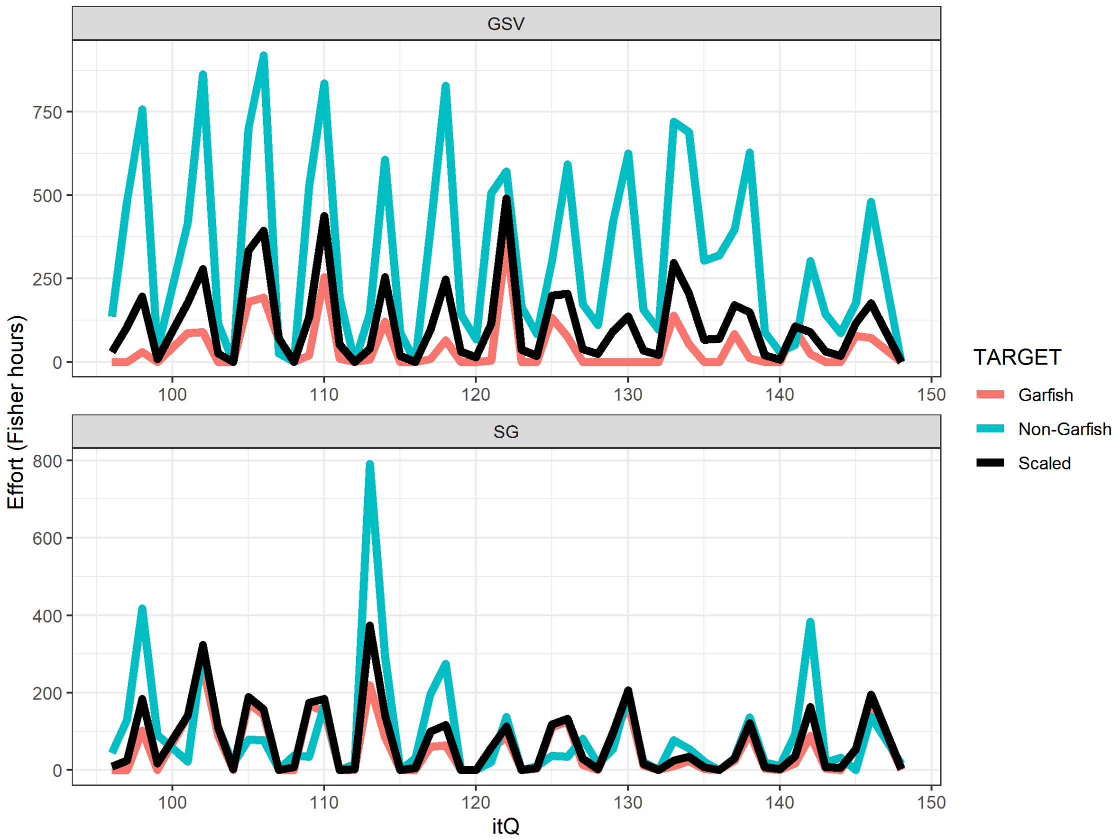

Figure 7-4. Total, target, and unscaled non-target garfish effort (number of fisher hours), by quarter-yearly time step since October 2007, for the South Australian charter boat fishery. Total effort was used in the GarEst stock assessment model. The total effort (Black line) included the target (red line) and scaled non-target (not shown) CPUE.

7.5. Appendix 5: Age-length 'slice' partitioning method

The GarEst model is based on the slice partition method for representing the population structure of Garfish numbers, breaking down model population number by age, and also by the lengths of fish within each recruited cohort. Representing population structure by both age and length-within-age, for each region, gulf and time step, improves model accuracy in a stock such as Garfish, where legal minimum length separates fish of high fishing mortality from those incurring only natural mortality. As shown in Figure 7-5, faster growing Garfish, because they reach legal size sooner, incur the higher exploitation levels of mortality 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 dynamically account for this length-asymmetric mortality with a method that is computationally efficient. In addition, the three principal data sources, catch totals in weight, age proportions, and length moments, are from the landed 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 catch-specific data quantities to be fitted. Note that from the 2021 garfish stock assessment onwards, in order to define adult biomass over a consistent Garfish size range (> 210 mm TL) for all model years, changes in legal minimum length (LML) that occurred in 2001 and 2015 are modelled by a modification of length selectivity (see Appendix 7.6). The slice partition length (denoted in figures of this Appendix as 'LML') is maintained at 210 mm for all years.

The programming steps for calculating the three slice partition quantities used by GarEst are outlined in this appendix, summarising the coding algorithm for adding slice partition to an age-based model. In a slice model approach, fish are not moved between fixed length bins as in a length-based assessment model. Rather it is the length bins themselves that grow. The Garfish within each bin, once assigned to it when they reach legal size, incur only mortality. Not requiring movement of fish among length bins 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 length-at-age distribution 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 distribution pdf grows with age. Thus, given the mean and standard deviation for all subsequent cohort ages from estimated growth parameters, 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 to obtain lower limits of integration for each slice. This computational short-cut requires an assumption of normally distributed lengths-at-age, though this is generally a quite good approximation. A fixed P_{slice} probability under the length-at-age pdf curve for each slice, which remains unchanged for all subsequent ages, underpins the overall slice partition and explains why the *z*-scores uniquely specify the slice partition for all model ages, given the mean and standard deviation of lengths for each 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, $\overline{l}(a)$, and (1.2) standard deviation, $\sigma(a)$, and thus, also, the (1.3) *z*-score, $z(a) = (LML - \overline{l}(a)) / \sigma(a)$, for every age (a) of growth. This step requires the input of growth submodel parameters specifying $\overline{l}$ 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 Stegun) (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, $P_{slice}(a) = P_{legal}(a) - P_{legal}(a-1)$, $a = a_b + 1, ..., a_{max}$, where, for GarEst, the birth age of cohort creation, a_b = 3, at the start of the fifth quarter of age (1 October the summer following the summer of spawning) for all cohorts.

Step 3. Calculate the first of 3 output quantities, the fish transfer coefficients, $f_{transfer}(a) = P_{slice}(a) \big/ P_{sublegal}(a-1)$, $a = a_b + 1, ..., a_{max}$. 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 $n_s(a) = a - a_b + 1$, $a = a_b,...,a_{max}$. (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, $a = a_b,...,a_{max}$. (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: $l_{lhs}(a,s) = \overline{l}(a) + \sigma(a) \cdot z(s-1+a_b)$.

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 Stegun 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 7-5 and 7-6.

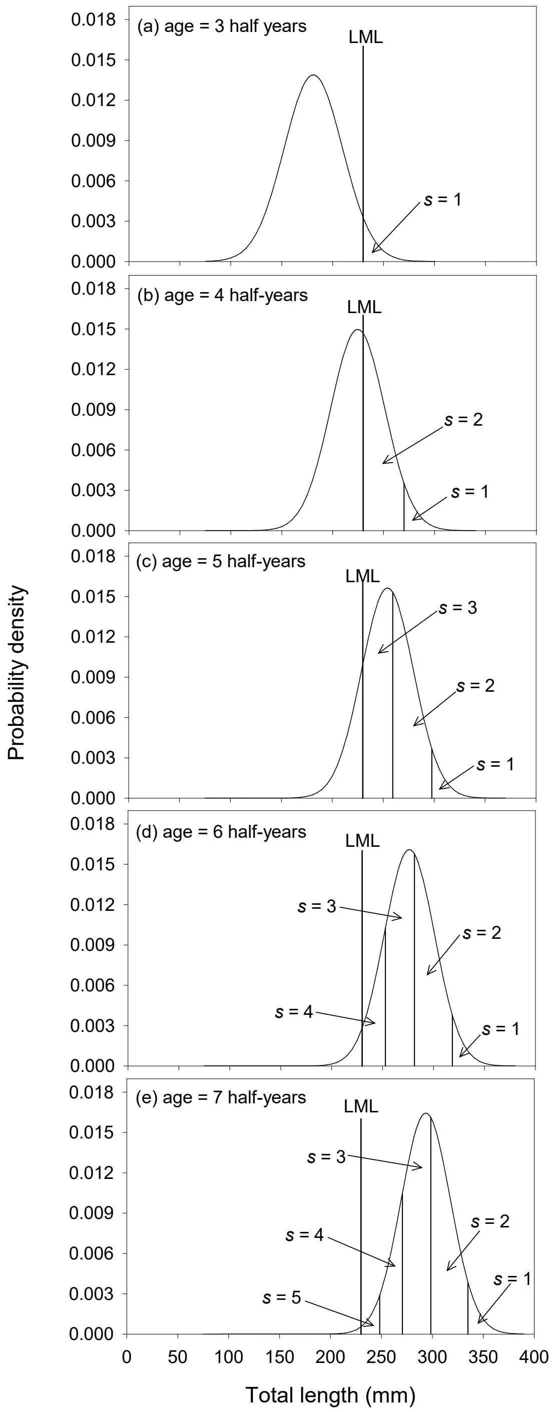

Figure 7-5. The growth of a normal length-at-age Garfish cohort is shown in successive panels. Here assuming a half-yearly time step, with each half-yearly time increment, a new slice, as the fish of length newly grown above LML, numbered *s*=1, 2, etc., is created as shown. See Steps 1 and 2 above.

