GOVERNMENT OF
WESTERN AUSTRALIA

Department of
**Primary Industries and
Regional Development**

Resource Assessment Report

No. 19

Statewide Large Pelagic Resource

in

Western Australia

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Executive Summary

- The large pelagic resource is distributed throughout Western Australia (WA) in offshore pelagic and nearshore waters and includes a range of tropical and temperate species, such as mackerels, barracuda, billfishes, cobia, large trevallies, mahi mahi and tunas.
- The three indicator species for the resource are Spanish mackerel (*Scomberomorus commerson*) and Grey mackerel (*Scomberomorus semifasciatus*) for the tropical species and Samson fish (*Seriola hippos*) for the temperate species.
- Status of Australian Fish Stocks (SAFS) reporting for the large pelagic resource requires the additional assessment and reporting of Cobia (*Rachycentron canadum*), Yellowtail kingfish (*Seriola hippos*), Mahi mahi (*Coryphaena hippurus*), School mackerel (*Scomberomorus queenslandicus*) and Spotted mackerel (*Scomberomorus munroi*), although the catch levels in WA for the later four are low (<5 t) or negligible.
- SAFS reporting also includes large pelagic species caught in the Commonwealth managed Western Tuna and Billfish Fishery (WTBF) such as, Swordfish (*Xiaphus gladius*), Bigeye tuna (*Thunnus obesus*), Southern bluefin tuna (*Thunnus maccoyii*), and Yellowfin tuna (*Thunnus albacares*), for which WA does not currently contribute to the reporting or assessment as state based commercial fishery catch levels are negligible but there is some minor state based recreational and charter catch of the latter two tuna species of up to 15 t.
- Commercially the resource is predominantly accessed by the Mackerel Managed Fishery (MMF) in the North Coast (NCB) and Gascoyne Coast Bioregions (GCB) using trolled lines targeting Spanish mackerel which constitutes up to 80% of the WA commercial large pelagic catch.
- The recreational and charter fishery accesses the large pelagic resource throughout the state mainly by line fishing and some spearfishing with high release rates.
- Annual catch data for each indicator species and annual commercial catch rate for Spanish mackerel are monitored in each management area of the MMF.
- From 2008-2017 the annual WA commercial catch range for Spanish mackerel of 272-320 t has been within the catch tolerance range of 246-430 t but the 2018 catch of 214 t was below this, for various reasons.
- The nominal catch rates (kg/day) for the two management areas in the NCB (Kimberley and Pilbara) of the MMF have been relatively stable but declined over the past 4 years.
- The annual commercial catches of Spanish mackerel in the Pilbara and Gascoyne/West Coast management areas of the MMF have been at or below catch tolerance levels for most years since they were set due to a reduction in fishing effort with the introduction of quotas in 2006 and require review.

- No reference levels are set for Grey mackerel or Samson fish and annual commercial catches for the later are at historically low levels, due primarily to low targeting and recent management changes, particularly in the West Coast Bioregion (WCB).
- The MMF has reported catches in a daily logbook for over 12 years and these finer scale data have been assessed to conduct a catch rate standardisation for the fishery, although 90% of catch is taken by four vessels so confidentiality is an issue.
- The estimated statewide retained harvest by boat-based recreational fishers of the three large pelagic indicator species over the past four surveys from 2011/12 to 2017/18 is 42-107 t. Over the past 10 years (2009-18) the charter boats combined retained catch for these species ranged 15-25 t. Spanish mackerel dominate the retained recreational and charter catches, at over 75% of the resource, and by weight are the 5th and 2nd highest retained finfish species, respectively.
- For most large pelagic species the majority of the recreational and charter catch is released/discarded, typically 70%, but up to 100% for some species with possible high mortality rates.
- Ongoing unknown, but likely high degree of depredation and discard mortality are common among the species in the large pelagic resource. This is particularly important with the high release rates reported by recreational and charter fishers for many species.
- Large pelagic species are generally highly resilient to fishing pressure with low risk PSA scores from 2.02-2.5, with the added resilience of size limits, bag limits for most species and commercial quotas for Spanish mackerel and Grey mackerel.
- Weight of evidence assessments have deemed that all large pelagic species have an acceptable/adequate level of fishing mortality and estimates of relative spawning biomass, with current management settings maintaining risk at acceptable (medium) level for Spanish mackerel, Samson fish, and Yellowtail kingfish plus acceptable (low) levels for Cobia, Grey mackerel, School mackerel, Spotted mackerel and Mahi mahi.
- Future monitoring includes the industry based collection of Spanish mackerel samples for an age-based assessment in 2021 of the main exploited commercial species and development of standardised catch rates from the daily logbook data.

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List of Abbreviations

CDR	Catch Disposal Record
CILF	Christmas Island Line Fishery
DPIRD	Department of Primary Industries and Regional Development (Western Australia, formerly Department of Fisheries)
DoF	Department of Fisheries, Western Australia
EBFM	Ecosystem-Based Fisheries Management
ESD	Ecologically Sustainable Development
EPBC	Environment Protection and Biodiversity Conservation (Act)
FRMA	Fish Resources Management Act
GCB	Gascoyne Coast Bioregion
GDSMF	Gascoyne Demersal Scalefish Managed Fishery
IOTC	Indian Ocean Tuna Commission
JASDGDLMF	Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery
MMF	Mackerel Managed Fishery
MSC	Marine Stewardship Council
NCB	North Coast Bioregion
NDS	Northern Demersal Scalefish
NPE	Northern Pelagic Ecosystem
PFTMF	Pilbara Fish Trawl Managed Fishery.
PLF	Pilbara Line Fishery
SCOAF	South Coast Open Access Fishery
SAFS	Status of Australian Fish Stocks
SBBSMNF	Shark Bay Beach Seine and Mesh Net Fishery
SCWL	South Coast Wetline open access fishery
TDGDLMF	Temperate Demersal Gillnet and Demersal Longline Managed Fishery
WA	Western Australia
WCB	West Coast Bioregion
WCDGDLMF	West Coast Demersal Gillnet and Demersal Longline Managed Fishery
WCDSMF	West Coast Demersal Scalefish Managed Fishery
VMS	Vessel Monitoring System

1.0 Scope

This document provides a cumulative description and assessment of the Large Pelagic Finfish Resource and all of the fishing activities (i.e. fisheries / fishing sectors) affecting this resource in Western Australia (WA). The overall resource comprises around 20 species of tropical and temperate pelagic finfish that inhabit pelagic waters of Western Australia.

The report is focused on the indicator species used to assess the suites of large pelagic scalefish that comprise this resource namely; Spanish mackerel (*Scomberomorus commerson*), Grey mackerel (*Scomberomorus semifasciatus*), and Samson fish (*Seriola hippos*). The former two species are primarily captured by trolled lines by the Mackerel Managed Fishery (MMF) in the North Coast (NCB) and Gascoyne Coast Bioregions (GCB) while the later species is predominantly taken as bycatch in the South Coast open access Wetline fishery (SCWL), Temperate Demersal Gillnet and Demersal Longline Managed Fishery (TDGDLMF), and West Coast Demersal Scalefish Managed Fishery (WCDSMF). The report also contains information and assessment of other non-indicator large pelagic species required for other reporting requirements.

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

2.0 How the Department Operates

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

Implementation of EBFM involves a risk-based approach to monitoring and assessing the cumulative impacts on WA's aquatic resources from all fishing activities (commercial, recreational, customary), operating at a bioregional or ecosystem level. The level of risk to each resource is used as a key input to the Department of Primary Industries and Regional Development (DPIRD) Risk Register, which is an integral component of the annual planning cycle for assigning activity priorities (research, management, compliance, education etc.) across each bioregion. A summary of the Department's risk-based planning annual cycle that is delivering EBFM in the long-term is provided in Figure 0.1.

To ensure that management is effective in achieving the relevant ecological, economic and social objectives, formal harvest strategies are being developed for each resource. These harvest strategies outline the performance indicators used to measure how well objectives are being met and set out control rules that specify the management actions to be taken in situations when objectives are not being met. The WA harvest strategy policy (DoF 2015) has been designed to ensure that the harvest strategies cover the broader scope EBFM and thus considers not only fishing impacts of target species but also other retained species, bycatch, endangered, threatened and protected (ETP) species, habitats and other ecological components (Fletcher et al. 2016).

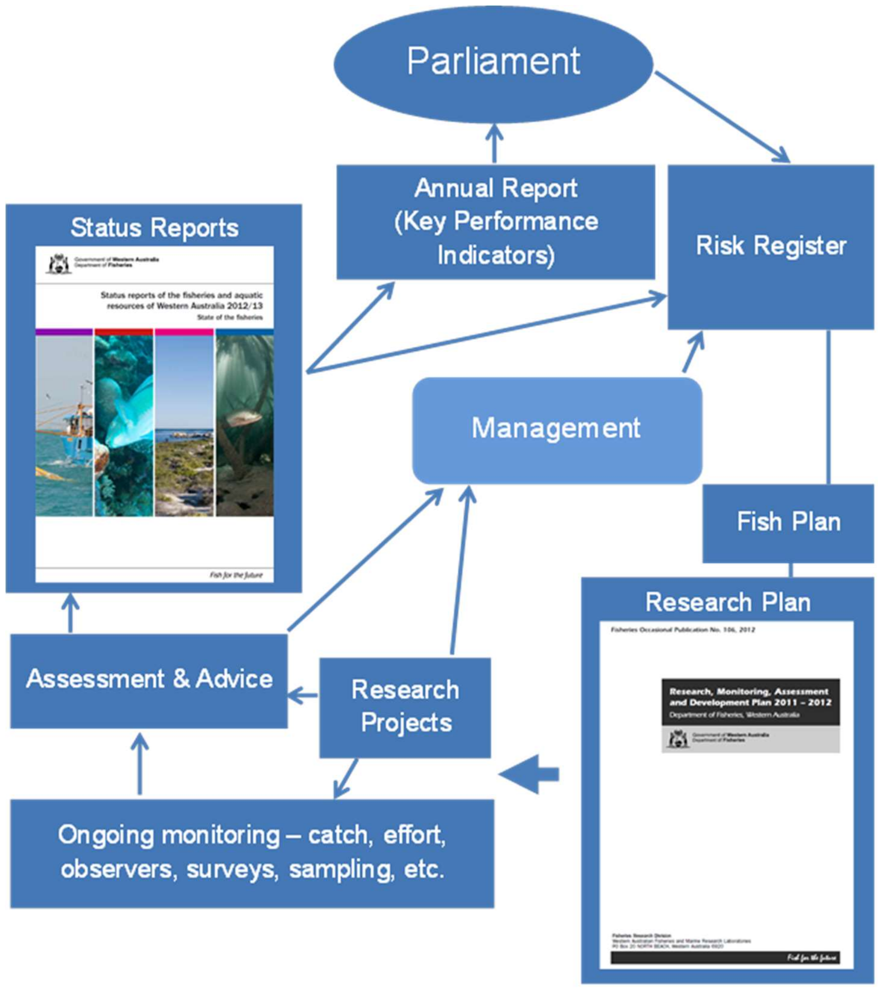

Figure 0.1. An outline of the risk-based planning cycle used for determining Departmental priorities and activities

3.0 Aquatic Environment

The large pelagic resource is distributed throughout all of the bioregions in WA (Figure 3.1), with most species undertaking broad scale movements and occurring in more than two bioregions. The species can be broadly split into the tropical (predominantly occurring in the Northern and Gascoyne Bioregions) and temperate (West and South Coast Bioregions) groups, although some species do occur in three or occasionally four bioregions.

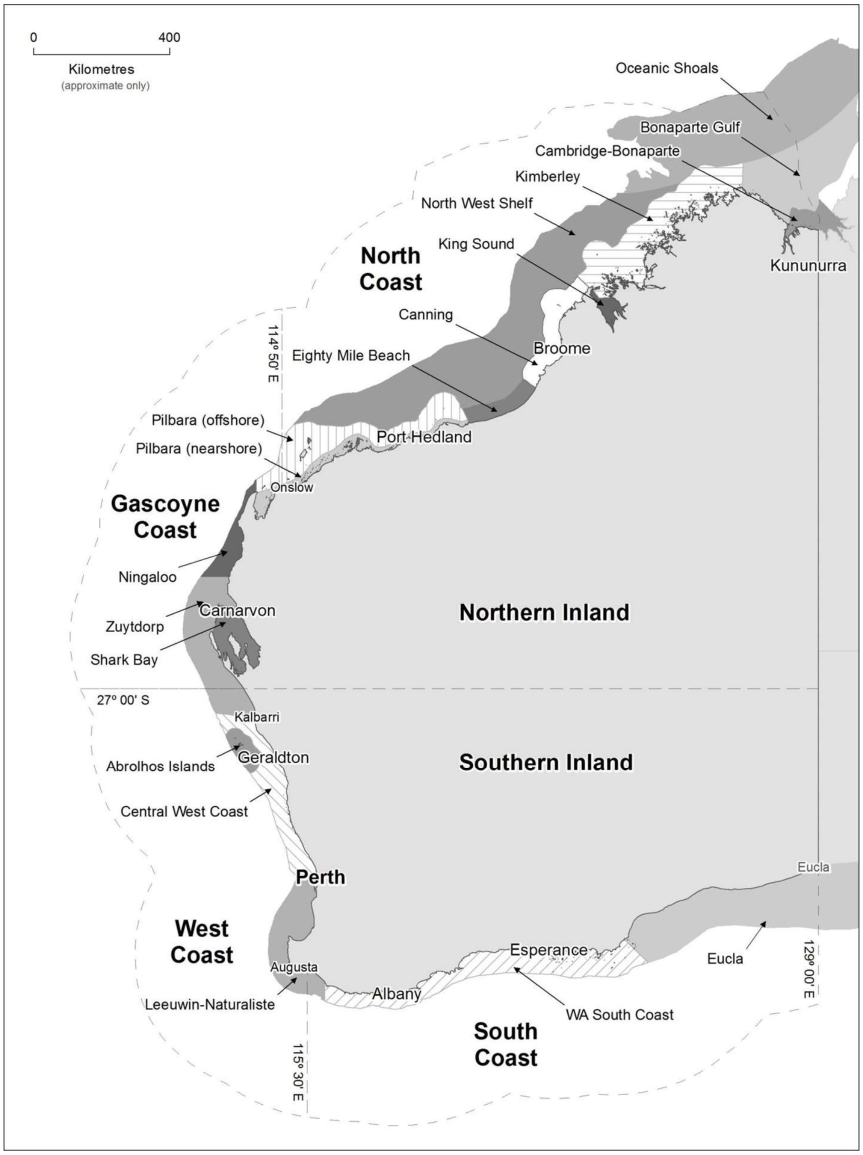

Figure 0.1. Locality of the ecosystems within the Bioregions of WA.

North Coast Bioregion

The **Northern Pelagic Ecosystem** (NPE) includes the pelagic waters and suite of species found within the NCB. The pelagic suite includes the pelagic fishes and invertebrate resources occurring in waters 'above' the inshore demersal and offshore demersal suites.

Within the NPE, there is a sharp break between the naturally turbid inshore waters and clearer offshore waters (at approximately 10 m depth off the Pilbara coast and 70 m depth off the Kimberley coast). The distribution and re-suspension of sediments on the inner shelf is strongly influenced by the strength of tides across the continental shelf, as well as episodic events such as cyclones. Further offshore, sediment movement is primarily influenced by ocean currents and internal tides, the latter causing re-suspension and deposition of sediments (DEWHA 2008).

The warm, low salinity waters of the Indonesian Throughflow (Figure 3.2) generally suppress upwellings across the shelf (Condie et al. 2006); however, biological productivity is thought to be stimulated through the action of physical drivers such as internal waves, tidal stirrings and cyclones (DEWHA 2008). The surface waters of this region are highly stratified during the summer months, with the thermocline occurring at 30 – 60 m depths, while in winter, surface waters are well mixed, with the thermocline occurring at 120 m depth (James et al. 2004).

Enhanced pelagic production occurs on the outer shelf as a result of the interaction of surface and deeper water masses on the adjacent shelf break, via vertical mixing and possibly internal wave action. The mixed water masses travel towards shore and can stimulate biological productivity when the deeper, nutrient-rich water move into the photic zone; however, such upwellings are likely to be sporadic and short-lived. The most favourable conditions for upwelling are associated with a weakening of the throughflow during summer, although some upwelling may still occur during the winter months (DEWHA 2008).

Higher productivity is also likely to be associated with topographical features such as escarpments along the ancient coastline (~ 125 m depth contour), mid-shelf shoals and shelf-edge islands and reefs (DEWHA 2008).

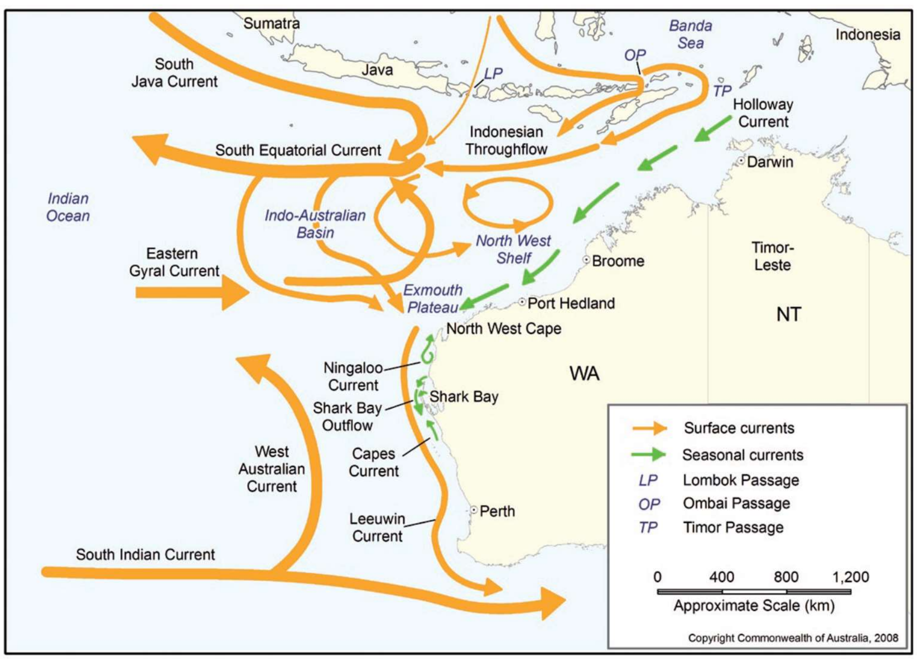

Figure 3.2. Surface currents of Western Australia (Source: Commonwealth of Australia [CoA] 2007b)

Gascoyne Coast Bioregion

The marine environment of the **Gascoyne** Bioregion represents a transition between the fully tropical waters of the North West Shelf and the temperate waters of the west coast, offshore ocean temperatures range from about 22 °C to 28 °C. The major fish stocks are generally tropical in nature, with the exceptions of temperate species such as pink snapper, whiting and tailor, which are at the northern end of their range off Shark Bay.

The coastline is characterised by fringing coral reefs in the north, changing to high cliffs in the south. The northern end of the bioregion is seasonally influenced by extreme tropical summer cyclones. Although these cyclones occur very infrequently in the southern end of the bioregion, this area is affected at times by river outflows from inland cyclone-based summer rainfall. The limited local rainfall comes mostly from the northern edge of winter storm fronts.

The waters off the Gascoyne coast are also strongly influenced by the unusual southward-flowing Leeuwin Current, generated by flow from the Pacific through the Indonesian archipelago (Figure 3.2). This current is known to reduce coastal nutrient levels (Johannes *et al.* 1994), influence species' distributions (Morgan and Wells 1991) and limit productivity at higher trophic levels (Caputi *et al.* 1996). This tropical current becomes evident in the North West Cape area and flows along the edge of the narrow continental shelf where, coupled with low rainfall and run-off, plus the north-flowing Ningaloo counter-current, it creates the highly diverse Ningaloo Reef system and associated fish fauna.

The low productivity associated with the Leeuwin Current restricts total finfish production off the Western Australian coast to a globally modest level (Lenanton *et al.* 2009; Molony *et al.* 2011b). While there are localised and sporadic upwelling events associated with the counter-currents, the absence of large, predictable nutrient-rich upwelling systems that are typical of other shelf systems along the eastern sides of ocean basins (Lenanton *et al.* 1991; Pearce 1991) results in low primary and secondary productivity. These low levels of productivity limit scalefish production. Ecological consequences of this limited productivity are high diversity (Hopper 2009), where no single species tends to dominate, and small stock sizes (Molony *et al.* 2011b). In Western Australian waters, stock sizes of individual scalefish species are in the hundreds or low thousands of tonnes per species (DoF 2011).

The transition in climate and ocean currents, along with the range of coastal landforms and morphology along the Gascoyne coast, combine to provide varied and complex marine habitats and associated flora and fauna. The Gascoyne has been identified as one of the 18 world 'hotspots' in terms of tropical reef endemism. This region of Western Australia has been identified as the second most diverse marine environment in the world in terms of tropical reef species, and is subject to the second lowest level of environmental threat of the 18 areas that were investigated (Roberts *et al.* 2002).

South West Bioregions

The South West Bioregions (SWB), are comprised of the West Coast Bioregion (WCB) and the South Coast Bioregion (SCB). The WCB extends from just north of Kalbarri (27°S) to southeast of Augusta (115° 30' E), while the SCB extends from the eastern border of the WCB to the South Australia border (129° E; see Figure 3.1).

Both the **West and South Coast Bioregions** have a Mediterranean climate, with most rainfall occurring during the winter months. Coastal water temperatures range from 18° C to about 24° C in the WCB and from approx. 15° C to 21° C in the SCB. The temperatures are generally higher than would be expected at these latitudes, especially in the SCB, due to the influence of the warm Leeuwin Current. From a global perspective, the West and South Coast Bioregions are generally characterised by low levels of nutrients and high species diversity, including a large number of endemic species. Biological communities are mainly comprised of temperate species, which mix with tropical species in the northern regions of the WCB. These characteristics are considered to be caused by the influence of the Leeuwin Current, the low level of terrestrial run-off and the relatively stable geological history of the south-west region (CoA 2008).

The SWB are known for their high species diversity and endemism. Temperate species dominate in the south-eastern part of the region, while tropical species become progressively more common in the north. Of the known species, more than 1000 species of macroalgae, 17 – 22 species of seagrass, 600 species of fish, 110 species of echinoderm and 189 species of ascidians have been recorded in the south-west marine region (i.e. from Shark Bay, WA, to Kangaroo Island, SA; CoA 2008). A global study of coral reef biodiversity hotspots also found that while the west coast of WA from Ningaloo Reef to Rottnest Island has moderate to high species richness, it is also one of the global hotspots for endemism (Roberts et al. 2002). The Great Australian Bight along the south coast is also known to have one of the world's most diverse soft sediment ecosystems, with over 360 species of sponge, 138 species of ascidians and 93 species of bryozoans (CoA 2008).

There are a number of ocean currents in the SWB, including the Leeuwin Current, the deeper subsurface Leeuwin Undercurrent on the west coast, the Flinders Current on the south coast and the seasonal coastal Capes and Cresswell Currents (**Figure 3.**; CoA 2008). The Leeuwin Current is considered to be a main influence on biological communities within the Bioregions because of its extent and its significant impact on biological productivity. The Leeuwin Current is shallow and narrow (less than 300 m deep and 100 km wide) and transports warm, low-nutrient water from the tropics southward along the shelf break and outer parts of the shelf (Church et al. 1989; Smith et al. 1991; Ridgway and Condie 2004). Although the Current flows year-round, it is strongest in the autumn/winter (April to August). The current is variable in strength from year-to-year, flowing at speeds typically around one knot but up to three knots on some occasions. Annual variation 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 (Fletcher and Santoro 2012).

The Leeuwin Current suppresses predictable large-scale upwellings on the west coast, and as a result, plays a role in maintaining low levels of productivity in the region. Consequently, the WCB can only support relatively small fisheries compared with other areas with eastern boundary currents in the world (CoA 2008). There are some areas of relatively small, periodic upwellings where the Current interacts with the seafloor and other currents, which locally enhance nutrient levels, e.g. at Cape Mentelle (Figure 3.3). Interactions of the Leeuwin Current with seafloor features also lead to the formation of meso-scale eddies, which occur in predictable locations, such as the western edge of the Abrolhos Islands, south-west of Jurien Bay, the Perth Canyon, south-west of Cape Naturaliste and Cape Leeuwin, and south of Albany and Esperance. These eddies are likely to have a large effect on pelagic production in the Bioregions, driving offshore production by transporting nutrients and entire pelagic communities offshore and generating upwelling of deeper waters that are higher in nutrients (CoA 2008).

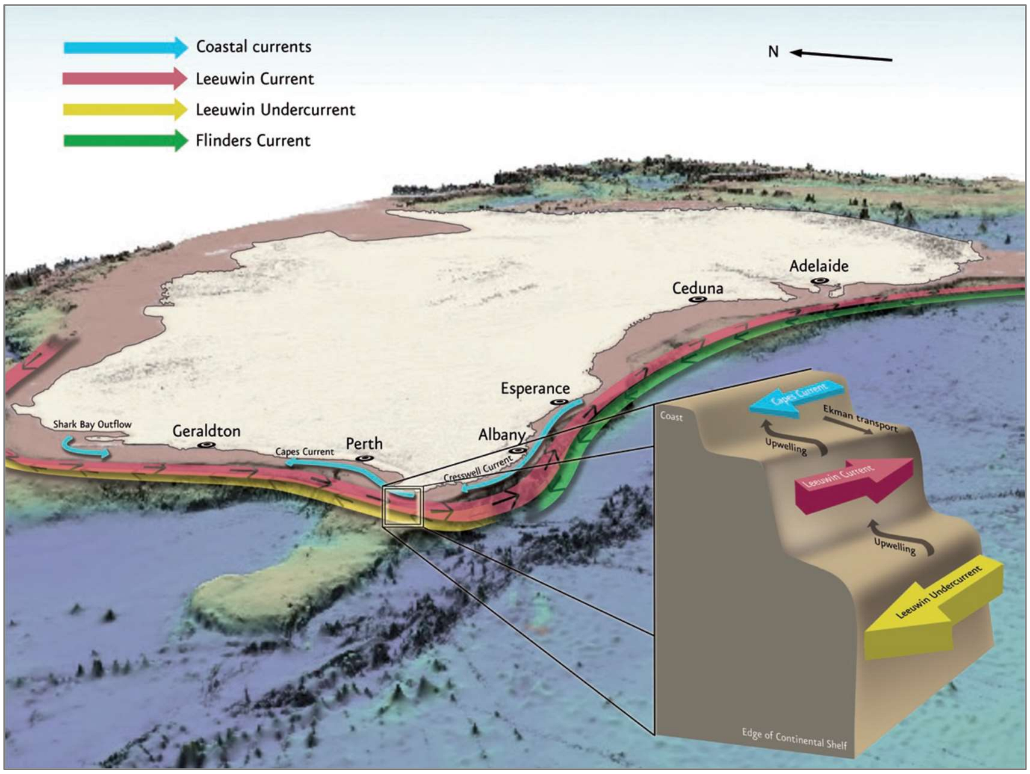

Figure 3.3. Schematic of major ocean currents flowing through the West and South Coast Bioregions. Inset: major currents contributing to the Cape Mentelle upwelling (Source: CoA 2008)

The Leeuwin Current also plays an important role in the distribution of species throughout the Bioregions; its warm water transports tropical and sub-tropical species, which become established further south than would otherwise be possible. Additionally, while the Leeuwin Current is predominantly found of the continental slope across the Bioregion, it does meander and has been shown to flood the continental shelf near the Jurien area and from Albany to Bremer Bay. These meanders influence the recruitment of various species, including western rock lobster and tropical species further south (McClatchie et al. 2006).

The most significant impact of the clear, warm, low-nutrient waters of the Leeuwin Current, however, is considered to be on the growth and distribution of temperate seagrasses. These form extensive meadows in protected coastal waters of the region, generally to depths of 20 m but up to 30 m (Fletcher and Santoro 2012).

The ecology of the Bioregions is also greatly influenced by the lack of river discharge along the coast. The few significant rivers adjacent to the SWB flow intermittently, with a low overall discharge. Consequently, there is a limited amount of terrigenous nutrient inputs. This low run-off and general low rate of productivity (due to the Leeuwin Current) also results in low turbidity, making the waters of the SWB relatively clear (CoA 2008).

4.0 Resource Description

4.1 Large Pelagic Resource

The large pelagic resource is distributed throughout Western Australia (WA) and includes a range of 21 tropical and 4 temperate pelagic finfish species in the families of Carangidae (large trevallies), Coryphaenidae (mahi mahi), Istiophoridae (billfishes), Scombridae (mackerels and tunas), Sphyraenidae (barracuda), and Rachycentridae (cobia). The species are generally found in the offshore pelagic ecosystem although most can be considered as neritic epi-pelagic with the juveniles for some occurring in nearshore and coastal waters. The species generally grow to a relatively large size (many over 30 kg), moderately long lived (most over 10 and some up to 27 years), migratory, high trophic level, and are highly fecund. The species are generally easily targeted by both commercial and recreational fishers at known locations with lures or baits.

4.2 Selection of Indicator Species for Resource

Following the adoption by the Department in 2002 of the ESD policy (Fletcher 2002), the process for monitoring and assessing the finfish resources of WA has involved allocating the species within each bioregion into one of five suites – Estuarine, Nearshore, Inshore Demersal, Offshore Demersal and Pelagic (Department of Fisheries 2011). A risk-based approach is used to quantify the risks to sustainability of the stocks based on biological and other criteria to develop a risk matrix. From the list of species within a suite for a given bioregion, indicator species are then identified based on their vulnerability to fishing and other considerations, such as whether they are target species in major fisheries, and their economic and social values (Lenanton et al. 2006). The status of these indicator species is assumed to represent the status of the entire suite and therefore the resource. The same concept has also been applied to determine appropriate indicator species for the invertebrate resources of WA.

Based on the inherent vulnerability and risk to the sustainability of the major species within the suite(s) of large pelagic scalefish in each Bioregion (Table 4.1), the indicator species selected for assessing the status of the Large Pelagic Resource include;

- Narrow-barred Spanish mackerel (*Scomberomorus commerson*), referred to as Spanish mackerel (NCB, GCB, WCB),
- Broad-barred Spanish mackerel (*Scomberomorus semifasciatus*), referred to as Grey mackerel (NCB, GCB),
- Samson fish (*Seriola hippos*) (WCB, SCB).

In addition to the indicator species there are a number of Large Pelagic species reported in the biennial Status of Australian Fish Stocks (SAFS) report, see below, with WA contributing to the chapters of the first four of these species. The limited catch, biological and weight of evidence assessment information for these four species is included in this Resource assessment report to document the information and assessment given in SAFS.

The Large Pelagic species included in the 2018 SAFS report were;

- Cobia (*Rachycentron canadum*) (NCB, GCB, WCB)*
- Mahi mahi (*Coryphaena sp.*) (NCB, GCB, WCB)*
- School mackerel (*Scomberomorus queenslandicus*) (NCB, GCB)*
- Spotted mackerel (*Scomberomorus munroi*) (NCB, GCB)*
- Yellowtail kingfish (*Seriola lalandi*) (WCB, SCB)*
- Bigeye tuna (*Thunnus obesus*) (NCB, GCB)
- Southern bluefin tuna (*Thunnus maccoyii*) (NCB, GCB, WCB, SCB)
- Swordfish (*Xiphias gladius*) (GCB, WCB)
- Yellowfin tuna (*Thunnus albacares*) (NCB, GCB)

Where * indicates a contribution by WA to the species chapter and assessment.

However, none of these species are indicator species and do not contribute ≥ 4 % of the total retained state commercial catch from the Large Pelagic Resource in WA. Of the SAFS species only the annual catch of Cobia (*Rachycentron canadum*), at 10-20 t, is significant with the catch of Mahi Mahi and School mackerel very low (<2 t) and the WA catch for the last six negligible (<200 kg). Thus, these species are considered Negligible in the SAFS reporting with assessment consisting of monitoring that the catches remain at low levels. Assessment for these species are done in other States or by Commonwealth Fisheries and the Indian Ocean Tuna Commission (IOTC), for the tunas and swordfish. There are some other large pelagic species, such as Amberjack (*Seriola dumerili*) and recently Golden trevally (*Gnathanodon speciosus*) that are landed in higher levels at ≥ 1 % of the total retained commercial catch from the Large Pelagic Resource in WA (Table 4.1). These non-indicator large pelagic species are also targeted to a much higher degree by charter and recreational fishers in WA resulting in a higher level of annual catch of up to 20 t, although most 50-60% of this catch is released.

Table 4.1. Vulnerability and catch assessment for the main retained large pelagic species in WA (i.e. which contribute ≥ 1 % of total retained commercial catches) to assess their suitability as Indicator species for the resource, from DoF 2011.

Suite	Common name	Species name	Catch Proportion	Inherent Vulnerability (Productivity)	Current Risk to Wild Stock	Overall risk to sustainability	Current Management requirements	GVP	Recreational Importance	Customary Importance	Community Significance	Management Risk Sum	Indicator Value Attributes
Tropical	Spanish mackerel	*Scomberomorus commerson*	79%	3	4	24	2	3	4	0	2	11	35
	Grey mackerel	*Scomberomorus semifasciatus*	2%	3	2	12	2	1	1	0	1	5	17
	Cobia	*Rachycentron canadum*	3%	3	2	12	1	1	2	1	1	6	18
	Amberjack	*Seriola dumerili*	4%	2	1	8	1	1	1	0	1	5	13
	Wahoo	*Acanthocybium solandri*	1%	3	3	18	1	1	2	0	1	5	23
	Golden trevally	*Gnathanodon speciosus*	1%	3	1	6	1	1	2	1	1	6	12
Temperate	Samson fish	*Seriola hippos*	10%	3	2	12	2	1	2	0	1	14	26
	Yellowtail kingfish	*Seriola lalandi*	<1%	3	1	6	1	1	2	0	1	13	19

5.0 Species Description

5.1 Spanish Mackerel (*Scomberomorus commerson*)

Figure 5.1. The Spanish mackerel, *Scomberomorus commerson*. Illustration © R. Swainston (www.anima.net.au)

5.1.1 Taxonomy and Distribution

The narrow-barred Spanish mackerel, *Scomberomorus commerson*, (Figure 5.1) is a member of the family Scombridae (mackerels, tunas and bonitos). Upper body varies from bright blue to dark grey with banded pattern on side. The prominent dip in lateral line below second dorsal fin is diagnostic for the species (Hutchins and Swainston 1999). This oceanodromous, pelagic neritic species is widely distributed throughout tropical and subtropical waters of the Indo-West Pacific (Collette and Nauen 1983). Its Australian distribution includes northern Australia to as far south as at least Geographe Bay in south-western Australia (**Error! Reference source not found.**) (Hutchins and Swainston 1999), although confirmed reports have come from east of Albany on the South Coast of WA (Mackie et al 2003), and Sydney on the east coast.

5.1.2 Stock Structure

Three genetic stocks of Spanish mackerel have been identified across northern Australia: (1) East coast of Australia; (2) Torres Strait and (3) Northern Australia (from the Gulf of Carpentaria west to Northern Territory and north Western Australian waters; Buckworth et al. 2007; Holmes et al. 2012). Management occurs at the jurisdictional scale (Torres Strait; Northern Territory; Queensland-East Coast; Queensland Gulf of Carpentaria; and Western Australia; Buckworth et al. 2007; Newman et al. 2009; Holmes et al. 2012) as adults exhibit limited movements (most recorded movements are at scales between 100-300 km and less than 1 000 km, as determined by otolith microchemistry and parasite analysis).

Spanish mackerel have been grouped nationally into four separate management units (Torres Strait, Northern Territory, Queensland- East Coast and Gulf of Carpentaria and Western Australia; Holmes et al. 2012). As the assessments of these units are based on stocks that receive the highest harvest rates, their status is assumed to be representative of the highest level of exploitation that occurs on any stock within each management unit.

Spanish mackerel is considered a single management unit as the same genetic stock is likely to extend throughout WA. The MMF is split into three management areas, see Figure 6.2.

5.1.3 Life History

The sub-sections below provide an overview of the life history characteristics of the Spanish mackerel, with a summary of the relevant biological parameters used in stock assessments presented in Table 5.1.

Table 5.1. Summary of biological parameters for Spanish mackerel (Mackie et al 2003, Newman et al 2012, Smallwood et al 2017)

Parameter	Value(s)	Comments / Source(s)
Growth parameters		e.g. Schnute $L_t = [(y_1^b+(y_2^b-y_1^b)\ (1-e^{(-a \times (t-t_1))}/1-e^{(-a \times (t_2-t_1))})]^{1/b}$
y_1 (mm)	Females 426.3, Males 286.8	Pilbara only- best age range
y_2 (mm)	Females 1411.2, Males 1250.9	(Newman et al. 2012)
a	Females 0.114, Males 0.155	
b	Females 4.11, Males 4.41	
Growth parameters		e.g. $L_t = L_\infty (1 - \exp(-K (t - t_0)))$
L_∞ (mm)	Females 1333.9, Males 1197.5	
K (year^{-1})	Females 0.36, Males 0.42	
t_0 (years)	Females -1.49, Males -1.31	
Maximum age (years)	22	(Mackie et al. 2003)
Maximum size (mm)	1800 (females), 1400 (males)	
Natural mortality, M (year^{-1})	0.16-0.2	
Length-weight parameters		e.g. $W = a\ (FL)^b$
a	1) 3.4 e^{-9}, 2) 5.0x 10^{-6}	1) Mackie et al. 2003 (kg, mm) 2) Smallwood et al. 2017 (g, mm)
b	1) 3.12, 2) 3.0242	
Reproduction	Gonochoristic, broadcast spawner etc.	(Mackie et al. 2005)
Maturity parameters		e.g. Logistic
A_{50} (years)	Females 1.4, Males 0.8	
L_{50} (mm)	Females 898, Males 706	
L_{90} (mm)	Females 981, Males 791	FL
Fecundity	=31,087 x WW $^{1.384}$ (n=19, 5.3-12.7kg)	Batch fecundity
Size-fecundity parameters		e.g. $BF = (a\ FL^b)$
a	0.0011	
b	2.896	
Spawning frequency	Multiple asynchronous spawners, spawn every 2-6 days	

5.1.3.1 Habitats and Movements

The main critical habitat for the species are oceanographic features such as reefs and islands occurring within the inshore and offshore pelagic zone. The pressure waves created by these features are utilised by small pelagic and reef associated demersal species which form the primary food source for Spanish mackerel and other large pelagic species. Notwithstanding seasonal movements south to the southern extent of their range with warmer water currents by some individuals, most Spanish mackerel appear to have fairly restricted long-shore movement patterns, although analysis of parasitic faunas suggest that this species may move more along the west coast of Australia than in other jurisdictions in northern Australia (see Section **Error! Reference source not found.** on parasites for more detail). The habitat of most of the population outside of the main fishing season (May -Oct) is still unclear, although anecdotal evidence suggests that they move off the coast into deeper water at this time (Mackie et al. 2003).

5.1.3.2 Age and Growth

The narrow-barred Spanish mackerel is the largest member of the genus *Scomberomorus*. Mackie et al. (2003) undertook detailed age and growth studies on this species in Western Australia, by analysis of microincrements (presumed to be formed daily) in small fish, and annually-formed growth zones in the otoliths of larger fish (employing sagittal otoliths, and using marginal increment analysis to validate the periodicity of zone formation).

