ESD risk assessment for ‘lesser known’ species to facilitate structural reform of South Australia’s commercial Marine Scalefish Fishery

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Abbreviations

B_{MSY}	Spawning stock biomass required to achieve the maximum sustainable yield
cMSY	Catch-only MSY models
CPUE	Catch per unit effort
ESD	Ecologically sustainable development
GSV	Gulf St. Vincent
H_{MSY}	Harvest fraction at MSY
IS	Investigator Strait
MFA	Marine Fishing Area
MSF	Marine Scalefish Fishery
MSFIS	Marine Scalefish Fishery information System
MSY	Maximum Sustainable Yield
NSW	New South Wales
PIRSA	Primary Industries and Regions SA
SA	South Australia
SARDI	South Australian Research and Development Institute
SG	Spencer Gulf
SGSV	Southern Gulf St. Vincent
SSG	Southern Spencer Gulf
TAC	Total Allowable Catch
TACC	Total Allowable Commercial Catch
WA	Western Australia

Executive Summary

Overview

A recent review of South Australia's Marine Scalefish Fishery (MSF) has indicated that the fishery is facing a number of issues that relate to complex and inefficient management arrangements that are ineffective at controlling fishing effort. These issues are serious enough to have compromised the profitability of fishing businesses and the sustainability of fish stocks. In response, a process has been initiated to implement a structural reform of the fishery. One particularly significant issue relates to the long-term reliance of the fishery on the three primary finfish species of King George Whiting, Snapper and Southern Garfish, which has compromised the status of a number of their stocks. The structural reform of the fishery provides an opportunity to implement strategies to divert fishing effort away from these primary species, and to diversify the fishery. However, this requires identifying other taxa that could support higher commercial catches. Achieving this would need to conform to the principles of ecologically sustainable development (ESD), particularly with respect to not compromising the demographic processes or stock sustainability of any taxa.

This project undertook to identify marine scalefish taxa that could sustainably support higher levels of commercial production. The methodological approach involved a number of operational steps that culminated in assessing biological and fishery data for a number of taxa. Of 111 different categories for which commercial fishery data are recorded from the catch returns of fishers, a total of 26 were chosen as candidate taxa for assessment. These were subjected to an assessment of the risk to population sustainability of increasing total catches by 25%, 50%, 100% and 200%. A risk assessment workshop concluded that for 13 taxa, any increase in fishery catch constituted too great a risk to population sustainability. These involved nine taxa of finfish, three species of sharks and the Southern Calamari. For these taxa, their biomass was considered too low and/or reproductive capacity not sufficient to cope with higher mortality rates. Alternatively, there were 13 other taxa that were considered capable of sustaining higher catches. These involved nine taxa of finfish, two species of sharks, as well as the *Octopus* spp. and also Sand Crabs.

For those taxa considered capable of supporting higher catches, the levels of stock biomass differed considerably. As such, the scale of potential increase in total catch would also differ, likely ranging between tonnes and hundreds of tonnes per year. A number of the finfish species are primarily taken with hauling nets. As such, a significant management impediment to increasing their catches is the extensive spatial netting closures. For other species for which specialised fishing gear is required, there are currently limits on the numbers of fishers and the numbers of gear that fishers are entitled to use. Achieving increases in catches would involve some challenges for fishery management and the commercial fishing sector. These pertain to easing fishing restrictions on some species without doing the same for fully exploited taxa. Furthermore, for most taxa, any increase in catch would need to be shared with the recreational sector. Also, for Ocean Jackets and Blue Mackerel, the bulk of the biomass is located in offshore waters outside of the gulfs, and so gearing up for appropriate fishing operations would be challenging.

Background

The MSF is South Australia's most complex fishery. As a consequence of its long history and development over many years, the commercial sector faces a number of issues that compromise the profitability of businesses and sustainability of fish stocks. One issue is that throughout its history there has been a reliance on the three primary finfish species of King George Whiting, Snapper, and Southern Garfish, which has led to the depletion of the biomass of a number of their stocks. Based on this and other significant issues, the fishery is undergoing a major structural reform. This structural reform provides an opportunity to implement measures to diversify the fishery. This would involve diverting fishing effort away from the compromised stocks of the primary species towards other taxa that are assessed as capable of supporting higher commercial production. Nevertheless, achieving this would need to conform to the principles of ESD. Overall, this strategy would facilitate the recovery of the stocks of the primary species and possibly increase the productivity and profitability of the commercial sector.

Objectives

The specific objectives addressed in this study were:

1. to assess the potential to diversify South Australia's Marine Scalefish Fishery by increasing production of currently lesser known species, whilst conforming to the principles of ecologically sustainable development;
2. to provide advice about the potential to increase fishery catch for individual species in the commercial MSF fishery, and to provide guidance in each case with respect to the need for further research, economic development and regulatory reform.

Methods

The methodological approach used in this project involved a number of significant operational steps. First, a comprehensive list of species available to the MSF was developed from the list of aquatic resources that are prescribed for the MSF under Schedule 1 of the *Fisheries Management (Marine Scalefish Fishery) Regulations 2017* and in the current Management Plan. This involved identifying the individual species that constitute the higher taxonomic categories that are listed in Schedule 1.

The assessment of taxa to support higher catches considered both fishery and biological data. Commercial fishery data from fishers' catch returns that are available in the Marine Scalefish Fishery information System (MSFIS), have been summarised for many taxa in the MSF stock status reports. Estimates of recreational catches were extracted from reports from State-wide recreational fishery surveys. For a number of taxa, a fishery modelling approach was undertaken to provide a comprehensive assessment of stock status using model-assisted, data-poor assessment methods.

The models used the estimates of commercial and recreational catches and basic life history information to generate estimates of fishery parameters and time-series of annual estimates of biomass and harvest fraction. Such outputs provided important insights into the performances, over time, of fisheries on the different taxa. Biological information was also collated, particularly relating to life history characteristics. This was achieved for 65 different species from >100 source documents. The life history characteristics were used to calculate estimates of 'population resilience', i.e. an estimate of the innate capacity of a species to increase in abundance and to cope with fishing pressure.

Candidate taxa were selected for assessment of their capacity to support higher catches, based on: (i) estimates of reported annual commercial catches from 2013 to 2017; and (ii) by excluding taxa whose fisheries were managed using specific management regulations to control catch. The 26 candidate taxa were subjected to a risk analysis that assessed their capacity to support higher catches. This qualitative process considered the biological and fishery information that included, when available, the outputs from catch-only models that estimate maximum sustainable yield. The risk assessment process considered the risk to population sustainability of increasing total catches by 25%, 50%, 100% and 200%. This was done in a workshop, which used predefined risk levels and a risk assessment matrix, based on assigning levels of consequence and likelihood. From the resulting levels of risk, a conclusion was drawn about whether a particular taxon was capable of sustainably supporting higher catches.

Finally, an industry workshop that involved representatives of the different sectors of the MSF considered those taxa that had been deemed capable of supporting higher levels of catch. The purpose here was primarily to gain a broader perspective for each taxon with respect to: (i) the regions and sectors of the fishery to which it most related; (ii) the current restrictions to its commercial catches; (iii) and any other matters that have not been considered.

Results

There are 111 different categories for which commercial fishery data are recorded in the MSFIS. Between 2013 and 2017, some commercial catch was reported for 74 of these categories (excluding the three primary finfish species). Then, 26 of these taxa were selected as candidates to assess their capacity to support higher catches. This was done at a risk assessment workshop.

From the risk assessment process it was concluded that for 13 taxa any increase in fishery catches constituted too great a risk for population sustainability. These taxa were: finfish - Bight Redfish, Black Bream, Bluethroat Wrasse, Flathead spp., Mulloway, Red Mullet, Silver Trevally, Yellowtail Kingfish, Yellowfin Whiting; elasmobranchs – Bronze Whaler and Dusky Sharks, Gummy Shark, School Shark; cephalopods – Southern Calamari. For these taxa, their biomass was either too low and/or their low levels of 'population resilience' meant that the reproductive capacity of the populations could not compensate for higher fishing mortality rates.

Alternatively, these remaining 13 taxa were considered capable of supporting higher catches: finfish - Australian Herring, Blue Mackerel, Leatherjackets, Ocean Jackets, Sea Sweep, Snook, Western Australian Salmon, Western Striped Grunter, and Yelloweye Mullet; elasmobranchs - Broadnose Shark, Whiskery Shark; cephalopods – Octopus; Crustaceans - Sand Crabs.

Implications

This study concluded that there were 13 taxa that could support higher catches. The levels of stock biomass differed considerably amongst these, and as such the scale of potential increase in total catch that could be supported would range from hundreds of tonnes per year for the Western Australian Salmon and Ocean Jackets to tens of tonnes per year for the other finfish species. There is uncertainty about the potential catches for *Octopus* spp. and Sand Crabs based on the potential for geographic expansion of their fisheries. Most of these taxa are shared with the recreational sector, and so any increases in catch would need to be shared with this sector.

Most of the 13 taxa are taken with hauling nets and so the current low commercial catches relate, at least partly, to the decline in the hauling net sector through the 2000s. So, a significant management impediment is the current extensive netting closures. For other species that require specialised fishing gear, there are currently limits on the numbers of fishers and the numbers of gear they are endorsed to use. Given these management restrictions, achieving increases in catches could be challenging in this multi-species fishery for both management and for the commercial fishers. The challenge for management is to ease restrictions on some taxa, without doing the same for fully exploited ones such as the primary finfish species. This also challenges the fishers with respect to how to further exploit some species without inadvertently increasing fishing pressure on others. Also, for the commercial sector, a further challenge, would relate to developing fishery operations in offshore waters for Blue Mackerel and Ocean Jackets. A final challenge for the industry as a whole relates to selling the higher volume of catch of a taxon without compromising its value. This is a complex issue that would require a multiplicity of considerations and a commitment from the whole-of-supply-chain to resolve.

Key words

Marine Scalefish Fishery (MSF), lesser known species, data-poor stock assessment models, population resilience, risk assessment.

1. General Introduction

1.1 Background

Despite its humble beginnings during the 19th Century, South Australia's Marine Scalefish Fishery (MSF) has developed into the State's most complex and challenging fishery (PIRSA 2013). It now involves several broad sectors that include a heterogeneous mixture of participants who can use a diverse range of fishing devices to target a diversity of species across a broad taxonomic range. For the commercial sector such complexity has contributed to numerous fishery-wide issues that significantly compromise the profitability of fishing businesses and sustainability of the fish stocks (Anon 2016). Profitability has declined since 2000/01 and has been low over the past 15 years. Recent rates of return to total boat capital have been very poor, with many licence holders making significant losses (BDO Econsearch 2019). With respect to fishery sustainability, the main issue relates to the fact that throughout its history, there has been a considerable but varying reliance on the three primary finfish species, i.e. King George Whiting (*Sillaginodes punctatus*), Snapper (*Chrysophrys auratus*) and Southern Garfish (*Hyporhamphus melanochir*) (Anon 2016, Steer *et al.* 2020). This targeting of fishing effort has ultimately culminated in depletion of the biomass of numerous stocks of these species, particularly those in Spencer Gulf (SG) and Gulf St. Vincent (GSV). Consequently, in recent years, various stocks of Snapper, King George Whiting and Southern Garfish have been assigned the stock classifications of either 'depleting' or 'depleted' (Fowler *et al.* 2014, 2016; Steer *et al.* 2016, 2018a, 2018b, 2020). In all cases, these situations have required significant, focussed, species-specific management responses. In late 2019, for Snapper, this culminated in the implementation of stringent, spatially-explicit fishery closures to be in place for three years (Fowler et al. 2020).

Based on considerable issues facing the MSF, the Marine Scalefish Strategic Review Committee strongly recommended that the fishery undergo significant structural reform in order to restore profitability of businesses and sustainability of fish stocks (Anon 2016). This broad recommendation has generally been accepted by the industry, government and broader community. To this end, in early 2019 the Commercial Marine Scalefish Fishery Reform Advisory Committee was established. To date, its activity has culminated in generating options for a reform strategy to transform the commercial fishery to become more vibrant and profitable (Anon 2019). The key features of this proposed strategy include: (i) rationalising the fleet; (ii) regionalising the fishery; (iii) and unitising access to the resource through well-defined, secure and transferable fishing rights. The development of such potential reforms has been underpinned by an understanding of the fleet dynamics and operational activities of the fishery provided by annual stock status reports (Steer *et al*. 2018a, 2018b, 2020), as well as analyses undertaken as part of the current FRDC project 2017/014.

The proposed structural reform of the MSF also provides a significant opportunity to consider ways to diversify the fishery in order to direct fishing effort away from the compromised stocks of the primary species. There are numerous and diverse taxa that can be legitimately taken by the commercial sector of the MSF (PIRSA 2013). Of these, it is likely that some are currently not fully exploited. Furthermore, there could be other species that are not currently permitted, but which may constitute potential commercial fishery resources. As such, there may be some fish species that could support higher commercial fishery production. If the commercial catches of such species could be increased and the products appropriately processed and marketed, this could contribute to increasing the overall productivity and profitability of the commercial sector of the fishery. Simultaneously, this could redirect fishing effort away from the primary target species and assist with recovery of their stocks. This current project has focussed on assessing the potential that some species could sustainably support higher catches than those taken recently, which could ultimately influence the profitability of individual MSF fishers.

Considering an increase in commercial fishery production for any species would need to conform to the principles of Ecologically Sustainable Development (ESD), primarily with respect to whether that fish species could support higher fishery production without compromising demographic processes or stock sustainability. This was the primary focus of this study. It involved a multi-step methodology whereby a number of candidate species were selected and then assessed for their capacity to support higher catches, based on their histories of commercial and recreational catches as well as their life history characteristics. The purpose of this study was not to consider the process of actually achieving such increases in productivity. That would be a complicated challenge that would require a whole-of-supply-chain approach, dependent on the participation of seafood businesses (Stephens 2017, Howieson *et al.* 2017). Topics that would need to be considered for any seafood product to achieve such increased productivity include; freight issues, product handling, processing, product development and value-adding, as well as marketing. Addressing the complex, multi-facetted approach required to achieve higher fishery productivity for any particular taxon was beyond the scope of this project.

1.2 Need

South Australia's MSF is faced with numerous issues that make its management difficult and challenging, causing considerable uncertainty for commercial fishers about the future of their industry. One issue relates to the poor stock status classifications recently assigned to the stocks of King George Whiting, Snapper and Southern Garfish. These reflect long-term targeting that has impacted on the levels of stock biomass, and it is recognised that the MSF must undergo significant structural reform to redress this and other issues. The Marine Scalefish Strategic Review Committee proposed a broad plan for overall structural reform by 2022. Such reform would provide opportunity to diversify the fishery in terms of target species, in order to: redirect fishing effort away from the compromised stocks of the primary species to facilitate their recoveries; and to increase overall MSF productivity and profitability.

There is a need to identify legitimate MSF species that are currently not fully exploited, as well as species that are not yet recognised as legitimate, but may be potential commercial fishery species. Any consideration of increasing fishery production for such species must conform to the principles of Ecologically Sustainable Development (ESD). There is a need to formally consider the potential barriers to enhancing production of these species from the perspectives of the environment, economics and governance. This will be addressed using an established risk assessment framework that is based on the National ESD Reporting Framework.

This project evolved from the discussions of the Marine Scalefish Strategic Review Working Group in order to provide direction for the strategic restructure of the MSF. For this purpose, it has been developed in association with FRDC Project 2017/014. Subsequently, the project has been discussed at several meetings of the Marine Fishers Association and with PIRSA Fisheries and Aquaculture (F&A).

1.3 Objectives

The specific objectives addressed in this study were:

1. to assess the potential to diversify South Australia's Marine Scalefish Fishery by increasing production of currently lesser known species, whilst conforming to the principles of ecologically sustainable development;

2. to provide advice about the potential to increase fishery catch for individual species in the commercial MSF fishery, and to provide guidance in each case with respect to the need for further research, economic development and regulatory reform.

2. Methods

The purpose of this project was to identify taxa that could potentially support higher levels of commercial production. It was undertaken as a sequence of operational steps. First, a comprehensive list of taxa that are available to commercial MSF fishers was developed. For many of these species biological information was collated. Then, from the new list of taxa, a number of candidate taxa were selected for assessment based on the recent histories of commercial catches. These were then considered in a risk assessment process at which risk ratings were assigned to different hypothetical percentage increases in catches. Then, those taxa that were suggested as capable of supporting higher catches were considered at an industry workshop, which involved participants from the different fishery sectors. Finally, the results from the various stages of this process were collated in this final report. Detailed descriptions of the methods used during these operational stages are presented below.

2.1 Updated list of taxa

A comprehensive list of the species and higher taxa that are available to the commercial sector of the MSF was developed based on several sources. Firstly, there was the list of aquatic resources that are prescribed for the MSF under Schedule 1 of the *Fisheries Management (Marine Scalefish Fishery) Regulations 2017* and in the current Management Plan (Table 2.1). Furthermore, the taxa identified in Schedule 1 were categorised in the Management Plan into the categories of 'primary', 'secondary', 'tertiary' and 'other', based on their importance to the fishery as determined from fishery productivity, commercial value, level of exploitation, variability in catches and reliability of catch estimates (PIRSA 2013). Finally, the development of the species list took into consideration the categories of taxa for which data are collected in the commercial MSF database (Marine Scalefish Fishery Information System), based on the monthly catch returns from commercial fishers. This process involved considering the higher level taxonomic groups that are identified in Schedule 1, such as for example 'the Flatheads' (Family Platycephalidae) and identifying the species that would contribute to the catches of such families in South Australia (SA), based on the distributions of the component species (Kailola *et al.* 1993, Gomon *et al.* 2008).

The various taxa in the new comprehensive species list were then classified to the categories of 'primary', 'secondary', 'tertiary' and 'other' based on the criteria summarised above. Furthermore, two new categories of species were also identified, i.e. species that are taken but not permitted, as well as species that the commercial sector have requested be included in Schedule 1, as they are by-catch species that are commonly caught.

Table 2.1. Aquatic resources prescribed for the Marine Scalefish Fishery under Schedule 1 of the *Fisheries Management (Marine Scalefish Fishery) Regulations 2017* (from PIRSA 2013).

Broad Taxonomic Group	Common name (Scientific name)
Annelids	Beachworm (Class Polychaeta)
	Bloodworm (Class Polychaeta)
	Tubeworm (Class Polychaeta)
Crustaceans	Blue Swimmer Crab (*Portunus armatus*)
	Sand Crab (*Ovalipes* spp)
	Velvet Crab (*Nectocarcinus tuberculosus*)
Molluscs	Southern Calamari (*Sepioteuthis australis*)
	Cockle (Suborder Teledonta)
	Cuttlefish (*Sepia apama*)
	Mussel (*Mytilus* spp)
	Octopus (*Octopus* spp)
	Oyster (Family Ostreidae)
	Scallop (Family Pectinidae)
	Gould's Squid (*Notodarus gouldi*)
Scalefish	Australian Anchovy (*Engraulis australis*)
	Barracouta (*Thyrsites atun*)
	Black Bream (*Acanthopagrus butcheri*)
	Cod of all marine species (Family Moridae)
	Dory (Family Zeidae)
	Flathead (Family Platycephalidae)
	Flounder (Family Bothidae or Pleuronectidae)
	Southern Garfish (*Hyporhamphus melanochir*)
	Bluespotted Goatfish (*Upeneichthys vlamingii*)
	Australian Herring (*Arripis georgianus*)
	Yellowtail Kingfish (*Seriola lalandi*)
	Leatherjacket (Family Monacanthidae)
	Pink Ling (*Genypterus blacodes*)
	Blue Mackerel (*Scomber australasicus*)
	Common Jack Mackerel (*Trachurus declivis*)
	Morwong (Family Cheilodactylidae)
	Mullet of all species (Family Mugilidae)
	Mulloway (*Argyrosomus hololepidotus*)
	Redfish (*Centroberyx affinis*)
	Bight Redfish (*Centroberyx gerrardi*)
	West Australian Salmon (*Arripis truttaceus*)
	Australian Sardine (*Sardinops sagax*)
	Snapper (*Pagrus auratus*)
	Snook (*Sphyraena novaehollandiae*)
	Southern Sole (*Aseraggodes haackeanus*)
	Sea Sweep (*Scopis aequipinnis*)
	Swallowtail (*Centroberyx lineatus*)
	Blue eye Trevalla (*Hyperoglyphe antarctica*)
	Trevally (Caranginae spp)
	Whiting (Family Sillaginidae)
	Bluethroat Wrasse (*Notolabrus tetricus*)
Sharks	Rays of all species (Class Elasmobranchii)
	Shark of all species (Class Elasmobranchii other than White Shark)
	Skate of all species (Class Elasmobranchii)

2.2 Consideration of fishery and biological data

2.2.1 Fishery Information

Individual taxa were assessed for their capacity to support higher catches based on fishery data from different sectors and biological data available for them. For the commercial sector, there is the MSFIS, a database that contains the data that are provided by licence holders on a monthly basis about their fishing activity. These data have been collected since 1984 and thereby constitute a 36-year dataset on commercial catch and effort and their spatial breakdown by Marine Fishing Area (MFA). For several species, annual estimates of State-wide commercial catch were available back to 1960, having previously been reconstructed from historical annual catch summaries. For the general recreational sector, there are estimates for many taxa of the numbers and total weights of catches at the State-wide and regional spatial scales available from a creel survey that was done through the period of 1994-96 (McGlennon and Kinloch 1997), and three telephone/diary surveys that were undertaken in 2000/01 (Henry and Lyle 2003, Jones and Doonan 2005), 2007/08 (Jones 2009), and 2013/14 (Giri and Hall 2015). There are also catch data available from the Charter Boat sector since June 2007 (Rogers *et al.* 2019). The annual commercial and recreational fishery data constitute the fundamental basis for the stock assessments of the primary species and for determination of stock status for the lower value taxa (Steer *et al.* 2018a, 2018b, 2020). The annual stock status reports for the MSF involve annual summaries of fishery statistics at several spatial scales. For this study, such summarised data for the different taxa were important considerations about future catch potential.

For some taxa, i.e. generally those that produced higher catches, a fishery modelling approach was undertaken to provide a more comprehensive assessment of stock status. This approach used catch-only models that estimate maximum sustainable yield (MSY). They are recognised as model-assisted, data-poor stock assessment tools (Martell and Froese 2013). Based on a time-series of estimates of total catch (i.e. combined across commercial and recreational sectors), as well as basic life history information, the modelling generated estimates of the fishery parameters of; MSY, the biomass required to support the MSY (B_{MSY}), and the harvest fraction of the B_{MSY} to provide the MSY (H_{MSY}). Furthermore, the modelling also provided estimates of the time-series of biomass and harvest fraction. The cMSY models were applied for numerous different taxa. Their outputs provided insights into how each fishery had performed over time in terms of total annual productivity, thereby providing a basis for assessing the potential to support higher catches in the future.

The cMSY models determined MSY through a Schaefer production model (Schaefer 1954), which is assisted by a stock reduction analysis (Walters *et al.* 2006). The parameters *r* (intrinsic rate of population increase) and *K* (carrying capacity) were determined through this process and then used to estimate MSY as:

$$MSY = \frac{rK}{4}$$

Appropriate levels of *r* and *K* were determined using the stock reduction analysis, which applied pairs of these parameters to a Schaefer production model using catch data:

$$B_{t+1} = B_t + rB_t\left(1 - \frac{B_t}{K}\right) - C_t$$

where B_t is the biomass at time *t* and C_t is the catch at time *t*.

The stock reduction analysis simulated the stock biomass using catch data and pairings of *r* and *K* determined from priors. The analysis then kept all successful pairings of *r* and *K* by determining if a population simulation either led to an extinction outcome (which is implausible if the species was still being caught) or if the population increased exponentially beyond what is biologically reasonable. The successful pairings of *r* and *K* were then summarised as means and 95% quantiles and were used to determine MSY. With information on catch, predicted biomass and MSY, the estimates of B_{MSY} and H_{MSY} were then calculated. The disadvantage of the cMSY approach is that, as it relies solely on catch data, it can only successfully be applied when population responses to exploitation are evident in the catch history. Since the catch history for a species reflects the influences of many factors, not just that of the fishery on the population, the resulting estimates of population parameters in terms of stock dynamics should be interpreted cautiously.

The use of cMSY models to calculate population and fishery parameters, requires estimates of time-series of total catches, not just the commercial catches. As such, for each of the taxa considered in this way, time series of recreational catches were developed based on the estimates of State-wide recreational catches from recreational fishery surveys that were done in 1995/96 (McGlennon and Kinloch 1997), 2000/01 (Jones and Doonan 2005), 2007/08 (Jones 2009) and 2013/14 (Giri and Hall 2015). From these surveys, the recreational harvest weight for a particular species and year was calculated from the number of fish harvested multiplied by the average legal individual fish weight. For the years between surveys, estimates of recreational catches were estimated using linear interpolation. For the estimates of recreational catches for the years following the last survey in 2013/14 (Giri and Hall 2015), the estimates were determined from the linear relationship between the estimates in 2007/08 and 2013/14 (based on linear regression), projected forward to 2017. For the years prior to the first survey in 1995/96, recreational harvest was estimated as a proportion of South Australia's population. For each taxon, annual estimates of recreational catch were added to those for commercial catch and the resulting estimates of total catch were used as the key input variable for the cMSY model.

There were a number of taxa that were considered in detail, for which cMSY modelling was not done. For a number of these, there was inadequate information available on catches, whilst for others the understanding of life history was limited. To consider the status of the stocks for these species, those State-wide commercial fishery statistics that were available from 1984 to 2018 were considered. Furthermore, the estimates of catches from the recreational surveys were also reported here for comparison with the commercial catches. In these cases, it was not considered necessary to interpolate the estimates of recreational catch for the intervening years between surveys.

2.2.2 Life History Information

In order to assess the capacity for individual species to support higher catches, biological information for individual species was also considered. For numerous species that were identified in the new comprehensive list of taxa, estimates of life history parameters were gleaned from the literature. The primary parameters of interest were: maximum length (L_{max}); longevity (A_{max}); size at which 50% of females attained sexual maturity (L_{50}); age at which 50% of females reach maturity (A_{mat}); and the von Bertalanffy growth constant (k). The estimates of these parameters for the different species are presented in Appendix 3. These parameter estimates were sourced from >100 documents that included; 12 FRDC final reports, 12 stock assessments from the South Australian Research and Development Institute (SARDI), five reports from the Commonwealth Scientific and Industrial Research Organisation, four reports from Western Australian Fisheries, 12 Status of Australian Fish Stock assessments, 37 journal articles, six Masters and PhD theses, as well as government websites of the New South Wales Department of Primary Industries, the Victorian Fisheries Authority and the Australian Fisheries Management Authority (Appendix 4). For the collation of such life history information, preference was given to using the most recent parameter estimates that were collected in closest geographic proximity to the area of operation of the MSF. Also, for some species the databases from market sampling of commercial catches in SA were used to provide updated estimates of A_{max}. Ecological information on aggregation behaviour and habitat preference were collated and scaled.

After collation of the life history parameters, estimates of 'population resilience' were calculated using the approach of Cheung *et al. (*2007). This is an estimate of the innate capacity of a species to increase in abundance, which thereby provides a quantitative measure of its ability to cope with fishing pressure. Since the MSF species include a broad range of taxa and life history characteristics that range from large-bodied, '*K*'-selected species to small, short-lived, '*r*'-selected ones, their 'resilience' to fishing pressure would cover a broad range. A quantitative species-vulnerability model was used to allocate species to groups by degrees of association, based on parameter estimates for the different sets of traits (Cheung *et al.* 2005, 2007). The model classified species into categories based on sets of traits and ecological characteristics, an approach that has been used to assess the relative 'resilience' of a diversity of species supporting other fisheries (Cheung *et al.* 2007). Sets of logical rules were used to estimate the degree of membership into categories, to calculate 'resilience' to fishing using life-history parameters, information on species spatial behaviour, and geographic range. An index score was calculated with a scale from 1 – 100, where species with scores of 100 were most resilient to fishing pressure. Spatial behavioural strength was attributed to species using the following bounds; low = ≤ 40, moderate = 41 to 60, high = 61 to 80, very high = 81 to 100 (40 for aggregations up to 30 individuals, and 80 for larger schools) (following Pitcher *et al*. 2002; Chueng 2007). Models were run using simplified Visual Basic Routines in MS Excel. The distance of ≤3 nautical miles was the cut-off distance to assign the species distribution parameters as 'coastal' or 'offshore' (shelf and gulf waters, respectively). Other information was also collated, including: information on current assessment strategies (e.g. State-based, single-species or jurisdiction-wide assessments); seasonal and spatial management restrictions that impact particular species or species groups; potential susceptibility to fishing gear types currently endorsed in the MSF; and current habitat restrictions that may impact the resilience of species to additional fishing.

