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Ecological Risk Assessment for the Temperate Demersal Elasmobranch Resource

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List of Acronyms

AFMA	Australian Fisheries Management Authority
ALC	Automatic Location Communicator
AS	Australian Standard
ASL	Australian Sea Lion
BC Act	*Biodiversity Conservation Act 2016*
BU	Unfished Biomass
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DPIRD	Department of Primary Industries and Regional Development
EBFM	Ecosystem Based Fisheries Management
ENSO	El Niño Southern Oscillation
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ERA	Ecological Risk Assessment
ETP	Endangered, Threatened and Protected Species
F	Fishing Mortality
FRMA	*Fish Resources Management Act 1994*
ISO	International Organisation for Standardisation
IUCN	International Union for Conservation of Nature
JANSF	Joint Authority Northern Shark Fishery
JASDGDLF	Joint Authority Southern Demersal Gillnet and Demersal Longline Fishery
KI	Kangaroo Island
M	Natural Mortality
MSC	Marine Stewardship Council
MSY	Maximum Sustainable Yield
NCB	North Coast Bioregion
NDF	Non-Detriment Finding
NSF	Northern Shark Fisheries
NSW	New South Wales
NZS	New Zealand Standard
OCP	Operational Compliance Plans

SA	South Australia
SCB	South Coast Bioregion
SCDSR	South Coast Demersal Scalefish Resource
SDGDLF	Southern Demersal Gillnet and Demersal Longline Fishery
SESSF	Southern and Eastern Scalefish and Shark Fishery
SPR	Spawning Potential Ratio
TDGDLF	Temperate Demersal Gillnet and Demersal Longline Fisheries
TL	Total Length
TSSC	Threatened Species Scientific Committee
VMS	Vessel Monitoring System
WA	Western Australia
WANCSF	Western Australian North Coast Shark Fishery
WCB	West Coast Bioregion
WCDGDLF	West Coast Demersal Gillnet and Demersal Longline Fishery
WCDSR	West Coast Demersal Scalefish Resource
WTO	Wildlife Trade Operation

Executive Summary

In March 2021, the Department of Primary Industries and Regional Development (Department) convened an ecological risk assessment (ERA) of the fisheries that access the Temperate Demersal Elasmobranch Resource (Resource). ERAs are conducted by the Department as part of its Ecosystem Based Fisheries Management framework.

The ERA considered the potential ecological impacts of the Temperate Demersal Gillnet and Demersal Longline Fisheries (TDGDLF) and recreational (including charter) fishers who catch sharks and rays. The assessment focussed on evaluating the impact of each fishing sector/method on all relevant retained and bycatch species, endangered, threatened and protected (ETP) species, habitats and the broader environment.

A broad range of stakeholders were invited to participate in the ERA workshop, including representatives of the commercial and recreational fishing sectors, State and Australian Government agencies, James Cook University, the Australian Marine Conservation Society, Humane Society International and Sea Shepherd.

Risk scores were determined based on available scientific monitoring, research information and expert knowledge on species, fishing activities, fishery regulations and management. This assessment conforms to the AS/NZS ISO 31000 risk management standard and the methodology adopted by the Department, which relies on a likelihood-consequence analysis for estimating risk.

Thirty-three broad ecological components were scored for risk. Noting, the ecological impacts of recreational line fishing on ETP species, habitats, ecosystem structure and broader environment will be assessed in future as part of the ERA for the West Coast Demersal Scalefish Resource and the South Coast Demersal Scalefish Resource.

The majority (22) of ecological components were evaluated as low or negligible risks, which do not require any specific control measures. There were 10 medium risks, which were assessed as acceptable under current monitoring and control measures already in place.

The risk assessment yielded three high risks that require further control measures. A high risk was given to Australian sea lions where there is potential for interaction with commercial gillnets and a data-poor environment (noting a lack of population modelling and fishery-independent data validation). High risks were given for snapper in the West Coast Bioregion and West Australian dhufish, on the basis of formal stock assessments completed by the Department in 2017. Both stocks are in recovery and managed through the West Coast Demersal Scalefish Resource Harvest Strategy.

As a result of their current stock status across southern Australia the risk to school shark was scored as severe. School sharks are managed under the Australian Fisheries Management Authority's School Shark (*Galeorhinus galeus*) Stock Rebuilding Strategy (Strategy), with an incidental catch limit in place since 1997

(AFMA 2015b). The Strategy aims to rebuild the school shark stock to 20% of unfished biomass within three generations (66 years from 2008; AFMA 2015b). The majority of catch in Australia is taken by the Southern and Eastern Scalefish and Shark Fishery under an incidental catch limit (2020/21: 195 t), with minimal take by the TDGDLF (an average of ~8 t/year for the last 5 years). While TDGDLF catches of school shark are unlikely to have significantly contributed to stock depletion, the assessment recognised that any catch may potentially impact the conservation dependent species.

It is recommended that the risks be reviewed in five years, or prior to the first review of the harvest strategy for the Resource, where risk scores are used as the performance indicator for the non-target ecological assets. Monitoring and assessment of the key target species will be ongoing, with the performance indicators evaluated on an annual basis.

1.0 Introduction

The Department of Primary Industries and Regional Development (DPIRD, Department) in Western Australia (WA) uses an Ecosystem-Based Fisheries Management (EBFM) approach that considers all relevant ecological, social, economic and governance issues to deliver community outcomes (Fletcher et al. 2010, 2012). Ecological risk assessments (ERA) are undertaken periodically to assess the impacts of fisheries on all the different components of the aquatic environments in which they operate. The outcomes of ERAs are used to inform EBFM-based harvest strategies and to prioritise the Department's monitoring, research and management activities (Fletcher 2015; Fletcher et al. 2016).

This report provides information relating to an ERA for the Temperate Demersal Elasmobranch (shark and ray) Resource (Resource) conducted in 2021. The assessment considered the potential ecological impacts of the commercial Temperate Demersal Gillnet and Demersal Longline Fisheries (TDGDLF) and recreational (including charter) fishers who catch sharks and rays. The ERA assessed the potential ecological impacts of these fisheries on all relevant retained and bycatch species, endangered, threatened and protected (ETP) species, habitats, and the broader ecosystem.

The risk assessment methodology utilised a consequence-likelihood analysis, which involved the examination of the magnitude of potential consequences from fishing activities and the likelihood that those consequences will occur given current management controls. Risk scores were determined during an external stakeholder workshop held on 22 March 2021. Once finalised, this risk assessment will help inform the development of a formal harvest strategy for the Resource.

The scope of this ERA is for the next five years (through to 2026). It is envisioned that ERA's will be undertaken periodically (approximately every five years) to reassess any current or new issues that may arise. However, a risk assessment can also be triggered if there are significant changes identified in fishery operations or management activities that may change current risk levels.

2.0 Temperate Demersal Elasmobranch Resource

The Resource comprises at least 53 species of elasmobranchs (Appendix A). The ranges of some species considered as part of the Resource extend across all WA waters; however, as they are predominantly targeted in the West Coast Bioregion (WCB) and South Coast Bioregion (SCB) they are discussed in the context of the temperate elasmobranch 'suite' (Braccini et al. 2018). Future ERA's may be expanded to assess the Statewide Elasmobranch Resource.

The Resource is accessed by the commercial, recreational and customary fishing sectors, with the primary harvest occurring in the WCB and SCB by the commercial TDGDLF. Recreational fishing for sharks and rays is permitted in WA, however, recreational catches comprise a small fraction of the total harvest of the Resource (Ryan et al. 2013, 2015, 2017, 2019).

Commercial fishers in the TDGDLF mainly target four shark species: whiskery shark (*Furgaleus macki*), gummy shark (*Mustelus antarcticus*), dusky shark (*Carcharhinus obscurus*) and sandbar shark (*Carcharhinus plumbeus*). Recreational fishers release the majority of shark species, with the exception of gummy and whiskery sharks, which are commonly retained (Braccini et al. 2018; Ryan et al. 2019).

Stock assessments conducted in the 1990s for dusky, gummy and whiskery sharks indicated stocks were either fully or over exploited (Simpfendorfer et al. 1996; Simpfendorfer et al. 1999; McAuley et al. 2005). In response, the Resource has been in a recovery phase since the mid-1990's with an operational objective to maintain the biomass of these stocks at or above 40% of their unfished levels by 2010 for gummy and whiskery sharks and by 2040 for dusky shark. These biomass targets were set by the WA Demersal Net and Hook Fisheries Management Advisory Committee at the time and were considered to represent the level at which long-term sustainable catches could be achieved in these shark populations (Donohue et al. 1993).

Following a 2003 stock assessment, additional management arrangements were introduced, including reducing effort in the TDGDLF to reach 2001-02 catch levels, in order to meet the recovery objectives for the Resource within the desired timeframes (Borg and McAuley 2004). Since 2010, whiskery and gummy sharks have maintained biomass above 40% of their unfished levels (Braccini et al. 2018).

Table 2.1 outlines the current recovery catch tolerance levels for the Resource (Gaughan and Santoro 2020).

Table 2.1. Current catch tolerance range for the Resource (Gaughan and Santoro 2020).

Sector	Fishery	Catch tolerance range
Commercial sector	TDGDLF	725 t – 1095 t
	NSF	20 t *
Recreational sector	Total recreational sector	TBD
Customary sector	Total customary sector	-

* sandbar shark (Gaughan and Santoro 2020).

The Northern Shark Fisheries (NSF), which operated in the North Coast Bioregion (NCB), historically accessed the Resource in the late 1990s and early 2000s but have reported no commercial shark catch since 2008-09 (Braccini et al. 2020). In April 2008, the Joint Authority Northern Shark Fishery's (JANSF) export approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) was revoked due to a lack of formal management arrangements and concerns with sustainability and ETP species interactions. In February 2009, the Western Australian North Coast Shark Fishery's (WANCSF) approval under the EPBC Act expired, and therefore, no product from either fishery can be legally exported. These fisheries were not considered in the assessment as they fall outside of the scope of the current ERA.

Historically, a range of commercial fisheries focused on invertebrates and teleosts incidentally captured and retained sharks and rays. However, the retention of sharks and rays in most other WA commercial fisheries has been prohibited since November 2006 when sharks and rays became commercially protected species under the *Fish Resources Management Act 1994* (FRMA). As a result, the discard of sharks and rays in those fisheries has been negligible in recent years (< 5 t; Braccini and Murua in review) and they were not considered in the current ERA.

Limited information is available on the current level of customary fishing for shark and ray species in the Resource, however, anecdotal information suggests it is very low.

Commercial vessels in the Australian Government managed Southern and Eastern Scalefish and Shark Fishery (SESSF) which operate outside of the 200 m isobath, also target demersal shark and ray species, including gummy shark. The Australian Fisheries Management Authority (AFMA) assesses the ecological impacts of the SESSF (AFMA 2015a). A Memorandum of Understanding between the Department and AFMA is being developed to ensure consistency in management arrangements for shared stocks.

TDGDLF fishers also retain demersal scalefish species (including western blue groper, blue morwong, snapper and WA dhufish) as a legitimate component of their catch (Braccini et al. 2018). These species are managed as part of the West Coast Demersal Scalefish Resource (WCDSR) and the South Coast Demersal Scalefish Resource (SCDSR). While included within the scope of this ERA, future ERAs for the WCDSR and SCDSR will assess the impact of all commercial and recreational (including charter) fishing sectors on these scalefish species.

Monitoring and assessment of the Resource is currently based on identification and sustainability evaluation of indicator species (Department of Fisheries 2011). Indicator species are determined using a risk-based approach that calculates the 'sustainability risk' of stocks (based on the inherent vulnerability and current risk to wild stock) and the current or likely future 'management risk' of the species or stock to the community (measured as a combination of the current management information requirements, and their economic and social values).

The following chapters of the report (Sections 3 to 5) outline the aquatic environment, fishing activities undertaken by each sector, available information on retained and discarded catches, and ecological impacts on habitats and ETP species. This background information was used during the workshop as the basis for scoring the individual and cumulative risks of these fishing activities impacting on each ecological component considered in this risk assessment.

3.0 Aquatic Environment

While accessed by commercial, recreational and customary fishing sectors, the Resource is predominately harvested by commercial fisheries operating in waters along the WCB and SCB.

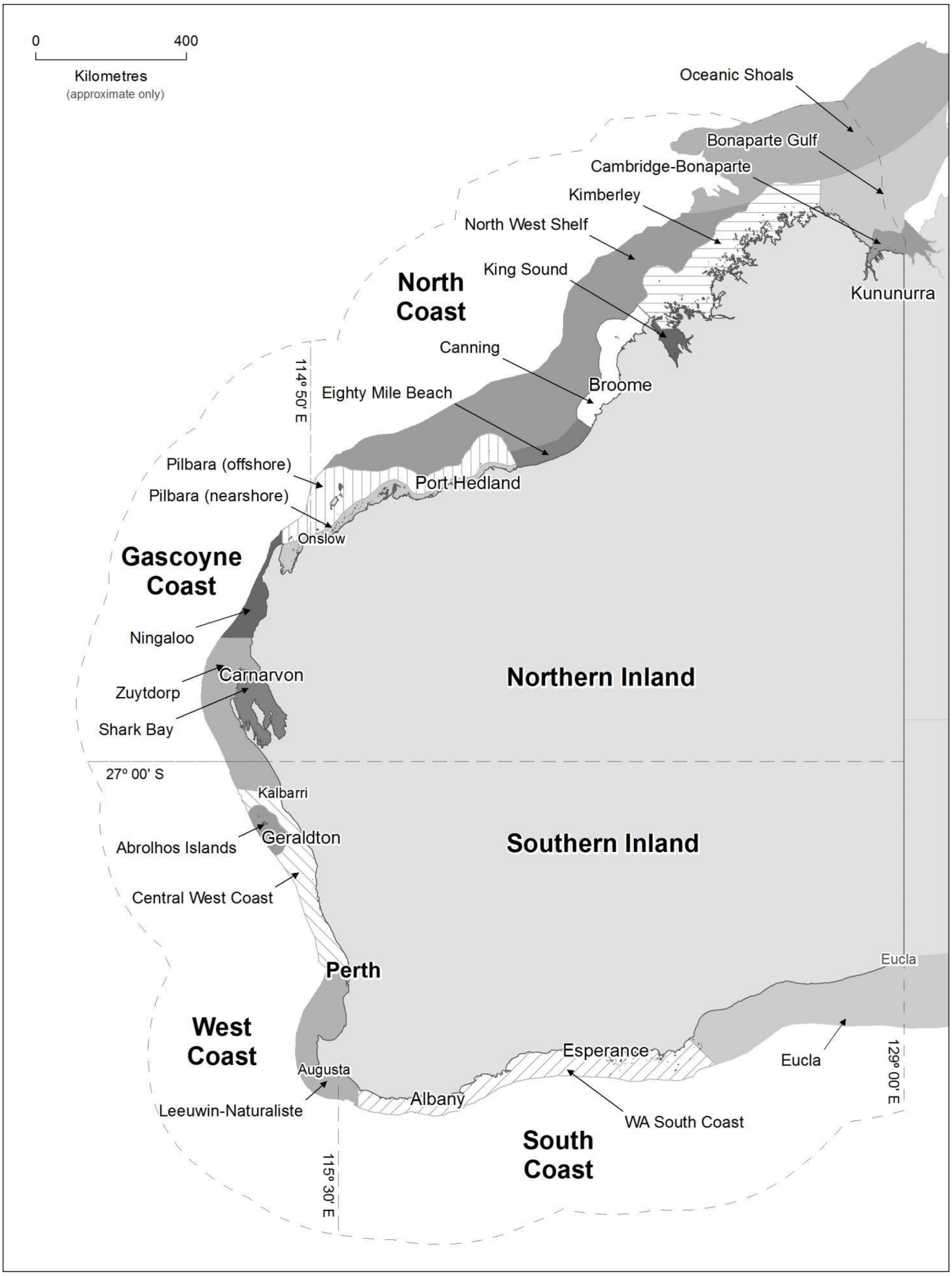


Figure 3.1. The Bioregions of Western Australia.

3.1 West Coast Bioregion

The marine environment of the WCB (Figure 3.1) between Kalbarri (27.70° S, 114.16° E) and Augusta (34.31° S, 115.16° E) is predominantly a temperate oceanic zone, but it is heavily influenced by the Leeuwin Current, which transports warm tropical water southward along the edge of the continental shelf. Most fish species of the region are temperate, in keeping with the coastal water temperatures that range from 18°C to about 24°C. The Leeuwin Current is also responsible for the existence of the Abrolhos Islands coral reefs at latitude 29° S and the extended southward distribution of many tropical species along the WCB and even into the SCB.

The Leeuwin Current, which can be up to several hundred kilometres wide along the WCB, flows most strongly in autumn/winter (April to August) and has its origins in ocean flows from the Pacific through the Indonesian Archipelago (Cresswell and Golding 1980; Feng et al. 2003; Lourey et al. 2006). The current is variable in strength from year-to-year, flowing at speeds typically around 1 knot, but has been recorded at 3 knots on occasions (Cresswell and Golding 1980; Feng et al. 2003; Lourey et al. 2006). The annual variability in current strength is reflected in variations in Fremantle sea levels and is related to El Niño Southern Oscillation (ENSO) events in the Pacific Ocean. Weaker counter-currents on the continental shelf (shoreward of the Leeuwin Current), such as the Capes Current that flows northward from Cape Leeuwin as far as Shark Bay, occur during summer and influence the distribution of many of the coastal finfish species (Cresswell and Golding 1980; Feng et al. 2003; Lourey et al. 2006).

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

The WCB is characterised by exposed sandy beaches and a limestone reef system that creates surface reef lines, often about 5 km off the coast. Further offshore, the continental shelf habitats are typically composed of coarse sand interspersed with low limestone reef associated with old shorelines. There are few areas of protected water along the WCB, the exceptions being within the Abrolhos Islands, the leeward sides of some small islands off the Midwest Coast, plus behind Rottnest and Garden Islands in the Perth metropolitan area.

The two significant marine embayments in the WCB are Cockburn Sound and Geographe Bay. In the WCB, there are four significant estuarine systems – the Swan-Canning, Peel-Harvey and Leschenault estuaries and Hardy Inlet (Blackwood estuary). All of these are permanently open to the sea and form an extension of the marine environment except when freshwater run-off displaces the oceanic water for a short period in winter and spring. Southward of Cape Naturaliste, the coastline changes from limestone to predominantly granite and becomes more exposed to the influences of the Southern Ocean.

3.2 South Coast Bioregion

The SCB (Figure 3.1) extends east from Augusta (34.31° S, 115.16° E) to the South Australian (SA) border. The continental shelf waters of the SCB are generally temperate but low in nutrients, due to the seasonal winter presence of the tail of the tropical Leeuwin Current and limited terrestrial run-off from an infertile landscape. Sea surface temperatures typically range from approximately 15°C to 21°C, which is warmer than would normally be expected in these latitudes due to the influence of the Leeuwin Current (Cresswell and Golding 1980; Feng et al. 2003; Lourey et al. 2006). The effect of the Leeuwin Current, particularly west of Albany, limits winter minimum temperatures (away from terrestrial effects along the beaches) to about 16°C to 17°C (Cresswell and Golding 1980; Feng et al. 2003; Lourey et al. 2006). Fish stocks in this region are predominantly temperate, with many species' distributions extending right across southern Australia. Tropical species are occasionally found, which are thought to be brought into the area as larvae as they are unlikely to form breeding populations.

The SCB is a high-energy environment, heavily influenced by large swells generated in the Southern Ocean. The coastline from Cape Leeuwin to Israelite Bay is characterised by white sand beaches separated by high granite headlands. East of Israelite Bay, there are long sandy beaches backed by large sand dunes, until replaced by high limestone cliffs at the SA border. There are few large areas of protected water in the SCB, the exceptions being around Albany and in the Recherche Archipelago off Esperance.

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

The marine habitats of the SCB are similar to the coastline, having fine, clear sand sea floors interspersed with occasional granite outcrops and limestone shoreline platforms and sub-surface reefs. A mixture of seagrass and kelp habitats occur along the coast, with seagrass more abundant in protected waters and some of the more marine estuaries. The kelp habitats are diverse but dominated by the relatively small *Ecklonia radiata*, rather than the larger kelps expected in these latitudes where waters are typically colder and have higher nutrient levels.

4.0 Temperate Demersal Gillnet and Demersal Longline Fisheries

4.1 History of Development

Sharks have been commercially harvested in WA waters since the 1940's. Beginning in the Leschenault Inlet, shark fishing expanded to the Albany, Fremantle and Geraldton ports in the late 1940s and early 1950s (Simpfendorfer and Donohue 1998; Braccini et al. 2018).

Throughout the 1960s, the shark fishery gradually moved further offshore, and demersally-set multifilament gillnets began to replace longlines as the preferred fishing method. Fishing effort peaked in 1988-89 at half a million gillnet hours, five times the level of effort in 1980-81 (Figure 4.4; McAuley 2007).

Unregulated shark fishing effort, together with declining catch rates of key shark species, prompted the introduction of the first WA limited entry commercial shark fishery in 1988, establishing the Joint Authority Southern Demersal Gillnet and Demersal Longline Fishery (JASDGDLF). Under a Joint Authority agreement between the State and Australian Governments the area south of 33° S to the SA border (129° E) was declared a limited entry fishery, with access restricted to fishers who could demonstrate a historical use of the stocks (Braccini et al. 2018).

To limit targeted exploitation of shark stocks outside the JASDGDLF, the number of vessels authorised to use powered net-reels north of 33° S was also restricted in 1988. However, despite this restriction, demersal gillnet effort continued to increase off the west coast (north of 33° S) throughout the late 1980s and early 1990s (Figure 4.4; Braccini et al. 2018). In 1993, the use of shark fishing gear (specifically large mesh gillnets and droplines or longlines with metal snoods) was prohibited north of 26° 30' S and west of 114° 06' E to protect the breeding stock of the dusky shark (Braccini et al. 2018).

An interim management plan for demersal gillnet and demersal longline fishing in the area between 33° S and 26° S was introduced in 1997 to provide more robust controls on targeted shark fishing effort north of the JASDGDLF (Braccini et al. 2018). This plan, which imposed similar unitised effort controls as the JASDGDLF, established the West Coast Demersal Gillnet and Demersal Longline Fishery (WCDGDLF; Figure 4.1).

Significant changes were implemented for the WCDGDLF in 2007 to manage sustainability and sectoral issues associated with the WCDSR. This package of management changes included the closure of the WCDGDLF in metropolitan waters and significant effort reductions elsewhere. This precipitated a Government-funded Voluntary Fishery Adjustment Scheme that bought out ~36% of WCDGDLF effort units. In 2014, further reductions in longline capacity in the WCDGDLF were introduced in response to high-targeted demersal scalefish catches.

In December 2018, the JASDGDLF transitioned from joint management between State and Australian Governments to State only management, with the introduction of the *Southern Demersal Gillnet and Demersal Longline Managed Fishery Management Plan 2018* (Joll et al. 2019).

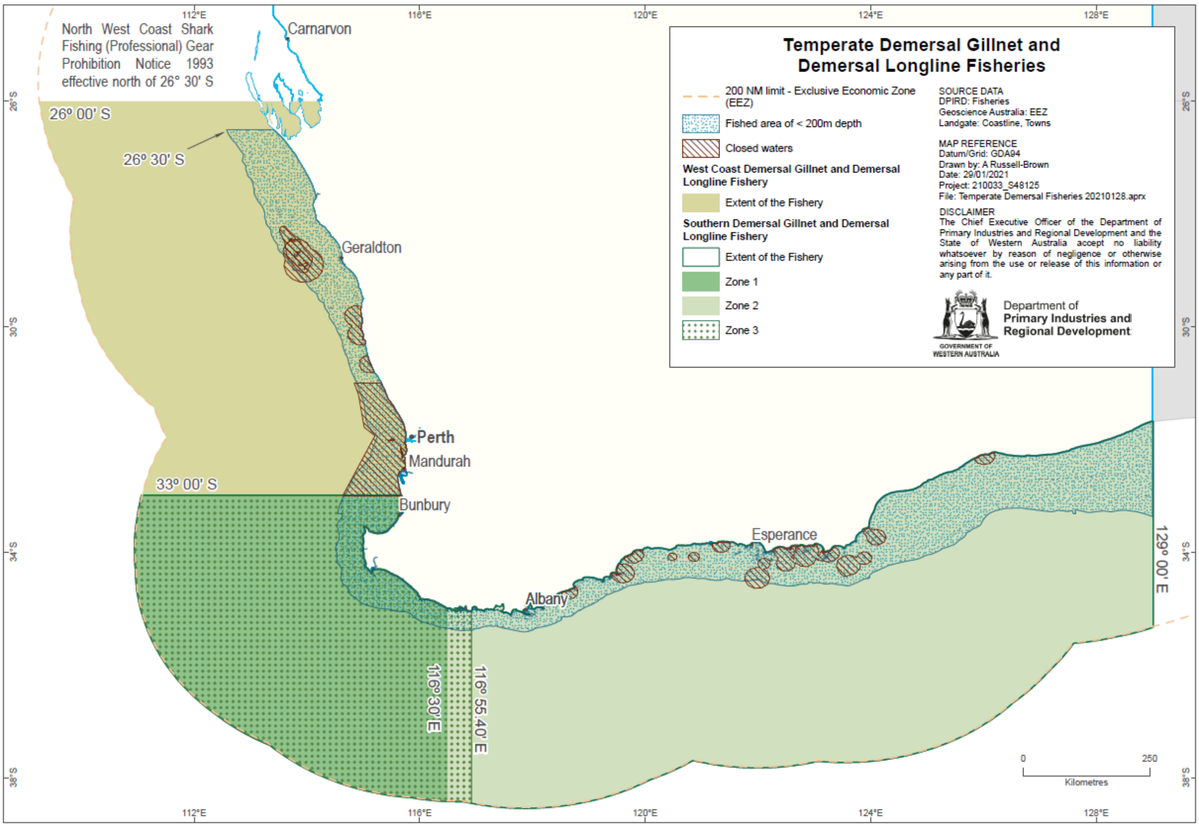


Figure 4.1. Management boundaries of the Temperate Demersal Gillnet and Demersal Longline Fisheries.

4.2 Current Fishing Activities

The Southern Demersal Gillnet and Demersal Longline Fishery (SDGDLF) and WCDGDLF (comprising the TDGDLF; Figure 4.1) are regulated through two complementary management plans, the *Southern Demersal Gillnet and Demersal Longline Managed Fishery Management Plan 2018* and the *West Coast Demersal Gillnet and Demersal Longline Interim Managed Fishery Management Plan 1997*.

There are currently 53 licenses (24 in Zone 1 and 30 in Zone 2) for the SDGDLF and 17 permits for the WCDGDLF.

The TDGDLF is managed via input controls, primarily in the form of transferable time and gear Individually Transferrable Effort units (Braccini et al. 2018). From 2006-07, statutory daily/trip catch and effort logbooks have been a requirement for fishers operating in the TDGDLF.

As part of the recovery strategy for the Resource, the catch tolerance levels for the WCDGDLF and SDGDLF are currently set at their respective 2001-02 levels (Table 2.1). These levels were set to deliver sustainable harvest of target shark species while allowing for ongoing stock recovery and rebuilding, as well as sustainable harvest of by-product teleost species (Braccini et al. 2018).

In the WCDGDLF, one unit currently permits the use of 27 m of demersal gillnet for 288 hours or the use of 1 hook on a demersal longline for 1 hour. The current unit/hook ratio effectively makes the WCDGDLF a demersal gillnet fishery and prevents the targeting of demersal scalefish by demersal longline methods. In the SDGDLF, one unit permits the use of 27 m of demersal gillnet or 9 hooks on a demersal longline for 264 hours in Zone 1 and Zone 3, or 380 hours in Zone 2.

Shark meat is predominately sold locally to wholesalers, retailers and food processors or interstate to wholesalers in Adelaide and Melbourne. Anecdotal evidence suggests that recent tourism expansion in south-west WA may have resulted in a higher proportion of shark meat being sold to restaurants and fish retailers around landing ports (Braccini and Blay 2020). The estimated annual value of the SDGDLF and WCDGDLF in 2017-18 was $2.7 million and $0.3 million, respectively (Braccini and Blay 2020).

The TDGDLF was first declared an approved Wildlife Trade Operation (WTO) in February 2006 (Braccini et al. 2018). The TDGDLF has since been reassessed several times, most recently in 2018, under Parts 13 and 13A of the EPBC Act. This accreditation allows continued export of product from these fisheries for a period of three years.

4.3 Compliance

Operational Compliance Plans (OCP), guide the enforcement of management arrangements for the TDGDLF. OCPs are informed and underpinned by a compliance risk assessment and are reviewed every 1-2 years. OCPs have the following objectives:

- to provide clear direction and guidance to officers regarding compliance activities that are required to support effective management of the fishery;
- to provide a mechanism that aids the identification of future and current priorities;
- to encourage voluntary compliance through education, awareness and consultation activities; and
- to review compliance strategies and their effective implementation.