Counts of otolith microincrements for small fish ranged from 23 to 204 (presumed to correspond to days). The smallest discernible male aged Spanish mackerel was 284 mm FL and 80 days old, and the smallest female was 396 mm FL and 122 days old (Mackie *et al*. 2003).

The microincrement analyses revealed that juvenile growth is most rapid up to ~ 300 – 500 mm fork length (FL). The greatest recorded average daily growth rate for Spanish mackerel in Western Australia is ~ 3 – 4 mm/day. Juveniles have been shown to grow faster in autumn (maximum 4.2 mm/day) than in winter (Mackie et al. 2003).

Although Mackie *et al*. (2003) showed that the pattern of growth of Spanish mackerel (throughout life) in the Kimberley, Pilbara and West Coast regions were described relatively well by fitting von Bertalanffy growth curves to the length at age data they collected, Newman *et al*. (2012) determined that Schnute (1981) growth curves provide statistically improved fits to those same data. The values of the estimated growth parameters are reported in Table 5.1, from Newman *et al*. (2012).

Growth curves demonstrate that this species grows very rapidly early in life (attaining about 800 mm fork length around the end of the first year of life). On average, females grow faster than males and attain larger lengths, but males tend to live longer (Mackie et al. 2003; Newman et al. 2012). The fishery is based on 2 – 4 year old fish, which comprise about 70 % of the commercial catch.

In WA, narrow-barred Spanish mackerel can live for at least 22 years with both sexes attaining similar maximum ages (Mackie et al. 2003). Elsewhere in Australia the species has been recorded up to 26 years of age (McPherson 1992).

TL (mm) = 1.06 FL + 42.74 (Mackie et al. 2003)
TL = 1.0147 FL + 99.954988 (TL 582-1540, Statewide) (Smallwood et al. 2017)

5.1.3.3 Natural Mortality

Mackie *et al*. (2003) derived several estimates of natural mortality (M) from life history equations, including that of Hoenig (1983) relating M to maximum age, and that of Brey (1999), employing the asymptotic length and growth coefficient (von Bertalanffy growth parameters) and mean water temperature. The equation of Brey is a modified version of the regression developed by Pauly (1980).

The values of *M* derived from Hoenig's (1983) equation were slightly less than values of total mortality (*Z*) derived from catch curve analysis, whereas those from Brey's equation were much higher than the estimated value of *Z*. The estimates of *M* from Hoenig's (1983) equation, which were considered by Mackie et al. (2003) and later by Newman et al. (2012) to be most accurate, and ranged from 0.2 $year^{-1}$ (Pilbara) to 0.37 $year^{-1}$ (Kimberley).

5.1.3.4 Reproduction

Narrow-barred Spanish mackerel is a pelagic, batch spawning species. Annual fecundity of Spanish mackerel is not fixed prior to the commencement of spawning, with immature oocytes exhibiting de novo vittelogenesis after the commencement of the spawning season. For such species (indeterminate spawners), annual fecundity is determined from information on the duration of the spawning season, batch fecundity, and spawning frequency. Batch fecundity and spawning frequency of Spanish mackerel has been estimated by Mackie et al. (2003, 2005) using the hydrated oocyte method (see Hunter and Macewicz 1985; Hunter et al. 1985).

Fifty per cent of females and 95 % of males attain maturity by 900 mm total length (e.g., 898 mm for females), which is the minimum legal size for capture and retention of this species (Mackie et al. 2003, 2005).

On the basis of reproductive variables (monthly prevalence of gonads at different stages in development and mean monthly gonadosomatic indices), the peak reproductive period for Spanish mackerel extends from October to January in the Pilbara region, and a month earlier in the Kimberley region. Little or no spawning was evident south of North West Cape, near Exmouth (Mackie et al. 2003).

Discussion with fish processors and fishers suggests, however, that limited spawning may possibly occur during some years in the Carnarvon area. Certainly, the known southern extent of spawning along the west coast (approx. 22º S) is less than that reported for *S. commerson* on the east coast, where spawning may occur as far south as Bundaberg (approx. 25º S; McPherson 1993). The Leeuwin Current, is an annually variable warm water current flowing southwards down the WA coastline which extends the southerly range of many tropical species (Caputi *et al.* 1996), and may also influence the southern spawning range of *S. commerson*. Based on counts of otolith micro-increments for small fish (which ranged between 23 to 204 days in age), birth dates for most of these fish were back-calculated to between November and January. Mackie et al. (2003) suggest that this species may spawn further south during years when the Leeuwin Current is strong (i.e. as spawning occurs at about 25ºC, determined from studies in eastern Australia; McPherson 1993).

Thus in years when the Leeuwin Current is stronger the southerly extent of spawning may be increased.

5.1.3.5 Factors Affecting Year Class Strength and Other Biological Parameters

No stock-recruitment relationship has been developed for this species in WA.

The species is likely to benefit under climate change, Section 7.3.1.1, through extended distribution with increasing SST, particularly in years of strong Leeuwin Current, down the WCB and potentially allowing growth of the resource. Although in northern parts of their range there may be detrimental effects with recruitment in Queensland negatively linked to SST during Spring spawning (Welch et al. 2014) and abundance negatively linked to SST in Vietnam (Nguyen and Nguyena 2017).

5.1.3.6 Diet and Predators

Trophic level 4.5 ± 0.4 se (Fishbase).

On the basis of 296 individuals whose stomachs did not contain fish presumed as bait and were not empty, Mackie et al. (2003) recorded that Spanish mackerel gut contents consisted mainly fish (85.8 %) and smaller amounts of cephalopods (11.5 %), fish and cephalopods (2.0 %) or crustaceans (0.7 %).

Predators of juvenile and adult Spanish mackerel are likely to include larger pelagic species such as marlin, sharks, and dolphins.

5.1.3.7 Parasites and Diseases

Detailed studies of the parasitic faunas of Spanish mackerel were undertaken by Buckworth et al. (2007) with the aim of determining stock structure and movements. Adult mackerel carry hundreds of parasites (harmless to people) mostly in the stomach wall and gills, some of which survive for the life of the fish. The parasitic faunas consisted of short-lived adult monogeneans and copepods on the gills, and longer-lived parasites, including larval and juvenile stage helminths encapsulated in the stomach wall or gills.

Comparison of the parasite faunas of fish from 16 sites around northern and Western Australia, from the Torres Strait to the Abrolhos Islands, revealed that Spanish mackerel in northern areas had distinct parasite faunas. This indicates that, for northern areas, once fish have recruited to an area, they are not likely to leave. Analysis of parasites in fish on the west coast of Australia, at the Abrolhos Islands, and at Shark Bay, Exmouth and Onslow, showed that there were strong similarities between the areas suggesting that either the fish were mixing or that the habitat was relatively uniform (Buckworth et al. 2007).

5.1.4 Inherent Vulnerability

The biology and behaviour of Spanish mackerel makes them low to moderately vulnerable to fishing. Spanish mackerel are a fast growing group, with most reaching spawning age and exploitation size by 2-3 years but with potential longevities in excess of 20 years. They are highly fecund with a long spawning season and broad dispersal. Whilst individuals may undergo size / age related migrations there is limited mixing amongst regions. They do form spawning aggregations at known locations so may be susceptible to hyper-stability in catch rates. Although with their wide distribution, stable catch and small fishery (less than 15 commercial vessels in WA) there is only a low risk of hyper-stability in catch rates. However, there is a risk of overfishing as seen in Queensland where spawning aggregations of this obligate transient aggregating species have been reduced in size and frequency by high fishing over a number of years at particular locations due to the high reef fidelity of the species during spawning (Tobin et al. 2014). In addition, the species is released in high amounts by recreational and charter fishers, up to 55% of the catch, with most releases due to being undersize. The species physiology, lack of swim bladder, and light lines used may contribute to high levels of post release mortality, in addition are the relatively high levels of depredation, up to 30% recorded in some areas with anecdotal reports of much higher losses, making the landed catch only a proportion of the total removals from the fishery.

The most common method of capture is by trolled lines close to reefs or other structures. Successful long-term management has been recorded for many fisheries in their wide Indo-Pacific distribution. The stock declines that have occurred in some large pelagic fisheries have following extended periods of high exploitation, these can, however, with their life history traits they recover in a relatively short (< 10 years) period once corrective actions are implemented. There is evidence from Queensland that recruitment levels are maintained even following significant reductions in spawning biomass. Further, whilst the level of recruitment varies annually, associated with environmental conditions as documented on the East Coast where recruitment is negatively correlated with spring sea surface temperatures (Welch et al. 2014), their extended distribution and spawning period generally allows some level of recruitment in most years.

5.2 Grey mackerel (*Scomberomorus semifasciatus*)

Figure 5.2. The Grey mackerel, *Scomberomorus semifasciatus*. Illustration © R. Swainston (www.anima.net.au)

5.2.1 Taxonomy and Distribution

The Grey mackerel or broad-barred Spanish mackerel, *Scomberomorus semifasciatus*, (Figure 5.1) is a member of the family Scombridae (mackerels, tunas and bonitos). It is distinguished by dark bars extending part way down sides, although these fade after death, and the black area at front of dorsal fin. The species is an oceanodromus, pelagic-neritic species and its Australian distribution includes northern Australia to as far south as at least Perth in south-western Australia (**Error! Reference source not found.**) (Allen and Swainston 1995) and Sydney on the east coast.

5.2.2 Stock Structure

A comprehensive study involving genetics, otolith chemistry and parasites of the species across northern Australia indicated there are at least five Grey mackerel biological stocks, with a possible additional stock in the north-east Gulf of Carpentaria (Newman et al. 2010). Grey mackerel is considered a single management unit in WA as the same genetic stock is likely to extend throughout the state (Roelofs et al. 2014).

5.2.3 Life History

The sub-sections below provide an overview of the life history characteristics of the Grey mackerel, with a summary of the relevant biological parameters used in stock assessments presented in Table 5.2. As there have been no biological studies conducted on Grey mackerel in WA waters much of the parameters used have been taken from studies on the East coast of Australia.

Table 5.2. Summary of biological parameters for Grey mackerel (Cameron & Begg 2002)

Parameter	Value(s)	Comments / Source(s)
Growth parameters		e.g. $L_t = L_\infty (1 - \exp(-K (t - t_0)))$
L_∞ (mm)	Females 1058, Males 929	
K (year^{-1})	Females 0.301, Males 0.475	
t_0 (years)	Females -3.174, Males -2.131	
Maximum age (years)	14	
Maximum size (mm, kg)	1200, 10.0	
Natural mortality, M (year^{-1})	0.32	
Length-weight parameters		e.g. $\ln(W) = b + a \ln(FL)$
a	1) 2.95, 2) $2.7*10^{-5}$	2) Smallwood et al. 2017 W (g)=a FL(mm)^b
b	1) -11.356, 2) 2.7637	
Reproduction	Gonochoristic, broadcast spawner etc.	
Maturity parameters		e.g. Logistic
A_{50} (years)	Females 2, Males 1-2	
L_{50} (mm)	Females 650-699, Males 550-599	
L_{95} (mm)	Females 806, Males 668	
Fecundity	250,000 (at size 500)	[Batch / Annual] fecundity
Size-fecundity parameters		e.g. $LnF = b + a\, FL$
a	0.003	
b	11.159	
Spawning frequency	Multiple spawners, spawn frequency unknown	

5.2.3.1 Habitats and Movements

Grey mackerel have a restricted distribution and are confined to the waters of southern Papua New Guinea and around northern Australia from the Houtman Abrolhos Islands area on the west coast (28°30′S) to northern New South Wales on the east coast. Adult Grey mackerel are known to commonly occur in turbid tropical and sub-tropical waters of approximately 3– 30 m depth. This is usually in the vicinity of bottom structure in close proximity to rocky headlands and reefs (where pelagic baitfish such as tropical sardines and herrings are concentrated) and on sandy-mud and muddy sand substrates. They rarely occur at the edge of the continental shelf to depths of 100 m. The habitats occupied by the species in WA outside the short fishing season of June-Sept when they form large schools at particular locations are unknown, although it is though they disperse in coastal waters. In WA this period of schooling does not coincide with the spawning season of Dec-Mar. Larval and juvenile life history stages of Grey mackerel are found in inshore coastal bays and the inner margin of the lagoon, often in estuarine environments. The larvae of this species inhabit coastal bays and nearshore areas that are typically influenced by freshwater run-off and low salinity surface waters.

5.2.3.2 Age and Growth

No age and growth studies have been conducted on Grey mackerel in WA waters. Parameters have been taken from studies on the East coast of Australia.

As with Spanish mackerel the males grow faster than females but attain a smaller asymptotic length. Maximum age of 14 years has been recorded for the species with no difference recorded between the sexes.

5.2.3.3 Natural Mortality

No age and growth studies have been conducted on Grey mackerel in WA waters. Parameters have been taken from studies on the East coast of Australia where maximum age for the species was 14 years and natural mortality is estimated at 0.32 $year^{-1}$ (Cameron & Begg 2002).

5.2.3.4 Reproduction

No reproductive biology studies have been conducted on Grey mackerel in WA waters. Parameters given in Table 5.2 have been taken from a few studies on the East coast of Australia. The species is a schooling, pelagic, batch spawner with spawning on East coast throughout its range from Sept – Jan. Based on the East Coast studies of their biology the LML in WA is above the size at maturity allowing the species to reproduce before being vulnerable.

5.2.3.5 Factors Affecting Year Class Strength and Other Biological Parameters

There is significant year to year variability in Grey mackerel catches, which is likely to be attributed to fishery-dependent factors as well as seasonal and environmental factors, particularly rainfall variability (GBRMPA 2013). This may leave Grey mackerel vulnerable to management arrangements that are not adaptive to seasonal or environmental variabilities.

As with Spanish mackerel the species is likely to benefit in range extension though climate change, see Section 7.3.1.1.

5.2.3.6 Diet and Predators

Trophic level 4.5 ± 0.8 se (Fishbase)

Grey mackerel are mid-size, pelagic predators in tropical, coastal habitats. They are only known to feed exclusively on baitfish, such as sardines, anchovies and herring (Cameron & Begg 2002). In some locations and at certain times of the year, they are relatively abundant. However, data relating to their ecological role and to their influence on other components of coastal ecosystems are lacking.

Predators of juvenile and adult Grey mackerel are likely to include larger pelagic species, sharks, and dolphins.

5.2.3.7 Parasites and Diseases

No known issues in WA.

5.2.4 Inherent Vulnerability

The biology and behaviour of Grey mackerel makes them low to moderately vulnerable to fishing. Grey mackerel are a fast growing group, with most reaching spawning age and exploitation size by 2-3 years but with potential longevities to 12 years. They are highly fecund with likely a long spawning season and broad dispersal. Whilst individuals may undergo size / age related migrations there is limited mixing amongst regions. They do form seasonal aggregations at known locations making them vulnerable to exploitation. As with Spanish mackerel there is likely a high post release mortality and depredation for the species.

The most common method of capture is by trolled or jigged lines close to reefs or other structures. With their wide distribution, stable catch and small fishery (less than 3 vessels in WA) there is only a low risk of hyper-stability in catch rates. The quota for the species in WA is set at much higher levels than the current catch and successful long-term management at much higher catch levels has been recorded elsewhere in Australia for the species. The stock declines that have occurred in some large pelagic fisheries have following extended periods of high exploitation, these can, however, recover in a relatively short (< 10 years) period once corrective actions are implemented. For such species there is evidence that recruitment levels are maintained even following significant reductions in spawning biomass. Further, whilst the level of recruitment often varies annually, associated with environmental conditions, there is generally some recruitment in most years.

5.3 Samson fish (*Seriola hippos*)

Figure 5.3. The Samson fish, *Seriola hippos*. Illustration © R. Swainston (www.anima.net.au)

5.3.1 Taxonomy and Distribution

The Samson fish (Figure 5.1) is a member of the family Carangidae. It is a temperate, bentho-pelagic species endemic to southern Australia and northern New Zealand. Inhabits pelagic-neritic, inshore oceanic waters and often associated with reefs, wrecks and pylons.

The species varies considerably in colouration and body shape with growth. Juveniles have a blunt head and five broad bars on a yellowish to green background. Adults have a less convex upper profile and vary in colouration from blue-green to dull purple brown above, paler flanks and silver to white belly (Hutchins and Swainston 1999).

5.3.2 Stock Structure

Samson fish is considered a single management unit in the Southwest of WA as the same genetic stock is likely to extend into the WCB and SCB.

5.3.3 Life History

The sub-sections below provide an overview of the life history characteristics of the Samson fish, with a summary of the relevant biological parameters used in stock assessments presented in Table 5.3.

Table 5.3. Summary of biological parameters for Samson fish (taken from Rowland 2009, Smallwood et al 2017)

Parameter	Value(s)	Comments / Source(s)
Growth parameters		e.g. Schnute $L_t = [(y_1^b+(y_2^b-y_1^b)X(1-e^{(-a\times(t-t_1))}/1-e^{(-a\times(t_2-t_1))})]^{1/b}$
y_1 (mm)	Females 435.3, Males 400.3	
y_2 (mm)	Females 1089.1, Males 1034.5	
a	Females 0.044, Males 0.1363	
b	Females 2.748, Males 1.971	
t_1 (mm)	Females 1, Males 1	
t_2 (mm)	Females 1, Males 10	
Maximum age (years)	29	
Maximum size (mm)	1800	(Gomon et al. 2008)
Natural mortality, M (year^{-1})	0.2	
Length-weight parameters		e.g. $W = a\ (FL)^{b}$
a	1) $1.497*10^{-4}$, 2) $8.4*10^{-5}$	2) Smallwood et al. 2017
b	1) 2.982, 2) 2.6788	
Reproduction	Gonochoristic, broadcast spawner etc.	
Maturity parameters		e.g. Logistic
A_{50} (years)	Females 4	(Rowland 2009)
L_{50} (mm)	Females 831	
L_{95} (mm)	Females 942	
Fecundity	322,924-3,335,524 (at size 1000-1600mm TL)	Batch fecundity
Size-fecundity parameters		e.g. $BF = (a\ FL - b)^3$
a	5021	
b	4698076	
Spawning frequency	Multiple spawners, spawn	

5.3.3.1 Life Cycle

Larvae and juveniles (TL<100 mm) are pelagic and often associated with floating algae. Pelagic sargassum mats are an important habitat for small juveniles. Larger juveniles (200-500 mm FL) are found in inshore areas where water depths <20 m associated with structures such as rocks, pylons or jetties and are occasionally found in estuaries (Smith-Vaniz 1999, Rowland 2009). This species can live to at least 29 years and can reach a maximum length of 173 cm (53 kg) (Smith-Vaniz 1999) with females attaining a larger size (May and Maxwell 1986, Rowland 2009). *S. hippos* is a serial spawner forming that can form large aggregations with a spawning period starting in late spring and going into early autumn. Aggregations have been recorded as being comprised of over 30,000 individuals at a site and covering a circular area of up to 1,875 m² (Parsons *et al* 2013). Growth is rapid in the first five years for both sexes which can attain 60 cm TL within the second year of life (Rowland 2009). Off the west and south coasts of Australia, *S. hippos* have been documented to undertake long distance migrations from Kangaroo Is., in South Australia, to spawning aggregation sites near Rottnest Island in Western Australia with some travelling over 2,400 km. Tag returns indicate this species exhibits strong temporal and spatial spawning site fidelity (Rowland 2009).

5.3.3.2 Habitats and Movements

Seriola hippos is a fast swimming bentho-pelagic predator that inhabits coastal reefs, wrecks and pylons areas or the open sea. The species undertakes large scale migrations from the South Coast to spawning aggregations in offshore waters of the West Coast Bioregion with larval dispersal dependent on intra and inter annual variations in northward and southward currents at these locations. A large number of Samson fish tagged on spawning aggregations to the west of Rottnest Island were recaptured off the south coast of WA and even as far as Kangaroo Island in South Australia, a few months later (Rowland 2009).

5.3.3.3 Age and Growth

The species can reach up to 29 years of age (Rowland 2009) with growth rapid and until 5 years of age when females grow faster and larger than males, 1600 versus 1380 mm FL, respectively. The only study to date on the species has been a PhD in early 2000 in WA (Rowland 2009) and all biological information is based on this study. Although differences exist in growth and size between the sexes the relationship between caudal fork length and whole weight was not significantly different.

A linear relationship exists between TL =1.09 FL + 17.84 (Rowland 2009).

FL =1.085 TL +37.12 (TL 515-1480, Statewide) (Smallwood et al. 2017)

5.3.3.4 Natural Mortality

Several estimates, based on different methods of calculation available (Rowland, 2009) off Western Australia, the instantaneous rate of total mortality (*Z*) was 0.4 year^{-1} and the instantaneous rate of natural mortality (*M*) was 0.2 year^{-1} (Rowland 2009).

5.3.3.5 Reproduction

The species is a highly fecund, serial spawner with extended summer spawning from Nov-March, with peak Nov-Jan. Spawning is prolonged and widespread in west and south coast waters of 5-200 m depth with some large aggregations formed in depths of 80-120 m over wrecks near Rottnest Is. from late spring to summer months. Species have an indeterminate fecundity due to multiple batches over a season with a single batch totalling almost 1.5 million eggs. The length at 50% maturity for females is 83.1 cm and about four years of age while all female over 95 cm are mature (Rowland 2009), this is well above the LML of 60 cm allowing the removal of immature fish.

5.3.3.6 Factors Affecting Year Class Strength and Other Biological Parameters

No stock-recruitment relationship has been developed for this species.

Spawning often in offshore waters during spring to summer where larvae are highly dependent upon prevailing oceanic conditions of southward Leeuwin and northward Capes Currents for distribution and eventual settlement in inshore waters. Intra and inter-annual variations in currents affect spawning and larval distribution and survival throughout the protracted spawning period.

5.3.3.7 Diet and Predators

The species is an opportunistic carnivore feeding on a variety of pelagic and demersal prey. Prey mainly teleost fishes (84%), predominantly pilchards and redfishes and yellowtail scad with cephalopod species both squids and cuttlefish (30%) (Rowland, 2009).

Trophic level 4.6 ± 08 se (Fishbase)

Predators of Samson fish are likely to include larger pelagic species, sharks, and dolphins.

5.3.3.8 Parasites and Diseases

Like many pelagic species Samson fish are prone to infections by skin, gill and blood flukes and sea lice. The species is also prone to infection by the microscopic myxosporean parasite, *Kudoa* sp. that upon cooking releases an enzyme causing musculature liquefaction or "milky flesh" where the flesh becomes mushy and inedible. It is the occurrence of this parasite which gives Samson fish their reputation for poor edibility as it is not easily detected before cooking.

5.3.4 Inherent Vulnerability

The biology and behaviour of Samson fish makes them low to moderately vulnerable to fishing. Temperate fish are a moderately fast growing group, with most reaching spawning age and exploitation size by 4-5 years but with potential longevities in excess of 20 years. They are highly fecund with a planktonic larval stage usually with broad dispersal. Individuals of the species may undergo large scale migrations so there are often mixing amongst regions as they form large spawning aggregations.

The most common method of capture by commercial and recreational is line fishing, often close to reefs or other structures. They are generally not targeted to a high degree by commercial fishers due to the occurrence of "milky flesh" in a percentage of fish due to the *Kudoa sp* protozoan. Recreational fishers release an estimated 70% of their catch for similar reasons or catching too many to retain higher eating quality species in their possession limit. The species possess a swim bladder âventâ, a highly specialised anatomical structure which permits some physoclistous fish species, such as the Samson fish, to vent swim bladder gas during ascent, a homologous structure was identified in *S. lalandi* and *S. dumerili* (Rowland 2009). This allows a high degree of post release survival due to reduced effects of barotrauma.

The catches in WA are widespread so there is only a low risk of hyper-stability in catch rates. For pelagic species there is evidence that recruitment levels are maintained even following significant reductions in spawning biomass. Further, whilst the level of recruitment often varies annually, associated with environmental conditions, there is generally some recruitment in most years.

5.4 Yellowtail kingfish (*Seriola lalandi*)

Figure 5.4. The Yellowtail kingfish, *Seriola lalandi*. Illustration © R. Swainston (www.anima.net.au)

5.4.1 Taxonomy and Distribution

The Yellowtail kingfish (Figure 5.1) is a member of the family Carangidae being the only species without a scutella on the caudal peduncle. It is a circum-global subtropical/temperate species consisting of a series of disjunct sub-populations. It is distributed through southern Australia, from Capricorn Group, Queensland to Shark Bay in WA, along with Norfolk Is, Lord Howe Is and New Zealand. It is a bentho-pelagic species that inhabits inshore oceanic waters, usually in depths between 0-50 m but occurs to 300 m.

The species are dark blue to greenish-blue on top, shading to almost white below with a distinctive yellow to bronze between the two colours, passing through the eye. Juveniles are yellowish with black bands.

5.4.2 Stock Structure

The population genetic survey of Yellowtail kingfish across temperate Australia and New Zealand showed that the WA stock were genetically distinctly, possessing unique haplotypes (Miller et al. 2011). No differences were found between New Zealand, Eastern or Central Australian stocks. Thus, in Western Australia Yellowtail kingfish is considered a single management unit as the same genetic stock is likely to extend into the GCB, WCB and SCB.

5.4.3 Life History

The sub-sections below provide an overview of the life history characteristics of the Yellowtail kingfish, with a summary of the relevant biological parameters used in stock assessments presented in Table 5.4. The information presented is primarily from the East Coast and New Zealand stocks as no biological studies have been done on the species in WA.

Table 5.4. Summary of biological parameters for Yellowtail kingfish (Gillanders et al 1998, McKenzie et al 2014, Stewart et al 2004).

Parameter	Value(s)	Comments / Source(s)
Growth parameters		e.g. Schnute $L_t = [(y_1^b+(y_2^b-y_1^b)(1-e^{(-a\times(t-t_1))}/1-e^{(-a\times(t_2-t_1))})]^{1/b}$
y_1 (mm)	Females 504, Males 513	Stewart et al, 2004
y_2 (mm)	Females 713, Males 690	
a	Females 0.07, Males 0	
b	Females 0, Males 0	
Growth parameters		e.g. $L_t = L_\infty(1 - \exp(-K(t - t_0)))$
L_∞ (mm)	1252, 1420	Gillanders et al, 1998, McKenzie et al, 2014
K (year^{-1})	0.189, 0.13	
Maximum age (years)	21 (NSW), 23 (NZ)	
Maximum size (mm)	2400	(Gomon et al, 2008)
Natural mortality, M (year^{-1})	0.2-0.25 (NZ)	
Length-weight parameters		e.g. $W = a\,(FL)^{b}$ *(cm)*
a	1) $1.82*10^{-2}$, 2) $1.16*10^{-4}$	2) Smallwood et al. 2017
b	1) 2.93, 2) 0.542843	
Reproduction	Gonochoristic, broadcast spawner etc.	
Maturity parameters		e.g. Logistic
A_{50} (years)	Females 5, Males 3	
A_{95} (years)	Females 7, Males 4	
L_{50} (mm)	Females 800, 970 Males 750, 830	Gillanders et al. 1998, McKenzie et al. 2014
L_{95} (mm)	Females 130, Males 95	
Fecundity	650,000 (100cm)	Batch fecundity
Spawning frequency	Multiple spawners, spawn	

5.4.3.1 Life Cycle

Larvae and juveniles (TL<100 mm) are pelagic and rarely seen as offshore associated with floating debris or algae, such as pelagic sargassum mats. Larger juveniles (200-500 mm FL) are often found in large schools in inshore areas where water depths <20 m that contain structures such as rocks, pylons or jetties and are occasionally found in estuaries.

S. lalandi is a serial spawner with a spawning period in spring and summer during which many individuals engage in large aggregations.

5.4.3.2 Habitats and Movements

Seriola lalandi often forms large schools associated with deep reefs, rocky outcrops and offshore islands but are also found in harbours around jetties and pylons.

A fast swimming predator that inhabits coastal reefs, wrecks and pylons areas or the open sea. Capable of long distance movements along coast and across the Tasman Sea, tagging has recorded movement of over 3,000 km from NSW to NZ.

5.4.3.3 Age and Growth

Yellowtail kingfish in eastern Australia have a moderate longevity (to at least 20 years) and reach a maximum size of over 1.9 metres (Total Length, TL). Estimated maturity occurs at between 800 - 1,250 mm TL and between five and 10 years of age. Most of the available biological information was collected from the New South Wales Stock[1,2] with limited information available for the West Australian stock. The species can reach up to 23 years of age and over 180 cm in length with initial growth rapid, reaching 2-3 kg in their first year, and females grow larger than males.

A linear relationship exists between TL (mm) =1.122 FL + 9 (Gillanders et al. 1999).

FL =1.15 TL +-6.80 (TL 384-1418, Statewide) (Smallwood et al. 2017)

5.4.3.4 Natural Mortality

The instantaneous rate of natural mortality (*M*) was 0.2-0.25 year^{-1} (Stewart et al. 2004).

5.4.3.5 Reproduction

The species is a highly fecund, serial spawner with a distinct summer spawning peak in Dec on the East Coast. Spawning is likely to occur in offshore waters, which may afford some degree of protection to the spawning stock from inshore commercial and recreational fishers. Species have an indeterminate fecundity due to multiple batches over a season with a single batch totalling almost 0.65 million eggs.

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[1] Stewart, J, Ferrell, DJ, Van der Walt, B, Johnson, D and Lowry, M 2001, Assessment of length and age composition of commercial kingfish landings, final report to the Fisheries Research and Development Corporation, project 1997/126, *New South Wales, Fisheries Final Report Series*.

[2] Stewart, J and Hughes, JM 2008, Determining appropriate sizes at harvest for species shared by the commercial trap and recreational fisheries in New South Wales, ***Fisheries Final Report Series***.

Females mature between 5-7 years of age and measure 80-130 cm while males mature between 75-95 cm (Gillanders et al. 1999), as with Samson fish this is well above the LML allowing immature fish to be removed.

5.4.3.6 Factors Affecting Year Class Strength and Other Biological Parameters

No stock-recruitment relationship has been developed for this species.

Spawning often in offshore waters during summer where larvae are highly dependent upon prevailing oceanic conditions of southward Leeuwin and northward Capes Currents for distribution and eventual settlement in inshore waters. Intra and inter-annual variations in currents affect spawning and larval distribution and survival throughout the protracted spawning period.

5.4.3.7 Diet and Predators

The species is an opportunistic carnivore feeding on mostly fishes, squids and crustaceans.

Trophic level 4.2 ± 0.1 se (Fishbase)

Predators of Yellowtail kingfish are likely to include larger pelagic species, sharks, and dolphins.

5.4.3.8 Parasites and Diseases

Like many pelagic species Yellowtail kingfish are prone to infections by skin, gill and blood flukes and sea lice. The species is also known to carry infection by the microscopic myxosporean parasite, *Kudoa* sp. that upon cooking releases an enzyme causing musculature liquefaction or "milky flesh" where the flesh becomes mushy and inedible.

5.4.4 Inherent Vulnerability

The biology and behaviour of Yellowtail kingfish makes them low to moderately vulnerable to fishing. Temperate fish are a moderately fast growing group, with most reaching spawning age and exploitation size by 4-5 years but with potential longevities in excess of 20 years. They are highly fecund with a planktonic larval stage usually with broad dispersal. Individuals of the species may undergo large scale migrations so there are often mixing amongst regions as they form large spawning aggregations.

The most common method of capture for Yellowtail kingfish by commercial and recreational is line fishing, often close to reefs or other structures. Recreational fishers release an estimated 50% of their catch with most for catch and release or sportfishing reasons and to retain higher eating quality species in their possession limit. Like Samson fish the species possess a swim bladder âventâ, to vent swim bladder gas during ascent and so avert swim bladder barotrauma associated with capture from depths greater than 30 m.

In WA the catches are widespread so there is only a low risk of hyper-stability in catch rates. Successful long-term management has been recorded for the species at higher catch levels on the East Coast. Further, whilst the level of recruitment often varies annually, associated with environmental conditions, there is generally some recruitment in most years.

5.5 Mahi mahi (*Coryphaena hippurus*)

Figure 5.5. The Mahi mahi, *Coryphaena hippurus*. Illustration © R. Swainston (www.anima.net.au)

5.5.1 Taxonomy and Distribution

The Common Mahi mahi, Dorado or Dolphinfish (Figure 5.1) is a member of the family Coryphaenidae. It is a surface dwelling, oceanodromous, pelagic-neritic species found in offshore temperate, tropical and subtropical waters worldwide, usually in depths between 0-100 m. It is distributed around Australia in water temperatures of 21-30^{o} C. There are two very similar species of Mahi mahi in Australian waters, the Common Mahi mahi (above) and Pompano Maho mahi (*Coryphaena equiselis*). The catch in WA is thought to be almost exclusively of the former but there is likely to be some unidentified catch of the later but consequently only the Common Mahi mahi is assessed.

The species have compressed bodies and a single dorsal fin. Males have a prominent forehead protruding well above the body but females have a rounded head. Colouration is a brilliant metallic blue green on back shading to golden on sides and ventrally with scattered bright iridescent blue and green spots. Juveniles are golden with about 12 black bands.

5.5.2 Stock Structure

Mahi mahi is considered a single management unit in the Indian Ocean, thus in WA the same genetic stock is likely to extend into the NCB, GCB, WCB and SCB.

5.5.3 Life History

The sub-sections below provide an overview of the life history characteristics of the Mahi mahi, with a summary of the relevant biological parameters used in stock assessments presented in Table 5.5.

Table 5.5. Summary of biological parameters for Mahi mahi, (Palko et al 1982).

Parameter	Value(s)	Comments / Source(s)
Growth parameters		e.g. $L_t = L_\infty (1 - \exp(-K(t - t_0)))$
L_∞ (mm)	1380 (Fishbase) 1049 (male), 938 (female), 1715 (Panama), 1940 (Columbia)	
K (year^{-1})	2.6, **ø** = 4.69 (Fishbase) 0.835 (male), 1.029 (female), 0.36 (panama), 0.91 (Columbia)	
Maximum age (years)	5	
Maximum size (mm)	2100	
Natural mortality, M (year^{-1})	0.52 (Panama), 0.57 (India)	
Length-weight parameters		e.g. $W = a\ (FL)^{b}\ (cm)$
a	1) 2.154x10^{-5} (male), 4.608x10^{-5}(female) 2) 2) 0.0295 3) 0.01622	1) Solano-Fernandez et al. 2015
b	1) 2.788 (male), 2.586 (female) 2) 2.75 3) 2.83	2) Froese & Pauly 2017 3) Fishbase
Reproduction	Gonochoristic, broadcast spawner etc.	
Maturity parameters		e.g. Logistic
A_{50} (years)	Females 0.5, Males 0.5	
L_{50} (mm)	Females 458-483, Males 476-506	
Fecundity	20,000-620,000 15 – 174 million	Batch fecundity Annual
Size-fecundity parameters		e.g. $BF = (a\ FL^{b})$
a	0.000005	McBride et al. 2012
b	3.62	
Spawning frequency	Multiple spawners, spawn	

5.5.3.1 Life Cycle

Larvae and juveniles (TL<100 mm) are pelagic and often associated with floating algae, such as pelagic sargassum mats which are an important habitat for juveniles.

Mahi mahi is a serial spawner with a year round spawning period in spring and summer during which many individuals engage in large aggregations.

5.5.3.2 Habitats and Movements

Mahi mahi inhabits offshore oceanic waters, often forms large schools associated with floating debris, FADs and structures such as oil rigs. In offshore waters 1000-3000 m water temps 24-31°C off India.

A fast swimming predator that inhabits coastal reefs, wrecks and pylons areas or the open sea. Capable of long distance movements along coast and across the Tasman Sea, tagging has recorded movement of over 3,000 km from NSW to NZ.

5.5.3.3 Age and Growth

The species is short lived and can reach up to 5 years of age. Initial growth is rapid reaching 2-3 kg in their first year, and females smaller than males. They can reach over 200 cm and 39 kg but are typically 7-13 kg.

A linear relationship exists between FL and TL: FL =0.84 TL (Lasso & Zapata 1999).

5.5.3.4 Natural Mortality

The instantaneous rate of natural mortality (*M*) was 0.52 $year^{-1}$ (Solano-Fernandez et al. 2015).

5.5.3.5 Reproduction

The species is a highly fecund, serial spawner with extended year round spawning in temperatures above 21°C with a peaks in Winter and Summer India (Kumar et al. 2017). The species mature in their first year by 4-7 months of age at lengths of 20-50 cm. Can spawn multiple times producing 80,000- 1.5 million eggs in each event.

5.5.3.6 Factors Affecting Year Class Strength and Other Biological Parameters

No stock-recruitment relationship has been developed for this species.

Spawning often in offshore waters where larvae are highly dependent upon prevailing oceanic conditions of southward Leeuwin and northward Capes Currents for distribution. Intra and inter-annual variations in currents affect spawning and larval distribution and survival throughout the protracted spawning period.

5.5.3.7 Diet and Predators

The species is an opportunistic carnivore feeding on mostly small pelagic fishes (flying fish, garfish), squids and crustaceans.

Trophic level 4.4 ± 0.0 se (Fishbase)

Predators of Mahi mahi are likely to include larger pelagic species, sharks, and dolphins.

5.5.3.8 Parasites and Diseases

Like many pelagic species Mahi mahi are prone to infections by skin, gill and blood flukes and sea lice. A review reported as at least 125 parasites in the species (William & Bunkley-Williams 2010). The species is also known to carry infection by the microscopic myxosporean parasite, *Kudoa* sp. that upon cooking releases an enzyme causing musculature liquefaction or "milky flesh" where the flesh becomes mushy and inedible.

5.5.4 Inherent Vulnerability

The biology and behaviour of Mahi mahi makes them low to moderately vulnerable to fishing. They mature in their first year, are highly fecund with a planktonic larval stage usually with broad dispersal. Individuals of the species may undergo large scale migrations so there are often mixing amongst regions as they form large spawning aggregations.

The most common method of capture by commercial and recreational is line fishing, often close to Fish Attracting Devices (FADs) or other floating structures. In WA recreational fishers release an estimated 50-65% of their catch for the species with many fishing for catch and release or sportsfishing reasons. As with Spanish mackerel their lack of swim bladder, physiology and light lines used for capture mean there is likely a high degree of post release mortality for the species.

The catches are widespread in WA so there is only a low risk of hyper-stability in catch rates. Successful long-term management has been recorded for the species at much higher catch levels in Indian Ocean fisheries. Further, whilst the level of recruitment and catch in WA may vary annually, associated with environmental conditions, there is generally some recruitment in most years.

5.6 School mackerel (*Scomberomorus queenslandicus*)

Figure 5.6. The School mackerel, *Scomberomorus queenslandicus*. Illustration © R. Swainston (www.anima.net.au)

5.6.1 Taxonomy and Distribution

The School mackerel, *Scomberomorus queenlandicus*, (Figure 5.16) is a member of the family Scombridae (mackerels, tunas and bonitos). It is distinguished by dark bars extending part way down sides, although these fade after death, the black area at front of dorsal fin and dip in lateral line being posterior to dorsal fin. It's Australian distribution includes northern Australia to as far south as at least Perth in south-western Australia (**Error! Reference source not found.**) (Allen and Swainston 1995) and Sydney on the east coast.