The species for which life history information could be collected were also assigned to the life history classifications of Winemiller and Rose (1992). This assignment was done qualitatively based on the estimates of life history traits as well as the output from a hierarchical cluster analysis (package 'hclust') in R version 3.4.2. These life history classifications were: (i) 'opportunistic strategists' that are species such as small pelagic finfish species and squid that are generally small, rapidly maturing, and have short to medium longevity; (ii) 'intermediate strategists' are species with intermediate size and strategies within the continuum between periodic and opportunistic strategists; (iii) 'periodic strategists' are generally large, highly fecund species with long life spans; (iv) 'equilibrium strategists' are species such as sharks and rays that are characterised by large body sizes and exhibit extended gestations, and produce low numbers of large, well-developed offspring. The life history classifications were used to inform the cMSY models.

2.3 Risk assessment to identify species

For a taxonomic group, i.e. either a species or a number of confamilial species to be considered as capable of supporting higher catches means that recent fishery production has been less than the potential maximum sustainable productivity. An approach was used here whereby different taxa were subjected to a risk analysis to determine whether they fitted into this category. The approach took into consideration the biological and fishery information as well as, when available, the parameter outputs from the cMSY modelling. For each taxon, the risk assessment addressed the question – 'could the stock support a higher level of production, whilst minimising the risk of recruitment overfishing?' Here, a qualitative assessment was done where the risk to the population was assigned for different scenarios of increases in total catch, considering the possible impacts on population processes. The risk level was determined using the Risk Assessment Matrix (Table 2.2), which assigned the level of risk based on an assessment of the consequence and likelihood levels (Appendix 5). The risk levels were assigned to hypothetical increases in total catch of 25%, 50%, 100% and 200%. A conclusion was reached about the capacity for a taxon to support higher catches based on the resulting levels of risk.

The risk assessment process was undertaken for 26 different taxa in a workshop that involved a number of fishery managers and fishery scientists. These taxa had been initially selected based on the estimates of reported annual commercial catches through the five-year period of 2013 to 2017. They were those for which: the annual commercial catches through this period exceeded 1 $t.yr^{-1}$; and which are also not considered in fisheries that are managed using specific regulations to control catch, such as for example, the various cockle fisheries for which management is based on a total allowable commercial catch (TACC). For those taxa for which cMSY modelling had been done, the risk assessment considered the risk of increasing the current catch by considering the current biomass, harvest fraction, the MSY, B_{MSY} and H_{MSY}. For those taxa for which such modelling was not done the risk assessment was primarily based on the trends in; the catches by the different sectors, and commercial catch rates, as well as the information available on life history and population resilience.

Table 2.2. Risk Level Matrix used in the risk assessment related to increasing catches of MSF fish species. The risk level relates to the Consequence and Likelihood levels (refer Appendix 5).

Consequence × Likelihood Risk Matrix		Likelihood			
		Remote (1)	Unlikely (2)	Possible (3)	Likely (4)
Consequence	Minor (1)	Negligible	Negligible	Low	Low
	Moderate (2)	Negligible	Low	Medium	Medium
	High (3)	Low	Medium	High	High
	Major (4)	Low	Medium	Severe	Severe

2.4 Lesser Known Species Workshop

The outcomes from the risk assessment workshop were risk ratings that were assigned to the different levels of increases in catch for each of the 26 candidate species. This identified those species for which there was some potential for increasing total catches. Following this, an industry workshop was held that involved the fishery managers from PIRSA F&A as well as representatives from the different sectors of the Marine Scalefish Fishery. Using the insights of representatives of the different fishery sectors, the aims of the workshop were to identify: (i) the geographic region(s) of SA waters for which the species was most relevant; (ii) the sectors of the MSF that would benefit from any increase in catch; (iii) the potential barriers or inhibitors for fishery catches; (iv) and any management impediments to fishery catches.

Around the time of the Lesser Known Species Workshop, PIRSA F&A was in the process of developing a strategy regarding lesser known species as well as a promotional strategy. This had involved establishing the Lesser Known Species Reference Group that included members of the commercial, recreational, and charter boat fishing sectors as well as fish processors and retailers. As it was desirable that the different industry sectors be represented at the Lesser Known Species Workshop, the members of this reference group as well as other industry representatives were invited to participate in the workshop. The workshop was held on the 20th February 2020 at the South Australian Aquatic Sciences Centre. The details regarding the agenda, invitees, attendees and outcomes are presented in Appendix 6. The workshop also provided the opportunity for industry representatives to propose other species for consideration of their capacity to support higher levels of productivity.

3. Results

3.1 Updated list of taxa

The species list for the commercial sector of the MSF that is currently available in Schedule 1 in the *Fisheries Management (Marine Scalefish Fishery) Regulations 2017* and in the current Management Plan (PIRSA 2013) was updated to provide a more comprehensive list of species (Table 3.1). Whereas in Schedule 1 some taxa were identified only to the taxonomic level of 'family' (Table 2.1), in the new list the individual species for most of these families that contributed to the fishery in SA were recognised. This was the case for: four species of trevally (Carangidae); 11 species of wrasse (Labridae); eight species of flathead (Platycephalidae); six species of cod (Moridae): 2 species of dory (Zeidae); and 12 species of flounder (Bothidae and Pleuronectidae). This process also assigned the different species or taxonomic groups to one of the four categories of 'primary', 'secondary', 'tertiary' and 'other', based on their relative significance in terms of total production and value to the fishery (PIRSA 2013). At the end of Table 3.1, there are also listed several species that are currently taken in the fishery but were not previously listed in Schedule 1, including several species of Flounder, Sole and the Weedy Whiting. The table also recognises six species that commercial licence holders have requested be placed on the species list, as they are common by-catch species.

Table 3.1 identifies the broad taxonomic range of species that can be legitimately taken by MSF fishers. Nevertheless, to date, the commercial catch and effort data have not necessarily been recorded at this low taxonomic level. Historically, in the reporting of their fishing activity the commercial fishers have not differentiated amongst the different species of trevally, wrasse, flathead, cod, dory and flounder. As such, the data for these species groups have been recorded in the MSFIS at the taxonomic grouping of family. It is envisaged that this will continue in the future until the fishers are trained to differentiate amongst the different species.

Table 3.1. Updated species list for the commercial sector of the Marine Scalefish Fishery.

Category	Common name (family)	Component species	Scientific name
Primary	King George Whiting		*Sillaginodes punctatus*
	Snapper		*Chrysophrys auratus*
	Southern Garfish		*Hyporhamphus melanochir*
	Southern Calamari		*Sepioteuthis australis*
Secondary	Vongole spp		*Katylesia* spp.
	Yellowfin Whiting		*Sillago schomburgkii*
	Australian Herring		*Arripis georgianus*
	Snook		*Sphyraena novaehollandiae*
	Mullet spp.		
	(Mugilidae spp.)	Sea Mullet	*Mugil cephalus*
		Jumper Mullet	*Liza argentea*
		Sand Mullet	*Myxus elongatus*
		Yelloweye Mullet	*Aldrichetta forsteri*
	Bronze Whaler and	Bronze Whaler Shark	*Carcharhinus brachyurus*
	Dusky Sharks	Dusky Shark	*Carcharhinus obscurus*
	Sand Crabs		*Ovalipes australiensis*
	Blue Swimmer Crabs		*Portunus armatus*
	Western Australian Salmon		*Arripis truttaceus*
Tertiary	Trevally	Silver Trevally	*Pseudocaranx georgianus*
	(Carangidae spp.)	Skipjack Trevally	*Pseudocaranx wrighti*
		Samson Fish	*Seriola hippos*
		Yellowtail scad	*Trachurus novaezelandiae*
	Ocean Jackets		*Nelusetta ayraudi*
	Leatherjackets	Horseshoe Leatherjacket	*Meuschenia hippocrepis*
	(Monacanthidae spp.)	Sixspine Leatherjacket	*Meuschenia freycineti*
		plus 17 other species	
	Gummy Shark		*Mustelus antarcticus*
	School Shark		*Galeorhinus galeus*
	Wrasse	Bluethroat Wrasse	*Notolabrus tetricus*
	(Labridae spp.)	Blackspotted Wrasse	*Austrolabrus maculatus*
		Western Blackspot Pigfish	*Bodianus vulpinus*
		Castelnaue's Wrasse	*Dotalabrus aurantiacus*
		Snakeskin Wrasse	*Eupetrichthys angustipes*
		Purple Wrasse	*Notolabrus fucicola*
		Striped Rainbow Wrasse	*Suezichthys bifurcatus*
		Brown Spotted Wrasse	*Notolabrus parilus*
		Senator Wrasse	*Pictilabrus laticlavius*
		Rosy Wrasse	*Pseudolabrus psittaculus*
		Foxfish	*Bodianus frenchii*
	Black Bream		*Acanthopagrus butcheri*
	Redfish spp.		
		Red Snapper	*Centroberyx gerrardi*
		Swallowtail	*Centroberyx lineatus*
	Yellowtail kingfish		*Seriola lalandi*
	Cuttlefish spp.	Giant Australian Cuttlefish	*Sepia apama*
	Octopus spp.	Unknown in SA	*Octopus spp*
	Scallop spp.		
		King Scallop	*Pecten fumatus*
		Queen Scallop	*Equichlamys bifrons*
		Doughboy Scallop	*Mimachlamys asperrima*
	Razorfish		Centriscidae
Other	Flathead spp.	Toothy Flathead	*Platycephalus aurimaculatus*
	(Platycephalidae spp.)	Southern Sand Flathead	*Platycephalus bassensis*
		Deepwater Flathead	*Platycephalus conatus*
		Dusky Flathead	*Platycephalus fuscus*
		Rock Flathead	*Platycephalus laevigatus*
		Tiger Flathead	*Platycephalus richardsoni*
		Southern Bluespotted Flathead	*Platycephalus speculator*
		Tasselsnout Flathead	*Platycephalus cirronasa*
	Sea Sweep		*Scorpis aequipinnis*

Category	Common name (family)	Component species	Scientific name
	School Whiting		*Sillago flindersi (Family Sillagindae)*
	Bluespotted Goatfish	Red mullet	*Upeneichthys vlamingii*
	Cod of all species	Red Cod	*Pseudophycis bachus*
	(Moridae spp.)	Finetooth Beardie	*Eeyorius hutchinsi*
		Largetooth Beardie	*Lotella rhacina*
		Bearded Rock cod	*Pseudophycis barbata*
		Bastard Red Cod	*Pseudophycis breviuscula*
		Grenadier Cod	*Tripterophycis gilchristi*
	Barracouta		*Thyrsites atun*
	Flounder *spp*	Bass Strait Flounder	*Arnoglossus bassensis*
	(Bothidae spp.)	Small eye Flounder	*Arnoglossus micrommatus*
		Mueller's Flounder	*Arnoglossus muelleri*
		Crested Flounder	*Lophonecters gallus*
	(Pleuronectidae)	Greenback Flounder	*Rhombosolea tapirina*
		Spotted Flounder	*Ammotretis lituratus*
		Longsnout Flounder	*Ammotretis rostratus*
		Shortfin Flounder	*Ammotretis brevipinnis*
		Elongate Flounder	*Ammotretis elongatus*
		Largescale Flounder	*Ammetretis macrolepis*
		Banded-fin Flounder or Spotted Flounder	*Azygopus pinnifasciatus*
		Derwent Flounder	*Taratretis derwentensis*
	Morwong spp.	Dusky Morwong	*Dactylophora nigricans*
	(Cheilodactylidae)	Blue Morwong	*Nemadactylus douglasii*
		Queen Snapper	*Nemadactylus valenciennesi*
		Jackass Fish	*Nemadactylus macropterus*
		Magpie Perch	*Cheilodactylus nigripes*
		Redlip Morwong	*Cheilodactylus rubrolabiatus*
	Blue Mackerel		*Scomber australasicus*
	Jack Mackerel		*Trachurus declivis*
	Gould's Squid		*Nototodarus gouldi*
	Mussels		*Mytilus galloprovincialis*
	Worm spp.	Beach worms	*Australonuphis teres*
	(Tubificidae)	Bloodworms, Seaweed Worms, Annelids	
	Western Striped Grunter		*Pelates octolineatus*
	Southern Sole		*Aseraggodes haackeanus*
	Pink Ling		*Genypterus blacodes*
	Dory spp.	John Dory	*Zeus faber*
	(Zeidae)	Mirror Dory	*Zenopsis nebulosa*
	Maray		*Etrumeus teres*
	Blue Sprat		*Spratelloides robustus*
	Sandy Sprat		*Hyperlophus vittatus*
	Mulloway		*Argyrosomus japonicus*
	Velvet Crab		*Nectocarcinus tuberculosus*
	Blue-eye Trevalla		*Hyeroglyphe antarctica*
	Australian Anchovy		*Engraulis australis*
	Sharks of all species except White Shark (protected)		Class Elasmobranchii
	Skates of all species		Class Elasmobranchii
	Rays of all species		Class Elasmobranchii
Taken	Flounder	Large-toothed Flounder	*Pseudorhombus arsius*
but not	(Paralichthyidae)	Small-toothed Flounder	*Pseudorhombus jenynsii*
permitted	Sole (Soleidae)	Duskbanded Sole	*Zebrias penescalaris*
	Cynglossidae	Southern Tongue Sole	*Cynoglossus broadhursti*
	Weedy Whiting		*Haletta semifasciata*
Requested	Silver Drummer		*Kyphosus sydneyanus*
MSF	Rock Crab		*Nectocarcinus itegrifons*
species	Spider Crab spp.		Family Majidae
	Harlequin fish		*Othos dentex*
	Sergeant Baker		*Latropiscis purpurissatus*
	Conger Eel		*Conger verreauxi*

3.2 Consideration of fishery and biological data

3.2.2 Life history parameters and population resilience

There were sufficient life history information available to estimate 'population resilience' for 65 different species of finfish, elasmobranchs and molluscs that are taken in the MSF (Appendix 3). The estimates of 'population resilience' covered the broad range from 10 to 60.4, and varied considerably according to life history strategy (Fig. 3.1). There were eight species of 'opportunistic strategists' that had the highest resilience levels that ranged from 48.5 to 60.4. The 26 species of 'intermediate strategists' also had relatively high resilience levels that were in the range from 27.9 to 51.0. Resilience estimates for the 19 species of 'periodic strategist' were considerably lower, i.e. ranged from 15.8 to 35.8. Finally, the 12 species of 'equilibrium strategists' were all elasmobranchs that had the lowest estimates of population resilience, ranging from 10 to 32.0.

3.2.3 Fishery Information

The fishery information for MSF species are summarised comprehensively in the annual stock status reports (Steer *et al.* 2018a, 2018b, 2020), and so are not repeated here. The following results are those used for the selection of the candidate species that were considered in the risk assessment workshop.

The selection of candidate species to assess for capacity to support higher catches was based on the commercial fishery data (MSFIS), which have been recorded for 111 different taxonomic categories. From this database, annual catch data were extracted for the five-year period of 2013 to 2017. There were 34 taxa for which no catch data were recorded for this period, which consequently excluded them from further consideration. The remaining 77 taxa included the three primary species of King George Whiting, Snapper and Southern Garfish, which were also excluded from this selection process. This left a total of 74 different categories for consideration (Fig. 3.2). The estimates of average annual catches for these varied from several hundred tonnes for Southern Calamari and Western Australian Salmon down to <1 $t.yr^{-1}$ for numerous taxa. Since those taxa that produced <1 $t.yr^{-1}$ are unlikely to support sufficient biomass to sustain other than incidental catches, this group of 32 categories was also excluded from further consideration. For the remaining taxa, which produced annual catches of >1 $t.yr^{-1}$, there were some for which catch is managed through specific regulations such as a TACC or with specific spatial management arrangements. Furthermore, there were higher taxonomic groupings for which component species were unknown, such as the categories called 'Sharks and Rays' or 'Other Sharks'. These two latter groups were also excluded from further consideration.

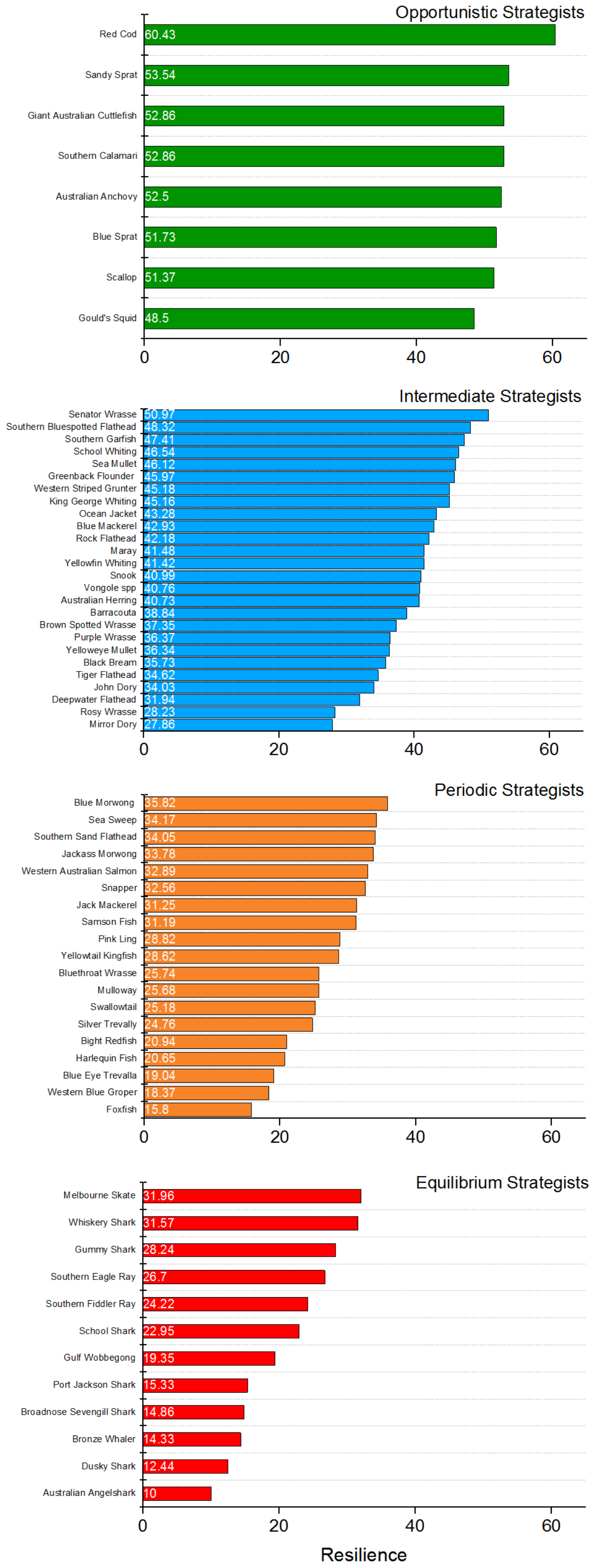


Fig. 3.1. Estimates of ‘population resilience’ and life history categories to which MSF species were assigned.

Overall, there remained 26 taxa for which to assess their potential to support higher catches. These included: 15 species of finfish and two finfish families (Leatherjackets and Flatheads); five species of sharks; two Cephalopod taxa, (Southern Calamari and *Octopus* spp.); as well as the Sand Crab, the single species of Crustacean. Two of these species produced catches of >250 t.yr^{-1}, and a further three species produced >100 t.yr^{-1} (Fig. 3.2, Table 3.2). There were two taxa of sharks and one species of crab that produced from 50-100 t.yr^{-1}. Six species of finfish, one shark species, and the *Octopus* species, produced 10-50 t.yr^{-1}. Eight finfish, two shark species and the Cuttlefish species produced <10 t.yr^{-1}.

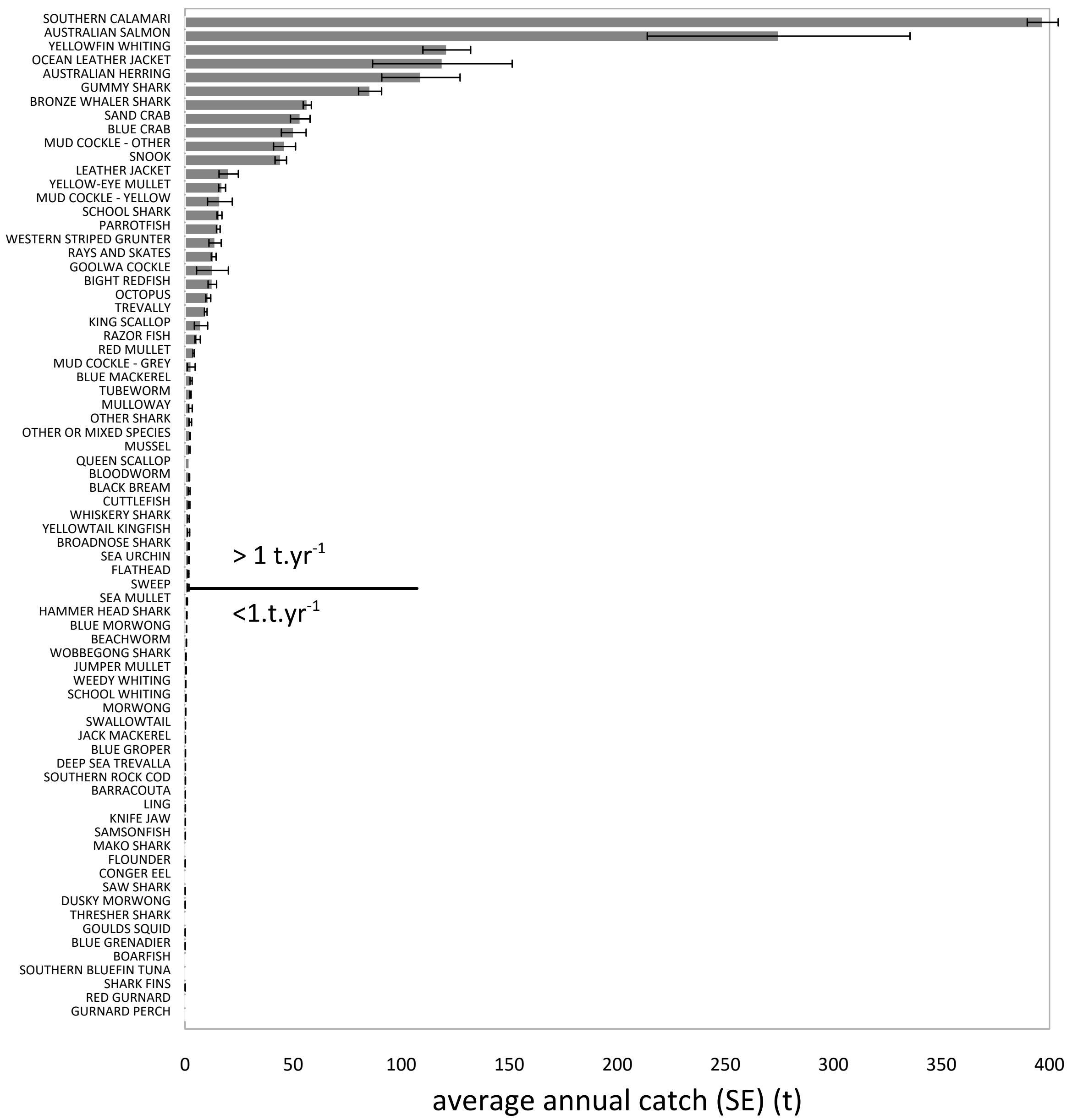


Fig. 3.2. Ranked estimates of average annual catches (+SE) based on commercial fishery data collected from 2013 to 2017. The division between taxa around the average catch of 1 t.yr^{-1} is indicated.

Table 3.2. Identification of taxonomic groups that produced average annual commercial catches between 2013 and 2017 of >1.0 $t.yr^{-1}$, based on data from the MSFIS. Data show the average (±SE) reported commercial catch through the five year period.

Broad Taxonomic Group	Common name	Ave. annual catch 2013-17 (±SE) (t)
Finfish	Western Australian Salmon	274.6 (60.8)
	Yellowfin Whiting	121.1 (11.0)
	Ocean jackets	119.0 (32.3)
	Australian Herring	109.1 (18.1)
	Snook	44.3 (2.7)
	Leatherjackets (excl. Ocean jackets)	20.2 (4.5)
	Yelloweye Mullet	17.1 (1.6)
	Bluethroat Wrasse	15.3 (0.8)
	Western Striped Grunter	13.9 (2.9)
	Bight Redfish	12.6 (2.0)
	Trevally	9.5 (0.6)
	Red Mullet	4.0 (0.4)
	Blue Mackerel	2.8 (0.5)
	Mulloway	2.4 (0.9)
	Black Bream	1.9 (0.4)
	Yellowtail Kingfish	1.6 (0.5)
	Flathead (family)	1.5 (0.2)
	Sweep	1.4 (0.3)
Sharks	Gummy Shark	85.6 (5.3)
	Bronze Whaler & Dusky Shark	56.5 (1.9)
	School Shark	15.9 (1.1)
	Whiskery Shark	1.6 (0.4)
	Broadnose Shark	1.6 (0.2)
Cephalopods	Southern Calamari	396.9 (7.2)
	Octopus spp.	10.7 (1.1)
Crustaceans	Sand Crabs	53.3 (4.5)

3.3 Risk assessment for identifying 'lesser known' species

For a total of 13 different taxa, the cMSY Model was applied to the time series of total catches (Sections 3.3.1 – 3.3.13). The resulting output data, as well as the fishery statistics and biological information were considered in the risk assessment process. For a further 13 taxa, cMSY modelling was not done so that the risk assessment was based only on fishery and biological data. The taxon-specific summaries for each are presented below (Sections 3.3.14 – 3.3.26).

3.3.1 Australian Herring *(Arripis georgianus)*

This is a small finfish species that is distributed between Western Australia (WA) and Victoria (Steer *et al.* 2020). There is a single stock across this broad distribution that is sustained from spawning grounds in southern WA, and the eastward transport of larvae to the eastern edge of the distribution. The juveniles and adults form pelagic schools over a range of habitats in nearshore waters. They can live up to about 12 years of age.

In SA, the species is broadly distributed in coastal waters and is abundant throughout the gulfs. Because of its schooling nature, it is particularly susceptible to the hauling net sector of the MSF (Steer *et al.* 2020). As such, catches have historically been highest in the northern gulfs. The species is targeted or taken as by-product when primary species are targeted. The commercial catches have declined since 2005, reflecting the reduction in hauling net effort associated with the restructure of the hauling net fishing sector. Targeted catch rates are highly variable, possibly reflecting variation in targeted effort (Steer *et al.* 2020). In late 2019, the status of SA's component of the biological stock was classified as **sustainable**, based on relatively low recent catches, low targeted effort and no long-term trend in catch rates (Steer *et al*. 2020). The estimates of recreational catch are considerable, i.e. 297 t in 2000/01 (Jones and Doonan 2005), 93 t in 2007/08 (Jones 2009), and 157 t in 2013/14 (Giri and Hall 2015).

For the assessment based on the cMSY models, estimates of total catch were developed for the period from 1960 to 2017 (Fig. 3.3A). These were highest between 1980 and 2006, declining between 2002 and 2017. The estimates of biomass increased through the 1960s and 1970s, but then declined from the 1980s to the early 2000s (Fig. 3.3B). Since 2006, the estimated biomass has been gradually increasing. In 2017, the estimated catch of ~180 t was considerably lower than the MSY of ~350 t (Fig. 3.3D). Nevertheless, in the same year the total biomass was estimated to be ~1,000 t, which was considerably lower than the B_{MSY} of 1,581 t. With harvest fraction declining and biomass increasing, the risk assessment suggested there was a medium risk to sustainability of increasing catch by either 25% or 50%. The risk to sustainability then increased to high and severe with 100% and 200% increases in catch, respectively. Overall, this suggests a marginal capacity to increase total catch.

