7-2020

Blue Swimmer Crab (Portunus armatus) and Sand Crab (Ovalipes australiensis) Resource in the South Coast Bioregion of Western Australia

D Johnston
danielle.johnston@dpird.wa.gov.au

David Harris
david.harris@dpird.wa.gov.au

Daniel Yeoh

Department of
Primary Industries and
Regional Development

GOVERNMENT OF
WESTERN AUSTRALIA

Fisheries Research Report No. 310

Blue Swimmer Crab (*Portunus armatus*) and Sand Crab (*Ovalipes australiensis*) Resource in the South Coast Bioregion of Western Australia

Johnston, D., Harris, D. and Yeoh, D.

July 2020

Correct citation:

Johnston, D., Harris, D. and Yeoh, D. (2020). Blue Swimmer Crab (*Portunus armatus*) and Sand Crab (*Ovalipes australiensis*) Resource in the South Coast Bioregion of Western Australia Fisheries Research Report No. 310. Department of Primary Industries and Regional Development, Western Australia. 62pp.

Enquiries:

WA Fisheries and Marine Research Laboratories, PO Box 20, North Beach, WA 6920
Tel: +61 8 9203 0111
Email: library@fish.wa.gov.au
Website: www.fish.wa.gov.au

A complete list of Fisheries Research Reports is available online at **www.fish.wa.gov.au**

Department of Primary Industries and Regional Development
Gordon Stephenson House
140 William Street
PERTH WA 6000
Telephone: (08) 6551 4444
Website: dpird.wa.gov.au
ABN: 18 951 343 745

ISSN: 1035-4549 (Print) ISBN: 978-1-921258-70-1 (Print)
ISSN: 2202-5758 (Online) ISBN: 978-1-921258-71-8 (Online)

Table of Contents

Table of Contents ..... **iii**
List of Abbreviations ..... **v**
Executive Summary **1**
1. Scope **3**
2. How the Department Operates **3**
3. Aquatic Environment **4**
4. Resource Description **7**
4.1 Blue Swimmer Crab (*Portunus armatus*) 7
4.2 Sand Crab (*Ovalipes australiensis*) 8
5. Species Description **9**
5.1 Blue Swimmer Crabs (*Portunus armatus*) 9
5.2 Sand Crab (*Ovalipes australiensis*) 10
5.2.1 Taxonomy and Distribution 10
5.2.2 Stock Structure 11
5.2.3 Life History 11
5.2.4 Inherent Vulnerability 14
6. Fishery Information **15**
6.1 Blue Swimmer Crab 15
6.1.1 Fisheries/Sectors Capturing Resource 15
6.1.2 Commercial Sector 15
6.1.3 Recreational Sector 19
6.1.4 Customary Fishing 21
6.1.5 Illegal, Unreported or Unregulated Fishing 21
6.2 Sand Crab 22
6.2.1 Fisheries/Sectors Capturing Resource 22
6.2.2 Commercial Sector 22
6.2.3 Recreational Sector 24
6.2.4 Customary Fishing 24
6.2.5 Illegal, Unreported or Unregulated Fishing 24
7. Fishery Management **25**
7.1 Management System 25
7.2 Harvest Strategy 25

7.3 External Influences 25
7.3.1 Environmental Factors 26
7.3.2 Introduced Pest Species 28
7.3.3 Market Influences 28
8. Information and Monitoring 28
8.1 Range of Information 28
8.2 Monitoring 28
8.2.1 Commercial Catch and Effort 28
8.2.2 Recreational/Charter Catch and Effort 29
8.2.3 Fishery-Dependent Monitoring 30
8.2.4 Fishery-Independent Monitoring 31
8.2.5 Environmental Monitoring 31
9. Stock Assessment 31
9.1 Assessment Principles 31
9.2 Assessment Overview 32
9.2.1 Peer Review of Assessment 32
9.3 Analyses and Assessments 32
9.3.1 Data Used in Assessment 32
9.3.2 Catch and Effort Trends 32
9.3.3 Catch Distribution Trends 37
9.3.4 Fishery-Dependent Catch Rate Analyses 39
9.3.5 Trends in Size Structures/Sex Ratios 42
9.3.6 Productivity Susceptibility Analysis 44
9.3.7 Fishery-Independent Data Analyses 49
9.4 Stock Status Summary 49
9.4.1 Weight of Evidence Risk Assessment 50
9.4.2 Current Risk Status 53
9.4.3 Future Monitoring 54
10. References 55
Appendix 1 59
Appendix 2 61

List of Abbreviations

CAES	Catch and Effort Statistic
CPUE	Catch per unit effort
CW	Carapace Width
DoF	Department of Fisheries (Western Australia)
DPIRD	Department of Primary Industries and Regional Development (Western Australia)
EBFM	Ecosystem-Based Fisheries Management
IOE	Instrument of Exemption
ESD	Ecologically Sustainable Development
EPBC	Environment Protection and Biodiversity Conservation (Act)
FRMA	Fish Resources Management Act
LC	Leeuwin Current
MSC	Marine Stewardship Council
PSA	Productivity Susceptibility Analysis
RFBL	Recreational Fishing from Boat Licence
SAFS	Status of Australian Fish Stocks
SCB	South Coast Bioregion
SCEMF	South Coast Estuarine Managed Fishery
WA	Western Australia
WCB	West Coast Bioregion

Executive Summary

The blue swimmer crab (*Portunus armatus*) is found along the entire coastline of Western Australia (WA) in a range of estuarine, inshore and continental shelf areas (<50 m). In the South Coast Bioregion (SCB), blue swimmer crabs are retained as by-product in commercial nets of the 25 licences operating in the South Coast Estuarine Managed Fishery (SCEMF) and targeted by purpose-designed crab traps allocated to fishers in Princess Royal and Oyster Harbours in Albany. Crabs were also retained during a short-term crab trap trial in the Wilson and Irwin Inlets during 2015–17.

Crabbing is a popular recreational fishing activity with blue swimmer crabs being one of the most important recreationally fished invertebrate species in WA. Recreational fishing in the SCB occurs primarily in the nearshore waters and estuaries of the south coast, targeting crabs using scoop nets, drop nets or by hand while scuba diving or snorkelling.

Management arrangements for the commercial and recreational blue swimmer crab fisheries specify effort controls, spatial closures, minimum size limits and protection of breeding females. The total commercial catch of blue swimmer crabs in the SCB in 2019 was 19 t, while the total 2017–18 boat-based recreational catch for this bioregion was estimated to be <1 t (Ryan *et al.*, 2019). However, commercial catches have reached 54 t following years of strong Leeuwin Current (LC) and warmer waters, such as during the 2011 extreme marine heatwave event.

The ocean sand crab (*Ovalipes australiensis*) (also referred to as the surf crab or sand crab) occurs on surf beaches, sandy bays and inlets (<100 m) across southern Australia. No commercial catches of *O. australiensis* had been reported in WA prior to an Instrument of Exemption (IOE) being issued in 2016 that endorsed one commercial fisher to target sand crabs using purpose-designed hourglass traps in waters between Augusta and Hopetoun. Subsequent fishing has concentrated along coastal beaches in and around Albany, with fishing effort primarily driven by market demand (annual catches ranging from 0.8–1.9 t). Although occasional catches have been reported by boat-based recreational fishers, the sand crab is not considered an important recreational species in WA.

The total commercial catch of sand crabs in the SCB in 2019 was 1.5 t. No *Ovalipes* spp. were reported by boat-based recreational fishers in WA during 2017–18 (Ryan *et al.*, 2019).

Harvest Strategy, Monitoring and Assessment

Given the difficulty in allocating effort for non-target species from statutory commercial catch and effort returns (CAES) in the SCEMF, a harvest strategy for the blue swimmer crab resource has not been determined. Consequently, crab stock assessment for the SCB is currently based on nominal commercial catch rates from CAES as a proxy for abundance.

The SCB sand crab resource is monitored through CAES returns and a daily research logbook that forms part of the Exemption requirements.

Effects of environmental variables on commercial crab catch rates in the SCB are being examined, as blue swimmer crab fisheries in nearshore coastal and estuarine waters are highly influenced by changes in the environment.

Status of stocks

Blue swimmer crab

The SCEMF reported a total annual blue swimmer crab catch of 19 t in 2019, more than double the 7.3 t landed in 2018. Most crabs were caught using dedicated traps in Oyster Harbour (5.5 t) and Princess Royal Harbour (4.4 t), and as by-product from the gill net fishery in the Wilson Inlet (5.7 t). Recreational catch is negligible in this fishery.

Stock abundance of blue swimmer crabs in the SCB appears to be heavily influenced by the strength of the warm, southward flowing LC. Crabs recruit to these waters during strong LC years which result in warmer water temperatures, with subsequent catch and effort highly variable in response to these pulses of abundance. While the size of stock and relative exploitation level along the south coast is not fully understood, the relatively low level of commercial and recreational catch and effort suggests that blue swimmer crab stocks in the SCB are **Sustainable**.

Sand crab

The total commercial catch of sand crabs in the SCB in 2019 was 1.5 t, a slight decline on the 1.9 t landed in 2018. Recreational fishing for this species is negligible.

Annual catches of sand crabs have been limited as the fisher develops a market for this species. While stock size and relative exploitation along the south coast is not fully understood, the very low level of commercial and recreational catch and effort suggests that sand crab stocks in the SCB are **Sustainable**.

1. Scope

This document provides a description and assessment of the blue swimmer crab (*Portunus armatus*) and sand crab (*Ovalipes australiensis*) resources, and all the fishing activities (i.e. fisheries / fishing sectors) affecting these resources in the South Coast Bioregion (SCB) of Western Australia (WA).

The report contains information relevant to assist the assessment of the resource against 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 of Primary Industries and Regional Development (DPIRD) Risk Register, which is an integral component of the annual planning cycle for assigning activity priorities (research, management, compliance, education etc.) across each bioregion. A summary of the Department's risk-based planning annual cycle that is delivering EBFM in the long-term is provided in Figure 2.1.

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).

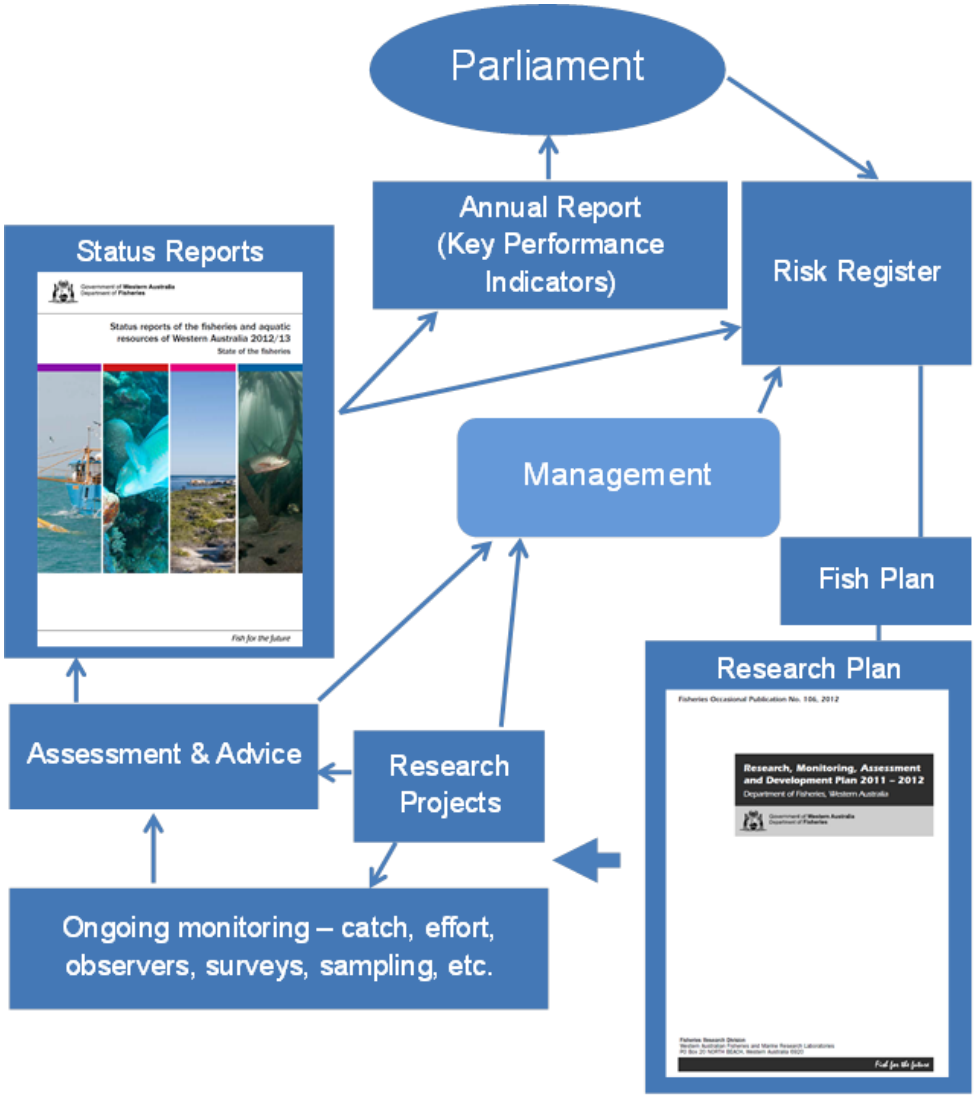


Figure 2.1. An outline of the risk-based planning cycle used for determining Departmental priorities and activities.

3. Aquatic Environment

The South Coast Bioregion (SCB) extends from Augusta in the west to the South Australian border to the east (Figure 3.1), encompassing the coastal towns of Denmark, Albany and Esperance. The continental shelf waters of the SCB represent a nutrient poor, high-energy environment subject to large swells generated in the Southern Ocean. While these waters are temperate (sea surface temperatures range from ~15–21°C), the influence of the warm, southward-flowing Leeuwin Current (LC) generally limits winter minimum temperatures to ~15–17°C. The distribution of many of the temperate species that inhabit these waters extends across southern Australia. However, tropical species such as the blue swimmer crab are also found in this region as a result of southwards flow during strong LC events that typically result in above-average water temperatures, with local environmental conditions unlikely to support breeding populations.

The coastline from Cape Leeuwin to Israelite Bay is characterised by white sand beaches separated by high granite headlands. East of Israelite Bay, long sandy beaches are backed by large sand dunes, until replaced by high limestone cliffs approaching the South Australian border. Habitat in these waters reflects the coastline, with fine, clear sand sea floors interspersed with occasional granite outcrops and limestone shoreline platforms and sub-surface reefs. The sea floor along the south coast boasts a mixture of seagrass and kelp habitats, with seagrass beds becoming more abundant in protected waters and more marine estuaries. Although these kelp habitats are diverse, they tend to be dominated by the relatively small *Ecklonia radiata*, rather than the larger kelps expected in these latitudes.

With the exception on several areas (e.g. Recherche Archipelago near Esperance and King George Sound near Albany), coastal waters in the SCB are vastly unprotected and subject to high wave energy. However, numerous estuaries along the coast provide sheltered habitats for many commercially and recreationally important fish and crustacean species. While several of these estuaries are permanently open to the ocean (e.g. Walpole–Nornalup Estuary, Oyster Harbour), most become isolated from the sea due to sandbars forming at their entrances and only open seasonally (e.g. Wilson Inlet, Irwin Inlet) or every few years (e.g. Wellstead Estuary) following heavy rainfall.

The SCB experiences warm dry summers and cool wet winters, with the western coastline receiving significant winter rainfall which inundates many estuaries in the region with fresh water from winter-flowing rivers. Although terrestrial run-off elevates nutrient levels in these estuaries during this period, their outflow to the ocean does not significantly influence the low nutrient status of nearshore coastal waters. The coastline becomes more arid to the east of Hopetoun, with a decrease in the number of rivers and estuaries.

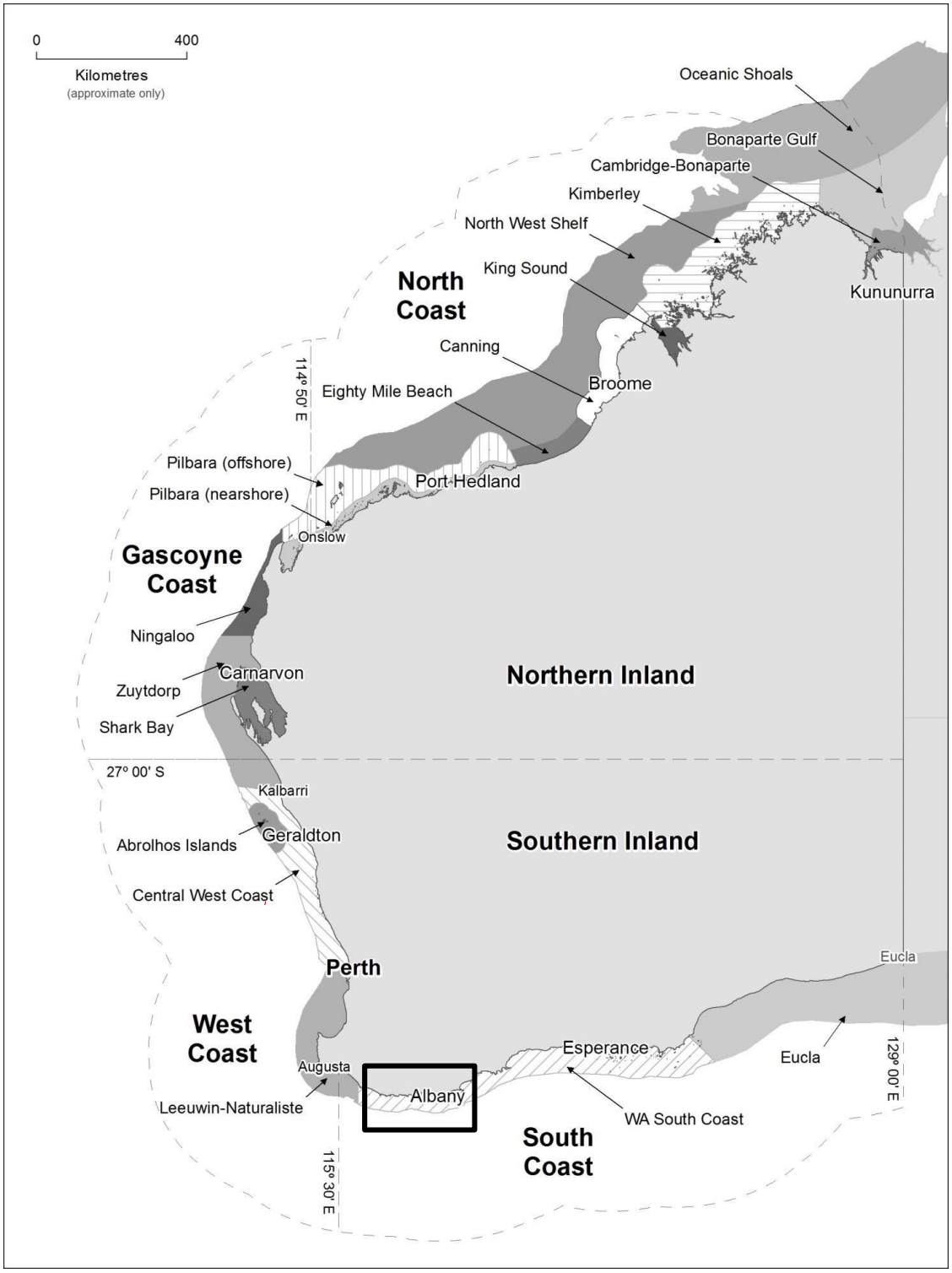


Figure 3.1. Bioregions of Western Australia and the locality of key blue swimmer crab and sand crab stocks within the South Coast Bioregion. Individual fishery locations (Wilson Inlet, Irwin Inlet, Princess Royal and Oyster Harbours) are denoted in Figure 4.1.