5.6.2 Stock Structure

There are at least two School mackerel biological stocks off the east Australian coast. Assumed stock level also includes northeastern, and northern stocks in northern Australia (SAFS). No stock structure studies have included WA stocks and School mackerel is considered a single management unit in WA as the same genetic stock is likely to extend throughout the state.

5.6.3 Life History

The sub-sections below provide an overview of the life history characteristics of the School mackerel, with a summary of the relevant biological parameters used in stock assessments presented in Table 5.6. As there have been no biological studies conducted on School mackerel in WA waters much of the parameters used have been taken from studies on the East coast of Australia.

Table 5.6. Summary of biological parameters for School mackerel (all from Cameron & Begg 2002, Begg 1998, Begg and Selin 1998)

Parameter	Value(s)	Comments / Source(s)
Growth parameters		e.g. $L_t = L_\infty(1 - \exp(-K(t - t_0)))$
L_∞ (mm)	Females 651, Males 628	
K (year^{-1})	Females 0.585, Males 0.704	
t_0 (years)	Females -1.411, Males -1.272	
Maximum age (years)	10	
Maximum size (mm)	1180	
Natural mortality, M (year^{-1})	0.421	
Length-weight parameters		e.g. ln(*W*)(*g*) = b+a (*FL*) (*mm*)
a	1) 3.775, 2) 0.000058	2) Smallwood et al. 2017
b	1) 0.006, 2) 0.731502	
Reproduction	Gonochoristic, broadcast spawner,	
Maturity parameters		e.g. Logistic
A_{50} (years)	Females 1-2, Males 1-2	
L_{50} (mm)	Females 460-510, Males 410-460	
Fecundity	250,000 (at size 500)	[Batch / Annual] fecundity
Size-fecundity parameters		e.g. *LnF* = b +a *FL*
a	0.003	
b	11.159	
Spawning frequency	Multiple spawners, spawn frequency unknown	Qld Oct-Jan.

5.6.3.1 Habitats and Movements

School mackerel have a restricted distribution and are confined to the waters of southern Papua New Guinea and around northern Australia from the Shark Bay area on the west coast to northern New South Wales on the east coast. Adult School mackerel are known to commonly occur in turbid tropical and sub-tropical waters of approximately 3– 30 m depth. This is usually in the vicinity of bottom structure in close proximity to rocky headlands and reefs (where pelagic baitfish such as tropical sardines and herrings are concentrated) and on sandy-mud and muddy sand substrates. They rarely occur at the edge of the continental shelf to depths of 100 m. Tagging studies on the east coast of Australia detected only small scale movements of less than 300 km, supporting the existence of a number of stocks. Larval and juvenile life history stages of School mackerel are found inshore coastal bays and the inner margin of the lagoon, often in estuarine environments that are typically influenced by freshwater run-off and low salinity surface waters.

5.6.3.2 Age and Growth

No age and growth studies have been conducted on School mackerel in WA waters. Parameters have been taken from studies on the East coast of Australia.

Like most mackerel species School mackerel grow fast for their first three years after which growth tends to slow. Males grow faster than females but attain a smaller asymptotic length. Maximum age of 10 years has been recorded for the species with no difference recorded between the sexes.

TL = 1.17 FL -26.61 (TL 320-1113, Statewide) (Smallwood et al. 2017)

5.6.3.3 Natural Mortality

No age and growth studies have been conducted on School mackerel in WA waters. Parameters have been taken from studies on the East coast of Australia where maximum age for the species was 10 years and natural mortality is estimated at 0.32 $year^{-1}$ (Cameron & Begg 2002).

5.6.3.4 Reproduction

No reproductive biology studies have been conducted on School mackerel in WA waters. Parameters given in Table 5.6 have been taken from a few studies on the East coast of Australia. The species is a schooling, pelagic, batch spawner with spawning on East coast throughout its range from Oct – Jan. The species mature at approximately 2 years of age and at 45-55 cm in length allowing the LML of 50 cm to give some protection to immature fish.

5.6.3.5 Factors Affecting Year Class Strength and Other Biological Parameters

There is significant year to year variability in School mackerel catches, which is likely to be attributed to fishery-dependent factors as well as seasonal and environmental factors, particularly rainfall variability. This may leave School mackerel vulnerable to management arrangements that are not adaptive to seasonal or environmental variabilities.

As with Spanish mackerel the species is likely to benefit in range extension though climate change, see Section 7.3.1.1.

5.6.3.6 Diet and Predators

Trophic level 4.5 ± 0.8 se (Fishbase)

School mackerel are small-size, pelagic predators in tropical, coastal habitats. They are only known to feed exclusively on baitfish, such as sardines, anchovies and herring (Cameron & Begg 2002). In some locations and at certain times of the year, they are relatively abundant. However, data relating to their ecological role and to their influence on other components of coastal ecosystems are lacking.

Predators of juvenile and adult School mackerel are likely to include larger pelagic species, sharks, and dolphins.

5.6.3.7 Parasites and Diseases

No known issues in WA.

5.6.4 Inherent Vulnerability

The biology and behaviour of School mackerel makes them low to moderately vulnerable to fishing. School mackerel are a fast growing group, with most reaching spawning age and exploitation size by 2-3 years but with potential longevities to 10 years. They are highly fecund with a long spawning season and broad dispersal. Whilst individuals may undergo size / age related migrations these are to a smaller scale than other large pelagic species and there is limited mixing amongst regions. They do form spawning aggregations at known locations.

The most common method of capture is by trolled or jigged lines close to reefs or other structures. There are high release rates of 60-70% for the species by both recreational and charter fishers with most releases due to being undersized or too many so as the LML for the species of 500 mm in TL is above the size at maturity there is some resilience for the species if targeting does increase. However, as with other mackerel species there may be a high degree of post release mortality for the species.

With their wide distribution, stable catch and small fishery (less than 10t per year in WA) there is only a low risk of hyper-stability in catch rates. Successful long-term management has been recorded for much higher catch levels of the species on the East coast. Whilst the level of recruitment often varies annually, associated with environmental conditions, there is generally some recruitment in most years.

5.7 Spotted mackerel (*Scomberomorus munroi*)

Figure 5.7. The Spotted mackerel, *Scomberomorus munroi*. Illustration © R. Swainston (www.anima.net.au)

5.7.1 Taxonomy and Distribution

The Spotted mackerel, *Scomberomorus munroi*, (Figure 5.7) is a member of the family Scombridae (mackerels, tunas and bonitos). The species was only recently described in 1980 and was previously confused with the Japanese Spanish mackerel (*S. niphonius*) but has more vertebrae and fewer gill rakers (Collette & Russo 1980). It is distinguished by numerous small spots extending down sides. It's Australian distribution includes northern Australia to as far south as at least Abrolhos Is. in western Australia (**Error! Reference source not found.**) (Allen and Swainston 1995) and Sydney on the East coast.

5.7.2 Stock Structure

There is a single stock of Spotted mackerel along the eastern coast of Australia, in northern and northwestern Australia the delineation of stocks is unclear but likely consists of a single stock.

Spotted mackerel is considered a single management unit in WA as the same genetic stock is likely to extend throughout the state (Roelofs et al. 2014).

5.7.3 Life History

The sub-sections below provide an overview of the life history characteristics of the Spotted mackerel, with a summary of the relevant biological parameters used in stock assessments presented in Table 5.7. As there have been no biological studies conducted on Spotted mackerel in WA waters and much of the parameters used have been taken from studies on the East coast of Australia.

Table 5.7. Summary of biological parameters for Spotted mackerel (all from Cameron & Begg 2002, Begg 1998, Begg and Selin 1998)

Parameter	Value(s)	Comments / Source(s)
Growth parameters		e.g. $L_t = L_\infty (1 - \exp(-K (t - t_0)))$
L_∞ (mm)	Females 862, Males 729	
K (year^{-1})	Females 0.410, Males 0.313	
t_0 (years)	Females -1.783, Males -3.134	
Maximum age (years)	8	
Maximum size (mm)	1230	
Natural mortality, M (year^{-1})	0.527	
Length-weight parameters		e.g. $\log(W) = b + a\ (FL)$
a	4.453	
b	0.005	
Reproduction	Gonochoristic, broadcast spawner	
Maturity parameters (LCF)		e.g. Logistic
A_{50} (years)	Females 1-2, Males 1-2	
L_{50} (mm)	Females 451-500, Males 410-450	
L_{95} (mm)	Females 806, Males 668	
Fecundity	250,000 (at size 500)	[Batch / Annual] fecundity
Size-fecundity parameters		e.g. $LnF = b + a\ FL$
a	0.003	
b	11.159	
Spawning frequency	Multiple spawners, spawn frequency unknown	Nth Qld Aug-Oct.

5.7.3.1 Habitats and Movements

Spotted mackerel have a restricted distribution and are confined to the waters of southern Papua New Guinea and around northern Australia from the Houtman Abrolhos Islands area on the west coast (28°30′S) to northern New South Wales on the east coast. Adult Spotted mackerel are known to commonly occur in turbid tropical and sub-tropical waters of approximately 3–30 m depth. This is usually in the vicinity of bottom structure in close proximity to rocky headlands and reefs (where pelagic baitfish such as tropical sardines and herrings are concentrated) and on sandy-mud and muddy sand substrates. They rarely occur at the edge of the continental shelf to depths of 100 m. Tagging on the East Coast of Australia detected temporal and spatial patterns of large scale movements of up to 1000 km consistent with a single stock undertaking a seasonal migration. Larval and juvenile life history stages of spotted mackerel are found inshore coastal bays and the inner margin of the lagoon, often in estuarine environments. The larvae of this species inhabit coastal bays and nearshore areas that are typically influenced by freshwater run-off and low salinity surface waters.

5.7.3.2 Age and Growth

No age and growth studies have been conducted on Spotted mackerel in WA waters. Parameters have been taken from studies on the East coast of Australia.

Like most mackerel species Spotted mackerel grow fast for their first three years after which growth tends to slow. Males grow faster than females but attain a smaller asymptotic length. Maximum age of 8 years has been recorded for the species with no difference recorded between the sexes.

TL = 1.06 FL + 42.48 (n=11, TL 535-780, Statewide) (Smallwood et al. 2017)

5.7.3.3 Natural Mortality

No age and growth studies have been conducted on Spotted mackerel in WA waters. Parameters have been taken from studies on the East coast of Australia where maximum age for the species was 8 years and natural mortality is estimated at 0.32 $year^{-1}$ (Cameron & Begg 2002).

5.7.3.4 Reproduction

No reproductive biology studies have been conducted on Spotted mackerel in WA waters. Parameters given in Table 5.7 have been taken from a few studies on the East coast of Australia. The species is a schooling, pelagic, batch spawner with spawning on the north Queensland coast from Aug – Oct.

5.7.3.5 Factors Affecting Year Class Strength and Other Biological Parameters

There is significant year to year variability in Spotted mackerel catches, which is likely to be attributed to fishery-dependent factors as well as seasonal and environmental factors, particularly rainfall variability due to the inshore occurrence of juveniles as recorded for other species (Halliday et al. 2008). This may leave Spotted mackerel vulnerable to management arrangements that are not adaptive to seasonal or environmental variabilities.

As with Spanish mackerel the species is likely to benefit in range extension though climate change, see Section 7.3.1.1.

5.7.3.6 Diet and Predators

Trophic level 4.3 ± 0.76 se (Fishbase)

Spotted mackerel are mid-size, pelagic predators in tropical, coastal habitats. They are only known to feed exclusively on baitfish, such as sardines, anchovies and herring (Cameron & Begg 2002). In some locations and at certain times of the year, they are relatively abundant. However, data relating to their ecological role and to their influence on other components of coastal ecosystems are lacking.

Predators of juvenile and adult Spotted mackerel are likely to include larger pelagic species, sharks, and dolphins.

5.7.3.7 Parasites and Diseases

No known issues in WA.

5.7.4 Inherent Vulnerability

The biology and behaviour of Spotted mackerel makes them low to moderately vulnerable to fishing. Spotted mackerel are a fast growing group, with most reaching spawning age and exploitation size by 2-3 years but with potential longevities to 8 years. They are highly fecund with a long spawning season and broad dispersal. Whilst individuals may undergo size / age related migrations there is limited mixing amongst regions. They form spawning aggregations at known locations.

The most common method of capture is by trolled or jigged lines close to reefs or other structures. The LML for the species of 500 mm in TL is below the size at maturity and there are high release rates of 60-70% for the species by both recreational and charter fishers so imparting some resilience for the species if targeting does increase. However, as with other mackerel species there may be a high degree of post release mortality for the species.

With their wide distribution, stable catch and small fishery (less than 1t per year in WA) there is only a low risk of hyper-stability in catch rates. Successful long-term management has been recorded for much higher catch levels of the species on the East coast. The stock declines that have occurred in some large pelagic fisheries have followed extended periods of high exploitation, these can, however, recover in a relatively short (< 10 years) period once corrective actions are implemented. There is evidence that recruitment levels are maintained even following significant reductions in spawning biomass. Further, whilst the level of recruitment often varies annually, associated with environmental conditions, there is generally some recruitment in most years.

5.8 **Cobia** (*Rachycentron canadum*)

Figure 5.8. The Cobia, *Rachycentron canadum*. **Illustration © R. Swainston (www.anima.net.au)**

5.8.1 Taxonomy and Distribution

The Cobia, *Rachycentron canadum*, (Figure 5.8) is the only species in the family Rachycentridae. The species is found worldwide in all tropical and subtropical continental waters, except in the Eastern Pacific. It is an oceanodromous, bentho-pelagic species that in Australia is known from south-western Western Australia, to Cape Naturaliste, around the tropical north of the country to the central coast of New South Wales. The Cobia has an elongate body with very short dorsal fin spines. Colour of back and sides dark brown, with two sharply defined narrow silvery bands and yellowish/pale belly.

5.8.2 Stock Structure

There has been no study on the stock structure in WA but is likely a single stock of Cobia along the western coast of Australia.

Cobia is considered a single management unit in WA as the same genetic stock is likely to extend throughout the state.

5.8.3 Life History

The sub-sections below provide an overview of the life history characteristics of the Cobia, with a summary of the relevant biological parameters used in stock assessments presented in Table 5.7. As there have been no biological studies conducted on Cobia in WA waters and the parameters used have been taken from studies elsewhere.

Table 5.7. Summary of biological parameters for Cobia (from Fry 2010, Fishbase, Van der Velde et al 2010, Richards 1967, Dippold et al 2017)

Parameter	Value(s)	Comments / Source(s)
Growth parameters		e.g. $L_t = L_\infty (1 - \exp(-K(t - t_0)))$
L_∞ (mm)	1210 1172 (1151-1192)	Richards 1967, Dippold *et al* 2017
K (year^{-1})	0.28 0.57 0.52-0.61)	
t_0 (years)	-0.06 N/A	
Maximum age (years)	13	
Maximum size (mm)	1633	
Natural mortality, M (year^{-1})	0.35	
Length-weight parameters		e.g. log(*W*) = b+a (*FL*)
a	0.0047	
b	3.07	
Reproduction	Gonochoristic, broadcast spawner	
Maturity parameters (LCF)		e.g. Logistic
A_{50} (years)	Females 1.5, Males 1.75	
L_{50} (mm)	Females 784	Van der Velde 2010
L_{95} (mm)	Females 630, Males 700	
Fecundity	0.58-7.4 million eggs	Batch fecundity
Size-fecundity parameters		e.g. *F (100,000)* = a *Wt-b*
a	9.8	
b	6.39	
Spawning frequency	Multiple spawners, spawn frequency 7.6 days	Qld Sept.-Jun Van der Velde 2010 Peak Oct-Dec

5.8.3.1 Life Cycle

Cobia larvae grow rapidly and are large at 3.5 mm TL in comparison to most marine species at hatching. Juvenile fish are found in both nearshore and offshore waters, often among *Sargassum* patches or weedlines where they seek shelter from predators and can feed. The species is considered to be one of the most suitable candidates for warm, open-water marine fish aquaculture in the world. Its rapid growth rate and the high quality of the flesh could make it one of the most important marine fish for future aquaculture production.

5.8.3.2 Habitats and Movements

The species occur in a variety of habitats, over mud, sand and gravel bottoms; over coral reefs, off rocky shores and inshore around pilings and buoys, and offshore around drifting and stationary objects and occasionally in estuaries throughout its range to a depth of 200 m.

The Cobia is often seen at the surface, frequently accompanying large rays and sharks, especially Whale Sharks. Elsewhere the species is known to form large spawning aggregations usually in open water, and spawning 15-20 times per season. Larval and juvenile life history stages of Cobia are generally found inshore coastal bays and the inner margin of the lagoon, often in estuarine environments. The larvae of this species inhabit coastal bays and nearshore areas that are typically influenced by freshwater run-off and low salinity surface waters.

5.8.3.3 Age and Growth

No age and growth studies have been conducted on Cobia in WA waters. Parameters have been taken from studies elsewhere and on the East coast of Australia. The species grows rapidly and reaches maturity at age 2; males at 60-65 cm FL and females at 80 cm FL. with no difference in growth recorded between the sexes. Its maximum size is 200 cm fork length (FL), commonly to 110 cm FL (Collette 2002). The largest recorded is 61kg from Shark Bay. Maximum ages on the east coast were to 15 years and in North Carolina were 14 years (males) and 13 (females) (Rodger and Zharen 2012).

5.8.3.4 Natural Mortality

No age and growth studies have been conducted on Cobia in WA waters. Parameters have been taken from studies on the East coast of Australia where maximum age for the species was 15 years and natural mortality is estimated at 0.32 year^{-1}.

5.8.3.5 Reproduction

No reproductive biology studies have been conducted on Cobia in WA waters. Parameters given in Table 5.7 have been taken from a few studies on the East coast of Australia. The Cobia is a pelagic spawner, releasing many tiny (1.2 mm), buoyant eggs into the water, that float freely with the currents until hatching. In northeastern Australia Cobia have a protracted spawning period from September to June with a GSI peak Oct-Dec and most likely spawn at night. (Van der Velde et al 2009) The larvae are also planktonic, being more or less helpless during their first week until the eyes and mouths develop. The male matures at two years and the female at three years. Both sexes lead moderately long lives of 15 years or more.

In the Gulf of Mexico spawning activity takes place diurnally from April to September in large offshore congregations, where the female is capable of spawning up to 30 times during the season. Age at maturity in the Gulf of Mexico is between one and two years, all individuals aged 3+ were mature. Maturity appears to be more closely correlated with size than age. During the spawning season it forms large aggregations and spawns once every 9-12 days or 15-20 times in a season, generally in open water (Rodger and Zharen 2012).

5.8.3.6 Factors Affecting Year Class Strength and Other Biological Parameters

In the NCB there is no significant year to year variability in Cobia catches, however, in the Gascoyne and West Coast the catch is variable and likely attributed to seasonal and environmental factors, particularly water temperature in the southern extent of their range.

As with Spanish mackerel the species is likely to benefit in range extension though climate change, see Section 7.3.1.1.

5.8.3.7 Diet and Predators

Trophic level 4.0 ± 0.0 se (Fishbase)

Cobia are mid-size, pelagic predators in tropical, coastal habitats although is primarily a demersal feeder, preying on crabs, squids, teleosts, and elasmobranchs. In some locations and at certain times of the year, they are relatively abundant. However, data relating to their ecological role and to their influence on other components of coastal ecosystems are lacking.

Predators of juvenile and adult Cobia are likely to include larger pelagic species, sharks, and dolphins.

5.8.3.8 Parasites and Diseases

No known issues in WA.

5.8.4 Inherent Vulnerability

The biology and behaviour of Cobia makes them low to moderately vulnerable to fishing. Cobia are a fast growing group, with most reaching spawning age and exploitation size by 2-3 years but with potential longevities to 15 years. They are highly fecund with a long spawning season and broad dispersal. Whilst individuals may undergo size / age related migrations there is limited mixing amongst regions. Elsewhere they form spawning aggregations at known locations but little is known of such aggregations in WA.

The most common method of capture is by trolled or jigged lines close to reefs or other structures. The large size and strong fighting abilities makes the Cobia a popular sports fish. It is most frequently taken on lures or with live fish bait. The dry white flesh is of excellent eating quality. The species do not possess a swim bladder so although they may not suffer from barotrauma they can suffer post release mortality, particularly if played on light line to exhaustion.

With their wide distribution, stable catch and small fishery (less than 35 t per year in WA, combined Commercial, Recreational and Charter retained catch) there is only a low risk to stock levels from fishing. Successful long-term management has been recorded for much higher catch levels of the species on the East Coast. The stock declines that have occurred in some large pelagic fisheries have followed extended periods of high exploitation, these can, however, recover in a relatively short (< 10 years) period once corrective actions are implemented. Further, whilst the level of recruitment may vary annually, associated with environmental conditions, there is generally some recruitment in most years.

6 Fishery Information

6.1 Fisheries / Sectors Capturing Resource

The species in the Large Pelagic Resource are distributed throughout WA but can be split into the tropical (NCB and GCB) and the temperate groups (WCB and SCB). Historically they have been exploited by a variety of fisheries and are currently taken in amounts of >1 t by 11 fisheries (Table 6.1). Apart from Spanish mackerel and occasionally Grey mackerel in the MMF most of the other Large pelagic species are taken as bycatch in other fisheries. In WA since 2006 only licences in the MMF are permitted to land species in the *Scomberomorous* (Mackerels), *Grammatorycnus* (Shark mackerel) and *Acanthocybium* (Wahoo) genera. The species in the tropical large pelagic resource are predominantly captured by troll line in the MMF and fish trawl net by the Pilbara Fish Trawl Managed Fishery (PFTMF) or Pilbara Trap and Line Fishery (PTLMF). The temperate large pelagic species are taken by the line fisheries WCDSMF, SCOAF and the demersal gillnet fishery TDGDLMF (West and South Coast).

The recreational fishery accesses the large pelagic resource throughout the state mainly by line fishing, spearfishing and on charter boats. The statewide estimated harvest by boat-based recreational fishers is dominated by Spanish mackerel. However, the majority of the recreational catch for most large pelagic species is released/discarded, typically 70% - 100% for most species, although 42-47% for Spanish mackerel (Ryan *et al*. 2015). The section(s) below provide more detailed information about the sectors that target the key species of Spanish mackerel, unless otherwise stated.

Table 6.1. Retained average annual catches (t) of all Large Pelagic species / groups reported in the WA for the 2011 – 2018 fishing seasons in the various fisheries. Dark blue shading indicates indicator species and light blue shading indicates species ≥1% that are currently reported at an individual species level.

			NCB			GCB		WCB		SCB		
Species	**CILF**	**MMF**	**NDS**	**PFTMF**	**PTLF**	**SBBSMNF**	**GDSMF**	**WCDGDL**	**WCDSMF**	**SCOA**	**JASDGDL**	**Total**
Spanish mackerel	-	296.6	-	-	-	-	-	-	-	-	-	297
Grey mackerel	-	10.2	-	-	-	-	-	-	-	-	-	10.2
Samson fish	-	-	-	-	0.2	-	0.9	2.0	12	13.7	6.7	35.5
Amberjack	-	-	2.6	5.6	4.5	-	2.4	-	0.2	-	-	15.3
Cobia	-	-	-	9.3	0.6	-	1.5	0.4	1.2	-	-	13
Golden trevally	-	-	0.8	3.7	-	1.2	0.3	-	-	-	-	6
Wahoo	4.6	0.2	-	-	-	-	-	-	-	-	-	4.8

6.2 Mackerel Managed Fishery

6.2.1 History of Development

The MMF lands over 80% of the annual Large Pelagic catch in WA and as such is the only key fishery. The MMF was not established until 2006 and developed from the open access wetline fishery. Commercial fishing for mackerel in Australia commenced along the Queensland coast during the 1920s and expanded rapidly after World War II. From the 1930s onwards, mackerel were targeted in northern Australian waters by Japanese, Russian, Chinese and Taiwanese fishers (Nowara and Newman 2001).

In particular, Taiwanese gill net fishers caught considerable amounts of Spanish mackerel throughout northern Australia, including Western Australia, until the declaration of the Australian Fishing Zone in 1979. Catches of Spanish mackerel peaked at nearly 1000 t per year (Millington and Walter 1981). After 1979, the fishing area was restricted and a catch quota was imposed. From 1979 to 1986, the total catch by Taiwanese gill net fishers in northern Australian waters ranged between approximately 100 and 500 t per year (Stevens and Davenport 1991). In the same period, the Taiwanese gill net catches in Western Australian waters (i.e. the region from Broome to approximately NT border) was between 5 and 80 t per year. Overall reductions in catch rate and mean fish size of Spanish mackerel in the Taiwanese fishery during the early 1980s suggested that stocks may have been overfished (Stevens and Davenport 1991).

The earliest reports of commercial fishing for Spanish mackerel by Western Australian fishers are from the Geraldton area in the 1950s. Since the Australian Fishing Zone was declared in 1979, the Western Australian Spanish mackerel fishery has grown substantially, particularly in the north of the state. In the mid-1980s, mackerel catches in the Pilbara Area increased rapidly as more fishers began targeting the species. This reportedly coincided with (and was probably due to) increased abundances of mackerel at that time. There are currently about 3 – 5 boats that target mackerel in the Pilbara Area, some of which also fish the Kimberley Area. The introduction of electronic aids (particularly GPS) has been crucial for the ability of fishers to target mackerel around isolated reefs, with retained fish being trunked, cooled in brine and layered in ice at sea, before being transported on ice to Perth for sale on the domestic market.

In 1981, the Department completed an exploratory research trip in the North West (mainly between Port Hedland and Broome; Donohue et al. 1982) to collect biological information on Spanish mackerel. Although mackerel had already been caught by foreign fishers in this region since the 1930, most gill net catches were taken in the Cape Londonderry area to the west of Joseph Bonaparte Gulf. At the time that the Taiwanese gill net operations ended in 1986, due to prohibitive restrictions imposed on the length of their nets, only a few Australian boats were targeting mackerel in the Kimberley Area. Some of these were based in the Northern Territory and spent about three months of the year catching Spanish mackerel in the area.

The seasonal appearance and fluctuating abundance of Spanish mackerel meant that historically most fishers caught them opportunistically with few exclusively targeting them and other troll caught species. The history of catches in WA gives little mention of mackerel until 1950. The current fishery expanded from Geraldton and moved northwards as the coast was opened up from the 1960s. The Kimberley area of the fishery was initially exploited by boats from Darwin and also by Taiwanese gillnets in the 1980s. At its peak, before management was introduced there were 86 boats landing mackerel in WA but of these only 20-30 were actively targeting Spanish mackerel and 42 were subsequently included in the Mackerel Managed Fishery, based on their catch history before the benchmark date of 3rd Nov 1997. Since the establishment of the management plan in 2006 the number of boats has stabilised at 11-16 and the effort between 550-680 block days / year (Figure 6.1). The catch is dominated by Spanish mackerel with some minor component of Grey mackerel each year.

The Fishery transitioned from an interim managed fishery to a managed fishery on 1 January 2012. The Mackerel Managed Fishery (MMF) operates under an Individual Transferable Quota (ITQ) system which includes the setting of Total Allowable Commercial Catches (TACCs) for each Area of the Fishery, allocation of the entitlement to take quota in the form of units, and establishment of minimum unit holding requirements to operate in the Fishery.

The Plan includes limitations on the number of licences to fish in the Fishery and the type of gear that can be used. Boats operating in the Fishery are monitored by VMS and the master of an authorised boat is required to submit logbook returns and catch and disposal records. Seasonal closures were removed in May 2008, as they were no longer a necessary tool to maintain sustainable and efficient management of the Fishery after quotas were put in place in 2006.

Licence holders may only fish for mackerel by trolling or handline. There are currently 48 licences in the Fishery with 14, 16 and 18 licences in Areas 1, 2 and 3 (Figure 6.2), respectively, with the combined quota allocations being consolidated onto 14 boats operating within the fishery.

The commercial mackerel fishery in WA was open-access (i.e. allowed any commercial fisher with a WA wetline license to catch mackerel) until it came under formal management arrangements in 2004. Under the new Interim Management Plan (IMP) arrangements, the fishery was divided into three management Areas (see Section **Error! Reference source not found.**), each with their own specific quotas, license restrictions and fishing seasons. According to criteria set down in the IMP, the number of permit holders allowed to fish for mackerel in each area was significantly reduced.

The MMF extends from the West Coast Bioregion to the WA/NT border (**Error! Reference source not found.**), with most effort and catches recorded north of Geraldton, especially from the Kimberley and Pilbara coasts. The fishery has three management areas, Area 1: Kimberley (121º E to the WA/NT border); Area 2: Pilbara (114º E to 121º E) and Area 3: Gascoyne (27º S to 114 º E) and West Coast (Cape Leeuwin to 27º S).

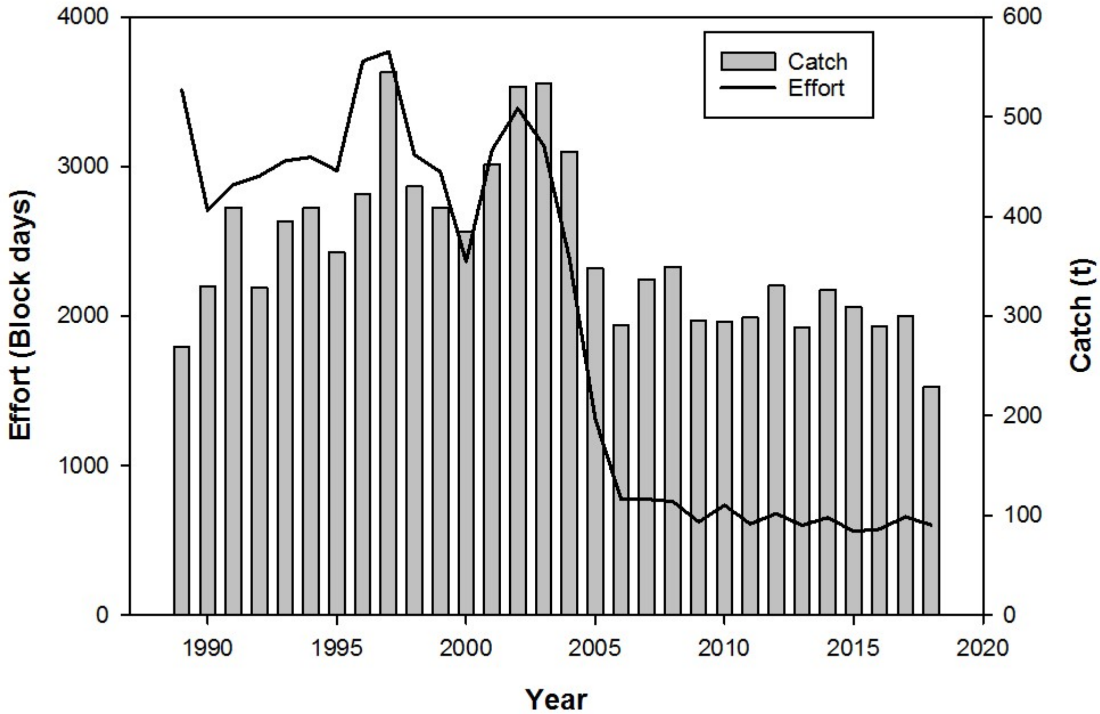

Figure 6.1. Annual total retained All mackerel species catches (tonnes) and fishing effort (block day) by the commercial fisheries in WA between 1989 and 2018 with catch quotas introduced in 2006.

6.2.2 Current Fishing Activities

A summary of key attributes of the current MMF and the fishing fleet is provided in Table 6..

Fishing operations of the main fishers in the Kimberley Area differ from those in other regions, partly because of the large distance to many of the fishing grounds. This is the only Area where dories are now permitted to be operated from main boats (mother ships) because of their historic use. As such, the crews usually number about 4 – 5. The trips are generally between 1 – 4 weeks, and the fish are filleted, layered into cardboard boxes and frozen at sea for sale on the domestic market. In other areas (Pilbara and Gascoyne/West Coast) the boats are generally smaller and trips are shorter with fish kept whole or trunked in ice slurry and sent in large fish bins to local and domestic markets. GPS and other electronic aids are used in all regions for finding the main reefs on which mackerel are found. At present there is no export market for the MMF but in the past Grey mackerel were exported in the early 2000s but this has since stopped.

The MMF extends from the West Coast Bioregion to the WA/NT border, with most effort and catches recorded north of Geraldton, especially from the Kimberley and Pilbara coasts of the Northern Bioregion. Catches are reported separately for three Areas: Area 1 - Kimberley (121º E to WA/NT border); Area 2 - Pilbara (114º E to 121º E); Area 3 - Gascoyne (27º S to 114º E) and West Coast (Cape Leeuwin to 27º S) (see Figure 6.2).

Table 6.2. Summary of key attributes of the commercial Mackerel Managed Fishery

Attribute	
Fishing methods	Troll, handline
Fishing capacity	430 t quota
Number of licences	18 (77.8% active)
Number of vessels	11-15
Size of vessels	8-18 m
Number of people employed	35
Value of fishery	$3-5 million

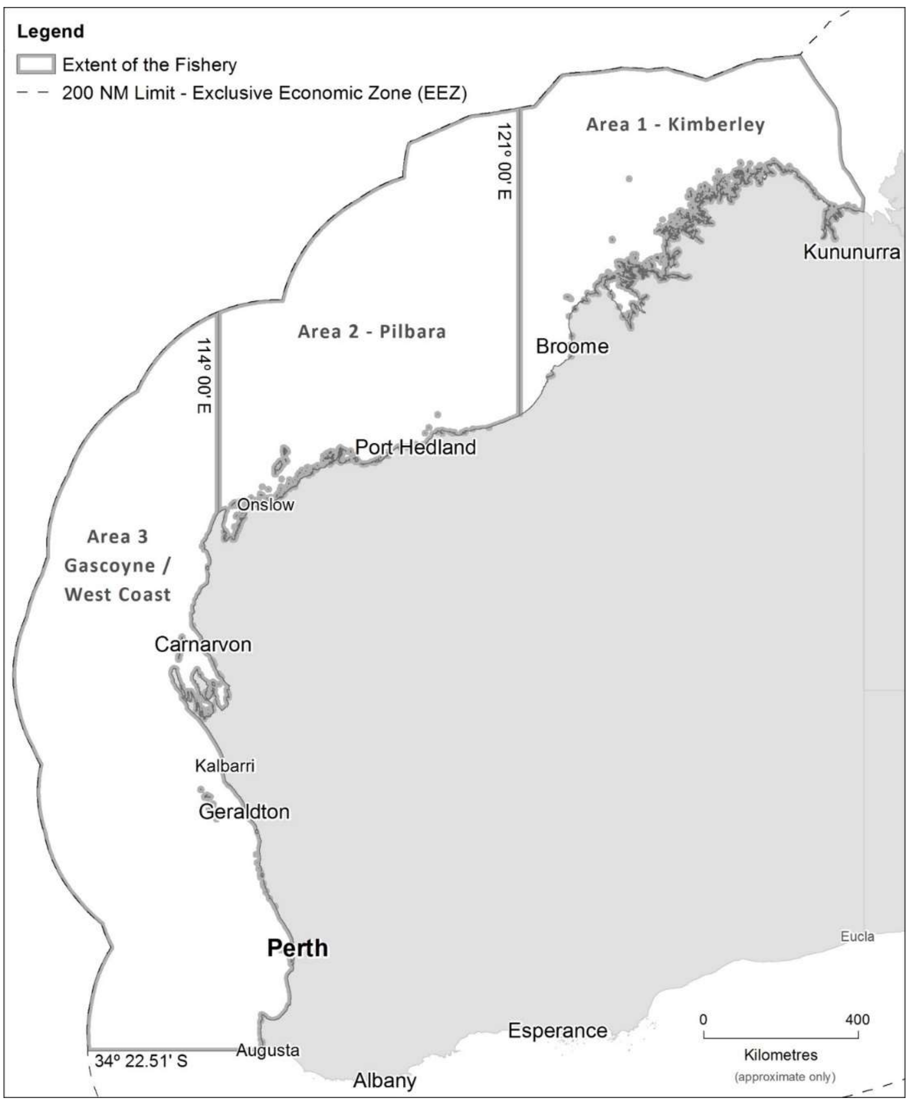

Figure 6.2. Boundaries of the commercial MMF and its Management Areas.

6.2.3 Fishing Methods and Gear

Trolling gear used in the West Coast region has changed through time. Originally the main line was made of thick, braided, nylon sash-cord and 250 pound breaking strain wire trace, with either baited triple-ganged 10/0 – 12/0 hooks, spoons or jigs. The troll rigs used in this region have become progressively lighter, with a switch in about 1980 to heavy (400 – 500 pound) monofilament main line and gunwhale mounted hand reels or game rods. There was a further change in the West Coast region during the early 1990s to lighter rod and reel outfits fitted with 40 – 80 pound line (although a combination of light and heavy lines are often used, including one line that is weighted with lead and sits deeper in the water).

Heavy sash cord main lines are still used by the main boats in the Kimberley Area, with perhaps the only change in gear being a shift from mostly jigs, spoons and lures towards triple-ganged hooks baited with garfish. The main boats troll up to seven lines whereas each dory will fish 2 – 3 lines. Each of these main boats therefore has considerably greater fishing power but also greater running costs than mackerel boats in other regions.

The narrow-barred Spanish mackerel, *Scomberomorus commerson*, is the largest and most abundant of the four *Scomberomorus* species found in the coastal waters of Western Australia. It is also the main target of the present day troll fishery, comprising more than 95 % of the total catch in the MMF. Spanish mackerel are rarely caught by any of the other commercial fishing methods used along the WA coast.

Of secondary importance in this fishery is the Grey (or broad-barred) mackerel, *S. semifasciatus*, which typically account for less than five per cent of the total catch in the MMF. Although usually captured by jigging rather than by trolling, *S. semifasciatus* is generally only targeted by mackerel fishers and is considered a part of the troll-based mackerel catch. The remainder of the catch in this fishery includes various species caught in minor quantities. The fishery also uses considerable numbers of smaller fish for bait (usually garfish and mullet). Because the gear and methods used in this fishery generally have little if any effect on the environment, the fishery is regarded as relatively benign.

The main fishing method for mackerel is trolling but baits or lures are also drifted or cast from anchored or drifting boats. Jigging methods are also used to catch Grey mackerel in the Gascoyne and West Coast sectors.

A variety of baits, lures and jigs will usually be trolled. Whole garfish, or mullet which have had the backbone removed so they 'swim', are the main baits and are secured to a set of 3 – 4 ganged hooks (often size 10/0-12/0). Silver 'spoons' and various coloured 'Smiths jigs' are also used. These are generally favoured over other types of lures that are more efficient but also more expensive and less robust. Baits are usually most successful and are used on about 70 % of lines.

Lines may be weighted to troll within about 1 m of the surface, but otherwise the baits lie near the surface. "Paravanes" (or "water kites") are occasionally used to get baits deeper in the water, and trolling speed can be varied to alter fishing depth. Line length varies from about 5 – 30 m behind the stern of the boat. Trolling speed also varies from 3 – 7 knots depending on conditions, fish catchability and fisher preference. A shiny 'teaser' made from mirrors may also be towed to attract fish to the baits.