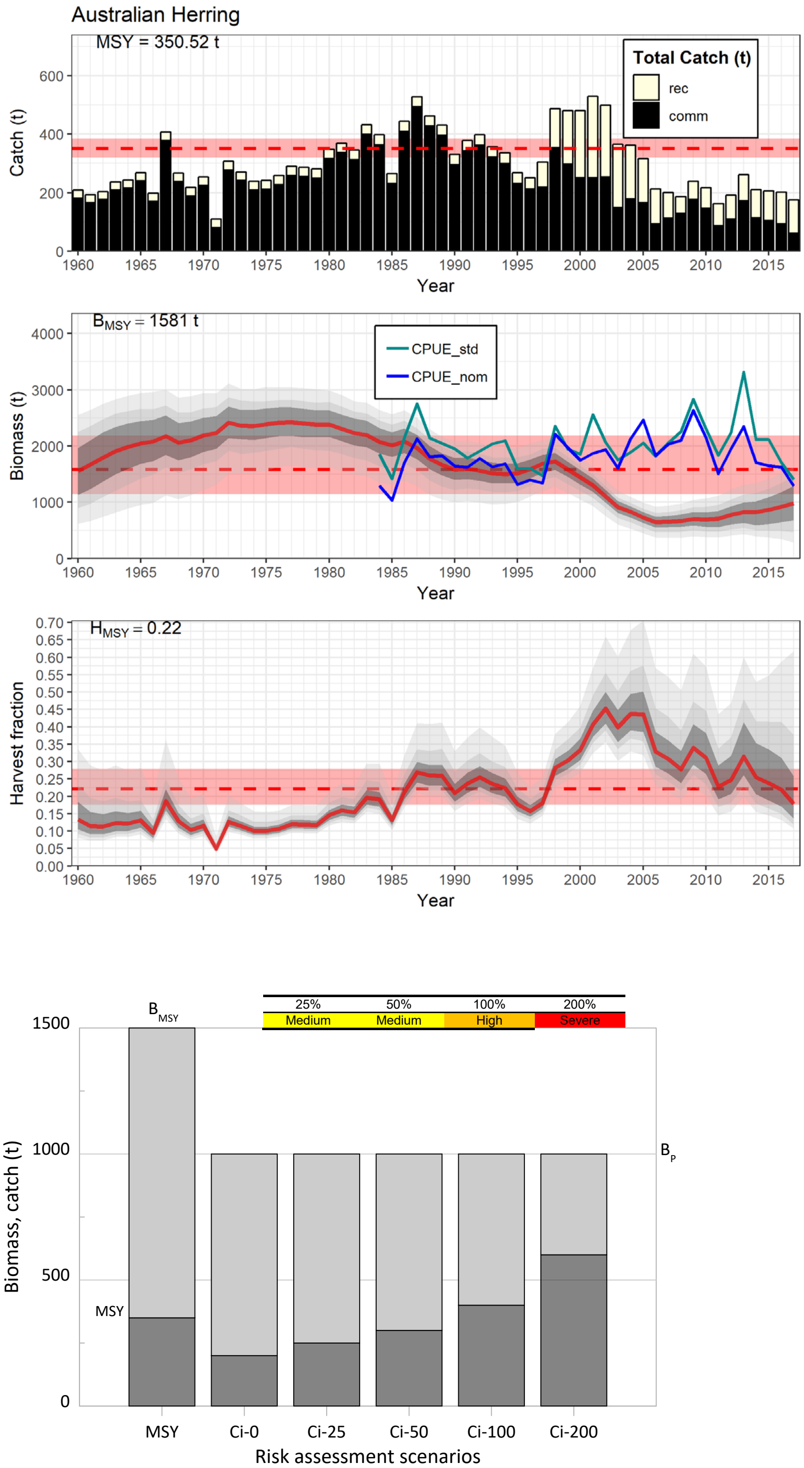


Fig. 3.3. Summary of results from the cMSY modelling and risk assessment for Australian Herring. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.2 Western Australian Salmon (*Arripis truttaceus*)

These are medium-large, stream-lined fish that form large schools in the coastal waters of southern Australia from southern WA to Victoria and around Tasmania (Gomon *et al.* 2008). They constitute a single stock that depends on spawning in the waters of south west WA (Steer *et al.* 2020). The larvae are transported eastward by the Leeuwin Current, facilitating recruitment into bays along the southern mainland coastline.

In SA, MSF fishers have taken Western Australian Salmon using a variety of nets including hauling nets, gill nets and purse seine nets. From 1984, the commercial catches were highest up to the early 2000s. As net fishing effort declined through the 1990s and 2000s, so did the commercial catches (Steer *et al*. 2020). In 2019, based on the medium-level catches throughout the 2000s, and stable catch rates, the status of SA's component of the biological stock was classified as **sustainable** (Steer *et al.* 2020). The Western Australian Salmon is an important recreational fishery species in SA for which the estimated recreational harvests throughout the 2000s have declined from 372 t in 2000/01 to 91 t in 2007/08 and 56.2 t in 2013/14 (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015).

For the cMSY modelling, the estimates of total catch were developed for the period of 1960 to 2017 (Fig. 3.4A). Those from the 1960s to the mid-1990s were dominated by the commercial sector. This reflects the particularly low estimate of recreational catch of only 17 t in 1994/95 (McGlennon and Kinloch 1997). The estimates of total catch from 1967 to 2001 were the highest, particularly during the 1960s and early 1970s. Total catch declined considerably from 2003 to 2013, but has subsequently increased from 2014 onwards. Based on output from the cMSY model, the recent estimate of annual catch of ~400 $t.yr^{-1}$ is still considerably lower than the estimated MSY of 665 $t.yr^{-1}$ (Fig. 3.4B). The trend in estimated biomass declined from the late 1960s to 2005, but then increased considerably to 2017. Nevertheless, the recent estimate of biomass of ~5000 t was considerably lower than the B_{MSY} of 7,043 t. As the drop in total catch from 2003 to 2013 was due to operational changes, i.e. declining net fishing effort, rather than to a decline in biomass, it is likely that the cMSY results are conservative, and the recent estimates of biomass are under-estimates. With the trend in these estimates increasing and harvest fraction relatively low, it was considered that there is only a medium risk associated with increasing catch by 25% (Fig. 3.4D). However, the risk level increased to high with a 50% increase in catch and eventually to severe for a 200% increase. This provides opportunity for a marginal increase in catch.

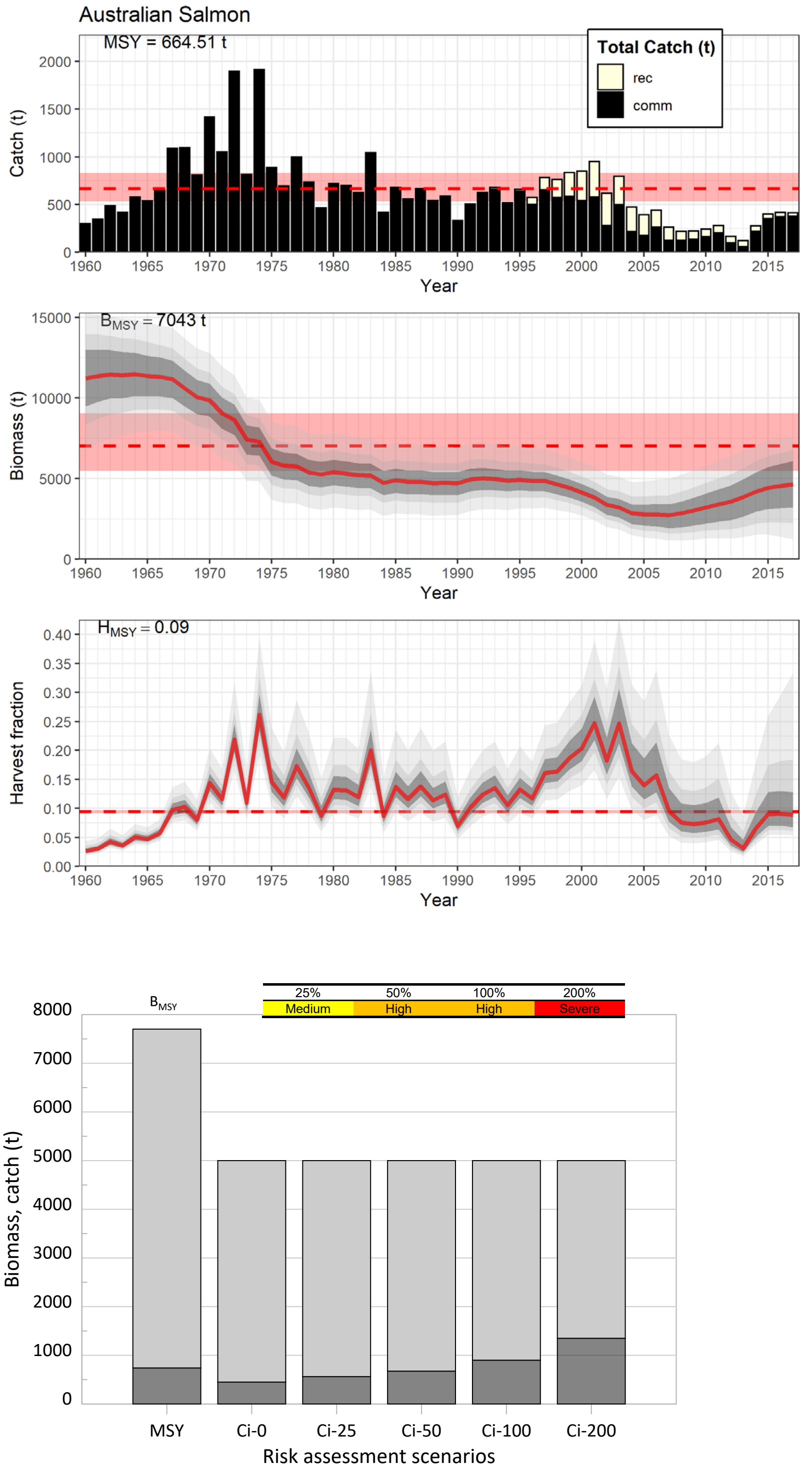


Fig. 3.4. Summary of results from the cMSY modelling and risk assessment for Western Australian Salmon. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.3 Southern Calamari (*Sepioteuthis australis*)

The Southern Calamari is a short-lived cephalopod species with fast growth, a sub-annual life-span and fast turn-over of individuals (Steer *et al.* 2020). As such, it has a relatively high 'population resilience' estimate of 52.8 and is an 'opportunistic strategist'. It is broadly distributed across southern Australia from WA to Queensland, including around Tasmania. In SA, the juveniles and adults occur in shallow, inshore waters, whilst the sub-adults are in offshore waters to a depth of ~70 m. The regional adult abundance patterns vary seasonally associated with water clarity, driven by wind patterns that influence the suitability of the shallow seagrass beds as spawning grounds.

For the MSF, Southern Calamari became an important target species towards which fishing effort was directed away from the primary finfish species in the 1980s and 1990s. The adults are now targeted by commercial, charter and recreational fishers on the inshore spawning grounds, whilst the juveniles and sub-adults are taken as by-catch by commercial prawn trawlers in the deeper waters of the gulfs. Southern Calamari are vulnerable to capture by fishers from all sectors using squid jigs and also by commercial fishers using hauling nets. At the State-wide level, the commercial catches have been relatively stable near their maximum level since the early 2000s (Steer *et al.* 2020). Catches have been considerably higher in the northern and southern parts of both gulfs, than the south east region or the west coast of Eyre Peninsula. The stock status is assigned at the State-wide level, and was recently determined to be **sustainable**, based on relatively stable high commercial catches and catch rates (Steer *et al.* 2020). Nevertheless, there have been some recent indications of localised depletion, particularly in both the northern and southern parts of SG, suggesting regional impacts on sustainability. These are likely to be a consequence of the increase in fishing pressure. Southern Calamari is also an important recreational species for which the estimates of catches are 83 t in 1994/95 (McGlennon and Kinloch 1997), 423 t in 2000/01 (Jones and Doonan 2005), 206 t in 2007/08 (Jones 2009) and 430 t in 2013/14 (Giri and Hall 2015).

Estimates of total annual catch, reflecting combined commercial and recreational catches, were developed for the period of 1984 to 2017 (Fig. 3.5A). Whilst the commercial catches increased up to 2000 and showed no subsequent long-term trend, the estimates of total catch declined from 2001 to 2008, before increasing subsequently. Except for 2016 and 2017, the estimates of total catch tracked lower than the MSY estimate of 900 t. The annual estimates of biomass have generally been higher than the B_{MSY} level, whilst the estimates of harvest fraction have been below the H_{MSY} level (Fig. 3.5B,C). Whilst these model outputs suggest that there is some opportunity for a marginal increase in catch of Southern Calamari, nevertheless, the concerns about localised depletion (Steer *et al.* 2020), resulted in the assignment of a high risk to sustainability even for a 25% increase in total catch and severe risks associated with higher increases in total catch (Fig. 3.5D).

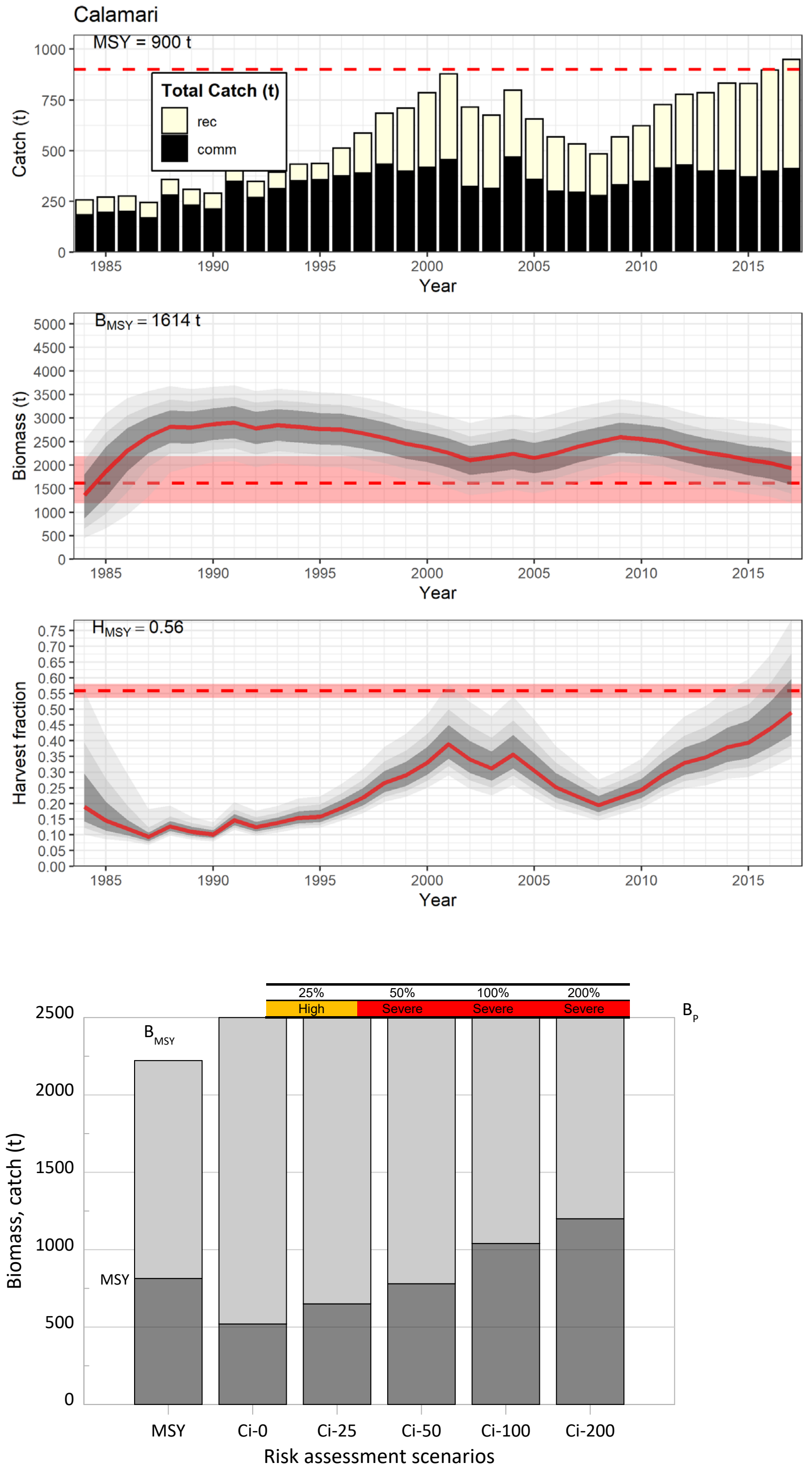


Fig. 3.5. Summary of results from the cMSY modelling and risk assessment for Southern Calamari. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.4 Leatherjackets

In SA, the generic term 'Leatherjackets' refers to a suite of 19 different species of the family Monacanthidae, excluding the Ocean Jackets (*Nelusetta ayraudi*). Their catches are likely to be dominated by the Horseshoe Leatherjacket (*Meuschenia hippocrepis*) and the Sixspine Leatherjacket (*M. freycineti*) (Steer *et al.* 2020). The Leatherjacket species are taken by line by both the commercial and recreational sectors of the MSF as well as with hauling nets by the commercial sector. They are predominantly taken as by-product when more valuable species are targeted. The State-wide commercial catches were highest during the 1990s, lower through the 2000s, before increasing again between 2016 and 2018. These trends in catch largely related to the changes in hauling net fishing effort. The fishery was recently assigned the status of **sustainable**, based on recent moderate levels of catch and effort as well as high catch rates.

Estimates of annual total catch were developed for the period of 1990 to 2017, and were strongly influenced by the commercial catches (Fig. 3.6A). The recent catches in 2016 and 2017 were 46 t and 38 t, respectively, which were lower than the estimate of MSY of 54 t. Furthermore, the estimated recent biomass of 280 t was considerably lower than the B_{MSY}, whilst the recent harvest fraction approximates the H_{MSY} (Fig. 3.6B,C). These figures suggest that there is little capacity for increasing fishery catches. As such, a medium risk was assigned to an increase of 25% in catch, whilst high and severe risks were associated with 50% and higher increases (Fig. 3.6D).

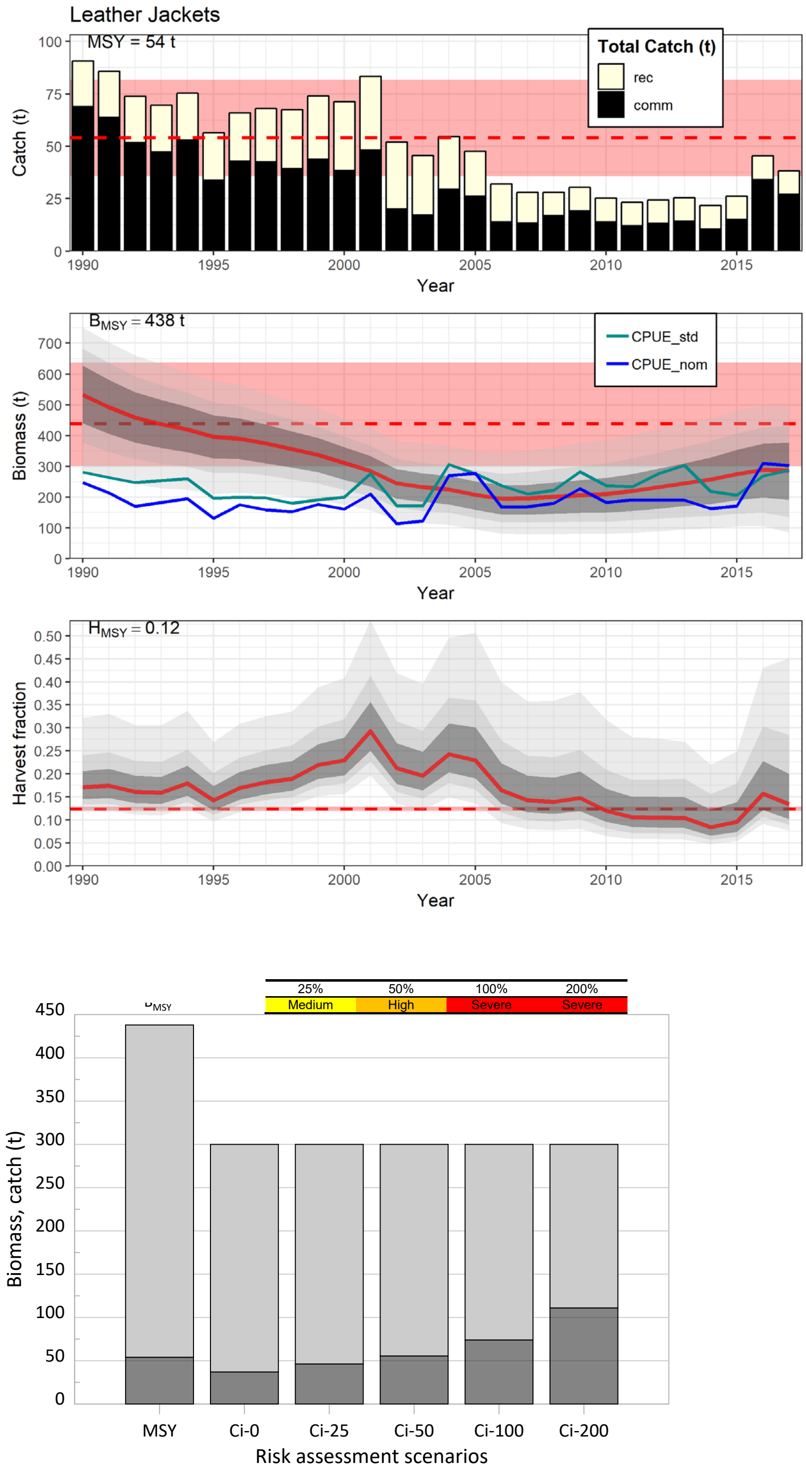


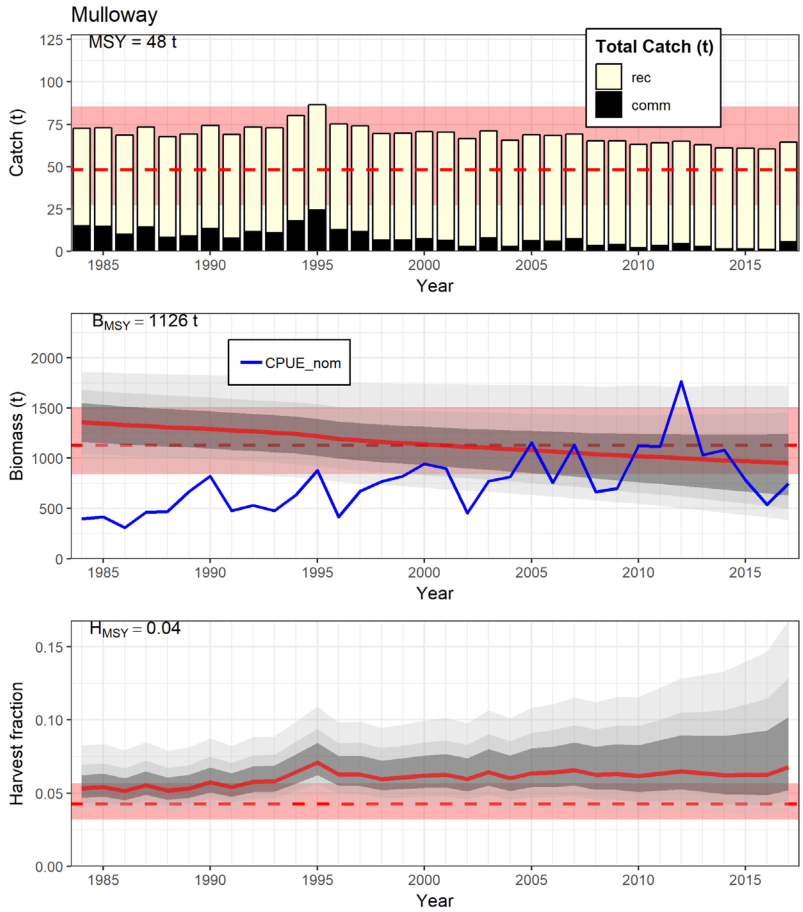
Fig. 3.6. Summary of results from the cMSY modelling and risk assessment for Leatherjackets. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.5 Mulloway (*Argyrosomus japonicus*)

Mulloway is a large, schooling species of finfish that occurs throughout sub-tropical to temperate regions of the Atlantic, Pacific and Indian Oceans. The Australian distribution ranges southward from North West Cape, WA to the Burnett River, Queensland, excluding Tasmania (Kailola *et al.* 1993). The juveniles are often abundant in estuaries, whilst the adults are predominantly found in nearshore, coastal waters including the surf zone and around the mouths of rivers (Griffiths 1997). This is a late-maturing species that can attain a maximum age of 42 years, and maximum length of 200 mm TL (Ferguson *et al.* 2014). Consequently, it has the relatively low 'population resilience' estimate of 25.7, and was classified as a 'periodic strategist' (Fig. 3.1). For SA, regional differences in otolith morphology and chemistry and genetic characteristics that suggest there are separate stocks between the eastern and western coasts (Ferguson *et al.* 2014, Barnes *et al.* 2015).

In SA, most of the commercial catch of Mulloway involves juveniles that are taken in the Lakes and Coorong Fishery. The commercial catch taken outside of the Coorong by the MSF has always been relatively low, and taken using setnets, fishing rods and handlines. Through the 1980s and 1990s, the annual commercial MSF catches of Mulloway ranged from <10 to 20 $t.yr^{-1}$, but throughout the 2000s have been consistently lower at <10 $t.yr^{-1}$ (Steer *et al*. 2020). These declines reflect significant reductions in fishing effort with setnets and handlines. Nevertheless, catch rates have shown no long-term trends suggesting that it is unlikely there has been a significant reduction in fishable biomass. As such, in 2019, based on commercial fishery statistics of the MSF, Mulloway was classified as **sustainable**. For the recreational sector, the Mulloway is an iconic target species that contributes a significant proportion of the total catch. The State-wide recreational catches have declined from 90 t in 2000/01 to 62 t in 2007/08 and 60 t in 2013/14 (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015).

The estimates of total catch of Mulloway by the MSF have generally been <75 $t.yr^{-1}$ (Fig. 3.7A). They were relatively consistent from 1984 to 1997, after which they have slowly declined. They have been dominated by the recreational sector, whose contribution in recent years has been >90% of the total catch. The estimates of total catch have always been consistently higher than the estimate of MSY. Furthermore, the estimates of biomass from the model have declined slowly over time and since 2000 have fallen below the B_{MSY} level of 1,126 t (Fig. 3.7B). Also, the estimates of harvest fraction have always exceeded the H_{MSY} of 0.04 (Fig. 3.7C). These model outputs suggest that the population is already fished harder than is sustainable. As such, this suggests that there is a high risk of increasing catch by 25%, and a severe risk for any higher increase (Fig. 3.7D).



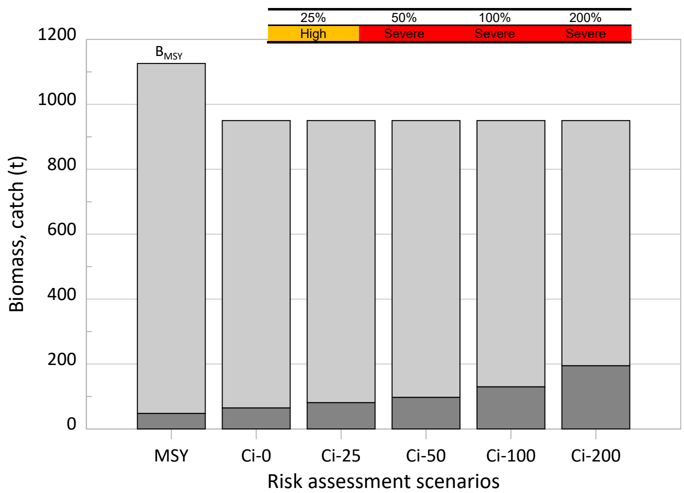


Fig. 3.7. Summary of results from the cMSY modelling and risk assessment for Mulloway. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.6 Ocean Jackets (*Nelusetta ayraudi*)

The Ocean Jacket is a relatively large, demersal schooling species of Leatherjacket that has a broad distribution throughout the waters of southern Australia from central Queensland, across the southern continental shelf and up to the central coast of WA (Kailola *et al.* 1993). The species occupies a wide depth range from very shallow coastal waters to >350 m depth, associated with offshore movement during ontogenetic development (Steer *et al.* 2020). As such, the adults are located in continental shelf waters of >60 m depth. The stock structure throughout the broad distribution is unknown. The species is fast-growing and short-lived, based on fish ageing from rings in vertebrae. As such, it has a high population resilience estimate of 43.3.

Because the adults are located in deep, offshore waters, the fishery is essentially a commercial one. A specialised trap fishery developed quickly during the 1980s as commercial catches and effort increased considerably through this period. They reached their highest levels in the early to mid-1990s, as regulations were introduced to control the expansion of the fishery (Steer *et al.* 2020). Total commercial catch and effort declined between 1991 and 2000 before stabilising for several years. The considerable decline that occurred in 2006 was associated with a reduction in fishing effort. Subsequently, commercial catches have remained at relatively low levels. Estimates of CPUE have been variable, but nevertheless show no long-term trends. On the basis of these fishery statistics the fishery was classified as **sustainable** in 2019.

The cMSY modelling work was based on the estimates of annual commercial catches, which declined between 1991 and 2006, and have subsequently remained relatively low (Fig. 3.8A). During the 1990s, the catches were considerably higher than the estimate of MSY of 433 t but since 2006 have been much lower than the MSY. The estimated biomass declined considerably between 1990 and 2006, but has since increased considerably back towards the B_{MSY} estimate of 2,537 t (Fig. 3.8B). This, along with estimates of harvest fraction since 2007 being consistently lower than the estimated H_{MSY}, suggests that there is capacity for increasing total catch (Fig. 3.8C). The risks to sustainability of increasing total catches by 25 and 50% were deemed to be negligible and low, respectively, but increased to high and severe with more significant increases in catch, associated with the removal of higher proportions of the standing stock (Fig. 3.8D).

