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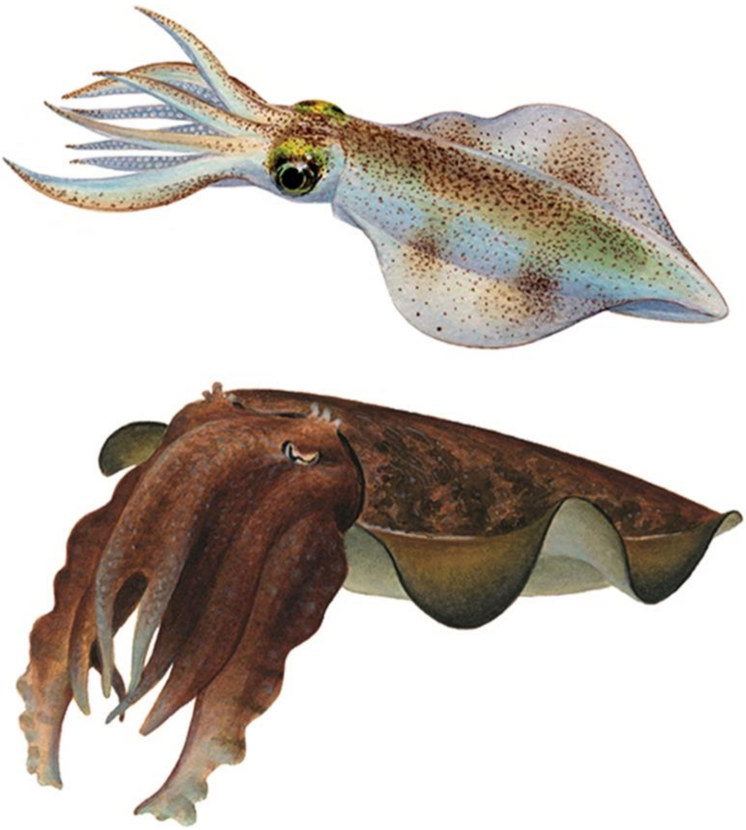
Fisheries Research Report No. 314

Squid and cuttlefish resources of Western Australia

Daniel Yeoh, Danielle Johnston, David Harris



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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: fish.wa.gov.au

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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

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1.0 Executive Summary

Cephalopods, including squid, cuttlefish and octopus, are short-lived, fast growing invertebrates that attain relatively large sizes, but typically spawn over one breeding season and then die. These characteristics are conducive to supporting productive fisheries and they are harvested globally for human consumption and bait.

The Western Australian squid and cuttlefish resource comprises multiple species in the orders Oegopsida and Myopsida (squid or ‘calamari’) and Sepiida (cuttlefish), which are harvested state-wide from shallow estuarine and inshore areas to deep offshore waters by both commercial and recreational fishers. The squid resource comprises southern calamari (*Sepioteuthis australis*), northern calamari (*Sepioteuthis lessoniana*), Gould’s squid (*Nototodarus gouldi*) and several species in the genus *Uroteuthis* (*Photololigo*). *Sepioteuthis australis* and *S. lessoniana* are typically caught inshore (typically <30 m depth), while *N. gouldi* and *Uroteuthis* spp. are typically caught further offshore (30–850 m depth). The cuttlefish resource includes giant cuttlefish (*Sepia apama*), broadclub cuttlefish (*Sepia latimanus*) and pharaoh cuttlefish (*Sepia pharaonis*), all of which are primarily caught in inshore waters.

The commercial sector mainly catches squid and cuttlefish by trawling in the North Coast Bioregion (NCB) and Gascoyne Coast Bioregion (GCB), and by jigging in the West Coast Bioregion (WCB) and South Coast Bioregion (SCB), with small catches also taken by haul and seine netting. The recreational sector primarily catches squid by jigging and cuttlefish by jigging or diving with a spear/snare.

The state-wide annual commercial squid catch from 1976 to 2019 ranged 23–1062 tonnes, with catches in most years ranging *c.* 30–90 tonnes. However, two periods of very high catches occurred, from 1993 to 1995 (563–609 t) and from 2003 to 2004 (172–1062 t), which reflected substantially increased catches in the NCB (annual totals up to 967 t). The state-wide commercial catch in 2019 was 49 t, 40% above the 2014–18 five-year average of 35 t. By bioregion, 43% of the 2019 commercial catch was taken from the SCB, 28% from the GCB, 22% from the WCB and 7% from the NCB. The 2017/18 recreational boat-based catch estimate was 88,519 squid (SE ± 8,037), with 85,565 individuals retained. A preliminary harvest weight estimate for this recreational catch was determined to be 34 t (range 27–40 t) based on a relatively small sample of squid weights obtained through boat-ramp surveys. The 2017/18 recreational catch represented a 38% increase from 2015/16 (62,424 individuals retained). The majority (75%) of the 2017/18 recreational squid catch was taken from the WCB, with the remainder of catch comprising 13% from the GCB, 9 % from the SCB and 3% from the NCB.

The state-wide annual commercial cuttlefish catch from 1976 to 2019 ranged <1–135 t. There was a substantial increase in catches from the early- to mid-1990s, reflecting an increase in landings from the NCB. Catches peaked in the mid-2000s (88–135 t from 2001–2003), and have ranged 30–65 t from 2009 to 2018. The 2019 cuttlefish catch was 54.7 t, representing a slight decrease from 2018 (62.6 t), but in line with the 2014–18 five-year average catch of 57 t. By bioregion, 55% of the 2019 commercial catch was taken from the NCB, 41% from the GCB, and ≤2% from each the WCB and SCB. The state-wide 2017/18 recreational boat-based cuttlefish catch estimate was 4,234 individuals, with 3,058 retained. This represented a 54% increase in recreational harvest from 2015/16 (1,974 cuttlefish retained). The vast majority (90%) of the 2017/18 catch was taken from the WCB.

Status of stocks

North Coast Bioregion squid resource

Annual commercial squid catches in the NCB, presumed to comprise mostly loligo squid *Uroteuthis* (*Photololigo)* spp. and northern calamari, have been highly variable over time. Catches since 1976 have ranged <1–967 t, with highest annual totals occurring during 1993–1995 (280–534 t) and 2003–2004 (79–967 t). However, catches in this bioregion since 2005 have been low (<5 t). It is possible that environmental conditions (e.g. cooler water temperatures) markedly increased squid abundances within fishing grounds during these high catch years, either through increased population abundance or inshore migration from offshore waters.

During 2019, nine commercial vessels landed a total of 3.48 t of squid across three managed fisheries, *i.e.*, the Nickol Bay Prawn Managed Fishery (77.4% of catch), Pilbara Fish Trawl (Interim) Managed Fishery (22.3%) and Kimberley Managed Prawn Fishery (0.3%). The annual catch represents an increase of ~40% from 2018 (2.5 t from 5 vessels) and was above the 2014–2018 five-year average of 2.1 t. Recreational boat-based fishers in the NCB retained an estimated 2,754 squid during 2017/18, presumed to be mostly northern calamari, and accounting for 3% of the state-wide recreational squid catch.

Due to uncertainties around the exact species that comprised the very high historical catches, as well as the level of targeted squid fishing effort, the sustainability of the NCB squid resource has not been formally assessed at this time. Research to determine the species composition of commercial catches in this bioregion will provide a better understanding of population dynamics (e.g. environmental influences, age and growth, natural mortality) will support improved management of stocks into the future (e.g. development of appropriate catch thresholds and limits).

Gascoyne Coast Bioregion squid resource

Annual commercial squid catches in the GCB, presumed to comprise mostly loligo squid and northern calamari, have ranged *c.* 8–100 t since 1976. Catches were highest from the early-1990s to late-2000s, with peaks of 99.6 t in 1995, 64.2 t in 1998, 62.3–75.1 t in 2003–2005 and 63.7 t in 2010. Commercial landings in the key fishing area of Shark Bay appear to be inversely correlated with water temperature, with very low catches following a marine heatwave during 2011–2013.

During 2019, 28 commercial vessels landed a total of 13.7 t of squid from four managed fisheries, as well as open access fishery areas, with the majority of catch taken from the Shark Bay Prawn Managed Fishery (86.1%) and Exmouth Gulf Prawn Managed Fishery (12.8%). The annual catch represents a ~20% increase from 2018 (11.3 t from 29 vessels) and was consistent with the 2014–2018 five-year average of 13.1 t. Recreational boat-based fishers in the GCB retained an estimated 10,896 squid during 2017/18, presumed to be mostly northern calamari, and accounting for 13% of the state-wide recreational squid catch.

A weight-of-evidence approach, with information from commercial and recreational fisheries, as well as environmental data, was used to assess this resource. On the basis of this evidence the GCB squid resource is considered **sustainable**.

West Coast Bioregion squid resource

Squid catches in the WCB are considered to predominately comprise southern calamari, although Gould's squid may be caught in deeper offshore waters (50–500+ m). The number of commercial fishing vessels retaining squid in the WCB peaked from the late-1980s to early-1990s (~50–70 vessels). Total annual catches since 1976 have ranged 3–16 t, peaking from 1988–1992 (14–16 t). Catches in most years came primarily from squid jigging, although handlining and trawling accounted for notable catches in several years, particularly from the 1980s to early 2000s. Since 2010, squid jigging has accounted for 77–92% of landings. Most commercial catches in this bioregion have come from sheltered coastal areas that contain substantial areas of seagrass, such as Cockburn Sound and inshore waters of the Perth metro region, with substantial contributions from Geographe Bay during 1976, 1987–1990 and 2010–2014.

Squid jigging catch rates in the WCB were positively correlated with water temperature, which was most apparent during recent years (2008–2018). Nominal CPUE increased markedly during 1995 and 1999 (15–16 kg/day) and again from 2010–2015 (21–31 kg/day) with increased water temperatures. Standardised annual squid jigging CPUE (accounting for effects of month, fisher and fishing location [60 × 60 nm CAES block]) has remained relatively constant over time, being lowest in 1985 and 1996 (4.2–4.4 kg/day) and highest during 1999 (9.8 kg/day).

The 2019 WCB commercial squid catch was 10.8 t landed by 24 vessels across eight managed fisheries, as well as open access fishery areas, the latter which accounted for 87.9% of catches. The annual total represents an approximately three-fold increase in catch from 2018 (3.2 t from 17 vessels) and is substantially above the five-year average catch from 2014–2018 of 5.1 t. Standardised commercial squid jigging CPUE during 2019 was 5.9 kg/day, representing a slight increase from 2018 (5.7 kg/day) and being above the threshold and limit of the draft harvest strategy (5 and 3.5 kg/day, respectively). Recreational boat-based fishers in the WCB retained an estimated 64,508 squid during 2017/18, presumed to be mostly southern calamari. This represents 75% of the state-wide recreational squid catch. Harvest weight estimates of this recreational catch range from 10.5 to 23.8 t. On the basis of all lines of evidence incorporating commercial and recreational catch information and environmental data, the WCB squid resource is considered **sustainable**.

South Coast Bioregion squid resource

Commercial squid catches in the SCB since 1976 have ranged 2–24 t. From the mid-1990s to 2010s there has been a general increase in catches, as well as the number of vessels targeting squid by jigging. Annual squid jigging effort increased from generally <100 fishing days during the 1970s and 1980s, to 500–1,100 fishing days since 2007. The vast majority (89%) of catches in this bioregion have come from the Albany region. Catches from inshore areas (<30 m deep) are thought to comprise predominately southern calamari, while catches from deeper waters closer to the continental shelf (50–850+ m) are likely to be Gould's squid.

Nominal commercial squid jigging CPUE has generally increased over time, from 1–13 kg/day in the late-1970s, to 13–22 kg/day since 2007. Annual nominal squid jigging CPUE in the Albany region was positively correlated with sea surface temperature ($R^2 = 0.45$, $P < 0.001$) and the highest CPUE on record (50 kg/day) occurred in 1999 during a marine heatwave. Standardised squid jigging CPUE (accounting for effects of month, fisher and fishing location [60 × 60 nm CAES block]) has also increased from 1.7–5.5 kg/day in the 1970s and 1980s to 12.3–18.4 kg/day in the mid-2000s. The highest annual standardised CPUE values were recorded in 2010 (18.7 kg/day) and 2011 (20.6 kg/day), declining to 11.7–16.3 kg/day during 2012–2018.

In the key fishing area of King George Sound, standardised squid jigging CPUE calculated as kg/day increased over time, from 2 kg/day in 1991 to peak of 12.6 kg/day in 2018. However, standardised CPUE calculated as kg/hook hour decreased from 0.2–0.5 kg/hr during the 1990s to 0.1–0.15 kg/hr during 2012–2019. This decline may have been due to reduced efficiency as vessels increase the number of hooks they use.

The 2019 commercial squid catch from the SCB was 21.1 t landed by 38 vessels across two fisheries, *i.e.*, the South Coast Wetline (96.6% of total catch) and South Coast Estuarine Managed Fishery (3.4%). The annual total represents a 40% increase from 2018 (15.1 t from 35 vessels) and was substantially above the 2014–2018 five-year average catch of 15 t. Commercial standardised squid jigging CPUE during 2019 was 15.1 kg/day, representing a ~1 kg/day decline from 2018, but above the threshold and limit of the draft harvest strategy (11.7 and 8.2 kg/day, respectively). Recreational boat-based fishers in the SCB retained an estimated 7,407 squid during 2017/18, presumed to be mostly southern calamari. On the basis of all lines of evidence incorporating commercial and recreational catch information and environmental data, the SCB squid resource is considered **sustainable**.

State-wide cuttlefish resource

The state-wide annual commercial cuttlefish catch from 1976 to 2019 ranged <1–135 t, peaking during the early-2000s (88–135 t from 2001–2003). The number of commercial fishing vessels retaining cuttlefish has ranged from four during the late-1970s to 64 in 1996, with trawling accounting for 98% of all landings. Historically, the vast majority of commercial cuttlefish catch has been taken from the north-west, specifically Shark Bay, Exmouth Gulf (GCB) and the Nickol Bay region (NCB). Key species in these areas are likely to be pharaoh cuttlefish and broadclub cuttlefish. Annual catches in the NCB were greatest from the mid-1990s to mid-2000s (up to 106 t) but have declined since 2010 (5–33 t). In contrast, catches in the GCB have generally increased over time, ranging 20–44 t during 2010–2019.

The 2019 state-wide commercial cuttlefish catch was 54.7 t landed by 55 fishing vessels across 11 managed fisheries, as well as open access fishery areas. The annual total represented a 7.9 t decrease from 2018 (62.6 t), but was in line with the 2014–2018 five-year average catch of 57 t. The 2019 catch comprised 30.3 t (55%) from the NCB, 22.7 t (41%) from the GCB, 1.1 t (2%) from the SCB and 0.7 t (1%)

from the WCB. Recreational boat-based fishers were estimated to have retained 3,058 cuttlefish state-wide during 2017/18, with 90% from the WCB. On the basis of all lines of evidence incorporating commercial and recreational catch information and environmental data, the state-wide cuttlefish resource is considered **sustainable**.

2.0 List of Abbreviations

CAES	Catch and Effort Statistics
CPUE	Catch per Unit of Effort
DML	Dorsal Mantle Length
DoF	Department of Fisheries (Western Australia)
FRMA	Fish Resources Management Act
DPIRD	Department of Primary Industries and Regional Development (Western Australia)
EBFM	Ecosystem-Based Fisheries Management
EPBC	Environment Protection and Biodiversity Conservation (Act)
ESD	Ecologically Sustainable Development
ETP	Endangered, Threatened and Protected Species
GCB	Gascoyne Coast Bioregion
RFBL	Recreational Fishing from Boat Licence
NCB	North Coast Bioregion
SCB	South Coast Bioregion
SST	Sea Surface Temperature
WA	Western Australia
WCB	West Coast Bioregion

3.0 Scope

This document provides a description and assessment of the squid and cuttlefish resource in Western Australia (WA) and all of the fishing activities (*i.e.* fisheries / fishing sectors) affecting this resource. The report encompasses multiple species in the orders Oegopsida and Myopsida (squid or 'calamari') and Sepiida (cuttlefish) that comprise this resource. Squid and cuttlefish occur along the entire WA coastline and inhabit waters from shallow inshore and estuarine areas to deep offshore waters off the continental shelf. They are primarily captured by trawling and squid jigging by the commercial sector and squid jigging by the recreational sector.

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).

4.0 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 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).

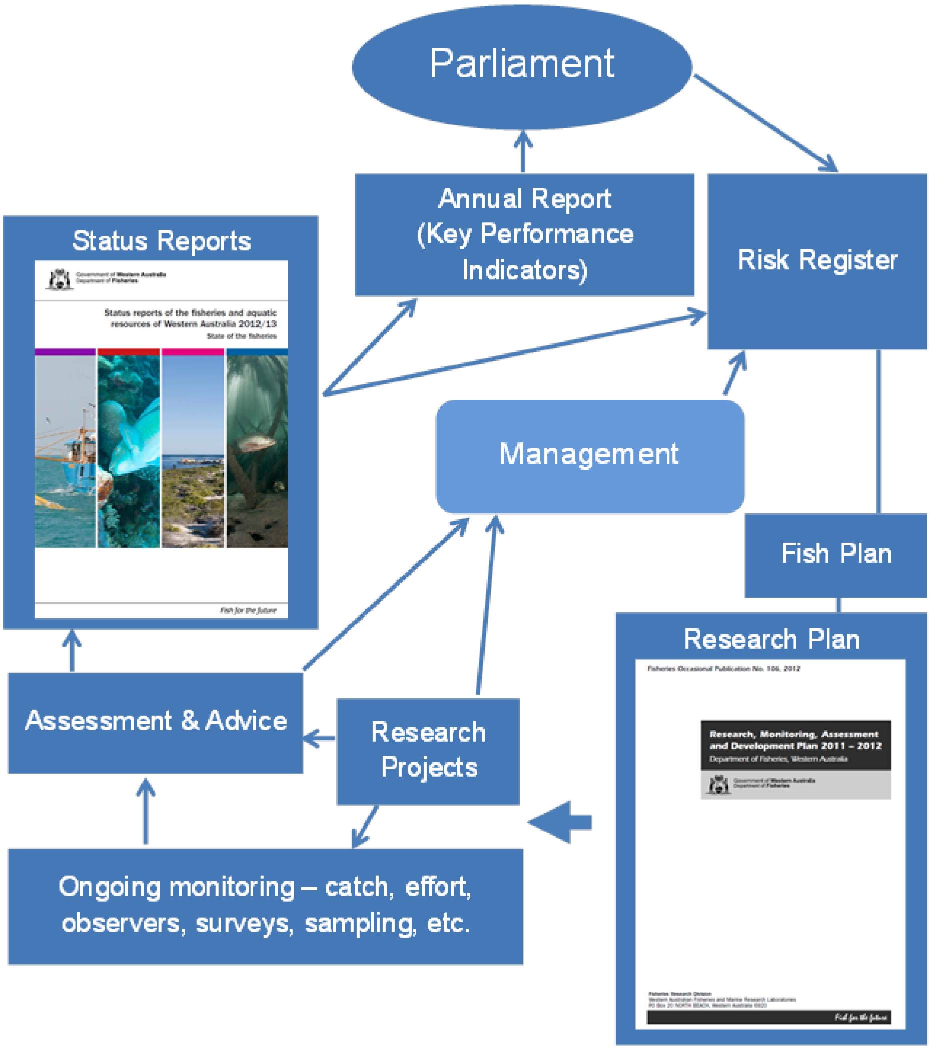


Figure 1. An outline of the risk-based planning cycle used for determining Departmental priorities and activities.

5.0 Aquatic Environment

Western Australia's expansive coastline covers numerous climatic zones, from cool-temperate areas in the south through to warm tropical environments in the north. An EBFM approach classifies areas of the states as 'Bioregions' based upon oceanographically and climate/rainfall characteristics. Four bioregions are defined for WA's marine and coastal environments; the North Coast, Gascoyne Coast, West Coast and South Coast (Figure 2).

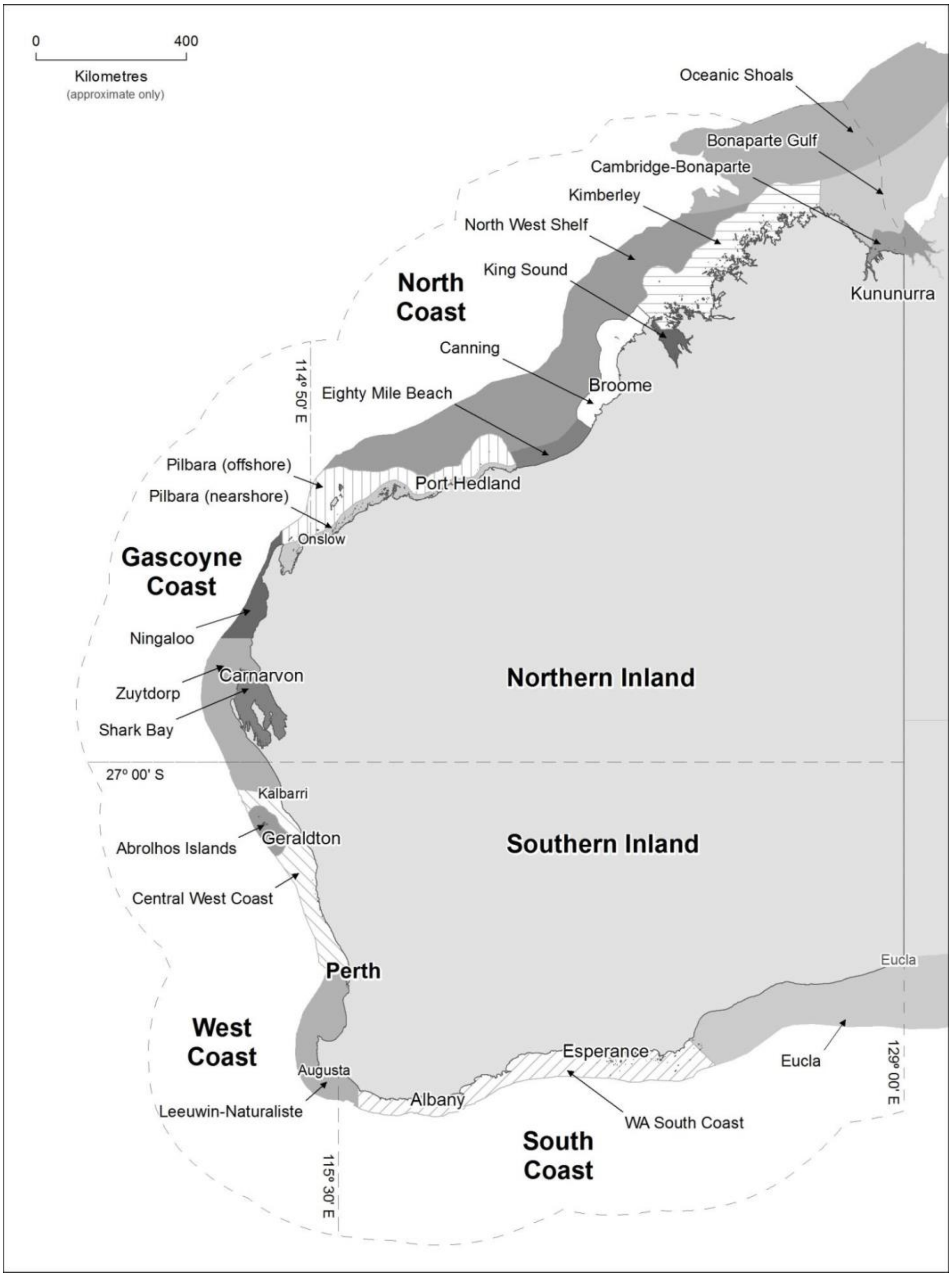


Figure 2. Location of the South Coast, West Coast, Gascoyne Coast and North Coast Bioregions in Western Australia. Mesoscale marine bioregions are shown within each major bioregion.

5.1 North Coast Bioregion

The North Coast Bioregion (NCB) extends from westwards the WA/NT border to just south of Onslow (114°50’E, 21°46’S). Major towns/ports encompassed in this bioregion include Kununurra, Broome, Port Headland and Karratha. The region has a tropical climate and receives the majority of its annual rainfall during summer. Coastal waters typically subject to low wave energy but are seasonally influenced by tropical cyclones and severe storm activity. Marine waters are influenced by the Indonesian Throughflow and Holloway Currents which flow polewards from the Indonesian archipelago. Sea surface temperatures range 22 to 33°C. The region is macro-tidal, with tidal ranges of *c.* 2 m in southern areas of the Pilbara to over 11 m in the Kimberley. Consequently, the nearshore coastal waters of the Kimberley are generally turbid due to high rates of water flow. Key aquatic habitats include intertidal mudflats, mangroves and coral reef systems.

5.2 Gascoyne Coast Bioregion

The Gascoyne Coast Bioregion (GCB) is a transitionary marine environment between tropical waters of the NCB and cooler temperate waters of the West Coast Bioregion (WCB). The GCB extends from just south of Onslow to 27° latitude, and encompasses Exmouth, Carnarvon and Denham/Shark Bay (Figure 2). Sea temperatures typically range from 22 to 28°C, but in shallow embayments such as Shark Bay, may fall to as low as 15°C during winter. Summer tropical cyclones occur in the northern part of the bioregion (Exmouth region) but are infrequent in southern areas. Rainfall is limited in the GCB and comes mostly during winter storm fronts. Key aquatic habitats include expansive seagrass beds (*e.g.* Shark Bay) and coral reef (*e.g*. Ningaloo Reef). Aquatic biota reflect the transitional marine environment and represent a mix of fully tropical and temperate species.

5.3 West Coast Bioregion

The WCB, which extends from north of Kalbarri to just east of Augusta, is predominately a temperate marine zone, but receives substantial warm tropical water from the southward flowing Leeuwin Current. The bioregion encompasses Geraldton, Perth, Bunbury, Busselton and Dunsborough. Marine waters typically range from 15 to 24 °C. The region is micro-tidal (*c.* 0.6 m tidal range) and a temperate climate with warm summers and cool winters. Rainfall is protracted and occurs mostly during winter. Average annual rainfall in coastal areas ranges from less than 400 mm in the north (Kalbarri) to approximately 1000 mm in the south (Augusta).

The Leeuwin Current system, which runs along the entire west coast and can be up to several hundred km wide, varies considerably in strength from year in relation to El Nino or Southern Oscillation Events. The clear, warm, low nutrient waters of the Leeuwin Current are key to the growth and distribution of seagrasses and influence the spawning success of many fish and invertebrate species with pelagic egg and larval development stages.

Predominant habitats of the WCB include exposed sandy beaches and limestone reef systems. A long limestone reef system approximately 5 km offshore runs along much of the coast which dissipates wave energy to nearshore coastal areas. The region also contains two significant coastal embayments (Cockburn Sound and Geographe Bay) and several large estuarine systems (the Swan-Canning, Peel-Harvey, Leschenault and Blackwood-Hardy estuaries). Additionally, the bioregion encompasses a unique southern coral reef system at 29° latitude, the Abrolhos Islands.

Aquatic biota are predominately temperate, although substantial populations of certain tropical species occur at the Abrolhos Islands and various offshore islands and reef systems southwards. Following a marine heatwave in 2011, tropical species have also been recorded in nearshore and estuarine waters, although generally sporadically and in low numbers.

5.4 South Coast Bioregion

The South Coast Bioregion (SCB) extends from Augusta, eastward to the WA/SA border and encompasses the coastal towns of Denmark, Albany and Esperance. Sea surface temperatures typically range from 15 to 21°C. Coastal waters are influenced by the Leeuwin Current, which results in warmer than would normally be expected water temperatures for these southern latitudes. The south coast is a high wave energy environment and is heavily influenced by large swells generated in the Southern Ocean. The coastline is characterised by white sandy beaches and massive granite headlands. The SCB experiences warm dry summers and cool wet winters, with annual rainfall highest in the Walpole region (*c.* 1300 mm) and decreasing eastwards. There are numerous rivers and estuaries along the south coast, although due to high wave energy and protracted rainfall the majority are isolated from the sea for extended periods due to sand bars forming at their mouths. A large permanently-open estuarine embayment occurs in Albany, *i.e.* Oyster Harbour, which is connected to a relatively protected coastal embayment, King George Sound. Aquatic vegetation throughout the SCB is a mix of seagrass and kelp dominated habitats. Biota are predominately temperate species, with sporadic occurrences of tropical species.

6.0 Resource Description

The WA squid and cuttlefish resource comprises multiple species in the orders Myopsida and Oegopsida (squids) and Sepiida (cuttlefish). Squid and cuttlefish are harvested state-wide from estuaries and nearshore waters, inshore marine waters and offshore marine waters by commercial and recreational fishers. The squid resource comprises mainly southern calamari (*Sepioteuthis australis*), northern calamari (*Sepioteuthis lessoniana*), Gould’s squid (*Nototodarus gouldi*) and several species in the genus *Uroteuthis* (*Photololigo*). *Sepioteuthis australis* and *S. lessoniana* are primarily caught in inshore fisheries (typically <30 m depth), while *Uroteuthis* spp. and *N. gouldi* are primarily caught further offshore (30–200 m and 50–850 m, respectively), and mainly by the commercial sector. Fishery important species of cuttlefish include, giant cuttlefish (*Sepia apama*), broadclub cuttlefish (*Sepia latimanus*) and pharaoh cuttlefish (*Sepia pharaonis*), which are caught by commercial and recreational fishers, primarily in inshore waters.

Squid are marketed for both human consumption and bait, which is largely dependent on the size and quality of the product. For consumption, *S. australis* and *S. lessoniana* are typically marketed as ‘calamari’, and are generally regarded as higher value than Gould’s squid (often marketed as simply ‘squid’ or ‘arrow squid’) because their flesh is more tender (Dunning *et al*., 2000). *Uroteuthis* spp. are generally marketed as loligo squid and considered of high value for consumption. Small squid are sold for commercial and recreational bait. Cuttlefish are primarily marketed for consumption, particularly as export to overseas markets. Further details on markets for this resource are provided in section 7.3.2.

7.0 Species Description

Fishery-important squid and cuttlefish are found throughout Australian marine waters, with individual species typically having broad and overlapping distributions. The approximate geographic distributions of the main commercially/recreationally important squid species in WA waters are shown in Figure 3 below.

All targeted squid and cuttlefish species are voracious predators, feeding typically on fish and crustaceans (Norman & Reid, 2000). Most species are highly variable in appearance and able to rapidly change colour to camouflage with surroundings or in response to stress. In addition, many species contain an ink sac and are able to squirt a plume of ink into the water as a defence mechanism.

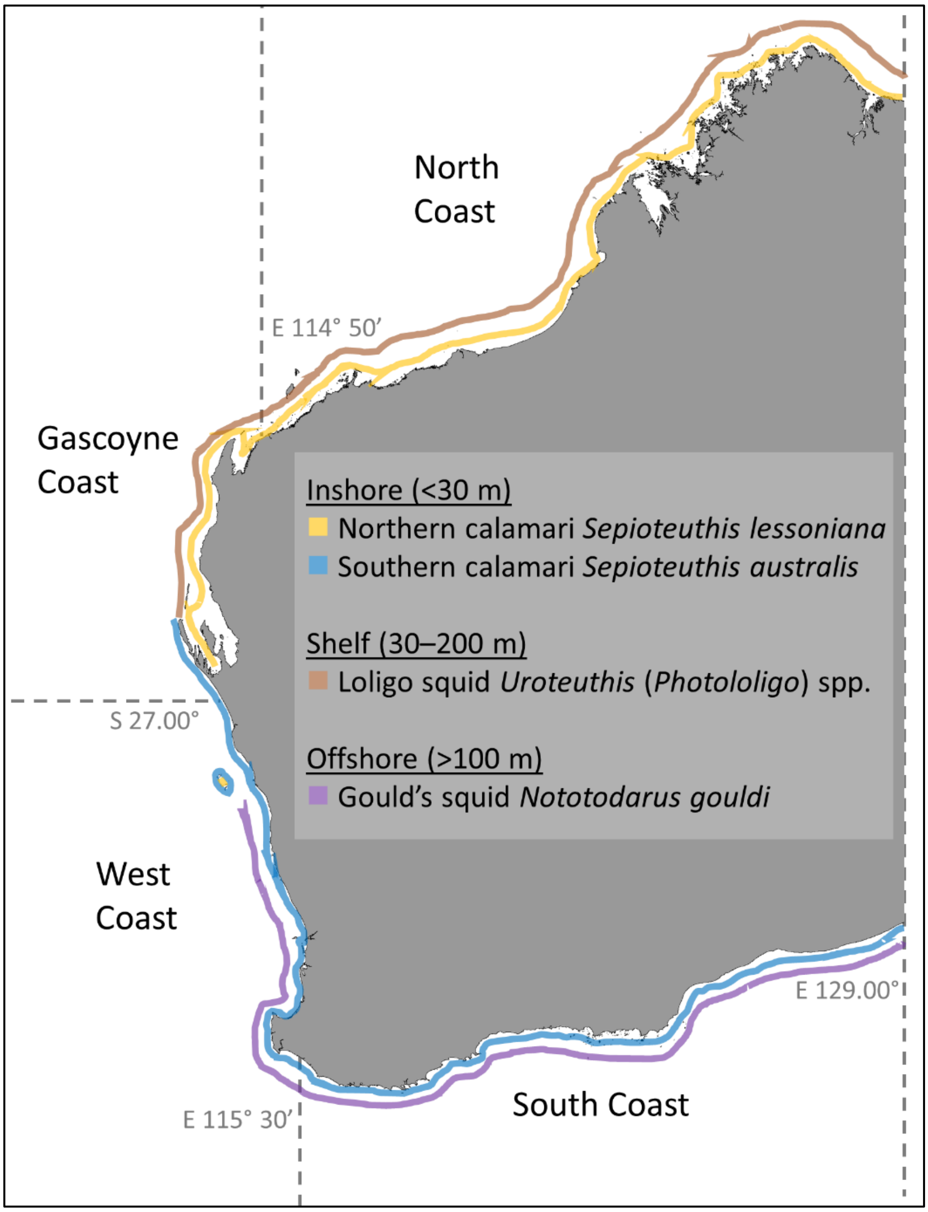


Figure 3. The approximate geographic distribution and typical depth range of key fishery important squid species in Western Australia.

Morphologically, all squid and cuttlefish have two feeding tentacles and eight arms, and an elongate muscular mantle tube (Figure 4). The feeding tentacles contain numerous powerful suckers which are used to grasp prey and pull it within reach of the animal's arms and mouth (Boyle & Rodhouse, 2005). The mouth of squid and cuttlefish contains a sharp hard two-piece rostrum or 'beak', which is used to kill prey and feed. Cuttlefish have an internal chambered shell called a cuttlebone, which is a broad, rigid structure used for controlling buoyancy. Squid lack this cuttlebone, instead having a gladius, which is a far thinner and narrower structure. Therefore, squid are generally more rounded and torpedo-shaped than cuttlefish, which are broader and dorso-ventrally flattened.

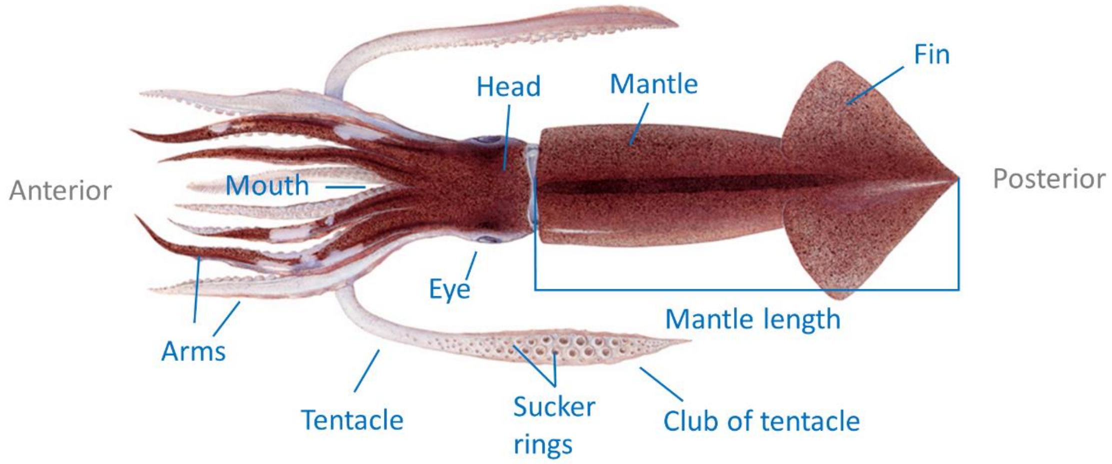


Figure 4. Key anatomical features of a squid/cuttlefish (Gould's squid *Nototodarus gouldi* illustrated; dorsal view).

7.1 Taxonomy and Distribution

7.1.1 *Southern Calamari (Sepioteuthis australis)*

Southern calamari (also known as southern reef squid) are a large squid in the family Loliginidae (pencil squids) and order Myopsida, which can reach up to 55 cm mantle length and 3–4 kg in weight (Table 1). They have fins that extend the whole length of the mantle and are widest mid-way along (Figure 5). Colouration is highly variable and ranges from uniform orange/brown, to white with dark stripes, to almost transparent (Norman & Reid, 2000). Southern calamari are common in the coastal waters of southern Australia from southern Queensland (QLD) to Exmouth WA (Figure 3). Individuals typically form small schools (<10 individuals) and are commonly found over seagrass beds and reef habitats less than 10 m depth (Norman & Reid, 2000; Coulson *et al*., 2016). They also occur in the lower reaches of estuaries when salinities are close to marine.