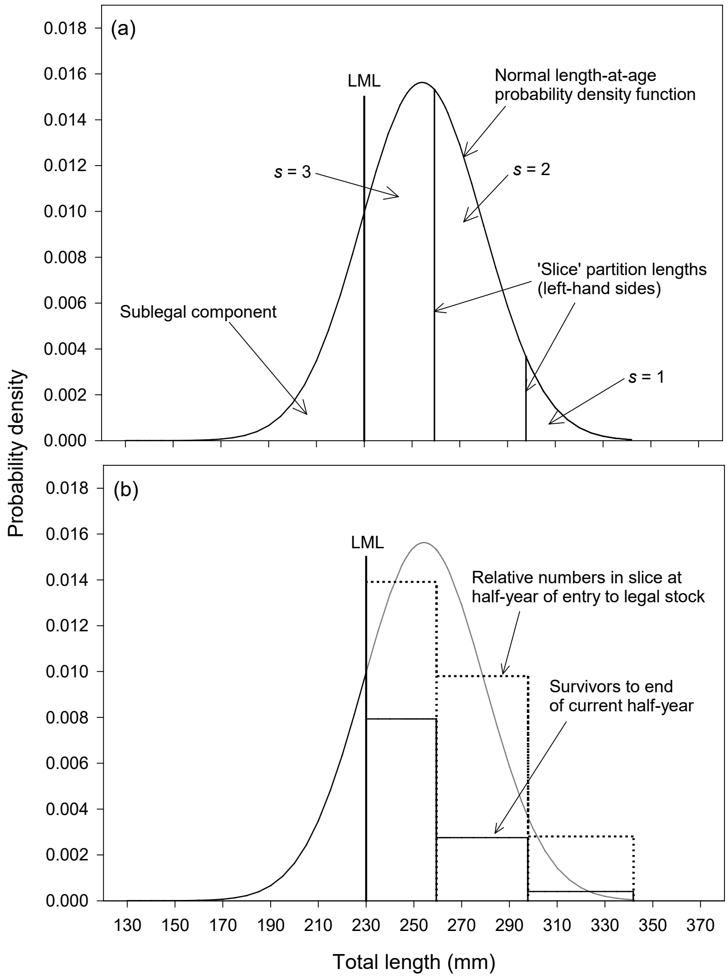

Figure 7-6 (a) The transfer of Garfish from sublegal sizes (left of LML) to each newly created slice, is done using Step 3. (b) Subsequently, the proportional reductions in the population number in each slice differ depending on how long it has been exposed to fishing mortality, and on the length selectivity applying to each slice, in each (here, half-yearly) 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.

7.6. Appendix 6. Garfish Stock Assessment Model

The starting point and basis of the slice method for partitioning fish cohorts by length is the normal length-at-age growth submodel, specified by the mean length and standard deviation at the start of each quarterly age. This represents the length distribution of fish in each cohort age that would be observed in the absence of length-asymmetric mortality. Changes in the numbers by length, notably fewer faster growing Garfish that result from length-selective capture mortality will subsequently be imposed on these model cohorts, after they are partitioned into slices. To model mean fish length $\overline{l}$, the mean of the normal length-at-age pdf, for any quarterly cohort age, a, we employed a 7-parameter seasonal von Bertalanffy curve for mean length-at-age (McGarvey and Fowler 2002):

$$\overline{l}(a) = L_\infty \left\{ 1 - \exp\left[-K\left(\frac{a-t_0}{4}\right) + \frac{u}{2\pi} \cdot \left\langle \cos\left(2\pi \cdot \left(\frac{a-w}{4}\right)\right) - \cos\left(2\pi \cdot \left(\frac{t_0-w}{4}\right)\right) \right\rangle \right] \right\}$$

. Using two additional parameters, the dependence of the length-at-age standard deviation $\sigma(a)$ is modelled as an allometric function of mean length: $\sigma(a) = \sigma_0 \cdot \left(\overline{l}(a)\right)^{\sigma_1}$.

The growth parameters $\{L_\infty, K, t_0, u, w, \sigma_0, \sigma_1\}$ can be estimated by fitting to length-at-age samples either (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 estimates for all growth parameters. The likelihood probability of observing a given length-at-age is truncated at LML to make explicit the absence of sublegal Garfish in catch samples (McGarvey and Fowler 2002). A second growth estimation was integrated into the GarEst stock assessment likelihood, re-estimating the two parameters that most directly determine the mean rate of growth, von Bertalanffy K, and the spread of lengths at each age, the normal length-at-age standard deviation coefficient σ_0.

In this most recent assessment (2021), this growth model was expanded to include seasonality expressed in the two cosine terms shown above. Accounting for seasonality in growth was made possible by improved temporal model resolution (quarterly rather than half-yearly). The phase parameter that determines the time of peak growth, w, is now also estimated in the second integrated stage of estimating growth. The seasonality amplitude, u = 0.9 fixed.

Starting from this growth submodel, an algorithm (described in Appendix 5) was devised to effectively 'slice off' the length subintervals of fish which have grown past a specified slice partition length in each model time step. For this assessment we have fixed this to 210 mm TL for all years in order to obtain a definition of biomass that is consistent over all model time. Thus, the increase in LML to 230 mm which occurred for all sectors in 2001, and to 250 mm in the commercial sector in 2015, means that a portion of the fishery's sublegal population is modelled by slices (indexed by values > 0). 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 (between slices). Fish within slices incur only mortality. 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.

7.6.1. Recruitment

Recruitment is defined as the creation of the (normal) length-at-age cohort at age a_b = 5 quarters (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 5) 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 5).

7.6.2. Model Population Array

The model Garfish population array $N\left(t,r,x,c,s\right)$ is 5-dimensional, fish numbers broken down by (1) quarterly 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.

The variable subscript that indicates the season (t_{season}) for a quarterly time step, is either "SUM1" (first summer quarter of Oct-Dec), "SUM2" (second summer quarter of Jan-Mar), "WIN1" (first winter quarter of Apr-Jun), or "WIN2" (second winter quarter of Jul-Sep). Each model year index commences in "SUM1"; for example, year 1983 commences as Oct-Dec 1983 which indexes the first model year as 1983. Cohort age in quarters (a), were calculated as functions of model time step, t , and cohort year, c . Ages ran from 5 to 24+ quarters, the oldest age being a 'plus' group.

Southern Garfish catch and effort, for data and model, were divided into five ordered effort types, i_E : (1) hauling nets targeting Garfish, (2) hauling nets not targeting Garfish, (3) dab nets and minor gears, (4) charter boats, and (5) recreationals. The two commercial gears, g , each with separate length selectivity, are hauling net (first gear type) and dab net (second gear type), with charter boats and recreationals having designated their own gear types. Data quantities, such as reported effort $\tilde{E}$, are denoted by a tilde.

7.6.3. 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 the slice partition length (210 mm for all model time steps), gear-specific length selectivity is modelled for legal size Southern Garfish. For all years the population numbers of garfish of length below 210 mm incur only natural mortality.

However, keeping the above cut-off at 210 mm means that from 2001 onwards ($t > 71$) sublegal Southern Garfish in the size range 210-230 mm are modelled using slices (i.e. those indexed > 0). These experience only natural mortality, which is implemented by introducing a cut-off size into length selectivity of 230 mm below which selectivity is set to 0 for any slice whose midpoint falls below 230 mm. Similarly, the LML increase specific to the commercial sector that occurred in 2015 ($t > 126$), from 230 mm to 250 mm, is implemented by setting to 0 commercial length selectivity for population length slices with midpoints below 250 mm. In this way, the exclusion of sublegal Garfish from model catches over time is accounted for in fits to the data catches. The indicator of adult biomass is defined by summing over all slices, i.e. all Garfish above 210 mm.

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

$$F(t,r,x,c,s,i_E) = q(r,\ t_{season},\ x,\ i_E) \cdot \tilde{E}(t,r,i_E) \cdot s_{len}(t,i_E,g(i_E),s). \quad (7.1)$$

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.