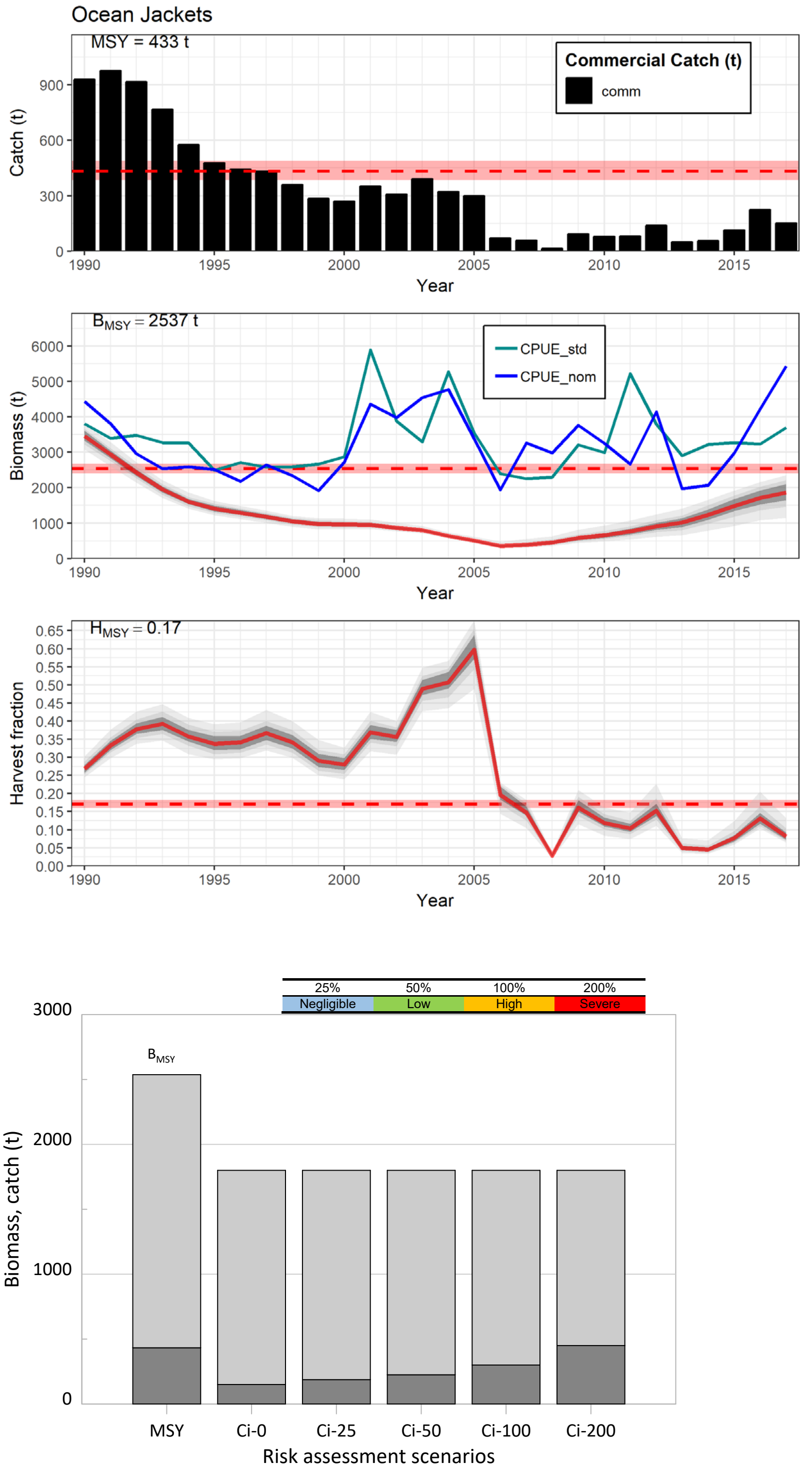


Fig. 3.8. Summary of results from the cMSY modelling and risk assessment for Ocean Jackets. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.7 *Octopus* spp.

There has been a commercial fishery for *Octopus* spp. in SA since at least 1984. However, until recently there has been a poor understanding about the species composition of these catches as well as the population ecology and life histories of the contributing species. *Octopus* spp. are generally short-lived with life-spans of one or two years (Reid 2016). They are terminal spawners, which means that they reproduce once and then die. Some species are holobenthic, i.e. they produce hundreds of large eggs that hatch into well-developed, benthic young, whilst others are merobenthic, producing thousands of pelagic planktonic larvae. A recent study has determined that of the five *Octopus* spp. that are taken in commercial fisheries across southern Australia, the catches in SA are dominated by *Octopus berrima* and *O. pallidus* (Martino and Doubleday 2020). Both appear to conform to the holobenthic life history. Because of the uncertainty until recently about species composition taken in the fishery, it was not possible to estimate 'population resilience'. Nevertheless, given the similarity to the life history characteristics of Southern Calamary, they are likely to have a relatively high resilience.

The total catches of the several *Octopus* spp. in SA have been dominated by those from the commercial sector. The catches increased from 1984 and peaked in 2008 (Fig. 3.9A). From 2010 to 2017, they have been variable, but generally below the MSY of 15 t. Nevertheless, the catch in 2017 was similar to the estimate of the MSY. The time series of estimates of biomass have generally been above the B_{MSY} of 32 t, whilst the harvest fraction has generally been below the H_{MSY} level (Fig. 3.9B,C). The data suggest that there is considerable capacity to increase the total catch. A risk level of low was assigned for a 25% increase in catch, a medium risk for each of 50 and 100% increases and high for a 200% increase (Fig. 3.9D).

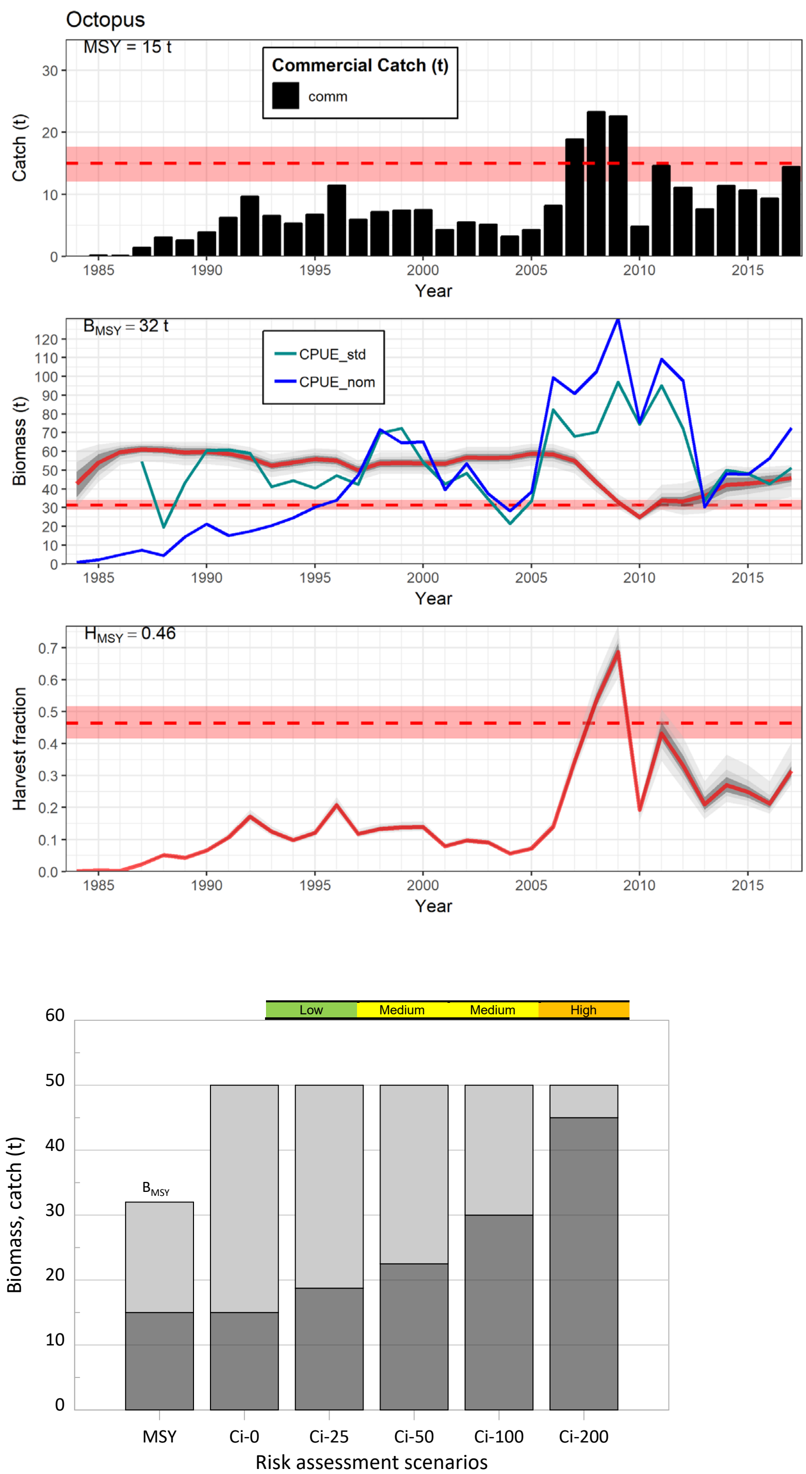


Fig. 3.9. Summary of results from the cMSY modelling and risk assessment for *Octopus* spp. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.8 Bluethroat Wrasse (*Notolabrus tetricus*)

There are a number of temperate wrasse species (Family: Labridae) that occur in SA waters (Gomon *et al.* 2008). As such species are generally associated with shallow, near-shore reef habitats they are particularly vulnerable to line-fishing. The commercial catches of this guild of species are generally reported as and recorded in the MSFIS as ‘parrotfish’. Nevertheless, since the Bluethroat Wrasse is the largest and most abundant species of wrasse of this region, it is likely that it has historically dominated the fishery catches (Steer *et al.* 2020). This species is distributed throughout south eastern Australia, i.e. the coastal waters of NSW, Victoria, Tasmania, extending as far west as central SA. It occupies algal beds and reefs throughout the depth range of 0 – 50 m. Bluethroat Wrasse are highly territorial and display long-term residency of their home ranges. This strong site fidelity is associated with a complex social structure and reproductive biology. The adult males only originate through sex change, and then defend territories which include harems of females that have overlapping home ranges. Such complex social and reproductive strategies complicate managing the fishery due to concerns about localised depletion and the need to maintain sufficient males in the population to ensure reproductive output (Shepherd *et al.* 2010). Due to this and the fact that the adults are relatively long-lived (Saunders *et al.* 2010), they have a relatively low ‘population resilience’ of 25.7. The species was categorised as a ‘periodic strategist’.

For the commercial sector, Bluethroat Wrasse are targeted in a small fishery for the fresh or live market in Sydney or are captured as by-product when other species are targeted. It is not a prized target species for the recreational sector, but is generally taken as by-catch, which can result in a high discard rate. The estimates of commercial catch and effort have declined since 2012, whilst the CPUE has declined since 2000 (Steer *et al.* 2020). The recent estimates are considerably lower than the high values recorded through the peak period of the early 2000s, but still remain higher than during the 1980s and 1990s. The recent declines were not sufficient to change the stock status which was retained as **sustainable**.

The estimates of total catch were relatively flat from 1984 to 1996, increased substantially to the peak in 2001, before decreasing to a lower level from 2006 to 2017 (Fig. 3.10A). The estimates of catch from 1997 to 2017 were considerably higher than the estimated MSY of 13 t. As such, the estimates of biomass declined from 1997 onwards and by 2017 were substantially lower than the B_{MSY} estimate of 334 t (Fig. 3.10B). Furthermore, over the same period, the estimated harvest fractions were above the H_{MSY} value of 0.04 (Fig. 3.10C). These model outputs suggest that there is no capacity to increase the total catch. The low population resilience of this species suggests that the management approach should be conservative. As such, the risk assessment identified that there is a high risk of increasing total catch by even 25%, with severe risks associated with higher increases in catch (Fig. 3.10D).

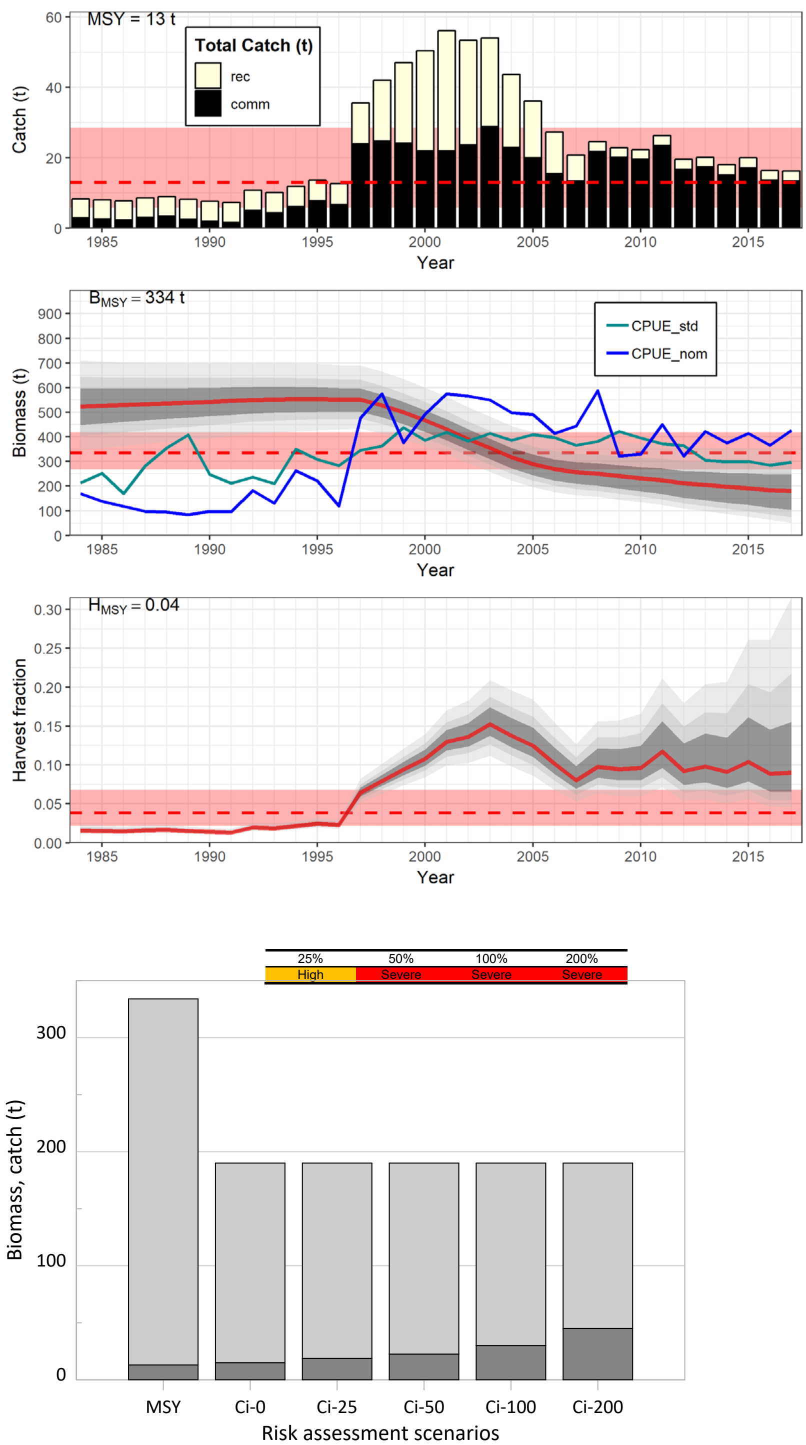


Fig. 3.10. Summary of results from the cMSY modelling and risk assessment for Bluethroat Wrasse. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.9 Sand Crab (*Ovalipes australiensis*)

The Sand Crab is a medium-sized crab species with a broad distribution across southern Australia from Wide Bay in Queensland to Rottnest Island, WA, including Tasmanian waters (Kailola *et al.* 1993). The stock structure throughout this broad distribution is unknown. In SA, Sand Crabs occur in most inshore waters except the northern gulfs and west coast bays, where Blue Crabs are most abundant (Jones 1985).

The commercial fishery for Sand Crabs developed and remains concentrated in Coffin Bay, although there has been some expansion outside of the bay particularly into southern SG (Steer *et al.* 2020). Commercial fishers require a specific licence endorsement to target Sand Crabs and have restricted numbers of crab nets/pots. The annual commercial catches have varied cyclically, ranging from 23 t to the record level of 177 t in 2005, but have since declined to a much lower level (Steer *et al.* 2020). This cyclical variation in catch appears to relate to three peaks in targeted fishing effort. The targeted catch rate has been variable but nevertheless demonstrated a long-term increase. Based on these data, in 2019 SA's Sand Crab fishery was classified as **sustainable**. There is also a recreational fishery for Sand Crabs where fishers use hoop or drop nets from jetties along the southern metropolitan Adelaide coastline and from small vessels in southern coastal waters. Sand Crabs contributed to a total crab catch across different species of 29 t in 2000/01 (Jones and Doonan 2005). Catches of Sand Crabs were estimated to be 11 t and 10 t, respectively in 2007/08 and 2013/14 (Jones 2005, Giri and Hall 2015).

The annual total catches of Sand Crabs have been variable and dominated by those from the commercial sector (Fig. 3.11A). The periodic high catches that were taken between 1989 and 1991 and then from 1999 to 2006, generally exceeded the MSY of ~105 t. The catches have declined since 2005 and have fallen below the MSY. The estimates of biomass declined through the 1980s, 1990s and 2000s until 2006, and have subsequently remained below the B_{MSY} of 443 t (Fig. 3.11B). As such, the estimates of harvest fraction throughout the 2000s, have been relatively high (Fig. 3.11C). Even though recent catches have been low, the relatively low recent biomass and high harvest fractions suggest that there is limited capacity for an increase, particularly in Coffin Bay. If there was geographic expansion of the fishery than there would be a low risk of increasing catches by 25 – 50%. The risks would increase to medium and high for 100% and 200% increases in total catch (Fig. 3.11D).

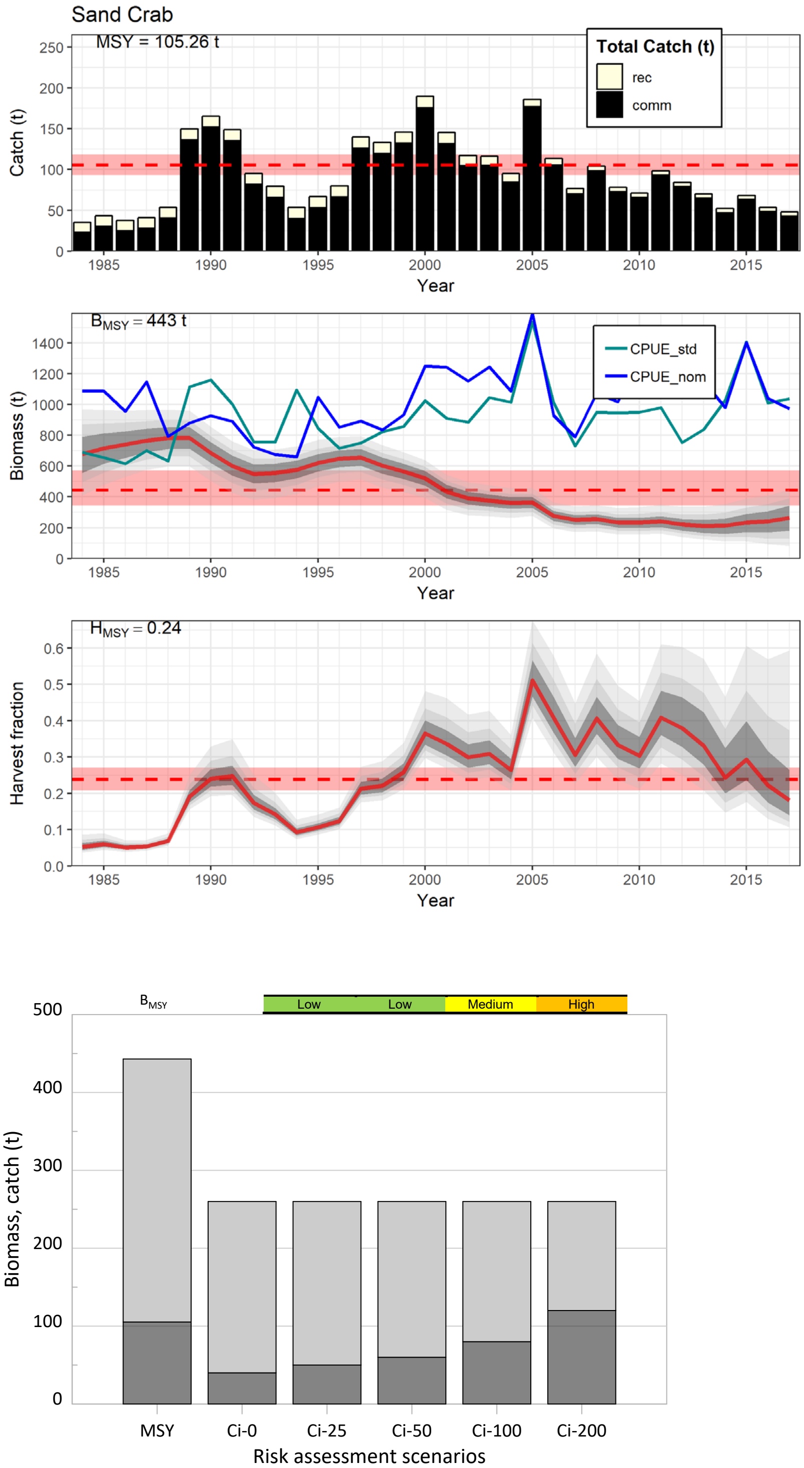


Fig. 3.11. Summary of results from the cMSY modelling and risk assessment for Sand Crabs. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.10 Snook (*Sphyraena novaehollandiae*)

This species has a broad distribution across southern Australia from Perth in WA to Sydney in NSW, including around Tasmania, and also New Zealand (Gomon *et al.* 2008). There is little information on stock structure throughout this broad Australasian distribution. Snook occur in surface waters over seagrass beds and kelp reefs in inshore and offshore waters (Emery *et al.* 2016). They are fast-growing and relatively short-lived, with the oldest fish aged in SA being 12 years (O'Sullivan and Jones 2003). Based on these life history characteristics, the species was classified as an intermediate strategist with an estimated 'population resilience' of 41.0.

In SA, Snook are taken by both the commercial and recreational sectors of the MSF (Steer *et al.* 2020). For the former sector, they are generally taken as by-catch by fishers using hauling nets and gill nets, but are also targeted using trolling lines. The estimates of total annual commercial catch have ranged from 39 to 147 t. Since 1995, there has been a long-term decline in commercial catches, associated with declining targeted hauling net effort, due to the reduction in numbers of hauling net fishers. Catch rates have increased over the long-term, and throughout the 2000s have generally been >50 kg.fisher-day^{-1}. On this basis, the Snook fishery in SA was recently classified as **sustainable** (Steer *et al.* 2020). Recreational fishers target Snook with rods and lines, and their catches constitute significant proportions of the total annual catches. The estimated catches from the telephone/diary surveys are 93 t in 2000/01, 83 t in 2007/08 and 126 t in 2013/14 (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015).

The estimates of total annual catch across both sectors have been relatively consistent since 1984, ranging between 100 and 200 t.yr^{-1} (Fig. 3.12A). Total catch peaked in 2001 and then fell to 2006, and has remained relatively consistent since then. In 2017, total catch was at the lower end of the boundary estimates of the MSY of 172 t. The long-term change in estimates of biomass have been relatively moderate (Fig. 3.12B). They declined throughout the 1990s until 2005 and fell marginally below the B_{MSY} estimate of 614 t. Subsequently, biomass has increased above the B_{MSY} level to a maximum in 2015. Overall, including throughout most of the 2000s, the estimates of harvest fraction have been considerably lower than the H_{MSY} of 0.28 (Fig. 3.12C). The relatively high recent estimates of biomass and low harvest fraction suggest that there is opportunity for a modest increase in total catch. As such, the risk associated with increasing total catch by 25% is low. The risk level then increases from medium to severe with further increases of 50 to 200% (Fig. 3.12D).

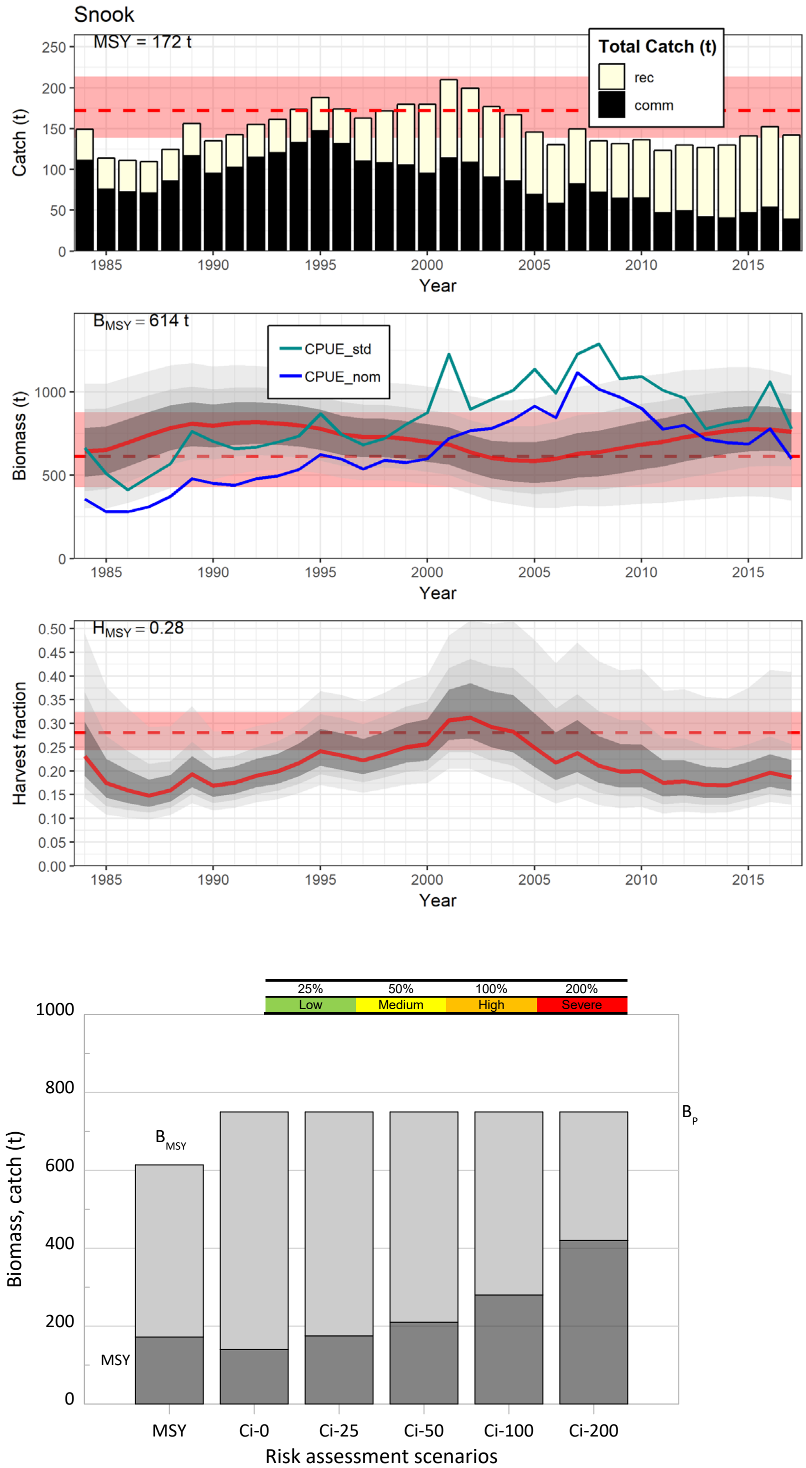


Fig. 3.12. Summary of results from the cMSY modelling and risk assessment for Snook. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.11 Silver Trevally (*Pseudocaranx georgianus*)

The Silver Trevally is a member of the Carangidae family that are characteristically active-swimming, highly streamlined fishes (Gomon *et al.* 2008). This species has a broad distribution from Coffs Harbour in NSW, across southern Australia to Perth in WA (Stewart 2015). It forms schools over sandy substrata, across a broad range of habitats that include estuaries, gulfs, nearshore coastal areas and waters of the continental shelf. They are slow-growing and long-lived with ages of up to 25 years recorded in NSW and 33 years recorded for fish from New Zealand waters (Steer *et al.* 2020). Based on such estimates of longevity, this species was assigned the relatively low 'population resilience' estimate of 24.8, and was categorised as a 'periodic strategist'.

In the MSF, Silver Trevally are taken by both the commercial and recreational fishery sectors (Steer *et al.* 2020). The commercial catches are dominated by those taken by line, but also include fish taken by various net types. The annual commercial catches have been highly variable over time, ranging from 2.1 to 21 $t.yr^{-1}$, but have generally been <10 $t.yr^{-1}$. Commercial effort has varied periodically, whilst CPUE has gradually increased over the long-term. In 2018, the stock was classified as **sustainable**. Estimates of recreational catches, also taken by line, were 18 t in 2000/01, 12 t in 2007/08 and 15 t in 2013/14 (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015).

The estimates of total catch of Silver Trevally have been relatively consistent over time, and have always exceeded the MSY of 16.4 t (Fig. 3.13A). This has gradually driven down biomass, which around 2000 fell below the B_{MSY} level of 358 t (Fig. 3.13B). Furthermore, the annual estimate of harvest fraction has generally always been above the H_{MSY} level (Fig. 3.13C). The relatively high recent catches, low and declining level of biomass and increasing harvest fraction, collectively indicate that there is little capacity to increase total catch. As such, a high risk was assigned to an increase in total catch of 25%, which was elevated to severe when considering further increases in catch (Fig. 3.13D).

