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Resource Assessment Report for Western Australian Salmon in Western Australia

Department of Primary Industries and Regional Development, Western Australia

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Resource Assessment Report for Western Australian Salmon in Western Australia

Rodney Duffy, Bianca Brooks, Alex Hesp, Amber Quinn, Blaine Hodgson, Marcus Newman

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Executive Summary

Western Australian salmon, *Arripis truttaceus* (Cuvier 1829), is a large pelagic finfish species endemic to southern Australia. This document provides the formal stock assessment advice and assessment of risk to sustainability for the state-wide *Western Australian Salmon Resource*, which is retained in both the West Coast Bioregion (WCB) and South Coast Bioregions (SCB) of Western Australia (WA). The results of this current assessment for Western Australian salmon, as outlined in this report, indicate a low sustainability risk for the stock, consistent with the results of the previous assessment by Wise and Molony (2018).

There is a long history of commercial and recreational fishing of Western Australian salmon in WA. Historically, this species was landed in large quantities with a peak of ~ 5,000 t retained by commercial fisheries in the mid- to late-1960s, the majority of which (~4,000 t) was taken in WA. Commercial catches over the last decade have been much lower, at a level less than 500 t per year. The reduction in catch across the resource can be attributed to a reduction in targeting in response to lack of markets and low wholesale prices for the species. Low catch levels may also be attributed to reduced availability of fish in some years due to environmental factors affecting catchability.

Western Australian salmon is an important recreational species, especially for shore-based fishers, noting that the state-wide recreational catch is difficult to estimate. The recreational catch of Western Australian salmon was estimated at between 150 to 200 t in 1994 and 1995 (Ayvazian et al., 1997), and 136 t in 2000/01 (Henry and Lyle, 2003). Recent research indicates that a large proportion of Western Australian salmon taken by boat-based recreational fishers in WA are released (69%) (Ryan et al., 2022).

The 2022 Western Australian salmon resource assessment followed the Department's risk-based Weight of Evidence approach and considered: vulnerability and susceptibility to fishing (PSA), catch (including catch-MSY (maximum sustainable yield) analyses), effort, catch distribution, catch rates (raw), length and age composition data, catch curve estimates of fishing mortality and per recruit estimates of female spawning potential ratio (SPR), and relative female spawning biomass (B_{rel}).

Summary of 2022 assessment key outcomes

All lines of evidence are consistent with the stock level of Western Australian salmon being acceptable. Recent catches were an order of magnitude less than those prior to 2005, and historic catches were sustained for decades and are well below the estimated maximum sustainable yield (MSY) of between 2,678 t and 3,219 t.

Commercial fishers attribute the decline in catch to lack of markets and this is supported through examination of recent length and age composition data, including an increase in the maximum age recorded since ~ 2000, after which catches decreased substantially. A marked reduction in fishing effort has coincided with decreases in length and age-based estimates of fishing mortality (*F*) and increases in female SPR and B_{rel}. The most recent estimates of *F* were higher than expected given the low levels of retained catch since 2000, however SPR and B_{rel} estimates were still above the target level of 0.4 and indicated a low level of exploitation. Female B_{rel} is considered to be a more informative indicator of stock status than *F* due to the inclusion of a range of information on species biology (e.g., growth, reproductive parameters, stock-recruitment dynamics) and fishing characteristics (e.g., gear selectivity and fish retention).

Stock Status

Based on the information available, the current risk level for the Western Australian salmon stock is estimated to be LOW (C2 x L2). The LOW risk reflects relatively low levels of F and high levels of female SPR and B_{rel}. All the lines of evidence are consistent with a low level of risk, hence the overall *Weight of Evidence Assessment* indicates the status of the Western Australian salmon stock is adequate and that current management settings are maintaining risk at an acceptable (low) level.

This score assumes the total catch will be maintained at near current levels over the next five years, however a moderate increase in catch is possible whilst still maintaining a risk level of medium or less.

Recommendations

The next major stock assessment for Western Australian salmon is currently scheduled for 2027. The data required for this next assessment are envisaged to be similar as those used in this assessment, i.e., commercial catch returns, recreational data, and size and age structure data collected over two consecutive years just prior to the assessment. Additional collections of size and age samples would be recommended for the next assessment if one or more of the following occurred: substantial increase in catches, changes in fishing methods used by commercial operators (e.g., purse seining) or substantial changes in spatial and temporal catch and/or effort.

List of Abbreviations

AMM	Annual Management Meeting
BMSY	Biomass at Maximum Sustainable Yield
B_{rel}	Relative biomass
CL	Confidence Limits
CPUE	Catch Per Unit Effort
DFZ	Designated Fishing Zone
DoF	Department of Fisheries (Western Australia)
DPIRD	Department of Primary Industries and Regional Development
EBFM	Ecosystem-Based Fisheries Management
ENSO	El Niño Southern Oscillation
ESD	Ecologically Sustainable Development
ETP	Endangered, Threatened and Protected
EPBC	Environment Protection and Biodiversity Conservation (Act)
F	Fishing Mortality
FBL	Fishing Boat Licence
FL	Fork Length
FRMA	Fish Resources Management Act
HL	Head Length
IMCRA	Integrated Marine and Coastal Regionalisation for Australia
K	Population carrying capacity
M	Natural Mortality
MI	Marginal Increment
MIA	Marginal Increment Analysis
MSC	Marine Stewardship Council
MSY	Maximum Sustainable Yield
PSA	Productivity Susceptibility Analysis
RBFL	Recreational Boat Fishing Licence
S	Survival
SA	South Australia

SAFS	Status of Australian Fish Stocks
SCB	South Coast Bioregion
SCEMF	South Coast Estuarine Managed Fishery
SCSMF	South Coast Salmon Managed Fishery
SPR	Spawning Potential Ratio
SST	Sea Surface Temperature
SWBSMF	South West Beach Seine Managed Fishery
SWCBNMF	South West Coast Beach Net Managed Fishery
SWCSMF	South West Coast Salmon Managed Fishery
TL	Total Length
WA	Western Australia
WCB	West Coast Bioregion
WTO	Wildlife Trade Operation
Z	Total Mortality

1 Scope

This document provides a cumulative description and assessment of the Western Australian Salmon Resource (Resource) and all fishing activities (i.e., fisheries / fishing sectors) affecting this Resource in WA. The overall Resource comprises a single species, Western Australian salmon, caught within WA, in both the WCB and SCB.

This species is primarily captured during the annual autumn ‘salmon run’ by recreational fishers and commercial beach seine fishers that operate on the South Coast.

The report contains information relevant to assist the assessment of the Resource against Environment Protection and Biodiversity Conservation (EPBC) Act export approval requirements / the Marine Stewardship Council (MSC) Principles and Criteria for Sustainable Fishing and for other reporting requirements, e.g., Status of Australian Fish Stocks (SAFS).

2 How the Department Operates

Fisheries management in WA has evolved over the last 40-50 years from a focus on managing catch of target species by commercial fishers to a fully integrated Ecosystem-Based Fisheries Management (EBFM) approach, which ensures that fishing impacts on the overall ecosystems are appropriately assessed and managed (Fletcher et al., 2010). In line with the principles of Ecologically Sustainable Development (ESD; Fletcher, 2002), the EBFM approach also recognises that the economic and social benefits of fishing to all users must be considered.

Implementation of EBFM involves a risk-based approach to monitoring and assessing the cumulative impacts on WA’s aquatic resources from all fishing activities (commercial, recreational, customary), operating at a bioregional or ecosystem level. The level of risk to each resource is used as a key input to the Department’s Risk Register, which is an integral component of the annual planning cycle for assigning activity priorities (research, management, compliance, education etc.) across each bioregion.

To ensure that management is effective in achieving the relevant ecological, economic and social objectives, formal harvest strategies are being developed for each resource. These harvest strategies outline the performance indicators used to measure how well objectives are being met and set out control rules that specify the management actions to be taken in situations when objectives are not being met. The WA harvest strategy policy (DoF, 2015) has been designed to ensure that the harvest strategies cover the broader scope EBFM and thus considers not only

fishing impacts of target species but also other retained species, bycatch, endangered, threatened and protected (ETP) species, habitats and other ecological components (Fletcher et al., 2016).

3 Aquatic Environment

3.1 West Coast Bioregion

The marine environment of the WCB between 27º00'S (north of Kalbarri) and 115º30' E (west of Augusta) is predominantly a temperate oceanic zone, but it is heavily influenced by the Leeuwin Current, which transports warm tropical water southward along the edge of the continental shelf. The Integrated Marine and Coastal Regionalisation for Australia (IMCRA V 4.0) scheme identifies four meso-scale regions, or parts thereof, within this bioregion: Zuytdorp, Abrolhos Islands, Central West Coast and Leeuwin Naturaliste (Figure 3.1).

Most of the fish stocks of the region are temperate, in keeping with the coastal water temperatures that range from 18° C to about 24° C. The Leeuwin Current is also responsible for the existence of the unusual Abrolhos Islands coral reefs at ~ 29° S and the extended southward distribution of many tropical species along the West Coast and even into the South Coast.

The Leeuwin Current system, which can be up to several hundred kilometres wide along the West Coast, flows most strongly in autumn/winter (April to August) and has its origins in ocean flows from the Pacific through the Indonesian archipelago. The current is variable in strength from year-to-year, flowing at speeds typically around 1 knot, but has been recorded at 3 knots on occasions. The annual variability in current strength is reflected in variations in Fremantle sea levels, and is related to El Niño-Southern Oscillation events in the Pacific Ocean.

Weaker counter-currents on the continental shelf (shoreward of the Leeuwin Current), such as the Capes Current that flows northward from Cape Leeuwin as far as Shark Bay, occur during summer and influence the distribution of many of the coastal finfish species.

The most significant impact of the clear, warm, low-nutrient waters of the Leeuwin Current is on the growth and distribution of the temperate seagrasses. These form extensive meadows in protected coastal waters of the WCB, generally in depths of < 20 m (but up to 30 m), and act as major nursery areas for many fish species and particularly for the western rock lobster.

The west coast is characterised by exposed sandy beaches and a limestone reef system that creates surface reef lines, often about 5 kilometres off the coast. Further offshore, the continental shelf habitats are typically composed of coarse sand interspersed with low limestone reef associated with old shorelines. There are few areas of protected water along the West Coast, the exceptions being within the

Abrolhos Islands, the leeward sides of some small islands off the mid-west coast, plus behind Rottnest and Garden Islands in the Perth metropolitan area.

The two significant marine embayments in the West Coast are Cockburn Sound and Geographe Bay. Along the West Coast, there are four significant estuarine systems – the Swan/Canning, Peel/Harvey, and Leschenault estuaries, and Hardy Inlet (Blackwood estuary). All of these are permanently open to the sea and form an extension of the marine environment except when freshwater run-off displaces the oceanic water for a short period in winter and spring.

Southward of Cape Naturaliste, the coastline changes from limestone to predominantly granite and becomes more exposed to the influences of the Southern Ocean.

3.2 South Coast Bioregion

The continental shelf waters of the SCB (Figure 3.1) are temperate but low in nutrients, due to the seasonal winter presence of the tropical Leeuwin Current and limited terrestrial run-off. Sea surface temperatures typically range from approximately 15°C to 21°C, which is warmer than would normally be expected in these latitudes due to the influence of the Leeuwin Current. The effect of the Leeuwin Current, particularly west of Albany, limits winter minimum temperatures (away from terrestrial effects along the beaches) to about 16 to 17°C. Summer water temperatures in 2012/13 were at a record high, which may have affected the recruitment of some species.

Fish stocks in this region are predominantly temperate, with many species' distributions extending right across southern Australia. Tropical species are occasionally found, which are thought to be brought into the area as larvae.

The South Coast is a high-energy environment, heavily influenced by large swells generated in the Southern Ocean. The coastline from Cape Leeuwin to Israelite Bay is characterised by white sand beaches separated by high granite headlands. East of Israelite Bay, there are long sandy beaches backed by large sand dunes, an extensive length (160 km) of high limestone cliffs and mixed arid coastline to the South Australian (SA) border. There are few large areas of protected water along the South Coast, the exceptions being around Albany and in the Recherche Archipelago off Esperance.

Along the western section of the coastline that receives significant winter rainfall, there are numerous estuaries fed by winter-flowing rivers. Several of these, such as Walpole/Nornalup Inlet and Oyster Harbour, are permanently open, but most are closed by sandbars and open only seasonally after heavy winter rains. The number of rivers and estuaries decreases to the east as the coastline becomes more arid. While these estuaries, influenced by terrestrial run-off, have higher nutrient levels, their outflow to the ocean does not significantly influence the low nutrient status of coastal waters.

The marine geography of the South Coast is similar to the coastline, having fine, clear sand sea floors interspersed with occasional granite outcrops and limestone shoreline platforms and sub-surface reefs.

A mixture of seagrass and kelp habitats occurs along the South Coast, with seagrass more abundant in protected waters and some of the more marine estuaries. The kelp habitats are diverse but dominated by the relatively small *Ecklonia radiata*, rather than the larger kelps expected in these latitudes where waters are typically colder and have higher nutrient levels.

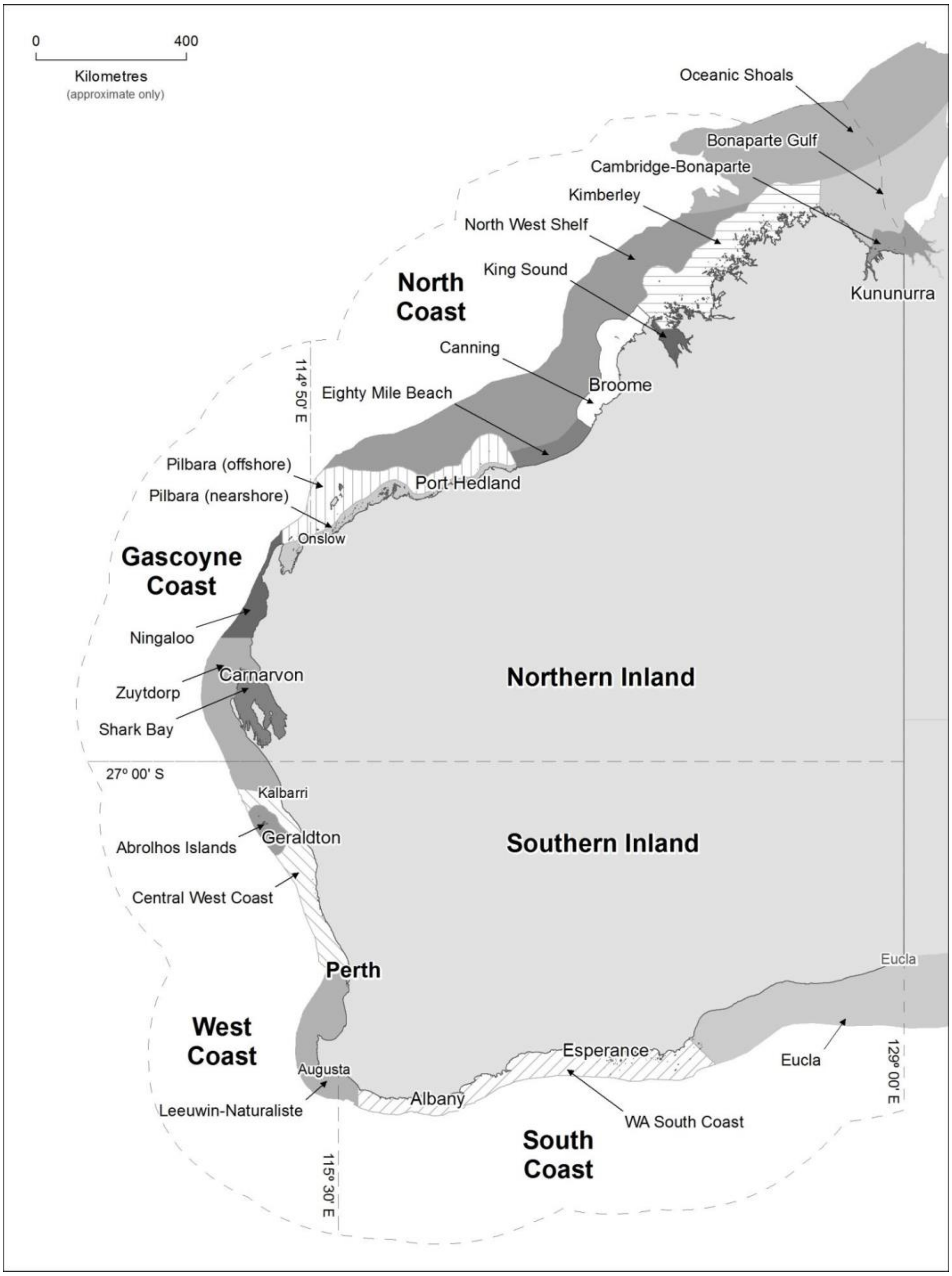


Figure 3.1. Location of bioregions within WA

4 Resource Description

The Resource covers the entire Western Australian salmon stock, including all fish in WA waters and those in other State waters.

5 Species Description

5.1 Western Australian salmon (*Arripis truttaceus*)

Figure 5.1. The Western Australian salmon, *Arripis truttaceus*. Illustration © R. Swainston (www.anima.net.au)

5.1.1 Taxonomy and Distribution

The Western Australian salmon (*Arripis truttaceus*; Cuvier 1829) is a perciform fish and one of four species in the monotypic family Arripidae (Figure 5.1). Western Australian salmon are endemic to southern Australia and occur from Kalbarri in WA to Eden in New South Wales (NSW), although they are predominantly found in WA and SA (Figure 5.2). A congeneric species, the eastern Australian salmon (*Arripis trutta*) occurs along the south-eastern and eastern coast of Australia as far north as Brisbane. Where the species overlap, they may be found in mixed schools together (Kailola et al., 1993). Until the mid-1980s Western Australian salmon was regarded as a subspecies of the eastern species, from which it can be separated by counts of gill rakers (Paulin, 1993). Western Australian salmon have a single continuous dorsal fin with a notch after the last fin spine, no black tips of caudal fin lobes and a yellowish pectoral fin with a black blotch at the base (Yearsley et al., 2001).

Figure 5.2 Distribution map of Western Australian salmon (https://fishesofaustralia.net.au/home/species/407)

5.1.2 Stock Structure

Western Australian salmon constitute a single genetic stock across its entire distribution (Moore and Chaplin, 2013).

5.1.3 Life History

Table 5.1. Summary of biological parameters for Western Australian salmon

Parameter	Value(s)	Comments / Source(s)
von Bertalanffy growth parameters		*Estimated this assessment*
L_∞ (mm)	Combined sexes 707.8 (704.1-711.4)	DPIRD data. Sex specific data provided in text below.
k (year^{-1})	Combined sexes 0.46 (0.45-9.48)	
t_0 (years)	Combined sexes 0.14 (0.12-0.15)	
Maximum age (years)	12 years	DPIRD data
Maximum size (mm)	961 mm	Hutchins and Swainston, 1986
Natural mortality, M (year^{-1})	0.35	Dureuil and Froese, 2021 based on t_{max} = 12 years
Weight-length-parameters		*Estimated this assessment*
a	11.176 (11.216-11.136)	
b	3.025 (3.018-3.032)	
Reproductive pattern	Gonochoristic, serial batch spawner	Stanley, 1980
Logistic maturity parameters		
L_{50} (mm)	F 536 (520-552) M 369 (303-434)	*Estimated this assessment* Numbers in brackets: 95% confidence limits. F=female, M=male.
L_{95} (mm)	F 595 (574-614) M 493 (433-553)	
A_{50} (years)	F 3.41 (3.1-3.6) M 1.95 (1.4-2.5)	
A_{95} (years)	F 4.75 (4.4-5.1) M 3.6 (3.0-4.3)	
Fecundity	Unknown	

5.1.3.1 Life Cycle, Movements and Habitats

Mature salmon form schools and undergo an annual westward spawning migration (Kailola et al., 1993, Walker 1982). Commercial fishers suggest that a 'front run'

occurs, consisting of large, mature fish from WA waters, with smaller fish on their initial spawning run being caught later in the season (P Benson, pers. comm., 2022).

Salmon spawning is thought to occur within the Cape Leeuwin to Busselton region (Bray and Gomon, 2022), although it may occur over a larger region between Albany and Busselton (Cappo, 1987a). Spawning takes place between February and June, with a peak between March and early May, near headlands (Cappo, 1987a). The exact timing and location may vary as it is understood to be dependent on the timing and strength of the Leeuwin Current (Cappo, 1987a).

Eggs, larvae and juvenile fish are moved eastward by the Leeuwin Current and westerly winds and are distributed along the southern coastline as far as Tasmania (Cappo 1987a, Lenanton et al., 1991). First year juveniles of 5–8 cm FL begin to appear in SA bays and inlets between July and September (Cappo 1987b, Malcolm 1966a), and in Victoria (VIC) and Tasmania between August and October (Cappo 1987b, Malcolm 1966a, Robertson 1982, Nicholls 1973). Juvenile salmon are found over soft substrates in shallow and sheltered coastal waters and estuaries from Western Australia to Tasmania (Kailola et al., 1993). They begin forming large schools at 35–40 cm FL (Cappo, 1987a).

Post-spawning fish do not return to eastern states but redistribute along the lower west and South Coast of WA (Kailola et al., 1993); a movement referred to as the ‘back-run’. During the non-spawning period, mature Western Australian salmon occur over continental shelf waters including estuaries, bays and inlets, forming schools in exposed coastal waters behind the surf zone and around reefs and rocky headlands (Kailola et al., 1993). They occasionally traverse deeper waters up to 80 m depth (Kailola et al., 1993).

5.1.3.2 Age and Growth

The maximum reported length for Western Australian salmon is 961 mm (Hutchins and Swainston, 1986), however, they are more frequently caught at 600 to 700mm. The oldest age recorded for salmon is 12 years; three fish of this age have been recorded since 2013 from fish sampled from both commercial and recreational catches (DPIRD data). Growth of salmon is rapid in the first few years of life and slows when maturity is attained. The von Bertalanffy growth model was fitted for this assessment to available length-at-age data collected for each sex and both sexes combined for samples collected since 2000 (Table 5.2, Figure 5.3). The growth curves for the two sexes (based on a likelihood ratio test) were significantly different ($p < 0.001$), but the differences were minor.

Table 5.2 von Bertalanffy growth parameters of Western Australian salmon.

Sex	L_∞ (mm)	k (year^{-1})	t_0 (years)
Male	696.8 (691.5-702.2)	0.47 (0.46-0.49)	0.14 (0.12-0.17)
Female	716.5 (711.8-721.1)	0.46 (0.44-0.47)	0.14 (0.12-0.16)
Combined	707.8 (704.1-711.4)	0.46 (0.45-0.48)	0.14 (0.12-0.15)

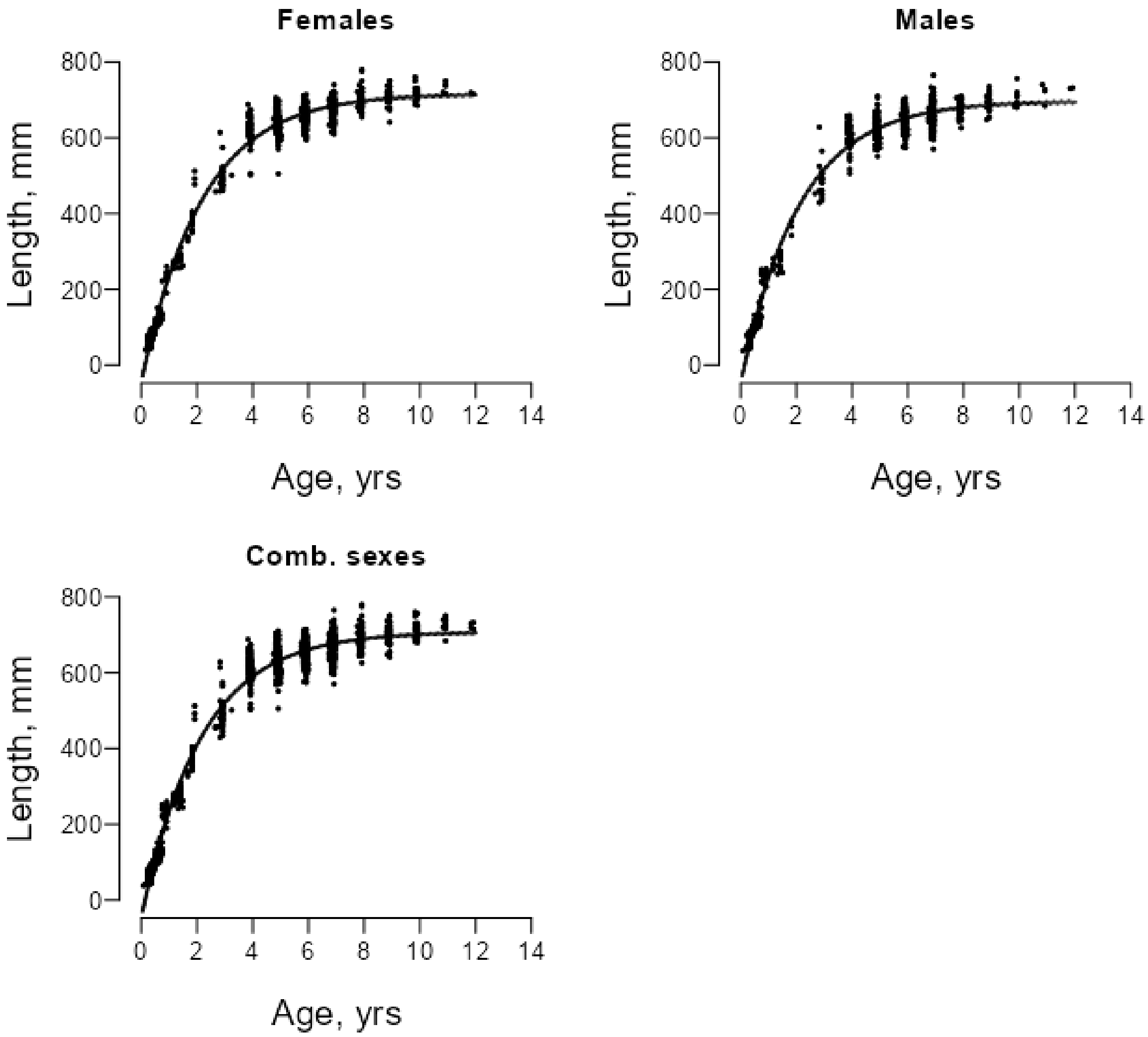


Figure 5.3 von Bertalanffy growth curves fitted to length-at-age data for females, males, and both sexes combined collected since 2000.

5.1.3.3 Natural Mortality

Natural mortality is one of the most important, yet most difficult to estimate, parameters used in stock assessment (Hewitt et al., 2007). Previous published estimates for Western Australian salmon, based on life history traits and sea temperature, generated estimates of *M* of 0.4 to 0.6 y^{-1} (Cappo et al., 2000). A natural mortality estimate of 0.4 y^{-1} was used in the 2018 stock assessment (Wise and Molony, 2018). This value was the same as that used for the 2018 Australian herring (*Arripis georgianus*) stock assessment (Wise and Molony, 2018) and selection of this value for salmon was justified based on the premise that both species had the same maximum observed age (Wise and Molony, 2018).

When direct estimates of *M* are unavailable, or uncertain, age-based empirical equations for estimating natural mortality, such as those of Dureuil et al., 2021 and Dureuil and Froese (2021) are now recommended. Several updated approaches in recent literature overcame a statistical issue in the analysis of Then et al., (2015) used to derive their age-based mortality estimator (Maunder et al., 2023). The approaches of Dureuil et al., (2021) and Dureuil and Froese (2021) utilised a subset of the dataset compiled by Then et al., (2015), removing species from this data set identified as having unknown exploitation status, or if the population was known to be exploited and thus could not be considered very lightly exploited. The approach of Dureuil et al., (2021) yields an estimate of $M = 0.35$ y^{-1}. This value is considerably lower than that derived through direct estimation of *M* via tagging, 0.61 yr^{-1}, however, those analyses used ages estimated from scale reading (Cappo et al., 2000), which has since been found to be much less reliable than otolith-based age estimation.

5.1.3.4 Reproduction and Maturity

Western Australian salmon are gonochoristic and serial batch spawners (Stanley, 1980). On average, females attain maturity at a greater size and age (536 mm & 3.41 years) than males (369 mm & 1.95 years) (Table 5.1, Figure 5.4). The relationship between size and fecundity is not known in Western Australian salmon. Western Australian salmon undertake a westerly migration run to spawn, as they approach maturity.