(7.2) $$s_{len}(t,i_E,g(i_E),s)=\begin{cases}0, & t>71 \ \& \ \bar{l}(s)<230 \ (commercial\ and\ recreational)\\ 0, & t>126 \ \& \ \bar{l}(s)<250 \ \& \ i_E<4 \ (commercial)\\ 1\Big/\left\{1+\exp\left[-r_{sel}\left(g(i_E)\right)\cdot\left(\bar{l}(s)-l_{50}\left(g(i_E)\right)\right)\right]\right\}, & otherwise\end{cases}.$$

Logistic length selectivity is varied in time to model 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 is given by regression equations relating mesh size to l_{50} derived from a series of mesh selectivity experiments undertaken by SARDI and industry:

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

On 1 April 2015 the mesh size was increased to 34 mm, on 1 April 2016 to 35 mm, and on 1 January 2019 to 36 mm.

For commercial effort, the catchability was written:

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

with q_{CSE} being the absolute catchability given as function of region, season (SUM1 and SUM2 combined, WIN1 and WIN2 combined), and effort type, a relative selectivity coefficient $s_{SS}(t_{season},x)$ describing the sex-dependent seasonality of catchability with SUM1 females fixed at 1, 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 is implemented as a fixed quarterly increase, q', the rate of catchability change relative to the time step t_{mid} = 44 quarters; q' = 0.00678012 or 0.68% increase per quarter. For some combinations of region and commercial effort type the parameter $q_{CSE}(r,t_{season},i_E)$ was replaced for limited time periods with alternative catchability parameters.

The estimate of adult biomass is computed in any given time step by summing over all of the length slices to include only fish above 210 mm (slice index > 0). In this way the biomass estimate is not altered by changes in LML. Adult biomass is calculated as follows

$$(7.5) \quad B_{adult}(t,r) = \sum_{\bar{l}(s) \geq 210} \sum_{a=a_b}^{24+} \sum_{x=0}^{1} N(t,r,x,c,s) \cdot w(a(t,c),s)$$

where the fish weights by age and slice $w(a(t,c),s)$ are derived in Appendix 5. Corresponding harvest fractions are then calculated per time step *t* as model-predicted catch divided by $B_{adult}(t,r)$.

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:

$$(7.6) \quad F(t,r,x,c,s) = \sum_{i_E=1}^{n_E} F(t,r,x,c,s,i_E).$$

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

$$(7.7) \quad N(t+1,r,x,c,s) = N(t,r,x,c,s) \cdot \exp\left[-\left(M + F(t,r,x,c,s)\right) \cdot p_{yr}(t)\right]$$

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

7.6.4. Estimation: Parameters and Model Likelihood

The model likelihood (Fournier and Archibald 1982) is fitted to (1) quarterly catch totals by weight, (2) SAFCOL market sample catch proportions by age and sex, (3) market sample catch moment properties of fish length for each age and sex, and (4) recent FRDC fishery-independent sample catch proportions by age and sex for Gulf St Vincent. The negative log-likelihood components for the fitting to age and length data respectively were down-weighted by factors of 0.2 and 0.025, while the recreational catch component was also down-weighted by a factor of 0.05. See the first four appendices and section 3.2.1 on Data Sources for more information on the data.

7.6.5. Parameters

Estimated parameters for the model fall into six categories: (1) yearly recruit numbers by region, (2) recruitment sex proportion by region, (3) catchabilities by effort type, region and summer-winter, (4) relative selectivities by sex and season, (5) growth by sex and region, and (6) likelihood standard deviations by gear, region and season of fits to quarterly catch totals. The following parameters were fixed: a) initial steady-state fishing mortality, b) length selectivity parameters, c) and all growth parameters except K, σ_0, and w, and d) the sigma parameter belonging to the likelihood for the fit to the age-sex proportion data from the fishery-independent sampling project (FRDC 2015/018).

7.6.6. Likelihood for Catch Totals by Weight

Model-predicted catch totals in weight (kg) are fitted to commercial and charter boat data, and model-predicted catch totals in number are fitted to recreational catch survey data, using a normal likelihood. The catch in weight is calculated using the standard Baranov formula as:

(7.8)
$$\hat{C}(t,r,x,c,s,i_E) = N(t,r,x,c,s)\cdot w(a(t,c),s)\cdot \frac{F(t,r,x,c,s,i_E)}{M+F(t,r,x,c,s)}\cdot\left\{1-\exp\left[-\left(M+F(t,r,x,c,s)\right)\cdot p_{yr}(t)\right]\right\}$$

The normal likelihood factor is written as:

(7.9)
$$L_C = \prod_{t=1}^{n_t}\prod_{i_E=1}^{n_E-1}\prod_{r=1}^{n_r}\frac{1}{\sqrt{2\pi}\cdot\sigma_C(t_{season},r,g(i_E))}\exp\left[-\frac{1}{2}\left(\frac{\hat{C}(t,r,i_E)-\tilde{C}(t,r,i_E)}{\sigma_C(t_{season},r,g(i_E))}\right)^2\right]$$

where

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

$\hat{C}(t,r,i_E)$ = model-predicted catch in weight (number) for each t, r, and i_E;

$\sigma_C(t_{season},r,g(i_E))$ = an estimated standard deviation parameter, one per season, region r, and gear.

Charter boat data is fittted ($i_E = n_E - 1$) from Apr-Sep-07 onwards, and for each of charter boat and recreational survey ($i_E = n_E$) the estimated standard deviation varies only by region. Full details of these data can be found in Appendix 7.4.

7.6.7. 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 distinct attributes of a single catch sample data set. The fitted data, from the principal gear, hauling nets, in the four time steps and regions where catch was monitored, consists of the counts of sampled fish falling into each possible combination of sex and quarterly 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:

$$(7.10)\quad L_{AX} = \prod_{i_{AX}=1}^{n_{AX}} \prod_{a=a_b}^{24+} \prod_{x=0}^{1} \hat{p}(a, x;\ i_{AX})^{\tilde{n}(a, x;\ i_{AX})}$$

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 quarter 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} .

The data on proportions by age and sex from the FRDC fishery-independent sampling project are fitted in an analogous manner to above, except these data are available only for Gulf St Vincent and the model-predicted proportions are formed using the population quantities of slices (fish > 210 mm), rather than the catch, assuming that these samples are representative of the age-sex population structure of Garfish in Gulf St Vincent. Thus also no relative discrepancy ratios are applied in the likelihood.

7.6.8. 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:

$$(7.11)\quad L_{mp} = \prod_{i_{AX}=1}^{n_{AX}(i_{mp})} \prod_{i_{mp}=1}^{4} \prod_{sex=0}^{1} \prod_{a=a_b}^{24+} \prod_{g=1}^{2} \left\{ \frac{\exp\left[-\frac{1}{2} \left(\frac{ \left\{ \begin{array}{l} \tilde{b}(i_{mp},x,a,g;i_{AX}) - \\ \hat{b}(i_{mp},x,a,g;i_{AX}) \end{array} \right\} }{\sigma_{mp}(g)} \right)^2 \right]}{\sqrt{2\pi}\cdot\sigma_{mp}(g)} \right\}^{\tilde{n}_a(x,a,g;\,i_{AX})} .$$

where

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

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

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

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 4 aged fish for kurtosis, 3 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.

7.7. Appendix 7. Model Fits to Data

Parameters and thus stock performance indicators in the GarEst model are estimated by fitting to data for commercial catch totals in weight, charter boat catches in number, interpolated recreational catches in number, commercial market catch proportions by age and sex, commercial market catch moments of length-at-age, and to fishery-independent sampling proportions by age and sex, in each quarterly time step when sampling occurred. In this Appendix, graphs comparing fitted model and data are presented (Figures 7-7 to 7-15).