Trolling methods differ between sectors:

Kimberley Area: Dories (5 m – 6.5 m dinghies) troll 2 – 3 lines and work to a refrigerated mother boat. The mother boat is about 20 m in length and also trolls 6 – 7 lines. Fishing gear used in this sector is relatively heavy (8 – 10 mm rope with a 200+ kg mono line and wire trace). Crews comprise 3 – 5 fishers per fishing operation.

Pilbara Area: Boats used in this sector are 9 – 15 m in length. They troll 6 – 7 lines and have 1 – 2 crew. The use of dories in this sector is restricted under the new management arrangements to those who are authorised to fish in both the Kimberley and Pilbara and who are permitted to use dories in the Kimberley. Boats in this area use 180 kg mono line and wire trace.

Gascoyne Coast/West Coast Area: Vessels used in this sector are 7 – 15 m in length. They troll 2 – 4 lines and have 1 – 3 crew. Dories are not permitted. Gear used is rod and reel with 20 – 30 kg line and wire trace.

Hooked mackerel are retrieved as quickly as possible to the boat. A gaff may be used to retrieve larger fish (preferably without damage to the fillet). In southern areas, where lighter lines and rods are used, fish are allowed to 'run' with the line before retrieval. Fish are killed and placed as quickly as possible into brine to reduce the body temperature. Fish are headed and gutted or filleted for the Australian market. Fish are mainly stored on board in an ice-slurry.

In the Kimberley Area, where trip durations are longest (typically 1 – 3 weeks), freezer boats are employed and almost all the mackerel are filleted and frozen. In the Pilbara sector, trip duration is usually > 1 week, and the product is trunked and brined before being sold locally or sent to Perth markets. In recent years, the main catches from this sector have been landed at Port Hedland. In the Gascoyne and West Coast sectors, trip duration is 1 – 5 days. Gascoyne-captured fish are usually trunked and sold locally or sent to Perth markets. Most catches in the West Coast sector occur in the Geraldton and Abrolhos areas.

Fishing success is affected by various environmental factors. Trolling gear is most efficient in clear water and moderate sea conditions with good water movement. Environmental factors including moon phase, tidal regime and weather all affect water conditions and therefore impact on fishing success. Water temperature is also important, with optimum temperatures decreasing with southerly latitudes.

Fishing success is usually higher in the morning and late afternoon. Fishers targeting mackerel therefore aim to be over the fishing ground in the morning. Fishers will stay at a location until fish stop biting and a school may be fished for several hours. Fishers may then wait for tides and conditions to improve or travel to another location. Traveling is usually undertaken during the middle of the day. A crew may fish several locations per day. 'Part-time' mackerel fishers will usually only target mackerel when they are abundant. These fishers may troll for mackerel in the early morning and late afternoon, and may target other species during other times of the day. In the Pilbara and Kimberley sectors, electronic aids such as GPS, plotters and echo sounders are required to locate fish, which are often found over reefs and other submerged structures in these sectors. Fishing generally occurs along the side of the reef facing the current. Electronic aids are less important in the Gascoyne/West Coast sector where fishing is usually done around prominent areas of coastline.

6.2.4 Susceptibility

For the key target species of Spanish mackerel there is a high degree of overlap of the fishery with the species range, apart from the Ningaloo zone closed to commercial fishing.

There is a high encounterability of the target species with the fishing gear however environmental conditions do influence catchability with water clarity a key factor which can be influenced by tides and winds.

There is a relatively high selectivity in the fishing method and the gear as large baits or lures are used which are suited to larger-sized fish and the juveniles are generally found inshore or in known areas which are avoided by the commercial fishers resulting in them rarely being caught.

The heavy-duty fishing gear used by commercial fishers generally results in juvenile fish being released quickly with little time for lactic acid build up and exhaustion, however, the damage inflicted by the large hooks and prevalence of sharks at some locations may make the survival rate of released mackerel very low.

6.3 Recreational / Charter Fishery

6.3.1 History of Development

The recreational and charter sectors target the Large Pelagic resource throughout the state with a similar or higher amount of the catch released/discarded as retained for most large pelagic species. Because of its fighting and eating qualities, Spanish mackerel is a popular target of recreational fishers. Light rod/reel outfits and small boats are typically used, generally in combination with trolled lures or drifted baits. Shore-based fishing for mackerel is also popular at Steep Point (Shark Bay) and the rock platforms of Quobba station north of Carnarvon. A drifted bait may be kept near the surface using balloons tied to the main line. Balloons (often gas filled) are also used by shore-based anglers to carry the line out to sea. Spanish mackerel are also targeted by spear fishers.

Most recreational catches of Spanish mackerel are taken between Perth and Dampier, with distance and isolation limiting recreational fishing in the north where most of the commercial catch is taken. Recreational catches may vary considerably from year to year, particularly in the southern areas at the limit of its distribution. For instance, during the summer of 1979/80 there were large schools of Spanish mackerel in close to the Perth metropolitan beaches (Craig Redman, pers. comm.) and recreational fishers targeted these schools. There have been periods of low abundance of Spanish mackerel in the south since that time, but higher abundances have occurred previously during strong Leeuwin Current flows, such as during the summer of 1988/89, early in both 2000 and 2001 and again in 2010/11 when fish were caught as far south as Albany on the south coast. These peaks in abundance followed the appearance in the previous year of large numbers of undersized fish in the Gascoyne and Pilbara regions, suggesting a link between good recruitment and subsequent higher abundances/extended distribution of Spanish mackerel.

There have been a number of changes to the recreational bag limits for Spanish mackerel, Grey mackerel and Samson fish. From a species limit of 6 per species to a Large Pelagic group possession limit of four for the resource in 2010 which has likely reduced the retained catch of the larger pelagics. A revised statewide mixed species daily bag limit of three was introduced for the Large Pelagic Finfish in 2013 as an outcome of the statewide recreational fishing review. Previously a combined daily bag limit of two in the West Coast and South Coast Bioregions and four in the Gascoyne and North Coast Bioregions applied.

In addition, the 20 kg possession limit of fish products has likely further reduced the retained recreational catch of large pelagic species. This is particularly so for holidaying anglers in the north of WA, as more prized eating quality demersal species are retained in preference to the Large Pelagic species which, due to their large size, can fill the possession limit with just one or two fish.

6.3.2 Current Fishing Activities

Recreational and charter fishing for the Large Pelagic Resource is undertaken in waters throughout WA. There are some seasonal factors in the targeting of the large pelagics by these sectors due to the cyclone season in the north and higher abundances due to water temperatures or spawning periods in the south. Many of the large pelagic species are targeted by specialised charter operators and recreational fishers practising tag and release fishing. As a result of this, their abundance throughout the state, ease of targeting and for many fine eating qualities there is a high social value for these species by fishers.

There is little historic data on actual catches of Spanish mackerel and other mackerel species by recreational fishers. Estimates of recreational catches are available from recreational fishing surveys conducted from Augusta to Kalbarri during 2005/06 (Sumner et al. 2008), from False Entrance (Shark Bay) to Exmouth Gulf during 1998/99 (Sumner et al. 2002), and in the Pilbara region during 1999/2000 (Williamson et al. 2006). More recently, an integrated recreational survey of boat-based fishers (iSurvey, Ryan et al. 2017) has provided bioregional-wide estimates of catches of all species. A summary of recreational catch information for Spanish mackerel is presented in Section **Error! Reference source not found.**.

6.3.3 Fishing Methods and Gear

A wide range of fishing gear used by predominantly boat-based fishers in most regions and some specific shore-based locations. Recreational and charter fishers use a combination lures and a wide range of baits including mullet, garfish and pilchards when targeting the species.

Mackerel and other large pelagic species are also regularly taken in small amounts by spear fishers throughout the state.

6.3.4 Susceptibility

The area overlap of the recreational and charter fishery for Spanish mackerel and large pelagic species is moderate as some more remote parts of the state, such as the Kimberley, have little effort.

As recreational fishers use a wide variety of gear and techniques there is a high encounterability of the target species by some recreational fishers, but likely low for others.

Similarly, as recreational fishers use a wide variety of techniques and gear, there is a limited selectivity in targeting fish above the size at maturity by some fishers and they are likely caught regularly.

There is likely a low survival following capture and release of some Large pelagic species, such as the mackerel species and cobia, by recreational fishers as they are often caught using light lines and playing the fish leading to lactic acid build-up and exhaustion, have difficulty releasing fish quickly due to thrashing fish with sharp teeth and hooks. These factors combined with a lack of swim bladder mean the released fish will sink if not able to quickly recover and resume a swimming speed plus at some locations there is likely to be a high mortality due to depredation of released or even hooked fish by sharks. However, for the Carangidae species there is likely to be a higher survival rate, even though some such as Samson fish are caught in offshore waters of over 100 m depth they have a swim bladder âventâ which allows release of excess pressure to avoid barotrauma injuries and so can withstand such capture and release.

6.4 Customary Fishing

The customary take of large pelagic species is likely to be very low as they generally occur in offshore waters so are not easily accessible. In a national survey of recreational and indigenous fishing conducted in Australia during 2000-01, it was estimated 93% of the indigenous fishing effort in WA was shore based and only 45% in saltwater. Overall 97 % of mackerel harvested by indigenous fishers in Australian waters are caught by line fishing, with some netting and spearfishing also occurring (Henry and Lyle 2003).

6.5 Illegal, Unreported or Unregulated Fishing

There is no known Illegal, Unreported or Unregulated (IUU) fishing of the resource, however it may be possible that unloads from boats in the MMF occur in Darwin where there is no jurisdiction to monitor catch that may have come from WA waters.

7.0 Fishery Management

7.1 Management System

Apart from the Mackerel Managed Fishery the Large Pelagic Resource is managed using a constant catch harvest strategy. A number of Large Pelagic species have a minimum legal length (Table 7.1) and for recreational fishers form part of a mixed Large Pelagic species statewide daily bag limit of three, which also includes Sharks and Rays. In addition, the billfish species have an individual species daily bag limit of one.

Table 7.1 Large pelagic species with a minimum legal size limit.

Minimum legal size (mm)	Species
500	Mahi mahi, School, Shark, & Spotted mackerel
600	Amberjack, Samson fish, Yellowtail kingfish
750	Cobia, Grey mackerel
900	Spanish mackerel, Wahoo

Mackerel Managed Fishery

The capacity of the MMF is determined through a Total Allowable Commercial Catch (TACC) for the maximum quantity of mackerel other than broad-barred Spanish mackerel (Class A) and broad-barred Spanish mackerel/grey mackerel (Class B) that may be taken from each Area of the Fishery. The TACC for each Area of the MMF is detailed in Table 7.2.

The TACC for the Fishery is distributed to Licensees via unit allocations for mackerel other than broad-barred Spanish mackerel (Class A units) or broad-barred Spanish mackerel (Class B units). The maximum number of units conferred to all licences with in each Area and unit Class of the MMF is outlined in Table 7.2.

The extent of entitlement to fish in an Area of the Fishery that arises from a unit during a licensing period is determined by calculating the unit value. The unit value is a calculation of the kilograms of mackerel are entitled to per unit of mackerel other than broad-barred Spanish mackerel (Class A) or broad-barred Spanish mackerel (Class B) within each area of the Fishery.

The Management Plan also includes limitations on the number of permits to fish in the MMF. There are currently 65 permits in the MMF with 23, 21 and 21 permits in Areas 1, 2 and 3 (respectively), with the combined quota allocations being consolidated onto 4, 3 and 9 boats operating within Areas 1, 2 and 3 (respectively).

Table 7.2. Current Total Allowable Commercial Catch (TACC), number of units and unit values within the Mackerel Managed Fishery for 2018.

Class of unit	*Current TACC (kg) (MMP Clause 12)*	*Maximum number of units (MMP Schedule 6)*	*Unit values (kg per unit) (MMP Schedule 7)*
Class 1A	***225,000***	***4326***	***52.01***
Class 1B	***60,000***	***1259***	***47.66***
Class 2A	***126,000***	***3059***	***41.19***
Class 2B	***60,000***	***1452***	***41.32***
Class 3A	***79,000***	***1720***	***45.93***
Class 3B	***60,000***	***1302***	***46.08***

Licensed vessels in the MMF are not permitted to fish in a number of closed waters that include waters of Port Areas, Commonwealth Marine Reserves, waters of Marine Protected Areas or Marine Parks closed to commercial fishing. Closed waters also include the Point Maud to Tantabiddi Commercial Fishing Closure from 23° 07.30’ S to 21° 56.30’ S, which applies offshore to 200 nautical miles (Figure 3.1).

Licensed vessels can only fish by hand line or troll line in the waters of the MMF. The use of wire or chain (metal) on the snood attached to the hook is prohibited. This does not include the sinker, swivel, crimp or connector. Additionally, you cannot spearfish in the MMF. The transferring of fish to or from another boat while at sea is prohibited, unless transferring from the auxiliary boat to the associated primary boat.

All boats operating in the MMF are monitored by a Vessel Monitoring System (VMS) and are required to nominate before commencing each fishing trip undertaken under the authority of a mackerel licence. The nomination to fish must specify the licence in which fishing will be carried out on, the Area or Areas of the Fishery where fishing will occur and be made where a fishing trip commences from outside the Fishery, immediately upon entering the Fishery or where the boat is in the waters of the Fishery, from a port area and not more than 2 hours prior to the boat commencing a fishing trip from a port area. The nomination must also specify the full name of the master of the boat for that fishing trip. The master of an authorised boat is also required to notify when taking the vessel out of the waters of the Fishery prior to the vessel leaving the waters of the Fishery and specify the whole weight of broad-barred Spanish mackerel and any mackerel other than broad-barred Spanish mackerel that will be taken out of the waters of the Fishery.

Masters of an authorised vessel are also required to submit daily logbook returns along with catch and disposal records (CDRs) which are related to one MFL per CDR booklet. When a master of an authorised boat requests a new CDR it is allocated the related MFL number before being sent to the master.

7.2 Harvest Strategy

A draft harvest strategy for the MMF component of the Large Pelagic Resource outlines the long- and short-term objectives for management (DPIRD *in prep.*). It also provides a description of the performance indicators used to measure performance against these objectives, reference levels for each performance indicator, and associated control rules that articulate pre-defined, specific management actions designed to maintain the resource at target levels.

The harvest strategy that is currently in place for Spanish mackerel in the MMF is responsive to the state of the stocks and elements of the harvest strategy work together towards achieving the management objectives reflected in the target, threshold and limit reference points. Target (acceptable) annual catch ranges (Table 7.3) were calculated by per recruit modelling (Mackie et al. 2003).
Although a recreational fishery also targets Spanish mackerel (and other pelagic species), the MMF takes the greatest share of the catch of Spanish mackerel in any year, especially in the Kimberley and Pilbara management areas where most of the biomass is located. Recreational Spanish mackerel catches were estimated to be 21 % of the commercial catch from the North Coast Bioregion (i.e. combined Kimberley and Pilbara areas) in 2015/16.

The harvest strategy is therefore based on using a constant commercial catch policy where the annual commercial catches of Spanish mackerel are allowed to vary within target catch ranges, with the upper limit (i.e. the commercial TACC) set at a level very unlikely to impair recruitment. Each area of the MMF has acceptable annual catch ranges for Spanish mackerel. The Kimberley Area's acceptable catch range (110 – 225 t), the Pilbara Area (acceptable catch range 80 – 126 t) and the Gascoyne/West Coast Area (56 – 79 t).

The stock of Spanish mackerel is assessed annually by comparing trends in commercial catches against WA total and Area target catch ranges. Trends in catch rates are also examined each year to assess fishery performance. These were initially calculated based on information from 2006 – 2011, a period when the fishery was considered to have stabilised and catches were sustainable. Catches, while varying, remained with the target ranges for the fishery in the Kimberley and Pilbara areas for most years but have been consistently below in the southern Gascoyne/West Coast management area. The stabilised catches and catch rates were part of the case for conversion of this fishery to fully-managed status.

Proposed target, threshold and limit ranges were also calculated in 2012, based on catch rates over the period 2006-2011 (Table 7.4). If the overall catch of Spanish mackerel moves outside the target catch range, or the catch rate for any management area falls outside the threshold values, a review is triggered to investigate the likely cause (e.g. market forces, other non-biological factors, poor recruitment, over-exploitation). If the review suggests that performance limits were (or may have been) exceeded because of a decline in spawning biomass, the management response could include a reduction in TACC or total effort (via changes to unit values), following consultation with industry.

Catch rates have been stable or increasing since the mid-2000s when the fishery came under formal management and fishers rationalised their operations (see Figure 9.2). If catch rates fall below the lower limit levels, the implication is that the spawning biomass is reduced to the level where recruitment overfishing may be occurring. Catch rates exceeding the upper limit level may be indicative of major changes in the operation of the fishery (e.g. efficiency increases) or increased stock size (e.g. increased recruitment) - a review would be required to ensure that sustainability was not at risk before determining whether, for example, effort needed to be reduced or catches could be increased.

The lower limit reference point for catch rate is set at 30% below the lower threshold (see next section). Given the relatively high inherent productivity of this species (fast growth and early maturity), a decline in catch rate of 30% below the threshold levels is deemed suitably precautionary; i.e. the stock can be expected to rebound relatively quickly. This means that while declines outside of the threshold but within the limits will be acted on to provide protection to the stock, fishers can have some degree of confidence that any required reductions in TACC will not be unnecessarily conservative. Alternatively, any breaches of the limit reference points will indicate that the risk to the stock requires immediate action, including a likelihood of significant catch reductions.

Recreational catches are managed with individual and vessel-based catch limits, minimum legal size and through the State-wide recreational marine boat-fishing license (see Section **Error! Reference source not found.**).

Table 7.3. Summary of the current performance indicators, reference levels and control rules for the Spanish mackerel in the MMF.

Management Objective	Performance Indicator(s)	Reference Levels	Control Rules
To maintain spawning stock biomass of each retained species above B_{MSY} to maintain high productivity and ensure the main factor affecting recruitment is the environment.	Annual commercial catch (tonnes) of Spanish mackerel in MMF.	**Target:** Annual commercial catch is [240 – 460] tonnes; Kimberley (Area 1) 110 – 225 tonnes yr^{-1}; Pilbara (Area 2) 80 – 126 tonnes yr^{-1}; Gascoyne/West Coast (Area 3) 56 – 79 tonnes yr^{-1}.	No management action is required.
		Threshold: Annual commercial catch is ≤ [240] or ≥ [460].	A review is triggered to investigate the reasons for the variation. If sustainability is considered to be at risk, appropriate management action will be taken to reduce the total catch by up to 50%.

Table 7.4. Summary of the proposed performance indicators, reference levels and control rules for nominal catch rate of Spanish mackerel in the MMF.

Reference Points	Performance Measures	Control Rules	Justification
Target	The midpoint of the catch threshold performance measures (below)	If catches are between the upper and lower threshold reference levels, the effort will remain unchanged.	A conservative level based on a historical reference period (2006 – 2011) when commercial fishery reporting was switched to fine scale daily logbooks and effort in the fishery had become relatively stable due to the conversion to ITQs (i.e. recruitment was unaffected) (Molony et al. 2012). This level is considered to correspond to 1.2 B_{MSY}.
Threshold	Minimum and maximum values of the commercial catch in the reference period as follows: Kimberley (Area 1) 412 – 614 kg day^{-1}; Pilbara (Area 2) 279 – 596 kg day^{-1}; Gascoyne/West Coast (Area 3) 148 – 290 kg day^{-1}.	If the catch falls outside the two threshold values, the effort level will be reviewed in consultation with industry to reduce the catch by 0-50% and bring it closer to the target value.	These performance measures are considered to correspond to 1 and 1.4 B_{MSY} respectively.
Limit	70% of the lower threshold and 130% of the upper threshold. Kimberley (Area 1) 288 – 814 kg day^{-1}; Pilbara (Area 2) 195 – 778 kg day^{-1}; Gascoyne/West Coast (Area 3) 103 – 416 kg day^{-1}.	If the lower limit is breached, the catch will be reduced by 50-100%, depending on investigation of causes and vulnerability of the species. If catch rate falls outside the upper limit, the cause will be investigated to determine if effort needs to be reduced.	These are considered to correspond to 0.5 B_{MSY} and below which there is considered risk to the reproductive ability of the stock.

7.3 External Influences

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

Spanish mackerel and the other mackerel species caught by this fishery are moderately long-lived, fast-growing species that exhibit annual variations in recruitment strength and adult movement due to environmental fluctuations.

Recent surveys indicate that the number of Spanish mackerel lost to sharks during capture were about 7 and 15% of the total recreational catch in the Gascoyne and Pilbara regions, respectively. Hence, in some areas the mortality of mackerel due to sharks taking hooked and released fish can result in a higher impact of recreational fishing than the bag limits imply. Commercial fishers traditionally lose few fish to sharks, typically 3-5%, because they are more mobile, avoid areas where sharks are more numerous and use heavier fishing gear (Mackie et al. 2003).

Finally, the last three assessments of Spanish mackerel catch in the Indian Ocean by the Indian Ocean Tuna Commission (IOTC) determined the species to be '*subject to overfishing and overfished*', with the estimated total landings in 2014 of 154,732 t (IOTC 2017). The IOTC plan to conduct a full assessment of Spanish mackerel in 2020.

7.3.1 Environmental Factors

7.3.1.1 Climate Change

A risk assessment of WA's key commercial and recreational finfish and invertebrate species has demonstrated that climate change is having a major impact on some exploited stocks (Caputi et al. 2015). This is primarily occurring through changes in the frequency and intensity of El Niño Southern Oscillation (ENSO) events, decadal variability in the Leeuwin Current, increase in water temperature and salinity, and change in frequency and intensity of storms and tropical cyclones affecting the state (Caputi et al. 2015). In 2010/11, a very strong Leeuwin Current resulted in unusually warm ocean temperatures in coastal waters of south-western WA (Pearce et al. 2011). This "marine heatwave" altered the distribution and behaviour (e.g. spawning activity and migration) of some species and caused widespread mortalities of others.

There is little direct data on the impacts of climate change. However, anecdotal information suggests that narrow-barred Spanish mackerel are distributed further south during periods of above-average water temperature. It is likely, therefore, that the range of narrow-barred Spanish mackerel will extend southwards and that the centre of the biomass of stock may also move more southerly. It is also possible that the total biomass of narrow-barred Spanish mackerel in Western Australia will increase due to the relatively high productivity the stock, the likely extension of the breeding season with higher water temperatures and the availability of additional suitable habitats further south.

Many large pelagic species experience annual variations in recruitment strength and adult movement due to environmental fluctuations. The changing marine environment off the WA coast may benefit some tropical species in the southern parts of their range as seen during the marine heatwave of WA when Spanish mackerel distribution shifted southwards (Pearce et al 2011). However, the impacts upon the species in the northern part of their range, where the majority of the commercial Spanish mackerel catch is taken, may be negative as the East Coast recruitment is negatively correlated with spring sea surface temperatures (Welch et al. 2014).

7.3.2 Introduced Pest Species

No known impacts of introduced pests on the MMF are recorded to date.

7.3.3 Market Influences

The value of the fishery is variable due to fluctuations in the quantity of annual landings and the prices of fish at markets. Domestic market forces have the potential to influence catch and effort levels in the fishery. For example, the timing of the Queensland mackerel fishing season partly overlaps with the Western Australian fishing season, placing the two fisheries in competition for several months.

7.3.4 Non-WA Managed Fisheries

Some of the tuna and billfish species that are part of the Large Pelagic resource are landed by the Commonwealth Western Tuna and Billfish Fishery (WTBF) which landed over 300 t of predominantly swordfish off WA in 2014/15 from a quota of 10,000 t.

7.3.5 Other Activities

Increasing activity by the petroleum industry, particularly in the Pilbara area, may also be impacting catches by mackerel fishers in some parts due to decreased access to fishing grounds and possible impacts of seismic surveys upon fish abundances. The gazettal of both Commonwealth and State marine parks over the past three years has further restricted fishing areas available to the MMF, particularly in the Kimberley (Figure 7.1).

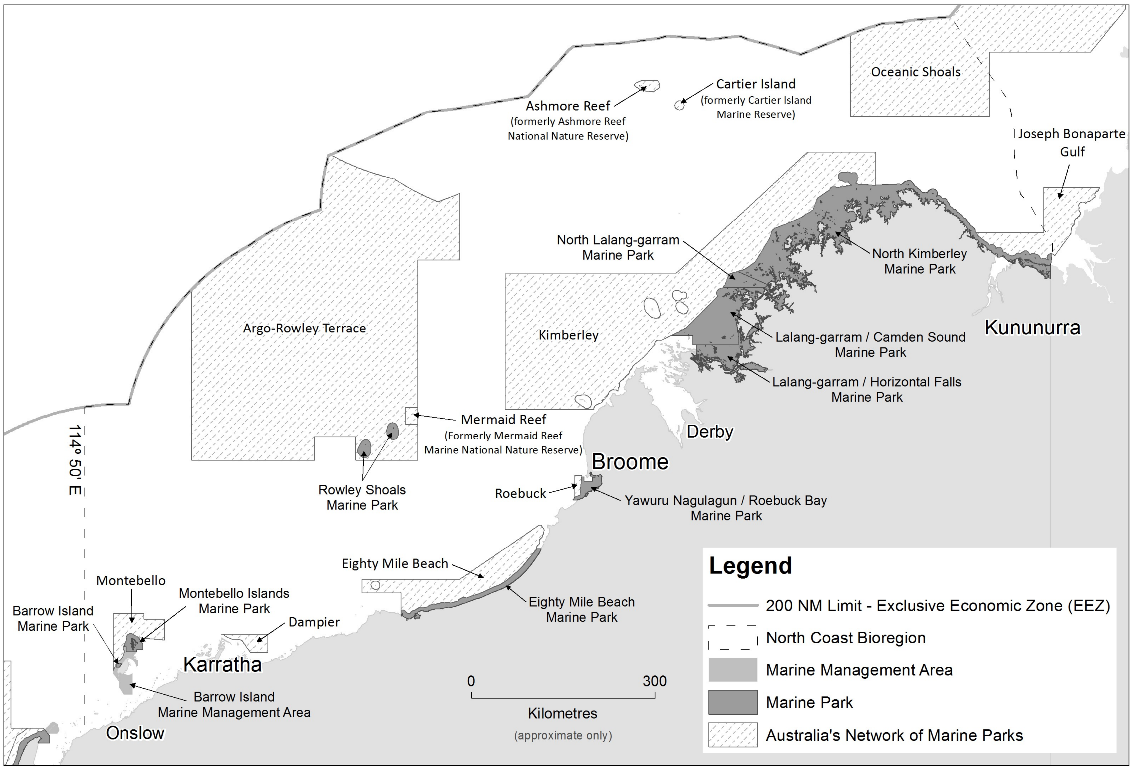

Figure 7.1 Map showing the North Coast Bioregion and current and proposed state and Commonwealth marine parks and reserves along the northern WA coast.

8.0 Information and Monitoring

8.1 Range of Information

The range of information available to support the assessment and harvest strategy for the Large Pelagic Resource in WA is given in Table 8.1.

Table 8.1. Summary of information available for assessing the Large Pelagic Resource

Data type	Fishery-dependent or independent	Purpose / Use	Area of collection	Frequency of collection	History of collection
Commercial catch and effort statistics ([CAES returns / Logbooks])	Dependent	Monitoring of commercial catch and effort trends, calculation of catch rates and the area fished	CAES block / Latitude and longitude	Monthly / Daily	Since [1979] Daily since 2006
Catch Disposal Records (CDRs)	Dependent	Validation of catch returns / logbooks	Management Area	Trip/Unload	Since [2006]
VMS data	Dependent	Verification of boat locations for logbook analysis	Latitude and longitude	Hourly	Since [2006]
Recreational catch and effort estimates	Dependent	Monitoring of recreational catch and effort trends	Statewide	Biannually	Since 2012
Charter catch and effort statistics	Dependent	Monitoring of charter catch and effort trends	Statewide	Daily	Since 2001

8.2 Monitoring

8.2.1 Commercial Catch and Effort

There is a high level of relevant information related to stock structure, stock productivity, fleet composition and other data to support the harvest strategy. Detailed research on mackerel stocks and the mackerel fishery was undertaken in the late 1990s and early 2000s (Mackie et al. 2003) incorporating previous research Australia-wide involving inter-state counterparts. This included comprehensive biological research critical to support stock assessments.

Catch and effort data have been collected by DPIRD since 1956. Up until 2006, there was a statutory obligation for fishers to provide a catch and effort monthly form (CAES returns). This detailed the location (1^{o} x 1^{o} blocks) of catch by species retained and associated effort.

From 2006, daily logbooks have replaced the CAES return as the statutory return in the MMF and some other fisheries that land large pelagic species. This supplies data on a finer spatial scale (either actual GPS position data 10 x 10 nm block). In addition, a detailed Catch Disposal Record (CDR) form was introduced for quota compliance purposes in the MMF. The 'official' catch is that which is recorded by fishers as verified by the CDR.

Regional Services Division enforce the compliance of returns and verify catches (see pp. 247 – 249 of Fletcher and Santoro (2012) for examples of summary compliance reports).

The MMF has a daily logbook that splits effort into sessions with the fishing details, estimated catch and location for each are reported. The daily logbook trip returns are used to generate catch and block days for each vessel which go into the monthly CAES database.

The catches and catch distribution in the daily logbook are monitored annually for discrepancies in locations and validated against the CDR records for the fisher unloads.

8.2.2 Recreational / Charter Catch and Effort

Recreational catches were assessed using boat-ramp and shore-based creel surveys between 1998/99 and 2005/06 (Sumner et al. 2002; Williamson et al. 2006; Sumner et al. 2008).

Since 2 March 2010, all persons fishing from a powered boat anywhere in the state have been required to hold a Recreational Fishing from Boat Licence or fish in the company of a licence holder. The Recreational Fishing from Boat Licence provides a state-wide database of recreational boat fishers that can be utilised for survey purposes.

A state-wide survey was implemented in 2011 to collect information on private (non-charter), boat-based recreational fishing in WA (Ryan et al. 2013, 2015, 2017). This survey uses three complementary components, off-site phone diary surveys, on-site boat ramp surveys and remote camera monitoring, to collect information on fishing catch, effort, location and other demographic information every two years.

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

8.2.3 Customary Catch

As the larger pelagic resource is primarily in offshore waters and the majority of the WA customary effort is in freshwater, shore based or inshore (Section 6.4, Henry & Lyle 2003) there is likely to be a very low customary take of large pelagic species. This survey produced a customary catch estimate of only 424 mackerel species group harvested in WA, which is 0.5% of the recreational estimate for this same group.

8.2.4 Fishery-Dependent Monitoring

No fishery-dependent onboard monitoring of the Large Pelagic Resource is currently undertaken.

8.2.5 Fishery-Independent Monitoring

No fishery-independent monitoring of the Large Pelagic Resource is currently undertaken.

8.2.6 Environmental Monitoring

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

8.3 Data Governance (Non-Public)

8.3.1 Data Storage

The source daily logbook data is stored in an Access database.

8.3.2 Data Treatment

There is no filtering or manipulation of the annual catch data, with nominal catch rates calculated from total block days and calculated whole fish weight of catch in each of the three management areas of the MMF.

9.0 Stock Assessment

9.1 Assessment Principles

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

Irrespective of the types of assessment methodologies used, all stock assessments undertaken by the Department take a risk-based, weight-of-evidence approach (Fletcher 2015). This requires specifically the consideration of each available line of evidence, both individually and collectively, to generate the most appropriate overall assessment conclusion. The lines of evidence include the outputs that are generated from each available quantitative method, plus any qualitative lines of evidence such as biological and fishery information that describe the inherent vulnerability of the species to fishing. For each species, all of the lines of evidence are then combined within the Department's ISO 31000 based risk assessment framework (see Fletcher 2015; Appendix 2) to determine the most appropriate combinations of consequence and likelihood to determine the overall current risk status.

9.2 Assessment Overview

The assessment is appropriate for the stock and for the harvest control rule. Acceptable catch ranges and catch rate levels used to assess the fishery are based on historically proven levels of sustainable harvest and so are robust indicators. That is, there has been no indication of depressed recruitment levels at the levels of catch removed and associated catch rates.

A comprehensive ESD assessment of the MMF in 2010 determined that levels of Spanish mackerel breeding stock should be used as an annual performance measure for the Fishery. As the minimum legal size of Spanish mackerel (900 mm total length) is similar to the size at maturity, the spawning stock is essentially the same as the exploited stock. Thus, catch rates across the different management areas of the fishery are a general indicator of breeding stock levels.

The acceptable catch range in the Gascoyne/West Coast (combined) sector is supported by estimates of regional biomass (Mackie et al. 2003). Since 1994, estimated biomass in the Gascoyne/West Coast sector has been relatively stable at around 850 t, and annual commercial catches in the sector have been equal to 9 – 11% of the total biomass. In 2001, the combined commercial and recreational catch was approximately 20 % of the estimated biomass (915 t) in the sector. Although modelling of biomass has not been successful in other sectors, higher catch rates suggest that the carrying capacities of the Kimberley and Pilbara sectors are likely to be higher than the Gascoyne/West Coast sector.

A limit of 20 – 30 % of the fishable biomass has been recommended as a safe level of fishing for Spanish mackerel (Buckworth and Hall 1993). Hence, the catch range in each sector is likely to represent a very precautionary level of harvest.

An Australian wide status review (Holmes et al. 2012) also concluded that the WA stock of Spanish mackerel is sustainable.

9.2.1 Peer Review of Assessment

The Spanish mackerel catch by the MMF has undergone Unit of Certification (UoC) pre-assessment / third party certification against the Marine Stewardship Council (MSC) standard for sustainable fishing (V1.3) in 2014. The outcome was that it would likely pass against the standard with the main strengths being 1) limited number of licenses, 2) regionally specific TACCs, minimum size to protect spawning potential of stock, and 3) catch and catch rate based reference points and rules. While the weaknesses were 1) the lack of spawning biomass data, 2) limited bait useage data and 3) lack of independent assessment of bycatch and ETP interactions.

A review of the acceptable catch ranges and TACCs for the MMF will be undertaken during 2020, with any changes being introduced in 2021. It is anticipated that a formal harvest strategy will be developed for the fishery in the future to assist in monitoring the fisheries performance and reviewing TACCs.

As stated in DoF's ESD policy, it is expected that the ESD report for the MMF, and therefore the objectives and performance measures, will be reviewed every five years to ensure that they remain relevant and appropriate with current scientific protocols, social attitudes and prevailing environmental conditions.

9.3 Analyses and Assessments

9.3.1 Data Used in Assessment

CAES / Logbook / Processor returns / VMS data Recreational fishing survey data Charter returns data Economic data

9.3.2 Catch and Effort Trends

9.3.2.1 Commercial Catches

The combined WA commercial landings of all Large pelagic species has ranged from 361-433 t over the past 10 years but dropped to 293 t in 2018 due primarily to a drop in the catch of Spanish mackerel but declines were recorded in other species as well. Spanish mackerel are the main targeted species in the Large Pelagic Resource and can only be landed by the MMF (Table 9.1). Grey mackerel are the other tropical large pelagic indicator species and are also only landed by the MMF. The temperate indicator species, Samson fish, is landed by a number of fisheries on the SCB and WCB but in low quantities and is generally not a target species. The catch of other large pelagic species is shared by a number of other fisheries where they are generally not one of the target species and landed in small amounts of <20 t annually (Table 6.1).

Table 9.1. Annual commercial catches (t) of each indicator species (blue shaded) and other large pelagic species retained in ≥1% by the commercial fisheries accessing the Large Pelagic Resource, with calculated average and percentage contribution to the catch from the resource for the past five years (2011-2018).

Species	2011	2012	2013	2014	2015	2016	2017	2018	Average	% of total
Spanish mackerel	284	318	277	322	302	276	283	214	285	75.9%
Grey mackerel	13	12	11	3.5	7	14	16	15	11.4	3.0%
Samson fish	42	36	36	38	31	25	23	22	31.6	8.4%
Wahoo	5.7	5.3	4.8	4.4	4.8	4.3	4.4	8.0	5.2	1.4%
Golden Trevally	1.8	3.5	3.1	3.9	4.2	12.3	45.6	18.8	11.6	3.1%
Cobia	12.2	14.8	12	11.5	14	14.4	20.6	19.6	14.9	4.0%
Amberjack	18.9	12.5	13.7	20.4	14.2	18.4	15	11.3	15.6	4.1%

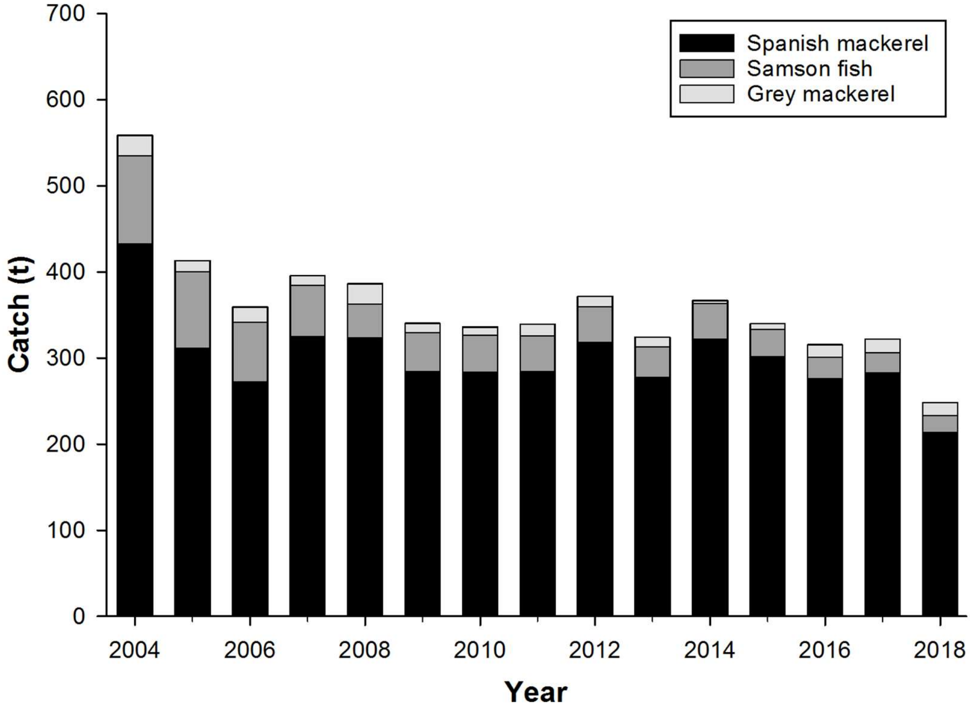

Figure 9.1. Annual total catch (tonnes) of indicator species by all commercial fisheries that target the Large Pelagic Resource between 2004 and 2018.

Spanish mackerel

The annual catch of Spanish mackerel by the MMF has been very stable at 272-320 t since management plan was developed in 2004, until 2018 when the catch dropped to the lowest on record (Figure 9.1). The drop in catch can be partially attributed to a major change in operators within the fishery and an associated decline in effort and catch rates of newer vessels along with fluctuating environmental conditions. In 2016 there was a sustained northern heat pulse over Nov – Feb where water temperatures were 3-4 ^{o}C above average which coincided with the spawning season and is likely to have had detrimental effects on recruitment levels to the fishery in the following 2-3 years.