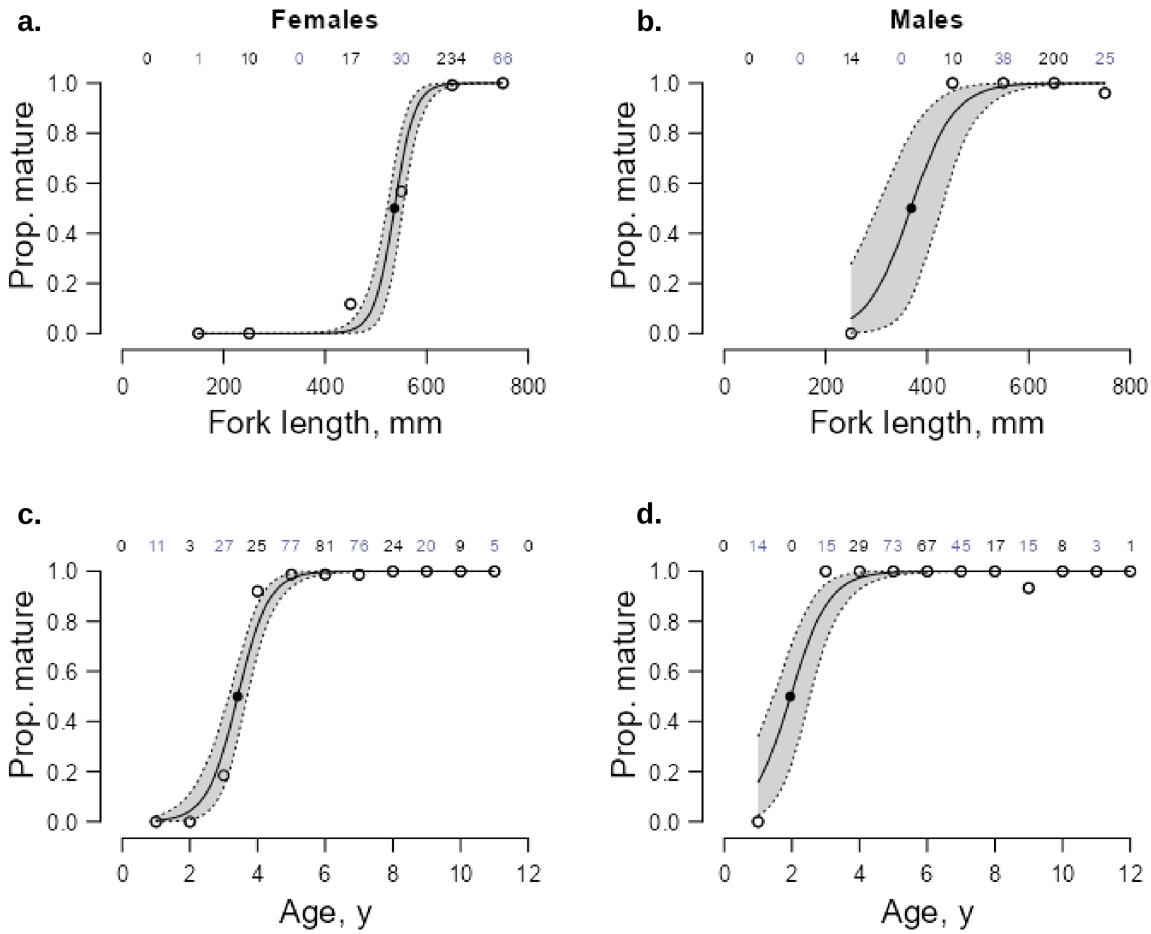


Figure 5.4 Logistic curves (solid line) describing the probability of maturity for Western Australian salmon at age for female (a) and male (b) fish and at length for female (c) and male (d) fish (and associated 95% confidence intervals, dotted lines) and observed proportions of mature fish (open circles). Solid circles represent the age (A_{50}) or length (L_{50}) at which 50% of fish are estimated to be mature.

5.1.3.5 Factors Affecting Year Class Strength and Other Biological Parameters

The strength of the Leeuwin Current in the year of recruitment is significantly, positively correlated with the recruitment of 0+ Western Australian salmon off SA (Lenanton et al., 1991).

5.1.3.6 Diet and Predators

Western Australian salmon are opportunistic feeders, but primarily piscivorous. Adults feed on pilchards, anchovies (Cappo et al., 1987a), Australian herring, garfish and calamari, while juveniles feed on bottom dwelling crustaceans and small fish, particularly in seagrass beds (Robertson, 1982). Feeding success is considered to be increased by their schooling behaviour (Foster et al., 2001).

Migrating schools of Western Australian salmon are preyed upon by whaler sharks, white sharks, grey nurse sharks, dolphins and occasionally seals (Kailola et al., 1993).

The trophic level of this species is estimated as 4.4 (±0.75 se) (Froese and Pauly, 2021).

5.1.3.7 Parasites and Diseases

The parasitic fauna of Western Australian salmon has been relatively well studied and is known to include several species of crustaceans and flatworms (Catalano and Hutson 2010; Catalano et al., 2010).

6 Fishery Information

6.1 Historic

Western Australian salmon have been caught by commercial fishers in WA since colonisation, primarily in the SCB and WCB. Salmon catch has varied over time, with a historical peak of ~ 5000 t retained in the mid- to late-1960s.

Following a period of open access fishing, two limited entry fisheries for Western Australian salmon were declared in WA in 1976, the South West Coast Salmon Managed Fishery (SWCSMF) and the South Coast Salmon Managed Fishery (SCSMF). Since their establishment, SWCSMF and SCSMF have landed the majority of salmon catch within the state. Smaller salmon catches are also recorded by fishers in the South West Coast Beach Net Managed Fishery (SWCBNMF) and the South Coast Estuarine Managed Fishery (SCEMF). The SWCBNMF was previously known as the South West Beach Seine Managed Fishery (SWBSMF). The sections below provide more detailed information about the fisheries that target Western Australian salmon, i.e., SCSMF, SWCSMF, SWCBNMF and SCEMF.

6.2 South West Coast Salmon Managed Fishery

6.2.1 History of Development

Following a period of open access fishing, the SWCSMF was established in 1976. The SWCSMF exclusively targets Western Australian salmon using a beach-seine method, predominantly during March and April.

Encompassing state waters from the northern boundary of WA to Cape Beaufort, fishers within the SWCSMF are permitted to operate throughout all areas of the fishery. In practice, fishing is restricted to a specific number of beaches and ‘designated fishing zones’ around the lower south-west coastline of WA (Walker, 1982).

The mode of operation of the professional salmon fisheries has undergone some change over time; motorboats are now generally used instead of rowing boats, and

nets are now nylon instead of cotton (Walker, 1982). Captured schools are hauled onto the beach by hand, winch or with the aid of vehicles and loaded into trucks directly or with conveyers (Walker, 1982).

In recent years, catches have been at historically low levels, associated with a reduction in targeting by commercial fishers in response to lack of markets and low wholesale prices for the species. Low catch levels may also be attributed to reduced availability of fish in some years due to environmental factors affecting catchability (See Figure 8.1). For example, landings of salmon in the SWCSMF are understood to be strongly influenced by the Leeuwin Current and water temperature. Low or nil catches in this fishery typically occur during years of strong Leeuwin Current (resulting in warmer water along the West Coast of WA).

The SWCSMF is an approved Wildlife Trade Operation (WTO), meaning that Western Australian salmon may be exported overseas. However, fishers from the SWCSMF are not currently exporting salmon. The current export approval for the Western Australian Salmon Managed Fisheries is valid until 30 May 2025.

Under the Fish Resources Management Act 1994 (FRMA), designated fishing zones are superseded if a marine nature reserve, a marine park or a marine management area is established in the same area. This has led to the dissolution of the Smith's Beach and Cape Naturalist DFZs in the SWCSMF.

6.2.2 Current Fishing Activities

A summary of key attributes of the current SWCSMF and the fishing fleet is provided in Table 6.1.

The SWCSMF operates in all WA waters from the eastern boundary of the state on the north coast (Northern Territory border) to Cape Beaufort (i.e., Black Point) on the south-west coast (Figure 6.1). Note, however, that the distribution of Western Australian salmon only extends as far north as Kalbarri and the majority of catches are taken south of Perth. Management arrangements outlined in the *South West Coast Salmon Fishery Management Plan 1982* include:

- Limited entry and effort controls;
- Species restrictions and minimum size limits;
- Gear restrictions; and
- Spatial closures

Note that some spatial closures throughout the fishery are legislated under the *Closed Waters Netting (Cape Naturaliste to Windy Harbour) Notice 1990* (Notice 444).

Table 6.1 Summary of key attributes of the commercial SWCSMF

Attribute	
Fishing methods	Beach Seine
Fishing capacity	One beach seine, net must be hauled from the beach, no specifications for net length or mesh size
Number of licences	5
Number of vessels	5
Size of vessels	n/a
Number of people employed	~10
Value of fishery	Level 1 (<$1 million)

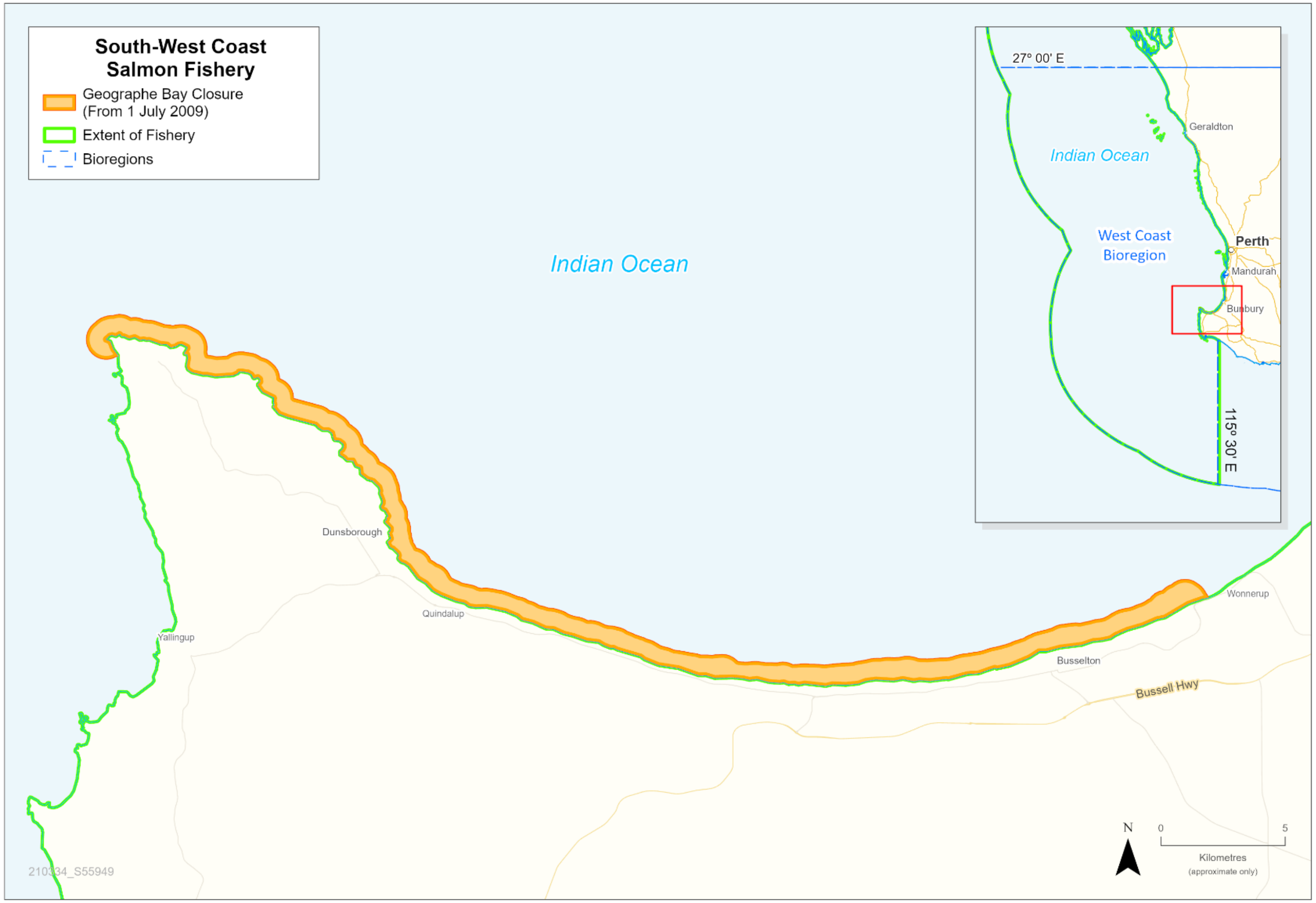


Figure 6.1. Boundaries of the South West Coast Salmon Managed Fishery

6.2.3 Fishing Methods and Gear

All nets must be hauled from the shore, with a limit of one beach seine per licenced fishing boat unit. There are no specifications for the net length or sizes that may be used from the beach, but they are typically around 400 m long. Larger nets become too cumbersome and heavy to haul onto the beach using a vessel or vehicle. The mesh size is not specified but is not intended to 'gill' the Western Australian salmon as it would make removing the fish from the net impractical.

Licence holders are permitted to pen the Western Australian salmon in their salmon net for up to 12 hours provided they have a market for the fish (i.e., they cannot be retained on speculation that someone may wish to buy them), noting that a Fisheries and Marine Officer may direct a licence holder to release penned catch at any time. Penning allows the Western Australian salmon to be transferred from the net over a period of up to 12 hours. For example, penning may occur if the Western Australian salmon are taken outside of factory operating hours or if the school size is too large to be handled at one time.

6.3 South Coast Salmon Managed Fishery

6.3.1 History of Development

Following a period of open access fishing, the SCSMF was declared in 1976. SCSMF exclusively targets Western Australian salmon using a beach-seine method, predominantly during February to April.

Within the SCSMF, individual licence holders are each restricted to a specific nominated beach (Figure 6.2).

The 18 licence holders within the SCSMF can only fish from 17 assigned beaches between Shoal Cape and Cape Beaufort. Most licensees are assigned a single beach although two licensees operate from Cheyne's Beach, 50 km east of Albany. Of the 17 beaches that can be fished, 13 have an area of that beach extending offshore to 800 m prescribed as a "Designated Fishing Zone" (DFZ). DFZs give some protection to a commercial salmon licence holder from disturbance by other users (e.g., jet ski riders or other vessels) between 15 February to 30 April each year. Fisheries and Marine Officers can direct other users to leave the DFZ area if they are disturbing Western Australian salmon schools.

Some licence holders are inactive each year. Effort (number of active licence holders) has followed a declining trend since 2002. In 2021, Western Australian salmon landings were reported by seven of the 18 licensed teams. The current annual level of Western Australian salmon catches is much lower than historic levels.

The SCSMF is an approved WTO, meaning that Western Australian Salmon is able to be exported overseas. The current export approval for the Western Australian Salmon Managed Fisheries is valid until 30 May 2025.

Licence holders from the SCSMF currently export salmon to Thailand for processing, where it is developed into value-added products before returned to Australia for the domestic food market. Approximately 20 t of salmon has been exported from the South Coast in the past two decades (Westerberg, B pers. comm., 2022).

6.3.2 Current Fishing Activities

A summary of key attributes of the current SCSMF and the fishing fleet is provided in Table 6.2.

The management arrangements for the SCSMF are contained in the *South Coast Salmon Fishery Management Plan 1982*. The fishery boundaries include all WA waters from Cape Beaufort to the SA border, and the fishery operates on assigned beaches between Cape Beaufort and Shoal Cape within this area (Figure 6.2). The management arrangements for this fishery include:

- Limited entry and effort controls;
- Species restrictions and minimum size limits;
- Gear restrictions; and
- Spatial closures

Note that some spatial closures throughout the fishery are legislated under the *Closed Waters Netting (Cape Naturaliste to Windy Harbour) Notice 1990* (Notice 444).

Table 6.2 Summary of key attributes of the commercial SCSMF

Attribute	
Fishing methods	Beach Seine
Fishing capacity	No specifications for net length or mesh size
Number of licences	18 (40% active)
Number of vessels	51 (50% active)
Size of vessels	n/a
Number of people employed	~20
Value of fishery	Level 1 (<$1 million)

Figure 6.2 Boundaries, extent and location of commercial salmon fishing beaches in the South Coast Salmon Fishery Resource.

6.3.3 Fishing Methods and Gear

There are no specifications for the net length or sizes that may be used by licence holders from the beach, but they are typically around 400 m long. Larger nets become too cumbersome and heavy to haul onto the beach using a vessel or vehicle. The mesh size is not specified but is not intended to 'gill' the Western Australian salmon as it would make removing the fish from the net impractical.

Licence holders are permitted to pen the Western Australian salmon in their salmon net for up to 12 hours provided they have a market for the fish (i.e., they cannot be retained on speculation that someone may wish to buy them). Penning allows the Western Australian salmon to be transferred from the net over a period of up to 12 hours. For example, penning may occur if the Western Australian salmon are taken outside of factory operating hours or if the school size is too large to be handled at one time. In practice, there are only three to four beaches of the 17 beaches in the SCSMF where it is possible to pen Western Australian salmon. To pen Western Australian salmon requires a sheltered beach and calm weather/oceanic conditions or the fish would escape from the net and the net would wash up on the beach.

6.4 South West Coast Beach Net Managed Fishery

6.4.1 History of Development

Prior to the establishment of the SWCSMF and SCSMF, commercial beach seine fishers primarily targeting whitebait (*Hyperlophus vittatus*), blue sprat (*Spratelloides robustus*) and mullet (*Mugil cephalus* and *Aldrichetta forsteri*) operated along the South West Coast of WA, from Tim's Thicket (south of Mandurah) to Point D'Entrecasteaux.

In October 1989, the (then) WA Minister for Fisheries announced a prohibition on commercial beach seining between Tim's Thicket (south of Mandurah) and Point D'Entrecasteaux (DoF 2005). The following year, the *South West Beach Seine Fishery Notice 1990 (No. 416)* (SWBS Notice) was gazetted to give effect to this freeze (DoF 2005) and allow for the continuation of fishing by SWBSMF Licence Holders. Whilst the SWCSF was the primary fishery targeting salmon in the South West at the time, a small number of fishing boat licence (FBL) holders within the SWBSMF Fishery that could demonstrate they had historically caught salmon had a permissive condition placed on their FBL (number 68) which allowed for continued salmon take.

In 2010, the SWB Notice was revoked and replaced by *Prohibition on Commercial Fishing (South-West Coast Beach Net) Order 2010* (SWCBN Order). As the previous Notice had permitted fishing with a beach seine net as far south as Point D'Entrecasteaux, a large section of southern Geographe Bay was effectively closed to commercial fishing.

6.4.2 Current Fishing Activities

SWCBNMF fishers operate mainly during the warmer months of the year (November to April). Licence holders endorsed to take salmon under condition 68 target the species from March to May.

A summary of key attributes of the current SWCBNMF and the fishing fleet is provided in Table 6.3.

The management arrangements for the SWCBNMF are contained in the SWCBN Order. The fishery boundaries include all waters of the Indian Ocean off the West and South Coast of WA between Busselton Jetty and the Northern limit of Timms Thicket (Figure 6.3). The management arrangements for this fishery include:

- Limited entry and effort controls;
- Species restrictions and minimum size limits;
- Gear restrictions; and
- Spatial closures

Table 6.3 Summary of key attributes of the commercial SWCBNMF

Attribute	
Fishing methods	Beach Seine
Fishing capacity	net must not exceed 250m in length and have a mesh size of not less than 7mm.
Number of licences	9 fishing units, of which 2 are endorsed with Co68 (27 FBLs) (25 active, 2 with Co68)
Number of vessels	n/a
Size of vessels	n/a
Number of people employed	~29
Value of fishery	Level 1 (<$1 million)

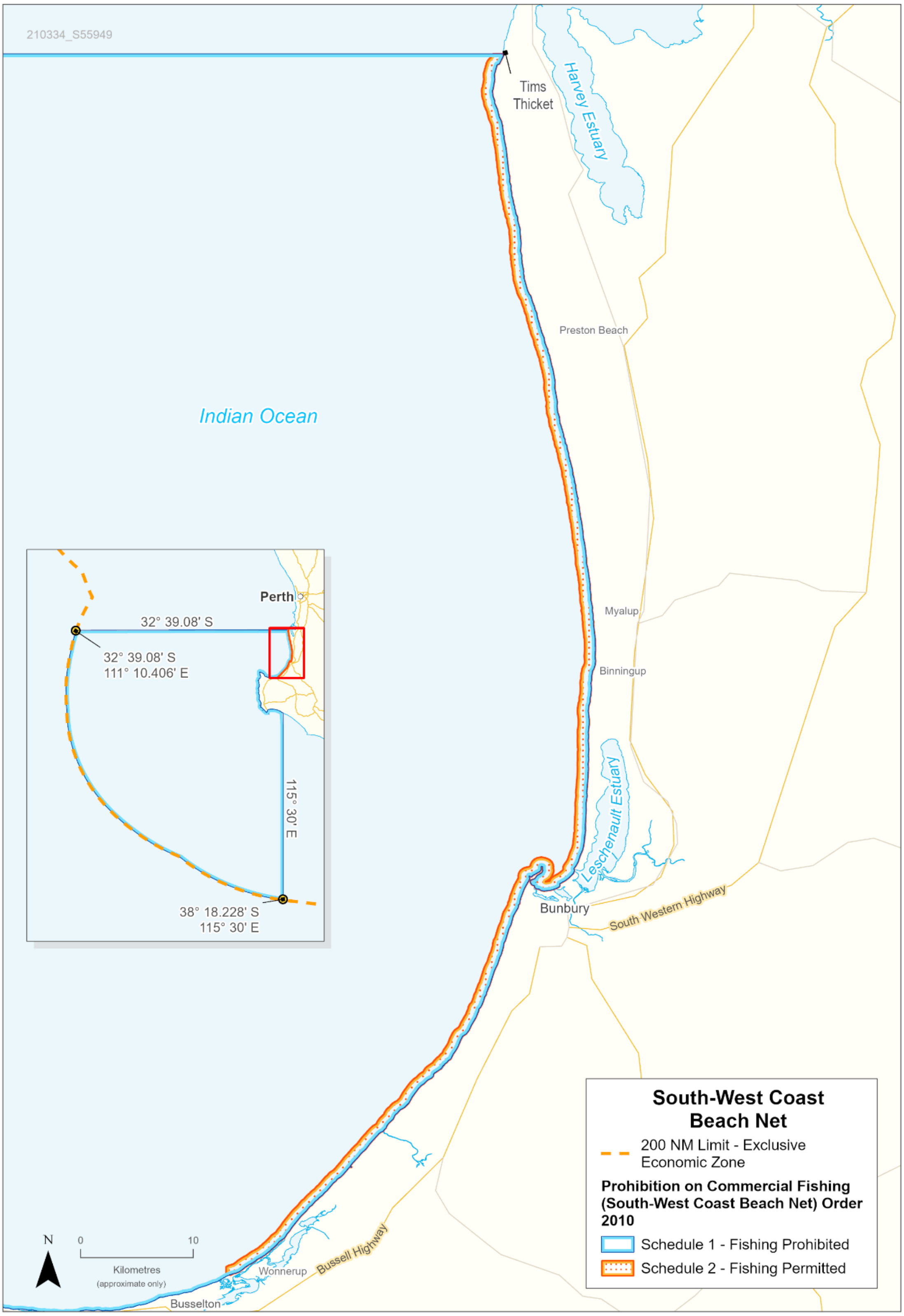


Figure 6.3. Boundaries of the South West Coast Beach Net Managed Fishery

6.4.1 Fishing Methods and Gear

Beach seine nets used within the SWCBNMF are hand-hauled from shore by small teams of fishers. A single net is allowed per licenced fishing boat unit and nets must not exceed more than 250 metres in length and have a mesh size of not less than 7mm.

A typical beach seine netting operation involves the fisherman driving along a beach in a four-wheel drive vehicle, towing a dinghy while searching for schools of fish. When a school is sighted, a decision is made whether the school is of a desirable species or size to warrant making a “shot”. A “shot” involves running the seine net off the dinghy in a semi-circle and enclosing the school of fish between the net and the shore.

Seine nets differ to haul nets in that they have a “bunt” or “pocket” built into the net that can further restrict the lateral movement of a school of fish when the net is being hauled. Having a bunt on the net is particularly useful when fish are hauled onto a beach.

6.5 South Coast Estuarine Managed Fishery

6.5.1 History of Development

The SCEMF is one of the oldest fisheries in WA and has been operating in much the same way since the mid-1800s (Wright, 1989). Although aluminium dinghies with outboard motors have now replaced the wooden boats that were sailed in the early days of the fishery, fishers still use gillnets and haul nets to target the same fish species in the same way as their predecessors did (Wright, 1989).

6.5.2 Current Fishing Activities

The management arrangements for the SCEMF are contained in the *South Coast Estuarine Fishery Management Plan 2005*. The area of the fishery includes all estuaries on the South Coast of WA between Cape Beaufort and 129ºE, including all river, streams and tributaries that flow into those estuaries (Figure 6.4). Since 2005, 13 South Coast estuaries have been open to commercial fishing; Broke Inlet, Irwin Inlet, Wilson Inlet, Princess Royal Harbour; Oyster Harbour, Waychinicup Inlet, Beaufort Inlet, Gordon Inlet, Hamersley Inlet, Culham Inlet, Jerdacuttup Inlet, Oldfield Inlet and Stokes Inlet. Some estuaries are fished year-round (e.g., Wilson Inlet, Princess Royal Harbour and Oyster Harbour), whilst others, in particular the smaller estuaries in the east, are open on seasonal basis (Wright, 1989).

A summary of key attributes of the current SWCBNMF and the fishing fleet is provided in Table 6.4.

Management arrangements for this fishery include:

- Limited entry and effort controls;

- Species restrictions and minimum size limits;
- Gear restrictions; and
- Spatial closures.

Table 6.4 Summary of key attributes of the commercial SCEMF

Attribute	
Fishing methods	Haul/set/seine/throw/ring nets, crab pot, fish trap, hand gathering
Fishing capacity	37, 500 metres of fishing net, 625 crab pots, 50 fish traps and 4 shellfish entitlements (subject to restrictions in Management Plan).
Number of licences	25 (22 active)
Number of vessels	59
Size of vessels	n/a
Number of people employed	~40
Value of fishery	Level 1 (<$1 million)

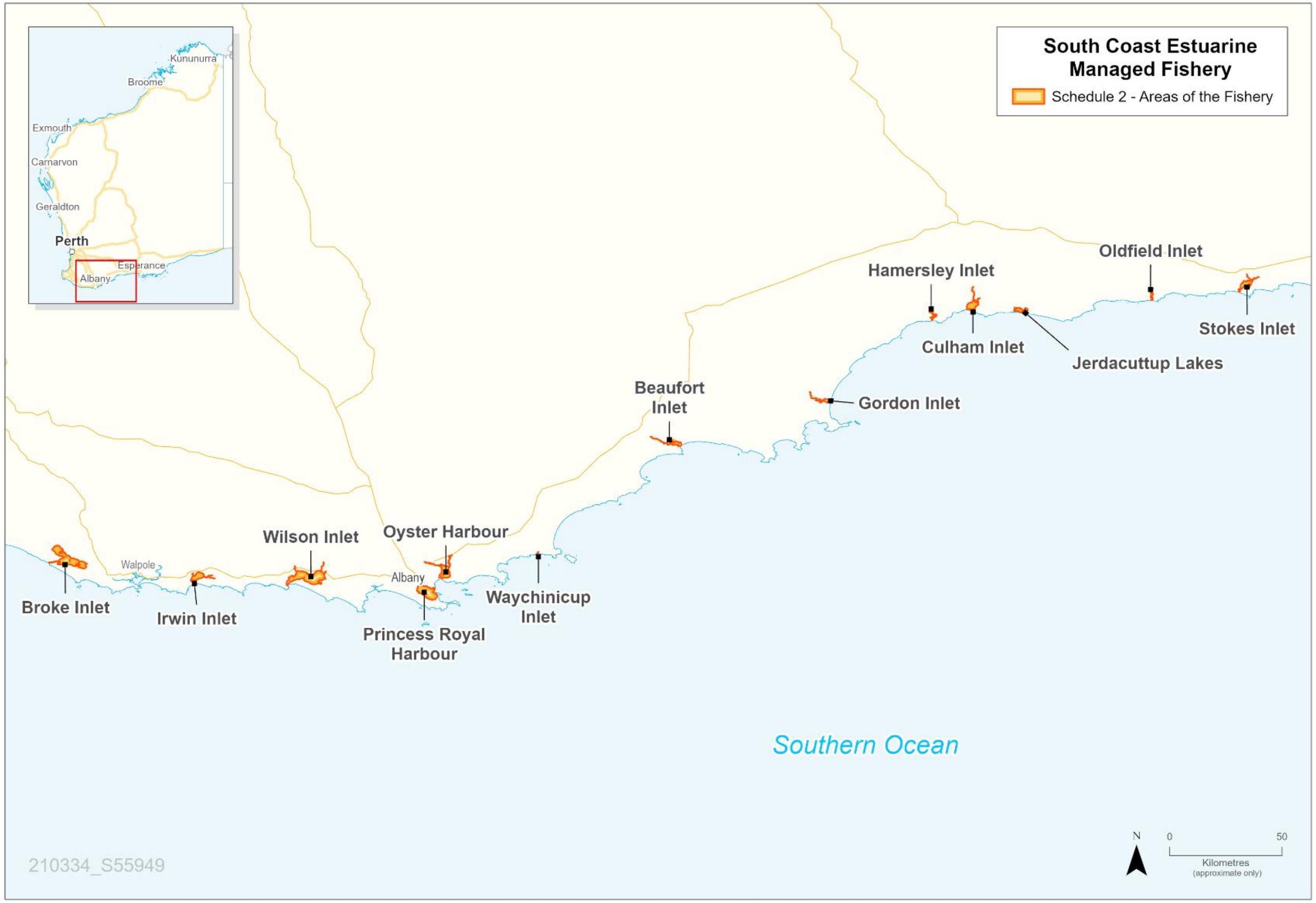


Figure 6.4. Boundaries of the South Coast Estuarine Managed Fishery

6.5.3 Fishing Methods and Gear

SCEMF is a multi-gear fishery, however licence holders predominately fish using haul nets, seine nets and gillnets. Gillnets are set overnight, with no gillnetting permitted in the estuaries on weekends and public holidays. As the estuaries are popular with recreational vessel users this restriction not only reduces the potential for conflict between commercial fishermen and recreational vessel users but reduces the potential for fishing gear to be damaged.

Fishers do not primarily target salmon, although they do sporadically retain catches of juvenile Australian salmon, know colloquially as “salmon trout”, especially if caught using gillnets.