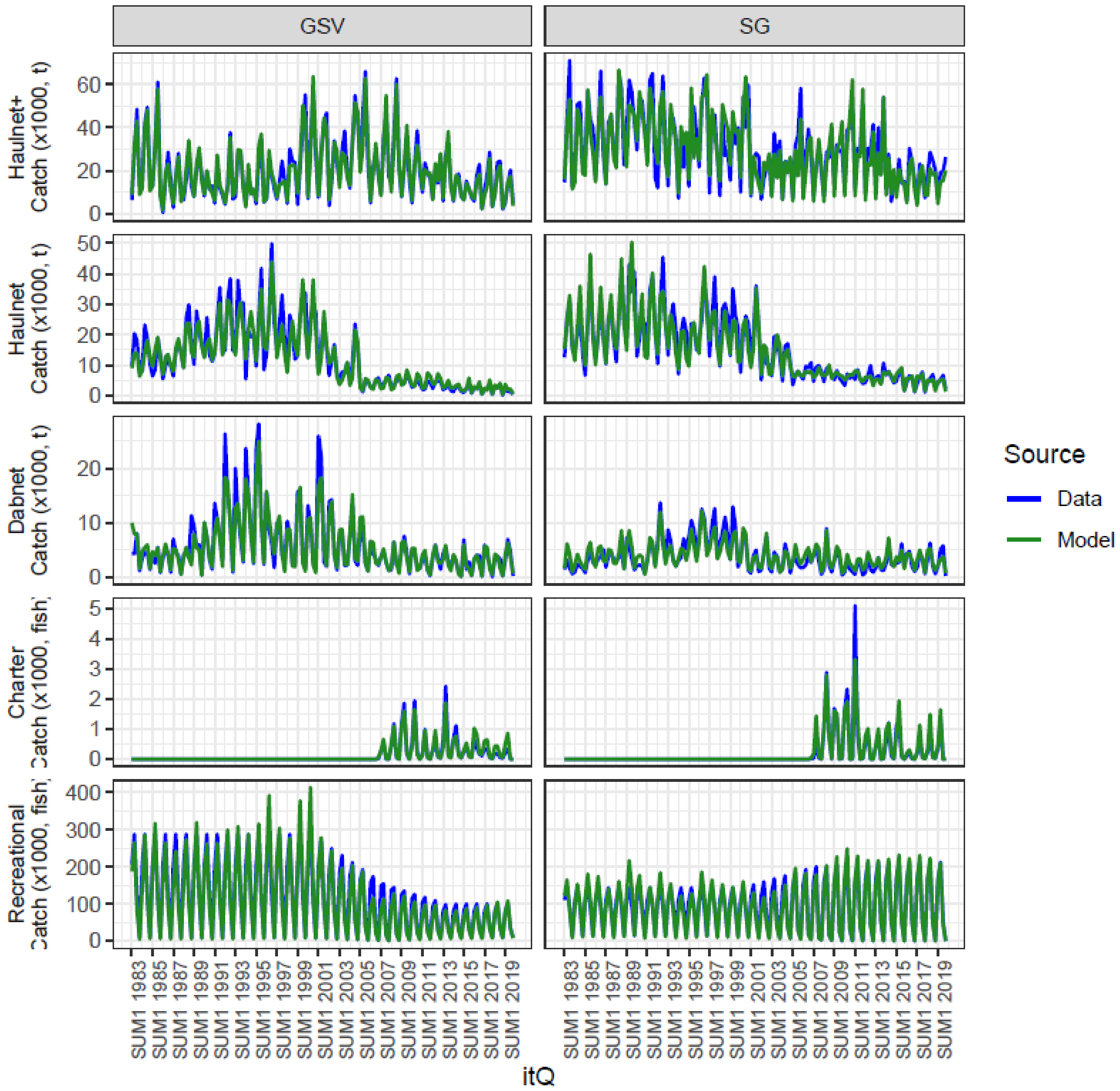

Figure 7-7. Fits of Spencer Gulf and Gulf St Vincent models to data quarterly catch totals for the 5 effort types.

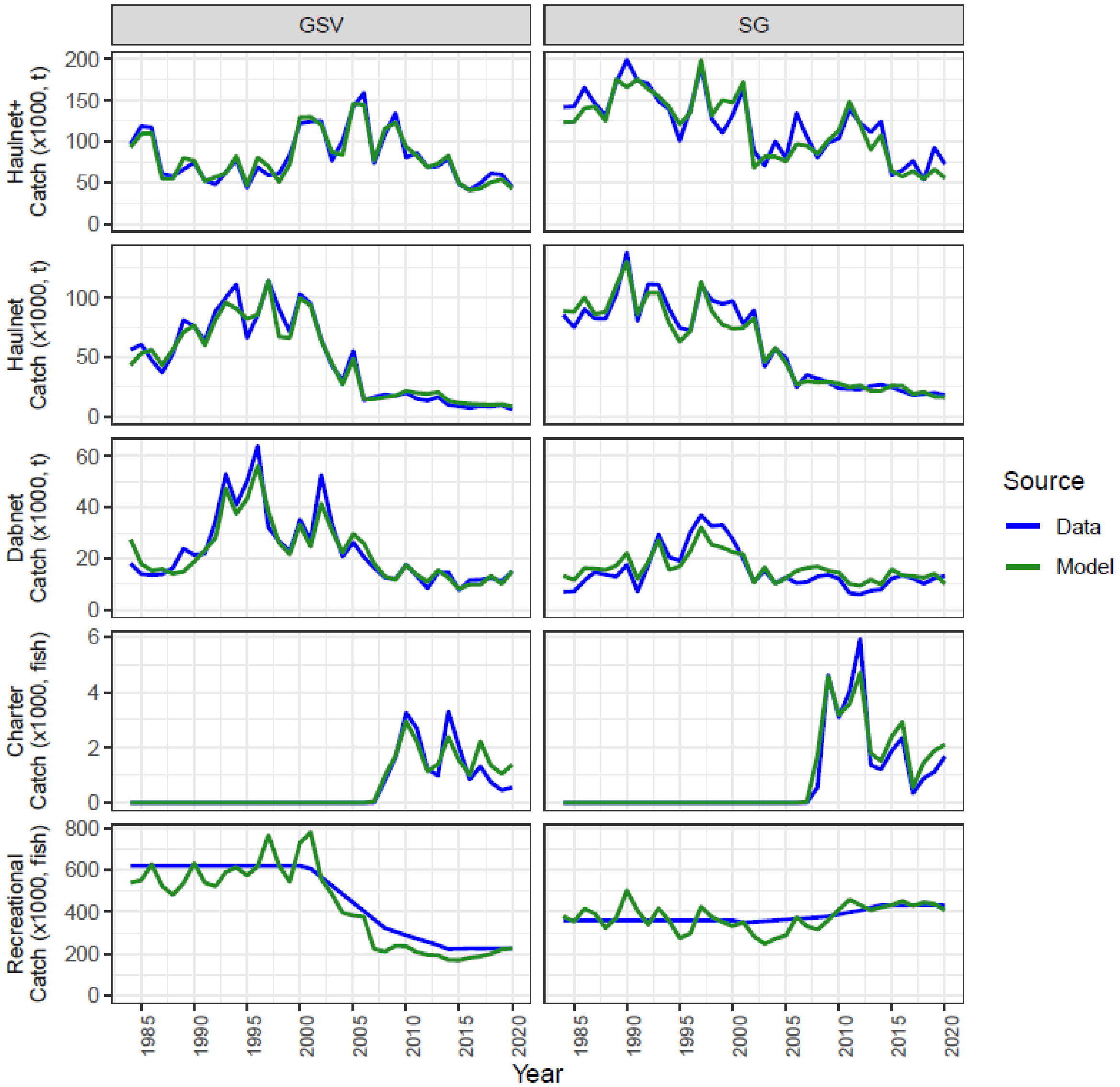

Figure 7-8. Comparisons of Spencer Gulf and Gulf St Vincent model yearly catch totals to data annual (calendar year) catch totals for the 5 effort types.

