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Ecological Risk Assessment for the Peel-Harvey Estuarine Fishery

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Table of Contents

Executive Summary

An ecological risk assessment (ERA) of the Peel-Harvey Estuarine Fisheries (Fisheries) was convened by the Department of Primary Industries and Regional Development, Western Australia (WA) on 9 September 2020. ERAs are conducted by the Department as part of its Ecosystem Based Fisheries Management framework and the outputs will inform the updated harvest strategies for these resources, as well as the upcoming Marine Stewardship Council (MSC) re-assessment of the Fisheries. The Fisheries within the scope of this current ERA include the commercial net and crab trap fishery (West Coast Estuarine Managed Fishery: Area 2), and the blue swimmer crab recreational (drop net and scoop net) fishery.

The Peel-Harvey Estuary is the largest natural inland water body in the south-west region of WA. Covering approximately 136 km2, the shallow water (mean depth ~ 0.9 m) estuarine system is comprised of the Peel Inlet and Harvey Estuary. Three rivers (Serpentine, Murray and Harvey) discharge into the estuary, which is connected to the Indian Ocean via a natural entrance channel (Mandurah Channel) in the northern Peel Inlet and an artificial entrance channel opened in 1994 (Dawesville Channel) in the northern Harvey Estuary. The shallow waters of the Peel-Harvey Estuary support extensive stands of macroalgae and seagrass which, in combination with high phytoplankton productivity, support large populations of invertebrates, finfish, birds and mammals.

The ERA estimated risk based on available scientific monitoring and research information relating to the Peel-Harvey Estuary and the fishing activities that occur in this environment, as well as relevant fishery regulations and management. This assessment conforms with the AS ISO 31000 risk management standard and the methodology adopted by DPIRD, which relies on a likelihood-consequence method for estimating risk.

A broad range of stakeholders were invited to participate in the ERA workshop. Although the total number of workshop participants was limited due to COVID restrictions and to allow for efficient consideration of risk issues, the ERA was attended by representatives of the commercial and recreational fishing sectors, as well as state and local government agencies, Peel Harvey Catchment Council, Peel Development Commission, Murdoch University, Birdlife WA and the Bindjareb Noongar Community.

Thirty issues associated with the ecological sustainability of the Fisheries were scored cumulatively for risk, noting that some were also scored separately for the different fishing sectors and methods. The majority (21) of these issues were evaluated as low or negligible risks, which do not require any specific control measures. There were 7 medium risks, which were assessed as acceptable under current monitoring and control measures already in place.

The risk assessment yielded two high risks that require further control measures, which will be determined following a review process initiated by the harvest strategies for these resources. The capture and retention of Perth herring in the commercial net fishery was considered a high risk, given the inherent vulnerability of

this anadromous species to fishing pressure and indications from available data that the total mortality in the Peel-Harvey Estuary is three times greater than that of the unfished stock in the Swan River. A high risk score was also given to the migratory and threatened shorebird species that inhabit estuary during the summer months, when there is potential for feeding and roosting birds to be disturbed by recreational scoop net fishers (and other recreational activities) in key areas of overlap.

It is recommended that the risks be reviewed in 5 years, or prior to the next review of the harvest strategies for the swimmer crab and estuarine and nearshore finfish resources in south-west WA, where the risk scores are used as the performance indicator for the non-target ecological assets. Monitoring and assessment of the key target species will be ongoing, with the performance indicators for those stocks evaluated on an annual basis.

1.0 Introduction

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

This report provides information relating to an ERA for the Peel-Harvey Estuarine Fishery in WA in 2020. The assessment considered the potential ecological impacts of the commercial fish net and crab trap fishers operating in Area 2 of West Coast Estuarine Managed Fishery (WCEMF), as well as recreational fishers who use drop nets and scoop nets to target blue swimmer crabs in the estuary. The assessment focused on evaluating the impact of each fishing sector/method on all relevant retained and bycatch species, endangered, threatened and protected (ETP) species, habitats, and the broader ecosystem.

The risk assessment methodology utilises a consequence-likelihood analysis, which involves the examination of the magnitude of potential consequences from fishing activities and the likelihood that those consequences will occur given current management controls. The assessment was initially undertaken by Departmental staff, updating the results of a previous risk assessment of the fishery undertaken in 2014 (see Johnston et al. 2015). These results were then sent to industry and stakeholders for review and risk scores were then re-evaluated through an external stakeholder meeting. Once finalised, this current risk assessment will help inform the harvest strategies for the estuarine and nearshore finfish and blue swimmer crab resources in south-west WA (DPIRD 2020a, b in review).

2.0 Aquatic Environment

The Peel-Harvey Estuary (32.53° S, 115.71° E) is the largest natural inland water body in the south-west region of WA (Brearley 2005). Covering approximately 136 km^2, the shallow water (mean depth ~ 0.9 m) estuarine system is comprised of the Peel Inlet (75 km^2) and Harvey Estuary (61 km^2), joined by a narrow channel through the Point Grey Sill (Figure 2.1).

Peel Inlet is a wide (~7 km diameter), shallow saucer-shaped basin with a central area (~2 m deep), surrounded by shallow intertidal flats on the eastern and southern sides (Hodgkin & Hesp 1998; Brearley 2005). The Harvey Estuary is a long (~20 km) and narrow (~2 km) barrier estuary with a maximum water depth of ~2 m bordered by shallow flats which ascend into samphire flats and marshes to the east and coastal sand dune systems to the west (Brearley 2005). Three rivers discharge into the Peel-Harvey Estuary (Serpentine, Murray and Harvey rivers) with the system connected to the Indian Ocean via a natural entrance channel (Mandurah Channel) in the northern Peel Inlet and an artificial entrance channel opened in 1994 (Dawesville Channel) in the northern Harvey Estuary (Figure 2.1). Both channels are kept open by regular dredging (Young 2000).

The shallow waters of the Peel-Harvey Estuary support extensive stands of macroalgae and seagrass (Krumholz 2019). These plants, in combination with high phytoplankton productivity, support large populations of small invertebrate animals, which in turn form the basis of a food chain that supports other invertebrates and numerous finfish, as well as birds and mammals. The estuary was listed as a Ramsar Wetland of International Importance in 1990, as part of the larger Peel-Yalgorup Wetland System, and is considered to be an internationally significant habitat for waterbirds.

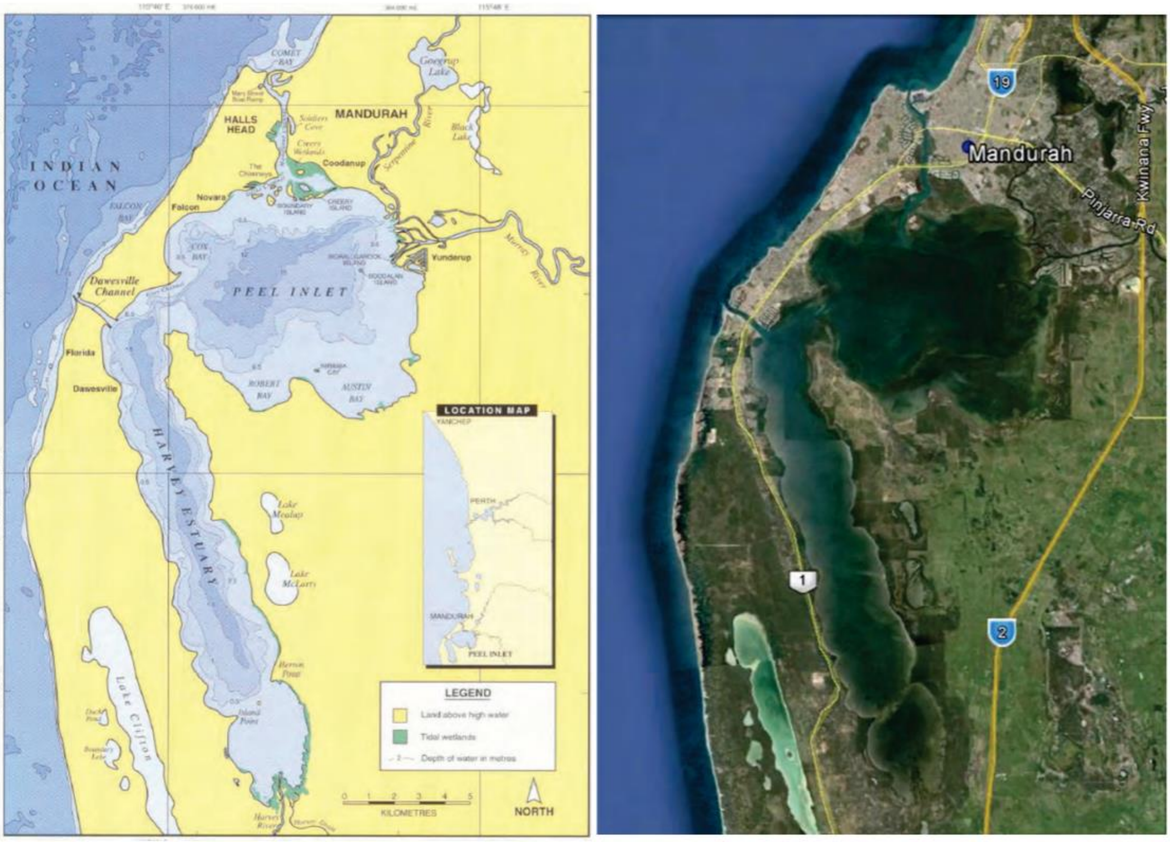


Figure 2.1. Schematic and aerial photo of the Peel-Harvey Estuarine system (Source: Department of Water 1998; Google Earth 2014).

Chlorophyta and seagrass and are the two main contributors to total macrophyte biomass within the Peel-Harvey Estuary (Krumholz 2019). However, there have been 17 significantly different habitat types identified among 102 nearshore sites, with seasonal changes due to the ephemeral nature of the estuary (Wilson et al. 1999; Valesini et al. 2009, 2010). Examination of the historical trends in the main macrophyte communities over a four-decade period (1978 to 2018) showed a general decline in Chlorophyta biomass over time, particularly in the eastern Peel Inlet and southern Harvey Estuary (Figure 2.2) (Krumholz 2019). This decline occurred concurrently with an increase in seagrass biomass, especially in the northern Harvey Estuary and western Peel Inlet, adjacent to the Dawesville Channel (Figure 2.3) (Krumholz 2019).

The benthic habitat changes in the Peel-Harvey Estuary are reported to have been influenced by anthropogenic impacts such as increased nutrient inputs from surrounding agricultural land in the 1960-1980s (McComb and Humphries 1992; Wildsmith et al. 2008; Krumholz 2019), as well as increased salinity and tidal exchange from the Dawesville Channel. This artificial channel was opened to increase water exchange throughout the Peel-Harvey Estuary and improve water quality (Wilson et al. 1999; Brearley 2005; Elliot et al. 2016), ultimately altering its ecology (Young and Potter 2003; Wildsmith et al. 2008; Pedretti et al. 2011; Potter et al. 2016). In recent years, freshwater discharge into the Peel-Harvey Estuary from the three rivers has reduced due to decreased rainfall (Veale et al. 2013; Cottingham et al. 2018; Hallet et al. 2018). This has resulted in sustained higher salinities (Potter et al. 2016) and further increases in seagrass biomass, with colonisation of the southern Harvey Estuary reported in 2017 and 2018 (Figure 2.2 and Figure 2.3) (Hallett et al. 2018; Krumholz 2019; Valesini et al. 2019).

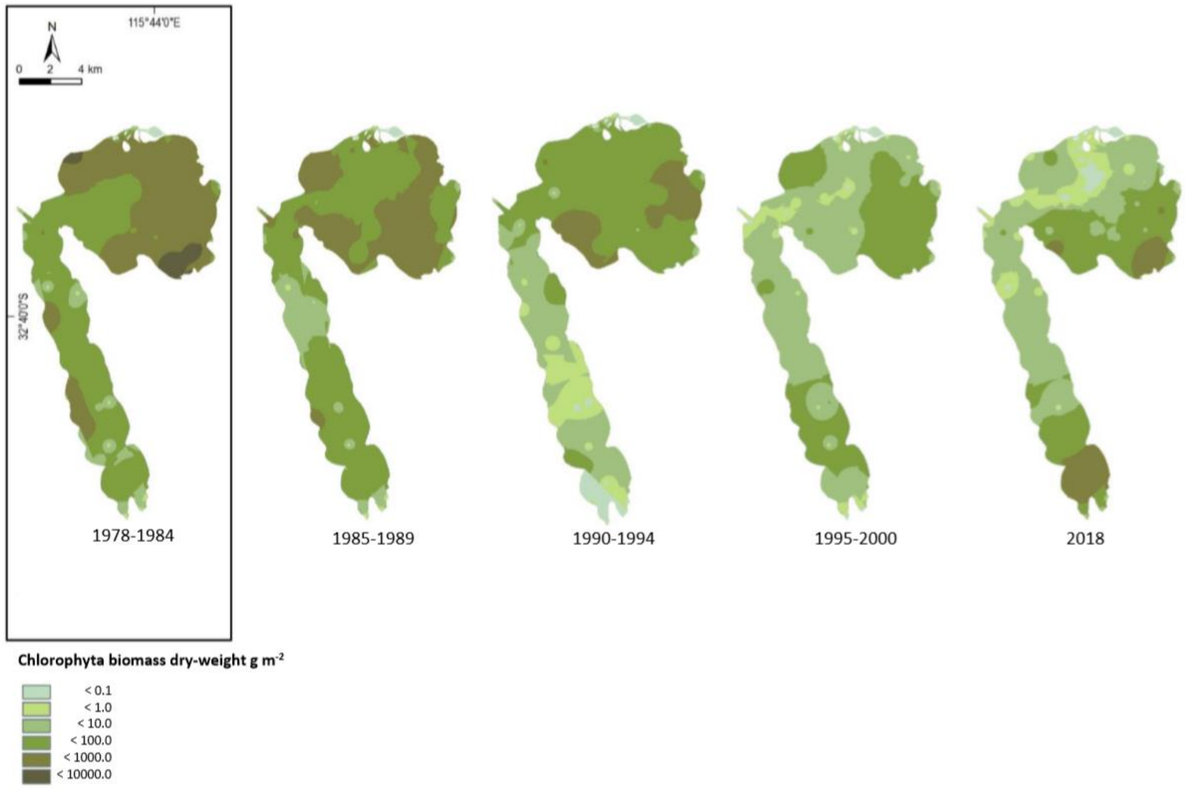


Figure 2.2. Interpolated Chlorophyta biomass (dry-weight in g m^{-2}) across the Peel-Harvey Estuary in each period. (Source: Krumholz 2019).

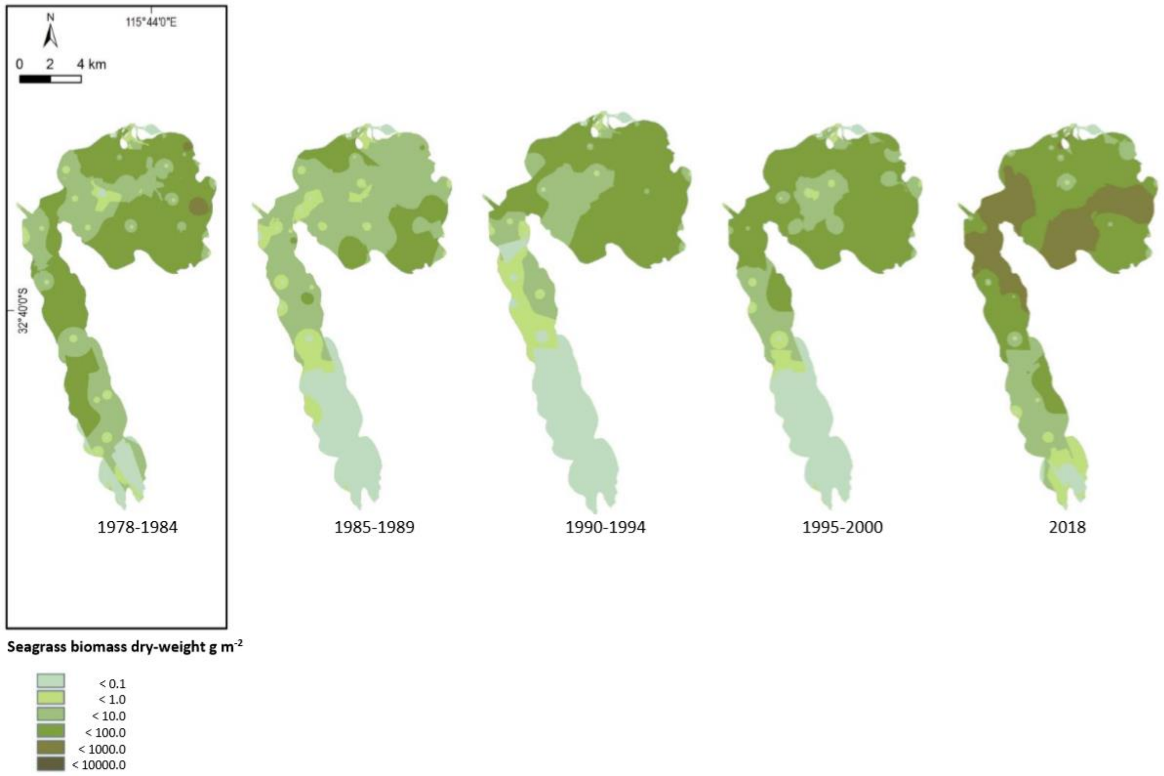


Figure 2.3. Interpolated seagrass biomass (dry-weight in g m^{-2}) across the Peel-Harvey Estuary in each period. (Source: Krumholz 2019).

3.0 Peel-Harvey Estuarine Fishery

A commercial net fishery was first established in the Peel-Harvey Estuary in the mid-1800s (Bradby 1997), with up to 150 fishers historically operating in family-based fishing units to supply fresh fish to the local markets (Mandurah Licenced Fishermen's Association [MLFA] 2008). Commercial fishers first began retaining blue swimmer crabs in the late-1950s, initially caught with the same gill nets used to target finfish (Johnston et al. 2014). Since 2000, blue swimmer crabs have been commercially targeted using purpose-built crab traps to improve fishing efficiency and reduce bycatch (Bellchambers et al. 2005). This has greatly reduced gill netting in the fishery, with finfish now mainly visually targeted using haul nets.

The commercial fishing sector operating in the Peel-Harvey Estuary is now managed as part of the WCEMF (Figure 3.1), with a substantial proportion of the current total fishing effort now directed towards blue swimmer crabs (Johnston et al. 2015). There are currently seven commercial fishers licensed to use haul and gill nets to catch finfish in the estuary, of which six are also permitted to use crab traps to target blue swimmer crabs.

Due to its size and proximity to the cities of Mandurah and Perth, the Peel-Harvey Estuary is one of the most popular estuaries for recreational fishing in the south-west of WA (Johnston et al. 2015; Taylor et al. 2018; Desfosses et al. 2019). Blue swimmer crabs are the most commonly targeted species by recreational fishers in the Peel-Harvey Estuary (Malseed and Sumner 2001) and crabbing has a large cultural and social significance in the local community.

A Voluntary Fisheries Adjustment Scheme (VFAS) was established in 2018 to reduce the number of commercial licenses in the Peel-Harvey Estuary. This initiative aimed to enhance and protect the recreational fishing experience in the estuary by re-allocating a component of the resource to recreational fishers and the ecosystem, with four of the original 11 licenses recently bought out as part of this process.