6.6 Recreational / Charter Fishery

6.6.1 History of Development

Western Australian salmon is an important recreational species, targeted primarily by shore-based fishers using rod and line (Ayvazian et al., 1997, McLeod and Lindner 2020, Tate et al., 2022). Recreational fishing for Western Australian salmon is currently regulated by a daily bag limit of four fish per person and a minimum size limit of 300 mm.

Since 2 March 2010, all persons fishing from a powered boat anywhere in WA have been required to hold a Recreational Boat Fishing Licence (RBFL) or fish in the company of a licence holder. The RBFL provides a Statewide database of boat-based recreational fishers that is used to complete periodic statewide surveys (Ryan et al., 2022). A licence is not required for shore-based line fishing. Annual monitoring of shore-based fishers occurs in the Perth metropolitan region (Tate et al., 2022). Charter catches of the species are negligible as charter boats primarily target demersal species in offshore waters, which accounts for this low catch.

6.6.2 Current Fishing Activities

Recreational fishing for Western Australian salmon is undertaken in an area generally stretching from the Perth metropolitan area to the Great Australian Bight. Fishing occurs from March to May each year.

6.6.3 Fishing Methods and Gear

Catches are taken predominantly by line fishing (Ryan et al., 2022).

6.7 Customary Fishing

Ngari is the Noongar word for Western Australian salmon. The species is traditionally eaten by the Wardandi Aboriginal people (Gaynor et al., 2008). Gibbs (2011) documented that a fish weir, a composite structure of stakes/brush and/or stone was constructed annually across the Serpentine River and juvenile salmon were caught as they swam through the race. The season of Bunuru (February and March)

marked the arrival of the fish from the ocean and the winter rains forced the species back downstream. Only those Aboriginal people who had salmon as a totem group were allowed to operate the weir.

The harvest of Western Australian salmon from Customary fishing is unknown.

6.8 Illegal, Unreported or Unregulated Fishing

Illegal activities (possession and size limit breaches) by recreational fishers are detected by compliance officers. The proportion of the recreational catch/effort represented by illegal activity is unquantified, but likely to be a minor part of total fishing mortality.

7 Fishery Management

7.1 Management System

The FRMA provides the overarching legislative framework to implement the management arrangements for the SCSMF and SWCSMF. Management arrangements for each fishery are described in detail in management plans and other legislation. The *Aquatic Resources Management Act 2016* (ARMA) will replace the existing FRMA (and the Pearling Act 1990) to become the primary legislation used to manage fisheries and aquatic resources in WA.

The fisheries capturing Western Australian salmon are managed using a range of management measures. Effort is primarily constrained by a cap on the number of licences / vessels (limited entry) in each fishery (input controls). A minimum size limit of 300mm applies to both the recreational and commercial sectors. Recreational fishing for Western Australian salmon is currently regulated by a daily bag limit of four fish per person and a minimum size limit of 300 mm.

7.2 Draft Harvest Strategy

The following is a draft harvest strategy for Western Australian salmon and outlines the objectives for management. It also provides a description of the performance indicators used to measure performance against these objectives, reference levels for each performance indicator, and associated control rules that articulate pre-defined, specific management actions designed to maintain the resource at target levels. Reference levels are consistent with those used by DPIRD in other similar resources and based on internationally accepted benchmarks for moderate to long-lived fish species (Caddy and Mahon 1995; Gabriel and Mace 1999; Mace 2001; Wise et al., 2007).

The draft harvest strategy aims to maintain Western Australian salmon biomass at a level above that at which maximum Sustainable Yield (MSY) can be achieved, i.e., $B > B_{MSY}$. Therefore, any stock size above the B_{MSY} threshold is consistent with

meeting the objectives for biological sustainability. The performance indicator, reference levels and control rules that are proposed as a result of the current assessment of the salmon fishery are defined in Table 7.1. Periodic Level 3 stock assessments are scheduled every five years. The assessment requires the collection of salmon otoliths from the spawning stock, collected during the spawning season, over the two consecutive years prior to the year of assessment. In years between assessments, an annual review of catches relative to the estimated MSY is undertaken.

Table 7.1. Summary of the draft performance indicators, reference levels and control rules for the Western Australian salmon.

Management Objective	Performance Indicator(s)	Reference Levels	Control Rules
To maintain spawning stock biomass above B_{MSY} to maintain high productivity and ensure the main factor affecting recruitment is the environment.	Periodic estimates of relative biomass (B_{rel}) as a proxy for female spawning stock biomass (B) and fishing mortality (F)	**Target:** B_{rel} = 0.4 as proxy for $B=B_{MSY}$ F = ⅔ M	No management action is required.
		Threshold: B_{rel} = 0.3 as proxy for $B = B_{MSY}$ $F= M$	If the Threshold is breached, a review is triggered to investigate the reasons for the variation. If sustainability is considered to be at risk, appropriate management action will be taken to reduce the total catch by up to 50%.
		Limit: B_{rel} = 0.2 as proxy for $B = 0.5B_{MSY}$ F = 1.5 * M	If the Limit is breached, management strategies to further protect the breeding stock will be implemented (50 – 100 % reduction of total catch).

7.3 External Influences

External influences include other activities and factors that occur within the aquatic environment that may or may not impact on the productivity and sustainability of fisheries resources and their ecosystems. The main external influences included here are environmental factors, market influences and non-WA managed fisheries.

7.3.1 Environmental Factors

Western Australian salmon are responsive to ocean temperatures, and their seasonal movements are understood to be closely related to the strengths of the Leeuwin Current and Capes Current and subsequent water temperatures. In some years warmer coastal waters result in the fish aggregating in deeper, cooler waters

offshore. In years when there is a strong Leeuwin Current (La Niña weather pattern) Western Australian salmon do not swim as far north on the West Coast in large numbers. Strength of the Leeuwin Current has a positive relationship with strength of recruitment of salmon to SA nursery ground as spawning occurs when the current is strengthening (Lenanton et al., 1991).

A risk assessment of WA's key commercial and recreational finfish and invertebrate species has concluded that climate change is having a major impact on some exploited stocks (Caputi et al., 2015). This is primarily occurring through changes in the frequency and intensity of El Niño-Southern Oscillation (ENSO) events, decadal variability in the Leeuwin Current, increase in water temperature and salinity, and change in frequency and intensity of storms and tropical cyclones affecting the state (Caputi et al., 2015). In 2010/11, a very strong Leeuwin Current resulted in unusually warm ocean temperatures in coastal waters of south-western WA (Pearce et al., 2011). Following this "marine heatwave", the distributions and behaviours (e.g., spawning activity and migration) of some species changed, and widespread mortalities of some other species were observed (e.g., Roe's abalone in Kalbarri). As recruitment and spatial distribution of migration of Western Australian salmon has been shown to be related to the strength of the Leeuwin Current, this species is likely to be affected by climate change through range shifts (Pecl et al., 2011).

7.3.2 Introduced Pest Species

No known introduced pest species are known to impact upon Western Australian salmon.

7.3.3 Market Influences

Catch levels for Western Australian salmon are understood to have been driven primarily by markets. The 1960s peak is likely attributable to use of Western Australian salmon for lobster bait and the development of WA canning operations (Walker, 1982), with the subsequent decline in the late 80s due to restrictions on the sale of salmon for bait to 7t per annum (Cappo, 1987a). During the early 1990s the regulations changed several times in regard to the proportion of catch that could be used as bait. Currently there are no restrictions regarding the quantity of Western Australian salmon that may be sold as bait. A report of the proportion of various species that comprised rock lobster bait during 2001/2002 indicated that 4% of the total bait used in the fishery was WA salmon (Department of Fisheries, 2004).

Commercial catches have been at historically low levels since 2011 because of weak market demand and low wholesale prices (historical landings in WA were primarily sold as bait).

7.3.4 Non-WA Managed Fisheries

Western Australian salmon are caught by some SA commercial fisheries and are also accessed by Victorian and SA recreational fishers. Catch of WA salmon in other

States are immature fish that migrate towards WA and are also produced by the spawning stock that resides in WA.

8 Stock Assessment

8.1 Assessment Principles

The different methods used by the Department to assess the status of aquatic resources in WA have been categorised into five broad levels, ranging from analyses applied to just catches (e.g. Catch-MSY) and/or standardised catch rates, through to the application of (equilibrium) analyses applied to size and/or age composition data, and incorporating various biological parameters (e.g. catch curve and per recruit analysis), and dynamic integrated modelling approaches, applied to all available data considered applicable and sufficiently reliable for assessment (Fletcher and Santoro 2015). The level of assessment varies depending on data availability and resourcing for assessment (e.g., Cope et al., 2023), with the level of resourcing directed towards assessment determined, at least in part, by the level of ecological risk, the biology and population dynamics of the relevant species, the characteristics of the fisheries exploiting the species.

Irrespective of the types of assessment methodologies used, all stock assessments undertaken by the Department take a risk-based, weight of evidence approach (Fletcher, 2015). This requires consideration of each available line of evidence, both individually and collectively, to generate the appropriate overall assessment conclusion. The lines of evidence include the outputs that are generated from each available quantitative method, plus any qualitative lines of evidence such as biological and fishery information that describe the inherent vulnerability of the species to fishing. For each species, all lines of evidence are then combined within the Department's ISO 31000 based risk assessment framework (see Fletcher, 2015; section 11) to determine the most appropriate combinations of consequence and likelihood to determine the overall current risk status.

8.2 Data and Monitoring

There is a range of information available to support the assessment and harvest strategy for the Western Australian salmon resource (see Table 8.1).

8.2.1 Commercial Catch and Effort

Commercial catches and fishing effort are monitored via compulsory monthly returns for each commercial fishery. These data were collected and collated by the DPIRD and stored in the Catch and Effort database system. Each licenced fisher records the monthly catch totals (to the nearest kilogram) for each retained species, monthly effort (total days fished), estimates of daily effort (e.g., average hours fished per day, average length of net deployed per day) and spatial information based as to which 60 x 60 NM 'blocks' were fished with each method.

In addition to catch data maintained by the Department, historic commercial catch data used in this assessment was constructed from a variety of sources (Hancock 1973, Hancock 1975, Australian Bureau of Statistics 2022). Any data from these sources after 1974/75 were not considered, as records for the subsequent time period are available from Departmental databases. Where multiple sources provided catch records for the same year(s), a review was undertaken to assess the validity of the data and a decision made as to which value was considered most appropriate based on available literature. Any data recorded as lbs, was converted to kgs using the appropriate conversion factor (1lb = 0.454 kgs).

Catch data was restricted to those from WA and SA, as the Western Australian salmon is the only salmon species caught in these two states. Smaller catches of immature Western Australian salmon occur in Victoria and Tasmania, however the closely related, and difficult to differentiate, eastern Australian salmon, is primarily captured in these jurisdictions. Catch from these states was not included in our catch data set as it is not possible to determine what proportion of the salmon catch can be attributed to each species. This approach will slightly underrepresent the actual total catch of Western Australian salmon and have limited impact on assessment outcomes. Where possible, the data set for WA is broken down by bioregion.

8.2.2 Recreational / Charter Catch and Effort

Historic estimates of the recreational catch of Western Australian salmon are available from a number of surveys (Ayvazian et al., 1997, Henry and Lyle 2003). Henry & Lyle (2003) categorised ‘Australian salmon’ as a group, however, based on distribution of the two species, the estimate for WA is wholly Western Australian salmon (Henry and Lyle, 2003).

Within Western Australia, a state-wide survey has been implemented every 2 – 3 years since 2011/12 to collect information on private (non-charter) boat-based recreational fishing in WA (Ryan et al., 2013, 2015, 2017, 2019, 2022). To date, five state-wide surveys have been undertaken. Each survey uses three complementary components: off-site phone diary surveys, on-site boat ramp surveys and remote camera monitoring, to collect information on fishing catch, effort, location, and other demographic information. An annual on-site survey of recreational shore-based fishers has occurred annually in the Perth Metropolitan area since 2015 (Tate et al., 2022).

The recreational catch level is uncertain due to a lack of information about shore-based fishers, who are believed to harvest a larger quantity of nearshore finfish than boat-based fishers. Recreational catches have been proportionately smaller than that of commercial catches for most of the history of the fishery, but this is likely to have changed in recent years, associated with the market-driven large reductions in commercial catches.

Since 2001, it has been a statutory requirement for boat-based charter fishing operators to submit monthly returns detailing catches and effort. Charter catches of

the species are negligible, with less than 5 tonnes retained by charter operators since 2000.

8.2.3 Fishery-Dependent Monitoring

In addition to catch and effort data, fishery-dependent data have also been collected from a biological monitoring program to obtain age and length composition data from commercial and recreational fishery landings.

8.2.3.1 Length data

Length data for salmon caught both recreationally and commercially are available since 1975. Data from 1975 to 1999 were measured as fork length (FL). Data from 2000 to 2022 were measured as total length (TL) and FL. Additionally, during 2019 and 2022, at times, only the head portion of a fish was available, and a head length (HL) measurement was recorded by measuring from the point of the snout to the furthest part of the branchiostegal membrane along the operculum. Reporting of length in this assessment is based on FL. To convert all lengths to FL, several equations were derived from existing data collected by DPIRD. All commercial and recreational data between 2012 and 2022 where TL and FL were recorded for each fish (n =1983) were used to calculate a relationship between TL and FL**.** HL was also recorded from commercial and recreational samples (n = 317) from 2015, 2019 and 2022, providing a relationship between HL and FL.

FL = 0.9011 * TL – 9.0292 (p < 0.001, R^2=0.99)

FL = 2.6877 * HL + 183.36 (p < 0.001, R^2=0.78)

Length data from earlier years (<1999) are abundant, often with thousands of measurements taken each year. However, the majority of the measures are not attributable to a particular sex. Since then, substantially less length data are available and these are largely generated from fish collected to provide biological information (e.g. growth and maturity), and for obtaining ages.

8.2.3.2 Age data

Western Australian salmon age data based on otoliths exists from 1990 to 2022. Sagittal otoliths are extracted from the otic capsule. The otoliths are sectioned and aged by identifying and counting the number of opaque bands, following Departmental quality control protocols. Otolith readers train with a reference collection prior to commencing routine ageing. Ages are agreed on by two experienced otolith readers. Readers compare counts using age bias plots (Campana et al., 1995) which must produce an acceptable Index of Average Percent Error (IAPE) (Beamish and Fournier, 1981).

Validation of annuli in otoliths of Western Australian salmon was attempted by Marginal Increment Analysis (MIA); however, the limited number of samples across all months and age classes limit confidence in these marginal increment (MI) results, although other strong evidence exists to indicate that the growth zones are formed

annually (Gaughan et al., 2006). Data from pooled year classes showed an increasing MI up until August and November followed by decline in December and January indicating an annual formation of opaque zones. Annual formation of opaque zones has been validated for the eastern Australian salmon (*A. trutta*) by MIA, tetracycline mark in wild and captive fish and daily increments (Stevens and Kalish 1998; Stewart et al., 2011).

The ageing formula for salmon is shown in the below schematics and a nominal birth date of May 1st is used based on the typical peak of the spawning season:

If capture month ≥7 (fish captured in the months of July to December) and MI category is 1 (<50% translucent), then:

$$\text{Age (years)} = \left[\text{No. of opaque zones x 12} + \text{Capture month} + \text{7 (months from nominal birth date to December in first year of life)} \right] / \text{12 (months)}$$

If, capture month ≥7 (fish captured in the months of July to December) and MI category is 1 (<50% translucent), then:

$$\text{Age (years)} = \left[\text{No. of opaque zones x 12} + \text{Capture month} + \text{7 (months from nominal birth date to December in first year of life)} - \text{12 (months)} \right] / \text{12 (months)}$$

In years of active collections, attempts were made to collect a minimum of 300 otoliths from each of the combinations of WCB/SCB and both the recreational and commercial fisheries (i.e., 1,200 otoliths). In practice these numbers were not always met and so interpretation of data require careful consideration of the representativeness of the samples, particularly in cases when sample sizes were low.

To improve the representativeness of samples, otoliths are actively collected throughout the migration and spawning season. In addition, attempts are made to maximise the spatial area from which they are collected. Ideally, samples are collected from many independent fishing events to reduce the risk of size/age related schooling dynamics negatively impacting representativeness of samples, however this is not always possible. Random samples of no more than 20 fish are collected from a single fishing event.

8.2.4 Fishery-Independent Monitoring

Fishery-independent seine netting was conducted by the Department annually from 1995 to 2001 (Gaughan et al., 2006) and 2005 to 2016 and recommenced in 2020. Netting occurred at multiple beaches in the WCB and SCB. A wide range of species

and sizes of fish were captured, including juveniles of key fishery species. The main aim of the project has been to develop indices of juvenile recruitment.

Sampling is undertaken using a large seine net, which has a total length of 60.6 m and height of 2.0 m, comprising two wings of length 29.1 m (22 mm stretched mesh) plus a bunt of length 2.4 m (8 mm mesh). The area swept by this net is approximately 592 m^2 per haul. Four replicate hauls per day are executed at sites where this net is used, two fixed areas at each site and two random areas chosen from a total of four random areas via coin toss each site. The net is deployed from a small dinghy rowed in a semicircle from/to the beach.

Replicate hauls are completed within a single day and do not overlap one another. There is a minimum of 45 minutes elapsing between replicate hauls. At the completion of each haul, fish are removed and placed in an aerated tub of seawater. All fish and macro-invertebrates in the catch are identified to the lowest possible taxon (usually species) and measured (total length, to the nearest mm) before being released alive where possible. Fish are released after all hauls are completed to avoid any recaptures.

An optimised annual sampling regime has been employed since 2005 and data from Poison Creek and Emu Point collected during the months of September, October and November were identified as providing the best index for salmon abundance due to higher catch rates (Gaughan et al., 2006). This was determined through year round sampling (Gaughan et al., 2006). Salmon peak spawning period is between March-May with juveniles reported in SA bays and inlets at ~ 5-8cm FL. It is not until September-November that these new recruits reach a size large enough to be selectively caught by DPIRD seine nets. Sampling of Emu Point has been not been possible since 2010 due to changes in access. Therefore, only data from Poison Creek is considered in this report. The index is based on the mean catch rate of recruits (0+) from the sampling period.

8.2.5 Environmental Monitoring

Databases with environmental variables (e.g., water temperature, wind and sea level) are continuously updated and extended as new data become available from collections by the Department, internet sources and from other agencies (see Caputi et al., 2015). The environmental variables from these databases have been used in analyses of correlations with biological parameters of species and allow for the examination of long-term trends.

Table 8.1. Summary of information available for assessing WA salmon

Data type	Fishery-dependent or independent	Purpose / Use	Area of collection	Frequency of collection	History of collection
Commercial catch	Dependent	Monitoring of commercial catch	State	Annual	1951-52 to 1974-75
Commercial catch and effort database	Dependent	Monitoring of commercial catch and effort trends, calculation of catch rates and the area fished	60 x 60 NM block	Monthly	Since 1975-76
Recreational catch and effort estimates	Dependent	Monitoring of recreational catch and effort trends	State-wide, boat-based	Every 2-3 years	Since 2011
			Metropolitan shore-based survey	Annual	2010 & 2014 onwards
			State	1994, 1995 2000/01	Avayzian et al. (1997), Henry and Lyle (2003)
Catch at age data	Dependent	Age structure, estimation of total mortality	WCB, SCB	Every 1 – 5 years	Since ~1990
Recruitment survey data	Independent	Catch rates (index of recruitment strength)	Poison Creek	Annual	Since ~1996
Biological information	Dependent and independent	Patterns of growth and reproduction, stock structure	WCB, SCB	Intermittent	Since ~1970s

8.3 Analyses

8.3.1 Productivity Susceptibility Analysis

Productivity Susceptibility Analysis (PSA) is a semi-quantitative risk analysis originally developed for use in Marine Stewardship Council (MSC) assessments to score data-deficient stocks, i.e., where it is not possible to determine status relative to reference points from available information (Hobday et al., 2011; MSC 2014). The PSA approach is based on the assumption that the risk to a stock depends on two characteristics: (1) the productivity of the species, which will determine the capacity of the stock to recover if the population is depleted, and (2) the extent of

the impact on the stock due to fishing, which will be determined by the susceptibility of the species to fishing activities (see Section 12 Appendix B - Productivity Susceptibility Analysis (PSA) Scoring Tables). Productivity of the species is scored against eight criteria and susceptibility is scored for each fishery targeting the species against four criteria.

Although a valuable tool for determining the overall inherent vulnerability of a stock to fishing, the PSA is limited in its usefulness for providing stock status advice. This relates to the simplicity and prescriptiveness of the approach, which does not involve producing estimates of spawning potential and exploitation for comparison against biological reference points, and there is also no ability to consider management measures implemented in fisheries to reduce the risk to a stock (Bellchambers et al., 2016). Consequently, the PSA is used by the Department DPIRD to produce a measure of the vulnerability of a stock to fishing, which is then considered within the overall weight of evidence assessment of stock status.

8.3.2 Catch MSY

The catch-MSY model is a “data-poor” analysis of population dynamics described according to the same production function as applied in the Schaefer surplus production model. The approach provides estimates of useful quantities such as MSY, although results can be highly dependent on specified priors. It requires input data in the form or a time series of total catch removals from a stock where the population can be assumed to be closed to immigration and emigration (Martell and Froese, 2013). Additionally, it requires a range to be provided for the level of population “resilience” (i.e., range for *r*), and specified prior distribution ranges for *K*, and initial and final stock depletion levels. The catch-MSY model produces a range of outputs relevant to stock assessment, including posterior distributions for population carrying capacity (*K*), maximum intrinsic population growth rate (*r*), maximum sustainable yield (MSY), and annual trends in biomass (*B*) and fishing mortality (*F*) and stock depletion.

Broadly, the catch-MSY model works by drawing many (e.g., 20,000) random pairs of *r* and *K* from their specified prior distributions, and then applying the discrete form of the Schaefer population dynamics equation and annual catches to simulate population biomass trajectories. Only those population trajectories (and associated results) that are consistent with the ranges specified for initial and final depletion are retained. Using the datalowSA R package, a catch-MSY model (see Haddon et al., 2018) was applied to commercial catch data for salmon from across the entire stock (i.e., WA and SA).

A time series of estimates of the recreational catch of Western Australian salmon (i.e., shore-based and boat-based) is unavailable. As the catch-MSY model should include catches from all sources, and all catches are uncertain, two data sets were analysed. The first was commercial catch from WA and SA only. The second, included a constant catch estimate for recreational catch of 158 tonnes per year; the

median estimate of catch from the two studies providing a total catch estimate for WA (Avayzian et al., 1997, Henry and Lyle 2003). It is acknowledged the model predictions have a high degree of uncertainty.

For each of the data sets the catch-MSY model was run using program default values for initial depletion and *K*. The final depletion range was changed from the calculated program default (0.05-0.5), to 0.4 to 0.9 to recognise that low catches for the last few years have been sustained due to market demand rather than abundance, which is expected to have allowed the stock to rebuild. Two resilience ranges were considered, low and medium. The assumption of "low resilience" (*r*=0.1-0.6) may be a conservative estimate of stock productivity, as this species is not particularly longer-lived (maximum age ~12 years). Model sensitivity runs allowing for a higher resilience level (medium) (*r*=0.3-0.8), however, tended to result in fewer "successful *r*-*K* pairs", indicating this latter assumption is not consistent with other modelling assumptions and the catch data.

8.3.3 Catch Curve Analyses

8.3.3.1 Length-based

Two length-based catch curve methods available in the L3Assess R package (Hesp, 2023), including a length-converted catch curve (see Pauly, 1990) and another form of length-based catch curve developed by S. A. Hesp, were applied. Although the latter method has been used successfully for several other species, it could not be applied successfully for Western Australian salmon, due to the very limited length range between estimated size at full selection into the fishery and maximum lengths in the samples. Thus, results are only presented for the length-based catch curve.

8.3.3.2 Age-based

The Chapman & Robson (1960) estimator (see also Smith et al., 2012 and Dunn et al., 2002), implemented in the L3Assess package, was used to estimate total mortality (*Z*) from age frequency data collected from commercial fishers fishing the spawning run on the south coast during a period of high catch, ~2000 t (1994 to 1998), and two recent periods of lower catches, <300 t (2012 to 2013 and 2021 to 2022). Suitable numbers of samples from the west coast were not available for a similar analysis. The impact of different assumptions regarding the age at full recruitment was examined by setting the recruitment age to either the age at peak frequency or one plus the age at peak frequency.

Subtracting an estimate of natural mortality ($M = 0.35\ y^{-1}$) from *Z* yields an estimate of fishing mortality (*F*). The value for *M* chosen was based on recommendations from recent research into empirical estimate of natural mortality and utilised the equations (see descriptions relating to natural mortality in the section 5.1.3.3). Mathematical

descriptions of all catch curve and per recruit analysis (see below) are provided in the vignette for the L3Assess package (Hesp, 2023).

8.3.4 Per Recruit Analyses

Per-recruit analyses, incorporating information on growth, maturity, selectivity, retention and natural mortality for Western Australian salmon, were applied to provide to alternative measures of reproductive output, including female spawning potential ratio (SPR) and female relative biomass (B_{rel}). SPR is calculated by applying a 'traditional' per-recruit analysis assuming constant recruitment. Applying this model, the level of spawning biomass per-recruit is

$$\Phi^{SB} = \sum_{t=1}^{T} 0.5\, W_t P_t \exp\left(-Z_t\right)$$

where t refers to age, T is the maximum age of fish considered by the model, 0.5 is the assumed proportion of fish which are females at birth, and W_t, P_t Z_t are the fish body weight, proportion mature and total mortality for females at age t (e.g. Wakefield et al., 2020).

Spawning potential ratio, based on spawning biomass, is calculated as

$$SPR = \Phi_F^{SB} / \Phi_{F=0}^{SB}$$

Female relative biomass (B_{rel}) is calculated from an extended form of per-recruit model allowing for potential effects of fishing on recruitment, through incorporation of a stock-recruitment relationship (Punt et al., 1993; Horbowy and Luzeńczyk, 2012), of the form described by Beverton and Holt (1957). The proportion to which female spawning biomass is reduced from its unfished level, B_{rel}, may be calculated as

$$B_{\mathrm{rel}} = (4hSPR + h - 1)/(5h - 1)$$

For the above equation, the steepness parameter, h, was set to 0.75 for Western Australian salmon, as used for many other fish species in WA. A more detailed description of the per-recruit model equations is provided in the vignette documentation for the L3Assess R package (Hesp, 2023).

8.4 Lines of Evidence

8.4.1 Productivity Susceptibility Analysis

8.4.1.1 Productivity

The oldest age recorded for Western Australian salmon was from samples collected by DPIRD (11 years and 8 months). The value for average age at maturity (A_{50}), 3.24 (both sexes), is based on published values generated from Departmental data (Wise and Molony, 2018). The largest Western Australian salmon measured by the Department is 87 cm TL, in comparison to 96 cm TL reported elsewhere (Hutchins and Swainston 1986, Gomon et al., 1994). Length at maturity is 60-65cm FL and average size at maturity has been selected as medium risk. Western Australian salmon are batch spawners (Stanley, 1980) with unknown fecundity, therefore a conservative score of 2 has been allocated. The trophic level is estimated as 4.4 (±0.75 se) (Froese and Pauly, 2021). Based on these values, Western Australian salmon productivity is scored as 1.71 (Table 8.2).

8.4.1.2 Susceptibility

Western Australian salmon susceptibility was assessed for five fisheries: SWCSMF, SCSMF, SCEMF, SWCBNMF, and the recreational fishery. The SWCSMF and SCSMF are restricted to a small number of South Coast beaches; however, the westward spawning migration results in most mature fish moving past each of those beaches over the course of a season. Migration along the West Coast is variable between years and so the SWCSMF and condition 68 authorisation holders may not have access to such a large proportion of the population annually. The SCEMF catches salmon from estuaries on the South Coast which fishers refer to as 'salmon trout'; a name used for juvenile salmon, indicating the greater reliance of this fishery on juveniles. Recreational fishers catch salmon from shore and boat across the species' entire range. It is unknown what proportion of the population move close enough to the beaches to allow capture, however given the historic catches of over 4000 t, it is suspected that a substantial portion are vulnerable to the commercial fisheries. A precautionary approach to scoring of areal overlap was taken due to migration patterns. A score of greater than 30% (i.e., highest susceptibility category) was assigned to each of these fisheries (Table 8.3).

Commercial fishing gear (hauling/seining nets) are constructed to be able to capture fish off the permitted beaches and cover the entire water column. As the beaches where nets are deployed are sandy and free of obstacles, fish have a high encounterability of commercial fisheries. Fishers in the SCEMF largely use gillnets that cover the majority of the water column. Recreational fishers can target the fish from beaches, headlands and boats, and are also assessed as having a high encounterability (Table 8.3).

The commercial fisheries in WA, with the exception of the SCEMF, are based on the spawning run of mature fish, and rarely catch individuals less than the average size

at maturity. In comparison to most of the commercial fisheries targeting Western Australian salmon, a large portion of the catch taken by the SCEMF is understood to be comprised of immature fish. Recreational fishers are able to retain fish with a minimum legal size of 300mm TL, i.e., less than size at maturity. However, the main recreational fishery is also based on the spawning migration, and smaller fish are unlikely to be retained. Therefore, these fisheries were scored a low risk based on selectivity, even though immature fish would not be able to escape or avoid gear (Table 8.3). Immature individuals are thought to form a large portion of the catch from the SCEMF; therefore, it received a high risk score for selectivity.

Commercial fisheries based on the spawning migration use gears that do not mesh the salmon, and unwanted fish can be released. As fishers catch salmon to fulfil market demand, the majority of the catch is retained, and post-capture mortality risk score is therefore high. Use of gillnets in the SCEMF means that salmon are either retained or unable to be released alive; a post-release mortality risk score of high is therefore also appropriate for the SCEMF.