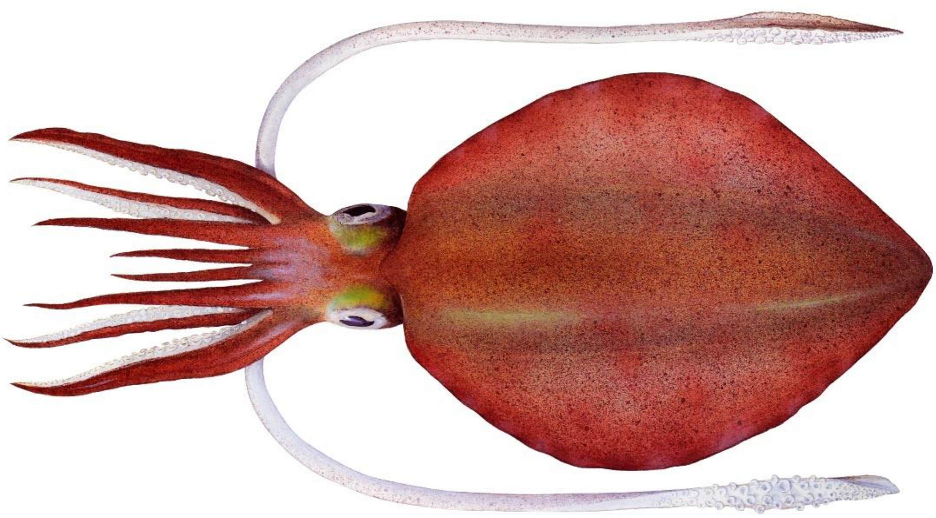


Figure 5. Southern calamari (*Sepioteuthis australis*).

7.1.2 *Northern Calamari (Sepioteuthis lessoniana)*

Northern calamari (also known as bigfin reef squid or tiger squid) are another species from the family Loliginidae, and are similar in appearance to southern calamari, but have a fin which is largest closer to the posterior of the mantle (Figure 6). They attain a maximum size of up to 40 cm mantle length, are variable in colour with bands that range from black to almost transparent, and have two iridescent transverse spots on the mantle. This species occurs in tropical waters throughout much of tropical Indo-Pacific. In Australia, Northern calamari are distributed north from Shark Bay in WA to southern QLD (Figure 3; Norman & Reid, 2000). They commonly occur in seagrass and coral reef habitats to depths of 100 m, and are known move over coral reef to feed at night (Norman and Reid, 2000; Pecl, 2000).

Figure 6. Northern calamari (*Sepioteuthis lessoniana*).

7.1.3 *Loligo squid Uroteuthis (Photololigo) spp.*

There are several tropical squid species in the genus *Uroteuthis* (*Photololigo*) (family Loliginidae, order Myopsida) that are commonly caught throughout south-east Asia and northern Australia, particularly along Australia's north-east coast from QLD to northern NSW (Norman & Reid, 2000; Dunning *et al*., 2000; Hall, 2015). These are commonly referred to as 'loligo squid' and include mitre squid (*U. chinensis*), swordtip squid (*U. edulis*), broad squid (*U. etheridge*), and pencil squid (*Uroteuthis* sp.). Members of this genus are elongate, with paired triangular fins that extend approximately half of their mantle length (Figure 7). They also contain two photophores, one on each side of their ink sack, allowing them to emit light (Yeatman & Benzie, 1994; Norman & Reid, 2000). Individual species from this genus are difficult to separate visually and it is believed there are several species in Australian waters which are yet to be formally described (Wadley & Dunning, 1998; Hall, 2015). A least two species have been documented from commercial trawl catches at depths of 30–200 m along WA's north-west shelf (Yeatman & Benzie, 1994; Wadley & Dunning, 1998). Further east from the Kimberley to QLD, it is thought at least four species occur (Yeatman & Benzie, 1994; Dunning *et al*., 2000). It has been proposed that individual species within the genus have restricted depth ranges (Yeatman & Benzie, 1994), with one species in north-west WA predominantly caught in depths of 30–100 m and another from 100–200 m. Spawning aggregations of squid, presumed to be *Uroteuthis* sp., have historically been targeted by prawn trawlers in the Kimberley region of WA, yielding very high catches during the 1990s (Wadley and Dunning, 1998; Dunning et al., 2000; see section 9.3 Commercial squid catch and effort trends).

Figure 7. Swordtip squid *Uroteuthis* (*Photololigo*) *edulis.*

7.1.4 *Gould's Squid (Nototodarus gouldi)*

Gould's squid (also known as arrow squid or red arrow squid) is a species in the family Ommastrephidae (flying squids) and order Oegopsida. This squid is typically maroon-red in colour, with a large muscular torpedo-shaped mantle up to 40 cm in length and an overall body weight of up to 1.6 kg (Norman & Reid, 2000; AFMA, 2019). Their fin is diamond-shaped and only extends for approximately one third of the length of the mantle (Figure 8). Gould's Squid are distributed throughout southern Australia, from southern QLD to Exmouth WA. Larvae and juveniles occur throughout coastal waters while adults inhabit deeper offshore oceanic waters up to depths of 825 m. Individuals often aggregate in large schools and are typically most abundant over the continental shelf at depths of 50–200 m (AFMA, 2019). This species is known to display distinct diel vertical migrations, residing near the sea bed during the day and moving upward in the water column at night (Nowara & Walker, 1998). This species feeds primarily on pelagic fish and crustaceans (*e.g.* pilchards, myctophids), as well as other squid (O'Sullivan & Cullen, 1983; Pethybridge *et al.*, 2012).

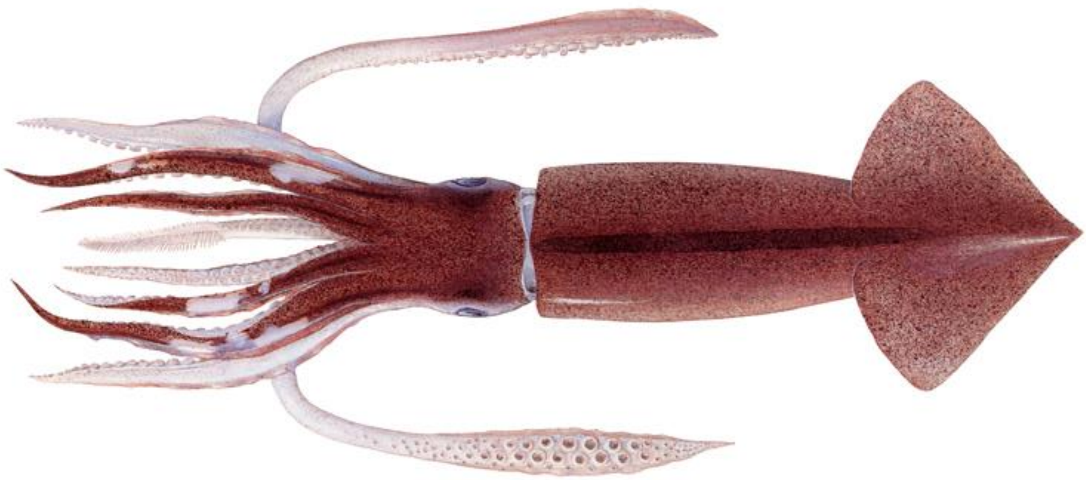


Figure 8. Gould's squid (*Nototodarus gouldi*).

7.1.5 *Giant Cuttlefish (Sepia apama)*

The giant cuttlefish (family Sepiidae, order Sepiida) is the largest species of cuttlefish, with a maximum mantle length up to 50 cm (Norman & Reid, 2000). It is identified by twin rows of three flap-like papillae over each eye (Figure 9). The cuttlebone of large animals lacks a spine and has rough v-shaped thickening at the posterior end similar to a callus. In adults, outer border of bone is also very wide and posteriorly flared. This species is able to rapidly change colour and camouflage. Giant cuttlefish are endemic to coastal waters of southern Australia from southern QLD to Exmouth, WA. They typically occur in reef habitat and seagrass beds, and at water depths of less than 100 m.

Figure 9. Giant cuttlefish (*Sepia apama*). Illustration © R. Swainston/anima.net.au.

7.1.6 *Broadclub Cuttlefish (Sepia latimanus)*

The broadclub cuttlefish (Sepiidae: Sepiida) is distinguished by large broad tentacles which resemble clubs, each of which contains 5–6 suckers in rows (Figure 10). It reaches up to 40 cm in mantle length and 5 kg weight, and is a tropical species, occurring from Exmouth WA to northern QLD (Norman & Reid, 2000). It inhabits coastal waters to a depth of at least 30 m, and is often found around coral reefs.

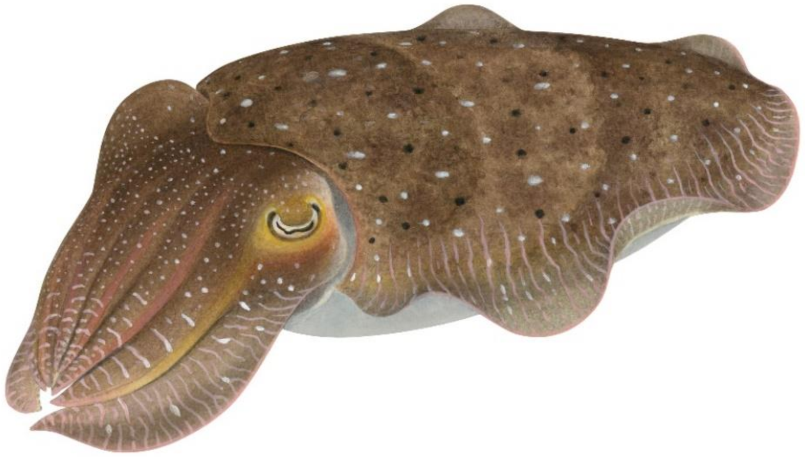


Figure 10. Broadclub cuttlefish (*Sepia latimanus*).

7.1.7 *Pharaoh Cuttlefish (Sepia pharaonis)*

Pharaoh cuttlefish (Sepiidae: Sepiida) is a large cuttlefish weighing up to 5 kg and reaching 43 cm mantle length (Wadley & Dunning, 1998; Norman & Reid, 2000). It is distinguished by a distinctive shiny bulbous swelling on its cuttlebone and a pale reflective line along the base of each fin (Figure 11). This species occurs in tropical waters throughout northern Australia (Shark Bay, WA to northern QLD) and is found at depths to 100 m, but is most common in inshore waters (<40 m; Wadley & Dunning, 1998). Pharaoh cuttlefish have thick, tender flesh which is considered of high eating quality and is prized in Asian markets (Norman & Reid, 2000).

Figure 11. Pharaoh cuttlefish (*Sepia pharaonis*).

7.1.8 *Other squid and cuttlefish species*

In addition to the various squid and cuttlefish species described above there are a number of other species that may occasionally be caught by commercial and recreational fishers in WA. Large squids in the family Ommastrephidae (flying squids) (order Oegopsida), such as the Antarctic flying squid (*Todarodes filippovae*), have been reported from deeper waters of southern WA. Other cuttlefish species that attain sizes conducive to being caught by fishers include Smith's cuttlefish (*Sepia smithi*), slender cuttlefish (*S. braggi*), Papuan cuttlefish (*S. papuensis*), knifebone cuttlefish (*S. cultrata*) and ovalbone cuttlefish (*S. elliptica*). Catches of these squid and cuttlefish species are likely to be sporadic and they are not believed to be targeted in any fisheries or areas of WA.

7.2 Stock Structure

Southern calamari are fished by recreational and commercial fishers throughout southern Australia, including marine waters of WA, South Australia (SA), Victoria and Tasmania. Recent genetic studies by Smith *et al.* (2015) determined there to be little genetic differences in *S. australis* samples collected from these four regions, suggesting high gene flow and connectivity of southern calamari populations throughout southern Australia.

In WA, southern calamari are commonly fished in three geographically separated marine embayments, Cockburn Sound (West Coast, 32° S latitude), Geographe Bay (West Coast, 33.5° S) and King George Sound (South Coast, 35°S; Coulson *et al*., 2016). Biological studies of *S. australis* in each of these areas undertaken by Coulson *et al*. (2016) identified differences in the morphology (length-weight relationships), growth rate and size at maturity of this species between locations (see Table 1). This suggests that distinct *S. australis* populations occur throughout WA, with their biological characteristics reflecting local environmental conditions (see next section).

Genetic studies of *Uroteuthis* (*Photololigo*) squid throughout northern Australia were conducted during the early- to mid-1990s by Yeatman & Benzie (1994). These authors suggested that species in a region may be segregated by depth (e.g. inshore 30–100m *vs* offshore 100–200m), but that substantial longshore mixing of populations occurred. Thus, each species was considered to have a homogenous population across their geographic range from north-western to north-eastern Australia.

There is little information on the stock structure of northern calamari, Gould's squid or various cuttlefish species in WA.

7.3 Life History

Cephalopods are typically short-lived species with rapid growth and development that spawn over one breeding season and then die (Boyle & Rodhouse, 2005). All key fishery species of squid in Australia have a life cycle of less than one year (*e.g.* Jackson & Yeatman, 1995; Pecl, 2000; Jackson *et al.*, 2003; Coulson *et al*., 2016). Among many species, spawning occurs throughout the year, with inshore fisheries therefore receiving continual recruitment and being made up of multiple 'microcohorts' (Moltschaniwskyj & Pecl, 2007; Steer & Moltschaniwskyj, 2007).

Southern calamari in south-western Australia attain a maximum age of 240 days in Cockburn Sound on the lower west coast and 283 days in King George Sound on the south coast (Table 1). Although spawning occurs year round, peak spawning in SWA takes place during spring and early summer (Coulson *et al*., 2016). Size at 50% maturity (DML_{50}) is reached at 167 and 141 mm dorsal mantle length (DML) for females and males, respectively, in Cockburn Sound, and at 152 mm for both sexes in King George Sound. Similarly, in fisheries on the east coast of Australia, maturity is reached at 3–6 months and 150–200 mm mantle length (Moore *et al*., 2018). Mature *S. australis* form large spawning aggregations where mating occurs, after which females deposit egg sacs in inshore seagrass beds (Moltschaniwskyj & Pecl, 2003; Figure 12). In south-eastern Australia the spawning frequency of *S. australis* has been shown to vary between regions, with populations in warmer waters being single batch spawners, while populations in cooler, more southern waters exhibiting multiple spawning (Pecl, 2000; Pecl, 2001). Relationships between DML and total weight of *S. australis* in south-western Australia are given in Table 1 and Figure 12.

A biological study of a *Uroteuthis* (*Photololigo*) squid was undertaken in north-western Australia (shelf waters off the Pilbara, 100–200 m depth) during the early to mid-1990s by Jackson and Yeatman (1995). Individuals from this species had a maximum age of 160 days. Mature females ranged in size from 58–145 mm ML and from 94–158 days in age. There was also evidence that females grew faster and attained larger sizes than males.

Little data exists for the biology of other commercially important squid and cuttlefish species in WA. Studies in southern and south-eastern Australia suggest that Gould's squid reach maturity at 6–9 months, with males maturing at a smaller size than females (Jackson *et al*., 2003). Spawning of *N. gouldi* occurs throughout the year, with 2–3 weeks of peak spawning activity, and individuals die after shortly after reproducing. Growth rates are estimated to be as rapid as 4 cm per month (AFMA, 2019).

Age at maturity of northern calamari in north-eastern Australia occurs at approximately 2.5 to 6 months, varying with latitude (Pecl, 2000). In the Townsville area this species matures at between 77 and 126 days for males and 107 and 150 days for females, while further south in Brisbane the minimum age of maturity was determined to be 141 and 174 days for males and females, respectively (Pecl, 2000).

Similar to squid, most cuttlefish species also have short life cycles of < 1 year, although the giant cuttlefish *Sepia apama* is thought to live for 2-4 years (Norman & Reid, 2000). Giant cuttlefish spawn in mass aggregations and die following spawning.

Compared to biological knowledge of finfish and crustaceans, many squid and cuttlefish species are data deficient. Given that the biological characteristics of several species are variable between regions, stocks are likely to be highly influenced by changing local environmental conditions such as water temperature (Pecl, 2001; Jackson *et al*., 2003; Coulson *et al*., 2016). Body size and growth rate can also vary markedly among sexes, and moreover, males and females may respond differently to changing environmental factors (Pecl *et al.*, 2004).

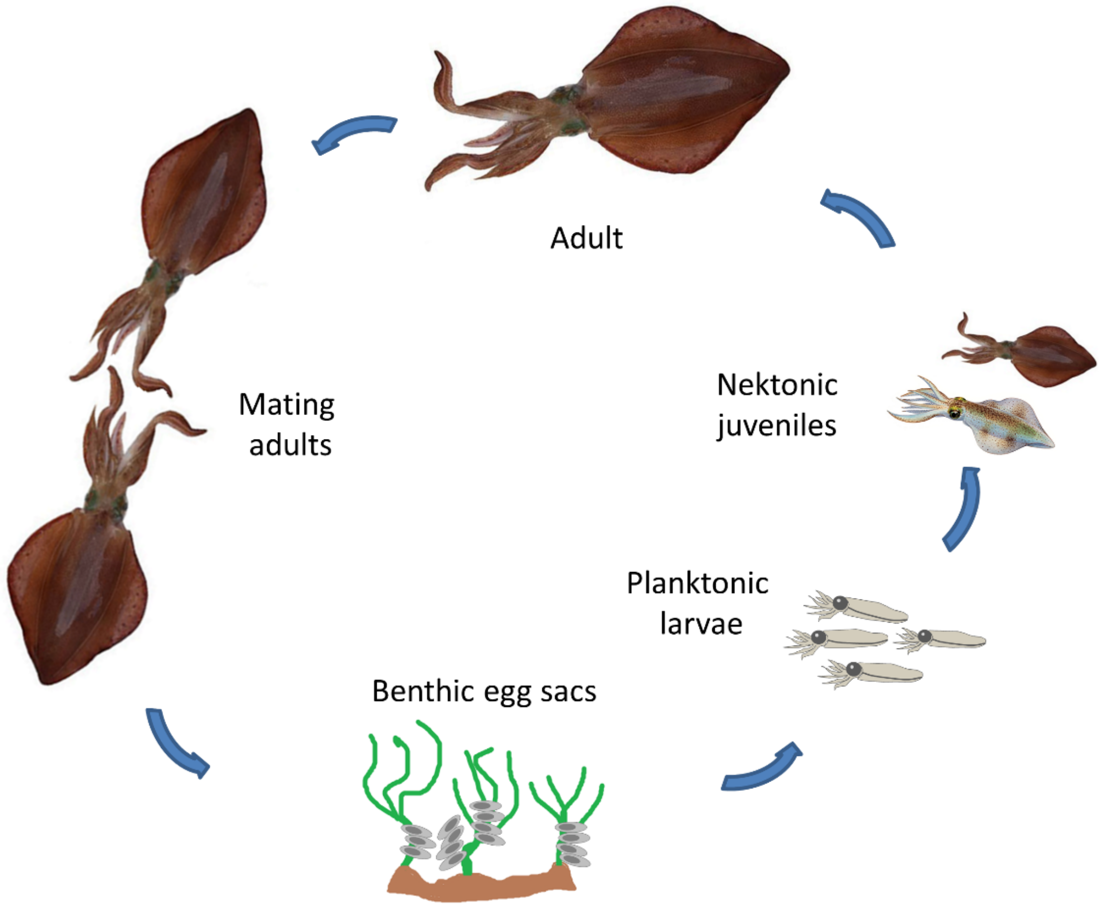


Figure 12. Simplified schematic of the life cycle of southern calamari *Sepioteuthis australis*. Adult and juvenile life stage figures adapted from Lyle *et al*. (2014) and R. Swainston/www.anima.net.au.

Table 1. Summary of biological parameters for southern calamari *Sepioteuthis australis*. Abbreviations are given in the table footnote.

Parameter	Value(s)	Comments / Source(s)
Growth rate (DML; mm *vs* age; days)	F & M: DML = (0.52 × *age*) + 83.28 (CS) F: DML = (0.32 × *age*) + 157.27 (KGS) M: DML = (0.47 × *age*) + 179.04 (KGS)	Coulson *et al.* (2016)
Maximum age	240 days (CS); 286 days (KGS)	Coulson *et al.* (2016)
Maximum size	550 mm DML, 3–4 kg	Lyle *et al*. (2014)
Natural mortality, *M* ($year^{-1}$)	Unknown	Data deficient
Length-weight relationship (DML; mm *vs* weight; g)	*Mantle weight (MW)* F & M: lnMW = (2.52 × lnDML)−8.69 (CS) F & M: lnMW = (2.3 × lnDML)−7.56 (KGS) *Whole weight (W)* F & M: lnW = (2.67 × lnDML)−8.36 (CS) F & M: lnW = (2.36 × lnDML)−6.65 (KGS)	Coulson *et al.* (2016) MW—Cleaned mantle weight. P. Coulson, unpubl. data.
Maturity DML_{50} (mm)	F: 167, M: 141 (CS) F: 152; M: 152 (KGS)	Coulson *et al.* (2016)
DML_{95} (mm)	F: 193, M: 177 (CS) F: 193; M: 193 (KGS)	Coulson *et al.* (2016)
Fecundity	Egg masses range from 1 to 1912 egg strands (typically <300; South Australia).	Steer *et al*. (2007).
Spawning	Spawning occurs year-round, peak spawning in south-western Australia during spring. Spawning frequency variable between populations; *e.g.* single batch southern QLD, multiple spawning Tasmania.	Coulson *et al.* (2016) Pecl (2001).

CS, Cockburn Sound; KGS, King George Sound; DML, dorsal mantle length.

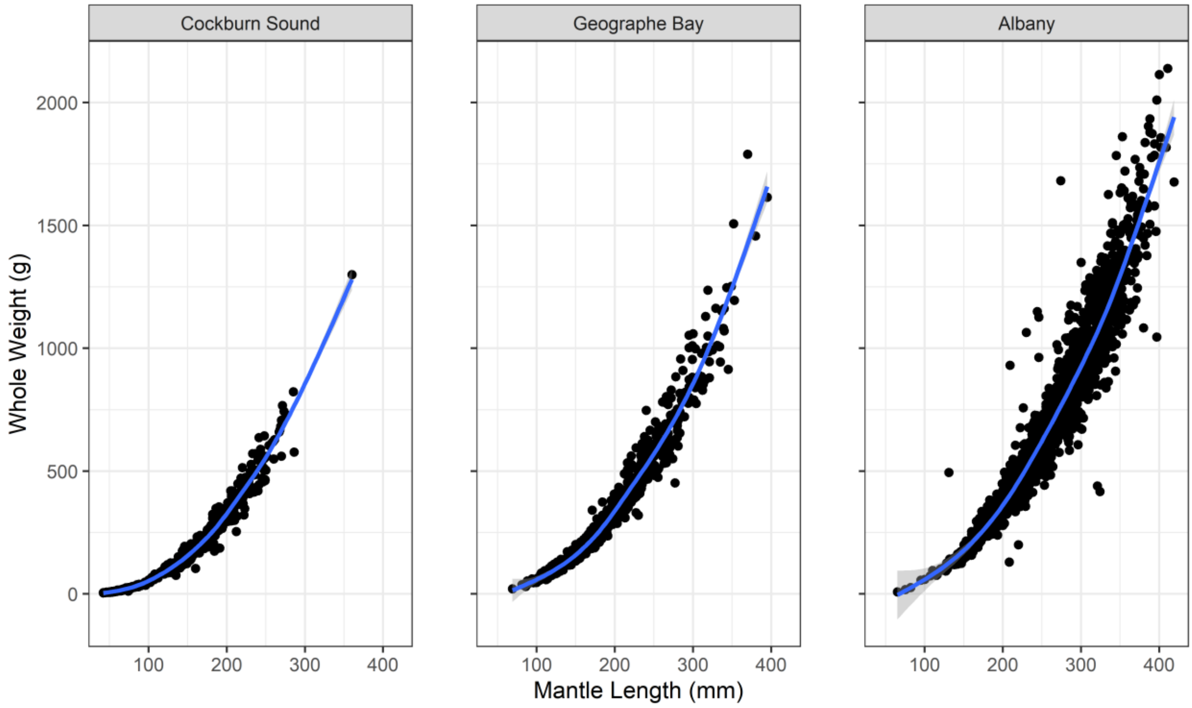


Figure 13. Length-weight relationships for southern calamari *Sepioteuthis australis* in Cockburn Sound, Geographe Bay and Albany.

7.4 Inherent Vulnerability

There is a lack of data on fishing mortality and the effects of fishing on squid and cuttlefish stocks. However, given the short life cycle (<1 year for squid, <4 years for cuttlefish) and rapid growth and development of most targeted species (*c.* half a year to maturity), they are likely to be reasonably resilient to over-fishing. Targeted squid species including *S. australis*, *S. lessoniana* and *N. gouldi* typically reproduce year-round, and multiple microcohorts enter the fishery in batches, which may further reduce vulnerability to fishing. However, several factors which may increase the vulnerability of squid and cuttlefish to fishing should also be noted. Firstly, many species are highly responsive to environmental conditions, which can lead to highly variable catches over time due to changing population abundances and/or fishing efficiency (see section Environmental factors and climate change). Additionally, many squid species form large aggregations to spawn, making it potentially easier for fishers (e.g. trawlers) to target squid and catch large quantities. Finally, there is currently no minimum legal size for retention of any squid or cuttlefish species in WA. While large animals are generally targeted for consumption, smaller animals (often below size at first maturity) may therefore also be kept, and are often used for bait (see section Market Influences and section Recreational fisheries).

8.0 Fishery Information

8.1 Fisheries / Sectors Capturing Resource

Squid and cuttlefish in WA are caught by numerous commercial fisheries, including various northern prawn trawl fisheries (*e.g.* Nickol Bay Prawn Managed Fishery, Kimberley Prawn Managed Fishery, Shark Bay Prawn Managed Fishery), open access fisheries and pot and line fisheries (*e.g.* Cockburn Sound Line and Pot Managed Fishery). From 1 July 2021, squid and cuttlefish will also be permitted to be taken in the South Coast Line and Fish Trap Managed Fishery and in the South Coast Nearshore Net Managed Fishery (which previously were open access areas). The distribution of squid and cuttlefish catch among key fisheries and methods is shown in Figure 14 and Figure 15.

Most trawl catches of squid occur northern areas of the state from Shark Bay to the Kimberley (GCB and NCB; Figure 16). In contrast, the majority of catch from southern squid fisheries (Perth to Esperance; WCB and SCB) is taken by targeted commercial fishing using lines and squid jigs (Figure 16). Cuttlefish are almost exclusively caught by trawling (99% of state-wide total catches since 1976), with very minor contributions caught by squid jigging and other methods (e.g. trapping, netting). Detailed descriptions of the fishing methods and gear used to capture squid and cuttlefish are given in section 6.2.3 below.

Recreational fishing for squid and cuttlefish occurs state-wide by both boat and shore based fishers, and is almost exclusively a line fishing activity (see section 6.4 below).

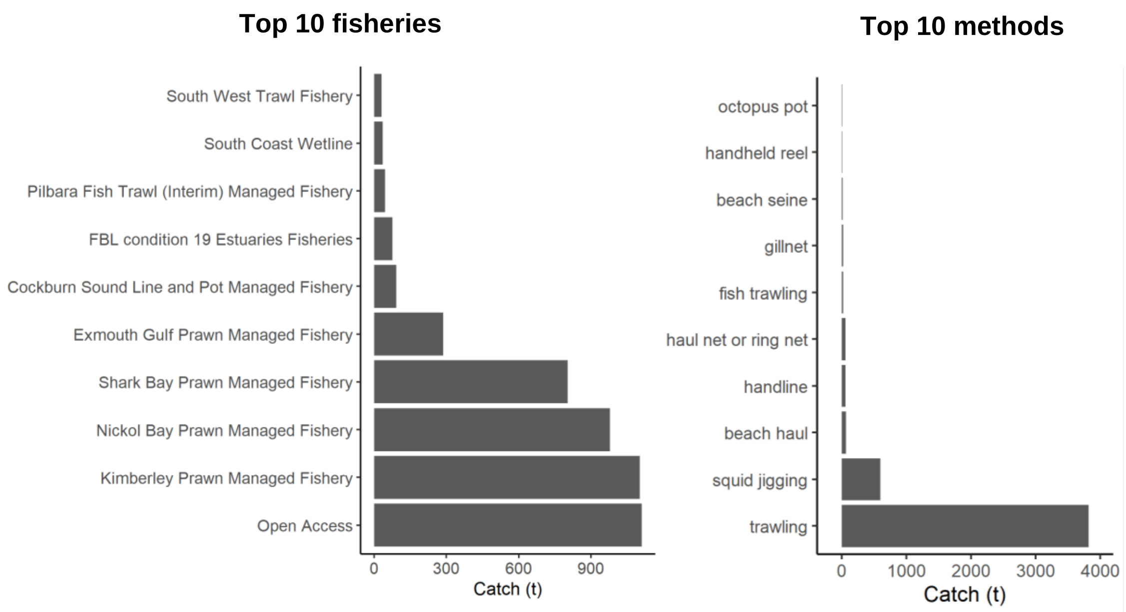


Figure 14. State-wide commercial catch totals of squid by fishery and method from 1976 to 2019. Only the top 10 fisheries and methods are shown for clarity. Open access fisheries are defined as those where there are no formal management arrangements in place, although other legislative restrictions may impact the activity. The open access squid fishery by line and jig requires operators to hold a Commercial Fishing Licence and an unrestricted Fishing Boat Licence, as well as a Licenced Fishing Boat Licence if fishing from a boat**.**

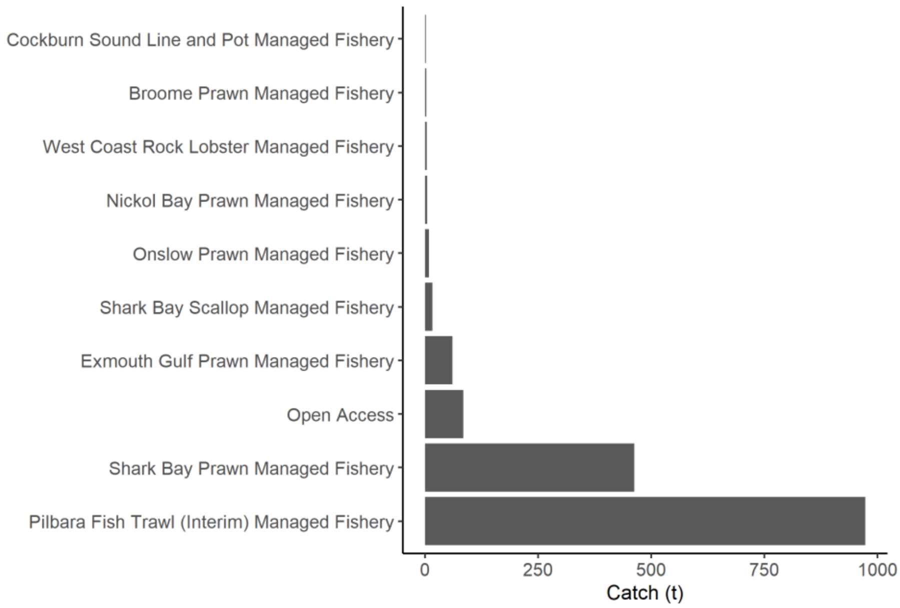


Figure 15. State-wide commercial catch totals of cuttlefish by fishery from 1976 to 2019. Only the top 10 fisheries and methods are shown for clarity. Open access fisheries are defined as those where there are no formal management arrangements in place, although other legislative restrictions may impact the activity.

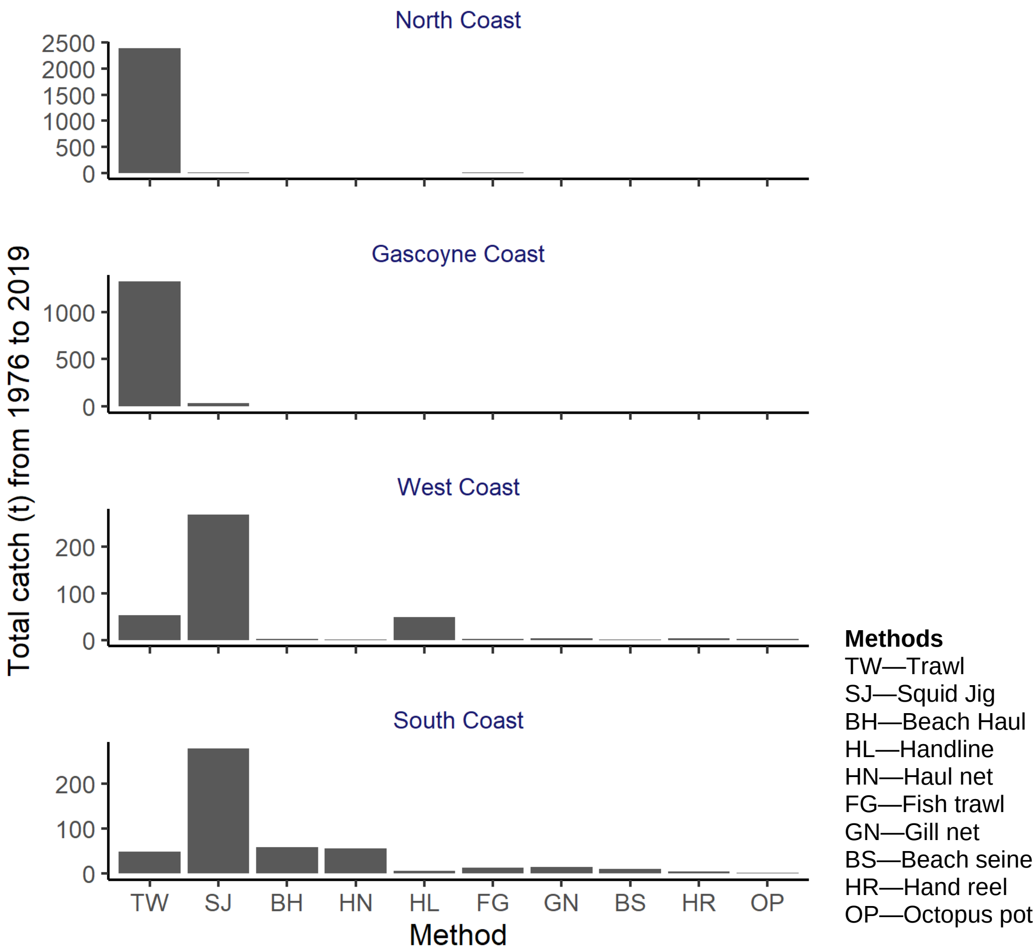


Figure 16. Contribution of squid catches from each fishing method in each WA bioregion from 1976 to 2019. Note, for clarity only the top 10 fishing methods (ranked by total state-wide catch) are shown.

9.0 Commercial fisheries

9.1 History of development

State-wide commercial squid catches annual catch from 1976 to 1992 ranged 23 to 79 t, before increasing markedly to 563–609 t during 1993–1995 (Figure 17). Catches then declined and ranged of 41–87 t for seven years from 1996 to 2002. In 2003, catches again increased, with a total annual catch of 172 t recorded, which was followed by a six-fold increase to 1062 t in 2004, the highest annual catches on record. As detailed in Section 9, these very high catches came predominantly from the NCB, and more specifically, Kimberley trawl fisheries during 1993–1995 and Pilbara trawl fisheries during 2003–2004. Since 2005, annual squid catches have generally ranged from 30–60 t, and have not exceeded 90 t (Figure 17). The number of commercial fishing vessels retaining squid state-wide increased from 75 vessels during 1976, to approximately 150 vessels during the 1990s. Since 2010, this has decreased to 68–93 vessels annually.

Fishing methods for capturing squid have remained relatively constant over time in the NCB, GCB and WCB, with trawling being the predominant method in the former two bioregions and line fishing (squid jigging, handlining) being mainly used in the latter (see also Section 9.3; Figure 31). However, in the SCB, most squid catches from 1976 to 1998 were resultant from haul netting, but since 1999, catches have come almost entirely from squid jigging. Since this transition from netting to targeted squid jigging in the late 1990s, the number of vessels fishing for squid and total annual catches in the SCB have generally increased (see Section 9.3.5). The majority of this catch was from the open access squid fishery. On 1 July 2021, fishing for squid and cuttlefish in the SCB was transitioned from open access to formal management. Under these arrangements, a limited number of managed fishery licences have been issued to allow commercial fishers to fish for squid and cuttlefish by line in the South Coast Line and Trap Managed Fishery (SCLTMF) and by net in the South Coast Nearshore Net Managed Fishery (SCNNMF). Fishers in both the SCLFTMF and the SCNNMF are subject to gear controls (i.e. maximum number of jigs) and the SCNNMF is subject to temporal (i.e. no fishing on weekends) and spatial closures (i.e. closed area in King George Sound). Further details on commercial squid and cuttlefish management arrangements in the SCB are available in the relevant management plans for the SCLFTMF and the SCNNMF.

Commercial cuttlefish catches from 1976 to 1991 were <15 t, increasing to 23 t in 1992, and since 1993 have generally ranged 35 to 55 t (Figure 18). Periods of very high catches occurred from 1996 to 1997 (69–75 t) and again from 2001 to 2005 (64–135 t). These high catches came predominantly from the NCB (77–88% of the annual totals; see Section 9.4 for further details). The number of commercial fishing vessels retaining cuttlefish state-wide has steadily increased, from six or less during the late 1970s, to 64 vessels in 1996 (Figure 18). There was then a decline in the mid-late 2000s, with only 25–32 vessels retaining cuttlefish from 2008 to 2011. This has since increased, and from 2012 to 2019 a total of 40–55 vessels have retained cuttlefish annually. There has not been any major shift in commercial fishing method for cuttlefish over time, with trawling consistently accounting for the vast majority of commercial landings.