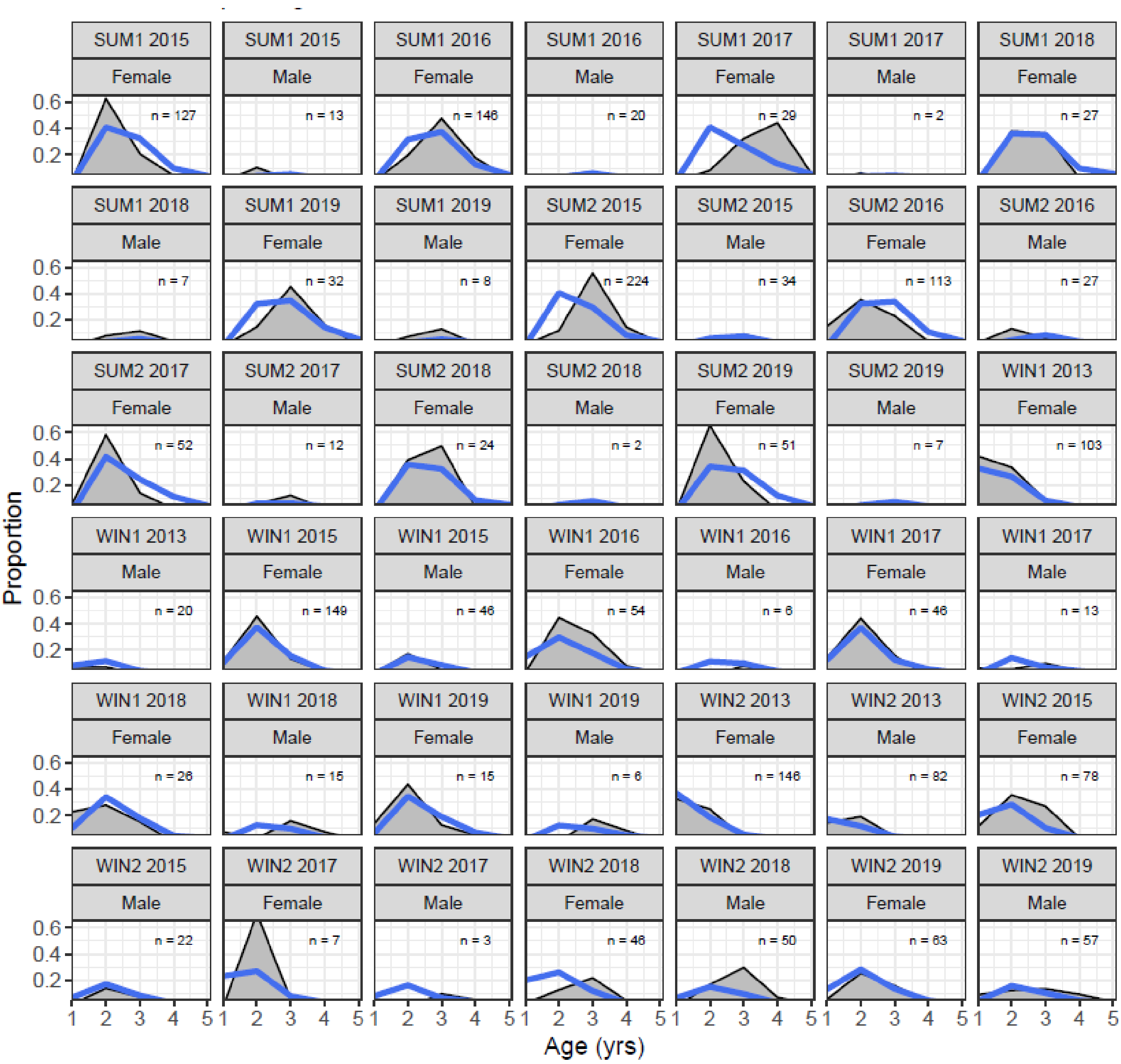

Figure 7-9. Model fits to age-sex proportions from SAFCOL market hauling net catch samples. The 42 most recent Spencer Gulf data sets are shown by sex and quarterly model time step. Blue lines indicate the model estimate.

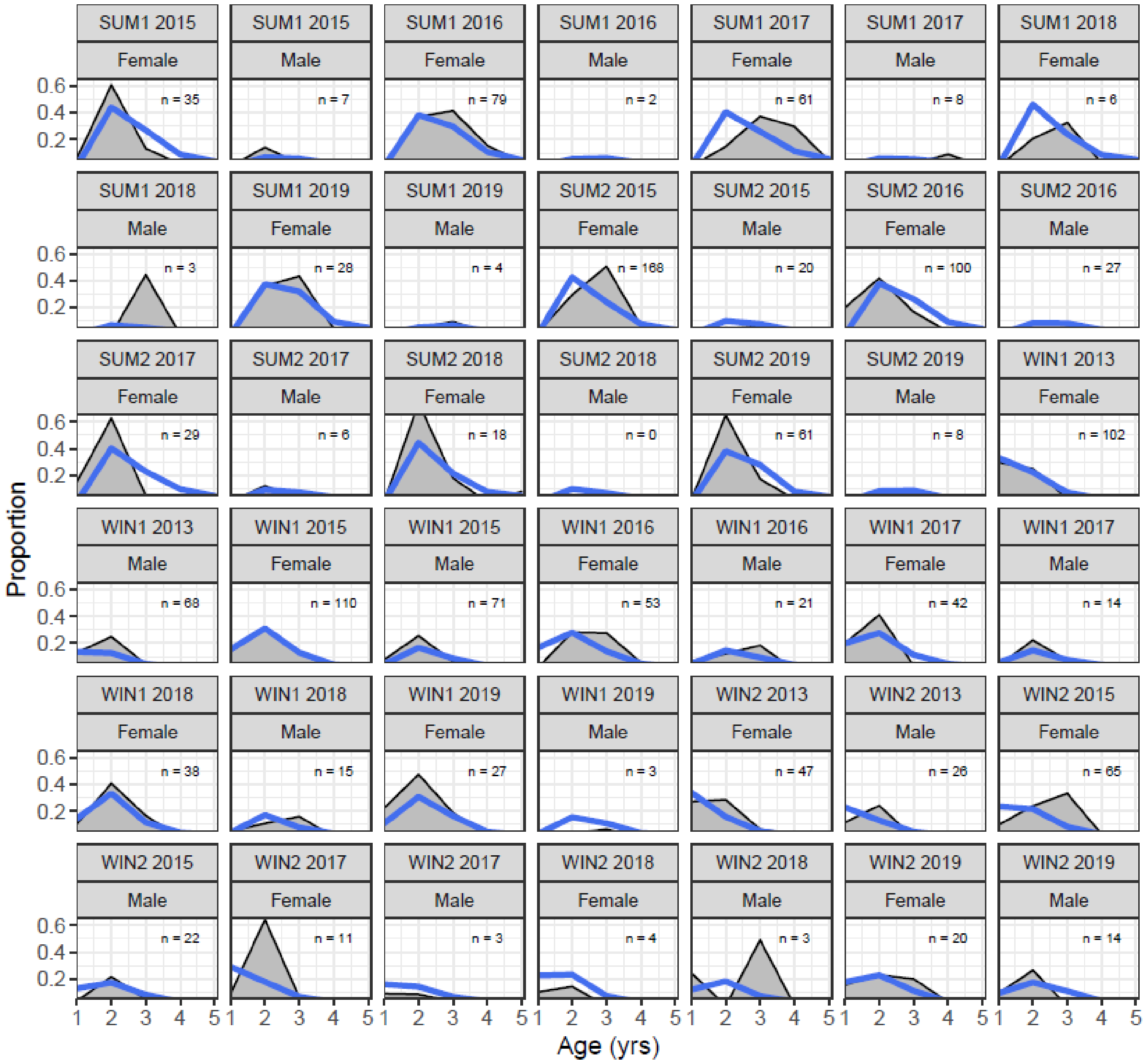

Figure 7-10. Model fits to age-sex proportions from SAFCOL market hauling net catch samples. The 42 most recent Gulf St Vincent data sets are shown by sex and quarterly model time step. Blue lines indicate the model estimate.