The recreational fishery has a high proportion of catch and release (Henry and Lyle 2003, Ryan et al., 2022, Tate et al., 2019), whilst some mortality is likely due to injuries associated with hooking and handling fish there is no evidence of substantial mortality. Therefore, a post-release mortality risk score of medium was assigned for the recreational fishery (Table 8.3).

Based on the productivity and susceptibility scores, the overall weighted (by fishery / sector catches) PSA scores for salmon was 2.49. This equates to an MSC PSA-derived score of 84, which is considered a low risk. Testing of the sensitivity of this scoring revealed that if catches of salmon from the SCEMF were above 55 t, and catch in other fisheries remained the same, the overall risk would increase to medium. This is due to weighting of risk by catch and the higher selectivity risk score of this fishery due to capture of immature fish.

8.4.1.3 Conclusion

PSA scoring considers salmon as a low risk. This was despite a conservative approach to scoring through use of values that would increase risk when the actual value was uncertain.

The low risk based on PSA score indicates that under current management arrangements, unacceptable stock depletion is considered unlikely.

Table 8.2. PSA productivity scores for each indicator species

Productivity attribute	Value	Score
Average maximum age	11.66	2
Average age at maturity	3.24	1
Average maximum size	96cm	1
Average size at maturity	60-65cm FL	2
Reproductive strategy	Broadcast spawner	1
Fecundity	100-20000 eggs per year	2
Trophic level	4.4	3
Total productivity (average)		1.71

Table 8.3. PSA susceptibility scores for each fishery / sector that impact on WA Salmon in WA

Susceptibility attribute	SCSMF	SWCSMF	SCEMF	SWCBNMF	WA - Recreational
Areal overlap	3	3	3	3	3
Vertical overlap	3	3	3	3	3
Selectivity	1	1	3	1	1
Post-capture mortality	3	3	3	3	2
Total susceptibility (multiplicative)	1.65	1.65	1.65	1.65	1.43

8.4.2 Catch

8.4.2.1 Commercial trends

Several trends are evident in commercial catch data for WA and SA. By far the majority of the catch has historically been taken in WA, and the data demonstrate three obvious peaks in catch, all of which were followed by declines of various strength. The first peak occurred at ~ 5000 t in the mid- to late-1960s, followed by a strong decline. The two subsequent peaks were similar in magnitude at over ~3500 t in the early- to mid-1980s, and the mid-1990s (Figure 8.1). There was generally an increasing trend from the mid- to late-1970s, ~1000t, through to a mid-1990s peak, and 5 years subsequent. After this time there was a very substantial decline in catch to 2010, after which catch has remained at ~200 t for a decade (Figure 8.1). Within WA, the majority of the catch has consistently occurred on the South Coast, and regional trends followed the pattern seen in the overall catch trends (Figure 8.1).

Variations in total catch of salmon from 1950s through to 2005 may reflect, to a much greater extent than for more recent years, changes in stock abundance (possibility associated with recruitment variation). Commercial fishers attribute recent low commercial catches to reduced fishing effort resulting from low prices and reduced market demand. The low catches of the last decade are therefore not considered to reflect low abundances of this species for this period.

Within WA, salmon were initially caught from the open access fisheries prior to the creation of managed fisheries (Section 6). Since then, catch has come largely from two managed fisheries; the SCSMF and the SWCSMF, other fisheries contribute only a very small proportion of the catch (Figure 8.2). Prior to 2004, the SCSMF took most of the commercial salmon catch, however after this time, catch was similar between the two fisheries (Figure 8.3). The change in catch share between the two fisheries is attributed by commercial fishers to a difference in the markets to which fish are supplied prior to 2004.

8.4.2.2 Recreational trends

Salmon are a popular recreational species. In a nationwide survey, ‘Australian salmon’ (*Arripis truttaceus* and *A. trutta*) was in the top 10 species groupings caught (Henry and Lyle, 2003) similar to the findings of a survey in WA for Western Australian salmon (Ayvazian et al., 1997). Within the metropolitan region of Perth, shore-based surveys indicate it is one of the top four species caught (Tate et al., 2019). Whilst the most recent survey of boat-based fishers in WA found it to be the second most caught species on the South-Coast of WA, it was not in the top 10 species on the West Coast (Ryan et al., 2022), noting that shore-based fishers catch a higher proportion of salmon than boat-based fishers (Avayzian et al.,1997).

Estimates of the weight of the recreational catch of salmon in WA has varied between surveys. It was estimated as 158 t in 1994, 189 t in 1995 (Avayzian et al., 1997) and 136 t in 2000/01 (Henry and Lyle, 2003). This recreational catch of

Western Australian salmon in the Perth metropolitan area was 0.4 t (95%CI 0 – 3 t) in 2022. Harvest was low except for 2015 – 2017, when a peak of 58 t (95%CI 0 – 119) occurred in 2016, although the large confidence intervals highlight the high uncertainty associated with this estimate. Charter catches of the species are negligible, with less than 5 tonnes retained by charter operators since 2000. Charter boats primarily target demersal species in offshore waters, which accounts for this low catch.

Western Australian salmon are caught by many recreational fishers for sport, and are generally not rated for their eating quality, therefore, many fish caught are released. The rate of release has been estimated as between 0 and 57% within the metro region (Tate et al., 2019), 33.7% for all of Australia (both species) (Henry and Lyle, 2003), and was 68.5% in the latest boat-based survey (Ryan et al., 2022). The release rate was not estimated by Avayzian et al., (1997).

8.4.2.3 Catch Analyses - Catch-MSY

The catch-MSY analysis produced a predicted mean value for maximum sustainable yield (MSY) for the stock of Western Australian salmon of 2,678 t, based on commercial catch only and a medium resilience level, and 3,219 t, based on commercial and recreational catch data and a low resilience level (Table 8.4, Figure 8.5). The 95% confidence intervals for the MSY predictions are far broader when assuming low resilience, than medium resilience. The predicted biomass to sustain a catch at MSY (B_{MSY}) was 13,276 t, based on the commercial catch only/medium resilience analysis, and more than double that for the combined catch data/low resilience analysis (27,893 t) (Table 8.4). This difference is largely due to the resilience value, as the model simulated projections for B_{MSY} across data sets using the same resilience value were similar, i.e., 25,190 t vs 27,893 t, commercial catch/low resilience v combined catch/low resilience; and, 13,276 t vs 13,749 t commercial catch/medium resilience v combined catch/medium resilience (Figure 8.5).

Catches of salmon since the 1950s, have largely been fluctuating around or below the predicted mean value for MSY regardless of the data used, or the level of resilience chosen (Figure 8.4). However, the large peaks in catches in the late 1960s, early 1980s and mid-1990s exceeded the upper 95% confidence interval for MSY estimated using a medium resilience value (Figure 8.4). Similarly, when using low resilience, the peaks in catch were near to or above the 95% confidence intervals estimated for MSY (Figure 8.4).

Predictions of biomass using the catch-MSY methods are heavily reliant on the assumed input priors for the analysis, including resilience, and initial and final depletion. Results of all catch-MSY analyses undertaken indicate that recent harvest rates have been very low, and well below the mean estimated harvest rate required to achieve MSY (H_{MSY}) (Figure 8.5). The low recent harvest rates have resulted in predicted biomass increasing over the last decade (Figure 8.5). The mean value of the predictions for current depletion (i.e., relative biomass, the ratio of current

biomass to unfished biomass in 2021/22) of >0.8 (Table 8.4, Figure 8.5) is well above the threshold (0.5) when the stock is at B_{MSY} (as calculated when using the Schaefer model). Thus, relative biomass is also well above the limit level (0.25), at which the stock would be considered at increased risk of recruitment failure.

The phase plots showing the annual relative stock biomass levels and harvest rates indicate different trends in biomass between commercial only and the combined catch data. Results based on commercial only catch data suggest that after an initial period of stability lasting more than a decade, harvest rates increased over a period of 3 years, corresponding to large peak in catches in the mid- to late-1960s, resulting in a decrease in biomass. Biomass then remained relatively stable over an approximate 30-year period, that was either above the target (low resilience) or fluctuation around the target (medium resilience). Harvest rates then increased again and reduced the biomass to below the target (low resilience) or below the limit (medium resilience). At that point in time, the early- to mid- 2000's there was a marked decline in the harvest rate, although biomass remained stable, until ~2010 when there was a sustained low harvest rate and continued increase in biomass, with both levels of resilience indicating that the stock is now above the target (Figure 8.5).

Catch-MSY results based on combined (commercial and recreational) catch data show a single period of stability, when both the annual harvest rates and biomass levels were at, or fluctuating around, their respective targets (Figure 8.5). As with the commercial only data, harvest rates declined in the 2000's and estimates of biomass continued to increase to well above the target for more than a decade (Figure 8.5). Although the influence of the recreational catch estimate on resultant estimates of biomass was substantial, its inclusion had essentially no impact on stock status. Therefore, further sensitivity testing based on substantial alternative recreational catch estimates was not undertaken, however, this could be pursued in future assessments.

8.4.2.4 Conclusion

Recent commercial catches of salmon are extremely low compared to historic averages and peaks. Commercial fishers attribute this to a lack of market demand and hence reduced targeting. This justification is supported by effort data (section 8.4.4). It is uncertain how estimates of recreational catch from the mid-1990's of 158 to 189 t compared to recent catches by recreational fishers, or if retention rates over the years are similar to that estimated in more recent surveys of between 30 and 75%. Anecdotal evidence from social media pages suggest recreational fishers are enjoying abundant catches, however West Coast catches are highly dependent on annual migration patterns.

Catch-MSY analysis, applied to commercial and combined recreational and commercial catch data, indicate that in the last decade there have been low harvest rates, with catches well below MSY. As a result, biomass has increased to well above the target. Point estimates of MSY ranged between 2,678 t and 3,219 t, the range of estimates reflect uncertainty around recreational catch and choice of resilience level.

Catch data and catch-MSY analysis provide evidence of recent catches being well below the estimated MSY and no indications of current unacceptable stock depletion.

Table 8.4 Catch-MSY model estimates (±95% CLs) of MSY (maximum sustainable yield), r (intrinsic increase) K (carrying capacity), and d (final depletion, i.e. current biomass relative to the unfished level), B (current biomass), H (current harvest rate), *F* (Fishing Mortality), B_{MSY} (stock biomass at MSY) and F_{MSY} (fishing mortality at MSY), for a.) total commercial catch from WA and SA using a value of low for resilience, b.) combined commercial and recreational catch using a value of low for resilience, c.) total commercial catch from WA and SA using a value of medium for resilience, and d.) combined commercial and recreational catch using a value of medium for resilience..

a.) Commercial catch only, r = Low

Parameter	Mean	Lower	Upper
MSY	2746	2077	4072
r	0.22	0.14	0.36
K	50380	32270	66588
d	0.8	0.54	0.9
B	43767	24429	58670
H	0	0	0
F	0	0	0
B_{MSY}	25190	16135	33294
H_{MSY}	0.11	0.07	0.18

b.) Commercial and Recreational catch, r = Low

Parameter	Mean	Lower	Upper
MSY	3218.78	2332.75	4971
r	0.23	0.13	0.4
K	55785	33340	77323
d	0.82	0.57	0.9
B	50570	26737	68542
H	0	0	0.01
F	0	0	0.01
B_{MSY}	27893	16670	38661
H_{MSY}	0.12	0.06	0.2

c.) Commercial catch only, r = Medium

Parameter	Mean	Lower	Upper
MSY	2678	2455	3278
r	0.4	0.35	0.54
K	26553	22374	28943
d	0.82	0.52	0.9
B	21914	12596	25744
H	0	0	0
F	0	0	0
B_{MSY}	13276	11187	14472
H_{MSY}	0.2	0.17	0.27

d.) Commercial and Recreational catch, r = Medium

Parameter	Mean	Lower	Upper
MSY	3015	2658	3746
r	0.44	0.35	0.61
K	27498	21451	31483
d	0.87	0.71	0.9
B	24118	17324	28092
H	0.01	0.01	0.01
F	0.01	0.01	0.01
B_{MSY}	13749	10726	15742
H_{MSY}	0.22	0.17	0.3

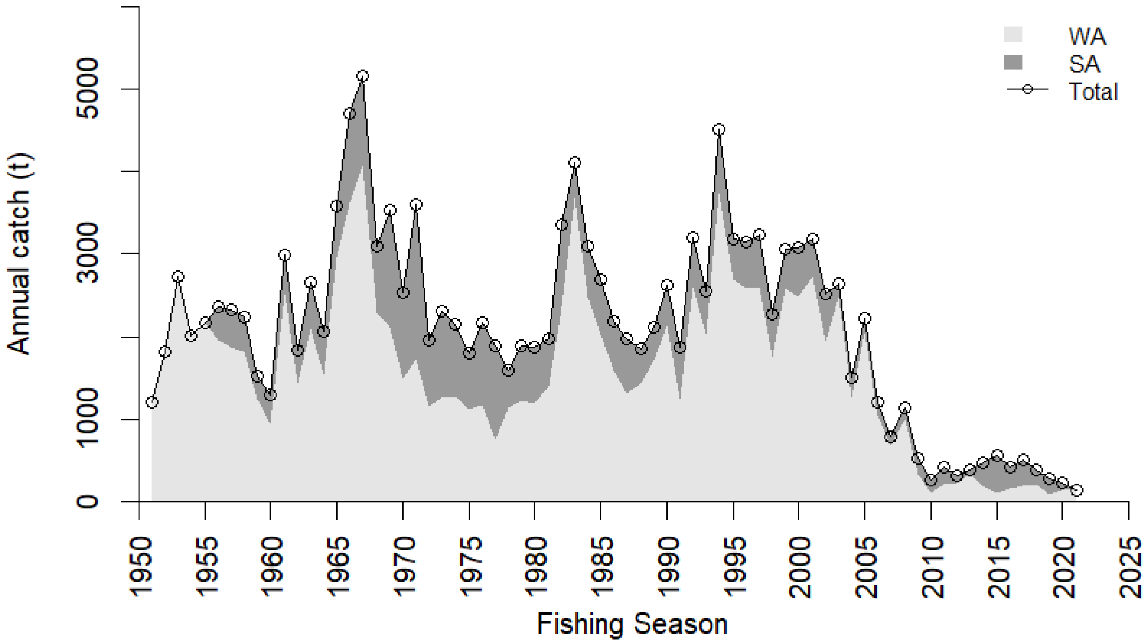


Figure 8.1 Commercial catch of Western Australian salmon from WA, SA, and the combined total since 1951. Year is the financial year, i.e., 1951 is the 1951/52 financial year. No catch data are available for SA prior to 1955.

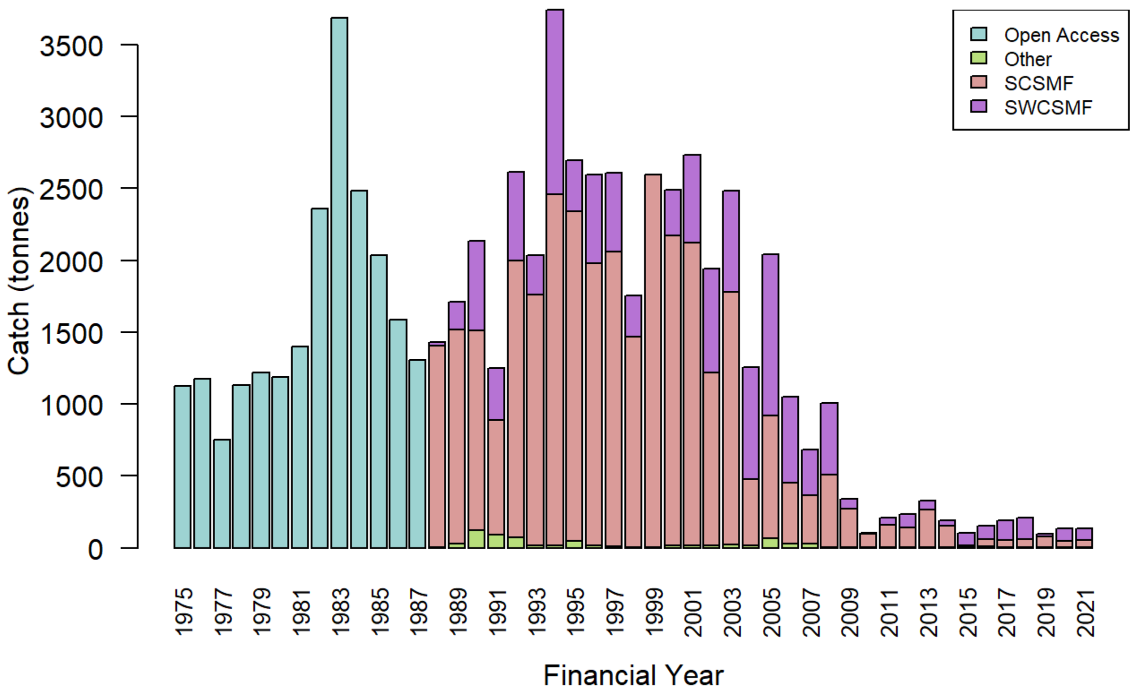


Figure 8.2 Catch of salmon (tonnes) by WA fishery for each financial year from 1975 to 2021 based on commercial catch returns.

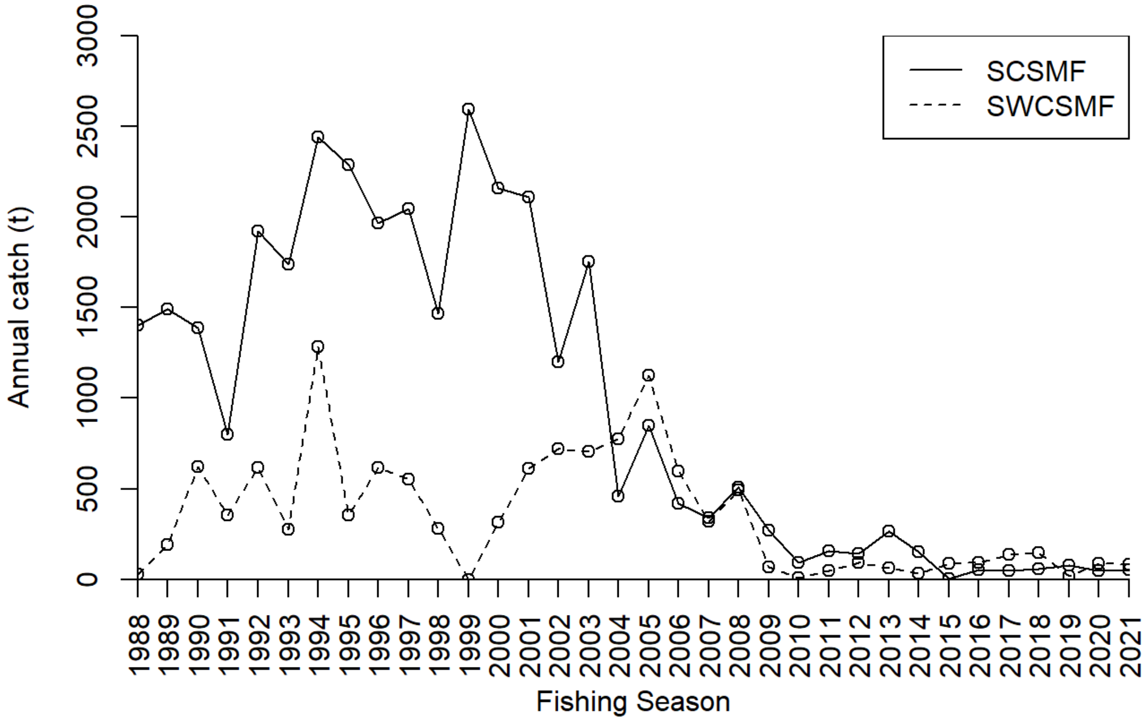


Figure 8.3 Annual catch (t) of salmon from the two main commercial fisheries, the SCSMF and the SWCSMF.

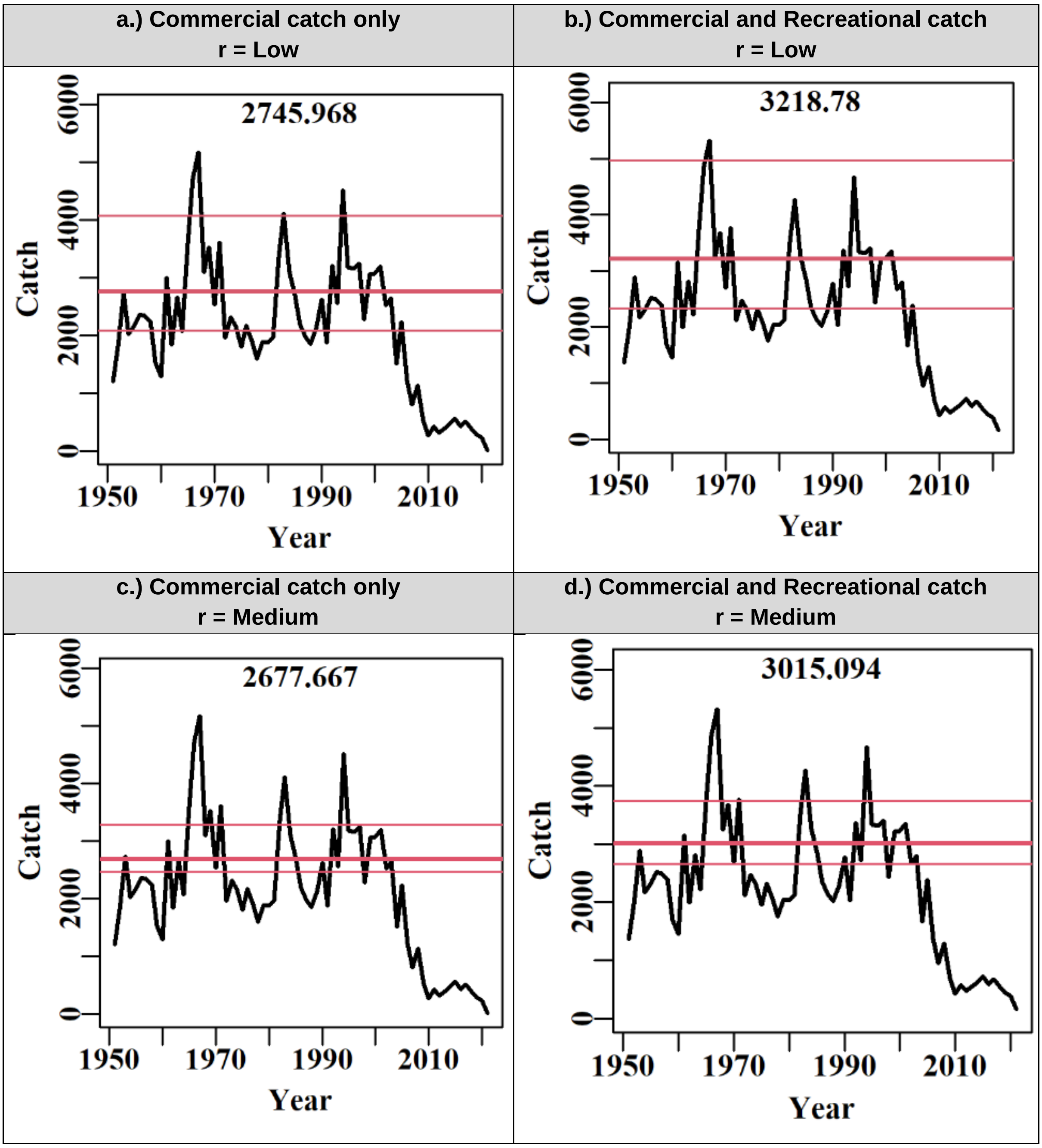


Figure 8.4. **Annual time series of catches for salmon relative to the estimated Maximum Sustainable Yield (MSY) (thick red line) and associated 95% CLs (thin red lines), estimated from catch-MSY analysis for a) total commercial catch from WA and SA using a value of low for resilience, b) combined commercial and recreational catch using a value of low for resilience, c) total commercial catch from WA and SA using a value of medium for resilience, and d) combined commercial and recreational catch using a value of medium for resilience. Value for catch is tonnes.**

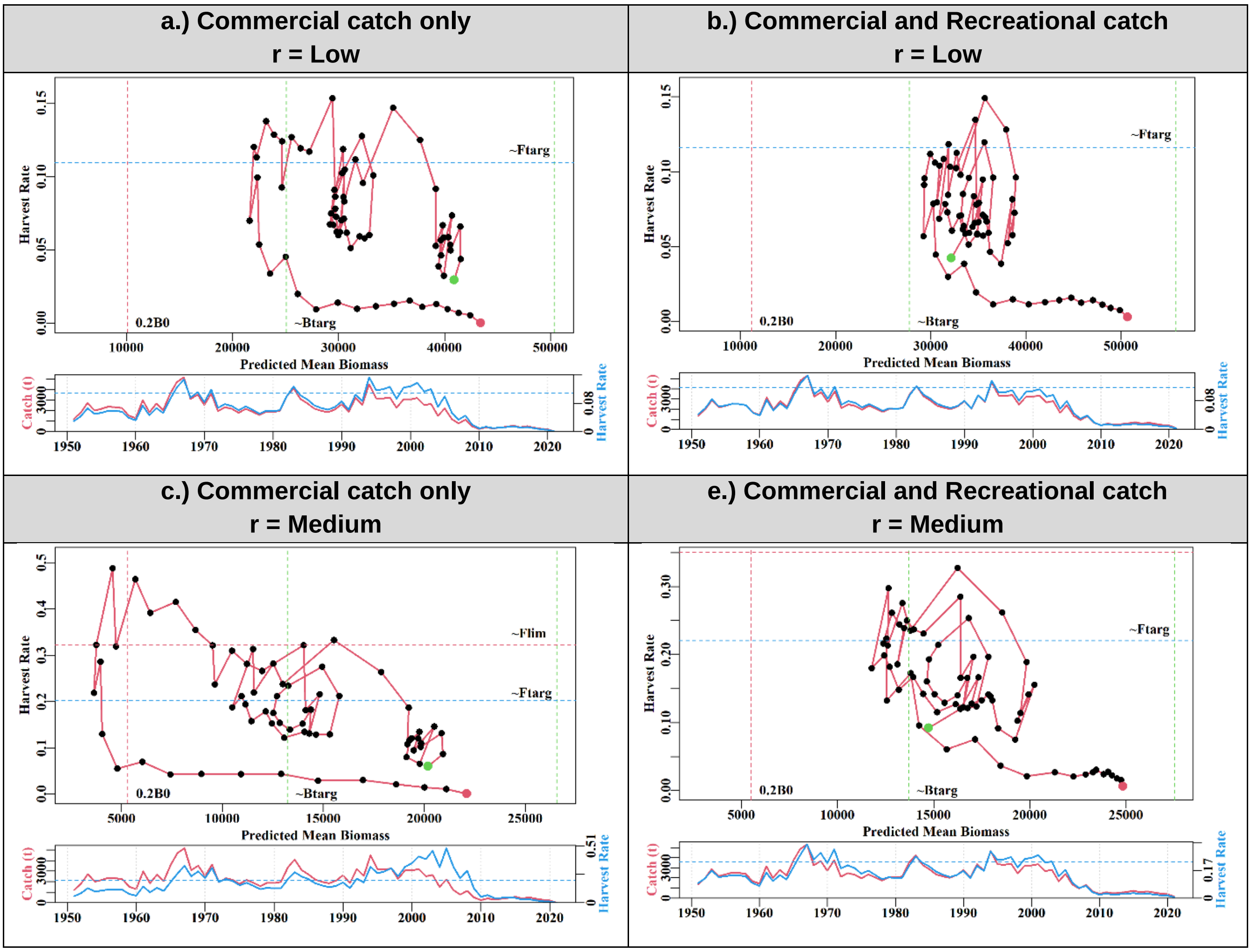


Figure 8.5. Phase plot (top) and biomass plot (bottom) showing annual estimates biomass and harvest rate values for salmon relative to associated threshold and limit reference points, from a catch-MSY model, and a plot of catch (t) and harvest rate (yr^{-1}) for a.) total commercial catch from WA and SA using a value of low for resilience, b.) combined commercial and recreational catch using a value of low for resilience, c.) total commercial catch from WA and SA using a value of medium for resilience, and d.) combined commercial and recreational catch using a value of medium for resilience. The green and red dots on the phase plot represent the beginning and end of the time series, respectively.

8.4.3 Catch Distribution Trends

8.4.3.1 Spatial

The majority of Western Australian salmon catches have consistently occurred around the south west of the state, i.e. the capes region to Bremer Bay, with the highest catches occurring just east of Albany (Figure 8.6). There has been a slight westward contraction in catch in recent years with no catches recorded in the Esperance regions since 2015/16 (Figure 8.6). Changes in concentration and distribution of catch on the South Coast are considered to reflect changes in effort and are not considered to reflect changes in distribution. However, commercial fishers at the 2022 Annual Management Meeting (AMM) indicated that they have observed changes in salmon behaviour, with fish often remaining further offshore during the annual spawning migration, resulting in decreased opportunity to catch the species. Another potential influence on catch is the anecdotal suggestion that salmon diet has shifted from pilchards to herring and these prey species occupy different habitats.

Salmon are targeted during the spawning migration, and the magnitude of the northward movement along the West Coast varies between years, therefore, environmental effects are likely to heavily influence catch in this region. Continued warming of waters on the West Coast are likely to result in a retraction in northerly distribution (Cheung et al., 2012), which may be reflected by the lack of catches of salmon on the mid-West Coast from ~ 2010 onwards. Very low catches north of Perth have consistently been recorded, however these are extremely small (<1 t in a five-year period) (Figure 8.6). At the 2022 AMM, commercial fishers attributed changes in the distribution of catches in the Capes region to access restrictions.