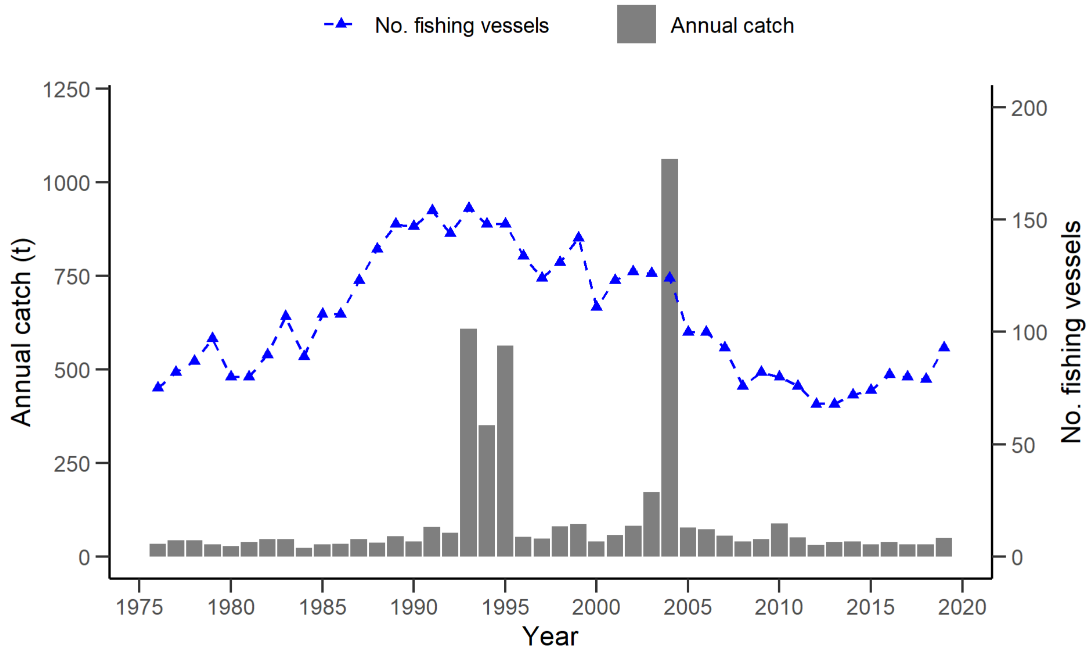


Figure 17. Total squid catch (t) and the number of vessels landing squid annually in Western Australia from 1976 to 2019.

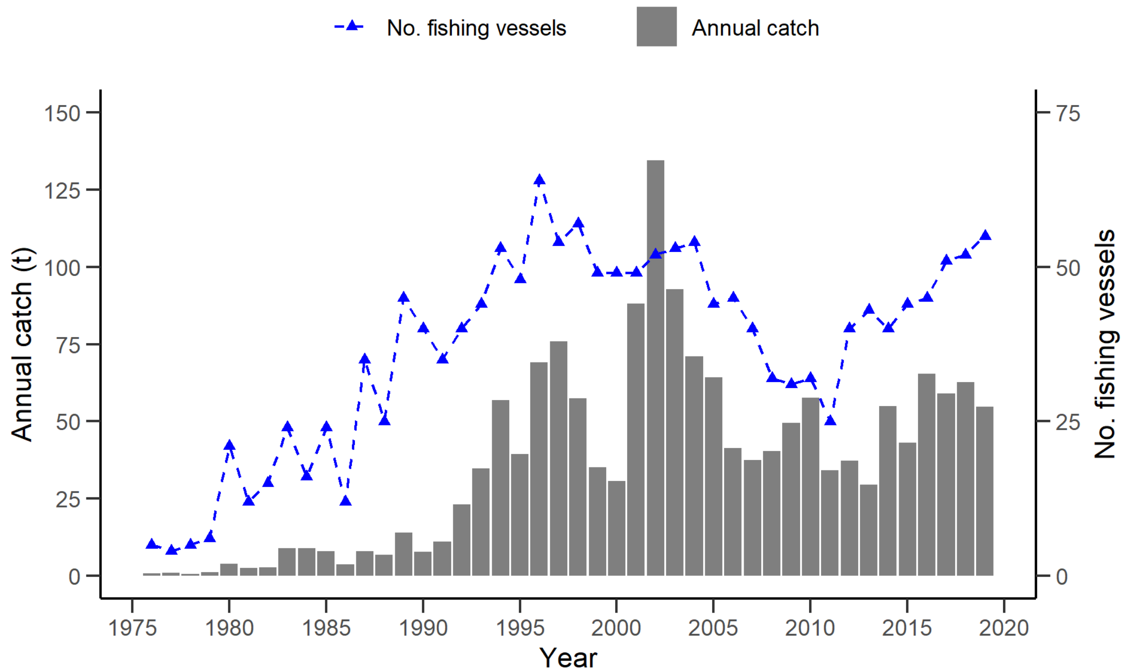


Figure 18. Total cuttlefish catch (t) and the number of vessels landing cuttlefish annually in Western Australia from 1976 to 2019.

9.2 Current fishing activities

From 2010 to 2019 the state-wide total catch of squid ranged from 31 to 89 t (Table 2). Commercial fishing occurred in all bioregions of the state, primarily by trawling in the NCB and GCB, and jigging in the WCB and SCB. The estimated value of the fishery during 2019 was $0.81 million AUD, based on 49 tonne landed by 93 vessels and a beach price of $16.75/kg.

Commercial cuttlefish catches from 2010 to 2019 have ranged 29–65 t (Table 3; Figure 18). The 2019 state-wide cuttlefish catch was 55 t landed by 55 vessels, representing a slight decrease from the 63 t landed during 2018. The estimated value of the State's commercial cuttlefish resource in 2019 was $0.29 million AUD.

Table 2. Summary of key attributes of commercial fishery for squid

Attribute	
Key fishing methods	Trawling, Squid Jigging, Handline, Beach haul
Number of vessels	93 (2019)
Size of vessels	~3–25 m
Number of people employed	Unknown
Annual catch	31 to 89 t (2010 to 2019), 49 t (2019)
Value of fishery	$821,000 (2019 year GVP at $16.75/kg) Level 1

Table 3. Summary of key attributes of commercial fishery for cuttlefish

Attribute	
Key fishing methods	Trawling
Number of vessels	55 (2019)
Size of vessels	~3–25 m
Number of people employed	Unknown
Annual catch	29 to 65 t (2010 to 2019), 55 t (2019)
Value of fishery	$290,000 (2019 year GVP at $5.30/kg) Level 1

9.3 Fishing Methods and Gear

9.3.1 *Trawling*

Trawling is one of the most common commercial fishing methods and involves towing a specifically designed net bag horizontally through the water column at a specified depth (Misund et al., 2002). Trawls that operate throughout the surface and middle of the water are termed pelagic trawls, whereas those operating low in the water column and along the substratum are defined as bottom trawls (Gabriel *et al.*, 2005).

Trawl design and construction (*e.g.* width, height, mesh size, material) is largely dependent on the habitat in which they are being deployed and the type of species targeted. The trawl nets are attached to the towing vessel by rope or steel lines, termed warp lines (Figure 19). Although the opening of trawls can be held apart in a variety of ways, most modern trawls employ either solid beams or otter boards (Gabriel *et al*., 2005). Otter boards are large wooden or steel boards attached to the extremities of nets which use hydrodynamic forces to maintain the net at a certain depth, while keeping the mouth open (Misund *et al.*, 2002; Gabriel *et al.*, 2005). In the NCB and GCB of WA, squid are commonly caught in prawn trawl fisheries which generally use low-opening demersal otter trawl nets (Figure 19).

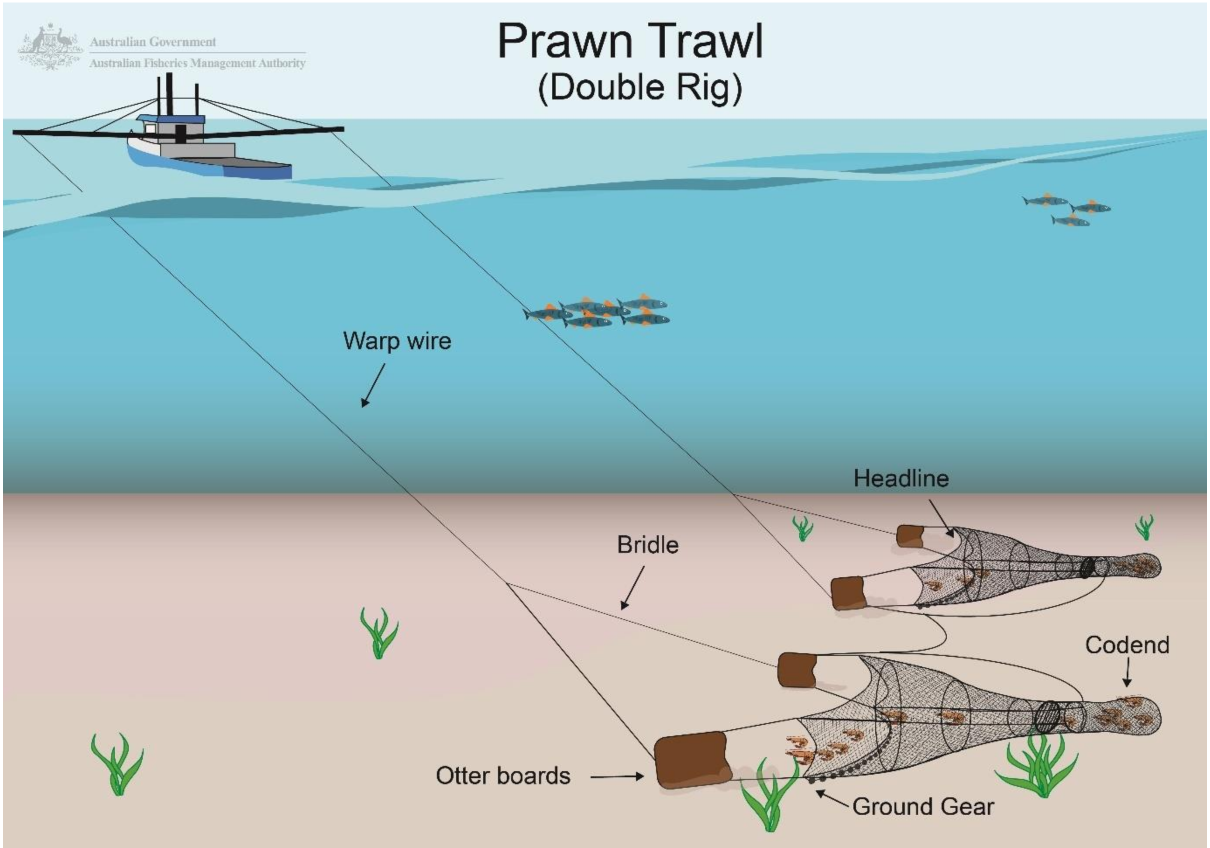


Figure 19. Schematic of a standard twin-rig otter trawl used by prawn trawling vessels in northern Australia. Illustration © Australian Fisheries Management Authority.

9.3.2 *Squid jigging*

Squid jigging is a highly productive method of catching squid, accounting for more than half of the global commercial cephalopod catch (Boyle & Rodhouse, 2005). In southern and eastern Australian fisheries, jigging annually accounts for approximately 1000 t of *N. gouldi* and 500 t of *S. australis* catch (Lyle *et al*., 2014; Moore *et al*., 2018; Noriega *et al*., 2018). Barbless hooks in clusters, attached to natural baits or plastic jigs, are almost exclusively used for targeting squid and cuttlefish by jigging. Jigs may be fished using single manually operated lines, or with automatically programmed reels and longlines (see below). In good conditions, catches of 10–20 kg of squid per jig may be achieved per day, which can be regarded as highly efficient considering the minimally destructive and fuel efficient nature of squid jigging compared with trawling, seine netting and other techniques (Boyle & Rodhouse, 2005). Squid jigging is regarded as one of the most selective commercial fishing techniques, almost exclusively catching target species (Boyle & Rodhouse, 2005).

9.3.3 *Automated squid jigging*

Automated squid jigging typically employs longlines, which may be up to 150 m long with jigs at one metre intervals, that are lowered rapidly through the water column before being retrieved at speeds of between 45 and 90 m/s (Boyle & Rodhouse, 2005). As the lines are retrieved, they pass over a v-shaped roller which, due to the barbless hooks, flings the squid free from line onto a mesh screen beneath, where they can be easily collected by the fisher. The use of multiple reels by vessels is not uncommon, with large vessels frequently operating up to 100 or more of these lines simultaneously (Boyle & Rodhouse, 2005). Lights are often also used to attract squid and enhance catch rates (Figure 20). Squid jigging with automated jigging equipment has been undertaken by several vessels operating in offshore waters (>200 m depth) of the SCB of WA to target Gould's squid.

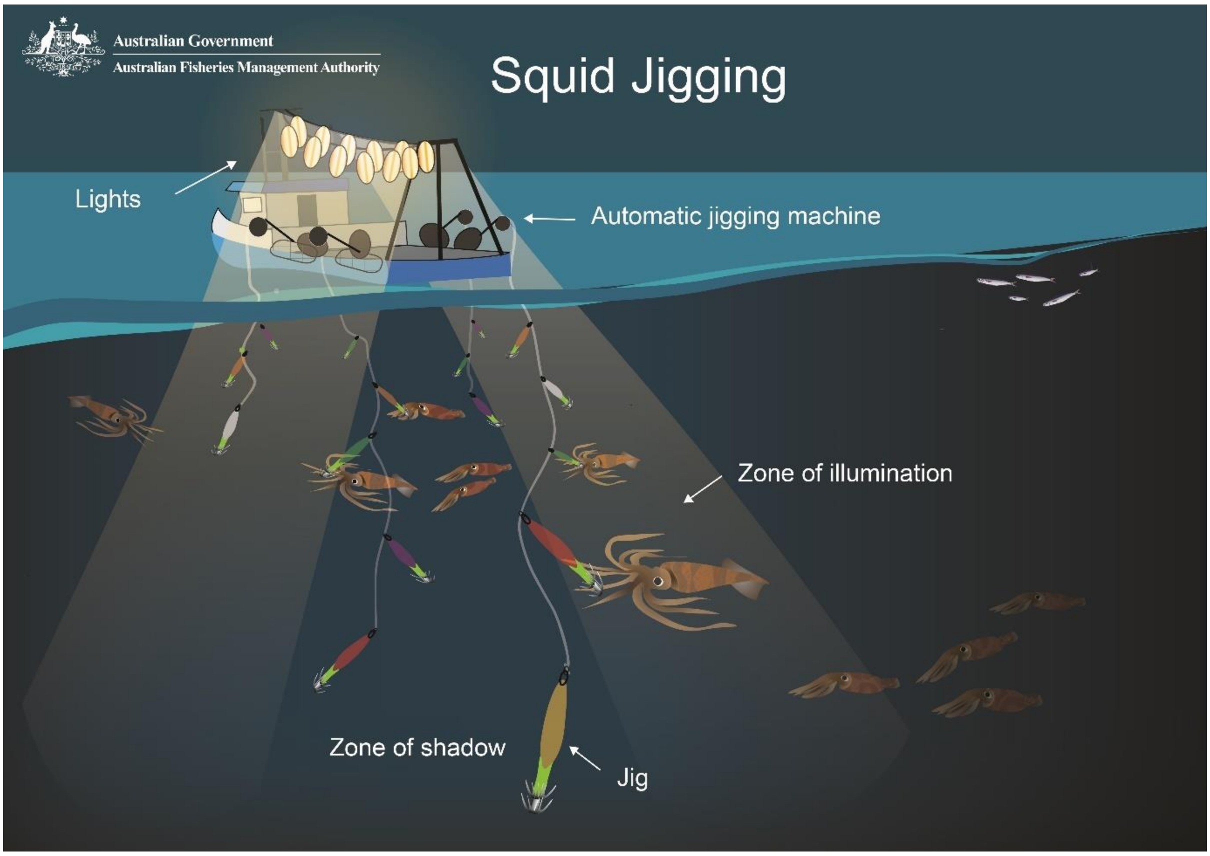


Figure 20. Schematic of squid jigging using artificial illumination. Illustration © Australian Fisheries Management Authority.

9.3.4 *Handlining*

Handlining is a squid fishing method typically employed by small scale fishers from smaller vessels, which involves using squid jigs on hand wound spools of line. In WA, this technique is used by fishers targeting southern calamari in inshore waters of the WCB and SCB (Coulson *et al*., 2016). A baited squid jig or ‘squid spike’ (see section 6.3 and Figure 22), typically baited with Australian herring (*Arripis georgianus*) or pilchard (*Sardinops sargax*), is attached to a float by a short (several metres) length of fishing line, and then allowed to drift freely in the wind and current (Figure 21). Fishers simultaneously use 10–20 lines which are checked and retrieved periodically (Coulson *et al*., 2016).

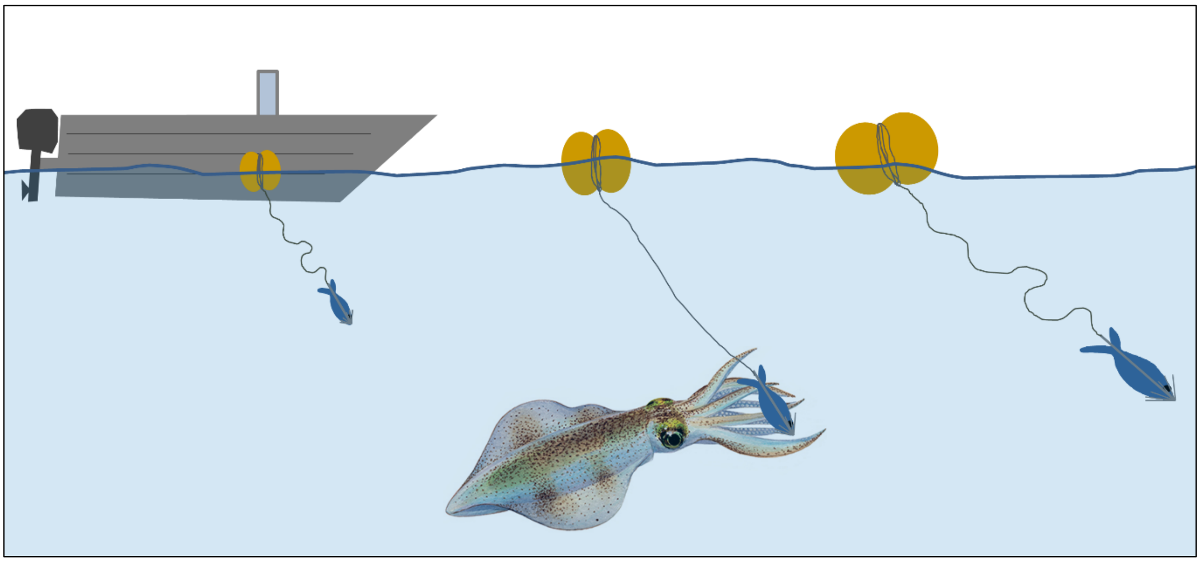


Figure 21. Schematic of drifting handline technique used by small-scale squid fishers to target southern calamari *Sepioteuthis australis* in shallow inshore waters. Southern calamari illustration © R.Swainston/www.anima.net.au.

9.3.5 *Other methods*

A relatively low proportion of commercial squid and cuttlefish harvest in WA is also taken using a variety of other fishing methods, which include traps, seine nets, haul nets and gill nets. While catch from these methods has been very low in recent decades (<1% of state-wide catch), prior to 1999 beach haul and seine netting accounted for a substantial proportion of south coast squid catch (50–99% by weight; see section 9.3.5). The latter netting techniques involve using a wall of net, often set from the beach using a small vessel, which surrounds fish (or squid) and thereby prevents their escape (Misund *et al*., 2002, Gabriel *et al.*, 2005). These nets may be set near the surface to target pelagic species or weighted to fish the entire water column in shallow inshore waters, and often have a central pocket or ‘cod end’ into which the catch is funnelled.

9.4 Recreational fisheries

Recreationally, squid and cuttlefish are targeted almost exclusively by line fishing, either using squid jigs, artificial baits designed to mimic prawns or fish, or natural baits on ‘squid spikes’, both of which typically have many barbless hooks in a cluster.

Examples of these are shown in Figure 22. Occasionally, squid and cuttlefish are also caught by divers using spears or lobster snares.

An estimated 88,519 squid and 4,234 cuttlefish were caught by recreational boat-based fishers throughout WA during a 12-month survey period in 2017/18 (Ryan *et al*., 2019). Of these catches, 97% of squid and 72% of cuttlefish were retained. During this survey squid were the fifth most retained species state-wide after western rock lobster (*Panulirus cygnus*), blue swimmer crab (*Portunus armatus*), Australian herring and school whiting (*Sillago* spp.).

Most recreational catches for both squid and cuttlefish occurred in the WCB (>85%). Minor squid catch was also taken in the NCB, GCB and SCB, and while some cuttlefish were caught in the SCB, negligible catch occurred in the NCB and GCB. Catches of both squid and cuttlefish were higher in autumn, winter and spring than summer. Squid catches were similar in 2017/18 to those from earlier surveys during 2015/16, 2013/14 and 2011/12 (Ryan *et al*., 2019). Cuttlefish catches were higher in 2017/18 than 2015/16 or 2013/14, but similar to 2011/12.

In recent years, squid jigging has increased in popularity and become more refined. Fishing tackle specifically designed for squid jigging, originally from Japan, has now become widely available in Australia (Lyle *et al*., 2014; Coulson *et al.*, 2016) and squid fishing tournaments have been established in the WCB and SCB (*e.g.* the 'Calamari Classic').

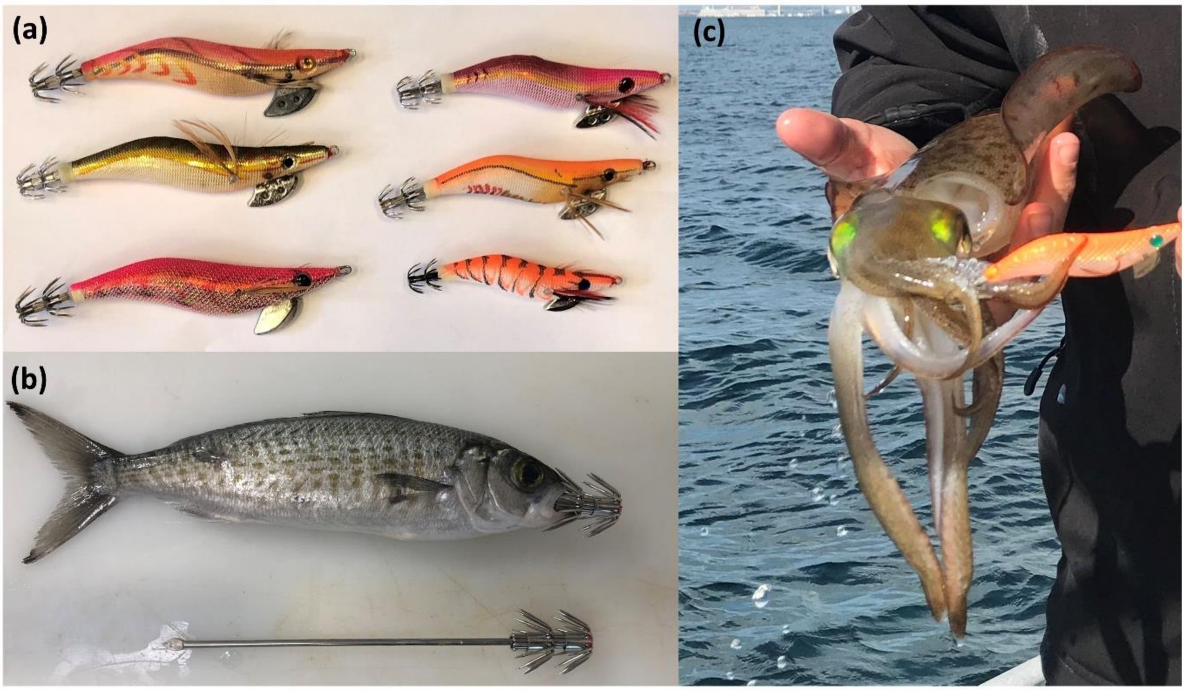


Figure 22. (a) A selection of recreational squid jigs, (b) a 'squid spike' used for catching squid with natural baits (pictured Australian herring *Arripis georgianus*) and (c) a southern calamari *Sepioteuthis australis* caught using a recreational squid jig.

9.5 Customary Fishing

The level of customary fishing for squid and cuttlefish in WA is unknown, however, on the basis of national indigenous fishing surveys conducted in northern Australia (Henry & Lyle, 2003), it is likely to be low in comparison to the harvest of other invertebrates (*e.g.* mud crabs, prawns, cockles) and finfish.

9.6 Illegal, Unreported or Unregulated Fishing

Illegal, unreported or unregulated fishing for squid and cuttlefish in WA is likely to be negligible.

10.0 Fishery Management

10.1 Management system

10.1.1 *Commercial Open Access Squid Fishery*

Commercial fishing for squid (and cuttlefish) by jigs is currently an open access activity in the West, Gascoyne and North Coast Bioregions of WA. This means that there are no management arrangements in place to specifically manage squid fishing, and a Managed Fishery Licence (MFL) to commercially fish for squid is not required, with the exception of fishing for squid in Cockburn Sound where a relevant MFL is required or in Pilbara waters where a relevant Fishing Boat Licence is required. To operate in the open access squid fishery a Commercial Fishing Licence (CFL) is required combined with an unrestricted Fishing Boat Licence and a Licenced Fishing Boat (LFB) if fishing from a vessel. Gear restrictions include fishing by jig only and lines must have jigs attached at all times. There is no limit on the number of lines and jigs permitted, and no minimum size limits or catch limits apply.

Whilst it is an open access activity, other legislative restrictions may impact ability to fish for squid and cuttlefish in certain circumstances. Spatial restrictions apply, as well as Marine Protected Areas and other fisheries' Management Plans will need to be taken into account, as these may limit or remove the capacity to operate in an area. Monthly catch records must be submitted to DPIRD to assist with the monitoring of catch and effort and the sustainable management of stocks.

10.1.2 *South Coast Bioregion Managed Fisheries*

On 1 July 2021, the fishery in the SCB was transitioned from open access to formal management. Under the new arrangements a limited number of Managed Fisheries Licences has been issued to allow fishers to catch squid and cuttlefish by line in the South Coast Line and Fish Trap Managed Fishery (SCLFTMF) and by net in the South Coast Nearshore Net Managed Fishery (SCNNMF). Fishers in both the SCLFTMF and the SCNNMF are subject to gear controls (e.g. maximum number of jigs, net length and mesh size) and the SCNNMF is subject to temporal (e.g. no fishing on weekends) and spatial closures (e.g. closed area in King George Sound). Further commercial management information is available in the *South Coast Line and Fish Trap Managed*

Fishery Management Plan (2020) and the *South Coast Nearshore Net Managed Fishery Management Plan (2020)*.

10.1.3 *Recreational fishing*

Recreational fishing for squid and cuttlefish is permitted throughout most areas of WA. Management of squid and cuttlefish catch is predominantly through the use of a combined daily bag limit with octopus, that is currently 15 per day for individuals and 30 per boat (when two or more licences people are on board). A recreational fishing from boat licence (RFBL) required when fishing from motorized vessels. Recreational gear restrictions include: no more than 3 baits or lures (e.g. squid jigs) per line, no more than 2 lines per shore based fisher, and lines must be attended at all times (unattended set or drifting squid jigs are not permitted). No minimum size limits apply. There are no spatial closures specific to squid or cuttlefish, but fishing for these species is restricted or prohibited in certain Marine Protected Areas.

10.1.4 *Harvest Strategy*

A harvest strategy for squid and cuttlefish resources of WA is currently being developed to outline long and short-term objectives for management. The harvest strategy will provide a description of the performance indicators used to measure performance against these objectives, reference levels for each performance indicator, and associated control rules that articulate predefined, specific management actions designed to maintain the resource at target levels.

The status of the squid and cuttlefish resources in WA are assessed annually using a weight-of-evidence approach of all available data for the key areas in which the resource is commercially and recreationally targeted. Currently, assessment is conducted at the bioregion level and is primarily based on commercial catch and standardised commercial catch rates relative to reference levels.

For squid fisheries of the West and South Coast Bioregions, draft reference levels have been calculated from the standardised squid jigging catch rates observed annually during a reference period of relative stability when the fisheries were considered to have been operating sustainably (2009–2018). The target range extends between the maximum and minimum values recorded during that reference period, where the latter denotes the threshold level assumed to represent a proxy for the stock level at which Maximum Sustainable Yield (MSY) can be achieved (DPIRD, 2020). Any stock size above this level is therefore consistent with meeting the objectives for biological sustainability and also satisfy stock status requirements under the Marine Stewardship Council (MSC) standard for sustainable fishing. A conservative approach has been taken to set the limit reference level at 70% of the threshold value (*i.e.* $0.7B_{MSY}$) and is considered to represent the level below which recruitment may be impaired (DPIRD, 2020). Appropriate reference levels for North and Gascoyne Coast Bioregion squid and cuttlefish fisheries are still to be determined.

10.2 External influences

10.2.1 *Environmental factors and climate change*

As short-lived and rapidly growing invertebrates, environmental factors exert strong influences on many squid and cuttlefish populations globally. For example, annual commercial landings and catch rates of the cuttlefish *Sepia officinalis* in the Mediterranean Sea fluctuate widely between months and years, reflecting changes in sea surface temperatures and local climatic conditions (Keller et al., 2014). Environmental variables such as wind speed and water clarity can also highly influence the catchability of many squid species since they are visual predators and targeted by jigging (Postuma & Gasalla, 2010; Cabanellas-Reboredo *et al*., 2012). In the NCB and GCB of WA, commercial squid and cuttlefish catches are negatively correlated with annual water temperatures (see Section 9.3 and 9.4). Moreover, the extraordinarily high catches in the Pilbara region which occurred during autumn and winter of 2004 (*c.* 967 t) coincided with far cooler than average late summer and autumn temperatures. In contrast, commercial squid catches and/or CPUE in south-western Australia (WCB and SCB), presumed to mostly comprise southern calamari *S. australis*), were positively correlated with temperature (Section 9.3).

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*., 2016). This is primarily occurring through changes in the frequency and intensity of ENSO events, decadal variability in the Leeuwin Current, increase in water temperature and salinity, and change in frequency and intensity of storms and tropical cyclones affecting the state (Caputi *et al*., 2016). Observed inter-annual changes in commercial squid and cuttlefish catches and catch rates (detailed in Section 9.3) appear in many cases to be closely related with water temperature, and particularly severe warming events (e.g. marine heatwaves which affected south-western Australia in 1999 and 2010/11; Pearce & Feng, 2013; Oliver *et al*., 2018). Range expansions or contractions of certain species may also be occurring with climate changes. For example, following the summer marine heatwave of 2011 there have been occasional catches of tropical loligo squid *Uroteuthis* (*Photololigo*) spp. reported by recreational fishers around Fremantle (Appendix 3). The effects of future climate change on squid and cuttlefish stocks are likely to vary between regions of WA and between species, and will continue to be monitored in future assessments.

10.2.2 *Market Influences*

Squid and cuttlefish are marketed on both domestic and overseas markets for food or bait, depending on the size and quality of the product. Larger animals are generally marketed whole for food, either fresh, frozen or dried, or as a cleaned mantle (e.g. 'tubes' or 'squid rings'). Small squid are generally sold whole for commercial or recreational bait. Market value also varies among species. Southern and northern calamari are typically marketed as 'calamari' and primarily sold for local seafood supply. *Uroteuthis* (*Photololigo*) spp. are generally marketed as 'loligo squid', and also mainly sold for consumption. Gould's squid is sold on domestic and export seafood markets and for bait supply. Calamari and loligo squid are generally more highly valued than Gould's squid for consumption as their flesh is considered more tender

(Dunning *et al.*, 2000). Cuttlefish is primarily marketed for consumption, both domestically and overseas, although small cuttlefish caught by trawlers are also sold for bait (Wadley & Dunning, 1998).

The total value of WA squid and cuttlefish exports (all species, fresh, frozen, dried and preserved) to overseas markets has ranged from <$5,000 to $184,000 AUD between 2001/02 and 2018/19 (financial year), with the highest GVP during 2002/03 ($95,000), 2004/04 ($184,000) and 2005/06 ($104,000). Exports from 2014/15 to 2018/19 have ranged $36,000–59,000. Asian markets, specifically Thailand, Hong Kong, China and Singapore, have accounted for the majority (77% by dollar value) of exports since 2001/02. Minor export also occurs to Europe (Turkey, Italy, North Macedonia) and smaller islands throughout the Indo-Pacific (e.g. Mauritius, Maldives, Cocos Keeling Islands).

11.0 Information and Monitoring

11.1 Commercial data sources

Under the *Fish Resources Management Act 1994* (FRMA), licensees involved in fishing operations and/or the master of every licensed fishing boat must submit an accurate and complete monthly catch and effort return on forms approved by the Department. The specific reporting requirements and the frequency by which data are reported (e.g. daily *vs* monthly totals) depended on the specific fishery area in which the fishing occurred and the licence under which fishers were operating. Commercial catch and effort data for squid and cuttlefish are therefore available from all fisheries state-wide since 1975 (Table 4).

The returns include catch totals (kg) for each retained species (recorded as ‘squid’ or ‘cuttlefish’), fishing method details (e.g. trawl, squid jig, trap, beach seine, haul net), estimates of effort (e.g. number of hooks/jigs used, distance trawled, number of days fished), spatial information (typically 60 × 60 nm block, i.e. Catch and Effort Statistics, CAES, blocks) and information on interactions with endangered and threatened species.

These data have been used to provide the basis for ongoing stock assessment for squid and cuttlefish and are critical to the development of stock performance indices and harvest strategy evaluation.

11.2 Recreational data sources

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; Table 4). 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. As for commercial data, catch are reported as 'squid' or 'cuttlefish'.

11.3 Biological information

A comprehensive biological study of southern calamari in south-western Australia was undertaken during 2013–2015 by researchers from Murdoch University in collaboration with DPIRD (Coulson *et al*., 2016). The study collected both fishery dependent and independent information to determine the age and growth, reproduction, size composition and length-weight relationship of this squid species in key fishery areas of Cockburn Sound, Geographe Bay and King George Sound (Table 4).

Table 4. Summary of information sources used for the assessment of squid and cuttlefish resources.

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 fished (CAES blocks)	State-wide	Monthly	Since 1975
Commercial catch and effort daily logbook returns	Dependent	Commercial catch and effort, catch rates and location fished (latitude/longitude)	Trawl fisheries (North and Gascoyne Coast Bioregions)	Daily	Since ~2008
Commercial catch and effort daily logbook	Dependent	Commercial catch and effort, fishing locations, species composition	South Coast Bioregion Managed Fisheries	Daily	Since 2021
Recreational state-wide survey	Dependent	Recreational catch and effort trends	State-wide	Biennial	Since 2011/12
Biological information	Dependent and Independent	Age and growth, reproduction, size composition, length-weight relationship	Cockburn Sound, Geographe Bay, King George Sound	Opportunistic	Since ~2013

12.0 Stock Assessment

12.1 Assessment principles

The different methods used by the Department to assess the status of aquatic resources in WA have been categorised into five broad levels, ranging from 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.

12.2 Assessment overview

12.2.1 *Data used in assessment*

Commercial CAES / Logbook data (1976 to 2019)
Recreational survey data
Environmental data

12.2.2 *Level 1/2 assessment*

Squid and cuttlefish resources are currently assessed primarily at the bioregion level. In the absence of a population model, the annual assessment of squid and cuttlefish resources, are based primarily on an analysis of commercial catches (Level 1 assessment) and catch rates (Level 2 assessment), the latter which are assumed to be an index of abundance and used as a proxy for spawning biomass. The availability of robust effort data for each species and bioregion determines the level of assessment able to be undertaken. Squid fishing in the WCB and SCB is primarily undertaken by targeted squid jigging, and therefore a reliable measure of effort is available, however squid and cuttlefish in the NCB and GCB are primarily retained as by-product from trawl and fish fisheries, and therefore, targeted effort is difficult to ascertain.

For commercial squid jigging fisheries of the WCB and SCB, annual standardised catch per unit of effort (CPUE) values are calculated from monthly commercial catch rate data (kg/day) using a generalised linear model to account for the effects of month, fisher (vessel ID) and fishing location (60 × 60 nm CAES block). Note, only vessels which landed squid for five or more years were included in the standardised CPUE calculations. The annual standardised CPUE values for each bioregion are compared to reference points specified in the harvest strategy (described earlier in Section 7.2).

A risk-based weight-of-evidence approach is applied, utilising lines of evidence from both commercial and recreational fisheries, with the results of a Productivity Susceptibility Analysis (PSA) used to evaluate the inherent vulnerability of each species group to fishing.

12.3 Commercial squid catch and effort trends

12.3.1 *Overview and state-wide catch trends*

The state-wide total annual catch from 1976 to 2019 ranged from 23 to 1062 tonnes (Figure 23). In most years, catches ranged from approximately 30–90 tonnes, although two periods of very high catches occurred, firstly from 1993 to 1995 (563–609 t) and again in 2003 and 2004 (172–1062 t). These very high catch totals primarily reflected increased catches in the North Coast Bioregion (NCB), as well as to a lesser extent in the Gascoyne Bioregion (GCB; Figure 24). The state-wide commercial catch in 2019 was 49 t (Table 5; Figure 23), which was a *c.* 50% increase from 2018 (32 t; Figure 23) and 40% above the average for the previous five years from 2014–18 (35 t; Table 5).

By bioregion, total squid catches over the time period 1976–2019 were far greater in the NCB and GCB (total 2413 and 1366 t, respectively), than in the West Coast Bioregion (WCB; 385 t) or South Coast Bioregion (SCB; 491 t; Figure 24). However, in recent years the total catches have been highest in the SCB and GCB, and lowest in the WCB and NCB (Table 5, Figure 24). Catch totals during 2019 were 21 t in the SCB, 14 t in the GCB, 11 t in the WCB and 3.5 t in the NCB. The number of fishing vessels retaining squid in the WCB peaked from the late-1980s to early-1990s (*c.* 50-70 vessels), and from the early 1990s to mid-200s in the NCB and GCB (30–50 vessels in each), but has declined in recent years (Figure 25). During 2019, nine vessels landed squid in the NCB, 28 vessels landed squid in the GCB, and 24 vessels landed squid in the WCB. In the SCB, the number of vessels landed squid was greatest during 1991 (46 vessels), but has remained relatively constant at 24–38 vessels since 1992.