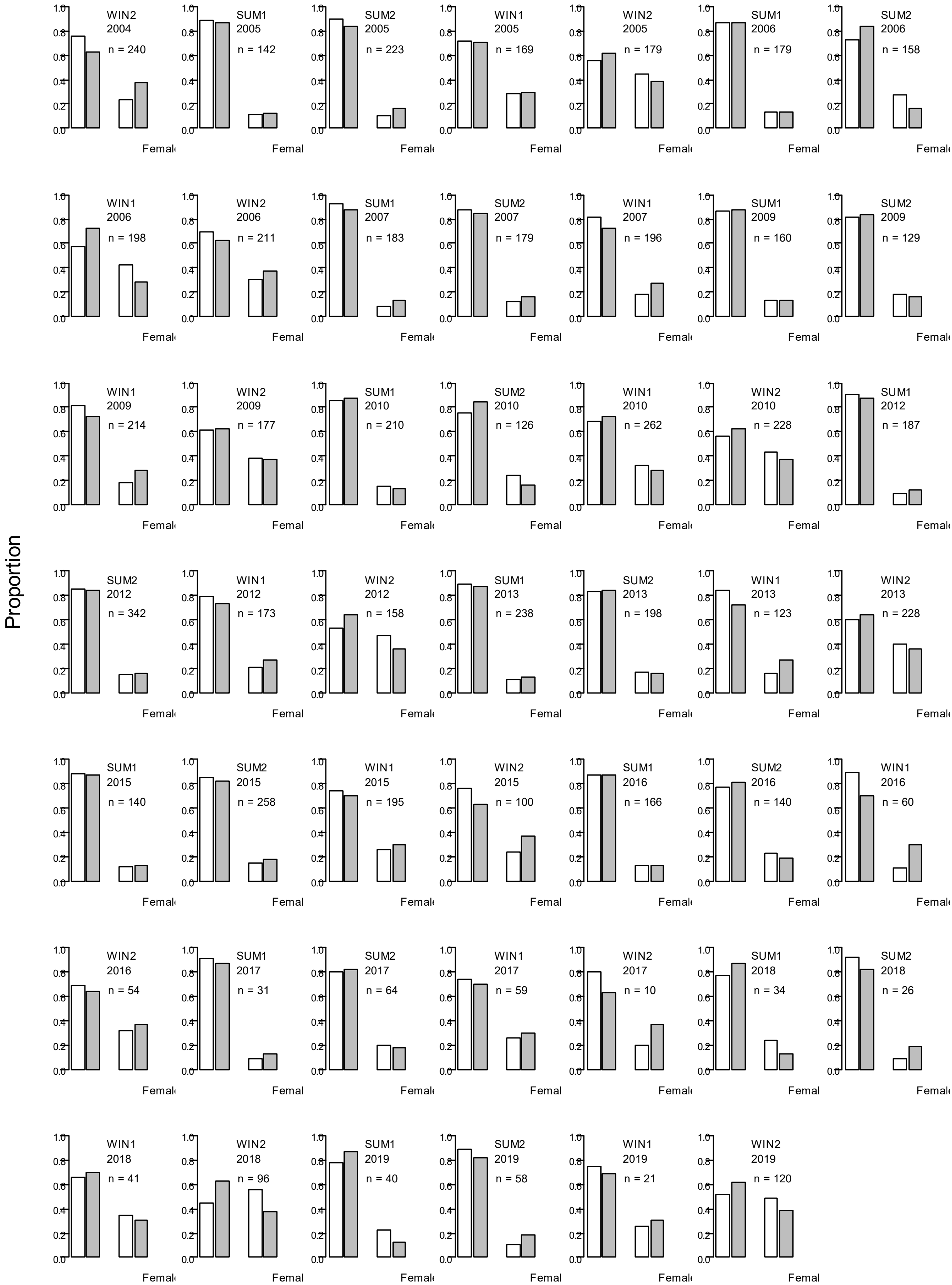

Figure 7-11. Model predicted and data sex ratios from SAFCOL market hauling net catch samples for Spencer Gulf are shown by quarterly model time step. Shaded bars indicate the model estimate.

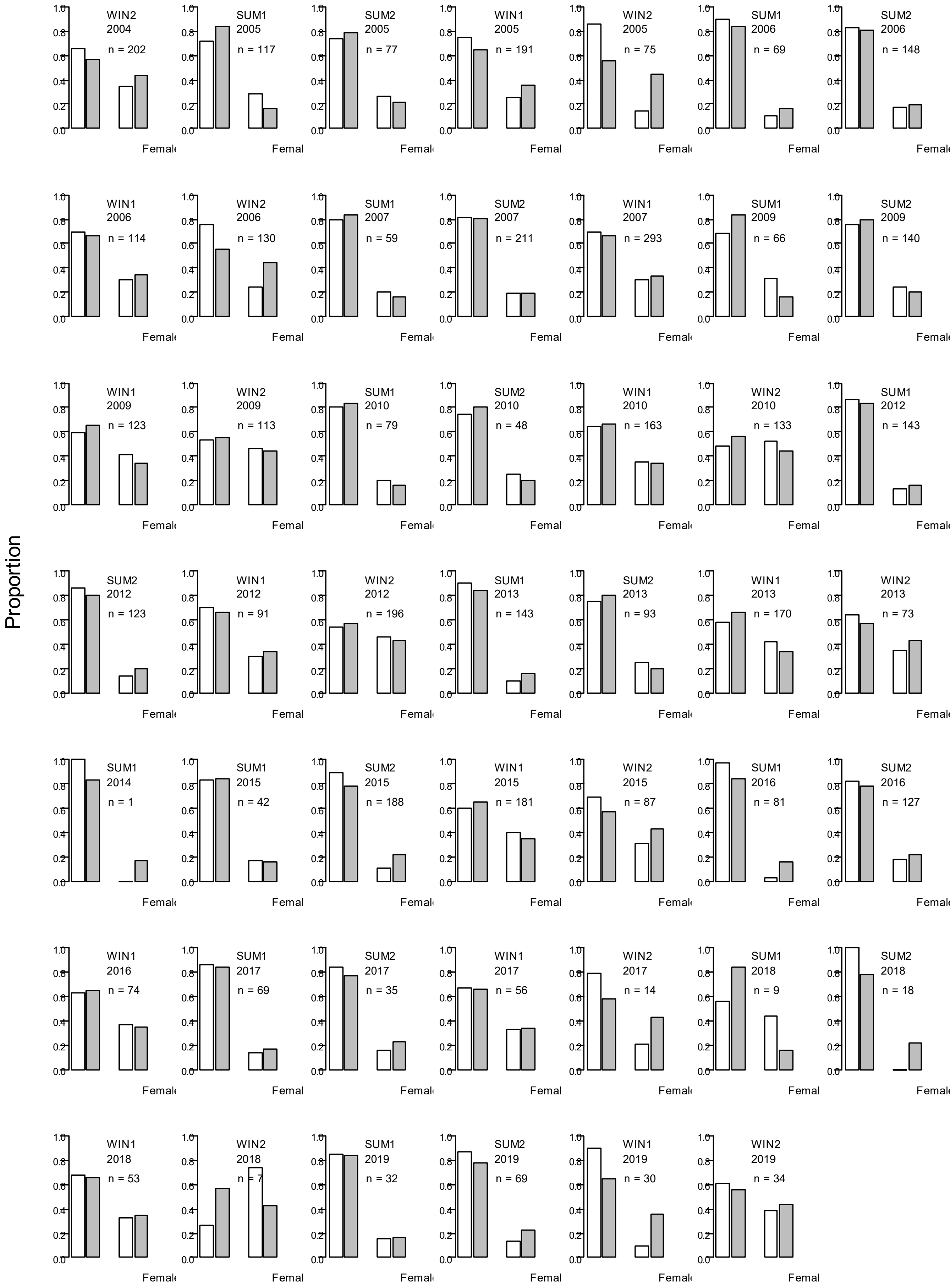

Figure 7-12. Model predicted and data sex ratios from SAFCOL market hauling net catch samples for Gulf St Vincent are shown by quarterly model time step. Shaded bars indicate the model estimate.

Figure 7-13. Model fits to catch mean lengths of modelled cohorts from SAFCOL market hauling net catch samples. The 42 most recent Spencer Gulf data sets are shown by sex and quarterly model time step. Green circles indicate the model estimate.