This risk assessment of the Peel-Harvey Estuarine Fishery considers the four primary fishing sectors and gears used to target finfish and blue swimmer crabs in the estuary, which were assessed and certified against the globally-recognised Marine Stewardship Council (MSC) standard for sustainable fishing in 2016. These include the

1. commercial haul and gill net fishery for finfish;
2. commercial trap fishery for blue swimmer crabs;
3. recreational drop net fishery for blue swimmer crabs; and
4. recreational scoop net fishery for blue swimmer crabs.

The following chapters of this report (Sections 4-7) outline the fishing activities undertaken by each of these fishing sectors and summarise available information on retained and discarded catches, as well as ecological impacts on benthic habitats and Endangered, Threatened and Protected (ETP) species. For simplicity, due to the haul and gill net fishers using the same nets and the very low gill netting effort in recent years, the commercial net fisheries have been described together (see Section 4.0). This background information was used as the basis for scoring the individual and cumulative risks of these fishing activities impacting on each ecological component considered in this risk assessment.

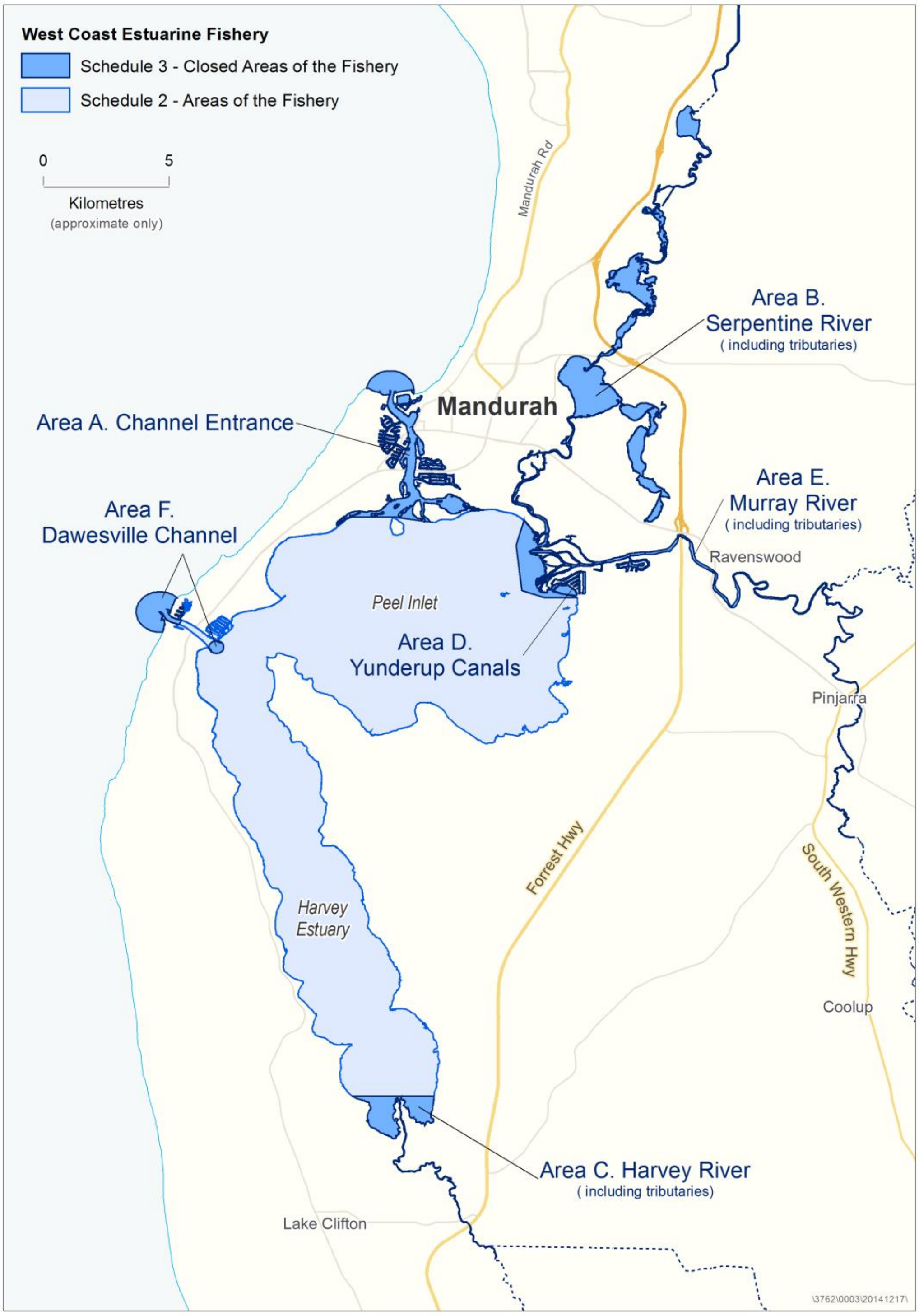


Figure 3.1. Boundaries and closed areas of the West Coast Estuarine Managed Fishery (Area 2: Peel-Harvey Estuary).

4.0 Commercial Net Fishery

Since commercial fishers in the Peel-Harvey Estuary started using crab traps to target blue swimmer crabs in 2000, the majority of finfish catches have been taken by haul nets used to visually target schools of mullet and other species in the estuary (Figure 4.1). Gill (set) net catches now only comprise a very minor component of the total retained catches (Figure 4.1), mostly used by some fishers in winter to target demersal species such as cobbler. The majority of the finfish catch is edible-quality and is delivered daily to local retailers. A smaller portion of the catch is used as bait by those fishers in the estuary who are also licensed to catch blue swimmer crabs. The remainder is delivered to metropolitan bait wholesalers, who in turn package this product for use by other fisheries (MLFA 2008).

There are currently seven licensed fishers in Area 2 of the WCEMF that are permitted to operate haul and gill nets within the Peel-Harvey Estuary. The net fishers operate throughout the year (except for weekends) using small motorised boats, some which have been purpose built to allow access to the very shallow areas along the fringes of the estuary. Owing to regulatory restrictions on commercial boat size (maximum 6.5 m boat length) no mechanised hauling systems are permitted in the fishery (MLFA 2008). More than half of the license holders typically fish by themselves, whilst some operate with a second person onboard the boat to help haul the net and sort catches. With a large number of access points around the estuary for vessels to be launched, the majority of fishing trips extend for only half a day and most involve a single net haul.

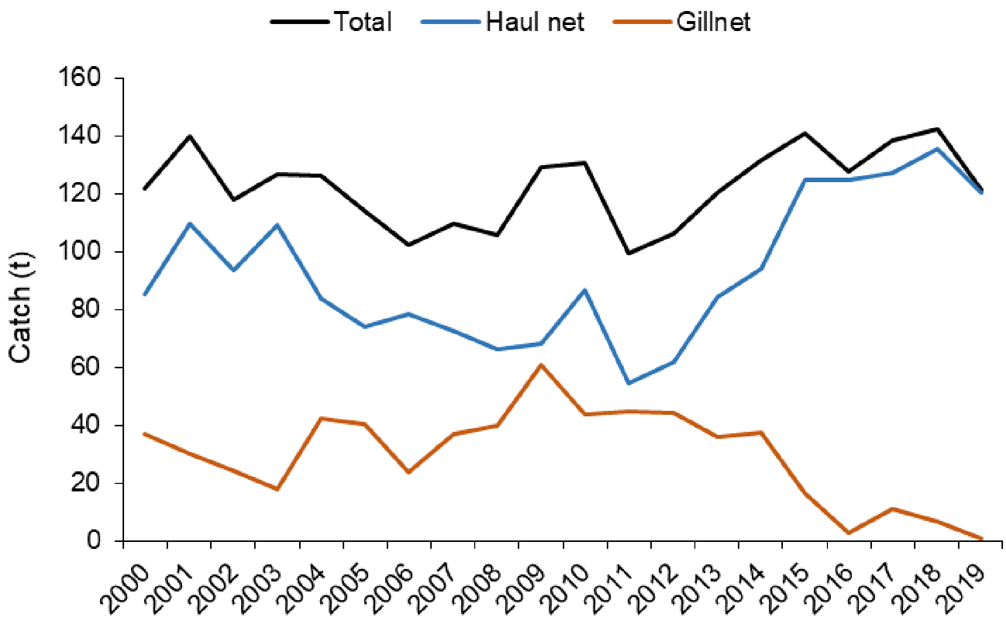


Figure 4.1. Retained catches (tonnes) of finfish by commercial haul and gill netting in the Peel-Harvey Estuary between 2000 and 2019.

4.1 Fishing Gear and Methods

The fishers in the Peel-Harvey Estuary all use a similar net, which is flat and rectangular with a weighted footrope and a float line to maintain an upright position in the water column (Figure 4.2). The use of the net as a haul or gill net depends on the targeted species and size of fish, the time of year and location (MLFA 2008). There are specific gear restrictions, including permitted mesh size and net length, in place under the current management arrangements. For example, an operator must not set, pull or haul more than a total of 1000 m of net in the estuary at any one time. The mesh sizes used in the fishery (typically 50 – 100 mm) allow for the escape of smaller individuals, thus virtually all captured fish are retained (see Section 4.3 on bycatch).

When haul netting, fishers visually target a school of fish, which generally consists of a single species. With more than half the estuary less than 1 m in depth, fish can be easily sighted from the vessels as fishers transit through known fishing grounds. Some fishers also target fish by looking for ripples from fish moving in very shallow waters, or searching for marks left on the sandy substrate by certain species when feeding. Haul netting is undertaken mainly on calm, clear days as wind chop and rain greatly reduce fishing efficiency and increase the time spent searching for fish.

Once a suitable school of fish is detected, a float attached to one end of the net is thrown overboard and the haul net deployed in a circular manner by motoring the vessel around the fish. The float at the loose net end is then retrieved and tied to the vessel to trap fish inside the net (Figure 4.3). The mesh size may vary along the length of the net, with larger meshes used in earlier sections allowing for smaller species to escape. Some fish will become meshed soon after the net is shot, whilst most continue swimming inside the net until hauled and the circle becomes smaller. Some fishers may deploy their haul net across the length of a small embayment in the estuary to trap a school of fish against the shore. The vessel is then typically driven up and down the net to herd the fish into the mesh before hauling.

The time taken to haul a net will depend on the length of net shot and the volume of the catch but typically varies between 0.5 to 1 hr. While the net is hauled from the water, fish are removed from the mesh and sorted, allowing the immediate release of any unwanted catch. The net end may also be detached from the boat at any time to provide an opening for the release of unmeshed fish (MLFA 2008). Retained catches are typically sorted into crates and covered with wet hessian bags, or kept in an ice slurry until the catch is landed, particularly during the warmer months of the year.

Gill netting tends to be undertaken by a few fishers primarily during the winter months due to the lower abundance of blue swimmer crabs in the estuary at this time. The nets are typically set overnight in areas where demersal species such as cobbler and whiting are likely to be caught. Gill nets are generally set in deeper, channel-like areas of the estuary, where there is greater fish movement. After setting one or multiple nets separately, the nets are left unattended and hauled early the next morning using the same process as described above for haul netting.

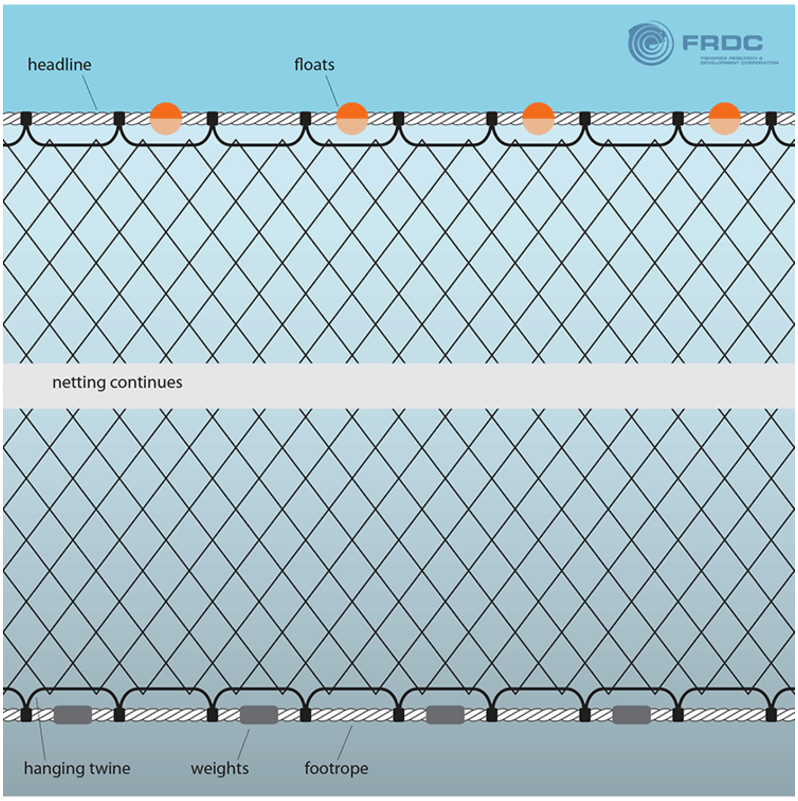


Figure 4.2. Schematic of typical fishing net, such as those used by commercial fishers to target finfish in the Peel-Harvey Estuary (Source: FRDC 2020).

Figure 4.3. Haul netting in the Peel-Harvey Estuary.

4.2 Retained Species

Sea mullet (*Mugil cephalus*) is the key finfish species retained by commercial net fishers in the Peel-Harvey Estuary (Figure 4.4) and comprised 69% of the total retained catch from haul and gill nets between 2015 and 2019 (Table 4.1). The remainder of the catch over that same period was largely comprised of yellowfin whiting (*Sillago schomburgkii*; 13%), yelloweye mullet (*Aldrichetta forsteri*; 8%) and, to a lesser extent, Australian herring (*Arripis georgianus*), Perth herring (*Nematalosa vlaminghi*), tailor (*Pomatomus saltatrix*) and estuary cobbler (*Cnidoglanis macrocephalus*) (Figure 4.4, Table 4.1).

Sea mullet is the only retained finfish species managed under a formal harvest strategy based on biomass-based reference levels (DPIRD 2020a, in review) and is therefore considered a primary species in the MSC assessment. Together with yellowfin whiting and yelloweye mullet, these are classified as main species in the MSC assessment, as they each comprise ≥5% of the catch (Table 4.1). Whilst only comprising 2% of the catch, Perth herring is also considered a main species due to its life history characteristics (being estuary-dependent) making it more vulnerable to fishing. Brief summaries of the four main species caught by the net fishery are provided below.

The catches retained separately by commercial haul and gill netting in the Peel-Harvey Estuary are shown in Appendix A. Note that while the total (retained and discarded) catch composition for the net fishery has not been determined (due to a lack of data on the weights of discarded species), the very low estimated discard rates in the haul and gill net fisheries (see Section 4.3) suggest that all other captured (and discarded) species collectively represent a very minor component (i.e. < 5%) of the overall catch weight.

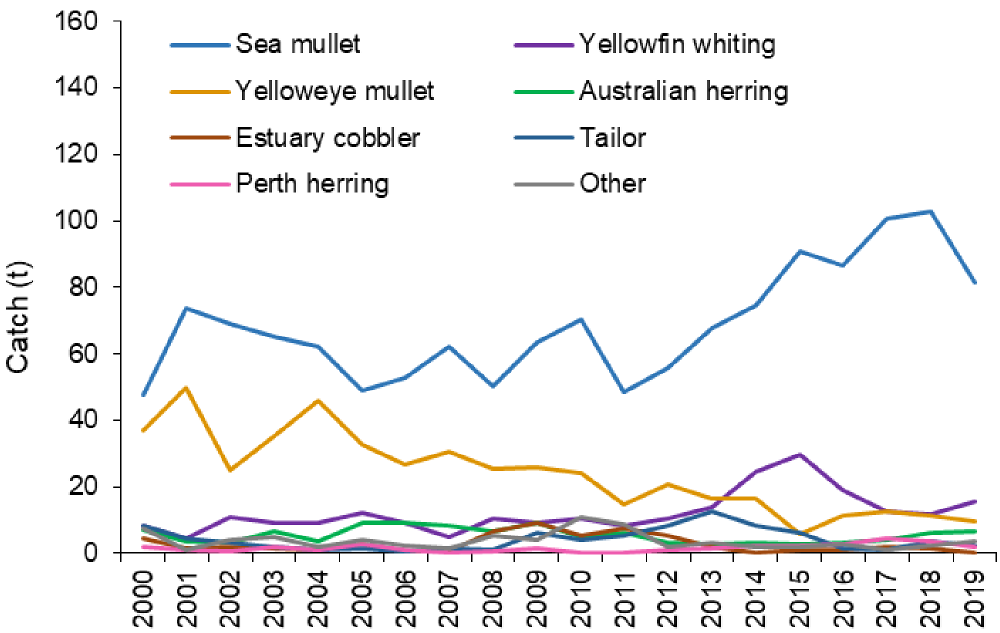


Figure 4.4. Retained catches (tonnes) of finfish by commercial netting (haul and gill nets) in the Peel-Harvey Estuary between 2000 and 2019.

Table 4.1. Retained catches (tonnes) in the Peel-Harvey Estuary haul and gill net fishery between 2015 and 2019, and proportions of the total retained catch.

Species	Retained catch (tonnes)						% of total retained
	2015	2016	2017	2018	2019	Average	
Sea Mullet	91.0	86.4	100.5	102.7	81.5	92.4	69%
Yellowfin Whiting	29.6	19.0	12.7	11.7	15.8	17.8	13%
Yelloweye Mullet	5.8	11.4	12.7	11.2	9.6	10.2	8%
Australian Herring	2.7	3.1	4.3	6.1	6.5	4.5	3%
Perth Herring	2.5	2.8	4.4	3.5	1.9	3.0	2%
Tailor	6.3	1.3	1.1	3.4	2.3	2.9	2%
Estuary Cobbler	1.3	1.2	1.9	1.7	0.2	1.2	0.9%
King George Whiting	0.4	0.8	0.1	1.6	1.8	0.9	0.7%
Whitings, other	0.1	0.8	0.4	0.3	1.4	0.6	0.5%
Trevallies	1.1	0.8	0.4	0.3	0.2	0.5	0.4%
Australian Sardine	0.2	0.1	0	0	0	0.05	0.04%
Common Silverbiddy	0.02	0.07	0.002	0.01	0.04	0.03	0.02%
Black Bream	0.01	0.02	0.03	0.02	0	0.02	0.01%
Silver Trevally	0.08	0	0	0	0	0.02	0.01%
Flatheads	0.01	0.01	0.03	0.01	0.02	0.01	0.01%
Southern Garfish	0.01	0	0	0	0.002	0.001	<0.01%
Squid	0	0	0	0	0.01	0.001	<0.01%
General Fish	0	0	0.01	0	0	0.001	<0.01%
Leatherjackets	0	0	0	0	0.01	0.001	<0.01%
Flounders	0	0	0.002	0	0.003	0.001	<0.01%
Total	141.0	127.8	138.6	142.5	121.3	134.2	

4.2.1 *Sea mullet*

Sea mullet has a global distribution in tropical and temperate waters and occurs around most of the eastern and western Australian coastline (Stewart et al. 2018). Although a marine species, juveniles typically inhabit freshwater and estuarine environments, where they associate with shallow weed beds and bare substrate. Upon reaching maturity at 3 – 4 years of age, they move out into open coastal waters and undertake a northward migration to spawn (Resource Assessment Report, in prep.). Although genetic studies have not yet been undertaken to examine the stock structure of sea mullet in WA, available biological data suggest a single stock in south-west WA that extends as far north as Shark Bay.