4. Resource Description

4.1 Blue Swimmer Crab (*Portunus armatus*)

Commercial blue swimmer crab (*Portunus armatus*) fisheries in the South Coast Bioregion (SCB) are centred in estuaries and coastal embayments from the Irwin Inlet in the west to the Princess Royal and Oyster Harbours in the east (Figure 4.1). The blue swimmer crab resides primarily in sandy nearshore and estuarine habitats <50 m in depth.

Blue swimmer crabs are retained as by-product by commercial net fishers in the South Coast Estuarine Managed Fishery (SCEMF), which also incorporates a dedicated crab trap allocation in the Princess Royal and Oyster Harbours. In addition, an Experimental Crab Trap Trial was undertaken in the Wilson and Irwin Inlets between 2015 and 2017, and is currently under review for extension or incorporation into the management plan.

Hourglass traps used to catch blue swimmer crabs are purpose-designed to minimise the capture of non-target species and undersized crabs, through minimum mesh size requirements and rigid escape gaps. The majority of fish and other bycatch species escape through the trap entrance gaps when the trap is soaking or hauled. The small quantity of bycatch that is caught and returned by commercial crab fishers is considered to pose a negligible risk to these stocks.

The blue swimmer crab is a short-lived, fast-growing species with a high fecundity and potential for wide dispersal and distribution of recruits. Taking into account these biological traits and the highly specific hourglass traps, a Productivity Susceptibility Analysis (PSA) indicates the risk and inherent vulnerability to fishing is low. Nevertheless, collapses of *P. armatus* stocks have occurred in Cockburn Sound and Shark Bay in Western Australia (WA), and in other Australian stocks, where adverse environmental conditions combined with heavy fishing pressure have led to declines in recruitment and breeding stock. Therefore, the vulnerability of the stocks, particularly at the southern extreme of their distribution in south-west WA, is likely to be higher than once thought.

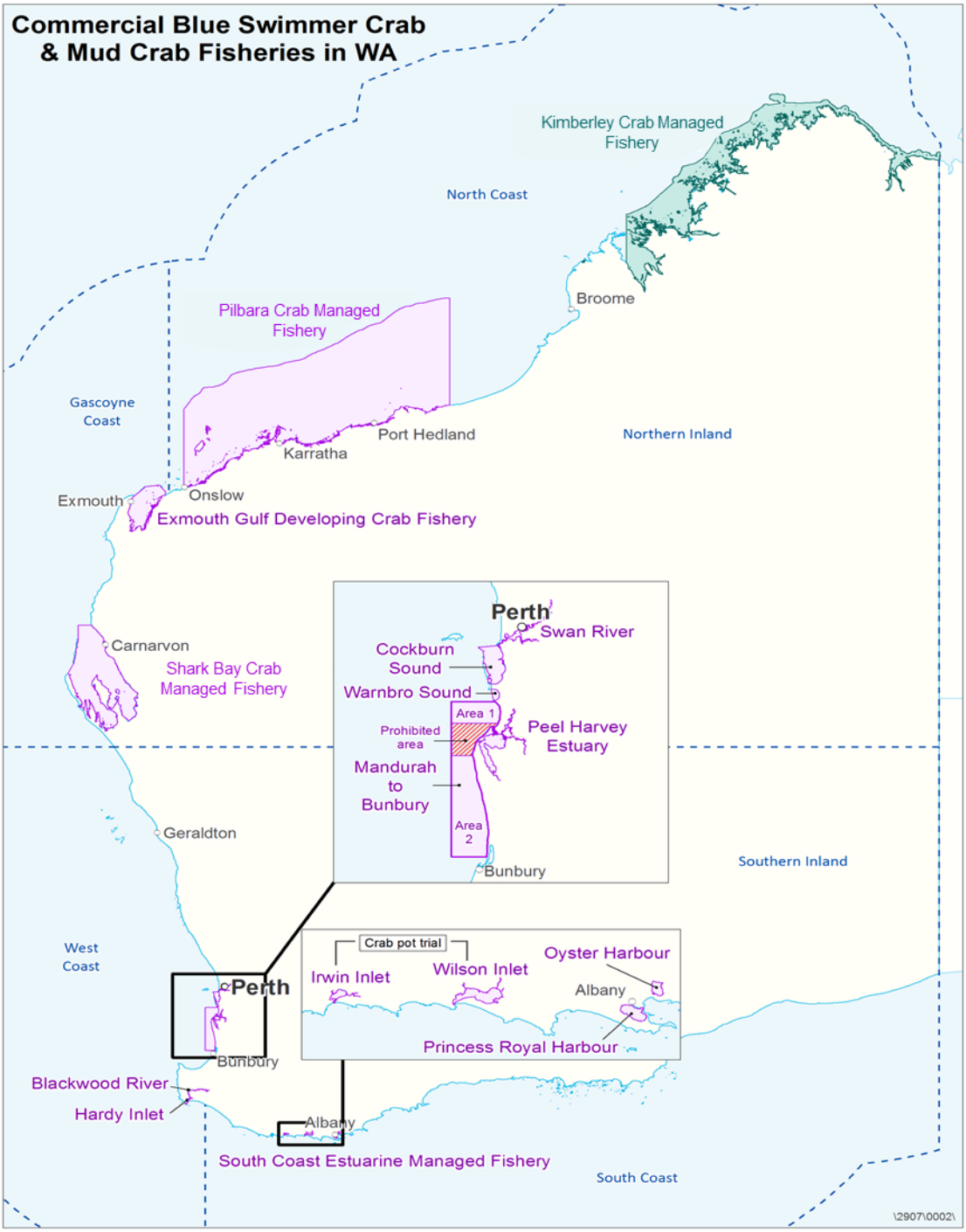


Figure 4.1. Location map of commercially important blue swimmer crab and mud crab fisheries in Western Australia.

4.2 Sand Crab (*Ovalipes australiensis*)

Commercial fishing for the sand crab (*Ovalipes australiensis*) in the SCB is undertaken by a single fisher operating under a five-year Instrument of Exemption (IOE) issued in July 2016. The Exemption endorses fishing in all waters of the SCEMF other than specific exclusion zones. However, current operations are concentrated along coastal beaches (< 150 m from

shore) in Albany region, as the fisher develops markets for this product. The fisher uses purpose-designed hourglass crab traps, and is prohibited from retaining any other species.

Like *P. armatus*, *O. australiensis* is a short-lived, highly fecund and fast-growing species with potential for wide dispersal and distribution of recruits. Consequently, PSA suggests the risk and inherent vulnerability to fishing for this species at current effort levels in the SCB is low.

5. Species Description

5.1 Blue Swimmer Crabs (*Portunus armatus*)

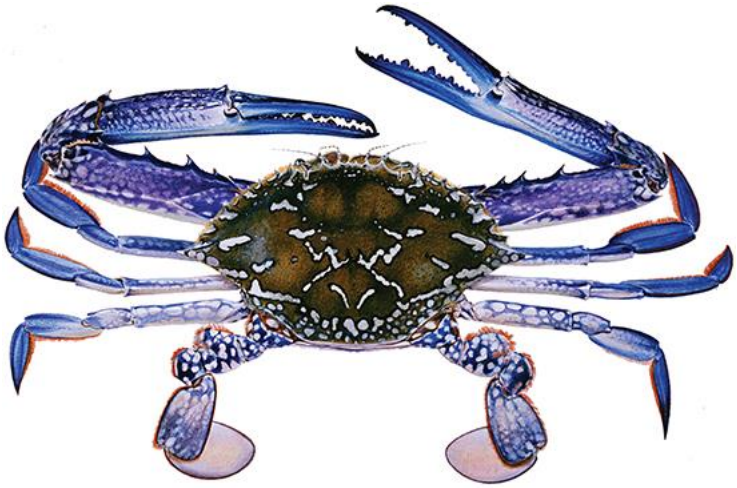


Figure 5.1 The blue swimmer crab, *Portunus armatus*. Illustration © R. Swainston (www.anima.net.au)

Although a substantial amount of research has been undertaken on blue swimmer crab (Figure 5.1) populations on the lower-west coast of Western Australia (WA), comparatively little is known of populations in the South Coast Bioregion (SCB). As the biological characteristics of south coast stocks are expected to be similar to those of the lower-west coast, please refer to Section 5 of Johnston *et al.* (2020b) for detailed information on the biology, taxonomy and distribution of this species.

5.2 Sand Crab (*Ovalipes australiensis*)

Figure 5.2 The sand crab, *Ovalipes australiensis*. Illustration © R. Swainston (www.anima.net.au)

5.2.1 Taxonomy and Distribution

The sand crab, *Ovalipes australiensis*, (also referred to as the surf crab or sand crab) is a member of the family Portunidae (Figure 5.2). The species is endemic to southern Australia, with a distribution stretching from Rottnest Island in WA to Wide Bay, Queensland, including Tasmanian waters (Figure 5.3; Kailola *et al.*, 1993; Steer *et al.*, 2018).

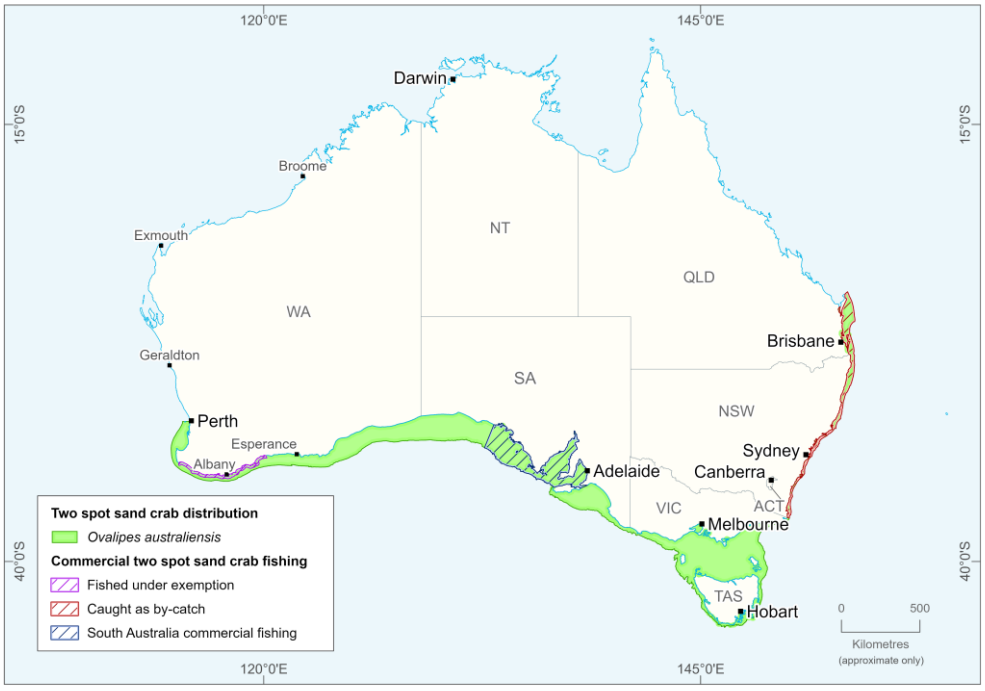


Figure 5.3 Geographic distribution (green) and generalised commercial fishing areas (purple, red and blue stripes) of the sand crab, *Ovalipes australiensis*, in Australian waters. Note: geographic distribution depends on suitable habitat within this range. Commercial fishing zones indicated on the maps are based on current commercial fishing zones.

5.2.2 Stock Structure

As stock delineation of sand crabs between regions in the SCB is unknown, assessment of stock status is presented at the management unit level of the individual fishery.

5.2.3 Life History

There has been no research undertaken on the biology of *O. australiensis* in WA. Consequently, the sub-sections below provide an overview of life history characteristics for the species that have been described in other Australian states.

5.2.3.1 Life Cycle

The WA fisher targeting the species has provided anecdotal evidence of berried female crabs with a carapace width (CW) of approximately 30 mm, suggesting it is substantially below that for blue swimmer crabs in WA (84–93 mm CW), However, it is possible these were actually sand crabs infected with the parasitic barnacle *Sacculina granifera*, as a number of infected crabs were captured during a commercial monitoring survey aboard the fisher's vessel in April 2019 (see section 5.2.3.8).

No distinct spawning season is apparent in the fisher's logbook data, with small quantities of berried female crabs reported across most months of the year (Figure 5.4). However, a study in Coffin Bay, South Australia (SA), described *O. australiensis* as winter spawners, with reproductive activity peaking in July and berried females present until August (Deakin, 1996). The study also noted that female sand crabs attain sexual maturity at a smaller size than males.

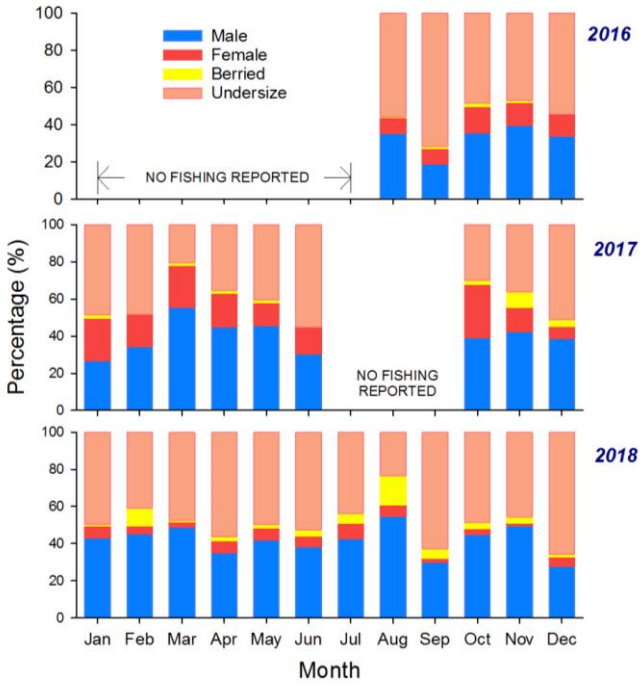


Figure 5.4 Percentages (%) of male, female, berried female and discarded undersize sand crabs in commercial catch by month between 2016–18 as reported in the Daily Research Logbook by the single fisher endorsed to operate in the South Coast Bioregion.

5.2.3.2 Habitats and Movements

The sand crab occurs on surf beaches, sandy bays and inlets offshore to approximately 150 m, often co-existing in similar habitat to the blue swimmer crab, *P. armatus*. However, *O. australiensis* tends to be more abundant in waters up to 100 m from shore, whereas blue swimmer crabs are often found > 200 m from the shore.

There is little information reported in the scientific literature about movement patterns of sand crabs. Analysis of data from fishery-independent surveys in south-west WA (Leschenault Estuary and Geographe Bay), and from the fisher targeting sand crabs on the south coast, indicates they are restricted to nearshore marine environments.

5.2.3.3 Age and Growth

Little is reported in the scientific literature about the age and growth of the sand crab, *O. australiensis*.

It is likely there is sexual dimorphism in growth of *O. australiensis, as* the mean size of female crabs (mean CW = 72.5 mm) caught in research hourglass traps during blue swimmer crab breeding stock surveys in south west WA (Leschenault Estuary and Geographe Bay) between 2013–18 were typically smaller than males (mean CW = 82.2 mm). Furthermore, all female crabs sampled in SA in the late 1990s were under 100 mm CW. As the SA fishery introduced a minimum size limit of 100 mm CW in 1992 for marketing purposes (Jones, 1995), the commercial fishery in this state is essentially based on males (Jones and Deakin, 1997). Although a commercial minimum size limit has yet to be set for sand crabs in WA, the South Coast fisher primarily retains crabs >100 mm CW for marketing purposes.

Sand crabs in WA appear to be significantly smaller than those in SA. Giri and Hall (2015) reported an average weight for retained blue swimmer crabs of 0.264 g during a 2013/14 recreational fishing survey, which is consistent with 0.229 – 0.254 g reported in WA (Ryan *et al.*, 2013; 2015; 2017). However, the average weight for legal-sized sand crabs of 0.361 g in SA, was around 40% heavier than for blue swimmer crabs in that State. In contrast, sand crabs caught in breeding stock trap surveys in the Leschenault Estuary and Geographe Bay between 2013-18 ranged in size from 55-105 mm CW and were notably smaller and lighter than legal sized (≥ 127 mm CW) blue swimmer crabs caught in the traps (unpublished data).

5.2.3.4 Natural Mortality

No information is available in the scientific literature with reference to natural mortality of the sand crab, *O. australiensis*.

5.2.3.5 Reproduction

Sand crabs are gonochoristic but exhibit sexual monomorphism. While male crabs tend to be larger, both sexes are largely identical in colour and external morphometric shape other than the abdominal flap. As with many Portunid species, the abdominal flap of both juvenile male and female *O. australiensis* is narrow and tightly fixed to the cephalothorax. However, while

the adult male flap remains narrow, the female abdominal flap broadens and loosens (from the cephalothorax) noticeably after undergoing the pubertal moult (Figure 5.5).

Figure 5.5 The broad abdominal flap of a mature female sand crab, *Ovalipes australiensis*, (left), compared to the narrow flap of a mature male crab (right), captured during a commercial monitoring survey on the south coast of Western Australia. Note, both crabs were infected with the parasitic barnacle, *Sacculina granifera*.

5.2.3.6 Factors Affecting Year Class Strength and Other Biological Parameters

Water temperature has been implicated as an important factor in the majority of the recruitment-environment relationships for marine fish and crustacean species (Caputi *et al.*, 1995; Uphoff, 1998). Water temperature typically has a positive effect on decapod recruitment by accelerating larval development and reducing the duration of the larval phase and larval mortality (Bryars and Havenhand, 2006; Fisher, 1999). Elevated water temperatures prior to spawning may also directly affect the timing of larval release by controlling gonad development, mating and the timing of spawning (Rosenkranz *et al.*, 2001). It may also influence the larval survival through changes to the abundances of larval foods and predators.

Levels of recruitment to crab fisheries fluctuate considerably between years. While the causes of these variations are not fully understood, it is considered most likely to be driven by the environmental variables on spawning success and larval survival through to recruitment. The breeding stock (egg production) is not often a significant factor unless there has been a major decline in the stock due to overfishing and/or a series of poor recruitment events due to very poor environmental conditions such as occurred in the blue swimmer crab stock in Cockburn Sound (de Lestang *et al.*, 2010; Johnston *et al.*, 2011b).

5.2.3.7 Diet and Predators

No information is available in the scientific literature with reference to the diet and known predators of the sand crab, *O. australiensis*.

5.2.3.8 Parasites and Diseases

Sacculina granifera is a parasitic barnacle that infects many Portunid species. The parasite brings about a number of major changes in the host crab, including degeneration of the sex

organs in both sexes and modification of the male crab to a more female form. While infection usually results in castration for both sexes, some infected hosts are still capable of mating with some females still able to produce a clutch of eggs.

Infestation by *S. granifera* amongst blue swimmer crab stocks is common in northern Australian waters, but extremely rare south of Exmouth Gulf. However, the parasite was present in several sand crabs captured during a commercial monitoring survey aboard a commercial vessel operating in nearshore waters around Albany on the south coast in April 2019 (Figure 5.7).