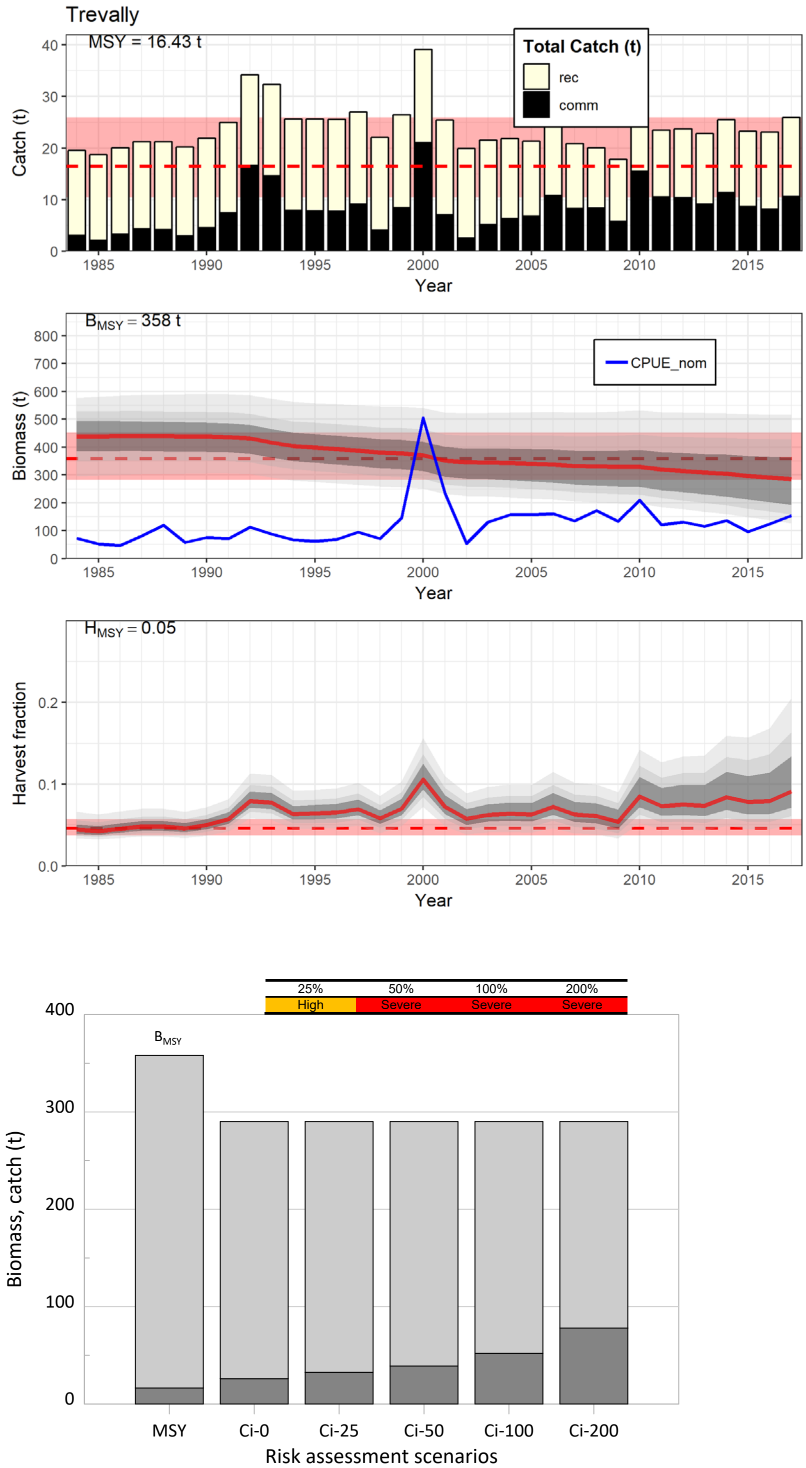


Fig. 3.13. Summary of results from the cMSY modelling and risk assessment for Silver Trevally. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.12 Yelloweye Mullet (*Aldrichetta forsteri*)

This is a small, schooling species of mullet that inhabits estuaries and nearshore coastal waters along Australia's southern coast from Kalbarri in WA to the Hunter River in NSW, and around Tasmania (Gomon *et al.* 2008). The biological stock structure throughout this distribution is poorly understood. The fish occur over sandy and muddy substrata to depths of 20 m and are often abundant in estuaries. The species is fast-growing and short-lived, attaining a maximum length of 440 mm and maximum age of 10 years. It is classified as an 'intermediate strategist', with a mid-level estimate of population resilience of 36.3.

In SA, Yelloweye Mullet are taken by both the commercial and recreational sectors of the MSF, mainly in the gulfs (Steer *et al.* 2020). In the commercial sector, they are either targeted or taken as by-product with hauling nets and set nets. The commercial catches peaked at 175 t in 1990, before undergoing a significant long-term decline to the minimum of 12.5 t taken in 2016. This decline largely reflects the reduction in hauling net effort that has occurred since the 1980s. Hauling net CPUE was relatively stable through the 1980s and 1990s, but since then has generally been higher, although more variable. On the basis of recent low estimates of catch and effort and moderately high estimates of CPUE, the fishery was recently classified as **sustainable**. For the recreational sector, Yelloweye Mullet are targeted by anglers using rod and line. The recreational catch represents a significant proportion of the total catch. The recreational catches of Mullet declined from 83 t in 2000/01 to 28 t in 2007/08 and again to 19 t in 2013/14 (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015).

The total annual catches of Yelloweye Mullet were dominated by those from the commercial sector up to the mid-1990s, when those from the recreational sector increased considerably (Fig. 3.14A). Total catch varied through two cycles by the early 2000s with peaks in 1990 and 2001. Since then, they have declined regularly with the lowest catch recorded in 2016. Prior to the mid-2000s, most catches were higher than the MSY of ~104 t, but have subsequently been below the MSY. The estimates of biomass declined from 1984 to 2007, falling below the B_{MSY} of 870 t around 1990 (Fig. 3.14B). Since 2007, the estimates of biomass have gradually increased. The annual estimates of harvest fraction were consistently above the H_{MSY}, but fell below this in 2012 and have remained so since then (Fig. 3.14C). The recent catches and harvest fraction are considerably below the MSY and H_{MSY} estimates, respectively. Nevertheless, even though biomass is increasing it has not yet reached the B_{MSY}. Based on these characteristics, there would appear to be some scope for increasing the catch of Yelloweye Mullet. The risks associated with increasing catch by 25, 50 and 100% were low to medium, which increased to high for a 200% increase in catch (Fig. 3.14D). This indicates some capacity for increasing catches.

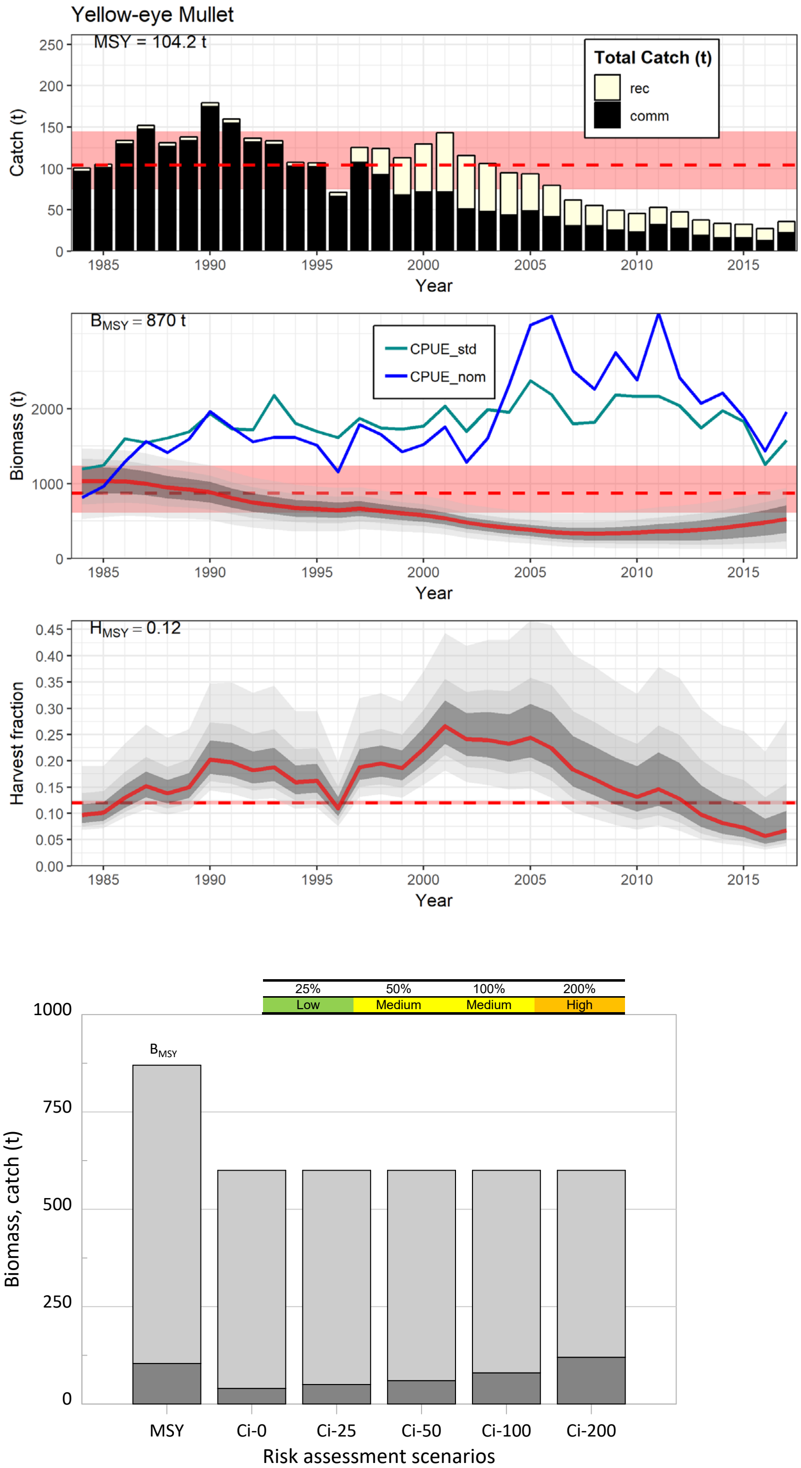


Fig. 3.14. Summary of results from the cMSY modelling and risk assessment for Yelloweye Mullet. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.13 Yellowfin Whiting (*Sillago schomburgkii*)

The Yellowfin Whiting is endemic to Australian coastal waters from Dampier in WA to the gulfs of SA. As there is some uncertainty about the continuity of distribution throughout the remote coastal waters across the two states (Kailola *et al.* 1993), their populations may constitute separate stocks. Nevertheless, even in SA, there is discontinuity between the populations in the two gulfs which may also constitute separate stocks (Steer *et al.* 2020). This species predominantly occupies relatively protected shallow, near-shore, gulf and coastal waters with the adults generally associated with shallow tidal creeks and coastal sand flats in waters of 1 – 10 m depth (Jones 1981). Age estimation of Yellowfin Whiting using otoliths has indicated a longevity of ~12 years (Ferguson 1999). It is considered an 'intermediate strategist' with a 'population resilience' estimate of 41.4.

The Yellowfin Whiting is an important secondary species of the MSF that is likely targeted by commercial fishers when the demand for or availability of the primary species is low (Steer *et al.* 2020). As this schooling species occupies sandy, shallow habitats in the northern gulfs, it is particularly vulnerable to capture by net gear types. As such, historically, the commercial catches have been dominated by the hauling net sector, followed by bottom-set gill nets. This species is also a popular target species for boat and shore-based recreational fishers who target them using hook and line. Throughout the 2000s, the commercial State-wide catches have varied between 79 and 179 t. The estimates of recreational catch were 105 t in 2000/01, 23 t in 2007/08 and 45 t in 2013/14 (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015).

For the Gulf St. Vincent Stock, the total annual catches were highest between 2002 and 2012, ranging between 20 and 40 $t.yr^{-1}$ (Steer *et al.* 2020). Relatively low levels of targeted catch and effort for this species have led to variable estimates of catch rate. These data suggested that the biomass of the stock was unlikely depleted, which led to a status of **sustainable** (Steer *et al.* 2020). The estimates of total catch across both sectors were relatively low until the mid-1990s (Fig. 3.15A). Thereafter, total catches increased considerably and remained high until 2012 when commercial catches declined whilst recreational catches remained quite high. Between 2000 and 2013, the total annual catches were regularly above the MSY estimate of 35 t, but in recent years fell below this. In 2017, the estimate of total catch was ~24 t. The estimates of biomass have conformed to a single cycle of increase and decrease (Fig. 3.15B). They were highest through the early 1990s and were above the B_{MSY} of 144 t until the mid-2000s. Biomass has declined since 1995 and since 2005 has fallen below the B_{MSY} estimate of 144 t. The declining estimates of biomass correspond to increasing levels of harvest fraction, which since 2000 have exceeded the H_{MSY} level of 0.24 (Fig. 3.15C). The current estimate of biomass is below the B_{MSY} level and that for harvest fraction above the H_{MSY} level, suggesting that there is little capacity to increase catches from this region. As such, the risk associated with increasing catch by 25 – 50% is considered high, whilst any further increase in catch is associated with a severe risk (Fig. 3.15D).

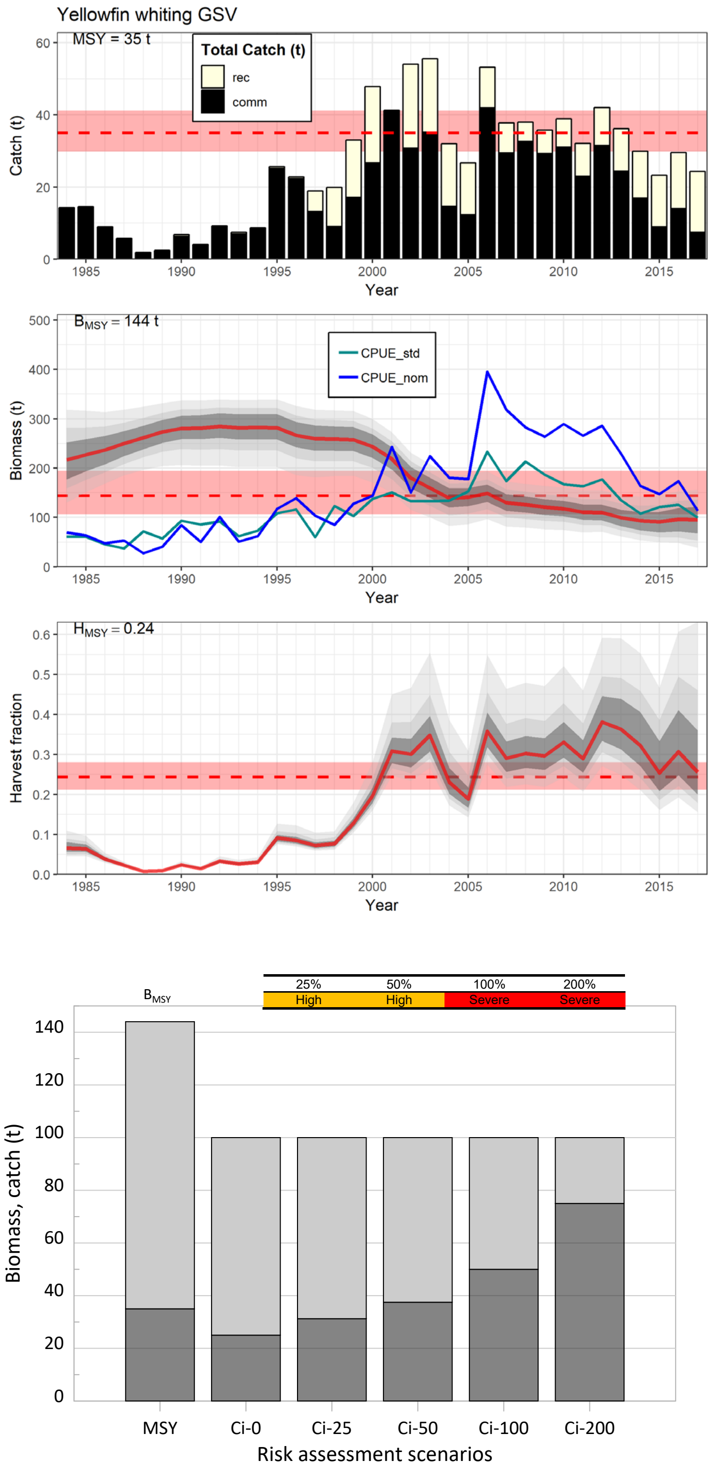


Fig. 3.15. Summary of results from the cMSY modelling and risk assessment for Yellowfin Whiting in GSV. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

Historically, the Spencer Gulf Stock has dominated the commercial catches of Yellowfin Whiting (Steer *et al.* 2020). Since 2000, these catches have varied between 50 and 150 $t.yr^{-1}$. This variation reflects, at least partly, the temporal variation in targeted fishing effort. Furthermore, targeted hauling net CPUE has varied considerably, with no obvious long-term trend. The fishery statistics show no long-term declining trend, suggesting that biomass is unlikely to be depleted. As such, the Spencer Gulf Stock was assigned the status of **sustainable**. The annual estimates of total catch across both sectors have been dominated by those from the commercial sector (Fig. 3.16A). They have been variable but relatively high throughout the 2000s, and have regularly exceeded the MSY value of 119 t. From the 1990s, estimates of biomass were relatively consistent except for a decline through the early 2000s (Fig. 3.16B). The biomass estimates have generally been above the B_{MSY} level of 398 t. Furthermore, the estimates of harvest fraction have generally been below the H_{MSY} of 0.3 (Fig. 3.16C). Nevertheless, recently, the harvest fraction has approximated the H_{MSY} estimate. With the current estimate of total catch above the MSY, the estimate of biomass marginally above the B_{MSY} and that of the harvest fraction similar to H_{MSY}, there appears to be little opportunity for further increase in fishery catch. As such, there is a high risk to sustainability of increasing catch by only 25%, and a severe risk associated with any further increases (Fig. 3.16D).

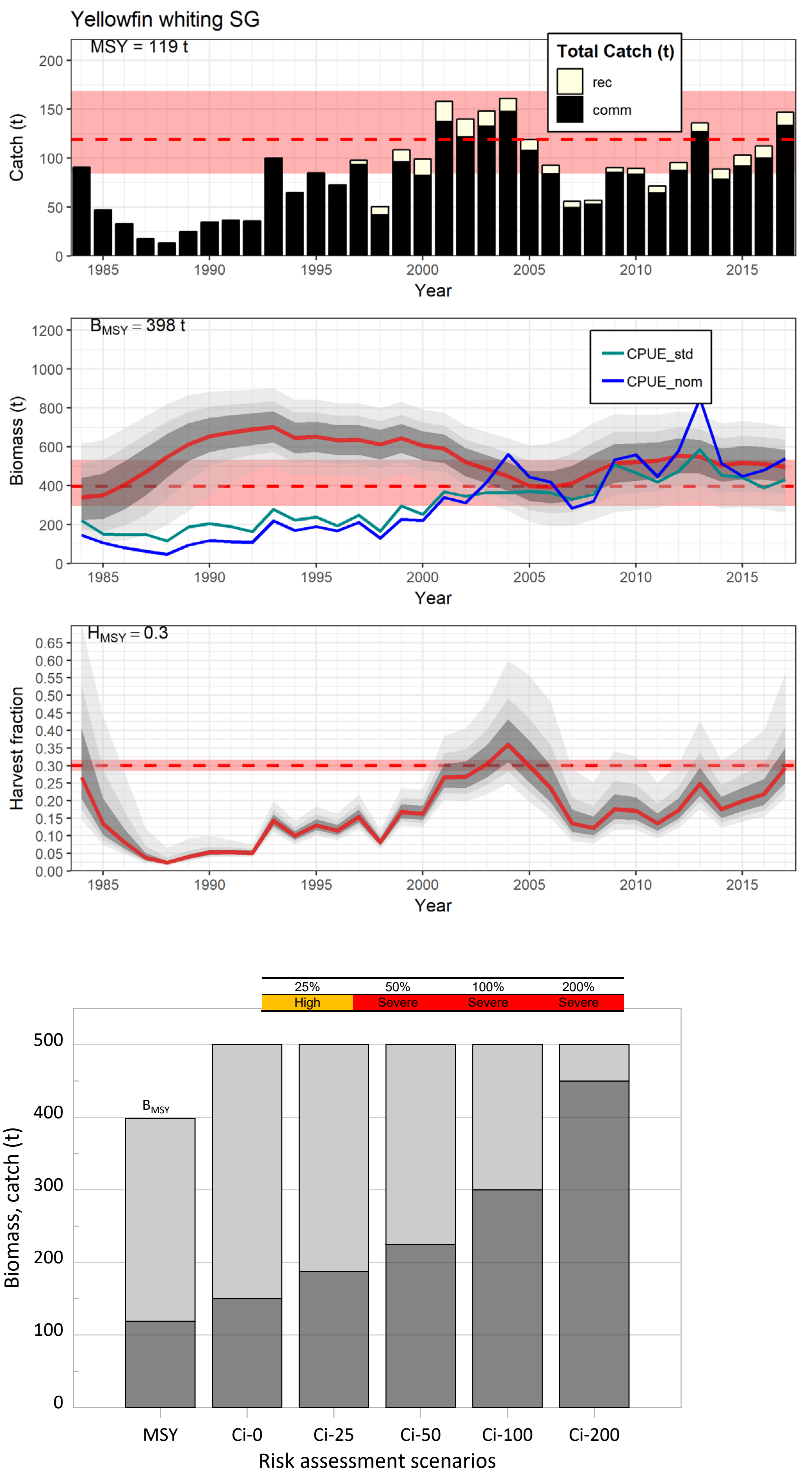


Fig. 3.16. Summary of results from the cMSY modelling and risk assessment for Yellowfin Whiting in SG. A. Time series of estimates of total catch, showing commercial and recreational components, and estimated MSY (broken red line). B. Time series of estimates of biomass and the B_{MSY} estimate (broken red line). Also shown are estimates of CPUE (standardised and nominal). C. Time series of estimates of harvest fraction and the H_{MSY} estimate (broken red line). For biomass and harvest fraction, the solid red line indicates the annual means and grey bands are the 50, 75 and 95 percentiles (from dark to light). Red shading represents 95% confidence limits around the respective estimate. D. Results from risk assessment comparing estimates of B_{MSY} and MSY with current estimates of catch and biomass (Ci-0) and with hypothetical increases in catch of 25, 50, 100 and 200% (i.e. Ci-25, Ci-50, Ci-100, Ci-200, respectively). For the estimate of recent biomass (Bp), the dark shading represents biomass removed by fishing and light shading represents the remaining biomass. The coloured bar shows the results of the risk assessment.

3.3.14 Bight Redfish (*Centroberyx gerrardi*)

The Bight Redfish has a broad distribution across southern Australia from Perth, WA to Bermagui in southern NSW, and around Tasmania (Gomon *et al.* 2008). It is a demersal species that inhabits reefs over the extensive depth range of 11 to 260 m. High numbers of this species are also taken in the Great Australian Bight (GAB) trawl fishery (Saunders *et al.* 2010). The Bight Redfish is a particularly long-lived species for which the oldest recorded fish from the GAB trawl fishery was 71 years (Stokie and Krusic-Golub 2005). Because of this high longevity, this species is a 'periodic strategist' with a low population resilience estimate of 20.9.

In the MSF, the Bight Redfish is targeted by both the commercial and recreational sectors. In the commercial sector, they are taken with line fishing gears, when targeted or as by-product when other species, particularly Snapper, are targeted. Most are taken from the southern gulfs, Investigator Strait (IS) or the west coast of Eyre Peninsula. The annual commercial catches have been quite variable but have generally been <20 $t.yr^{-1}$ (Fig. 3.17A). Whilst low catches that were generally <5 $t.yr^{-1}$ were recorded from 1998 to 2008, they have subsequently increased considerably up to 2018, relating to marginal increases in effort but more particularly to a significant increasing trend in CPUE (Fig. 3.17B,C). The estimates of recreational catches for this species are considerable, i.e. 40 t in 2000/01, 15 t in 2007/08 and 19 t in 2013/14 (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015).

Due to the presumed relatively low abundances that are available to the MSF, their extended longevity, low population resilience, the assessment of risk to sustainability associated with increasing catches indicated that even a small increase of 25% was associated with severe risk.

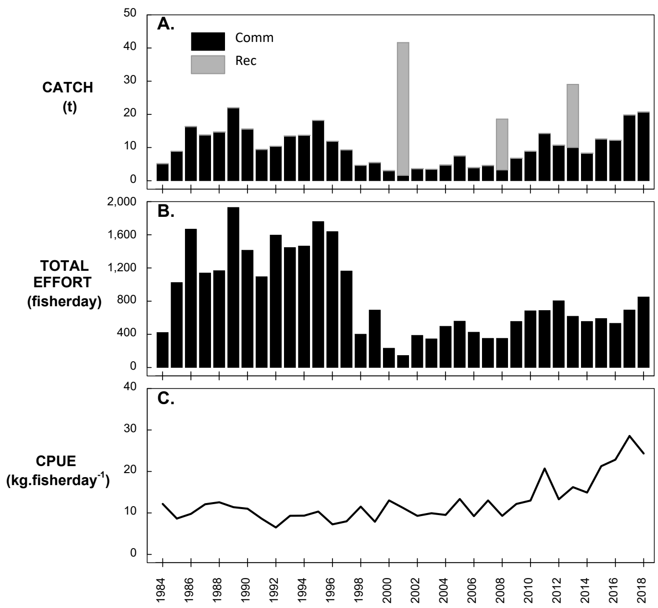


Fig. 3.17. Summary of fishery statistics for the Bight Redfish. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

3.3.15 Black Bream (*Acanthopagrus butcheri*)

Black Bream have a broad distribution across southern Australia from the Murchison River in WA to the Myall Lakes in NSW, including around Tasmania (Gomon *et al.* 2008). This is an estuarine-dependent species that completes much of its life cycle within a single estuary. It is a medium-bodied, slow-growing species that can grow to 600 mm TL and live to 32 years (Ye *et al.* 2015). It was classified as an 'intermediate strategist' with an estimated 'population resilience' of 35.7.

Black Bream are taken by the commercial and recreational sectors of the MSF. For the commercial sector, the catch is either targeted or taken as by-product particularly by fishers using set nets but are occasionally taken in hauling nets. Historically, most catch has come from the northern and central parts of GSV. From 1984 to 2013, the commercial catches were generally <1.5 $t.yr^{-1}$ (Fig. 3.18A). In most years from 2014 onwards, these have increased to >2 $t.yr^{-1}$, associated with a considerable increase in CPUE (Fig. 3.18C). On the basis of the recent increases in catch and CPUE, the stock was recently classified as **sustainable** (Steer *et al.* 2020). The Black Bream is also targeted by recreational fishers. The estimates of annual catches by this sector of several tonnes exceed the commercial catches.

Given that Black Bream is a high value species for the commercial sector, it is expected that the low annual catches are limited by the biomass available. Given that, and the low migration rates between estuaries, any increases in catches could lead to localised depletions. As such, the risk levels associated with increasing catches by 25 or 50% are considered to be high, which elevated to severe for increases in catch of 100 and 200%.

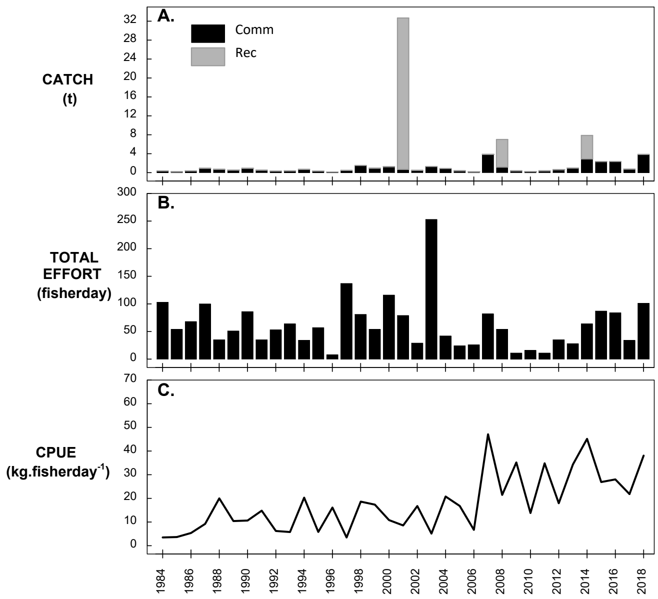


Fig. 3.18. Summary of fishery statistics for the Black Bream. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

3.3.16 Blue Mackerel (*Scomber australasicus*)

Blue Mackerel have a broad distribution throughout the tropical and temperate zones of the western and eastern Pacific Ocean (Kailola *et al.* 1993, Gomon *et al.* 2008). The Australian distribution is extensive, and includes most tropical and temperate oceanic and coastal regions around the country. These fish are pelagic, displaying a migratory and shoaling habit in coastal waters and the open sea. The juveniles and small adult fish usually inhabit inshore waters, whilst large adult fish form schools over the continental shelf in depths of 40 – 200 m.