Compliance strategies and activities that are used to protect the Resource include:

- land and sea patrols;
- catch validation against managed fishery licenses/interim managed fishery permits;
- inspections at wholesale and retail outlets, and processing facilities;
- inspections of fishing vessels in port and at-sea;
- closed area/entitlement monitoring via VMS; and
- aerial surveillance.

4.3.1 *Vessel Monitoring System (VMS)*

VMS was introduced in the TDGDLF in 2006 to allow real time entitlement monitoring of the commercial fleet and to support the fishing nomination system. VMS also helps to ensure fishers are working in their designated fishing areas.

Vessels are fitted with an automatic location communicator (ALC), which is used to track the location of a boat by transmitting information such as the geographical position, course and speed. Information from the ALC is submitted to the Department via satellite. The information is processed by specialised software designed to receive, analyse, display and record position reports and messaging via satellites.

Operating requirements for ALCs in the WCDGDLF and SDGDLF are outlined in their respective VMS Approved Directions, which are publicly available on the Department's website.

4.4 Fishing Gear and Methods

The majority of vessels in the TDGDLF use demersal gillnets to catch a wide variety of sharks and teleosts (Braccini et al. 2018). Demersal longlines are also permitted in the TDGDLF, however, these are only used by a few and mainly part-time operators (Braccini et al. 2018).

The specifications for construction and use of demersal gillnets and demersal longlines are outlined in the *Southern Demersal Gillnet and Demersal Longline Managed Fishery Management Plan 2018* and the *West Coast Demersal Gillnet and Longline Interim Managed Fishery Interim Managed Fishery Management Plan 1997*.

4.4.1 *Demersal gillnet*

Demersal gillnets are constructed of nylon monofilament with a diameter of between 1 mm and 1.3 mm (Braccini et al. 2018). The mesh is hung between a negatively buoyant 'ground line', which sinks the net to the seabed and a positively buoyant 'head line', which floats the net vertically off the bottom (Figure 4.2). As fish do not easily 'gill' in taut mesh, the net is attached to the head and ground lines using a hanging ratio of 1.5 m to 2 m of net for every metre of line to ensure some slack (Braccini et al. 2018). Additional ballast is usually attached to each end of the net and often intermittently along its length to prevent dragging. Floats are attached at each end to assist with relocation and recovery. It is common practice for intermediate surface float lines to be attached to nets to reduce the amount of net that is susceptible to two or more double 'bite-offs' (where both the head line and ground line are severed between the float lines) and the fragments of net would otherwise be difficult to retrieve (Braccini et al. 2018).

In the SDGDLF, fishers must not use a demersal gillnet that has a mesh size of less than 162.5 mm, or a depth greater than 20 meshes. While in the WCDGDLF, gillnets are restricted to a mesh size of no less than 175 mm and a mesh depth not exceeding 20 meshes.

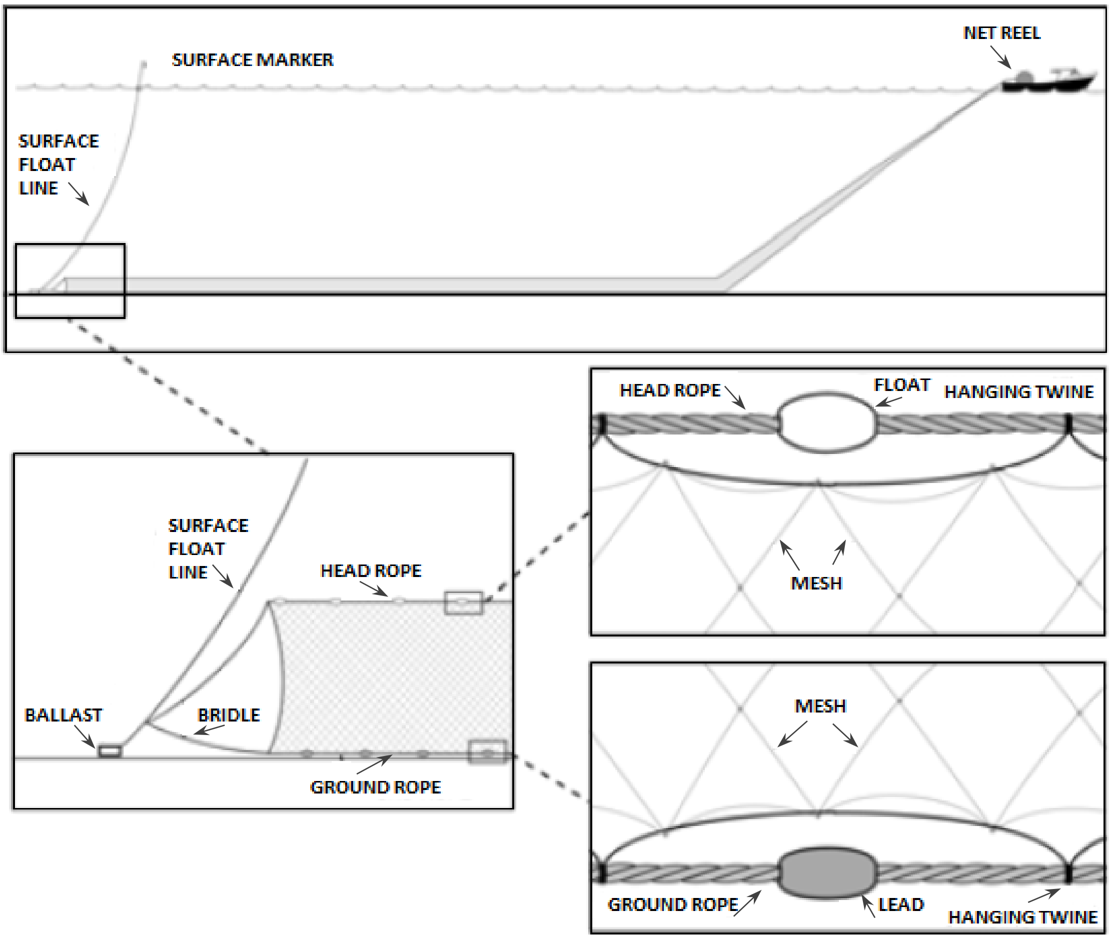


Figure 4.2. Typical demersal gillnet configuration.

Fishers generally set between one and four nets at any one time, depending on their unit allocation, vessel size, area of operation and expected catch rates. Nets cannot exceed 8,235 m (in the SDGDLF) and are typically between 1,000 m and 2,500 m long. Demersal gillnets may be set in close proximity to each other or separated by distances of several kilometres (Braccini et al. 2018). Estimating catch rate is complex as most vessels deploy their gear overnight but some deploy and recover their gear several times each day.

4.4.2 *Demersal longline*

Demersal longlines (see Figure 4.3) are currently only used by a few vessels in the SDGDLF. Longlines consist of a mainline (rope or monofilament), which is weighted in such a way that it lies roughly parallel to the seabed (Braccini et al. 2018). Baited hooks are attached to the mainline via ‘snoods’ and since 2008, the use of metal wire or chain within one metre of any hook has been prohibited. Demersal longlines in the TDGDLF may consist of up to 2,745 circle/ezi-baiter hooks (ranging between 7/O and 14/O), but without automatic baiting machines it is unlikely that more than 1,500 hooks could be set at a time (Braccini et al. 2018).

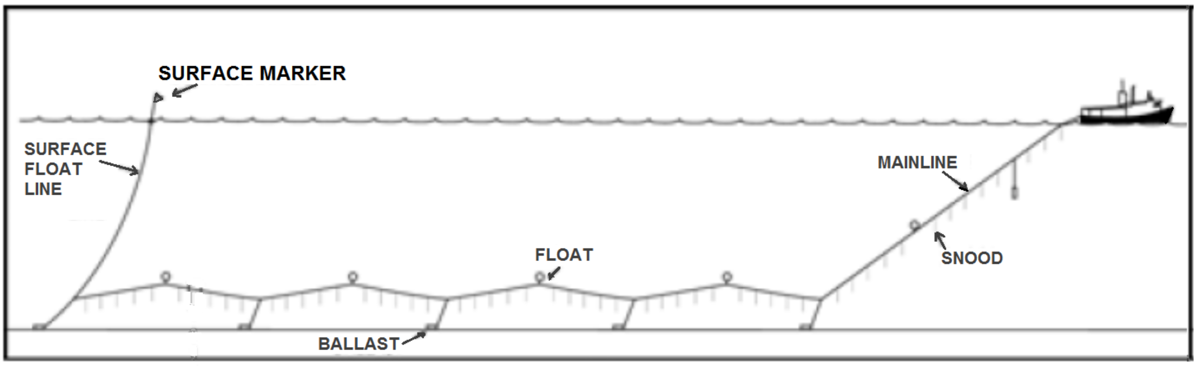


Figure 4.3. Typical demersal longline configuration.

4.4.3 *Bait*

The majority of operators employ demersal gillnets and power-hauled reels, which do not require bait. Demersal longlines are not widely used, with current longline effort levels at < 4% of the total effort. Anecdotal observations indicate that the bait used while longlining includes octopus heads, yellow-eye mullet and herring.

4.5 Retained Species

For the TDGDLF, reported elasmobranch catches and fishing effort peaked during the late 1980s and early 1990s and have stabilised at much lower levels in recent years (Figure 4.4). The spatial distribution of reported catches follows a similar trend (Figure 4.4 and Figure 4.5).

A summary of reported catches (from 2014-15 to 2018-19) of the main species retained by the TDGDLF is provided in Table 4.1, with a full list of all retained species in Appendix A (Table A.1). For the main retained species, full time-series of annual catches since 1975 are provided in Figure 4.6.

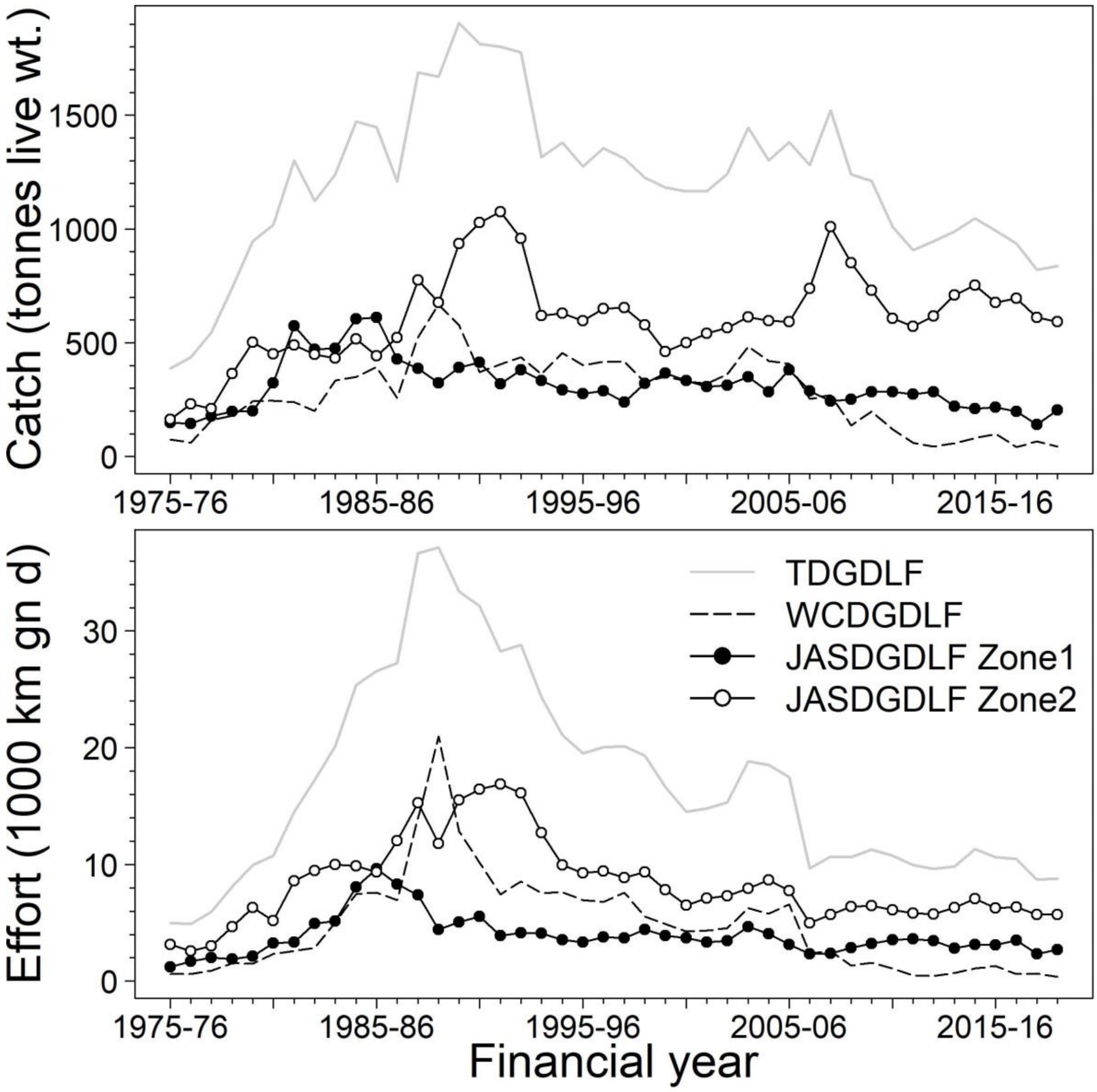


Figure 4.4. Total reported elasmobranch catch, and demersal gillnet and longline effort (in km gillnet days, km gn d^{-1}) in the TDGDLF. Black circles = SDGDLF Zone 1; white circles = SDGDLF Zone 2; dashed black line = WCDGDLF; plain grey line = total from the three management zones.

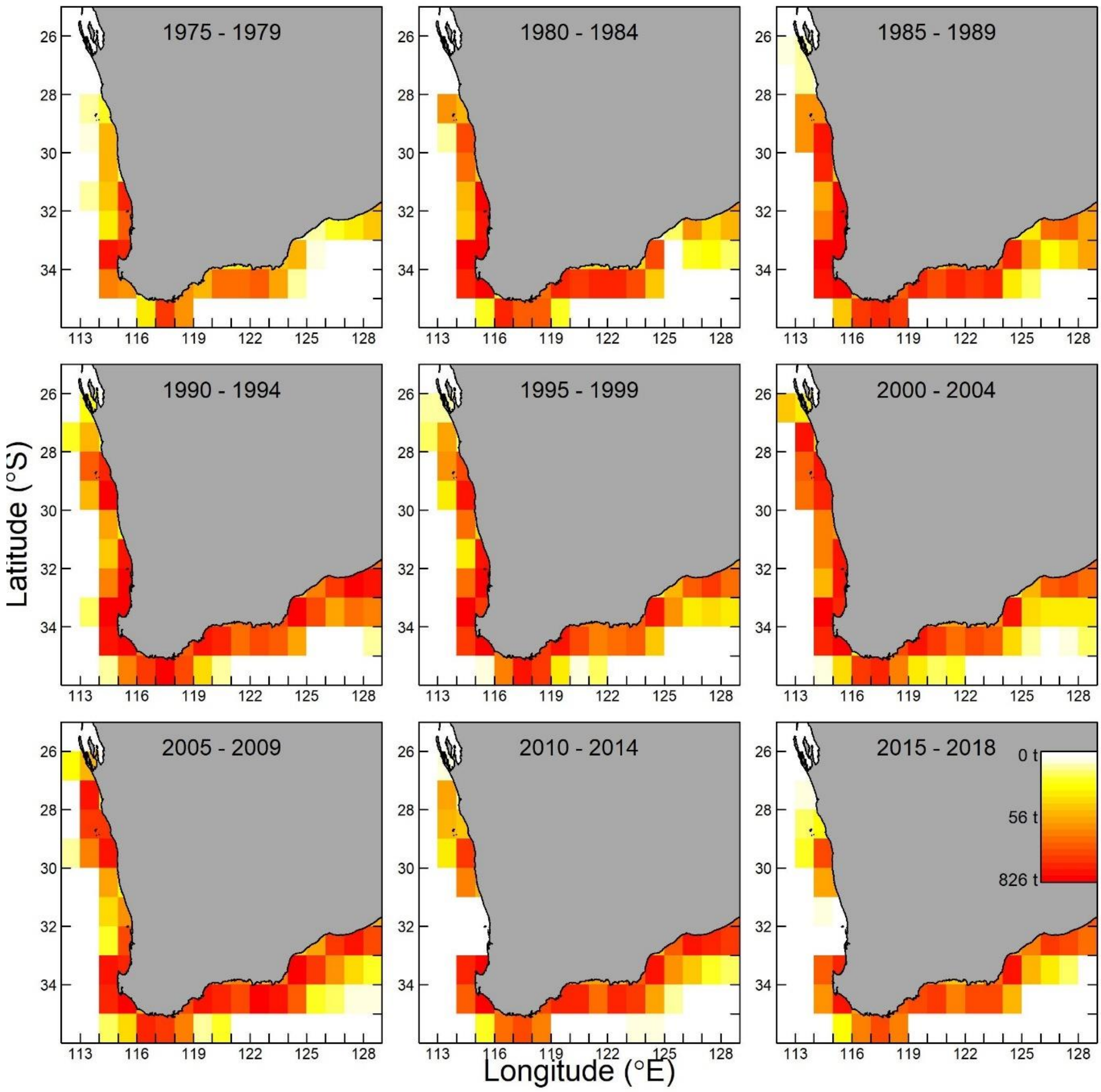


Figure 4.5. Spatio-temporal distribution of reported catch in the TDGDLF by five-year intervals (financial year) and 60 nm block.

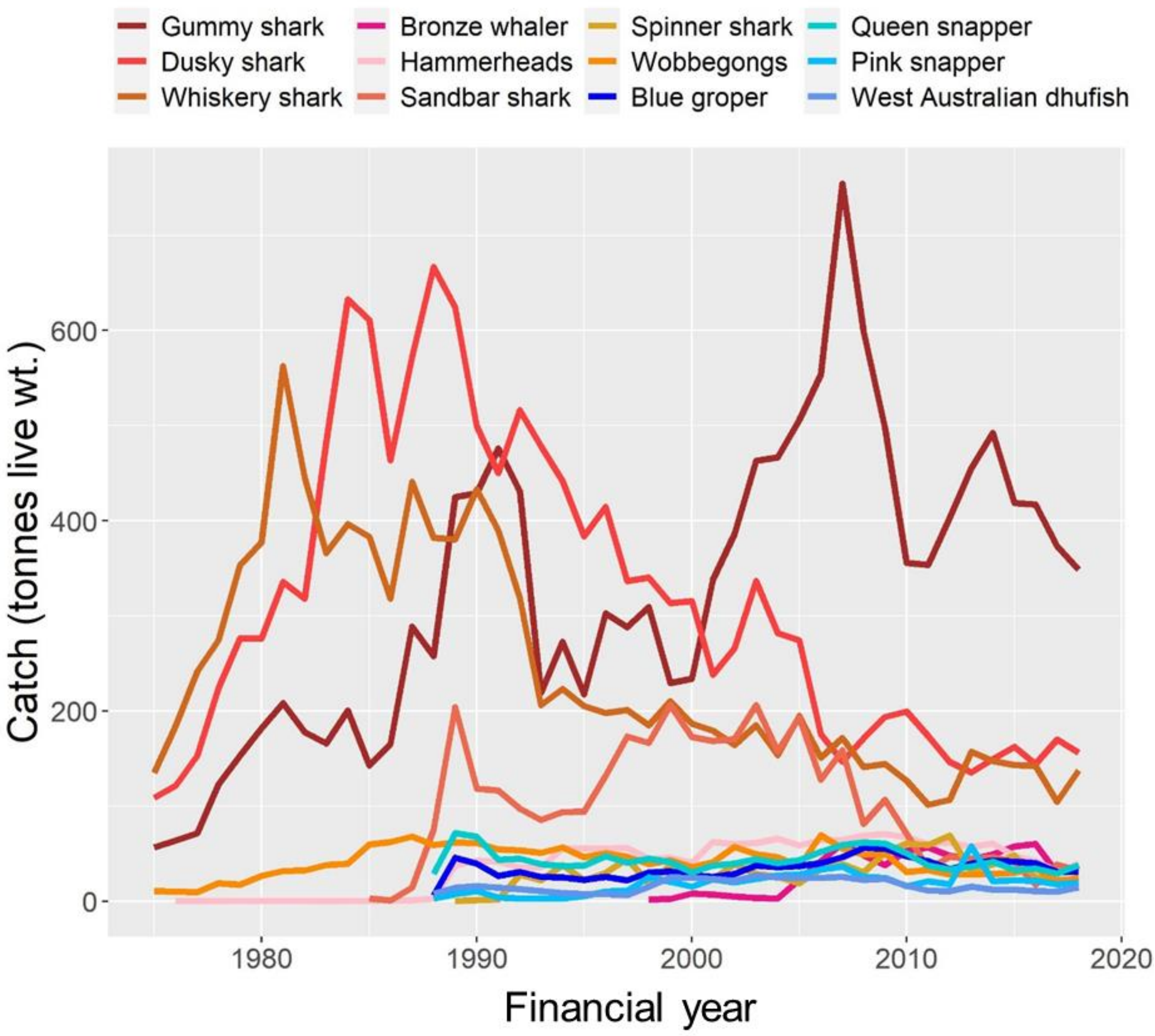


Figure 4.6. Full time series of reported catch in the TDGDLF for the main commercial species.

Table 4.1. Reported catches (whole weight, in tonnes) of the main species retained in the TDGDLF in the last five years.

Species	Scientific name	Reported catch (tonnes)						% of total reported catch
		2014-15	2015-16	2016-17	2017-18	2018-19	Average	
Gummy shark	*Mustelus antarcticus*	492.30	418.57	417.26	373.23	348.34	409.94	38.6
Dusky shark	*Carcharhinus obscurus*	149.53	162.10	144.02	170.22	155.90	156.35	14.7
Whiskery shark	*Furgaleus macki*	147.38	143.37	142.29	104.38	137.40	134.96	12.7
Bronze whaler	*Carcharhinus brachyurus*	49.06	57.49	59.89	29.86	38.93	47.05	4.4
Hammerheads	*Sphyrna spp.*	60.80	47.75	42.49	31.17	39.42	44.32	4.2
Blue groper	*Achoerodus gouldii*	42.79	41.36	40.07	30.84	31.11	37.23	3.5
Sandbar shark	*Carcharhinus plumbeus*	46.35	41.49	17.28	38.29	32.19	35.12	3.3
Blue morwong	*Nemadactylus valenciennesi*	41.66	32.64	34.33	29.07	37.72	35.08	3.3
Spinner shark	*Carcharhinus brevipinna*	38.65	48.38	25.04	22.26	21.88	31.24	2.9
Wobbegongs	*Orectolobus spp.*	28.73	29.42	34.92	20.13	24.61	27.56	2.6
Snapper	*Chrysophrys auratus*	20.88	21.91	21.64	17.94	19.24	20.32	1.9
West Australian dhufish	*Glaucosoma hebracium*	12.09	12.20	10.54	10.27	14.59	11.94	1.1
School shark	*Galeorhinus galeus*	1.27	11.63	26.71	0.01	0.86	8.09	0.8

4.5.1 *Mustelus antarcticus* (gummy shark)

Figure 4.7. Gummy shark, *Mustelus antarcticus*.
Illustration © R.Swainston/www.anima.net.au.

The gummy shark is a small to moderate sized (up to 1.85 m TL) houndshark (Family Triakidae), likely to be endemic to southern Australia. Gummy sharks occur in temperate waters from Geraldton in WA to Port Stephens in NSW (Last and Stevens 2009). The gummy shark population is composed of a single genetic stock across southern Australia (MacDonald 1988; Gardner and Ward 1998). Nonetheless, differing environmental conditions mean that individuals from the east and west regions differ substantially in life history characteristics. Kangaroo Island (KI) in SA provides an approximate east-west boundary that separates individuals with differing life history characteristics (Walker 2007). Given the relatively low mixing between regions, the population is divided into a number of sub-stocks for assessment purposes (Walker et al. 2000). Structuring by size and sex also occurs within the gummy shark population, with sharks forming small schools composed mainly of one sex or size group (Last and Stevens 2009).

Gummy sharks are relatively fast-growing and moderately long lived with males reaching at least 17 years and females 20 years (Moulton et al. 1992) with growth bands formed annually (Walker et al. 2001). Like most sharks, growth is sexually dimorphic and females grow larger and live longer than males. The gummy shark has a reproductive mode of aplacental viviparity with minimal histotrophy. Developing embryos are initially nourished by a yolk sac during the early part of gestation, and uterine secretions once the yolk is absorbed (Walker 2007). The gestation period of the gummy shark is ~1 year throughout southern Australia with parturition, mating and ovulation occurring between November and early February (Lenanton et al. 1990; Walker 2007). Neonate gummy sharks are born at a length of 30-36 cm in inshore areas. Parturition is synchronous across the population but the frequency of reproduction varies between different geographic regions. West of KI and in WA waters, gummy sharks reproduce annually, while east of KI reproduction is biennial (Lenanton et al. 1990; Walker 2007). Length at maturity also differs spatially; west of KI 50% of males and females are mature by 978 mm (~4 years) and 1,129 mm TL (~5 years), respectively, and 50% of females are in maternal condition by 1,263 mm TL (~6 years) (Walker 2007). Fecundity increases exponentially with increasing size in gummy sharks. The relationship between fecundity and maternal total length, TL, is given by Fecundity = exp (-4.13398 + 0.049171 TL) (Lenanton et al. 1990).

For gummy sharks, almost all of the reported catch in WA is taken by the TDGDLF (Braccini et al. 2018, 2021a). For these fisheries, annual catches gradually increased from just over 50 t in 1975-76 to over 750 t in 2007-08. The historic peak observed in 2007-08 was assumed to be due to an increase in abundance/availability as effort since the early 2000s has remained relatively constant at approximately 25–30% of the historic effort peak observed in the late 1980s (Figure 4.4).

In the last five years, the TDGDLF has retained on average ~410 t annually (Table 4.1). Reported catches from other commercial fisheries and estimated recreational catches are minor in comparison. With an estimated ~13 t taken annually by recreational fishers over the last five years (Table 5.1; Braccini et al. 2021b).

Gummy sharks were recently assessed using a risk-based weight of evidence approach using all available lines of evidence, including simulated biomass trajectories derived from a combination of demographic modelling and catch-only stock reduction analysis. This assessment estimated a MEDIUM current risk level with 78%, 92% and 100% of the simulated current relative total biomass trajectories being above the target, threshold and limit biomass reference points, respectively (Braccini et al. 2021a).

4.5.2 *Carcharhinus obscurus* (dusky shark)

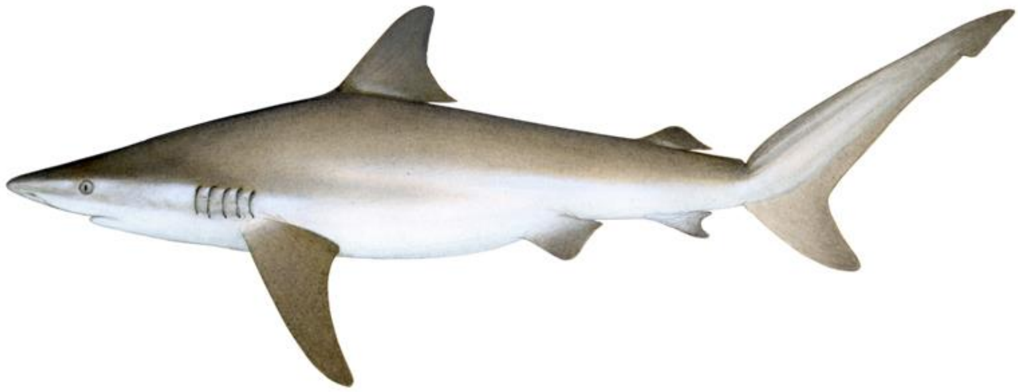


Figure 4.8. Dusky shark, *Carcharhinus obscurus*.
Illustration © R.Swainston/www.anima.net.au.

The dusky shark is a large (~3.5 m) species of coastal whaler shark (Family Carcharhinidae) found in tropical and temperate seas circumglobally and throughout Australian waters (Last and Stevens 2009). Dusky sharks in WA constitute a single stock, although different life stages occur in different geographical regions. Newborn and juvenile sharks occur in the south-west of WA, while adults mainly occur in north-western waters between the Abrolhos Islands and the North West Cape. Adults migrate seasonally between the two regions for parturition. Genetic analyses suggest there is restricted gene flow between eastern and western Australia (Geraghty et al. 2014a).