Figure 5.6 A female (left) and male (right) sand crab, *Ovalipes australiensis*, infected with the parasitic barnacle, *Sacculina granifera*. captured during a commercial monitoring survey on the south coast of Western Australia in April 2019.

Chitinoclastic shell disease is an external bacterial infection found in crabs and other crustaceans that have been subjected to stress. While the disease has been detected in some blue swimmer crab stocks in south-west WA, it has not been identified amongst sand crabs in the same locations, nor in the SCB.

5.2.4 Inherent Vulnerability

Ovalipes australiensis is assumed to be a highly fecund species with a relatively short life span. The sand crab is targeted in WA by a single fisher operating under an Instrument of Exemption (IOE) on the south coast, while state-wide recreational catches are negligible. Therefore, WA sand crab stocks are currently considered to have a low inherent vulnerability to fishing.

6. Fishery Information

6.1 Blue Swimmer Crab

6.1.1 Fisheries/Sectors Capturing Resource

In the South Coast Bioregion (SCB), blue swimmer crabs are retained as by-product by net fishers in the South Coast Estuarine Managed Fishery (SCEMF). The Management Plan also endorses dedicated crab trap allocations in the Princess Royal and Oyster Harbours in Albany. In addition, an Experimental Crab Trap Trial commenced in the south coast estuarine fisheries of the Wilson Inlet and Irwin Inlet in 2015.

Blue swimmer crabs are also targeted by the recreational sector in the SCB. They represent one of the two most important recreationally boat-based fished species in WA in terms of numbers caught (Ryan *et al.*, 2017), although recreational catch and effort in the SCB is minimal compared with that in the West Coast Bioregion (WCB). Recreational fishers on the south coast use drop nets or scoop nets, while diving for crabs becoming increasingly popular.

The sections below provide more detailed information about the main fisheries/sectors that target the south coast blue swimmer crab resource.

6.1.2 Commercial Sector

6.1.2.1 History of Development

The SCEMF is one of the oldest commercial fisheries in WA, with fishers using gillnets and haul nets to target fish species in the estuaries, river systems and tributaries along the south coast of WA since the mid-1800s (Pearn and Cappelluti, 1999). Key finfish species targeted by the SCEMF include Australian herring, cobbler, black bream and sea mullet, with blue swimmer crabs retained as a by-product of the fishers' netting activities (Smith *et al.*, 2013). In addition, 25 SCEMF fishers are endorsed to use a maximum of 25 purpose-designed crab traps each to target blue swimmer crabs in the Princess Royal and Oyster Harbours in Albany.

Historically, annual blue swimmer crab catches in the SCEMF have fluctuated considerably in response to variation in fishing effort, the abundance of target fish species, and changing environmental conditions. Annual catch over the last 20 years has ranged from 1–54 t (Figure 6.1), with peak catches in 2000–02 and 2012–15 coinciding with years of strong Leeuwin Current (LC) and warmer waters. The majority of catch has historically come from waters in Albany region (Princess Royal and Oyster Harbours, and King George Sound), with notable catches from the Wilson and Irwin Inlets during the two peak catch periods. Although blue swimmer crabs were traditionally retained as by-product from set nets, crab trap catches have become of a similar magnitude in recent years (Figure 6.2).

Following a submission by the West Australian Fishing Industry Council (on behalf of the SCEMF) during a period of increased crab catches, a trial was implemented in February 2015 to determine the merit of using purpose-designed crab traps to target blue swimmer crabs in the Irwin and Wilson Inlets. A total of eight fishers applied for the trial, with seven Exemptions issued for the Wilson Inlet (endorsing a maximum of 17 traps per Exemption for a total trap

allocation of 119 traps), and four for the Irwin (endorsing a maximum of 20 traps per Exemption for a total allocation of 80 traps). However, subsequent commercial trap catch and effort was minimal in either water body, with only two exemption holders using traps to target blue swimmer crabs in the Wilson Inlet and one in the Irwin Inlet. Furthermore, these fishers continued to fish predominantly with nets, trialling a maximum of 2–4 traps per day, usually setting a trap at the end of a line of net.

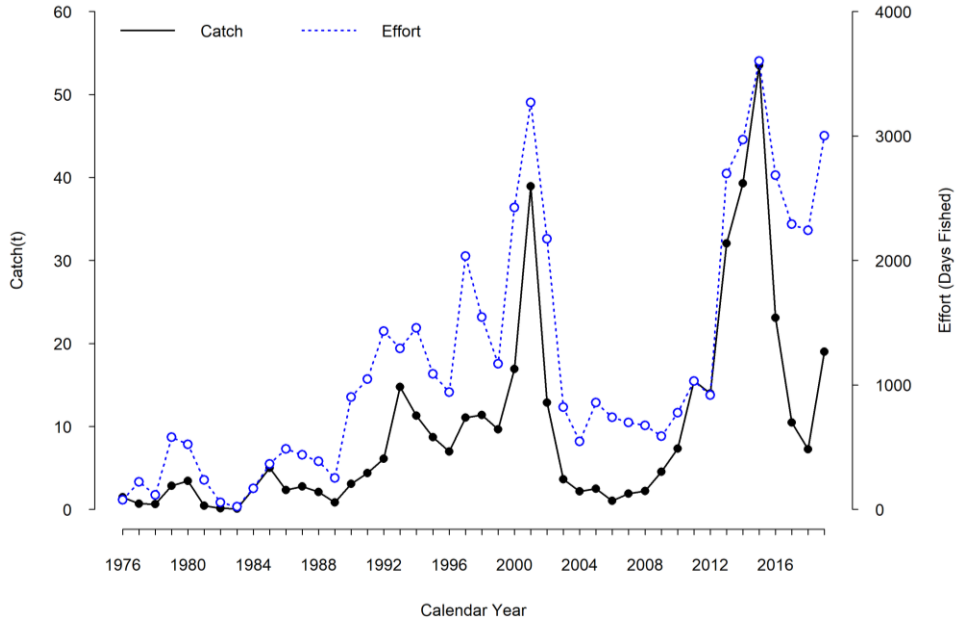


Figure 6.1 **Annual commercial catch (tonnes) and fishing effort (days fished) of blue swimmer crabs (all methods) by calendar year, in the South Coast Estuarine Managed Fishery between 1975 and 2019.**

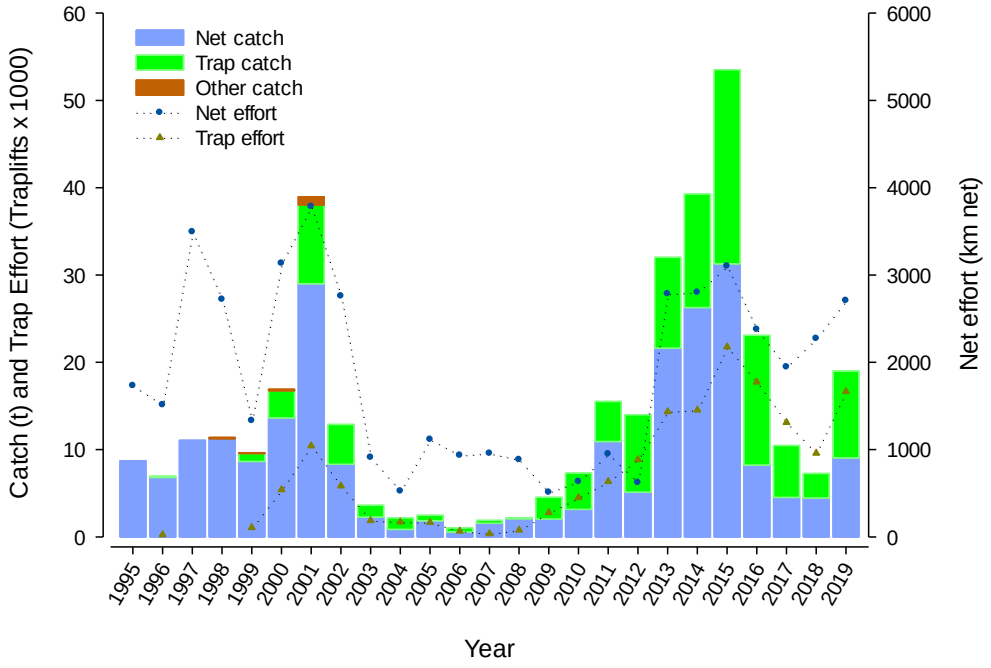


Figure 6.2 Annual (calendar year) commercial blue swimmer crab catch (t) and effort (km net, traplift x 1000) by method for the South Coast Estuarine Managed Fishery between 1995 and 2019.

6.1.2.2 Current Fishing Activities

A summary of key attributes of the current SCEMF and its fishing fleet is provided in Table 6.1

The SCEMF encompasses the waters of all estuaries on the south coast of WA between Cape Beaufort and 129° E longitude (the WA/South Australia border), including Princess Royal and Oyster Harbours, and all the rivers, streams and tributaries that flow into those estuaries (Figure 6.3).

Refer to the South Coast Estuarine Fishery Management Plan 2005 for details of the permitted areas to fish and periods of use for nets, crab traps and fish traps within each of the specific Areas of the Fishery listed above.

A total of 25 SCEMF fishers have endorsements to use a maximum of 25 purpose-designed crab traps each in the Princess Royal and Oyster Harbours. There are no set seasonal closures for the use of these crab traps, and retained catch is sold through local markets.

Table 6.1 Summary of key attributes for the commercial fishing of blue swimmer crabs in the South Coast Estuarine Managed Fishery.

Attribute	
Fishing methods	Gill nets Haul nets Hourglass crab traps
Fishing capacity	37,500 m of set net (maximum of 1500 m per fisher) 625 crab traps (maximum of 25 traps per fisher)
Number of licences	25
Number of vessels	56 (only one fishing operation permitted per licence at any given time)
Size of vessels	3.5–6.5 m
Number of people employed	25
Value of fishery	< $1 million; Level 1

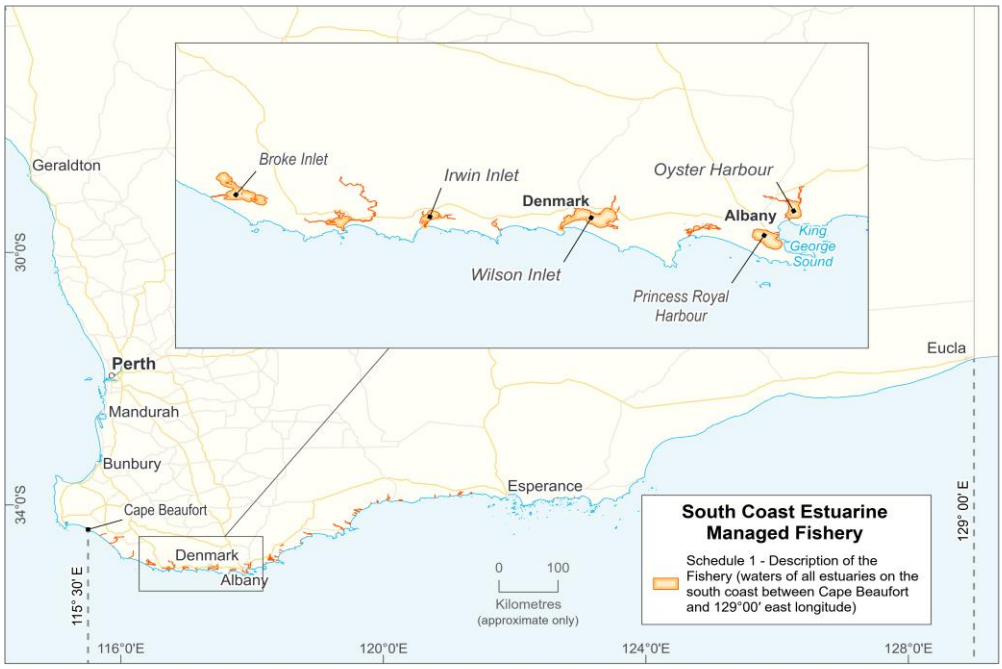


Figure 6.3 Boundaries of the South Coast Estuarine Managed Fishery and its Management Areas.

6.1.2.3 Fishing Methods and Gear

The total commercial capacity of the SCEMF includes 37,500 m of set net (Figure 6.4) and 625 crab traps (Figure 6.5). Individual commercial licensees are restricted to a maximum of 6 set nets with a combined length of 1500 m at any one time, and 25 purpose-designed crab traps per day. Crab traps are typically baited using fish caught by the fisher during his netting activities.

Refer to the South Coast Estuarine Fishery Management Plan 2005 for specific fishing and gear restrictions for the use of set nets, haul nets, seine nets and ring nets in the various areas of the Fishery.

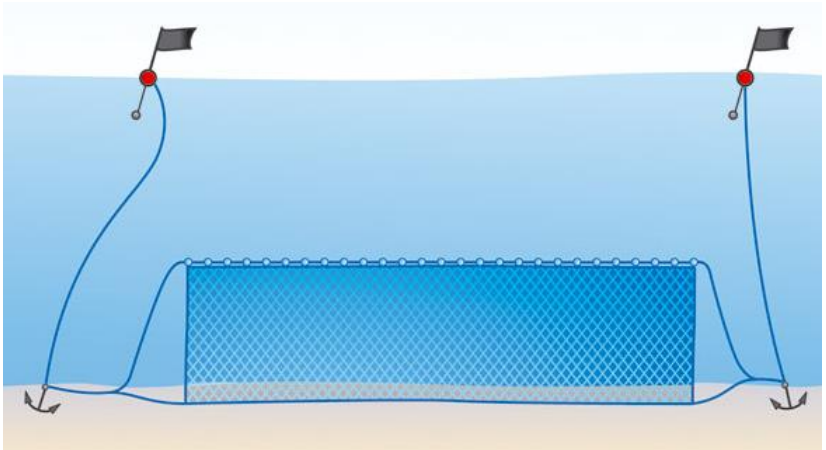


Figure 6.4 Conceptual illustration of a benthic set (gill) net as used by commercial crab fishers in the South Coast Estuarine Managed Fishery. Note, surface floats are not always used.

Figure 6.5 Examples of purpose-designed crab traps used in the South Coast Estuarine Managed Fishery.

6.1.2.4 Susceptibility

Although yet to be confirmed by genetic analysis the blue swimmer crab assemblages in the estuaries and embayments along the south coast of WA are likely to comprise the one stock. Therefore, they will be deemed a single stock for the purposes of Productivity and Susceptibility Analysis (PSA).

The waters of the SCEMF span more than 1000 km of coastline along the south coast of WA, with a significant proportion of the estuaries and embayments in the western half of this fishery providing suitable habitat for the blue swimmer crab. Consequently, areal overlap of this fishery is deemed to be approximately 10–30% of the total south coast stock.

As both gill-nets and purpose-designed baited traps used in the SCEMF are set on the benthos, the encounterability of the blue swimmer crab stock is high as they are primarily a benthic dwelling species. However, the mesh size used in both nets and traps allows the majority of juvenile and undersize crabs to escape.

Blue swimmer crabs can survive out of water for up to several hours provided their gills remain moist. As regulations stipulate that commercial and recreational fishers operating in WA waters must return berried and undersize crabs to the water within 5 minutes of being landed, post-release mortality rates of non-retained catch are considered low (Bellchambers *et al.*, 2005; Leland, 2014; Ullman *et al.*, 2009).

6.1.3 Recreational Sector

6.1.3.1 History of Development

Blue swimmer crabs represent one of the most important recreationally-fished inshore species in WA, with most recreational fishing occurring in the WCB (Ryan *et al.*, 2019). A national survey of recreational and indigenous fishing was conducted in Australia during 2000–01 by Henry and Lyle (2003). Blue swimmer crabs represented the most numerous of the crabs taken

by recreational fishers, with a national harvest of approximately 3.9 million crabs (Henry and Lyle, 2003). Harvest levels were greatest in WA (57% of total). More recent recreational catch statistics for WA crab fisheries have been gathered through 'iSurveys' (recreational fishing from boat surveys) conducted biannually since 2011/12.

While the majority of the recreational blue swimmer crab fishing in WA occurs in the WCB, this activity nevertheless provides a high social amenity to recreational fishing and diving in the SCB. Recreational fishing in the SCB has been focused in, and around, the coastal town of Albany, although fishing has also occurred on a regular basis in the various estuaries and inlets along the south coast.

Recreational fishers use either baited drop nets, scoop nets or diving. The WA minimum legal recreational size limit is set at a carapace width (CW) of 127 mm CW, which is substantially above the size at 50% maturity. Further protection is provided to the breeding stock through a ban on keeping berried females. Recreational fishers are subject to a daily bag limit of 20 crabs per fisher per day in the SCB, with a boat limit of 40 crabs. There is no specific recreational crabbing licence in WA, however, crabbers fishing from a powered vessel have required a Recreational Fishing from Boat Licence (RFBL) since March 2010.

The boat-based recreational harvest range for blue swimmer crab in the SCB in 2011/12 was estimated to be 1–4 t (95% CI), compared with 1–3 t in 2013/14, and 0.2–1.2 t in 2015/16 (Ryan *et al.*, 2013; 2015; 2017).

6.1.3.2 Current Fishing Activities

The estimated boat-based recreational catch of blue swimmer crab in the WCB represented 92% of the state-wide, boat-based recreational catch in 2017/18, with an estimated boat-based recreational harvest range of 45–63 t (95% CI; Ryan *et al.*, 2019). In contrast, the estimated boat-based recreational catch from the SCB accounted for just 0.13% of the 2017/18 state-wide catch, with an estimated boat-based recreational harvest range of 0–0.14 t.

6.1.3.3 Fishing Methods and Gear

Regulations govern the methods recreational fishers can use to fish for blue swimmer crabs in WA. Crabs may only be caught by hand while diving and snorkelling, using hand-held wire or plastic scoop nets, drop nets or hand-held blunt wire hooks. Scoop nets must be bowl-shaped and made of rigid mesh not capable of entangling a crab (Figure 6.6). Scoop nets must be no deeper than 210 mm and the internal diameter must be no greater than 375 mm. Drop nets must be no more than 1.5 m in diameter (Figure 6.6). There is a maximum limit of 10 drop nets per person when fishing from shore, or when fishing from a boat regardless of how many people are on board. Hooks must not be capable of piercing the crab.

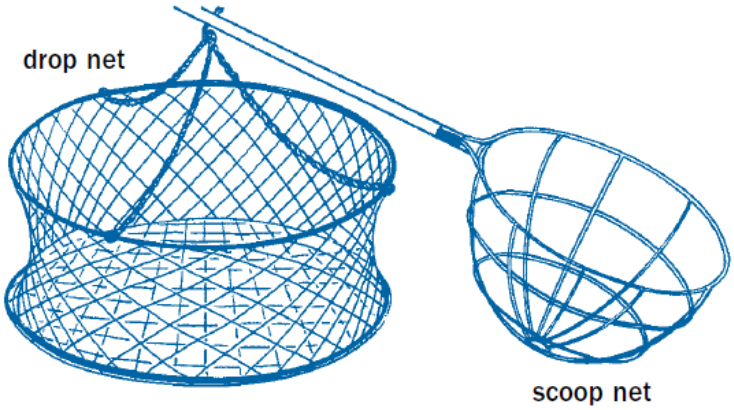


Figure 6.6 Drop and scoop nets employed by recreational fishers to target blue swimmer crabs.

6.1.3.4 Susceptibility

For the purposes of the PSA, the blue swimmer crab assemblages in the SCB have been considered one stock, including King George Sound, Oyster and Princess Royal Harbours, and the Wilson and Irwin Inlets.