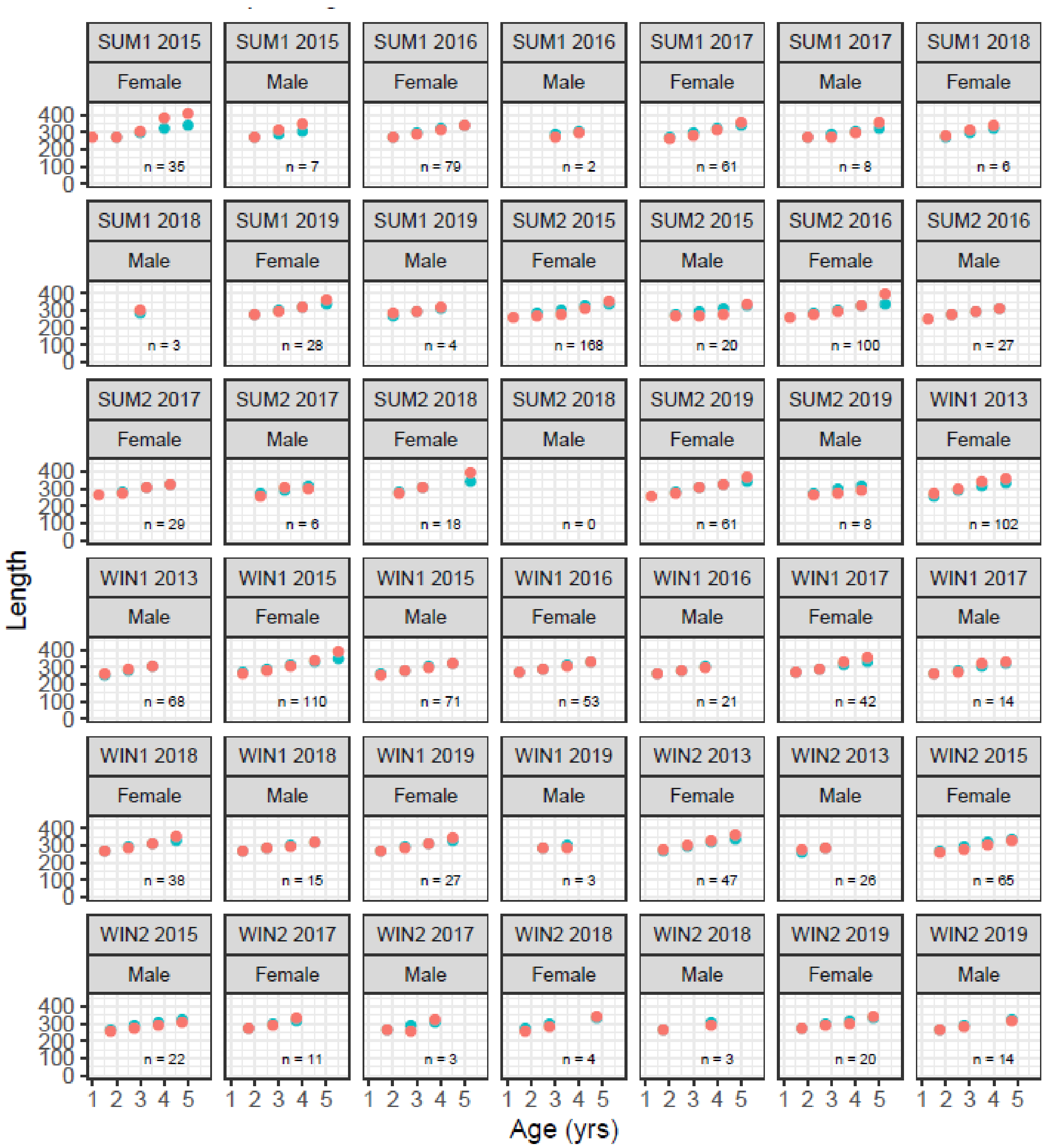

Figure 7-14. Model fits to catch mean lengths of modelled cohorts from SAFCOL market hauling net catch samples. The 42 most recent Gulf St Vincent data sets are shown by sex and quarterly model time step. Green circles indicate the model estimate.

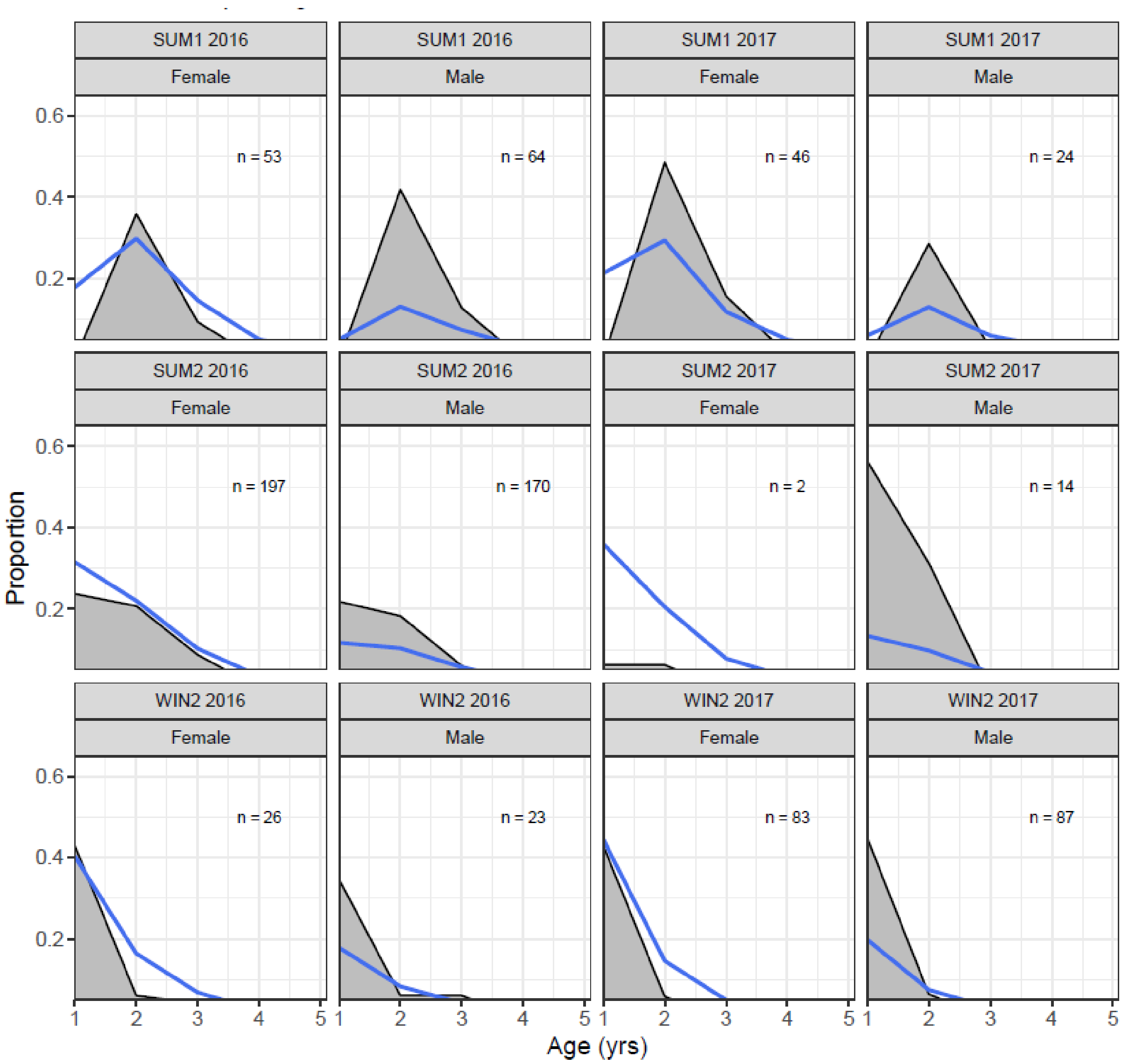

Figure 7-15. Model fits to age-sex proportions from FRDC fishery-independent samples of Gulf St Vincent, by sex and quarterly model time step. Blue lines indicate the model estimate.

7.8. Appendix 8. GarEst Model Sensitivity Analysis.

7.8.1. Introduction

In this Appendix, we present GarEst model sensitivity testing under (1) different assumed levels of natural mortality rate, and (2) alternative relative weightings for one of four principal data sources in the model likelihood, age-sex sample proportions from the commercial catch.

7.8.2. Method

Sensitivity to M

The choice of instantaneous natural mortality rate (*M*) is made prior to estimation in most fishery assessment models because the information in fishery data describes the fates only of fish that are captured. To test for sensitivity of GarEst model biomass estimates to the choice of *M*, we have run several alternatives to the GarEst baseline value of *M* = 0.4, namely *M* = 0.5, *M* = 0.3, and *M* = 0.2.

Sensitivity to data source weighting

Age and sex data are fitted together in a single multinomial likelihood term, the model predicting a catch proportion for each combination of age and sex in each quarter and region where catch sampling was undertaken.

For this second sensitivity analysis, we adjusted the weighting on the age-sex data component, leaving the likelihood weightings for fits to catch totals by effort type, length-at-age moments of the catch, and FRDC fishery-independent samples of the population unaltered. The value of this age-sex weighting for the baseline (i.e. the current GarEst model, as reported in this assessment) is 1. The two alternatives we examine for this weighting are 2 and 4. This sensitivity test thus examines the effect of increasing by 2- and 4-fold the relative influence of age-sex sample data.

7.8.3. Results

Sensitivity to M

The observed sensitivity impact of lowering assumed natural mortality rate *M* was a reduction in model estimates of biomass. This was confirmed for both regions, SG and GSV, in the sensitivity results for GarEst (Figure 7-16). Lower values of natural mortality, *M*=0.2 and *M*=0.3, relative to the baseline value (*M*=0.4), produced respective decreases in average biomass of -22% and -12% in SG and -21% and -12% in GSV. Increasing the value of natural mortality to *M*=0.5 resulted in average biomass increasing by 16% (SG) and 15% (GSV) relative to baseline.

The values of the negative log likelihood (-lnL) could suggest that the higher value of *M* = 0.5 is slightly better fitting than the baseline and the other 2 choices of *M* tested. The baseline -lnL value is 5.4 units worse (higher) than for *M* = 0.5, but *M* = 0.3 and 0.2 are respectively 6.9 and 15.4 units worse than the baseline. These differences in -lnL modestly favour higher *M*.