On average, the haul net and gill net fisheries in the Peel-Harvey Estuary have retained 92.4 t sea mullet annually between 2015 and 2019 (Table 4.1), of which 95% have been taken by haul netting (see Appendix A). The commercial sea mullet catch in the Peel-Harvey Estuary equates to 45% of the catch taken from the broader stock over the same period, with the remainder taken by the Shark Bay Beach Seine and Mesh Net Managed Fishery (19%) and a number of other small-scale fisheries operating in estuarine and nearshore waters of south-west WA. There is limited recreational fishing for sea mullet in WA, with no catches reported by boat-based fishers in the most recent 2017/18 survey of boat-based recreational fishing (Ryan et al. 2020). Some sea mullet is caught by shore-based licensed recreational net fishers, however, catches are considered negligible relative to commercial catches.

A recent weight-of-evidence assessment of the sea mullet stock, based primarily on a Schaefer biomass dynamics model fitted to commercial catch rates of sea mullet in Shark Bay estimated that the biomass in 2018 was well above the level expected to achieve Maximum Sustainable Yield (MSY; Resource Assessment Report, in prep.), which is used as a threshold reference level in the current harvest strategy for this resource (DPIRD 2020a, in review). As the fishing mortality in 2018 was estimated to be much lower than the level associated with MSY, there is a low likelihood of recruitment impairment of this stock over the next five years if catches are maintained around the current level. On the basis of this information, sea mullet in WA is classified as a sustainable stock.

4.2.2 *Yellowfin whiting*

Yellowfin whiting is endemic to Australia and inhabits coastal and estuarine waters of south-west WA where it is targeted by both commercial and recreational fishers (Smith et al. 2019). This species attains maturity at approximately 2 years of age (Hyndes and Potter 1997; Coulson et al. 2005), with spawning occurring only in ocean waters. In WA, populations within the Gascoyne Coast Bioregion and West Coast Bioregion are believed to have limited connectivity and so are regarded as separate stocks (Steer and Smith 2018).

Commercial catches of yellowfin whiting in the Peel-Harvey Estuary have typically comprised around half of the commercial catch from the West Coast Bioregion stock but increased in 2014 and 2015 (Figure 4.4) after a period of above-average recruitment resulting from the 2010/11 marine heatwave (Smith et al. 2019). Recreational catches from the broader stock are unknown as the majority are likely to be caught by shore-based anglers and catches are often estimated together with other similar whiting species such as *Sillago bassensis* and *S. vittata* (e.g. Ryan et al. 2019).

A catch curve and per-recruit assessment of yellowfin whiting age composition data sampled in 2015 and 2016 indicated that the stock is being fished at a sustainable level (Steer and Smith 2018; Resource Assessment Report, in prep.).

4.2.3 *Yelloweye mullet*

Yelloweye mullet inhabit coastal waters and estuaries as well as riverine environments, with a single stock likely in WA (Earl at al. 2018). This species matures at approximately 2-3 years of age (Gaughan et al. 2006), with no evidence of spawning within estuarine waters (Crisafulli 2008).

Annual commercial catches of this species peaked around 1980 and have since gradually declined, with the majority currently taken by the WCEMF and the South Coast Estuarine Managed Fishery (SCEMF). Since commercial fishers in the Peel-Harvey Estuary converted from gill nets to traps for targeting blue swimmer crabs in

2000, annual retained catches of yelloweye mullet have declined to a level of around 10-12 t annually (Figure 4.4).

Stock status of yelloweye mullet in WA has been evaluated using a data-poor method (CMSY; Froese et al. 2016) that uses a time series of catch to provide estimates of annual biomass and harvest rate. As a result of the reduced targeting of this species, the current level of catch is well below the estimated MSY of 24 t (Earl at al. 2018). The harvest rate has been maintained well below the level required to achieve MSY for at least the last decade, suggesting the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On the basis of this information, yelloweye mullet in WA is classified as a sustainable stock.

4.2.4 *Perth herring*

Perth herring is endemic to the lower west coast of WA between Shark Bay and Geographe Bay (i.e. latitudes 26-34 °S). It is anadromous, i.e. adults spawn in rivers then return to the sea (Smith and Grounds 2020). Available biological data suggest adults 'home' back to their natal estuary and its tributaries (Smith et al. in prep.). In the West Coast Bioregion, there are probably four main breeding stocks, corresponding to the four permanently open estuaries in the region (Murchison River, Swan-Canning, Peel-Harvey, Leschenault).

Adult Perth herring migrate from the sea into the lower (brackish) parts of rivers to spawn. Spawning occurs during November-March, with a distinct peak in December-January (Chubb and Potter 1984). Adults are typically caught by commercial fishers in spring/early summer, as they pass through the lower estuary on their pre-spawning migration. After spawning adults return to ocean waters, but juveniles remain in the estuary until maturity (typically 2-4 years; Chubb and Potter 1986). Perth herring attain a maximum age of 20 years (Smith et al. in prep.). Their spawning and nursery areas of the lower rivers and upper estuaries have experienced environmental degradation, including declining river flows, hypoxia and toxic algal blooms (e.g. Cronin-O'Reilly et al. 2019; Hallett et al. 2019).

Since 2007, commercial harvesting of Perth herring has been restricted to the Peel-Harvey Estuary. The catch increased in 2017 and 2018 to 4.4 and 3.5 t, respectively, but returned to a lower level of around 2 t in 2019 (Table 4.1). Age structure data sampled between 2016 and 2018 indicated that the total mortality of the Peel-Harvey stock was around three times higher than the unexploited Swan-Canning stock (Smith et al. in prep.).

4.2.5 *Minor species*

The remainder of the species caught and retained by the commercial haul and gill net fishers in the Peel-Harvey Estuary are mostly retained (or sometimes discarded, see section below) in very small quantities (Table 4.1). Some of the species (e.g. Australian herring) are widely distributed across south-west WA and catches in the Peel-Harvey Estuary comprise a very small component of the overall take (see Wise and Molony 2018), whilst others (e.g. estuary cobbler) are estuarine-dependent species that complete their entire life cycles within individual estuaries.

Although estuary cobbler, as a species that is often considered more vulnerable to fishing due its life history characteristics, has previously comprised a larger component of the commercial net catch in the Peel-Harvey Estuary (5% of the catch from 2009 to 2013; Johnston et al. 2015), the reduction in gill netting in the estuary has seen a lower level of targeting of this species in recent years (<1% of the catch from 2014 to 2019; Table 4.1). Whilst there is evidence of historical stock declines of estuary cobbler in all west coast estuaries due to exploitation and environmental degradation, the current population in the Peel-Harvey Estuary appears to be stable (Smith and Lenanton, submitted).

A trial has recently been proposed to allow commercial net fishers in the Peel-Harvey Estuary to retain a low catch of the southern eagle ray (*Myliobatis tenuicaudatus*), which has increased in abundance following the completion of the Dawesville Channel and the estuary becoming more marine in character (e.g. Hallett et al. 2019). This species occurs in southern Australian waters from Moreton Bay in Queensland to Jurien Bay in WA, including Tasmania (Last and Stevens 2009). It can be found in depths up to 130 m but is most common in waters <50 m deep. The species grows to around 150 cm in disc width (DW) and has an estimated maximum age of 32 years (Walker et al. 2007). Estimates of maturity for this species in WA range from around 70 cm DW for males to 90 cm DW for females (Jones et al. 2010). The southern eagle has a low productivity due to being viviparous (live bearer) and having a low fecundity, giving birth to between 2 and 15 young every 1-3 years (Last and Stevens 2009).

4.3 Bycatch Species

As the haul nets that are mostly used by the commercial net fishers in the Peel-Harvey Estuary are deployed in a targeted manner, few non-target species are captured. In addition, the mesh sizes used (typically 50-100 mm, depending on net type and species/size targeted) allow for the escape of many smaller or unwanted fish. Therefore, the majority of captured fish are retained. Any discarded fish are returned to the water as the nets are being hauled or as soon as possible after landed. Fishers are also able to drop the nets completely to allow fish to escape, should a large number of unwanted fish be enclosed in the net.

A bycatch monitoring program for the Peel-Harvey Estuary commercial net fishery was implemented in 2017 to collect data on the component of catches that are discarded. The program consisted of two components: fishery-dependent reporting through monthly log sheets and bi-monthly observation trips of Departmental research staff on board the commercial fishing vessels to verify reported data. A summary of results from the first year of data collection, from 1 May 2017 to the end of April 2018, are provided below, with the study expected to be repeated every 5 years to inform the harvest strategy for the estuarine and nearshore finfish resource in south-west WA.

Participation in the bycatch monitoring program was voluntary, however, it included all licence holders that were active in the net fishery during the time of sampling. From a total of 538 net shots recorded by eight commercial fishers operating over the 12-month monitoring period, 96% (514) of shots targeted finfish by active haul netting and 4% (24) by gill nets set overnight. As these proportions closely resemble those of overall net fishing activity reported in recent years (Figure 4.1), the data are likely to provide a representative sample of the total retained and discarded catches reported by fishers over this period.

The majority of haul net shots retained sea mullet as the main target species and 29% had no discards. The two most commonly discarded species from haul nets were blue swimmer crabs and silver bream (tarwhine), which occurred in 49% and 31% of reported net shots, respectively (Table 4.2). Less commonly discarded species in the haul net shots included the common blowfish and yelloweye mullet (Table 4.2). There was an overall average of fewer than four discarded individuals (all species) per haul net shot.

Catches from gill net shots were all reported during winter between July and September and mainly targeted cobbler or yellowfin whiting. Although the sample size of reported gill net shots was much lower than that for haul net shots, the data suggest some slight differences in the composition and quantity of discards between the two fishing methods. Four of the 24 reported net shots (17%) had no discards. The most commonly discarded species from gill nets was yelloweye mullet, which occurred in 54% of reported net shots, followed by silver bream, blowfish and blue swimmer crabs (Table 4.2). There was an overall average of 12 discarded individuals (all species) per gill net shot.

Although only 29 net shots (haul and gill nets) were independently observed by Departmental research staff during the monitoring period, the quantity and type of bycatch on these trips broadly reflected the data reported by fishers (Table 4.2). Twenty-four percent of observed net shots (haul and gill nets combined) had no discards. The main reasons for not retaining discarded species were due to it being prohibited (e.g. blue swimmer crabs, which can only be retained by crab traps), the catch being below the minimum legal size (e.g. silver bream, tailor), or the catch being of no economic value (e.g. blowfish) or of poor quality from predation whilst in the net.

Due to a lack of information on the weights of discarded fish and invertebrates, the overall catch composition (i.e. retained and discarded catch) of the haul and gill net fishery could not be easily determined. Based on an assumed, conservative multiplier of 0.25 kg per discarded individual reported by fishers, the discard rate (proportion of the total catch discarded) was estimated to be 0.6% for the haul net fishery and 1.5% for the gill net fishery. Due to these very low levels of discarding, none of the discarded species that are not also represented in the retained catches from the fishery (see Table 4.1) would be ≥ 5% of the total catch. The majority of observed discards were released alive back into the water, however, the survival of the haul net discards is likely greater than those from gill nets.

Table 4.2. Percentage occurrence of bycatch species in individual haul and gill net shots reported by commercial net fishers and independent observers in the Peel-Harvey Estuary between May 2017 and April 2018. n = number of net shots.

	Reported by fishers		Observed
Species	**Haul nets (n = 514)**	**Gill nets (n = 24)**	**Haul and Gill nets (n = 29)**
Blue swimmer crab (*Portunus armatus*)	49%	13%	38%
Silver bream (*Rhabdosargus sarba*)	31%	38%	34%
Common blowfish (*Torquigener pleurogramma*)	7%	33%	21%
Yelloweye mullet (*Aldrichetta forsteri*)	6%	54%	17%
Leatherjacket (Monacathidae)	3%	13%	7%
Common silverbiddy (*Gerres subfasciatus*)	1%		7%
King George whiting (*Sillaginodes punctata*)	1%	4%	7%
Tailor (*Pomatomus saltatrix*)	1%	4%	7%
West Australian salmon (*Arripis truttaceus*)	1%		3%
Black bream (*Acanthopagrus butcheri*)	1%		
Yellowtail grunter (*Amniataba caudavittata*)	0.4%		3%
Australian herring (*Arripis georgianus*)	0.2%		7%
Western striped trumpeter (*Pelates octolineatus*)	0.2%		7%
Smooth ray (*Dasyatis* sp.)	0.2%		
Estuary cobbler (*Cnidoglanis macrocephalus*)		4%	3%
Mulloway (*Argyrosomus japonicus*)		4%	3%

4.4 Ecological Impacts

Finfish can be targeted by commercial net fishers across most of the estuary, however, a number of closed areas, covering 14% of estuary, prohibit commercial fishing in the entrance channels as well as in the adjoining rivers and tributaries (Figure 2.1). Although netting is permitted throughout the remainder of the estuary, the nets are deployed at specific depths and habitats depending on the species targeted. Sea mullet are primarily targeted by haul netting in shallow (< 1 m deep) areas of the estuary, while gill nets are generally set in deeper, channel-type areas where there is greater fish movement. Netting is undertaken over predominantly muddy and sandy bottoms to avoid the nets becoming too heavy with weeds for manual hauling.

During the 12-month bycatch monitoring program undertaken in 2017/18 (see Section 4.3) fishers reported net shots from more than 60 sites throughout the estuary, with effort relatively evenly distributed between the Peel Inlet and Harvey Estuary. Around a half of all net shots in the Peel Inlet were from the southern parts around Boggy Bay and Roberts Bay, whilst key fishing locations in the Harvey Inlet included the eastern and southern parts, around Long Island. Whilst fishing in the Peel Inlet occurred year round, fishing in the Harvey Inlet appeared to focus on the southern parts over the warmer months, and northern parts (around the Dawesville Channel) over the colder months.

Commercial net fishing activities have the potential to interact with a number of ETP species that inhabit the estuary, including dolphins, syngnathids and waterbirds. It is a statutory requirement for commercial fishers to report any interactions of ETP species in their logbooks, however, none have been reported by fishers to date in the Peel-Harvey Estuary. The limited interactions of the fishing gear with ETP species is also supported by bycatch monitoring of commercial haul and gill net fishing trips by Departmental staff in 2017/18, during which no interactions with the fishing gear were recorded.

The main ecosystem impacts from these fishing activities in the Peel-Harvey Estuary would likely result from the removal of the target species. As catches are comprised of a variety of species, however, it is not likely that commercial netting will significantly impact trophic interactions within the estuary.

5.0 Commercial Crab Trap Fishery

A trial was implemented in the mid-1990s to allow fishers in the Peel-Harvey Estuary to use purpose-built crab traps to target blue swimmer crabs. Trapping proved to be less time-consuming than gill netting, produced less bycatch and improved catch quality (Bellchambers et al. 2005). Fishers were also able to extend their winter fishing season as traps were more effective in winter than gill nets, resulting in an increase in annual crab catches (Figure 5.1). Crabs are now only landed using traps, with the majority taken during summer between December and April.

There are currently six licenced commercial operators in the WCEMF that are permitted to use traps to catch crabs in the Peel-Harvey Estuary, with each licensee entitled to 42 traps (see Section below for description). Following a recent review of management of the south-west blue swimmer crab resource (DPIRD 2018), the closed season for this fishery was increased from two to three months (1 September to 31 November). Fishing is also prohibited during weekends, and in localised spatial closures that encompass the Mandurah Entrance Channel, Dawesville Channel and rivers entering the Estuary (Figure 3.1). Changes in the spatial distribution of fishing effort throughout the fishing season are described in Section 5.4.

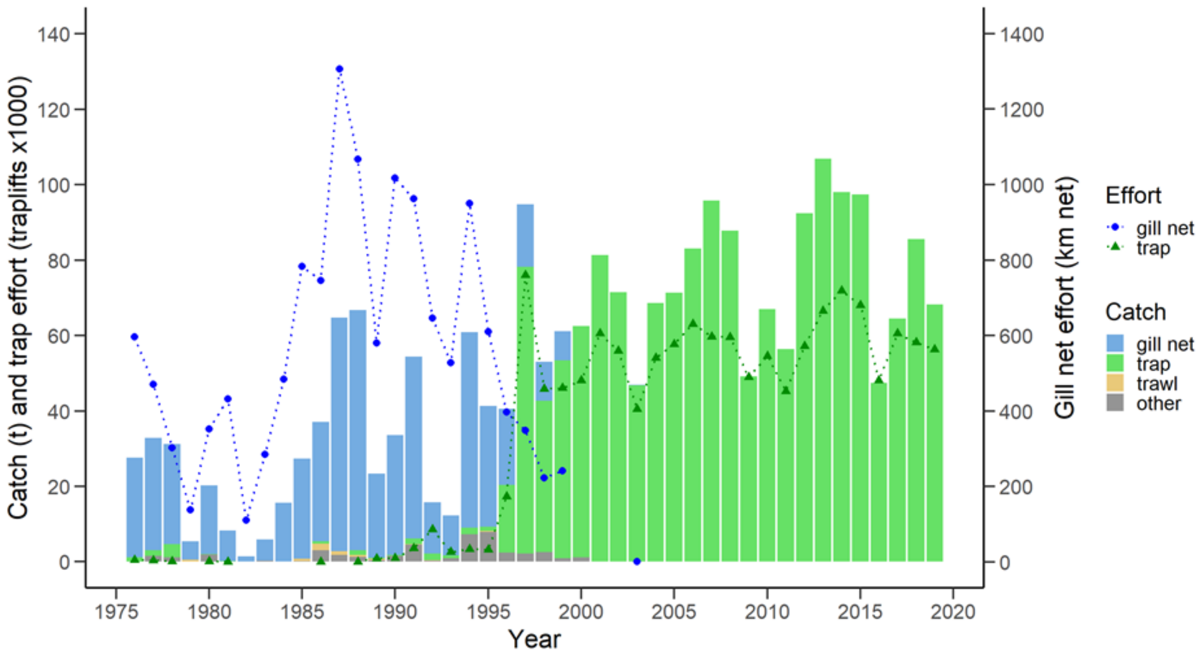


Figure 5.1. Fishing effort and retained catch (tonnes, t) of blue swimmer crabs by commercial gill netting and crab trapping in the Peel-Harvey Estuary since 1976.

5.1 Fishing Gear and Methods

The blue swimmer crab catch in the WCEMF Area 2 is taken by purpose-designed ‘hourglass’ crab traps (Figure 5.2). For ease of transport, the hourglass traps are collapsible, with solid stainless metal base and upper rings separated by a central PVC bait pipe. Traps must have an internal volume ≤ 0.31 m^3 or, if the trap is cylindrical, the diameter must be ≤1 m (Johnston et al. 2015). Traps typically have one, two or three pairs of opposing side entry funnels and are typically baited with sea mullet and yelloweye mullet from the local net fishery (see Section 5.1.1).

Mesh size is not legislated and all fishers use slightly different configurations, ranging from around 50 to 90 mm. Traps may also be made of two different mesh sizes, with the smaller mesh usually on the bottom half of the trap and the larger mesh on top half. The smaller mesh on the bottom is thought to allow for the crabs to walk up and sit in the upper ring with higher water flow through the larger mesh. This arrangement may also prohibit smaller crabs from walking in the trap through the larger mesh. All fishers use slightly different gear and are constantly trying new mesh sizes, colours and net grade, i.e. thickness. Since 2000, fishers have included voluntary escape gaps in all crab traps (Figure 5.2), with the intention of reducing the catch of undersize and juvenile crabs (Johnston et al. 2015).