Recreational fishing in the south coast is considered to have a medium areal overlap of 10–30% availability of the overall south coast blue swimmer crab stock.

Encounterability of blue swimmer crabs with recreational fishing methods in the SCB crab stock is high, as drop nets, scoop nets and divers specifically target blue swimmer crabs.

Selectivity attributed to recreational fishers is considered moderate. Although sub-legal and juvenile crabs are often caught by recreational drop net fishers, divers and scoop netters actively avoid berried female or undersize crabs.

Post-capture mortality of blue swimmer crabs is generally low. Blue swimmer crabs can survive out of water for up to several hours provided their gills remain moist, while recreational fishers are required to return non-retained catch to the water within 5 minutes of being landed.

6.1.4 Customary Fishing

There is currently no customary fishing of the blue swimmer crab resource occurring in the SCB.

6.1.5 Illegal, Unreported or Unregulated Fishing

Management arrangements for the SCB fisheries are enforced regularly by the Department's Fisheries and Marine Officers in the district offices. Compliance is monitored via both sea and land-based inspections, with the majority of checks being carried out on land at the point of landing (boat ramps). Compliance by the commercial sector is generally high, however illegal fishing activities by the recreational sector present a risk to some fisheries.

6.2 Sand Crab

6.2.1 Fisheries/Sectors Capturing Resource

Commercial fishing for the sand crab, *Ovalipes australiensis*, in the SCB is undertaken by a single fisher operating under an Instrument of Exemption (IOE). The fisher uses purpose-designed hourglass crab traps, and is prohibited from retaining any other species.

Recreational fishing for the sand crab on the south coast is negligible.

6.2.2 Commercial Sector

6.2.2.1 History of Development

Commercial fishing for the sand crab in the SCB is undertaken by a single fisher operating under a five-year IOE issued in July 2016. The Exemption endorses fishing in all waters of the SCEMF other than specific exclusion zones. However, current operations are concentrated along coastal beaches (< 150 m from shore) in and around Albany, as the fisher develops a market for this product. Catches between 2016–19 have ranged from 0.8–1.9 t, with fishing effort primarily driven by market demand (Figure 6.7). Fishing efficiency (higher catch for a given amount of effort) has improved since 2016 due to increased fisher knowledge as the fishery develops.

The fisher uses purpose-designed hourglass crab traps, and is prohibited from retaining any other species.

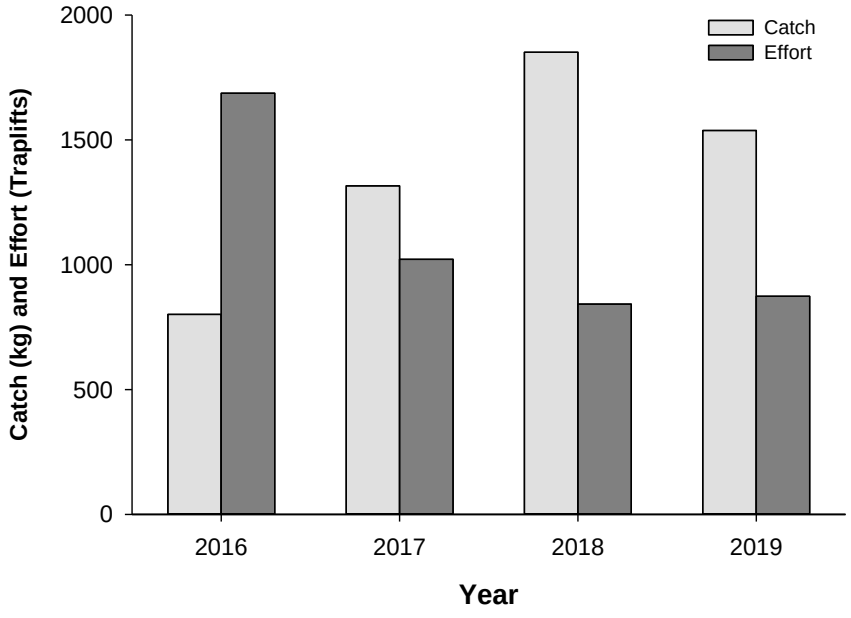


Figure 6.7 Annual commercial catch (kg) and fishing effort (traplifts) of sand crabs by calendar year between 2016 and 2019 for the single fisher operating under an Instrument of Exemption in the South Coast Bioregion.

6.2.2.2 Current Fishing Activities

A summary of key attributes of current commercial fishing for the sand crab in the SCB is provided in Table 6.2.

The commercial fisher is endorsed to target sand crabs using (a maximum of 50) purpose-designed crab traps along the south coast in all the waters off the south coast between longitudes of 115^0 08.091' E (Cape Leeuwin) and 120^0 07.572' E (Mary Ann Point, Hopetoun), from the high water mark to a distance offshore of 5 kilometres. Refer to the IOE for details of permitted areas to fish within these boundaries.

There are no set seasonal closures related to the sand crab Exemption. Retained catch is sold through local markets.

Table 6.2 Summary of key attributes of the Instrument of Exemption to fish for the Sand Crab in the South Coast Bioregion.

Attribute	
Fishing methods	Hourglass crab traps
Fishing capacity	50 traps
Number of licences	1 (100% active)
Number of vessels	1
Size of vessels	7 m
Number of people employed	2
Value of fishery	< $0.1 million; Level 1

6.2.2.3 Fishing Methods and Gear

Due to the experimental nature of this fishery, the IOE issued to the fisher targeting sand crabs on the south coast included no restrictions on the type, or dimensions, of trap that could be used. The fisher currently uses hourglass traps constructed with 51 mm (2-inch) mesh (Figure 6.8).

Figure 6.8 The hourglass crab trap design used by the sole fisher targeting the sand crab on the south coast of Western Australia.

6.2.2.4 Susceptibility

The sand crab assemblages along the south coast of WA are highly likely to be the same genetic stock. Thus for the purposes of PSA, these will be deemed to be one stock.

The IOE to fish for sand crabs in the SCB endorses fishing along some 1000 km of coastline. Thus the areal overlap of this fishery is currently deemed to be approximately 5–15% of the total south coast stock.

The purpose-designed baited traps used to target sand crabs are set on the benthos. Thus the encounterability of the sand crab stock is high as they are primarily a benthic dwelling species. However, post-release mortality rates of non-retained catch are low.

6.2.3 Recreational Sector

6.2.3.1 History of Development

Recreational catch and effort for the sand crab in the SCB is negligible. Sand crabs have a daily bag limit of 10 in WA.

6.2.3.2 Current Fishing Activities

No boat-based recreational catch of sand crab was reported for the SCB in 2017/18 (Ryan *et al.*, 2019).

6.2.3.3 Fishing Methods and Gear

There are no method or gear restrictions specific to the recreational capture of sand crabs in WA. Sand crabs are often caught in drop nets by fishers targeting blue swimmer crabs.

6.2.3.4 Susceptibility

For the purposes of PSA, the sand crab assemblages in the SCB are considered one stock.

6.2.4 Customary Fishing

There is currently no customary fishing of the sand crab resource in the SCB.

6.2.5 Illegal, Unreported or Unregulated Fishing

Management arrangements for the south-west fisheries are enforced regularly by the Department's Fisheries and Marine Officers in the district offices. Compliance is monitored via both sea and land-based inspections, with the majority of checks being carried out on land at the point of landing (boat ramps). There are few known illegal fishing activities on sand crabs in the SCB for both commercial and recreational sectors.

7. Fishery Management

7.1 Management System

The harvest strategy for the blue swimmer crab and sand crab resource of Western Australia (WA) is, essentially, a constant exploitation approach, where the annual catch varies in proportion to variations in stock abundance. To implement this strategy, commercial and recreational fisheries capturing crabs are managed using a range of input controls. Commercial fishing effort is constrained by a cap on the number of licences/vessels operating in each fishery (limited entry) and restrictions on fishing gear, including the number and size of crab traps, and the length of nets. Recreational fishing effort is managed by gear controls (*e.g.* limits on the number of drop nets used) and daily bag and boat limits. Recreational fishers operating from a boat are required to hold a current Recreational Fishing from Boat Licence (RFBL). Other restrictions include retainable species, minimum carapace width (CW) size limits and spatio-temporal fishing closures.

The minimum size limit for blue swimmer crabs in the SCB is 127 mm CW (commercial and recreational). There is currently no minimum size limit for sand crabs in WA. The principal management tools to ensure sand crab catches remain at a sustainable level are effort (single fisher, maximum of 50 traps) and spatial controls.

7.2 Harvest Strategy

Commercial fishing for blue swimmer crabs in the South Coast Estuarine Managed Fishery (SCEMF) has been highly variable (annual commercial catch 1–54 t), and correlated with periods of strong warm Leeuwin Current (LC) flow. Consequently, a draft harvest strategy has yet to be developed as there has not been a suitable period of relative stability in catch and effort to set appropriate reference levels. Furthermore, calculating effort and catch rate for non-target species such as blue swimmer crabs is problematic. It is possible that a future harvest strategy for the SCEMF may be based on catch and effort from the dedicated crab trap fishers that operate in the Princess Royal and Oyster Harbours.

Commercial catch and effort for both the trap and net sectors of this fishery will be used in a Weight of Evidence approach to assess the blue swimmer crab resource in the South Coast Bioregion (SCB).

As the commercial harvesting of the sand crab in the SCB is currently operating on an exploratory basis under a five-year Instrument of Exemption (IOE), the development of a draft harvest strategy for this species is not currently being considered.

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 and market influences.

7.3.1 Environmental Factors

As a short-lived, invertebrate species, environmental factors are presumed to have a strong influence on the blue swimmer crab resource. Recent analyses have demonstrated that a number of environmental variables, including water temperature, rainfall, wind speed and lunar illumination can influence commercial catch rates (Johnston *et al.*, 2020a), and changes in temperature and primary production may also be linked to declines in recruitment, growth and overall abundance (Marks *et al.*, 2020). Given that the crab resource is, at any given time, essentially comprised of only two cohorts (Marks *et al.*, 2020), environmental perturbations could be expected to result in major fluctuations in population size.

Levels of recruitment to many crab fisheries fluctuate considerably, primarily due to environmental influences (e.g. water temperature) on spawning success and larval survival through to recruitment (Johnston *et al.,* 2019). The relationship between environmental factors, recruitment and catch in SCB crab fisheries is being further evaluated as data becomes available.

The blue swimmer crab is a tropical species that is widely distributed along the WA coast between latitudes 20–34º South (de Lestang, 2002; Johnston *et al.,* 2011a), with the temperate waters along the south coast of WA representing the southern end of the species' distribution. Consequently, blue swimmer crab stocks in these waters are highly vulnerable to environmental fluctuations as there is a strong correlation between water temperature and spawning and recruitment success (de Lestang *et al.,* 2010).

Water temperatures on the WA coastline are strongly influenced by the strength of the LC; a body of warm water that flows southwards from the Indonesian Archipelago down the west coast of Australia. Since 1992, two periods of above average LC strength (measured using Fremantle sea level) have coincided with above average crab catches in the SCB (Figure 7.1). These events may have transported larvae and juvenile crabs south from more northern stocks (e.g. Geographe Bay) to settle in the estuaries and embayments of the SCB. It is not clear whether the increased water temperatures associated with a strong LC have promoted spawning and recruitment success of resident stocks (i.e. closed life cycle on the south coast).

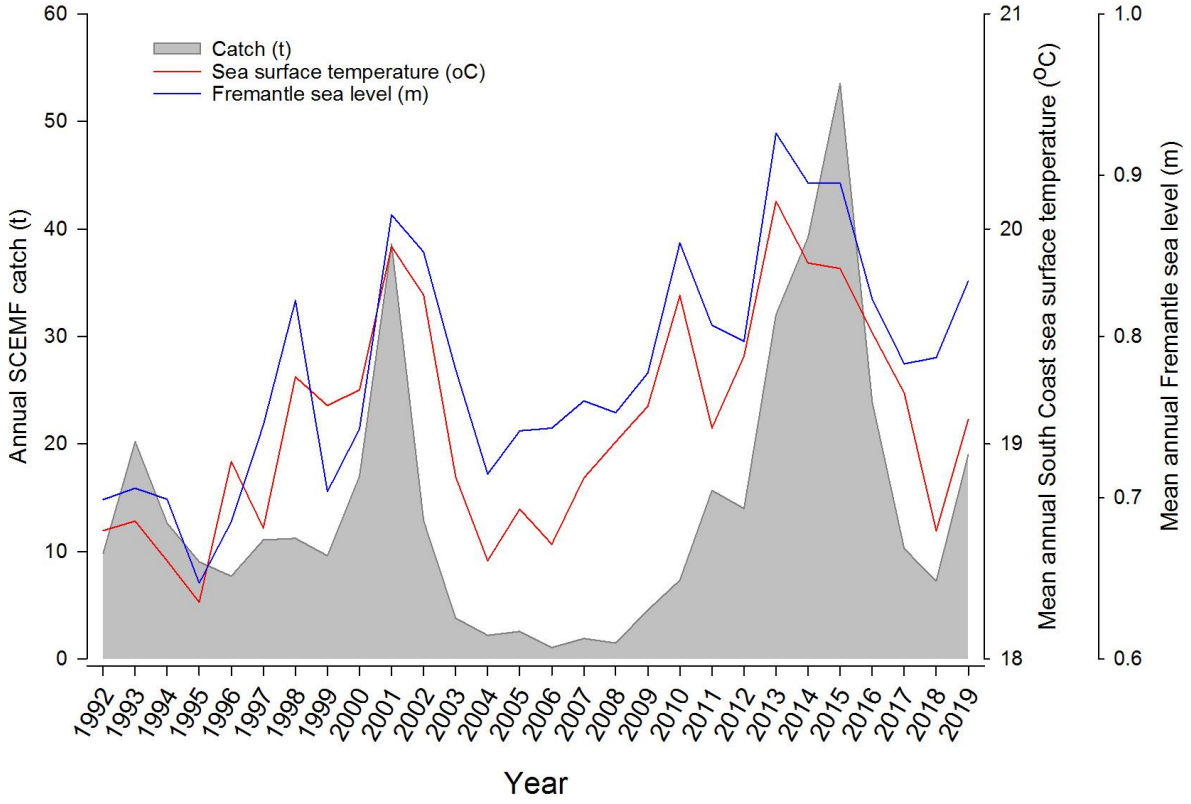


Figure 7.1 Total annual blue swimmer crab catch by calendar year for the South Coast Estuarine Managed Fishery (year t) between 1992 and 2019, compared with the mean annual sea level (m) at Fremantle, Western Australia (year t−2) and annual mean of coastal sea surface temperatures (^{0}C) adjacent to Albany and the Hardy, Irwin and Wilson Inlets (year t−2), from two years prior.

7.3.1.1 Climate Change

A risk assessment of WA's key commercial and recreational finfish and invertebrate species has demonstrated 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 LC, 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 LC resulted in unusually warm ocean temperatures in coastal waters of south-western WA (Pearce *et al.*, 2011). This "marine heatwave" altered the distribution and behaviour (e.g. spawning activity and migration) of some species and caused widespread mortalities of others, such as blue swimmer crabs in Shark Bay resulting in the collapse of this fishery (Chandrapavan *et al.*, 2017; 2019), whereas an increase in catch occurred in the SCB.

A risk screening of WA's key commercial and recreational finfish and invertebrate species revealed *P. armatus* to have a high overall sensitivity to climate change (Caputi *et al.*, 2015). Many of the biological processes of crabs are highly influenced by environmental variables, suggestive of a high sensitivity to climate change. The effects of climate change are likely to differ between blue swimmer crab fisheries in WA, based on the large latitudinal range between crab fisheries.

7.3.2 Introduced Pest Species

The introduction and spread of marine pests in WA waters poses a serious threat to native biodiversity and can have widespread effects on both the economy and public health. The Asian paddle crab (*Charybdis japonica*) has the potential to outcompete native species such as the blue swimmer crab if it becomes established in Australia. There is a biosecurity program run by the Department of Primary Industries and Regional Development (DPIRD) to record sightings of the Asian paddle crab with only very small numbers reported sporadically in south-western Australia.

7.3.3 Market Influences

Blue swimmer and sand crab fishers on the south coast of WA sell their product on the domestic market. Consequently, local demand often dictates the level of catch and effort, and therefore the value, for these small fisheries,

8. Information and Monitoring

8.1 Range of Information

There is limited information available to support the assessment and harvest strategy for the blue swimmer and sand crab resources on the south coast of Western Australia (WA; Table 8.1).

8.2 Monitoring

8.2.1 Commercial Catch and Effort

Monthly statutory catch and effort statistics (CAES) have been used to provide the basis for ongoing stock monitoring in all commercial crab fisheries in the South Coast Bioregion (SCB). This data is critical to the development of stock performance indices and future harvest strategy evaluation.

Under the Fish Resources Management Act (FRMA) *1994*, licensees involved in fishing operations and/or the master of every licensed fishing boat must submit an accurate and complete monthly CAES return on forms approved by the Department. The returns record monthly catch totals (in kg) for each retained species, estimates of daily effort (e.g. number of traps pulled per day), and spatial information by (60 x 60 nm) block. These CAES returns are submitted monthly, with a deadline of 15 days after the end of the month. All CAES returns are validated by Departmental staff, with inconsistencies verified directly with fishers. The information provided in CAES returns is confirmed by processor unloads, which are also provided to the Department on a monthly basis.

In addition to CAES, a Research Daily Logbook is submitted for sand crab as part of the exemption requirements.

Table 8.1 Summary of information available for assessing the crab resource in the South Coast Bioregion: South Coast Estuarine Managed Fishery – SCEMF; Sand Crab, Instrument of Exemption

Data type	Fishery-dependent/ independent	Purpose / Use	Area of collection	Frequency of collection	History of collection
Commercial catch and effort statistics (CAES returns)	Dependent	Commercial catch and effort, catch rates and location of area fished (CAES blocks)	SCEMF IOE	Monthly	Since 1975
Daily Research Logbooks	Dependent	Fine(r) scale monitoring of commercial catch and effort trends, calculation of catch rates and the area fished	Wilson and Irwin Inlet Crab Trap Trial IOE	Daily	2015/16
Commercial monitoring Length-frequency estimates, catch rates	Dependent	Size structure and catch composition and catch rates	SCEMF IOE	Opportunistic	Since 2016
Recreational catch and effort estimates	Dependent	Monitoring of recreational catch and effort trends through boat-based iSurveys	South Coast Bioregion	Biennial	Since 2011/12

8.2.2 Recreational/Charter Catch and Effort

Recreational surveys have been undertaken periodically for a number of specific fisheries over specific time frames. Since 2011, a biennial state-wide recreational survey has been undertaken to collect information on recreational boat-based catch and effort in WA (Ryan *et al.*, 2013; 2015; 2017; 2019). This survey uses three complementary components, off-site phone diary surveys, on-site boat ramp surveys and remote camera monitoring, to collect information on catch, effort, location and other demographic information, every two to three years. The latest 2017/18 survey also collected some information on shore-based recreational fishing by surveyed fishers.

These surveys provide a state-wide and bioregional estimate of the boat-based recreational catch; both kept and released. In each survey, state-wide on-site biological surveys were completed at key boat ramps to obtain length and weight information that would allow estimates of catch by numbers from the phone-diary surveys to be converted to catch by weight. This enables direct comparison of recreational harvest estimates to commercial fishery information, which is routinely recorded as weights.