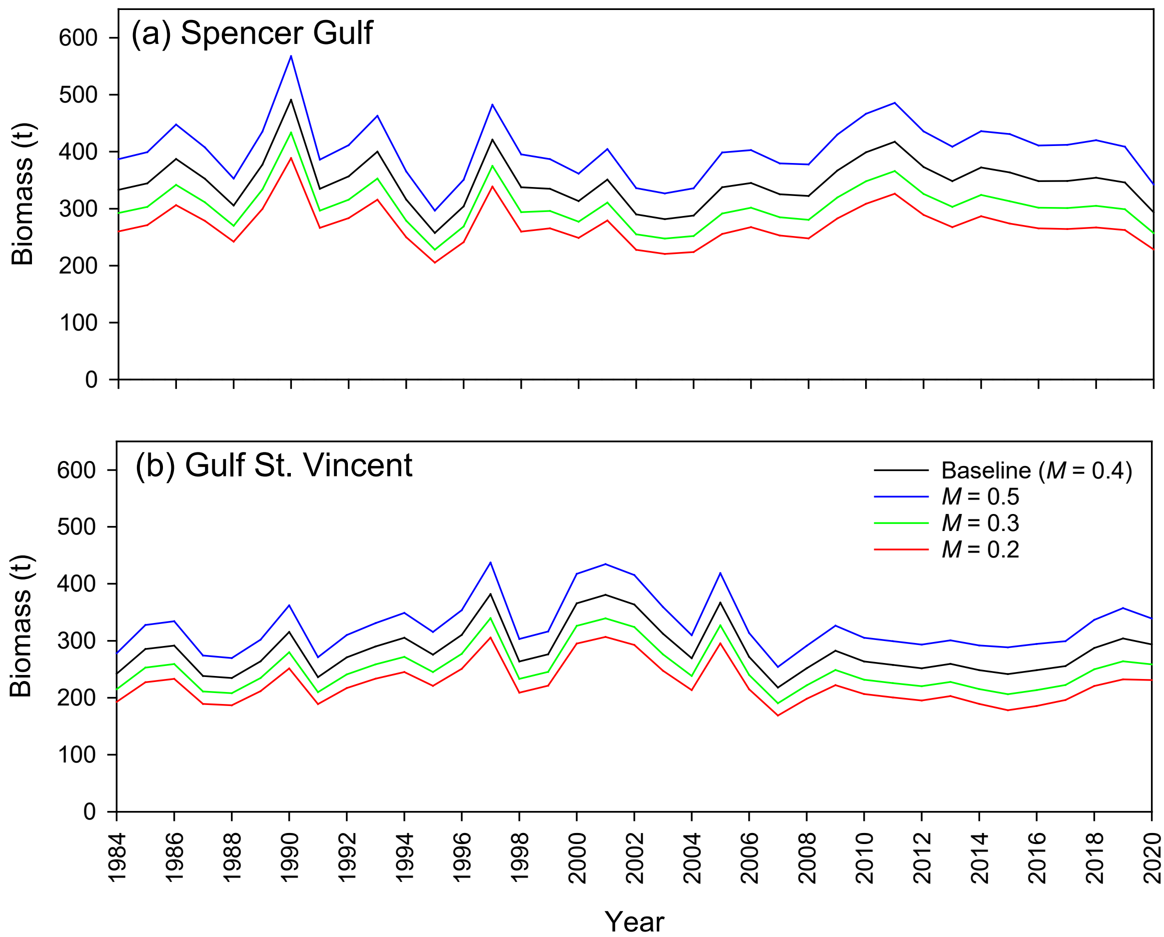

Figure 7-16. Plot of yearly biomass by region from four runs of GarEst: the baseline (with *M* = 0.4), and three alternatives of *M* = 0.5, *M* = 0.3, and *M* = 0.2.

Sensitivity to data source weighting

Biomass estimates were relatively insensitive to the choice of relative weighting on age-sex sample data. In both gulfs, a small decrease in absolute biomass levels across all years resulted from increasing this weighting, but the time trends were not affected.

In Spencer Gulf, time-average absolute levels of biomass for 1984-2020 were reduced by -6% for age-sex weighting = 2 and -9% for age-sex weighting = 4 (Figure 7-17a). The extent of deviation increased in later years.

The biomass results for Gulf St Vincent were also modestly sensitive to the weighting of the age-sex data source (Figure 7-17b). Biomass estimates were on average -5% and -8% lower than baseline for 1984-2020 for age-sex weighting = 2 and 4 respectively.

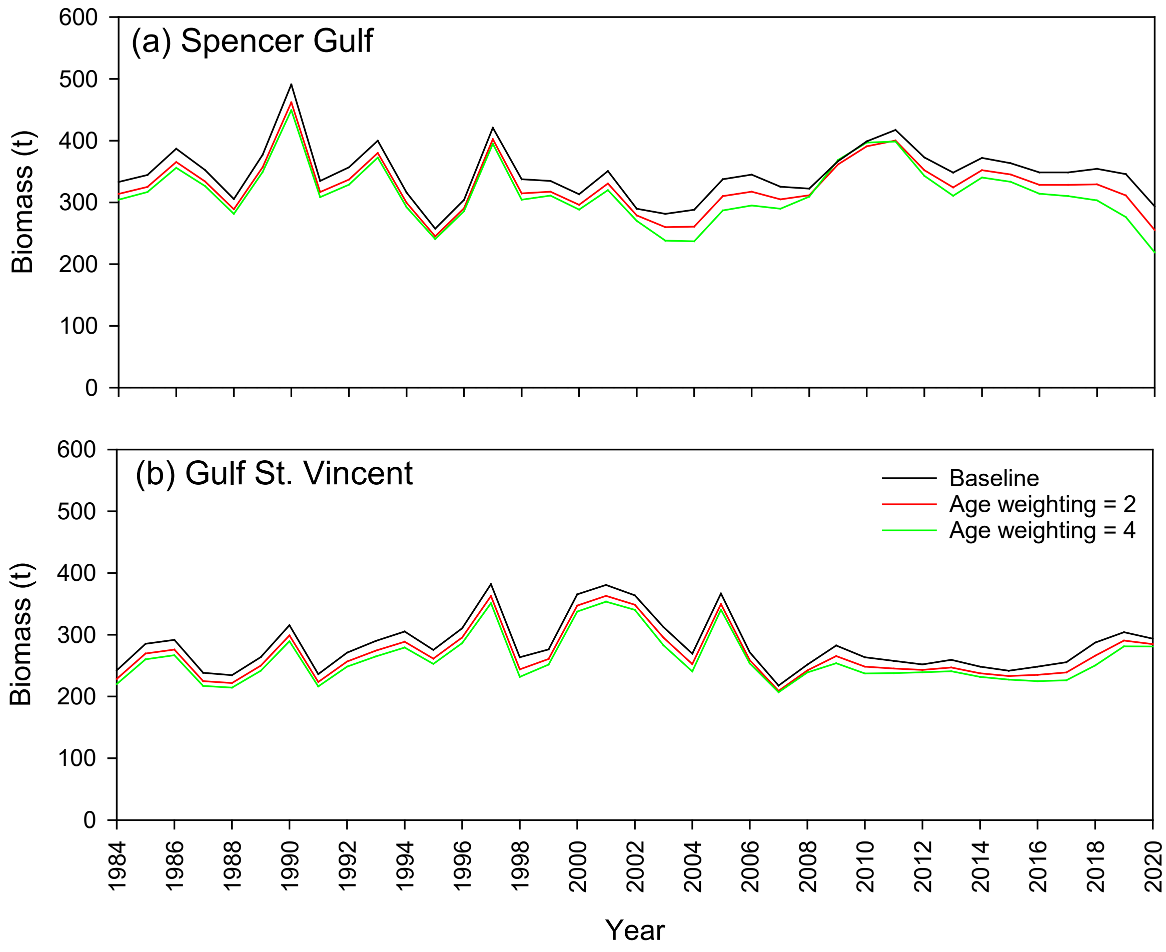

Figure 7-17. Plot of biomass by region from three runs of GarEst: the baseline (with age-sex weighting = 1), and two alternatives: age-sex weighting = 2 and age-sex weighting = 4.

7.8.4. Discussion

Sensitivity to M

The outcomes for both SG and GSV of absolute biomass level estimates decreasing with assumed lower natural mortality rate *M* were anticipated for single-region stock assessments as Garfish is in each gulf. We can explain this expectation intuitively as follows: The main source of data about mortality, age proportions, convey information only about total mortality rate, $Z = M + F$. Thus for any given age-inferred estimate of *Z*, if assumed *M* is lowered, the estimate of *F* is expected to increase. And since the model estimate of *B* is inferred approximately as $B = C/F$, for a given reported catch total C, B will decrease as the F proportion of biomass removed in $B = C/F$ increases.

Sensitivity to data source weighting

The low sensitivity to changes in the weighting of the age-sex catch proportions relative to catch totals and length moments in both regions is a positive indication that these data sources are mutually consistent. Increasing the relative influence of the age-sex composition data having little impact implies that those biomass estimates are correspondingly robust.