The crab traps are typically set individually, attached to a surface float clearly branded or stamped with the licensed fishing boat number of the authorized boat from which the crab trap was used. Traps may also be set with a maximum of 10 traps attached to each other by negatively buoyant rope, provided at least one crab trap is attached to a surface float. Traps can only be pulled once in every 24-hour period when the fishery is open, noting that all traps are removed from the water during seasonal and weekend closures (Johnston et al. 2015).

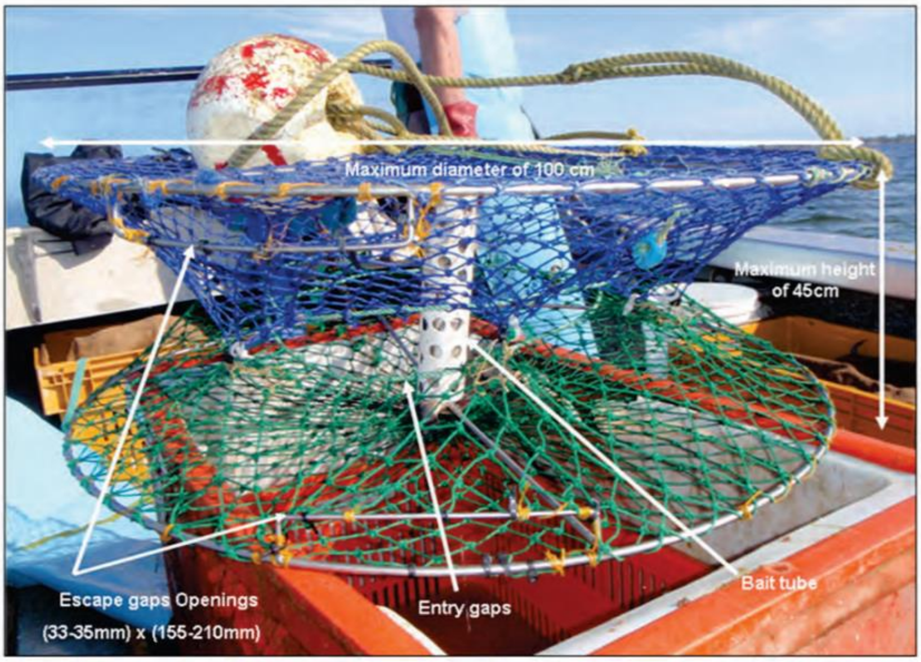


Figure 5.2. Commercial crab trap used in the Peel-Harvey Estuary, showing escape gap at the bottom. Source: Johnston et al. 2015.

5.1.1 *Bait*

Commercial monitoring of the trap crab fishery since 2007 shows a consistent use of bait in crab traps, with around 300 g of locally-caught sea mullet or yelloweye mullet typically used per trap. Since 2014/15, the bait conversion rate (kg bait used per kg of blue swimmer crab caught) has fluctuated between 0.19 and 0.29 as a result of annual variability in crab abundance (Table 5.1).

Table 5.1. Summary of bait usage in the Peel-Harvey Estuary commercial crab trap fishery since 2014/15.

Year	No. of traplifts	Bait type	Amount used per trap (kg)	Total bait used (kg)	Crab catch (kg)	Conversion rate
2014/15	69,888	Sea mullet Yelloweye mullet	0.3	20,966	96,753	0.22
2015/16	56,746	Sea mullet Yelloweye mullet	0.3	17,024	57,702	0.29
2016/17	52,874	Sea mullet Yelloweye mullet	0.3	15,862	55,095	0.29
2017/18	62,400	Sea mullet Yelloweye mullet	0.3	18,720	96,600	0.19
2018/19	58,044	Sea mullet Yelloweye mullet	0.3	17,413	65,439	0.27

5.2 Retained Species

Blue swimmer crabs represent the key target species of the commercial trap fishery in the Peel-Harvey Estuary, with octopus comprising a very low proportion of the overall retained catch (Table 5.2). Both of these stocks are managed under formal harvest strategies (DPIRD 2018; 2020b, in review).

Table 5.2. Retained catches in the Peel-Harvey Estuary commercial crab trap fishery between 2014/15 and 2018/19.

Species	Retained catch (tonnes)						% of total retained
	2014/15	2015/16	2016/17	2017/18	2018/19	Average	
Blue swimmer crab	96.8	57.7	55.1	96.6	65.4	74.5	99.92%
Octopus	0.005	0.023	0.032	0.103	0.129	0.058	0.08%

5.2.1 *Blue Swimmer Crabs*

Blue swimmer crabs are a tropical species widely distributed throughout the Indo-West Pacific, ranging from east Africa to Japan, Tahiti and northern New Zealand (Kailola et al. 1993). In Australia, the species inhabits estuarine and coastal marine waters from the south coast of WA, around the north to the south coast of New South Wales. Southerly populations are also found in the warmer waters of the South Australian gulfs.

The blue swimmer crab resource in south-west WA is likely represented by a series of overlapping biological stocks, with gene flow between geographical regions largely controlled by the degree of water exchange (Sezmiş 2004). Genetic studies have shown that the genetic compositions of the assemblages of blue swimmer crabs in Cockburn Sound and the Swan-Canning Estuary are homogenous and genetically distinct from other south-west assemblages, including crabs in the Peel-Harvey Estuary (Chaplin and Sezmiş 2008). Given the uncertainty around stock structure, a conservative approach is taken to assess the key fisheries that target this resource as separate management units.

Annual catches of blue swimmer crabs in the Peel-Harvey Estuary have ranged between 55 t and 97 t since 2014/15 (Table 5.2), which has been within the acceptable catch range specified in the harvest strategy for this resource (DPIRD 2020b, in review). It is anticipated that commercial catches will decline as a result of the current VFAS, which has seen the buy-back of four of the previously 10 commercial trap licences in the Peel-Harvey Estuary.

The primary performance indicator for blue swimmer crabs in the Peel-Harvey Estuary (commercial standardised CPUE) has remained within the target range specified in the harvest strategy (DPIRD 2020b, in review) for the past five seasons (Johnston et al. 2020). Annual catch and size structure have remained relatively constant over time, with fluctuations correlated with effort and environmental conditions. There is no evidence of recruitment levels decreasing over time. Recent management changes introduced in 2019 (extended seasonal closure during spawning period and commercial fishery reduction in the Peel-Harvey Estuary and closures in adjacent marine waters) will provide additional protection for the Peel-Harvey Estuary breeding stock.

5.2.2 *Octopus*

The western rock octopus (*Octopus djinda*; formerly *O.* aff. *tetricus*) is endemic to WA and is distributed from Shark Bay to Esperance (Edgar 1997). They are found in cryptic habitats, particularly inshore limestone reefs to about 60 m depth and are highly fecund (Joll 1976).

The annual catch of octopus by commercial crab trap fishers in the Peel-Harvey Estuary is minor, ranging from 5 to 129 kg annually over the past five-year period (Table 5.2). This represents a very small component of the total catch from the broader WA stock, which is primarily targeted by the Octopus Interim Managed Fishery (Hart et al. 2019).

A recent weight-of-evidence assessment of the octopus stock in WA indicates the risk of unacceptable stock depletion is currently low, with fishery-independent data from depletion experiments suggesting that the fisheries currently target less than 10% of potential octopus habitat (Hart et al. 2019).

5.3 Bycatch Species

The shift from using nets to traps to target blue swimmer crabs has resulted in a substantial reduction in bycatch from crab fishing (Bellchambers et al. 2005). The traps used in the Peel-Harvey Estuary are purpose-designed to minimise the capture of non-target species and are therefore an inefficient way to capture fish, the majority of which are able to escape through the entrance gaps when the trap is soaking or being hauled (Johnston et al. 2019). Research monitoring of the commercial trap fishery since 2007 has shown very little unwanted catch (Johnston et al. 2015; Table 5.3).

Over the last five years (2014-2019), 48% of the total catch recorded in numbers by Departmental research staff undertaking monthly commercial monitoring trips was discarded, however, the majority of discards comprised sub-legal or berried female blue swimmer crabs that are prohibited from being retained (Table 5.3). The only other bycatch species recorded in more than one of the 4,596 trap lifts observed in the commercial trap fishery was the four-lobed swimming crab, representing 0.3% of the total catch by numbers (Table 5.3). Other invertebrate and finfish species were observed as bycatch from only a single trap lift during the observed monitoring trips (Table 5.3). The same finfish species were also recorded as discarded from the commercial net fishery in the Peel-Harvey Estuary (see Section 4.3).

Table 5.3. Retained and discarded catch (in numbers) by commercial trap fishers in the Peel-Harvey Estuary recorded by Departmental research staff during monthly monitoring trips between May 2014 and May 2019 (n = 4,596 trap lifts).

Species	Retained catch	Discarded catch	Total catch	% of total
Blue swimmer crab (*Portunus armatus*)	30,156	14,382	44,538	99.96%
Four-lobed swimming crab (*Thalamita sima*)	0	12	12	0.03%
Green mud crab (*Scylla serrata*)	0	1	1	<0.01%
Common blowfish (*Torquigener pleurogramma*)	0	1	1	<0.01%
Western striped trumpeter (*Pelates octolineatus*)	0	1	1	<0.01%
Estuary cobbler (*Cnidoglanis microcephalus*)	0	1	1	<0.01%
Total	30,156	14,398	44,554	

5.4 Ecological Impacts

Fourteen per cent of the area of the Peel-Harvey Estuary is closed to commercial fishing activities (see Figure 2.1). Commercial monitoring of the crab trap fishery shows there are seasonal changes in the spatial patterns of fishing effort within the remainder of the estuary (Figure 5.3). Fishing during the summer months (November – March) is generally focused on the central regions of the Peel Inlet and Harvey Estuary. During autumn, fishing shifts towards the north-west region of the Peel Inlet and top end of the Harvey Estuary, and by winter, fishing is largely concentrated around the entrance to the Dawesville Channel (Figure 5.3). Very little fishing activity for blue swimmer crabs occurs in the lower region of the Harvey Inlet and the southeast region of the Peel Inlet, where the water is very shallow (see Figure 5.3).

Although commercial crab traps may affect the substrate or organisms that settle upon the substrate during retrieval, the level of impact will depend on the size and weight of traps, hauling depth and speed, weather conditions and the composition of the substrate (Johnston et al. 2015). Due to the relatively small size and number of commercial traps used in the Peel-Harvey Estuary and the limited distribution of effort in the deeper parts of the estuary, the fishery is considered to be a low risk to macroalgal and seagrass habitats. The overall 'footprint' of the fishery is approximately 33 km^2, which covers around a quarter of the estuary (Johnston et al. 2015). Sand and associated biota do not get caught in the traps or brought to the surface, and the mesh used is sufficiently large enough to allow for the escape of any sand-dwelling macrobenthos that might be captured. Seagrass is occasionally brought to the surface with the trap, however, the infrequent nature of this occurrence and the small amount of seagrass removed is considered to result in minimal habitat damage (Johnston et al. 2019).

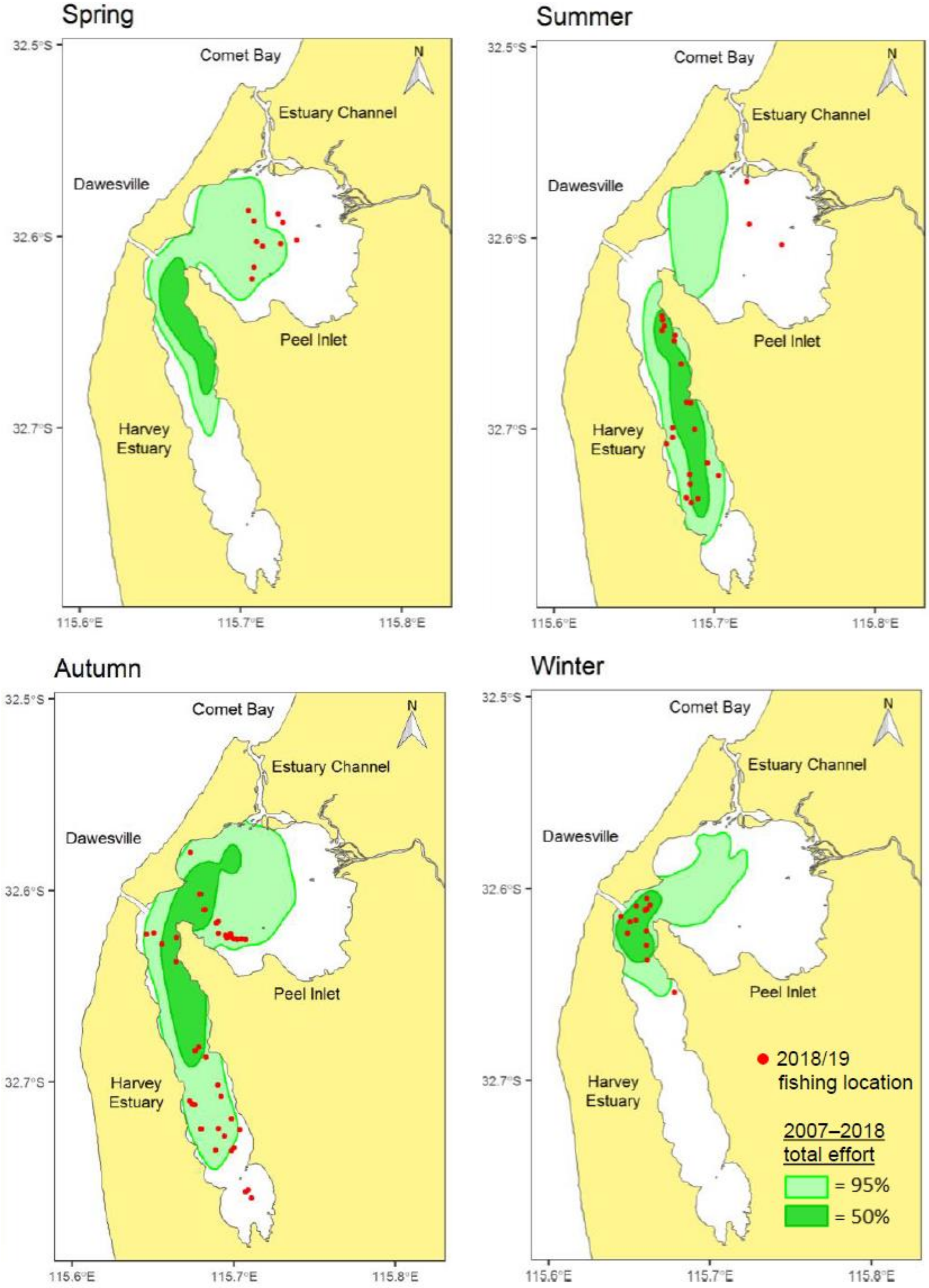


Figure 5.3. Spatial and seasonal patterns in fishing effort by commercial crab trap fishers between 2007 and 2018, based on monthly commercial monitoring trips. Seasons are defined as: Summer (Dec – Feb), Autumn (Mar – May), Winter (Jun – Aug) and Spring (Sep – Nov).

Whilst no interactions with ETP species have been reported by commercial crab fishers to date, these trap fishing activities have the potential to interact with a number of ETP species that inhabit the estuary. These include dolphins, syngnathids (pipefishes and sea horses) and a large number of waterbirds, including several species listed as migratory and/or threatened (see Appendix B). One cormorant (*Phalacrocorax* sp.) has been recorded in a crab trap during Departmental research monitoring. The three-month closure that prohibits all fishing for blue swimmer crabs in the estuary between 1 September to 30 November each year occurs during the same time that migratory shorebirds arrive at these important feeding grounds.

The main ecosystem impacts from these fishing activities in the Peel-Harvey Estuary would likely result from the removal of the target species. Fishery-independent data shows that there are high abundances of juvenile crabs in the estuary that are below the size that can be legally retained by fishers. Thus, it is not likely that the commercial take will significantly impact the trophic interactions within this system.

6.0 Recreational Drop Net Fishery

The blue swimmer crab recreational fishery in the Peel-Harvey Estuary comprises fishers crabbing from boats, bridges, jetties, private houses along canals, hire houseboats and along the estuary shoreline (Johnston et al. 2015). While boat-based fishers typically use drop nets when fishing for crabs, shore-based fishers use both drop and scoop nets (Lai et al. 2014). A small number of fishers also collect crabs by hand whilst snorkelling and freediving. Recreational fishers are also permitted to capture crabs using a hand-held, blunt wire hook, although this method is not often used.

Recreational crabbing activities occur primarily over the summer and autumn months (December – May) each year, with the greatest activity in January and February (Lai et al. 2014). This is the time of year when legal-size crabs are most abundant in the estuary and are therefore available for capture. No crabbing is permitted during a three-month closure extending from 1 September to 30 November each year. Boat-based fishers can access the Peel-Harvey Estuary using 16 major boat ramps within the estuary and there are four bridges and jetties in the Mandurah entrance channel that are also commonly used by blue swimmer crab recreational fishers (Malseed and Sumner 2001; Lai et al. 2014).

6.1 Fishing Gear and Methods

Drop nets are commonly used by recreational fishers to target blue swimmer crabs in deeper areas of the estuary (generally 2 – 2.5 m depths). The drop nets are typically cylindrical in shape with mesh sides and no top (Figure 6.1) and must be no wider than 1.5 m in diameter. The bottom of the drop nets may be made of either the same flexible nylon mesh as the sides or of galvanised wire mesh (Hotbite 2012). Drop nets are typically baited (see Section 6.1.1 below), with bait-holding devices, such as wire clips or plastic bait baskets, attached on the inside of the bottom of the net (Figure 6.1).

When set from a boat, the drop nets are typically set individually on a single line attached to a float, with fishers setting groups of drop nets in a line for easy retrieval. After all the drop nets are set, fishers typically remain near their line for easy retrieval 10 – 15 minutes later (Johnston et al. 2015). There is a maximum limit of 10 drop nets per person or 10 drop nets per boat, regardless of how many people are on board. Fishers may also set drop nets from bridges and jetties in the entrance channels or from the shore.

Figure 6.1. Drop net typically used by boat-based recreational fishers to target blue swimmer crabs in the Peel-Harvey Estuary, shown here baited with a chicken wing.

6.1.1 *Bait*

A survey of bait usage among recreational drop net fishers in December 2014 showed that a variety of bait is used (Table 6.1). The main bait types used by survey respondents that set drop nets from a variety of locations around the estuary was sea mullet (whole), chicken (carcass, wings, necks and other pieces) and lamb (necks, chops and other pieces) (Johnston et al. 2015). The survey indicated that sea mullet and tuna used in drop nets were sourced from bait shops, with other fish species caught by the fishers themselves either within the estuary (e.g. tailor, bream, trumpeter) or elsewhere (e.g. dhufish and silver trevally). All meat products (chicken, lamb and spleen) were purchased from supermarkets (Johnston et al. 2015).

Table 6.1. Bait usage among recreational drop net fishers surveyed in the Peel-Harvey Estuary in December 2014. U = unknown number (Source: Johnston et al. 2015).