The dusky shark is long-lived and slow growing. Empirical estimates of longevity are 32 years for females and 25 years for males based on vertebrae, validated up to

4 years of age (Simpfendorfer et al. 2002). Maximum longevity is likely substantially higher and has been assumed to be 55 years (McAuley et al. 2007a). Females attain a larger size and grow more slowly than males. Dusky sharks have a reproductive mode of placental viviparity; developing embryos are initially nourished by the yolk sac, which subsequently attaches to the uterine wall forming a placental connection to the mother. Details on the duration of the gestation period are scant, but it is estimated that the gestation period is up to two years and that the frequency of reproduction is every 2-3 years (McAuley et al. 2005). Females give birth to between 6-13 embryos with a mean size at birth of 921 mm TL. Young are born year-round with pupping rates highest during autumn (Simpfendorfer et al. 1996). Length at 50% maturity of female dusky sharks is estimated at 3012 mm TL (McAuley et al. 2005). Size-fecundity relationships are not known for this species, although it is likely that fecundity increases in proportion to length.

For dusky sharks, almost all of the reported catch in WA is currently taken by the TDGDLF, although the NSF historically took up to 40 t in the early 2000s (Braccini et al. 2018, 2021a). For the TDGDLF, annual catches gradually increased from ~110 t in 1975-76 to over 670 t in 1988-89. Following management intervention, catches subsequently decreased, and have fluctuated at ~200 t since the late 2000s remaining within the recommended target catch ranges (200–300 t).

In the last five years, the TDGDLF has retained on average ~156 t annually (Table 4.1). Reported catches from other commercial fisheries and estimated recreational catches are minor in comparison. Recreational fishers took an estimated ~ 25 t annually over the last five years (Table 5.1; Braccini et al. 2021b).

Dusky sharks were recently assessed using a risk-based weight of evidence approach using all available lines of evidence, including simulated biomass trajectories derived from a combination of demographic modelling and catch-only stock reduction analysis. This assessment estimated a MEDIUM current risk level with 51%, 76% and 100% of the simulated current relative total biomass trajectories being above the target, threshold and limit biomass reference points, respectively (Braccini et al. 2021a).

4.5.3 *Furgaleus macki* (whiskery shark)

Figure 4.9. Whiskery shark, *Furgaleus macki*.
Illustration © R.Swainston/www.anima.net.au.

The whiskery shark is a small to moderate sized (up to 1.6 m TL) species of houndshark (Family Triakidae) endemic to Australia (Last and Stevens 2009). Whiskery sharks occur in temperate continental shelf waters from the North West

Cape in WA to Wynyard in Tasmania. Little is known about the stock structure of whiskery sharks. The length and sex composition of the commercial catch differs markedly between regions; adult males are more common in southeast regions of WA while females dominate the catch numerically around the lower south-west coast (McAuley and Simpfendorfer 2003).

Whiskery sharks are relatively fast growing and short to moderately long-lived; males have been aged to 10.5 years and females to 11.5 years (Simpfendorfer and Chidlow 2000) although the periodicity of band formation has not been validated. Growth rates and maximum sizes are similar between the sexes with males growing slightly faster than females. Whiskery sharks are viviparous giving birth to between 4-28 pups, with an average of 19 pups (Simpfendorfer and Unsworth 1998). The reproductive cycle is synchronous with mating thought to occur from August to September and females storing sperm until ovulation occurs in late January to early April. Parturition occurs in August to October after a gestation period of approximately 7–9 months. Although adult males reproduce each year females only reproduce every second year. Length at birth is between 22–27 cm fork length (FL) and FL at maturity is 107 cm for males and 112 cm for females, corresponding to an age at maturity of approximately 4.5 years for males and 6.5 years for females (Simpfendorfer and Chidlow 2000). Fecundity increases in proportion to FL (in cm) following the relationship Fecundity = 0.314 FL – 17.8 (Simpfendorfer and Unsworth 1998).

For whiskery sharks, almost all of the reported catch in WA is taken by the TDGDLF (Braccini et al. 2018, 2021a). For these fisheries, annual catches increased from over 100 t in 1975-76 to over 500 t in 1981-82. Between the mid-1980s and early-1990s annual catches fluctuated at ~400 t. Following management intervention, catches subsequently decreased to between ~150-200 t since the early 1990s and have fluctuated around these levels ever since.

In the last five years, the TDGDLF has retained on average ~135 t annually (Table 4.1). Reported catches from other commercial fisheries and the estimated recreational catches are negligible. Recreational fishers took an estimated ~2 t annually over the last five years (Table 5.1; Braccini et al. 2021b).

Whiskery sharks were recently assessed using a risk-based weight of evidence approach using all available lines of evidence, including simulated biomass trajectories derived from a combination of demographic modelling and catch-only stock reduction analysis and an integrated stock assessment. This assessment estimated a MEDIUM current risk level with 63%, 82% and 100% of the simulated current relative total biomass trajectories being above the target, threshold and limit biomass reference points, respectively. The integrated model showed a similar pattern (Braccini et al. 2021a).

4.5.4 *Carcharhinus plumbeus* (sandbar shark)

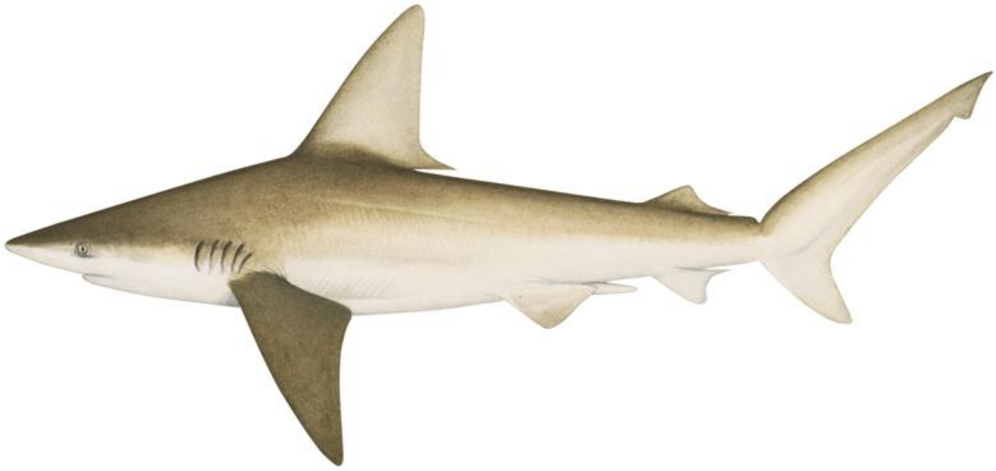


Figure 4.10. Sandbar shark, *Carcharhinus plumbeus.*
Illustration © R.Swainston/www.anima.net.au.

The sandbar shark is a medium sized whaler shark (up to 2.5 m) with a cosmopolitan but patchy distribution in tropical and warm temperate seas (Last and Stevens 2009). Within Australian waters, populations exist on both the east and west coast. In WA waters, the sandbar shark ranges from at least Cape Leveque to Point D'Entrecasteaux (McAuley et al. 2005). The WA sandbar shark stock exhibits considerable segregation between juveniles, which occur mainly in deeper continental shelf waters south of 26° S, and adults, which occur in more northerly waters (McAuley et al. 2005). Adult sandbar sharks migrate seasonally from the waters in the north-west of WA into temperate waters to give birth. The limited gene flow between eastern and western Australia (Portnoy et al. 2010) and limited reported catches in northern WA, the Gulf of Carpentaria and southern Australia suggest sandbar sharks are largely separate from populations on the east coast of Australia.

Sandbar sharks are slow-growing and long-lived; males have been empirically aged to 19 years and females to 25 years based on vertebral ageing and growth bands are formed annually (McAuley et al. 2006). However, maximum longevity is thought to be at least 30–40 years (McAuley et al. 2007a). Growth is sexually dimorphic with females attaining a larger size and growing at a slower rate than males. Sandbar sharks have a reproductive mode of placental viviparity. Mating occurs during summer and autumn, and females ovulate during March (McAuley et al. 2007b). The gestation period is 12 months, with females giving birth to between 4-10 pups (mean 6.5) of length 509–565 mm TL. Females reproduce biennially and have a resting year between pregnancies. Male sandbar sharks reach sexual maturity at a smaller size than females; 50% maturity occurs at 1484 mm TL for males and 1585 mm TL for females. These lengths correspond to age at maturity of around 14 years for males and 16 years for females. There is a weak but statistically significant increase in fecundity with increasing female length (McAuley et al. 2007b).

For sandbar sharks, significant catches were historically reported from the NSF (Braccini et al. 2018, 2021a). Catches in these fisheries increased rapidly from negligible levels in the 1980s and early 1990s to more than 750 t in 2004-05. Catches then rapidly declined (as a result of management intervention) and no catches have been reported since 2008-09.

Currently, almost all of the reported catch in WA is taken by the TDGDLF, specifically the WCDGDLF. For these fisheries, annual catches fluctuated between ~100 t and more than 200 t between 1989-90 and 2009-10. Following management intervention, catches subsequently decreased, fluctuating at ~40 t since 2011-12 and remaining below the recommended target catch limit (<120 t).

In the last five years, the TDGDLF has retained on average ~35 t annually (Table 4.1). Reported catches from other commercial fisheries and the estimated recreational catches are negligible. Recreational fishers took an estimated ~3 t annually over the last five years (Table 5.1; Braccini et al. 2021b).

Sandbar sharks were recently assessed using a risk-based weight of evidence approach using all available lines of evidence, including simulated biomass trajectories derived from a combination of demographic modelling and catch-only stock reduction analysis. This assessment estimated a MEDIUM current risk level with 63%, 83% and 99% of the simulated current relative total biomass trajectories being above the target, threshold and limit biomass reference points, respectively (Braccini et al. 2021a).

4.5.5 *Carcharhinus brachyurus* (bronze whaler)

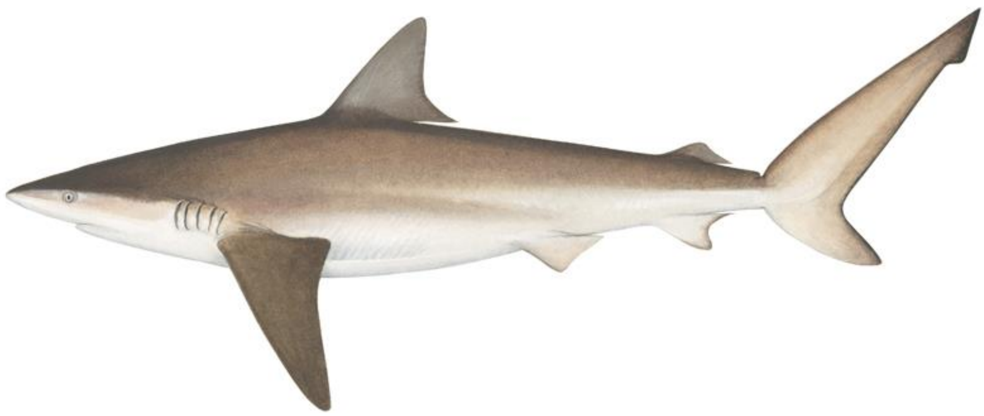


Figure 4.11. Bronze whaler, *Carcharhinus brachyurus.*
Illustration © R.Swainston/www.anima.net.au.

The bronze whaler is a highly mobile and seasonally migratory species with a cosmopolitan warm-temperate distribution. Adult and juvenile sharks inhabit coastal and shelf waters of the west, south and north coasts of Australia between Coffs Harbour, NSW and Geraldton, WA (Last and Stevens 2009). Genetic analyses, conventional tagging and electronic telemetry suggest there is a well-mixed stock ranging between western, southern and eastern Australia (Rogers et al. 2013; Drew et al. 2019).

Bronze whalers are relatively long-lived (maximum age: at least 31 years) and large (maximum size: 295 cm TL) carcharinids with slow growth (k= 0.15 years^{-1}), late maturation (age at 50% maturity: 16 years) and moderate fecundity (litter size: 7-24 pups) (Last and Stevens 2009; Drew et al. 2017).

In WA, bronze whalers are predominately taken in the TDGDLF but they constitute only a minor component of the catch, <50 t per year for the last five years (Table 4.1). Noting, species-specific catch records of bronze whaler are available from 1998 (Figure 4.6). Recreational catch is lower than the commercial catch, with an estimated average catch of 11 t per year over the last five years (Table 5.1; Braccini et al. 2021b).

There is no published quantitative assessment for the bronze whaler stock. Stable catches and size structure have been recorded in Australia (Huveneers et al. 2019a).

The current status of bronze whaler is Least Concern in the Australian IUCN Red List and Vulnerable in the global IUCN Red List. Additionally, bronze whaler was assessed as 'sustainable' in 2019 at current levels of fishing (Huveneers et al. 2019a).

4.5.6 *Sphyrna* species (hammerheads)

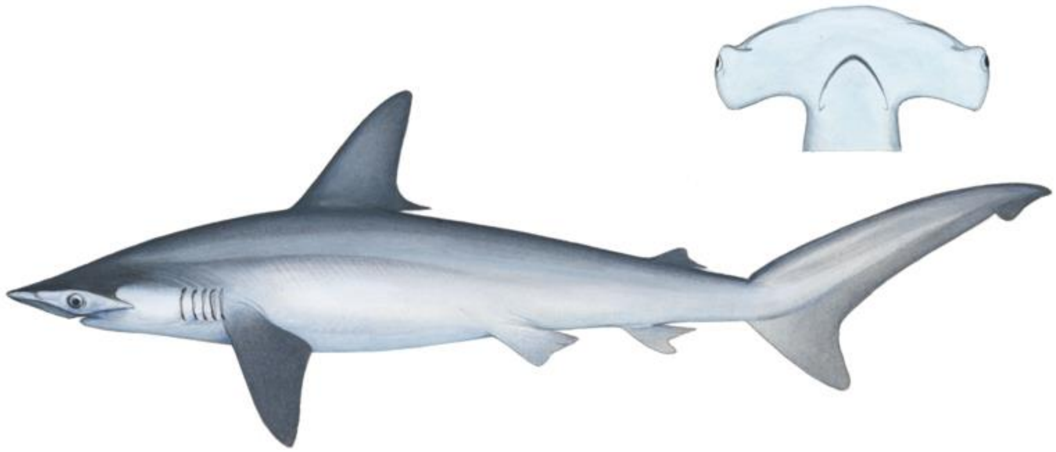


Figure 4.12. Smooth hammerhead, *Sphyrna zygaena.*
Illustration © R.Swainston/www.anima.net.au.

Hammerheads are highly mobile species with a worldwide distribution. TDGDLF fishers currently do not report hammerheads to species levels; however, based on on-board observer data, 97% of the TDGDLF catch comprises smooth hammerhead (*Sphyrna zygaena*) with the remainder being scalloped (*S. lewini*) and great (*S. mokarran*) hammerheads (McAuley and Simpfendorfer 2003). Hence, the current risk assessment is based on smooth hammerhead.

Smooth hammerheads have coastal-pelagic and semi-oceanic distributions to depths of 200 m (Ebert 2003). In Australia, the smooth hammerhead is found from the Coral Sea (Queensland; QLD) south through NSW, Victoria, SA, Tasmania and WA, as far north as the Montebello Islands (Last and Stevens 2009). They are considered to form single stock within Australian waters (Simpfendorfer 2014).

There is limited data on the life history of smooth hammerhead, though it is presumably at least as biologically sensitive as the scalloped hammerhead (Simpfendorfer et al. 2019). Smooth hammerheads are long-lived (maximum age: at least 26 years) and large (maximum size: 350 cm TL) sharks with slow growth ($k = 0.09$ $years^{-1}$). They have late maturation (age at 50% maturity: 22 years) and relatively high fecundity (litter size: 20-49 pups) (Last and Stevens 2009; Rosa et al. 2017; Simpfendorfer et al. 2019).

In WA, hammerheads are predominately taken in the TDGDLF but constitute a minor component of the catch (Figure 4.6), averaging 44 t per year for the last 5 years (Table 4.1). Recreational catch is negligible, with an estimated average catch of ~3 t and <1 t per year of smooth and scalloped hammerheads over the last five years, respectively (Table A.3; Braccini et al. 2021b).

In 2014, smooth, great and scalloped hammerheads were listed under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). A Non-Detriment Finding (NDF) for the export of these species has been in place since 2014, with the current catch level accepted as non-detrimental to smooth hammerhead defined as 70 t per year (DoE 2014a).

Reported annual catches in other jurisdictions are small (<10 t; Simpfendorfer 2014).

There is currently no published quantitative assessment for the smooth hammerhead stock. The catch rates from the TDGDLF have shown stable or increasing levels over a 20-year period to 2010 suggesting a stable population (Simpfendorfer 2014), and the total population decline in Australia over three generations is estimated to be 20% (Simpfendorfer et al. 2019). However, data from the NSW shark control program shows an approximate 85% decline in general hammerhead catch rates, with smooth hammerhead thought to make up the majority of the catch (Reid et al. 2011).

The current status of smooth hammerhead is Near Threatened in the Australian IUCN Red List and Vulnerable in the global IUCN Red List. Additionally, smooth hammerhead was assessed as ‘sustainable’ in 2019 at current levels of fishing (Simpfendorfer et al. 2019).

4.5.7 *Achoerodus gouldii* (western blue groper)

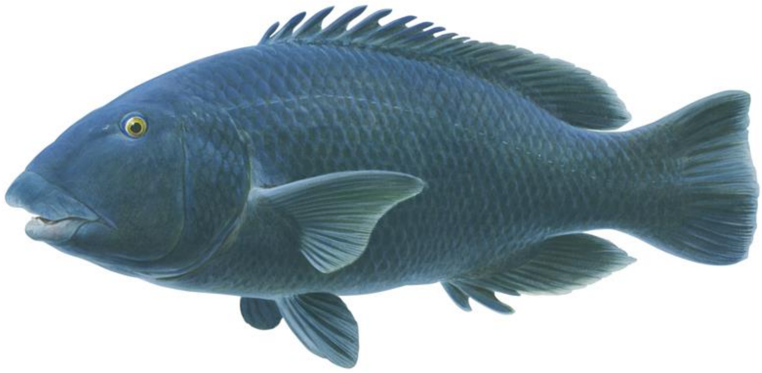


Figure 4.13. Western blue groper, *Achoerodus gouldii.*
Illustration © R.Swainston/www.anima.net.au.

Western blue groper is endemic to coastal waters of south-western Australia, from Geraldton, WA, to Victoria. Juveniles occur in sheltered inshore waters, and then move to deeper offshore reefs as they mature. Adults inhabit coastal and offshore reefs up to 100 m depth and maintain small home ranges (Bryars et al. 2012), making them vulnerable to localised depletion from fishing. Western blue groper is a protogynous hermaphrodite (i.e. some individuals change from female to male). Individuals mature as females at ~17 years and as males at ~35 years. This species has a maximum observed age of 71 years and total length of 80 cm. The IUCN Red List status for western blue groper is Vulnerable.

Western blue groper is taken by TDGDLF fishers using demersal gillnets in the lower west and south coasts of WA. In the past 5 years, annual catches of blue groper by the TDGDLF ranged from 31 t to 43 t, which represented 3.5% of total TDGDLF landings (Table 4.1). Minor quantities of this species are also taken by commercial and recreational line fishers and recreational spear fishers.

Catches by all fishing sectors are taken into account in the assessment of the stock.

The stock structure of this species in WA is uncertain. Western blue groper in the SCB, where most of the TDGDLF catch is taken, is currently managed as a single breeding stock.

The most recent age-based assessment of the south coast stock is based on a sample of 682 fish obtained from the TDGDLF catch in 2013 and 2014 (Norriss et al. 2016). The sample contained a substantial proportion of older fish (>35 years) in the population, up to a maximum of 71 years (Norriss et al. 2016). From these data, two alternative methods were used to generate median estimates of female spawning potential ratio (SPR ± 95 per cent CI): SPR1 = 0.74 (0.52–0.97) and SPR2 = 0.71 (0.48–0.97). There was an almost zero chance of breaching the threshold reference point (SPR=0.30) for either method (Norriss et al. 2016). For males, SPR1 = 0.49 (0.23–0.94) and SPR2 = 0.48 (0.21–0.93), with a 14% and 18% chance of breaching the threshold reference point, respectively, and an almost zero chance of breaching the limit reference point (SPR=0.20) for either method. Estimates of natural mortality (M) and fishing mortality (F, year^{-1}) were 0.077 (0.059–0.097) and 0.023 (0.002–0.047), respectively, giving a point estimate of F/M of 0.30. The probability of F breaching the threshold level (F/M = 1) was almost zero.

The above evidence indicated that the biomass of this stock was unlikely to be depleted and that recruitment was unlikely to be impaired. The evidence also indicated that the level of fishing mortality was unlikely to cause the stock to become recruitment impaired. Recent total catches have been well within historical limits, implying that mortality remains at an acceptable level (Norriss and Walters 2020). The south coast breeding stock is therefore considered adequate and fished sustainably.

The current risk level for the south coast stock is assessed as LOW (Norriss and Walters 2020).

4.5.8 *Nemadactylus valenciennesi (*blue morwong)

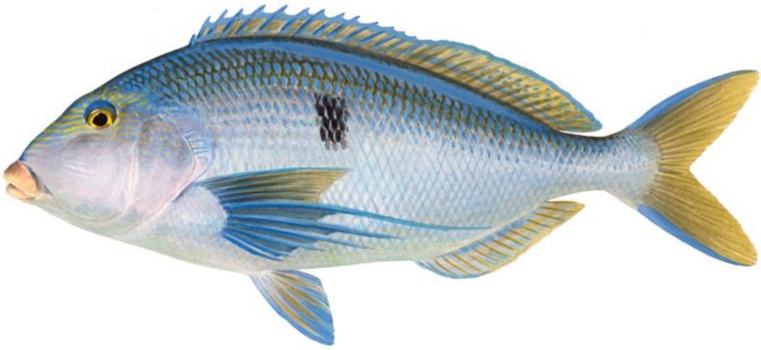


Figure 4.14. Blue morwong, *Nemadactylus valenciennesi.*
Illustration © R.Swainston/www.anima.net.au.

Blue morwong is endemic to southern Australia, from Lancelin, WA, to Wooli, NSW, including northern Tasmania. It inhabits offshore rocky reefs to a depth of 240 m. This species is gonochoristic (does not change sex). Individuals attain maturity at about 70-75 cm TL and 7-8 years of age (Coulson et al. 2010). Blue morwong has a maximum size of 98 cm TL and a lifespan of at least 24 years (Norriss et al. 2016). Blue morwong in WA are believed to comprise a single breeding stock (Coulson et al. 2010).

Blue morwong are taken by TDGDLF fishers using demersal gillnets off the lower west and south coasts of WA. In the past 5 years, annual catches of blue morwong by the TDGDLF ranged from 29 t to 42 t, which represented 3.3% of total TDGDLF landings (Table 4.1). Minor quantities of this species are also taken by commercial and recreational line fishers, mainly off the south coast.

Catches by all fishing sectors are taken into account in the assessment of the stock.

The most recent age-based assessment of the stock is based on a total sample of 2,621 south coast fish collected from commercial and recreational catches during 2012-2014 (Norriss et al. 2016). The age composition suggested regular and consistent recruitment for the previous two decades (Norriss et al. 2016). The demersal gillnet sample (n = 1,234) from the eastern sub-region of the south coast was considered the most representative for an age-based stock assessment. Based on these data, two alternative methods were used to generate median estimates (± 95% CI) of SPR. For females, SPR1 = 0.58 (0.46–0.71) and SPR2 = 0.54 (0.41–0.68), with an almost zero chance of breaching the threshold reference point (SPR=0.30) for either method. For males, SPR1 = 0.36 (0.25–0.51) and SPR2 = 0.34 (0.23–0.50) with a 19% and 31% chance of breaching the threshold reference point, respectively, and an almost zero chance of beaching the limit reference point (SPR=0.20). Estimates of M were 0.22 (0.18–0.26) and F were F_{female} = 0.106 (0.072–0.137) and F_{male} = 0.180 (0.123–0.231), giving a point estimates of F/M of 0.49 for females and 0.84 males. The probability of F breaching the threshold level (F/M = 1) was almost zero for females and 25% for males, and almost zero for either sex breaching the limit (F/M = 1.5). The size selectivity of the nets, coupled with the larger size reached by males, results in a higher level of fishing mortality for males.

Recent total catches of blue morwong have been well within historical limits, implying that mortality remains at an acceptable level (Norriss and Walters 2020). The south coast breeding stock is therefore considered adequate and fished sustainably.

The current risk level for the blue morwong stock is assessed as MEDIUM (Norriss and Walters 2020).

4.5.9 *Carcharhinus brevipinna* (spinner shark)

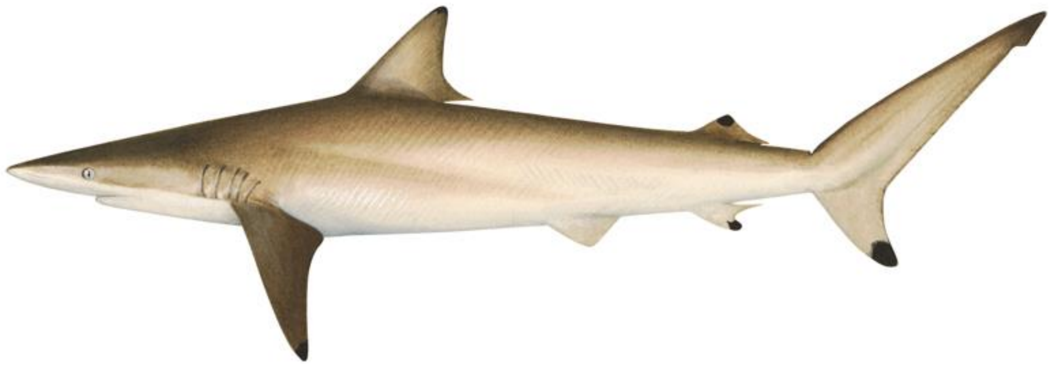


Figure 4.15. Spinner shark, *Carcharhinus brevipinna.*
Illustration © R.Swainston/www.anima.net.au.

The spinner shark is a cosmopolitan species with a warm-temperate and tropical distribution worldwide found in coastal habitats such as beaches, bays, river mouths but also in offshore pelagic waters (Burgess and Smart 2019).

Spinner sharks are relatively long-lived (maximum age: at least 31 years) and large (maximum size: 300 cm TL) carcharinids with slow growth (k= 0.12 years^{-1}), relatively late maturation (8-12 years) and low fecundity (litter size: 5-14 pups) (Carlson and Baremore 2005; Dudley and Simpfendorfer 2006; Last and Stevens 2009; Geraghty et al. 2014b; Liu et al. 2015). Their stock structure in Australia is unknown.

In WA, spinner sharks are predominately taken in the TDGDLF but they constitute only a minor component of the catch (Figure 4.6), averaging 31 t per year for the last 5 years (Table 4.1). The recreational catch is negligible, with an estimated average catch of ~2 t per year over the last five years (Table A.3; Braccini et al. 2021b).

There is no published quantitative assessment for the spinner shark stock. Although little is known on the status of spinner shark throughout its distribution, in Australia, fishing pressure is considered to be well managed (Burgess and Smart 2019).

The current status of spinner shark is Least Concern in the Australian IUCN Red List and Vulnerable in the global IUCN Red List. Additionally, spinner shark was assessed as ‘sustainable’ in 2019 at current levels of fishing (Burgess and Smart 2019).

4.5.10 *Orectolobus* species (wobbegongs)

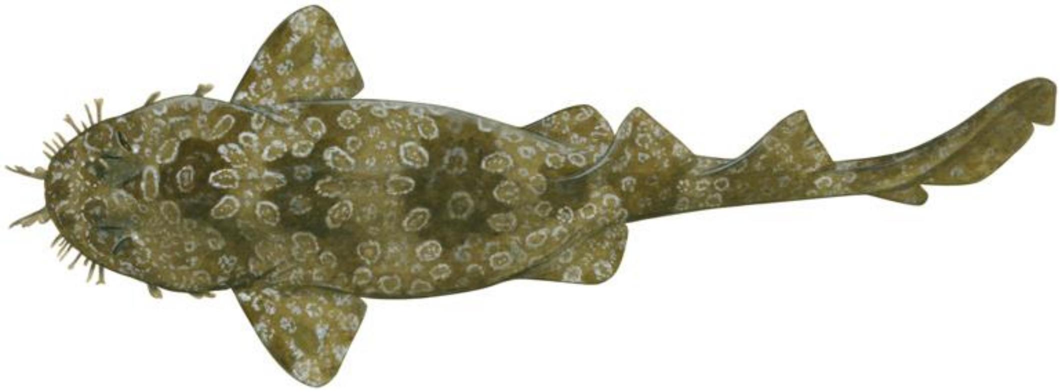


Figure 4.16. Spotted wobbegong, *Orectolobus maculatus.*
Illustration © R.Swainston/www.anima.net.au.