Blue Mackerel are taken by both sectors of the MSF. The reported annual commercial catch has generally been <5 t.yr^{-1}, taken as targeted catch and by-product when other species are targeted (Fig. 3.19A). They are primarily taken using line-fishing methods that include trolling. Historically, most catch has been taken along the eastern GSV and southern Fleurieu Peninsula. The commercial catches, effort and catch rates show no long-term trends (Fig. 3.19A,B,C). Blue Mackerel are taken by recreational fishers using rod and line. The estimated recreational catch in 2000/01 was 9.0 t (Jones and Doonan 2005), which was substantially higher than the commercial catch. It also increased considerably in 2013/14 (Giri and Hall 2015).

The combined catches of the two sectors of the MSF are likely to constitute a small proportion of the biomass of this species in SA waters. There is uncertainty about the dispersion of the fish throughout oceanic and gulf waters. Nevertheless, given the migratory nature of the species, it is likely that the gulf populations could support higher catches, for which the risks to sustainability of populations are likely to be low.

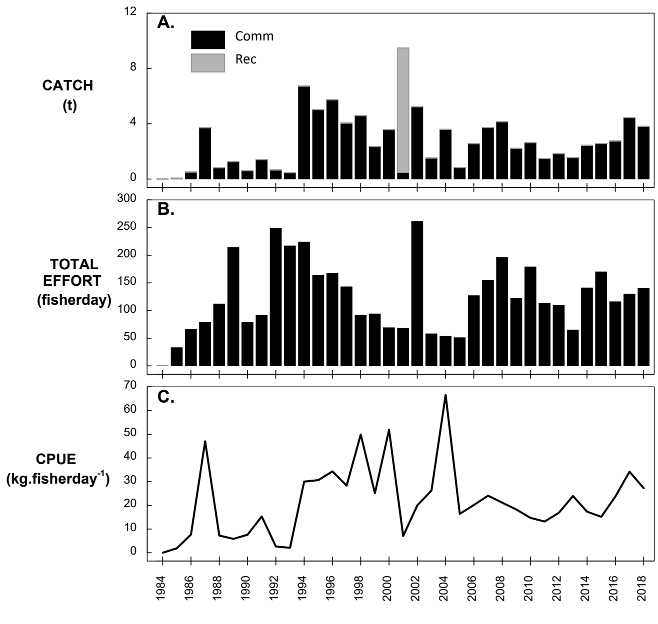


Fig. 3.19. Summary of fishery statistics for the Blue Mackerel. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

3.3.17 Flathead species (family: Platycephalidae)

There is a suite of seven species of Flathead that occur in SA waters (Gomon *et al.* 2008). They are demersal species that occupy habitats with a diversity of different substrata and depth zones. Their distributions differ with respect to the extent to which they include all or part of the coastal and shelf waters of SA (Gomon *et al.* 2008). Flathead species are taken by both sectors of the MSF, but there is no differentiation amongst species in the reporting of catches. These species are generally taken as by-product when the primary species are targeted, with catches shared between line and net gears. Catches of Flathead have been reported from the coastal waters of all regions of SA. Throughout the 1990s and 2000s, the commercial catches were generally <3.0 $t.yr^{-1}$ (Fig. 3.20A). Fishing effort declined over time in line with the general reduction in numbers of commercial fishers, whilst the catch rate gradually increased, but varied periodically (Fig. 3.20B,C). Catches and catch rates have declined since 2011. Flathead are taken by the recreational sector, using rod and line. The estimated catches in 2000/01 of 19.0 t and in 2007/08 of 18.4 t, were higher than that of 8.3 t for 2013/14 (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015).

The low catches and targeted effort of the commercial sector of the MSF for Flathead indicate that these fish are rarely targeted in SA waters. Given that these species are a premium seafood product, it is expected that commercial fishers would target them if they were more abundant. This indicates that the low catches reflect low biomass, whilst the variable catches and catch rates suggest that populations are limited by recruitment variability. Based on these limiting influences on the demographics of the species, there would likely be considerable risk to population processes if the targeted fishing effort and catches were to increase. As such, a high risk was assigned to a 25% increase in catch and severe risks for higher increases.

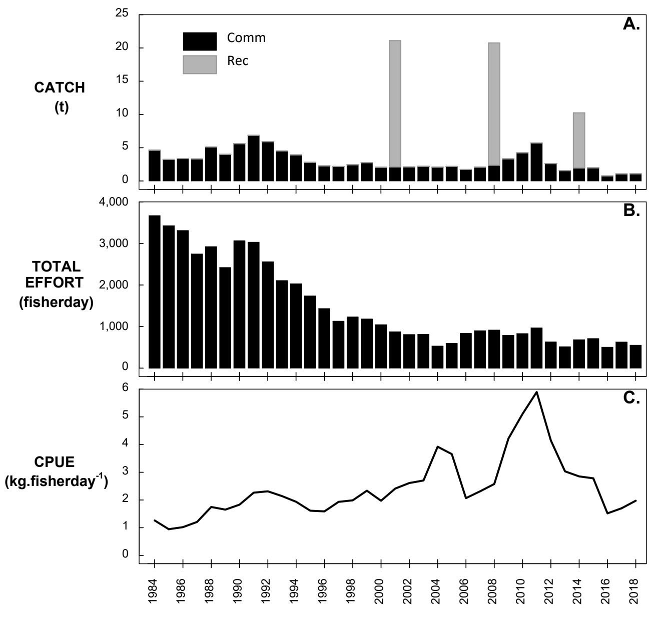


Fig. 3.20. Summary of fishery statistics for the Flathead spp. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

3.3.18 Red Mullet (*Upeneichthys vlamingii*)

This species has a broad distribution across southern Australia. It is a schooling species that occurs in shallow, sandy, coastal waters to depths of approximately 40 m. It is a demersal species that reaches approximately 40 cm in length. An estimate of 'population resilience' could not be calculated because of a lack of life history information.

Red Mullet are taken by both the commercial and recreational sectors of the MSF. In the commercial sector they are rarely targeted but are taken primarily as by-product when King George Whiting is targeted. The primary gear type with which they are captured is handline. Furthermore, the commercial catches are mainly reported from southern SG, GSV and IS. The annual reported commercial catches have shown relatively minor variation over the years, and have generally ranged from 3 to 5 t.yr^{-1} (Fig. 3.21A). The fishing effort to produce these catches has declined regularly, possibly reflecting the decline in numbers of fishers who target King George Whiting (Fig.3.21B) (Steer *et al.* 2020). Commercial catch rates have generally increased over time (Fig. 3.21C). This species is taken by the recreational sector using rod and line. The estimated State-wide recreational catch in 2000/01 was 17.0 t, which was considerably greater than the commercial catch. The recreational catch declined in 2013/14.

This species would likely be more heavily targeted if more abundant, and so is also considered to be recruitment limited. This suggests that there would be a high risk in increasing total catch by 25%, and severe risks associated with higher increases in total catch.

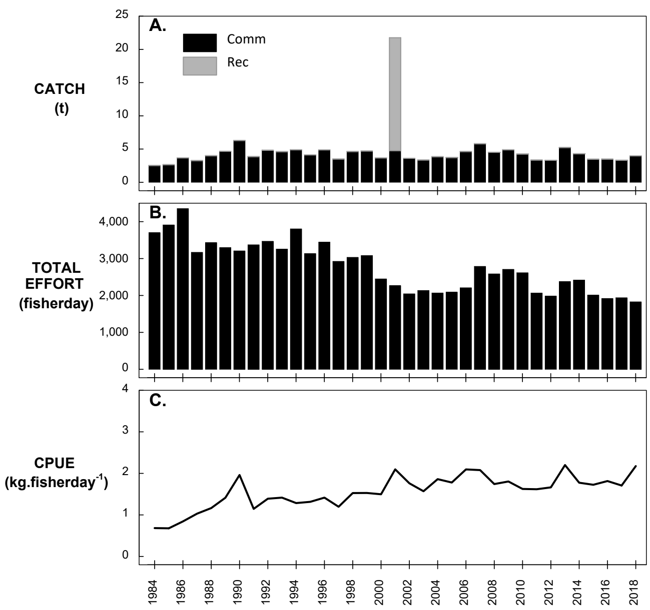


Fig. 3.21. Summary of fishery statistics for Red Mullet. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

3.3.19 Sea Sweep (*Scorpis aequipinnis*)

This is a deep-bodied, laterally-compressed species of fish that has a broad distribution throughout southern Australia, including Tasmania (Gomon *et al.* 2008). It occurs associated with rocky reefs in coastal waters to depths of at least 40 m (Saunders *et al.* 2010). They occur in small groups, but around the offshore islands of SA, can form large schools. The species is relatively long-lived, with a small sample from SA being aged up to 23 years (Saunders *et al.* 2010). It has a medium-level 'population resilience' of 34.12.

Sweep are taken by the commercial and recreational sectors of the MSF. In the commercial fishery, the annual catches are relatively low. Prior to 2000, they were variable and ranged up to approximately 10 $t.yr^{-1}$, but since then have generally been <3 $t.yr^{-1}$ (Fig. 3.22A). The catches have either been targeted or taken as by-product when other species such as Bight Redfish, Gummy Shark, King George Whiting and particularly Bluethroat Wrasse have been targeted. Most commercial catch has been taken using line-fishing gears, whilst a considerable proportion has also been taken with set gill nets. The catches have been highest on the west coast, in southern SG, IS and the south east region. The lower catches from 2000 onwards, have been associated with low fishing effort and a long-term declining trend in catch rate (Fig. 3.22C). The recreational catches in 2000/01, 2007/08 and 2013/14 were 11.6 t, 7.7 and 8.7 t, respectively (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015). These were considerably higher than the commercial catches.

Based on the medium level of population resilience and relatively low levels of commercial and recreational catches, the risk assessment suggested a low risk to increasing catches from between 25 and 200%.

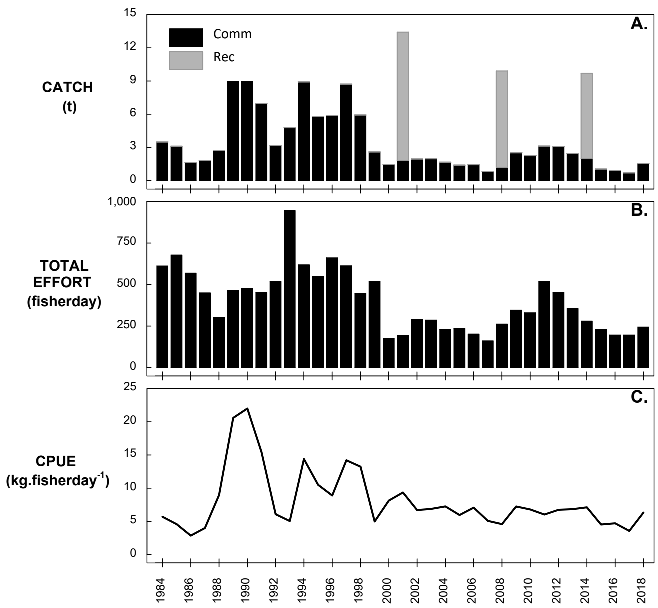


Fig. 3.22. Summary of fishery statistics for Sea Sweep. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

3.3.20 Yellowtail Kingfish (*Seriola lalandi*)

The Yellowtail Kingfish is a large, pelagic finfish species of the family Carangidae that is distributed globally throughout the cool temperate waters of the Indo-Pacific region. In Australian waters, these fish occupy inshore and continental shelf waters from south east Queensland, around the southern coast to north of Shark Bay in WA, and down the east coast of Tasmania (Kailola *et al.* 1993). Adults can be solitary or live in small schools, near rocky shores, reefs and islands. Juveniles are often found in offshore waters near or beyond the continental shelf, and prefer water temperatures of 17 – 24°C. The species is highly migratory, capable of moving over substantial distances such as between the waters of SA and NSW. Genetic studies have differentiated two stocks, i.e. an Eastern Stock that involves the populations in the waters of SA, NSW, Victoria and New Zealand waters, which is distinct from the WA Stock (Hughes *et al.* 2018).

The Yellowtail Kingfish has limited significance as a commercial species in SA, with catches generally <1 $t.yr^{-1}$, although they were marginally higher at 1.5 to 3 $t.yr^{-1}$ between 2014 and 2018 (Fig. 3.23A). The catches are primarily taken as by-product, with hauling nets in the northern gulfs. This is an iconic target species of the recreational sector. Its catches have consistently been greater than the commercial catches and estimates increased throughout the 2000s from 62 t in 2000/01, 101 t in 2007/08 and 199 t in 2013/14 (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015).

In NSW, Yellowtail Kingfish can live up to 21 years of age. They were classified as 'periodic strategists' and have relatively low 'population resilience' of 28.62. Given this and the relatively high recreational catch, it is considered that there are high risks in increasing the total catches by 25% or 50%, and severe risks of increases of 100% or greater.

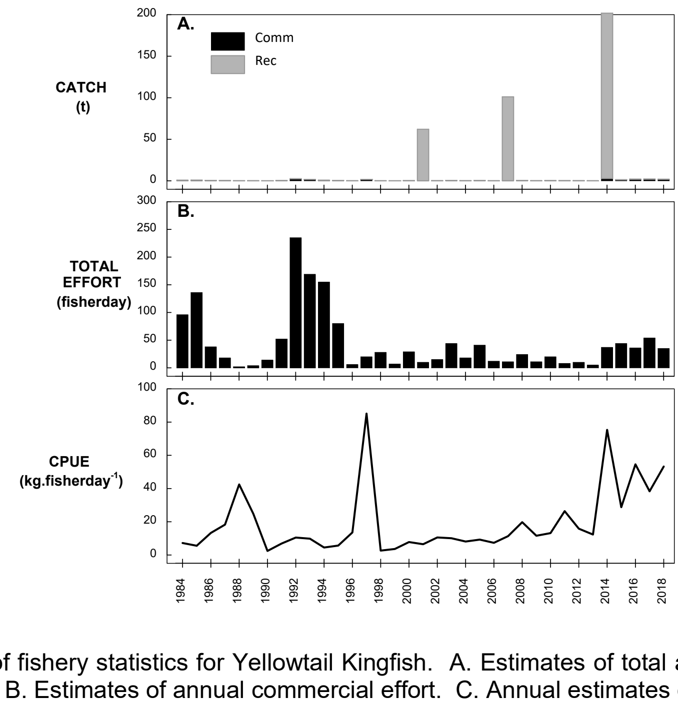


Fig. 3.23. Summary of fishery statistics for Yellowtail Kingfish. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

3.3.21 Broadnose Shark (*Notorynchus cepedianus*)

This species is a powerful predatory shark that has a global distribution that includes the cooler waters of the Pacific and Indian Oceans, as well as the Atlantic Ocean (Gomon *et al.* 2008). It is mostly a demersal species that is found in inshore habitats and offshore to approximately 136 m in depth. It has an estimated longevity of 49 years and age-at-maturity of 10 years. As such, it is considered an 'equilibrium strategist' with a relatively low 'population resilience' of 14.86.

For the MSF, estimates of annual commercial catches are available from 2001 to 2018 that range from <1 to 8.5 $t.yr^{-1}$ (Fig. 3.24A). Catches increased from 2007 to 2011 but have subsequently declined to 2018. They have primarily been taken as by-product when Snapper have been targeted with longlines. Catches were highest in the southern SG, IS and the south east region. The results from recreational surveys provide no specific information on catches and catch rates for this species (Jones and Doonan 2005, Jones 2009 and Giri and Hall 2015), but are likely to be low given the locations and fishing methods that produced catches for the commercial sector.

The annual catches for this broadly-distributed species by the MSF appear to have been very low. As such, despite its low 'population resilience', it is considered that the risk to sustainability of increasing catches by 25% up to 200% would be low.

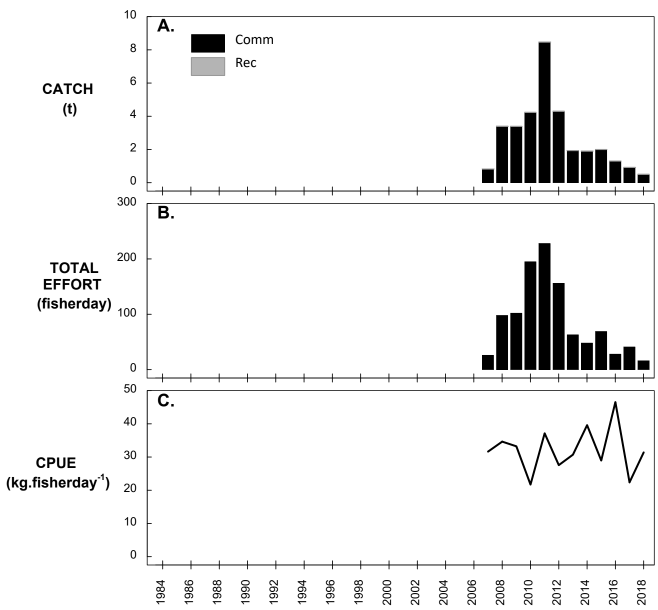


Fig. 3.24. Summary of fishery statistics for Broadnose Sharks. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

3.3.22 Bronze Whalers (*Carcharhinus brachyurus*) and Dusky Sharks (*C. obscurus*)

Two species of Whaler sharks are taken in SA waters, i.e. the Bronze Whaler (*Carcharinus brachyurus*) and Dusky Sharks (*C. obscurus*), which both have global distributions. The former prefers warm temperate waters and occurs in the surf zone to approximately 100 m depth whilst the latter occupies both temperate and tropical waters along continental margins from the surf zone to 400 m in depth (Gomon *et al.* 2008). Both species migrate considerable distances, resulting in cross-jurisdictional stocks with WA and Victoria. These species are viviparous, i.e. produce live young and have well-developed placenta (Kailola *et al.* 1993). Bronze Whalers can live to 31 years and 25 years for females and males, respectively, whilst Dusky Sharks can live to 50 years. Both sexes reach sexual maturity at around 16 years (Steer *et al.* 2020). They are 'equilibrium strategists' with low estimates of 'population resilience'.

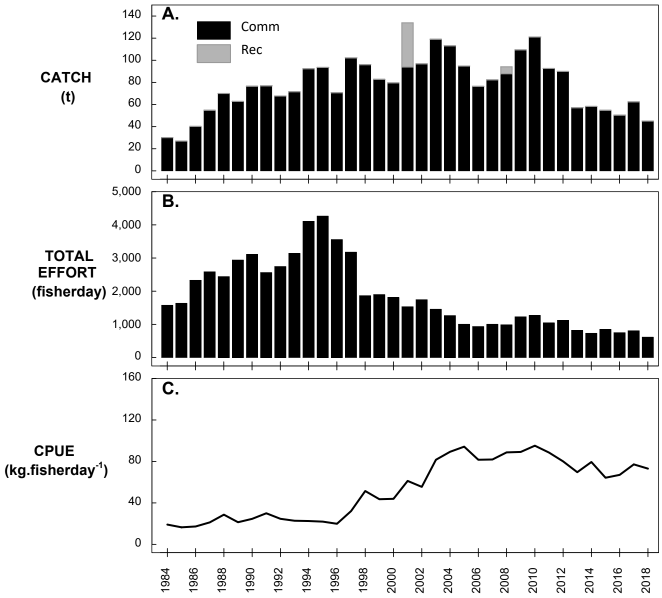


Fig. 3.25. Summary of fishery statistics for Whaler Sharks. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

Whaler sharks are taken by both sectors of the MSF. For the commercial sector most catch is targeted with longlines or large mesh set nets, from broadly across the State's waters. Commercial catches increased from 1990 to 2010, when they were generally above 70 t.yr^{-1}, and peaked at 121 t.yr^{-1} (Fig. 3.25A). Fishing effort declined from the mid-1990s to 2018. Catch rates were highest from 2005 to 2010, before declining to 2018. In the recreational sector, several thousand Whaler Sharks were captured in 2000/01 which declined to 104 sharks in 2007/08, and to zero in 2013/14 (Jones and Doonan 2005, Jones 2009, Giri and Hall 2015). Based on the species identification issue, and unknown proportional contributions to total catch, the fishery was recently classified as **undefined** (Steer *et al.* 2020). The Whaler Sharks have low 'population resilience'. A recent assessment for the Bronze Whalers indicated that a 20% increase in catch would bring the catch up to the MSY (Bradshaw *et al.* 2018). The risk assessment determined that if catch increased by 25% it would exceed the MSY, indicating a severe risk for any higher increase in catch.

3.3.23 Gummy Shark (*Mustelus antarcticus*)

The Gummy Shark has a broad distribution throughout southern Australia from coastal NSW to Geraldton in WA (Woodhams *et al*. 2018). The Southern Stock includes the broad distribution from WA to southern NSW, including SA, based on their capacity for long distance movement. This is a demersal, coastal species primarily found to depths of 80 m. It is ovoviviparous (i.e. produces young by eggs which are hatched within the body of the female), with litter sizes that range from 14 to 40, after a long gestation period of 11-12 months (Gomon *et al.* 2008). They can live to 16 years with sexual maturity attained by about 4.5 years. It is an 'equilibrium strategist', with a relatively low estimated 'population resilience' of 28.2, reflecting low reproductive potential.

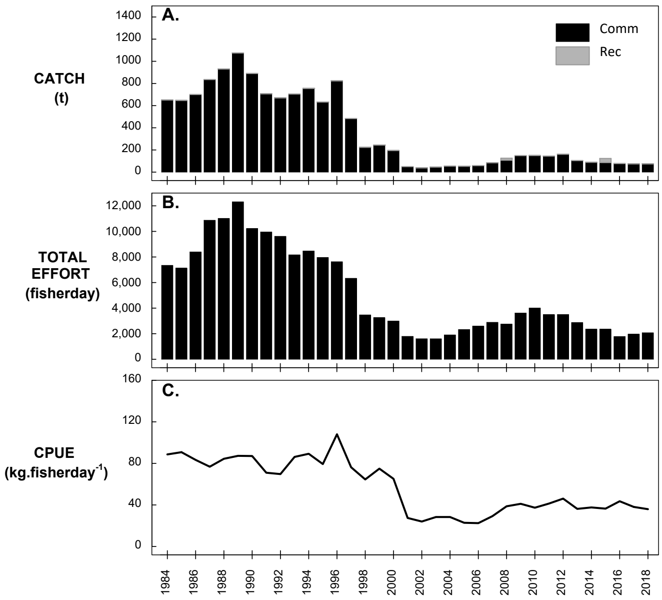


Fig. 3.26. Summary of fishery statistics for Gummy Sharks. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

Gummy Sharks are taken in both sectors of the MSF. Since 2000, the commercial catches have ranged from 39 to 195 $t.yr^{-1}$ (Fig. 3.26A). These catch estimates are low relative to those taken in offshore waters by Commonwealth fisheries. The MSF catches were highest from 2009 to 2012, reflecting the period of highest fishing effort (Fig. 3.26B). Catch rates increased through the early 2000s, and were relatively stable from 2007 to 2018 (Fig. 3.26C). Gummy Sharks have primarily been taken on line-fishing gears, particularly longlines, when targeted or when other shark species or Snapper have been targeted. The commercial catches have been highest from the open waters of the west coast, southern SG, IS and the south east. In the recreational sector, an estimated 4,433 Gummy Sharks were captured in 2007/08 with a total weight of 18.7 t (Jones 2009). This amount was considerably lower than the estimated catch of 98 t by the commercial sector in the same year. For 2013/14, the number harvested was higher at 8,822 individuals with an estimated total weight of 27.0 t, compared with the 103 t, taken by the commercial sector. Stock status is not determined for the South Australian component of the Southern Stock, but in 2018 the whole stock was classified as **sustainable** (Woodhams 2018).

This species has a low 'population resilience' associated with low reproductive potential and relatively high fishery catches. As such, the risk associated with increasing catches was considered to be high for increases of 25 to 50% and severe for higher increases.

3.3.24 School Shark (*Galeorhinus galeus*)

The School Shark occurs throughout temperate regions of the world's oceans. In Australia, it's range is from southern Queensland, around the southern coastline including Tasmania to southern WA. The stock structure is thought to involve a single genetic stock throughout Australian and New Zealand waters (Woodhams 2018). Historically, this species was heavily targeted in southern Australia, and the biomass was significantly reduced. However, measures have been implemented to re-build the biomass across the distribution. Nevertheless, as School Shark are taken as by-catch when Gummy Shark is targeted, it is difficult to minimise their fishing mortality (Woodhams *et al.* 2018). As such, the stock status, as determined for the whole genetic stock is **depleted**. The School Shark occurs throughout the broad depth range from the surf zone to 500 m depth. School sharks are ovoviviparous that produce litters in numbers from 15 to 43, after a 12-month gestation period. The species can live up to 60 years of age, with maturity attained after 8 - 10 years (Gomon *et al.* 2008). Based on these life history characteristics, it is considered an 'equilibrium strategist' with an estimated 'population resilience' of 22.95.

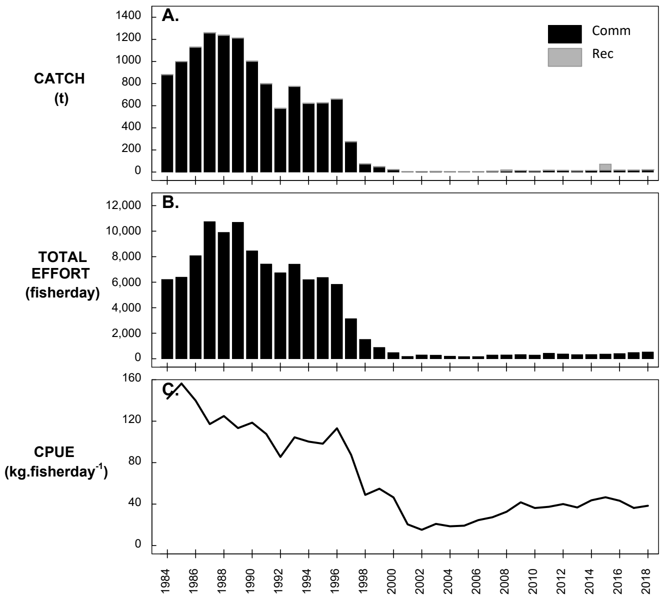


Fig. 3.27. Summary of fishery statistics for School Sharks. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

Since 2000, only very low catches of School Sharks have been reported by the commercial sector of the MSF that range from 3.3 to 22.5 t.yr^{-1} (Fig. 3.27A). These catches have primarily been taken as by-product when other species of shark or Snapper have been targeted, generally in open coastal regions outside the gulfs, particularly on the west coast. For the recreational sector in 2007/08, the estimated number of School Sharks harvested was 1,278 with a total weight of 10 t (Jones 2009). In 2013/14, the estimated number harvested increased to 7,208, with a weight of 53.5 t, which was considerably higher than the catch of the commercial sector (Giri and Hall 2015).

A stock status is not applied to the SA management unit. Given the current **depleted** status for the whole stock, and the strategy for re-building the biomass, the risk assessment has determined that there is a severe risk associated with increasing the catch in SA by even 25%.

3.3.25 Whiskery Shark (*Furgaleus macki*)

The Whiskery Shark is endemic to Australia, and inhabits continental shelf waters from eastern Victoria and Tasmania to Shark Bay, WA (Kailola *et al.* 1993). It is a demersal species that commonly occurs in continental shelf waters to about 220 m depth. They are ovoviviparous, with litters of 4 – 24 young, born after a gestation period of 9 – 12 months. They have an estimated longevity of 15 years, and achieve sexual maturity at around six years. They are considered an 'equilibrium strategist' with a 'population resilience' of 31.6.

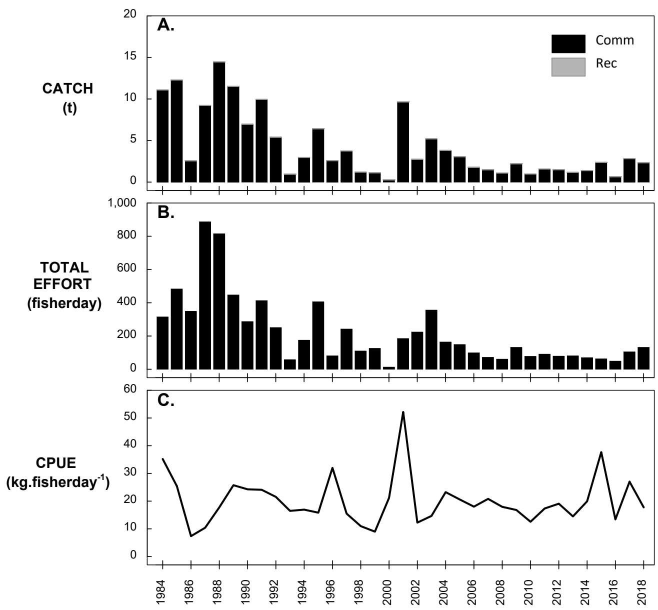


Fig. 3.28. Summary of fishery statistics for Whiskery Sharks. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

The annual estimates of total catch of the Whiskery Shark by the commercial sector of the MSF have always been low, ranging from <1 t.yr^{-1} to 14.5 t.yr^{-1} (Fig. 3.28A). The highest catches were made prior to 2000, with later ones mostly <4 t.yr^{-1}. The species is generally taken as by-product when other species of shark are targeted, and are taken with large mesh set nets and longlines outside southern SG, throughout IS and the south east region. The annual catches largely reflect effort, with catch rate showing no long-term trend (Fig. 3.28B,C). There are no estimates of catches of Whiskery Sharks by the recreational sector. The risk assessment suggested that there are medium risks associated with increasing catches by 25 to 50% and high risks associated with 100 and 200% increases.