The majority of the commercial catch is taken in the Kimberley management area, with a lower level in the Pilbara. The level of catch in each management area has been relatively stable until recently when catches have declined in the Gascoyne/West Coast area (Figure 9.2), which is in line with declining effort (Figure 9.6) and a recent drop in the Kimberley, also associated with a drop in effort.

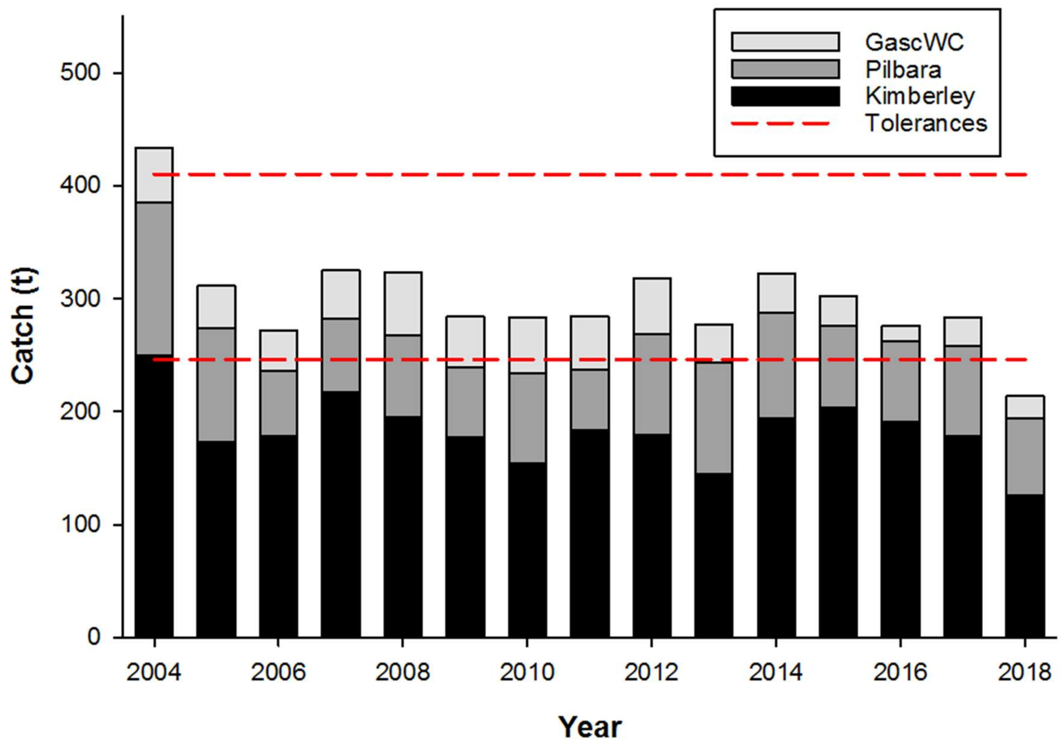

Figure 9.2. Annual catch (tonnes) of Spanish mackerel in each of the management areas of the commercial MMF between 2004 and 2018, with overall catch tolerance range.

Grey mackerel

Grey mackerel has only been recorded by species in the CAES database since 2000 as previously was grouped with 'other mackerel' that includes all of the smaller Scomberomorus species. Since 2006 the annual catch of Grey mackerel by the MMF has been low and variable in comparison to that of the highly targeted Spanish mackerel (Figure 9.1). The species has only been targeted sporadically by two vessels, one in each of the Pilbara and Gascoyne/West Coast areas of the MMF with virtually no catch taken in the northern Kimberley area (Figure 9.3). In each area there is a short fishing season for the species with catches occurring almost exclusively from June-Sep, 96.5% of the total catch since 2006. Reallocation of the catch history for the Other Mackerel group from 1975 to 2000 by examining fishing returns for specification to species allowed the catch history of Grey mackerel to be extended to 1990 and showed the peak catch for Grey mackerel of 25 t occurred in 2000. It is likely there are more historical catches of the species recorded as simply "Mackerel" that are not included in the catch history, regardless the WA catch of Grey mackerel is very low in comparison to the 1000-1500 t taken annually across northern Australia since 2008, predominantly by net fishing methods (SAFS 2018).

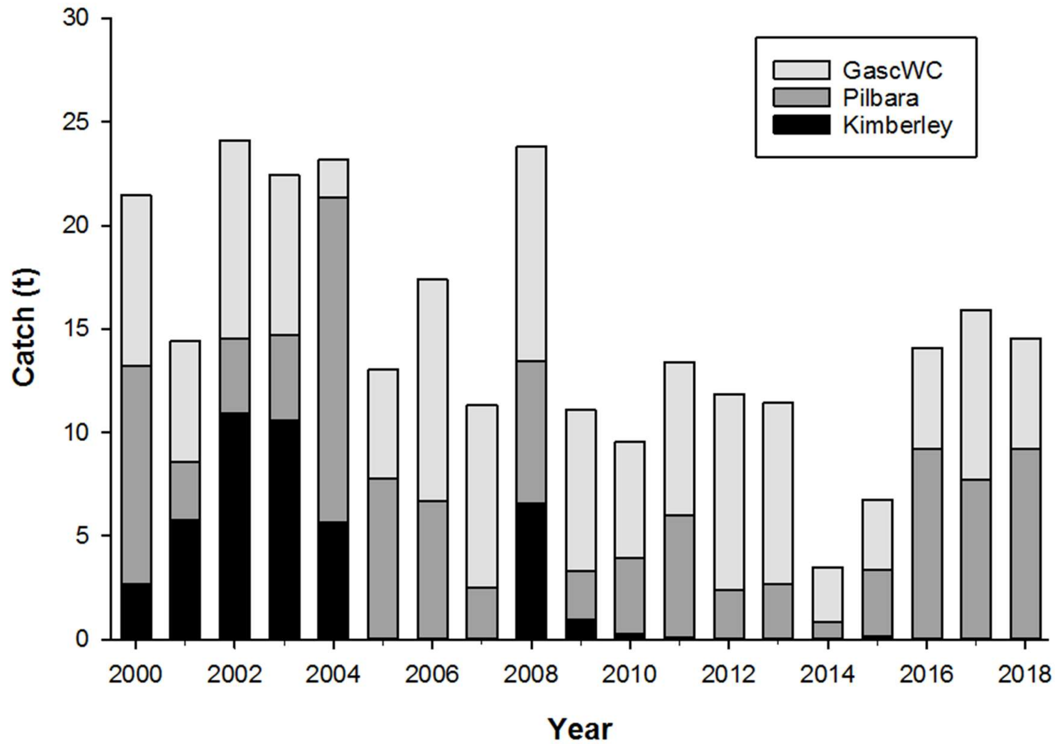

Figure 9.3. Annual catch (tonnes) of Grey mackerel in each of the management areas of the commercial MMF between 2000 and 2018.

Samson fish

Samson fish catch prior to 2000 was rarely reported as Samson fish and often recorded as Sea kingfish, or simply as "Kingfish" which likely included catches of Amberjack, some Yellowtail kingfish and possibly Cobia, known as black kingfish. Regardless, the annual catch of Samson fish has declined from previous levels of over 100 t up until 2004 to where recent catches are the lowest on record for the species at 21.5t in 2018, mainly due to management changes in WCB fisheries (Figure 9.4). The majority of the catch has historically been taken in the WCB (Figure 9.4), however, this is where management changes including the rationalisation of the open access wetline fishing fleet to the WCDSMF resulting in targeting of higher value species and further restrictions to the catch in the TDGDLMF by introduction of commercial closed areas between 2004 and 2007 have reduced the catch. The catch in the SCB has remained fairly consistent between 9-21 t since 1991 and has been higher than the WCB for the past 2 years (Figure 9.4). The catches in the NCB are likely to be the similar congener Amberjack and not Samson fish.

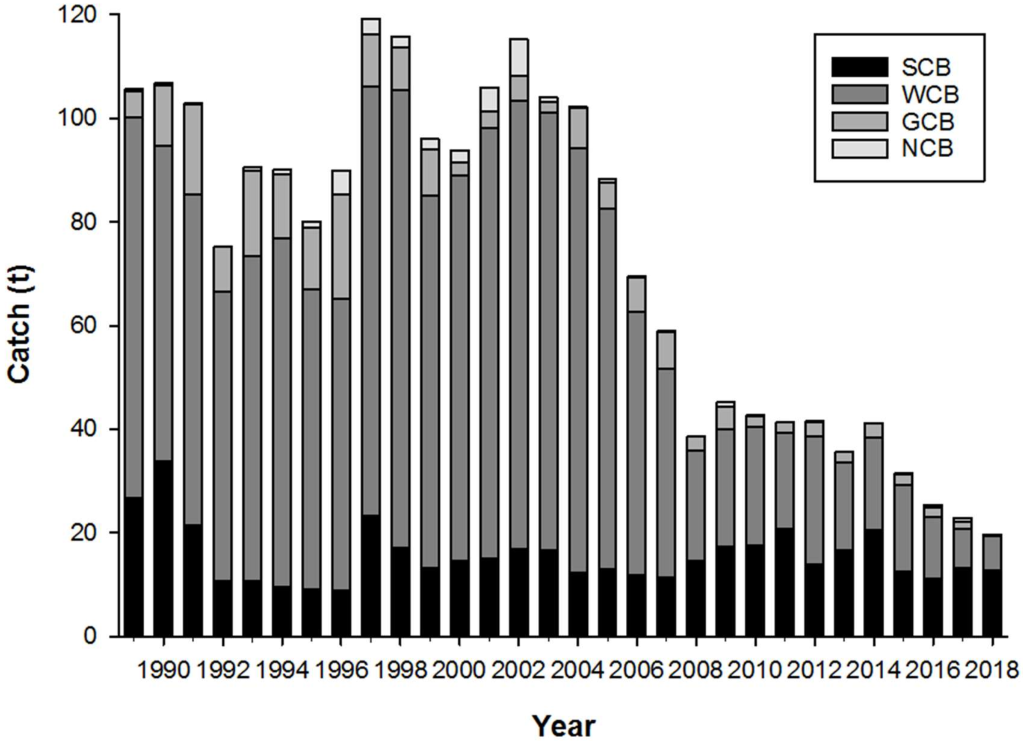

Figure 9.4. Annual catch (tonnes) of the Samson fish, temperate large pelagic indicator species, from each Bioregion between 1989 and 2018.

Yellowtail kingfish

Revision of the historical catch data for Yellowtail kingfish has brought into doubt the previously reported high catches of up to 70 t for the species in the 1980s that were reported as "Kingfish" but are likely mostly Samson fish. Since 1988 the annual catch of Yellowtail kingfish has declined from previous historical levels of 6 t in 1989 to be less than 2 t for most years until 2017, although as mentioned above there is some uncertainty about the historical catches. The catches in WA have been predominantly on the WCB and less than 2 t until 2003-06 but then dropped to a record low of less than 300 kg in 2009. However, catches over the past 6 years have been slowly increasing, particularly on the SCB and were over 3 t in 2018 split evenly between the SCB and WCB (Figure 9.5).

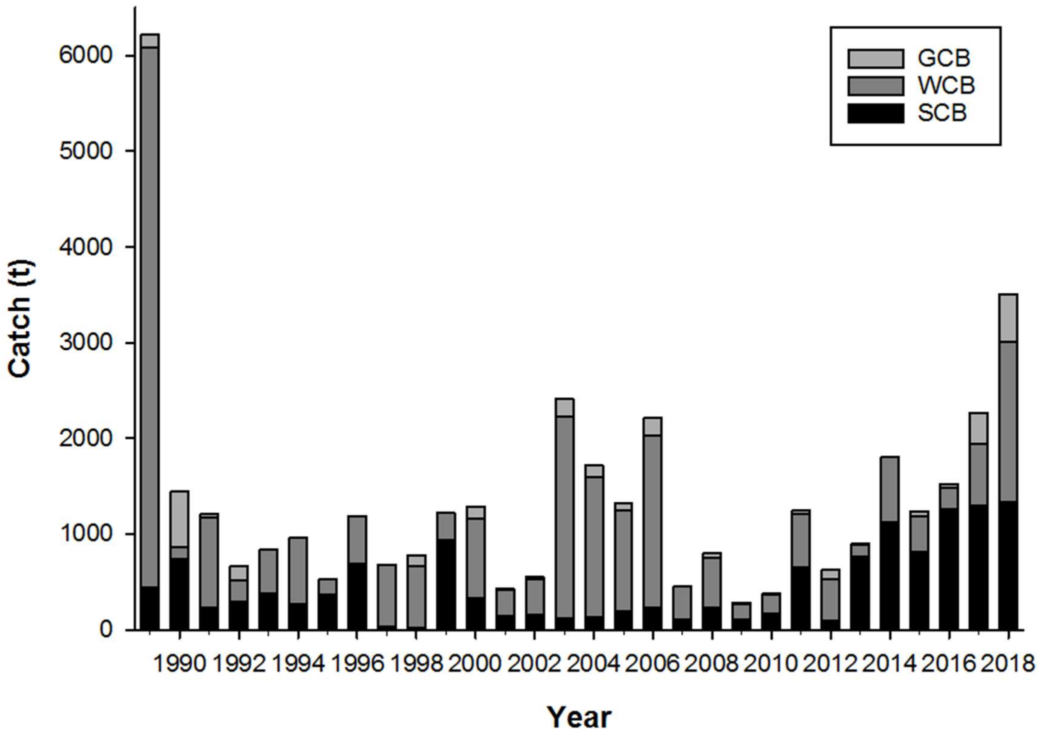

Figure 9.5. Annual catch (tonnes) of the Yellowtail kingfish, temperate large pelagic species, from each Bioregion between 1989 and 2018.

Mahi mahi

The annual commercial catch of Mahi mahi in WA has generally been <0.5t and reached an historical high of 0.8 t in 2003. It is taken by line fishing methods in the North Coast Bioregion.

Spotted and School mackerel

As with Grey mackerel the annual commercial catch of school and spotted mackerel can only be landed by the MMF and has only been recorded by species since 2000 which for both have been below 2t. Historically catches of these two species were taken by the Open access line fishery, net fisheries and beach seine fisheries in amounts of up to 8t in 1991.

Cobia

The annual commercial catch of Cobia has generally been below 20t but reached an historical high of 42 t in 2003 and ranged from 12-20 t since 2006 (Table 6.1). The catches in WA are predominantly in the NCB, 65-91% which are mainly taken by the PFTMF. As with other tropical species the combined catches in the GCB /WCB increased during the period of 2012-2016 to be 3-5t but have since returned to previous levels of 2-3t.

9.3.2.2 Commercial Effort

The commercial effort targeting the Large Pelagic Resource is only monitored in the MMF. The effort is not standardised or adjusted and is the total number of vessels and annual block days in each management area. Since the formal management of the fishery in 2004 the number of vessels landing mackerel in WA has dropped from over 80 to between 11 and 15 per year since 2013, with a commensurate decline in effort (Figure 9.6). The catch is not even between these vessels and in 2018 the main three of the 15 vessels landed 76% of the commercial Spanish mackerel catch and contribute the majority of the effort. Of the three management areas in the MMF the highest and most stable effort is in the Kimberley area. The effort in the Pilbara and Gascoyne/WC areas are lower and more variable. In the later area the level of effort has declined since 2012, which may be related to the 2010/11 extreme marine heatwave when water was up to 5°C warmer than average (Pearce et al. 2015) and Spanish mackerel were more abundant in this southern extent of their range for the following 3 years.

The effort in the Kimberley area of the fishery is restricted mainly to the dry season, from May to November. In the Pilbara area the effort is spread throughout the year for some vessels and restricted to months of September to November for others, when catch rates are generally higher. In the Gascoyne and West Coast area the effort is restricted to months when water temperatures are higher, which generally occurs from March until May.

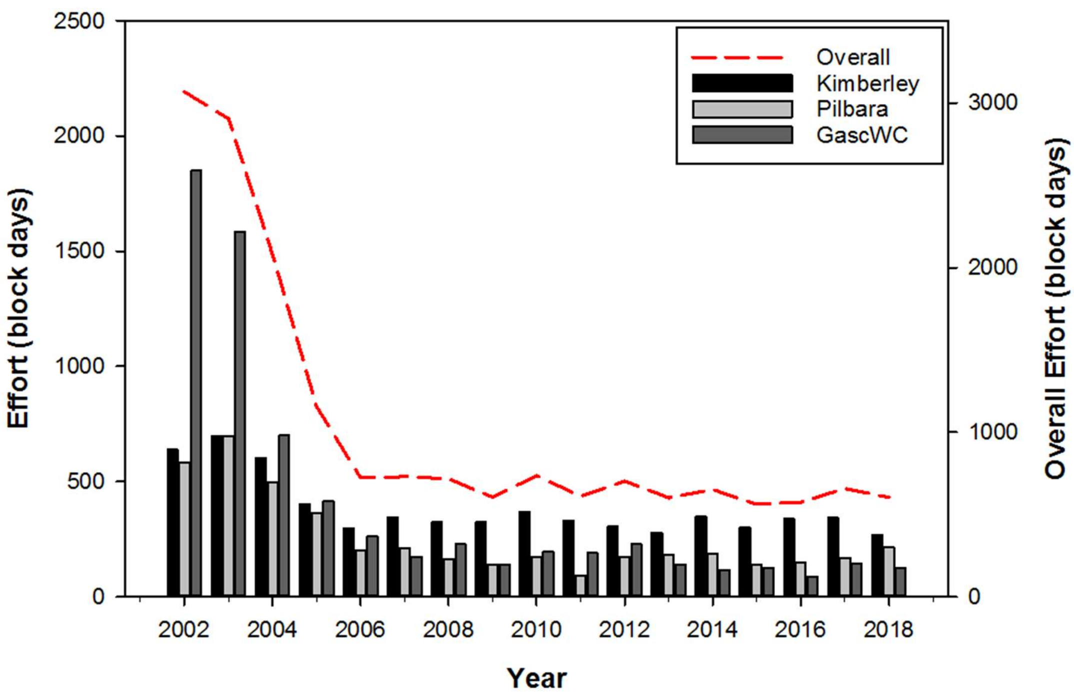

Figure 9.6. Annual fishing effort (block day) by each management area of the MMF which targets the Spanish mackerel in the Large Pelagic Resource, between 2002 and 2018, note management changes with introduction of quota occurred in 2006.

9.3.2.3 Recreational / Charter Catches

The estimated statewide recreational retained catch of the top 10 large pelagic species for the 2017/18 survey was 104t (95% CI 87-121 t), which is similar to the 106 t (95% CI 93–118 t) in 2015/16, but lower than 143 t (95% CI 124–163) in 2013/14 and 174 t (95% CI 154–193) in 2011/12 (Ryan et al. 2019). Spanish mackerel are by far the highest retained large pelagic species by weight for both the recreational and charter fishers (Tables 9.2 and 9.3). Other large pelagic species are only retained in amounts of up to 10-20 t. However, when release amounts are considered other large pelagic species, such as Samson fish and Golden trevally, are annually caught and released in amounts of 40-80 t. Below is a summary of the recreational and charter catches for the indicator and SAFS species only.

Spanish mackerel

For Spanish mackerel the most recent 2017/18 estimated total annual boat-based recreational catch (landed and discarded) of 9,566 fish or 89 t (95% CI = 66-112 t) is similar to the 8,303 fish or 77 t (95% CI = 59-95 t) but less than the 2013/14 estimate (Table 9.2) and considerably less than the estimate from 2011/12 of 18,925 fish or 176 t (95% CI = 141-210 t) (Ryan et al. 2020), which equate to approximately 25% and 50% of the annual commercial catch, respectively. The only previous statewide estimate of recreational catch in 2001 for all Mackerels in WA, including all 6 main mackerel species, of 85,208 fish or 360 t (Henry & Lyle 2003) is similar to the current commercial catch. In comparison the most recent surveys estimated the numbers of fish for this same group of six Mackerel species is 8,440 or 87 t (95% CI 59-115 t). A possible reason for the marked decline in retained catch in more recent estimates could be the introduction of the 20 kg possession limit for recreational fishers in 2005, reducing the targeting and amount of mackerel retained in favour of more highly prized demersal species, particularly for the holidaying fishers. The release rate for mackerels was 36.5 % in 2001 whereas the current estimate is over 50%.

The charter boat operators' annual total catch of Spanish mackerel in WA has been estimated at 17-37 t since 2003 with 34-61% of this released/discarded and was 22 t in 2018.

Grey mackerel

The estimated annual boat based recreational catches of Grey mackerel are very low at less than 4 t in all surveys conducted to date, although as numbers are low there is a high degree of uncertainty with these estimates, see Table 9.2 (Ryan et al. 2019). Similarly, the annual charter logbook catch is consistently less than 1 t for Grey mackerel (Table 9.3). For both recreational and charter a similar or higher amount 30-80% of Grey mackerel is released.

Samson fish

Although the retained amounts for Samson fish are rarely more than 20 t and 4 t for the recreational and charter fishers respectively, the amounts released are considerably higher at up to 80 t and 8 t (Table 9.2 and 9.3). The previous Henry and Lyle (2003) recreational catch estimate for the Kingfish group, which included the species Kingfish, Amberjack and Samson fish, was 10,890 fish or 98 t for WA with an overall release rate of 54.6%. In more recent surveys the landed/retained boat-based recreational catch of the same Kingfish group in WA was estimated at 3,231 or 23 t (95% CI= 15-31 t) (Ryan *et al*. 2017). Samson fish were the main component of this group contributing 1,962 or 61%, with a high release rate of 84%.

The charter boat operators' annual total catch of Samson fish in WA has been 10-17 t since 2010 with 68-76% of this released/discarded but in 2018 was the lowest at 6 t with 62% released.

Yellowtail kingfish

The estimated annual boat based recreational retained catches of Yellowtail kingfish are very low at less than 10 t in all surveys conducted to date, although a similar or higher amount is released each survey. As numbers are low there is some uncertainty with these estimates, see Table 9.2 (Ryan et al. 2017). Similarly, the annual charter logbook catch is consistently less than 1 t for Yellowtail kingfish (Table 9.3). For both recreational and charter a similar amount 25-60% of Yellowtail kingfish is released.

Mahi mahi

The estimated boat based recreational retained catches of Mahi mahi are very low at less than 3 t in all surveys conducted to date, although a similar or higher amount is released each survey. As numbers are low there is some uncertainty with these estimates, see Table 9.2 (Ryan et al. 2017). Similarly, the annual charter logbook catch is consistently less than 1 t for Mahi mahi (Table 9.3). For both recreational and charter a similar or higher amount 30-80% of Mahi mahi is released. The planned deployment of additional FADs along the WA coast is likely to increase the catch of the species in coming years.

Spotted mackerel

The estimated boat based recreational retained catches of Spotted mackerel are very low at less than 2 t in all surveys conducted to date, although a similar or higher amount is released each survey. As numbers are low there is some uncertainty with these estimates, see Table 9.2 (Ryan et al. 2017). Similarly, the annual charter logbook catch is consistently less than 1 t for Spotted mackerel (Table 9.3). For both recreational and charter a similar or higher amount 45-75% of Spotted mackerel is released.

School mackerel

The estimated annual boat based recreational retained catches of School mackerel are low at less than 6 t in all surveys conducted to date, although a similar or higher amount of 40-65% is released each survey, see Table 9.2 (Ryan et al. 2017). The estimated total recreational catch of School mackerel for the 2017/18 surveys of 1.5-3.5t is dramatically lower than the 2011/12 survey estimate of 8-18 t although the numbers are low and there is some uncertainty. Similarly, the annual charter logbook catch is consistently less than 1 t for School mackerel (Table 9.3). For both recreational and charter a similar or higher amount 30-65% of School mackerel is released.

Cobia

The estimated annual boat based recreational retained catches of Cobia are low at less than 12 t in all surveys conducted to date, although a further amount of 2-5t is released each survey. As numbers are low there is some uncertainty with these estimates, see Table 9.2 (Ryan et al. 2017). Similarly, the annual charter logbook catch is consistently less than 4 t for Cobia (Table 9.3). For both recreational and charter an additional 20-50% of Cobia is released.

Table 9.2. Boat based recreational retained and released catch estimates (t), with se, for each indicator species (blue shaded), SAFS species (*) and other Large pelagic species, calculated for each of the statewide iSurveys, where italics indicates low confidence and bold indicates high error.

Survey	**2011/12**				**2013/14**				**2015/16**				**2017/18**			
Species	**Retained**	**SE**	**Released**	**SE**	**Retained**	**SE**	**Released**	**SE**	**Retained**	**SE**	**Released**	**SE**	**Retained**	**SE**	**Released**	**SE**
Spanish mackerel*	90.85	7.46	84.68	13.44	83.50	8.48	74.20	12.98	44.41	4.67	32.60	6.07	47.79	5.40	39.76	7.99
Grey mackerel*	*0.95*	*0.31*	*1.22*	*0.41*	*1.12*	*0.35*	***0.67***	***0.32***	***0.50***	***0.35***	***0.68***	***0.32***	***2.93***	***0.98***	***1.93***	***1.97***
Samson fish	16.34	1.90	77.56	13.65	21.11	3.0	60.85	8.10	14.95	1.96	80.29	14.30	13.07	1.78	48.42	7.85
Yellowfin tuna	14.87	2.80	14.84	4.85	10.63	2.81	7.51	2.23	4.38	1.00	**7.08**	**4.99**	6.07	1.29	**5.17**	**1.91**
Golden trevally	12.30	1.78	45.73	6.98	8.91	2.17	26.40	5.68	5.97	0.92	13.98	2.47	10.32	1.79	24.92	8.32
Yellowtail kingfish*	9.99	3.04	11.57	3.77	7.31	1.44	11.38	6.84	7.45	1.67	**5.98**	**1.70**	7.14	1.66	**3.25**	**8.79**
Cobia	6.22	1.1	1.7	0.46	6.26	1.02	3.76	0.96	11.4	1.97	4.96	1.6	8.36	1.34	2.62	4.08
School mackerel*	5.41	1.11	7.84	1.95	5.60	1.70	**10.30**	**6.03**	3.61	1.11	**5.06**	**3.12**	1.36	0.44	**0.87**	**1.03**
Longtail tuna	5.26	1.49	**8.21**	**4.68**	2.90	0.65	5.22	1.4	*2.77*	*0.79*	*2.76*	*1.01*	*0.84*	*0.43*	*1.56*	*0.88*
Mahi mahi*	2.75	0.63	1.55	0.50	*1.41*	*0.46*	*0.89*	*0.32*	*1.03*	*0.32*	***0.16***	***0.09***	*0.97*	*0.29*	***1.78***	***0.99***
Spotted mackerel*	1.51	0.33	2.14	0.75	1.09	0.31	0.90	0.30	*0.77*	*0.27*	*0.67*	*0.24*	*0.60*	*0.18*	*1.43*	*0.61*
Amberjack	***0.70***	***0.37***	***4.45***	***2.10***	*1.61*	*0.60*	***1.42***	***0.68***	***0.64***	***0.45***	***3.24***	***1.67***	***0.58***	***0.26***	***1.15***	***0.63***

Table 9.3. Boat based recreational charter retained (bold) and released catch estimates (t) of each indicator species (blue shaded), SAFS species (*) and other Large pelagic species reported landed in significant amounts for the past four years (2015-2018), based on numbers multiplied by an average weight for each species, where amounts >2t in larger font.

	2015		2016		2017		2018	
	Retain	Release	**Retain**	Release	**Retain**	Release	**Retain**	Release
Spanish mackerel*	**15.20**	9.41	**14.65**	10.31	**11.55**	10.3	**14.3**	7.6
Grey mackerel*	**0.40**	0.14	**0.90**	0.14	**0.69**	0.22	**0.16**	0.05
Samson fish	**3.81**	8.31	**3.07**	6.41	**2.25**	4.13	**2.1**	3.8
Cobia*	**2.60**	0.73	**3.37**	0.73	**2.20**	0.53	**2.1**	0.6
Yellowfin tuna	**2.15**	2.33	**1.41**	1.01	**1.49**	0.96	**1.35**	1.0
Longtail tuna	**0.85**	1.10	**0.73**	0.81	**0.54**	1.42	**0.63**	0.75
Giant trevally	**0.34**	4.79	**0.76**	4.17	**0.87**	5.16	**0.63**	4.47
Golden Trevally	**0.52**	6.35	**0.88**	7.0	**0.85**	6.36	**1.05**	5.05
Yellowtail kingfish*	**0.43**	0.15	**0.53**	0.12	**0.47**	0.31	**0.41**	0.13
School mackerel*	**0.34**	0.12	**0.24**	0.32	**0.16**	0.24	**0.18**	0.33
Amberjack	**0.38**	0.54	**0.31**	0.45	**0.34**	0.61	**0.28**	0.33
Mahi mahi*	**0.09**	0.16	**0.10**	0.27	**0.15**	0.18	**0.17**	0.12
Spotted mackerel*	**0.03**	0.09	**0.21**	0.13	**0.09**	0.24	**0.07**	0.20

9.3.2.4 Recreational / Charter Effort

Broad measures of recreational boat based effort are available for iSurvey periods in 2011/12, 2013/14, 2015/16 and 2017/18. In the latest survey the estimates of recreational fishing effort declined compared to the previous (Ryan et al. 2017), particularly for inshore line fishing in the NCB and GCB in the months from April to August when the catches of Spanish mackerel were previously highest due to aggregating to spawn. Recreational effort when specifically targeting Large Pelagic species by trolling or jigging is not available from current survey design.

Overall reported charter effort, number of trips landing Spanish mackerel, has been variable since 2003 ranging from 580 to 990. However, in the GCB the catch and hence trips landing Spanish mackerel has steadily declined since a high of 306 in 2012 to a low of 71 in 2016, which could be related to the marine heat wave effects in 2010/11 and following years which increased the local abundance of Spanish mackerel and hence the number of trips on which they were caught.

Reported charter effort, measured as the number of trips where Samson fish were caught in the WCB steadily declined from 900 in 2002 to only 440 in 2007 but has since remained stable.

9.3.2.5 Conclusion

The commercial effort and catches of the Large Pelagic Resource indicator species are dominated by Spanish mackerel, with catches of other species at low levels. The catches are relatively stable over the past 10 years although there has been some decline in the effort and catch of Spanish mackerel in the southern part of their distribution, Area 3 Gascoyne/ West Coast. This decline in the catch of tropical species is also evident in the recreational and charter catches over recent years. The estimated recreational catches of most tropical large pelagic species have declined from 2011/12 and 2013/14 recreational boat based surveys to the 2015/16 and 2017/18 surveys, which is likely reflective of declining effort and unfavourable environmental conditions in the southern parts of their ranges.

Spanish mackerel	Stable overall catch and effort, decline in southern part of range
Grey mackerel	Limited targeting and catch
Samson fish	Reduced targeting and declining catch due to management changes
Yellowtail Kingfish	Limited targeting and low stable catch
Mahi mahi	Limited targeting and low stable catch
Spotted mackerel	Limited targeting and low stable catch
School mackerel	Limited targeting and low declining catch
Cobia	Stable overall catch, decline in southern part of range

9.3.3 Catch Distribution Trends

Commercial catch distribution in the MMF is available at the 5x5 nm block. Similarly, the recreational and charter catch estimates are available at this scale. The catch distributions were examined for changes over time which may indicate particular areas are being fished out and the fishery is having to expand to new areas, as has occurred on the East Coast.

9.3.3.1 Spanish mackerel

The commercial catch of Spanish mackerel over the past 10 years has predominantly been in the NCB with 52-69% in the Kimberley management area, 19-36% in the Pilbara area and only 5-17% in the combined GCB and WCB area (Figure 6.2).

The catch data indicates the commercial Spanish mackerel catch in each area of the fishery has be caught from 50-80 of the 10x10 nm blocks each year but also that the majority (90%) of the catch has been caught in the same 30 blocks since 2006. This indicates the fishery is not changing in its catch distribution but is reliant on aggregations in a small part of the total area of occurrence.

In each management area of the MMF a high proportion of over 40% of the total catch since 2006 has been caught in a small number of 10x10nm blocks, see table below. This indicates the fishery is reliant, to some degree, on the aggregations that occur in these blocks and any changes in these areas can have significant impact on the annual catch and fishery. Recent results of a study on the shark depredation within the fishery (Carmody *et al In Prep*) indicating it to be higher in blocks with higher fishing effort and annually increasing are cause for concern as this is more likely to occur in these important blocks and could significantly impact the fishery.

Area	Number of blocks	% of 2006-18 total catch
Kimberley	12	57
Pilbara	12	44
Gascoyne/West Coast	4	54

In the 2011/12 and 2013/14 surveys the estimated retained boat based recreational catch of Spanish mackerel was evenly distributed through NCB, GCB and WCB at an estimated 20-30 t landed in each. However, in the most recent 2015/16 and 2017/18 surveys the estimated retained recreational catch of 16-18 t in the NCB and GCB but considerably lower in the WCB with only 6 t landed. Similarly, the released amount of Spanish mackerel declined in the WCB between the 2 survey groups from 25-27% to 9-16 % but remained the same in the NCB and GCB staying at 50-60% and 40-50%, respectively.

9.3.3.2 Grey mackerel

Grey mackerel is mainly caught in the NCB and GCB. The commercial catch is predominantly taken by two vessels (86%) in the vicinity of Port Hedland and Carnarvon. Recreational catch estimate is very low at 1-3 t (95% CI) with most, 65%, taken in the GCB (Ryan et al. 2017). The charter catch of Grey mackerel is low at 1-2 t and predominantly taken in the NCB, 72-98% over the past 5 years.

9.3.3.3 Samson fish

Commercial catch taken in both the WCB and SCB, with similar areas for recreational and charter catch. Since management changes in the WCDSMF and TDGDLMF from 2004 the catches in the WCB have reduced (Figure 9.4) with important spawning aggregation areas for the species closed to commercial fishing.

9.3.3.4 Yellowtail kingfish

Commercial catch taken in WCB and SCB, with similar areas for recreational and charter catch. Since management changes in the WCDSMF and TDGDLMF from 2004 the catches in the WCB have reduced (Figure 9.5).

9.3.3.5 Cobia

Commercial catch primarily taken in NCB with some in the GCB and limited in WCB, with similar areas for recreational and charter catches. Recent decline in GCB and WCB catches after previously higher catches during heatwave and following years likely linked with lower SST influencing abundance of tropical species.

9.3.3.6 Conclusion

The available catch distribution evidence indicates that Spanish mackerel are exploited throughout their range but that Grey mackerel, Samson fish, Yellowtail kingfish and Cobia are only exploited in a small proportion of their range and this pattern has been consistent over the past 10 years.

Spanish mackerel	Catch NCB and GCB, with main catch in Kimberley
Grey mackerel	Limited catch in GCB and NCB
Samson fish	Decreasing catch in WCB and stable in SCB
Yellowtail kingfish	Even catch in WCB and SCB
Cobia	Catch NCB, limited GCB with temperatures

9.3.4 Fishery-Dependent Catch Rate Analyses

Only the nominal catch rates for Spanish mackerel by the MMF are monitored annually as a very coarse measure of estimated landed whole weight of Spanish mackerel (kg)/ total number of fishing block days when Spanish mackerel were caught, for each management area from total catch and total effort. The nominal catch rates are not standardised as only recent data used since management arrangements introduced in 2006 changed the fishery from open access to a restricted quota with limited licences. Before 2006 the species was open access and the effort data could not be used with many boats not actively targeting but landing small quantities of Spanish mackerel. Since 2006 catches are generally taken by less than six boats in each area of the fishery and the majority of the WA Spanish mackerel catch (92%) in 2016 is taken by just four boats, in the two NCB management areas of the MMF. For comparison with historical catch rates the data from these main boats only are used prior to 2006.

The standardised daily logbook catch rate is only available from 2006 onwards when the daily logbook was introduced for the MMF and cannot be compared to historical data. The catch rate is generated from the number of Spanish mackerel caught, number of hours fished and number of lines used that are reported for each fishing session.

Grey mackerel are only targeted occasionally with different methods and areas than Spanish mackerel and generally by only two boats in the MMF.

Samson fish are generally not targeted and taken as bycatch species in the line and net fisheries on the WCB and SCB making the catch rate information difficult to discern and not representative.

9.3.4.1 Spanish mackerel

The nominal catch rates for Spanish mackerel have generally been fairly stable but recently decreasing in the two main northern management areas, Kimberley and Pilbara, since the management plan came into effect in 2006 (Figure 9.7). The variation in catch rates recorded in the West Coast Bioregion and to a lesser extent Gascoyne Bioregion, that form Area 3 of the MMF, appear to have responded to annual water temperature 0.5°C above the long term averages, between 2010 and 2015, but have recently declined when temperatures returned to average (Figure 9.8).

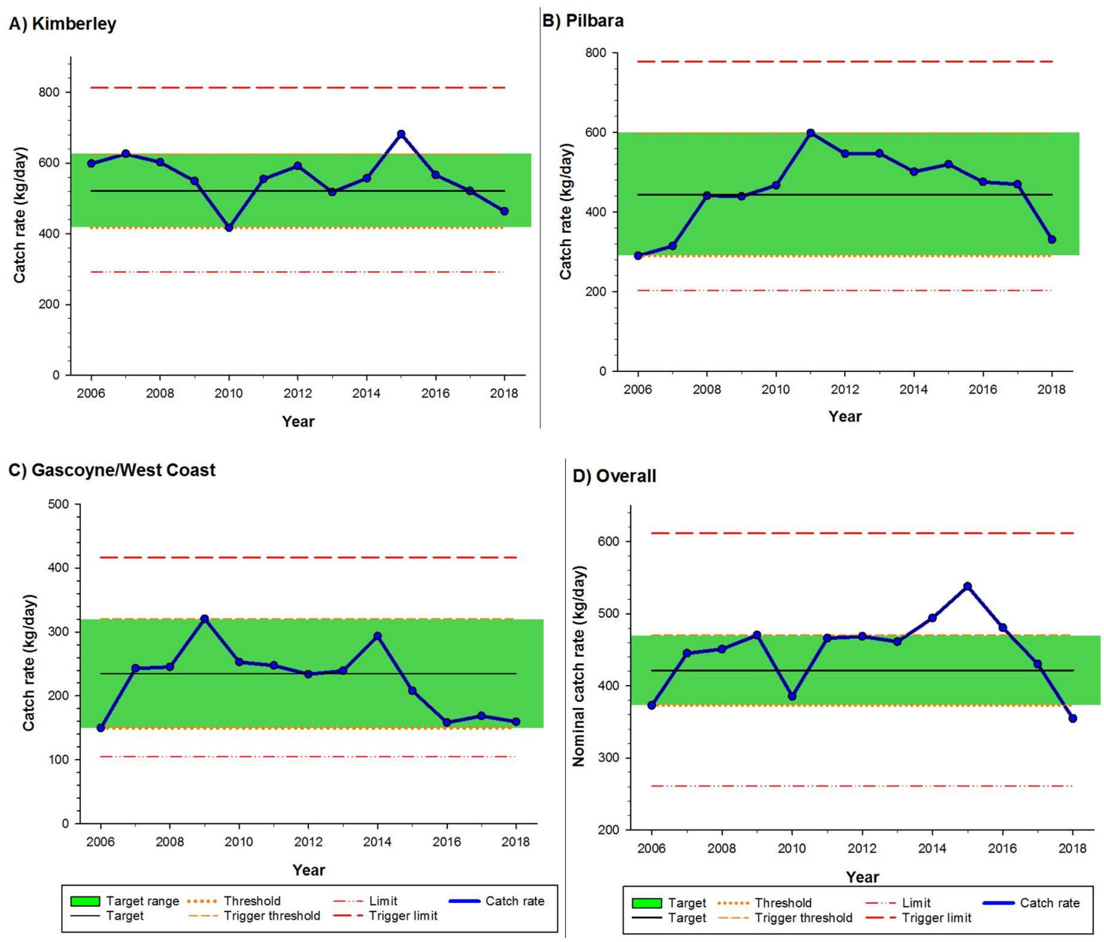

Figure 9.7 Annual catch rates of Spanish mackerel (kg/block day) in each of the three management areas of the MMF A) Kimberley, B) Pilbara, C) Gasc/WC and D) Overall from 2006 – 2018 with target, threshold and limits.