Species	Number recorded	% of total*
Sea mullet	45	34%
Chicken	32	24%
Lamb	21	16%
Tailor	15	11%
Tuna	6	5%
Bream	4	3%
West Australian dhufish	4	3%
Silver trevally	3	2%
Trumpeter	2	2%
Crab	1	1%
Sand whiting	U	-
Spleen	U	-
Total	133*	

*Does not include records of sand whiting and spleen

6.2 Retained Species

Blue swimmer crabs represent more than 99% of the total catch (and the retained catch) of recreational drop net fishers surveyed in the Peel-Harvey Estuary in 1998/99 (Malseed and Sumner 2001) and 2007/08 (Lai et al. 2014) (Table 6.2). Very minor catches of non-target species retained by recreational crab fishers using drop nets included a number of finfish and invertebrates, including Australian herring and mussels (Table 6.2).

More recent recreational fishing surveys show that the retained recreational catch of blue swimmer crabs by boat-based fishers, of which the majority use drop nets, in the West Coast Bioregion has been steady at 54 t (95% CI 45-63 t) in 2017/18 compared with 43 t (95% CI 36-50 t) in 2015/16 and 59 t (95% CI 50-68 t) in 2013/14, but lower than 87 t (95% CI 76-98 t) in 2011/12 (Ryan et al. 2019). In 2017/18, the retained boat-based blue swimmer crab catch in the Metropolitan zone, which includes the Peel-Harvey Estuary and the Swan-Canning Estuary, was estimated at 42 t (95% CI 35-49 t).

6.3 Bycatch Species

As recreational drop net fishers actively target blue swimmer crabs with gear designed specifically to catch crabs, bycatch of other species is minimal. Recreational blue swimmer crab surveys conducted in the Peel-Harvey Estuary in 1998/99 and 2007/08 show that the most commonly discarded species caught in drop nets was blue swimmer crabs (56% of catch released; Table 6.2), for which minimum legal size and bag/boat limits can prohibit their retention. More recent surveys of boat-based recreational fishing have indicated that the proportion of annual blue swimmer crab catch in the West Coast Bioregion that is released can vary markedly between years, from 53-70% between 2011/12 to 2017/18 (Ryan et al. 2013, 2015, 2017, 2019), as a consequence of variations in recruitment and juvenile abundance.

The earlier surveys in the Peel-Harvey Estuary recorded other species as discarded in very low numbers by recreational crab fishers using drop nets, included tailor, Australian herring and blowfish (Table 6.2).

Table 6.2. Retained and discarded catch (in numbers) by recreational drop net fishers in the Peel-Harvey Estuary recorded by surveys undertaken in 1998/99 and 2007/08, and the overall percentage catch composition across both survey years (Source: Johnston et al. 2015).

Species	Retained catch		Discarded catch		Total catch	% of total
	1998/99	2007/08	1998/99	2007/08		
Blue swimmer crab	21,142	8,646	25,762	12,093	67,643	99.49%
Australian herring	70	49	14	2	135	0.20%
Tailor	10	18	5	37	70	0.10%
Mussels	48	0	0	0	48	0.07%
Common blowfish	12	0	10	11	33	0.05%
General/sand whiting	11	1	0	5	17	0.03%
King George whiting	6	4	0	0	10	0.01%
Western school whiting	1	0	7	0	8	0.01%
Rough leatherjacket	0	0	2	3	5	0.01%
Pufferfish, toadfish and tobies	0	0	0	5	5	0.01%
Wrasses/gropers	0	0	0	5	5	0.01%
Western rock lobster	0	4	0	0	4	0.01%
Striped trumpeter	0	2	0	0	2	<0.01%
Trumpeters/grunters	2	0	0	0	2	<0.01%
Southern school/silver whiting	0	1	0	0	1	<0.01%
Silver trevally	0	1	0	0	1	<0.01%
Western buffalo bream	1	0	0	0	1	<0.01%
Octopus	1	0	0	0	1	<0.01%
Brown-spotted wrasse	1	0	0	0	1	<0.01%
Stingray	0	0	0	1	1	<0.01%
Total	21,305	8,726	25,800	12,162	67,993	

6.4 Ecological Impacts

Recreational blue swimmer crab drop nets are primarily set from boats in the deeper areas of the estuary (Johnston et al. 2015). Due to the movement of blue swimmer crabs between the estuary and waters outside the estuary, crabbing effort is highly seasonal and primarily occurs over the summer and autumn months (December through May). Fishing activities are distributed throughout the estuary, with no known areas of detectable localised disturbance from drop netting activities. Due to the relatively low-impact nature of the method used and the naturally-dynamic nature of the sand/mud bottom habitats where fishing occurs, recreational drop net fishing is considered to be highly unlikely to reduce habitat structure and function to a point where there would be serious or irreversible harm.

Drop nets are very similar to the crab traps used by the commercial blue swimmer crab sector and result in limited habitat disturbance. Recreational drop nets are light, with a wire rim and mesh frame, and are not weighted. Additionally, the nets are unlikely to be dragged across the bottom during retrieval, due to the shallow nature of the estuary. Sand and associated biota does not get caught in the drop nets and are not brought to the surface. Additionally, the mesh used is generally sufficiently large enough to allow for the escape of any sand-dwelling macrobenthos that might be captured (Johnston et al. 2015).

There is no known published information available on the level of interactions of recreational drop net fishers with ETP species in the Peel-Harvey Estuary. Impacts are considered likely to be low, given the similarity of the fishing gear with those used by commercial trap fishers. No crabbing is permitted between 1 September and 30 November each year, which is the time when migratory shorebirds arrive from their breeding grounds in the Northern Hemisphere (see Appendix B).

7.0 Recreational Scoop Net Fishery

Scoop netting for blue swimmer crabs in the shallow waters of the Peel-Harvey Estuary is a popular activity among shore-based recreational fishers (Malseed and Sumner 2001; Lai et al. 2014). Recreational scoop-net fishing activities occur primarily over the summer and autumn months (December – May) each year, with the greatest activity in January and February (Lai et al. 2014).

7.1 Fishing Gear and Methods

Scoop nets (Figure 7.1) are bowl-shaped and made of rigid wire mesh not capable of entangling a crab. They are required to have an internal diameter of ≤ 375 mm and a depth of ≤ 210 mm (Johnston et al. 2015). These nets are used in the shallower areas around the shore of the estuary (generally < 1 m deep), predominantly by wading or from a drifting boat, and are not baited. Individual crabs are targeted as fishers spot them through the water column.

Figure 7.1. Scoop net used primarily by shore-based recreational fishers in the Peel-Harvey Estuary to target blue swimmer crabs.

7.2 Retained Species

Recreational scoop nets are used in a very targeted manner to catch blue swimmer crabs, with very little catch of other species (Table 7.1). Based on data collected as part of recreational blue swimmer crab surveys conducted in the Peel-Harvey Estuary in 1998/99 and 2007/08, 97% of the total (retained and discarded) catch comprised blue swimmer crabs. Blue swimmer crabs represented 95% of the retained catch from both surveys, with only minor catches of Australian herring, mussels and tailor recorded as retained by scoop net fishers (Table 7.1).

7.3 Bycatch Species

As scoop netters target crabs visually, bycatch is limited. Recreational blue swimmer crab surveys conducted in 1998/99 and 2007/08 show that the most commonly discarded species caught in scoop nets was blue swimmer crabs, for which minimum legal size and bag/boat limits may prohibit their retention (Johnston et al. 2015). Similar to the survey results for the recreational drop net fishery for the same years, around half of the blue swimmer crab catches were recorded as released (Table 7.1). The only other species reported as discarded by recreational scoop net fishers was the common blowfish, of which all captured individuals were discarded (Table 7.1).

Table 7.1. Retained and discarded catch (in numbers) in the Peel-Harvey Estuary recreational scoop net fishery recorded by surveys undertaken in 1998/99 and 2007/08, and the overall percentage catch composition across both survey years (Source: Johnston et al. 2015).

Species	Retained catch		Discarded catch		Total catch	% of total
	1998/99	2007/08	1998/99	2007/08		
Blue swimmer crab	1000	983	998	1533	4514	97.3%
Australian herring	26	45	0	0	71	1.5%
Common blowfish	0	0	0	34	34	0.7%
Mussels	18	0	0	0	18	0.4%
Tailor	0	1	0	0	1	0.02%
Total	1044	1029	998	1567	4638	

7.4 Ecological Impacts

Scoop nets are primarily used in the shallow, inter-and subtidal shore areas of the estuary that can be accessed by wading (Figure 7.2). Approximately 42% of the main basin area is less than 0.8 m deep and is considered to be available to wading scoop-netters. The scoop nets may occasionally come into contact with the estuary floor, as fishers target the crabs while they are swimming or moving along the bottom, however, this interaction is highly unlikely to result in serious habitat damage due to the naturally dynamic nature of the estuary. Rather, the primary habitat impacts from recreational fishers relate to the movement of fishers along the shoreline and shallow areas of the estuary.

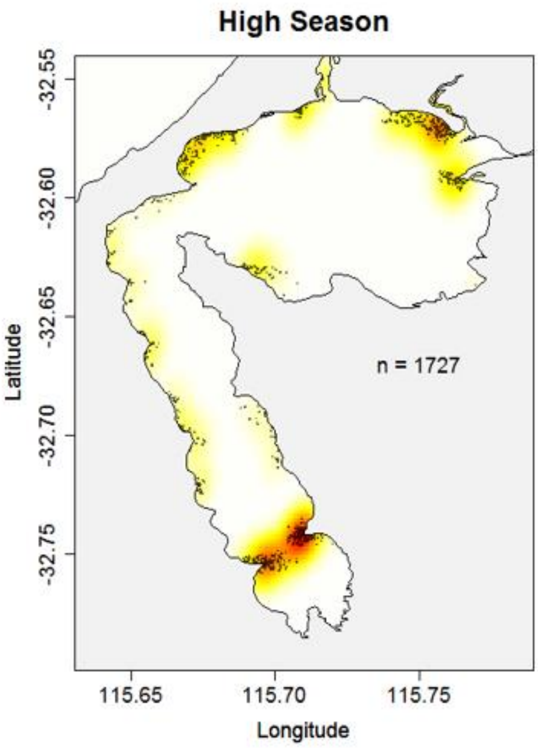


Figure 7.2. Kernel density plots of recreational scoop netting effort in the Peel-Harvey Estuary.

Due to seasonal changes in the distribution of crabs, fisher preferences and limited access points to some parts of the estuary, certain areas are more frequently utilised by fishers using scoop nets. A recent survey of the spatial footprint of recreational scoop netters in the Peel-Harvey Estuary shows that the key scooping locations include the shallow area between Island Point and Herron Point in the southern Harvey Estuary, as well as Coodanup and Novara in the Peel Inlet (Figure 7.2; Desfosses et al. in prep.).

Benthic habitats in the estuary may experience some seasonal and localised impacts from wading scoop netters, primarily over the summer months when recreational fishing activity is highest (e.g. Taylor et al. 2018). Overlaying the scooping footprint with available habitat information shows that scooping effort in the southern Harvey occurs in an area in which Chlorophyta biomass has markedly increased since the mid-1990s (cf. Figure 7.2 and Figure 2.2), suggesting any wading impacts on this habitat would be minor. Key scoop netting areas in the Peel Inlet also show an increase in seagrass cover and biomass compared to historical levels (cf. Figure 7.2 and Figure 2.3). Given the naturally dynamic environment of this estuary, it is considered likely that any localised habitat impacts would recover prior to the beginning of the next fishing season.

The Peel-Harvey Estuary, as part of the broader Peel-Yalgorup system, supports a large number of waterbirds, including many migratory shorebird species for which the wetlands provide important feeding and roosting habitats during the summer months (Hale and Butcher 2007; Birdlife WA 2019). There is potential for shore-based scoop netters to both directly and indirectly impact these shorebirds through disturbance or trampling of habitats while accessing fishing areas or undertaking fishing activities. Although a crabbing closure extends over the months when the migratory birds arrive (September-November), the peak period of fishing activity in January and February coincides with the period where they are preparing to leave for their return migration to their northern hemisphere breeding grounds.

A recent study of shorebird disturbance by recreational activities in the Peel-Harvey Estuary identified boats and crabbers (including both drop net and scoop net fishers) as the main causes of the total anthropogenic disturbances observed across five sites during the summer of 2018/19 (Birdlife WA 2019). The study showed that two thirds of the 116 anthropogenic disturbance events recorded during the 66 surveys (each 2 hours long) resulted in the cessation of shorebirds feeding for an average duration of around 45 seconds (Birdlife WA 2019). Around half of the anthropogenic disturbances resulted in shorebirds taking flight for approximately one minute.

A higher number of anthropogenic disturbance events were observed during weekends than weekdays, with the levels and sources of disturbance also varying markedly between the different sites (Birdlife WA 2019). Crabbing was the most common source of disturbance events observed at Herron Point and Lake Goegrup (the latter being located adjacent to the Peel-Harvey Estuary) and was second to boating at Nairns (Coodanup). No disturbances by crab fishers were observed at Austin Bay or the Chimneys (near the Mandurah Channel).

8.0 External Factors

While a number of external influences and activities within the Peel-Harvey Estuary have the potential to impact on the productivity and sustainability of the fisheries resources and the broader ecosystem in the future (e.g. urban developments, dredging and climate change), these were not explicitly assessed within the scope of this ERA (see Section 9.1).

9.0 Risk Assessment Methodology

Risk assessments have been extensively used as a mean to filter and prioritise the various fisheries management issues identified in Australia (Fletcher et al. 2002). The risk analysis methodology utilised for this risk assessment of the Peel-Harvey Estuarine Fishery is based on the global standard for risk assessment and risk management (AS/NZS ISO 31000), which has been adopted for use in a fisheries context (see Fletcher et al. 2002, Fletcher 2005; 2015). The broader risk assessment process is summarised in Figure 9.1.

The first stage establishes the context or scope of the risk assessment, including determining which activities and geographical extent will be covered, a timeframe for the assessment and the objectives to be delivered (Section 9.1). Secondly, risk identification involves the process of recognising and describing the relevant sources of risk (Section 9.2). Once these components have been identified, risk scores are determined by evaluating the potential consequences (impacts) associated with each issue, and the likelihood (probability) of a particular level of consequence actually occurring (Section 9.3).

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

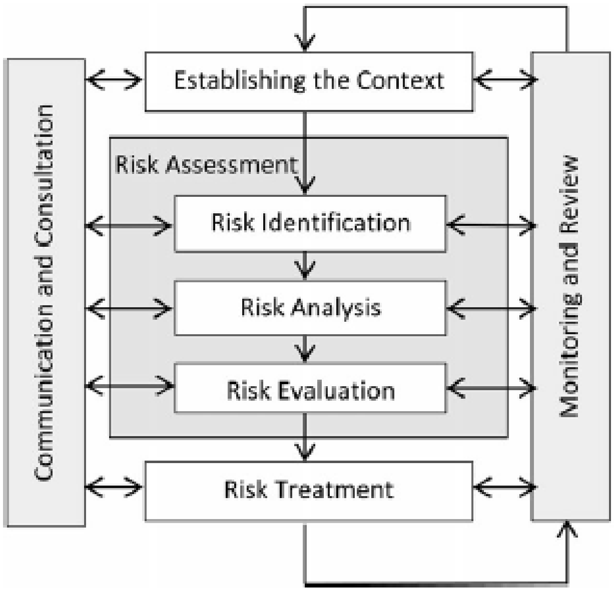


Figure 9.1. Position of risk assessment within the risk management process.

9.1 Scope

This risk assessment covers the ecological impacts of the four key fishing sectors and methods operating within the Peel-Harvey Estuary that are part of the MSC certification; the commercial net and crab trap fisheries, and the recreational drop net and scoop net crab fisheries. The calculation of risk in the context of a fishery is usually determined within a specified period, which for this assessment is the next five years (i.e. until 2025).

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

An important part of the risk assessment and risk management process is communication and consultation with stakeholders. Ecological risk assessments undertaken by the Department typically engage all stakeholders of the fishery to participate in a workshop for collectively scoring risk issues. This allows the assessment to consider not only the ecological sustainability of the fishing activities but also how different external environmental, social and economic drivers may affect the performance of the fishery. The current assessment considered only the ecological impacts of fishing, as required to inform the harvest strategies for these resources.

9.2 Risk Identification

The first step in the risk assessment process was to identify issues relevant to the fishery being assessed. Issues were identified using a component tree approach (see Figure 9.2 for a generic example), where major risk components are deconstructed into smaller sub-components that are more specific to allow the development of operational objectives (Fletcher et al. 2002). The component trees are tailored to suit the individual circumstances of the fishery being examined by adding and expanding some components and collapsing or removing others.

The development of the component tree for evaluating the ecological sustainability of the Peel-Harvey Estuarine Fishery was based on:

- previous risk assessments undertaken for the fisheries (Johnston et al. 2015);
- identified gaps in MSC performance indicators, as identified during the assessment of this fishery against the MSC Fisheries Standards in 2015; and
- an internal risk assessment workshop undertaken by Departmental staff in July 2020.

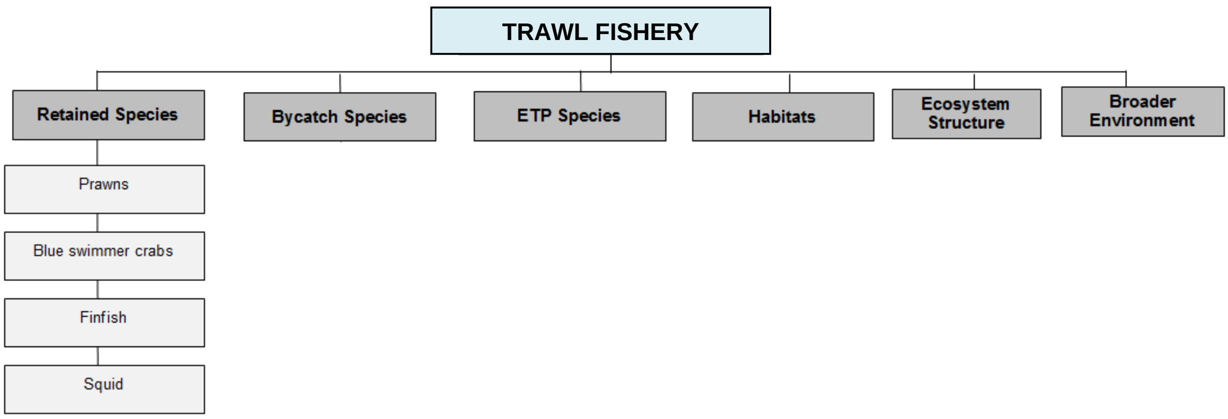


Figure 9.2. An example of a component tree for ecological sustainability, identifying the main components (dark grey boxes) and sub-components for retained species in a trawl fishery.

9.3 Risk Assessment Process

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

Although consequence and likelihood analyses can range in complexity, this assessment utilised a 4×4 matrix (Figure 9.3). The consequence levels ranged from 1 (e.g. minor impact to fish stocks) to 4 (e.g. major impact to fish stocks) and likelihood levels ranged from 1 (Remote; i.e. < 5 % probability) to 4 (Likely; i.e. ≥ 50 % probability). Scoring involved an assessment of the likelihood that each level of consequence is occurring, or is likely to occur within the 5-year period specified for this assessment. If an issue is not considered to have any detectable impact, it can be considered to be a 0 consequence; however, it is preferable to score such components as there being a remote (1) likelihood of a minor (1) consequence.

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

1. Target/retained species – measured at a stock level;
2. Non-retained (bycatch) species – measured at a stock level;
3. ETP species – measured at a population or regional level;
4. Habitats – measured at a regional level; and
5. Ecosystem/Environment – measured at a regional level.