3.3.26 Western Striped Grunter (*Pelates octolineatus*)

The Western Striped Grunter are found down the WA coast and eastwards along the south coast to Kangaroo Island, and are abundant in SA's gulfs (Gomon *et al.* 2008). They are short-lived, i.e. can live to up to 10 years, and as a result have a medium level 'population resilience' of 45.2.

=Western Striped Grunter are captured by both the commercial and recreational sectors of the MSF. The reported commercial catches between 1984 and 2018 ranged from 0.5 to 26 $t.yr^{-1}$ (Fig. 3.29A). They are primarily taken in hauling nets when other species are targeted, with the highest catches recorded from the northern gulfs. The estimated recreational catch of grunters and trumpeters from the 2000/01 survey was 33.5 t, which involved 268,366 fish harvested, but it is uncertain what component of this involved the Western Striped Grunter (Jones and Doonan 2005). The estimated numbers of striped trumpeter harvested by SA anglers in 2007/08 and 2013/14 were 97,111 and 33,900, respectively (Jones 2009, Giri and Hall 2015).

The species is relatively short-lived and has a medium level 'population resilience'. The reported commercial and recreational catches are relatively low. The risk assessment suggests that there are low risks associated with catch increases of 25 and 50%, and medium to high risks associated with 100% and 200% increases in catch.

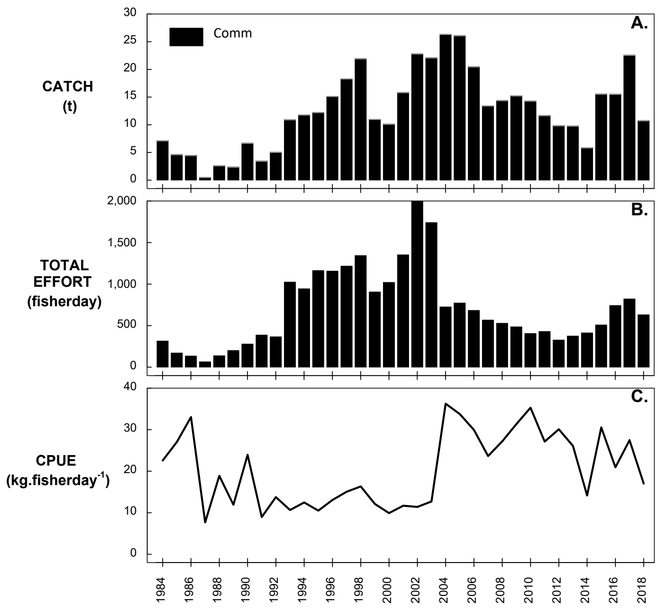


Fig. 3.29. Summary of fishery statistics for Western Striped Grunter. A. Estimates of total annual commercial and recreational catches. B. Estimates of annual commercial effort. C. Annual estimates of commercial CPUE.

3.4 Lesser Known Species Workshop

The risk assessment process for the different candidate taxa considered in Section 3.3, culminated in risk levels that were assigned to hypothetical increases in total catch. The outcomes are collated in Table 3.3, in which the taxa are ranked according to the assigned risk levels. The ranking allowed differentiation of the taxa into those that were considered capable of supporting higher catches and those that could not. For half of the taxa, high or severe risks were assigned to a 25% increase in catch. These are considered undesirable or unacceptable levels of risk (Appendix 5), and so these taxa were assessed as not capable of supporting higher catches. Alternatively, there were 13 taxa for which there were acceptable levels of risk associated with higher catches (Table 3.3). These included 11 taxa for which there were low-medium risk levels associated with increases in catches of up to 50%, and a further two taxa for which a medium risk level was assigned to an increase in catch of 25%. For these 13 taxa, the industry workshop considered each, to identify the regions(s) and sector(s) to which they relate, as well as current barriers and regulatory inhibitors to an increase in catches. Since the industry workshop involved representatives from the commercial, recreational and charter boat sectors, some species were considered that related to the different sectors. Nevertheless, here the focus is on those species that were considered as most relevant to the commercial sector. The following text summarises the nature of the discussions at the workshop for these different taxa. Further details about the workshop are presented in Appendix 6.

Table 3.3. Summary of risk levels assigned to the nominated percentages in total catch for the candidate taxa assessed in the risk assessment process. Taxa are ranked according to assigned risk levels. Colour coding for risk levels as for Table 2.2.

Broad taxonomic group	Taxonomic Group	25%	50%	100%	200%
Finfish	Ocean jackets	Negligible	Low	High	Severe
Finfish	Blue Mackerel	Low	Low	Low	Low
Finfish	Sea Sweep	Low	Low	Low	Low
Elasmobranch	Broadnose Shark	Low	Low	Low	Low
Crustacean	Sand Crab	Low	Low	Medium	High
Cephalopod	*Octopus* spp.	Low	Low	Medium	High
Finfish	Western Striped Grunter	Low	Low	Medium	High
Finfish	Yelloweye Mullet	Low	Medium	Medium	High
Finfish	Snook	Low	Medium	High	Severe
Finfish	Australian Herring	Medium	Medium	High	High
Elasmobranch	Whiskery Shark	Medium	Medium	High	High
Finfish	Western Australian Salmon	Medium	High	High	Severe
Finfish	Leatherjackets	Medium	High	Severe	Severe
Finfish	Yellowfin Whiting (GSV)	High	High	Severe	Severe
Finfish	Black Bream	High	High	Severe	Severe
Finfish	Yellowtail Kingfish	High	High	Severe	Severe
Elasmobranch	Gummy Shark	High	High	Severe	Severe
Finfish	Bluethroat Wrasse	High	Severe	Severe	Severe
Finfish	Mulloway	High	Severe	Severe	Severe
Finfish	Trevally	High	Severe	Severe	Severe
Finfish	Yellowfin Whiting (SG)	High	Severe	Severe	Severe
Finfish	Flathead spp.	High	Severe	Severe	Severe
Finfish	Red Mullet	High	Severe	Severe	Severe
Cephalopods	Southern Calamari	High	Severe	Severe	Severe
Finfish	Bight Redfish	Severe	Severe	Severe	Severe
Elasmobranch	Bronze Whaler & Dusky Shark	Severe	Severe	Severe	Severe
Elasmobranch	School Shark	Severe	Severe	Severe	Severe

Australian Herring

At the workshop it was suggested that the commercial significance of this species has fallen due to the decline in the hauling net sector, and as such it is no longer a major species of this sector. This relates in part to the fish captured in SA being juveniles, which means that they are small relative to the adult fish taken in the WA fishery. Fishers also indicated that these fish have a low market value. Furthermore, their small size makes filleting them challenging, thereby creating an issue for commercial-level processing. The management impediment to increasing commercial catches of Australian Herring relates to the spatial closures for the hauling net sector.

Western Australian Salmon

This species has also experienced a decline in catches in SA throughout the 2000s. Nevertheless, at the workshop it was recognised as the species with the most potential for a high-volume increase in catch. However, there are several barriers to achieving this. The market demand is currently low, being mostly driven by the need for bait for the Southern Rock lobster fishery. The low demand also relates to a lack of awareness amongst seafood consumers about its quality as a fresh fish product. This translates to it attracting a low value, which means that freight costs for high volumes can be expensive. This issue could be addressed with an education program for seafood consumers. Whilst some fish that are handled well by fishers are sold to high-end restaurants and attract premium prices, this represents a limited market. There are a number of regulatory restrictions on this species, which include spatial closures for the hauling net sector.

Ocean Jackets

The catches throughout the 2000s have been considerably lower than those taken during the 1990s. The risk assessment identified considerable opportunity for increasing commercial catches, but there are a number of regulatory restrictions that relate to the limited numbers of fishers with endorsements for restricted numbers of Ocean Jacket traps. As such, there is currently an upper limit to the number of Ocean Jacket traps available to the MSF. Nevertheless, even if these regulatory restrictions were eased, given the offshore locations of the fishing grounds, it would be expensive for any new fishers to ‘gear-up’ for operating in this environment. A further consideration for this species is that the recovery from filleting individual fish is relatively low, providing a low return per fish, even though the eye fillet is a premium product.

Octopus spp.

There is likely considerable potential for expansion of the commercial fishery for *Octopus* spp. in SA since the current fishing effort and spatial coverage of the fishery are quite restricted. There are currently limited licenses with sufficient gear endorsements, given that many traps are required to ensure a viable fishing operation. Also, for this taxon, marketing may be challenging due to competition with imported products. There are particular research requirements for this taxon as there is a lack of biological knowledge with respect to the species composition, the dispersion patterns of the different species, and their life histories and population biology. These issues have been partly addressed by the recent study of Martino and Doubleday (2020).

Sand Crabs

For Sand Crabs, the commercial fishery has developed in and largely remained centralised in Coffin Bay (Steer *et al*. 2020). The low risk level assigned to this species was based on the considerable potential for spatial expansion of the fishery throughout the southern gulfs and the west coast of Eyre Peninsula. Currently, the management impediments relate to limited endorsements for hoop and drop nets. This species currently attracts a lower wholesale price than do Blue Crabs, which might relate to them being more difficult to process for the extraction of meat.

Snook

For Snook, there was some ambiguity between the outcome of the risk assessment and the advice from commercial fishers. The former suggested some capacity for increasing catches. This, however, was questioned by one hauling net fisher from the northern part of SG who indicated that the biomass in this region was considerably reduced and could not support higher catches. This might reflect that even though commercial catches have declined through the 2000s, the recreational catches have increased. Another issue for Snook is that there is considerable loss of yield associated with filleting, which would likely affect the price that can be paid to fishers for whole fish. The management restrictions relate to the spatial closures of the hauling net sector.

Leatherjackets

For this guild of species, the risk assessment suggested that there was capacity for a moderate increase in catch. These fish are primarily taken as by-product when more valuable species are targeted with hauling nets. As such, hauling net spatial closures are restrictive of overall catch. Also, whilst these species provide high quality product, the skinning, preparing and filleting of them can be difficult.

Yelloweye Mullet

This species has a good reputation in SA because of the premium product from the Lakes and Coorong Fishery (LCF), which accounts for 80-90% of the State-wide commercial catches. Consequently, any marketing or financial success that might eventuate from increasing the catches by the MSF in the gulfs would likely be tied to the seasonal availability and pricing for the product from the LCF. The netting spatial closures are the major management impediment.

Sea Sweep

The risk assessment for this species suggested that it could support considerably higher commercial catches. Whilst this species may have marketability issues, it is recognised as a preferred species of the Asian market where it is seen as a Pomfret substitute. As such, commercial success for this species might relate to appropriate cultural marketing.

Blue Mackerel

This species could also support considerably higher commercial catches. Nevertheless, to capture these fish in sufficient quantity would require a purse-seine fishing operation or specialist poling equipment, most likely in offshore waters. This would involve considerable set-up costs, and could potentially result in competition with Commonwealth licenced fishers.

Other Candidate Species

Several of the candidate species identified in Table 3.3 were not considered at the industry workshop. These included the Western Striped Grunter, which in recent years has produced annual catches of 6 – 22 $t.yr^{-1}$. The other species are the Broadnose and Whiskery Sharks that have recently produced very low commercial catches of approximately 1.6 t. yr^{-1} as by-product when other species were targeted. The Broadnose Shark in particular, has a low commercial value.

Other Species Suggested by Commercial Sector

Several other taxa were suggested by commercial fishers as capable of supporting higher catches and were considered at the industry workshop. These included the Sea Mullet (*Mugil cephalus*) and the Southern Garfish on the west coast of Eyre Peninsula. The former species was not considered previously as a candidate species as the average annual catches between 2013 and 2017 were <1 $t.yr^{-1}$, which likely reflected the reduction in catch associated with the netting closure in this region. Similarly, for Southern Garfish on the west coast, the netting closure has reduced catches considerably. Catches of Southern Garfish in this region are now primarily taken with dab nets (Steer *et al*. 2020). The stock status for this regional fishery is currently considered **sustainable**. For both these species in this region, the current regulatory restriction is the spatial netting closures. The resulting lack of fishery information limits the capacity to determine whether the stocks could support higher catches. Nevertheless, the immediate issue here relates to management regulations rather than to stock sustainability.

A further taxon that was suggested by the commercial sector to consider was the 'Rays and Skates'. It was concluded that this taxon was difficult to assess because of the lack of information on species composition. It was recently assigned the stock status of **undefined** (Steer *et al*. 2020), on the basis of the taxonomic uncertainty and the lack of information on recreational catches. Nevertheless, since this taxon is likely to include taxa that are 'equilibrium strategists', they would likely have low levels of population resilience. As such, a conservative approach to management is recommended for this category.

4. Discussion

4.1 Identification of Species

The primary purpose of this project was to identify taxa that are available to the commercial sector of SA's MSF that could support higher levels of fishery production. The timing for such a diversification of the commercial sector of the MSF is appropriate given the reform process that has recently been initiated (Anon 2019). Given the major structural changes that have been mooted as part of this reform, it is now appropriate to consider redirecting fishing effort away from the compromised stocks of the primary finfish species onto some lesser known alternatives (Steer *et al*. 2018a, 2018b, 2020). The requirement to achieve this became even more emphatic in the context of the poor stock statuses that were assigned to the Snapper stocks in 2019 (Fowler *et al*. 2019). The significant management action that ensued for SA's Snapper fishery in response to these classifications i.e. stringent fishery closures, has provided a strong incentive to identify alternative species that the commercial sector can target.

It is important that any decision about the capacity for taxa to support higher catches must conform to the principles of ESD. Assessing a fishery in an ESD context involves considering ecological, economic, social and governance issues to deliver benefits at a holistic level (Fletcher 2014). Nevertheless, for this study, the focus was first on determining the capacity of species to sustain higher levels of catch without compromising sustainability. It was only for those candidate species that were ultimately considered capable of supporting higher catches were further, more extensive issues considered. This was done at the Lesser Known Species Workshop.

The methodology that was applied throughout the study firstly selected, from the numerous taxa available in the MSF, a number of 'candidate' taxa that were assessed for their capacity to support higher catches. They were selected based on several criteria that related to: commercial catches between 2013 and 2017; and managing their fishery with respect to whether or not there were specific arrangements to control catch, such as through a TACC or particular spatial management arrangements. Ultimately, of the 74 out of 111 different taxonomic categories for which some commercial catch was reported between 2013 and 2017 (excluding the three primary finfish species), there were 26 'candidate' taxa that were assessed for their capacity to support higher catches. The assessment process adopted was qualitative but based on considerable empirical data that related to: life history characteristics of the species; and recent and historical fishery information from the different sectors. For a number of these taxa, the assessment also considered the output from data-limited, stock assessment cMSY models that provided estimates of fishery parameters and time-series of biomass and harvest fractions. Such output provided some insight into how the fisheries on different taxa had performed over time, which was informative about the capacity to support higher catches in the future. The output was then interpreted to assess the capacity of the stocks to support higher catches using a risk assessment process. This qualitative process involved fishery scientists and fishery managers in an interactive workshop.

For a number of the 26 different taxa, the risk assessment process concluded that increasing fishery catches constituted too great a risk to population sustainability. These taxa included: a number of finfish species - Bight Redfish, Black Bream, Bluethroat Wrasse, Flathead spp., Mulloway, Red Mullet, Silver Trevally, Yellowtail Kingfish, Yellowfin Whiting; several elasmobranchs – Bronze Whaler and Dusky Sharks, Gummy Shark, School Shark; as well as the cephalopod – Southern Calamari. For some of these taxa, their biomass was considered to be naturally too low to support higher catches. For others, the biomass had already been compromised by earlier fishing activity. Furthermore, for some taxa, their low levels of ‘population resilience’, indicated that the reproductive capacity of the populations were too low to compensate for higher fishing mortality rates.

In contrast to the 13 taxa considered above, the risk assessments indicated that there were some taxa that could support higher catches by SA’s MSF, which included: nine species of finfish; two species of elasmobranchs; the *Octopus* spp.; and Sand Crabs (Table 4.1). For seven of these taxa, cMSY modelling had been done using time-series of total fishery catches. The model outputs were estimates of fishery statistics and time-series of stock biomass. When compared amongst these, the estimates of B_{MSY} and recent estimates of biomass ranged over several orders of magnitude, whilst estimates of recent commercial and recreational catches also covered considerable ranges.

Table 4.1. Summary of results for SA’s MSF species that relate to the commercial fishery sector that were assessed as capable of supporting higher total fishery catches. Blank spaces – no data available.

Broad Taxonomic Group	Common name	cMSY modelling done	B_{MSY}	MSY	Recent biomass (t)	Ave. annual commercial catch 2013-17 (t)	Rec catch 2000/01 (t)	Rec catch 2007/08 (t)	Rec catch 2013/14 (t)
Finfish	Australian Herring	Y	1581	351	1000	109	297	93	157
	West Australian Salmon	Y	7043	665	5000	275	372	91	56
	Ocean Jackets	Y	2537	433	1750	119			
	Snook	Y	614	172	750	44	93	83	126
	Yelloweye Mullet	Y	870	104	500	17	83	28	19
	Leatherjackets	Y	438	54	280	20	40		
Cephalopod	*Octopus* spp.	Y	32	15	45	11	0.2		
Crustacean	Sand Crabs	Y	443	105	300	53		11	10
Finfish	Western Striped Grunter	N				14			
	Blue Mackerel	N				3	9		
	Sea Sweep	N				1.4	12	8	9
	Broadnose Shark	N				1.6			
	Whiskery Shark	N				1.6			

For eight taxa presented in Table 4.1, cMSY modelling outputs provided insight into the scale of potential increases in catch that could be supported. By far, the Western Australian Salmon supports the highest biomass of any of the nominated taxa, and was recognised at the industry workshop as the species with the greatest potential as a ‘commodity’ species that could support an increase in volume of catch of up to several hundred tonnes per year. For Ocean Jackets, the potential increase in production could also be of the order of several hundred tonnes per year. For the remaining finfish species for which there were estimates of biomass and recent catches, i.e.

Australian Herring, Snook, Yelloweye Mullet, and Leatherjacket spp., the potential increases in catch would be considerably lower, i.e. in the order of tens of tonnes.yr^{-1}.

For several finfish species for which cMSY modelling was not done, i.e. the Western Striped Grunter and Sea Sweep, it is also likely that the potential increases in catches would be limited to tens of tonnes.yr^{-1}. Alternatively, for the Blue Mackerel, the potential would likely be greater, but would require specialised fishing operations in offshore waters outside of the gulfs. The low estimate of biomass of 45 t for the *Octopus* spp. is probably an under-estimate that reflects the limited spatial scale over which the fishery currently operates. This is likely also the case for Sand Crabs, given the focus of its fishery in the Coffin Bay area. As such, there remain some uncertainties about the levels of higher catches that the *Octopus* spp. and Sand Crab fisheries could sustain, considering the limited biological and life history information available with which to assess the statuses and resilience of their stocks.

For the finfish species for which increases in catch are likely to be limited to tens of tonnes.yr^{-1}, the estimates of recreational catches throughout the 2000s have generally exceeded the recent commercial catches (Table 4.1). As such, according to SA's Allocation Policy that determines the need to maintain appropriate proportional shares amongst sectors (PIRSA 2013), any potential increases in catch in the future would need to be shared with the recreational sector. For such limited volumes to be useful for the commercial sector, suggests that the fishery product would need to be of 'premium' quality in order to attract a high enough value to justify the expense of capture, transport and processing. This is also true for the remaining species, i.e. the Broadnose Shark and Whiskery Shark, which currently account for very low volumes of commercial catches. The Broadnose Shark is a long-lived, slow growing, high trophic level predator that is occasionally taken as by-catch. It has a low market value relative to the Gummy Shark, School Shark and Whiskery Shark. It is currently not considered a viable target species.

4.2 Further Considerations

This study has determined that there are some taxa that are taken in SA's MSF that could sustainably support higher levels of catch. Furthermore, amongst the different taxa, the scale of potential increases vary over several orders of magnitude, up to 100s of tonnes.yr^{-1}. It was not the focus of this project to devise strategies by which the seafood industries could achieve such increases in production. The latter would be extremely challenging to achieve, requiring the involvement and commitment of the whole-of-supply-chain. Such issues that would need to be addressed include: the capacity of fishers, boats and gear set-up; transport of the whole product; product development, processing, value-adding and packaging; as well as market assessment and development (Stephens 2016; Howieson *et al*. 2017, 2019). These are specialist fields that require considerable effort. For example, over the past decade there has been commitment in WA to further develop its fishery for the Western Australian Salmon. This has involved considerable research effort towards product enhancement, development and value-adding. This has included the assessment of techniques to maintain the quality of fresh and frozen fillets and whole fish, whilst several value-added products have been developed and trialled, including: canning of flavoured fish; smoking of fish; production of fish cakes; and packaging of cooked fish in oil (Howieson *et al*. 2017). Furthermore, a national workshop was held in 2019 that involved a diverse array of stakeholders whose aim was to develop a national approach for developing a bigger and stronger fishing industry for the Australian Salmon (Howieson et al. 2019).

For the taxa that the risk assessment indicated could support higher levels of commercial production (Table 4.1), the industry workshop provided opportunity to consider the current barriers and management impediments to increasing catches. A number of the nominated species are taken primarily by the hauling net sector. Their catches have declined throughout the 2000s, due to the general decline that has occurred in this sector following its restructure in 2005 (Fowler 2019). The increase in spatial closures that were imposed at that time related to stock sustainability issues for the Southern Garfish fisheries in both gulfs (Steer *et al.* 2016, Fowler 2019). Nevertheless, stock sustainability issues for this premium species have persisted throughout the 2000s (Steer *et al*. 2016, 2018a, 2018b, 2020). There have also been concerns in recent years about the statuses of the fisheries for King George Whiting in the gulfs (Fowler *et al*. 2014, Steer *et al*. 2018a), and about issues of localised depletion for Southern Calamari (Steer *et al.* 2020). Both of these primary species are taken with hauling nets. This presents a challenge for the management of the net sector of the MSF, i.e. to differentiate amongst target species whilst using a net-based fishing methodology to allow increases in catches of Western Australian Salmon, Australian Herring, Snook, Yelloweye Mullet, Leatherjacket spp., and Western Striped Grunter without compromising the recovery of the stocks of Southern Garfish or affecting the stock sustainability for the King George Whiting and Southern Calamari fisheries.

For some other candidate species that were recognised as capable of supporting higher catches, specialised fishing gear or fishing operations are required for their capture. These include the Ocean Jacket, *Octopus* spp., Sand Crabs and Blue Mackerel. The management impediments for these taxa relate to the limited numbers of fishers and the numbers, types of non-transferability of fishing devices that are endorsed on their individual licenses. Furthermore, for the two species for which the main fishing grounds are located in offshore waters of the continental shelf, i.e. Ocean Jackets and Blue Mackerel, the capacity of vessels and equipment that would be required are considerably greater and more costly than those used for fishing operations in gulf waters.

The industry workshop also identified that there was a lack of a comprehensive biological understanding for some species and the ecological systems of which they are a part. These include such knowledge limitations as: the species composition and dispersion patterns of the *Octopus* spp. despite some recent progress in this area (Martino and Doubleday 2020); the dispersion of the biomass of Blue Mackerel between offshore and inshore gulf waters; the age and growth for species such as the Ocean Jackets, Sea Sweep, Sand Crabs; as well as stock structure for species such as Yellowfin Whiting, Snook and Yelloweye Mullet. In order to develop or enhance fisheries, these shortfalls in biological understanding would need to be addressed appropriately. This may depend on the pursuit of diverse sources of research funds, as was the case recently-completed for the research project on *Octopus* spp. (Martino and Doubleday 2020).

4.3 Limitations of Study

This project undertook a comprehensive process to identify taxa that could sustainably support higher commercial catches of MSF species in SA. It has taken several years to complete, reflecting several complexities. First, there was no established methodology to address the primary focus of the project. Ultimately the methodology that was used, evolved throughout the course of the study. The outcomes of the study are based on the methods that were used to select the 'candidate' species whose subsequent assessment was based on life history and fishery information. To achieve this, there were several complexities that had to be overcome. Primarily, the process of assessment was complicated by the taxonomic complexity inherent in the reporting that is used in the fishery. The main dataset that was used, i.e. the MSFIS contains a 36-year historical dataset for 111 different taxonomic categories. These categories include numerous ones that are at high taxonomic levels or are broad groupings of taxa. As such, for many individual species that are recognised in the new comprehensive species list there are no specific commercial fishery data available in the commercial fishery database, as any data for them have been grouped into broader taxonomic categories. Nevertheless, generally, life history information needs to be considered at the taxonomic level of 'species'. Whilst such data were available for 65 different species of finfish, elasmobranchs and molluscs, there was incomplete overlap between this list of species and the taxa for which the commercial fishery data were available. This contributed to the limited numbers of taxa that could be considered as 'candidate' species.

A further limitation of the study pertains to the cMSY modelling. Such modelling is based on minimal inputs, particularly time-series of estimates of total catch. In this study, these datasets were constructed for time periods that were as extensive as possible, from commercial catches and annual estimates of recreational catch based on results from occasional State-wide surveys. Consequently, there must be considerable uncertainty associated with these annual estimates of recreational catch. This is an on-going issue for the MSF fishery that has often been highlighted for undertaking stock assessments (Fowler *et al*. 2014, 2019; Steer *et al.* 2018a, 2018b, 2020). Furthermore, the cMSY modelling can only be applied successfully when population responses to exploitation are evident in the catch history. However, the catch histories of different taxa are likely to reflect the consequences of a multiplicity of factors. These include fishing effort, which can be driven by the market value of a target species as well as the behaviour of the fishers. Overall, these points suggest that the modelling results should be interpreted cautiously.

5. Conclusions

The objectives of this project have largely been achieved, as indicated by the key findings and outcomes below.

Objective 1: to assess the potential to diversify South Australia's (SA) Marine Scalefish Fishery (MSF) by increasing production of currently lesser known species whilst conforming to the principles of ESD.

The key findings for the different methodological steps are as follows.

- The development of the new comprehensive list of taxa available to the MSF demonstrated the broad diversity of finfish, elasmobranchs, crustaceans, molluscs and worms that can be legitimately taken. This list also recognises several taxa that are not currently considered legitimate and several others that the commercial sector has requested be incorporated as legitimate taxa.
- The assessments of taxa for their capacities to support higher catches were based on historical fishery data as well as biological data that specifically pertain to the life history characteristics of the species. Commercial fishery data were not available for all species that were identified in the new comprehensive species list. Whilst commercial fishery data are available for 111 different taxonomic categories that include some higher taxonomic levels and broad groupings of taxa, the life history data were available for 65 different species of finfish, elasmobranchs and molluscs. The incomplete overlap between the taxa for which there were fishery data and those for which there were biological data limited the numbers of taxa that could be assessed.
- The 26 candidate taxa that were assessed were selected based on their recent commercial catches (2013-17), and whether their fishery was independently managed.
- Of these 26 taxa, half were considered not capable of supporting higher catches in SA's marine coastal waters by the MSF. For these, the biomass was too low and/or the 'population resilience' was too low so that the reproductive capacity could not maintain sufficient population biomass to support higher catches.
- Alternatively, there were 13 taxa that were considered capable of supporting higher catches. The levels of higher catches that might be sustainable varied amongst the different taxa, i.e. up to several hundred tonnes per year for Western Australian Salmon and Ocean Jackets; down to 10s of tonnes per year for most remaining finfish species. There is uncertainty about the potential catches for *Octopus* spp. and Sand Crabs, based on the possibility for geographic expansion of their fisheries. Given the low recent catches of Broadnose and Whiskery Sharks their potential increases may be quite limited.

Objective 2: to provide advice about the potential to increase fishery catches for individual species in the commercial MSF and to provide guidance in each case with respect to the need for further research, economic development and regulatory reform.

- The primary purpose of the project was to identify taxa towards which the commercial sector could redirect fishing effort away from the primary species. The purpose was not to devise strategies to achieve such potential increases in production as the latter is extremely difficult to achieve, requiring the involvement and commitment of the whole-supply-chain of seafood production.
- The industry workshop considered a number of the selected candidate species that were relevant to the commercial sector to identify the barriers and potential management impediments to increasing catches. Since most of the identified species are taken with hauling nets, the current limited catches relate, at least partly, to the decline in the hauling net sector throughout the 2000s. As such, one major management impediment is the extensive hauling net spatial closures. For other species such as Ocean Jackets, *Octopus* spp. and Sand Crabs, which require specialised fishing equipment, there are limited numbers of fishers and numbers of gear that are currently endorsed. For Blue Mackerel, purse seine fishing or poling operations followed by processes for careful on-board handling and storage would need to be established.
- The lack of biological understanding for fishery management was recognised for some taxa. These include: species composition and dispersion patterns for the *Octopus* spp. as well as the Rays and Skates; for the Blue Mackerel, the dispersion of biomass of market-sized fish between offshore waters and inshore and gulfs waters; age and growth for Ocean Jackets, Sea Sweep and Sand Crabs; and stock structure for Snook and Yelloweye Mullet.