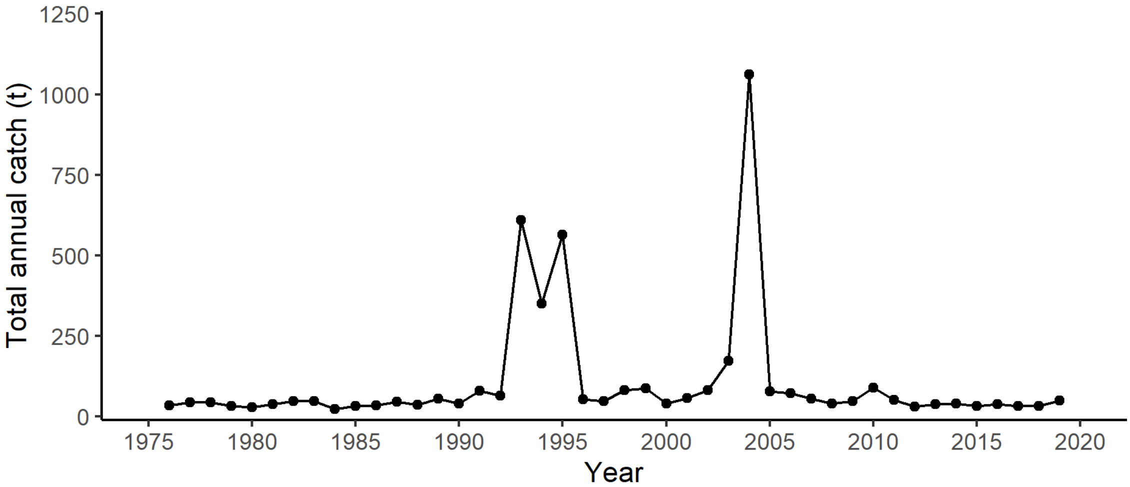


Figure 23. Total annual commercial catch of squid in Western Australia from 1976 to 2019.

Table 5. Total and average commercial squid catch in each bioregion and state-wide from 2014–18 and the total catch in 2019.

	Catch 2014–2018 (t)		Catch 2019
Bioregion	**Total**	**Average ± SD**	**Total (t)**
North Coast	10.3	2.1 ± 0.6	3.5
Gascoyne Coast	65.6	13.1 ± 4.3	13.7
West Coast	25.4	5.1 ± 1.4	10.8
South Coast	73.9	14.8 ± 2.6	21.1
State-wide	175.2	35.0 ± 3.7	49.0

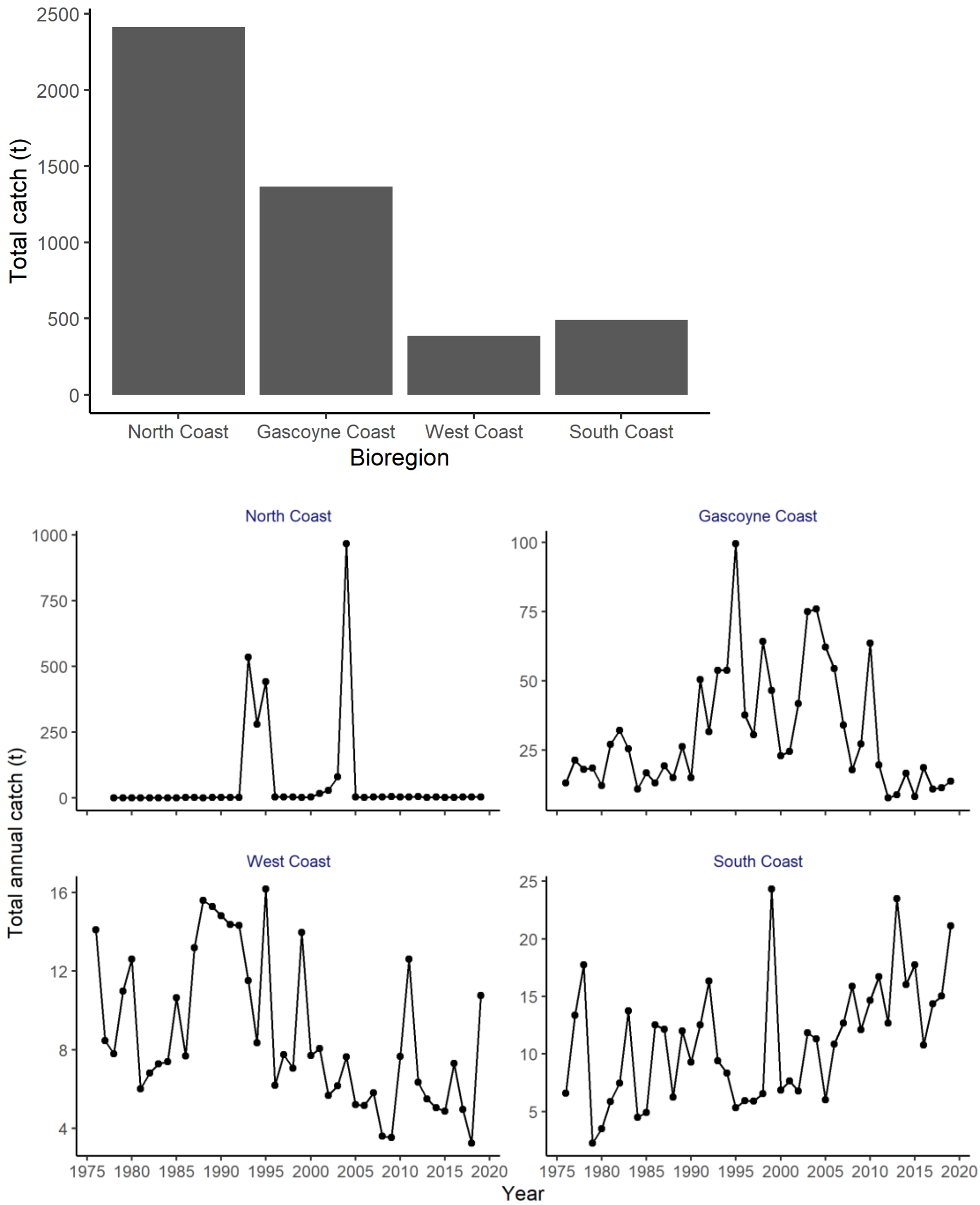


Figure 24. Commercial squid catches in the North Coast, Gascoyne Coast, West Coast and South Coast bioregions of Western Australia from 1976 to 2019. Bars display the total catch in each bioregion (across all years) and points display annual catches.

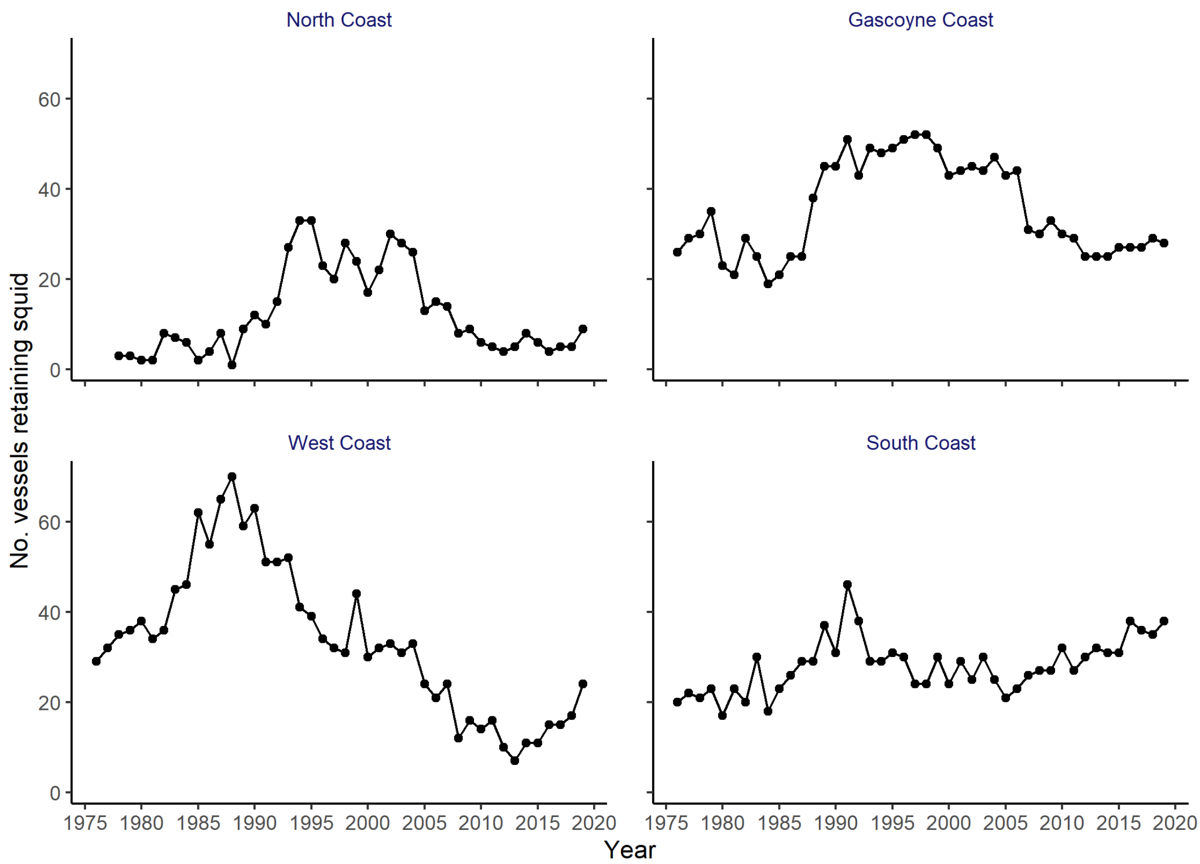


Figure 25. The annual number of vessels retaining squid in each Western Australian bioregion from 1976 to 2019.

At a finer spatial scale, the greatest catches and numbers of vessels retaining squid in the NCB came from the Kimberley region (north-east of Broome) and Pilbara region (near Karratha; Figure 26; Figure 27; Figure 28). Catches in the Kimberley region mainly occurred during 1993–1995, and also 2003, while the greatest Pilbara catch occurred during 2004 (Figure 28). Squid catches from the GCB primarily came from trawl fisheries in Shark Bay and Exmouth, with relatively consistent catch contributions from both areas since 1976 (Figure 26; Figure 27). Throughout the north-west (NCB and GCB) squid catches were essentially restricted to nearshore waters, e.g. CAES blocks comprising mostly waters <200 m depth (Figure 26). In the south-west (WCB and SCB) the majority of catch has been taken from the Perth Metro region and Albany region, with minor catches in Geographe Bay (Busselton region), as well as east of Esperance in the Great Australian Bight (Figure 26; Figure 29). While most catches were taken from nearshore waters <200 m depth, there were catches taken in deeper waters (200–3000+ m) offshore from Perth and Albany, and between Esperance and Eucla (Figure 26). During the 1970s and 1980s the majority of squid catch in the south-west occurred on the lower-west coast near Perth, as well as along the 200 m isobath on the south coast near Esperance (Figure 30). Since the 1990s squid landings and the number of vessels fishing for squid have steadily increased in the Albany region, and in 2010–2019 this region accounted for the greatest contribution of catches in the south-west (Figure 29; Figure 30).

Squid were reported from 36 different fisheries, with catches ranging from over 800 tonnes (Kimberley, Nickol Bay and Shark Bay Prawn Managed Fisheries) to less than 50 kg (*e.g.* West Coast Estuarine Managed Fishery, Gascoyne Demersal Scalefish Managed Fishery; see Figure 14, Section 6.1). Approximately 1,100 t of squid was also taken from the open access fishery throughout the WA. By method, trawling accounted for 82% of all squid caught (3820 t), followed by squid jigging (13%; 593 t) and beach hauling (1%; 61 t; Figure 14). Over time, trawling consistently accounted for the greatest proportion of squid catches in the NCB and GCB, while line fishing (squid jigging and handlining) accounted for the greatest catches in the WCB (Figure 31). Notably, however, squid jigging accounted for a substantial portion >10% of squid catch in NCB during 1992 and 1996–1998, and in the GCB during 1987/88 and 1990. In the SCB, haul netting consistently accounted for the vast majority of squid catches from 1976 to 1998, but since 1999 the majority of catches have come from squid jigging. Squid catches during 2019 in the NCB and GCB were taken almost exclusively (99–100% of annual total) by trawl (Figure 31). In contrast 77% of the WCB catch was taken by squid jigging, 16% was taken by handline and minor contributions came from trawling and other methods, while 92% of the SCB catch came from squid jigging with minor catch from other methods (e.g. beach seine, gill net, handline).

Squid catches in the NCB and GCB are presumed to comprise predominately either northern calamari (*Sepioteuthis lessoniana*) or species of the genus *Uroteuthis* (*Photololigo*) (e.g. slender squid, swordtip squid and mitre squid), dependent on the time of year and location fished as well as fishing method used. Catches from inshore waters (<30 m deep) waters are likely to comprise a high proportion of *S. lessoniana*, while in deeper waters (e.g. 30–200 m) *Uroteuthis* spp. would be most likely to be caught (see also Section 5, Species Description). In contrast, catches from the cooler waters of the WCB and SCB are presumed to comprise predominantly southern calamari (*S. australis*) in inshore waters (<30 m) and Gould’s squid (*Nototodarus gouldi*) in offshore waters (e.g. 50–850 m depth).

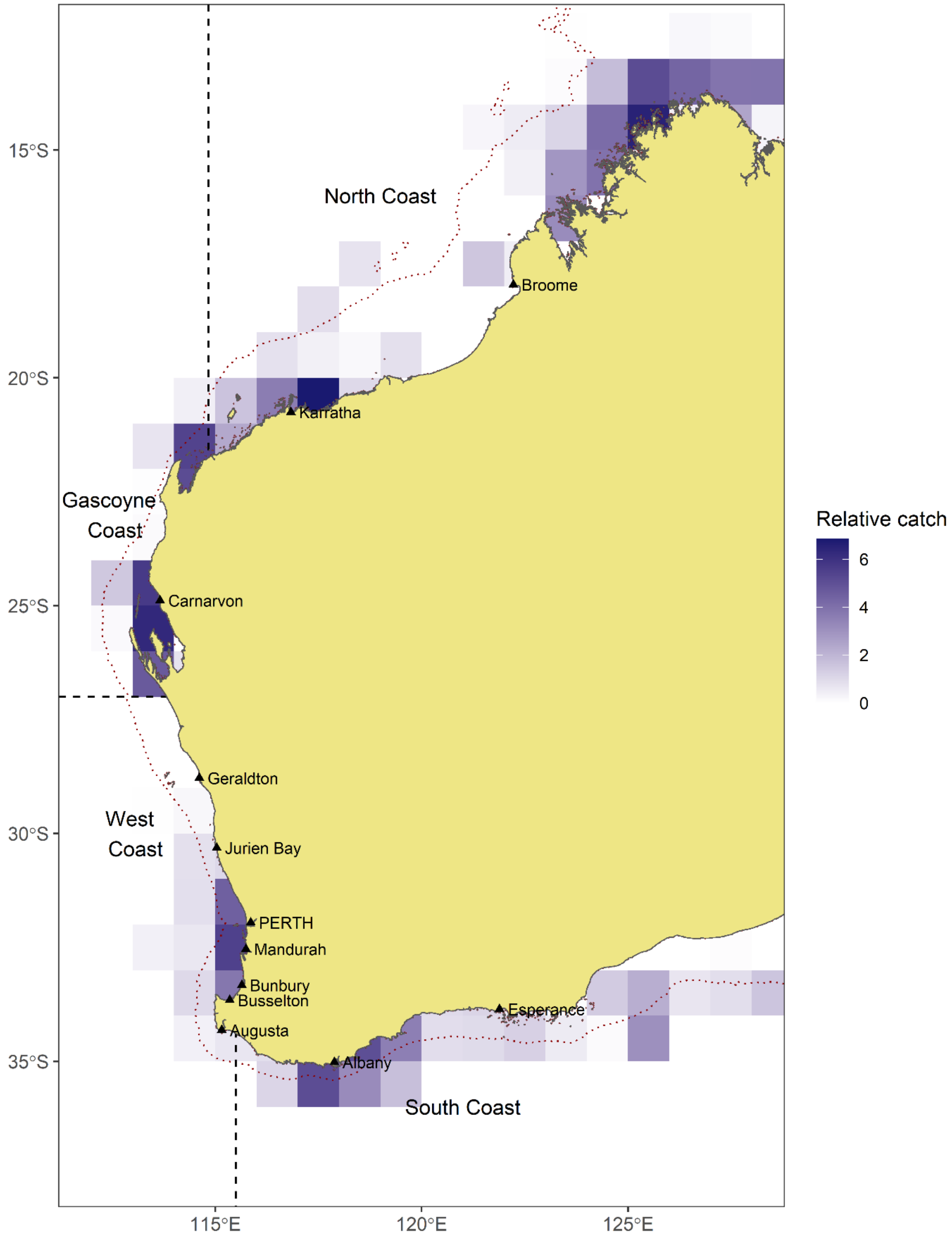


Figure 26. Total catch of squid in each 60 x 60 nm CAES block throughout Western Australia from 1976 to 2019. Catch totals (t) have been log(x + 1) transformed. Dashed lines denote bioregion boundaries and the dotted line denotes the 200 m isobath.

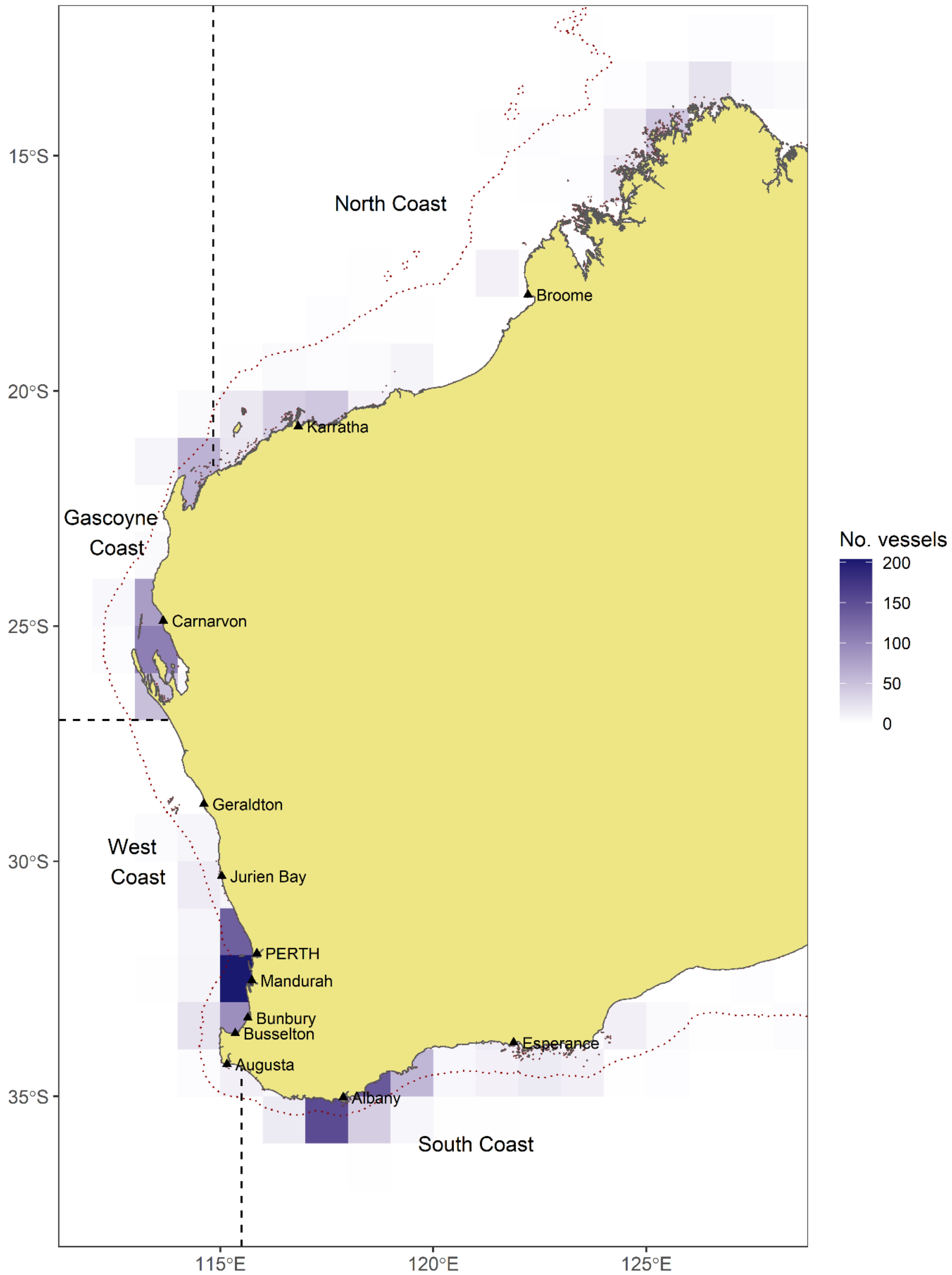


Figure 27. Total number of vessels retaining squid from each 60 x 60 nm CAES block **throughout Western Australia** between 1976 and 2019. Dashed lines denote bioregion boundaries and the dotted line denotes the 200 m isobath.

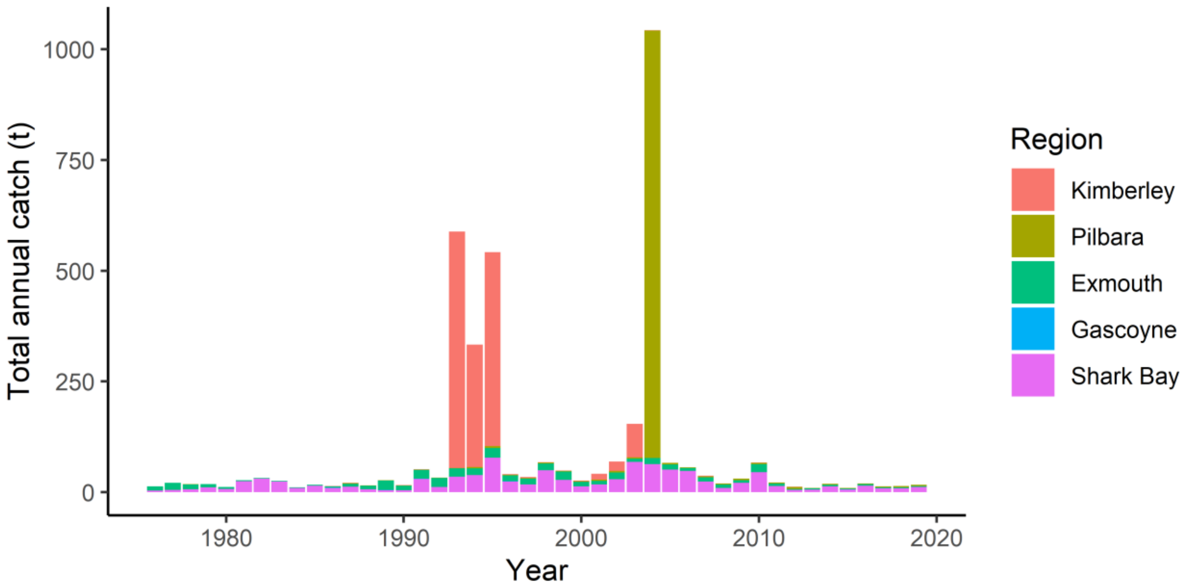


Figure 28. Total annual squid catch by region within north-western Australia (North and Gascoyne Coast Bioregions). Region locations are shown in Figure 3.

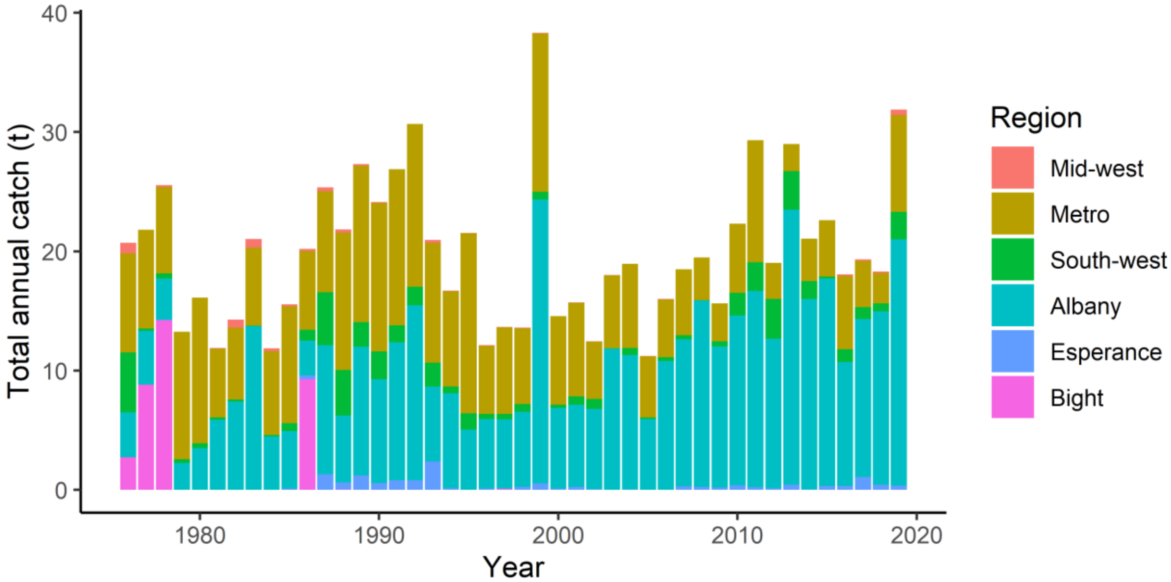
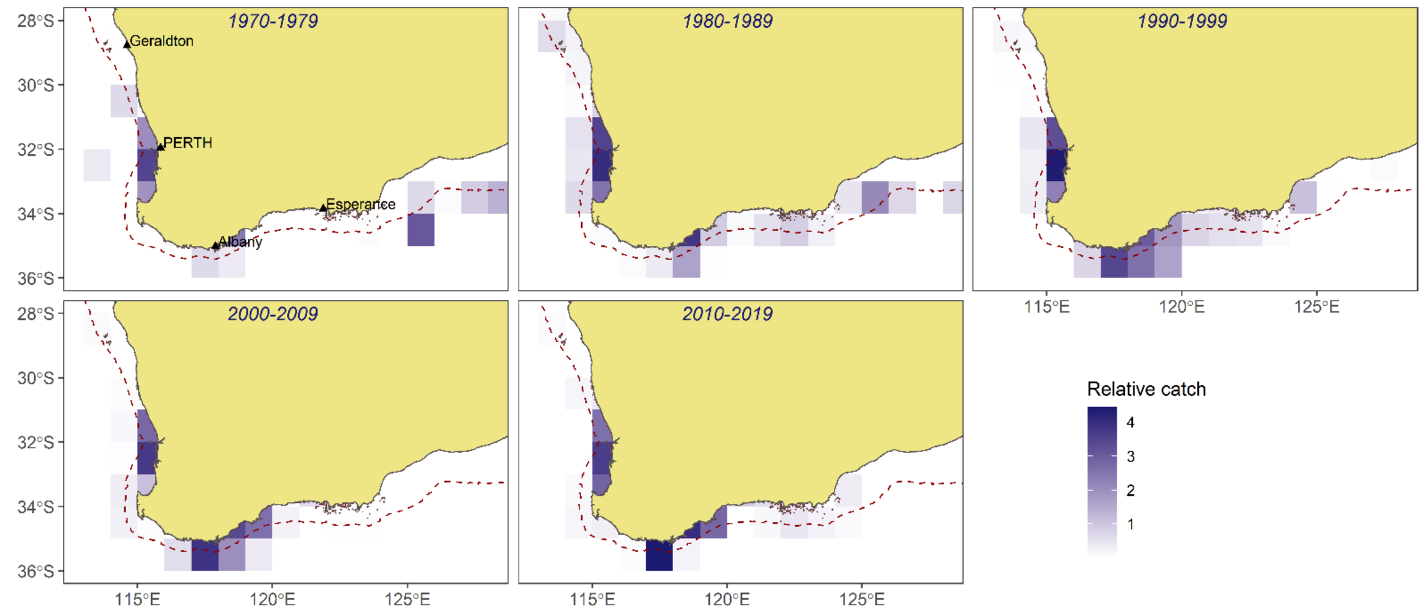


Figure 29. Total annual squid catch by region within south-western Australia (West and South Coast Bioregions). Regions: Mid-west, Kalbarri to Two Rocks; Metro, Two Rocks to Mandurah; South-west, Mandurah to Albany region; Albany, within ~100 nm of Albany; Esperance, within ~100 nm of Esperance; Bight, Esperance region to Eucla.



(b)

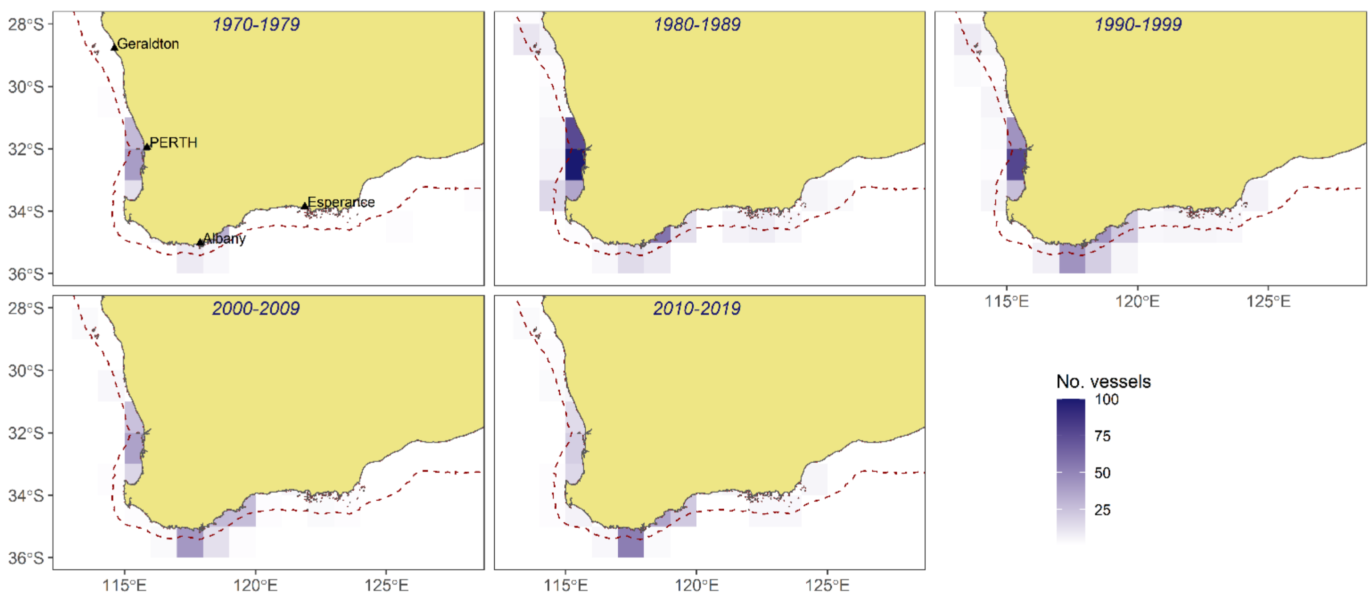


Figure 30. (a) Total squid catch (t; log[x+1] transformed) and (b) number of vessels retaining squid from each 60 × 60 nm CAES block in the West and South Coast Bioregions during each decade from 1970–79 to 2010–19. The dotted line denotes the 200 m isobath.

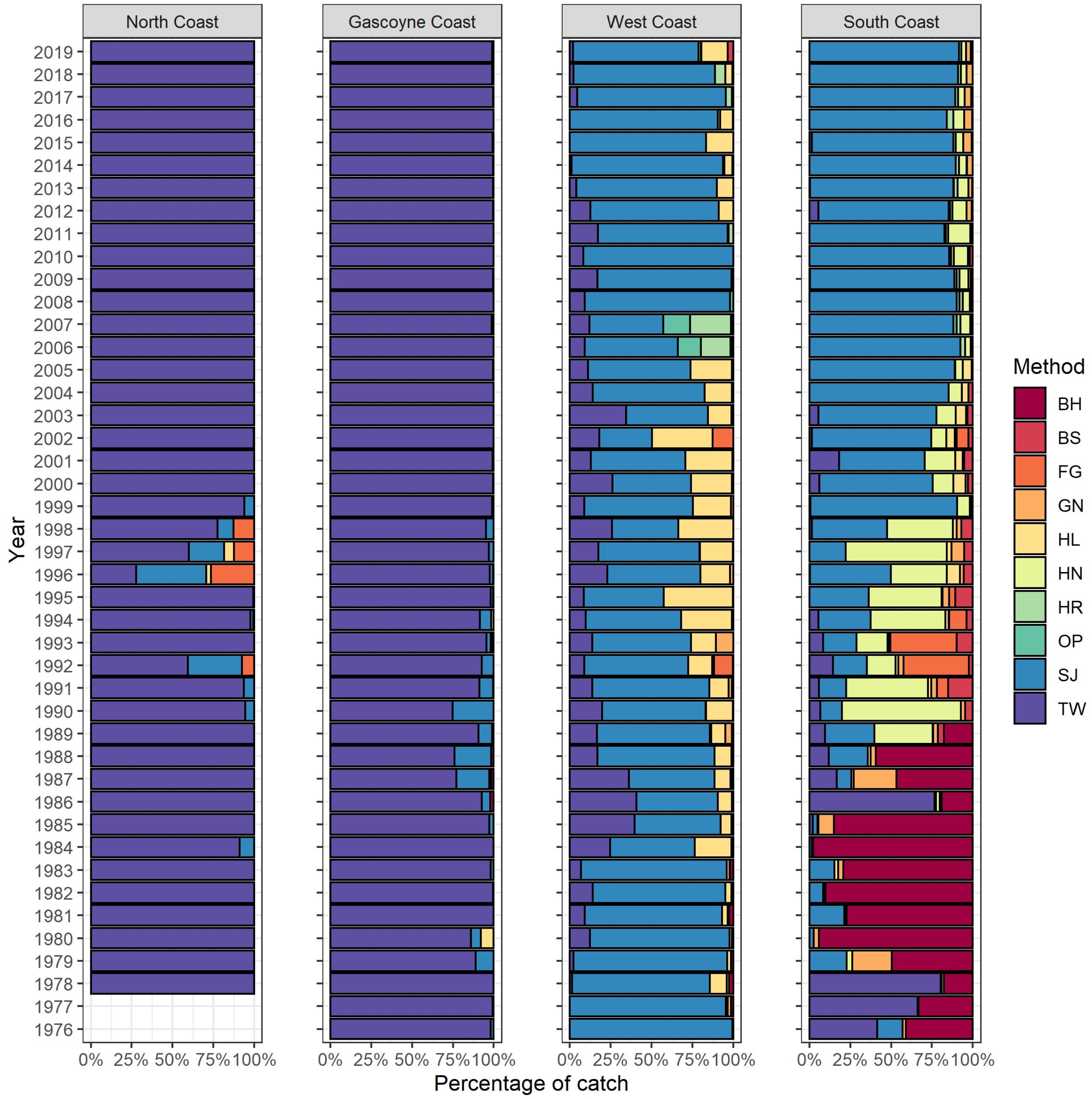


Figure 31. Annual proportion of squid catch in each WA bioregion caught by different fishing methods. Note, for clarity only the top 10 fishing methods (ranked by total state-wide catch from 1976 to 2019) are shown. Method abbreviations: BH—Beach haul, Beach seine, FG—Fish trawl, GN—Gillnet, Haul, HL—Handline, HN—Haul net, HR—Hand reel, OP—Octopus pot, SJ—Squid jig, TW—Trawl.

12.3.2 *North Coast Bioregion*

A total of 114 fishing vessels have landed squid in the NCB from 1976 to 2019, with individual vessels landing up to 223 t during the period (Figure 32). During 2019, nine vessels landed a total of 3.48 t of squid. This catch was spread across three fisheries, the Nickol Bay Prawn Managed Fishery (77.4% of total), Pilbara Fish Trawl (Interim) Managed Fishery (22.3%) and Kimberley Prawn Managed Fishery (0.3%). The annual total represents an increase of approximately 40% from 2018 (2.5 t from 5 vessels) and is above the five-year average catch from 2014–2018 of 2.1 t (Table 5; Figure 24; Figure 25). These catches in recent years, however, are far below historical maximum catches in the NCB which exceeded 500 t during the mid-1990s and 900 t in 2004 (Figure 24). As described in the previous subsection, squid catches from the NCB are predominantly taken by trawling, and since 2004 this method has accounted for 100% of landings (Figure 31).

Monthly catch trends (Figure 33) illustrate that in most years since 2005 commercial landings occur throughout the year, with slightly higher catches in autumn and winter months. In 2003 and 2004, however, when very high catches of 79 and 967 t, respectively occurred, the vast majority of catch was taken during April and May (Figure 33). Resultantly, the monthly distribution of catches for the NCB over the past 20 years displays a clear mode during autumn (Figure 33). In contrast, during 1993–1995 when annual catches of 280–535 t were recorded, the vast majority of catch occurred in late winter and spring (August–October). This difference in seasonal catch composition between 1993–1995 and 2003–2004 reflects the fact that catches during the former period were taken from the Kimberley region, while those in the latter period came from the Pilbara region, which has different climate and oceanographic characteristics.