8.4.3.2 Temporal

Over the time period for which Departmental records are available (1975/76 to 2020/21), ~60% of the commercial catch on the South Coast occurs in the peak month of March, and the combined months of March and April account for more than 80% of the catch in the region (Figure 8.7 a), resulting in a two month season. Catches in the SCSMF during these peak months, prior to 2004/05, were much greater than is currently taken (Figure 8.8a), although months for peak catch have remained the same, i.e., March or April (Figure 8.8b). Prior to 2000, there were noticeable catches of salmon from June, July and August, which fishers attribute to a “back-run” of salmon. These catches were low compared to catches in the peak season at that time, however they are comparable to the catches currently taken in the peak season due to the overall much reduced level of catch (Figure 8.8a & b). Two major marine heatwave events have occurred during the data time series, 1999/00 and 2010/11, and appear to have caused a delay in peak catch by a month i.e., April instead of March (Figure 8.8b). The delay in peak catch persisted following the initial event; 1 year for the 1999/00 heatwave and 2-3 years for the 2010/11 heatwave (Figure 8.8b).

Catch on the West Coast shows a similar pattern to that on the South coast, although with some slight differences. Peak catch generally occurs a month later (April rather than March) (Figure 8.7b), and whilst the catch in the peak month still accounts for a very large proportion of the total annual catch, ~50%, the shoulder months contribute more equally to annual catch, resulting in a 3 month season on the West Coast (March to May) rather than the 2 month season on the South Coast (Figure 8.7a & b). Within the main fishery on the West Coast, the SWCSMF, catches during these peak months have declined since 1988/89 and minimal catch outside these peak months is recorded (Figure 8.9a). In years of marine heatwave events (1999/00 and 2010/11) catches in the SWCSMF were very low, easily seen in years adjacent to 1999/00, but less obvious in years around 2010/11 as overall catch was also lower (Figure 8.9a). The unusually large proportion of catch in November in 1999/00 is an artefact of the heatwave reducing catch in peak months (Figure 8.9b). Despite April accounting for most of the catch, there is some interannual variability in the month of peak catch (Figure 8.9b). Other substantial weather events, e.g., cyclones, have not been considered, but may have an impact on catch. Commercial fishers at the 2022 AMM suggested the impacts could occur through making conditions unsuitable for commercial fishers, or through impacts on adult movement.

The patterns in timing of catch reflect the movement of salmon during their spawning migration. Fish from SA and WA form schools and begin their migration, reaching the South Coast first and becoming vulnerable to capture in the SCSMF in March. The fish continue to move westward, then north along the West Coast where they become vulnerable to capture by the SWCSMF. In years where the peak month of catch in the SCSMF occurs later than usual (i.e., April in 1988/89, 1999/00, 2010/11 to 2012/13, 2017/18 & 2018/19), there was no corollary delay in peak month of catch by the SWCSMF. However, in those years prior to 2012/13 when peak catch in the SCSMF was delayed, catch in the SWCSMF appeared to be reduced when compared to catch in adjacent years. Although not apparent for 2017/18 & 2018/19 this may be due to the overall much lower catch. Therefore, delayed timing in the migration of salmon on the South Coast does not appear to impact timing of peak catch on the West Coast, but the abundance is likely to be much reduced and attributed to warm water events.

8.4.3.3 Conclusion

The main salmon fisheries (SCSMF & SWCSMF) in WA are reliant on the annual spawning migration of salmon that occurs in autumn. Overall, spatial changes in catch distribution are minor. Where they have occurred, e.g., the Esperance region and Capes region, they are not believed to be due to a change in species distribution, but rather to changes in fishing effort or access restrictions. Anecdotal evidence from fishers suggests there may be some localised changes to movement patterns due to water temperature or diet shift.

Interannual temporal changes in catch have occurred at times. These may be associated with variations in water temperature, e.g. marine heatwaves, and delayed the peak season on the South Coast and likely resulted in reduced catches on the West Coast due to lower abundance of migrating fish.

Minor shifts in catch distributions have occurred which appear to be associated with variations in environmental conditions. There are no indications of these shifts being associated with unacceptable stock depletion.

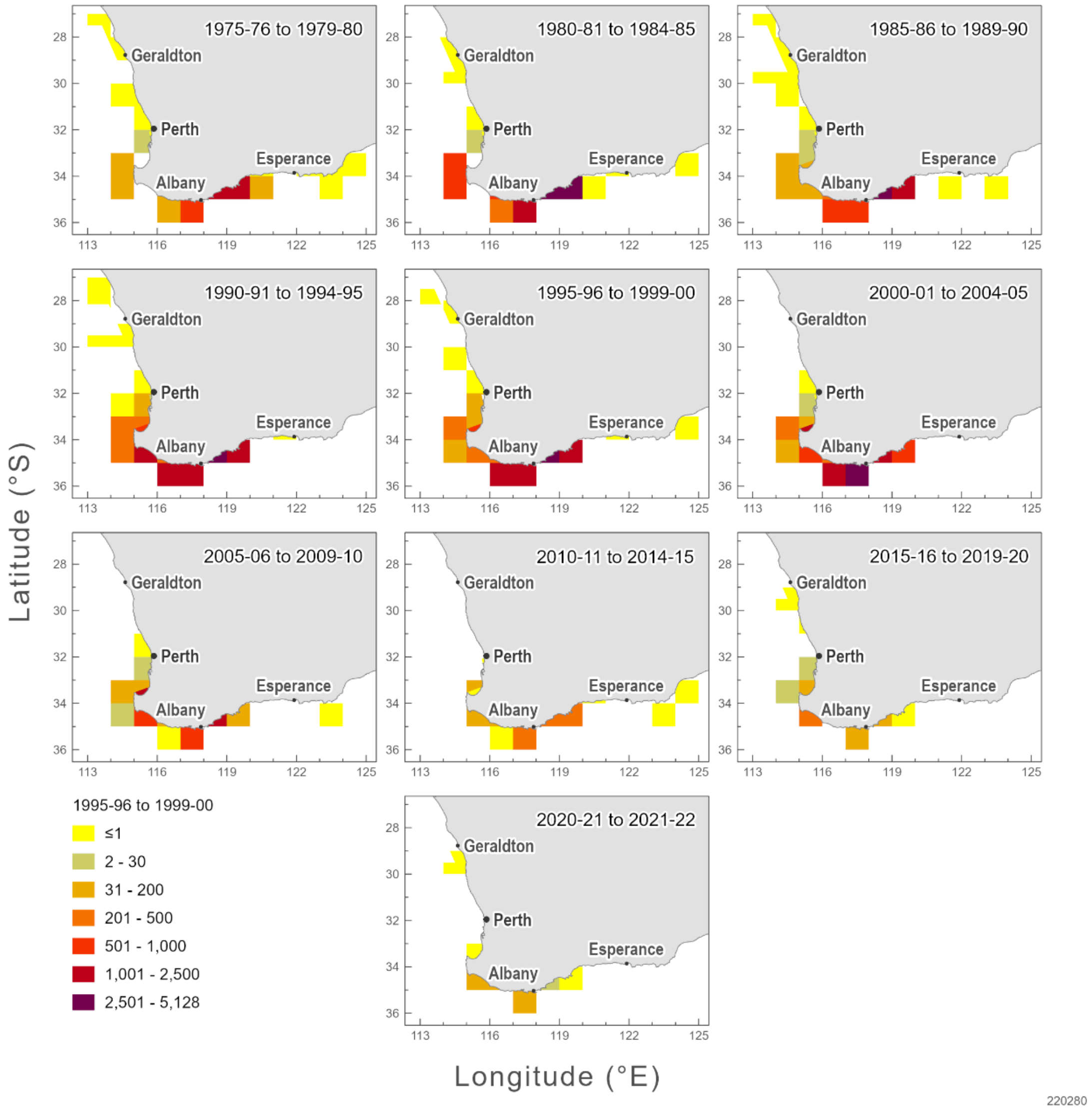


Figure 8.6. Spatial distribution of Western Australian salmon catches in 5 year blocks since 1975/76 through to 2021/22. Note that grouped catches (in tonnes) from 2020/21 to 2021/22 are only for 2 years.

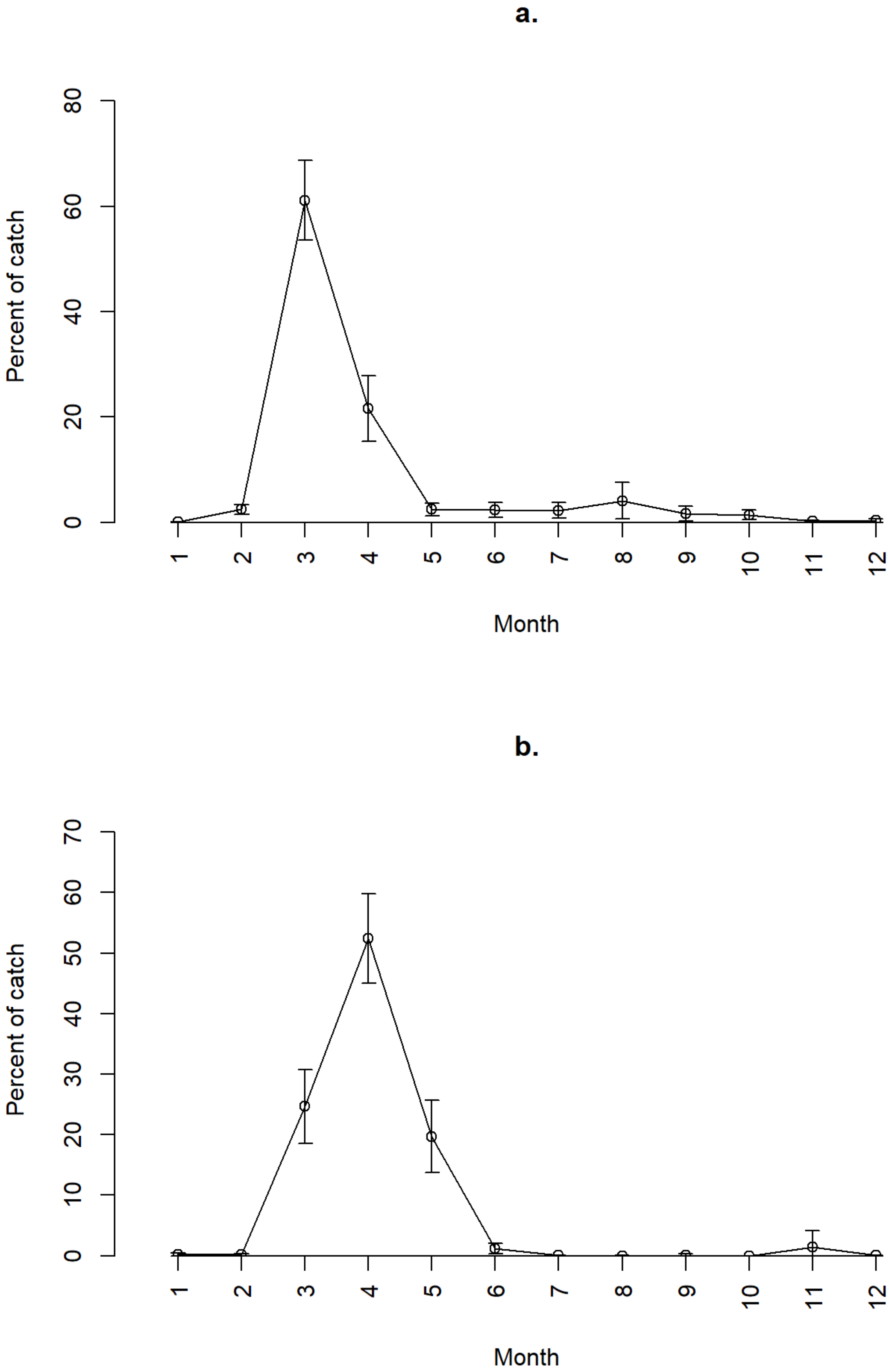


Figure 8.7 Distribution (percent ± 95% CI) of commercial salmon catch by month for a) the SCSMF, and b) the SWCSMF for years between 1975 and 2021.

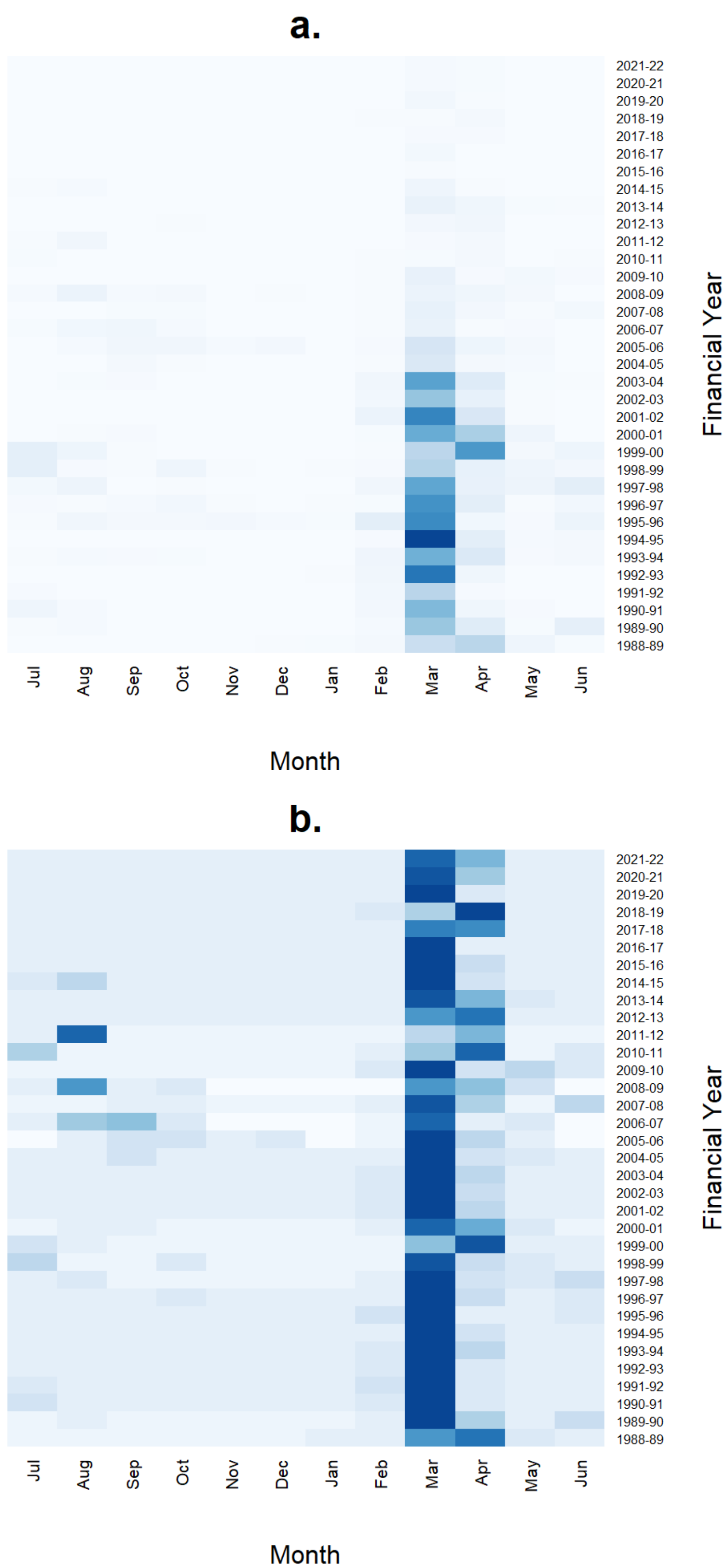


Figure 8.8 Heatmaps showing a) distribution of catch amongst months and years, and b) percent distribution of catch by month within each year for the SCSMF. Darker shading represents a larger value.

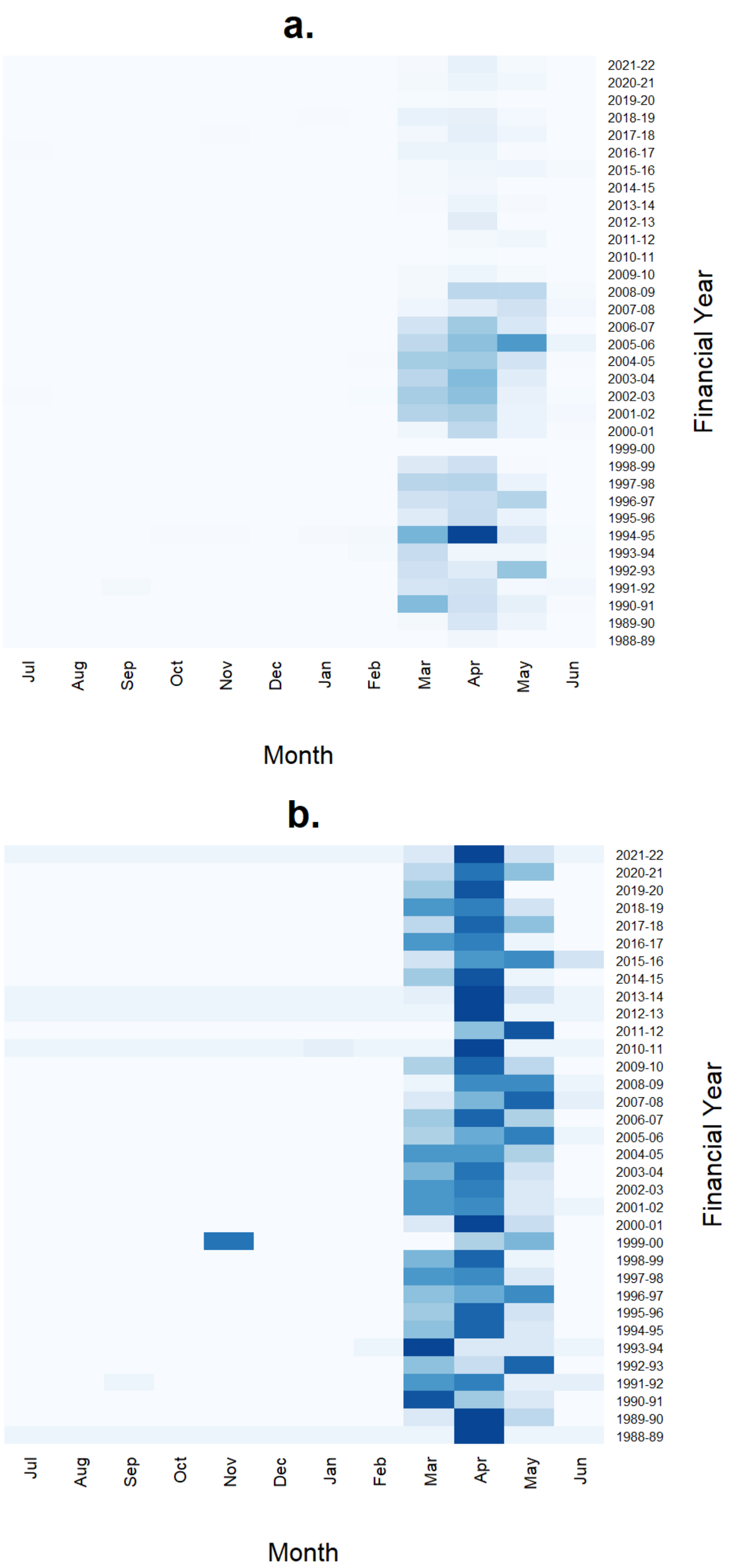


Figure 8.9 Heatmaps showing a) distribution of catch amongst months and years, and b) percent distribution of catch by month within each year for the SWCSMF. Darker shading represents a larger value.

8.4.4 Effort

8.4.4.1 Commercial trends

The number of vessels operating in the SCSMF has declined over the course of the fishery, from ~20 to 25 vessels per year, to a low of three vessels in the mid- to late-2010s (Figure 8.10a). The number of vessels operating in 2019 and 2020 increased to ~six to eight in the last two years. The SWCSMF had ~10 to 13 vessels operating from 1988 to 2003, except for 1999 when there were only four vessels (Figure 8.10b). After 2003 vessels operating in the fishery declined to a low of two vessels in 2012 & 2013. The number has since increased slightly to three to five vessels since 2014. The number of vessels operating in the fishery indicates participation, however, a single licence may have multiple vessels attached to it, therefore, as a measure of effort, number of vessels can be misleading.

Trends in the number of licences reflect how many licence holders are permitted to operate in the fishery. At initiation of the SCSMF in 1988/89, 21 licences existed, after 1994 this declined to 18 licences, where it has remained (Figure 8.11a). At initiation of the SWCSMF, 13 licences existed, and this number has undergone a gradual decline to 2020, and now there are only five licences in the fishery (Figure 8.11b). The fine scale trends in number of vessels and number of licences differ as too does the timing of declines, however, overall, both measures show a reduction in effort since initiation of the fisheries.

Capture of salmon in the two main fisheries (SWCSMF & SCSMF) is undertaken using active netting methods, i.e., haul netting. A single day of fishing may involve one or more net deployments, therefore, days fished, as a measure of effort, is not directly comparable. To further examine trends in effort, number of shots (days fished x number of shots) was used.

Effort measured as the total annual number of net shots in the two fisheries that target salmon, SWCSMF and SCSMF, trended gradually downwards from 1988 to 2005, beginning around ~3200 shots y^{-1}, declining to ~2000 shots y^{-1} (Figure 8.13a). After 2005 there was a strong decline to ~ 200 to 400 shots y^{-1} by 2010 where effort remained for most of the next decade. Annual effort trends in the SCSMF and the SWCSMF were similar to the overall trend, with the exception of a notable dip in effort in the SWCSMF in 1998 and 1999 (Figure 8.13).

Effort measured as the number of shots of hauling nets (beach haul, beach seine, and haul net) in the main salmon fisheries (SCSMF and SWCSMF) demonstrates the seasonality of the fishery. Most of the effort (shots) in the SCSMF occurs in March (~60%) and April (~30%), and combined accounts for ~90% of annual effort (Figure 8.12a). Seasonal effort trends in the SWCSMF differ slightly to the SCSMF, in that the main period of effort extends for an additional month (March to May) but also accounts for ~90% of the effort, peak effort occurs a month later (April instead of March) and accounts for less of the total effort (~42%), and effort across the main months is more similar, i.e. < 20% difference (Figure 8.12b). These trends and the

differences in trends between coasts reflect the reliance of the fisheries on schools of salmon undertaking their spawning migration. Refer to section 8.4.3.2 for further explanation.

Given the strong seasonality of the fishery, we examined annual effort trends (number of shots) both within the season and outside of the season (Figure 8.13b & c). The trends in effort in the peak fishing season differed slightly from the annual trend as it was stable from 1988/89 to 2005/06 (Figure 8.13b). Seasonal effort then followed a similar pattern to the annual trend, declining to 2010/11 where it stabilised. The trend in effort in the non-peak season showed an increase to 1995/96 where it peaked at ~600 shots due to effort in the SCSMF before declining to the end of the timeseries in 2020/21 (Figure 8.13c).

Trends in the various effort measures (number of vessels, number of licences and number of net shots) in both the SCSMF and the SWCSMF showed similar patterns of decline. Between 1988/89 and 2005/06 the decline is due to less effort in the non-peak season, however after this time effort in both peak and non-peak seasons decline. A similar decline in effort was observed in SA (Smart et al., 2022). Commercial fishers have indicated that decline in effort is related to market demands and resultant changes to targeting by fishers. The decline is not considered to have occurred due to a decline in salmon abundance.

8.4.4.2 Conclusion

Effort in the fishery is highly seasonal, restricted mostly to autumn when salmon undertake their annual spawning migration and become more accessible to fishers. The various measures of effort examined consistently show a decline in effort to recent years, particularly for the SCSMF and the SWCSMF. The decline is attributed to changes in targeting by the fishers due to poor markets and prices and therefore not considered reflective of a decline in salmon abundance.

The marked decline in commercial fishing effort in recent years was driven primarily by market factors, and does not reflect unacceptable stock depletion.

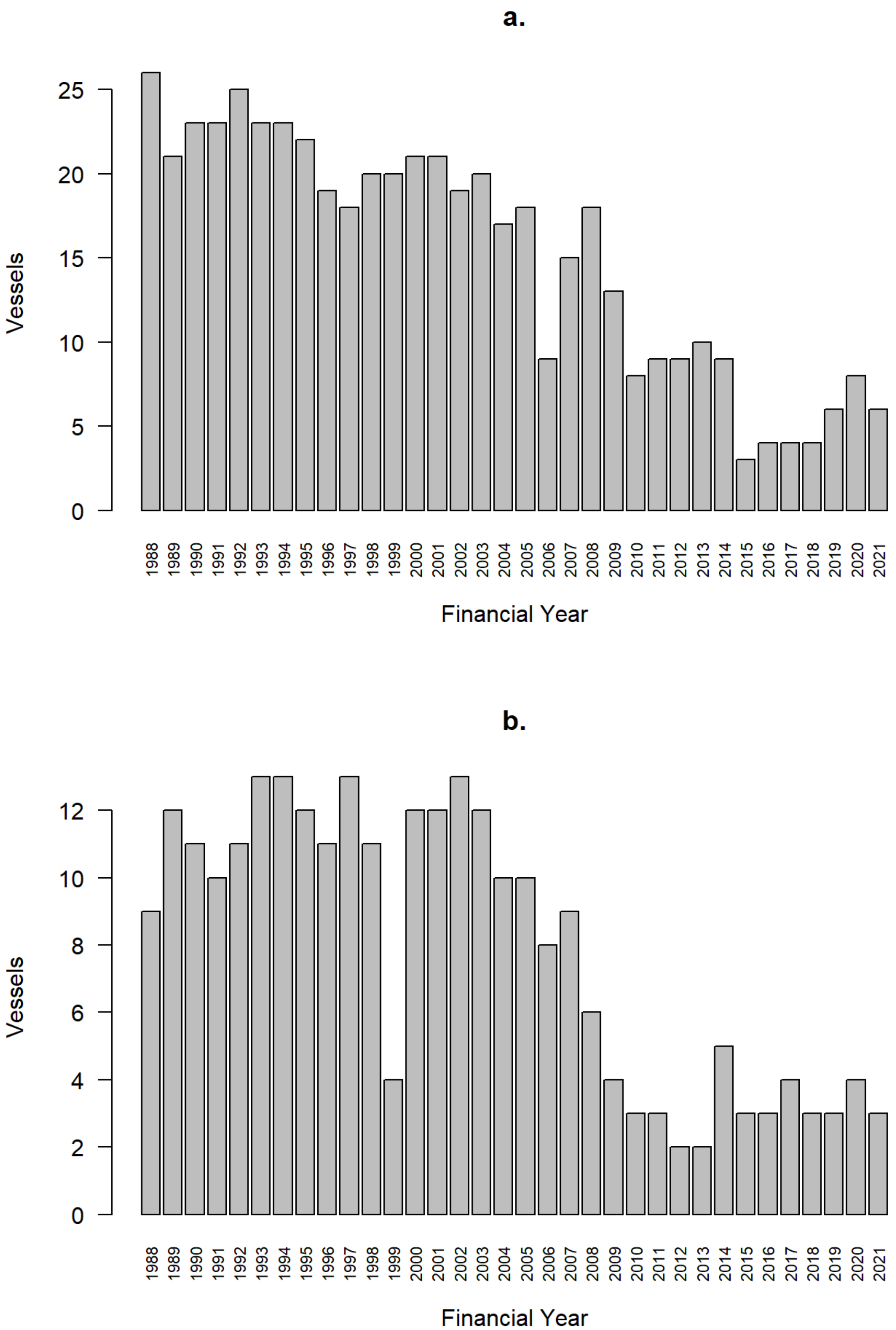


Figure 8.10 Number of vessels operating in a) SCSMF and b) SWCSMF each financial year since initiation of fishery.