8.2.3 Fishery-Dependent Monitoring

8.2.3.1 Commercial monitoring

In addition to catch and effort data, Departmental research staff undertake fishery–dependent monitoring on commercial vessels (commercial monitoring surveys) in the SCB on an opportunistic basis. These surveys provide data on catch composition (size structure, sex ratios, berried state), abundance data used to calculate standardised legal catch rates, female size at maturity and spatial distribution of commercial fishing. During each survey, all crabs captured are measured by carapace width (CW) to the nearest mm (spine to spine) using Vernier calipers. Biological information, including sex, moult stage, sexual maturity status and berried state, are collected for each crab based upon visual examination. Any bycatch, obvious predation (*e.g.* by octopus) or dead crabs are also recorded. Data is recorded per line of traps or length of net, and includes the number of traps or metres of net in the line, soak time (number of hours traps or nets have been in the water since last serviced), a start latitude and longitude and a mean depth.

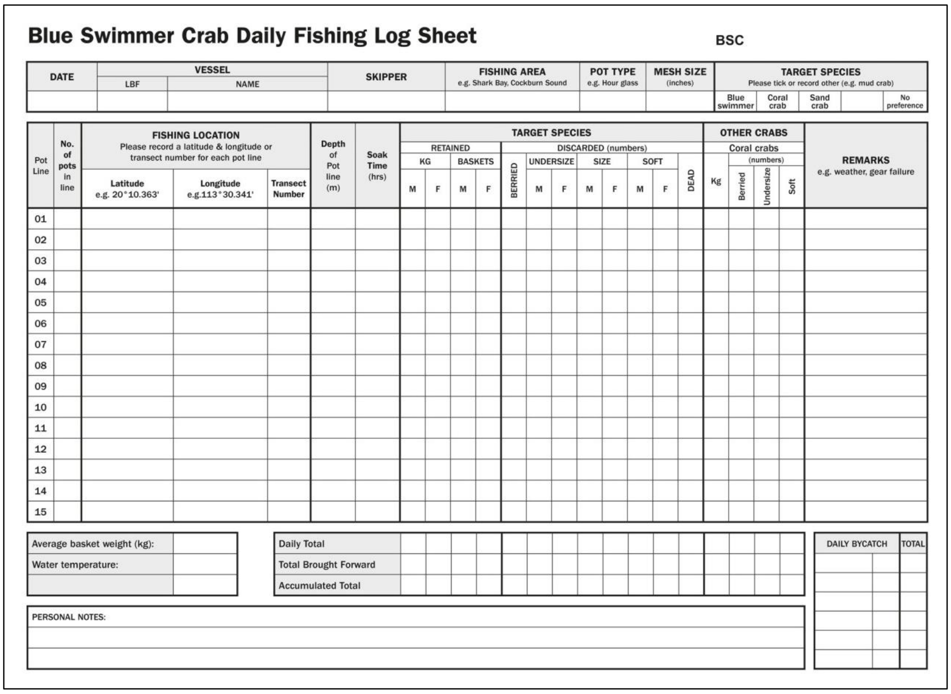
Commercial monitoring of blue swimmer crab fishing was undertaken during 2015 and 2016 in the Irwin and Wilson Inlets and Princess Royal and Oyster Harbours.

Commercial monitoring of sand crab fishing was undertaken in the Albany region in April 2019.

8.2.3.2 Daily Research trap logbooks

Daily Research trap logbooks were introduced as part of Exemption requirements to fish for blue swimmer crabs in the Wilson and Irwin Inlet Crab Trap Trial, and sand crabs on the south coast, to gain finer resolution daily catch and effort data from commercial trap fishers (Figure 8.1). For each line of crab traps, fishers record a latitude and longitude or block reference, the number of traps in the line, depth, trap soak-time and a total catch estimate in either kilograms or numbers of crabs.

Logbook data are validated by comparison with CAES returns, and spatially when transect grid numbers or latitude and longitude details are recorded by fishers. As with CAES requirements, fishers are required to submit monthly logbook returns by the 15th day of the following month.



Blue Swimmer Crab Daily Fishing Log Sheet BSC

DATE	VESSEL LBF	VESSEL NAME	SKIPPER	FISHING AREA e.g. Shark Bay, Cockburn Sound	POT TYPE e.g. Hour glass	MESH SIZE (inches)	TARGET SPECIES Please tick or record other (e.g. mud crab)				
							Blue swimmer	Coral crab	Sand crab		No preference

Pot Line	No. of pots in line	FISHING LOCATION Please record a latitude & longitude or transect number for each pot line: Latitude e.g. 20°10.363'	Longitude e.g.113°30.341'	Transect Number	Depth of Pot line (m)	Soak Time (hrs)	TARGET SPECIES RETAINED KG M	F	BASKETS M	F	DISCARDED (numbers) BERRIED	UNDERSIZE M	F	SIZE M	F	SOFT M	F	DEAD	OTHER CRABS Coral crabs Kg	(numbers) Berried	Undersize	Soft	REMARKS e.g. weather, gear failure
01																							
02																							
03																							
04																							
05																							
06																							
07																							
08																							
09																							
10																							
11																							
12																							
13																							
14																							
15																							

Average basket weight (kg):
Water temperature:

Daily Total
Total Brought Forward
Accumulated Total

DAILY BYCATCH | TOTAL

PERSONAL NOTES:

Figure 8.1 Daily Research log sheet recorded by fishers targeting blue swimmer crabs in the Irwin Inlet and Wilson Inlet Crab Trap Trial, and under an Instrument of Exemption to target sand crabs, in the South Coast Bioregion.

8.2.4 Fishery-Independent Monitoring

There are currently no fishery-independent monitoring surveys carried out on blue swimmer or sand crab fisheries in the SCB.

8.2.5 Environmental Monitoring

Environmental databases for the SCB are continuously updated and extended as new data becomes available from various agency sources such as the Bureau of Meteorology, Department of Water and Environmental Regulation, and the Department of Biodiversity, Conservation and Attractions. The strength of the Leeuwin Current (LC) is monitored using the Fremantle sea level and coastal sea surface temperatures are monitored using satellite data.

9. Stock Assessment

9.1 Assessment Principles

The different methods used by the Department to assess the status of aquatic resources in Western Australia (WA) have been categorised into five broad levels, ranging from relatively simple analysis of catch levels and standardised catch rates, through to the application of more sophisticated analyses and models that involve estimation of fishing mortality and biomass (Fletcher and Santoro, 2015). The level of assessment varies among resources and is determined based on the level of ecological risk, the biology and population dynamics of the relevant species, the characteristics of the fisheries exploiting the species, data availability and historical level of monitoring.

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 specifically the consideration of each available line of evidence, both individually and collectively, to generate the most 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 of the lines of evidence are then combined within the Department's ISO 31000 based risk assessment framework (see Fletcher, 2015) to determine the most appropriate combinations of consequence and likelihood to determine the overall current risk status.

9.2 Assessment Overview

In the absence of a population model, the annual assessment of *P. armatus* is based primarily on an analysis of commercial catch rates, which are assumed to be an index of abundance (Level 2 assessment). Assessment of the south coast blue swimmer and sand crab resources are primarily based on estimates of nominal annual commercial catch and catch rate data from statutory catch and effort returns (CAES). This approach is consistent with Department policy for assessing data-poor fisheries for which available data may not be suitable for producing reliable estimates of biomass. The overall weight-of-evidence assessment also considered the results of a Productivity Susceptibility Analysis (PSA) to evaluate the inherent vulnerability of each species to fishing.

9.2.1 Peer Review of Assessment

Stock assessments of key target species are internally reviewed as part of the Department's process for providing scientific advice to management and the Minister on the status of fish stocks. All blue swimmer crab fisheries underwent pre-assessment against the Marine Stewardship Council (MSC) standard for sustainable fishing in 2013-14 using a bioregional assessment approach (Bellchambers *et al.*, 2016).

9.3 Analyses and Assessments

9.3.1 Data Used in Assessment

CAES / Logbook
Economic data
Environmental data
Fishery-dependent data (commercial and recreational)

9.3.2 Catch and Effort Trends

9.3.2.1 Commercial Catch and Effort

The annual blue swimmer crab catch from the South Coast Bioregion (SCB) has fluctuated considerably over the last 24 years, largely in response to the distribution and amount of fishing effort, the abundance of target fish species, and changing environmental conditions. Peaks in

total annual catch in 2001 (39 t) and 2013–15 (32–54 t) followed years of strong Leeuwin Currents (LC) and above-average water temperatures. The majority of the annual catch has historically come from the Albany region (Princess Royal and Oyster Harbours), with a substantial increase in effort from purpose-designed crab traps over the last 20 years (Figure 9.1,Figure 9.2). However, notable catches have also come from the Wilson and Irwin Inlets during peak catch periods (Figure 9.1).

The total annual blue swimmer crab catch for the South Coast Estuarine Managed Fishery (SCEMF) for 2019 was 19 t, representing a substantial increase on the 7.3 t landed in 2018 (Figure 9.1). The Albany region accounted for 13.2 t of the 2019 total (Princess Royal Harbour: 6 t; Oyster Harbour: 7.2 t), with 5.7 t landed from the Wilson Inlet. While overall catches during 2019 were shared between fishers using purpose-designed crab traps (9.9 t) and set nets (9.1 t; Figure 9.2), there was substantial variation in fishing method between areas. All crabs landed from the Wilson Inlet were captured by net, whereas 75% of the catch from the Albany region was caught using crab traps (Figure 9.2).

As with blue swimmer crab fisheries in the West Coast Bioregion (WCB), catch and effort in the SCB fisheries is highest over summer and autumn (Figure 9.3).

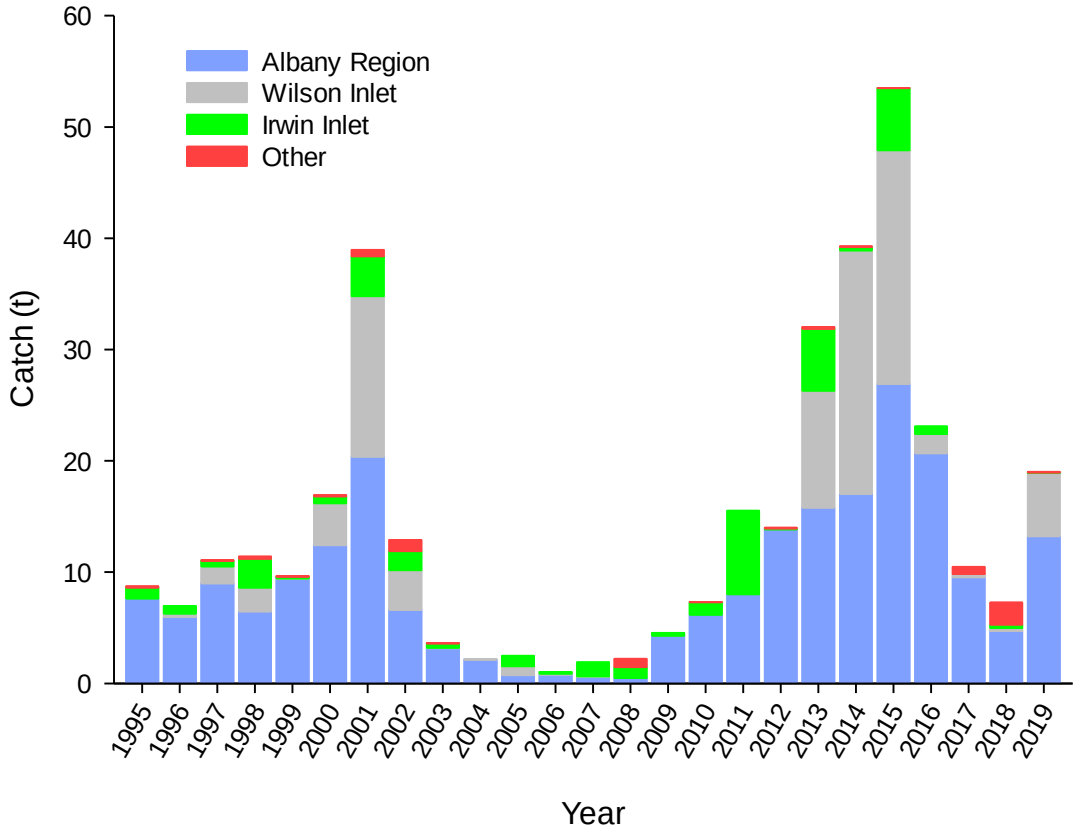


Figure 9.1 Annual commercial blue swimmer crab catch history for the South Coast Estuarine Managed Fishery by fishing area between 1995–2019. The Albany region incorporates primarily the Princess Royal and Oyster Harbours, and King George Sound.

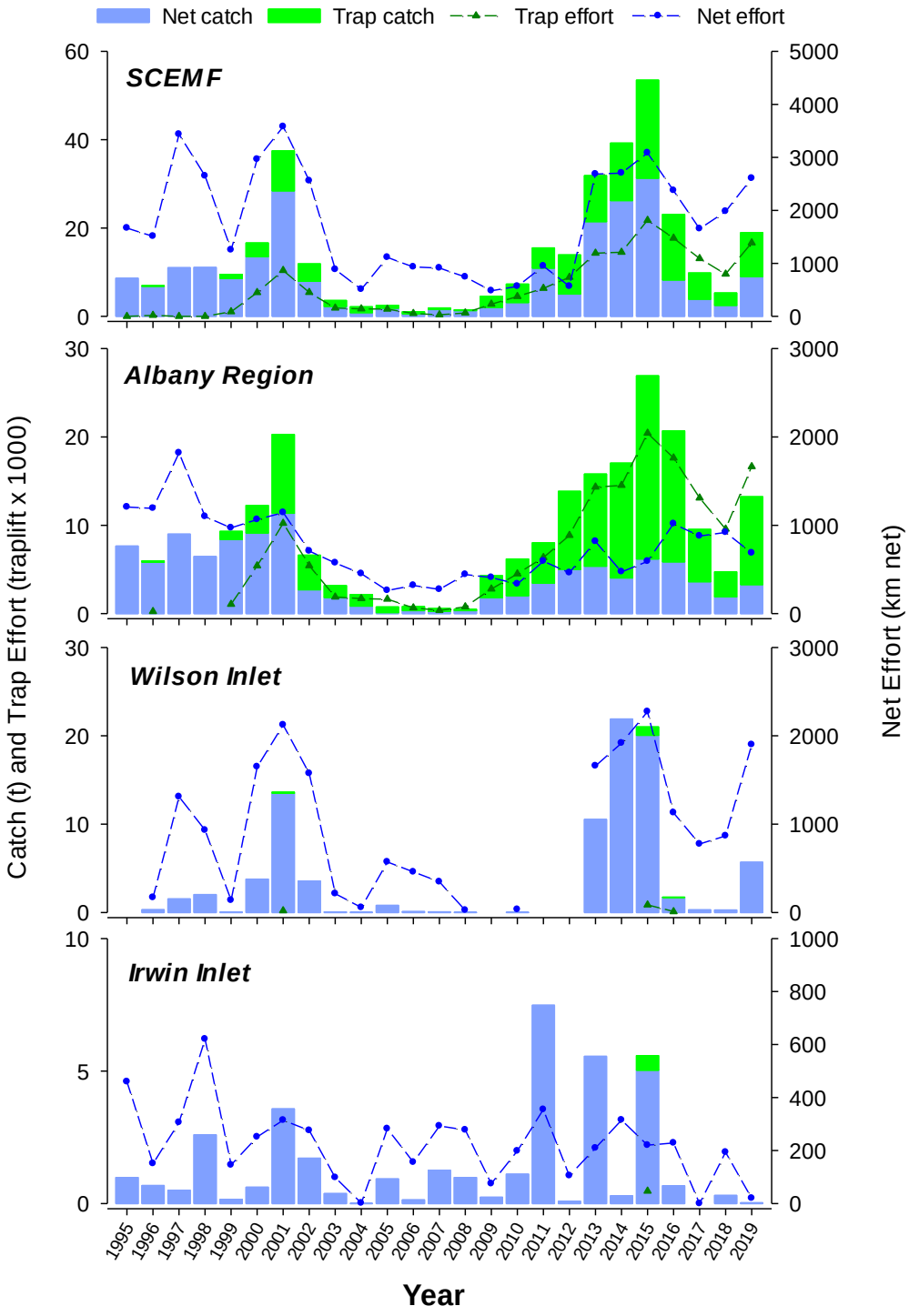


Figure 9.2 Annual (calendar year) commercial blue swimmer crab catch (t) and effort (km net; traplifts x 1000) by method for the South Coast Estuarine Managed Fishery, and by main fishing area, between 1995 and 2019. The Albany Region includes the Princess Royal and Oyster Harbours and King George Sound.

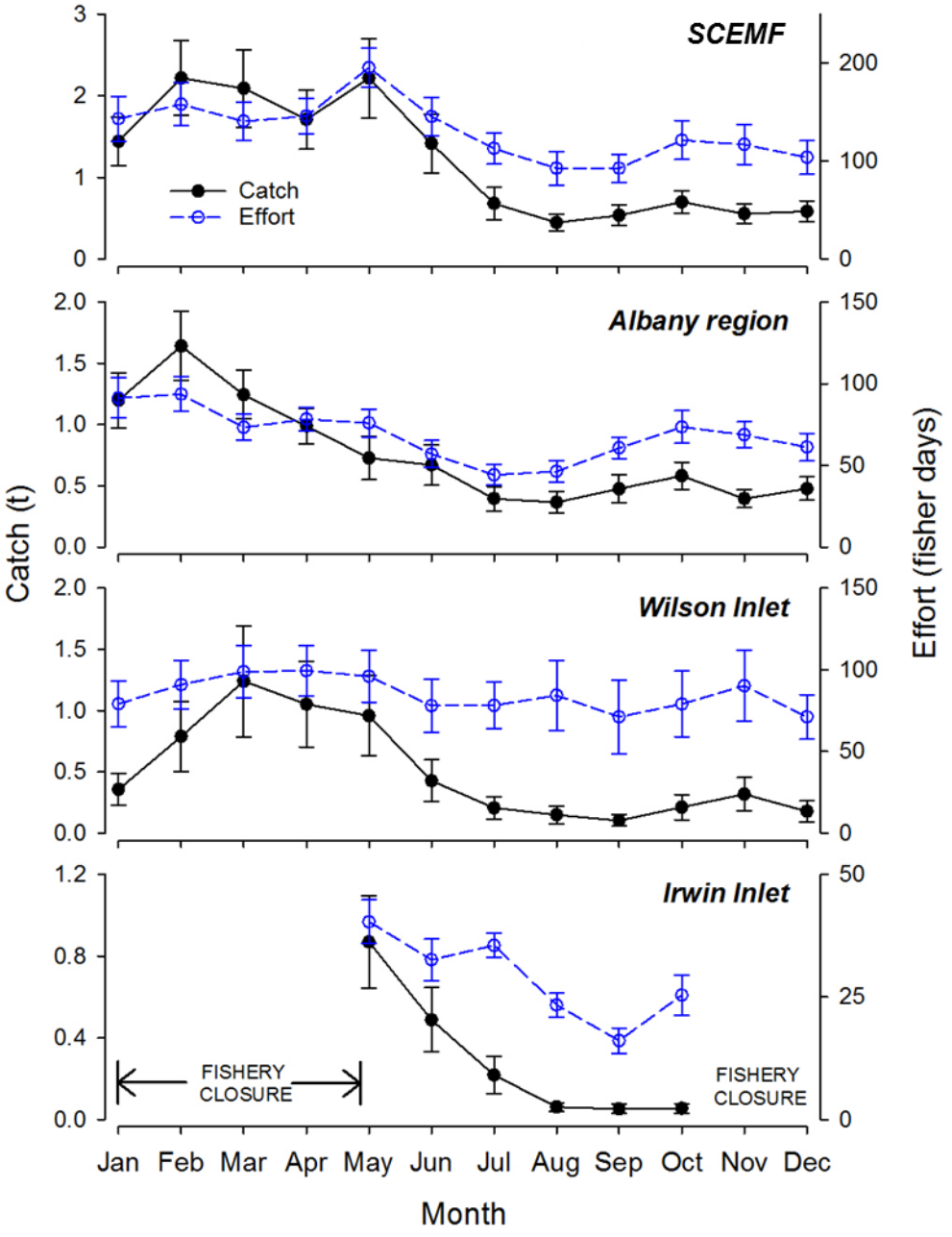


Figure 9.3 Mean monthly commercial blue swimmer crab catch (t) and effort (fisher days) by all methods for the whole South Coast Estuarine Managed Fishery (SCEMF), Albany region (Princess Royal and Oyster Harbours and King George Sound), the Wilson Inlet and the Irwin Inlet between 1995 and 2016. SE bars included. The annual commercial fishing season in the Irwin Inlet runs from May to October.