Wobbegongs are demersal coastal sharks. TDGDLF fishers do not currently report wobbegongs to species levels; however, based on on-board observer data, the TDGDLF landings comprise a mix of banded (*Orectolobus halei*) and spotted (*O. maculatus*) wobbegongs, whereas western (*O. hutchinsi*) and cobbler (*Sutorectus tentaculatus*) wobbegongs are mostly discarded (McAuley and Simpfendorfer 2003).

Banded and spotted wobbegongs are endemic to southern Australia in coastal and inshore waters on the continental shelf to at least 195 m and 218 m, respectively (Last and Stevens 2009; Huveneers et al. 2019b).

Banded and spotted wobbegongs are relatively long-lived (maximum age: at least 27 years and 22 years, respectively) and large (maximum size: 206 cm and 320 cm TL, respectively) sharks with slow growth (k=0.2 years^{-1} and 0.09 years^{-1}, respectively). These species have relatively late maturation (size at 50% maturity: 161 cm and 120 cm TL, respectively) and relatively high fecundity (litter size: 12-47 pups, average of 21 pups but up to 37, respectively) (Last and Stevens 2009; Huveneers et al. 2013; Huveneers et al. 2019b; Huveneers et al. 2019c). Their stock structure in Australia is unknown.

In WA, wobbegongs are predominately taken in the TDGDLF but constitute only a minor component of the catch (Figure 4.6), averaging 28 t per year for the last five years (Table 4.1). The recreational catch is negligible in comparison, with an estimated ~4 t per year over the last five years (Table 5.1; Braccini et al. 2021b).

There is currently no published quantitative assessments for the banded or spotted wobbegong stocks. There is also no information on population size, structure, or trends, but based on catch data from various Australian fisheries the stocks are considered to be ‘sustainable’ (Huveneers et al. 2019b; Huveneers et al. 2019c). The IUCN Red List status for these two wobbegong species in Australia is Least Concern.

4.5.11 *Chrysophrys auratus* (snapper)

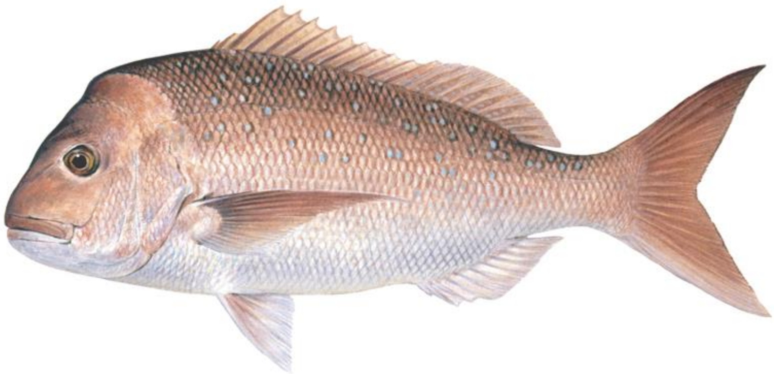


Figure 4.17. Snapper, *Chrysophrys auratus.*
Illustration © R.Swainston/www.anima.net.au.

Snapper has a wide distribution in coastal waters of Australia, from Carnarvon, WA, to Hinchinbrook Island, QLD, including Lord Howe Island and Norfolk Island. Within this broad distribution, the stock structure is complex. Juveniles and small adults occur in bays, inlets and estuaries, whereas adults are usually offshore near rocky reefs. Snapper has a maximum size of 1300 mm TL and a longevity of 30-40 years. Maturity is attained at 2–7 years and 220–560 mm TL. Individuals in southern areas tend to reach greater maximum lengths and ages than those further north.

In WA, snapper is currently divided into six management units, including three genetically related units within Shark Bay (Eastern Gulf, Denham Sound and Freycinet Estuary), and three oceanic units (Shark Bay Oceanic, West Coast and South Coast). The oceanic units comprise a semi-continuous genetic stock where gene flow is primarily limited by geographic distance (Gardner and Chaplin 2011; Gardner et al. 2017). Adults are typically resident within a particular area and so gene flow mainly occurs via dispersal of planktonic eggs and larvae (Moran et al. 2003; Wakefield et al. 2011; Fairclough et al. 2013; Crisafulli et al. 2019).

In the SCB, recent annual commercial landings of snapper were 30-40 t. Line fisheries took about 50% of these landings, ~30% by the TDGDLF (Table 4.1) and the remainder was taken in estuaries. Significant quantities were also taken recreationally, with an estimated 10 t of snapper retained in 2017/18 by boat-based recreational fishers in the SCB (Ryan et al. 2019).

The most recent age-based assessment of the south coast snapper stock is based on sampling of the commercial line catch in 2013 and 2014 (Norriss et al. 2016). SPR and F were each estimated to be between their management target and threshold levels, indicating that stock level was adequate and fished sustainably. Recent total catches have been well within historical limits, implying that fishing mortality and stock status remain unchanged (Norriss and Walters 2020). The current risk level for the south coast snapper stock is assessed as MEDIUM (Norriss and Walters 2020).

In the WCB of WA, recent annual commercial landings of snapper were 55-65 t. About 85% of these landings were taken by the West Coast Demersal Scalefish

Fishery, and about 15% by the TDGDLF (Table 4.1). Significant quantities are also taken recreationally, with an estimated 48 t of snapper retained by boat-based recreational fishers in the WCB and a further 22 t by charter fishers in 2017/18 (Fairclough and Walters 2020). Previous age-based assessments of the west coast stock of snapper were completed in 2007, 2009, and 2014, which indicated that F was above the limit reference level. The most recent assessment in 2017 (based on age structure data from 2012–14) indicated that F was still above the limit but had decreased since the previous sampling period in 2009-11. In 2017, SPR was between the limit and threshold reference level.

The assessment indicated that fishing mortality was being constrained by current management arrangements to a level that should allow the stock to recover from its recruitment impaired state. The current risk level for the west coast snapper stock is assessed as HIGH (Fairclough and Walters 2020).

4.5.12 *Glaucosoma hebraicum* (West Australian dhufish)

Figure 4.18. West Australian dhufish, *Glaucosoma hebraicum.*
Illustration © R.Swainston/www.anima.net.au.

West Australian dhufish is endemic to south-western WA from Esperance to Shark Bay but is most abundant in the WCB. Adults inhabit rocky outcrops and ledges, to a depth of 200 m but typically 20-50 m, while juveniles usually occur in sandy areas near seagrass or reefs. West Australian dhufish comprises a single biological stock (Berry et al. 2012, Fairclough et al. 2013). This species is gonochoristic (does not change sex). Individuals attain maturity at about 30 cm TL and 3 years of age (Hesp et al. 2002). West Australian dhufish attains a maximum size of 122 cm TL and has a lifespan of at least 41 years (Smallwood et al. 2013).

West Australian dhufish are taken predominantly by commercial and recreational line fishers off the lower west coast and, to a lesser extent, the south coast. Recent total commercial landings of this species were 40-65 t per year, with 24% of these landings taken by gillnets deployed by the TDGDLF. In the past 5 years, annual catches of West Australian dhufish by the TDGDLF ranged from 10 t to 14 t, which represented 1.1% of total TDGDLF landings (Table 4.1). Significant quantities of this species are taken recreationally, with an estimated 135 t of West Australian dhufish retained by boat-based recreational and charter fishers in 2017/18 (Fairclough and Walters 2020).

Catches by all fishing sectors are taken into account in the assessment of the stock.

Stock assessments for West Australian dhufish completed in 2007 and 2009 indicated F was above the limit reference point and deemed unacceptable. A series of management actions to reduce F were subsequently implemented (Fairclough 2018). The most recent assessment in 2017, which included age composition data from 2012/13-2014/15, demonstrated that F and SPR had not reached acceptable levels (i.e. the threshold) at that time. F estimates had not decreased although there was preliminary evidence that year classes recruited to the fishery after management changes have experienced lower F than those that recruited prior to changes, suggesting some reduction in recent fishing mortality (Fairclough and Walters 2020). Additional post-release mortality associated with high recreational sector release rates and unknown commercial release rates may be impairing the rate of stock recovery.

The current risk level for the West Australian dhufish stock is assessed as HIGH (Fairclough and Walters 2020).

4.5.13 *Galeorhinus galeus* (school shark)

Figure 4.19. School shark, *Galeorhinus galeus.*
Illustration © R.Swainston/www.anima.net.au.

School shark are long-lived (~50 years) hound sharks with a global distribution across temperate waters. They are a highly migratory species, feeding on a variety of schooling prey and are distributed across southern Australia, mainly on the continental shelf and upper slope where they have been recorded from Moreton Bay (southern QLD) to Perth, including Tasmania (AFMA 2015b). They are considered to be a single Australia-wide stock.

The school shark has a moderate growth rate (k=0.168 y^{-1}) and relatively high fecundity (up to 52 pups) but with a three-year reproductive cycle (Walker et al. 2019). Heavily pregnant females are commonly found in warm shallow waters, thought to promote embryo growth (AFMA 2015b).

AFMA have been managing school shark under an incidental catch limit since 1997, when management measures aimed at eliminating targeted fishing for school shark were first implemented (AFMA 2015b). In 2013, the South East Management Advisory Committee endorsed a rebuilding timeframe of three mean generation times (or 66 years), which was then adoped by AFMA (AFMA 2015b).

AFMA's current incidental catch limit is set at 195 t (2020-21) to cover unavoidable bycatch only in the SESSF. In 2019-20, the SESSF landed 184 t of school shark (with a 2019-20 TAC of 189 t; ABARES 2020).

In WA, school shark are mostly taken in the TDGDLF (~8 t per year for the last 5 years, Table A.1) and the recreational catch is negligible (Table A.3; Braccini et al. 2021b).

The current status of school shark is Vulnerable in the Australian IUCN Red List and Critically Endangered in the global IUCN Red List. The latest stock assessment indicated that current mature biomass is below 20% unfished levels and is considered to be 'depleted' (Walker et al. 2019).

While the level of school shark catch in WA is relatively low, given their current stock status and some higher than average catches in recent years they were assessed separately to other minor species.

4.5.14 *Minor species*

The remainder of the species caught and retained by TDGDLF fishers operating in the TDGDLF are presented in Table A.1. These species have a wide geographical range and reported catch ranges are low, collectively comprising < 7% of the total reported catch. TDGDLF catches of these species are not predicted to increase in the next five years.

4.6 Bycatch Species

Currently, it is not mandatory for fishers in the TDGDLF to report on the component of catch that is discarded. Hence, bycatch information is only available from on-board observer programs. Scientific observers have been collecting catch composition information since 1993 across the TDGDLF's distribution (McAuley and Simpfendorfer 2003). Total annual discards (including an account for post-capture mortality) have been calculated based on the ratio estimator method combining all observed years to calculate an overall discard ratio by spatial block (1 degree fishing cell), which was scaled up by the total annual retained catch in that block (Braccini and Murua in review).

The observed catch composition of retained and discarded elasmobranchs and teleosts is shown in Figure 4.20 and Figure 4.21, respectively. Most of the bycaught species were discarded due to no economic value; only white (*Carcharodon carcharias*) and grey nurse (*Carcharias taurus*) sharks were discarded as protected species under the EPBC Act and *Biodiversity Conservation Act 2016* (BC Act).

Based on the observer data, the TDGDLF retained ~3/4 of the catch (by number) and 18 elasmobranch and 19 teleost species were discarded (Figure 4.20 and Figure 4.21). Based on the reconstruction of total annual catches, dusky morwong (*Dactylophora nigricans*), buffalo bream (*Kyphosus spp.*) and Port Jackson shark (*Heterodontus portjacksoni*) were the most commonly discarded species, averaging 19 t, 10 t and 5 t per year, respectively, in the last five years (Table 4.2). These catches are 1.7%, 0.9% and 0.5% of the total annual retained catch by the TDGDLF.

For the other discarded species, reconstructed annual catches were lower (Table A.2).

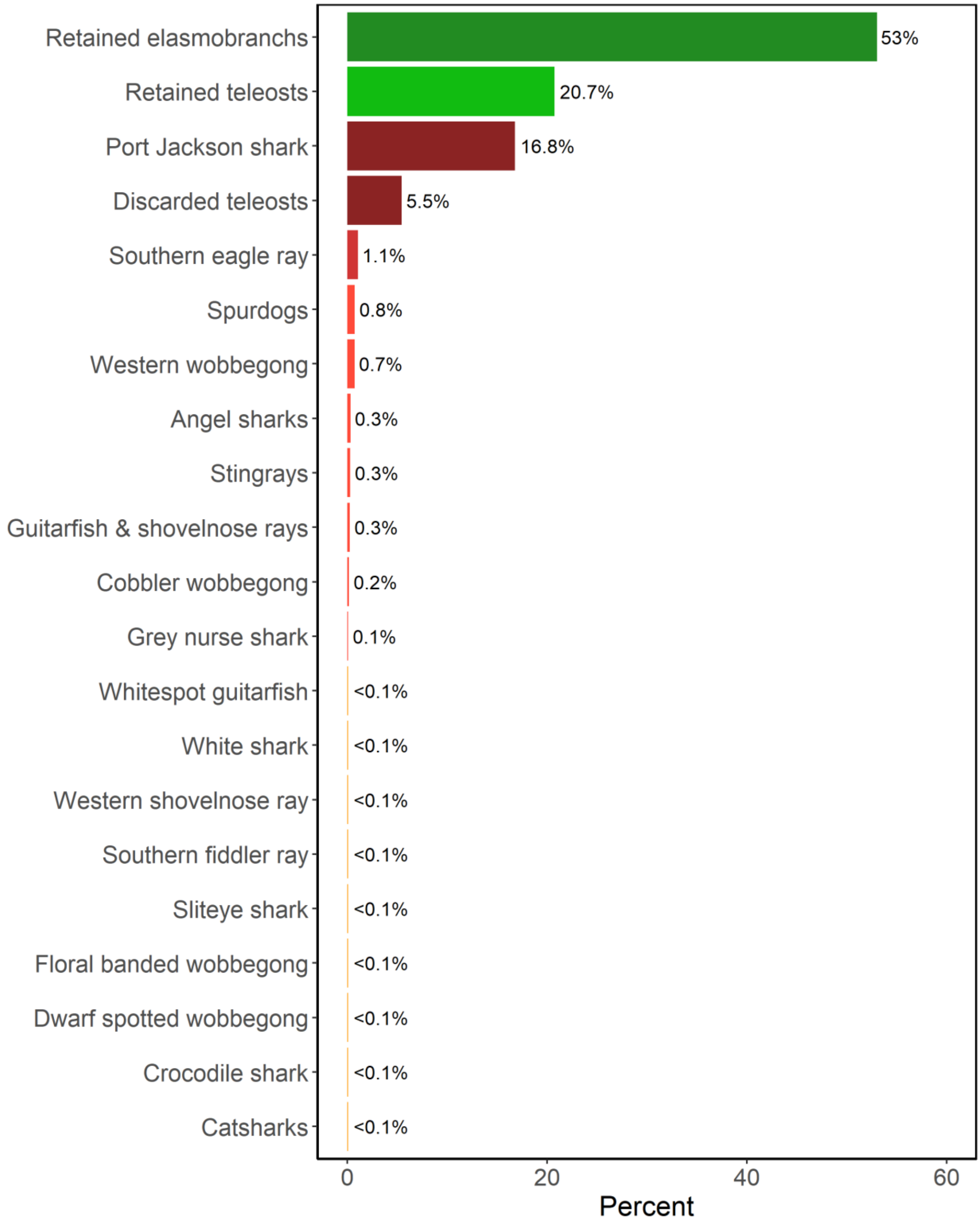


Figure 4.20. Percentage (by number) of retained (elasmobranchs and teleosts) and discarded elasmobranchs in 2,932 observed demersal gillnet sets.

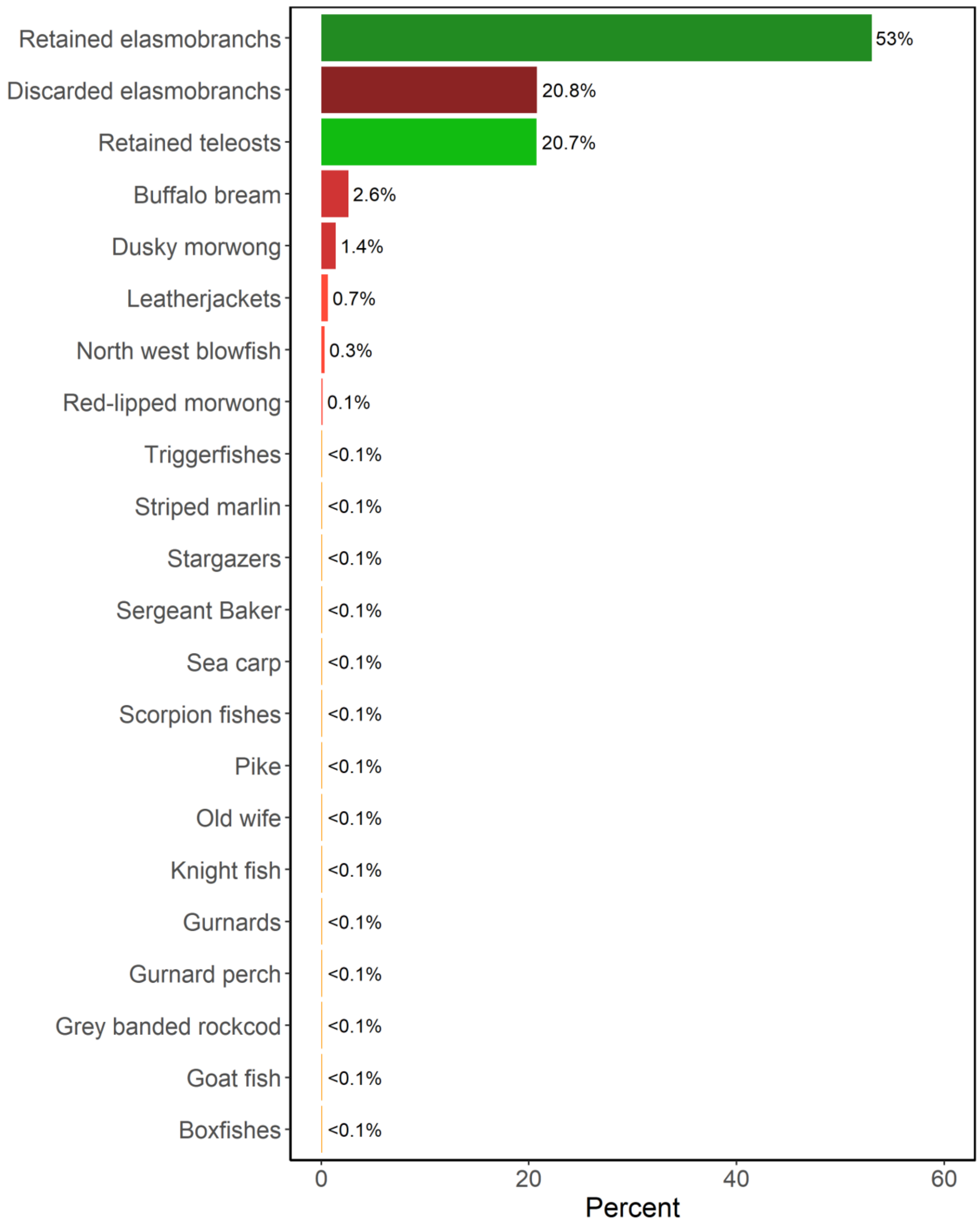


Figure 4.21. Percentage (by number) of retained (elasmobranchs and teleosts) and discarded teleosts in 2,932 observed demersal gillnet sets.

Table 4.2. Reconstructed bycatch (whole weight, in tonnes) of the main species discarded by the TDGDLF in the last five years.

Species	Scientific name	Reconstructed bycatch (tonnes)						% of total bycatch
		2014-15	2015-16	2016-17	2017-18	2018-19	Average	
Dusky morwong	*Dactylophora nigricans*	21.973	20.345	18.767	17.474	15.153	18.742	42.254
Buffalo bream	*Kyphosus spp.*	11.429	12.279	9.515	8.350	6.340	9.583	21.604
Port Jackson shark	*Heterodontus portjacksoni*	6.537	6.099	5.476	4.679	3.999	5.358	12.08

4.6.1 *Dactylophora nigricans* (dusky morwong)

Figure 4.22. Dusky morwong, *Dactylophora nigricans.*
Illustration © R.Swainston/www.anima.net.au.

The dusky morwong is widely distributed across southern Australia, from the Clarence River, NSW, to the Houtman Abrolhos, WA, including around Tasmania (https://fishesofaustralia.net.au/home/species/431, accessed 27 Jan 2021). Adults are associated with reefs, to depths of at least 30 m while juveniles are often found in seagrass and weed beds. Dusky morwongs are omnivorous, mainly consuming benthic invertebrates and have a maximum reported length of 120 cm.

The stock structure of dusky morwong is currently unknown. Other morwong species (i.e. those in the families Latridae and Cheilodactylidae) typically have a very extended (lasting many months) offshore larval phase which facilitates widespread dispersal via ocean currents and extensive population mixing (Bruce et al. 2001). On this basis, dusky morwong within south-western Australia is assumed to comprise a single genetic stock.

The biology of dusky morwong is also poorly understood. Most morwong species are relatively long-lived (20-90 years; Coulson 2019), and so it is likely that dusky morwong also have a relatively long lifespan. Limited data indicate a lifespan of at least 20 years (P. Coulson pers. comm). Long-lived species are inherently more vulnerable to over-exploitation than short-lived species (Jennings et al. 1998; Reynolds et al. 2005; Beamish et al. 2006).

Dusky morwongs are slow moving and relatively sedentary, making them potentially vulnerable to certain fishing methods such as spearfishing. However, this species is regarded as poor eating and is rarely targeted or retained by any fishery.

Recreational catches of dusky morwong in WA are negligible as the species is generally not susceptible to line fishing methods (Ryan et al. 2019). The species is at relatively low risk of incidental capture by commercial netting and trawling because these fisheries generally avoid operating close to reefs which is the main habitat for this species.

The TDGDLF is the only fishery that is known to capture significant quantities of dusky morwong in WA. The annual catch is estimated to be around 19 t, all of which are discarded (Table A.2). Individuals are likely to be dead when discarded (M. Braccini pers. obs.). The total number of dusky morwong caught and discarded by the TDGDLF is relatively small compared to the likely size of the total population in south-western Australia.

4.6.2 *Kyphosus* species (buffalo bream)

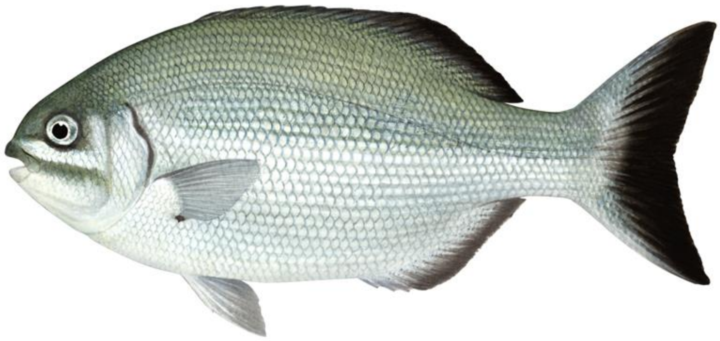


Figure 4.23. Buffalo bream, *Kyphosus sydneyanus.*
Illustration © R.Swainston/www.anima.net.au.

The TDGDLF is estimated to capture and discard around 10 t of 'buffalo bream' per year (Table A.2). This bycatch was previously reported to be *Kyphosus cornelii (*McAuley and Simpfendorfer 2003) but may actually include up to three morphologically similar *Kyphosus* species which all occur in the fishery area.

Kyphosus cornelli is endemic to WA, from Exmouth to Cape Leeuwin (Hutchins and Swainston 1986). Schools of this species are commonly observed across this range, typically over shallow reefs or in deeper water adjacent to the reef. It frequently forms mixed schools with other *Kyphosus* species, especially *K. sydneyanus*. In some areas, larger adults are territorial and will defend and maintain small algal 'gardens' (Hamilton et al. 2003). It attains a maximum length of 70 cm TL.

K. sydneyanus occurs around southern Australia from the Houtman Abrolhos Islands, WA, to Fraser Island, QLD, and also in New Zealand. It occurs on reefs to a depth of 30 m and attains a maximum length of 80 cm TL. Recently a third species, *K. gladius*, which was previously thought to be a variant of *K. sydneyanus*, was recognised to occur between the Houtman Abrolhos Islands and Albany (Knudsen and Clements 2013). This species occurs on reefs to at least 15 m and attains a maximum length of at least 52 cm TL.

The majority of effort by the TDGDLF occurs along the south coast, and most buffalo bream catches in this area are likely to be *K. sydneyanus.*

The biology of each buffalo bream species is poorly understood. Kyphosids have planktonic egg and larval phases in coastal waters which facilitates potentially widespread dispersal and population mixing. On this basis, each buffalo bream species in the TDGDLF area is assumed to comprise a single genetic stock.

Most kyphosids appear to have moderate to long lifespans. Recent examination of several specimens obtained from TDGDLF catches indicates *K. sydneyanus* can live for at least 95 years (P. Coulson pers. comm). *K. sydneyanus* is reported to reach at least 46 years in New Zealand (Ayling and Cox 1982). *K. bigibbus* attains maturity at 2-3 years, reaches its maximum size after ~10 years and has a longevity of 46 years (Ogino *et al.* 2020). A closely related species, *Scorpis aequipinnis* lives for at least 68 years (Coulson et al. 2012). These observations suggest all buffalo bream species in WA are relatively long-lived. Long-lived species are inherently more vulnerable to over-exploitation than short-lived species (Jennings et al. 1998; Reynolds et al. 2005; Beamish et al. 2006).

Buffalo bream are omnivorous. They are regarded as poor eating and rarely targeted or retained by any fishery. Recreational catches in WA are negligible (Ryan et al. 2019). The TDGDLF is the only commercial fishery that is known to capture significant quantities of buffalo bream in WA, all of which are discarded. Individuals are likely to be dead when discarded (M. Braccini pers. obs.). The total number of buffalo bream caught by the TDGDLF is relatively small compared to the likely size of the total population for each species in south-western Australia.

4.6.3 *Heterodontus portusjacksoni* (Port Jackson shark)

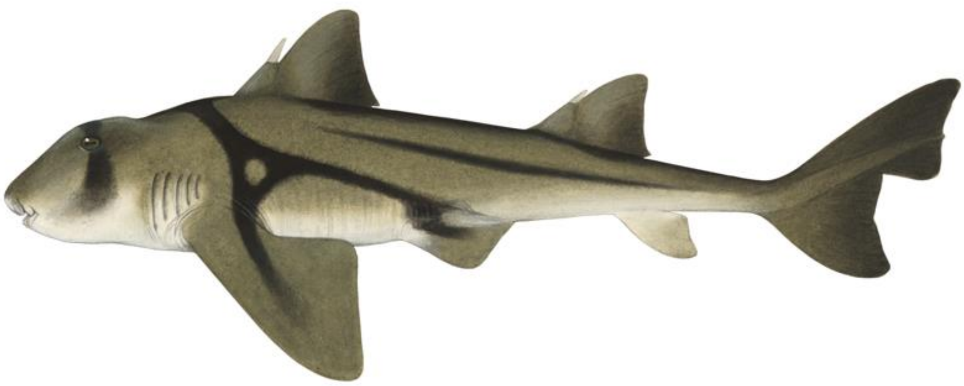


Figure 4.24. Port Jackson shark, *Heterodontus portusjacksoni.*
Illustration © R.Swainston/www.anima.net.au.

The Port Jackson shark is widespread around southern Australia from northern NSW to the Houtman Abrolhos, WA, including Tasmania. It inhabits rocky reefs and adjacent sandy and seagrass areas, to depths of 275 m. The species is nocturnal, and individuals usually shelter in caves and under ledges during the day (https://fishesofaustralia.net.au/home/species/1982, accessed 27 Jan 2021).

There are two major subpopulations of Port Jackson shark in Australia, western (WA, SA, Victoria) and eastern (NSW, Victoria and Tasmania). There may be further structuring within these subpopulations (Day et al. 2019).

Males and females aggregate in large numbers in gutters and caves during the winter/spring breeding season. Females lay 10-16 soft leathery spiral egg cases that usually become wedged into crevices on shallow reefs (Powter and Gladstone 2008). The young hatch at about 23 cm after about a year. On the east coast of Australia, Port Jackson sharks are known to migrate southwards after breeding, moving up to 850 km before returning to the same breeding reefs the next year (Powter and Gladstone 2009).

Maturity is attained by males at 55-80 cm and 6-12 years, and by females at 65-95 cm and 7-17 years, depending on region (Tovar-Ávila et al. 2007; Jones et al. 2008; Powter and Gladstone 2008; Simpfendorfer et al. 2019). Port Jackson sharks have a maximum reported length of 170 cm and estimated longevity of 35 years.