For this ERA, where relevant, the risks of each fishing sector and fishing method considered within the scope of the assessment were assessed separately, as well as cumulatively. For each risk issue, the consequence and likelihood scores were evaluated to determine the highest risk score using the risk matrix (Figure 9.3). Each issue was thus assigned a risk level within one of five categories: Negligible, Low, Medium, High or Severe (Table 9.1).

The risk analysis of the Peel-Harvey Estuarine Fishery was initially conducted by Department staff during an internal workshop held on 27 July 2020. This primarily focused on scoring the risks to the target and retained species for which quantitative information is available to assess stock status and/or their vulnerability to fishing. For Primary species, which are managed under a formal harvest strategy against biologically-based reference levels, the risk of all fishing on the broader stocks has typically been determined as part of their stock assessments and thus there was no need to re-evaluate these scores.

		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

Figure 9.3. 4×4 Consequence – Likelihood Risk Matrix (based on AS 4360 / ISO 31000; adapted from Department of Fisheries 2015).

Table 9.1. Risk levels applied to evaluate individual risk issues (modified from Fletcher 2005).

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

An external stakeholder ERA workshop was held at the Western Australian Fisheries and Marine Research Laboratories on 9 September 2020. A broad range of stakeholders were invited to participate in the ERA workshop (Appendix D). Although the total number of workshop participants was limited due to COVID restrictions and to allow for efficient consideration of risk issues, the ERA was attended by representatives of the commercial and recreational fishing sectors, as well as state and local government agencies, Peel Harvey Catchment Council, Peel Development Commission, Murdoch University, Birdlife WA and the Bindjareb Noongar Community (Appendix D). While the risk scores and associated narrative relating to the retained species were presented and discussed, the workshop focused on assessing the risks of fishing impacts on bycatch and ETP species, benthic habitats and the broader ecosystem.

10.0 Risk Analysis

Twenty-three broad ecological components were identified as potentially impacted by the Peel-Harvey Estuarine Fishery (Figure 10.1). Where relevant, some of these were further separated into smaller categories to score the risks for individual species or groups of species. Where the individual risks of the different fishing sectors and methods could not be easily distinguished, or were assessed to be the same, these have been reported together as the cumulative risk.

The risk ratings for each of risk issue considered in the assessment are summarised in Table 10.1. Note the risk justifications include comments from stakeholders that attended the workshop. While these are a summary of individual views and may not be representative of every stakeholder at the workshop, the risk scores are reflective of the group consensus at the workshop.

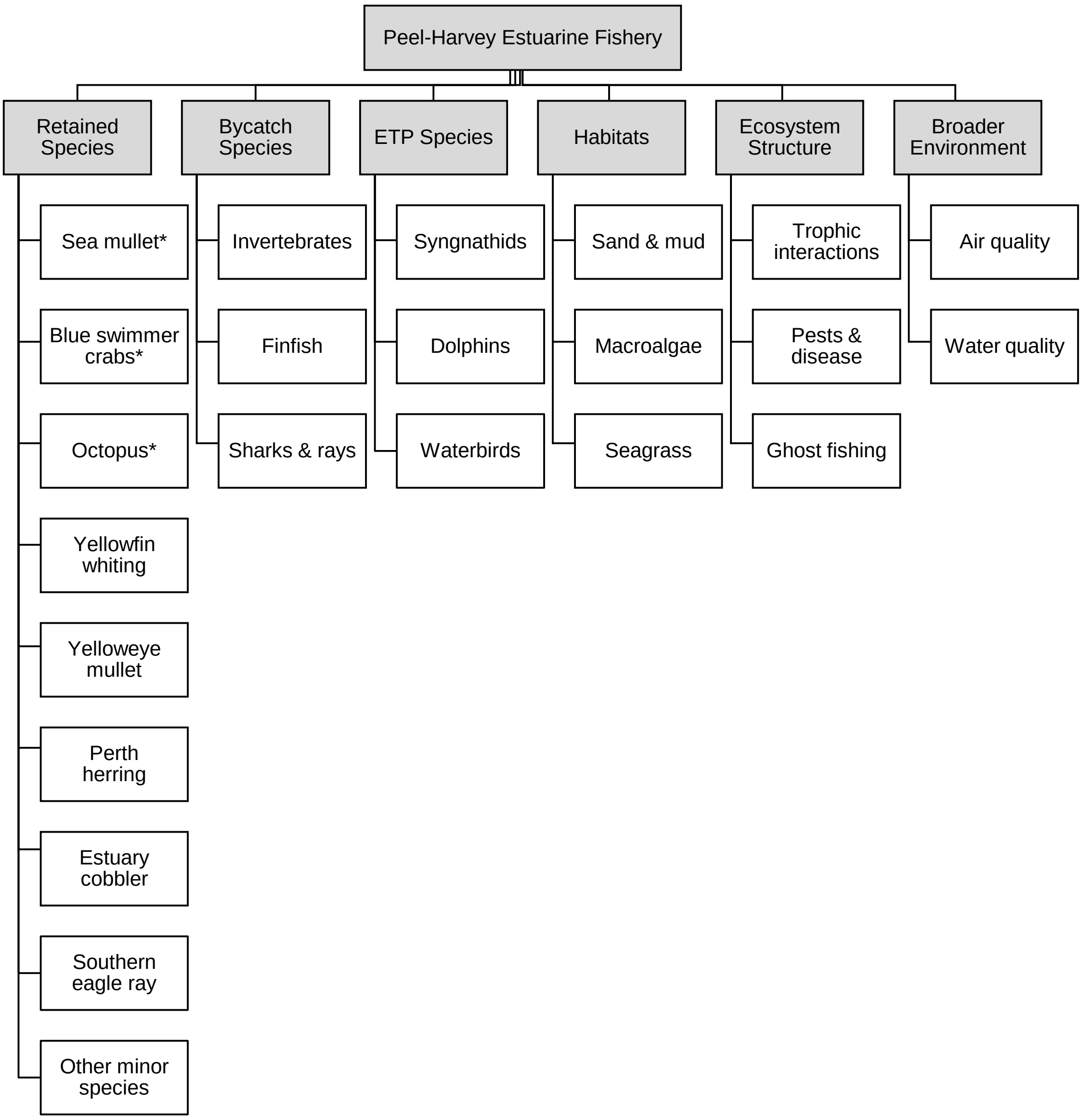


Figure 10.1. Component tree for assessing the ecological sustainability of the Peel-Harvey Estuarine Fishery. *denotes Primary species, managed against formal harvest strategy reference levels.

Table 10.1. Overview of the objectives, components, and risk scores and ratings considered in the 2020 ecological risk assessment of the Peel-Harvey Estuarine Fishery. (M) indicates main retained species, which represent at least 5% of the catch or, if considered vulnerable, ≥2% of the catch.

Aspect	Fishery Objective	Component	Issues	Risk Scoring	Risk rating
Retained Species (Primary)	To maintain spawning stock biomass of each retained species at a level where the main factor affecting recruitment is the environment	Sea mullet (M)	All fishing on stock	C2, L4	MEDIUM
		Blue swimmer crabs (M)	All fishing on stock	C2, L4	MEDIUM
		Octopus	All fishing on stock	C2, L2	LOW
Retained Species (Secondary)	To maintain spawning stock biomass of each retained species at a level where the main factor affecting recruitment is the environment	Yellowfin whiting (M)	Peel-Harvey Estuarine Fishery	C2, L3	MEDIUM
		Yelloweye mullet (M)	Peel-Harvey Estuarine Fishery	C2, L2	LOW
		Perth herring (M)	Peel-Harvey Estuarine Fishery	C3, L3	HIGH
			Commercial net fishing	C3, L3	HIGH
			Commercial trap fishing	C1, L1	NEGLIGIBLE
			Recreational drop net fishing	C1, L1	NEGLIGIBLE
			Recreational scoop net fishing	C1, L1	NEGLIGIBLE
		Estuary cobbler	Peel-Harvey Estuarine Fishery	C2, L4	MEDIUM
			Commercial net fishing	C2, L4	MEDIUM
			Commercial trap fishing	C1, L1	NEGLIGIBLE
			Recreational drop net fishing	C1, L1	NEGLIGIBLE
			Recreational scoop net fishing	C1, L1	NEGLIGIBLE
		Southern eagle ray	Peel-Harvey Estuarine Fishery	C2, L4	MEDIUM
			Commercial net fishing	C2, L4	MEDIUM
			Commercial trap fishing	C1, L1	NEGLIGIBLE
			Recreational drop net fishing	C1, L1	NEGLIGIBLE
			Recreational scoop net fishing	C1, L1	NEGLIGIBLE

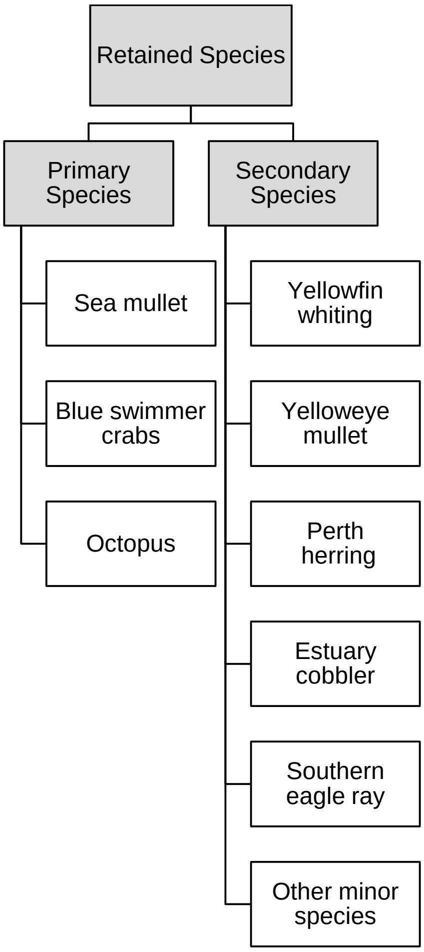
Aspect	Fishery Objective	Component	Issues	Risk Scoring	Risk rating
		Other minor species	Peel-Harvey Estuarine Fishery	C1, L1	NEGLIGIBLE
Bycatch Species	To ensure fishing impacts do not result in serious or irreversible harm to bycatch (non-retained) species populations	Invertebrates	Peel-Harvey Estuarine Fishery	C1, L4	LOW
		Finfish	Peel-Harvey Estuarine Fishery	C1, L4	LOW
		Sharks & rays	Peel-Harvey Estuarine Fishery	C1, L1	NEGLIGIBLE
ETP Species	To ensure fishing impacts do not result in serious or irreversible harm to ETP species' populations	Dolphins	Peel-Harvey Estuarine Fishery	C1, L1	NEGLIGIBLE
		Syngnathids	Peel-Harvey Estuarine Fishery	C1, L1	NEGLIGIBLE
		Migratory, threatened shorebirds	Peel-Harvey Estuarine Fishery	C3, L3	HIGH
			Commercial net fishing	C1, L1	NEGLIGIBLE
			Commercial trap fishing	C1, L1	NEGLIGIBLE
			Recreational drop net fishing	C1, L1	NEGLIGIBLE
			Recreational scoop net fishing	C3, L3	HIGH
		Migratory, non-threatened shorebirds	Peel-Harvey Estuarine Fishery	C3, L2	MEDIUM
			Commercial net fishing	C1, L1	NEGLIGIBLE
			Commercial trap fishing	C1, L1	NEGLIGIBLE
			Recreational drop net fishing	C1, L1	NEGLIGIBLE
			Recreational scoop net fishing	C3, L2	MEDIUM
		Hooded plover	Peel-Harvey Estuarine Fishery	C1, L1	NEGLIGIBLE
		Other resident shorebirds (incl. the fairy tern)	Peel-Harvey Estuarine Fishery	C2, L4	MEDIUM
			Commercial net fishing	C1, L1	NEGLIGIBLE
			Commercial trap fishing	C1, L1	NEGLIGIBLE
			Recreational drop net fishing	C1, L1	NEGLIGIBLE
			Recreational scoop net fishing	C2, L4	MEDIUM

		Other resident waterbirds (e.g. ducks)	Peel-Harvey Estuarine Fishery	C1, L4	LOW
			Commercial net fishing	C1, L1	NEGLIGIBLE
			Commercial trap fishing	C1, L1	NEGLIGIBLE
			Recreational drop net fishing	C1, L1	NEGLIGIBLE
			Recreational scoop net fishing	C1, L4	LOW
Habitats	To ensure the effects of fishing do not result in serious or irreversible harm to habitat structure and function	Sand & mud	Peel-Harvey Estuarine Fishery	C2, L2	LOW
			Commercial net fishing	C1, L4	LOW
			Commercial trap fishing	C1, L2	NEGLIGIBLE
			Recreational drop net fishing	C1, L3	LOW
			Recreational scoop net fishing	C2, L2	LOW
		Macroalgae	Peel-Harvey Estuarine Fishery	C1, L2	NEGLIGIBLE
			Commercial net fishing	C1, L2	NEGLIGIBLE
			Commercial trap fishing	C1, L1	NEGLIGIBLE
			Recreational drop net fishing	C1, L2	NEGLIGIBLE
			Recreational scoop net fishing	C1, L2	NEGLIGIBLE
		Seagrass	Peel-Harvey Estuarine Fishery	C2, L2	LOW
			Commercial net fishing	C1, L4	LOW
			Commercial trap fishing	C1, L2	NEGLIGIBLE
			Recreational drop net fishing	C1, L3	LOW
			Recreational scoop net fishing	C2, L2	LOW

Ecosystem Structure	To ensure the effects of fishing do not result in serious or irreversible harm to ecological processes	Trophic interactions (removal of retained species)	Peel-Harvey Estuarine Fishery	C1, L4	LOW
		Trophic interactions (discarding/provisioning)	Peel-Harvey Estuarine Fishery	C1, L3	LOW
			Commercial net fishing	C1, L1	NEGLIGIBLE
			Commercial trap fishing	C1, L3	LOW
			Recreational drop net fishing	C1, L3	LOW
			Recreational scoop net fishing	C1, L1	NEGLIGIBLE
		Translocation of pests and/or disease (vessel hulls, bait)	Peel-Harvey Estuarine Fishery	C1, L3	LOW
			Commercial net fishing	C1, L1	NEGLIGIBLE
			Commercial trap fishing	C1, L1	NEGLIGIBLE
			Recreational drop net fishing	C1, L3	LOW
			Recreational scoop net fishing	C1, L1	NEGLIGIBLE
		Ghost fishing (lost fishing gear)	Peel-Harvey Estuarine Fishery	C1, L2	NEGLIGIBLE
			Commercial net fishing	C1, L1	NEGLIGIBLE
			Commercial trap fishing	C1, L2	NEGLIGIBLE
			Recreational drop net fishing	C1, L2	NEGLIGIBLE
			Recreational scoop net fishing	C1, L1	NEGLIGIBLE
Broader Environment	To ensure the effects of fishing do not result in serious or irreversible harm to the broader environment	Air quality (exhaust)	Peel-Harvey Estuarine Fishery	C1, L2	NEGLIGIBLE
			Commercial net fishing	C1, L1	NEGLIGIBLE
			Commercial trap fishing	C1, L1	NEGLIGIBLE
			Recreational drop net fishing	C1, L2	NEGLIGIBLE
			Recreational scoop net fishing	C1, L1	NEGLIGIBLE

	Air quality (greenhouse gas emissions)	Peel-Harvey Estuarine Fishery	C1, L1	NEGLIGIBLE
	Water quality (debris/litter)	Peel-Harvey Estuarine Fishery	C2, L2	LOW
		Commercial net fishing	C1, L1	NEGLIGIBLE
		Commercial trap fishing	C1, L1	NEGLIGIBLE
		Recreational drop net fishing	C1, L4	LOW
		Recreational scoop net fishing	C2, L2	LOW
	Water quality (oil/fuel discharge)	Peel-Harvey Estuarine Fishery	C1, L3	LOW
		Commercial net fishing	C1, L1	NEGLIGIBLE
		Commercial trap fishing	C1, L1	NEGLIGIBLE
		Recreational drop net fishing	C1, L3	LOW
		Recreational scoop net fishing	C1, L1	NEGLIGIBLE

10.1 Retained Species



10.1.1 *Sea mullet*

Risk Rating: Impact of all fishing on the sea mullet stock in south-west WA (C2×L4 = MEDIUM)

- Sea mullet represents the key target species in the commercial net fishery in the Peel-Harvey Estuary, with the same stock also targeted by other small-scale net fisheries in WA (extending as far north as Shark Bay).
- The current weight-of-evidence assessment of sea mullet in south-west WA (Resource Assessment Report, in prep.) indicates that the stock is being fished at a sustainable level.

10.1.2 *Blue swimmer crabs*

Risk Rating: Impact of all fishing on the blue swimmer crab stock in south-west WA (C2×L4 = MEDIUM)

- The blue swimmer crab stock targeted in the Peel-Harvey Estuary also extends to coastal waters outside the estuary but is considered a separate stock to that in Cockburn Sound and Swan-Canning Estuary.
- The current weight-of-evidence assessment of blue swimmer crabs in south-west WA (Johnston et al. in prep.) indicates that the stock is being fished at a sustainable level.
- Multiple lines of evidence give no indication of unacceptable stock depletion. Standardised commercial catch rates have been maintained above harvest strategy thresholds over the long-term and fisheries independent monitoring has not revealed any issues with stock sustainability.
- The reduction in commercial crab fishing licences in the Peel-Harvey Estuary (10 to 6) through a recent VFAS, and the current buy-out out of licences in Warnbro Sound and coastal waters between Mandurah and Bunbury is likely to improve the protection of the breeding stock over the next 5 years.

10.1.3 *Octopus*

Risk Rating: Impact of all fishing on the octopus stock in WA (C2×L2 = LOW)

- Catches of octopus in the commercial trap fishery in the Peel-Harvey Estuary comprises a minor component of overall catches from the stock, ranging from 5 to 129 kg annually over the past five-year period. This is negligible compared to the fisheries that target this stock, primarily the Octopus Interim Managed Fishery.
- A 2018 weight-of-evidence assessment of the octopus stock in WA indicates the risk of unacceptable stock depletion is low, with fishery-independent data from depletion experiments suggesting that fishers currently target less than 10% of potential octopus habitat (Hart et al. 2019).

10.1.4 *Yellowfin whiting*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on the yellowfin whiting stock (C2×L3 = MEDIUM)

- Yellowfin whiting is one of the main species caught by the commercial net fishery (i.e. >5% of the catch) and is also an important recreational species in the Peel-Harvey Estuary.
- Commercial catches in the Peel-Harvey Estuary exceeded the threshold level set out in the original harvest strategy in 2014 and 2015, which an assessment showed was due to a pulse in recruitment following the 2011 marine heatwave.
- The current weight-of-evidence assessment of yellowfin whiting in the West Coast Bioregion (Resource Assessment Report, in prep.) indicates that the stock is being fished at a sustainable level.

- Warming climate is expected to result in a continuation of the increasing abundance trend in southern parts of WA, including in the Peel-Harvey Estuary.

10.1.5 *Yelloweye mullet*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on the yelloweye mullet stock (C2×L2 = LOW)

- Yelloweye mullet is a main species in the commercial net fishery catch in the Peel-Harvey Estuary (i.e. comprises around >5% of the catch), however, catches have declined since fishers converted from gill nets to traps for targeting blue swimmer crabs.
- A data-poor assessment of the broader WA stock shows that current level of catch is well below the estimated Maximum Sustainable Yield (MSY). On the basis of this information, yelloweye mullet in WA is classified as a sustainable stock.