Annual catches landed by the single fisher targeting sand crabs in the SCB increased from 801 kg in 2016 to 1,854 kg in 2018, before dropping slightly to 1,538 kg in 2019 (Figure 9.4). During this same period annual effort decreased from 1,687 traplifts in 2016 to 874 traplifts in 2019 representing an increased efficiency since exploratory fishing commenced. Catch and effort in this fishery has largely been regulated by market demand for this product.

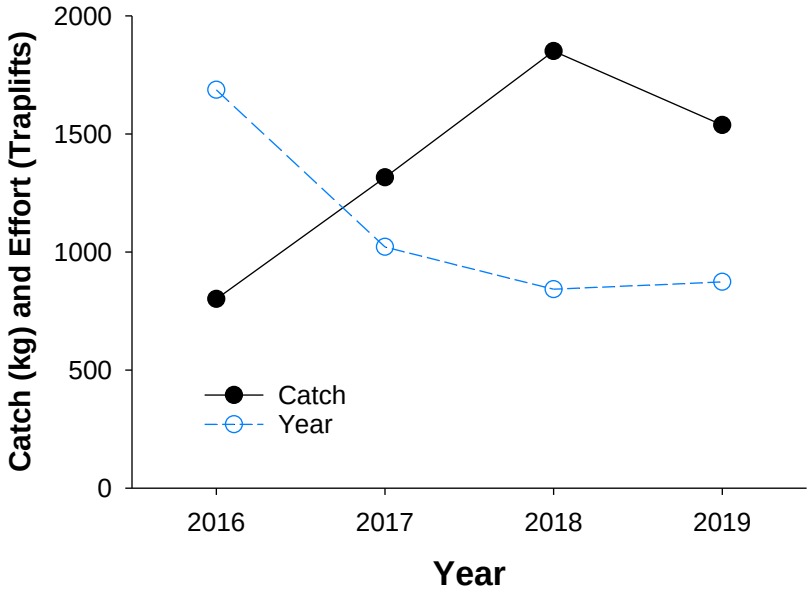


Figure 9.4 Annual commercial catch (kg) and fishing effort (traplifts) of sand crabs by calendar year, in the South Coast Bioregion between 2016–19.

9.3.2.2 Recreational Catch and Effort

Most recreational blue swimmer crab fishing in WA occurs in the WCB. The boat-based recreational harvest range for this region in 2017/18 was estimated to be 45–63 t (95% CI), accounting for 89% of the state total (Ryan *et al.*, 2019).

The boat-based recreational harvest range for blue swimmer crab in the SCB in 2017/18 was estimated to be 0–0.14 t (95% CI), representing <1% of state wide catch (Ryan *et al.*, 2019).

The recreational take of sand crabs in the SCB is negligible, with no boat-based recreational catch reported in 2013/14, 2015/16, 2017/18 (Ryan *et al.*, 2015; 2017; 2019). Estimates of 50 retained, and 31 released, sand crabs were reported for the SCB in the 2011/12 survey (Ryan *et al.*, 2013).

9.3.2.3 Conclusion

South Coast Estuarine Managed Fishery	Historically, annual commercial blue swimmer crab catches in the South Coast Estuarine Managed Fishery have fluctuated considerably in response to variation in fishing effort, abundance, and changing environmental conditions. Annual catch over the last 20 years has ranged from 1–54 t, with peak catches in 2000–02 and 2012–15 coinciding with years of strong Leeuwin Currents. There has been a notable increase in trap effort in the Albany region over the last 20 years that requires ongoing monitoring. The total annual blue swimmer crab catch for the South Coast Estuarine Managed Fishery for 2019 was 19.0 t, representing an increase on the 7 t reported in 2018. Annual recreational catch of blue swimmer crabs in the South Coast Bioregion has been minimal compared with the West Coast Bioregion. In 2017/18, the estimated boat-based recreational catch from the South Coast Bioregion accounted for <1% of the state-wide catch, with an estimated boat-based recreational harvest range of 0–0.14 t.
Instrument of Exemption, sand crab	Annual commercial catch (0.8–1.9 t) and effort (842–1,687 traplifts) by the single fisher targeting sand crabs in the South Coast Bioregion between 2016–19 has remained low, largely regulated by market demand. There was no boat-based recreational catch of sand crabs reported for the South Coast Bioregion in either 2013/14, 2015/16, 2017/18. Estimates of 50 retained, and 31 released, sand crabs were reported for the South Coast Bioregion in the 2011/12 survey.

9.3.3 Catch Distribution Trends

Data to examine the spatial catch distribution trends for blue swimmer crabs in the SCB is restricted to 60 × 60 nm blocks reported in statutory monthly CAES returns, with specific block numbers prescribed for the major inlets and harbours.

The majority of blue swimmer crab catch has historically come from the waters in and around Albany (Princess Royal and Oyster Harbours, and King George Sound), with notable catches from the Wilson and Irwin Inlets during the two peak catch periods (Figure 9.1). The Albany region accounted for 13.2 t of the 2019 annual blue swimmer catch in the SCEMF (Princess Royal Harbour: 6 t; Oyster Harbour: 7.2 t), with 5.7 t landed from the Wilson Inlet (Figure 9.1).

Fishers participating in the Wilson and Irwin Inlet Crab Trap Trial were required to maintain daily research logbooks. As these fishers do not have GPS provision on their vessels, a map was provided that divided the Wilson Inlet fishery into four zones and the Irwin fishery into two. The majority of fishing in both Inlets during 2015 and 2016 took place in the zone closest to the estuary mouth, with 60% of blue swimmer crabs caught in area A in The Wilson Inlet (Figure 9.5), and 97% in Area B in the Irwin Inlet (Figure 9.6).

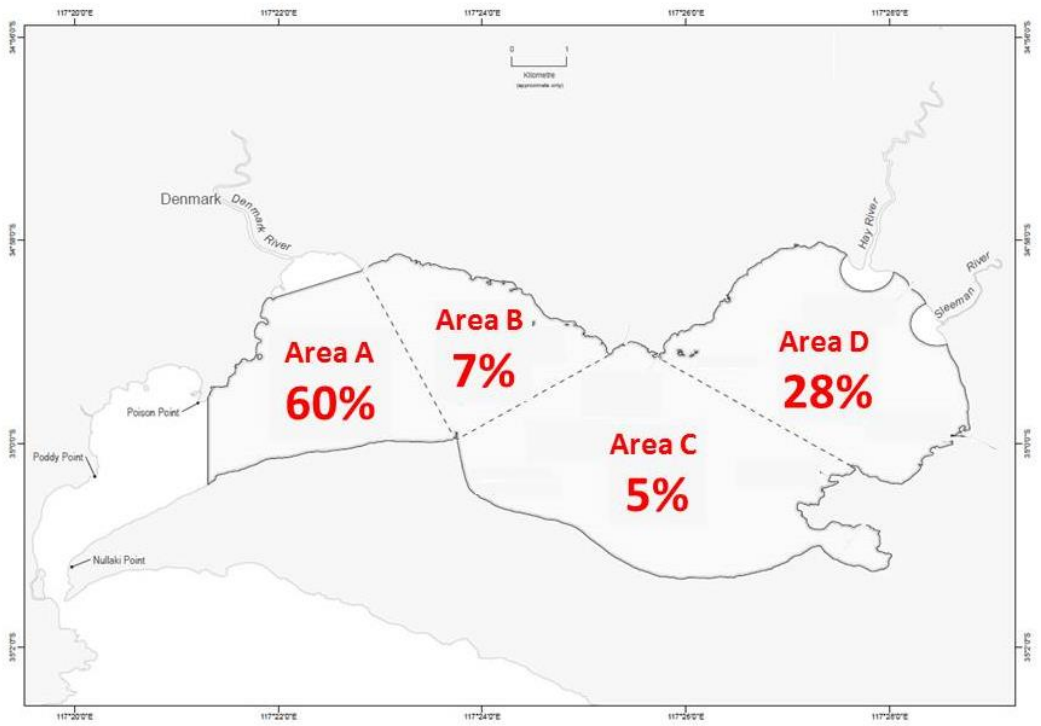


Figure 9.5 Percentage of the blue swimmer crab catch by area in the Wilson Inlet reported by fishers in daily research logbooks during the Wilson and Irwin Inlet Crab Trap Trial in 2015 and 2016.

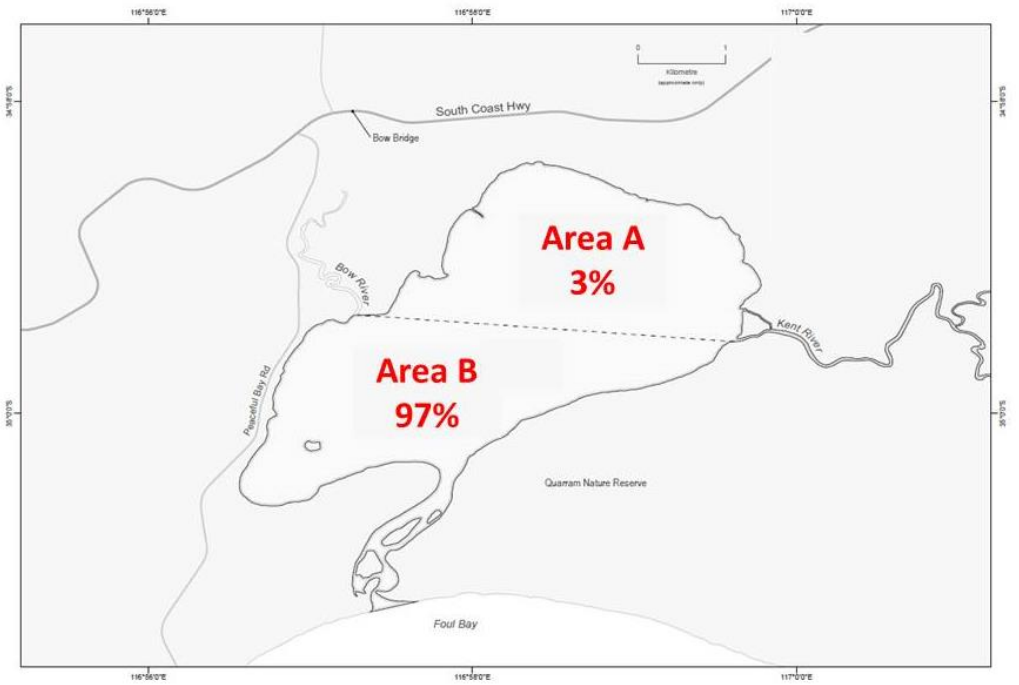


Figure 9.6 Percentage of the blue swimmer crab catch by area in the Irwin Inlet reported by fishers in daily research logbooks during the Wilson and Irwin Inlet Crab Trap Trial in 2015 and 2016.

Due to limited market demand for this product, sand crab effort during the first four years of the (five-year) Exemption has been restricted to the beaches in, and around, the Albany region of the SCB.

9.3.3.1 Conclusion

South Coast Estuarine Managed Fishery	The South Coast Estuarine Managed Fishery spans over 1000 km of nearshore waters along the south coast of WA, and. analysis of spatial data from commercial catch and effort data confirms that the blue swimmer crab stock spans a substantial proportion of the fishery.
Instrument of Exemption, sand crab	During the first four years of the current (five-year) Exemption, limited market demand for this product resulted in fishing for the sand crab being restricted to the beaches in, and around, the Albany region.

9.3.4 Fishery-Dependent Catch Rate Analyses

Overall fishery effort is presented by fisher day, with catch rate (i.e. catch per unit effort; CPUE) as weight (kg) per fisher day, to account for the different effort measures for net and trap sectors. Effort for trap fisheries is presented in traplifts (number of traps pulled per day), and catch rate as weight (kg) per traplift. Net effort is based on net length (number of shots of net length per day), with catch rate presented as weight (kg) per metre of net length. It should be noted that apportioning effort to blue swimmer crab catch from net fishers in the SCEMF is problematic, as the species is generally retained as a by-product while targeting finfish species. Consequently, caution should be exercised in assuming net catch rates present a reliable indicator of crab stock abundance in this fishery.

The total annual nominal catch rate of blue swimmer crabs in the SCEMF (all methods) has fluctuated notably over the last 20 years, from 1.4 kg/fisher day in 2006 to a peak of 15.2 kg/fisher day in 2012 (Figure 9.7). The nominal blue swimmer crab catch rate for 2019 was 6.3 kg/fisher day, almost double the 2018 catch rate of 3.2 kg/fisher day.

Trap catch rates in the Albany region were comparatively consistent across years (~0.4–0.9 kg/traplift); Figure 9.8). However, net catch rates in this area were more variable, with peaks in 2001 and 2010–15 followed periods of strong LC (2000 and 2010–12).

Blue swimmer crab net catch rates were also highly variable across years in the Wilson and Irwin Inlets (Figure 9.8). As with the Albany region, peaks in net catch rate also occurred around 2001 and 2012–15.

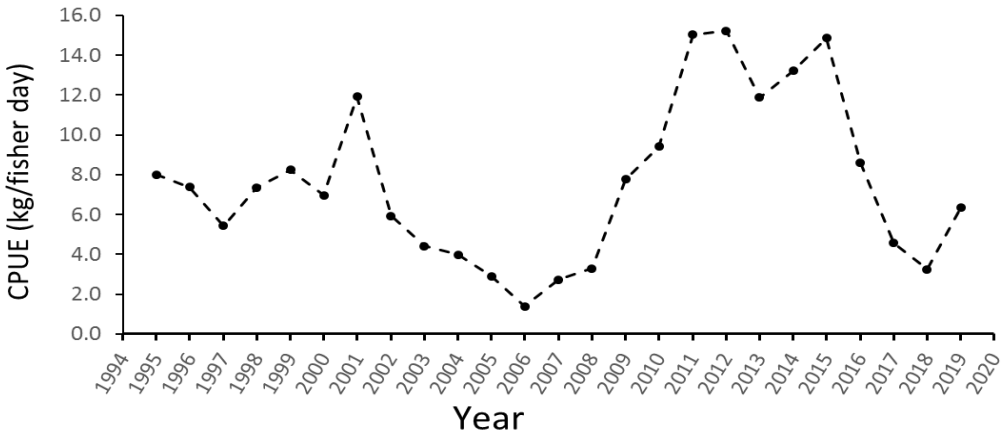


Figure 9.7 Nominal annual commercial blue swimmer crab catch per unit effort (CPUE; kg/fisher day) for all fishing methods in the South Coast Estuarine Managed Fishery from 1995–2019.

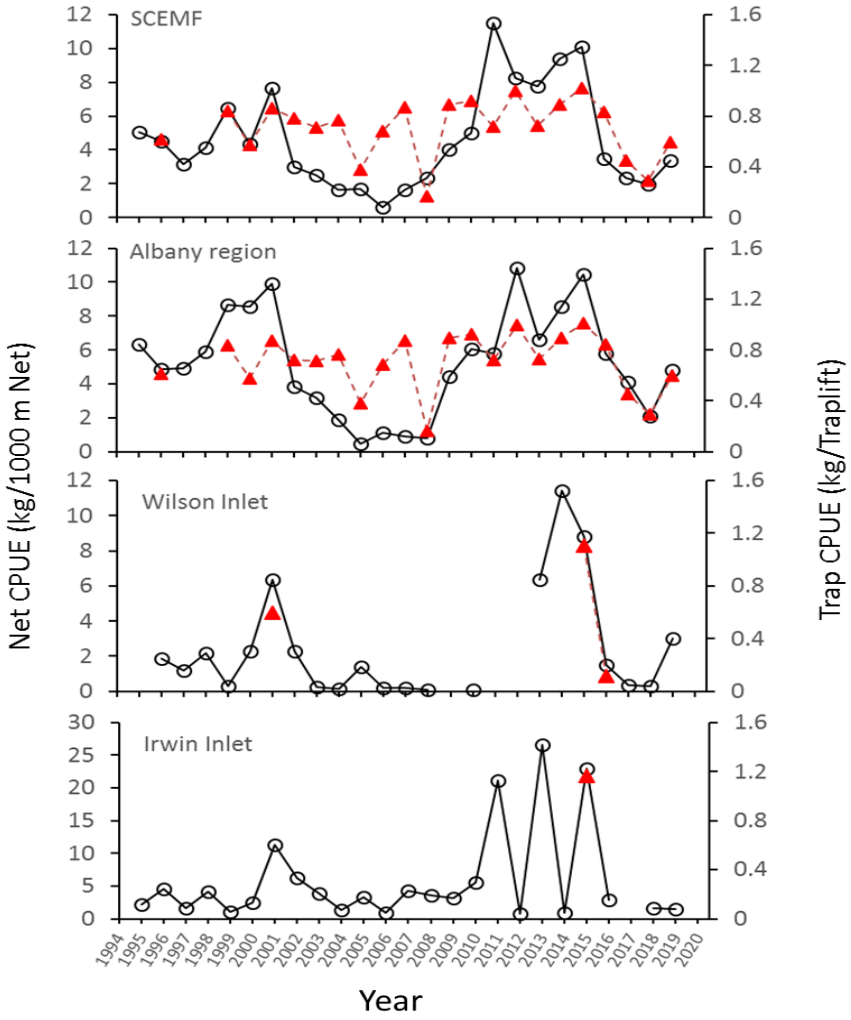


Figure 9.8 Nominal annual commercial blue swimmer crab catch per unit effort (CPUE) for net fishing (kg/1000 m net; O) and trap fishing (kg/traplift; ▲) in the South Coast Estuarine Managed Fishery and its main fishing areas from 1995–2019.

The annual nominal catch rate for sand crabs in the SCB increased from 0.5 kg/traplift in 2016 to 2.2 kg/traplift in 2018, before declining slightly to 1.8 kg/traplift in 2019 (Figure 9.9). This gradual increase was due primarily to increases in fisher knowledge and gear development by the single commercial operator.