Although not targeted, Port Jackson sharks are taken in various commercial fisheries across its distribution, sometimes in high numbers, and also occasionally by recreational anglers. They are discarded (often alive) as the flesh and fins are considered to be of poor quality.

In WA, recreational boat-based fishers in the WCB and SCB catch relatively small numbers of Port Jackson sharks, with 1217 individuals estimated to have been captured and then released by boat-based fishers in 2017/18 (Ryan et al. 2019).

Port Jackson sharks are commonly discarded species in the TDGDLF (McAuley and Simpfendorfer 2003; Walker et al. 2005; Braccini and Murua in review). Over the last five years, an estimated 4-7 t is discarded annually (Table A.2). The WA Marine Aquarium Fish Managed Fishery also retains this species in small quantities, mainly in the Perth region. During 2015-2019, the annual catch ranged from 47 to 349 individuals (i.e. <2 t, assuming an average body weight of 5 kg).

Port Jackson sharks are very resilient to capture stress from gillnet, trawl, and longline gear (Frick et al. 2009; Frick et al. 2010a, 2010b; Braccini et al. 2012), suggesting that the species is likely to have high post-release survival rates from a range of fishing methods.

The status of the Port Jackson shark across its range was assessed as ‘sustainable’ in 2019 (Simpfendorfer et al. 2019). The IUCN Red List status for this species globally and in Australia is Least Concern.

4.7 Ecological Impacts

The spatial distribution of fishing effort in the TDGDLF has changed over the fishery’s development, including an expansion phase in the 1970s and early 1980s, followed by a period of peak effort during the late 1980s and 1990s, and a recent phase of lower effort levels due to management intervention (Figure 4.4 and Figure 4.26).

4.7.1 *Endangered, Threatened and Protected (ETP) Species*

ETP species interacting with vessels operating in the TDGDLF include protected sharks and rays, marine mammals, seabirds and turtles but the interaction rate is low (McAuley and Simpfendorfer 2003). Based on on-board observations collected by scientific staff across the entire distribution of these fisheries (observer coverage of 7.4% of the total fishery effort), marine mammals were caught at a rate of 1 capture per 10,000 km gn.hours, seabirds at 4 captures per 100,000 km gn.hours and turtles at 1 capture per 100,000 km gn.hours (McAuley and Simpfendorfer 2003). These data were collected between 1994 and 1999, when fishing effort was higher than current levels (Figure 4.26; 156,100 km gn.hours were reported for 2017-18, Braccini and Blay 2020).

TDGDLF fishers are required to report any interaction with ETP species in their statutory fishing returns (since 2005-06). The Department is responsible for reporting these interactions in the publicly available annual State of the Fisheries reports. The number of interactions reported by fishers operating in the TDGDLF since 2006 is shown in Figure 4.25.

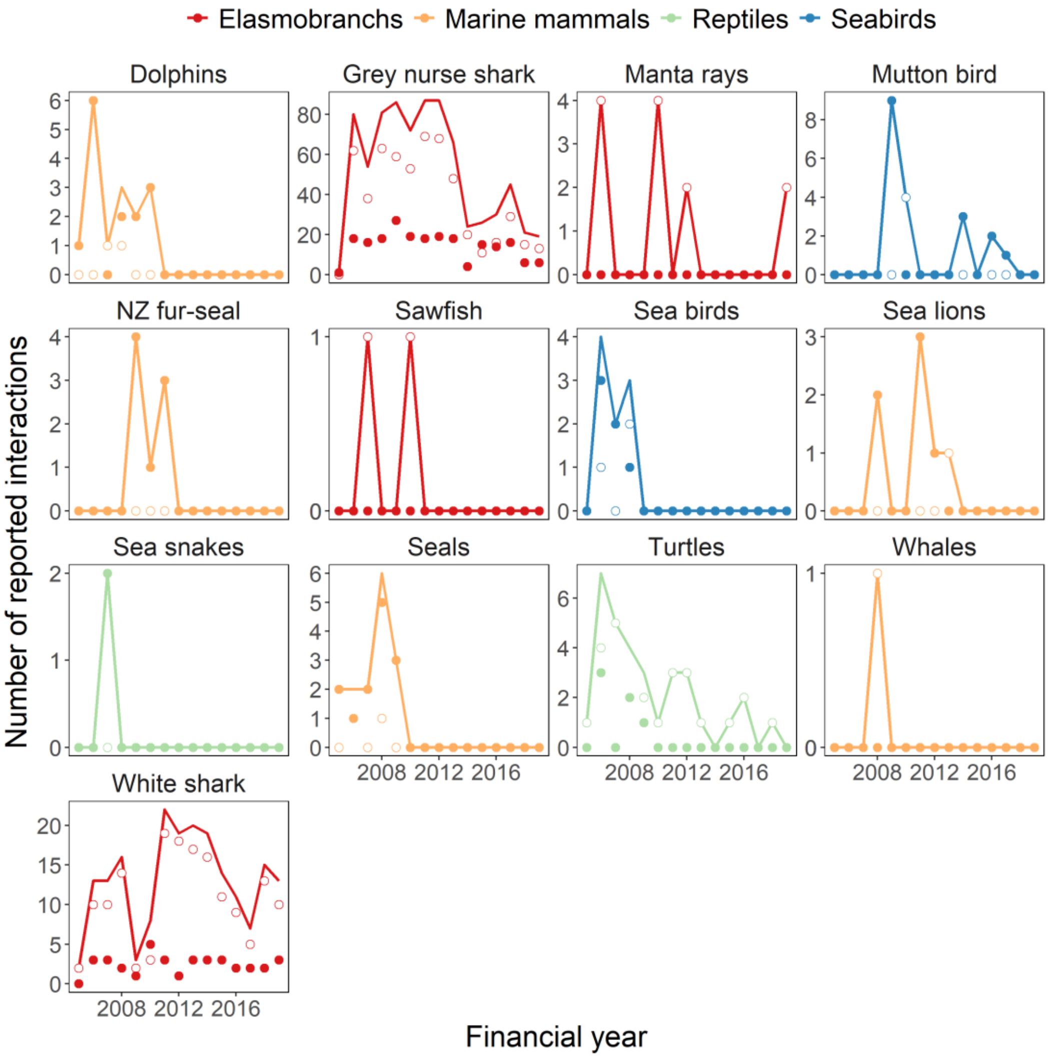


Figure 4.25. Number of ETP interactions reported by commercial fishers operating in the TDGDLF (Total, solid line; Alive, open circle; Dead, solid circle).

The large reduction in the spatio-temporal distribution of the TDGDLF is likely to have resulted in a large reduction in the bycatch of ETP species (Figure 4.26).

Quantitative information on the interactions between vessels operating in the TDGDLF and ETP species is currently being collected as part of a Parks Australia funded research project due to be completed in December 2021. This information will be available and included in the next ERA.

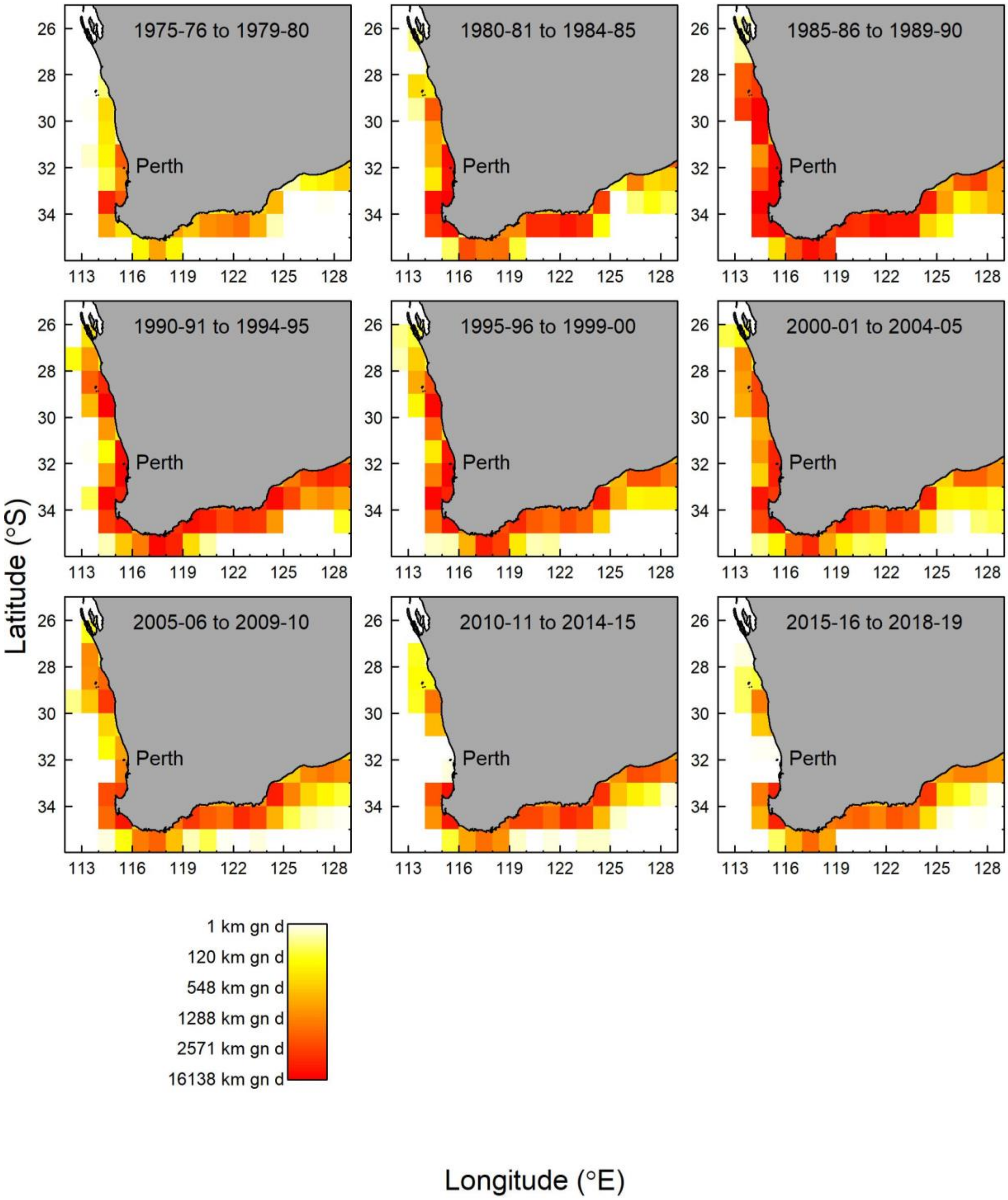


Figure 4.26. Spatio-temporal distribution of effort (km gillnet days^{-1}) in the TDGDLF by five-year intervals (financial year) and 60 nm block.

4.7.1.1 *Carcharias taurus (grey nurse shark)*

Figure 4.27. Grey nurse shark, *Carcharias taurus.*
Illustration © R.Swainston/www.anima.net.au.

The grey nurse shark has a biennial reproductive cycle and produces only two pups per litter (Chidlow et al. 2006). As a result, this species has one of the lowest intrinsic rates of population growth of all large coastal elasmobranch species and their ability to sustain fishing pressure is consequently very low (Branstetter and Musick 1994).

Two genetically distinct populations have been identified in Australia, on the east and west coasts (DoE 2014b). Populations in eastern Australia have shown severe declines as a result of commercial fishing, spearfishing and beach meshing (Reid and Krogh 1992, 1994; Pollard et al. 1996; Parker and Bucher 2000; Otway and Parker 2000; Otway et al. 2003). As a result, the eastern Australian population of grey nurse sharks is listed as Critically Endangered under the EPBC Act and is subject to a national recovery plan (DoE 2014b).

In WA, no persistent grey nurse shark aggregation sites have been known to occur (Chidlow et al. 2006; DoE 2014b). Catch and effort data supplied by commercial fishers suggest that aggregation sites may not occur within the functional area of the TDGDLF. Assuming such sites do occur within the fishery's broader geographic boundaries, they are likely to be in areas of heavy reef and/or in deeper coastal waters (>100 m), where commercial gillnet vessels do not regularly operate (Chidlow et al. 2006).

As a result, unlike other regions, grey nurse sharks are unlikely to have been subjected to targeted fishing in WA. The only significant source of mortality is from incidental capture by the TDGDLF.

The largest number of ETP species interactions in the TDGDLF are with grey nurse sharks, peaking at ~80 individuals per year between 2007-08 and 2012-13 and dropping to ~ 20 in recent years (Figure 4.25).

The west coast grey nurse shark population has been assessed as Near Threatened by the Australian IUCN Red List and as Vulnerable under the EPBC Act. The grey nurse shark is also protected in WA waters under the BC Act.

4.7.1.2 *Carcharodon carcharias (white shark)*

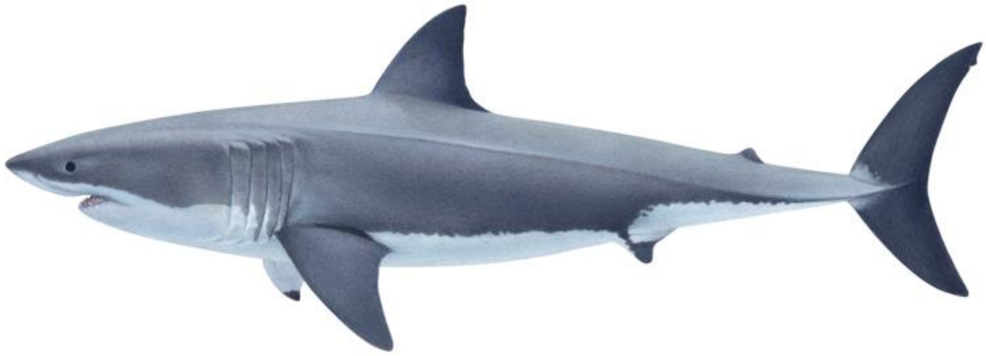


Figure 4.28. White shark, *Carcharodon carcharias.*
Illustration © R.Swainston/www.anima.net.au.

The white shark is a cosmopolitan species distributed throughout temperate oceanic and coastal waters (Last and Stevens 2009; Harasti et al. 2017). In Australia, it is most commonly found in southern waters ranging from southern QLD through to North West Cape in WA. Two genetically distinct populations have been identified in Australian waters (Blower et al. 2012): an eastern Australasian population, and a south-western Australian population ranging from western Victoria to North West Cape, WA and extending into Southern Ocean waters as far as 55° S (Bruce et al. 2018). With a few notable exceptions, white sharks are sparsely distributed throughout their range.

White sharks are long-lived and have low fecundity and late maturation, which make them sensitive to anthropogenic impacts (Bruce et al. 2018). Perceived worldwide declines in population levels, largely due to fishing pressure, have resulted in protection, through various international and national legal instruments, throughout most of their range (Bruce et al. 2018).

A 2018 study by Bruce et al. (2018), estimated the mean number of adults in the southern-western population as 1,460 (uncertainty range 760 to 2,250). Despite conducting targeted surveys in SA and WA, the study was unable to locate any nursery grounds where juvenile white sharks could reliably be found and tagged. For this reason there is currently no juvenile survival estimates for this population and no estimate of total population abundance (Bruce et al. 2018).

Modelling of population trajectories in 2017, estimated white shark population increases under most scenarios of 10% or less since protection (Braccini et al. 2017). The study also found for individuals >3 m in total length, two out of 120 scenarios showed increases of between 43% and 49% (Braccini et al. 2017; Taylor et al. 2016).

For white sharks, catch time series were reconstructed by Taylor et al. (2018) based on interviews with fishers. The reconstructed catches of white sharks in the TDGDLF reflected the history of gillnet fishing effort, peaking in the late 1980s at a level approximately fourfold greater than the estimated catch of ~30 individual sharks in 2014-15 (Taylor et al. 2018), when fishing effort was similar to current levels

(Figure 4.4). For 2014-15, commercial fishers reported 19 interactions in total (3 dead and 16 alive white sharks, Figure 4.25).

The status of the white shark globally and in Australia is Vulnerable in the IUCN Red List. The white shark is listed as Vulnerable under the EPBC Act and is the subject of a national recovery plan (DSEWPaC 2013) and protected in WA waters under the FRMA and BC Act.

4.7.1.3 *Neophoca cinerea* (*Australian sea lion)*

Figure 4.29. Australian sea lion, *Neophoca cinerea.*
Illustration © R.Swainston/www.anima.net.au.

The Australian sea lion (ASL) is the only pinniped species endemic to Australia (Gales et al. 1992). Based on geographic distance analysis among colonies, 13 distinct ASL metapopulations or regions have been identified, six in WA and seven in SA (Pitcher 2018). Although the geographic range of this species extends across WA and SA, the vast majority of pup production occurs in SA (86%; Shaughnessy et al. 2011), which is likely to also reflect the distribution of adult animals.

The ASL is slow to mature, and females have few young over their lifetime (Gales and Costa 1997). It is the only pinniped species, which has a non-annual breeding cycle, with intervals between pupping seasons of 17-18 months (Ling and Walker 1978; Higgins and Gass 1993; Shaughnessy et al. 2006; Goldsworthy et al. 2014). Female ASLs become sexually mature at 4.5−6 years of age, and males at 6 years or more (Goldsworthy 2015). The mean age of breeding females is 11 years, with the oldest breeding female recorded being 24 years old (McIntosh 2007). Age-specific survival probabilities are high (0.98) after 6 years of age and are similar for males and females; the maximum longevity recorded is 26 years for females and 21.5 years for males (McIntosh 2007).

Breeding colonies for the ASL are found only in SA and WA waters, from KI, SA, to the Houtman Abrolhos Islands, WA (Gales et al. 1994). However, the species is known to forage in Commonwealth waters adjacent to these states (DSEWPaC 2013a).

Breeding colonies occur on islands or remote sections of coastline and have been recorded at 81 sites: 34 in WA and 47 in SA (Goldsworthy 2015). Of these, around 58 are considered regular breeding colonies at which five or more pups per breeding cycle have been recorded (Shaughnessy et al. 2011). These regular breeding colonies are habitat critical to the survival of the species, because they are used to meet essential life cycle requirements (DSEWPaC 2013b). Only five sites currently produce more than 100 pups per breeding season, all of which are in SA (Goldsworthy et al. 2015).

Historically, the main threat to the ASL was over-harvest due to commercial seal hunting during the late 18th, 19th and early 20th centuries (Dennis and Shaughnessy 1996; Ling 1999). In recent times, interactions with commercial fishing, entanglement in fisheries-related marine debris and disease have been identified as key threats to the species (DSEWPaC 2013a; TSSC 2020). Additionally, there is uncertainty around fishery reported interactions with ASLs and the potential for bycatch mortalities to occur before reaching the deck (i.e. gillnet dropouts; Goldsworthy et al. 2010).

Disease is also a significant cause of mortality in ASLs, with hookworm-associated haemorrhagic enteritis a major threat to pup health and survival (TSSC 2020; Marcus et al. 2014, 2015; Lindsay et al. 2018). The extent to which hookworm may be limiting growth in colonies is unclear, but small colonies are particularly susceptible to the impacts of a disease outbreak (TSSC 2020; DSEWPaC 2013a).

In 2018, the Department implemented a refined science-based network of ASL gillnet exclusion zones in the waters of the TDGDLF. The Department's science-based approach used a model that combined the most recent data on ASL colonies, foraging behaviour and vulnerability, with gillnet effort data from fisher's statutory returns to simulate potential encounters between ASLs and gillnets (DPIRD 2018).

In total, 33 exclusion zones are in place along the WA coast ranging from 6 km to 33 km in radius. The area of each exclusion zone is based on a modelled reduction in potential encounters of 75% around the most vulnerable colonies, and 50% for the remaining colonies.

The gillnet exclusion zones closed the following areas to gillnet fishing:

- Total area (across the whole TDGDLF) of 17,390.9 km² including 493 km of coastline, including:
    - WCDGDLF - a total area of 6,725.2 km² including 127.4 km of coastline; and
    - SDGDLF – a total area of 10,655.7 km² including 365.6 km of coastline.

The location of TDGDLF fishing shots for the financial years 2016-17 to 2019-20 in relation to the ASL exclusion zones implemented in June 2018 is show in Figure 4.30. TDGDLF fishers have the option of reporting the latitude and longitude of each shot or the fishing block number. For 2018-19 and 2019-20, the minor overlap between zones and fishing shots is due to fishers reporting the block number instead of the actual shot position.

ASLs are subject to a national recovery plan and in December 2020, the Australian Government Minister for Environment, on the basis of advice from the Threatened Species Scientific Committee (TSSC), upgraded the listing status of the ASL under the EPBC Act from Vulnerable to Endangered (TSSC 2020; DSEWPaC 2013a). The TSSC noted in their assessment that, using IUCN terminology, the category change from Vulnerable to Endangered is considered a 'Nongenuine change' in listing category as it is the result of new information and a more rigorous synthesis of available information; rather than a genuine deterioration in status (TSSC 2020).

Several projects are currently in progress within the Department and with research partner organisations, which will contribute to the body of knowledge required to manage fishery interactions with ASLs. This information will be available and included in the next ERA.

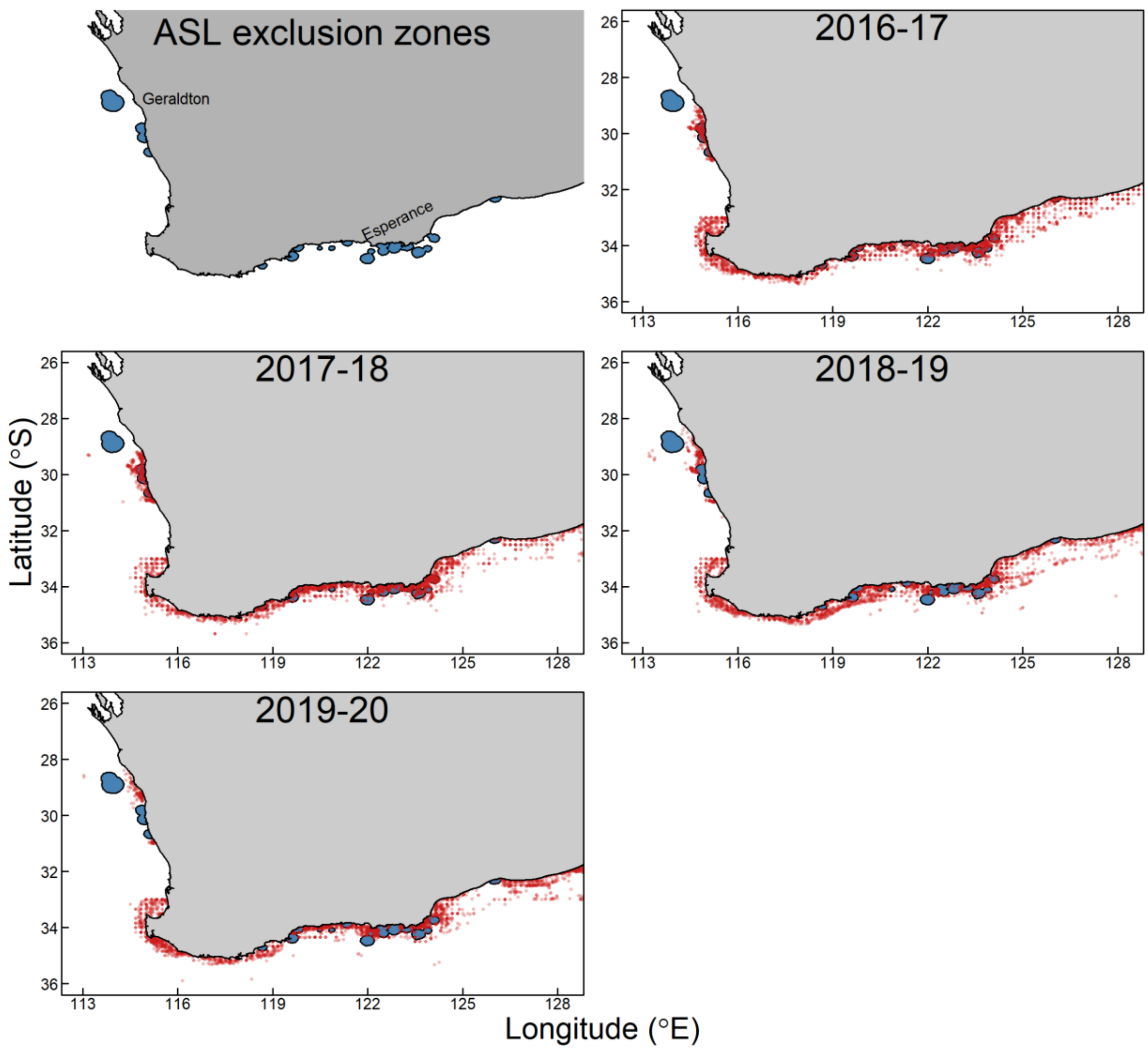


Figure 4.30. Location of ASL gillnet exclusion zones (blue polygons) for the financial years just before and after their implementation (June 2018). Also show is the reported location of TDGDLF fishing shots (red dots). NB, TDGDLF have the option of reporting the latitude and longitude of the shot or the fishing block number (10 nm block).

4.7.1.4 *Seabirds*

Although many species of seabirds occur within the boundaries of the TDGDLF, numbers of reported seabird interactions are low. A total of 15 interactions with Flesh-footed shearwaters (*Ardenna carneipes*) resulting in death have been reported within the last decade (Figure 4.25). Flesh-footed shearwaters are listed migratory species under the EPBC Act and there is currently no Conservation Advice or Recovery Plan for this species. At a State level, this species is listed as Vulnerable under the BC Act.

Pursuit predators such as shearwaters are capable of diving past 60 m in depth and typically target schools of small baitfish such as sardines and anchovy (Norriss et al. 2020). The TDGDLF employs fishing gear designed at targeting elasmobranchs and larger teleosts. Therefore, the interactions observed from the TDGDLF are likely to be incidental and random rather than through bird and fishery competition for the same resource.

4.7.1.5 *Dolphins*

All cetacean species are protected under the EPBC Act. While listed as protected species, there are currently no specific concerns for the population status of dolphins within southern WA.

A total of 16 interactions with dolphins have been reported from the TDGLDF since 2005 (Figure 4.25), with just three occurring within the last decade.

Southern Australia is recognised as important habitat for dolphin species (Bilgman et al. 2017). Some population structure is evident over regional scales (~1500 km) but at local scales populations appear to be relatively well mixed (Bilgman et al. 2008).

The South Australia Sardine (purse seine) Fishery has, in the past, been identified as a potential threat to the local dolphin population around the Adelaide Gulfs, with an estimated 450 dolphin interactions in 2004-05 (Ward et al. 2018). Due to mitigation measures introduced through an industry Code of Practice this level of interaction was drastically decreased by 2018, with only 4 dolphin mortalities in that 12-month period.

By comparison, the three dolphin interactions reported by the TDGDLF over an entire decade and over a much larger spatial scale is highly unlikely to represent a significant threat to the dolphin populations present within the waters of the fishery.

4.7.1.6 *Other ETP species*

Several other protected species have been recorded via the fishery-dependant logbook reporting, including manta rays, long-nosed fur seals, sawfish, sea snakes, turtles and a whale. The encounter rates for these groups are presented in Figure 4.25, noting the majority of these interactions are recorded as returned alive.

Sea snakes, sawfish, manta rays and the majority of turtle species have predominantly tropical distributions, and as such these interactions are likely to be edge-of-range and not detrimental to the species’ populations overall.

4.7.2 *Habitats*

The level of effort in the TDGDLF is such that the gear is deployed infrequently over approximately 40% of the fisheries' areas and under normal circumstances the physical impact of the gear on the benthic habitat is minimal. Moreover, the very small footprint of each net would combine to make a very small percentage (< 5%) of the area that would be contacted by these gears annually.

Gear is typically set on sandy substrate and occasionally on or near reef habitats. Quantitative information on the interactions between vessels (and gear) operating in the TDGDLF and habitats is currently being collected as part of a Parks Australia funded research project due to be completed in December 2021. This information will be available and included in the next ERA.

4.7.3 *Ecosystem Structure*

4.7.3.1 *Trophic interactions*

The main shark species caught by the TDGDLF are mesopredators. Although the removal of top predators can have cascading effects through marine food webs, the removal of reef sharks from coral reefs had no impact on teleost mesopredators or prey and hence no evidence of trophic cascading (Desbiens et al. 2021). Hence, the trophic effects of removing marine mesopredators remains uncertain.

A previous investigation found no evidence of any systematic change in species diversity, richness or trophic index for the TDGDLF, suggesting these fisheries were not having a material impact on food chain or ecosystem structure (Hall and Wise 2011). In addition, the spatio-temporal distribution of the TDGDLF has decreased substantially in recent years (Figure 4.26).