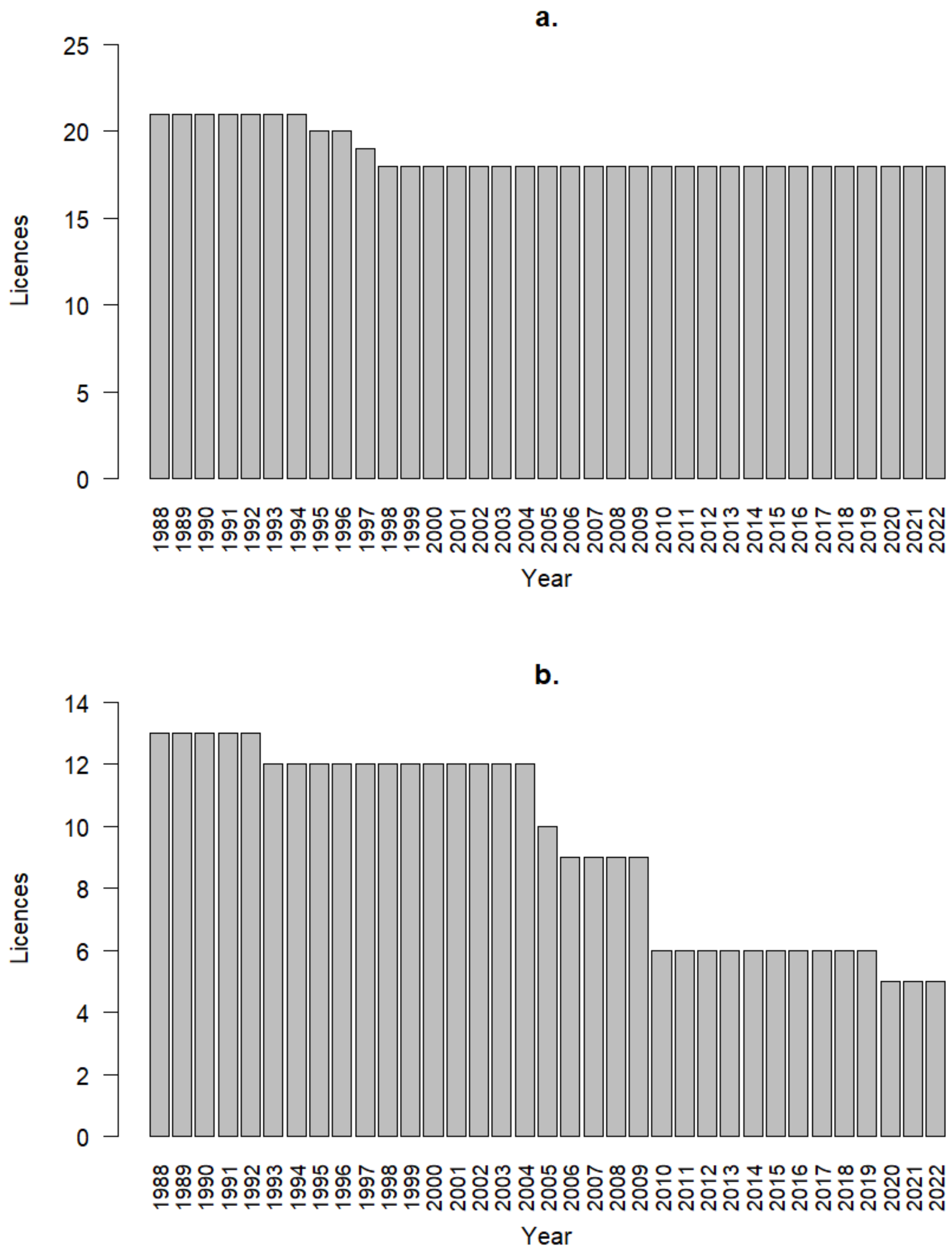
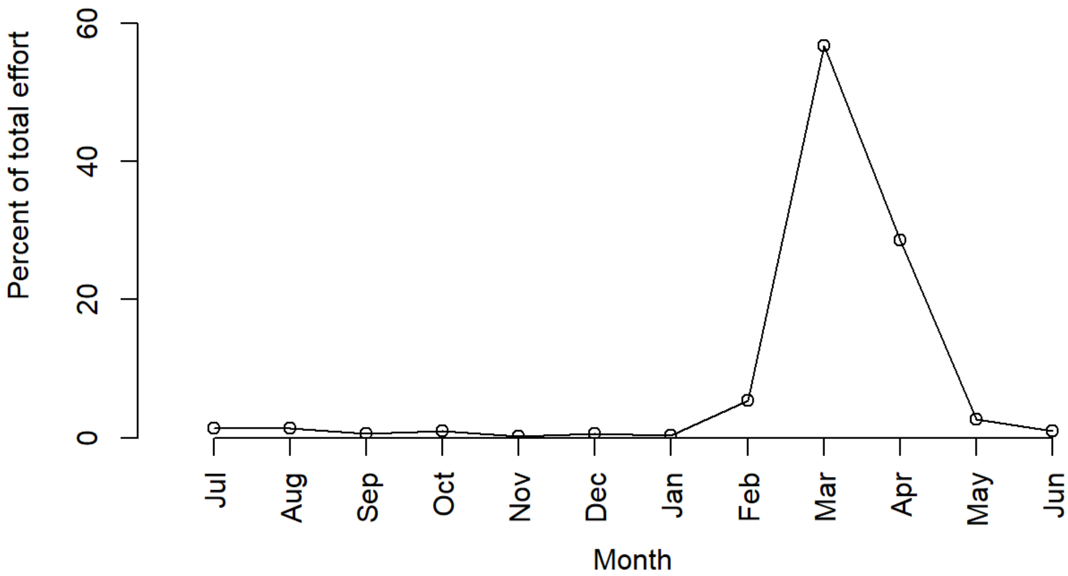


Figure 8.11 Number of licences operating in a) SCSMF and b) SWCSMF each year since initiation of fishery.

a.



b.

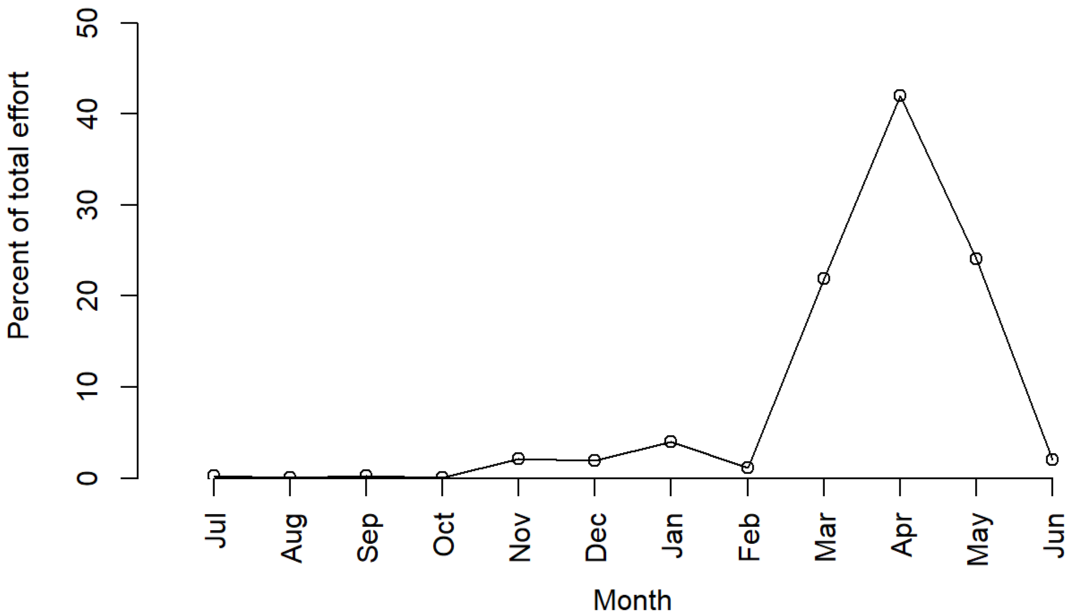


Figure 8.12. Percentage of fishing effort (shots) by hauling nets from 1989 to 2021: a) SCSMF and b) SWCSMF.

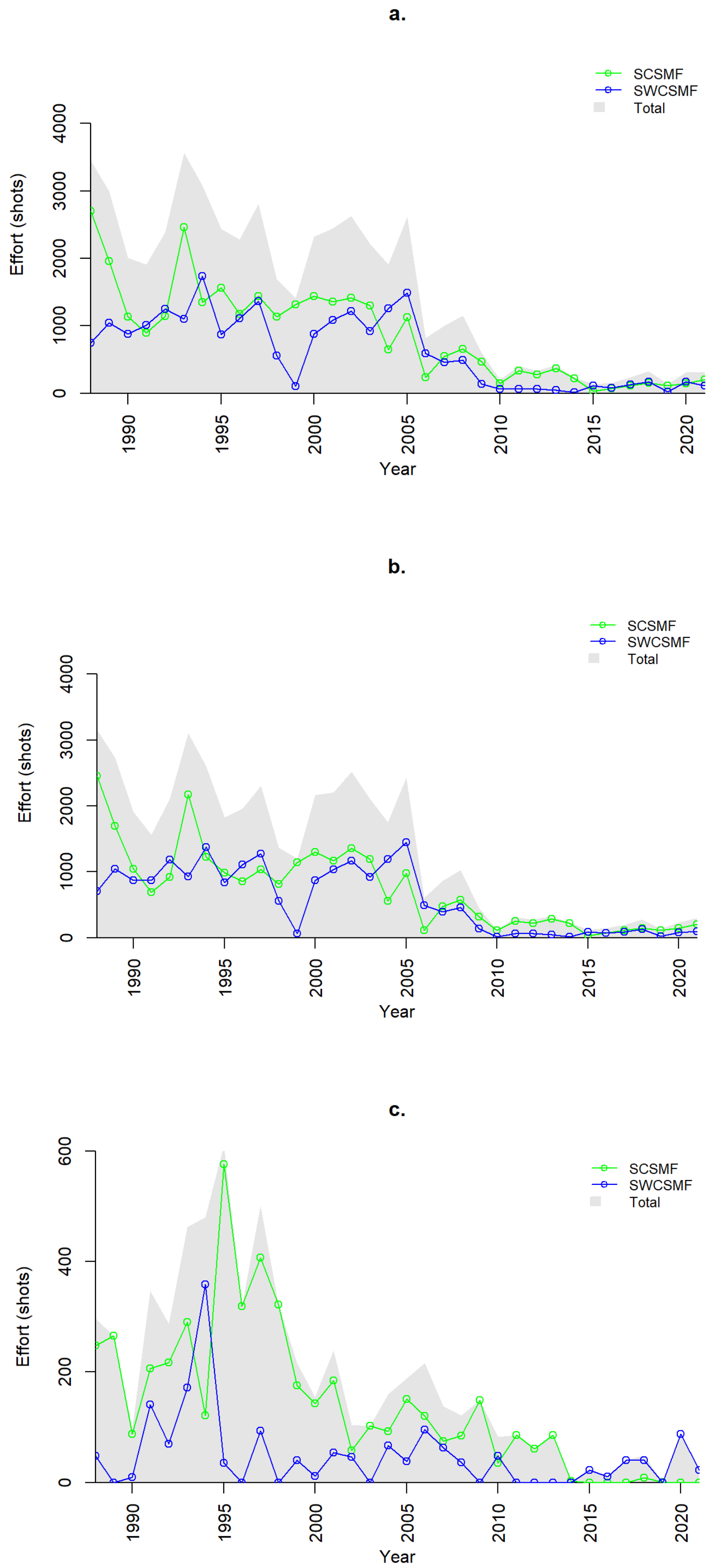


Figure 8.13. Effort (shots) of hauling nets for the main commercial fisheries that target the Western Australian salmon a) annually, b) during each fisheries peak season, and c) out of season effort between 1988/89 and 2020/21.

8.4.5 Fishery-Dependent Catch Per Unit Effort (CPUE)

8.4.5.1 Commercial

Nominal annual catch per unit effort (CPUE) (tonnes per vessel operating in fishery) for the SCSMF increased since initiation of the fishery from ~60 t per vessel to ~ 120 t per vessel in the late 1990s (Figure 8.14). After this time CPUE declined steeply to approximately 20 t in the late 2000s, followed by a continued decline to a much lower rate of between 0 and 10 t per vessel. Annual CPUE for the SWCSMF increased from below 20 t per vessel to a peak of ~100 t in 1994, followed by a rapid decline to less than 5 t per vessel in 1999 (Figure 8.14). The pattern was then replicated with a rapid increased in catch rate to ~ 110 t per vessel in 2005, followed by a decline to less than 5 t per vessel in 2010. After this time catch rate fluctuated between 5 and 40 t per vessel. The observed declines in CPUE after the mid-1990s (most obvious in the SCSMF) are considered likely to be mainly driven by market impacts on effort and catch retention (see below for more discussion of this issue).

One of the limitations to vessel as a measure of effort to calculate CPUE is that effort expended by a vessel can increase or decrease depending on days fished, nets shots and the number of vessels a licence holder operates. To address these limitations, trends in CPUE measured as catch (t) per net shot were examined for the SCSMF and the SWCSMF. The CPUE (tonnes/shot) of salmon in the SCSMF increased rapidly from the late 1980s, over a four-year period, to a peak of approximately 2 t per shot (Figure 8.15). It remained between 1 and 2 t per shot until the early 2000's, when it declined to a relative low level of ~ 0.5 t per shot in the mid- to late-2000s. After this time, CPUE has fluctuated around 0.5 t per shot (and thus well below historical levels). Trends in CPUE (tonnes/shot)in the SWCSMF differ from those in the SCSMF tending to increase over the course of the time series from <0.5 t to ~1 t, although after ~2010 there is increased inter-annual variation (Figure 8.15).

Trend in catch per shot differs from the trend in catch per vessel in that catch per shot increases over the time series and catch per vessel has decreased. Catch per net is considered to provide a better descriptor of catch rate compared to catch per vessel as it better captures variations in effort (nets shot, days fished). Additionally, commercial fishers present at the 2022 AMM, indicated a fisher might have multiple vessels and that choice of vessel is influenced by external factors. As such, catch per vessel is a poor measure of effort. In discussions with fishers at the 2022 AMM, the following were cited as limitations to use of catch per net as an effort measure as a relative index of abundance; it does not account for time fishers spend searching for fish (including nil days), it ignores fisher decisions on whether to deploy nets once a school is sighted and does not account for fish that are released if excess to market demand or processing capacity. The fishery is focussed on the schools formed for migration to the spawning ground, and often entire schools are netted. If there is no change in the size of schools as abundance declines, then CPUE series

that do not consider time spent searching, may not reflect actual changes in abundance, i.e., Western Australian salmon CPUE are likely to be prone to hyperstability. Standardizing catch rates were not conducted, although this is recommended for future assessments.

8.4.5.2 Conclusion

Catch rate trends based on catch per vessel and catch per shot for the SCSMF show similar declining trends. Catch per vessel in the SWCSMF is variable with peaks and troughs, however, catch per shot increased. The contrasting trends are likely heavily influenced by market demands with commercial fishers on the South Coast potentially releasing a substantial portion of their catch, and this proportion of catch is not recorded in catch returns. Many years of low catch since the mid-2000s has likely allowed salmon abundance to increase, and this may be reflected in the increasing catch rate (catch per net) in the SWCSMF.

Recreational CPUE indices are not available.

Although the annual CPUE series, particularly for SCSMF, show declining trends in recent years, this likely reflects changes in fisher behaviour (e.g., retaining only some fish that are caught due to low market demand). Therefore, commercial nominal CPUE does not reflect abundance, and do not provide evidence of unacceptable stock depletion.

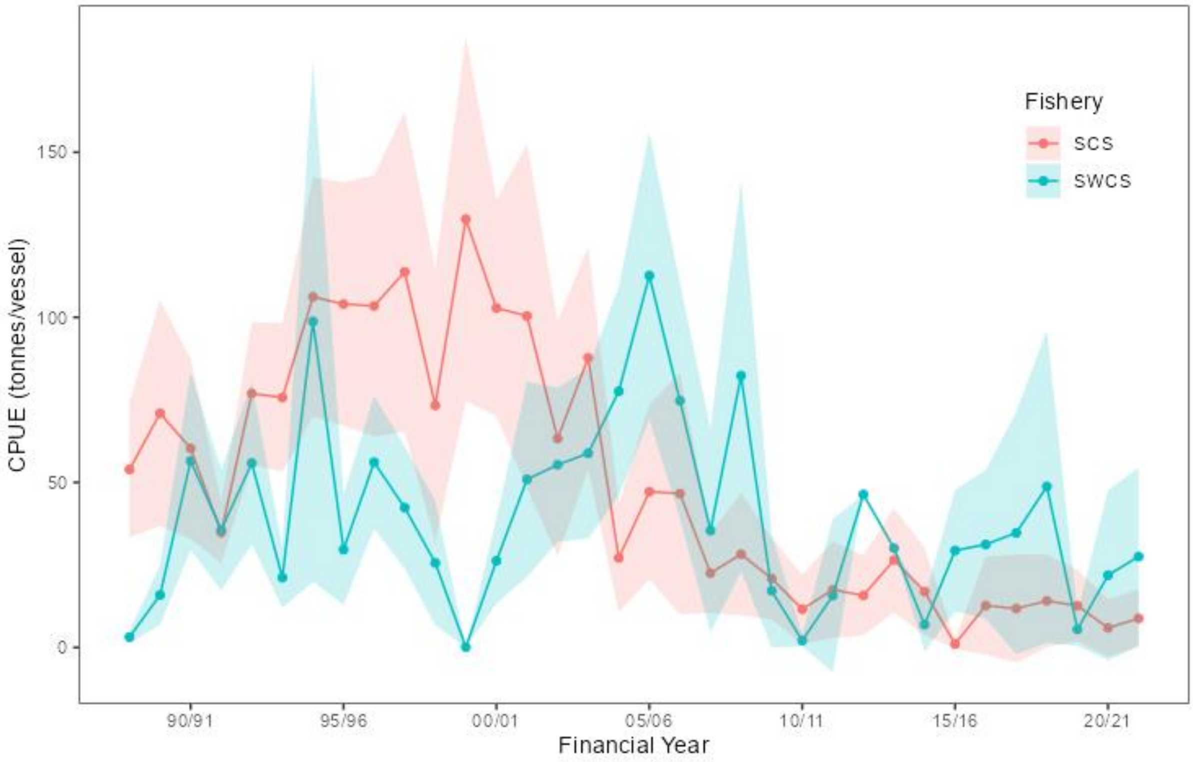


Figure 8.14 Catch rate (tonnes per vessel) of salmon in the South Coast Salmon Managed Fishery and South West Coast Salmon Managed Fishery.

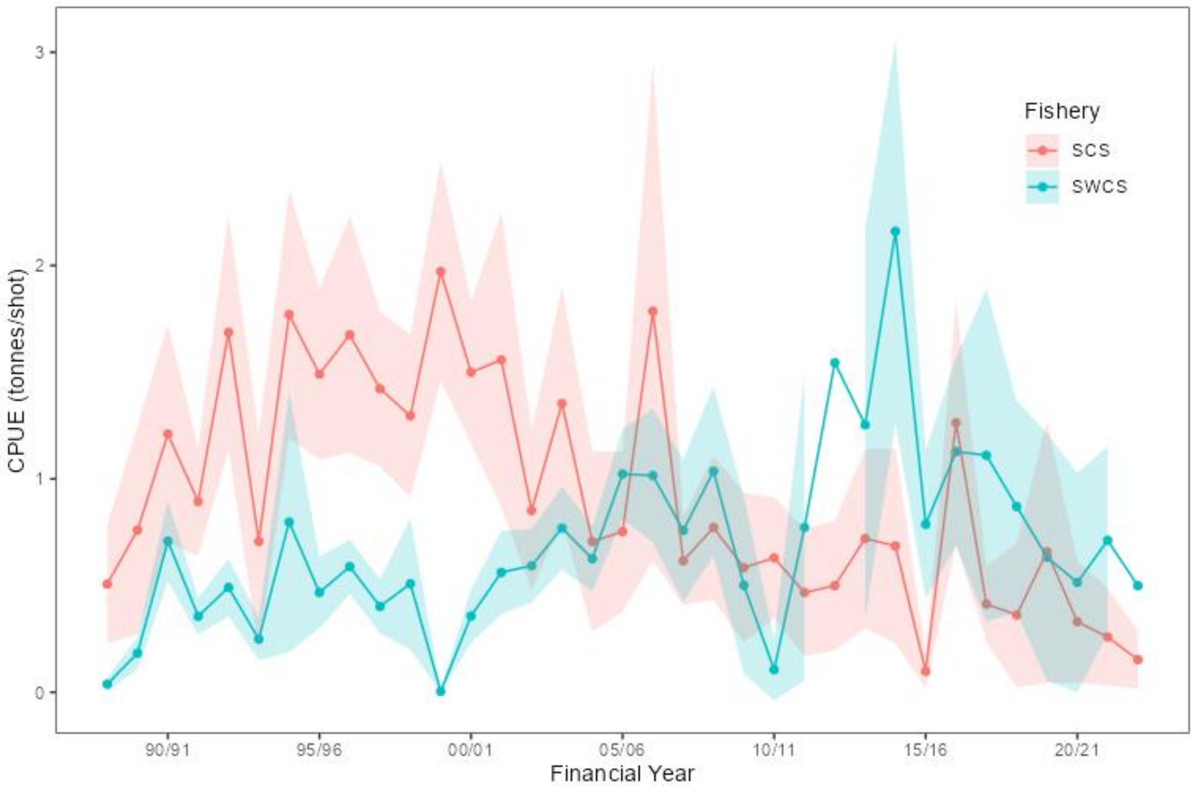


Figure 8.15. Catch rate (tonnes/shots) of salmon in the South Coast Salmon Managed Fishery and South West Coast Salmon Managed Fishery.

8.4.6 Fishery-Independent Catch Per Unit Effort (CPUE)

CPUE of 0+ salmon (number of fish caught across three sampling events in spring) from two sites on the South Coast of WA, Poison Creek and Emu Point, has previously been identified as an index of relative abundance (Gaughan et al., 2006). Continuation of the survey methodology was not possible at Emu Point (due to erosion control measures), but data collection has continued at Poison Creek for the years 2005 to 2015 and 2020 to present. Whilst 0+ salmon occur in WA, most juveniles are thought to recruit to more easterly areas, i.e., SA. Therefore, it is important to consider whether the Poison Creek catch rate is reflective of wider recruitment patterns for the species.

The lowest juvenile CPUE occurred in years of strong Leeuwin Current in 1999/00, 2010/11 and 2011/12, and catch (Figure 8.16), which may reflect increased eastward transport of eggs and juveniles by this current following spawning. The CPUE appears to have declined in recent years, however, access to the site has been confounded due to rough and unseasonal weather, and accumulation of large volumes of wrack making replicate hauling of the net not possible. Therefore, data since 2020 may not be directly comparable to earlier years.

As the CPUE index for Poison Creek has very large uncertainty (i.e., confidence intervals) for most years when abundance was not very low, the data are relatively uninformative for tracking juvenile recruitment trends.

8.4.6.1 Conclusion

The 0+ catch rate index has reached historic lows since 2020, although this may be due to issues with lack of site access. Catch rates in 1999/00, 2010/11 and 2011/12 were some of the lowest recorded, likely associated with strong Leeuwin Current years.

Variations in the fishery-independent juvenile CPUE index may reflect environmental drivers, but these data are likely inadequate for providing an index of recruitment. Fishery independent CPUE are not considered to provide evidence of unacceptable stock depletion.

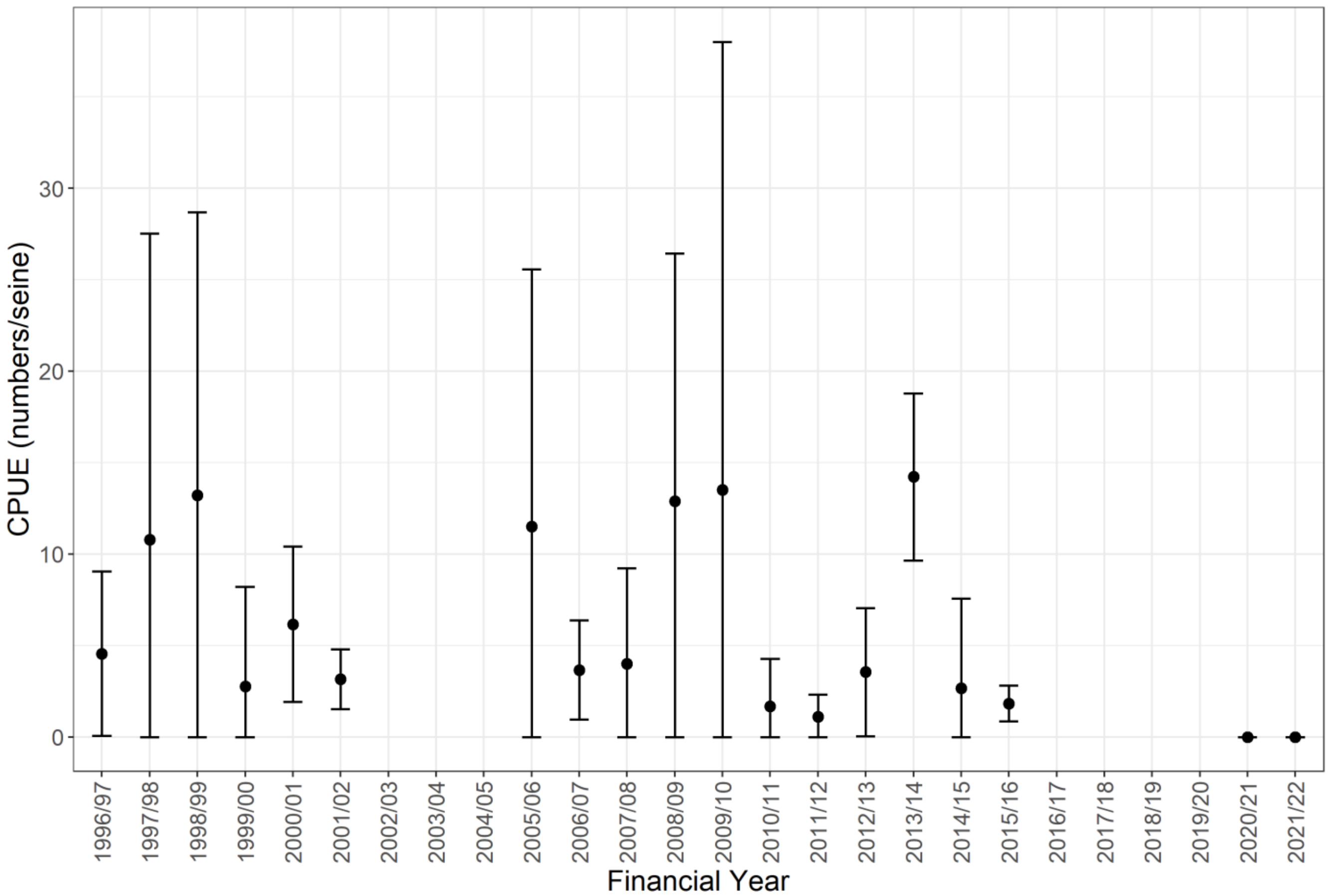


Figure 8.16 Mean catch rate with 95% CI of 0+ WA Salmon from Poison Creek sampling site on the South Coast.

8.4.7 Trends in Fish Length Distributions

Initial examination of length data revealed that samples collected outside of the spawning season tended to be smaller immature fish. Collection of these samples was not consistent across years, and so were excluded. Length data presented here are restricted to only fish collected during the spawning migration season of February to April on the South Coast and March to May on the West Coast.

Substantial sample numbers are available for assessing trends in length structure (fork length – FL) for most years since 1975. Length frequency distributions for each sex were compared within each year, and trends across years compared between sex. Within each year, the mode, maximum length, and patterns in distributions were similar between males and females, which was repeated on both the West Coast and the South Coast. Therefore, length data for both sexes were pooled, as with the data for those animals not sexed, to provide more data for years when sample numbers were lower.

Comparisons of length frequency distributions between years within a bioregion showed similar trends. Modal class in most years from 1975 to 2000 showed little change (Figure 8.17, Figure 8.18), despite commercial catches in WA during this time increasing from ~ 1000 to ~2500 t, including 2 years where catches were ~3500 to ~4000 t (Figure 8.1). Where substantial sample sizes were available, the modal class in years after 2000 tended to be slightly higher (> 640 mm FL) than the earlier years on the South Coast. The pattern was less clear on the West Coast due to lower sample numbers, but still apparent in data collected in 2019. The apparent increase in modal class occurred after catches declined to low levels around ~2010, consistent with the change expected with decreased exploitation of the stock. Also, correlating with the decreased catch was an increase in frequency of fish above 700m FL, however, even during periods of high catch, any truncation of length structure appeared mild.

8.4.7.1 Conclusion

The fish body length distributions for salmon from 1975 to 2000, a period where catch increased from 1000 t to 2000 t, were relatively stable with the mode occurring at ~ 620 mm FL each year. Following the large decline in catch to 2010, the modal length class has increased to > 650 mm FL on both the South Coast and West Coast. The increase in mode is also reflected in an increase in frequency of fish above 700 mm FL.

Changes in length composition data for salmon over time indicate that the relatively high levels of historical catch had reduced length structure of the population, prior to it increasing during the recent decade of low catches. This indicates that the stock became less depleted in recent years, relative to the past.

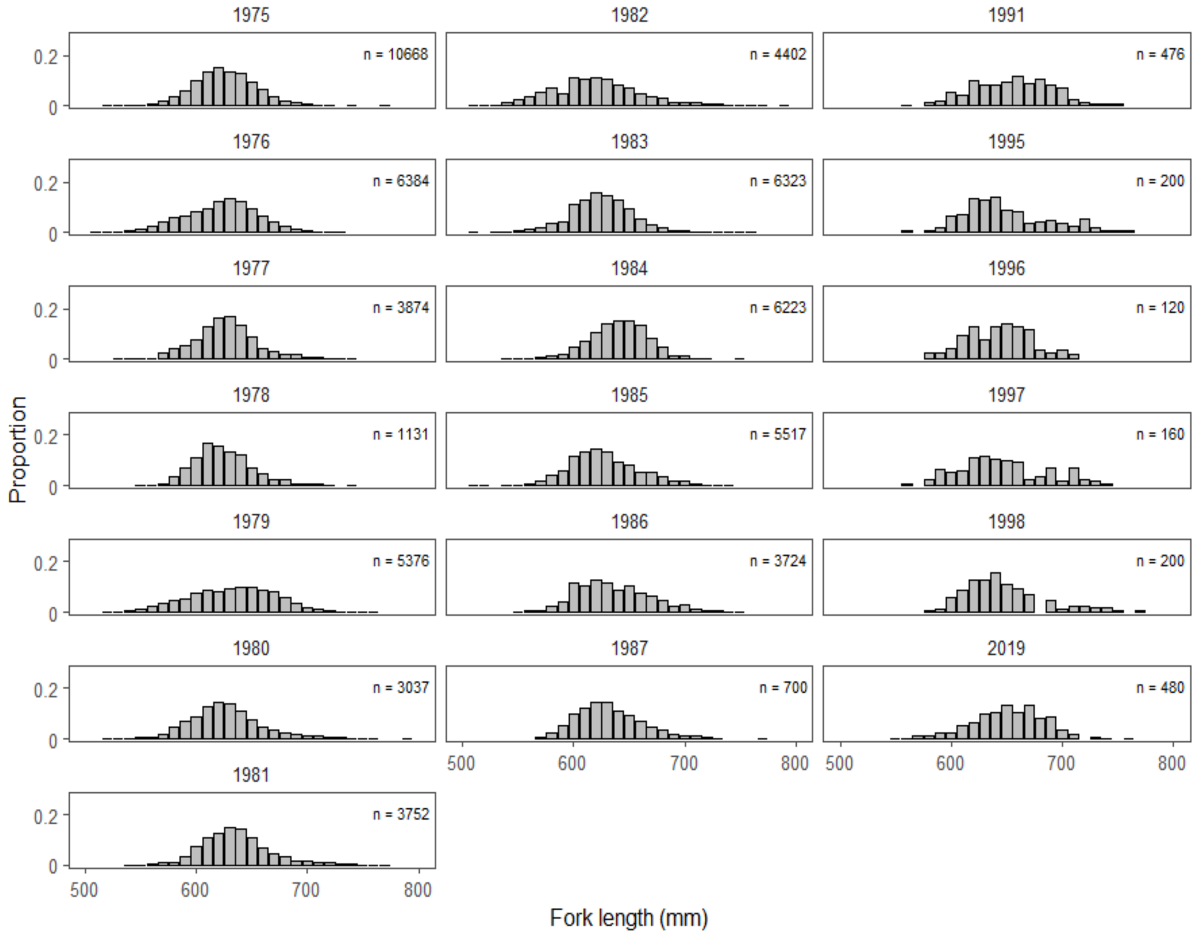


Figure 8.17. Length frequency distribution of commercially caught salmon from the West Coast in years from 1975 to 2022.