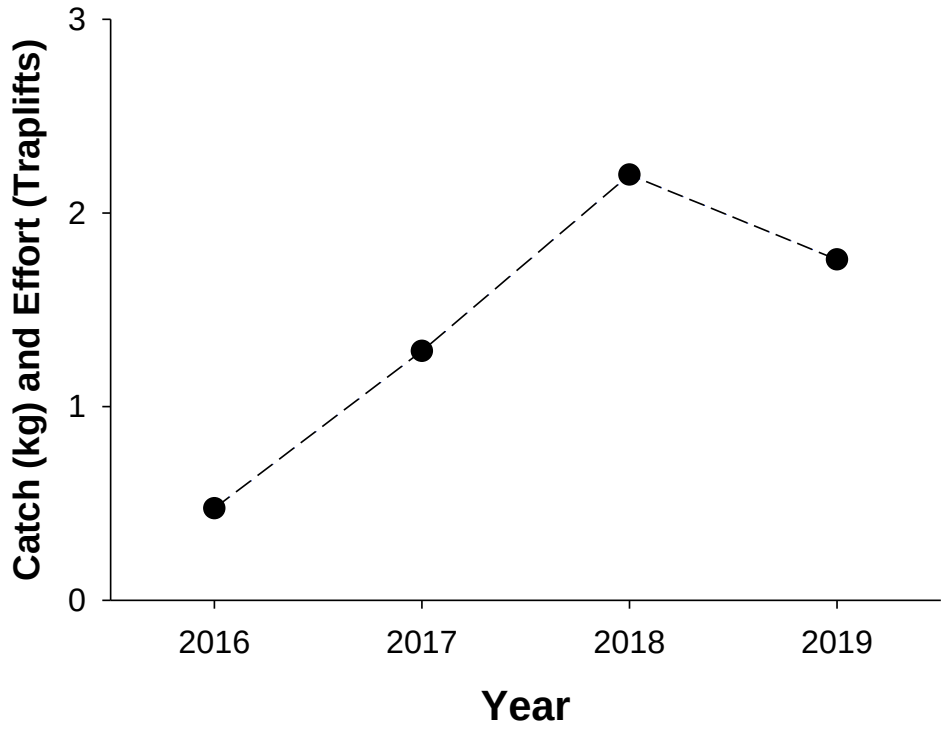


Figure 9.9 Nominal annual commercial sand crab catch per unit effort (CPUE; kg/traplift) for the single fisher operating under Exemption in the South Coast Bioregion from 2016–19.

9.3.4.1 Conclusion

South Coast Estuarine Managed Fishery	The annual nominal catch rate of blue swimmer crabs in the South Coast Estuarine Managed Fishery has fluctuated notably over the last 20 years (from 1.4 kg/fisher day in 2006 to 15.2 kg/fisher day in 2012), primarily in response to variations in fishing effort, the abundance of target fish species, and changing environmental conditions. Peaks in catch rate around 2001 and 2010-15 followed periods of a strong Leeuwin Current. Due to the lack of a suitable period of stable catch and effort data, a harvest strategy for the South Coast Estuarine Managed Fishery has yet to be developed.
Instrument of Exemption, sand crab	The annual nominal catch rate for sand crabs in the South Coast Bioregion increased from 0.5 kg/traplift in 2016 to 2.2 kg/traplift in 2018, before declining slightly to 1.8 kg/traplift in 2019. This gradual increase was due primarily to increases in fisher knowledge and gear development by the single commercial operator as the fishery has developed.

9.3.5 Trends in Size Structures/Sex Ratios

Monitoring aboard commercial blue swimmer crab vessels was undertaken by the Department of Primary Industries and Regional Development (DPIRD) researchers in several south coast estuaries on an opportunistic basis during 2015 and 2016.

The catch recorded during monitoring surveys in the Irwin and Wilson Inlets during the autumn/winter months of 2015 was composed primarily of large (mean: 155 mm carapace width; CW) female crabs and smaller (mean: 147 mm CW) male crabs (Figure 9.10). These results mirrored daily research logbook data reported over the same period by fishers participating in the Wilson and Irwin Inlet Crab Trap Trial (Figure 9.11). In contrast, blue swimmer crabs captured during monitoring surveys aboard commercial vessels in the Princess Royal and Oyster Harbours over the summer/autumn of 2015/16 were also large (mean male: 157 mm CW; mean female: 160 mm CW), and mostly male. These trends are consistent with sex ratios in other WA blue swimmer crab fisheries, where male crabs dominate the catch over the summer months and females over winter.

The proportion of berried females in catches from monitoring surveys in the Princess Royal (76%) and Oyster (66%) Harbours in December 2015 were notably higher than reported in other WA blue swimmer crab fisheries (~20–40%) for this month (Johnston *et al.*, 2020b; Figure 9.10).

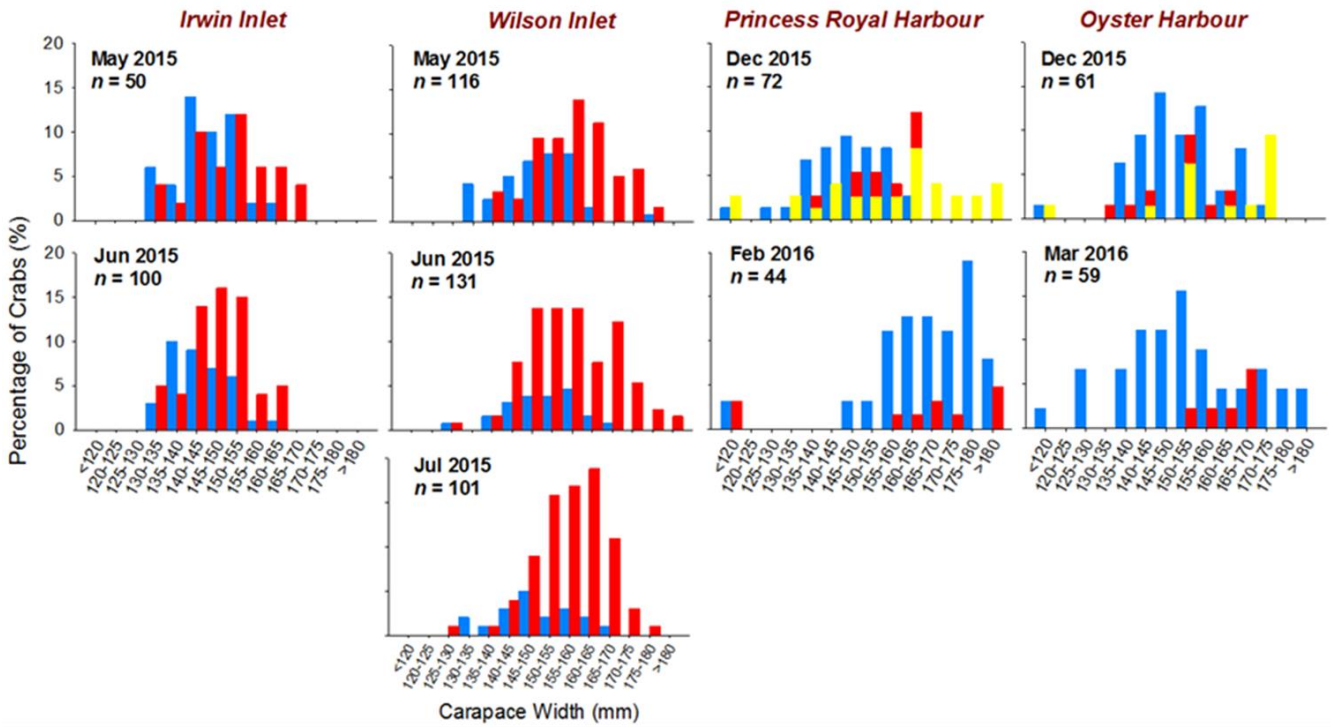


Figure 9.10 Size frequency distributions of male (■), non-berried female (■), and berried female (■) blue swimmer crabs captured by purpose-designed crab trap during opportunistic catch monitoring surveys in several estuaries in the South Coast Estuarine Managed Fishery during 2015 and 2016.

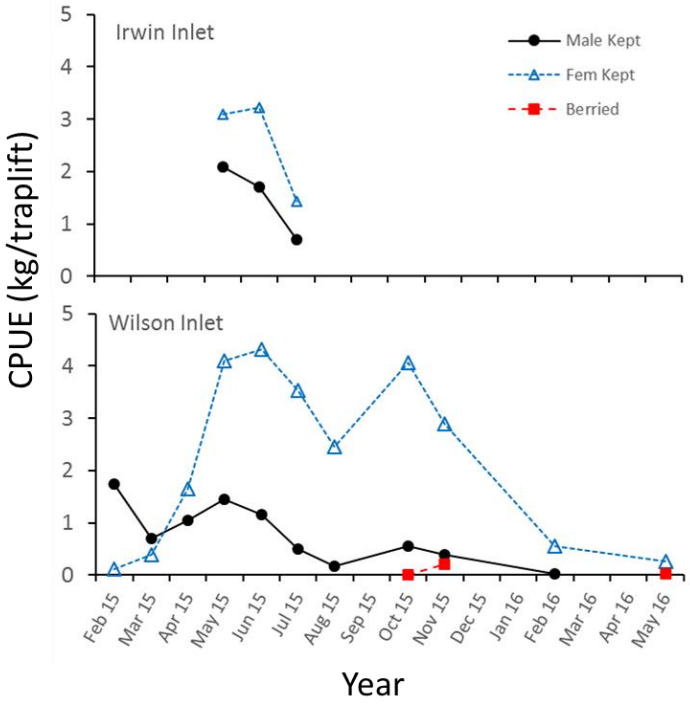


Figure 9.11 Nominal catch per unit effort (CPUE) of retained male, retained female, and berried female blue swimmer crabs reported in Daily Research Logbooks by fishers endorsed to participate in the Wilson and Irwin Inlet Crab Trap Trial between February 2015 and May 2016.

Monitoring aboard a commercial sand crab vessel was undertaken by DPIRD researchers in the Albany region during April 2019. Two cohorts of crabs were identified: a smaller cohort (40–85 mm CW) composed of equal numbers of male and female crabs, and a larger cohort (75–110 mm CW) composed exclusively of male crabs (Figure 9.12). It is unclear whether male domination of the larger cohort reflected trap selectivity or variation in the spatial distribution of sexes.

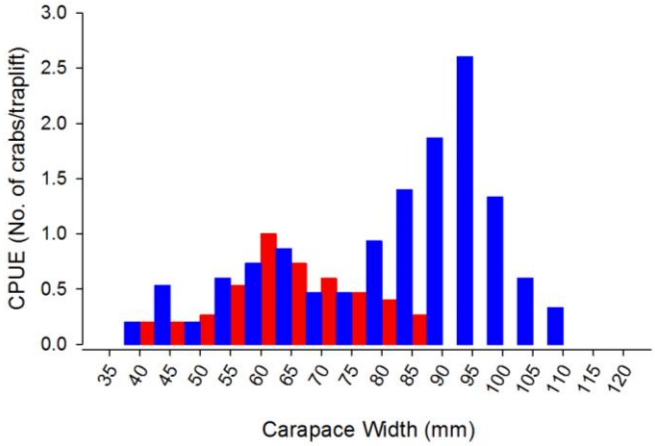


Figure 9.12 Nominal catch rates (numbers of crabs/traplift) of male ( ) and female ( ) sand crabs sampled during a catch monitoring survey in the Albany region in April 2019.

9.3.5.1 Conclusion

South Coast Estuarine Managed Fishery	The carapace width of the majority of blue swimmer crabs sampled during commercial monitoring surveys in the main fishing areas of the South Coast Estuarine Managed Fishery (Wilson and Irwin Inlets, Princess Royal and Oyster Harbours) ranged between 130–180 mm CW, which is similar to the Swan-Canning estuary but substantially higher than many other estuarine fisheries in Western Australia. Further research needs to be undertaken to identify nursery areas for juvenile crabs in this fishery. Crab sex ratios across months in the South Coast Estuarine Managed Fishery are consistent with other West Australian fisheries, with males dominating the catch over summer and females over winter.
Instrument of Exemption, sand crab	While there is no information on size structure in the literature for the sand crab in Western Australian waters, data from a commercial monitoring survey in the Albany region identified two size cohorts in the catch. Sand crabs in the South Coast Bioregion appear to be notably smaller than those in South Australian fisheries.

9.3.6 Productivity Susceptibility Analysis

PSA is a semi-quantitative risk analysis originally developed for use in 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 Appendix 1; 2).

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 is because of the simplicity and prescriptiveness of the approach, which means that risk scores are very sensitive to input data and there is 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 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.

For the purposes of this PSA analysis, productivity scores are attributed to both commercial and recreational sectors that access the blue swimmer crab, *Portunus armatus*, and the sand crab, *Ovalipes australiensis* in the SCB.

9.3.6.1 Productivity

9.3.6.1.1 Blue Swimmer Crab

Key factors influencing the productivity score for *P. armatus* include a short lifespan (and thus also low age at maturity), high fecundity, broadcast spawning strategy, and a mid-trophic level (Table 9.1). Density dependence is uncertain, with no clear evidence for either compensatory or depensatory dynamics. Therefore, a precautionary approach has been taken and a moderate score allocated. The total productivity score for this species averaged 1.33 (Table 9.1).

Table 9.1 PSA productivity scores for the blue swimmer crab, *Portunus armatus,* in all fisheries targeting the resource in the South Coast Bioregion.

Productivity attribute	Portunus armatus
Average maximum age	**1**
Average age at maturity	**1**
Reproductive strategy	**1**
Fecundity	**1**
Trophic level	**2**
Density dependence	**2**
Total productivity (average)	**1.33**

9.3.6.1.2 Sand Crab

For the purposes of this PSA analysis, the sand crab assemblages in the SCB are deemed to comprise a single stock.

Key factors influencing the productivity score for *O. australiensis* include a short lifespan (and thus also low age at maturity), high fecundity, broadcast spawning strategy, and mid-trophic level (Table 9.2).

The total productivity score for this species averaged 1.33 (Table 9.2).

Table 9.2 PSA productivity scores for the sand crab, *Ovalipes australiensis,* in all fisheries targeting the resource in the South Coast Bioregion.

Productivity attribute	Ovalipes australiensis
Average maximum age	**1**
Average age at maturity	**1**
Reproductive strategy	**1**
Fecundity	**1**
Trophic level	**2**
Density dependence	**2**
Total productivity (average)	**1.33**

9.3.6.2 Susceptibility

9.3.6.2.1 Blue Swimmer Crab

Key factors influencing the score for susceptibility of the blue swimmer crab stock targeted by the commercial and recreational sectors in the SCB include low to medium availability (areal overlap), high encounterability (vertical overlap), and medium selectivity and post-capture mortality. Taking into account these factors, the commercial sector scored 1.58 for susceptibility while the recreational sector scored 1.28 (Table 9.3).

The overall weighted PSA score for this stock was 2.05, and the MSC PSA-derived score was 94 (≥80 = low risk).

Table 9.3 PSA susceptibility scores for each sector that impacts on *Portunus armatus* in the South Coast Bioregion, which for the purpose of PSA analysis have been regarded as one stock.

Susceptibility attribute	Commercial	Recreational
Areal overlap	**2**	**1**
Encounterability	**3**	**3**
Selectivity	**2**	**2**
Post-capture mortality	**2**	**2**
Total susceptibility (multiplicative)	**1.58**	**1.28**

9.3.6.2.2 Sand Crab

Key factors influencing the score for susceptibility of the sand crab stock in the SCB included low availability (areal overlap) and post-release mortality, but high encounterability (vertical overlap) and selectivity.

The sand crab stock scored 1.20 for susceptibility for both the commercial and recreational sector (Table 9.4).

The overall weighted PSA score for this stock was 2.05 and the MSC PSA-derived score was 98 (≥80 = low risk).

Table 9.4 PSA susceptibility scores for each sector that impacts on *Ovalipes australiensis* in the South Coast Bioregion, which for the purpose of PSA analysis have been regarded as one stock.

Susceptibility attribute	Commercial	Recreational
Areal overlap	**1**	**1**
Encounterability	**3**	**3**
Selectivity	**3**	**3**
Post-capture mortality	**1**	**1**
Total susceptibility (multiplicative)	**1.20**	**1.20**

9.3.6.3 Conclusion

Based on the productivity and susceptibility scores, the overall weighted (by fishery and sector catches) PSA scores for *Portunus armatus* in the SCB was 2.05.

South Coast Estuarine Managed Fishery	The blue swimmer crab stock in the South Coast Bioregion scored 1.33 for productivity, with short longevity (and thus also low age at maturity), high fecundity, a broadcast spawning strategy, and mid-trophic level as key factors influencing this score. The commercial and recreational sectors scored 1.58 and 1.28 for susceptibility, respectively, accounting for key factors like low to medium availability (areal overlap), high encounterability (vertical overlap), and medium selectivity and post-capture mortality. The overall PSA score was 2.05, with an MSC PSA-derived score of 94 (≥80 = low risk). The PSA analysis indicates that the risk of unacceptable stock depletion is low under current management arrangements and fishing effort. It assumes that the productivity of the stock is constant and not impacted by environmental conditions.
Instrument of Exemption, sand crab	The crab stock in the South Coast Bioregion scored 1.33 for productivity, with short longevity (and thus also low age at maturity), high fecundity, a broadcast spawning strategy, and mid-trophic level the key factors influencing this score. The stock scored 1.20 for susceptibility, with key factors including low availability (areal overlap) and post-release mortality, but high encounterability (vertical overlap) and selectivity. The overall PSA score was 1.79, with an MSC PSA-derived score of 98 (= low risk). The PSA analysis indicates that the risk of unacceptable stock depletion is low under current management arrangements and fishing effort. It assumes that the productivity of the stock is constant and not impacted by environmental conditions.

9.3.7 Fishery-Independent Data Analyses

No fishery independent surveys are undertaken on blue swimmer or sand crab stocks in the SCB.

9.4 Stock Status Summary

Presented below is a summary of each line of evidence considered in the overall Weight of Evidence assessment of the stocks that comprise the blue swimmer and sand crab resources in the SCB, followed by management advice and recommendations for future monitoring of the species.

9.4.1 Weight of Evidence Risk Assessment

9.4.1.1 Blue Swimmer Crab

Category	Lines of evidence (Consequence/Status)
Catch and Effort	Historically, annual commercial blue swimmer crab catches in the South Coast Estuarine Managed Fishery have fluctuated considerably in response to variation in fishing effort, abundance, and changing environmental conditions. Annual catch over the last 20 years has ranged from 1-54 t, with peak catches in 2000–02 and 2012–15 coinciding with years of strong Leeuwin Currents. The total annual blue swimmer crab catch for the South Coast Estuarine Managed Fishery for 2019 was 19.0 t, representing an increase on the 7 t reported in 2018. Annual recreational catch of blue swimmer crabs in the South Coast Bioregion has been minimal compared with the West Coast Bioregion. In 2017/18, the estimated boat-based recreational catch from the South Coast Bioregion accounted for <1% of the state-wide catch, with an estimated boat-based recreational harvest range of 0–0.14 t.
Catch Distribution Trends	The South Coast Estuarine Managed Fishery spans over 1000 km of nearshore waters along the south coast of WA, and. analysis of spatial data from commercial catch and effort data confirms that the blue swimmer crab stock spans a substantial proportion of the fishery.
Fishery-Dependent Catch Rate Analyses	The annual nominal catch rate of blue swimmer crabs in the South Coast Estuarine Managed Fishery has fluctuated notably over the last 20 years (from 1.4 kg/fisher day in 2006 to 15.2 kg/fisher day in 2012), primarily in response to variations in fishing effort, the abundance of target fish species, and changing environmental conditions. Peaks in catch rate around 2001 and 2010–15 followed periods of strong Leeuwin Currents. Due to the lack of a suitable period of stable catch and effort data, a harvest strategy for the South Coast Estuarine Managed Fishery has yet to be developed.
Trends in Size Structures/Sex Ratios	The carapace width of the majority of blue swimmer crabs sampled during commercial monitoring surveys in the main fishing areas of the South Coast Estuarine Managed Fishery (Wilson and Irwin Inlets, Princess Royal and Oyster Harbours) ranged between 130–180 mm CW, substantially higher than many other estuarine fisheries in Western Australia. Crab sex ratios across months in the South Coast Estuarine Managed Fishery are consistent with other West Australian fisheries, with males dominating the catch over summer and females over winter.
Productivity and Susceptibility Analysis	The blue swimmer crab stock in the South Coast Bioregion scored 1.33 for productivity, with short longevity (and thus also low age at maturity), high fecundity, a broadcast spawning strategy, and mid-trophic level as key factors influencing this score. The commercial and recreational sectors scored 1.58 and 1.28 for susceptibility, respectively, accounting for key factors like low to medium availability (areal overlap), high encounterability (vertical overlap), and medium selectivity and post-capture mortality. The overall PSA score was 2.05, with an MSC PSA-derived score of 94 (≥80 = low risk). The PSA analysis indicates that the risk of unacceptable stock depletion is low under current management arrangements and fishing effort. It assumes that the productivity of the stock is constant and not impacted by environmental conditions.