4.7.3.2 *Translocation (pests and disease)*

Pests and diseases may be transferred via vessels in wet areas such as bilges, decks, anchor wells and sea chests and in niche area of the hull. Fishing vessels may present additional areas including on wet fishing gear or holding tanks. Overall, fishing vessels are typically rated very low risk in terms of translocation of marine pests and diseases at an international scale but examples of local transmission of pest species such as *Undaria pinnatifida* can be identified (Bridgwood and McDonald 2014).

Given that commercial fishers are not permitted to use their boats or gear outside of Australian waters, the risk of international transmission of introduced marine pests and diseases is effectively zero. At a local level, the vessels operating in the TDGDLF have low susceptibility to inoculation from pests and diseases because they typically work in remote ocean locations and from a limited number of predominantly low-risk ports. This suggests a negligible risk of translocation of pests and diseases due the activity of this fishery.

4.7.3.3 *Ghost fishing*

Fishing vessels operating in the TDGDLF have the potential to lose fishing gear whilst fishing, which could result in the continued capture of species. It is common practice for intermediate surface float lines to be attached to nets to reduce the amount of net that is susceptible to two or more double 'bite-offs' (where both the head line and ground line are severed between the float lines) and the fragments of net would otherwise be difficult to retrieve.

4.7.4 *Broader Environment*

4.7.4.1 *Air quality*

Commercial fishing vessels operating in the TDGDLF use fuel and emit greenhouse gases. Currently, there are 25 vessels actively fishing in the TDGDLF, with an average annual effort of 150 fishing days per vessel. This fleet operates over a large geographical area and the impact of vessel emissions on air quality over this area is expected to be minor.

4.7.4.2 *Water quality*

Fishing vessels operating in TDGDLF have the potential to reduce water quality through discarding of debris and litter as well as by accidental oil and fuel spills. As discussed in Section 4.4.3, the majority of operators do not use packaged bait, reducing the likelihood of littering. The fishery also operates over a large geographical area and the impact of accidental spills on water quality over this area is expected to be negligible.

4.7.4.3 *Noise pollution*

Water is an efficient medium for transporting sound waves. In the marine environment sound transmission is highly variable and can be dependent on the acoustic properties of the seabed and surface, variations in sound speed and the temperature and salinity of the water (Richardson et al. 1995).

For most marine animals, sound is important for communication; for locating particular features, prey and peers; and for short-range and long-range navigation (Evans et al. 2016; Erbe et al. 2015). Sounds from anthropogenic sources can mask vocal communication, disrupt normal behaviours, and cause temporary or permanent threshold shifts in hearing (Evans et al. 2016; Hazel et al. 2009).

Currently, little is known regarding the effects of noise pollution for most marine species in Australia. The main anthropogenic activities producing high levels of noise are seismic surveys of sub-bottom strata, active sonars, explosions, pile driving, vessels, dredging and drill rig activities (Evans et al. 2016).

The size of vessels and low-density nature of fishing mean any impact of noise pollution from TDGDLF vessels is expected to be minor.

5.0 Recreational Fishery

In WA, recreational fishers predominantly target teleosts and crustaceans (mostly crabs and lobster). The ecological impacts of recreational fishing for teleosts and crustaceans is outside the scope of this ERA and will be assessed elsewhere.

The scope of this ERA is restricted to the impacts of catches of elasmobranchs by recreational fishers.

Estimates of recreational fishing effort and demersal elasmobranch catches and releases in the WCB and SCB are available from a number of recreational fishing surveys undertaken by the Department, including two boat-based recreational fishing surveys in the WCB in 1996/97 (Sumner and Williamson 1999) and 2005/06 (Sumner et al. 2008). More recently, a periodic state-wide survey providing a broader-scale and integrated system involving several survey methods has been used to estimate effort and catch by boat-based recreational fishers in WA (Ryan et al. 2013). Four state-wide recreational fishing surveys have been completed to date using this methodology, in 2011/12 (Ryan et al. 2013), 2013/14 (Ryan et al. 2015), 2015/16 (Ryan et al. 2017) and 2017/18 (Ryan et al. 2019).

Information on charter fishing catch and effort have been routinely collected since 2001, when a licensing framework and compulsory logbook system was implemented. Recreational, charter and commercial catches inform the stock assessment of indicator species.

Although recreational fishing is a popular pastime in WA, sharks are generally not targeted. Integrated surveys of boat-based recreational fishing in WA indicate statewide retention rates of sharks are less than 20% (Ryan et al. 2013, 2015, 2017, 2019). Although most species of sharks are generally released, gummy and whiskery sharks as exceptions, are commonly retained.

Recreational catches of sharks in WA are managed using a range of input and output controls (e.g. size, bag and possession limits; Braccini et al. 2018). Additionally, a Recreational Fishing from Boat Licence is required for any fishing activity from a powered vessel.

5.1 Fishing Gear and Methods

Sharks and rays comprise a very small fraction of the total recreational catch and are mainly taken by boat-based and shore-based recreational line fishers in the WCB and SCB (Braccini et al. 2021b; Ryan et al. 2013, 2015, 2017, 2019).

Recreational fishers are permitted to catch sharks and rays by hook and line (up to three hooks per line) or by pointed instrument.

5.2 Retained Species

Annual time series of recreational elasmobranch catches were reconstructed by Braccini et al. (2021b; Table A.3 and Table 5.1). Quantification of time series used the collected data from boat-based recreational fishing surveys (Ryan et al. 2013, 2015, 2017, 2019) and tour operator returns (charter logbooks) across the multiple bioregions of WA and scaled these data by financial year. Data were adjusted to account for known sources of bias and to improve accuracy of estimated recreational catches based on the following steps: 1) proportional allocation of catches from generic to specific taxa, 2) adjustment of estimated catch from private-boat recreational fishing to account for shore-based recreational fishing, 3) adjustment of estimated catch to account for post release mortality, and 4) conversion of estimated catch in numbers to weights (Braccini et al. 2021b).

The reconstruction of shore-based recreational catches was done by scaling the catch from private-boat anglers. This is a limitation as it assumes that both sectors have the same elasmobranch species composition. To improve the current catch estimates, targeted shore-based surveys would be required, as some elasmobranch species, such as wedgefish (Rhinidae) and guitarfish (Rhinobatidae and Glaucostegidae) are caught and released by shore-based anglers (M. Braccini pers. obs.) but do not occur in the reported boat-based catch. Estimates of post-release mortality were not available for several species so estimates from related species were used.

A total of 33 elasmobranch species were identified in the reconstructed recreational fishery catch (Table A.3). In the last five years, the reconstructed catch was predominately dusky and gummy sharks, bronze whalers and wobbegongs, averaging 25 t, 13 t, 11 t and 4 t per year, respectively (Table 5.1). These annual catches are small relative to the retained commercial catch of the same species (Table A.3).

Further information on dusky shark, gummy shark, bronze whaler, wobbegongs, hammerheads, sandbar shark and whiskery shark can be found in Section 4.5.2, Section 4.5.1, Section 4.5.5, Section 4.5.10, Section 5.4.6, Section 4.5.4 and Section 3.5.3, respectively.

Table 5.1. Reconstructed catches (whole weight, in tonnes) of the main elasmobranch species taken by recreational fishers in WA in the last five years (Braccini et al. 2021b).

Species	Scientific name	Reconstructed catch (tonnes)						% of total catch
		2014-15	2015-16	2016-17	2017-18	2018-19	Average	
Dusky shark	*C. obscurus*	24.694	24.844	25.046	25.334	25.621	25.108	30.772
Gummy shark	*Mustelus antarcticus & M. stevensi*	12.484	12.560	12.662	12.807	12.953	12.693	15.557
Bronze whaler	*Carcharhinus brachyurus*	10.884	10.950	11.039	11.165	11.292	11.066	13.562
Blacktip reef shark	*C. melanopterus*	5.384	5.417	5.461	5.523	5.586	5.474	6.709
Wobbegongs	Family Orectolobidae	3.831	3.854	3.886	3.930	3.975	3.895	4.774

Species	Scientific name	Reconstructed catch (tonnes)						% of total catch
		2014-15	2015-16	2016-17	2017-18	2018-19	Average	
Whitetip reef shark	*Triaenodon obesus*	3.236	3.256	3.282	3.320	3.357	3.290	4.032
Smooth hammerhead	*Sphyrna zygaena*	2.815	2.832	2.855	2.888	2.921	2.862	3.508
Tiger shark	*Galeocerdo cuvier*	2.746	2.763	2.786	2.818	2.850	2.792	3.422
Sandbar shark	*C. plumbeus*	2.682	2.699	2.721	2.752	2.783	2.727	3.343
Whiskery shark	*Furgaleus macki*	2.450	2.464	2.484	2.513	2.542	2.491	3.052

5.3 Ecological Impacts

Sharks and rays comprise a very small fraction of the total recreational catch and the vast majority of recreational line fishing effort is spent targeting scalefish. The ecological impacts of this activity (i.e. recreational line fishing) will be assessed in future as part of the ERA for the West Coast Demersal Scalefish Resource and South Coast Demersal Scalefish Resource.

6.0 External Factors

While a number of external influences and activities (e.g. urban developments, dredging and climate change), have the potential to impact on the productivity and sustainability of the fisheries, the Resource and the broader ecosystem in the future, these were not explicitly assessed within the scope of this ERA (see Section 2.0).

The impacts of external factors on species and their habitats will be reflected in the data collected for each fishery - for example, age and length composition, catch and effort distribution, rates of recruitment and mortality, and biomass trends. Current and future impacts of external factors, such as climate change, are considered in the risk-based weight-of-evidence stock assessments conducted for primary species. The risks posed by external factors are then managed through the harvest strategy for the Resource.

7.0 Risk Assessment Methodology

Risk assessments have been extensively used as a means to filter and prioritise the various fisheries management issues identified in Australia (Fletcher et al. 2002). The risk analysis methodology utilised for this risk assessment of the Resource is based on the global standard for risk assessment and risk management (AS/NZS

ISO 31000), which has been adopted for use in a fisheries context (see Fletcher et al. 2002; Fletcher 2005, 2015). The broader risk assessment process is summarised in Figure 7.1.

The first stage establishes the context or scope of the risk assessment, including determining which activities and geographical extents will be covered, a timeframe for the assessment and the objectives to be delivered (Section 7.1). Secondly, risk identification involves the process of recognising and describing the relevant sources of risk (Section 7.2). Once these components have been identified, risk scores are determined by evaluating the potential consequences (impacts) associated with each issue, and the likelihood (probability) of a particular level of consequence actually occurring (Section 7.3).

Risk evaluation is completed by comparing the risk scores to established levels of acceptable and undesirable risk to help inform decisions about which risks need treatment. For issues with levels of risk that are considered undesirable, risk treatment involves identifying the likely monitoring and reporting requirements and associated management actions, which can either address and/or assist in reducing the risk to acceptable levels.

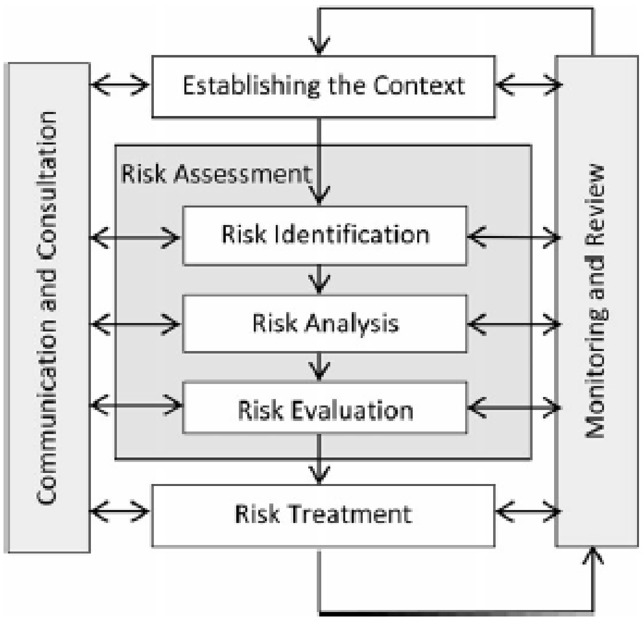


Figure 7.1. Position of risk assessment within the risk management process.

7.1 Scope

This risk assessment covered the ecological impacts of the TDGDLF, and recreational (including charter) fishers who catch sharks and rays. The calculation of risk in the context of a fishery is usually determined within a specified period, which for this assessment is the next five years (i.e. until 2026).

For the purpose of this assessment, risk is defined as *the uncertainty associated with achieving a specific management objective or outcome* (adapted from Fletcher 2015). For the Department, 'risk' is the chance of something affecting the agency's performance against the objectives laid out in their relevant legislation. In contrast, for the commercial fishing industry, the term 'risk' generally relates to the potential impacts on their long-term profitability. For the general community, 'risk' could relate to possible impact on their enjoyment of the marine environment. The aim for each of these groups is to ensure the 'risk' of an unacceptable impact is kept to an acceptable level.

An important part of the risk assessment and risk management process is communication and consultation with stakeholders. Ecological risk assessments undertaken by the Department typically engage all stakeholders of the Resource to participate in a workshop and collectively score risk levels. This allows the assessment to consider not only the ecological sustainability of all fishing activities but also how different external environmental, social and economic drivers may affect the Resource.

The current assessment considered only the ecological impacts of fishing, as required to inform the harvest strategy for the Resource.

7.2 Risk Identification

The first step in the risk assessment process was to identify ecological components relevant to the Resource being assessed. These were identified using a component tree approach (see Figure 7.2), where major risk components are deconstructed into smaller sub-components that are more specific to allow the development of operational objectives (Fletcher et al. 2002). The component trees are tailored to suit the individual circumstances of the Resource being examined.

The development of the preliminary component tree for evaluating the ecological sustainability of the Resource was based on:

- previous informal risk assessments undertaken for the fisheries and sectors;
- risks identified during previous Australian Government assessments under Parts 13 and 13A of the EPBC Act;
- identified gaps in Marine Stewardship Council (MSC) performance indicators, as identified during the pre-assessment of the TDGDLF against the MSC Fisheries Standards in 2015; and
- an internal risk assessment workshop undertaken by Departmental staff in March 2021.

There was an opportunity to add to the preliminary component tree during the ERA workshop held on 22 March 2021.

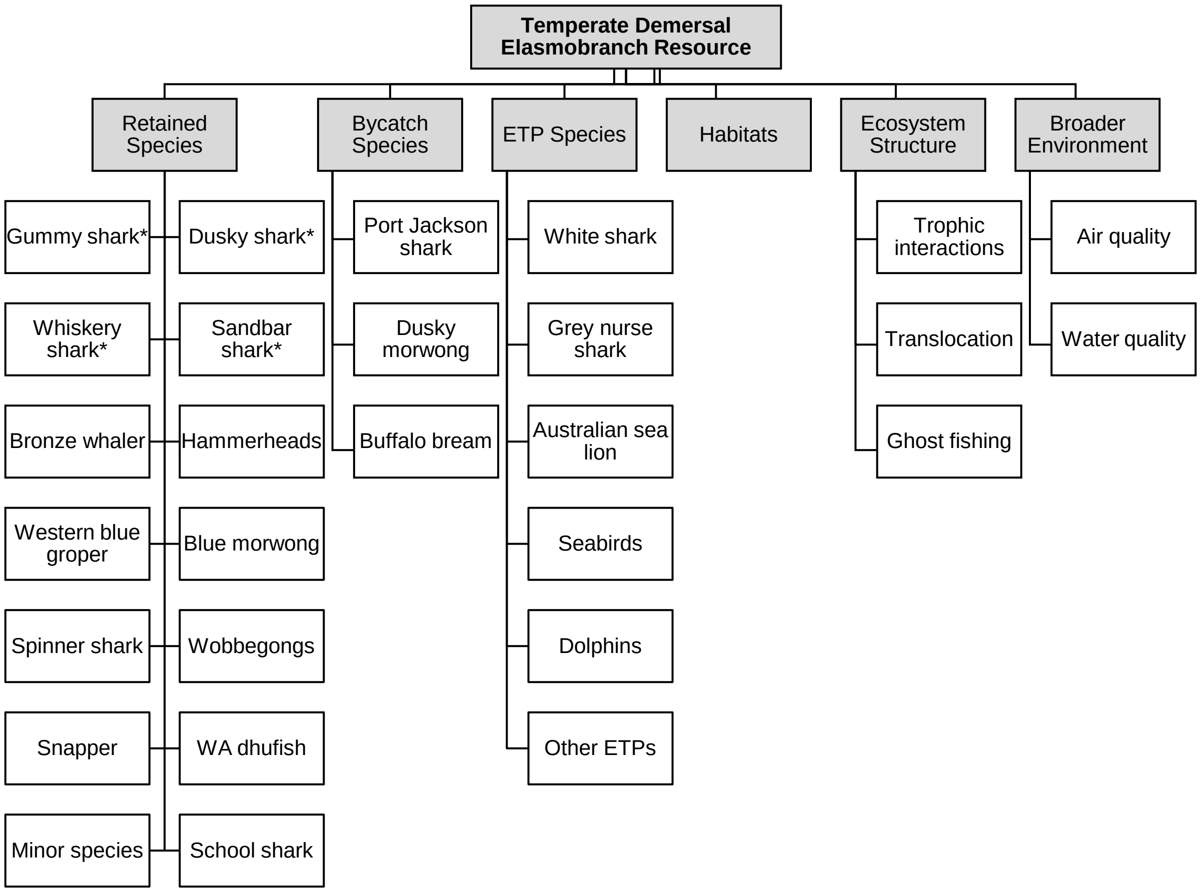


Figure 7.2. Preliminary component tree for assessing the ecological sustainability of the Temperate Demersal Elasmobranch Resource.
* denotes Primary species, that will be managed against formal harvest strategy reference levels.

7.3 Risk Assessment Process

The risk analysis process assists in separating minor acceptable risks from major, unacceptable risks and prioritising management actions. Once the relevant components for the Resource were identified, the process to prioritise each was undertaken using the ISO 31000-based qualitative risk assessment methodology. This methodology utilised a consequence-likelihood analysis, which involved the examination of the magnitude of potential consequences from fishing activities and the likelihood that those consequences will occur given current management controls (Fletcher 2015).

Although consequence and likelihood analyses can range in complexity, this assessment utilised a 4×4 matrix (Table 7.1). The consequence levels ranged from 1 (e.g. minor impact to fish stocks) to 4 (e.g. major impact to fish stocks) and likelihood levels ranged from 1 (remote: i.e. <5% probability) to 4 (likely: i.e. ≥50% probability).

Scoring involved an assessment of the likelihood that each level of consequence is occurring or is likely to occur within the five-year period specified for this assessment. If an issue is not considered to have any detectable impact, it can be considered to be a “0” consequence; however, it is preferable to score such components as there being a remote (1) likelihood of a minor (1) consequence.

The assessment used a set of pre-defined likelihood and consequence levels (see Appendix B). In total five consequence tables were used in the risk analysis to accommodate for the variety of issues and potential outcomes:

- Target/retained species – measured at a stock level;
- Non-retained (bycatch) species – measured at a stock level;
- ETP species – measured at a population or regional level;
- Habitats – measured at a regional level; and
- Ecosystem/environment – measured at a regional level.

Where relevant, the risks of each fishing sector and fishing method considered within the scope of the assessment were assessed cumulatively. For each component, the consequence and likelihood scores were evaluated to determine the highest risk score using the risk matrix (Table 7.1). Each component was then assigned a risk level within one of five categories: Negligible, Low, Medium, High or Severe (Table 7.2).

Department staff conducted an initial risk analysis of the Resource during an internal workshop held on 16 March 2021. This primarily focused on scoring the risks to the target and retained species for which quantitative information is available to assess stock status and/or their vulnerability to fishing. For Primary species, that are managed against biologically based reference levels, the risk of all fishing on the broader stocks has typically been determined as part of their stock assessments and thus there was no need to re-evaluate these scores.

An external stakeholder ERA workshop was then held at the Western Australian Fisheries and Marine Research Laboratories on 22 March 2021. A broad range of stakeholders were invited to participate in the ERA workshop (Appendix C). While the risk scores and associated narrative relating to the retained species were presented and discussed, the workshop primarily focused on assessing the risks of fishing impacts on bycatch, ETP species, benthic habitats and the broader ecosystem.

Table 7.1. 4×4 Consequence – Likelihood Risk Matrix (based on AS 4360 / ISO 31000; adapted from Department of Fisheries 2015).

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

Table 7.2. Risk levels applied to evaluate individual risk issues (modified from Fletcher 2005).

Risk Levels	Description	Likely Reporting & Monitoring Requirements	Likely Management Action
Negligible	Acceptable; Not an issue	Brief Notes – no monitoring	Nil
Low	Acceptable; No specific control measures needed	Full Notes needed – periodic monitoring	None specific
Medium	Acceptable; With current risk control measures in place (no new management required)	Full Performance Report – regular monitoring	Specific management and/or monitoring required
High	Not desirable; Continue strong management actions OR new / further risk control measures to be introduced in the near future	Full Performance Report – regular monitoring	Increased management activities needed
Severe	Unacceptable; Major changes required to management in immediate future	Recovery strategy and detailed monitoring	Increased management activities needed urgently

8.0 Risk Analysis

Thirty-three broad ecological components were identified as potentially impacted by the Resource (Figure 8.1). Where relevant, some of these were further separated into smaller categories to score the risks for individual species or groups of species. Where the individual risks of the different fishing sectors and methods could not be easily distinguished, or were assessed to be the same, these have been reported together as the cumulative risk.

The risk ratings for each risk issue considered in the assessment are summarised in Table 8.1. Note the risk justifications include comments from stakeholders who attended the workshop. While these are a summary of individual views and may not be representative of every stakeholder at the workshop, the risk scores are reflective of the group consensus at the workshop.

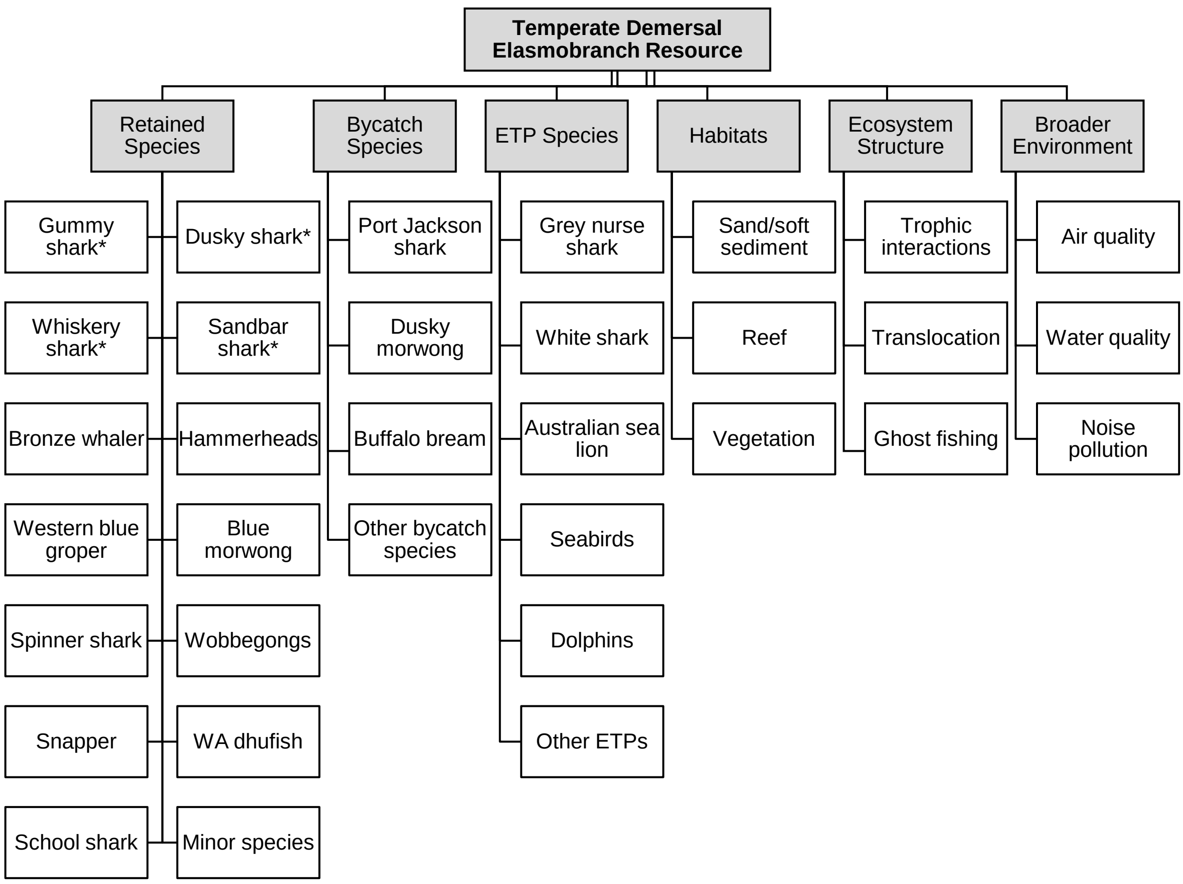


Figure 8.1. Final component tree for assessing the ecological sustainability of the Temperate Demersal Elasmobranch Resource.
* denotes Primary species, that will be managed against formal harvest strategy reference levels.

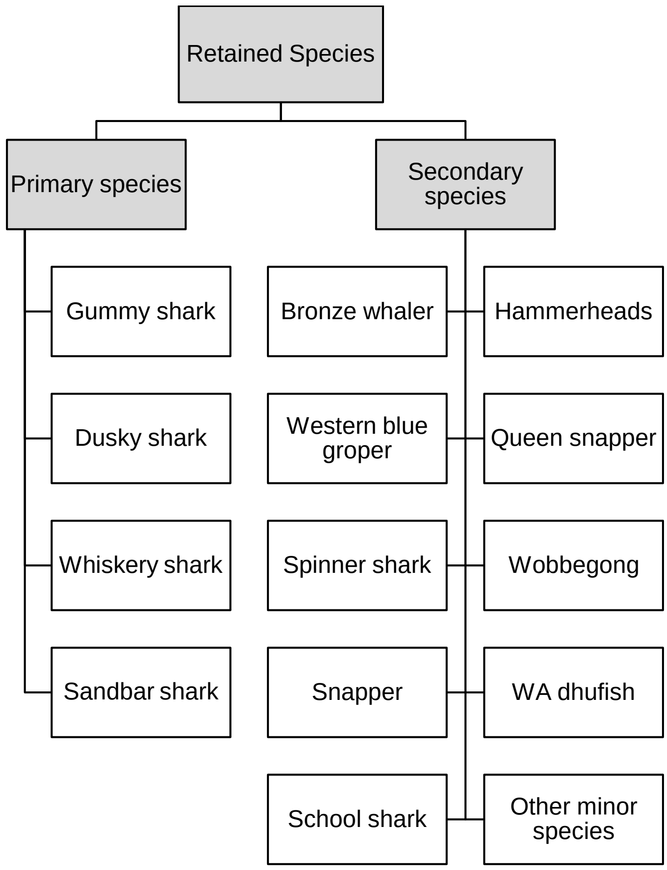
Table 8.1. Overview of the objectives, components, and risk scores and ratings considered in the 2021 ecological risk assessment of the Resource.

Aspect	Fishery Objective	Component	Fishing activities	Risk Scoring	Risk rating
Retained species (primary)	To maintain biomass of each retained species at a level where the main factor affecting recruitment is the environment	Gummy shark *	All fishing on stock	C3, L2	MEDIUM
		Dusky shark *	All fishing on stock	C3, L2	MEDIUM
		Whiskery shark *	All fishing on stock	C3, L2	MEDIUM
		Sandbar shark *	All fishing on stock	C3, L2	MEDIUM
Retained species (secondary)	To maintain biomass of each retained species at a level where the main factor affecting recruitment is the environment	Bronze whaler	All fishing on stock	C3, L2	MEDIUM
		Hammerheads	All fishing on stock	C4, L2	MEDIUM
		Western blue groper	All fishing on stock	C3, L1	LOW
		Blue morwong	All fishing on stock	C2, L4	MEDIUM
		Spinner shark	All fishing on stock	C1, L3	LOW
		Wobbegongs	All fishing on stock	C1, L3	LOW
		Snapper (WCB)	All fishing on stock	C3, L4	HIGH
		Snapper (SCB)	All fishing on stock	C2, L4	MEDIUM
		WA dhufish	All fishing on stock	C3, L4	HIGH
		School shark	All fishing on stock	C4, L4	SEVERE
		Other minor species	All fishing on stock	C1, L4	LOW
Bycatch species	To ensure fishing impacts do not result in serious or irreversible harm to bycatch (non-retained) species populations	Port Jackson shark	All fishing on stock	C1, L1	NEGLIGIBLE
		Dusky morwong	All fishing on stock	C1, L3	LOW
		Buffalo bream	All fishing on stock	C1, L3	LOW
		Other bycatch species	All fishing on stock	C1, L1	NEGLIGIBLE

Aspect	Fishery Objective	Component	Fishing activities	Risk Scoring	Risk rating
ETP species	To ensure fishing impacts do not result in serious or irreversible harm to ETP species' populations	Grey nurse shark	TDGDLF	C3, L2	MEDIUM
		White shark	TDGDLF	C3, L2	MEDIUM
		Australian sea lion	TDGDLF	C3, L3	HIGH
		Seabirds	TDGDLF	C2, L1	NEGLIGIBLE
		Dolphins	TDGDLF	C2, L2	LOW
		Other elasmobranchs	TDGDLF	C1, L1	NEGLIGIBLE
		Marine mammals	TDGDLF	C1, L1	NEGLIGIBLE
		Marine reptiles	TDGDLF	C1, L1	NEGLIGIBLE
Habitats	To ensure the effects of fishing do not result in serious or irreversible harm to habitat structure and function	Sand/soft sediment	TDGDLF	C1, L1	NEGLIGIBLE
		Reef	TDGDLF	C1, L2	NEGLIGIBLE
		Vegetation	TDGDLF	C1, L2	NEGLIGIBLE
Ecosystem Structure	To ensure the effects of fishing do not result in serious or irreversible harm to ecological processes	Trophic interactions	TDGDLF	C2, L2	LOW
		Translocation (pests, diseases)	TDGDLF	C1, L1	NEGLIGIBLE
		Ghost fishing (lost gear)	TDGDLF	C1, L1	NEGLIGIBLE
Broader Environment	To ensure the effects of fishing do not result in serious or irreversible harm to the broader environment	Air quality	TDGDLF	C1, L1	NEGLIGIBLE
		Water quality	TDGDLF	C1, L1	NEGLIGIBLE
		Noise pollution	TDGDLF	C1, L1	NEGLIGIBLE

* denotes Primary species, that will be managed against formal harvest strategy reference levels.