10.1.6 *Perth herring*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on the Perth herring stock (C3×L3 = HIGH)

Risk Rating: Impact of commercial net fishing in the Peel-Harvey Estuary on the Perth herring stock (C3×L3 = HIGH)

Risk Rating: Impact of all other components of the Peel-Harvey Estuarine Fishery on the Perth herring stock (C1×L1 = NEGLIGIBLE)

- Perth herring in the Peel-Harvey Estuary are caught in relatively low amounts by the commercial net fishery, with no known catch by crab fishers.
- Perth herring in the Peel-Harvey Estuary represents a discrete stock and as its biological traits (e.g. anadromous) make it inherently vulnerable to depletion, it is considered a main species in the commercial net fishery (2% of the catch).
- Spawning occurs during summer in the rivers. Adults return to sea in winter, whereas juveniles remain in rivers until maturity. All life history stages are vulnerable to water quality problems (hypoxia, fish kills, toxic algal blooms) that occur in rivers during warmer months. Barriers to migration and declining freshwater flows due to climate change also threaten this species.
- Compared to the Swan-Canning stock, the Peel-Harvey stock is inherently vulnerable due to its small population size and higher mortality rates. Impact of fish kills unclear, but may contribute to total mortality in both stocks.
- Higher mortality rates may be due to external factors such as water quality of the tributaries, decreased freshwater flows and increased salinity, as well as commercial fishing pressure.

10.1.7 *Estuary cobbler*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on the cobbler stock (C2×L4 = MEDIUM)

Risk Rating: Impact of commercial net fishing in the Peel-Harvey Estuary on the cobbler stock (C2×L4 = MEDIUM)

Risk Rating: Impact of all other components of the Peel-Harvey Estuarine Fishery on the cobbler stock (C1×L1 = NEGLIGIBLE)

- Cobbler in the Peel-Harvey Estuary represent a discrete stock and is primarily caught by commercial net fishers.
- Biological and ecological traits of cobbler make it inherently vulnerable to fishing and to benthic habitat degradation in the estuary. Both processes likely contributed to a historical stock decline.
- Over the past two decades there has been a substantial decrease in commercial catch of cobbler due to reductions in gillnetting effort, with the current annual catch now relatively low (<1% of the net fishery catch). Simultaneously, there has been an improvement in benthic habitat quality in the estuary basin. Thus, in contrast to Perth herring (which is more vulnerable to water quality issues in the rivers and is primarily caught by haul netting), the risk to cobbler has been partly mitigated in the Peel-Harvey Estuary. Available evidence suggests the current stock level is stable, albeit at a level lower than historical.
- There are compliance reports of cobbler catches by non-compliant recreational gillnet fishers, however, these are out of scope for this risk assessment.

10.1.8 *Southern eagle ray*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on the southern eagle ray stock (C2×L4 = MEDIUM)

Risk Rating: Impact of commercial net fishing in the Peel-Harvey Estuary on the southern eagle ray stock (C2×L4 = MEDIUM)

Risk Rating: Impact of all other components of the Peel-Harvey Estuarine Fishery on the southern eagle ray stock (C1×L1 = NEGLIGIBLE)

- A trial has been proposed to allow commercial net fishers to retain up to 1 t southern eagle rays per year to establish the sustainability of the fishery.
- The southern eagle ray is a marine species that has increased in abundance in several south-west estuaries (including Peel-Harvey and Swan-Canning), probably due to estuaries becoming more marine (reduced rainfall).
- Like other elasmobranchs it has biological traits that make it inherent vulnerability to fishing (e.g. low fecundity). A Productivity Susceptibility Analysis

(PSA) on the southern eagle ray stock suggested a moderate risk to overfishing.

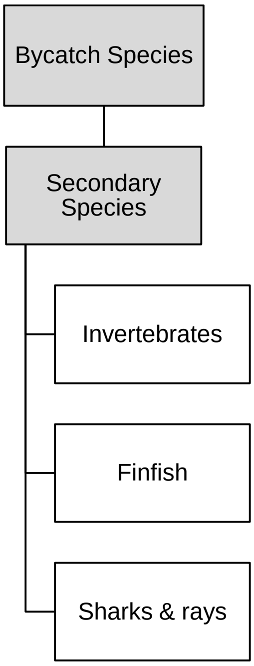
- Also caught in very low amounts as a by-product by some other commercial (demersal trawl and gillnet) fisheries in WA, and in south-east Australia.
- There are no known catches of southern eagle rays by commercial and recreational crab fishers in the Peel-Harvey Estuary.

10.1.9 *Other minor finfish and invertebrates*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on minor finfish and invertebrate stocks (C1×L1 = RISK)

- Other finfish and invertebrate species caught and retained in the Peel-Harvey Estuarine Fishery only comprise a minor component (i.e. each less than 5%) of overall catches of each fishing sector/method.

10.2 Bycatch Species



10.2.1 *Invertebrates*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on invertebrate bycatch species (C1×L1 = NEGLIGIBLE)

- While there is potential for fishers in the Peel-Harvey Estuary to catch and discard low numbers of invertebrates, available data suggest the discarding ratios of the different sectors/method are low. This does not include the discarding of undersize blue swimmer crabs, which is considered as part of the assessment of the overall stock.
- Post-release mortality of discarded invertebrates is expected to be low.
- Both the four-lobed crab and the mud crab that has been occasionally caught and released by the commercial trap fishery have a broad tropical distribution outside of the Peel-Harvey Estuary; therefore, the likelihood of any fishing in the Peel-Harvey Estuary having even a noticeable consequence on the broader stock is remote.

10.2.2 *Finfish*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on finfish bycatch species (C1×L1 = NEGLIGIBLE)

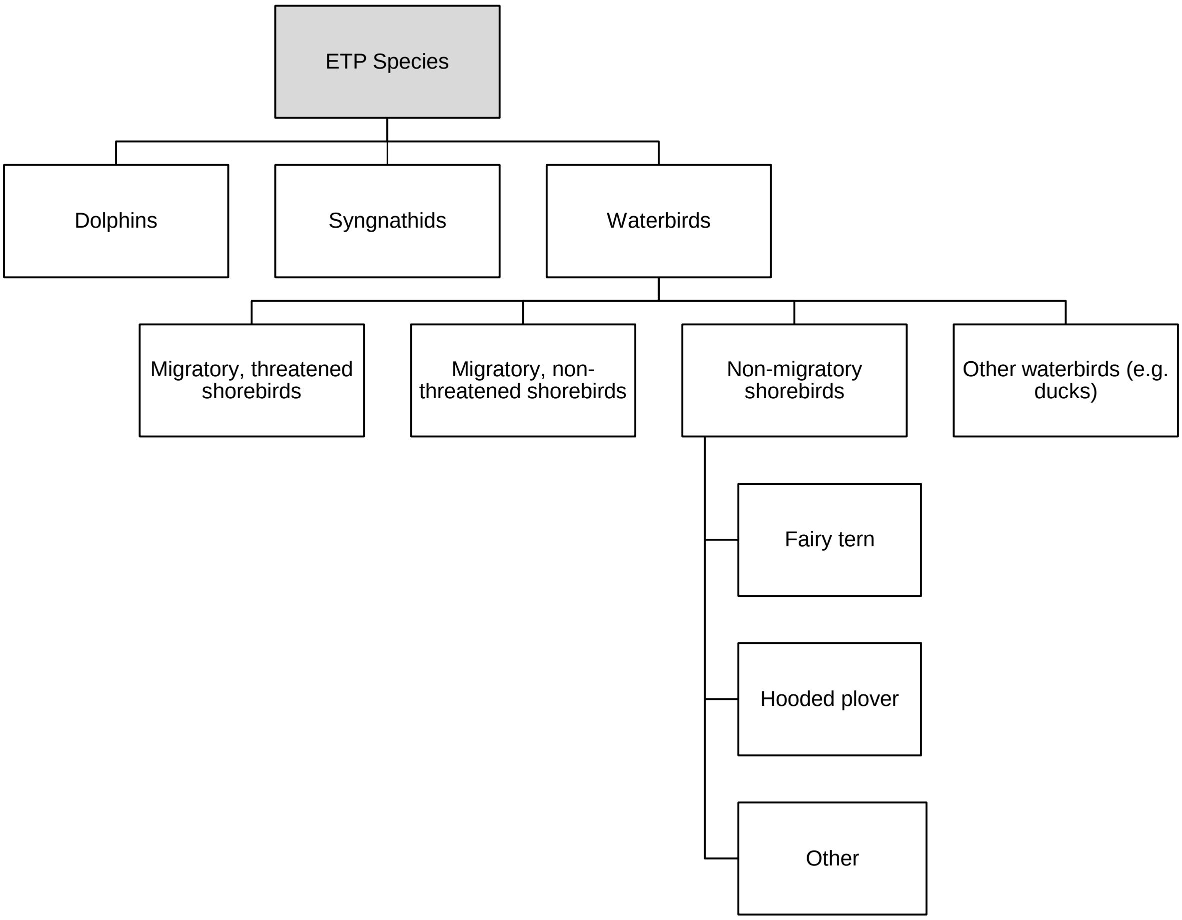
- While there is potential for fishers in the Peel-Harvey Estuary to catch and discard low numbers of finfish*, available data suggest the discarding ratios of the different sectors/method are low.*
- From the list of species recorded as discarded in the Peel-Harvey Estuarine Fishery, mulloway is considered the most vulnerable, however, it is not targeted by haul net fishers and gill netting effort is declining.

10.2.3 *Sharks & rays*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on shark and ray bycatch species (C1×L1 = NEGLIGIBLE)

- While there is potential for fishers in the Peel-Harvey Estuary to catch and discard low numbers of elasmobranchs*, available data suggest the discarding is limited to a very low number of rays.*
- Rays are currently not targeted by commercial fishers and are released from haul nets before they are landed. Gillnet effort is declining, so is not expected to be an issue over the next five years.

10.3 ETP Species



10.3.1 *Dolphins*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on dolphins (C1×L1 = NEGLIGIBLE)

- While there is potential for the Peel-Harvey Estuarine Fishery to interact with dolphins, there have been no reported interactions with commercial fishers or recreational crab fishers to date.

10.3.2 *Syngnathids*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on syngnathids (C1×L1 = NEGLIGIBLE)

- Syngnathids generally associate with macroalgae and seagrass, which are sometimes caught in commercial fishing nets. As these weeds are typically shaken out of the net as it is being hauled, the syngnathids are rarely landed on the vessel.
- There have been no reported interactions with commercial fishers or recreational crab fishers to date.

10.3.3 *Waterbirds*

10.3.3.1 *Migratory, threatened species*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on migratory, threatened shorebird species (C3×L3 = HIGH)

Risk Rating: Impact of recreational scoop net fishing in the Peel-Harvey Estuary on migratory, threatened shorebird species (C3×L3 = HIGH)

Risk Rating: Impact of all other components of the Peel-Harvey Estuarine Fishery on migratory, threatened shorebird species (C1×L1 = NEGLIGIBLE)

- There is potential for the Peel-Harvey Estuarine Fishery (and other recreational users of the estuary) to interact with waterbirds, including several shorebird species listed as migratory and threatened species (see Appendix B). These migratory species are present in the estuary during late spring and summer (around October to March).
- When the crab fishing season opens on 1 December, recreational scoop-net fishing occurs in the same shallow fringes of the estuary that the wading birds use for feeding and roosting. If birds are disturbed as they are feeding, there is an energetic cost to the birds resulting in reduced ability to gain condition or be sufficiently rested to undertake their migration back to the northern hemisphere to breed.
- Migratory shorebirds will feed throughout both the day and night and are only limited by the high tide covering feeding grounds. Scoop-net fishing also occurs at all times of the day and night (Taylor et al. 2018), reducing the opportunities for birds to feed undisturbed.
- The potential for disturbance is not uniform across the estuary and surveys of scoop netting effort (Desfosses et al. in prep.) and bird disturbance (Birdlife WA 2019) have indicated some key hotspots of overlap (e.g. Coodanup). Findings from the latter study suggest that birds avoid high-activity scooping areas once the crabbing season opens, even though those same areas were being used by the birds during the closed season (Birdlife WA 2019).
- Impacts of disturbance in the Peel-Harvey Estuary occur on top of external factors along the migratory flyway throughout southeast Asia, resulting in cumulative impacts on migration success that are very difficult to measure. For the species that have been assessed as Threatened in Australia or globally, it is considered possible that the disturbance could impact on recovery.
- Boat-based commercial and recreational fishers are considered to have a negligible impact as their vessels travel slower in shallow waters and cannot get as close to bird wading areas as scoop net fishers.

10.3.3.2 *Migratory, non-threatened species*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on migratory, non-threatened shorebird species (C3×L2 = MEDIUM)

Risk Rating: Impact of recreational scoop net fishing in the Peel-Harvey Estuary on migratory, non-threatened shorebird species (C3×L2 = MEDIUM)

Risk Rating: Impact of all other components of the Peel-Harvey Estuarine Fishery on migratory, non-threatened shorebird species (C1×L1 = NEGLIGIBLE)

- Migratory birds are inherently vulnerable to the impacts of disturbance on their ability to successfully undertake and complete their migration (see above).
- The slightly lower overall risk rating for species that have not been assessed as Threatened in Australia or globally is reflective of the stability of these populations, not the impacts resulting from recreational fishing.
- Boat-based commercial and recreational fishers are considered to have a negligible impact as their vessels travel slower in shallow waters and cannot get as close to bird wading areas as scoop net fishers.

10.3.3.3 *Hooded plover*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on hooded plovers (C1×L1 = NEGLIGIBLE)

- Resident (non-migratory) species listed as Threatened in Australia or globally include the hooded plover.
- As the hooded plover has not been counted within the Peel-Harvey Estuary as part of the Shorebird 2020 surveys, there is a remote likelihood that fishing activity in the estuary would have even a noticeable impact on the population.

10.3.3.4 *Other resident shorebirds*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on other resident shorebirds (C2×L4 = MEDIUM)

Risk Rating: Impact of recreational scoop net fishing in the Peel-Harvey Estuary on other resident shorebirds (C2×L4 = MEDIUM)

Risk Rating: Impact of all other components of the Peel-Harvey Estuarine Fishery on other resident shorebirds (C1×L1 = NEGLIGIBLE)

- Other resident (non-migratory) species counted within the Peel-Harvey Estuary as part of the Shorebird 2020 surveys include the Threatened fairy tern and species such as the banded and black-winged stilts.
- Although commonly counted in the Peel-Harvey Estuary as part of the Shorebird 2020 surveys, these species are not as reliant on this area as migratory species.

- Boat-based commercial and recreational fishers are considered to have a negligible impact as their vessels travel slower in shallow waters and cannot get as close to bird wading areas as scoop net fishers.

10.3.3.5 *Other resident waterbirds*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on other waterbirds (C1×L4 = LOW)

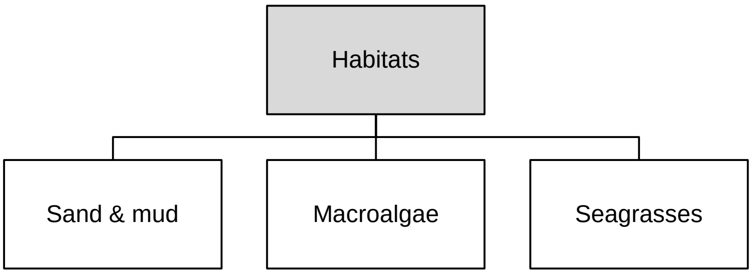
Risk Rating: Impact of recreational scoop net fishing in the Peel-Harvey Estuary on other waterbirds (C1×L4 = LOW)

Risk Rating: Impact of all other components of the Peel-Harvey Estuarine Fishery on other waterbirds (C1×L1 = NEGLIGIBLE)

- Other waterbird species (e.g. ducks) that have been commonly counted in the Peel-Harvey Estuary as part of the Shorebird 2020 surveys are not considered as reliant on this area as migratory species.

- Fishing activity within the Peel-Harvey Estuary is considered to have only a negligible impact on feeding and roosting activity for common waterbirds as they are not as limited to feeding in the very shallow fringes of the estuary as wading shorebirds.

10.4 Habitats



10.4.1 *Sand & mud*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on sand/mud habitats (C2×L2 = LOW)

Risk Rating: Impact of commercial net fishing in the Peel-Harvey Estuary on sand/mud habitats (C1×L4 = LOW)

Risk Rating: Impact of commercial crab trap fishing in the Peel-Harvey Estuary on sand/mud habitats (C1×L2 = NEGLIGIBLE)

Risk Rating: Impact of recreational drop net fishing in the Peel-Harvey Estuary on sand/mud habitats (C1×L3 = LOW)

Risk Rating: Impact of recreational scoop net fishing in the Peel-Harvey Estuary on sand/mud habitats (C2×L2 = LOW)

- There is potential for the Peel-Harvey Estuarine Fishery to impact on sand and mud habitats as the fishing gear or wading fishers come into contact with the substrate.
- While there will be some drag of commercial fishing nets over the benthos as the nets are being hauled, the impact on sand and sediment is considered minor, noting there are only 7 remaining licences that operate throughout the estuary.
- Commercial crab traps (a maximum of 42 used by each of the 6 licenced crab fishers) are lifted directly from the benthos, rather than being dragged. Therefore, they are unlikely to have even a minor impact on the sand and sediment.
- Recreational drop nets are also lifted directly from the benthos, however, there are substantially more recreational fishers than commercial fishers in the estuary, resulting in a slightly higher likelihood of having a minor impact on the sand and sediment.
- An unknown (though large) number of recreational scoop-net fishers wade in the shallow fringes of the estuary during the summer months and has a greater potential consequence of impacting the sediment through trampling than the other components of the fishery.

10.4.2 *Macroalgae*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on macroalgal habitats (C1×L2 = NEGLIGIBLE)

Risk Rating: Impact of commercial net fishing in the Peel-Harvey Estuary on macroalgal habitats (C1×L2 = NEGLIGIBLE)

Risk Rating: Impact of commercial crab trap fishing in the Peel-Harvey Estuary on macroalgal habitats (C1×L1 = NEGLIGIBLE)

Risk Rating: Impact of recreational drop net fishing in the Peel-Harvey Estuary on macroalgal habitats (C1×L2 = NEGLIGIBLE)

Risk Rating: Impact of recreational scoop net fishing in the Peel-Harvey Estuary on macroalgal habitats (C1×L2 = NEGLIGIBLE)

- While there is potential for the Peel-Harvey Estuarine Fishery to impact macroalgal habitats, these are highly dynamic, particularly species that are not anchored to the substrate).
- All fisheries were assessed to have negligible discernible impacts on macroalgae biomass in the estuary.
- Commercial net fishers actively avoid macroalgal areas as the nets are too hard to haul if they are full of weeds.

- Commercial crab traps were assessed to have a lower likelihood of impact as they are not dragged across the substrate like the commercial nets, there are much lower numbers than the recreational drop-net fishery, and the commercial fishers can only fish on weekdays.