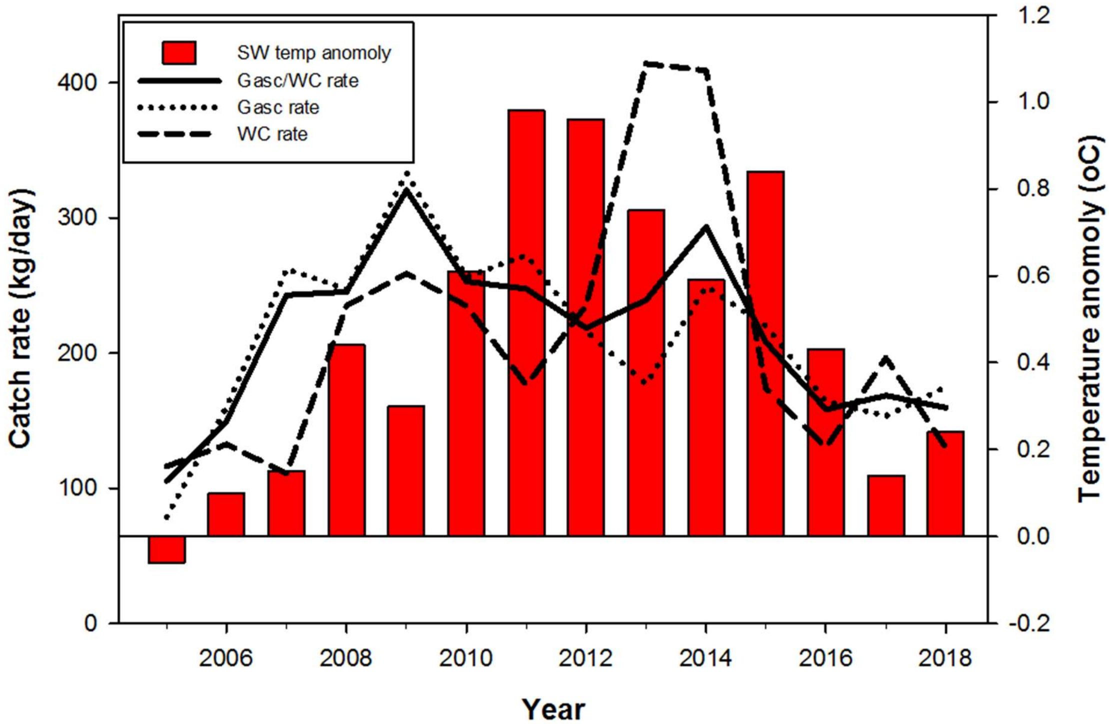

Figure 9.8 Annual catch rates of Spanish mackerel (kg/block day) in Gascoyne, West Coast and combined for Area 3 of the MMF from 2006 – 2018 with annual sea surface temperature anomaly (°C) in the Southwest.

9.3.4.2 Conclusion

The fishery-dependent nominal catch rates are only assessed for Spanish mackerel which have been stable but are both recently decreasing in the two main northern areas but low and variable in the southern area, likely in response to environmental variables influencing abundance.

Spanish mackerel	Kimberley area	Variable but recently decreasing
	Pilbara area	Decreasing since 2011 high
	Gascoyne/WC area	Variable, recent decline to all time low
Grey mackerel	NCB and GCB	No catch rate data
Samson fish	WCB and SCB	No catch rate data
Yellowtail kingfish	WCB and SCB	No catch rate data

9.3.5 Fishery-Independent Data Analyses

No fishery-independent surveys are undertaken for the Large Pelagic Resource.

9.3.6 Trends in Size Structures

The commercial MMF daily logbook provides information on the number of fish caught allowing an average size of Spanish mackerel and Grey mackerel to be estimated for each session, area and year, since 2006.

The FTO logbook provides annual size structured information from the measured lengths of the fish they catch. There is usually only sufficient data for Spanish mackerel and Samson fish to utilise this information, with other species at less than 200 lengths / year.

9.3.6.1 Spanish mackerel

The annual average size of Spanish mackerel in each area of the MMF has been relatively stable in the main two northern areas of the fishery, Kimberley and Pilbara, for the past 14 years, where data is available. In the southern Gascoyne/West Coast area the data is more variable but fits the pattern of smaller average size in the years immediately following the 2010/11 marine heatwave due to predicted higher recruitment in these years.

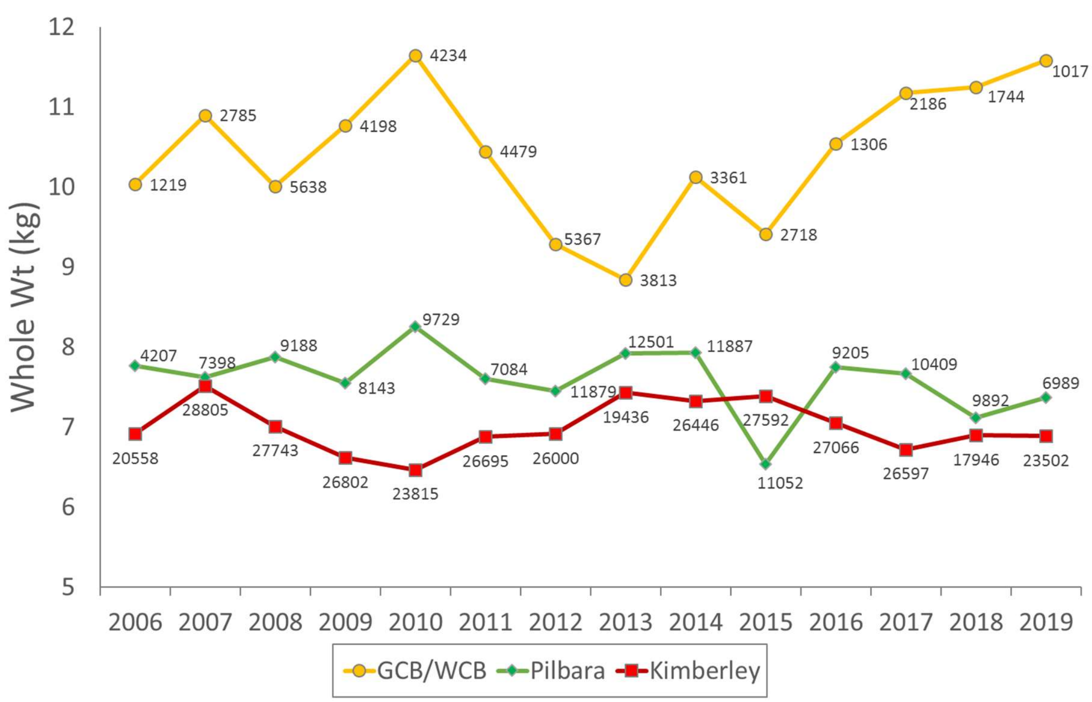

Figure 9.9 Annual average weight of Spanish mackerel caught by the MMF in each area of the fishery, with total numbers of fish given.

The average size data for Spanish mackerel from the FTO logbooks indicate the annual sizes have been declining in the North Coast Bioregion over the past 13 years and are variable in the Gascoyne and West Cast Bioregions with a similar decline in size following the 2010/11 heatwave as seen in the MMF sizes, although numbers of fish measured are low (Figure 9.10). The catches are generally restricted to close proximity of population centres and do not cover the entire range and the decline in the NCB coincides with an increase in numbers of fish measured so may not be representative of the total population.

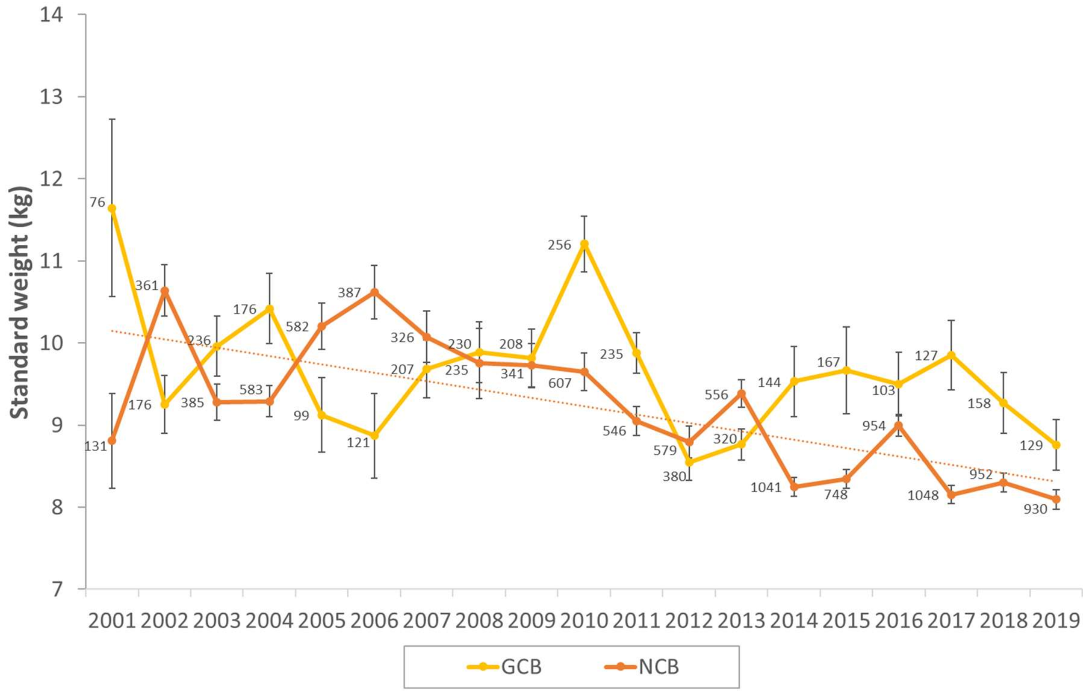

Figure 9.10 Annual average weight of Spanish mackerel caught by the FTO in each bioregion, with standard errors and sample sizes given.

9.3.6.2 Grey mackerel

The annual average size of Grey mackerel caught by the MMF has been generally increasing in the Pilbara area for the past 14 years, where data is available, but variable and relatively stable in the southern Gascoyne/West Coast area (Figure 9.11). The average size of up to 8kg is approaching the maximum known size for the species of 10kg, which supports the assumption that it is a lightly exploited stock in WA. The FTO data provides very few measurements for Grey mackerel in WA so is not utilised.

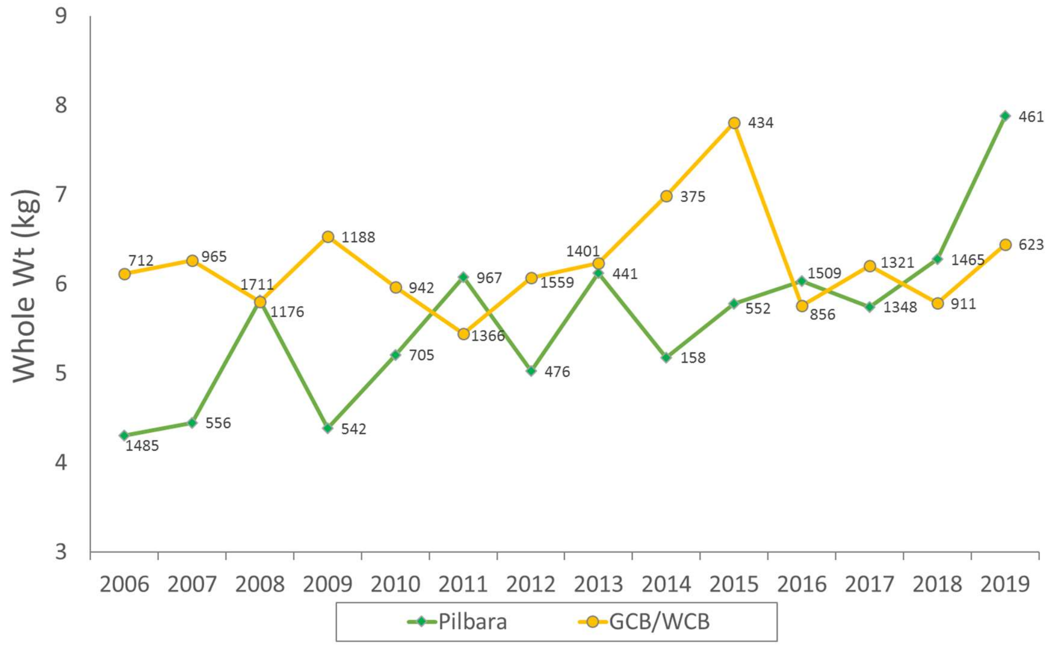

Figure 9.11 Annual average weight of Grey mackerel caught by the MMF in each area of the fishery, with numbers of fish given.

9.3.6.3 Samson fish

The average size data for Samson fish from the FTO logbooks indicate the annual sizes are consistently larger in the SCB than the WCB but follow a similar pattern in both (Figure 9.12). In both bioregions the average sizes reached a peak in 2005-06 then declined to be half of this size by 2011-13 and have been slowly increasing since. As with Spanish mackerel in the Gascoyne/WC this may indicate a strong recruitment of Samson fish in the years following the 2010/11 heatwave although the decline in average size started a few years before this event. Regardless the fact that changes in average sizes are occurring in similar patterns across both bioregions indicates there is one WA stock that is being affected and these also coincide with the substantial decrease in commercial catch for the species in the WCB, from 2005.

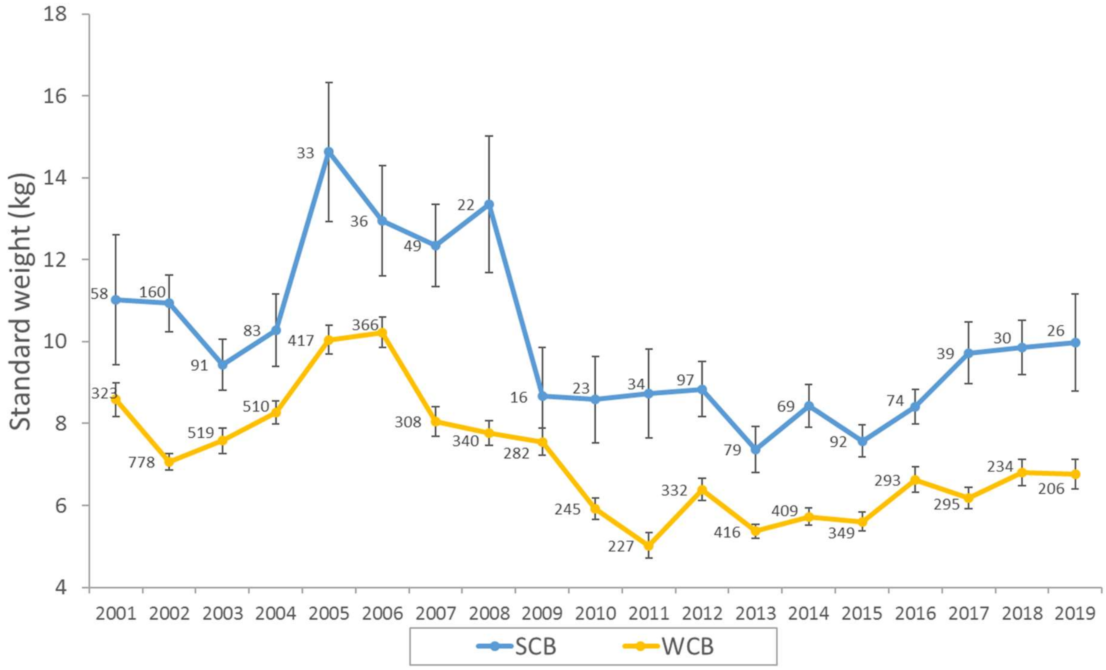

Figure 9.12 Annual average standard weight of Samson fish caught by the FTO in the South Coast and West Coast Bioregions, with standard errors and sample sizes given.

9.3.6.4 Conclusion

The trends in annual Commercial MMF and FTO logbook size structure data suggest.

Spanish mackerel	NCB	Stable MMF, decreasing sizes FTO
	Gascoyne/WC area	Variable, 2011 recruitment, no clear trend
Samson fish	SCB and WCB	Similar patterns, larger in SCB, no clear trend
Grey mackerel	NCB	Generally increasing and large sizes

9.3.7 Productivity Susceptibility Analysis

Productivity Susceptibility Analysis (PSA) is a semi-quantitative risk analysis originally developed for use in Marine Stewardship Council (MSC) assessments to score data-deficient stocks, i.e. where it is not possible to determine status relative to reference points from available information (Hobday et al. 2011; MSC 2014). The PSA approach is based on the assumption that the risk to a stock depends on two characteristics: (1) the productivity of the species, which will determine the capacity of the stock to recover if the population is depleted, and (2) the extent of the impact on the stock due to fishing, which will be determined by the susceptibility of the species to fishing activities (see Appendix 3).

Although a valuable tool for determining the overall inherent vulnerability of a stock to fishing, the PSA is limited in its usefulness for providing stock status advice. This is because of the simplicity and prescriptiveness of the approach, which means that risk scores are very sensitive to input data and there is no ability to consider management measures implemented in fisheries to reduce the risk to a stock (Bellchambers et al. *in prep*.). Consequently, the PSA is used by the Department to produce a measure of the vulnerability of a stock to fishing, which is then considered within the overall weight of evidence assessment of stock status.

The sections below outline the PSA scores for each indicator species of the Large Pelagic Resource.

9.3.7.1 Productivity

The large pelagic indicator and SAFS species generally share similar productivity attributes of being moderately long lived, early maturity, a large body size, high fecundity and high trophic level (Table 9.4). Some minor differences between the indicator species, which do not influence scores, are in maximum age and size where the smaller Grey mackerel live to 14 years and get to 12 kg whereas Spanish mackerel and Samson fish have both been recorded to over 20 years of age and attain a size of over 40 kg but regardless they all score 2 on the scale for these attributes. The only differences are Samson fish and Yellowtail kingfish are slightly older to mature at 4 years compared to the mackerel species which are at 2 years of age and maximum age of Spotted mackerel and Mahi mahi being less than 10 years, unlike the other species.

Table 9.4. PSA productivity scores for each indicator* and SAFS large pelagic species

Productivity attribute	*Spanish mackerel	*Grey mackerel	*Samson fish	Yellowtail Kingfish	School mackerel	Spotted mackerel	Mahi mahi	Cobia
Average maximum age	2	2	2	2	2	1	1	2
Average age at maturity	1	1	2	2	1	1	1	1
Average maximum size	2	2	2	2	2	2	2	2
Average size at maturity	2	2	2	2	2	2	2	2
Reproductive strategy	1	1	1	1	1	1	1	1
Fecundity	1	1	1	1	1	1	1	1
Trophic level	3	3	3	3	3	3	3	3
Density dependence	-	-	-	-	-	-	-	-
Total productivity (average)	**1.71**	**1.71**	**1.86**	**1.86**	**1.71**	**1.57**	**1.57**	**1.71**

9.3.7.2 Susceptibility

9.3.7.2.1 Spanish mackerel

The commercial MMF is the only fishery in WA licenced to land mackerel species. It targets Spanish mackerel throughout most of their WA distribution, although vessel numbers are limited to 12 or less in most years. Catch distribution covers approximately 40% of the coastal blocks from 10-100m depth from Geraldton to the WA border and there is incomplete coverage with the Ningaloo commercial fishing exclusion zone, resulting in a moderate areal overlap score of 2. The species occur predominantly in a narrow depth range and the fishery operates throughout most of this depth range giving a moderate vertical range score of 2. The MMF use line and large lures or baits and are able to avoid immature and undersized fish, which are often inshore, giving a selectivity score of 2. The inability of the MMF to release undersized mackerel catch quickly, without significant hook damage from the large gear and in areas where there may be a high depredation of released catch gives a high post release mortality score of 3.

The recreational and charter fisheries target Spanish mackerel throughout WA, but predominantly close to towns, resulting in an areal overlap score of 2. The species occur predominantly in a narrow depth range and the fishery operates throughout this depth range giving a vertical range score of 2. Recreational and charter fishers use predominantly line fishing methods with a variety of lures or baits so do catch immature and undersized fish, giving a selectivity score of 3. The inability of recreational and charter fishers to successfully release unwanted mackerel quickly and without hook damage along with high depredation levels of released catch in some areas, particularly regularly fished locations, gives a post capture mortality score of 3.

Table 9.5. PSA susceptibility scores for each fishery / sector that impact on Spanish mackerel in WA (taken from Pre assessment)

Susceptibility attribute	Commercial MMF	Recreational Fishery
Areal overlap	2	2
Vertical overlap	3	2
Selectivity	2	3
Post-capture mortality	3	3
Total susceptibility (multiplicative)	1.88	1.88
PSA	2.54	2.54

9.3.7.2.2 Grey Mackerel

The commercial MMF catches of Grey mackerel occur in a limited portion of their WA distribution, predominantly by only 2 vessels in the vicinity of Pt Hedland and Carnarvon, resulting in an areal overlap score of 1. The species occur predominantly in inshore waters and the fishery generally operates outside of this depth range giving a vertical range score of 2. The MMF use line and large lures or baits and are able to avoid immature and undersized fish, giving a selectivity score of 1. The ability of the MMF to successfully release unwanted catch quickly and without injury from the large gear is likely to be low and gives a post release mortality score of 2, although in some areas there may also be a high depredation level of released catch.

The recreational and charter fisheries generally only target Grey mackerel close to towns, resulting in an areal overlap score of 1. The species occur predominantly in a narrow depth range and the fishery operates in this depth range giving a vertical range score of 2. Recreational and charter fishers use predominantly line fishing methods with lures or baits so do catch immature and undersized fish, giving a selectivity score of 2. The ability of recreational and charter fishers to successfully release unwanted catch quickly and without injury is likely to be low, which combined with high depredation level of released catch in some areas gives a high post capture mortality score of 3.

Table 9.6. PSA susceptibility scores for each fishery / sector that impact on Grey Mackerel in WA

Susceptibility attribute	MMF	Recreational Fishery
Areal overlap	1	2
Vertical overlap	2	2
Selectivity	1	2
Post-capture mortality	2	2
Total susceptibility (multiplicative)	1.08	1.38
PSA	2.02	2.20

9.3.7.2.3 Samson fish

The commercial catches of Samson fish are limited by a commercial closure on the WCB and by limited coverage away from towns on the SCB parts of their WA distribution, resulting in an areal overlap score of 2. The species occur predominantly in coastal waters and the fishery generally operates in this depth range giving a vertical range score of 2. The commercial line fisheries use line and large baits while the net fishery targets shark with large mesh so both are able to avoid catching immature and undersized fish, giving a selectivity score of 2. The ability of the commercial line fisheries to avoid smaller fish but also successfully release unwanted catch quickly and without barotrauma gives a post release mortality score of 2. However, the commercial net fishery has limited ability to successfully release unwanted catch, giving a post capture mortality score of 3.

The recreational and charter fisheries generally catch Samson fish throughout their distribution on the WCB but in limited coverage on the SCB, resulting in an areal overlap score of 2. The species occur predominantly in coastal waters and the fishery operates in this depth range giving a vertical range score of 3. Recreational and charter fishers use predominantly line fishing methods with lures or baits so do occasionally catch immature and undersized fish, giving a selectivity score of 2. The ability of recreational and charter fishers to successfully release unwanted Samson fish catch quickly and without barotrauma (Rowland 2009) gives a post release mortality score of 1, although in some areas there may be a high depredation level of hooked and released catch and this score could be reviewed.

Table 9.7. PSA susceptibility scores for each fishery / sector that impact on Samson fish in WA

Susceptibility attribute	Com Line WCDSMF SCOAF	Com net TDGDL	Recreational Fishery
Areal overlap	2	2	2
Vertical overlap	3	3	3
Selectivity	2	2	2
Post-capture mortality	1	3	1
Total susceptibility (multiplicative)	1.28	1.88	1.28
PSA	2.25	2.64	2.25

9.3.7.2.4 Yellowtail kingfish

The susceptibility scores were based on a high (3) (>30%) areal overlap (distribution of fishing effort relative to stock range) for the recreational fisheries, noting that the commercial fisheries extend over a more limited area due to closures in the WCB. The vertical overlap (by depth) was assumed low (1) for all fisheries as yellowtail kingfish are not a commonly targeted species. Selectivity of fish, as reflected by the relative proportion of captured fish that are immature, was scored as medium (2) for all fisheries as the species is not targeted and details of selectivity unknown. Recreational and line caught post-capture mortality is scored as low (1) for this species as it is not always retained (see Ryan et al. 2018) and has good survival due to resistance to barotrauma but is high (3) for the commercial net fisheries.

Table 9.8. PSA susceptibility scores for each fishery / sector that impact on Yellowtail kingfish in WA

Susceptibility attribute	Com Line WCDSMF SCOAF	Com net TDGDL	Recreational Fishery
Areal overlap	2	2	3
Vertical overlap	1	1	2
Selectivity	2	2	2
Post-capture mortality	2	3	1
Total susceptibility (multiplicative)	1.18	1.28	1.18
PSA	2.20	2.25	2.20

9.3.7.2.5 Mahi mahi

The commercial catches of Mahi mahi are limited to southern parts of their WA distribution, resulting in an areal overlap score of 1. The species occur predominantly in offshore waters so the inshore net fishery and commercial line fisheries generally operate inside this depth range giving a vertical overlap score of 1. The commercial line fisheries use line and large baits while the net fishery targets shark with large mesh so both are able to avoid catching immature and undersized fish, giving a selectivity score of 1. The ability of the commercial line fisheries to avoid smaller fish but also successfully release unwanted catch quickly and without barotrauma gives a post release mortality score of 2. However, the commercial net fishery has limited ability to successfully release unwanted catch, giving a post capture mortality score of 3.

The recreational and charter fisheries generally catch Mahi mahi seasonally throughout their distribution but in limited coverage, resulting in an areal overlap score of 1. The species occur predominantly in offshore waters and the majority of the recreational fishery generally operates inside this depth range giving a vertical range score of 1. Recreational and charter fishers use predominantly line fishing methods with lures or baits so do occasionally catch immature and undersized fish, giving a selectivity score of 2. The ability of recreational and charter fishers to successfully release unwanted Mahi mahi quickly and without barotrauma gives a post release mortality score of 2, as in some areas there may be a high depredation level of hooked and released catch and this score could be reviewed.

Table 9.9. PSA susceptibility scores for each fishery / sector that impact on Mahi mahi in WA

Susceptibility attribute	Com Line WCDSMF SCOAF	Com net TDGDL	Recreational Fishery
Areal overlap	1	1	1
Vertical overlap	2	1	1
Selectivity	2	2	2
Post-capture mortality	2	3	1
Total susceptibility (multiplicative)	1.08	1.13	1.03
PSA	1.90	1.93	1.88

9.3.7.2.6 School and Spotted mackerel

The commercial catches of School and Spotted mackerel are minimal, the species can only be landed by the MMF and only occur in small amounts from the NCB resulting in an areal overlap score of 1. The species occur predominantly in inshore waters away from where the commercial MMF line fishery generally operates giving a vertical overlap score of 1. The commercial line fishery uses large baits and lures so are able to avoid catching immature and undersized fish, giving a selectivity score of 1. The ability of the commercial line fisheries to avoid smaller fish but also successfully release unwanted catch quickly and without barotrauma gives a post release mortality score of 2.

The recreational and charter fisheries generally catch School and Spotted mackerel throughout their distribution but in limited coverage, resulting in an areal overlap score of 1. The species occur predominantly in inshore waters where the majority of the recreational fishery generally operates giving a vertical range score of 2. Recreational and charter fishers use predominantly line fishing methods with lures or baits so do occasionally catch immature and undersized fish, giving a selectivity score of 2. The ability of recreational and charter fishers to successfully release unwanted School and Spotted mackerel quickly and without barotrauma gives a post release mortality score of 2, however in some areas there may be a high depredation level of hooked and released catch and this score could be reviewed.

Table 9.9. PSA susceptibility scores for each fishery / sector that impact on School and Spotted mackerel in WA

Susceptibility attribute	Com Line WCDSMF SCOAF	Com net TDGDL	Recreational Fishery
Areal overlap	1	1	1
Vertical overlap	1	1	1
Selectivity	2	2	2
Post-capture mortality	1	3	1
Total susceptibility (multiplicative)	1.08	1.13	1.03
PSA	1.90	1.93	1.88

9.3.7.2.7 Cobia

The commercial catches of Cobia are low and generally restricted mainly to the Pilbara trawl fishery giving an areal overlap of 2. The species occurs in coastal waters giving a vertical overlap of 2 for the line fisheries but only 1 for the trawl given operate in narrow depth range and not nearshore. The methods use do not generally select for mature fish giving a selectivity score of 2. The survival of released fish is likely high in line fisheries 1 but low in trawl 3.

The recreational and charter fisheries generally catch Cobia throughout their distribution but in limited coverage, resulting in an areal overlap score of 1. The species occur predominantly in shelf waters where the majority of the recreational fishery generally operates giving a vertical range score of 1. Recreational and charter fishers use predominantly line fishing methods with lures or baits so do occasionally catch immature and undersized fish, giving a selectivity score of 2. The ability of recreational and charter fishers to successfully release unwanted Cobia quickly and without barotrauma gives a post release mortality score of 1, however in some areas there may be a high depredation level of hooked and released catch and this score could be reviewed.

Table 9.9. PSA susceptibility scores for each fishery / sector that impact on Cobia in WA

Susceptibility attribute	Com Line PLF WCDSF	Com trawl net PTMF	Recreational Fishery
Areal overlap	1	1	1
Vertical overlap	2	1	1
Selectivity	2	2	2
Post-capture mortality	1	3	1
Total susceptibility (multiplicative)	1.08	1.58	1.08
PSA	2.02	2.33	2.02

9.3.7.3 Conclusion

Based on the productivity and susceptibility scores, the overall weighted (by fishery / sector catches) PSA scores for the Indicator and SAFS species of the Large Pelagic Resource were all low risk, ranging from 1.88 for Mahi mahi to 2.54 for Spanish mackerel, see below.

Spanish mackerel	2.54-Low risk
Grey mackerel	2.10-Low risk
Samson fish	2.35-Low risk
Yellowtail kingfish	2.20-Low risk
Mahi mahi	1.88-Low risk
School mackerel	2.19-Low risk
Spotted mackerel	2.03-Low risk
Cobia	2.20-Low risk

9.3.8 Stock Reduction Analyses

9.3.8.1 Overview

The CatchMSY stock reduction analysis procedure in the SimpleSA R-package was used to assess the biomass levels and MSY along with predictions about biomass level trends at current catch levels for Spanish mackerel, Grey mackerel, Samson fish/Kingfish group and Yellowtail kingfish. Other Indicator and SAFS large pelagic species were considered but catch levels were too low or catch history restricted, as the smaller mackerel only reported by species since 2001, to precluded them from such analysis.

9.3.8.2 Model Description

The CatchMSY model is a simpler method that is applicable to data poor situations where a reliable abundance index is not available. Model inputs are a catch time series, prior ranges of r (the intrinsic rate of increase of the population) and K (the carrying capacity of the population), and possible ranges of relative stock sizes in the first and final years of the time series. It then uses the Schaefer production model to calculate annual biomasses for a given set of r and K parameter values (Martell & Froese 2013). This method assumes that catch is a proxy of stock abundance so any decline in catches is interpreted as a decline in stock abundance and not a response to management or market fluctuations. Process error was incorporated using a lognormal distribution with standard deviation of 5%.

Martell & Froese's (2013) model was fit to the total catch time series of each species with a constraint on the K parameter given by the constructed priors and explicit assumptions on other input parameters. The model was projected 5 years into the future by setting future catches to the average total catch of the last 5 years in the model.

9.3.8.3 Input data and parameters

The available commercial, and FTO catch history data from 1975 along with recreational catch estimates were utilised with considerations given to historical differences in reporting for each species, see below. A range of scenarios were used with resilience (medium or low), catch histories (1975-2018 or 2000-2018), initial depletion (low 0.7-0.9, moderate 0.4-0.7, or high 0.2-0.4) and for projections a constant catch of the average statewide catch of the species since 2008 was applied.

Commercial catches of "Mackerel" were recorded as Spanish mackerel or mackerel-other until 2000 when Scomberomorus species in the mackerel-other group were distinguished individually. Some historical catches of "Mackerel" were assigned to mackerel-other and some assigned to Spanish mackerel with a likely degree of misappropriation. As the current Mackerel catch proportions are 90% Spanish mackerel it is likely the high historical catches of mackerel-other are mostly Spanish mackerel. Also some catches of "mackerel" reported by purse seine vessels are likely to be Blue mackerel (*Scomber australis*) rather than any of the Scomberomorus species so all purse seine catches were excluded from the input data.

Historically both Samson fish and Yellowtail kingfish reported simply as just "Kingfish", with species codes 425 and 426 respectively introduced and used for some returns. The catch history shows it is likely some reporting of Kingfish were recorded as Samson fish and others recorded as Yellowtail kingfish. Also some catches of "yellowtail" reported by purse seine vessels are likely to be Yellowtail scad (*Trachus novazealandia*) and not Yellowtail kingfish so all purse seine catches were excluded from the input data.

9.3.8.4 Results and Diagnostics

9.3.8.4.1 Spanish Mackerel

Catch MSY analyses were undertaken using Spanish mackerel commercial, recreational and FTO catch data or all mackerel catch data for the Western Australian stock, due to uncertainty with catch reporting, see above. A range of scenarios were used with resilience (medium or low), catch histories (1975-2018 or 2000-2018), initial depletion (low 0.7-0.9, moderate 0.4-0.7, or high 0.2-0.4) and for projections a constant catch of 350 or 430 t was applied (average statewide catch since 2008).

While some scenarios failed to converge, scenarios including full all mackerel catch history data, low initial depletion and low resilience produced plausible outputs (Figure 9.15). These scenarios suggested that mackerel, predominantly Spanish, have been heavily exploited since 1990 as the analysis indicates a moderate r (intrinsic rate of population increase) of 0.25 and a K (carry capacity) of 7500 t for the species in WA and an associated MSY of 502.5 t (Figure 9.13). Noting the pre-2000 information was based on the total catches of all Mackerel (Spanish and Other mackerel) of which Spanish mackerel likely made up the majority as recent catches of other mackerel species amount to less than 20t with most being Grey mackerel. However, as catches were reduced as a result of management changes and not necessarily stock reduction in the post-2000 catch history data, the results must be considered as indicative only. Even so results suggest biomass was likely above the target level in 2018 and would remain above the target level at current catch levels (Figure 9.14). It is likely the actual catches of Spanish mackerel used for the 1990s and early 2000s could be lower as an artefact of catches reported as “Mackerel” including other mackerel species not specified on returns at the time.

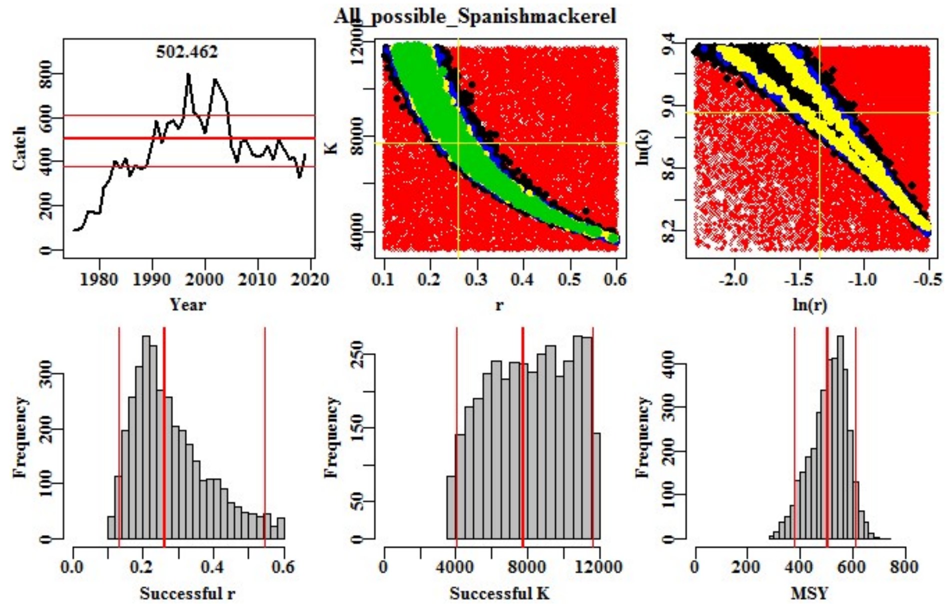

Figure 9.13. Spanish mackerel 2018 catch MSY assessment outputs, based on input settings. a) Catch history with overlaid estimate of MSY (502.462) shown as red line and the 90% percentiles (thin lines), b) outputs of r (intrinsic rate of population increase) and K (carry capacity) analyses with increasing colours depicting more combinations of initial depletion that succeeded, highest distribution successful scenarios (black, blue, yellow, green), unsuccessful pairs (red), and medians (yellow lines), c) r-k pairs in log space, d-f) posterior densities of the successful r, k and the resulting MSY, respectively with mean and 90th percentile confidence interval lines.

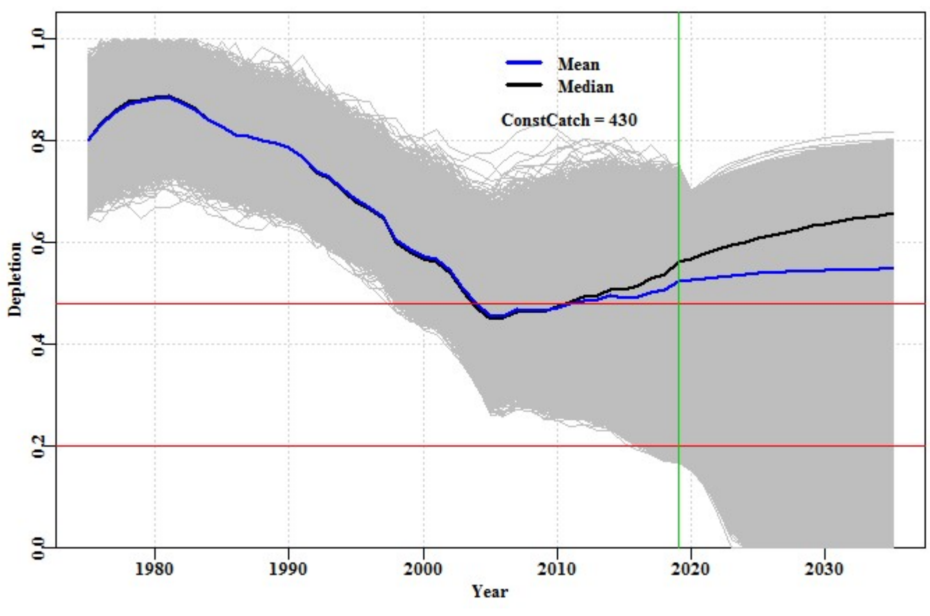

Figure 9.14. Spanish mackerel 2018 catch MSY assessment outputs. Summary of estimated biomass depletion trends for Spanish mackerel based on successful Catch MSY runs, grey lines and unto the future under a constant catch of 430t (mean of recent years). The vertical green line indicates the current year (2018), with projections to the right of the line, and the red lines indicate the target and the limit.