6. Implications and Recommendations

There is a broad diversity of taxa that can be taken by the commercial sector of the MSF. This study assessed whether it might be possible to increase the fishery productivity for some taxa, without compromising their population recruitment processes and hence their sustainability. Numerous taxa were assessed as not capable of supporting higher catches, even though for some they had recently been assigned stock statuses of 'sustainable' (Steer *et al*. 2018a, 2018b, 2020). This reflected their limited biomass and/or limited reproductive capacity to maintain biomass. In contrast, the study: (i) concluded that there were 13 different taxa that could support higher catches; (ii) identified the current limiters and management impediments for these taxa; and (iii) provided some insight about the extent of increases in catch that could be sustained.

The project findings indicate that there are different taxa towards which the commercial fishers could redirect some fishing effort. Nevertheless, achieving this would present some challenges both for the management of the fishery and for the fishers with respect to the logistics of the fishing operations. The challenges for fishery management relate to the current restrictions on numbers of fishers and gear, as well as spatial and temporal closures on fisheries that are used to control fishing catch and effort. The difficulty here relates to easing restrictions on some taxa, without doing the same for other species that are otherwise fully exploited. Similarly, the challenges to fishers relate to the logistics of how to exploit lesser known species without inadvertently increasing fishing pressure on fully exploited ones, particularly the primary finfish species. This might require the development of innovative targeted fishing practices to ensure selective fishing of the lesser known species. A further challenge for the commercial sector would relate to developing fishing operations in offshore waters for species such as Ocean Jackets and Blue Mackerel. Undertaking such fishing operations would involve considerable commitment, expertise and expense.

A further challenge with respect to increasing commercial catches for some MSF taxa, particularly those for which the increases might be of the order of hundreds of tonnes per year, relates to selling the higher volume of the product without compromising its value. This is a complex issue whose resolution would require a multiplicity of considerations and a commitment from the whole-of-supply-chain. The challenge of achieving this is apparent from the multi-sector workshop that focussed on market development and supply for the Australian Salmon fisheries at the national level (Howieson *et al*. 2019).

7. Extension and adoption

The development of this project and its early progress was discussed at several meetings of the Marine Fishers Association, particularly in the context of the restructure of this fishery (Anon 2016, 2019). However, its significance developed momentum in late 2019 as a consequence of the stringent closures that were implemented for SA's Snapper fishery. These closures reinforced the need to direct fishing effort away from the primary species onto ones that were less heavily exploited. This led PIRSA F&A to establish the 'Lesser Known Species' strategy. This project has been important in providing advice to PIRSA F&A about which species to consider as 'lesser known' ones that could support higher catches, not just for the commercial sector but also for the recreational and charter boat sectors as well as the Aboriginal traditional sector. As such, the identification of lesser known species that could support higher catches and their management impediments (Appendix 6) has been used as the basis for the development of a promotional advertising campaign. This campaign is primarily targeted at seafood consumers and the recreational sector, and its purpose is to educate about alternative species for consumption or towards which to divert fishing effort, ultimately to diversify the fishery and to relieve fishery pressure on the primary species. This has culminated in the development of a PIRSA website, i.e. 'Same Dish, New Fish' (http://samedishnewfish.sa.gov.au/). The purpose of the website is to encourage fishers and consumers to think about catching and cooking 'lesser known' seafood taxa. Of the six 'lesser known' taxa that are promoted on the website, four were identified in this study.

8. Appendices

8.1 Appendix 1. Project Staff

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8.3 Appendix 3. Life history information

Table 8.1. Life history information for species for which 'population resilience' was calculated. Also shown is the life history strategy to which each was assigned.

Life history strategy	Common name	Scientific name	L_{50} (mm)	Lmax TL (mm)	*K*	Age mat (yr)	Age max (yr)	Resilience	Source
Opportunistic Strategists	Australian Anchovy	*Engraulis australis*	99	152	1.30	0.9	5	52.5	Dimmlich et al. 2006
	Blue Sprat	*Spratelloides robustus*	60	140		0.37	0.66	51.73	Blackburn 1941, Rogers et al. 2003
	Giant Australian Cuttlefish	*Sepia apama*	200	365		0.5	2	52.86	Hall and Fowler 2003
	Gould's Squid	*Nototodarus gouldi*	310	400	0.26	0.625	0.90	48.5	AMFA website; Stark 2008 PhD thesis
	Red Cod	*Pseudophycis bachus*	315	600	1.00	1	2.5	60.43	Kemp et al. 2012, 2013
	Sandy Sprat	*Hyperlophus vittatus*	58	120	1.83	1.5	4	53.54	Rogers et al. 2007; Gaughan et al. 1996
	Scallop	*Pecten fumatus*	75	145	1.57	2	16	51.37	Gwyther and McShane 1988 in Bruce et al. 2002; Semmens et al. 2012 in SAFS 2012
	Southern Calamari	*Sepioteuthis australis*	175	550		0.38	0.9	52.86	FRDC SAFS 2016; Steer et al. 2007
Intermediate strategist	Greenback Flounder	*Rhombosolea tapirina*	198	450	0.09	1	10	45.97	Gomon et al. 2008; Earl and Ye 2016; Ferguson 2006
	Australian Herring	*Arripis georgianus*	228	400	0.57	2.6	12	40.73	Smith et al. 2013
	Barracouta	*Thyrsites atun*	500	1400	0.26	3	10.5	38.84	Shepherd and Edger 2013; Horn 2002
	Black Bream	*Acanthopagrus butcheri*	218	550	0.04	2.2	29	35.73	Morison et al. 1998; Sarre, G. A., Potter, I. C., 1999. in Smallwood et al. 2013.
	Blue Mackerel	*Scomber australasicus*	287	420	0.50	2	7	42.93	Ward and Rogers 2007
	Brown Spotted Wrasse	*Notolabrus parilus*	195	385	0.15	2.9	12	37.35	Lek et al., 2012; Lek, 2012 In Smallwood et al. 2013
	Deepwater Flathead	*Neoplatycephalus conatus*	450	770	0.20	3.8	26	31.94	Brown and Sivakumaran 2006; SAFS - Moore (2016).
	John Dory	*Zeus faber*	280	900	0.15	4	12	34.03	Smith and Stewart (1994) in Bruce et al. 2002
	King George Whiting	*Sillaginodes punctatus*	320	640	0.70	3.3	22	45.16	Fowler and McGarvey 2000; SARDI unpubl.
	Maray	*Etrumeus teres*	135	280	0.25	2	5	41.48	Osman et al. 2011; Farrag et al. 2014; NO DATA for Aust waters.
	Mirror Dory	*Zenopsis nebulosa*		700	0.10	5	14	27.86	Bruce et al. 2002; Fishbase 2018
	Ocean Jacket	*Nelusetta ayraudi*	300	700	0.48	2.5	9	43.28	Grove-Jones and Burnell 1991
	Purple Wrasse	*Notolabrus fucicola*	113.5	600	0.11	2.5	20	36.37	Ewing 2004; Ewing et al. 2003
	Rock Flathead	*Platycephalus laevigatus*	264	540	0.17	0.14	21	42.18	Koopman et al. 2004
	Rosy Wrasse	*Pseudolabrus psittaculus*		250	0.09		11	28.23	fishes of Australia website
	School Whiting	*Sillago flindersi/bassensis*	170	250	0.51	2	7	46.54	Hobday and Wankanowski (1987) . In Bruce et al. 2002
	Sea Mullet	*Mugil cephalus*	373	787	0.59	2	16	46.12	Gaughan et al., 2006; Smallwood et al. 2013
	Senator Wrasse	*Pictilabrus laticlavius*	138	270	0.28	0.9	5	50.97	Morton et al. 2008
	Snook	*Sphyraena novaehollandiae*	420	880	0.23	2.5	11	40.99	Bertoni 1994

Life history strategy	Common name	Scientific name	L_{50} (mm)	Lmax TL (mm)	*K*	Age mat (yr)	Age max (yr)	Resilience	Source
	Southern Bluespotted Flathead	*Platycephalus speculator*	250	900	0.59	2	12	48.32	Smallwood et al. 2013; Gomon et al., 2008; Hyndes et al., 1992a
	Southern Garfish	*Hyporhamphus melanochir*	215	410	0.33	1.46	7	47.41	Steer et al. 2012
	Tiger Flathead	*Platycephalus richardsoni*	300	600	0.13	3	20	34.62	Maloney 2016 - SAFS; Barnes et al. 2011
	Vongole spp	*Katylesia spp.*	27	55		4	29	40.76	Dent stock assess, SAFS 2016
	Western Striped Grunter	*Pelates octolineatus*	155	280	0.44	2	10	45.18	Veale et al. 2015
	Yelloweye Mullet	*Aldrichetta forsteri*	242	390	0.08	3	10	36.34	Earl and Feguson 2013
	Yellowfin Whiting	*Sillago schomburgkii*	238	420	0.53	3	12	41.42	Steer et al. 2018; Ferguson 2000; Hyndes and Potter 1997
Periodic strategists	Bight redfish	*Centroberyx gerrardi*	250	660	0.03	9	71	20.94	Saunder et al. 2009; Brown and Sivakumaran 2006; Smith and Wayte (2001).
	Blue eye trevalla	*Hyperoglyphe antarctica*	720	1400	0.08	11.5	76	19.04	Baelde, P. (1995). In Bruce et al. 2002, AFMA 2018 website; SAFS 2016 Georgeson et al.
	Blue Morwong	*Nemadactylus douglasii*	240	800	0.22	3	22	35.82	Saunder et al. 2009; Stewart and Hughes 2009
	Bluethroat Wrasse	*Notolabrus tetricus*	225	500	0.12	5	23	25.74	Smith et al. In Saunders et al 2009
	Foxfish	*Bodianus frenchii*	223	483	0.09	9.14	78	15.8	Cossington et al. 2010
	Harlequin fish	*Othos dentex*		760	0.17		42	20.65	Saunder et al. 2009
	Jack Mackerel	*Trachurus declivis*	270	500	0.23	3.5	25	31.25	Webb 1976; Webb and Grant 1979. in Bruce et a; 2002
	Jackass Morwong	*Nemadactylus macropterus*	220	700	0.34	3	41	33.78	Smith and Wayte 2001 in Bruce et al. 2002
	Mulloway	*Argyrosomus japonicus*	850	2000	0.22	6	32	25.68	Earl and Ward 2014; Farmer 2008
	Pink Ling	*Genypterus blacodes*	720	2100	0.15	4.5	28	28.82	Lyle and Ford 1993; Morrison et al. 1999. In Bruce et al. 2002
	Samson Fish	*Seriola hippos*	831	1800	0.19	4	29	31.19	Rowland 2009
	Sea Sweep	*Scorpis aequipinnis*	170	610		2.5	54	34.17	Stewart and Hughes 2005
	Silver Trevally	*Pseudocaranx georgianus*	195	800	0.05	5.5	20	24.76	Rowling, K and Raines, L. (2000)., Chick et al. 2016 - SAFS
	Snapper	*Chrysophrys auratus*	280	1010	0.02	2.5	39	32.56	Fowler et al. 2016; Stewart et al. 2010; Francis et al. 1992; McGlennon 2000
	Southern Sand Flathead	*Platycephalus bassensis*	235	480	0.23	3.9	17	34.05	Andrews et al. 2016 - SAFS. Jordan et al. 1998
	Swallowtail	*Centroberyx lineatus*		460	0.18		32	25.18	Saunder et al. 2009,
	Western Australian Salmon	*Arripis truttaceus*	630	961	0.21	4	10	32.89	Stanley 1980; Gaughan et al., 2006; Hutchins and Swainston 1986; Nicholls, 1973; Cappo, 1987, In Smallwood et al. 2013
	Western Blue groper	*Achoerodus gouldii*	653	1750	0.14	17	70	18.37	Coulson et al. 2009
	Yellowtail kingfish	*Seriola lalandi*	830	2500	0.10	4.5	24	28.62	Gomon et al. 2008; Gillanders et al. 1999; McKenzie 2014
Equilibrium strategists	Australian angelshark	*Squatina australis*	970	1150		13	35	10	Max age and L50 from Pacific angel shark *S. californica*; natanson and Cailliet 1986.
	Broadnose sevengill shark	*Notorychus cepedianus*	2200	3000	0.07	10	49	14.86	Camhi et al. 1998; Last and Stevens 2009; Bracinni et al. Fishbase 2018
	Bronze Whaler Shark	*Carcharhinus brachyurus*	1770	3000	0.04	20	32	14.33	Rogers et al. 2013, Drew et al. 2016; Last and Stevens 2009

Life history strategy	Common name	Scientific name	L_{50} *(mm)*	Lmax TL (mm)	*K*	Age mat (yr)	Age max (yr)	Resilience	Source
	Dusky Shark	*Carcharhinus obscurus*	2540	3650	0.04	29.6	55	12.44	McAuley et al. 2007, In Rogers et al. 2013 MFR; Last and Stevens 2009; McAuley et al
	Gulf wobbegong	*Orectolobus halei*	1792	2060	0.08	16	25	19.35	Huveneers 2007 PhD thesis; Last and Stevens 2009
	Gummy Shark	*Mustelus antarcticus*	1253	1850	0.06	4.5	16	28.25	AFMA, 2018 website, SAFS Marton et al. 2016, Moulton et al.. 1992
	Melbourne Skate	*Dipturus whitleyi*	590	2000	0.16	5.7	9	31.96	Last and Stevens 2009; Francis et al 2001 - Age, Size maturity and Amax all for 2 NZ species.
	Port Jackson shark	*Heterodontus portusjacksoni*	880	1650	0.08	12.5	35	15.33	Last and Stevens 2009; Izzo and Rodda 2012
	School Shark	*Galeorhinus galeus*	1240	1800	0.14	11.5	60	22.95	AFMA, 2018 website, SAFS Marton et al. 2016; Moulton et al 1992
	Southern Eagle Ray	*Myliobtis australis*	800	1600				26.7	Last and Stevens 2009
	Southern fiddler ray	*Trygonorrhina fasciata*	892	1460	0.16	10	15	24.22	Marshall et al. 2007; Izzo and Gillanders 2008;
	Whiskery shark	*Furgaleus macki*	1400	1600	0.40	6.5	15	31.57	Simpfendorfer refs in IUCN assessment 2016; Simpfendorfer et al 1996;

8.4 Appendix 4. References for Life History Information

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8.5 Appendix 5. Consequence, Likelihood and Risk Level Tables

This appendix shows the tables that were used for the risk assessment process as applied to the candidate species that assessed whether they could support higher levels of catch. The level of risk assigned to each hypothetical level of increase in catch that was assigned for each candidate species (Table 3.2) was based on the descriptions of risk levels in Table 8.2 and the definitions of consequence and likelihood levels that are presented in Tables 8.3 and 8.4. These were modified from general descriptions of Likelihood and Consequence Levels that are provided in Fletcher *et al.* (2015).

Table 8.2. Description of Risk Levels.

Risk Levels	Description	Likely Reporting & Monitoring Requirements	Likely Management Action
1 Negligible	Acceptable; Not an issue	Brief justification – no monitoring	Nil
2 Low	Acceptable; No specific control measures needed	Full justification needed – periodic monitoring	None specific
3 Medium	Acceptable; With current risk control measures in place (no new management required)	Full performance report – regular monitoring	Specific management and/or monitoring required
4 High	Not desirable; Continue strong management actions OR new / further risk control measures to be introduced in the near future	Full performance report – regular monitoring	Increased management activities needed
5 Severe	Unacceptable; If not already introduced, major changes required to management in immediate future	Full performance report – recovery strategy and detailed monitoring	Increased management activities needed urgently

Table 8.3. Description of Likelihood levels that were used to assigned risk levels associated with increasing fishery catches of candidate species. The levels are defined as the likelihood of a particular consequence level actually occurring within the assessment period.

1	Remote	The consequence has never been heard of in these circumstances, but it is not impossible within the timeframe (Probability <5%).
2	Unlikely	The consequence is not expected to occur in the timeframe but it has been known to occur elsewhere under special circumstances (Probability 5 - <20%).
3	Possible	Evidence to suggest this consequence level is possible and may occur in some circumstances within the timeframe (Probability 20 - <50%).
4	Likely	A particular consequence level is expected to occur in the timeframe (Probability ≥50%).

Table 8.4. Description of Consequence levels that were used to assigned risk levels associated with increasing fishery catches of candidate species. The levels are defined as the level of consequence on the populations of the candidate species for nominated levels of increases in total catch.

1. Ecological: Target/Retained Species		
1	Minor	Fishing impacts either not detectable against background variability for this population; or if detectable, minimal impact on population size and none on dynamics. Spawning biomass > Target level
2	Moderate	Fishery operating at maximum acceptable level of depletion. Spawning biomass < Target level but > Threshold level (B_{MSY})
3	High	Level of depletion unacceptable but still not affecting recruitment levels of stock. Spawning biomass < Threshold level (B_{MSY}) but > Limit level (B_{REC})
4	Major	Level of depletion is already affecting (or will definitely affect) future recruitment potential of the stock. Spawning biomass < Limit level (B_{REC})

8.6 Appendix 6. Industry Workshop

This appendix shows the agenda, final summary and completed matrix from the industry workshop that was held on 20th February 2020 at the South Australian Aquatic Sciences Centre.

Agenda

PIRSA

Lesser Known Species Workshop

Date & Time 10.00am to 4.00pm

Venue SARDI Conference Room, Hamra Ave, West Beach

Facilitator Belinda McGrath-Steer, General Manager, Fisheries Policy and Management

Participants Franca Romeo, Dennis Holder, Michael Angelakis, Tom Consentino, Gary Lloyd, Merilyn Nobes, Brian Wheadon, Jo Collins, Ebrahim Bidhendi, Bart Butson, Simon Manners, Neil Schmucker, Chris Izzo, Keith Rowling, Chloe Benton, Karen Teaha, Paul Rogers, Troy Rogers, Tony Fowler

Apologies Graham Keegan, Nathan Bicknell

Item	Topic	Time allocated	Lead
1	**Welcome and introductions**	15 mins	Facilitator
2	**Introduction and purpose of the day**	15 mins	Facilitator
3	**Review of work done by SARDI in under-utilised species** Presentation by Tony Fowler	30 mins	Tony Fowler

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4	**Workshop discussion** - Focus on completing matrix table: o Species/Region o Risk Level o Data needs o Sector o Barriers o Messaging o Accessibility o Management needs	1.5 hours	Facilitator / All
5	**Lunch –** 12:30 to 13:00 during workshop discussion		
6	**Workshop discussion** - continued	60 mins	Facilitator / All
7	**Lesser known species draft promotional strategy** – Presentation of strategy and seek feedback	60 mins	Karen / All
8	**Out of the Blue Opportunity** - Matrix for 12 episodes	45 mins	Facilitator / All
9	**Close and next steps**	15 mins	Facilitator

Final Summary

PIRSA

Lesser Known Species Workshop

Date & Time	10.00am to 4.00pm
Venue	SARDI Conference Room, Hamra Ave, West Beach
Facilitator	Belinda McGrath-Steer, General Manager, Fisheries Policy and Management
Participants	Michael Angelakis, Tom Cosentino, Merilyn Nobes, Brian Wheadon, Jo Collins, Bart Butson, Keith Rowling, Chloe Benton, Karen Teaha, Tony Fowler, Paul Rogers, Chris Izzo, Neil Schmucker, Simon Manners, Gavin Begg, Troy Rogers
Apologies	Franca Romeo, Dennis Holder, Graham Keegan, Gary Lloyd, Ebrahim Bidhendi, Nathan Bicknell

Welcome and introductions

Facilitator clarified there were two key aims, providing information for SARDI to finalise the FRDC project and to inform a Lesser Known Species Campaign for South Australia.

Facilitator explained the relationship between Lesser Known Species Reference Group and investigating team for the FRDC project.

It was clarified that the initial scope of the project is State-based only - but could expand into Commonwealth species into the future.

Industry representatives from the MFA clarified they had little knowledge of project so far. It was acknowledged that the MFA Executive Officer was a co-investigator on the FRDC project.

Review of work done by SARDI on FRDC project - SARDI

Presented an overview of science underpinning FRDC project, which seeks to identify alternative target species for the commercial fishery (MSF) to support the reform and spread effort away from the over-exploited primary species. The project focused on understanding the potential of the 60+ species listed on the MSF licence as these are considered the most easily accessible.

The project PI presented the key steps that have been undertaken:

1. Collating fisheries data – available information on catch and effort from commercial and recreational sectors for the identified species

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2. Fishery data used in data-limited models - output fishery parameters of MSY, B_{MSY}, H_{MSY}, time series of estimates of biomass and harvest fraction

4. Collation of biological information for individual key species – data was integrated and used to estimate a parameter called 'population resilience', which is a measure of the capacity for the population of a species to increase in abundance logic step to select candidate species based on commercial catches from the 5 years of 2013 – 2017. Generally, population resilience is low in species that are long-lived and slow to mature (e.g. sharks & rays), and resilience high in short-lived species that reproduce early in their lives (e.g. cephalopods).

5. Risk assessment - assessed the risk to the sustainability of population processes of potential catch increases of 25, 50, 100 and 200 percent - used Ecological Risk Assessment matrix approach using likelihood and consequence

6. Summary of the results - which species with respect to the risks associated with increasing catches that were fed into the matrix

Comments on the FRDC report included:

- Timeframe of data, with the commercial representatives indicating 35 years of commercial data could have been used
- Biomass estimates may reflect changes in catch and effort in response to a range of factors including:
  - Consumer behaviour
  - Fisher behaviour
  - Amalgamation scheme
  - Logistical and freight issues, particularly from more remote areas like the West Coast
  - Barriers like netting closures and seasonal closures, and the fact nets are a key gear type for catching lesser known species
- What is the confidence in the output models – how is the data used and can they be back calculated?
- What about the recreational and charter sectors, with recreational data acknowledged as a key limitation?

Other species identified by the workshop include:

- Rays and skates
- Freshwater fish in general
- Blue Swimmer Crabs outside of the quota zones
- Samson fish and Yellowtail Kingfish for the charter and recreational sectors

Summary of first meeting of Reference Group

Facilitator summarised some of the impediments and messaging required to promote and raise awareness of lesser known species from the first meeting of the reference group in 2019.

Key items that were raised included linking to seasonality – primarily to allow for greater affordability and increase product quality through freshness. Other factors discussed included the need for convenience and value-adding to maximise value.

It was noted the concept of what consumers are doing with the fish is understood more as consumers/restaurants are promoting more of what they are eating and preparing on various media sources; which flows through to fishers/consumers.

Key concept is, if we are going to increase catch, is there a market or opportunities to sell the fish, for the best price.

Workshop Discussion

Participants worked through and populated a matrix for candidate lesser known species, which is provided at **Attachment A**.

A number of factors were discussed at the workshop including the impact of increasing catch of any sector in relation to the current allocated shares of individual species, particularly if there is significant targeting away from the primary species.

Lesser Known Species Campaign

PIRSA advised they would further develop a campaign strategy following the prioritisation of the species from the workshop, consistent with the matrix. Given there is a focus on behaviour change of key stakeholders, it was stressed that there will need to be a focussed campaign that targets a limited number of species in the first instance. This will serve as a foundation for future promotional work.

PIRSA will circulate the campaign strategy with reference group. The MFA requested representation on the reference group, which will be considered by PIRSA.

Out of the Blue

Michael gave an update on the history of Out of the Blue and the key role they had played over a number of years in promoting seafood and the sectors in South Australia. Traditionally this has been a stepwise approach – from the biology to the wholesaler, retailer and ultimately the consumer.

Next Steps

Finalise the matrix and prioritise the key species for the campaign. There was some discussion over the utilisation of the river fishery – including the question of any scope for MSF licence holders to move inland.

Participants acknowledge this workshop was a good step in the journey into co-management, including the journey towards PIRSA and SARDI working together on future of fisheries and aquaculture.

It was clarified the summary could be distributed to Charter operators.

Key linkages were identified with the Seafood Forum, and opportunities for fisheries enhancement like fish stocking to increase stock size and allow for higher productivity.

Table 8.5 Summary of the discussion points from the Lesser Known Species Workshop that considered issues surrounding the increase in fishery production for numerous candidate MSF species.

Species	Region	Risk Level*ERA	Data needs	Sector	Barriers	Messaging	Management impediments
Australian Salmon	Statewide	25% increase Medium risk	FRDC project underway to understand biology and biomass	Commercial Recreational Charter	Marketability Handling Wholesale Awareness Education Freight	Sportfish Good eating Catchability - Rec/Charter Value add	Netting closures incl 5m Gear types Sector issues Indicative quotas - TACC, allowances
Australian Herring	Statewide	25% Med	Nil	Consumer Recreational	Preparation Size class in SA	Easy access Introductory species	Netting closures incl 5m
Ocean Jackets	Offshore	50% Low	Ageing Check Commonwealth data	Commercial	Cost of investing/infrastructure Recovery of fish Commonwealth catch		Gear types Limited licences with sufficient gear Licence conditions for setting traps
Other Leather jackets	Statewide	25% Med	Species composition Biology Reported commercial weights	Commercial Recreational	Investing in alternative gear types	Preparation Value to consumer Quality flesh	Netting closures incl 5m
Octopus	Statewide	25% Low	UniSA project species composition - gear selectivity	Commercial	Gear availability Market potential/overseas competition		Gear types Limited licences with sufficient gear Limited information on gear types
Sand Crabs	Gulfs WC	50% Low	Biology	Commercial Recreational Charter	Gear Price/Marketing		Limited regionally Gear restrictions hoop/drop Spatial restriction of stock
Snook	Statewide	25% Low	Stock structure	Commercial Recreational Charter	Catchability/fisher ability Processing/Yield loss Messaging	Match as species to a cultural target Education as target species for younger generation	Netting closures incl 5m Size limits
YE Mullet (not LCF)	Statewide (Gulfs)	25% Low	Stock structure	Commercial Recreational	Seasonality Market price Market competition with LCF	Reputation	Netting closures incl 5m
Blue Mackerel	Offshore	25% Low	Commonwealth stock assessment	Commercial	Investment in gear/nets		Gear types - purseine/poling Offshore fishing Comm fishery competition
Sea Sweep	Lower Gulfs Offshore	25% Low	Ageing	Commercial Recreational Charter	Localised access	Pomfret substitute for asian market Fighting fish	Netting closures incl 5m Gear types Marketability
Carp	Inland waterways	Not included, but low	Increased gear interaction with native fish	Commercial Recreational	Perception NCCP Market price Investment in gear	Large supply of cheap sustainable protein	NCCP? Native fish gear interactions

Species	Region	Risk Level*ERA	Data needs	Sector	Barriers	Messaging	Management impediments
Redfin	Inland waterways	Not included, but low					Inland fishing restrictions Gear - access
Queen Snapper (Blue Morwong)	Statewide	n.a.	Ageing	Charter Recreational			
Sardine							
Nannygai (Bight Redfish)	Offshore	25% High	Commonwealth stock assessment	Charter	Handling Naming/Identification Accessibility	Naming/Identification	Fished in Commonwealth
Red Mullet	Inshore, gulfs and bays	25% High	Stock structure	Commercial Recreational		Loved in Mediterranean	Netting closures 5 m
Silver Trevally	Statewide	25% High	Nil	Commercial Recreational Charter	Limited capacity to increase catch Messaging Seasonality Commonwealth Species	Sashimi quality if handled well Selectivity of high quality fish Seasonality	Netting closures 5 m Commonwealth management
Cuttlefish	Point Lowly Statewide	n.a.	Nil	Commercial Recreational Charter	False Bay closure NSG closure	Bait species	Closures
YTK	Statewide	25% high	National workshop in March 2020 movement, stock structure, post-release survival, Interaction with Aquaculture	Charter Recreational	Aquaculture fish in market Specialised to catch Seasonality Accessibility	Fighting fish, prized offshore sport fish.	Charter Bag limit Size limit
West Coast Garfish	West Coast	n.a.	Biology etc Stock structure	Commercial	Netting closures	Best gar in the state	Netting closure 5m
Sea Mullet	West Coast	n.a.	Biology etc Stock structure	Commercial	Netting closures	Roe and fillets	Netting closure 5m
Flathead	State-wide	25% high		Consumer			
Sampson Fish	Offshore	n.a.	Post-release survival (mainly catch & release sp.), connectivity and stock structure	Consumer, Recreational, Charter	Offshore accessibility, seasonality.	Prized offshore sport fish species.	
Rays and Skate	Statewide	Not included, but similar to shark, difficult to determine withour species ID	Biology				
Other freshwater species							
West Coast Blue Swimmer Crab	West Coast	n.a.					
Rock Crab	West Coast	n.a.					
Toadfish	Gulfs	n.a.					
Blue Throat Wrasse	Southern gulfs	25% high					