It is thought that the main group of squid caught by trawlers in the Kimberley and Pilbara are members of the genus *Uroteuthis* (*Photololigo*) spp. (loligo squid), of which at least two species are found in the Pilbara region, and four may occur in the Kimberley (Yeatman & Benzie, 1994; see also Section 7.0 Species Description). Anecdotal reports suggest that during the early- to mid-1990s loligo squid spawning aggregations were targeted in spring by prawn trawlers using banana prawn nets (Wadley & Dunning, 1998; Dunning et al., 2000). This targeting behaviour would explain the very high NCB squid catches during 1993–1995. It is possible that environmental conditions during those years, which coincided with an El Niño climate event, were conducive to squid aggregating in areas where they were more accessible to fishers than usual, for example in shallower waters. The extraordinarily high Pilbara catches of 967 t during 2004 coincided with cooler than average late summer and autumn temperatures (Jan–Feb SST 28 °C *vs* long-term avg. of 29–30 °C, March 29 °C *vs* long-term avg. 30 °C; Appendix 2).

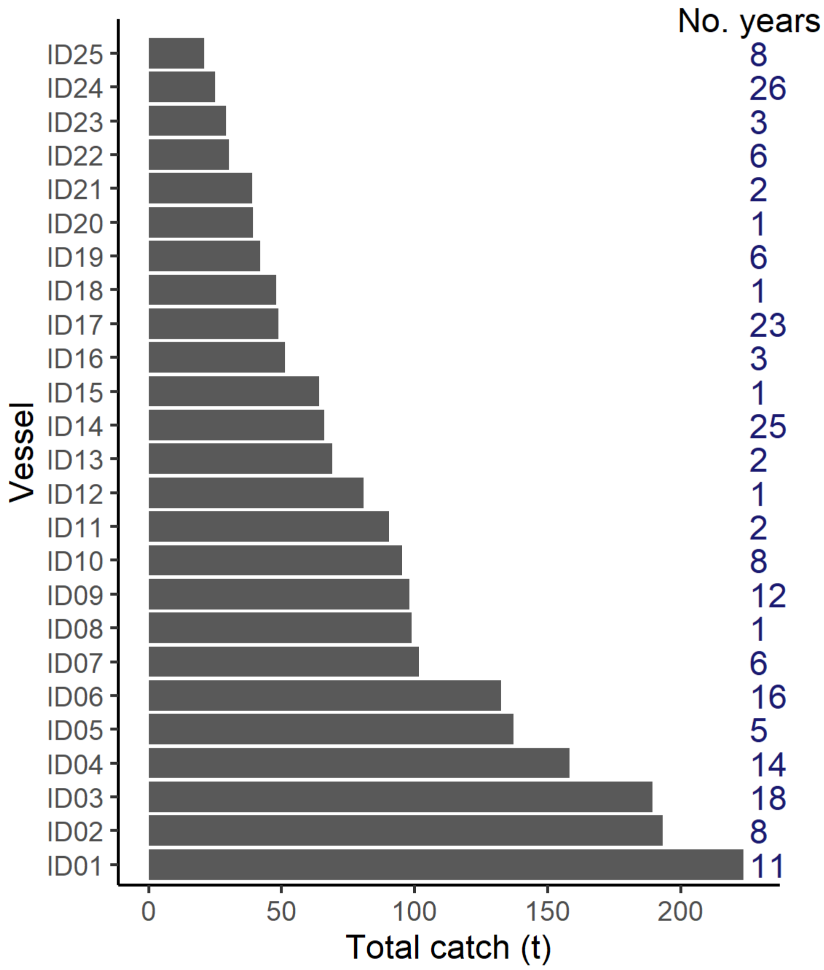


Figure 32. The top 25 vessels (by LFB) in the North Coast Bioregion which retained the greatest catches of squid from 1976 to 2019, and the total number of years which they landed squid. Vessel LFBs have been anonymised for confidentiality.

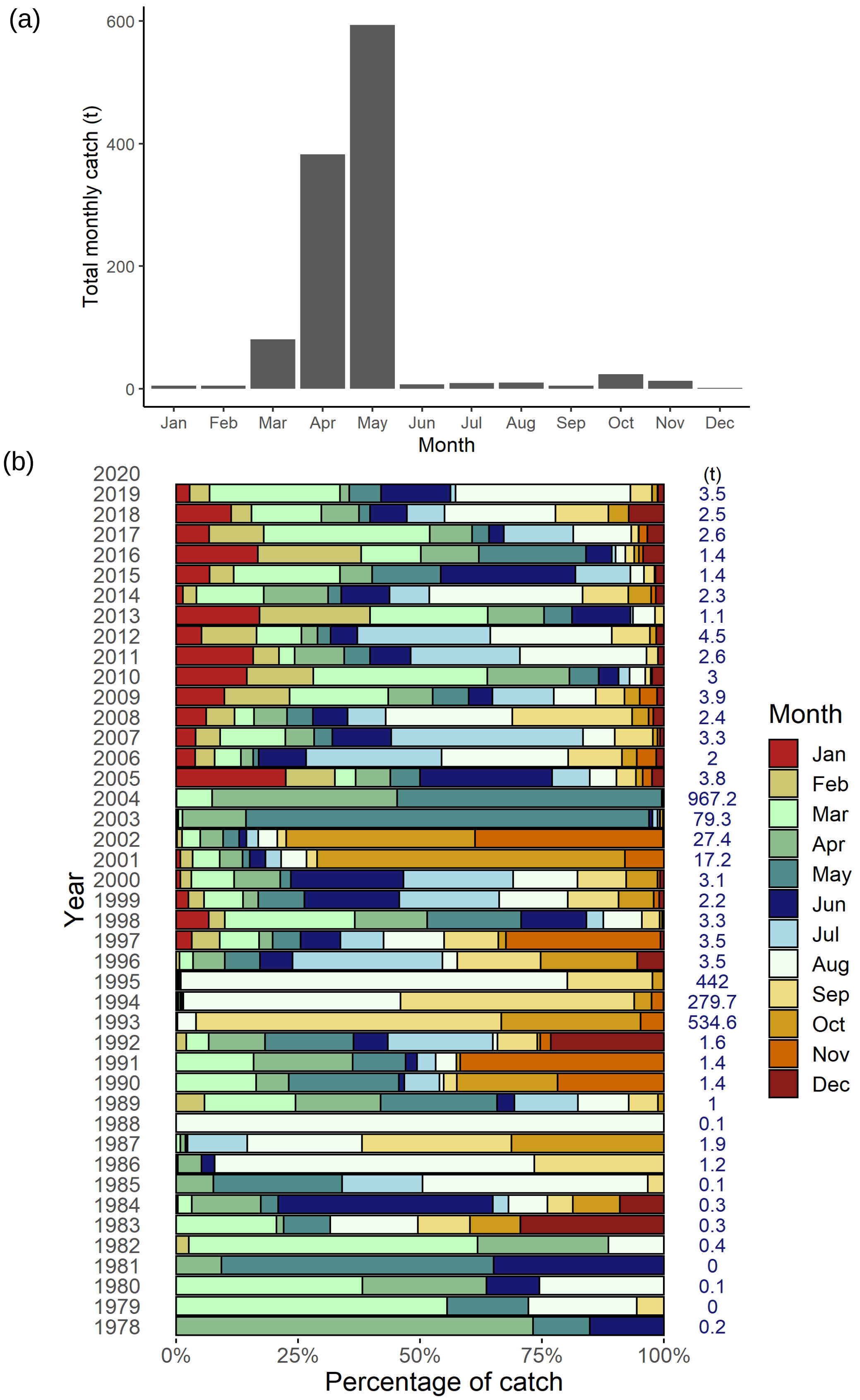


Figure 33. Total squid catch each month in the North Coast Bioregion (a) (across all years) from 1998 to 2019 and (b) the proportion of catch each year from 1976 to 2019. The total annual catch (t) is also given on (b).

12.3.3 *Gascoyne Coast Bioregion*

A total of 131 fishing vessels have landed squid in the GCB from 1976 to 2019, with individual vessels landing up to 73 t during the period (Figure 34). Twenty vessels have consistently caught squid from the GCB, with landings occurring over 30 or more years. Catches in the GCB peaked from the early-1990s to late-2000s, with peaks of 99.6 t in 1995, 64.2 t in 1998 and 62.3–75.1 t in 2003–2005 and 63.7 t in 2010 (Figure 24). During 2019, 28 vessels landed a total of 13.7 t of squid. This catch was spread across four fisheries, as well as open access fishery areas, with the majority of catch taken from the Shark Bay Prawn Managed Fishery (86.1% of total) and Exmouth Gulf Prawn Managed Fishery (12.8%). The annual total represents an increase of approximately 20% from 2018 (11.3 t from 29 vessels) and is consistent with the five-year average catch from 2014–2018 of 13.1 t (Table 5; Figure 24; Figure 25). As occurred in the NCB, the vast majority of squid catches in the GCB were taken by trawling, with the 2019 catch comprising 13.5 t from trawling, 75 kg from haul netting and 57 kg from squid jigging (Figure 31).

The majority of squid landings for 1976 to 2019 from the GCB have occurred during autumn, particularly in March and April (Figure 35). Minor catch has also been taken during winter and spring, with negligible catch during summer. In recent years from 2013 to 2019, however, there has been a decline in catches during March, and an increase in the proportion of catch taken from August–October (Figure 35). It is unclear whether this change in catch composition is due to a climatic shift (e.g. warmer summer temperatures) or a change in fisher behaviour.

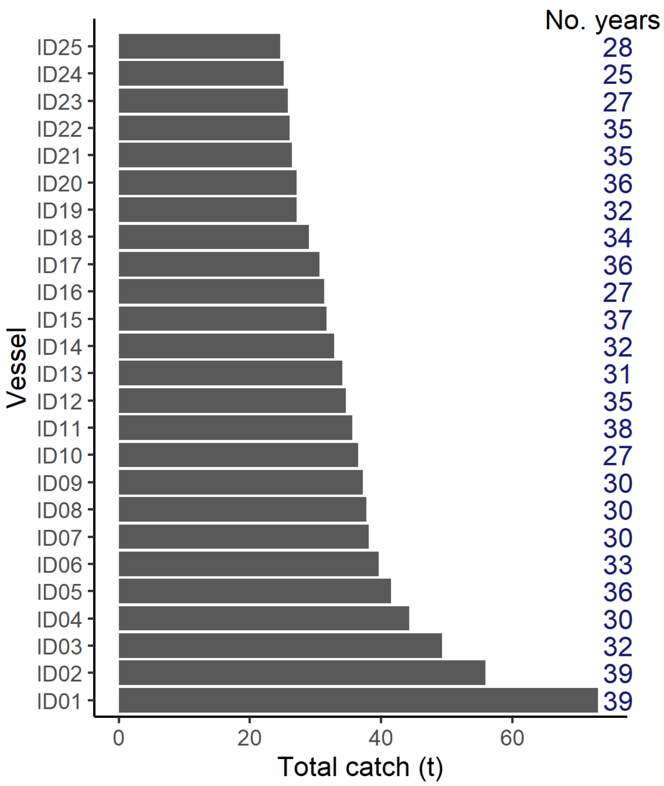


Figure 34. The top 25 vessels (by LFB) in the Gascoyne Coast Bioregion which retained the greatest catches of squid from 1976 to 2019, and the total number of years which they landed squid. Vessel LFBs have been anonymised for confidentiality.

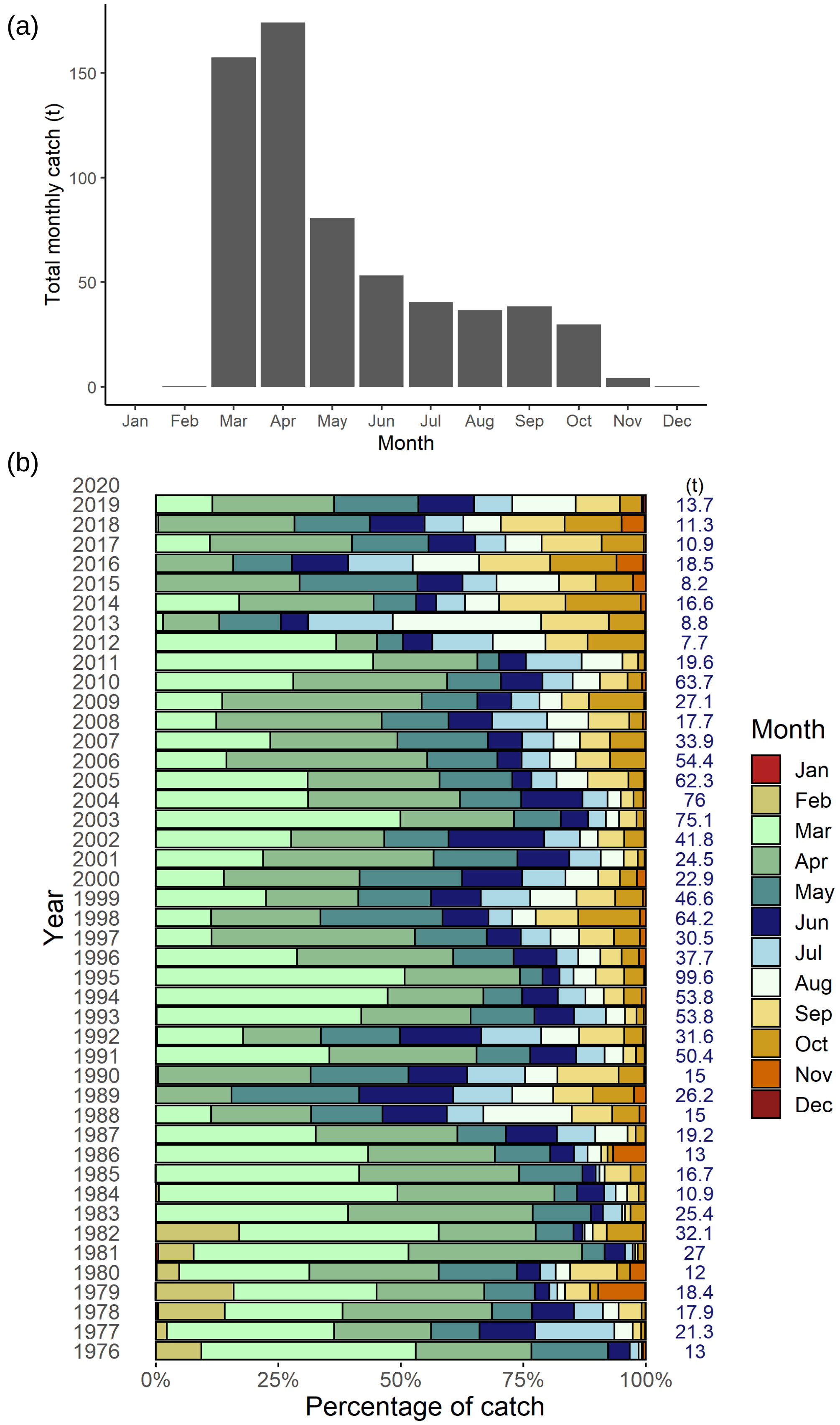


Figure 35. Total squid catch each month in the Gascoyne Coast Bioregion (a) (across all years) from 1998 to 2019 and (b) the proportion of catch each year from 1976 to 2019. The total annual catch (t) is also given on (b).

12.3.4 *Shark Bay*

Squid landings from Shark Bay (CAES Blocks 96021, 96022 and 96023) account for the majority of the total GCB catch in most years (Figure 28). Opportunistic observer data from prawn trawlers in Shark Bay suggests this catch comprises mostly loligo squid *Uroteuthis* spp. and northern calamari *Sepioteuthis lessoniana*. Catches in Shark Bay peaked during 1995 and 1998 at 42–43 t, and again from 2002 to 2005 at 29–55 t (Figure 36). During most years since 1989 there were 15–21 vessels retaining squid, although this increased to 29 vessels during 2004, likely reflecting increased stock abundances. There was a significant correlation between total annual catches in Shark Bay and average sea surface temperatures during summer (Jan–Feb average; $R^2 = 0.29$, $P < 0.01$; Figure 36). Thus, when temperatures were warmest in the summer marine heatwave during 2011–2013 (26.5–28.1°C) catches were very low (3–6 t), while the highest catches generally occurred in years when summer temperatures were less than 25°C (e.g. 1995, 1998, 2003, 2004; catches >40 t).

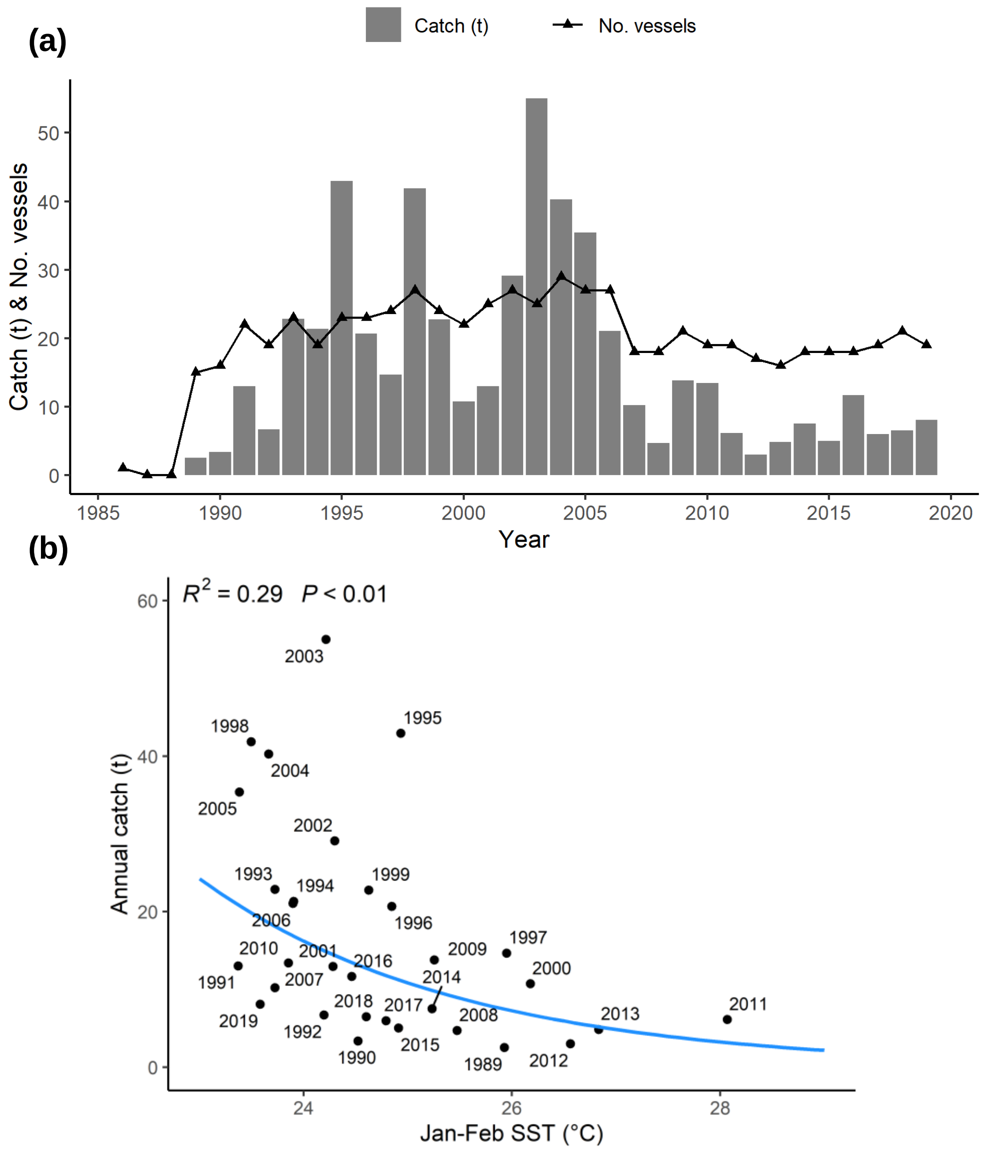


Figure 36. (a) Total annual squid catch (t) and the total number of vessels retaining squid from Shark Bay from 1986 to 2019. (b) Relationship between sea surface temperature (January to February average) and annual squid catches.

12.3.5 *West Coast Bioregion*

A total of 311 fishing vessels have landed squid in the WCB from 1976 to 2019, with individual vessels landing up to 49.5 t during the period (Figure 37). Only seven vessels, however, reported landings of >10 t over the four-decade period. Among regions, the majority of catches over time have come from Cockburn Sound (CAES block 9600) and the broader Perth metro region, with substantial contributions also from Geographe Bay (CAES block 9601) during 1976, 1987–1990 and 2010–2014 (Figure 38). These are predominately sheltered coastal areas that contain substantial seagrass habitat. By method, catches in most years came predominantly from squid jigging, although handlining and trawling accounted for notable squid catches in several years, particularly from the 1980s to early 2000s (Figure 31). Since 2010, targeted squid jigging has accounted for 77–92% of the total WCB squid catch. Seasonally, the greatest contribution of catches came from late-autumn to early spring (May-September), with moderate catches in March–April and October, and minor catches from other months of the year (Figure 39). This has been relatively consistent over time from 1976 to 2010, however, since 2010 there has been a further reduction in summer catches, particularly during January and February.

The 2019 WCB squid catch was 10.8 t landed by 24 vessels. This catch was spread across eight fisheries as well as open access fishery areas, with the majority of catch taken from open access waters (87.9% of total) and the Cockburn Sound Line and Pot Managed Fishery (9.2%). The annual total represents an approximately three-fold increase in catch from 2018 (3.2 t from 17 vessels) and is substantially above the five-year average catch from 2014–2018 of 5.1 t (Table 5; Figure 24; Figure 25). During 2019 catch increased in each the Perth metro region, Cockburn Sound and Geographe Bay, with the former region accounting for the greatest proportion of catches (7.1 t, 66% of WCB total; Figure 38). The notable increase in total catch in the Perth metro region reflects both an increase in targeted squid jigging effort (6594 days in 2019 *vs* 2145 days in 2018) as well as increased CPUE (22.6 kg/day *vs* 11.7 kg/day). By method, 77% of the 2019 WCB catch came from squid jigging, with a further 16% caught by handline (Figure 31). The remaining minor catch was attributed to netting (beach seine & haul netting) and trawling. Throughout the year, 95% of the annual catch occurred from April to October, with a relatively even distribution of catches between months (Figure 41).

Over time, targeted squid jigging catch in the WCB has been variable, ranging from 3–14 t, and generally being in line with changing effort (Figure 40). There were, however, several periods where CPUE notably increased, specifically during 1995 and 1999 (15–16 kg/day) and again from 2010 to 2015 (21–31 kg/day). Water temperature during the main fishing season (April–October) in these years was generally warmer than average (Figure 41). There was only a weak positive correlation between CPUE and temperature from 1984 to 2007 ($R^2 = 0.16$, $P = 0.056$), but strong and significant positive correlation occurred more recently from 2008 to 2018 ($R^2 = 0.7$, $P < 0.001$). While total catches in several years also appeared to reflect water temperature (e.g. 2.7 t in 2018 when temperatures were *c.* 18 ° *vs* 10 t in 2011 when temperatures were *c.* 22 °C), there was no significant correlation between temperature and total catch in either the early (1984–2007) or late (2008–2018) periods ($P > 0.05$).

Standardised annual squid jigging CPUE for the WCB (accounting for effects of month, fisher and fishing location [60 × 60 nm CAES block]) has remained relatively constant over time, being lowest in 1985 and 1996 (4.2–4.4 kg/day) and highest during 1999 (9.8 kg/day; Figure 42). During a ten-year reference period from 2009 to 2018, standardised CPUE values ranged from 5.0 to 8.5 kg/day, with the 2019 value of 5.9 kg/day being within this target range (Figure 42).

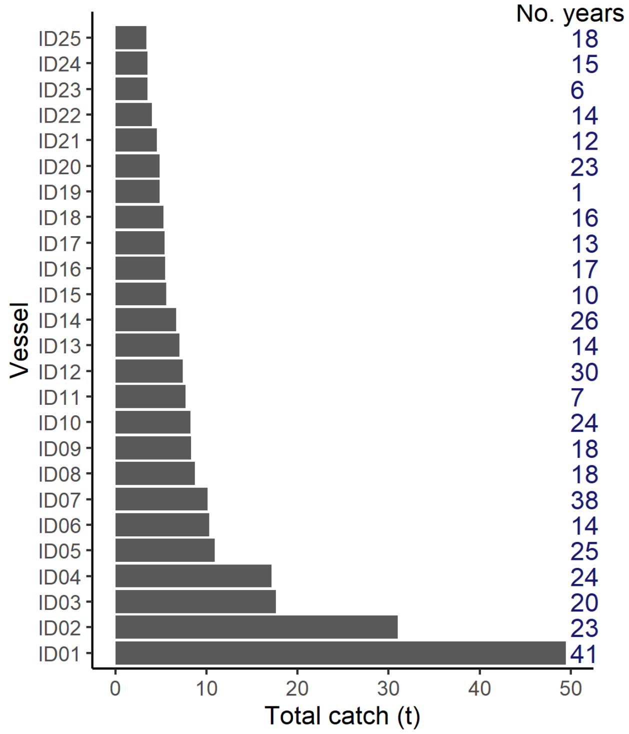


Figure 37. The top 25 vessels (by LFB) in the West Coast Bioregion which retained the greatest catches of squid from 1976 to 2019, and the total number of years which they landed squid. Vessel LFBs have been anonymised for confidentiality.

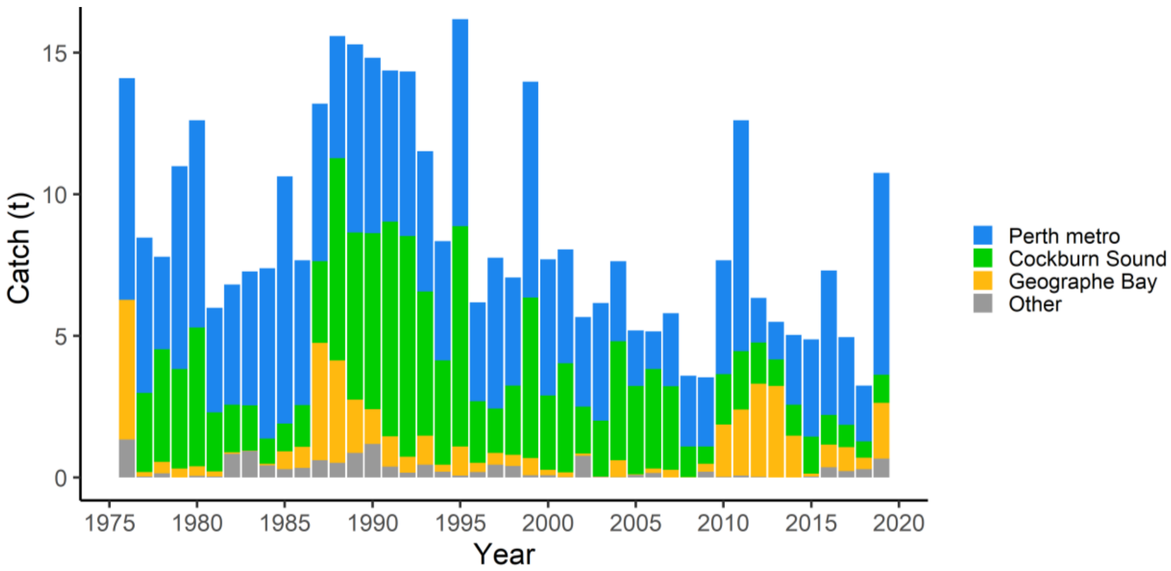


Figure 38. Total annual squid catch in the West Coast Bioregion by reporting area. ‘Cockburn Sound’ refers to CAES block 9600, ‘Perth metro’ refers to CAES blocks other than Cockburn Sound in the Perth metro region (e.g. 31150, 32150, 31140, 32140), Geographe Bay refers to CAES block 9601 and ‘Other’ refers to all other areas in the bioregion.

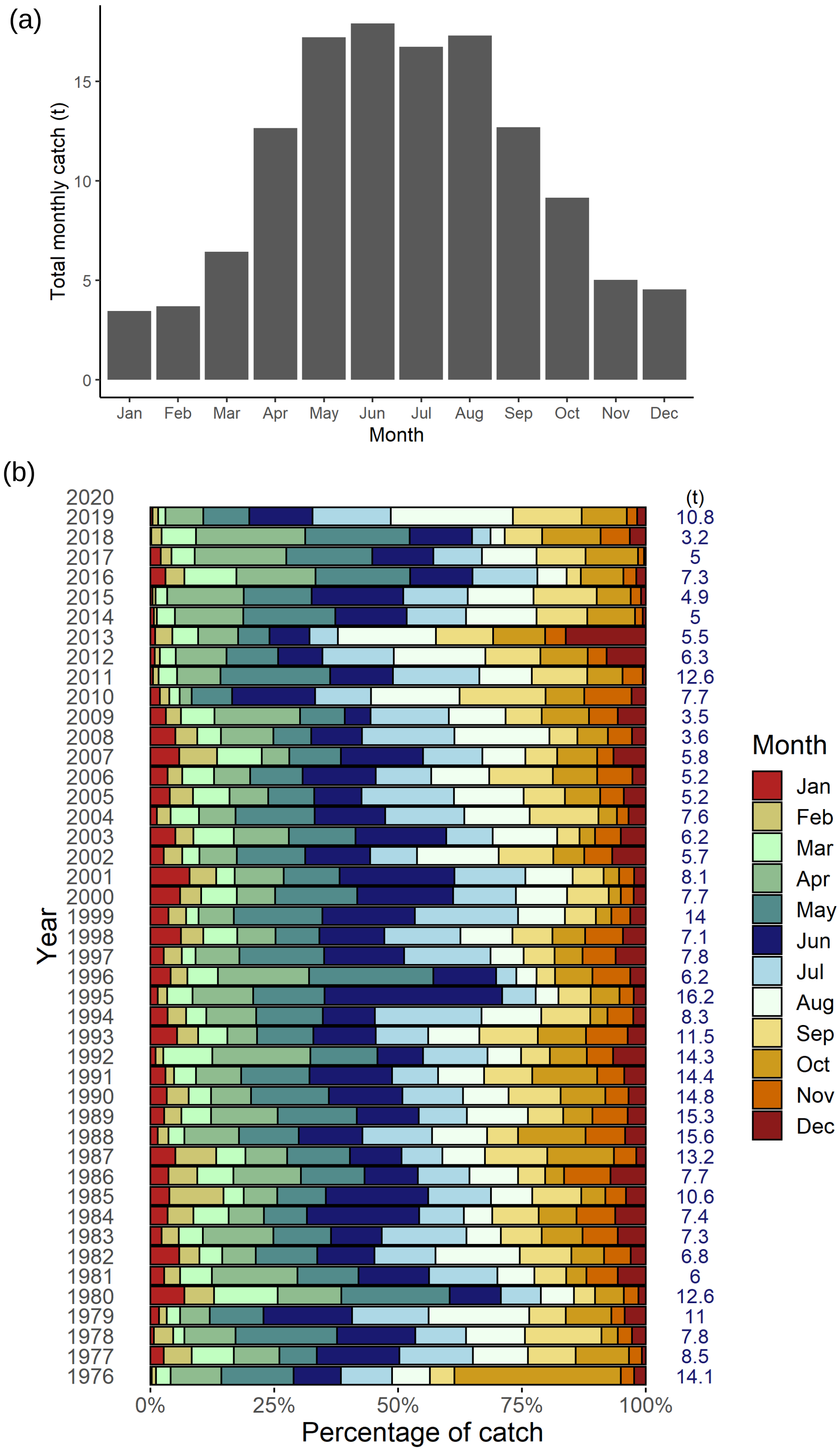


Figure 39. Total squid catch each month in the West Coast Bioregion (a) (across all years) from 1998 to 2019 and (b) the proportion of catch each year from 1976 to 2019. The total annual catch (t) is also given on (b).

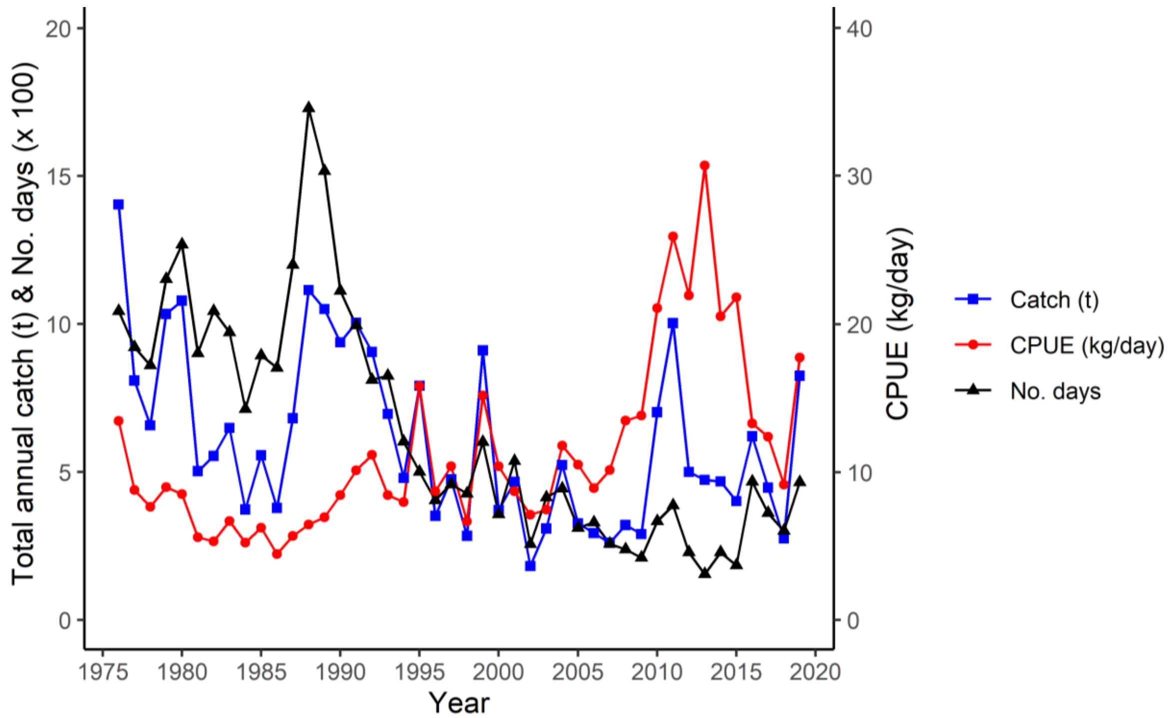


Figure 40. Annual squid jigging catch, nominal CPUE (total catch/total effort), and the number of vessels retaining squid by squid jigging in the West Coast Bioregion from 1976 to 2019.

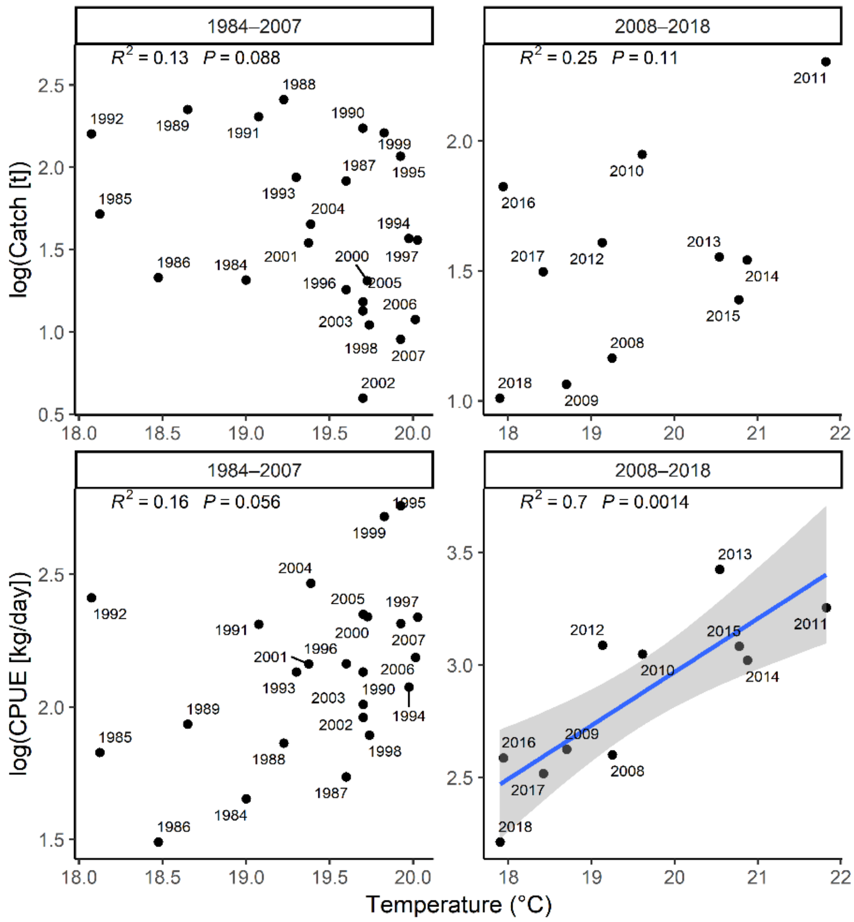


Figure 41. Relationships between mean April–October sea surface temperature in coastal waters of the Perth metro region (Warnbro Sound) and annual West Coast Bioregion squid jigging catch and nominal CPUE (total catch/total effort; kg/day).