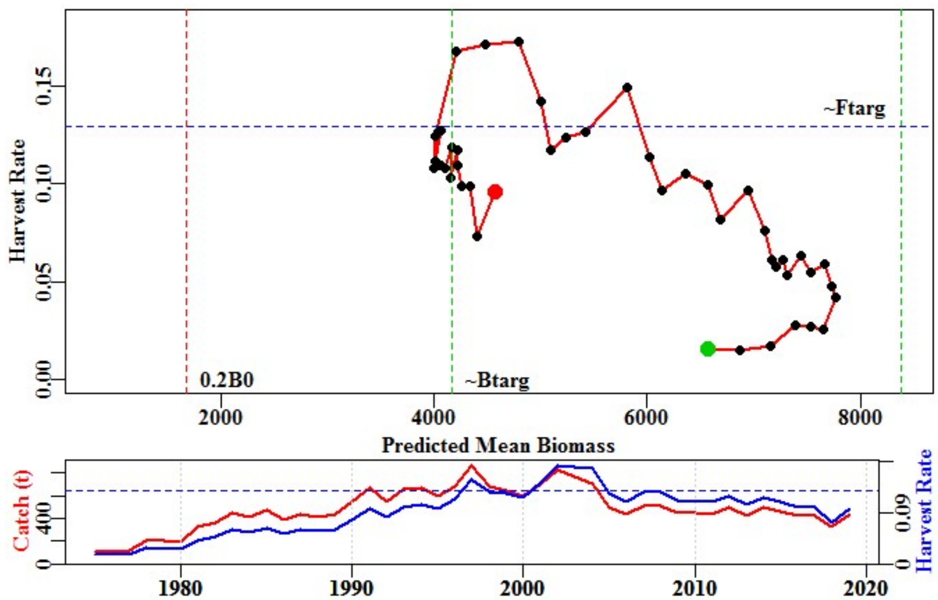

Figure 9.15. Spanish mackerel 2018 catch MSY assessment outputs. Plots of estimated biomass and harvest rates for the full time series of catch data from 1975 for successful Catch MSY analyses. Phase plot (top) where the Green dot is the starting year (1975) and the red dot the current year (2018) and lines labelled as such. The lower plots summaries the catch history (red) and estimated harvest rates (blue), with blue dashed line indicating the F target.

9.3.8.4.2 Grey Mackerel

Catch MSY analyses were undertaken using Grey mackerel commercial, recreational and FTO catch data for the Western Australian stock. A range of scenarios were used, medium or low resilience, the entire known catch history (1990-2018) and MMF only catches (2006-2018), for projections a constant catch of 12 t was applied (average catch since 2008 including recreational and FTO catch estimates).

All of the scenarios suggested that Grey mackerel in WA have been lightly exploited since 1990, although the full catch history is unknown, and may currently be below the target biomass (Figure 9.18). The available catch history with low initial depletion and medium resilience scenario suggest an intrinsic rate of increase (r) of 0.44, a carrying capacity (K) of just 120 t and a low MSY of 14-18t (Figure 9.16). It is unlikely the results are representative of the stock as there is evidence it has been and still is only lightly exploited, noting pre-2000 catch data was based on the few reported catches where Grey mackerel where specified as many catches reported simply as Mackerel could contain catches of Grey mackerel but based on current catch proportions are likely mostly Spanish mackerel, see above. Furthermore, as with Spanish mackerel these results should be used with caution as the decline in catch from 2000 is a result of management changes, along with reduced demand and not stock levels. Thus, CatchMSY is not currently suitable for the analysis of Grey mackerel stocks in WA.

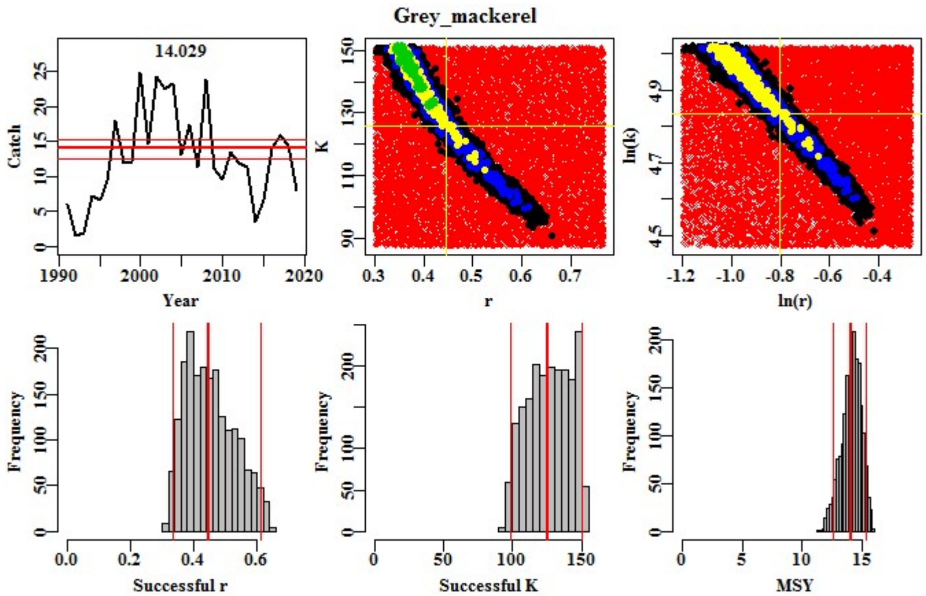

Figure 9.16. Grey mackerel 2018 catch MSY assessment outputs, based on input settings. a) Catch history with overlaid estimate of MSY (14.029) shown as red line and the 90% percentiles (thin lines), b) outputs of r (intrinsic rate of population increase) and K (carry capacity) analyses with increasing colours depicting more combinations of initial depletion that succeeded, highest distribution successful scenarios (black, blue, yellow, green), unsuccessful pairs (red), and medians (yellow lines), c) r-k pairs in log space, d-f) posterior densities of the successful r, k and the resulting MSY, respectively with mean and 90th percentile confidence interval lines.

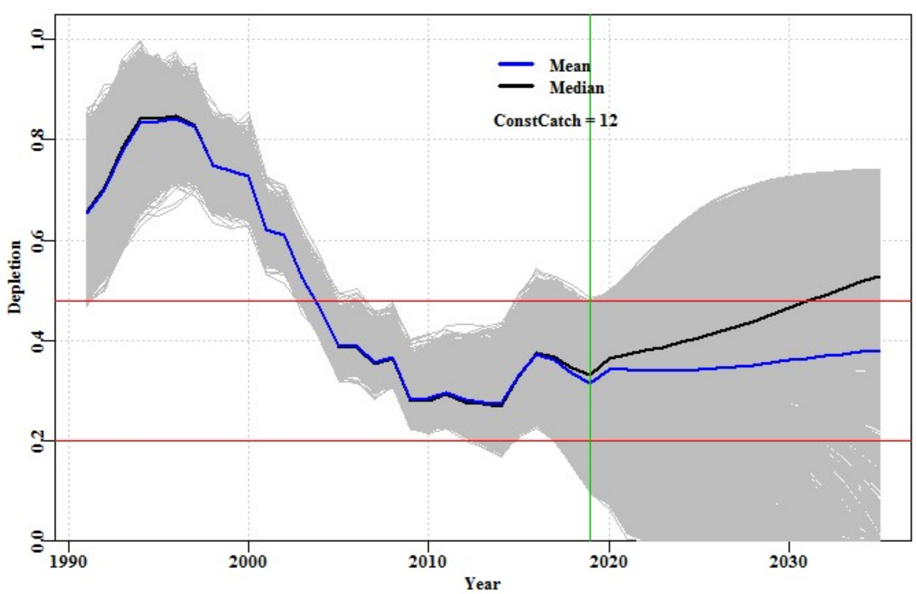

Figure 9.17. Grey mackerel 2018 catch MSY assessment outputs. Summary of estimated biomass depletion trends for Spanish mackerel based on successful Catch MSY runs, grey lines and unto the future under a constant catch of 12t (mean of recent years). The vertical green line indicates the current year (2018), with projections to the right of the line, and the red lines indicate the target and the limit.

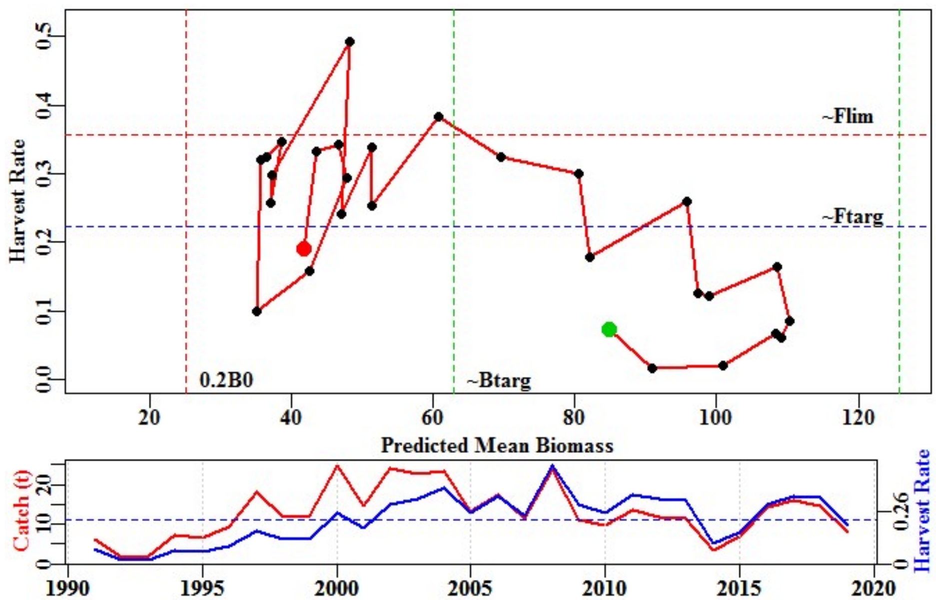

Figure 9.18. Grey mackerel 2018 catch MSY assessment outputs. Plots of estimated biomass and harvest rates for the full time series of catch data from 1990 for successful Catch MSY analyses. Phase plot (top) where the Green dot is the starting year (1990) and the red dot the current year (2018) and lines labelled as such. The lower plots summaries the catch history (red) and estimated harvest rates (blue), with blue dashed line indicating the F target.

9.3.8.4.3 Samson fish/ Kingfish group

As mentioned above there is some uncertainty with the historical catch data for Samson fish in WA as a result of general reporting in the past as Kingfish or Sea Kingfish. In the current catch data prior to 1985 there were very low catches of 4-7 t for the species while the catches of Yellowtail kingfish were high at up to almost 70 t in 1983, see below. Post 1985 the catches of Samson fish increased and peaked at 120 t in 1996 and averaged 110 t until 2005 while the catch of Yellowtail kingfish declined to less than 5 t and have been ever since, see below. Since then the catch of Samson fish has declined in a definitive step down in 2006 to 55 t with further declines since to 21.5 t in 2018. In addition, there was no recorded catch of the very similar and related tropical *Seriola* species, Amberjack, prior to 2000 when the accuracy of recording species in the catch increased and was recorded as up to 19 t (2009 and 2016).

Catch MSY analyses were undertaken using the combined Samson fish, Yellowtail kingfish and Amberjack catch data for the Western Australian stock, representing the Sea kingfish. The FTO average from 2001-2010 was added to the catch history as was the average of the 4 isurveys for the recreational kept catch for each species. A range of scenarios were used (medium or low resilience, the entire catch history (1975-2018) and for projections a constant catch of 80 t was applied (approximately the average annual commercial catch since 2008).

All of the scenarios suggested that the Kingfish group have been heavily exploited since 1985 and may currently be below the target biomass but above the limit (Figure 9.21). The full catch history with moderate initial depletion and low resilience scenario suggest an intrinsic rate of increase (r) of 0.21, a carrying capacity (K) of 1900 t and an MSY of 113t, noting as Samson fish made up a large component, 60-70% since catch history reporting deemed reliable, so possible Samson fish MSY of 68-79 t (Figure 9.19). However, as with Spanish mackerel since catches were reduced as a result of management changes in the WCB and not necessarily stock reduction in the post-2006 catch history data the results must be considered as indicative only. Even so biomass of the Kingfish group and particularly Samson fish was likely above the limit level in 2018 and was likely to exceed the target level within 8-10 years at current catch levels (Figure 9.20).

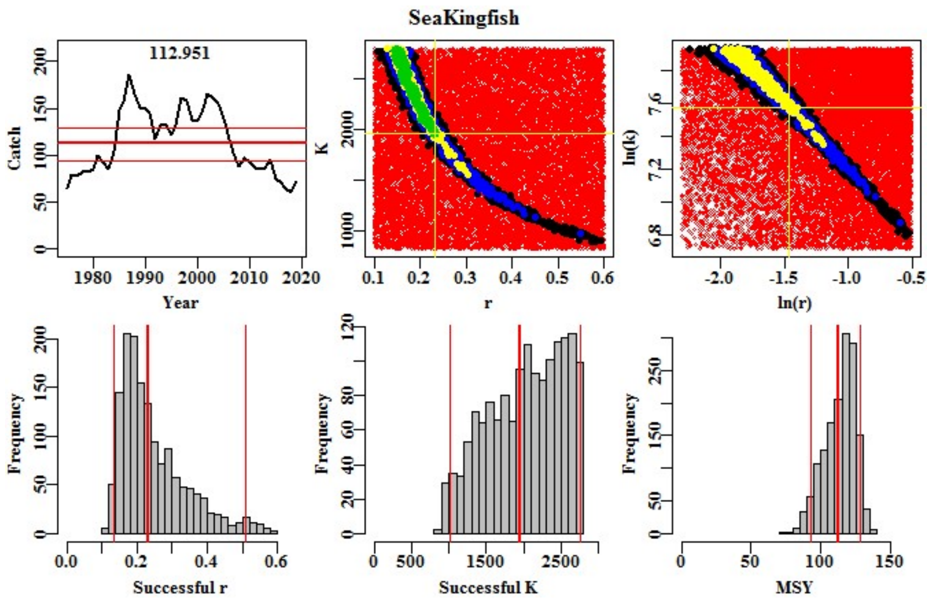

Figure 9.19. Kingfish group 2018 catch MSY assessment, based on input settings. a) Catch history with overlaid estimate of MSY (112.951) shown as red line and the 90% percentiles (thin lines), b) outputs of r (intrinsic rate of population increase) and K (carry capacity) analyses with increasing colours depicting more combinations of initial depletion that succeeded, highest distribution successful scenarios (black, blue, yellow, green), unsuccessful pairs (red), and medians (yellow lines), c) r-k pairs in log space, d-f) posterior densities of the successful r, k and the resulting MSY, respectively with mean and 90th percentile confidence interval lines. Note includes Samson fish, Yellowtail kingfish and Amberjack catches which are likely incorporated in kingfish catch, see above.

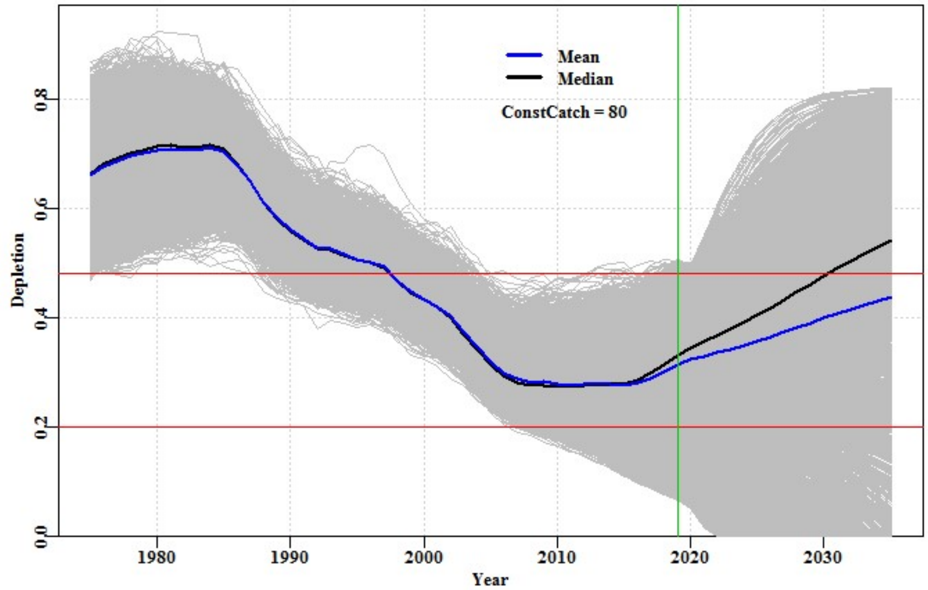

Figure 9.20. Kingfish group 2018 catch MSY assessment outputs. Summary of estimated biomass depletion trends for Sea kingfish group based on successful Catch MSY runs, grey lines and unto the future under a constant catch of 80t (mean of recent years). The vertical green line indicates the current year (2018), with projections to the right of the line, and the red lines indicate the target and the limit.

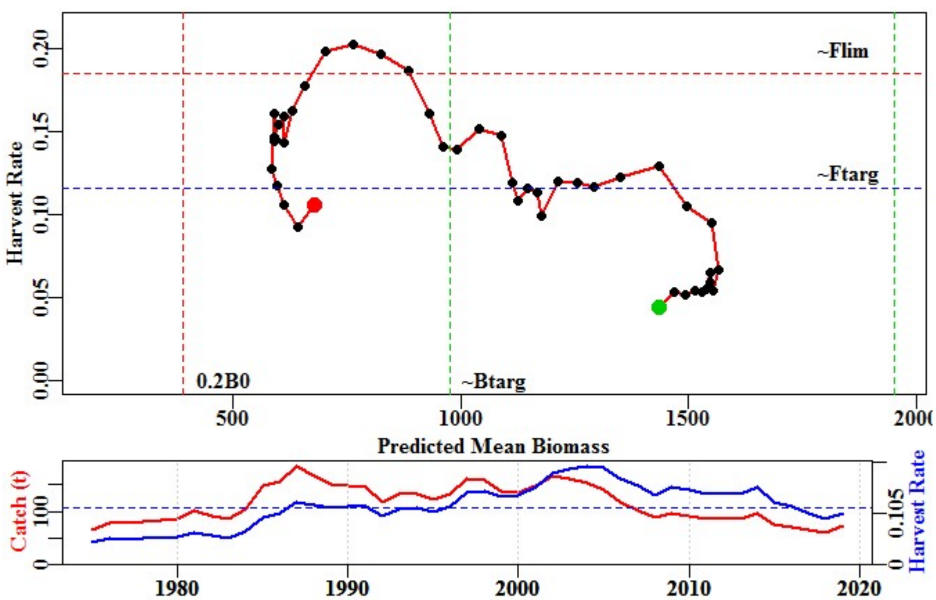

Figure 9.21. Kingfish group 2018 catch MSY assessment outputs. Plots of estimated biomass and harvest rates for the full time series of catch data from 1975 for successful Catch MSY analyses. Phase plot (top) where the Green dot is the starting year (1975) and the red dot the current year (2018) and lines labelled as such. The lower plots summaries the catch history (red) and estimated harvest rates (blue), with blue dashed line indicating the F target.

9.3.8.4.4 Yellowtail kingfish

As with Grey mackerel and Samson fish there is some uncertainty with the historical catch data for Yellowtail kingfish in WA. Total commercial catches of yellowtail kingfish have been below 5 t in Western Australia since 1990. Prior to this, in the 1980s, a peak catch of nearly 70 t was reported from Western Australia. However, during this period species in the kingfish group appear to have often been recorded as Yellowtail kingfish, see above for historical Samson fish catches recorded during this same period. Previous Catch MSY assessments for Yellowtail kingfish used this catch history but due to uncertainty in catches for this period prior to 1990 these have been excluded from the current Catch MSY assessment.

A range of scenarios were used with medium or low resilience on the estimated WA catch history (1990-2018), including 1t of FTO catch and an estimated annual recreational catch of 10t for projections a constant catch of 10.5 t was applied (average of past 10 years). As with Grey mackerel the analysis of the Yellowtail kingfish catch data, indicates a moderate r (intrinsic rate of population increase) of 0.55 and a low K (carry capacity) of just 85 t for the species in WA and an associated low MSY of just 11.7 t (Figure 9.12), although combinations of r<0.1 and K>600 may also be possible, as data appears truncated. Regardless the stock levels of Yellowtail kingfish in WA are likely to be low but stable at current catch levels as recent annual catches are consistently very low at 10-13t (Figure 9.13).

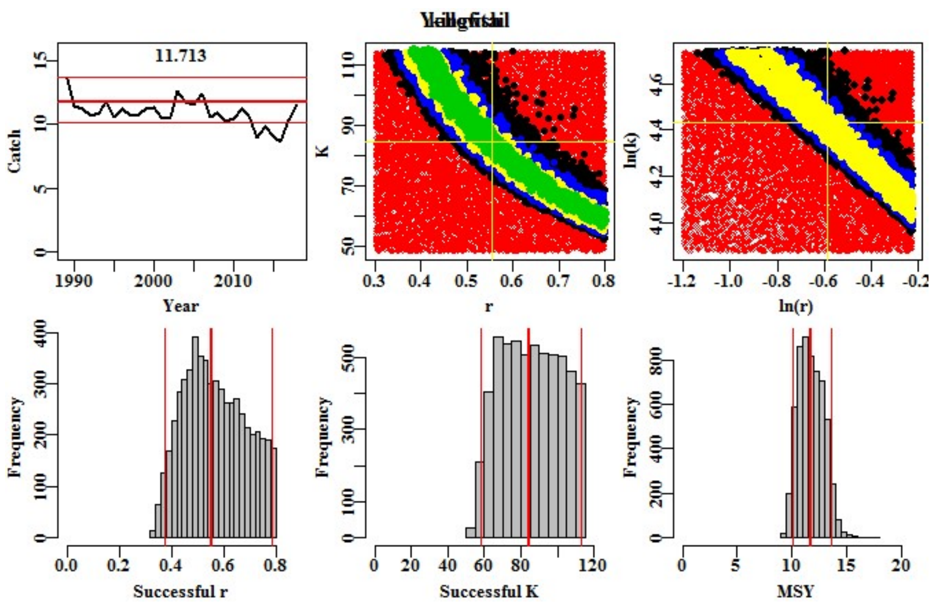

Figure 9.22. Yellowtail kingfish 2018 catch MSY assessment outputs, based on input settings. a) Catch history with overlaid estimate of MSY (11.713) shown as red line and the 90% percentiles (thin lines), b) outputs of r (intrinsic rate of population increase) and K (carry capacity) analyses with increasing colours depicting more combinations of initial depletion that succeeded, highest distribution successful scenarios (black, blue, yellow, green), unsuccessful pairs (red), and medians (yellow lines), c) r-k pairs in log space, d-f) posterior densities of the successful r, k and the resulting MSY, respectively with mean and 90th percentile confidence interval lines.

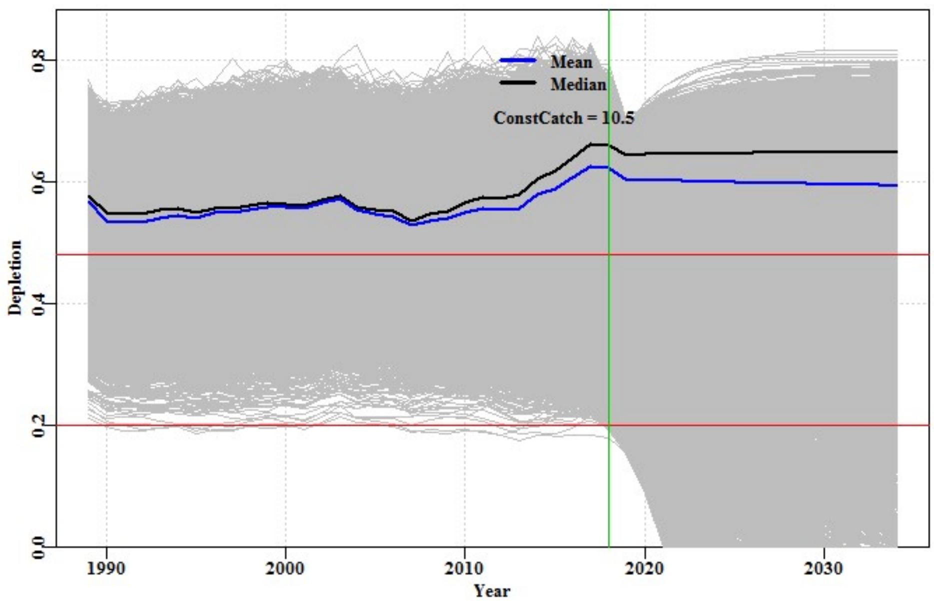

Figure 9.23. Yellowtail kingfish 2018 catch MSY assessment outputs. Summary of estimated biomass depletion trends for Yellowtail kingfish based on successful Catch MSY runs, grey lines and unto the future under a constant catch of 10.5t (mean of recent years). The vertical green line indicates the current year (2018), with projections to the right of the line, and the red lines indicate the target and the limit. Note that pre-1990 data include catches of all *Seriola* species, of which yellowtail kingfish made up a minor component.

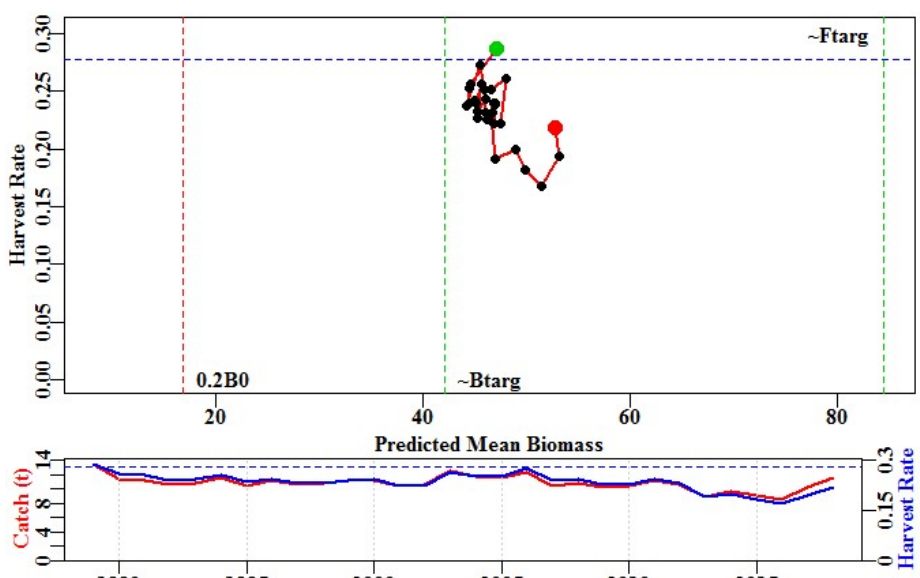

Figure 9.24. Yellowtail kingfish 2018 catch MSY assessment outputs. Plots of estimated biomass and harvest rates for the full time series of catch data from 1975 for successful Catch MSY analyses. Phase plot (top) where the Green dot is the starting year (1990) and the red dot the current year (2018) and lines labelled as such. The lower plots summaries the catch history (red) and estimated harvest rates (blue), with blue dashed line indicating the F target.

9.3.8.5 Accounting for uncertainty

Uncertainty was accounted for by running the models for at least 10,000 iterations. In each iteration, random samples of the input parameters were drawn. Parameter combinations that were able to maintain the population such that it neither collapsed nor exceeded the assumed carrying capacity over the catch time series period were retained (Martell & Froese 2013).

9.3.8.6 Conclusions

The restricted or low catch history and uncertainty in data preclude a number of large pelagic species from stock reduction analysis, and although assessments were conducted there is considerable uncertainty with the historical catch figures and reduction in catch due to management actions and not stock levels for all species, meaning results should be used with caution. Regardless of these limitations the stock reduction analysis indicates recent catches are below MSY and biomass is likely stable or increasing for all species assessed at current catch levels, summary table.

Spanish mackerel	Likely above target biomass and stable at current catch levels
Grey mackerel	Likely below target biomass, low targeting and limited contrast in data
Samson fish/Kingfish	Likely below target biomass but increasing at current catch levels
Yellowtail kingfish	Likely above target biomass and stable at current catch levels

9.4 Stock Status Summary

Presented below is a summary of each line of evidence considered in the overall weight of evidence assessment of the stocks that comprise the Large Pelagic Resource, followed by the management advice and recommendations for future monitoring of the species.

9.4.1 Spanish mackerel

9.4.1.1 Weight of Evidence Risk Assessment

Assessment based on the available data, annual commercial, charter boat operator and estimated recreational boat-based catch data along with nominal catch rates (kg/day). No higher level assessment has been conducted for the species since 2002. Multiple lines of evidence strongly suggest that fishing by the MMF is currently sustainable, and that levels have remained sustainable since the fishery came under formal management in 2006, although recent declines in nominal catch rates and reliance on a small number of blocks are of enough concern to instigate a higher level age based assessment. The lines of available evidence indicate it is possible that there has been moderate stock depletion for Spanish mackerel in WA, due mainly to the influence of environmental conditions and level of targeting by commercial and recreational fishers. The landed catch is relatively stable although recent reductions in the Gascoyne/West Coast commercial and Statewide boat based recreational estimates linked with reducing effort show evidence that the abundance in the area is reducing. The species also has a low vulnerability, high resilience, and the LML being above the size at maturity provides added resilience. It is highly likely that the Spanish mackerel stock is above the point where recruitment would be impaired.

Category	Lines of evidence (Consequence / Status)
Catch	**Commercial sector** All commercial catches of Spanish mackerel are made by the MMF, with 76% of the 2018 catch taken by just three vessels. Prior to management, which included fleet rationalization resulting in reduced effort, catches peaked at 492 t in 2003. However, catches have since fluctuated between a peak of 325 t (2007) and low of 214 t (2018). Until 2018 catches have generally remained stable and within narrow ranges in each of the two main northern management areas, Kimberley (144-217 t) and Pilbara (58-100 t) since the MMF came under interim management in 2006, although the Pilbara is often below the catch tolerance range of 80-126 t, primarily due to unfished quota. The 2018 decline is partially attributed to a change of operators in the fishery but may also be due to recent environmental fluctuations. Catch of 14- 56 t in the southern Gascoyne/West Coast (Area 3) has been consistently below the acceptable catch range since set in 2004 due to low effort levels and environmental variability influencing the abundance of this tropical species in the southern part of its distribution. **Recreational and Charter sector** The estimated retained recreational boat based catches of Spanish mackerel are 36-55 t (13-20% of the total WA catch). These estimates for the most recent 2015/16 survey are lower than previous surveys of 69-103 t (2011/12) and 78-108 t (2013/14). These can be attributed to declines in effort and water temperature variations in the Gascoyne/ West coast. A high proportion of the recreational catch is discarded/released (45-60%) with likely high mortality and high depredation in some areas contributing to higher recreational removals from the fishery. The retained charter catches of Spanish mackerel have been consistently low at 10-15 t or 3-4% of the total catch with approximately a further 40% released. **Until 2018 catches of Spanish mackerel by the commercial sector have been stable over the past ten years, fluctuating around 270-320 t. Recreational catches represent approximately 15-20% of total landings. The catch series provides little evidence that the stock has been depleted to an unacceptably low level or is currently being overfished.**
Effort	Commercial effort targeting Spanish mackerel by the MMF has been stable in each of the Kimberley and Pilbara management areas since management was introduced in 2006. In the Gascoyne/West Coast area, effort has declined since 2012 which may be attributed to lower abundances associated with cooler water temperatures since the 2010/11 heatwave. Recreational effort has declined by 20-35% in the most recent iSurvey (2015/16), particularly in the North Coast Bioregion (NCB) and Gascoyne Coast Bioregion (GCB) during the April to August period when highest Spanish mackerel catches previously occurred, resulting in lower catches. **The effort information does not provide any indication of unacceptable stock depletion.**

Catch distribution	Commercial catches of Spanish mackerel are made predominantly in the Kimberley area (69%). Catches are distributed throughout the entire northern WA distribution of the species, where most of the spawning stock is located and there is no evidence that the commercial catch distribution has changed since 2006, although the fishery relies on a small number of blocks where aggregations occur. Recreational catches in 2011/12 and 2013/14 were spread among the three bioregions whilst in 2015/16 the estimated catch was very low in the West Coast Bioregion (WCB). Catches are generally located adjacent to population centres. The charter catch of Spanish mackerel occurs predominantly in the NCB (84%) in the vicinity of population centres. **The catch distribution information does not provide an indication of unacceptable stock depletion.**
Catch rates	Commercial catch rates of the predominantly single species MMF have been relatively stable but have recently been declining since 2014 in the two northern management areas of MMF, where the majority of the stock occurs. Catch rates in the southern Gascoyne/West Coast management area are also declining, particularly since 2015, apparently due to the influence of environmental conditions, e.g. water temperature, on local stock abundance towards the southern distribution of the species. There is no reliable measure of the recreational catch rate for large pelagic species. For the charter fishery the number of Spanish mackerel per year is a coarse measure of the catch rate as it is not clear if charter operators are always targeting Spanish mackerel. Nonetheless, catches have been stable in each bioregion for the past 15 years. **The catch rate information provides evidence there has been some depletion of the stock but little evidence that the overall stock has been depleted to an unacceptably low level.**
Size distribution	The annual average sizes of Spanish mackerel in the commercial catch does not show any trend in the NCB however the charter catch does show signs of a general decreasing trend in areas near population centres where they fished. The size of Spanish mackerel in the GCB is variable but both commercial and charter data shows the influence of the heatwave in decreasing the average size for a number of years. **The catch size distribution information gives some indication of stock depletion near population centres in the NCB but little evidence that the overall stock has been depleted to an unacceptably low level.**

Stock Reduction Analyses (Catch-MSY methods)	Catch MSY analyses were undertaken using Spanish mackerel catch data for the Western Australian stock. A range of scenarios were used (medium or low resilience, the entire catch history (1975-2018) and a constant catch of 280 t was applied (approximately the average commercial catches since 2008). While some scenarios failed to converge, scenarios including full catch history data and low resilience produced plausible outputs. These scenarios suggested that Spanish mackerel have been heavily exploited since 1990, noting pre 2000 information was based on the total catches of all Mackerel (Spanish and Other mackerel) of which Spanish mackerel likely made up a large component. However, as catches were likely reduced as a result of management changes and not necessarily stock reduction in the post 2000 catch history data the results must be considered as indicative only. Even so results suggest biomass was likely above the target level in 2018 and would remain above the target level at current catch levels. It is likely the estimated catches in the 1990s and 2000s is an artefact of catches including all mackerel species reported as mackerel. **Catch-MSY analyses, although not necessarily applicable to this species catch history, suggested that there was a distinct likelihood that the Spanish mackerel biomass was above the limit level in 2018. Catch-MSY results suggested that biomass will increase in the next three years.**
Vulnerability (PSA)	The species is moderately long lived (max age of 26) with an early age at maturity (less than 2 years) and a relatively high fecundity. PSA score of 2.54 for species indicating low vulnerability. **This low level of vulnerability would indicate that an unacceptable level of stock depletion is unlikely for this species. The risk is further reduced due to the management settings**.
Age composition	No current data
Fishing mortality	No current data**.**
Spawning biomass	No current data.

Consequence (Stock Depletion) Level	Likelihood				Risk Score
	L1 Remote (<5%)	L2 Unlikely (5- <20%)	L3 Possible (20- <50%)	L4 Likely (≥50%)	
C1 Minimal			X		3
C2 Moderate			X		6
C3 High		X			6
C4 Major	X				4

C1 (Minor Depletion): **Possible L3 -** Based on the catch history, current catch and catch rates along with previous age structure and fishing mortality estimates, it is possible that the level of current stock depletion is still only minimal. This would only be supported by the distribution of catches still being concentrated closer to main fishing ports rather than covering the entire stock.

C2 (Moderate Depletion): **Possible L3 -** All of the lines of evidence are consistent with the stock level of Spanish mackerel likely to be at an acceptable moderate level of depletion. The current catch, catch rates and stock reduction analysis along with previous age structure, *F* and SPR lines of evidence are consistent with the level of depletion currently being somewhere close to the maximum level of acceptable depletion. These lines of evidence also suggest that if the current total levels of annual capture are maintained, the stock level is likely to remain within this band during the next five years.

C3 (High Depletion): **Unlikely L2 -** All of the lines of evidence are consistent with it being unlikely that at the current (historic) levels of fishing that the stock depletion is or will become unacceptably high within the next five years.

C4 (Major Depletion): **Remote L1 -** Given there is no evidence that recruitment levels have been affected at any point over the past 40 years it is not plausible that the stock has experienced major depletion. There remains a remote likelihood of this occurring within 5 years based on the potential for unknown factors influencing recruitment.

9.4.1.2 Current Risk Status

Based on the information available, the current risk level for Spanish mackerel in WA is estimated to be MEDIUM (C2 × L3). The Medium Risk (see **Error! Reference source not found.**) reflects acceptable/adequate level of fishing mortality and estimates of relative spawning biomass. All the lines of evidence are consistent with a moderate level of risk, hence the overall Weight of Evidence assessment indicates the status of the Spanish mackerel stock is adequate and that current management settings are maintaining risk at acceptable (medium) levels.

This score assumes the total catch will be maintained at near current levels which could require the development and implementation of a suitable set of management arrangements for all sectors to ensure this is maintained and that the stock status is monitored at regular intervals into the future.

9.4.1.3 Future Monitoring

Last formal assessment was in 2000-2002, a future age based assessment is planned for 2021 with sampling to be done in 2019 and 2020. This assessment will include a review of temporal and spatial catch data and catch rates with the potential to development a standardised catch rate from the 12 years of fine scale daily logbook data from the MMF.

As outlined in the above section, the 2016 Spanish mackerel catch was only within the catch tolerance range for the Kimberley management area and below the range, as it has been for most years since set for the Pilbara and Gascoyne/West Coast areas. Meanwhile, the nominal catch rates have been consistently at or above the threshold catch rate level. With consistently higher catch rates evident in the fishery since 2006, a review of the reference period used to calculate the catch and catch rate reference points is required for each area of the fishery in developing a harvest strategy.