8.1 Retained Species



8.1.1 *Gummy shark*

Risk Rating: Cumulative impact of harvesting the Resource on gummy shark stock (C3×L2 = MEDIUM)

- Gummy shark is considered a single stock across southern Australia. However, with little genetic connectivity across regions, it is currently assessed by sub-stock.
- The majority of reported catch in WA is taken by the TDGDLF, with minor take from the recreational sector.
- The current weight-of-evidence assessment of gummy shark in WA indicates that the stock is being fished at a sustainable level (Braccini et al. 2021a).

8.1.2 *Dusky shark*

Risk Rating: Cumulative impact of harvesting the Resource on dusky shark stock (C3×L2= MEDIUM)

- The majority of reported catch in WA is taken by the TDGDLF, with minor take from the recreational sector.

- The current weight-of-evidence assessment of dusky shark in WA indicates that the stock is being fished at a sustainable level (Braccini et al. 2021a).
- There were concerns in the workshop that there is a single stock for some of the key primary species (e.g. dusky and sandbar shark) and potential fishing from the NSF would affect the southern biomass. However, hypothetical future fishing could not be addressed in this scoring as it was unlikely to occur in the five-year scope of the assessment. Should NSF operations recommence in the future, it is likely this risk assessment would need to be revised.

8.1.3 *Whiskery shark*

Risk Rating: Cumulative impact of harvesting the Resource on whiskery shark stock (C3×L2 = MEDIUM)

- Little is known about the stock structure of whiskery sharks. It is currently assessed at the state level.
- The majority of reported catch in WA is taken by the TDGDLF, with minor take from the recreational sector.
- The current weight-of-evidence assessment of whiskery shark in WA indicates that the stock is being fished at a sustainable level (Braccini et al. 2021a).

8.1.4 *Sandbar shark*

Risk Rating: Cumulative impact of harvesting the Resource on sandbar shark stock (C3×L2 = MEDIUM)

- The majority of reported catch in WA is taken by the TDGDLF, with minor take from the recreational sector.
- The current weight-of-evidence assessment of sandbar shark in WA indicates that the stock is being fished at a sustainable level (Braccini et al. 2021a).

8.1.5 *Bronze whaler*

Risk Rating: Cumulative impact of harvesting the Resource on bronze whaler stock (C3×L2 = MEDIUM)

- Bronze whaler is considered a well-mixed single stock ranging between western, southern and eastern Australia.
- Catch of bronze whalers in WA is predominately attributable to the TDGDLF but constitutes only a minor component of the total catch (average of 47 t taken annually over the last five years). There is a minor take by the recreational sector.
- There is no published quantitative assessment for the bronze whaler stock. The Shark Report Card found a stable size composition with all age classes

represented, indicating the stock is currently fished at a sustainable level (Huveneers et al. 2019a).

- It was noted that there are currently a broad distribution of size and age classes in the stock, indicating that current fishing is not affecting breeding capacity.

8.1.6 *Hammerheads*

Risk Rating: Cumulative impact of harvesting the Resource on hammerhead stocks (C4×L2 = MEDIUM)

- TDGDLF fishers currently do not report hammerheads to species levels; however, on-board observer data indicates 97% of hammerhead catch by the TDGDLF is smooth hammerhead.
- Smooth hammerhead in Australian waters comprise a single stock.
- There is no published quantitative assessment for the smooth hammerhead stock. The Shark Report Card indicated the stock is currently fished at a sustainable level (Huveneers et al. 2019a).
- The catch rates from the TDGDLF have shown stable or increasing levels over a 20-year period to 2010 suggesting a stable population (Simpfendorfer 2014).
- *Specific comment recorded for Hammerheads, AMCS.* Hammerhead species should be considered as a suite, including great and scalloped, even if they are considered a small component of the TDGDLF's hammerhead catch. AMCS noted that better species level reporting of hammerheads is required to meet the recommendations of the NDF. AMCS noted they would be seeking a review of the NDF.

8.1.7 *Western blue groper*

Risk Rating: Cumulative impact of harvesting the Resource on western blue groper stock (C3×L1 = LOW)

- The stock structure of Western blue groper in WA is uncertain. The SCB, where most of the TDGDLF catch is taken, is currently managed as a single breeding stock.
- Recent total catches are within historical limits, implying that mortality remains at an acceptable level. The south coast breeding stock is considered adequate and fished sustainably (Norriss and Walters 2020).
- It was noted that a new stock assessment is imminent for this species.

8.1.8 *Blue morwong*

Risk Rating: Cumulative impact of harvesting the Resource on blue morwong stock (C2×L4 = MEDIUM)

- Blue morwong occurs from mid-west WA to northern NSW and is believed to comprise a single stock.
- Recent total catches of blue morwong are within historical limits, implying that mortality remains at an acceptable level. The south coast breeding stock is considered adequate and fished sustainably (Norriss and Walters 2020).

8.1.9 *Spinner shark*

Risk Rating: Cumulative impact of harvesting the Resource on spinner shark stock (C1×L3 = LOW)

- The stock structure for spinner shark in Australia is currently unknown.
- Spinner sharks are predominately taken by the TDGDLF but constitute only a minor component of the catch, averaging 31 t per year for the last 5 years. Recreational fishers were estimated to have taken 1.7 t annually over the same period.
- The majority of TDGDLF catch is of smaller sharks and not the breeding stock.
- There is no published quantitative assessment for spinner shark stock. The Shark Report Card indicated the stock is currently fished at a sustainable level (Burgess and Smart 2019).

8.1.10 *Wobbegongs*

Risk Rating: Cumulative impact of harvesting the Resource on wobbegong stocks (C1×L3 = LOW)

- TDGDLF fishers currently do not report wobbegongs to species levels; however, on-board observer data suggests banded and spotted wobbegongs are likely retained and western and cobbler wobbegongs are released.
- The stock structure of banded and spotted wobbegongs is currently unknown.
- Wobbegongs are predominately taken by the TDGDLF but constitute only a minor component of the catch, averaging 28 t per year for the last 5 years. Recreational fishers are estimated to have taken 3.9 t annually over the same period.
- There are currently no published quantitative assessments for the banded or spotted wobbegong stocks. Based on catch data from various Australian fisheries the Shark Report Card currently considers the stocks to be ‘sustainable’ (Huveneers et al. 2019b, Huveneers et al. 2019c).
- Given the uncertainty around the stock, the suite of wobbegong species was scored the same as spinner sharks.

8.1.11 *Snapper*

Risk Rating: Cumulative impact of harvesting the Resource on west coast snapper stock (C3×L4 = HIGH)

Risk Rating: Cumulative impact of harvesting the Resource on south coast snapper stock (C2×L4 = MEDIUM)

- In WA, snapper stocks are divided into six management units, including three genetically related units within Shark Bay, and three oceanic units (Shark Bay oceanic, West Coast and South Coast).
- Spawning potential ratio and fishing mortality for the South Coast snapper stock are estimated to be between their management target and threshold levels (Norriss and Walters 2020).
- In 2017, fishing mortality for the West Coast snapper stock was estimated to be above the limit and spawning potential ratio was estimated to be between the limit and threshold (Fairclough and Walters 2020).
- The HIGH and MEDIUM risk ratings take into account catches by all fishing sectors. Only 15% and 30% of catches are taken by the TDGDLF in the west coast and south coast, respectively. Recreational (including charter) and commercial line fishing is the predominant driver behind the risk rating.
- Snapper in the WCB is in recovery and managed through the West Coast Demersal Scalefish Resource Harvest Strategy.

8.1.12 *WA dhufish*

Risk Rating: Cumulative impact of harvesting the Resource on West Australian dhufish stock (C3×L4 = HIGH)

- Stock assessments for West Australian dhufish completed in 2007 and 2009 indicated F was above the limit reference point and deemed unacceptable. The most recent assessment in 2017, demonstrated that F and SPR had not reached acceptable levels (i.e. the threshold) at that time.
- The HIGH risk rating takes into account catches by all fishing sectors in WA, with only 24% of commercial take of West Australian dhufish attributed to the TDGDLF. Recreational (including charter) and commercial line fishing is the predominant driver behind the risk rating.
- West Australian dhufish in the WCB is in recovery and managed through the West Coast Demersal Scalefish Resource Harvest Strategy.

8.1.13 *School shark*

Risk Rating: Cumulative impact of harvesting the Resource on school shark stock (C4×L4 = SEVERE)

- School shark is considered a single stock across southern Australia.

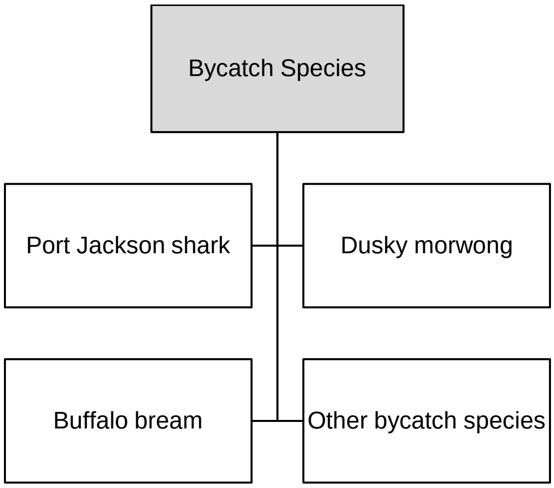
- The latest stock assessment indicated current mature biomass is below 20% unfished levels and is considered to be 'depleted' (Walker et al. 2019).
- Currently listed as Conservation Dependant under the EPBC Act.
- School shark catches in the TDGDLF are in the order of 8 t per year and are unlikely to have significantly contributed to the depletion. However, it was noted that any catch may impact a conservation-dependent species.
- School sharks are managed under AFMA's School Shark (*Galeorhinus galeus*) Stock Rebuilding Strategy (AFMA 2015b).
- The SEVERE risk rating is a result of their current stock status across southern Australia, noting the SESSF under an incidental catch limit (2020/21: 195 t) takes the majority of catch. Their schooling behaviour also makes them inherently vulnerable to large one-off catches.
- *Specific comment recorded for school shark, AMCS.* Consideration should be given to a similar but appropriately scaled approach to that implemented for the SESSF. *i.e.* incidental catch limit and move-on-rule as an action against 'severe' risk-rating.

8.1.14 *Other minor species*

Risk Rating: Cumulative impact of harvesting the Resource on other minor elasmobranch and teleost species (C1×L4 = LOW)

- Other elasmobranch and teleost species caught and retained by the TDGDLF only comprise a minor component (i.e. collectively less than 7%) of overall catches.

8.2 Bycatch Species



8.2.1 *Port Jackson shark*

Risk Rating: Cumulative impact of harvesting the Resource on the Port Jackson shark stock (C1×L1 = NEGLIGIBLE)

- Although not targeted, the Port Jackson shark is taken in various commercial fisheries across its distribution, and occasionally by recreational anglers.
- Post-release mortality of discarded Port Jackson sharks is low.
- The Port Jackson shark is widespread around southern Australia from northern NSW to the Houtman Abrolhos, WA; therefore, harvesting of the Resource is not expected to result in any measurable impact on the total Port Jackson shark stock.

8.2.2 *Dusky morwong*

Risk Rating: Cumulative impact of harvesting the Resource on dusky morwong stock (C1×L3 = LOW)

- The stock structure and biology of dusky morwong is currently unknown. They are likely to be long-lived, slow moving and relatively sedentary, making them potentially vulnerable to overfishing by certain fishing methods.
- Post release mortality is expected to be high.
- The actual level of bycatch of dusky morwong in the TDGDLF is unknown. Commercial fishery representatives at the workshop believed that the reconstructed catch of 19 t per year was an over-estimate.
- Dusky morwong is widely distributed across southern Australia, from the Clarence River, NSW, to the Houtman Abrolhos, WA; anecdotal reports suggest it is reasonably common over this range; it is not targeted or retained by any fishery in Australia; the overall stock is unlikely to be depleted.

8.2.3 *Buffalo bream*

Risk Rating: Cumulative impact of harvesting the Resource on buffalo bream stocks (C1×L3 = LOW)

- Three species of buffalo bream are potentially taken as bycatch by the TDGDLF. The current TDGDLF bycatch is thought to be mainly *K. sydneyanus*.
- The stock structure and biology of each buffalo bream species is poorly understood. They are long-lived, making them potentially vulnerable to overfishing.
- Post release mortality is expected to be high.
- Each buffalo bream species is very commonly observed over its range; they are rarely targeted or retained by any fishery; the stocks are unlikely to be depleted. The total number of each buffalo bream species caught by the

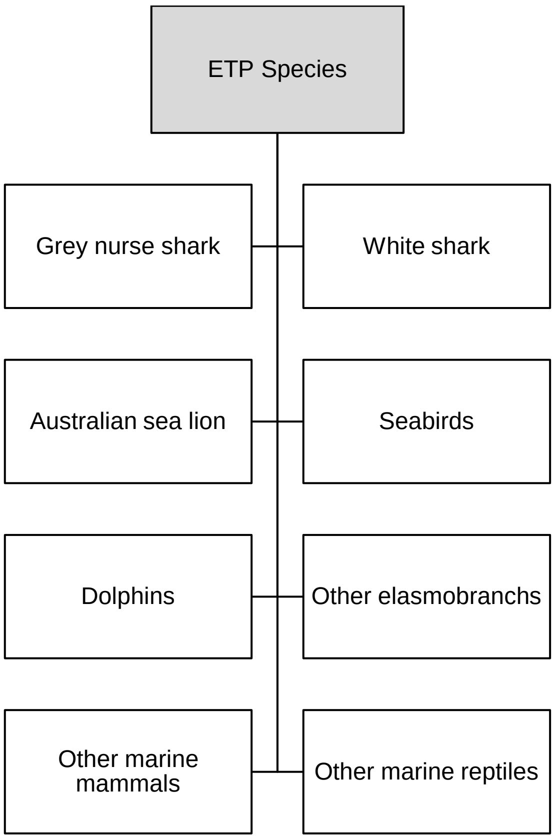
TDGDLF is relatively small compared to the likely size of the total population in south-western Australia. Therefore, the impact of the TDGDLF on each stock is expected to be minor.

8.2.4 *Other bycatch species*

Risk Rating: Cumulative impact of harvesting the Resource on other minor elasmobranch and teleost bycatch species (C1×L1 = NEGLIGIBLE)

- Available data suggests that the TDGDLF catches and discard low numbers of other elasmobranchs and teleosts species, in estimated quantities that are too low to have any measurable impact on each species.

8.3 ETP Species



8.3.1 *Grey nurse shark*

Risk Rating: Impact of fishing in the TDGDLF on grey nurse sharks (C3×L2 = MEDIUM)

- There are two separate grey nurse shark stocks in Australia (east and west coasts). There is limited information on population dynamics of the west coast population.

- Unlike other regions, grey nurse sharks are unlikely to have been subjected to targeted fishing in WA. The only significant source of mortality is from incidental capture by the TDGDLF.
- Grey nurse sharks are more likely to occur in the waters of the WCB than the SCB, as they prefer warmer waters. Effort in the WCDGDLF has decreased substantially since the 1990s and mid-2000s and the closure of the metropolitan waters has reduced the number of interactions.
- Although catches are low, the score reflects limited post-release mortality data for the species, limited data to inform a stock assessment, and the fact that they are a listed species.

8.3.2 *White shark*

Risk Rating: Impact of fishing in the TDGDLF on white sharks (C3×L2 = MEDIUM)

- There are two separate white shark populations in Australia (eastern and south-western). There is a lack of data on juvenile aggregation sites in WA. Post release mortality is also unknown.
- White sharks are a totally protected species for both commercial and recreational fishers.
- Effort in the TDGDLF has decreased since the 1980s and 1990s, which has reduced the number of interactions. ASL exclusion zones are also likely to protect white sharks from interactions with the fishery.
- Reported (fishery-dependent) catches are a very small proportion of the estimated population. Even if there was some under-reporting of interactions, these levels are unlikely to affect the recovery of the south-western population.

8.3.3 *Australian sea lions (ASL)*

Risk Rating: Impact of fishing in the TDGDLF on Australian sea lions (C3×L3 = HIGH)

- ASLs are endemic to southern Australia, with 13 distinct ASL metapopulations, six in WA waters and the remainder in SA. Due to the life history characteristics of the species, even the death of one animal per colony is likely to have demonstrable impacts.
- A network of ASL gillnet exclusion zones were implemented in the waters of the TDGDLF in 2018.
- No interactions have been reported since the zones were introduced.
- Recent research estimates a 64% reduction in the Australian population over the last 42 years; however, the modelling was primarily based on SA data and only incorporated three WA colonies. Long-term comprehensive monitoring of ASL population status in the south coast of WA has not occurred. This is

problematic when assessing the success of current spatial closures because there is an absence of baseline population data for the WA colonies.

- Since 2013, ASLs have been subject to the national *Recovery Plan for the Australian Sea Lion (Neophoca cinerea)* (DSEWPaC 2013a).
- It is within the remit of the Department of Biodiversity, Conservation and Attractions and the Australian Government Department of Agriculture, Water and the Environment to assess the status of ASL populations in WA. Noting challenges with operations, logistics and funding to support the monitoring levels required for comprehensive assessment.
- Currently, there are no reliable estimates of rates of 'drop out' (cryptic mortality) from gillnets that could occur at or below the water surface. A 2010 study in SA found 10 of 12 observed ASL bycatch mortalities dropped out of the gillnet before reaching the deck (Goldsworthy et al. 2010).
- Current understanding of the population dynamics of the species (highly fragmented, low productivity) and of WA populations (data poor) implies that the impact of interacting with a small number of ASLs, per breeding colony per cycle will have an impact on the recovery of the species.
- *Specific comment recorded for Australian sea lion, commercial fishery representatives:* The commercial sector supports the current level of management in place and noting no interactions since the exclusion zones were introduced, did not believe additional management was required. That while the lack of population data may increase the uncertainty, the very low reported interactions should help to inform the level of risk. Commercial sector representatives also highlighted that the current exclusion zones are based on simulation modelling that reduced potential encounters by 75% around the most vulnerable colonies, and 50% around remaining colonies.
- *Specific comment recorded for Australian sea lion, SARDI:* Reports of interactions are a fishery-dependent data source and require validation through independent observer programs. The lack of baseline data, systematic surveys of populations and on-board monitoring programs should increase the risk.
- *Specific comment recorded for Australian sea lion, AMCS:* Favoured a 'severe' risk rating based on the expert advice/information provided by SARDI, and ongoing concerns with lack of independent monitoring.
- A HIGH risk rating was supported as a compromise, acknowledging that additional action is desirable, and this species is susceptible to fishery induced mortality, but with the current gillnet exclusion zones in place there is no evidence that the recovery of ASL populations is clearly being impacted by the TDGDLF. The HIGH consequence is also a compromise between the fishery-dependent data reporting no interactions, and the level of uncertainty

due to lack of baseline data, systematic population surveys and on-board monitoring programs.

8.3.4 *Seabirds*

Risk Rating: Impact of fishing in the TDGDLF on seabirds (C2×L1 = NEGLIGIBLE)

- 28 interactions with seabirds have been reported through fishery-dependent logbooks since 2004, most of which were with flesh-footed shearwaters (*Ardenna carniepes)*.
- The number of reported mortalities by the TDGDLF are well below the total level of human-induced mortality that is considered unsustainable for seabird populations inhabiting the south coast of WA (Norriss et al. 2020).

8.3.5 *Dolphins*

Risk Rating: Impact of fishing in the TDGDLF on dolphins (C2×L2 = LOW)

- There are currently no specific concerns for the population status of dolphins within southern WA.
- 16 interactions with dolphins have been reported through fishery-dependent logbooks since 2005, with just three of those occurring within the last decade.
- Three dolphin interactions reported by the TDGDLF over a ten-year period and a large spatial area is highly unlikely to represent a significant threat to dolphin populations in the SCB and WCB.
- *Specific comment recorded for dolphins, AMCS*: Would like to see independent monitoring of fishing activity in the TDGDLF to address concerns over interactions with ASLs and dolphins.

8.3.6 *Other ETP species - elasmobranchs*

Risk Rating: Impact of fishing in the TDGDLF on other elasmobranch ETP species (C1×L1 = NEGLIGIBLE)

- Interactions with other elasmobranch species by the TDGDLF occur in small numbers for mostly vagrant species.

8.3.7 *Other ETP species – marine mammals*

Risk Rating: Impact of fishing in TDGDLF on other marine mammal ETP species (C1×L1 = NEGLIGIBLE)

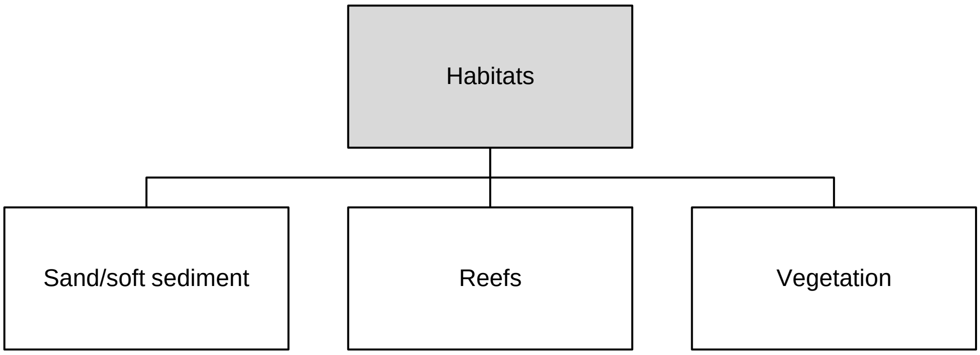
- Interactions with other marine mammal species by the TDGDLF occur in small numbers for mostly vagrant species, which are likely to be released alive.

8.3.8 *Other ETP species – marine reptiles*

Risk Rating: Impact of fishing in the TDGDLF on reptile ETP species (C1×L1 = NEGLIGIBLE)

- Interactions with reptile species by the TDGDLF occur in small numbers, mostly vagrant species and likely to be released alive.

8.4 Habitats



8.4.1 *Sand/soft sediment*

Risk Rating: Impact of fishing in the TDGDLF on sand/soft sediment habitats (C1×L1 = NEGLIGIBLE)

- Sand and soft sediment are inherently unstable, dynamic habitats.
- Demersal gillnets are lifted directly from the benthos, rather than dragged. Therefore, are unlikely to have even a minor impact on the sand and sediment.

8.4.2 *Reefs*

Risk Rating: Impact of fishing in the TDGDLF on reef habitats (C1×L2 = NEGLIGIBLE)

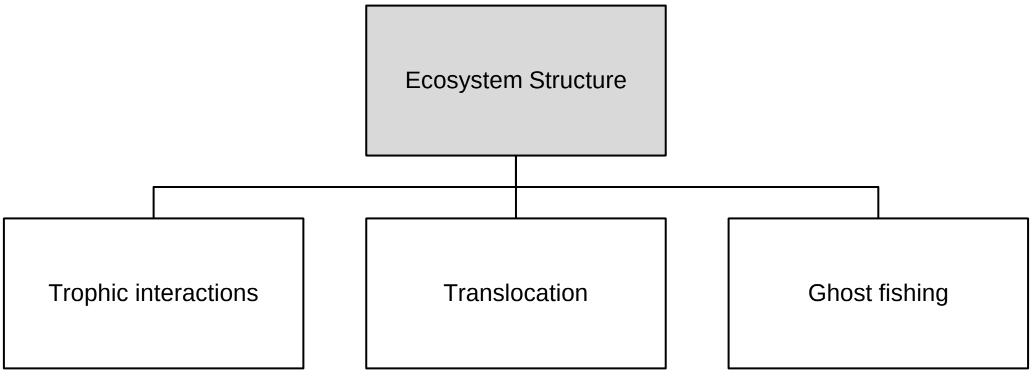
- Demersal gillnets are deployed infrequently over approximately 40% of the fisheries' area. As they're lifted directly from the benthos (rather than dragged), each net is likely to have a small footprint.
- The TDGDLF was assessed to have negligible discernible impacts on reef habitats.

8.4.3 *Vegetation*

Risk Rating: Impact of fishing in the TDGDLF on marine vegetation (e.g. macroalgae and seagrass) (C1×L2 = NEGLIGIBLE)

- Demersal gillnets are deployed infrequently and are lifted directly from the benthos, and so each net has a small footprint.
- The TDGDLF was assessed to have negligible discernible impacts on vegetated habitats.

8.5 Ecosystem Structure



8.5.1 *Trophic interactions*

Risk Rating: Impact of the TDGDLF on trophic interactions (C2×L2 = LOW)

- The removal of species retained by the TDGDLF has the potential to alter key elements of the ecosystem, including predator-prey interactions.
- Gummy, whiskery, dusky and sandbar shark stocks are currently being fished to sustainable levels and there has been no perceived material change to ecosystem structure or function.

8.5.2 *Translocation (pests & disease)*

Risk Rating: Impact of the TDGDLF on the ecosystem by translocating pests and diseases (C1×L1 = NEGLIGIBLE)

- Fishing vessels in the TDGDLF that move between different areas have the potential to introduce or translocate marine pests and/or disease.
- TDGDLF vessels do not travel into international waters and have a low susceptibility to inoculation from pests and diseases because they typically work in remote ocean locations and from a limited number of predominantly low-risk ports.

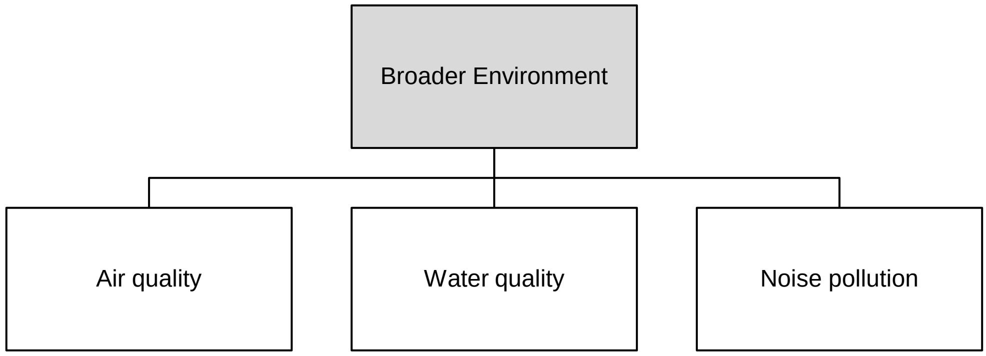
8.5.3 *Ghost fishing*

Risk Rating: Impact of the TDGDLF on the ecosystem by ghost fishing of lost gear (C1×L1 = NEGLIGIBLE)

- Fishing vessels operating in the TDGDLF have the potential to lose fishing gear whilst fishing, which could result in the continued capture of species.
- The impact of ghost fishing was assessed as negligible as the TDGDLF have not recorded any lost gear in recent history. Due to floats, partial sections of a damaged gillnet (e.g. following a bite-off event) can easily be retrieved.

- TDGDLF fishers will change their gillnet configuration depending on what species they are targeting. For example, when expecting migrations of bigger sharks, more float lines will be added to the net to mitigate potential risk of lost gear.
- Under current management arrangements, gear in the TDGDLF must also be removed from the water at least once a day.