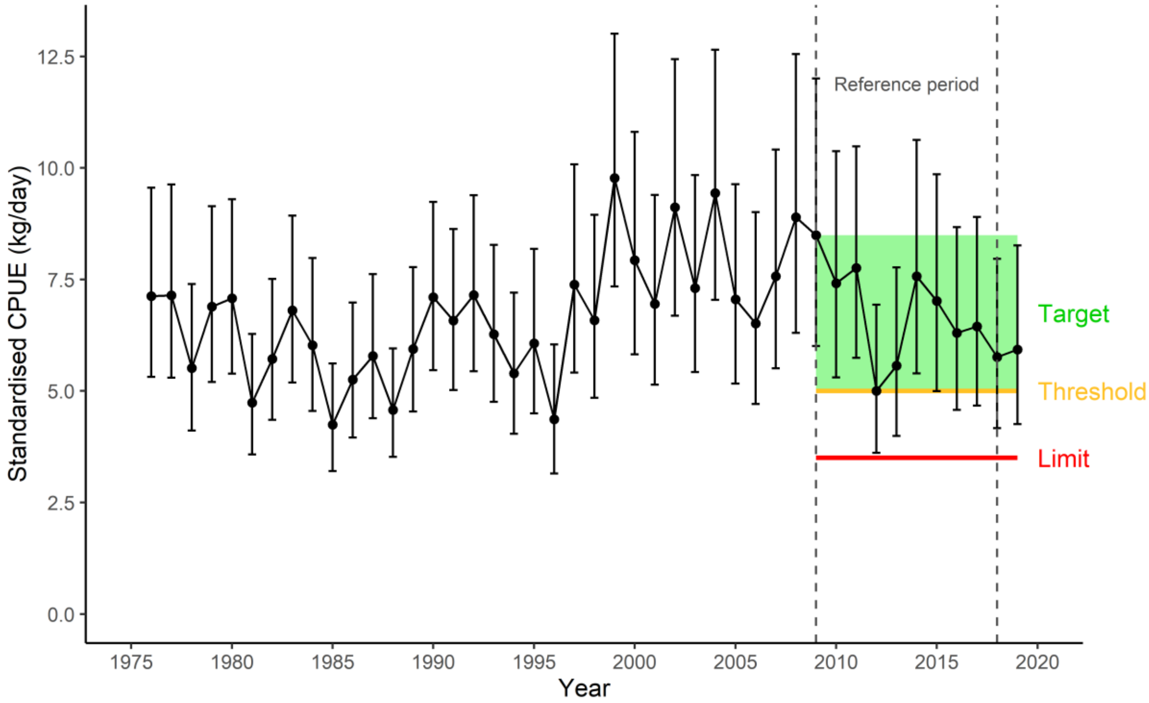


Figure 42. Primary performance indicator, annual standardised squid jigging CPUE (kg/day) for the West Coast Bioregion, with 95% confidence limits, relative to the associated reference points (target, threshold and limit) of the draft harvest strategy. The 10-year reference period extends from 2009 to 2018.

12.3.6 *Cockburn Sound*

Squid catches in Cockburn Sound, which are presumed to comprise predominately or exclusively southern calamari, have contributed a substantial proportion of the WCB total catch since 1976 (Figure 38). Annual catches in this fishery, which came almost exclusively from squid jigging, ranged from <1 t to 7.6 t, largely in line with the number of vessels fishing and their fishing effort (Figure 43). The highest catches were recorded from the late-1980s to mid-1990s, with 3.6–7.6 t landed from 4,000–10,500 hook hrs (nominal CPUE = 0.5–0.8 kg/hr). Since 1995, there has been a general decline in both the number of vessels landing squid and the total annual catch, with catches during 2017 and 2018 among the lowest on record (789 and 571 kg, respectively). Notably, the 2018 catch of 571 kg came from 3,726 hook hrs at a catch rate of 0.15 kg/hr, by far the lowest nominal CPUE on record for this fishery. Total catch and CPUE increased slightly in 2019 to 984 kg and 0.51 kg/hr.

In contrast to nominal CPUE, annual standardised squid jigging CPUE values accounting for effects of month and fisher displayed relative consistency from 1985 to 2000, but increased to their maxima during the early 2000s (up to 0.9 kg/hook hr and 15.9 kg/day during 2002 and 2004; Figure 44). Standardised CPUE calculated as kg/day since declined relatively consistently, reaching a minima in 2018 at 2.7 kg/day. Standardised CPUE calculated as kg/hook hr remained relatively constant from 2005 to 2011 (0.56–0.76 kg/hr), but decreased notably in 2012 to 0.4 kg/hr, before increasing to 0.93 kg/hr two years later in 2014. From 2014 to 2018 there was another decrease, with 0.24 kg/hr reported during the latter year. In 2019, both CPUE metrics increased from the previous year by *c.* 75% (0.42 kg/hr and 4.8 kg/day, respectively).

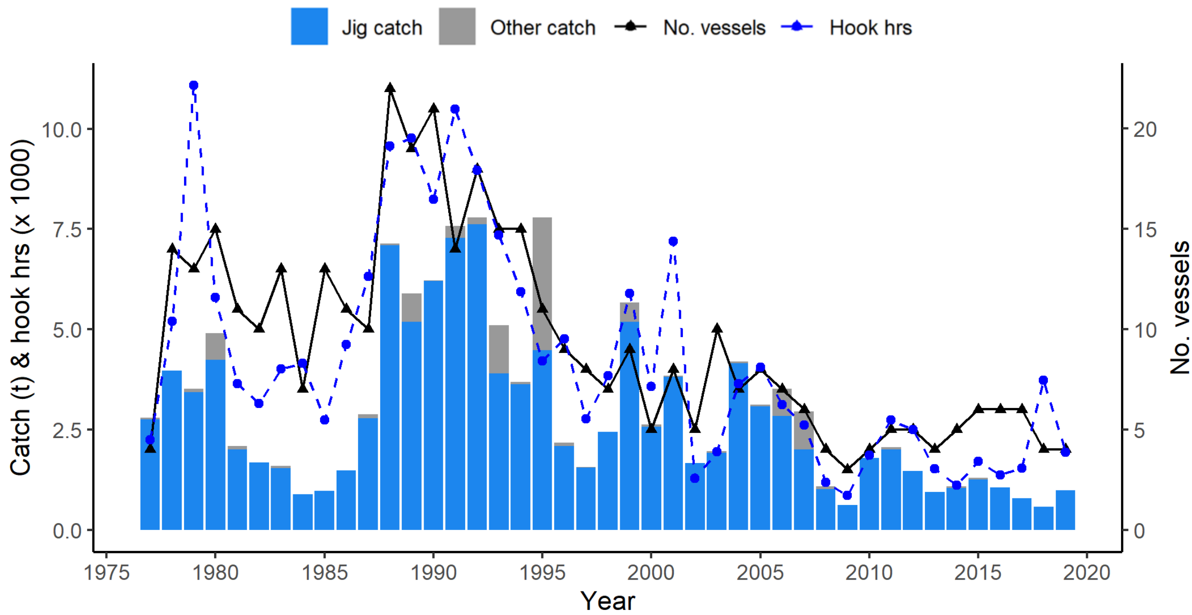


Figure 43. Total annual squid catch and effort in Cockburn Sound from 1977 to 2019. Hook hours is the total hook hours used by squid jigging vessels.

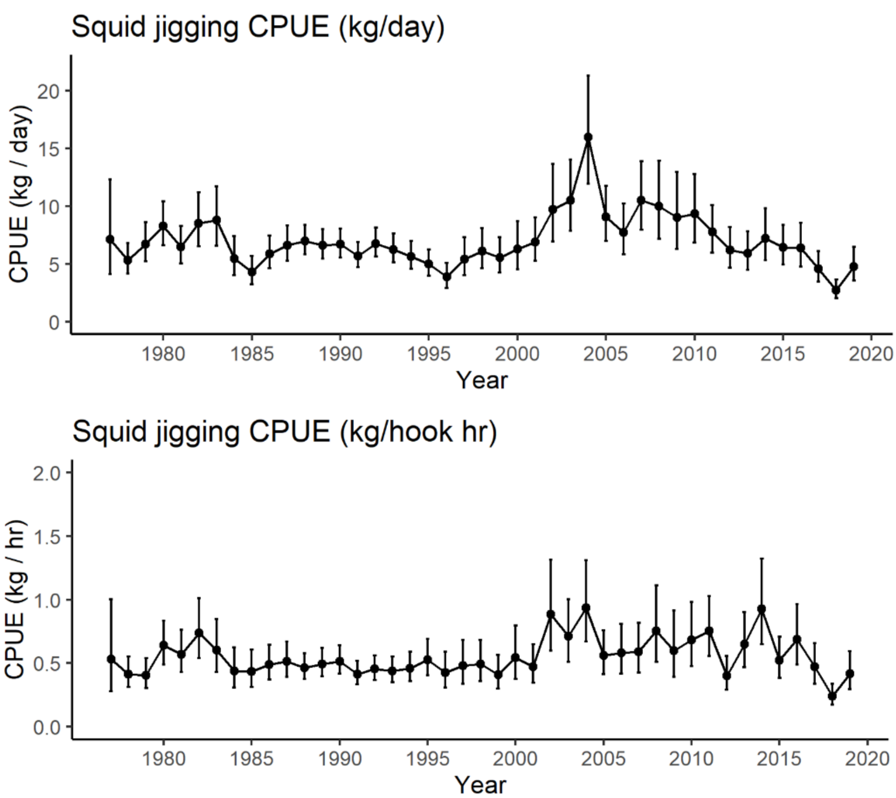


Figure 44. Standardised squid jigging catch per unit of effort (CPUE) in Cockburn Sound from 1977 to 2019. Values have been standardised for months and vessel ID using a generalised linear model.

12.4 South Coast Bioregion

A total of 195 fishing vessels have landed squid in the WCB from 1976 to 2019, with individual vessels landing up to 50 t during the period (Figure 45). Seven vessels caught >20 t and reported landing squid across periods ranging from 16 to 44 years. The vast majority of catches over time have come from the Albany region, including Oyster Harbour (11% of total catch from 1976 to 2019), Princess Royal Harbour (4% of catch), King George Sound (24 % of catch) and other areas within the Albany region (50% of catch; Figure 46). Collectively, all other fishing areas in the SCB therefore accounted for only *c.* 11% of landings. Catches from inshore areas (<30 m deep) such as King George Sound and Oyster Harbour are thought to comprise predominately or exclusively southern calamari (*S. australis*), while catches from deeper waters closer to the continental shelf (50–850 m) are likely to comprise almost exclusively Gould's squid (*N. gouldi*).

From the mid-1990s to 2010s there has been a general increase in overall catch from the bioregion, which is largely attributable to increased landings from King George Sound which increased form <0.5 t in the 1991 to 13 t during 2019. Moreover, from 2010 to 2019 King George Sound comprised 29–63% of the entire SCB squid catch (mean 43%; Figure 46). However, during 1999, when the highest catches on record occurred (24.3 t), the majority of squid catch (79% of the annual total) was taken from other waters of the Albany region outside King George Sound (Figure 49). Catches in Princess Royal Harbour and Oyster Harbour made substantial contributions to the SCB total catch during the 1990s (up to 70% of total landings in 1997–1998), but in recent years have typically accounted for <5% of total catches (Figure 46).

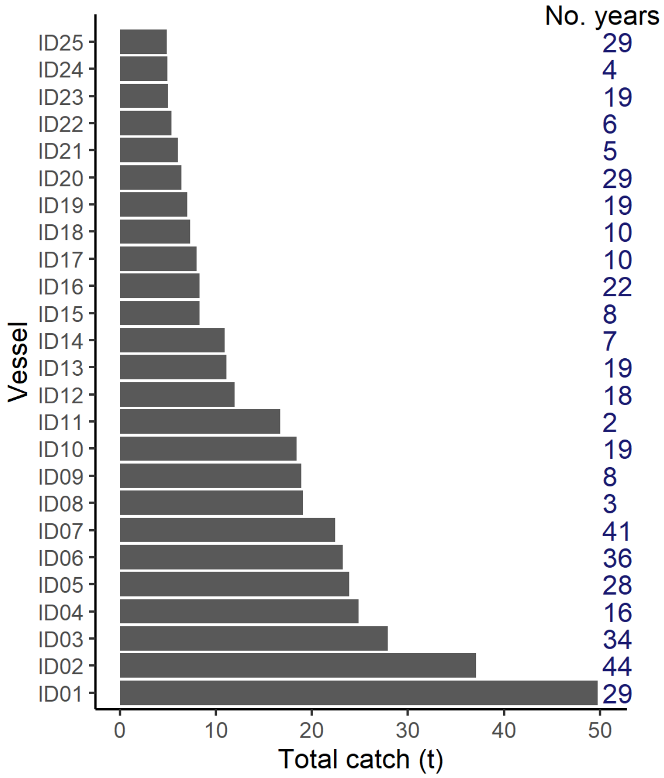


Figure 45. The top 25 vessels (by LFB) in the West Coast Bioregion which retained the greatest catches of squid from 1976 to 2019, and the total number of years which they landed squid. Vessel LFBs have been anonymised for confidentiality.

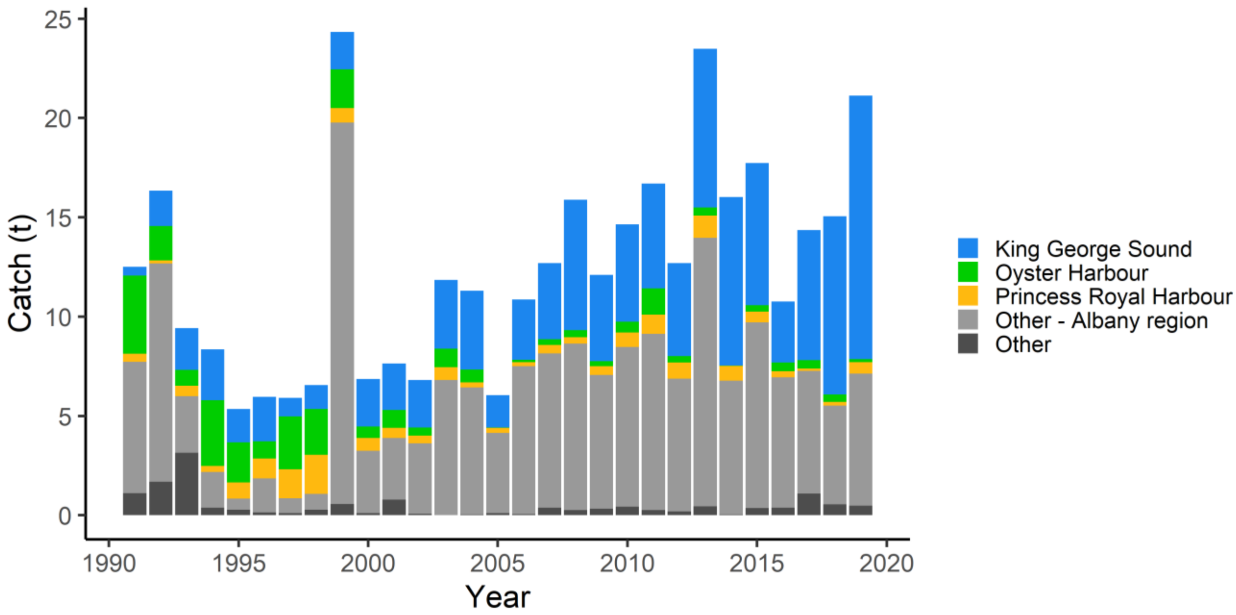


Figure 46. Total annual squid catch in the South Coast Bioregion by reporting area. 'Other - Albany region' refers to CAES blocks other than King George Sound, Oyster Harbour and Princess Royal Harbour that are within 100 nm of Albany (e.g. 34170, 35170, 34180, 35180, 34190), and 'Other' refers to all other areas in the bioregion.

Throughout the year, catches are lowest from January to March, but increase in April and are at their maximum during May and June (Figure 47). From July to December, catches are moderately high, but progressively decline. This has been relatively consistent over time since 2000. During 1999, when 24.3 t was landed, there was a notably higher contribution of catches from August than had occurred in previous years (Figure 47). Similarly, in several earlier years where high catches were recorded (e.g. 1977, 1983, 1986, 1987), one or two months had unusually high catch contributions.

The 2019 SCB squid catch was 21.1 t landed by 38 vessels. This catch was spread across two fisheries, the South Coast Wetline (96.6% of total catch) and South Coast Estuarine Managed Fishery (3.4%). The annual total represents a 40% increase in catch from 2018 (15.1 t from 35 vessels) and is substantially above the five-year average catch from 2014–2018 of 15 t (Table 5; Figure 24; Figure 25). During 2019, 63% of catch was taken from King George Sound (13.3 t), 32% was taken from the broader Albany region (6.7 t), 3% was taken from Princess Royal Harbour (0.6 t), <1% was taken from Oyster Harbour (0.1 t) and 2% was taken from other areas in the SCB (0.5 t; Figure 46). Compared to earlier years, there was a greater contribution of catch from January and February, and landings were relatively consistent throughout all months of the year (Figure 47).

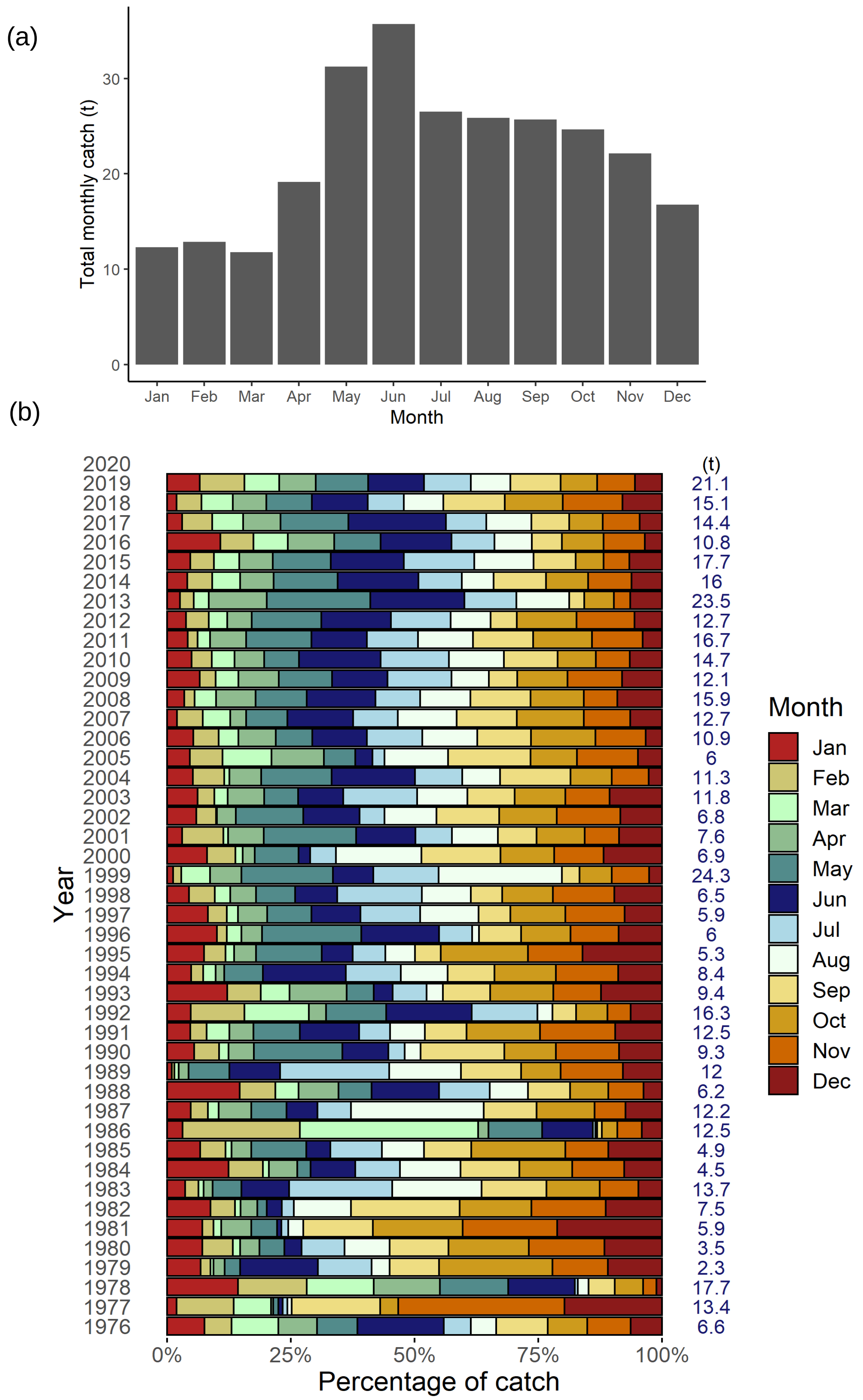


Figure 47. Total squid catch each month in the South Coast Bioregion (a) (across all years) from 1998 to 2019 and (b) the proportion of catch each year from 1976 to 2019. The total annual catch (t) is also given on (b).

Over time, targeted squid jigging catch in the SCB has significantly increased, from < 1 t during the late-1970s to consistently >10 t since 2007 (Figure 48). This trend reflects both changing effort and CPUE. Thus, effort has increased from <100 days during many years in the 1970s and 1980s to 500–1,100 days annually since 2007. Nominal CPUE has also generally increased over this time period, from 1–13 kg/day in the earlier years to 13–22 kg/day in the later years. The very high catches in 1999 of 21.7 t also reflected markedly increased CPUE, from 15 kg/day during 1998 to 50 kg/day in 1999 (Figure 48).

This 3-fold increase in CPUE is very likely to reflect warmer than average water temperatures during autumn of the latter year (Albany SST 22.9 °C in May 1999 *vs* 20.6° C during 1998; Appendix 2). Very high CPUE also occurred during marine heatwave period of 2011–2013. Overall, there was a significant and relatively strong positive correlation between annual nominal squid jigging CPUE in the Albany region and sea surface temperatures (R^2 = 0.45, P < 0.001; Figure 49), as well between total annual squid catch (all fishing methods combined) and sea surface temperatures (R^2 = 0.47, P < 0.001).

Standardised annual squid jigging CPUE for the SCB (accounting for effects of month, fisher and fishing location [60 × 60 nm CAES block]), like nominal CPUE, has generally increased over time, from 1.7–5.5 kg/day in the 1970s and 1980s to 12.3–18.4 kg/day in the mid-2000s (Figure 50). The highest annual standardised CPUE values were recorded in 2010 and 2011 at 18.7 and 20.6 kg/day, respectively, which declined to 11.7–16.3 kg/day from 2012–2018. Standardised CPUE during 2019 was 15.1 kg/day, representing a *c.* 1 kg/day decline from 2018, but being within the target range of a reference period based on values from 2009–2018 (Figure 50).

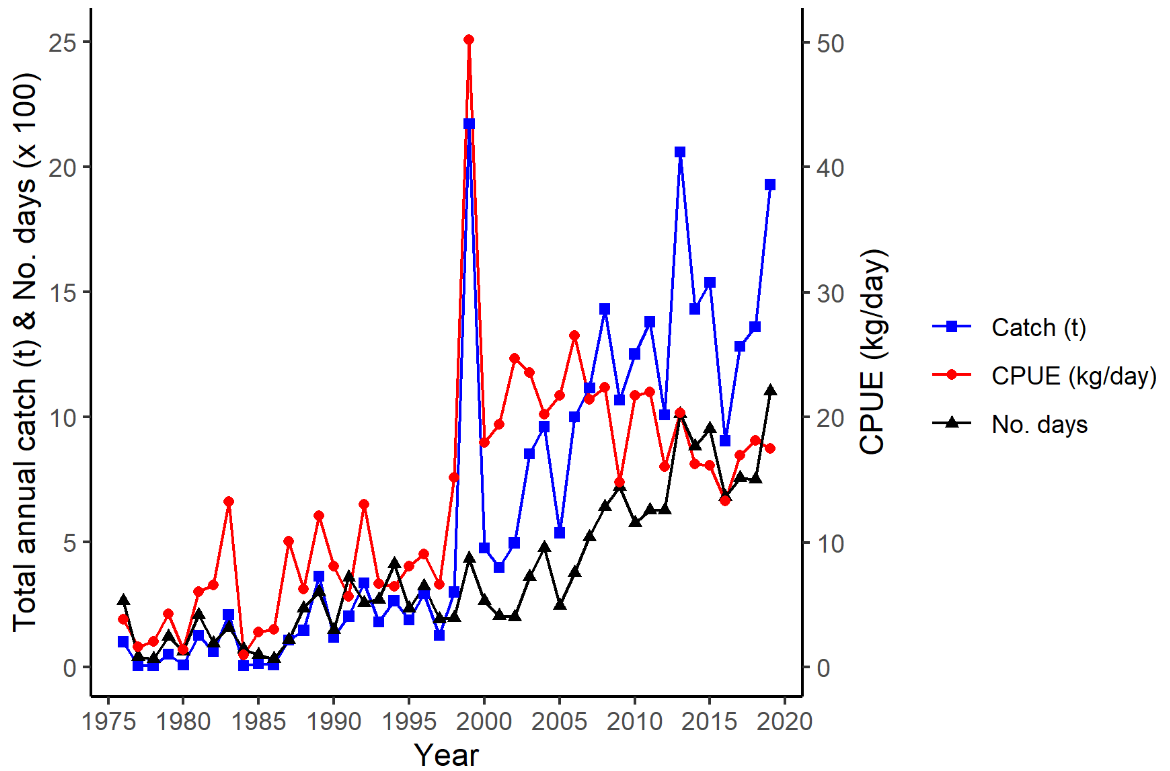


Figure 48. Annual squid jigging catch, nominal CPUE (total catch/total effort), and the total number of vessels retaining squid by squid jigging in the South Coast Bioregion from 1976 to 2019.

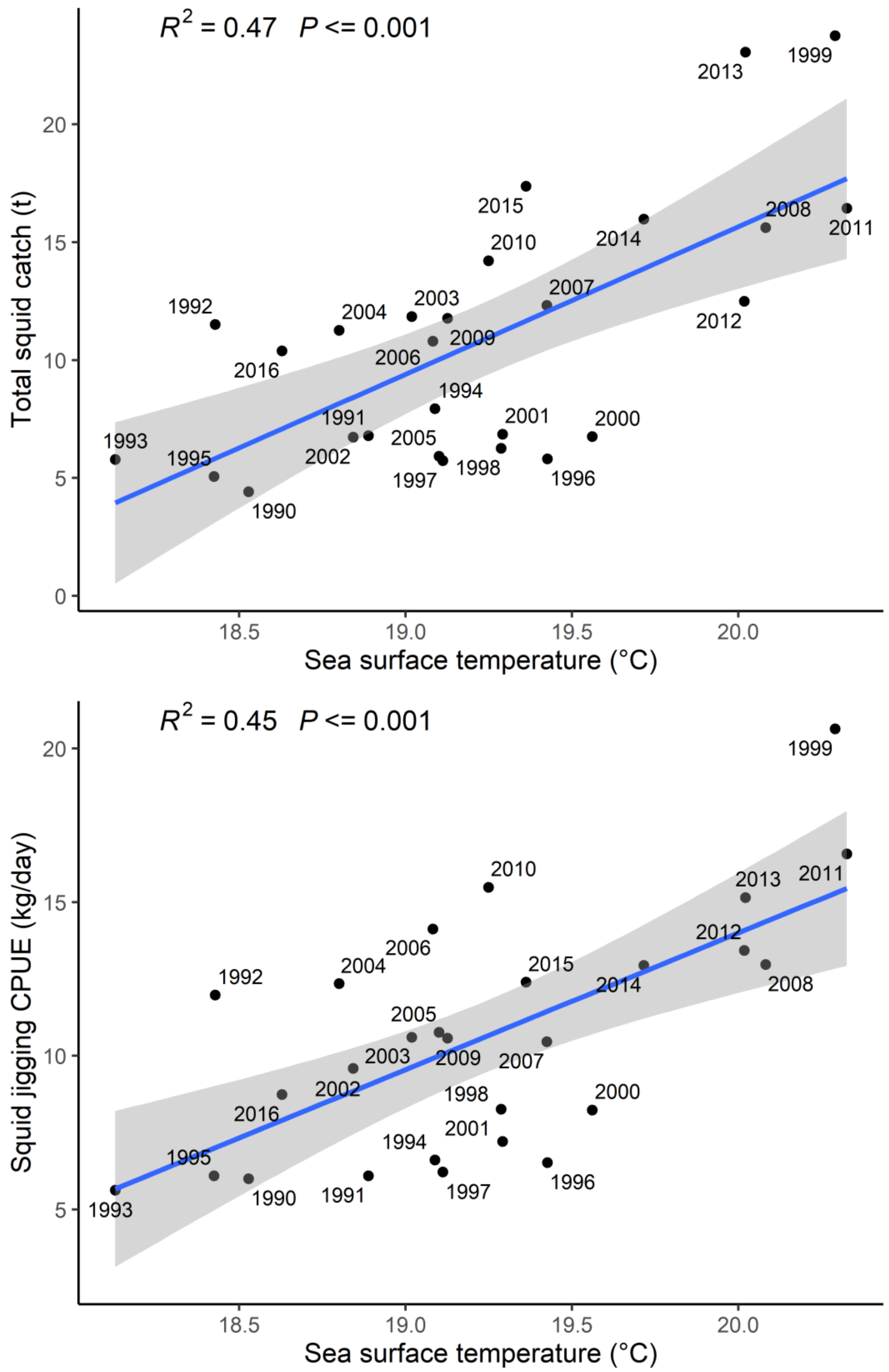


Figure 49. Correlation between mean annual sea surface temperatures (March to September average) and total annual squid catches (all methods) and squid jigging nominal CPUE in the Albany region of Western Australia (includes King George Sound, Oyster Harbour, Princess Royal Harbour and the wider Albany region).

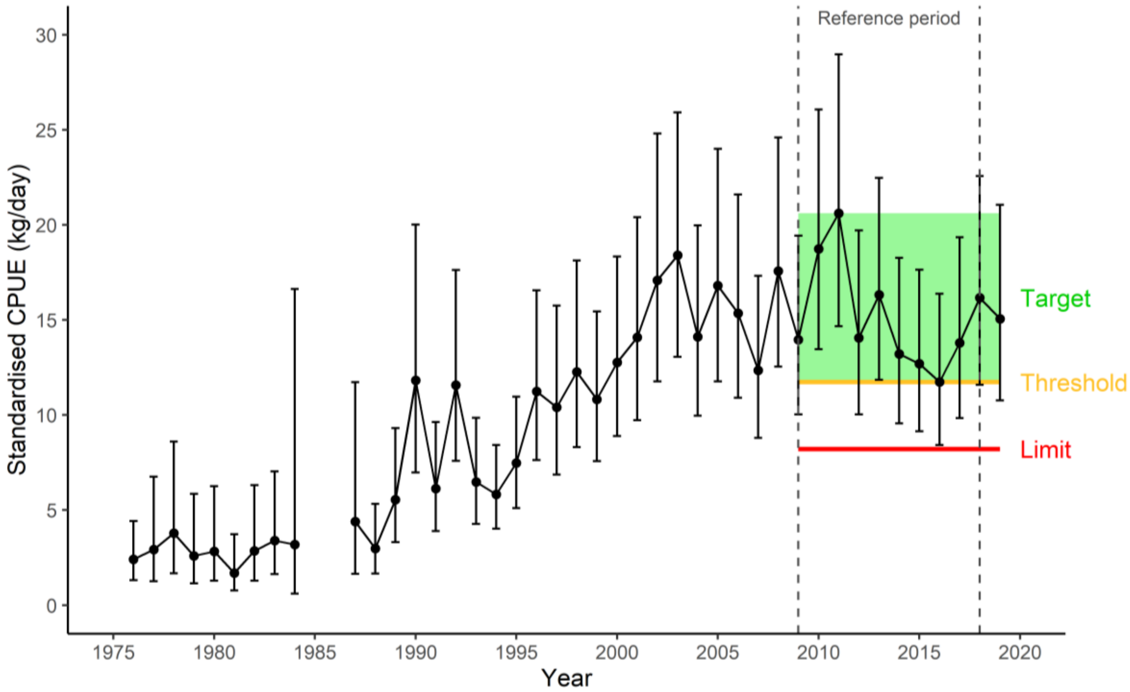


Figure 50. Primary performance indicator, annual standardised squid jigging CPUE (kg/day) for the South Coast Bioregion, with 95% confidence limits, relative to the associated reference points (target, threshold and limit) of the draft harvest strategy. The 10-year reference period extends from 2009 to 2018.

12.4.1 *King George Sound*

Squid catches in King George Sound, which are presumed to comprise predominately or exclusively southern calamari and come almost exclusively from squid jigging, have steadily increased from 0.5–2.5 t during the early 1990s to 13.2 t during 2019 (Figure 51). In this fishery the total number of vessels landing squid annually has only increased slightly over time, from 4–13 vessels prior to 2002 to 14–18 since 2013 (Figure 51), but the number of vessels squid jigging and the total number of jigs used (hook hours) has increased considerably. Thus, during the 1990s there were 2–9 squid jigging vessels (average 6) operating an average of 3,000 hook hours annually, compared with 8–16 vessels (average 13) operating an average of 56,800 hook hours annually from 2010–2019 (Figure 51). The unusually low catches which occurred in both 2005 and 2016 (1.6 and 3.1 t, respectively) reflected substantially decreased fishing effort in those years (9,100 and 23,300 hook hours, respectively). There was a significant negative correlation between the total annual hook hours fished and annual nominal squid jigging CPUE (R^2 = 0.82, P < 0.001; Figure 52).

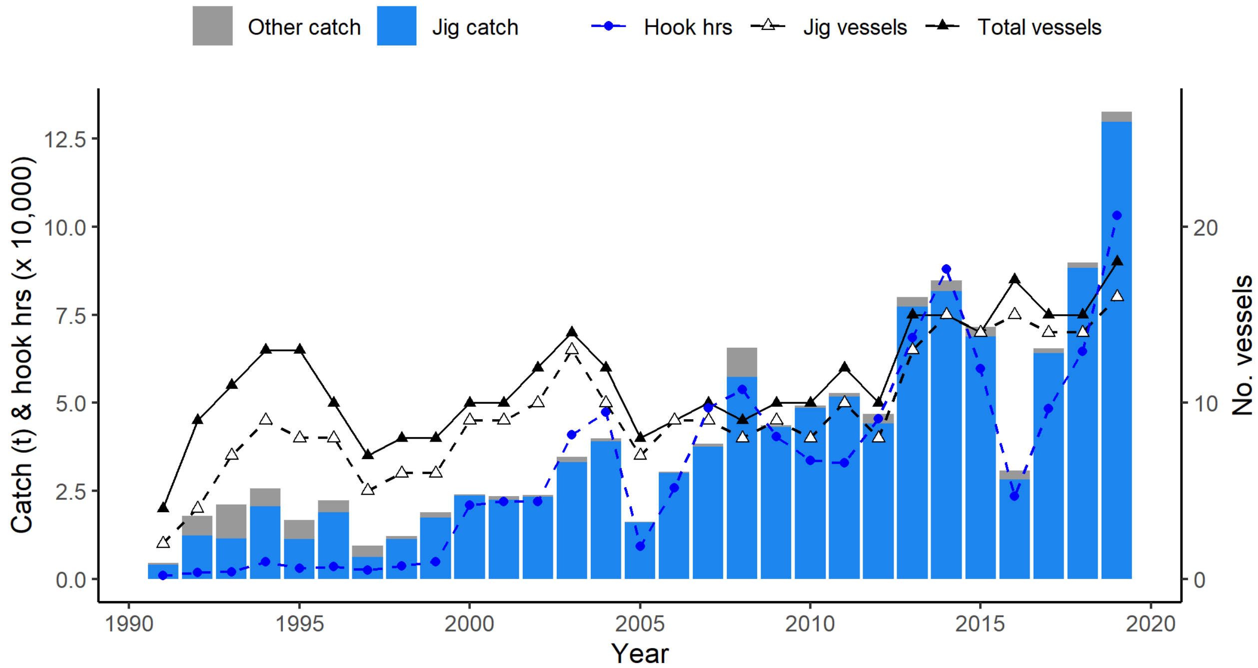


Figure 51. Total annual squid catch, the number of vessels retaining squid and total annual hook hours fished in King George Sound from 1991 to 2019.

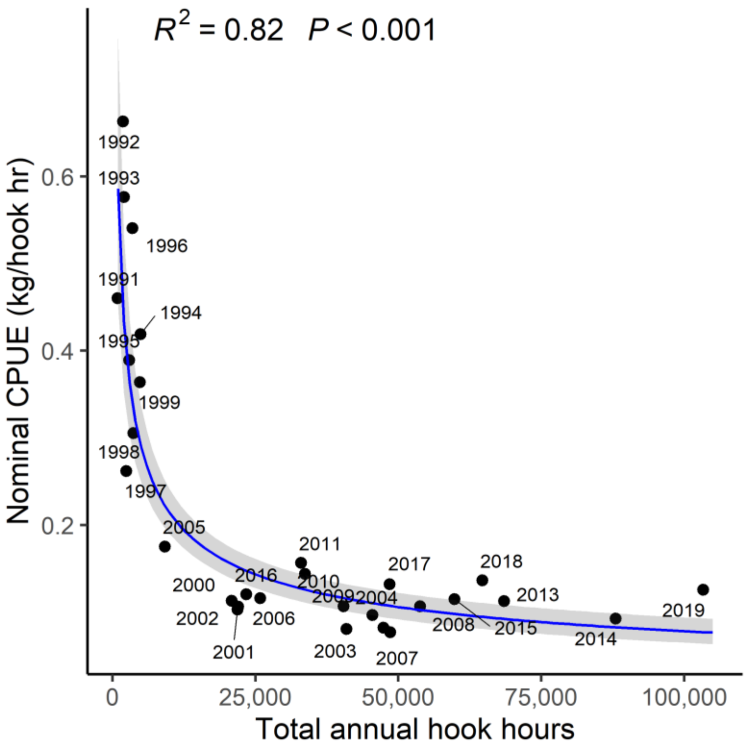
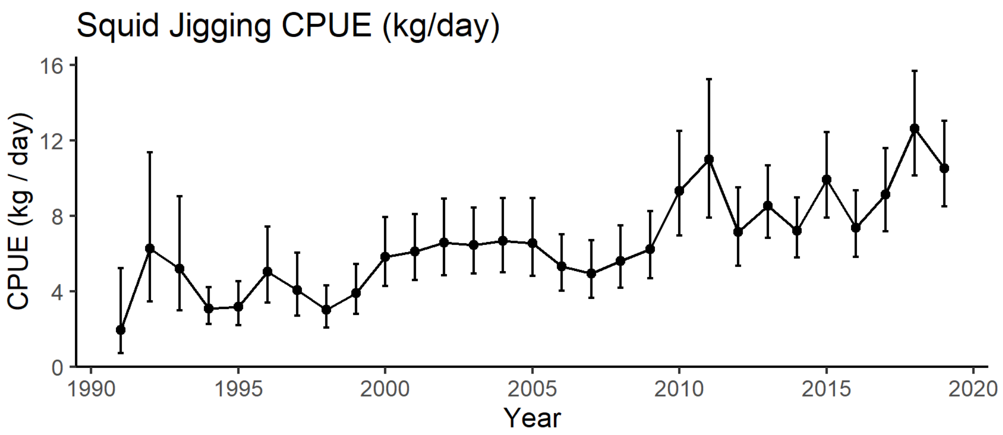


Figure 52. Relationship between total annual squid jigging hook hours (all fishers combined) and annual nominal squid jigging catch per unit of effort (CPUE) in King George Sound from 1990 to 2019.