9.4.2 Grey mackerel

9.4.2.1 Weight of Evidence Risk Assessment

Assessment based on annual commercial, charter boat operator and estimated recreational boat-based catch data only. No higher level assessment has been conducted for the species. All of the available evidence indicates there is a high likelihood of minimal stock depletion for Grey mackerel in WA, due mainly to the low level of targeting by commercial and recreational fishers. The landed catch is restricted in inshore areas near population centres and is further reduced by the low retention by recreational and charter fishers. The species also has a low vulnerability, high resilience, is provided further protection by the LML being above the size at maturity and is likely resilient to much higher levels of fishing pressure, as seen elsewhere in its range where annual Australian catch is over 1,000 t annually (Helmke et al. 2016). It is highly likely that the Grey mackerel stock is well above the point where recruitment would be impaired.

Category	Lines of evidence (Consequence / Status)
Catch	Commercial catch The species can only be landed commercially by the MMF. Annual catches are low and variable, fluctuating between 24 t and 3.5 t in 2009 and 2015 respectively. Low catches are due to low targeting and low value, difficulty catching and different gear to the targeted Spanish mackerel. Majority of 2018 catch (86%) was taken by only two vessels. Australian catch of species in 2018 was 1200 t (Helmke et al. 2016) of which WA only contributed 12 t or 1%. Recreational and charter catches were estimated to be very low at 1-2 t with a high release rate of 60-70%. **The current low level of catch and lack of targeting does not provide an indication of unacceptable stock depletion.**
Effort	Commercial effort by MMF when Grey mackerel are caught has been very low at 21-90 block days since 2013, although not all days are necessarily targeting only Grey mackerel. Recreational effort has declined by 20-35% in the most recent iSurvey (2015/16), particularly in the NCB and GCB during the period Apr-Aug when previously Grey mackerel catches occurred. **The effort information does not provide an indication of unacceptable stock depletion.**

Catch distribution	The very limited commercial catch of Grey mackerel is distributed mostly near the population centres of Port Hedland and Carnarvon where the two vessels targeting grey mackerel are based and so covers a very small proportion of the species range in WA. Recreational and charter catches are very low for Grey mackerel at <1 t retained by each, with a limited distribution of catches. **The catch distribution does not provide an indication of unacceptable stock depletion.**
Size distribution	The annual average sizes of Grey mackerel in the commercial catch does not shows an increasing trend and large size in the NCB and variable with no clear trend in the GCB. **The catch size distribution information gives no evidence that the overall stock has been depleted to an unacceptably low level.**
Stock Reduction Analyses (Catch-MSY methods)	Catch MSY analyses were undertaken using available Grey mackerel catch data for the Western Australian stock. A range of scenarios were used (medium or low resilience, the revised catch history (1990-2018) and a constant catch of 20 t was applied (approximately the average combined catch since 2008). All of the scenarios suggested that Grey mackerel in WA have been lightly exploited since 1990, although the full catch history is unknown, and may currently be below the target biomass. The available catch history with low initial depletion and medium resilience scenario suggest an intrinsic rate of increase (r) of 0.44, a carrying capacity (K) of just 120 t and a low MSY of 14-18t. It is unlikely the results are representative of the stock as there is evidence it has been and still is only lightly exploited, noting pre-2000 catch data was based on the few reported catches where Grey mackerel where specified as many catches reported simply as Mackerel could contain catches of Grey mackerel. Furthermore, as with Spanish mackerel these results should be used with caution as the decline in catch from 2000 is a result of management changes, along with reduced demand and not stock levels. **Catch-MSY analyses, although not necessarily applicable to this species catch history, suggested that there was a distinct likelihood that the Grey mackerel biomass was above the limit level in 2018. Catch-MSY results suggested that biomass will increase in the next three years.**
Vulnerability (PSA)	The species is moderately long lived (max age of 12) with an early age at maturity (less than 2 years) and a relatively high fecundity. PSA score of 2.10 for the species indicating a low vulnerability. **This low level of vulnerability would indicate that an unacceptable level of stock depletion is unlikely for this species. The risk is further reduced due to the management settings.**

Consequence (Stock Depletion) Level	Likelihood				Risk Score
	L1 Remote (<5%)	L2 Unlikely (5- <20%)	L3 Possible (20- <50%)	L4 Likely (≥50%)	
C1 Minimal				X	4
C2 Moderate	X				2

C3 High	X				3
C4 Major					NA

C1 (Minor Depletion): **Likely L4 -** Based on the catch history, it is likely that the level of current stock depletion is only minimal. The lack of targeting and restricted distribution of catches to only a few areas rather than covering the entire stock supports this.

C2 (Moderate Depletion): **Remote L1 –** The low level of exploitation indicates there is only a remote chance of there being a moderate depletion to the stock level of Grey mackerel. The lack of targeting and resulting low catch levels that are not indicative of the stock levels but do indicate a lack of demand and little historical exploitation.

C3 (High Depletion): **Remote L1 -** All of the lines of evidence are consistent with it being remote that at the current (historic) levels of fishing that the stock depletion has or will become unacceptably high within the next five years.

C4 (Major Depletion): **Not Plausible -** Given there is no evidence that recruitment levels have been affected at any point over the past 40 years it is not plausible that the stock has experienced major depletion. There remains a no likelihood of this occurring within 5 years based on the potential for unknown factors.

9.4.2.2 Current Risk Status

Based on the information available, the current risk level for Grey mackerel in WA is estimated to be LOW (C1 × L4). The Low Risk (see **Error! Reference source not found.**) reflects acceptable very low level of fishing mortality. All the lines of evidence are consistent with a Low level of risk, hence the overall Weight of Evidence assessment indicates the status of the Grey mackerel stock is adequate and that current management settings are maintaining risk at acceptable (low) levels.

This score assumes the total catch will be maintained at near current levels which could require the development and implementation of a suitable set of management arrangements for all sectors to ensure this is maintained and that the stock status is monitored at regular intervals into the future]. It should also be noted that there is no information from lines of evidence for *F* and SPR presented in the above analyses.

9.4.2.3 Future Monitoring

There has been no formal assessment of Grey mackerel in WA. There is also a high degree of uncertainty about the biology of the species in WA, with no study to date and biology parameters used from Queensland studies. However, the current low levels of targeting and subsequent catch make any future higher level assessments of the stock in WA unlikely.

9.4.3 Samson fish

9.4.3.1 Weight of Evidence Risk Assessment

Assessment based on annual commercial, charter boat operator and estimated recreational boat based catch data only. No higher level assessment has been conducted for the species. All evidence indicates considerably lower catches than historical levels but as the three main fisheries catching this species have been recently or are currently undergoing significant changes there is likely to be further reductions in targeting of this lower value species. The species also has a low vulnerability, high resilience, but is provided little resilience to fishing by the LML being below the size at maturity although the high release rates and ability to avoid barotrauma give it additional resilience. It is likely that the Samson fish stock is above the point where recruitment would be impaired.

Category	Lines of evidence (Consequence / Status)
Catch	Recent commercial catches are split among three commercial fisheries: 34% WCDSMF, 38% SCDSF and 25% TDGDLF. Commercial catches have declined since a high of 119 t in 1997 to low historical levels of 21 t in 2018. Recent management changes in the above fisheries and limited targeting are likely to have contributed to lower catches. Declines in WCB were likely associated with rationalisation of the open access wetline fishery and development of the WCDSMF with effort quota and management changes including a large closed area for the TDGDLF which occurred during the mid to late 2000s. Recreational boat based retained catch estimates are low and stable at 9-20 t with high proportion (74-84%) released over the past 2 surveys but declined from the previous 2 surveys. The charter fishers catch in 2018 was the lowest recorded for the species with a similar high proportion of catch released by charter fishers. Mortality of released fish is likely to be low although shark depredation may increase recreational and charter fishing mortality at some locations. **The catch information does not provide an indication of unacceptable stock depletion**
Catch distribution	Commercial catch distributions have declined on the WB since 2008, after management changes, but been stable on the SCB. Commercial catches are split between WCB and SCB. Recreational and charter catches are restricted to near population centres but have declined in the WCB. **The catch distribution information does not provide an indication of unacceptable stock depletion**
Size distribution	The annual average sizes of Samson fish in the FTO catch does show similar patterns of variability across both the WCB and SCB indicating there could be impacts of environmental conditions and variable recruitment affecting the entire WA stock. Average size has declined in line with declines in catch and may be associated with the 2010/11 heatwave. **The catch size distribution information does not provide an indication of unacceptable stock depletion**

Stock Reduction Analyses (Catch-MSY methods)	Catch MSY analyses were undertaken using Samson fish catch data for the Western Australian stock. A range of scenarios were used (medium or low resilience, the entire catch history (1975-2018) and a constant catch of 40 t was applied (approximately the average commercial catches since 2008). While some scenarios failed to converge, scenarios including full catch history data and low resilience produced plausible outputs. These scenarios suggested that Samson fish have been heavily exploited since 1990, noting pre-1990 information was based on the total catches of "Kingfish" which could include all *Seriola* species and cobia, known as "black kingfish", nevertheless Samson fish likely made up a large component. However, as catches were likely reduced as a result of management changes in two of the key fisheries and not necessarily stock reduction in the post 2006 catch history data the results must be considered as indicative only. Even so biomass was likely above the limit level in 2018 and was likely to exceed the target level within 3 years at current low catch levels. It is likely the estimated catches in the 1990s is an artefact of pre 1990 catches including all species of *Seriola* as kingfish. **Catch-MSY analyses, although not necessarily applicable to this species catch history, suggested that there was a distinct likelihood that the Samson fish biomass was above the limit level in 2018. Catch-MSY results suggested that biomass could rapidly increase in the next three years with lower catches.**
Vulnerability (PSA)	Low vulnerability, PSA score of 2.35. **The PSA information does not provide an indication of unacceptable stock depletion**

Consequence (Stock Depletion) Level	Likelihood				Risk Score
	L1 Remote (<5%)	L2 Unlikely (5- <20%)	L3 Possible (20- <50%)	L4 Likely (≥50%)	
C1 Minimal			X		3
C2 Moderate			X		6
C3 High	X				3
C4 Major					NA

C1 (Minor Depletion): **Possible L3 -** Based on the catch history, it is possible that the level of current stock depletion is only minimal. The lack of targeting and distribution of catches still being restricted to only a few areas rather than covering the entire stock support this.

C2 (Moderate Depletion): **Possible L3** – The low and reducing level of exploitation indicates there is a possible chance of there being a moderate depletion to the stock level of Samson fish due to previously higher catches. The reduced targeting and resulting moderate catch levels since 2006 that are likely not indicative of the stock levels but do indicate management changes, a lack of demand and low historical exploitation.

C3 (High Depletion): **Remote L1 -** All of the lines of evidence are consistent with it being remote that at the current (historic) levels of fishing that the stock depletion has or will become unacceptably high within the next five years.

C4 (Major Depletion): **Not Plausible -** Given there is no evidence that recruitment levels have been affected at any point over the past 40 years it is not plausible that the stock has experienced major depletion. There remains a remote likelihood of this occurring within 5 years based.

9.4.3.2 Current Risk Status

Based on the information available, the current risk level for Samson fish in the WCB and SCB is estimated to be MEDIUM (C2 × L3). The MEDIUM Risk (see **Error! Reference source not found.**) reflects acceptable/adequate level of fishing mortality and estimates of relative spawning biomass. All the lines of evidence are consistent with a Medium level of risk, hence the overall Weight of Evidence assessment indicates the status of the Samson fish stock is adequate and that current management settings are maintaining risk at acceptable (medium) levels.

This score assumes the total catch will be maintained at near current levels which could require the development and implementation of a suitable set of management arrangements for all sectors to ensure this is maintained and that the stock status is monitored at regular intervals into the future. It should also be noted that there is no information from the lines of evidence for *F* and SPR presented in the above analyses.

9.4.3.3 Future Monitoring

Assessment is based on catch levels only. No formal higher level assessment has been conducted for Samson fish in WA and no future higher level assessments are planned for the species.

9.4.4 **Yellowtail kingfish**

9.4.4.1 Weight of Evidence Risk Assessment

Assessment based on annual commercial, charter boat operator and estimated recreational boat based catch data only. No higher level assessment has been conducted for the species in WA but recent assessment has included stock reduction analysis modelling (CatchMSY-SimpleSA). The available evidence indicates there is are low but increasing catches by all sectors and overall low stock levels for Yellowtail kingfish in WA with a high likelihood of low/moderate stock depletion. However, due to the uncertain but possibly high historical catch levels there is a remote likelihood that the stock is highly depleted and has not recovered since. As the three main fisheries catching this species have been recently or are currently undergoing significant changes there is likely to be further reductions in targeting of this lower value species. The species also has a low vulnerability, high resilience, but is provided little resilience to fishing by the LML being below the size at maturity although, like Samson fish, the high release rates and ability to avoid barotrauma give it additional resilience. It is likely that the Yellowtail fish stock is above the point where recruitment would be impaired.

Category	Lines of evidence (Consequence / Status)
Catch	A range of commercial fisheries have captured small quantities (< 3 tonnes) of yellowtail kingfish in Western Australian, typically using hook and line or gillnets. Smaller quantities of yellowtail kingfish (<1 t) have been reported from charter fisher operators. Recreational fishers have also reported yellowtail kingfish, with most caches being boat based. The most recent state-wide boat based estimate (2017/18) of retained recreational yellowtail kingfish catch was approximately 7 tonnes (95% CI=4-10t), with a similar amount released [3]. Total catches of yellowtail kingfish have been below 5 t in Western Australia since 1990. Prior to 1980s, a peak catch of nearly 70 t was estimated from Western Australia. However, returns from this period likely included other species of *Seriola* referred to as "kingfish" including the more common amberjack (*S. dumerili*) and Samson fish (*S. hippos*), and not only the less common yellowtail kingfish (*S. lalandi*). Commercial catch returns since 1990 and particularly since 2001 have reported yellowtail kingfish separately and typically remained below 3 t and do not show a trend. In comparison the East Australian commercial catch was 100 t in 2017 and the recreational is estimated at 320 t in 2013/14 (Hughes et al. 2016). Recreational and charter operators catches are low and stable. **The catch information does not provide an indication of unacceptable stock depletion**
Catch distribution	As yellowtail kingfish are not targeted by commercial fishers, there is limited catch distribution data. However, the commercial catches for the species have increased recently in the SCB but there is no evidence in data or from anecdotal reports that catch distributions have significantly changed through time. **The catch distribution information does not provide an indication of unacceptable stock depletion**
Vulnerability (PSA)	Low vulnerability, PSA score of 2.25. **The PSA information does not provide an indication of unacceptable stock depletion**

Stock Reduction Analyses (Catch-MSY methods)	Catch MSY analyses were undertaken using yellowtail kingfish catch data for the Western Australian stock. A range of scenarios were used (medium or low resilience, the entire catch history of yellowtail kingfish or post 1990 data only) and a constant catch of 10.5 t was applied (the average combined sector catches since 1990). The scenarios including full catch history data and low resilience produced high depletion outputs while the post 1990 catch data produced low MSY estimates. These scenarios suggested that yellowtail kingfish stock levels in WA are low and have been lightly exploited since 1990, noting pre 1990 information was based on the total catches of all *Seriola* of which yellowtail kingfish made up a small component. The full catch data suggest biomass was above the limit level in 2018 (and before) and were likely to exceed the target level within 5 years. It is likely the estimated depleted biomass in the 1990s is an artefact of pre 1990 catches including all species of *Seriola*. While the models converged they generated unrealistically low MSY estimates as a result of the limited contrast in the post 1990 catch history data. **Full history Catch-MSY analyses suggested that there was a remote but uncertain likelihood that the yellowtail kingfish biomass was below the limit level in 2018. Post 1990 Catch-MSY results suggested that biomass is above target and will remain stable in the next five years.**

Consequence (Stock Depletion) Level	Likelihood				Risk Score
	L1 Remote (<5%)	L2 Unlikely (5- <20%)	L3 Possible (20- <50%)	L4 Likely (≥50%)	
C1 Minimal		X			2
C2 Moderate				X	8
C3 High		X			6
C4 Major					NA

C1 (Minor Depletion): **Unlikely L2 -** Catch data, catch distribution, effort and stock reduction analyses all suggest that yellowtail kingfish have low stock levels and are lightly exploited. Yellowtail kingfish are not targeted to any great extent by commercial or recreational fishers and thus future catches are unlikely to significantly increase in out years. Stock reduction analyses, while uncertain, indicate that current biomass (2018) is well above the limit and projections suggest increasing biomass in the future. However, the limited data and high uncertainty suggest that it is **Unlikely** that the biomass is currently (2018) above the target.

C2 (Moderate Depletion): **Likely L4** – Catch data, catch distribution, effort and stock reduction analyses all suggest that yellowtail kingfish are currently lightly exploited but may have been fished at high levels in the past. Yellowtail kingfish are not targeted by commercial or recreational fishers to any great extent and thus future catches are unlikely to significantly increase in out years. Stock reduction analyses, while uncertain, indicate that mean and median biomass estimates in 2018 were above the threshold level. Projections suggest rapidly increasing biomass in the future. It is therefore **Likely** that the biomass is currently (2018) above the threshold.

C3 (High Depletion): **Unlikely L2 -** Catch data, catch distribution, effort and stock reduction analyses all suggest that yellowtail kingfish are lightly exploited since 1990. Yellowtail kingfish are not targeted by commercial or recreational fishers to any great extent and thus future catches are unlikely to significantly increase in out years. Stock reduction analyses on the uncertain full catch history resulted in a proportion of biomass estimates being between the threshold and limit levels in 2018, with projections suggesting rapidly increasing biomass in the future. It is therefore **Remote** that the biomass is currently (2018) between the threshold and limit.

C4 (Major Depletion): **Not Plausible -** Despite some stock reduction analyses runs suggesting that yellowtail kingfish biomass in 2018 could be below the limit, the number of runs was few. Other lines of evidence do not support a major depletion of the stock. This level of depletion is not plausible based on all available lines of evidence.

9.4.4.2 Current Risk Status

The current risk level for the yellowtail kingfish stock was estimated to be **Medium** (C2 × L4) (see Appendix 1). The Medium Risk (see **Error! Reference source not found.**) reflects acceptable/adequate level of fishing mortality and estimates of relative spawning biomass. The main lines of evidence are consistent with a Medium level of risk, hence the overall Weight of Evidence assessment indicates the status of the Yellowtail kingfish stock is adequate and that current management settings are maintaining risk at acceptable (medium) levels.

The current status of the Yellowtail kingfish stock in Western Australia is **Acceptable-Sustainable** and no new management required. Forward projections indicate a rapidly increasing trend in biomass under current management arrangements.

This score assumes the total catch will be maintained at near current levels which could require the development and implementation of a suitable set of management arrangements for all sectors to ensure this is maintained and that the stock status is monitored at regular intervals into the future. It should also be noted that there is no information from the lines of evidence for *F* and SPR presented in the above analyses.

9.4.4.3 Future Monitoring

Assessment is based on catch levels only. No formal higher level assessment has been conducted for Yellowtail kingfish in WA and no future higher level assessments are planned for the species. The planned expansion of the aquaculture industry for this species in WA has the potential to impact upon wild stocks.

9.4.5 Mahi mahi

9.4.5.1 Weight of Evidence Risk Assessment

This highly migratory stock is part if the broader Indian Ocean Biological stock from which there were commercial catches of 20,000 t in 2016. There is currently no formal assessment or relevant indicators of biomass available. On this basis the Indian Ocean Biological stock of Mahi mahi is classified as an **Undefined** stock (SAFS 2018).

The assessment below is based on annual commercial, charter boat operator and estimated recreational boat based catch data for WA state based fisheries only. No higher level assessment has been conducted for the species. For the Western Australian part of the biological stock, commercial and recreational landings are negligible with the stock generally not subject to targeted fishing. All evidence indicates consistently low historical catch levels in WA. The species also has a low vulnerability, a high resilience and is provided further resilience to fishing by the LML being around the size at maturity and is likely resilient to higher levels of fishing pressure. It is highly likely that the Mahi mahi stock is well above the point where recruitment would be impaired.

Category	Lines of evidence (Consequence / Status)
Catch	The Western Australian commercial and charter catches in 2008–18 each averaged less than 0.2 t per annum. Mahi mahi is not a major component of recreational landings, comprising less than 1,000 fish in the state-wide boat based recreational fishing survey [Ryan et al 2019]. This level of catch is negligible in comparison to the India Ocean catch of 20,000 t in 2016 which is regarded as an Undefined stock. **The catch information does not provide an indication of unacceptable stock depletion**
Catch distribution	Commercial catch distributions have been scattered in limited areas. Recreational and charter catches are restricted to near population centres. **The catch distribution information does not provide an indication of unacceptable stock depletion**
Vulnerability (PSA)	Low vulnerability, PSA score of 1.88. **The PSA information does not provide an indication of unacceptable stock depletion**

Consequence (Stock Depletion) Level	Likelihood				Risk Score
	L1 Remote (<5%)	L2 Unlikely (5- <20%)	L3 Possible (20- <50%)	L4 Likely (≥50%)	
C1 Minimal				X	4
C2 Moderate	X				2
C3 High					NA
C4 Major					NA

C1 (Minor Depletion): **Likely L4 -** Based on the catch history, it is likely that the level of current stock depletion in WA waters is only minimal. The lack of targeting and distribution of catches still being restricted to only a few areas rather than covering the entire stock support this. However, as the stock boundaries are undefined for this oceanic species but likely to be large even though the catch levels are relatively low for the entire Indian Ocean the species is undefined, by the IOTC.

C2 (Moderate Depletion): **Remote L1 –** The low level of exploitation indicates there is an unlikely chance of there being a moderate depletion to the stock level of Mahi mahi due to WA fishing pressure. The lack of targeting and resulting low catch levels that are not indicative of the stock levels but do indicate a lack of targeting and low historical exploitation of this highly migratory species by WA state fisheries.

C3 (High Depletion): **Not Plausible -** All of the lines of evidence are consistent with it being not plausible that at the current (historic) levels of fishing that the stock depletion has or will become unacceptably high within the next five years due to WA fishing pressure.

C4 (Major Depletion): **Not Plausible -** Given there is no evidence that recruitment levels have been affected at any point over the past 40 years it is not plausible that the stock has experienced major depletion. There remains no likelihood of this occurring within 5 years based on WA catches.

9.4.5.2 Current Risk Status

Based on the information available, the current risk level for Mahi mahi in WA is estimated to be LOW (C1 × L4). The Low Risk (see **Error! Reference source not found.**) reflects acceptable/adequate level of fishing mortality and estimates of relative spawning biomass. All the lines of evidence are consistent with a Low level of risk, hence the overall Weight of Evidence assessment indicates the status of the Mahi mahi stock is adequate and that current management settings are maintaining risk at acceptable (low) levels.

This score assumes the total catch will be maintained at near current levels which could require the development and implementation of a suitable set of management arrangements for all sectors to ensure this is maintained and that the stock status is monitored at regular intervals into the future. It should also be noted that there is no information from the lines of evidence for *F* and SPR presented in the above analyses.

9.4.5.3 Future Monitoring

Assessment is based on catch levels only. No formal higher level assessment has been conducted for Mahi mahi in WA and no future higher level assessments are planned for the species.

9.4.6 School mackerel

9.4.6.1 Weight of Evidence Risk Assessment

Assessment based on annual commercial, charter boat operator and estimated recreational boat-based catch data only. No higher level assessment has been conducted for the species. All of the available evidence indicates there is a high likelihood of only minimal stock depletion for School mackerel in WA, due mainly to the low level of targeting by commercial and recreational fishers. The landed catch is restricted to nearshore areas near population centres and is further reduced by the low retention and high release rate by recreational and charter fishers (50-70%). The species also has a low vulnerability, high resilience, is provided further protection to fishing by the LML being above the size at maturity and is likely resilient to much higher levels of fishing pressure, as seen elsewhere in its range where annual Australian recreational catch is estimated at over 40 t annually (Litherland et al. 2016). It is highly likely that the School mackerel stock is well above the point where recruitment would be impaired.

Category	Lines of evidence (Consequence / Status)
Catch	Commercial catch In WA the species can only be landed commercially by the MMF. Annual catches are zero or low with 0.5 t and 0.2 t landed in 2017 and 2018. Low catches are due to low targeting and low value, and different gear to the targeted Spanish mackerel. Australian commercial catch of species in 2016 was 110 t (SAFS). Recreational and charter catches were estimated to be low at 3-5 t (95% CI) and 0.5 t, respectively with a high release rate of 60-70%. **The current low level of catch and lack of targeting does not provide an indication of unacceptable stock depletion.**
Effort	Commercial effort by MMF when School mackerel are caught has been very low and they are not a targeted species. Recreational effort has declined by 20-35% in the most recent iSurvey (2017/18), particularly in the NCB and GCB during the period Apr-Aug when previously School mackerel catches occurred. **The effort information does not provide an indication of unacceptable stock depletion.**
Catch distribution	The very limited commercial catch of School mackerel covers a very small proportion of the species range in WA. Recreational and charter catches are very low for School mackerel at <4 t retained by each, with a limited distribution of catches. **The catch distribution does not provide an indication of unacceptable stock depletion.**
Vulnerability (PSA)	The species is relatively short lived (max age of 12) with an early age at maturity (less than 2 years) and a relatively high fecundity. PSA score of 2.19 for the species indicating a low vulnerability. **This low level of vulnerability would indicate that an unacceptable level of stock depletion is unlikely for this species. The risk is further reduced due to the management settings.**

Consequence (Stock Depletion) Level	Likelihood				Risk Score
	L1 Remote (<5%)	L2 Unlikely (5- <20%)	L3 Possible (20- <50%)	L4 Likely (≥50%)	
C1 Minimal				X	4
C2 Moderate	X				2
C3 High	X				3
C4 Major					NA

C1 (Minor Depletion): **Likely L4 -** Based on the catch history, it is likely that the level of current stock depletion is only minimal. The lack of targeting and restricted distribution of catches to only a few areas rather than covering the entire stock supports this.

C2 (Moderate Depletion): **Remote L1 –** The low level of exploitation indicates there is only a remote chance of there being a moderate depletion to the stock level of School mackerel. The lack of targeting and resulting low catch levels that are not indicative of the stock levels but do indicate a lack of demand and little historical exploitation.

C3 (High Depletion): **Remote L1 -** All of the lines of evidence are consistent with it being remote that at the current (historic) levels of fishing that the stock depletion has or will become unacceptably high within the next five years.

C4 (Major Depletion): **Not Plausible -** Given there is no evidence that recruitment levels have been affected at any point over the past 40 years it is not plausible that the stock has experienced major depletion. There remains a no likelihood of this occurring within 5 years based on the potential for unknown factors.

9.4.6.2 Current Risk Status

Based on the information available, the current risk level for School mackerel in WA is estimated to be LOW (C1 × L4). The Low Risk (see **Error! Reference source not found.**) reflects acceptable very low level of fishing mortality. All the lines of evidence are consistent with a Low level of risk, hence the overall Weight of Evidence assessment indicates the status of the School mackerel stock is adequate and that current management settings are maintaining risk at acceptable (low) levels.

This score assumes the total catch will be maintained at near current levels which could require the development and implementation of a suitable set of management arrangements for all sectors to ensure this is maintained and that the stock status is monitored at regular intervals into the future]. It should also be noted that there is no information from lines of evidence for *F* and SPR presented in the above analyses.

9.4.6.3 Future Monitoring

There has been no formal assessment of School mackerel in WA. There is also a high degree of uncertainty about the biology of the species in WA, with no study to date and biology parameters used from Queensland studies. However, the current low levels of targeting and subsequent catch make any future higher level assessments of the stock in WA unlikely.

9.4.7 Spotted mackerel

9.4.7.1 Weight of Evidence Risk Assessment

Assessment of spotted mackerel is based on annual commercial, charter boat operator and estimated recreational boat-based catch data only. No higher level assessment has been conducted for the species in WA. All of the available evidence indicates there is a high likelihood of only minimal stock depletion for Spotted mackerel in WA, due mainly to the low level of targeting by commercial and recreational fishers. The landed catch is restricted to nearshore areas near population centres and is further reduced by the low retention by recreational and charter fishers with release rates of 60—70%. The species also has a low vulnerability (PSA score), is provided some resilience to fishing by the LML being around the size at maturity and is likely resilient to much higher levels of fishing pressure, as seen elsewhere in its range on the east coast of Australia where annual commercial catch is 70-240 t and recreational is over 100 t annually (Litherland et al. 2016). It is highly likely that the Spotted mackerel stock is well above the point where recruitment would be impaired.

Category	Lines of evidence (Consequence / Status)
Catch	Commercial catch In WA the species can only be landed commercially by the MMF. Annual catches are low, less than 0.1 t except in 2008 and 2014 when 0.5 and 0.7 t were landed. Low catches are due to low targeting and low value, difficulty catching and different gear to the targeted Spanish mackerel. Australian landings of the species from 2014-2016 declined from 145 to 56 t (SAFS) of which WA only contributed < 1%. Recreational and charter catches were estimated to be very low at <1 t with a high release rate of 60-70%. **The current low level of catch and lack of targeting does not provide an indication of unacceptable stock depletion.**
Effort	Spotted mackerel are not targeted by the commercial MMF giving no meaningful measures of effort when they are caught. Recreational effort has declined by 20-35% in the most recent iSurvey (2017/18), particularly in the NCB and GCB during the period Apr-Aug when previously higher catches occurred. **The effort information does not provide an indication of unacceptable stock depletion.**

Catch distribution	The very limited commercial catch of Spotted mackerel in the GCB covers a very small proportion of the species range in WA. Recreational and charter catches are very low for Spotted mackerel at <1 t retained by each, with a limited distribution of catches. **The catch distribution does not provide an indication of unacceptable stock depletion.**
Vulnerability (PSA)	The species is relatively short lived (max age of 8) with an early age at maturity (less than 2 years) and a relatively high fecundity. PSA score of 2.03 for the species indicating a low vulnerability. **This low level of vulnerability would indicate that an unacceptable level of stock depletion is unlikely for this species. The risk is further reduced due to the management settings.**

Consequence (Stock Depletion) Level	Likelihood				Risk Score
	L1 Remote (<5%)	L2 Unlikely (5- <20%)	L3 Possible (20- <50%)	L4 Likely (≥50%)	
C1 Minimal				X	4
C2 Moderate	X				2
C3 High	X				3
C4 Major					NA

C1 (Minor Depletion): **Likely L4 -** Based on the catch history, it is likely that the level of current stock depletion is only minimal. The lack of targeting and restricted distribution of catches to only a few areas rather than covering the entire stock supports this.

C2 (Moderate Depletion): **Remote L1 –** The low level of exploitation indicates there is only a remote chance of there being a moderate depletion to the stock level of Spotted mackerel. The lack of targeting and resulting low catch levels that are not indicative of the stock levels but do indicate a lack of demand and little historical exploitation.

C3 (High Depletion): **Remote L1 -** All of the lines of evidence are consistent with it being remote that at the current (historic) levels of fishing that the stock depletion has or will become unacceptably high within the next five years.

C4 (Major Depletion): **Not Plausible -** Given there is no evidence that recruitment levels have been affected at any point over the past 40 years it is not plausible that the stock has experienced major depletion. There remains a no likelihood of this occurring within 5 years based on the potential for unknown factors.

9.4.7.2 Current Risk Status

Based on the information available, the current risk level for Spotted mackerel in WA is estimated to be LOW (C1 × L4). The Low Risk (see **Error! Reference source not found.**)

reflects acceptable very low level of fishing mortality. All the lines of evidence are consistent with a Low level of risk, hence the overall Weight of Evidence assessment indicates the status of the Spotted mackerel stock is adequate and that current management settings are maintaining risk at acceptable (low) levels.

This score assumes the total catch will be maintained at near current levels which could require the development and implementation of a suitable set of management arrangements for all sectors to ensure this is maintained and that the stock status is monitored at regular intervals into the future]. It should also be noted that there is no information from lines of evidence for *F* and SPR presented in the above analyses.

9.4.8 Cobia

9.4.8.1 Weight of Evidence Risk Assessment

Assessment of Cobia is based on annual commercial, charter boat operator and estimated recreational boat-based catch data only. No higher level assessment has been conducted for the species in WA. All of the available evidence indicates there is a high likelihood of only minimal stock depletion for Cobia in WA, due mainly to the low level of targeting by commercial and recreational fishers. The landed catch is restricted to nearshore areas near population centres and is further reduced by the low retention by recreational and charter fishers with release rates of 60—70%. The species also has a low vulnerability (PSA score), is provided some resilience to fishing by the LML being around the size at maturity and is likely resilient to much higher levels of fishing pressure. It is highly likely that the Cobia stock is well above the point where recruitment would be impaired.

Category	Lines of evidence (Consequence / Status)
Catch	Commercial catch Annual catches are low and variable, averaging less than 20 t between 2009 and 2018. The peak historical catch was 42 t in 2003. Low catches are due to low targeting, mainly taken as bycatch in Pilbara fish trawl fishery and line fisheries. Australian catch of species in 2018 was 240 t (SAFS) of which WA only contributed < 10%. Recreational and charter catches were estimated to be low at <3 t annually with moderate release rates of 20-40%. **The current low level of catch and lack of targeting does not provide an indication of unacceptable stock depletion.**
Effort	Cobia are not targeted by the commercial fishers in WA giving no meaningful measures of effort when they are caught. Recreational effort has declined by 20-35% in the most recent iSurvey (2015/16), particularly in the NCB and GCB during the period Apr-Aug when previously higher Cobia catches occurred. **The effort information does not provide an indication of unacceptable stock depletion.**

Catch distribution	The very limited commercial catch of Cobia in the Pilbara covers a very small proportion of the species range in WA. Recreational and charter catches are very low for Cobia at <3 t retained, with a limited distribution of catches. **The catch distribution does not provide an indication of unacceptable stock depletion.**
Vulnerability (PSA)	The species is relatively short lived (max age of 14) with an early age at maturity (less than 3 years) and a relatively high fecundity. MLL is set at around the size at maturity. PSA score of 2.20 for the species indicating a low vulnerability. **This low level of vulnerability would indicate that an unacceptable level of stock depletion is unlikely for this species. The risk is further reduced due to the management settings.**

Consequence (Stock Depletion) Level	Likelihood				Risk Score
	L1 Remote (<5%)	L2 Unlikely (5- <20%)	L3 Possible (20- <50%)	L4 Likely (≥50%)	
C1 Minimal				X	4
C2 Moderate	X				2
C3 High	X				3
C4 Major					NA

C1 (Minor Depletion): **Likely L4 -** Based on the catch history, it is likely that the level of current stock depletion is only minimal. The lack of targeting and restricted distribution of catches to only a few areas rather than covering the entire stock supports this.

C2 (Moderate Depletion): **Remote L1** – The low level of exploitation indicates there is only a remote chance of there being a moderate depletion to the stock level of Cobia. The lack of targeting and resulting low catch levels that are not indicative of the stock levels but do indicate a lack of demand and little historical exploitation.

C3 (High Depletion): **Remote L1 -** All of the lines of evidence are consistent with it being remote that at the current (historic) levels of fishing that the stock depletion has or will become unacceptably high within the next five years.

C4 (Major Depletion): **Not Plausible -** Given there is no evidence that recruitment levels have been affected at any point over the past 40 years it is not plausible that the stock has experienced major depletion. There remains a no likelihood of this occurring within 5 years based on the potential for unknown factors.

9.4.8.2 Current Risk Status

Based on the information available, the current risk level for Cobia in WA is estimated to be LOW (C1 × L4). The Low Risk (see **Error! Reference source not found.**) reflects acceptable very low level of fishing mortality. All the lines of evidence are consistent with a Low level of risk, hence the overall Weight of Evidence assessment indicates the status of the Cobia stock is adequate and that current management settings are maintaining risk at acceptable (low) levels.

This score assumes the total catch will be maintained at near current levels which could require the development and implementation of a suitable set of management arrangements for all sectors to ensure this is maintained and that the stock status is monitored at regular intervals into the future]. It should also be noted that there is no information from lines of evidence for *F* and SPR presented in the above analyses.

9.4.8.3 Future Monitoring

There has been no formal assessment of Cobia in WA. There is also a high degree of uncertainty about the biology of the species in WA, with no study to date and biology parameters used from Queensland studies. However, the current low levels of targeting and subsequent catch make any future higher level assessments of the stock in WA unlikely.

9.5 Stock Status Advice

For the Large pelagic resource the risk levels are Low to Medium that current management settings are maintaining stocks at acceptable levels, see below for each species.

For the main targeted Spanish mackerel stock, the current risk level is estimated to be Medium (C2 × L3) (see **Error! Reference source not found.**). Hence, the current stock status is acceptable and current risk control measures in place are adequate (i.e. no new management required). Forward projections indicate an increasing trend in biomass under current management settings.

For the other tropical indicator Grey mackerel stock, the current risk level is estimated to be Low (C1 × L4). Hence, the current stock status is acceptable and the current management settings are adequate.

For the temperate indicator species Samson fish stock, the current risk level is estimated to be Medium (C2 × L3). Hence, the current stock status is acceptable and the current management settings are adequate.

For the temperate Yellowtail kingfish stock, the current risk level is estimated to be Medium (C2 × L4). Hence, the current stock status is acceptable and the current management settings are adequate.

For the tropical Cobia stock, the current risk level is estimated to be Low (C1 × L4). Hence, the current stock status is acceptable and the current management settings are adequate.

For the tropical mahi-mahi stock, the current risk level is estimated to be Low (C1 × L4). Hence, the current stock status is acceptable and the current management settings are adequate.

For the tropical school and spotted mackerel stocks, the current risk level is estimated to be Low (C1 × L4). Hence, the current stock status is acceptable and the current management settings are adequate.

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Appendix 1

Justification for Harvest Strategy Reference Levels

The performance indicator used to evaluate the stock status of indicator species in the [Region] is spawning biomass (*B*), or an appropriate proxy such as spawning potential ratio (SPR) (see Table A1.1). For each stock, the performance indicator is estimated periodically (at least every 5 years) and compared to associated reference levels (Table A1.1). The reference levels are consistent with those used by the Department in other similar assessments and are based on internationally accepted benchmarks for moderate to long-lived fish species (Mace 1994; Caddy and Mahon 1995; Gabriel and Mace 1999; Wise et al. 2007). Note that the threshold level of B_{30} (and SPR_{30}) corresponds to B_{MSY} (Table A1.1).

Table A1.1. Performance indicators and associated reference levels used to evaluate the status of indicator species and secondary indicator species in the Pilbara and Kimberley

Performance Indicator	Reference Levels		
	Target	Threshold (B_{MSY})	Limit
Spawning biomass (*B*)	B_{40}	B_{30}	B_{20}
Spawning potential ratio (SPR)	SPR_{40}	SPR_{30}	SPR_{20}

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Appendix 2

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

CONSEQUENCE LEVELS

As defined for major target species

1. Minor – Fishing impacts either not detectable against background variability for this population; or if detectable, minimal impact on population size and none on dynamics

   Spawning biomass > Target level (B_{MEY})

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

   Spawning biomass < Target level (B_{MEY}) but > Threshold level (B_{MSY})

3. High – Level of depletion unacceptable but still not affecting recruitment levels of stock

   Spawning biomass < Threshold level (B_{MSY}) but >Limit level (B_{REC})

4. Major – Level of depletion is already affecting (or will definitely affect) future recruitment potential/ levels of the stock

   Spawning biomass < Limit level (B_{REC})

LIKELIHOOD LEVELS

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

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

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

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

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Appendix 3

Productivity Susceptibility Analysis (PSA) Scoring Tables

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

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