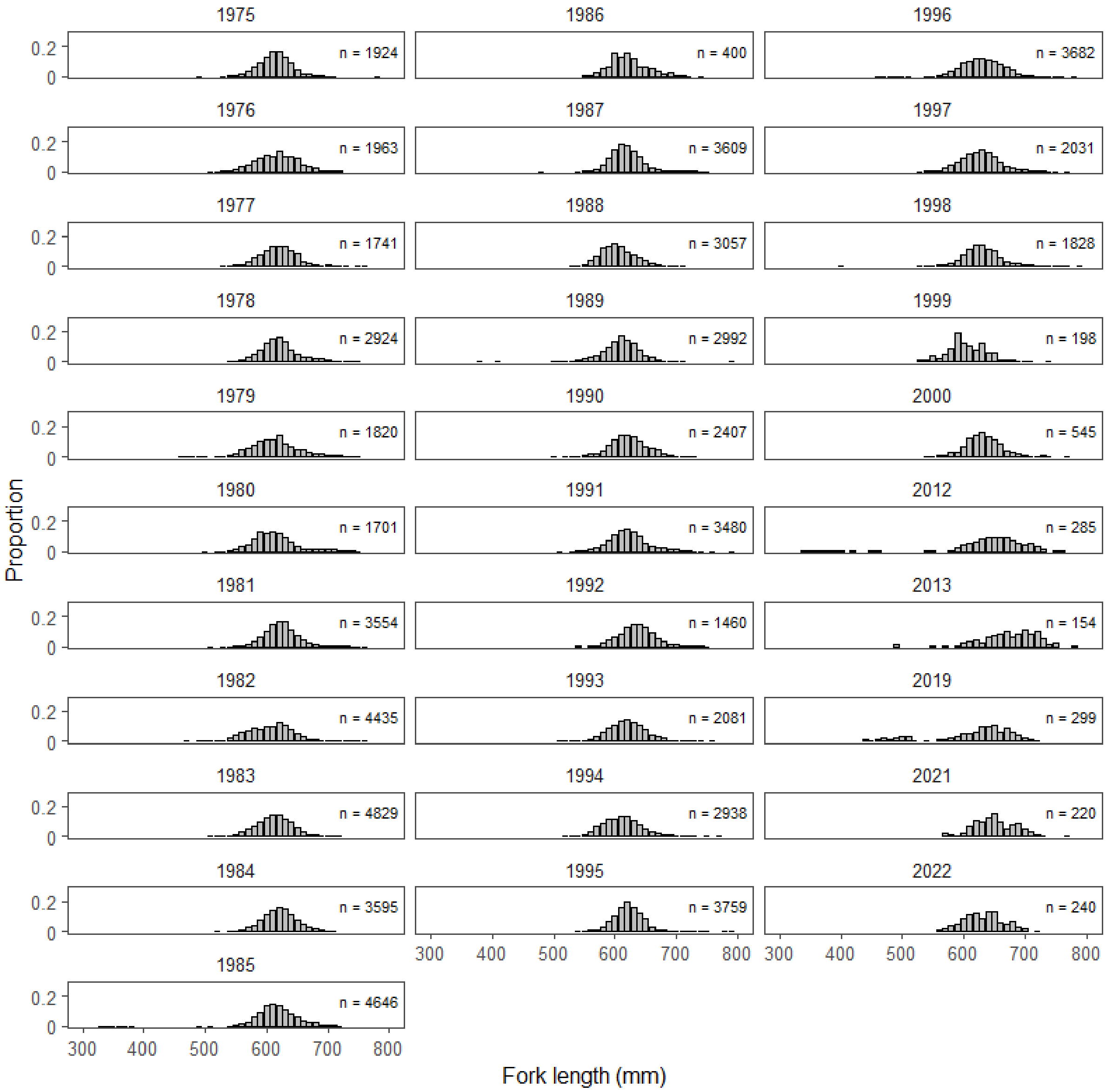


Figure 8.18. Length frequency distribution of commercially caught salmon from the South Coast from 1975 to 2022.

8.4.8 Trends in Age Distributions

Collection of recreational samples proved difficult in recent years, with 2015 and 2022 being the only years where sufficient samples were collected (Table 8.5). The maximum age collected in both years was 11 years, with fish of this age collected from both the West Coast and the South Coast in 2015, and only the South Coast in 2022 (Figure 8.19). The most common age classes were similar between coasts in 2015, 5 to 7 years, however, in 2022 the West Coast were dominated by the 6 year old fish, whilst the South Coast was dominated by 4 and 5 year old fish. Further interpretation of patterns in the recreational samples is confounded by the low sample numbers.

Similar to length data, age samples collected outside of the main spawning period consisted of younger immature fish. Therefore, commercial age data were restricted to the months February to May to optimise representation of adult spawning biomass. Collection of substantial age samples from the commercial fishery on the West Coast occurred in 2019 only (Table 8.5). Compared to samples on the South Coast in 2019, both showed an even distribution of frequencies across three main age classes, 4, 5 and 6 year-old fish (Figure 8.20).

A higher number of age samples has generally been collected from the commercial fishery on the South Coast, allowing greater temporal comparison of trends. Visual analyses of data indicated that within a year, modal age class, the minimum and maximum ages, and the pattern of age frequency data were similar between males and females, therefore, age data for each sex were pooled.

Age frequency distributions of commercial data from the South Coast for the years between 1990 and 2000 were strongly dominated by four-year-old fish (Figure 8.21). The maximum age of fish collected was nine, although in most years it was eight or less. During this period, commercial catch was regularly at, or above, 2000 t (Figure 8.1). From 2012 onwards, several changes in the age structure occurred that are indicative of decreased harvest rates, consistent with the lower catch. The maximum age recorded each year was generally nine years or above, with 11-year-old fish collected in 2013, 2019 and 2021 (Figure 8.21). Age structure was also no longer dominated by a single year class that had just recruited into the fishery (at four years), rather, sampled individuals were more evenly distributed across three ages, i.e., four to six years old. Therefore, whilst in the past the fishery was able to sustain catches much higher than currently being experienced, the age structures of the spawning population were more truncated. Ultimately, a heavily truncated age structure can reduce a stock's ability to buffer against climate variability and stock abundance may become more sensitive to recruitment variations (Hidalgo et al., 2011; Planque et al., 2010; Rouyer et al., 2011). The age structures of samples from 2022 lacked fish older than 8 years, and the modal age class was 4 years, lower than that in recent years of collection. These attributes, whilst characteristic of the stock during periods of higher catch, are not considered likely indicative of higher fishing pressure in 2022 as catch has remained at historic lows following a period when the stock had clearly experienced recovery. Rather, they are interpreted as representing a possible sampling issue (low 'effective' sample size, with relatively few fish, collected from limited sampling events).

Substantial age samples from the adult spawning stock have been collected from South Coast commercial fishers that target salmon during their spawning migration. Samples from the spawning stock on the West Coast have proven more difficult to obtain. As the majority of the spawning stock is thought to reside on the South Coast, most fish caught on the West Coast are derived from fish that would have migrated through the South Coast. Evidence to support this concept is provided by

the 2019 age samples collected from both the South Coast and the West Coast that demonstrate a similar distribution in frequency of fish in each age class.

The recreational fishery for salmon is largely catch and release, and collection of adequate numbers from this fishery to assess stock status is difficult. As recreational fishers and commercial fishers target the same schools migrating along the coast, recreational samples are not likely required to adequately assess the spawning stock if commercial samples are sufficiently representative.

8.4.8.1 Conclusion

Trends in age composition data indicate that heavy exploitation from fishing resulted in the age structures of the spawning stock becoming truncated. During the 1990's when commercial catch was regularly above 2000 t, age structure was dominated by 4 year-old fish recruiting into the fishery. The maximum age of fish recorded in years during this period was 9 years.

Since 2012, when commercial catches were less than ~ 300 t, the model ages ranged from 4 to 6, and the relative abundances of older age classes increased, with a maximum age of 11 years recorded on multiple occasions. The recent changes in age structure are reflective of a stock experiencing reduced fishing mortality.

The age structure in recent years are less truncated than in the past, associated with low ongoing catches. This trend is not indicative of current unacceptable stock depletion.

Table 8.5 Number of fish ages for each sex, available for trend analysis between 1990 and 2022, collected from recreational and commercial fisheries on the South Coast and West Coast of WA.

	South Coast		West Coast	
Year	Commercial	Recreational	Commercial	Recreational
1990	151	0	0	0
1992	94	0	0	0
1993	66	0	0	0
1994	71	0	0	0
1995	62	0	16	0
1996	90	0	0	0
1998	115	0	6	0
1999	104	0	5	0
2000	513	0	0	0
2012	284	0	0	0
2013	153	0	0	0
2014	0	1	0	0
2015	0	74	0	47
2016	0	0	0	1
2017	66	3	0	13
2018	0	12	0	0
2019	292	9	310	0
2020	25	7	0	3
2021	220	2	0	0
2022	236	65	19	47

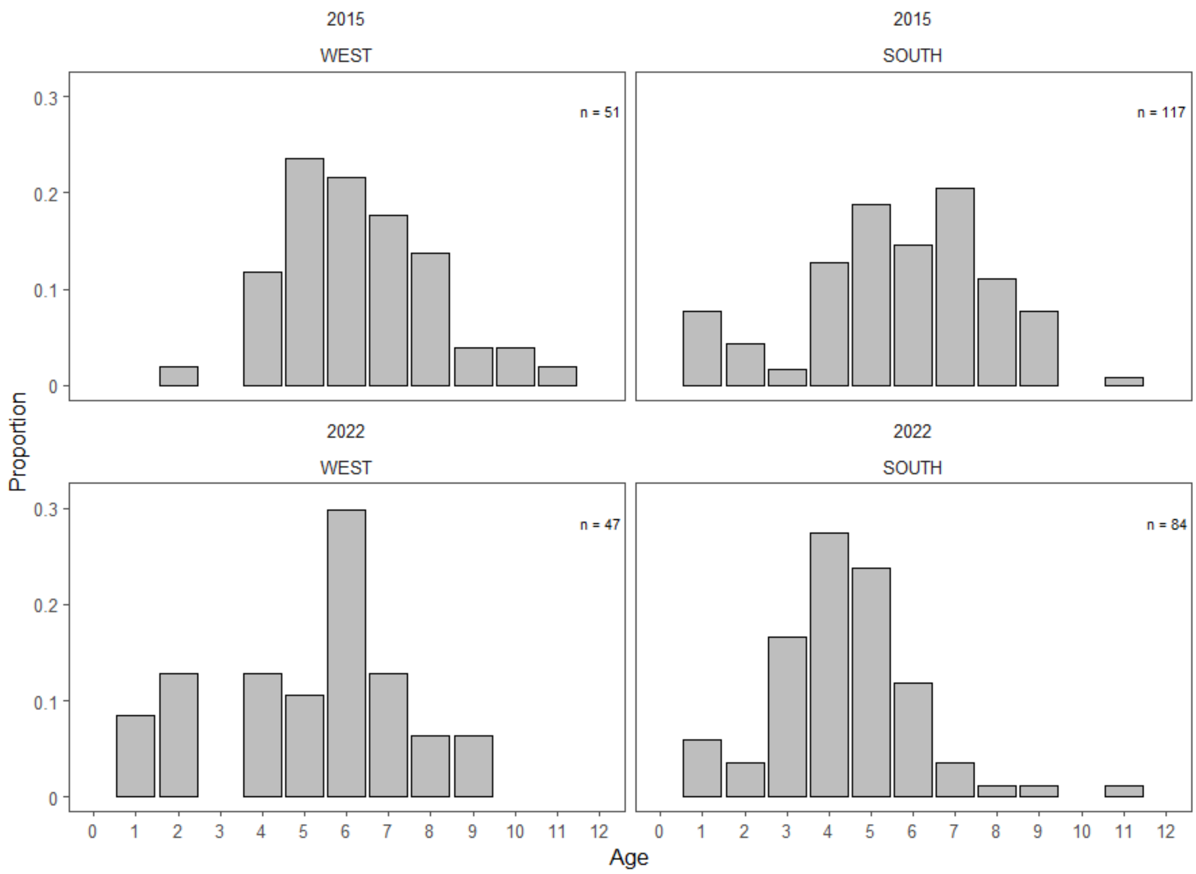


Figure 8.19 Age frequency distribution for salmon caught by recreational fishers on the West Coast and the South Coast in 2015 and 2022.

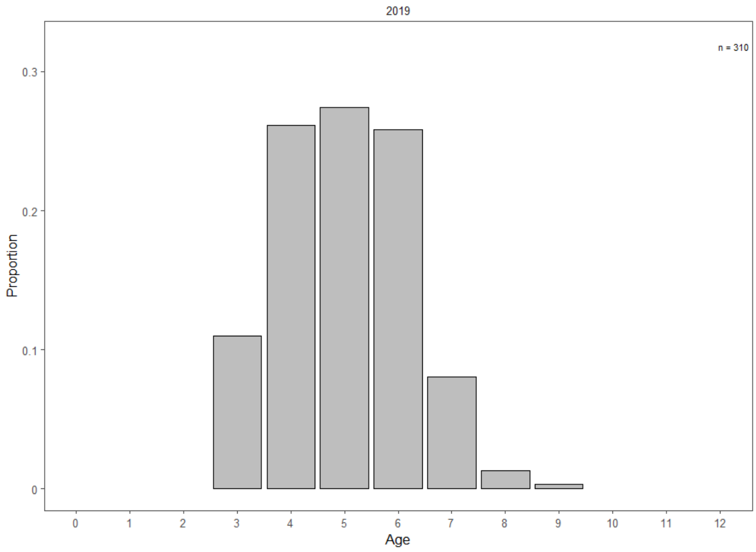


Figure 8.20 Age frequency distribution of commercially caught salmon from the West Coast collected during the spawning run in 2019.

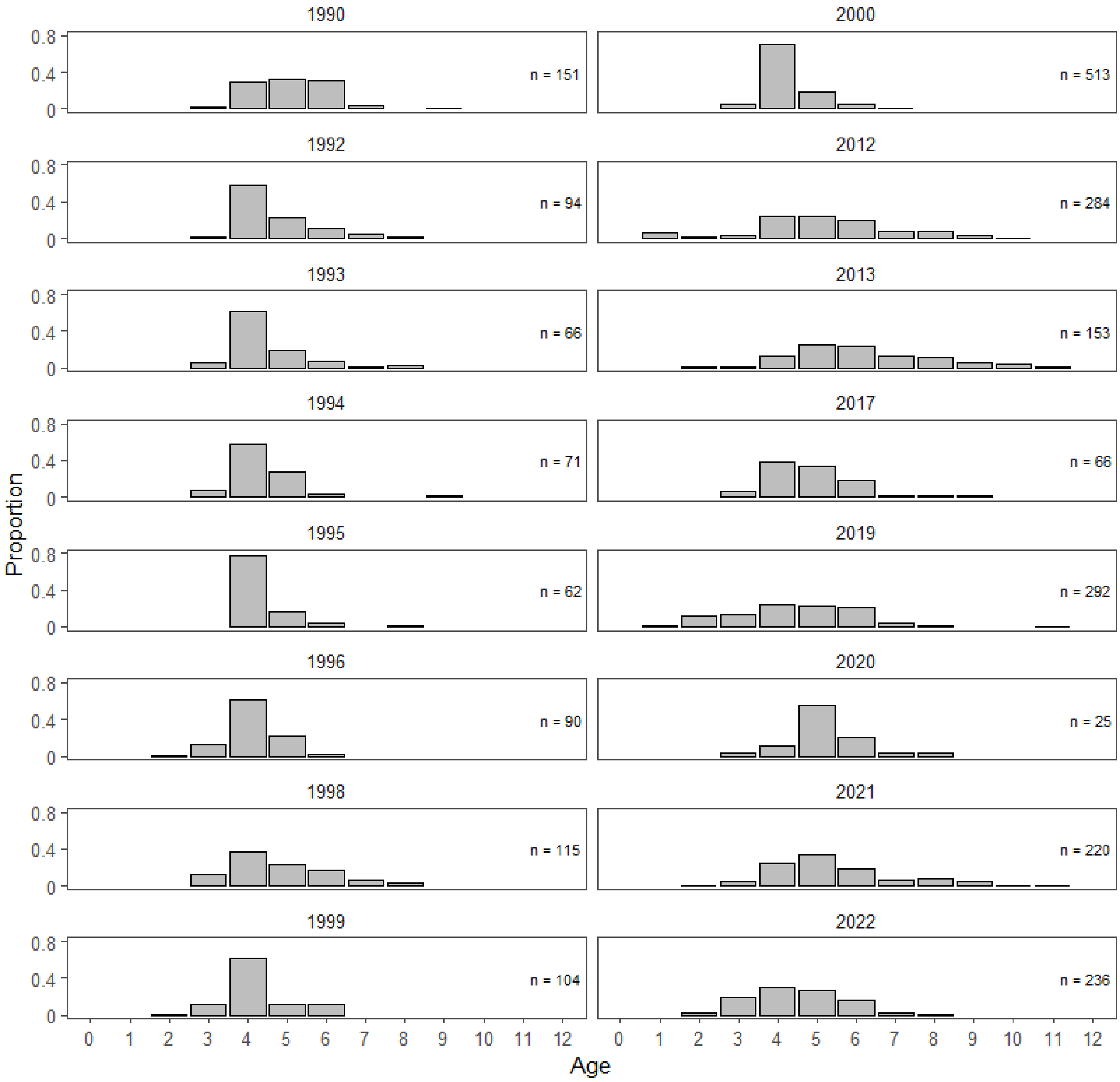


Figure 8.21 Age frequency distribution of commercially caught salmon from the South Coast collected during the spawning run between 1990 and 2022.

8.4.9 Catch Curve Analysis

Estimates of fishing mortality (*F*) were calculated through subtraction of a natural mortality (*M*) value of 0.32 y^{-1} from the total mortality (*Z*) estimates from catch curve analyses for both length- and age-based methods. The reference levels for *F* (based on *F* to *M* ratios), using *M* = 0.35 y^{-1}, are F_{target} = 0.23 y^{-1}, $F_{threshold}$ = 0.35 y^{-1} and F_{limit} = 0.53 y^{-1} (Section 7.2).

In interpreting estimates of mortality produced by catch curve analyses, such as that of Chapman & Robson (1960), it is important to recognise that these methods assume that the population was in equilibrium, with respect to mortality and recruitment (for the period covering the life spans of the fish in the sample collections). Thus, an estimate of 'fishing mortality' represents the average fishing mortality experienced by fish in the samples collected, over their life spans. If there is substantial variation in recruitment, this can impact the reliability of catch curve mortality estimates. This latter issue was explored, to a certain extent in the analyses undertaken for Western Australian salmon, using sensitivity analysis comparing the impact of different assumed ages at recruitment of fish into the fishery (see below). If recruitment is variable, use of different recruitment ages can result in different mortality estimates (for model runs using different values for recruitment age).

8.4.9.1 Length-based

Estimates of *F* varied between the three time periods examined. The estimate (*F*= 0.77 y^{-1}) was above the limit (0.53 y^{-1}) for the period 1994 to 1998 (Figure 8.22). At *F* = 0.30 y^{-1}, it is below the threshold (0.35 y^{-1}) for the period 2012 to 2013, (Figure 8.23), and at *F* = 0.33 y^{-1}, it is just below the threshold for the period 2021 to 2022 (Figure 8.24). The decline in *F* from the earliest period to more recent years reflects a less truncated length structure, coinciding with a decline in catch from >~2000 t to <~300 t. Given the prolonged period of low catch since ~2000 (20+ years), however, the value for *F* for the most recent period is higher than might be expected. The unexpectedly high value of *F* may be associated with the relatively small number of length samples collected from the two recent periods (<300 fish). Uncertainty in the length-based F estimates is also increased due to the small length range between the size fish are fully selected into the fishery compared to L_{inf} (Figure 8.22, Figure 8.23, Figure 8.24), therefore limiting the signal in the length data for estimating mortality.

8.4.9.2 Age-based

Estimates of instantaneous total mortality (Z) of salmon using the Chapman & Robson (1960) method were calculated for three time periods, 1994 to 1998, 2012 to 2013, and 2021 to 2022, and by setting age at full recruitment to either peak age frequency or peak age frequency + 1 (Figure 8.25). Estimates of *F* (*F = Z – M, M =* 0.35 y^{-1}), using the peak age as the age at full recruitment, varied between the three time periods examined and was above the limit (0.53 y^{-1}) for the period 1994 to 1998, at *F*= 0.64 y^{-1} (0.52-0.75 CL), at close to the target (0.23 y^{-1}) for the period

2012 to 2013, at $F = 0.20\ y^{-1}$ (0.14-0.26), and about midway between the threshold and limit (0.53 y^{-1}) for the for the period 2021-2022, at $F = 0.44\ y^{-1}$ (0.34-0.54). Similar to the situation with the length data, the decline in *F* estimated using age data from the earliest period to the more recent years reflects a less truncated age structure, coinciding with a decline in catch from >~2000 t to <~300 t. Given the prolonged period of low catch since ~2000 (20+ years), the stock status might be expected to be well below the target. Estimates of *F* from catch curve analyses using peak age +1, rather than the peak age as the age at full recruitment, yielded similar trends, although slightly higher values ($F = 0.70\ y^{-1}$ (0.50-0.90 CL) 1994 to 1998, at $F = 0.30\ y^{-1}$ (0.241-0.39 CL) for 2012 to 2013, and F = 0.52 y^{-1} (0.36 to 0.66 CL) for 2021 to 2022).

The unexpectedly high values of *F* may reflect sampling issues, associated with relative low sample sizes (from limited sampling events) producing an age structure sampled that may not be fully representative of that in the exploitable component of the population. This may also, in part, be an artefact of the low level of commercial exploitation in recent years, not catching fish from the entire spatial area of the spawning stock, leading to non-representative collection of age samples.

8.4.9.3 Conclusion

Fishing mortality, based on either length or age, declined substantially from the period of high catch prior to 2000, to the period of historically low catches, which have remained well below estimated MSY since ~2000 (Section 8.4.2.3). Estimates of *F* in the 1990's were high, either at or above the limit, and indicate that at the time, heavy stock depletion was possible.

The more recent estimates of *F* are higher than expected given the 20+ years of low catch, which may reflect issues associated with fish sampling. For instance, despite collecting samples from all recent fishing events, the low frequency of commercial fishing events may mean that catches of commercial fishers were not representative of the overall exploitable component of the fish stock. This scenario is supported by comments from commercial fishers indicating that, in recent years, many salmon are occurring further offshore and thus not able to be caught by the gear, given the fishing method used.

The change in estimates of *F*, associated with an extended period of historically low catches, likely reflect reduced exploitation of the salmon stock in recent years, associated with length and age structures being less truncated. Therefore, recent unacceptable stock depletion is unlikely.

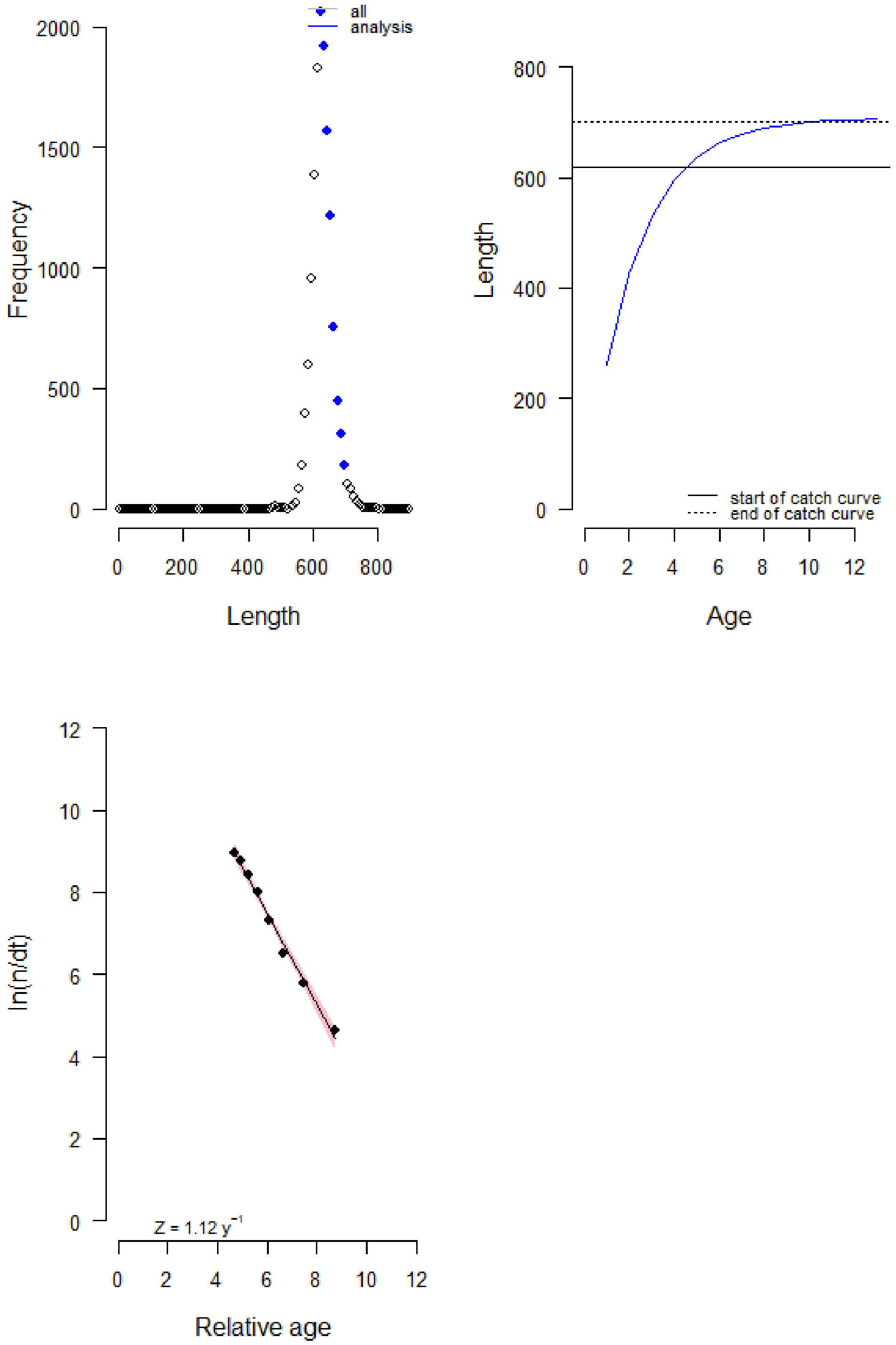


Figure 8.22 Results of a length-converted catch curve analysis using commercial samples of Western Australian salmon collected from 1994 to 1998. Top left. Length frequency data used for analysis (indicated by blue dots); top right, comparison of the estimated von Bertalanffy growth curve, and the range of lengths than can be used for analysis; bottom left, plot showing fit of the model (line) to the relevant information for this analysis, derived from the available length frequency data and growth curve (black dots).