Annual standardised squid jigging CPUE values for King George Sound calculated as kg/day show a steady increase over time, from 2 kg/day during 1991 to a maximum of 12.6 kg/day in 2018 (Figure 53). Standardised CPUE during 2019 was 10.5 kg/day, representing a slight decline from 2018. In contrast, however, standardised CPUE calculated as kg/hook hour has declined from 0.2–0.5 kg/hr during the 1990s to 0.1–0.15 kg/hr during 2015–2019 (Figure 53). This catch rate decline per individual hook in recent years is likely due to changing fishing behaviour as the fishery evolves. Over time there has been a substantial increase the number of hooks/jigs that each fishing vessel operates, with the average number hooks fished per day by each vessel increasing from <6 in the 1990s to 25 by 2015 (Figure 54). Moreover, several key fishing vessels operated <10 hooks/day during the 1990s compared with 30–50 hooks/day in recent years (Figure 54). Therefore, the relative efficiency of each hook is likely reduced compared with earlier years when they were operating smaller quantities. Nevertheless, squid jigging CPUE in King George Sound will be monitored closely in future years to ensure that CPUE does not decline further now that hook numbers are consistently high.



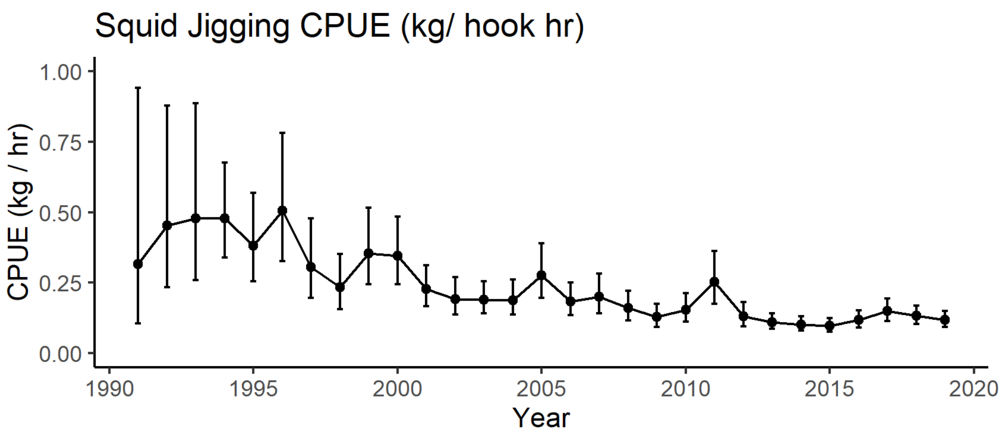


Figure 53. Standardised squid jigging catch per unit of effort (CPUE; ±95% confidence limits) in King George Sound from 1990 to 2019. Values have been standardised for months and vessel ID using a generalised linear model.

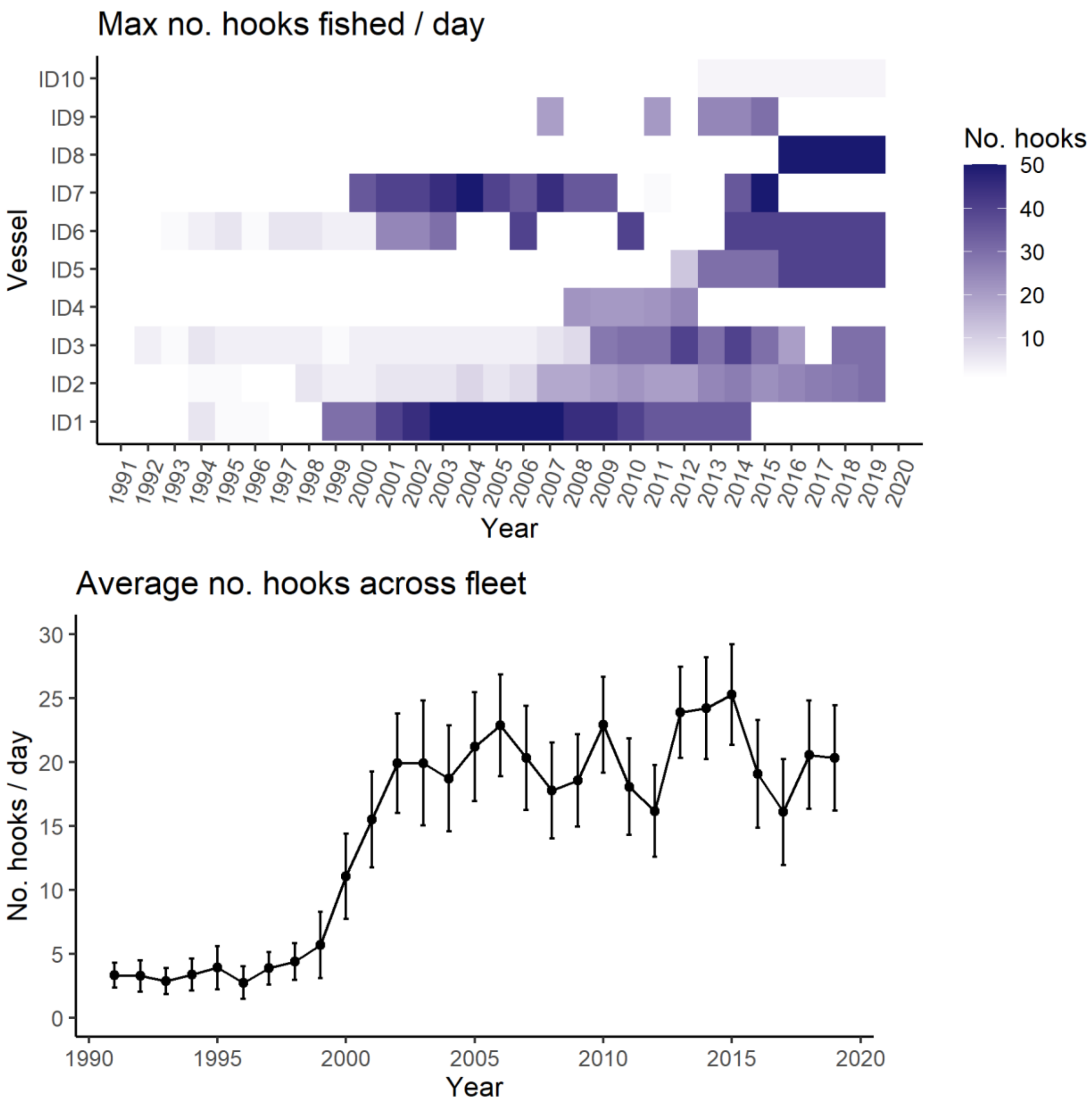


Figure 54. The annual maximum daily number of hooks (squid jigs) used by ten key commercial squid jigging vessels (based on total catch history) in King George Sound from 1990 to 2019, as well as the average (±SE) daily number of hooks used across the squid jigging fleet in King George Sound.

12.5 Commercial cuttlefish catch and effort trends

The state-wide total cuttlefish catch from 1976 to 2019 ranged from <1 to 135 t (Figure 55). There was a substantial increase in catches from the early-1990s to mid-1990s (7–11 t during 1990–1991 *vs* 70–75 t during 1996–1997) which reflected an increase in cuttlefish catches from the NCB. Catches peaked in the mid-2000s (88–135 t from 2001–2003), and have ranged 30–65 t from 2009 to 2018. The number of individual fishing vessels retaining cuttlefish state-wide has ranged from 4 during the late-1970s to 64 in 1996 (Figure 55). From 2009 to 2018 between 25 and 52 vessels landed cuttlefish. Trawling has accounted for the vast majority (~98%) of cuttlefish catches state-wide and other methods (e.g. squid jigging, netting, trapping) collectively accounted for <2% of catches from 2009 to 2018 (Figure 55).

By bioregion, total cuttlefish catches over the time period 1976–2019 were far greater in the NCB and GCB (62 and 36% of total catches, respectively) than in the WCB or SCB (1.4 and 0.6%, respectively; Figure 55). Annual catches in the NCB were greatest from the mid-1990s to mid-2000s (up to 106 t) and have declined since 2010 (5–33 t). In contrast, catches in the GCB have generally increased over time and from 2010–2019 ranged 20–44 t (Figure 55). At a finer spatial resolution, the highest cuttlefish catches in the GCB have come from Shark Bay and Exmouth Gulf (Figure 56). In the NCB most catches have come from the Pilbara, particularly the Nickol bay region near Karratha, with very minimal catch north of Broome (Figure 56). State-wide, cuttlefish catches have only been reported from CAES blocks containing waters <200 m deep.

The 2019 total cuttlefish catch was 54.7 t landed by 55 fishing vessels (Table 6; Figure 56). This catch was spread across 11 fisheries, as well as open access fishery areas, with the majority of catch taken from the Pilbara Fish Trawl (Interim) Managed Fishery (55.3%), Shark Bay Prawn Managed Fishery (30.7%) and Exmouth Gulf Prawn Managed Fishery (10.7%). The annual total represents a 7.9 t decrease from 2018 (62.6 t; Figure 55), but is in line with the average catch of 57 t for the previous five years from 2014–18 (Table 6). The 2019 catch comprised 30.3 t (55%) from the NCB, 22.7 t (41%) from the GCB, 1.1 t (2%) from the SCB and 0.7 t (1%) from the WCB (Figure 55). By method, 97% was taken by trawling, with minor contributions from squid jigging (2.6%) and other methods (e.g. beach seine; 0.4%).

Table 6. Total and average commercial cuttlefish catch in each bioregion and state-wide from 2014–18 and the total catch in 2019.

	Catch 2014–2018 (t)		Catch 2019
Bioregion	**Total**	**Average ± SD**	**Total (t)**
North Coast	119.3	23.9 ± 9.4	30.3
Gascoyne Coast	162	32.4 ± 8.4	22.7
West Coast	1.7	0.3 ± 0.2	0.7
South Coast	2.1	0.4 ± 0.2	1.1
State-wide	285.2	57 ± 8.7	54.7

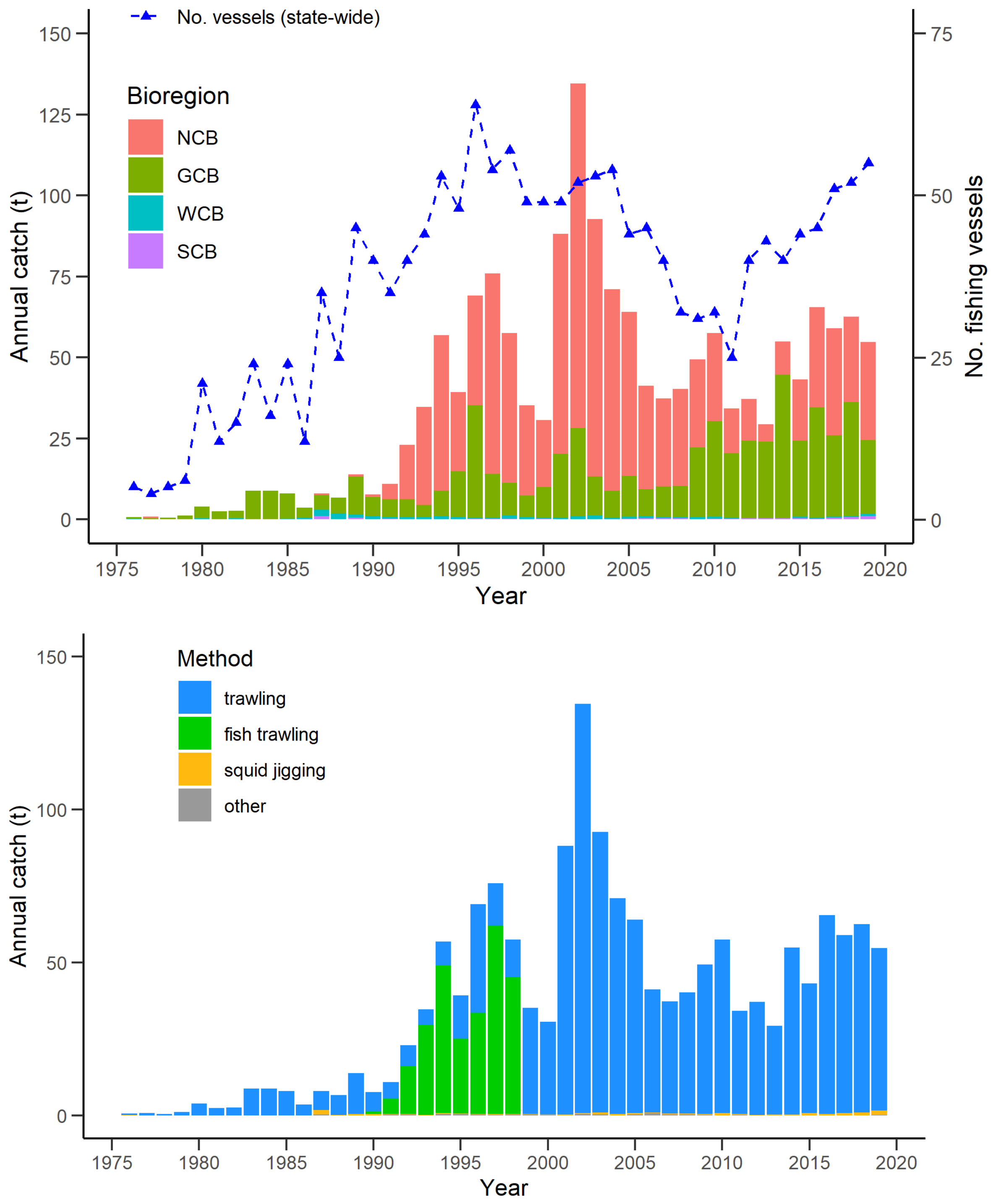


Figure 55. State-wide annual total catch of cuttlefish from 1976 to 2019 by bioregion and method. The number of fishing vessels is also shown. Bioregions, NCB – North Coast, GCB – Gascoyne Coast, WCB – West Coast, SCB – South Coast.

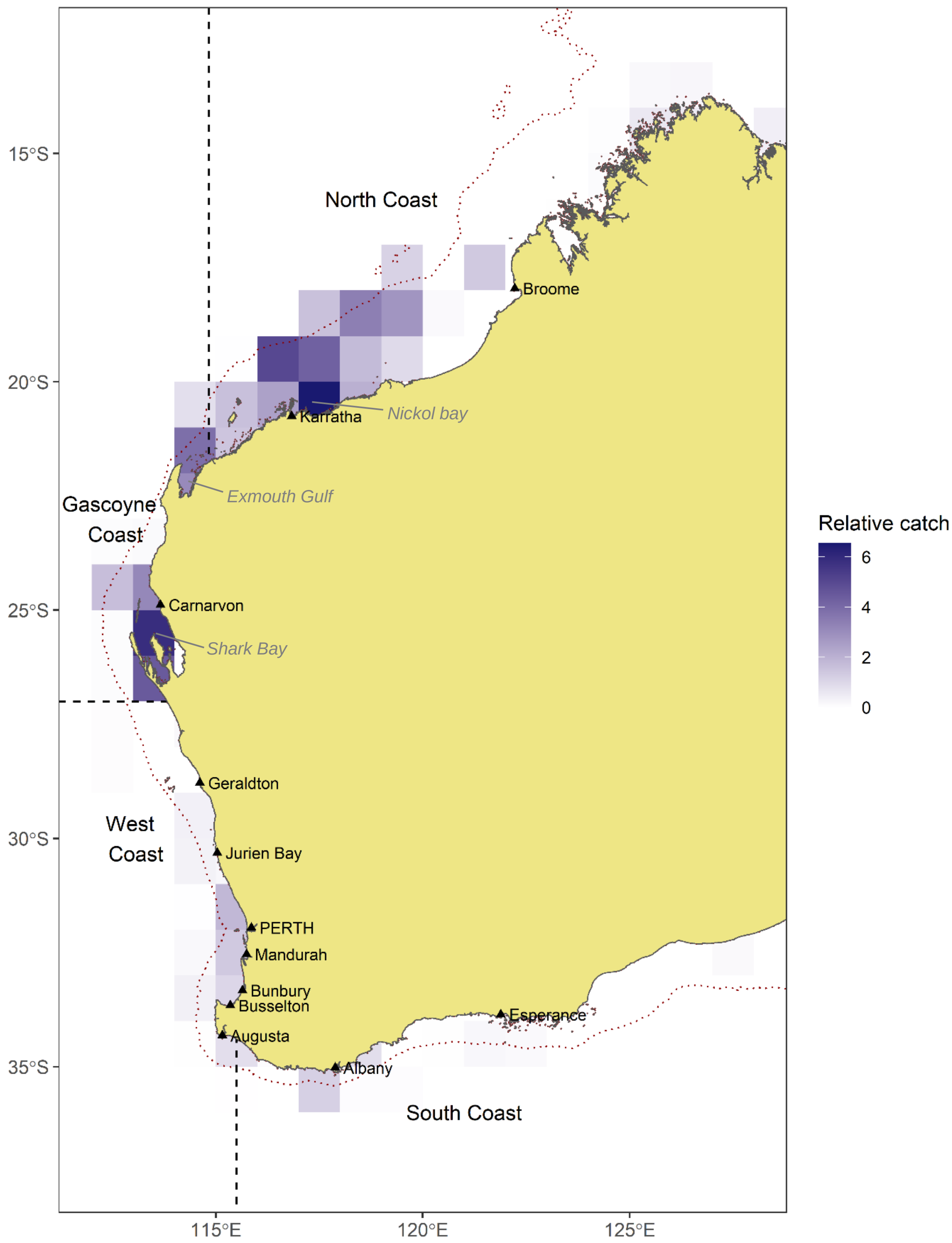


Figure 56. Total catch of cuttlefish in each 60 x 60 nm CAES block throughout Western Australia from 1976 to 2019. Catch totals (t) have been log(x + 1) transformed. Dashed lines denote bioregion boundaries and the dotted line denotes the 200 m isobath.

12.6 North Coast Bioregion

Table 6). It is thought that NCB cuttlefish catches comprise mostly pharaoh cuttlefish *Sepia pharaonis* and broadclub cuttlefish *S. latimanus*, but other smaller and/or less abundant species may also be caught.

Throughout the year, cuttlefish catches are highest from January to March and July to August, although in most years landings have occurred throughout all months of the year (Figure 58). This monthly distribution of catches has been relatively consistent over time, although the 2019 catch of 30.3 t contained a notably higher catch contribution from February and March than earlier years, but far lower landings during winter.

A significant, but relatively weak, negative correlation between spring and summer sea surface temperatures (September to February average) and total annual cuttlefish catch in the Pilbara region was detected ($R^2 = 0.24$, $P = 0.03$; Figure 59). Thus, when spring and summer temperatures exceeded 27.3 °C, catches were <30t, while high catches of 30–106 t occurred at temperatures ranging 26–26.5°C. Contrastingly, there was a weak positive relationship ($R^2 = 0.19$) between winter (July) water temperature and catches (temperature range 21–23.5 °C; data not shown), although this was not significant ($P = 0.11$). This suggests an optimal temperature range of *c.* 23.5–27 °C throughout the year results in the highest cuttlefish landings.

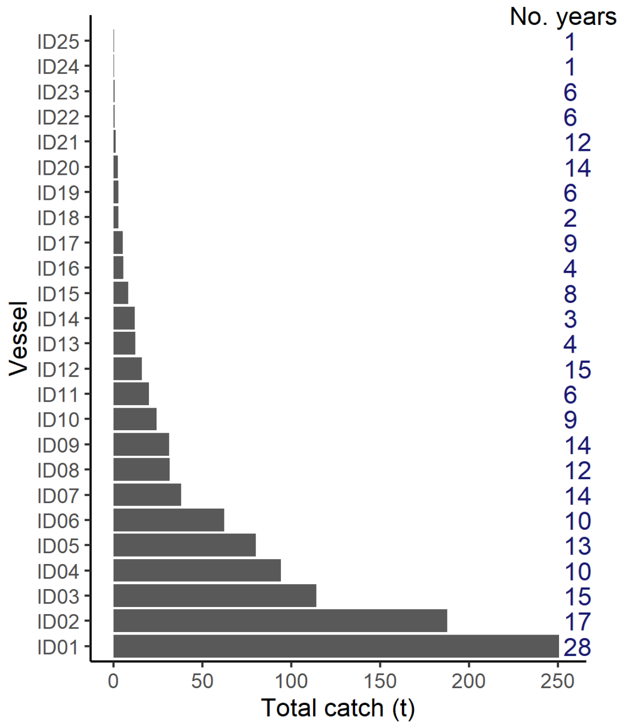


Figure 57. The top 25 vessels (by LFB) in the North Coast Bioregion which retained the greatest catches of cuttlefish from 1976 to 2019, and the total number of years which they landed cuttlefish. Vessel LFBs have been anonymised for confidentiality.

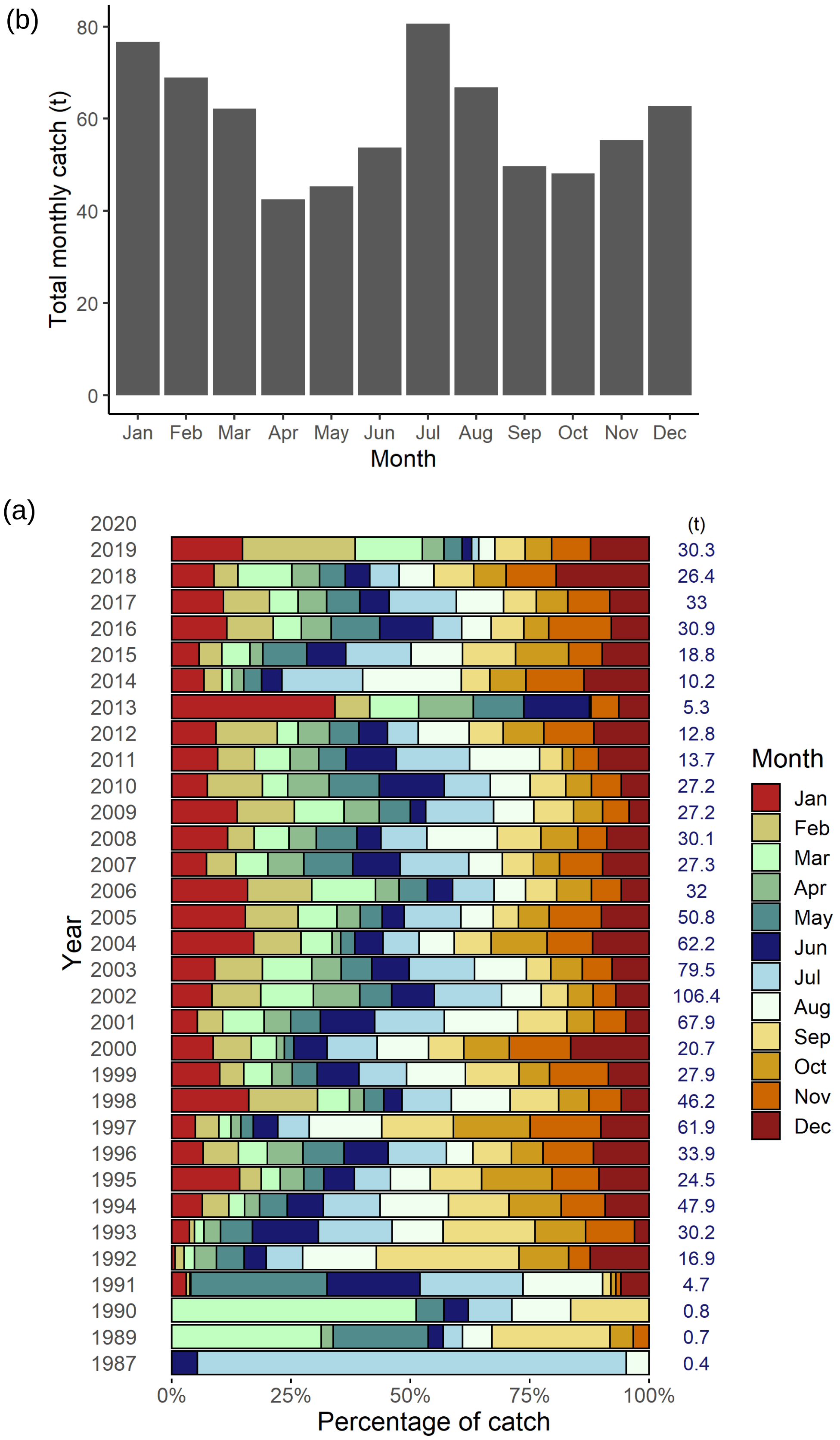


Figure 58. Total cuttlefish catch each month in the North Coast Bioregion (a) (across all years) from 1998 to 2019 and (b) the proportion of catch each year from 1976 to 2019. The total annual catch (t) is also given on (b).

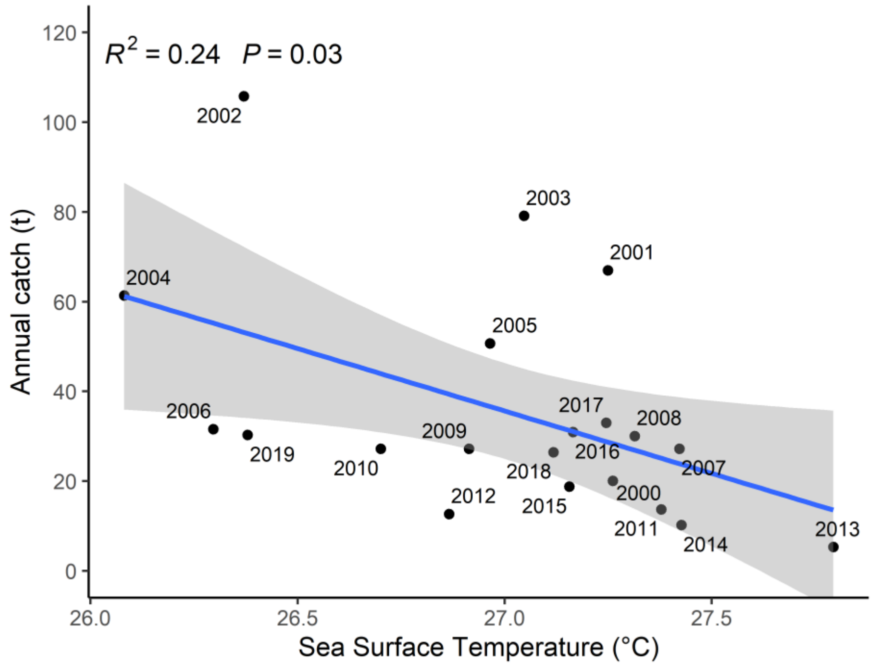


Figure 59. Relationship between spring and summer sea surface temperatures (September to February) and total annual cuttlefish catch in the Pilbara region from 2000 to 2019.

12.7 Gascoyne Coast Bioregion

A total of 81 fishing vessels have landed cuttlefish in the GCB from 1976 to 2019, with individual vessels landing up to 54 t during the period (Figure 55). Like the NCB, it is thought that commercial cuttlefish catches in the GCB comprise mostly pharaoh cuttlefish *Sepia pharaonis* and broadclub cuttlefish *S. latimanus*, but other smaller species such as Smith's cuttlefish *S. smithi* and Papuan cuttlefish *S. papuensis* may also be landed on occasion. Fishery independent surveys conducted in Shark Bay during 2002/03 also recorded Giant cuttlefish *S. apama* (Kangas *et al*., 2007), suggesting this temperate species may be landed by fishers in southern areas of the GCB.

Three vessels landed >40 t and 21 vessels landed >10 t. A total of 22.7 t of cuttlefish was landed during 2019 by 24 vessels, representing catch decline of 12.5 t from 2018 (35.2 t landed by 25 vessels; Figure 55). The 2019 GCB catch was also substantially below the 2014–2018 average catch of 32.4 t (Table 6). Throughout the year, catches were very minimal in summer, increasing during autumn to their peak in winter, before declining in spring (Figure 61). This reflects the seasonal distribution of prawn fishing effort. There has been no major shift in the seasonal distribution of catches since the early 1980s when consistent catches >5 t have been recorded. In Shark Bay, where the majority of cuttlefish catch from the GCB has been landed over time, a significant negative correlation between average water temperature from May–July (the start of the peak fishing period) and annual catch was detected ($R^2 = 0.29$, $P < 0.01$; Figure 62). When May–July water temperatures exceeded 24°C annual catches were < 9 t, while when temperatures ranged 21–22 °C annual catches of 22–43 t occurred.

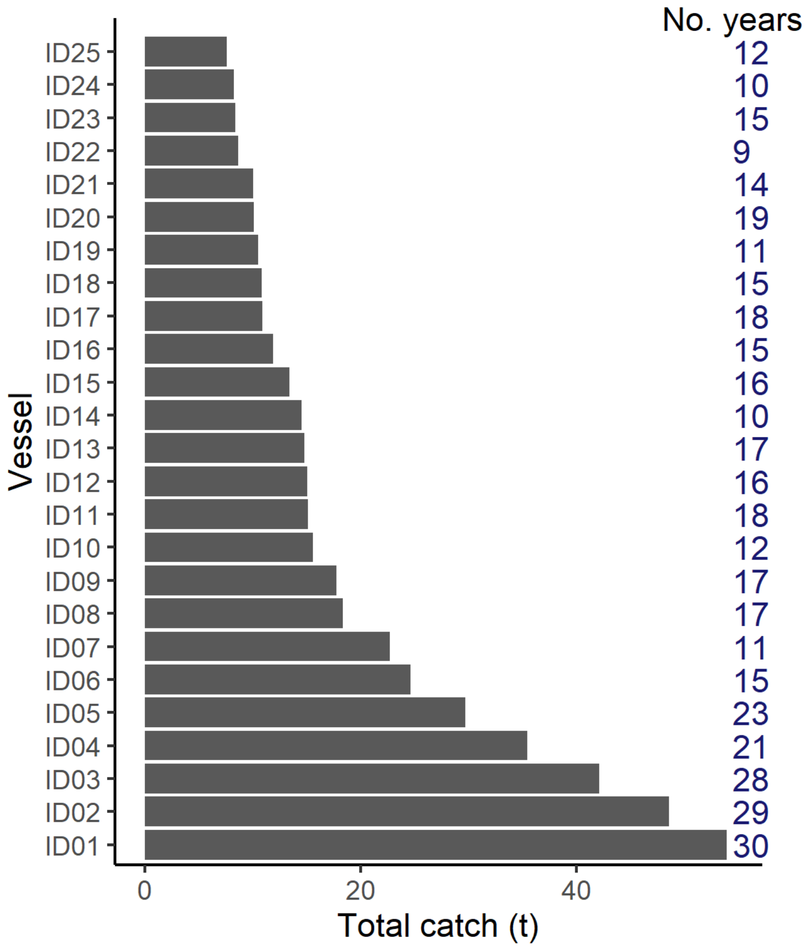


Figure 60. The top 25 vessels (by LFB) in the Gascoyne Coast Bioregion which retained the greatest catches of cuttlefish from 1976 to 2019, and the total number of years which they landed cuttlefish. Vessel LFBs have been anonymised for confidentiality.

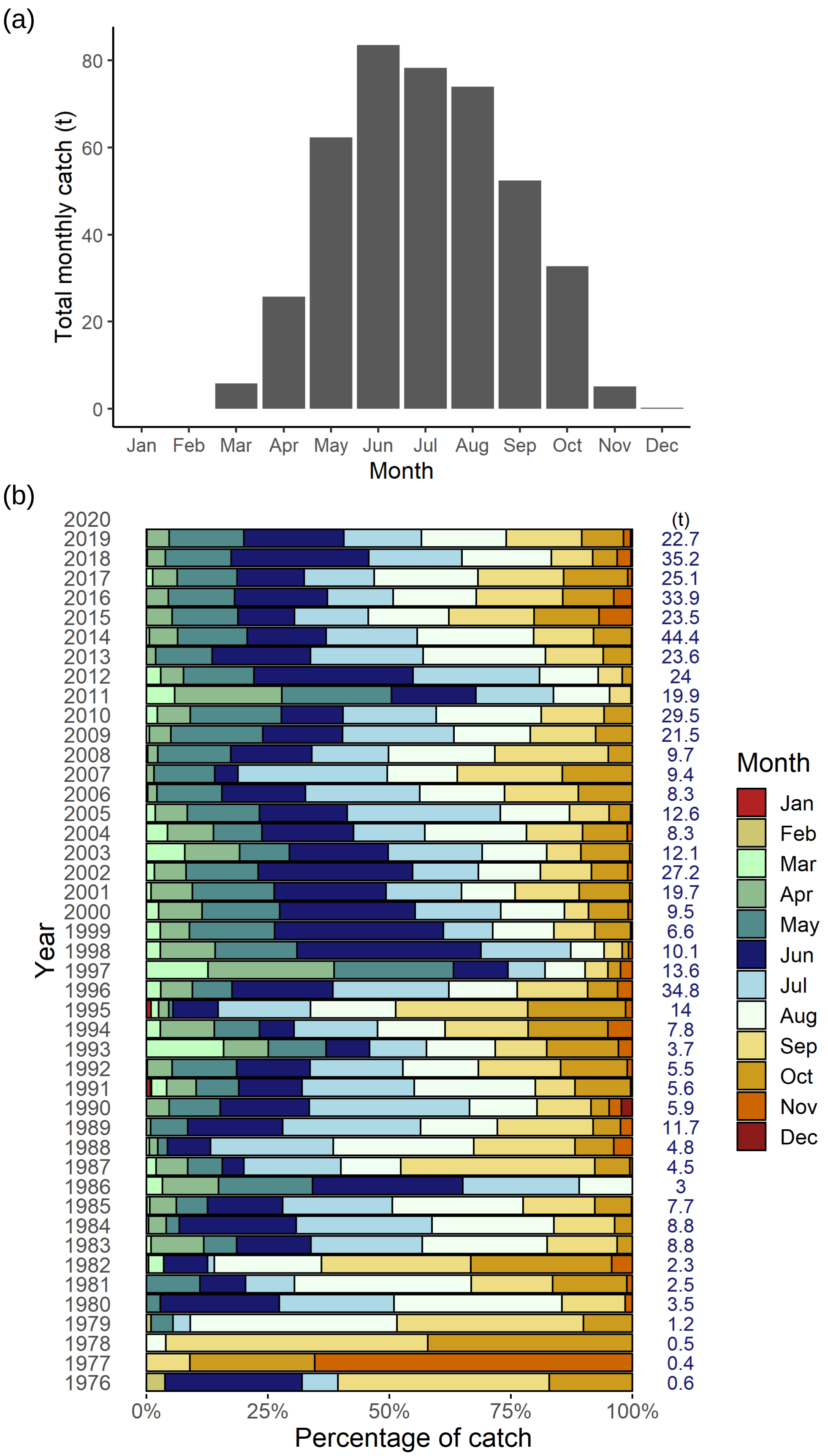


Figure 61. Total cuttlefish catch each month in the Gascoyne Coast Bioregion (a) (across all years) from 1998 to 2019 and (b) the proportion of catch each year from 1976 to 2019. The total annual catch (t) is also given on (b).

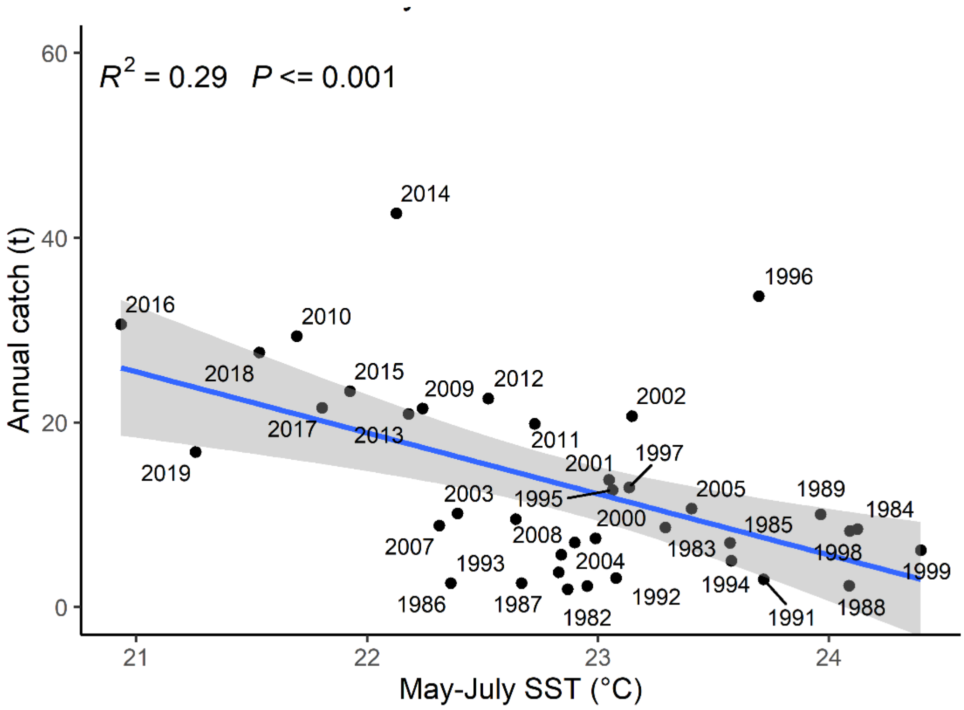


Figure 62. Correlation between mean sea surface temperature (SST) in Shark Bay from May to July and total annual commercial cuttlefish catch.