Blue Swimmer Crab Risk Matrix

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

As a specific harvest strategy has yet to be developed for the SCEMF blue swimmer crab stock, relevant lines of evidence from the Weight of Evidence Risk Assessment have been used to determine the following Likelihood and Risk levels:

C1 (Minimal Depletion): **Possible L3 -** Although a harvest strategy has yet to be developed for the SCEMF blue swimmer crab stock, historical fluctuations in catch have largely been in response to variations in fishing effort, the abundance of target fish species (blue swimmer crabs are generally taken as by-product), or changing environmental conditions. As all other lines of evidence (including spatial footprint of fishing and available information on population distribution) are indicative of low exploitation pressure on a large overall population, it is possible that the stock has only experienced minimal depletion to date.

C2 (Moderate Depletion): **Unlikely L2 -** All of the lines of evidence are consistent with the stock level to be acceptable (see above). Although fishery-independent sampling will be needed to more accurately estimate stock biomass, the current estimates suggest that it is unlikely that the stock has experienced moderate depletion to date.

C3 (High Depletion): **Remote 1 –** As highest crab abundance in the SCB coincides with periods of a strong LC, it is likely that recruitment is supplemented by larval flow from more northern stocks. An unacceptable level of depletion in this fishery is therefore remote due to low levels of fishing effort and recruitment primarily occurring in more northern waters of the West Coast Bioregion.

C4 (Major Depletion): **NA –** Not plausible given available lines of evidence.

9.4.1.2 Sand Crab

Category	Lines of evidence (Consequence/Status)
Catch and Effort	Annual commercial catch (0.8–1.9 t) and effort (842–1,687 traplifts) by the single fisher targeting sand crabs in the South Coast Bioregion between 2016-19 has remained low, largely regulated by market demand. There was no boat-based recreational catch of sand crabs reported for the South Coast Bioregion in either 2013/14, 2015/16, 2017/18. Estimates of 50 retained, and 31 released, sand crabs were reported for the South Coast Bioregion in the 2011/12 survey.
Catch Distribution Trends	During the first four years of the current (five-year) Exemption, limited market demand for this product resulted in fishing for the sand crab being restricted to the beaches in, and around, the Albany region.
Fishery-Dependent Catch Rate Analyses	The annual nominal catch rate for sand crabs in the South Coast Bioregion increased from 0.5 kg/traplift in 2016 to 2.2 kg/traplift in 2018, before declining slightly to 1.8 kg/traplift in 2019. This gradual increase was due primarily to increases in fisher knowledge and gear development by the single commercial operator as the fishery has developed.
Trends in Size Structures/Sex Ratios	While there is no information on size structure in the literature for the sand crab in Western Australian waters, data from a commercial monitoring survey in the Albany region identified two size cohorts in the catch. sand crabs in the South Coast Bioregion appear to be notably smaller than those in South Australian fisheries.
Productivity and Susceptibility Analysis	The crab stock in the South Coast Bioregion scored 1.33 for productivity, with short longevity (and thus also low age at maturity), high fecundity, a broadcast spawning strategy, and mid-trophic level the key factors influencing this score. The stock scored 1.20 for susceptibility, with key factors including low availability (areal overlap) and post-release mortality, but high encounterability (vertical overlap) and selectivity. The overall PSA score was 1.79, with an MSC PSA-derived score of 98 (= low risk). The PSA analysis indicates that the risk of unacceptable stock depletion is low under current management arrangements and fishing effort. It assumes that the productivity of the stock is constant and not impacted by environmental conditions.

Sand Crab Risk Matrix

Consequence (Stock Depletion) Level	Likelihood				Risk Score
	L1 Remote (<5%)	L2 Unlikely (5- <20%)	L3 Possible (20- <50%)	L4 Likely (≥50%)	
C1 Minimal				X	2
C2 Moderate	X				2
C3 High	NA				NA
C4 Major	NA				NA

C1 (Minimal Depletion): **Unlikely L2 -** Although a harvest strategy has yet to be developed for the sand crab stock in the SCB, current commercial fishing levels are extremely low and recreational effort is negligible. As all lines of evidence (including spatial footprint of fishing and available information on population distribution) are indicative of low exploitation pressure on a large overall population, it is likely that the stock has experienced minimal depletion to date.

C2 (Moderate Depletion): **Remote L1 -** All of the lines of evidence are consistent with the stock level to be acceptable (see above). Although fishery-independent sampling will be required to more accurately estimate stock biomass, the current estimates suggest there is only a remote likelihood that the stock has experienced moderate depletion to date.

C3 (High Depletion): **NA –** Not plausible given available lines of evidence.

C4 (Major Depletion): **NA –** Not plausible given available lines of evidence.

9.4.2 Current Risk Status

9.4.2.1 Blue Swimmer Crab

Based on the information available, the current risk level to the blue swimmer crab in the SCB is estimated to be LOW (C2 × L2). The Low Risk (see Appendix 2) reflects an acceptable level of current fishing mortality, with all lines of evidence consistent with this conclusion. Hence, the overall Weight of Evidence assessment indicates the status of the blue swimmer crab stock is adequate and that current management settings are maintaining risk at acceptable (low) levels.

However, it should be noted that this score assumes total catch and effort will be maintained at near current levels. Any sustained increase could require the development and implementation of a suitable set of management arrangements for all sectors to ensure current levels are restored, and that the stock status is monitored at regular intervals into the future.

9.4.2.2 Sand Crab

Based on the information available, the current risk level to the sand crab in the SCB is estimated to be LOW (C1 × L4). The Low Risk reflects an acceptable level of current fishing mortality, with all lines of evidence consistent with this conclusion. Hence, the overall Weight

of Evidence assessment indicates the status of the sand crab stock is adequate and that current management settings are maintaining risk at acceptable (low) levels.

However, it should be noted that this score assumes total catch will be maintained at near current levels. Any sustained increase could require the development and implementation of a suitable set of management arrangements for all sectors to ensure current levels are restored, and that the stock status is monitored at regular intervals into the future.

9.4.3 Future Monitoring

Due to the low level of fishery data available for the commercial fishing of blue swimmer and sand crabs in the SCB, a conservative management regime is required. Until harvest strategies are developed, nominal commercial blue swimmer and sand crab catch and effort in the SCB will be used in a Weight of Evidence approach to assess each crab resource in this fishery. If either of these fisheries expands to consistent fishing across a greater regional area, and temporally across more months within each year, analyses may include the standardisation of catch rates to account for differences across months and CAES blocks to assess the performance of the fishery.

However, future monitoring will need to be assessed in relation to the value of each crab resource (i.e. size and social value of each fishery).

10. References

Bellchambers, L.M., Smith, K.D. and Evans, S.N., 2005. Effect of Exposure to Ice Slurries on Nonovigerous and Ovigerous Blue Swimmer Crabs, *Portunus pelagicus*. *Journal of Crustacean Biology*, **25(2):** 274-278.

Bellchambers, L.M., Gaughan, D.J., Wise, B.S., Jackson, G. and Fletcher, W.J., 2016. Adopting Marine Stewardship Council certification of Western Australian fisheries at a jurisdictional level: the benefits and challenges. *Fisheries Research*, **183**: 609-616.

Bryars, S.R. and Havenhand, J.N., 2006. Effects of constant and varying temperatures on the development of blue swimmer crab (*Portunus pelagicus*) larvae: Laboratory observations and field predictions for temperate coastal waters. *Journal of Experimental Marine Biology and Ecology*, **329:** 218-229.

Caputi, N., Brown, R.S. and Chubb, C.F., 1995. Relationship between spawning stock, environment, recruitment and fishing effort for the western rock lobster, *Panulirus cygnus*, fishery in Western Australia. *Crustaceana*, **68:** 213-226.

Caputi, N., Feng, M., Pearce, A., Benthuysen, J., Denham, A., Hetzel, Y., Matear, R., Jackson, G., Molony, B., Joll, L. and Chandrapavan, A., 2015. Management implications of climate change effect on fisheries in Western Australia. Part 1. Environmental change and risk assessment. Department of Fisheries, Western Australia.

Chandrapavan A, Kangas MI, Johnston D, Caputi N, Hesp A, Denham A and Sporer E., 2017. Improving confidence in the management of the blue swimmer crab (*Portunus armatus*) in Shark Bay. Part 1. Rebuilding of the Shark Bay Crab Fishery. FRDC Project No. 2012/15. Fisheries Research Report No. 283. Department of Fisheries, Western Australia.

Chandrapavan, A., Caputi, N. and Kangas, M.I., 2019. The Decline and Recovery of a Crab Population from an Extreme Marine Heatwave and a Changing Climate. *Frontiers in Marine Science*, **6:** 510.

de Lestang, S., 2002. Biology of the blue swimmer crab, *Portunus pelagicus* (Linnaeus), in Western Australia. *PhD thesis*. Murdoch University, Western Australia.

de Lestang, S., Bellchambers, L.M., Caputi, N., Thomson, A.W., Pember, M.B., Johnston, D.J. and Harris, D.C., 2010. Stock-Recruitment-Environment Relationship in a *Portunus pelagicus* Fishery in Western Australia. In, Kruse, G.H., Eckert, G.L., Foy, R.J., Lipcius, R.N., Sainte-Marie, B., Stram, D.L. and Woodby, D. (eds.). Biology and Management of Exploited Crab Populations under Climate Change. Alaska Sea Grant, University of Alaska Fairbanks.

Deakin, S., 1996. Reproductive biology of the sand crab (*Ovalipes australiensis*) found in the Farm Beach/Point Longnose Area. *Honours thesis*, Adelaide University, South Australia. 54 pp.

Department of Fisheries – DoF, 2015. Harvest Strategy Policy and Operational Guidelines for the Aquatic Resources of Western Australia. Fisheries Management Paper No. 271. Department of Fisheries, Western Australia.

Fisher, M.R., 1999. Effect of temperature and salinity on size at maturity of female blue crabs. *Transactions of the American Fisheries Society,* **128(3):** 499-506.

Fletcher, W.J., 2002. Policy for the implementation of ecologically sustainable development for fisheries and aquaculture within Western Australia. Fisheries Management Paper No. 157. Department of Fisheries, Western Australia.

Fletcher, W.J., 2015. Review and refinement of an existing qualitative risk assessment method for application within an ecosystem-based fisheries management framework. *ICES Journal of Marine Science,* **72:** 1043-1056.

Fletcher, W.J. and Santoro, K. (eds.), 2015. Status reports of the fisheries and aquatic resources of Western Australia 2014/15: State of the fisheries. Department of Fisheries, Western Australia.

Fletcher, W.J., Shaw, J., Metcalf, S.J. and Gaughan, D.J., 2010. An Ecosystem Based Fisheries Management framework: the efficient, regional-level planning tool for management agencies. *Marine Policy,* **34**: 1226-1238.

Fletcher, W.J., Wise, B.S., Joll, L.M., Hall, N.G., Fisher, E.A., Harry, A.V., Fairclough, D.V., Gaughan, D.J., Travaille, K., Molony, B.W. and Kangas, M., 2016. Refinements to harvest strategies to enable effective implementation of Ecosystem Based Fisheries Management for the multi-sector, multi-species fisheries of Western Australia. *Fisheries Research,* **183**: 594-608.

Giri, K. and Hall, K., 2015. South Australian Recreational Fishing Survey. Fisheries Victoria Internal Report Series No. 62.

Henry, G. and Lyle, J., 2003. The National Recreational and Indigenous Fishing Survey, Fisheries Research and Development Corporation, Natural Heritage Trust and NSW Fisheries, Australian Capital Territory.

Hobday, A.J., Smith, A.D.M., Stobutzki, I.C., Bulman, C., Daley, R., Dambacher, J.M., Deng, R.A., Dowdney, J., Fuller, M., Furlani, D., Griffiths, S.P., Johnson, D., Kenyon, R., Knuckey, I.A., Ling, S.D., Pitcher, R., Sainsbury, K.J., Sporcic, M., Smith, T., Turnbull, C., Walker, T.I., Wayte, S.E., Webb, H., Williams, A., Wise, B.S. and Zhou, S., 2011. Ecological risk assessment for the effects of fishing. *Fisheries Research,* **108:** 372-384.

Johnston, D., Harris, D., Caputi, N., de Lestang, S. and Thomson, A., 2011a. Status of the Cockburn Sound Crab Fishery. Fisheries Research Report No. 219. Department of Fisheries, Western Australia. 104 pp.

Johnston, D.J., Harris, D., Caputi, N. and Thomson, P., 2011b. Decline of a blue swimmer crab (*Portunus pelagicus*) fishery in Western Australia – history, contributing factors and future management strategy. *Fisheries Research,* **109:** 119-130.

Johnston, D., Marks, R. and Marsh, C., 2019. West Coast Blue Swimmer Crab Resource Status Report 2018. In, Gaughan, D.J. and Santoro, K., (eds.). Status Reports of the Fisheries and Aquatic Resources of Western Australia 2017/18: The State of the Fisheries. Department of Primary Industries and regional Development, Western Australia. pp 36–42.

Johnston, D., Yeoh, D. and Harris, D., 2020a. Environmental drivers of commercial blue swimmer crab (*Portunus armatus*) catch rates in Western Australian fisheries. *Fisheries Research*. *In Press*.

Johnston, D., Yeoh, D., Harris, D., Denham, A. and Fisher, E., 2020b. Blue Swimmer Crab (*Portunus armatus*) Resource in the West Coast Bioregion, Western Australia. Part 1: Peel-Harvey Estuary, Cockburn Sound and Swan-Canning Estuary. Resource Assessment Report. Department of Primary Industries and Regional Development, Western Australia. 186 pp.

Jones, G.K., 1995. A review of the catch and effort and fisheries biology of the Coffin Bay (*Ovalipes australiensis*) fishery. SARDI Research Report Series, No. 7. 23 pp.

Jones, G.K. and Deakin, S., 1997. Sand crabs (*Ovalipes australiensis*). Fisheries Assessment Report to PIRSA for the Marine Scalefish Fishery Management Committee. South Australian Fisheries Assessment Series. 97/12. 20 pp.

Kailola, P., Williams, M, Stewart, P., Reichelt, R., McNee, A. and Grieve, C., 1993. Australian Fisheries Resources. Bureau of Resource Science and Fisheries Research and Development Corporation, Australian Capital Territory.

Leland, J.C., 2014. Injury, physiological stress and mortality of recreationally discarded crustaceans in New South Wales, Australia. *PhD Thesis*, Southern Cross University, Lismore.

Marine Stewardship Council – MSC, 2014. MSC Guidance for the Fisheries Certification Requirements, V2.0, 1st October 2014.

Marks, R., Hesp, S.A., Johnston, D., Denham, A. and Loneragan, N., 2020. Temporal changes in the growth of a crustacean species, *Portunus armatus*, in a temperate marine embayment: evidence of density dependence. *ICES Journal of Marine Science,* **77:** 773–790.

Pearce, A., Lenanton, R., Jackson, G., Moore, J., Feng, M. and Gaughan, D., 2011. The "marine heat wave" off Western Australia during the summer of 2010/11. Fisheries Research Report No. 222. Department of Fisheries, Western Australia.

Pearn, R. and Cappelluti, T., 1999. The South Coast Estuarine Fishery – A Discussion Paper. Fisheries Management Paper No. 126. Department of Fisheries, Western Australia. 47pp.

Rosenkranz, G.E., Tyler, A.V. and Kruse, G.H., 2001. Effects of water temperature and wind on year class success of Tanner crabs in Bristol Bay, Alaska. *Fisheries Oceanography,* **10:** 1-12.

Ryan, K.L., Wise, B.S., Hall, N.G., Pollock, K.H., Sulin, E.H. and Gaughan, D.J., 2013. An integrated system to survey boat-based recreational fishing in Western Australia 2011/12. Fisheries Research Report No. 249. Department of Fisheries, Western Australia. 168pp.

Ryan, K.L., Hall, N.G., Lai, E.K., Smallwood, C.B., Taylor, S.M. and Wise, B.S., 2015. State-wide survey of boat-based recreational fishing in Western Australia 2013/14. Fisheries Research Report No. 268, Department of Fisheries, Western Australia. 208pp.

Ryan, K.L., Hall, N.G., Lai, E.K., Smallwood, C.B., Taylor, S.M. and Wise, B.S., 2017. State-wide survey of boat-based recreational fishing in Western Australia 2015/16. Fisheries Research Report No. 287, Department of Primary industries and Regional Development, Western Australia. 205pp.

Ryan, K.L., Hall, N.G., Lai, E.K., Smallwood, C.B., Tate, A., Taylor, S.M. and Wise, B.S., 2019. State-wide survey of boat-based recreational fishing in Western Australia 2017/18. Fisheries Research Report No. 297, Department of Primary industries and Regional Development, Western Australia. 195pp.

Smith, K., Brown, J., Lewis, P., Dowling, C., Howard, A., Lenanton, R. and Molony, B., 2013. Status of nearshore finfish stocks in south-western Western Australia Part 1: Australian herring. Fisheries Research Report No, 246. Department of Fisheries, Western Australia. 194pp.

Steer, M.A., Fowler, A.J., McGarvey, R., Feenstra, J., Smart, J., Rogers, P.J., Earl, J., Beckmann, C., Drew, M. and Matthews, J., 2018. Assessment of the South Australian Marine Scalefish Fishery in 2017. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences). Adelaide. SARDI Publication No. F2017/000427.2. SARDI Research Report Series No. 1002. 230pp.

Uhlmann, S.S., Broadhurst, M.K., Paterson, B.D., Mayer, D.G., Butcher, P. and Brand, C. P., 2009. Mortality and blood loss by blue swimmer crabs (*Portunus pelagicus*) after simulated capture and discarding from gillnets. *ICES Journal of Marine Science,* **66:** 455–461.

Uphoff, J.M., 1998. Stability of the blue crab stock in Maryland. *Journal of Crustacean Biology*, **17:** 519-528.

Appendix 1

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

References

Fletcher, W.J, 2015.. Review and refinement of an existing qualitative risk assessment method for application within an ecosystem-based management framework. *ICES Journal of Marine Science*, **72(3)**: 1043-1056.

Fletcher, W.J., Shaw, J., Gaughan, D.J. and Metcalf, S.J., 2011. Ecosystem Based Fisheries Management case study report – West Coast Bioregion. Fisheries Research Report No. 225. Department of Fisheries, Western Australia. 116 pp.

Appendix 2

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