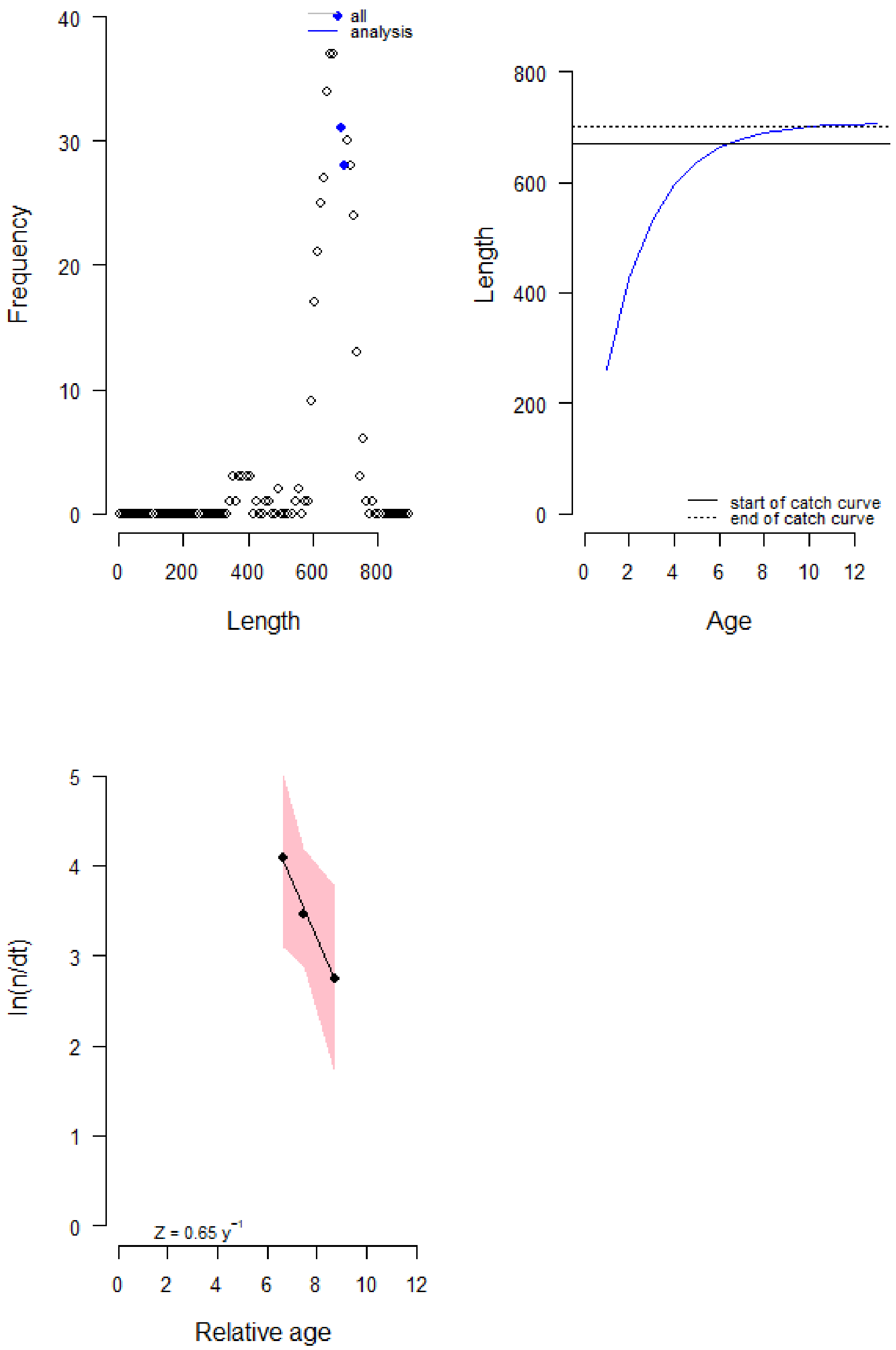


Figure 8.23 Results of a length-converted catch curve analysis using commercial samples of Western Australian salmon collected from 2012 to 2013. Top left. Length frequency data used for analysis (indicated by blue dots); top right, comparison of the estimated von Bertalanffy growth curve, and the range of lengths than can be used for analysis; bottom left, plot showing fit of the model (line) to the relevant information for this analysis, derived from the available length frequency data and growth curve (black dots).

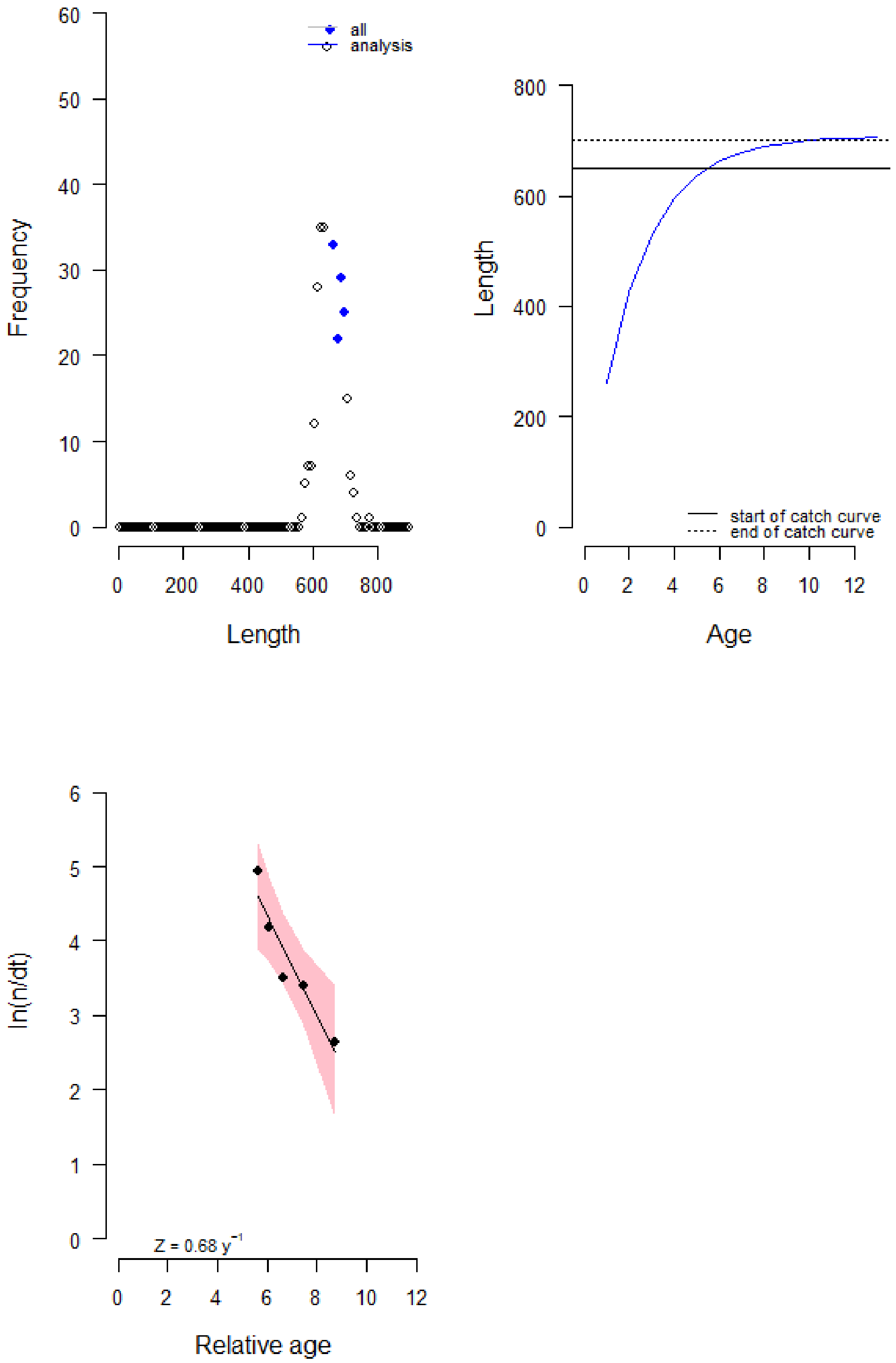


Figure 8.24 Results of a length-converted catch curve analysis using commercial samples of western Australian Salmon collected from 2021 to 2022. Top left. Length frequency data used for analysis (indicated by blue dots); top right, comparison of the estimated von Bertalanffy growth curve, and the range of lengths than can be used for analysis; bottom left, plot showing fit of the model (line) to the relevant information for this analysis, derived from the available length frequency data and growth curve (black dots).

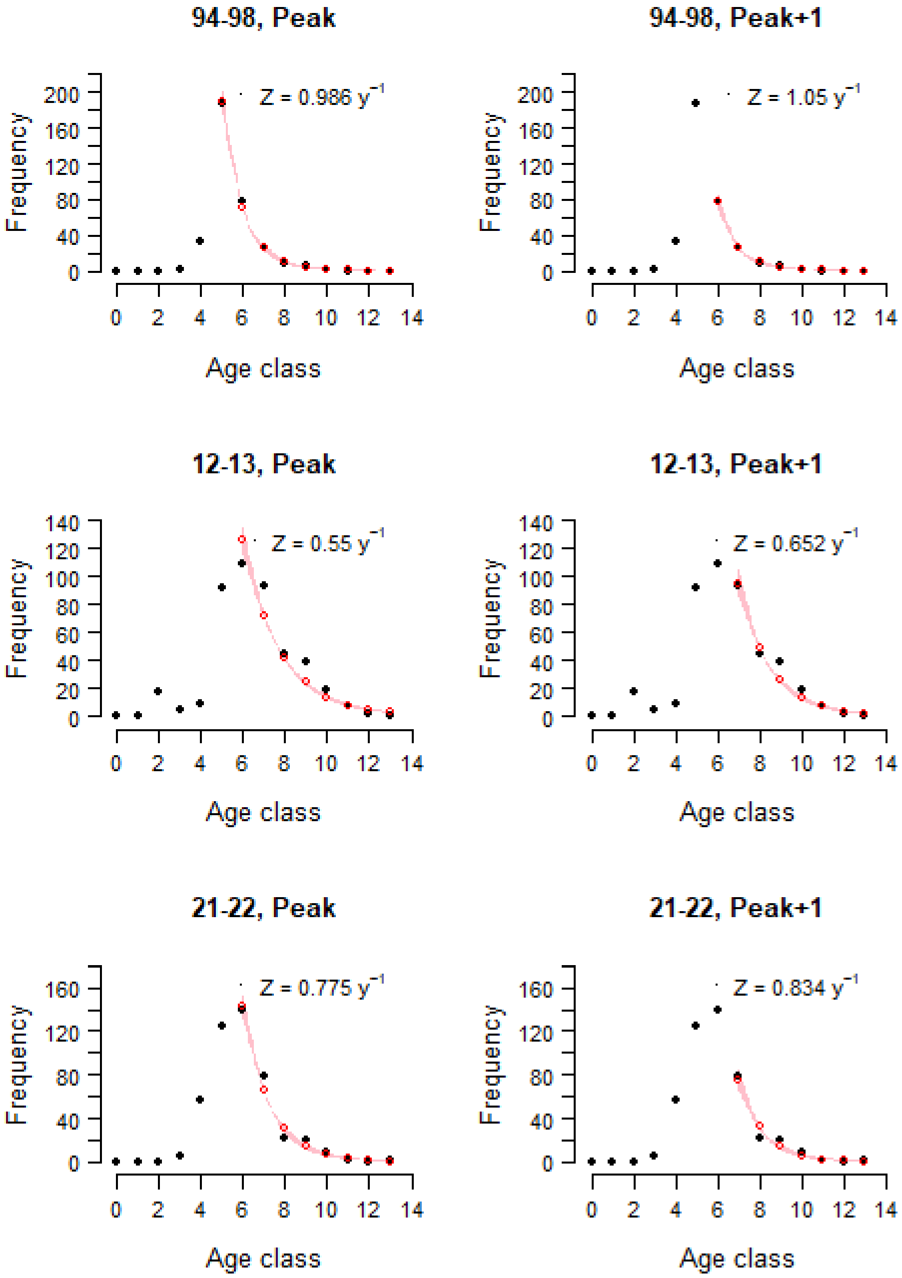


Figure 8.25 Estimates of instantaneous total mortality (Z) of salmon using the Chapman & Robson (1960) method for three time periods, 1994 to 1998, 2012 to 2013, and 2021 to 2022, setting age at full recruitment to either peak age frequency (left-hand charts) or peak age frequency + 1 (right-hand charts).

8.4.10 Per recruit analysis

The estimate of relative female spawning potential ratio (SPR) for 1994-1998 of 0.383 (95% confidence limits=0.338-0.425) is between the threshold (0.3) and target (0.4) value. The SPR for females increased substantially to 0.708 (0.658-0.749) for 2012-2013, and thus to well above the target value, and remained substantially above the target in 2021-2022 at 0.538 (0.486-0.585). The estimates for relative female biomass (B_{rel}), considered to provide a better measure of female population reproductive potential (because this is calculated accounting for possible impacts of fishing on recruitment, through reducing spawning biomass), was relatively close to the threshold level in 1994-1998 at 0.324 (0.276-0.373) (Figure 8.26). The values of B_{rel} were above the target value (0.4) in both 2012-2013, at 0.679 (0.628-0.727), and in 2021-2022, at 0.493 (0.440-0.549) (Figure 8.26).

The lower values of SPR and B_{rel} for the early period relative to the two latter periods reflect the higher estimated levels of fishing mortality (from the equilibrium catch curve analysis applied to age composition data for each respective period). As the recent value of B_{rel} is well above the target level, this indicates that the current level of biomass is sustainable.

From the above, it is clear that the results of the per recruit analyses (i.e., comparing B_{rel} values to proxy biomass reference points), for each period, yielded more optimistic information regarding stock status than those based on just catch curve analysis (i.e., comparison of estimates of fishing mortality to proxy fishing mortality-based reference points, based on F:M ratios). A key difference between the two types of analyses is that the per recruit analysis includes substantially more information (biological parameters) than catch curve analysis (the results of which are also incorporated into the per recruit analysis). The rate at which relative female biomass is reduced by fishing mortality depends on a range of factors, that include the age at which fish typically attain maturity, relative to that at which fish become selected into the fishery, the pattern of growth, and longevity. In the case of Western Australian salmon, this species is not long-lived, grows relatively rapidly, and it has been assumed that fish maturity slightly earlier than the size at which fish typically enter the commercial fishery. With this set of assumptions, this species would be predicted to be relatively resilient to exploitation pressure (if not excessive).

8.4.10.1 Conclusion

The estimates of female relative spawning biomass (B_{rel}) estimated for the most recent period are well above the target value of 0.4, indicative that the stock is not unacceptably depleted. However, the results of the per recruit analysis are subject to relatively strong assumptions relating to the stock being in equilibrium with respect to mortality and recruitment, which increases uncertainty of assessment results. As catches in recent years have remained relatively stable,

and at historically low levels for more than a decade, and the species does not live much beyond 10 years, mortality is not likely to have changed markedly.

The most recent estimate for B_{rel} does not provide an indication that the current level of stock depletion is unacceptable.

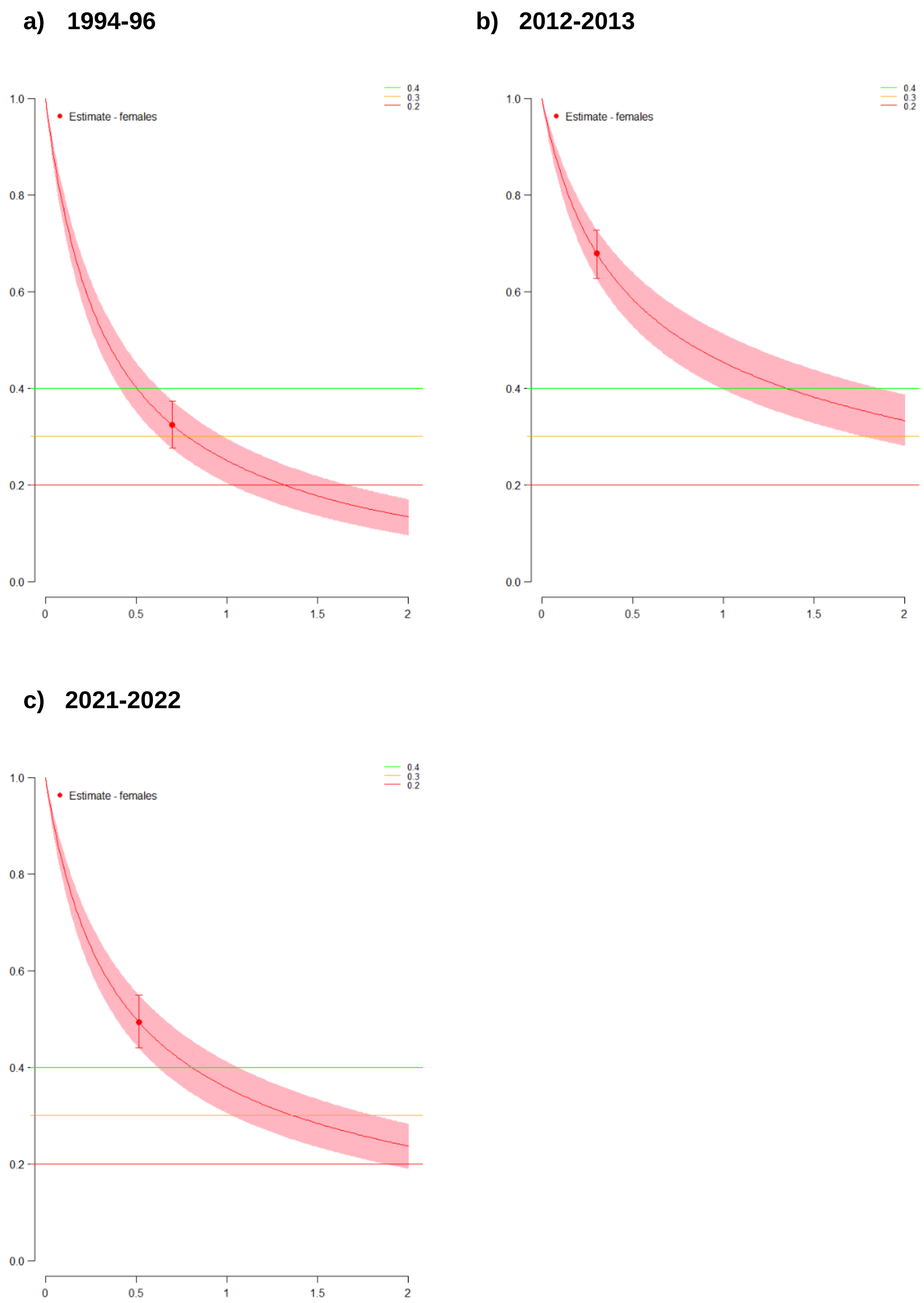


Figure 8.26 Estimates of relative female spawning biomass (Brel) for the periods a) 1994 to 1998, b) 2012 to 2013, and c) 2021 to 2022. Red dot and error bars indicate point estimate and associated confidence intervals for Brel, at the estimated of fishing mortality for the given period, Red line with shading shows the relationship between Brel with different levels of fishing mortality. The green, orange and red lines are the (proxy) reference levels for biomass, i.e. the target (0.4), threshold (0.3), and limit (0.2), respectively.

8.5 Stock Status Summary

Category	Lines of evidence (Consequence / Status)
Biology and Vulnerability (PSA)	PSA scoring considers salmon as a low risk. This was despite a conservative approach to scoring through use of values that would increase risk when the actual value was uncertain. **The low risk based on PSA score indicates that under current management arrangements, unacceptable stock depletion is considered unlikely.**
Catch	
Catch distribution	The main salmon fisheries (SCSMF & SWCSMF) in WA are reliant on the annual spawning migration of salmon that occurs in autumn. Overall, spatial changes in catch distribution are minor. Where they have occurred, e.g., the Esperance region and Capes region, they are not believed to be due to a change in species distribution, but rather to changes in fishing effort or access restrictions. Anecdotal evidence from fishers suggests there may be some localised changes to movement patterns due to water temperature or diet shift. Interannual temporal changes in catch have occurred at times. These may be associated with variations in water temperature, e.g. marine heatwaves, and delayed the peak season on the South Coast and likely resulted in reduced catches on the West Coast due to lower abundance of migrating fish. **Minor shifts in catch distributions have occurred which appear to be associated with variations in environmental conditions. There are no indications of these shifts being associated with unacceptable stock depletion**.
Effort	Effort in the fishery is highly seasonal, restricted mostly to autumn when salmon undertake their annual spawning migration and become more accessible to fishers. The various measures of effort examined consistently show a decline in effort to recent years, particularly for the SCSMF and the SWCSMF. The decline is attributed to changes in targeting by the fishers due to poor markets and prices and therefore not considered reflective of a decline in salmon abundance. **The marked decline in commercial fishing effort in recent years was driven primarily by market factors, and does not reflect unacceptable stock depletion.**

Catch rates – fishery dependent	Catch rate trends based on catch per vessel and catch per shot for the SCSMF show similar declining trends. Catch per vessel in the SWCSMF is variable with peaks and troughs, however, catch per shot increased. The contrasting trends are likely heavily influenced by market demands with commercial fishers on the South Coast potentially releasing a substantial portion of their catch, and this proportion of catch is not recorded in catch returns. Many years of low catch since the mid-2000s has likely allowed salmon abundance to increase, and this may be reflected in the increasing catch rate (catch per net) in the SWCSMF. Recreational CPUE indices are not available. **Although the annual CPUE series, particularly for SCSMF, show declining trends in recent years, this likely reflects changes in fisher behaviour (e.g., retaining only some fish that are caught due to low market demand). Therefore, commercial nominal CPUE does not reflect abundance, and do not provide evidence of unacceptable stock depletion.**
Catch rates – fishery independent	The 0+ catch rate index has reached historic lows since 2020, although this may be due to issues with lack of site access. Catch rates in 1999/00, 2010/11 and 2011/12 were some of the lowest recorded, likely associated with strong Leeuwin Current years. **Variations in the fishery-independent juvenile CPUE index may reflect environmental drivers, but these data are likely inadequate for providing an index of recruitment. Fishery independent CPUE are not considered to provide evidence of unacceptable stock depletion.**
Length composition	The fish body length distributions for salmon from 1975 to 2000, a period where catch increased from 1000 t to 2000 t, were relatively stable with the mode occurring at ~ 620 mm FL each year. Following the large decline in catch to 2010, the modal length class has increased to > 650 mm FL on both the South Coast and West Coast. The increase in mode is also reflected in an increase in frequency of fish above 700 mm FL. **Changes in length composition data for salmon over time indicate that the relatively high levels of historical catch had reduced length structure of the population, prior to it increasing during the recent decade of low catches. This**

	indicates that the stock became less depleted in recent years, relative to the past.
Age composition	Trends in age composition data indicate that heavy exploitation from fishing resulted in the age structures of the spawning stock becoming truncated. During the 1990's when commercial catch was regularly above 2000 t, age structure was dominated by 4 year-old fish recruiting into the fishery. The maximum age of fish recorded in years during this period was 9 years. Since 2012, when commercial catches were less than ~ 300 t, the model ages ranged from 4 to 6, and the relative abundances of older age classes increased, with a maximum age of 11 years recorded on multiple occasions. The recent changes in age structure are reflective of a stock experiencing reduced fishing mortality. **The age structure in recent years are less truncated than in the past, associated with low ongoing catches. This trend is not indicative of current unacceptable stock depletion.**
Fishing mortality	Fishing mortality, based on either length or age, declined substantially from the period of high catch prior to 2000, to the period of historically low catches, which have remained well below estimated MSY since ~2000 (Section 8.4.2.3). Estimates of *F* in the 1990's were high, either at or above the limit, and indicate that at the time, heavy stock depletion was possible. The more recent estimates of *F* are higher than expected given the 20+ years of low catch, which may reflect issues associated with fish sampling. For instance, despite collecting samples from all recent fishing events, the low frequency of commercial fishing events may mean that catches of commercial fishers were not representative of the overall exploitable component of the fish stock. This scenario is supported by comments from commercial fishers indicating that, in recent years, many salmon are occurring further offshore and thus not able to be caught by the gear, given the fishing method used. **The change in estimates of *F*, associated with an extended period of historically low catches, likely reflect reduced exploitation of the salmon stock in recent years, associated with length and age structures being less truncated. Therefore, recent unacceptable stock depletion is unlikely**
Per recruit analysis	The estimates of female relative spawning biomass (*Brel*) estimated for the most recent period are well above the target

	value of 0.4, indicative that the stock is not unacceptably depleted. However, the results of the per recruit analysis are subject to relatively strong assumptions relating to the stock being in equilibrium with respect to mortality and recruitment, which increases uncertainty of assessment results. As catches in recent years have remained relatively stable, and at historically low levels for more than a decade, and the species does not live much beyond 10 years, mortality is not likely to have changed markedly. **The most recent estimate for *Brel* does not provide an indication that the current level of stock depletion is unacceptable.**

Consequence (Stock Depletion) Level	Likelihood				Risk Score
	L1 Remote (<5%)	L2 Unlikely (5- <20%)	L3 Possible (20- <50%)	L4 Likely (≥50%)	
C1 Minor				X	4
C2 Moderate		X			**4**
C3 High	X				3
C4 Major	NA				NA

C1 (Minor Depletion): **Likely L4 –** All lines of evidence suggest that is likely that the stock level of Western Australian salmon is at an acceptable level. Current catch is an order of magnitude less than historic catches that were sustained for decades, and substantially less than estimated MSY. Commercial fishers attribute the decline in catch to markets and this is supported through improved length and age structure, including an increase in the maximum age recorded since catch decreased, and a decrease in the estimate of *F*. The estimate of *F* in the most recent period was higher than expected based on the low level of catch, suggesting samples may not have been representative of the spawning stock. Estimates of relative female spawning biomass (B_{rel}) were above the target and are considered to be a more informative indicator of stock status than using *F* alone, due to the inclusion of biological information. On the balance of information available, if current catches are maintained, the stock status is likely to remain at the level of minor depletion during the next five years.

C2 (Moderate Depletion): **Unlikely L4 –** Recreational catch estimates are uncertain and if they are an order of magnitude higher than estimated, or if there is substantial unknown mortality associated with release of recreationally caught salmon, depletion may be greater than expected. However, these possibilities are inconsistent with the other lines of evidence, therefore a moderate level of depletion is considered unlikely.

C3 (High Depletion): **Remote L1 –** Historic commercial catches exceeded estimates for MSY, and correlated with a reduced age structure and estimates of *F* below the threshold and possibly below the limit, depending on the value used for *M.* This indicates that high exploitation rates are possible, however, recent catches are extremely low, well below MSY, and estimates of *F* and SPR over the last decade indicate the stock is not experiencing high depletion. Catch is driven by market demand and it is highly unlikely that catch will increase to above MSY, as would be required for the stock to experience high depletion, within the next 5 years.

C4 (Major Depletion): **NA –** No analyses, or data streams provide evidence of major depletion occurring. Therefore, this consequence is rated as Not Applicable.

8.6 Current Risk Status

Based on the information available, the current risk level for the Western Australian salmon stock is estimated to be LOW (C2 x L2). The LOW Risk (see Section 11 Appendix B) reflects a low level of fishing mortality. All the lines of evidence are consistent with a low level of risk, hence the overall *Weight of Evidence Assessment* indicates the status of the Western Australian salmon stock is adequate and that current management settings are maintaining risk at acceptable (low) level.

This score assumes the total catch will be maintained at near current levels, however a moderate increase in catch is possible whilst still maintaining a risk level of medium or less.

8.7 Future Monitoring

The next major stock assessment for Western Australian salmon is currently scheduled for 2027. The data required for this next assessment are envisaged to be similar as those used in this assessment, i.e., commercial catch returns, and size and age structure data, collected over 2 consecutive years just prior to the assessment. Additional collections of size and age samples would be recommended for the next assessment if one or more of the following occurred: substantial increase in catches, changes in fishing methods used by commercial operators (e.g., purse seining) or substantial changes in spatial and temporal catch and/or effort.

Other opportunities for research include work on the influence of environmental factors on recruitment, fish movements, dietary studies, and investigation of the feasibility of applying novel methods (e.g., close-kin mark-recapture, drone surveys) for determining biomass, and application of additional methods of assessment, including dynamic approaches (e.g., Stock Synthesis Data-Limited Tool, SS-DL). Such work has potential to provide additional inputs into the stock assessment and assist in interpreting stock assessment outputs.

9 Acknowledgements

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11 Appendix A - Consequence, Likelihood and Risk Levels (based on AS 4360 / ISO 31000) modified from Fletcher et al. (2011) and Fletcher (2015)

CONSEQUENCE LEVELS

As defined for major target 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 (B_{MEY})

2. Moderate – Fishery operating at maximum acceptable level of depletion

   Spawning biomass < Target level (B_{MEY}) 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/ levels of the stock

   Spawning biomass < Limit level (B_{REC})

LIKELIHOOD LEVELS

These are defined as the likelihood of a particular consequence level actually occurring within the assessment period (5 years was used)

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

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

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	Recovery strategy and detailed monitoring	Increased management activities needed urgently

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12 Appendix B - Productivity Susceptibility Analysis (PSA) Scoring Tables

Productivity attribute	**High productivity** **Low risk** **Score = 1**	**Medium productivity** **Medium risk** **Score = 2**	**Low productivity** **High risk** **Score = 3)**
Average maximum age	<10 years	10-25 years	>25 years
Average age at maturity	<5 years	5-15 years	>15 years
Average maximum size (not to be used when scoring invertebrates)	<1000 mm	1000-3000 mm	>3000 mm
Average size at maturity (not to be used when scoring invertebrates)	<400 mm	400-2000 mm	>2000 mm
Reproductive strategy	Broadcast spawner	Demersal egg layer	Live bearer
Fecundity	>20,000 eggs per year	100-20,000 eggs per year	<100 eggs per year
Trophic level	<2.75	2.75-3.25	>3.25
Density dependence (only to be used when scoring invertebrates)	Compensatory dynamics at low population size demonstrated or likely	No depensatory or compensatory dynamics demonstrated or likely	Depensatory dynamics at low population sizes (Allele effects) demonstrated or likely

Susceptibility attribute	**Low susceptibility** **Low risk** **Score = 1**	**Medium susceptibility** **Medium risk** **Score = 2**	**High susceptibility** **High risk** **Score = 3)**
Areal overlap (availability) i.e. overlap of fishing effort with stock distribution	<10% overlap	10-30% overlap	>30% overlap
Encounterability i.e. the position of the species / stock within the water column / habitat relative to the position of the fishing gear	Low encounterability / overlap with fishing gear	Medium overlap with fishing gear	High encounterability / overlap with fishing gear (Default score for target species in a fishery)
Selectivity of gear type i.e. potential of gear to retain species	a) Individual < size at maturity are rarely caught	a) Individual < size at maturity are regularly caught	a) Individual < size at maturity are frequently caught
	b) Individual < size can escape or avoid gear	b) Individual < half the size can escape or avoid gear	b) Individual < half the size are retained by gear
Post-capture mortality i.e. the chance that, if captured, a species would be released and that it would be in a condition permitting subsequent survival	Evidence of majority released post-capture and survival	Evidence of some released post-capture and survival	Retained species or majority dead when released