12.8 Recreational squid and cuttlefish catch trends

Recreational squid and cuttlefish data for WA are primarily collected through biennial state-wide catch and effort surveys conducted during 2011/12, 2013/14, 2015/16 and 2017/18 (Ryan *et al*., 2013; 2015; 2017; 2019). Estimates of squid catches from boat-based fishers were highest in 2011/12 (110,624 squid) and lowest in 2015/16 (65,025 squid; Table 7). The 2017/18 boat-based catch was 88,519 squid (SE ± 8,037), with 85,565 (97%) retained. This represented a 38% increase in recreational catch from 2015/16 (62,424 individuals retained). A preliminary recreational harvest weight estimate for 2017/18 was determined to be 34 t (range 27–40 t) based on a relatively small sample of squid weights obtained through boat-ramp surveys (average weight 336–643 g; see Smallwood *et al*., 2017). Annual estimates of boat-based cuttlefish catches were substantially lower than for squid, and ranged from 1,477 to 4,234 individuals (Table 7). The 2017/18 boat-based cuttlefish catch was 4,234 individuals, with 3,058 retained. This represented a 54% increase in recreational harvest from 2015/16 (1,974 cuttlefish retained).

The vast majority of squid caught by recreational anglers were retained (93–97% of catch). This very high retention rate, which is among the highest of all recreational species state-wide (Ryan *et al*., 2019), is likely due to the fact that squid have no minimum legal-size limit in WA and that recreational fishers often use small squid for bait. While the majority of cuttlefish were also kept, release rates were higher than for squid (61–74% retained).

The majority of the 2017/18 recreational boat-based squid catch was taken from the WCB (64,508 squid; 75% of the state-wide catch), with small contributions from the

GCB (10,896 squid; 13%), SCB (7,407 squid; 9%) and NCB (2,754 squid; 3%; Table 8; Figure 63). Squid catches from nearshore waters were far higher than inshore, pelagic, offshore and estuarine environments (Figure 63). While species specific data were not collected, this suggests most squid caught by recreational anglers in the NCB and GCB would be northern calamari, while catches in the WCB and SCB would comprise mostly southern calamari, as these are the two main squid species found in nearshore waters (see section Taxonomy and Distribution). Catches were highest in autumn, winter and spring and lowest in summer. Squid were almost exclusively caught by line fishing (e.g. squid jigging), with very minimal catch from pots and diving (e.g. by spear; Figure 63).

Squid (southern calamari) size composition data from the Perth metro region in the WCB were obtained from two years of monthly squid jigging (mid-2013 to mid-2015) by both recreational anglers and researchers mimicking recreational techniques (Coulson *et al*., 2016). This data determined an average weight of 214 g (SE ± 18 g) per animal (standardised across months and for fishers). Using this average weight, the total 2017/18 recreational harvest of squid from the WCB (presumed to comprise mostly southern calamari) is estimated to be ~13.8 t (12.4–15.3 t range based on catch estimates). Additional squid weight data in the WCB was also collected from boat-based fishers during boat ramp surveys (Smallwood *et al.*, 2017), which determined an average weight of 336 g (SE ± 36 g) from a small sample of 47 squid. Using this higher average weight, the WCB total harvest weight for 2017/18 would be estimated at 21.5 t (19.3–23.8 t range).

The majority of cuttlefish caught by recreational fishers during the 2017/18 survey were also taken in the WCB (estimated 2,740 individuals, 90% of state-wide catch), with minor catch from the SCB (291 individuals) and GCB (28 individuals; Table 8; Figure 64). Most cuttlefish were caught in nearshore or inshore waters, with only small numbers reported from estuarine, pelagic and offshore environments (Figure 64). Cuttlefish were caught predominantly by line fishing, with a small proportion also caught by diving (e.g. with a lobster snare or spear). Catches were highest in autumn and lowest in summer. Species composition data for recreational cuttlefish catches has not yet been formally collected, but it is presumed that most retained cuttlefish were giant cuttlefish *S. apama*, given the large sizes of animals weighed during boat ramp surveys (750 g to 3.4 kg; Smallwood *et al.*, 2017).

Table 7. Recreational boat-based catch of squid and cuttlefish in Western Australia estimated from state-wide surveys (Ryan *et al*., 2013; 2015; 2016; 2019).

Survey year	Number caught (% kept)	
	Squid	Cuttlefish
2011/12	110,624 (95%)	3,319 (61%)
2013/14	78,857 (93%)	1,477 (72%)
2015/16	65,025 (96%)	2,667 (74%)
2017/18	88,519 (97%)	4,234 (72%)

Table 8. Recreational boat-based catch of squid and cuttlefish in the North Coast, Gascoyne Coast, West Coast and South Coast Bioregion during 2017/18 (Ryan *et al.*, 2019).

Bioregion	Number kept (± SE)	
	Squid	Cuttlefish
North Coast	2,754 (68)	0
Gascoyne Coast	10,896 (3,510)	28 (17)
West Coast	64,508 (6,816)	2,740 (432)
South Coast	7,407 (1,834)	291 (78)

Recreational boat-based squid catches

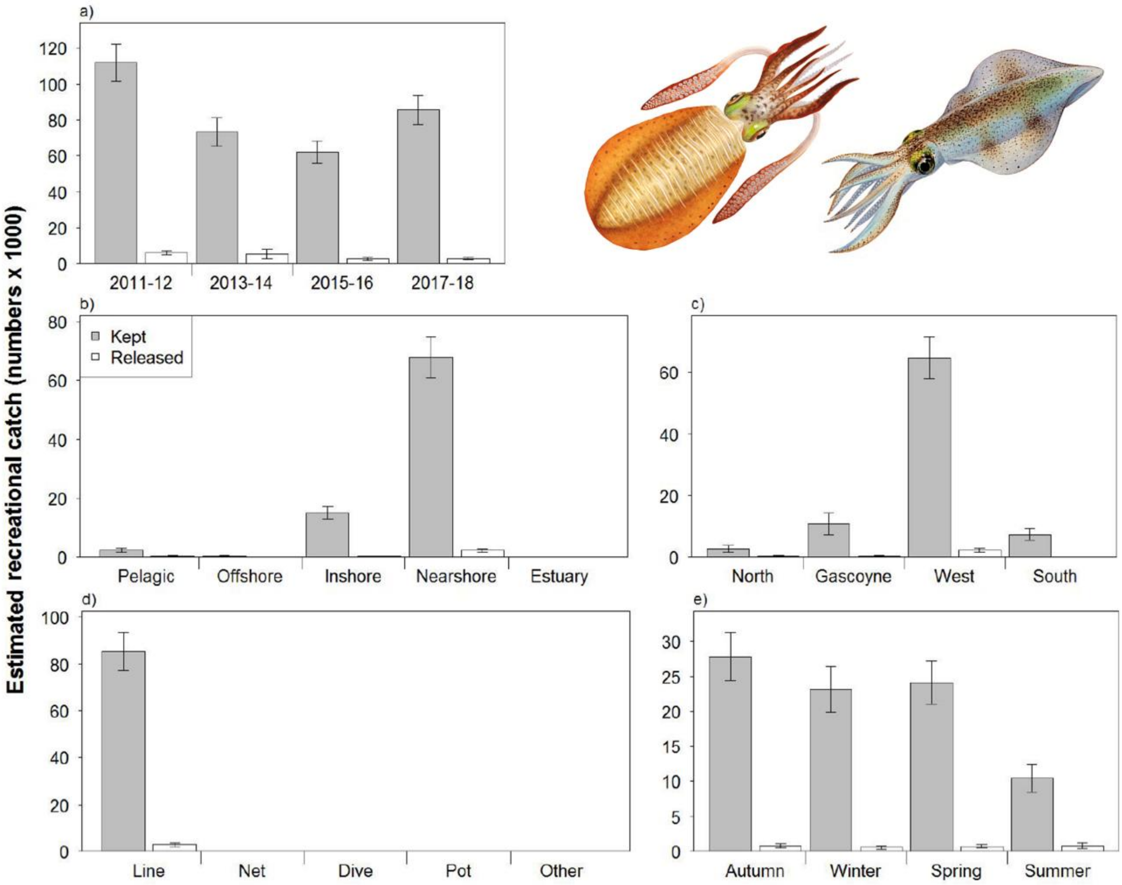


Figure 63. Recreational boat-based squid catch statistics for Western Australia (Ryan et al., 2019). (a) Total number of squid kept (grey bars) and released (white bars) during state-wide surveys conducted during 2011/12, 2013/14, 2015/16 and 2017/18, as well as, catch during 2017/18 by (b) habitat, (c) bioregion, (d) method and (e) season.

Recreational boat-based cuttlefish catches

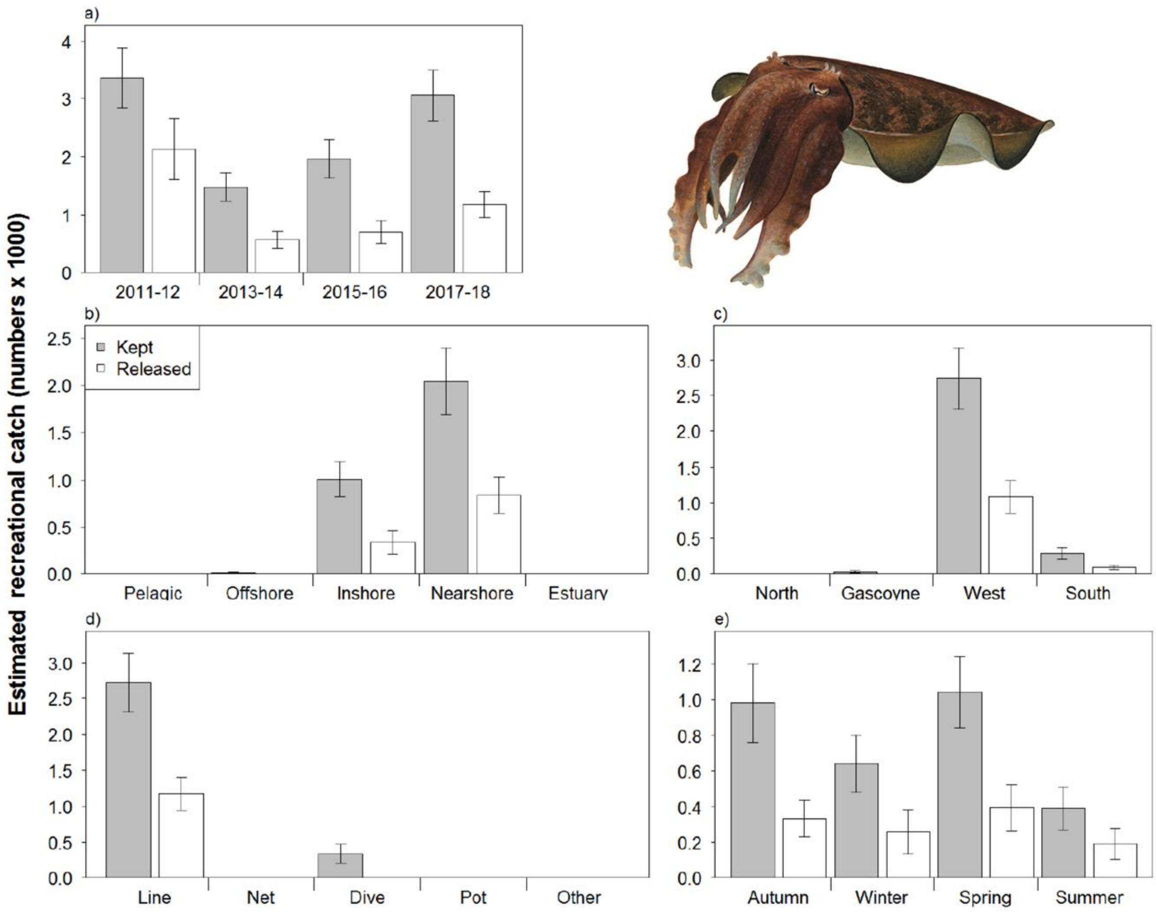


Figure 64. Recreational boat-based cuttlefish catch statistics for Western Australia (Ryan et al., 2019). (a) Total number of cuttlefish kept (grey bars) and released (white bars) during state-wide surveys conducted during 2011/12, 2013/14, 2015/16 and 2017/18, as well as, catch during 2017/18 by (b) habitat, (c) bioregion, (d) method and (e) season.

12.9 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 WA squid and cuttlefish resources.

12.9.1 *Weight of evidence risk assessment*

North Coast Bioregion squid resource

Category	Lines of evidence (Consequence/Status)
Commercial catch trends	Annual squid catches in the NCB since 1976, presumed to comprise mostly loligo squid *Uroteuthis* (*Photololigo)* spp. and northern calamari (*S. lessoniana*), have been highly variable (<1 t to 967 t), with the highest catches on record occurring during 1993–95 (280–534 t) and 2003–04 (79–967 t). The vast majority of catch has come from trawling. These very high catches likely reflect changes in fishing behaviour, such as targeting squid aggregations. Environmental variables (e.g. temperature) may also influence population abundances and catchability. Since 2005, squid catches throughout the NCB have been low (<5 t). Nine vessels landed a total of 3.48 t in 2019, a catch increase of ~40% from 2018 (2.5 t from 5 vessels) and above the 2014–18 average of 2.1 t.
Commercial catch distribution	Squid catches in the NCB have predominantly come from coastal areas where prawn and/or fish trawlers operate. The very high catches during 1993–1995 came from the Kimberley region, while very high catches during 2004 came from the Pilbara region (Nickol Bay and surrounding waters). The spatial distribution of catches therefore appears to largely reflect targeted fishing effort in areas of high squid abundances.
Recreational catch trends	An estimated 2,754 squid were retained by boat-based fishers in the NCB during 2017/18, presumed to comprise predominately northern calamari (*S. lessoniana*). This represents 3% of the state-wide squid catch. Squid were almost exclusively caught by line fishing (e.g. squid jigging). The NCB recreational boat-based harvest for 2017/18 was 33% lower than during 2015/16 (4,125 squid).

North Coast Bioregion squid resource 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				1
C2 Moderate				X	8
C3 High		X			6
C4 Major		X			8

C1 (Minimal Depletion): L1 Remote – There is a remote chance that fishing has had a minimal impact on squid stocks in the NCB given the historical levels of catch which have occurred.

C2 (Moderate Depletion): L4 Likely –It is likely that fishing has had a moderate impact on squid stocks in the NCB given that very high catches occurred in some areas of the bioregion on several occasions historically, but minimal catch has been taken from other areas and targeted species have broad distributions with high population connectivity. Catch variation over time appears largely driven by environmental variables (e.g. water temperature) and changing fishing effort, i.e. targeted trawling for squid vs retention as by-product in prawn trawls.

C3 (High Depletion): L2 Unlikely **–** It is possible that high depletion of squid stocks occurred in areas of the NCB during the 1990s and mid-2000s when very high annual catches up to 967 t occurred. These catches were resultant from trawlers actively targeted aggregations of squid during periods of high abundance. Given the lack of knowledge around the exact species composition of catches, both historically and currently, there is a chance that unacceptable levels of fishing for some species occurred in years when catches were very high. However, as squid catches in recent years have been minimal and trawl effort focused on other species such as prawns and fish, it is unlikely that fishing has caused high depletion of squid stocks in recent years.

C4 (Major Depletion): Unlikely L2 **–** Although very high catches occurred during the 1990s and mid-2000s, catches have decreased to far lower levels during the past decade. These high catches were also taken from relatively localised areas. Given the fast growth and reproduction of targeted squid species, the broad geographic range over which populations occur, and low levels of fishing mortality in recent years, it is unlikely that fishing has caused major stock depletion.

Gascoyne Coast Bioregion squid resource

Category	Lines of evidence (Consequence/Status)
Commercial catch trends	Annual squid catches in the GCB, presumed to comprise mostly loligo squid *Uroteuthis* (*Photololigo)* spp. and northern calamari, have ranged from ~8 to 100 t since 1976. Catches were highest from the early-1990s to late-2000s, with peaks of 99.6 t in 1995, 64.2 t in 1998, 62.3–75.1 t in 2003–2005 and 63.7 t in 2010. The vast majority of catch has come from trawling, and predominately during autumn. During 2019, 28 vessels landed a total of 13.7 t of squid, a catch increase of ~20% from 2018 (11.3 t from 29 vessels) and consistent with the 2014–2018 five-year average of 13.1 t. Catches in Shark Bay appear to be inversely correlated with water temperature, with very low catches following a summer marine heatwave during 2011–2013.
Commercial catch distribution	The majority of squid catch from the GCB has historically been taken from Shark Bay, with minor catch from the Exmouth region. Major prawn trawl fisheries operate in both regions and the spatial distribution of squid catches is largely reflectively of the spatial boundaries of these fisheries.
Recreational catch trends	An estimated 10,896 squid were retained by boat-based fishers in the GCB during 2017/18, presumed to comprise predominately northern calamari. This represents 13% of the state-wide squid catch. Squid were caught almost exclusively by line fishing (e.g. squid jigging). The GCB recreational boat-based harvest for 2017/18 was 67% higher than during 2015/16 (6,530 squid).

Gascoyne Coast Bioregion squid resource 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				1
C2 Moderate				X	8
C3 High		X			6
C4 Major	X				4

C1 (Minimal Depletion): L1 Remote – There is a remote chance that fishing has had a minimal impact on squid stocks in the GCB given the historical levels of trawling which have occurred throughout areas where squid occur.

C2 (Moderate Depletion): L4 Likely – It is likely that fishing has had a moderate impact on squid stocks in the GCB given that prawn trawlers have consistently landed squid by-product since the 1970s. Catch variation over time appears largely driven by changing fishing effort and environmental influences (e.g. marine heatwaves).

C3 (High Depletion): L2 Unlikely **–** It is unlikely that fishing has caused high depletion of squid stocks in the GCB, given the relatively low catches that have been taken and the fast growth and reproduction of targeted squid species, as well as the broad geographic range over which populations occur.

C4 (Major Depletion): Remote L1 **–** There is a remote chance that fishing has caused high depletion of squid stocks in the GCB. Catches have remained relatively low over time and been relatively consistent over the past decade, suggesting fishing is occurring at sustainable levels.

West Coast Bioregion squid resource

Category	**Lines of evidence (Consequence/Status)**
Commercial catch trends	Squid catches in the WCB predominately comprise southern calamari (*Sepioteuthis australis*), although Goud’s squid (*Nototodarus gouldi*) may be caught in deeper offshore waters (50–500+ m). The number of fishing vessels retaining squid in the WCB peaked between the late-1980s and early-1990s (*c.* 50–70 vessels). Total annual catches since 1976 ranged between 3–16 t, and peaked between1988–1992 (14–16 t). Catches in most years came predominantly from squid jigging, although handlining and trawling accounted for notable catches in several years, particularly from the 1980s to early 2000s. Since 2010, squid jigging has accounted for 77–92% catches. The 2019 WCB squid catch was 10.8 t landed by 24 vessels. This represents an approximately three-fold increase in catch from 2018 (3.2 t from 17 vessels), and is substantially above the 2014–2018 five-year average of 5.1 t. Squid catch in the WCB appears to largely reflect changing fishing effort, but may also reflect increased abundances and/or catchability with changing environmental conditions.

Category	Lines of evidence (Consequence/Status)
Commercial catch distribution	The majority of squid catches over time have come from Cockburn Sound (CAES block 9600) and the broader Perth metro region, with substantial contributions also from Geographe Bay (CAES block 9601) during 1976, 1987–1990 and 2010–2014. These are predominately sheltered coastal areas that contain substantial seagrass habitat. The spatial distribution of catches appears to largely reflect areas of suitable habitat where fishing effort is concentrated.
Commercial catch rates	Squid jigging catch rates in the WCB were positively correlated with water temperature, which was most apparent during recent years from 2008–2018. Nominal CPUE notably increased during 1995 and 1999 (15–16 kg/day) and again from 2010 to 2015 (21–31 kg/day) when water temperatures were warm. Standardised annual squid jigging CPUE (accounting for effects of month, fisher and fishing location [60 × 60 nm CAES block]) has remained relatively constant over time, being lowest in 1985 and 1996 (4.2–4.4 kg/day) and highest in 1999 (9.8 kg/day). Standardised squid jigging CPUE for the WCB during 2019 was 5.9 kg/day, representing a slight increase from 2018 (5.7 kg/day) and being above the threshold and limit of the draft harvest strategy (5 and 3.5 kg/day, respectively).
Recreational catch trends	During 2017/18, an estimated 64,508 squid were retained by boat-based fishers in the WCB, presumed to comprise predominately southern calamari. This represents the vast majority (75%) of the state-wide squid catch. Harvest weight estimates of this recreational catch range from 12.4 to 23.8 t. Squid were almost exclusively caught by line fishing (e.g. squid jigging). The WCB recreational boat-based harvest for 2017/18 was 23% higher than during 2015/16 (52,295 squid).

West Coast Bioregion squid resource 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				1
C2 Moderate				X	8
C3 High		X			6
C4 Major	X				4

C1 (Minimal Depletion): L1 Remote – There is a remote chance that fishing has had a minimal impact on squid stocks in the WCB given the historical levels of catch and effort that have occurred.

C2 (Moderate Depletion): L4 Likely – It is likely that fishing has had a moderate impact on squid stocks in the WCB given the considerable levels of historical commercial effort. Recreational fishing effort is also substantial in the WCB and squid are among the most retained of all species. However, as commercial catch rates have remained relatively stable in recent years and are within the target range of the draft harvest strategy, it is likely that fishing is occurring at sustainable levels. Recreational catches have also been relatively consistent over time. Catch variation appears largely driven by changing fishing effort and environmental influences (e.g. water temperature variation).

C3 (High Depletion): L2 Unlikely **–** The lower 95% confidence interval of the primary performance indicator in the WCB (commercial standardised CPUE) extends below the draft harvest strategy threshold for 2019. There is also considerable recreational fishing effort targeting squid in the WCB. However, given the fast growth and reproduction of targeted squid species (namely southern calamari), as well as the broad geographic range over which populations occur, it is unlikely that fishing is causing high stock depletion.

C4 (Major Depletion): Remote L1 **–** There is a remote chance that fishing has caused high depletion of squid stocks in the WCB. The primary performance indicator in the WCB (commercial standardised CPUE) has never approached the limit of the draft harvest strategy.

South Coast Bioregion squid resource

Category	**Lines of evidence (Consequence/Status)**
Commercial catch trends	Squid catches in the SCB since 1976 have ranged from 2–24 t. From the mid-1990s to 2010s there has been a general increase in catches, and the number of vessels targeting squid by jigging. Squid jigging effort has increased from typically <100 fishing days annually (across the entire fleet) during the 1970s and 1980s, to 500–1,100 fishing days since 2007. Catches from inshore areas (<30 m deep) are thought to comprise predominantly southern calamari, while catches from deeper waters closer to the continental shelf (50–850+ m) are likely to comprise Gould's squid. The majority of catch is taken from autumn to spring, with annual catches positively correlated with water temperature. The 2019 SCB squid catch was 21.1 t landed by 38 vessels, a 40% increase in catch from 2018 (15.1 t from 35 vessels) and substantially above the 2014–2018 five-year average of 15 t.
Commercial catch distribution	The majority of squid catches in the SCB between 1976 and 2019 have come from the Albany region, including Oyster Harbour (11% of total catch), Princess Royal Harbour (4%), King George Sound (24 %) and other surrounding areas within 100 km (50%). Collectively, all other fishing areas along the south coast therefore accounted for only ~11% of landings. In recent years the proportion of SCB catch taken from King George Sound has increased, accounting for 29–63% of the bioregion catch from 2010–2019, which is largely due to an increase in targeted squid jigging effort.

Category	Lines of evidence (Consequence/Status)
Commercial catch rates	Nominal CPUE has generally increased over time, from 1–13 kg/day in the late-1970s to 13–22 kg/day since 2007. There was a significant and relatively strong positive correlation between annual nominal squid jigging CPUE in the Albany region and sea surface temperatures ($R^2 = 0.45$, $P < 0.001$), with very high CPUE (50 kg/day) recorded in 1999 during a marine heatwave. Like nominal CPUE, standardised annual squid jigging CPUE (accounting for effects of month, fisher and fishing location [60 × 60 nm CAES block]) has increased over time, from 1.7–5.5 kg/day in the 1970s and 1980s to 12.3–18.4 kg/day in the mid-2000s. The highest standardised CPUE values were recorded in 2010 (18.7 kg/day) and 2011 (20.6 kg/day), decreasing to 11.7–16.3 kg/day since 2012. Standardised squid jigging CPUE (kg/day) in the key fishing area of King George Sound also increased over time, from 2 kg/day during 1991 to peak at 12.6 kg/day in 2018. In contrast, standardised CPUE calculated as kg/hook hour gradually declined over time, from 0.2–0.5 kg/hr during the 1990s to 0.1–0.15 kg/hr during 2015–2019. This decline may have been due to changing efficiency as vessels increase the number of hooks they use. For the SCB overall, standardised CPUE during 2019 was 15.1 kg/day, representing a ~1 kg/day decline from 2018, but above the threshold (11.7 kg/day) and limit (8.2 kg/day) of the draft harvest strategy.
Recreational catch trends	An estimated 7,407 squid were retained by boat-based fishers in the SCB during 2017/18, presumed to comprise predominately of southern calamari and representing 9% of the state-wide squid catch. Squid were almost exclusively caught by line fishing (e.g. squid jigging). The SCB recreational boat-based harvest for 2017/18 was 27% lower than during 2015/16 (10,247 squid).

South Coast Bioregion squid resource 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				1
C2 Moderate			X		6
C3 High	X				3
C4 Major	X				4

C1 (Minimal Depletion): L1 Remote – There is a remote chance that fishing has had a minimal impact on squid stocks in the SCB given the historical levels of catch and effort.

C2 (Moderate Depletion): L3 Possible – It is likely that fishing has had a moderate impact on squid stocks in the SCB given that considerable levels of historical commercial effort have occurred. As standardised commercial catch rates have remained relatively stable in recent years and are within the target range of the draft harvest strategy, it is likely that fishing is occurring at sustainable levels. Recreational catches are relatively low and have been relatively consistent over time. Catch variation appears largely driven by changing fishing effort and environmental influences (e.g. water temperature variation).

C3 (High Depletion): L2 Unlikely **–** The lower 95% confidence interval of the primary performance indicator in the SCB (commercial standardised CPUE) extends slightly below the draft harvest strategy threshold for 2019. Fishing effort has also increased over time. However, given the fast growth and reproduction of targeted squid species (namely southern calamari) and the broad geographic range over which populations occur, it is unlikely that fishing is causing high stock depletion.

C4 (Major Depletion): Remote L1 **–** There is a remote chance that fishing has caused high depletion of squid stocks in the SCB. The primary performance indicator in the SCB (commercial standardised CPUE) has remained relatively stable for the past decades without approaching the limit of the draft harvest strategy.

State-wide cuttlefish resource

Category	Lines of evidence (Consequence/Status)
Commercial catch trends	The state-wide cuttlefish catch from 1976 to 2019 ranged from <1 to 135 t, peaking during the early-2000s (88–135 t from 2001–2003). The number of individual fishing vessels retaining cuttlefish has ranged from 4 during the late-1970s to 64 in 1996, with trawling accounting for the vast majority of catches (~98%). The 2019 state-wide cuttlefish catch was 54.7 t landed by 55 fishing vessels, a 7.9 t decrease from 2018 (62.6 t) but in line with the 2014–18 five-year average of 57 t.
Commercial catch distribution	Since 1976, the vast majority of commercial cuttlefish catch has been taken from the NCB and GCB. The 2019 cuttlefish catch comprised 30.3 t (55%) from the NCB, 22.7 t (41%) from the GCB, 1.1 t (2%) from the SCB and 0.7 t (1%) from the WCB. At a finer-spatial scale, the highest cuttlefish catches have come from Nickol bay region of the NCB, as well as Shark Bay and Exmouth Gulf in the GCB. Key species in the NCB and GCB are likely to be pharaoh cuttlefish *Sepia pharaonis* and broadclub cuttlefish *S. latimanus*. Annual catches in the NCB were greatest from the mid-1990s to mid-2000s (up to 106 t), but have declined since 2010 (5–33 t). In contrast, catches in the GCB have generally increased over time, from <12 t prior to the mid-1990s to 20–44 t since 2010.
Recreational catch trends	The 2017/18 recreational boat-based cuttlefish catch was estimated to be 4,234 individuals, with 3,058 retained. This represented a 54% increase in recreational harvest from 2015/16 (1,974 cuttlefish retained). The majority of cuttlefish caught by recreational fishers during 2017/18 were taken in the WCB (2,740 individuals, 90% of state-wide catch), with minor catch from the SCB (291 individuals) and GCB (28 individuals). Cuttlefish were caught predominantly by line fishing, with a small proportion also taken by diving (e.g. with a lobster snare or spear). These recreational catches are far lower than for squid or other invertebrates (blue swimmer crab, rock lobster).

State-wide cuttlefish resource 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	4
C2 Moderate		X			4
C3 High	X				3
C4 Major	X				4

C1 (Minimal Depletion): L4 Likely – It is likely that fishing has had a minimal impact on cuttlefish stocks state-wide given the relatively low levels of commercial and recreational catch, the broad spatial distribution of many cuttlefish species, and their rapid growth and reproductive rates.

C2 (Moderate Depletion): L2 Unlikely – It is unlikely that fishing has caused moderate depletion of cuttlefish stocks state-wide as commercial and recreational catches are very low in most areas. Catch variation appears largely driven by changes in fishing behaviour and environmental influences (e.g. water temperature). However, given that substantial commercial harvest does occur in some areas of the NCB and GCB, and a lack of knowledge surrounding the exact species composition in catches, there is a moderate chance that fishing may exert pressure on populations of some species in these areas.

C3 (High Depletion): L1 Remote **–** There is a remote chance that fishing has caused high depletion of cuttlefish stocks state-wide as commercial and recreational catches have remained relatively low in most areas.

C4 (Major Depletion): L1 Remote **–** There is a remote chance that fishing has caused major depletion of cuttlefish stocks state-wide as commercial and recreational catches have remained relatively low in most areas.

12.10 Current risk status

North Coast Bioregion squid resource

Based on the above lines of evidence, the current risk level for the NCB squid resource is considered to be **MEDIUM** (C2 × L4). The medium risk (see Appendix 1) reflects that although very high commercial catches have occurred in some areas of the bioregion historically, current catches over the past decade have been minimal. It is likely that these very high catches were taken by fishers targeting spawning aggregations during periods of high abundances, however, the exact species composition and level of targeted fishing effort is unknown. While current catches are low, targeting of aggregations could occur in the future (e.g. under favourable environmental conditions), which has contributed to this risk status. Research to determine the species composition of commercial catches in this bioregion will provide a better understanding of population dynamics (e.g. environmental influences, age and growth, natural and fishing mortality), and in turn, inform robust assessment and management of stocks into the future (e.g. the development of appropriate catch thresholds and limits). On this basis, the sustainability of the NCB squid resource has **not been formally assessed** at this time.

Gascoyne Coast Bioregion squid resource

Based on the above lines of evidence, the current risk level for the GCB squid resource is considered to be **MEDIUM** (C2 × L4). The medium risk (see Appendix 1) reflects acceptable levels of fishing mortality and stock abundances, with all lines of evidence consistent with a medium level of risk. Hence, the overall Weight of Evidence assessment indicates the status of the GCB squid resource is adequate and that current management settings are maintaining risk at acceptable levels. Research to determine the species composition of commercial catches in this bioregion will provide a better understanding of population dynamics (e.g. environmental influences, age and growth, natural mortality) and support on-going sustainable management of stocks. On this basis, the GCB squid resource is classified as **Sustainable**.

West Coast Bioregion squid resource

Based on the above lines of evidence, the current risk level for the WCB squid resource is considered to be **MEDIUM** (C2 × L4). The medium risk (see Appendix 1) reflects acceptable levels of fishing mortality and stock abundances, with all lines of evidence consistent with a medium level of risk. Hence, the overall Weight of Evidence assessment indicates the status of the WCB squid resource is adequate and that current management settings are maintaining risk at acceptable levels. Research to determine the species composition of commercial and recreational catches in this bioregion will provide a better understanding of population dynamics (e.g. environmental influences, age and growth, natural mortality) and support on-going sustainable management of stocks. On this basis, the WCB squid resource is classified as **Sustainable**.

South Coast Bioregion squid resource

Based on the above lines of evidence, the current risk level for the SCB squid resource is considered to be **MEDIUM** (C2 × L3). The medium risk (see Appendix 1) reflects acceptable levels of fishing mortality and stock abundances, with all lines of evidence consistent with a medium level of risk. Hence, the overall Weight of Evidence assessment indicates the status of the SCB squid resource is adequate and that current management settings are maintaining risk at acceptable levels. Recent management changes have been implemented for the commercial fishery, including gear and access restrictions specific to the squid resource and a finer resolution of reporting from fishers (species specific reporting and finer-spatial scale information on fishing locations), which will provide a greater understanding of fishery and population dynamics to support on-going sustainable management of stocks. On this basis, the SCB squid resource is classified as **Sustainable**.

State-wide cuttlefish resource

Based on the above lines of evidence, the current risk level for the NCB squid resource is considered to be **LOW** (C1 × L4). The low risk (see Appendix 1) reflects historically minimal commercial and recreational catches of cuttlefish throughout much of the state, with no evidence of stock declines in areas where cuttlefish are regularly fished (NCB and GCB). On this basis, the state-wide cuttlefish resource is classified as **Sustainable**.

13.0 Further work

- Relationships between water temperature and squid and cuttlefish catches were detected in several WA regions. Further work is required to assess the influence of other environmental variables (e.g. Leeuwin Current strength, chlorophyll, wind and turbidity) which may influence the abundance or catchability of targeted squid and cuttlefish species.
- Collection of species composition data. Squid and cuttlefish have generally been reported by commercial and recreational fishers at the species group level (‘squid’ or ‘cuttlefish’). As of July 2021, fishers operating in the South Coast Line and Fish Trap Managed Fishery (SCLFTMF) are required to record the individual species of squid landed (e.g. southern calamari *vs* Gould’s squid). This will provide a greater understanding of population dynamics and enable more robust stock assessments for this bioregion. The potential for species-specific reporting in other commercial fisheries will be examined. Where possible, species-specific information will be collected from recreational fishers (e.g. during boat ramp surveys).
- Collection of finer-scale spatial data on fishing locations. Daily logbooks implemented for the SCLFTMF now collect fishing locations from the Albany region on a 10 × 10 nm block scale, representing a considerable improvement on the previously used CAES reporting blocks (60 × 60 nm). This finer-scale spatial data needs to be examined in future when sufficient data are available to provide a greater understanding of population dynamics. Fine scale fishing location data could also be gathered from fishers in other key areas (e.g. Perth metro, Geographe Bay) through on-board fisheries observers or voluntary logbooks.
- Effort and CPUE analysis for commercial trawl fisheries. While catch data has been analysed for trawl fisheries, CPUE has not been calculated due to uncertainties around effort. While typically targeting other species such as prawns or fish, there is anecdotal evidence that trawlers may have targeted aggregations of squid during certain seasons and years. Similarly, the type of net used and depth fished would influence catch rates. Therefore, robust CPUE calculation for these trawl fisheries requires standardisation of a number these factors to be explored in the future. Once CPUE measures have been developed, these data can be used as performance indicators in harvest strategies with targets, thresholds and limits.
- Fishery independent surveys. Currently, data used to assess WA’s squid and cuttlefish resources are obtained almost exclusively from fishery dependent sources (e.g. commercial returns, recreational surveys). Fishery independent surveys are used to gather spatio-temporally explicit abundance and size composition data for many key species in WA, and could provide valuable information on squid and cuttlefish populations. Therefore, a fishery independent survey of southern calamari has been proposed for Cockburn Sound in the WCB, a key recreational and commercial fishery. The survey will

begin in mid-2021 and will use standardised squid jig sampling to gather seasonal population data on squid stocks (abundance, size and weight composition, sex ratios, biological data). If successful, there is the possibility of expansion of similar surveys to other key areas such as King George Sound in the SCB.

- Identification of key spawning areas. Research from south-eastern Australia suggests that southern calamari aggregate over seagrass beds to mate, after which eggs are deposited on specific benthic habitat such as *Amphibolis* seagrass (Moltschaniwskyj & Pecl, 2003; 2007). Similarly, squid *Uroteuthis* (*Photololigo*) spp. spawn in large aggregations throughout tropical waters of northern Australia (Dunning *et al*., 2000). Key spawning areas for WA's squid populations are not currently well understood, nor are the specific benthic habitats where species such as southern calamari may be laying eggs. Further research to identify these breeding areas would support spatio-temporal management strategies, e.g. protection of critical habitat and spatial closures during periods when stocks are vulnerable.

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