8.6 Broader Environment



8.6.1 *Air quality*

8.6.1.1 *Fuel exhaust*

Risk Rating: Impact of fuel exhaust from commercial fishing vessels in the TDGDLF on air quality (C1×L1 = NEGLIGIBLE)

- Fishing vessels operating in the TDGDLF utilise fuel and emit exhaust fumes.
- Commercial fishing vessels steam through open ocean and when fishing, vessels are anchored with no running engines emitting exhaust fumes.
- The likelihood of any measurable impact of fuel exhaust on air quality was considered negligible.

8.6.1.2 *Greenhouse gas emissions*

Risk Rating: Impact of greenhouse gas emissions from fishing vessels in the TDGDLF on air quality (C1×L1 = NEGLIGIBLE)

- Fishing vessels operating in TDGDLF utilise fuel and emit greenhouse gas.
- The likelihood of any measurable impact of greenhouse gas emissions on air quality was considered negligible.

8.6.2 *Water quality*

8.6.2.1 *Debris/litter*

Risk Rating: Impact of debris/litter from fishing in the TDGDLF on water quality (C1×L1 = NEGLIGIBLE)

- Fishing vessels operating in TDGDLF have the potential to reduce water quality through discarding of debris and litter.
- The TDGDLF do not use packaged bait, reducing the likelihood of littering in this fishery.

8.6.2.2 *Oil/fuel discharge*

Risk Rating: Impact of oil/fuel discharge from fishing vessels in the TDGDLF on water quality (C1×L1 = NEGLIGIBLE)

- Fishing vessels operating in TDGDLF have the potential to reduce water quality through oil and fuel spills.
- The likelihood of any measurable impact of oil/fuel discharge on water quality was considered negligible.

8.6.3 *Noise pollution*

Risk Rating: Impact of noise pollution from fishing vessels in the TDGDLF (C1×L1 = NEGLIGIBLE)

- Fishing vessels operating in TDGDLF have the potential to contribute to noise pollution.
- The impact of TDGDLF vessels on noise pollution levels was assessed as negligible. There is potential for noise pollution from other sources (e.g. other larger vessels, seismic surveys), to have a greater impact upon the Resource.

9.0 Risk Evaluation & Treatment

This risk assessment assisted in the identification and evaluation of the different types of ecological risks associated with the Resource. Different levels of risk have different levels of acceptability, monitoring and reporting requirements, and management actions (see Table 7.2 for a summary).

Risks identified as negligible or low are considered acceptable, requiring either no or periodic monitoring, and no specific management actions. Issues identified as medium risk are considered acceptable provided specific monitoring, reporting, and management measures are implemented. Risks identified as high are considered ‘not desirable’, requiring strong management actions or new control measures to be introduced in the near future. Severe risks are considered ‘unacceptable’ with major changes to management required in the immediate future (Fletcher et al. 2002).

Thirty-three components associated with the ecological sustainability of the Resource were scored for risk (Table 9.1). The majority (22) were evaluated as low or negligible risks, which do not require any specific control measures (as per Fletcher et al. 2002; Table 7.2). There were 10 medium risks, which were assessed as acceptable under current monitoring and control measures already in place (i.e. no new management actions are required). This risk category mostly included retained species, where this level corresponds to the stock being above the threshold level and thus being sustainably fished.

Table 9.1. Summary of scores across each risk issue scored in the 2021 ERA of the Temperate Demersal Elasmobranch Resource.

	Component	Risk Score					Total
		Negligible	Low	Medium	High	Severe	
Ecological Sustainability	Retained species	-	4	8	2	1	15
	Bycatch species	2	2	-	-	-	4
	ETP species	4	1	2	1	-	8
	Habitats	3	-	-	-	-	3
	Ecosystem structure	2	1	-	-	-	3
	Broader environment	3	-	-	-	-	3
	Total	**14**	**8**	**10**	**3**	**1**	**36**

The risk assessment yielded three high risks that require further control measures. A high risk was given to ASLs where there is potential for interaction with commercial gillnets and a data-poor environment (noting a lack of population modelling and fishery-independent data validation). High risks were given for snapper in the West Coast Bioregion and West Australian dhufish, on the basis of formal stock assessments completed by the Department in 2017. Both stocks are in recovery and managed through the West Coast Demersal Scalefish Resource Harvest Strategy.

As a result of their current stock status across southern Australia the risk to school shark was scored as severe. School sharks are managed under AFMA's School Shark (*Galeorhinus galeus*) Stock Rebuilding Strategy (Strategy), with an incidental catch limit in place since 1997 (AFMA 2015b). The Strategy aims to rebuild the school shark stock to 20% of unfished biomass within three generations (66 years from 2008; AFMA 2015b). The majority of catch in Australia is taken by the SESSF under an incidental catch limit (2020/21: 195 t), with minimal take by the TDGDLF (an average of ~8 t/year for the last 5 years). While TDGDLF catches of school shark are unlikely to have significantly contributed to stock depletion, the assessment recognised that any catch may potentially impact the conservation dependent species.

It is recommended that the risks be reviewed in five years, or prior to the next review of the harvest strategy for the Resource, where risk scores are used as the performance indicator for the non-target ecological assets. Monitoring and assessment of the key target species will be ongoing, with the performance indicators evaluated on an annual basis.

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Appendix A: Full list of retained, bycatch and recreational catches.

Table A.1. Reported catch (whole weight, in tonnes) for all species retained in the TDGDLF for the last five years.

Species	Scientific name	Reported catch (tonnes)						% of total reported catch
		2014-15	2015-16	2016-17	2017-18	2018-19	Average	
Gummy shark	*Mustelus antarcticus*	492.30	418.57	417.26	373.23	348.34	409.94	38.6
Dusky shark	*Carcharhinus obscurus*	149.53	162.10	144.02	170.22	155.90	156.35	14.7
Whiskery shark	*Furgaleus macki*	147.38	143.37	142.29	104.38	137.40	134.96	12.7
Bronze whaler	*Carcharhinus brachyurus*	49.06	57.49	59.89	29.86	38.93	47.05	4.4
Hammerheads	*Sphyrna spp.*	60.80	47.75	42.49	31.17	39.42	44.32	4.2
Western blue groper	*Achoerodus gouldii*	42.79	41.36	40.07	30.84	31.11	37.23	3.5
Sandbar shark	*Carcharhinus plumbeus*	46.35	41.49	17.28	38.29	32.19	35.12	3.3
Blue morwong	*Nemadactylus valenciennesi*	41.66	32.64	34.33	29.07	37.72	35.08	3.3
Spinner shark	*Carcharhinus brevipinna*	38.65	48.38	25.04	22.26	21.88	31.24	2.9
Wobbegongs	*Orectolobus spp.*	28.73	29.42	34.92	20.13	24.61	27.56	2.6
Snapper	*Chrysophrys auratus*	20.88	21.91	21.64	17.94	19.24	20.32	1.9
West Australian dhufish	*Glaucosoma hebracium*	12.09	12.20	10.54	10.27	14.59	11.94	1.1
Other skates and rays	-	7.45	12.28	5.95	13.12	19.98	11.76	1.1
Other sharks	-	7.41	6.75	8.11	9.87	9.70	8.37	0.8
School shark	*Galeorhinus galeus*	1.27	11.63	26.71	0.01	0.86	8.09	0.8
Samson fish	*Seriola hipos*	11.46	8.98	6.86	4.12	6.22	7.53	0.7
Common sawshark	*Pristiophorus cirratus*	7.70	6.10	6.33	1.24	3.95	5.07	0.5
Boarfishes	Family Pentacerotidae	5.67	5.37	3.86	3.94	5.96	4.96	0.5
Mulloway	*Argyrosomus japonicus*	5.81	6.68	5.11	2.71	3.78	4.82	0.5
Nannygai	*Centroberyx spp.*	6.66	4.81	3.66	2.44	3.53	4.22	0.4
Other fish	-	4.76	4.03	3.38	4.07	4.11	4.07	0.4
Tiger shark	*Galeocerdo cuvier*	4.31	4.18	3.01	3.73	2.24	3.49	0.3
Shortfin mako	*Isurus oxyrinchus*	2.13	2.74	1.66	1.08	1.28	1.78	0.2
Baldchin groper	*Choerodon rubescens*	0.83	1.06	0.81	1.11	0.52	0.87	0.1

Species	Scientific name	Reported catch (tonnes)						% of total reported catch
		2014-15	2015-16	2016-17	2017-18	2018-19	Average	
Guitarfish & shovelnose rays	Families Rhinobatidae & Rhynchobatidae	1.08	1.03	0.65	0.91	0.61	0.86	0.1
Leatherjackets	Family Monacanthidae	0.65	0.23	0.35	0.38	1.79	0.68	0.1
Sweetlips	Family Haemulidae	0.40	0.72	0.55	0.44	1.01	0.62	0.1
Cobia	*Rachycentron canadus*	0.77	0.65	0.13	0.32	0.34	0.44	<0.1
Pencil shark	*Hypogaleus hyugaensis*	0.56	0.61	0.45	0.08	0.24	0.39	<0.1
Spurdogs	*Squalus spp.*	0.36	0.00	0.00	0.00	0.00	0.07	<0.1
Trevallies	*Pseudocaranx spp*	0.19	0.16	0.26	0.23	0.75	0.32	<0.1
Knifejaw	*Oplegnathus woodwardi*	0.39	0.12	0.37	0.09	0.42	0.28	<0.1
Yellowfin tuna	*Thunnus albacares*	0.09	0.14	0.22	0.21	0.00	0.13	<0.1
Tunas	Family Scombridae	0.10	0.20	0.28	0.07	0.13	0.16	<0.1
Parrotfishes	Family Scaridae	0.16	0.26	0.02	0.11	0.22	0.15	<0.1
Hapuku	*Polyprion oxygeneios*	0.11	0.17	0.00	0.00	0.00	0.06	<0.1
Yellow tailed kingfish	*Seriola lalandi*	0.24	0.14	0.16	0.09	0.05	0.14	<0.1
Broadnose sevengill	*Notorynchus cepedianus*	0.29	0.11	0.12	0.09	0.03	0.13	<0.1
Red throat emperor	*Lethrinus miniatus*	0.03	0.14	0.12	0.24	0.09	0.12	<0.1
Grey Banded rockcod	*Hyporthodus octofasciatus*	0.11	0.00	0.00	0.00	0.00	0.02	<0.1
Western footballer	*Neatypus obliquus*	0.01	0.13	0.24	0.06	0.07	0.10	<0.1
Deepsea trevalla	*Hyperoglyphe antarctica*	0.06	0.13	0.00	0.00	0.00	0.02	<0.1
Banded sweep	*Scorpis georgianus*	0.14	0.11	0.13	0.04	0.02	0.09	<0.1
Breaksea cod	*Epinephelides armatus*	0.07	0.02	0.05	0.10	0.16	0.08	<0.1
Bull shark	*Carcharhinus leucas*	0.08	0.00	0.00	0.00	0.00	0.02	<0.1
Spangled emperor	*Lethrinus nebulosus*	0.01	0.00	0.00	0.15	0.04	0.05	<0.1
Gurnards	Family Triglidae	0.00	0.00	0.00	0.00	0.09	0.02	<0.1
Goldspotted rockcod	*Epinephelus coioides*	0.00	0.00	0.01	0.00	0.12	0.03	<0.1
Rankin cod	*Epinephelus multinotatus*	0.00	0.00	0.00	0.06	0.05	0.02	<0.1

Species	Scientific name	Reported catch (tonnes)						% of total reported catch
		2014-15	2015-16	2016-17	2017-18	2018-19	Average	
Northern bluefin tuna	*Thunnus orientalis*	0.00	0.04	0.00	0.00	0.00	0.01	<0.1
Lemon shark	*Negaprion acutidens*	0.00	0.00	0.03	0.04	0.00	0.01	<0.1
John Dory	*Zeus faber*	0.02	0.02	0.04	0.04	0.04	0.03	<0.1
Morwongs	Family Cheilodactylidae	0.03	0.02	0.00	0.01	0.07	0.03	<0.1
Angel sharks	Family Squatinidae	0.05	0.00	0.00	0.00	0.00	0.01	<0.1
Sawsharks	Family Pristiophoridae	0.00	0.00	0.00	0.00	0.02	0.01	<0.1
Mackerels	Family Scombridae	0.00	0.02	0.00	0.00	0.00	0.01	<0.1
Emperors	Family Lethrinidae	0.02	0.05	0.01	0.00	0.00	0.02	<0.1
Spanish mackerel	*Scomberomorus commerson*	0.02	0.00	0.01	0.00	0.00	0.01	<0.1
Cods	Family Serranidae	0.00	0.01	0.02	0.00	0.04	0.01	<0.1
Chinaman rockcod	*Epinephelus rivulatus*	0.00	0.00	0.01	0.03	0.00	0.01	<0.1
Coral trout	*Plectropomus leopardus*	0.00	0.00	0.00	0.02	0.01	0.01	<0.1
Striped scat	*Selenotoca multifasciata*	0.02	0.00	0.01	0.01	0.00	0.01	<0.1
Golden trevally	*Gnathanodon speciosus*	0.02	0.00	0.00	0.00	0.00	0.01	<0.1
Bluetail mullet	*Crenimugil buchanani*	0.00	0.01	0.00	0.00	0.00	0.01	<0.1
Alfonsinos	Family Berycidae	0.00	0.00	0.00	0.00	0.01	0.01	<0.1
Amberjack	*Seriola dumerili*	0.00	0.00	0.00	0.01	0.00	0.01	<0.1
Harlequin fish	*Othos dentex*	0.00	0.00	0.01	0.01	0.01	0.01	<0.1
Yellowtail scad	*Trachurus novaezelandiae*	0.00	0.01	0.00	0.00	0.00	0.01	<0.1
Tailor	*Pomatomus saltator*	0.00	0.00	0.00	0.02	0.00	0.01	<0.1
Grey mackerel	*Scomberomorus semifasciatus*	0.00	0.00	0.01	0.00	0.01	0.01	<0.1
Red emperor	*Lutjanus sebae*	0.00	0.00	0.01	0.00	0.01	0.01	<0.1

Table A.2. Reconstructed bycatch (whole weight, in tonnes) in the TDGDLF for the last five years (Braccini and Murua in review).

Species	Scientific name	Reconstructed bycatch (tonnes)						% of total bycatch
		2014-15	2015-16	2016-17	2017-18	2018-19	Average	
Dusky morwong	*Dactylophora nigricans*	21.973	20.345	18.767	17.474	15.153	18.742	42.254
Buffalo bream	*Kyphosus spp.*	11.429	12.279	9.515	8.350	6.340	9.583	21.604
Port Jackson shark	*Heterodontus portjacksoni*	6.537	6.099	5.476	4.679	3.999	5.358	12.08
Leatherjackets	Family Monacanthidae	3.430	3.410	3.143	2.543	3.266	3.158	7.121
Southern eagle ray	*Myliobatis australis*	3.256	2.549	2.548	2.642	2.256	2.650	5.974
Angel sharks	Family Squatinidae	1.745	1.770	1.820	1.415	1.642	1.679	3.785
Guitarfish & shovelnose rays	Families Rhinobatidae & Rhynchobatidae	0.809	0.845	0.703	0.646	0.628	0.726	1.638
North west blowfish	*Lagocephalus scleratus*	0.839	0.940	0.468	0.793	0.568	0.722	1.627
Western wobbegong	*Orectolobus hutchinsi*	0.426	0.434	0.351	0.313	0.313	0.367	0.828
Spurdogs	*Squalus* spp.	0.286	0.356	0.336	0.203	0.294	0.295	0.665
Stingrays	Family Dasyatidae	0.262	0.286	0.249	0.245	0.267	0.262	0.59
Striped marlin	*Kajikia audax*	0.292	0.238	0.198	0.180	0.252	0.232	0.523
Red-lipped morwong	*Cheilodactylus rubrolabiatus*	0.231	0.264	0.169	0.206	0.099	0.194	0.437
Sergeant Baker	*Latropiscis purpurissatus*	0.089	0.087	0.066	0.078	0.062	0.076	0.172
Whitespot guitarfish	*Rhynchobatus australiae*	0.083	0.082	0.058	0.062	0.074	0.072	0.162
Scorpion fishes	*Scorpaena sumptuosa*	0.053	0.061	0.055	0.056	0.058	0.057	0.128
Sea carp	*Aplodactylus westralis*	0.038	0.046	0.038	0.030	0.027	0.036	<0.1
Sliteye shark	*Loxodon macrorhinus*	0.033	0.034	0.011	0.017	0.058	0.030	<0.1
Cobbler wobbegong	*Sutorectus tentaculatus*	0.032	0.028	0.025	0.019	0.026	0.026	<0.1
Gurnards	Family Triglidae	0.022	0.023	0.016	0.019	0.016	0.019	<0.1
Triggerfishes	Family Balistidae	0.012	0.010	0.007	0.008	0.009	0.009	<0.1
Crocodile shark	*Pseudocarcharias kamoharai*	0.005	0.011	0.009	0.005	0.007	0.007	<0.1
Southern fiddler ray	*Trygonorrhina dumerilii*	0.007	0.008	0.006	0.007	0.005	0.006	<0.1
Boxfishes	Family Ostraciidae	0.006	0.006	0.006	0.004	0.006	0.006	<0.1
Floral banded wobbegong	*Orectolobus floridus*	0.008	0.006	0.006	0.002	0.005	0.005	<0.1

Species	Scientific name	Reconstructed bycatch (tonnes)						% of total bycatch
		2014-15	2015-16	2016-17	2017-18	2018-19	Average	
Dwarf spotted wobbegong	*Orectolobus parvimaculatus*	0.006	0.006	0.003	0.005	0.003	0.005	<0.1
Pike	*Dinolestes lewini*	0.003	0.005	0.003	0.006	0.001	0.004	<0.1
Goat fish	*Upeneichthys vlamingii*	0.003	0.004	0.002	0.003	0.004	0.003	<0.1
Western shovelnose ray	*Aptychotrema vincentiana*	0.004	0.003	0.001	0.002	0.005	0.003	<0.1
Gurnard perch	*Neosebastes spp.*	0.003	0.003	0.002	0.003	0.003	0.003	<0.1
Catsharks	Family Scyliorhinidae	0.003	0.003	0.003	0.002	0.003	0.003	<0.1
Knight fish	*Cleidopus gloriamaris*	0.003	0.003	0.002	0.002	0.002	0.002	<0.1
Stargazers	Family Uranoscopidae	0.001	0.001	0.001	0.001	0.001	0.001	<0.1

Table A.3. Reconstructed catch (whole weight, in tonnes) for all sharks and rays taken by recreational in WA for the last five years (Braccini et al. 2021b).

Species	Scientific name	Reconstructed catch (tonnes)						% of total catch
		2014-15	2015-16	2016-17	2017-18	2018-19	Average	
Dusky shark	*Carcharhinus obscurus*	24.694	24.844	25.046	25.334	25.621	25.108	30.772
Gummy shark	*Mustelus antarcticus & M. stevensi*	12.484	12.560	12.662	12.807	12.953	12.693	15.557
Bronze whaler	*C. brachyurus*	10.884	10.950	11.039	11.165	11.292	11.066	13.562
Blacktip reef shark	*C. melanopterus*	5.384	5.417	5.461	5.523	5.586	5.474	6.709
Wobbegongs	Family Orectolobidae	3.831	3.854	3.886	3.930	3.975	3.895	4.774
Whitetip reef shark	*Triaenodon obesus*	3.236	3.256	3.282	3.320	3.357	3.290	4.032
Smooth hammerhead	*Sphyrna zygaena*	2.815	2.832	2.855	2.888	2.921	2.862	3.508
Tiger shark	*Galeocerdo cuvier*	2.746	2.763	2.786	2.818	2.850	2.792	3.422
Sandbar shark	*C. plumbeus*	2.682	2.699	2.721	2.752	2.783	2.727	3.343
Whiskery shark	*Furgaleus macki*	2.450	2.464	2.484	2.513	2.542	2.491	3.052
Pigeye shark	*C. amboinensis*	2.117	2.130	2.147	2.171	2.196	2.152	2.638
Spinner shark	*C. brevipinna*	1.694	1.704	1.718	1.738	1.757	1.722	2.111
Port Jackson shark	*Heterodontus portjacksoni*	1.129	1.136	1.145	1.158	1.171	1.148	1.407
Lemon shark	*Negaprion acutidens*	1.120	1.127	1.136	1.149	1.162	1.139	1.396
Rays & skates	-	0.731	0.736	0.742	0.750	0.759	0.744	0.911
Scalloped hammerhead	*S. lewini*	0.719	0.723	0.729	0.738	0.746	0.731	0.896
Sawfishes	Family Pristidae	0.679	0.683	0.688	0.696	0.704	0.690	0.846
Grey nurse shark	*Carcharias taurus*	0.410	0.413	0.416	0.421	0.426	0.417	0.511
Australian blacktip shark	*C. tilstoni*	0.078	0.078	0.079	0.080	0.081	0.079	<0.1
Blue shark	*Prionace glauca*	0.065	0.065	0.065	0.066	0.067	0.066	<0.1
Bignose shark	*C. altimus*	0.058	0.058	0.059	0.059	0.060	0.059	<0.1
School shark	*Galeorhinus galeus*	0.053	0.053	0.054	0.054	0.055	0.054	<0.1
Nervous shark	*C. cautus*	0.052	0.053	0.053	0.054	0.054	0.053	<0.1
Grey reef shark	*C. amblyrhynchos*	0.039	0.040	0.040	0.040	0.041	0.040	<0.1
Silvertip shark	*C. albimarginatus*	0.036	0.036	0.036	0.036	0.037	0.036	<0.1
Tawny shark	*Nebrius ferrugineus*	0.025	0.025	0.025	0.026	0.026	0.025	<0.1
Zebra shark	*Stegastoma tigrinum*	0.013	0.013	0.014	0.014	0.014	0.014	<0.1

Species	Scientific name	Reconstructed catch (tonnes)						% of total catch
		2014-15	2015-16	2016-17	2017-18	2018-19	Average	
Pencil shark	*Hypogaleus hyugaensis*	0.007	0.007	0.007	0.007	0.007	0.007	<0.1
Oceanic whitetip shark	*C. longimanus*	0.005	0.006	0.006	0.006	0.006	0.006	<0.1
Silky shark	*C. falciformis*	0.005	0.006	0.006	0.006	0.006	0.006	<0.1
Sliteye shark	*Loxodon macrorhinus*	0.004	0.004	0.004	0.004	0.005	0.004	<0.1
Dogfishes	Family Squalidae	0.002	0.002	0.002	0.002	0.002	0.002	<0.1
Thresher shark	*Alopias vulpinus*	0.002	0.002	0.002	0.002	0.002	0.002	<0.1

Appendix B: Likelihood and Consequence Levels

LIKELIHOOD LEVELS

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

CONSEQUENCE LEVELS

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

2. Ecological: Non-Target/Secondary (Retained & Discarded) Species		
1	Minor	Measurable but minor levels of depletion of fish stock.
2	Moderate	Maximum acceptable level of depletion of stock.
3	High	Level of depletion of stock unacceptable but still not affecting recruitment level of the stock.
4	Major	Level of depletion of stock are already affecting (or will definitely affect) future recruitment potential of the stock.

3. Ecological: Threatened, Endangered and Protected Species (ETPs)		
1	Minor	Few individuals directly impacted in most years.
2	Moderate	Level of capture is the maximum that will not impact on recovery.
3	High	Recovery may be affected.
4	Major	Recover times are clearly being impacted.

4. Ecological: Habitat		
1	Minor	Measurable impacts but very localized. Area directly affected well below maximum accepted.
2	Moderate	Maximum acceptable level of impact to habitat with no long-term impacts on region-wide habitat dynamics.
3	High	Above acceptable level of loss/impact with region-wide dynamics or related systems may begin to be impacted.
4	Major	Level of habitat loss clearly generating region-wide effects on dynamics and related systems.

5. Ecological: Ecosystem/Environment		
1	Minor	Measurable but minor changes to the environment or ecosystem structure but no measurable change to function.
2	Moderate	Maximum acceptable level of change to the environment or ecosystem structure with no material change in function.
3	High	Ecosystem function altered to an unacceptable level with some function or major components now missing and/or new species are prevalent.
4	Major	Long-term, significant impact with an extreme change to both ecosystem structure and function; different dynamics now occur with different species/groups now the major targets of capture or surveys.

Appendix C: ERA workshop stakeholders

Table C.1. List of invited ERA workshop stakeholders.

Name	Organisation
Darryl Hockey	Western Australian Fishing Industry Council
Matt Pember	Western Australian Fishing Industry Council
Bev Cooke	Commercial representative
Steve Buckridge	Commercial representative
Neville Mansted	Commercial representative
Nils Stokke	Commercial representative
Matt Benson-Lidholm	Southern Seafood Producers WA Association
Neil MacGuffie	Southern Seafood Producers WA Association
Andrew Rowland	Recfishwest
Leyland Campbell	Recfishwest
Kelly Waples	Department of Biodiversity, Conservation and Attractions
Holly Raudino	Department of Biodiversity, Conservation and Attractions
Tooni Mahto	Australian Marine Conservation Society
Leo Guida	Australian Marine Conservation Society
Lawrence Chlebeck	Humane Society International
Jeff Hansen	Sea Shepherd
Simon Goldsworthy	South Australian Research and Development Institute
Lesley Gidding-Reeve	Department of Agriculture, Water and the Environment
Darci Wallis	Australian Fisheries Management Authority
Sally Weekes	Australian Fisheries Management Authority
Natalie Couchman	Australian Fisheries Management Authority
Colin Simpfendorfer	James Cook University
Brett Molony	CSIRO
Vicki Stokes	Birdlife Australia
James Woodhams	Australian Bureau of Agricultural and Resource Economics and Sciences
Richard Campbell	The Nature Conservancy
Lynda Bellchambers	DPIRD (Aquatic Science and Assessment)
Matias Braccini	DPIRD (Aquatic Science and Assessment)
Steve Taylor	DPIRD (Aquatic Science and Assessment)
Mat Hourston	DPIRD (Aquatic Science and Assessment)
Kim Smith	DPIRD (Aquatic Science and Assessment)
Cameron Desfosses	DPIRD (Aquatic Science and Assessment)
Alex Hesp	DPIRD (Aquatic Science and Assessment)
Clinton Syers	DPIRD (Aquatic Resource Management)
Shane Walters	DPIRD (Aquatic Resource Management)
Maddison Watt	DPIRD (Aquatic Resource Management)
Russell Adams	DPIRD (Compliance)
Stephanie Nicoloff	DPIRD (VMS)
Louise Russell-Cargill	DPIRD (VMS)

Table C.2. List of ERA workshop attendees.

Name	Organisation
Lynda Bellchambers (Facilitator)	DPIRD (Aquatic Science and Assessment)
Mat Hourston (Facilitator)	DPIRD (Aquatic Science and Assessment)
Kim Smith (Facilitator)	DPIRD (Aquatic Science and Assessment)
Matt Pember	Western Australian Fishing Industry Council
Bev Cooke	Commercial representative
Steve Buckridge	Commercial representative
Neville Mansted	Commercial representative
Nils Stokke	Commercial representative
Neil MacGuffie	Southern Seafood Producers WA Association
Leyland Campbell	Recfishwest
Kelly Waples	Department of Biodiversity, Conservation and Attractions
Leo Guida	Australian Marine Conservation Society
Lawrence Chlebeck	Humane Society International
Jeff Hansen	Sea Shepherd
Simon Goldsworthy	South Australian Research and Development Institute
Natalie Couchman	Australian Fisheries Management Authority
Darci Wallis	Australian Fisheries Management Authority
Colin Simpfendorfer	James Cook University
Richard Campbell	The Nature Conservancy
Matias Braccini	DPIRD (Aquatic Science and Assessment)
Steve Taylor	DPIRD (Aquatic Science and Assessment)
Cameron Desfosses	DPIRD (Aquatic Science and Assessment)
Clinton Syers	DPIRD (Aquatic Resource Management)
Shane Walters	DPIRD (Aquatic Resource Management)
Maddison Watt	DPIRD (Aquatic Resource Management)
Louise Russell-Cargill	DPIRD (VMS)

Table C.3. List of ERA workshop apologies.

Name	Organisation
Darryl Hockey	Western Australian Fishing Industry Council
Matt Benson-Lidholm	Southern Seafood Producers WA Association
Andrew Rowland	Recfishwest
Holly Raudino	Department of Biodiversity, Conservation and Attractions
Tooni Mahto	Australian Marine Conservation Society
Lesley Gidding-Reeve	Department of Agriculture, Water and the Environment
Sally Weekes	Australian Fisheries Management Authority
Brett Molony	CSIRO
Vicki Stokes	Birdlife Australia
James Woodhams	Australian Bureau of Agricultural and Resource Economics and Sciences
Russell Adams	DPIRD (Compliance)
Stephanie Nicoloff	DPIRD (VMS)