10.4.3 *Seagrass*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on seagrass habitats (C2×L2 = LOW)

Risk Rating: Impact of commercial net fishing in the Peel-Harvey Estuary on seagrass habitats (C1×L4 = LOW)

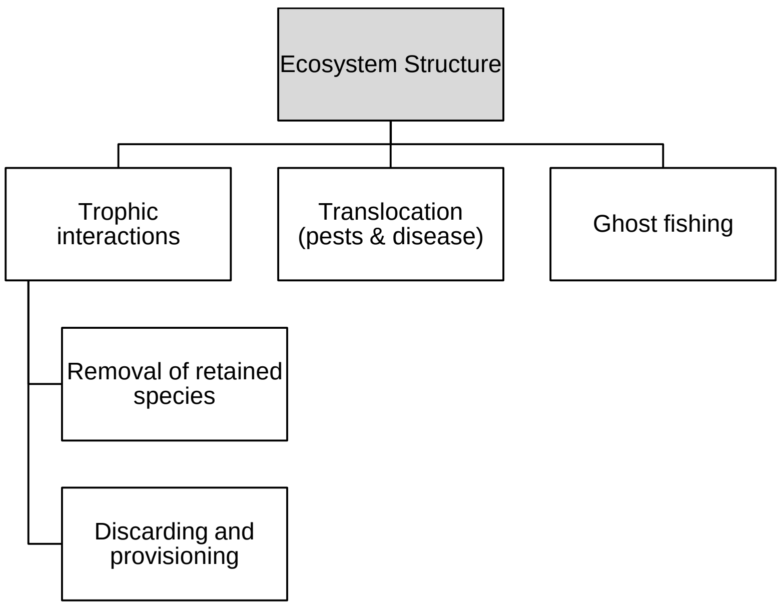
Risk Rating: Impact of commercial crab trap fishing in the Peel-Harvey Estuary on seagrass habitats (C1×L2 = NEGLIGIBLE)

Risk Rating: Impact of recreational drop net fishing in the Peel-Harvey Estuary on seagrass habitats (C1×L3 = LOW)

Risk Rating: Impact of recreational scoop net fishing in the Peel-Harvey Estuary on seagrass habitats (C2×L2 = LOW)

- Impacts of fishing on seagrass were assessed higher than macroalgae because the seagrass is anchored to the sediment and is less mobile, making it more susceptible to trampling (recreational scoop-net fishery) and dragged nets (commercial net fisheries).

10.5 Ecosystem Structure



10.5.1 *Trophic interactions*

10.5.1.1 *Removal of retained species*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on trophic interactions by removing retained species (C1×L4 = LOW)

- The removal of species retained by the Peel-Harvey Estuarine Fishery has the potential to alter key elements of the ecosystem, including predator-prey interactions.
- Sea mullet and blue swimmer crabs and are not considered species that provide the only food source to predators in the estuary and their stocks have been assessed as sustainable.
- Fishery-independent surveys show an abundance of small crabs in the estuary and net fishers retain a number of different finfish species. Therefore, their removal by the various fisheries was considered likely to have only minor impacts on trophic interactions.

10.5.1.2 *Discarding/provisioning*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on trophic interactions by discarding/provisioning (C1×L3 = LOW)

Risk Rating: Impact of commercial net fishing in the Peel-Harvey Estuary on trophic interactions by discarding/provisioning (C1×L1 = NEGLIGIBLE)

Risk Rating: Impact of commercial crab trap fishing in the Peel-Harvey Estuary on trophic interactions by discarding/provisioning (C1×L3 = LOW)

Risk Rating: Impact of recreational drop net fishing in the Peel-Harvey Estuary on trophic interactions by discarding/provisioning (C1×L3 = LOW)

Risk Rating: Impact of recreational scoop net fishing in the Peel-Harvey Estuary on trophic interactions by discarding/provisioning (C1×L1 = NEGLIGIBLE)

- The discarding of bycatch and bait in the Peel-Harvey Estuarine Fishery has the potential to alter key elements of the ecosystem by providing a source of food that would not normally be available to other organisms.
- Commercial bycatch monitoring and recreational fishing surveys have indicated that blue swimmer crabs represent the most commonly discarded species by fishers, however, post-release survival is likely high.
- The likelihood of minor fishing impacts through discarding and provisioning are considered slightly greater for the sectors that use bait. Commercial fishers use only locally-caught bait for their crab traps. There is no evidence from previous surveys that recreational fishers use large quantities of bait for their drop nets.
- Commercial net fishers and recreational scoop-net fishers do not use bait and have minimal discard mortality.

10.5.2 *Translocation (pests & disease)*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on the ecosystem by translocating pests and diseases (C1×L3 = LOW)

Risk Rating: Impact of commercial net fishing in the Peel-Harvey Estuary on the ecosystem by translocating pests and diseases (C1×L1 = NEGLIGIBLE)

Risk Rating: Impact of commercial crab trap fishing in the Peel-Harvey Estuary on the ecosystem by translocating pests and diseases (C1×L1 = NEGLIGIBLE)

Risk Rating: Impact of recreational drop net fishing in the Peel-Harvey Estuary on the ecosystem by translocating pests and diseases (C1×L3 = LOW)

Risk Rating: Impact of recreational scoop net fishing in the Peel-Harvey Estuary on the ecosystem by translocating pests and diseases (C1×L1 = NEGLIGIBLE)

- Fishing vessels in the Peel-Harvey Estuarine Fishery that move between different areas and/or use bait have the potential to introduce or translocate marine pests and/or disease.
- Commercial fishers are not permitted to use their boats or gear outside of the Peel-Harvey Estuary and, as the bait used by crab fishers is all sourced from within the estuary, there is a remote likelihood they will be responsible for introducing pests or diseases.
- Recreational drop-net fishers can use their boats without restriction throughout the state and can source their bait from anywhere and therefore have a higher likelihood of impact. Based on historical events, the consequence was assessed as minor.
- Most recreational scoop net fishing occurs from the shore and do not use bait.

10.5.3 *Ghost fishing*

Risk Rating: Cumulative impact of the Peel-Harvey Estuarine Fishery on the ecosystem by ghost fishing of lost gear (C1×L2 = NEGLIGIBLE)

Risk Rating: Impact of commercial net fishing in the Peel-Harvey Estuary on the ecosystem by ghost fishing of lost gear (C1×L1 = NEGLIGIBLE)

Risk Rating: Impact of commercial crab trap fishing in the Peel-Harvey Estuary on the ecosystem by ghost fishing of lost gear (C1×L2 = NEGLIGIBLE)

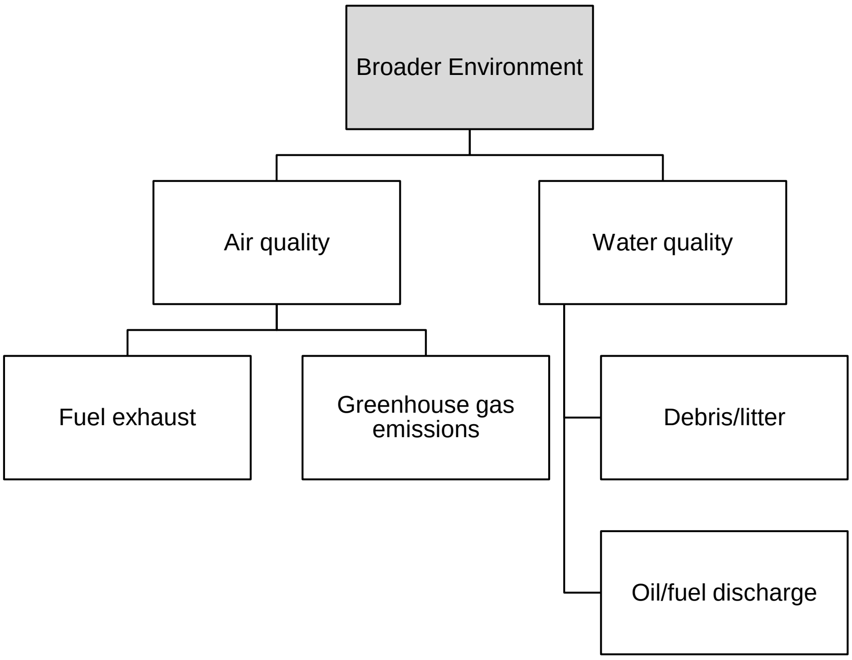
Risk Rating: Impact of recreational drop net fishing in the Peel-Harvey Estuary on the ecosystem by ghost fishing of lost gear (C1×L2 = NEGLIGIBLE)

Risk Rating: Impact of recreational scoop net fishing in the Peel-Harvey Estuary on the ecosystem by ghost fishing of lost gear (C1×L1 = NEGLIGIBLE)

- Fishing vessels operating in the Peel-Harvey Estuary have the potential to loose fishing gear whilst fishing, which could result in the continued capture of species.

- The impact of lost gear was assessed as negligible as the commercial net fisheries have recorded any lost gear, which would easily be recovered in the relatively shallow waters of the estuary. Recreational drop-net fishers have more fishers in the estuary, but generally stay close to their gear and pull the nets frequently.

10.6 Broader Environment



10.6.1 *Air quality*

10.6.1.1 *Fuel exhaust*

Risk Rating: Cumulative impact of fuel exhaust from fishing vessels in the Peel-Harvey Estuarine Fishery on air quality (C1×L2 = NEGLIGIBLE)

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

Risk Rating: Impact of fuel exhaust from recreational drop net fishing vessels in the Peel-Harvey Estuary on air quality (C1×L2 = NEGLIGIBLE)

Risk Rating: Impact of fuel exhaust from recreational scoop net fishing vessels in the Peel-Harvey Estuary on air quality (C1×L1 = NEGLIGIBLE)

- Fishing vessels operating in the Peel-Harvey Estuarine Fishery utilise fuel and emit exhaust fumes.
- All commercial fishing vessels in the Peel-Harvey Estuary have transitioned from two-stroke to more efficient four-stroke motors, reducing the amount of exhaust being emitted.

- There are substantially more recreational than commercial fishing vessels in the estuary and thus the likelihood of any measurable impact of fuel exhaust on air quality was considered slightly greater than the other sectors.
- The majority of recreational scoop net fishing occurs from the shore rather than from vessels.

10.6.1.2 *Greenhouse gas emissions*

Risk Rating: Cumulative impact of greenhouse gas emissions from fishing vessels in the Peel-Harvey Estuarine Fishery on air quality (C1×L1 = NEGLIGIBLE)

- Fishing vessels operating in Peel-Harvey Estuary utilise fuel and emit greenhouse gas.

10.6.2 *Water quality*

10.6.2.1 *Debris/litter*

Risk Rating: Cumulative impact of debris/litter from fishing in the Peel-Harvey Estuarine Fishery on water quality (C2×L2 = LOW)

Risk Rating: Impact of debris/litter from commercial fishing in the Peel-Harvey Estuary on water quality (C1×L1 = NEGLIGIBLE)

Risk Rating: Impact of debris/litter from recreational drop net fishing in the Peel-Harvey Estuary on water quality (C1×L4 = LOW)

Risk Rating: Impact of debris/litter from recreational scoop net fishing in the Peel-Harvey Estuary on water quality (C2×L2 = LOW)

- Fishing vessels operating in Peel-Harvey Estuary have the potential to reduce water quality through discarding of debris and litter.
- The commercial crab fishing sector do not use packaged bait for their traps and undertake only short fishing trips, reducing the likelihood of littering in this fishery.
- Recreational fishers may use packaged bait for drop nets and there have been issues with scoop-net fishers leaving litter and waste behind at some remote sites around the estuary.

10.6.2.2 *Oil/fuel discharge*

Risk Rating: Cumulative impact of oil/fuel discharge from fishing vessels in the Peel-Harvey Estuarine Fishery on water quality (C1×L3 = LOW)

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

Risk Rating: Impact of oil/fuel discharge from recreational drop net fishing vessels in the Peel-Harvey Estuary on water quality (C1×L3 = LOW)

Risk Rating: Impact of oil/fuel discharge from recreational scoop net fishing vessels in the Peel-Harvey Estuary on water quality (C1×L1 = NEGLIGIBLE)

- Fishing vessels operating in Peel-Harvey Estuary have the potential to reduce water quality through oil and fuel spills.
- All commercial vessels have transitioned from two-stroke to more efficient four-stroke motors and re-fuelling does not occur when the vessels are in the water.
- There are substantially more recreational than commercial fishing vessels in the estuary and thus the likelihood of any measurable impact of oil/fuel discharge on water quality was considered slightly greater than the other sectors.
- The majority of recreational scoop net fishing occurs from the shore rather than from vessels.

11.0 Risk Evaluation & Treatment

This risk assessment has assisted in the identification and evaluation of the different types of ecological risks associated with the Peel-Harvey Estuarine Fishery. Different levels of risk have different levels of acceptability, with different requirements for monitoring and reporting, and management actions (see Table 9.1 for a summary). Risks identified as negligible or low are considered acceptable, requiring either no or periodic monitoring, and no specific management actions. Issued identified as medium risk are considered acceptable providing there is specific monitoring, reporting, and management measures are implemented. Risks identified as high are considered 'not desirable', requiring strong management actions or new control measures to be introduced in the near future. Severe risks are considered 'unacceptable' with major changes to management required in the immediate future (Fletcher et al. 2002).

Thirty issues associated with the ecological sustainability of the Peel-Harvey Estuarine Fisheries were scored cumulatively for risk (Table 11.1), noting that some were also scored separately for sectors and methods. The majority (21) of these issues were evaluated as low or negligible risks, which do not require any specific control measures (as per Fletcher et al. 2002; Table 9.1). There were 7 medium risks, which were assessed as acceptable under current monitoring and control measures already in place (i.e. no new management actions are required). This risk category mostly included retained species, where this level corresponds to the stock being above the threshold level and thus being sustainably fished.

The risk assessment yielded two high risks that require further control measures, to be determined following a review process initiated by the harvest strategies for these resources (DPIRD 2020a, b). The capture and retention of Perth herring in the commercial net fishery was considered a high risk, given the inherent vulnerability of this anadromous species to fishing pressure and indications from available data that the total mortality in the Peel-Harvey Estuary is three times greater than that of the unfished stock in the Swan River. A high risk score was also given to the migratory and threatened shorebird species that inhabit estuary during the summer months, when there is potential for feeding and roosting birds to be disturbed by recreational scoop net fishers (and other recreational activities) in key areas of overlap.

It is recommended that the risks be reviewed in 5 years, or prior to the next review of the harvest strategy for the swimmer crab and estuarine and nearshore finfish resources in south-west WA, where the risk scores are used as the performance indicator for the non-target ecological assets. Monitoring and assessment of the key target species will be ongoing, with the performance indicators for those stocks evaluated on an annual basis.

Table 11.1. Summary of scores across each risk issue scored cumulatively in the 2020 risk rating of the Peel-Harvey Estuarine Fishery.

	Component	Risk Score					Total
		Negligible	Low	Medium	High	Severe	
Ecological Sustainability	Retained Species	1	2	5	1	-	**9**
	Bycatch Species	1	2	-	-	-	**3**
	ETP species	3	1	2	1	-	**7**
	Habitats	1	2	-	-	-	**3**
	Ecosystem Structure	1	3	-	-	-	**4**
	Broader Environment	2	2	-	-	-	**4**
Total		**9**	**12**	**7**	**2**	**0**	**30**

12.0 References

Bellchambers, L., Sumner, N. and Melville-Smith, R. (2005). Development of stock allocation and assessment techniques in Western Australia blue swimmer crab fisheries. Report to the FRDC on Project No. 2001/068. Department of Fisheries, WA. 205 pp.

Birdlife WA (2019). Shorebird disturbance on the Peel-Harvey Estuary. Birdlife WA. 52 pp.

Bradby, K. (1997). Peel-Harvey: the decline and rescue of an ecosystem. Greening the Catchment Taskforce (Inc.), Mandurah, WA. 223 pp.

Brearley, A. (2005). Ernest Hodgkin’s Swanland: Estuaries and Coastal Lagoons of South-western Australia. University of Western Australia Press, Perth. 550pp

Chaplin, J.A. and Sezmiş, E. (2008). A genetic assessment of the relationships among the assemblages of the blue swimmer crab, *Portunus pelagicus*, in Cockburn Sound, the Swan River Estuary and Warnbro Sound. Report prepared for the Department of Fisheries, WA. Murdoch University, WA.

Chubb, C.F., Potter, I.C. (1984). The reproductive biology and estuarine movements of the gizzard shad, *Nematalosa vlaminghi* (Munro). Journal of Fish Biology 5: 527-543.

Chubb, C.F., Potter, I.C. (1986). Age, growth and condition of the Perth herring, *Nematalosa vlaminghi* (Munro) (Dorosomatinae), in the Swan Estuary, south-western Australia. Australian Journal of Marine and Freshwater Research 37: 105-112.

Cottingham, A., Huang, P., Hipsey, M.R., Hall, N.G., Ashworth, E., Williams, J., Potter, I.C. (2018). Growth, condition and maturity schedules of an estuarine fish species change in estuaries following increased hypoxia due to climate change. *Ecology and Evolution* 8: 7111-7130.

Coulson, P. G., Hesp, S. A., Potter, I. C., and Hall, N. G. (2005). Comparisons between the biology of two co-occurring species of whiting (Sillaginidae) in a large marine embayment. *Environ. Biol. Fishes* 73: 125–139.

Crisafulli, B. (2008). Biology of two fish species of mullet (Mugilidae) in five estuaries on the south coast of Western Australia, Honours thesis, School of Biological Sciences. Murdoch University, WA. 121 pp.

Cronin-O'Reilly, S., Valesini, F., Hallett, C. (2019). Assessing the health of the Peel-Harvey Estuary through its benthic invertebrate fauna. Balancing estuarine and societal health in a changing environment, ARC Linkage Project LP150100451. Murdoch University, WA.

Desfosses, C., Adams, P., Blight, S., Smallwood, C., Taylor, S. (2019). The feasibility of using remotely piloted aircraft systems (RPAS) for recreational fishing surveys in Western Australia. Fisheries Occasional Publication No. 137. DPIRD, WA. 39 pp.

Department of Primary Industries and Regional Development (DPIRD) (2018). Octopus Resource of Western Australia Harvest Strategy. Fisheries Management Paper No. 286. DPIRD, WA.

DPIRD (2020a). Estuarine and Nearshore Finfish Resource of South-West Western Australia Harvest Strategy 2020-2025. Fisheries Management Paper No. 303. DPIRD, WA.

DPIRD (2020b). Blue Swimmer Crab Resource of South-West Western Australia Harvest Strategy 2020-2025. Fisheries Management Paper No. 304. DPIRD, WA.

Earl, J., Duffy, R., Conron, S., Moore, B. (2018). Yelloweye mullet. In: Status of Australian fish stocks reports 2018, Carolyn Stewardson, James Andrews, Crispian Ashby, Malcolm Haddon, Klaas Hartmann, Patrick Hone, Peter Horvat, Stephen Mayfield, Anthony Roelofs, Keith Sainsbury, Thor Saunders, John Stewart, Simon Nicol and Brent Wise (eds.). Fisheries Research and Development Corporation, Canberra.

Edgar, G. J. (1997). Australian marine life: the plants and animals of temperate waters. Reed Books, Melbourne.

Fletcher, W. (2005). Application of qualitative risk assessment methodology to prioritise issues for fisheries management. *ICES Journal of Marine Research* 62: 1576-1587.

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

Fletcher, W., Chesson, J., Sainsbury, K., Fisher, M., Hundloe, T., Whitworth, B. (2002). Reporting on Ecologically Sustainable Development: A "how to guide" for fisheries in Australia. Canberra, Australia. 120 pp.

Fletcher, W.J., Shaw, J., Metcalf, S.J., Gaughan, D.J. (2010). An ecosystem based fisheries management framework: the efficient, regional-level planning tool for management agencies. *Marine Policy* 34: 1226-1238.

Fletcher, W.J., Gaughan, D.J., Metcalf, S.J., and Shaw, J. (2012). Using a regional level, risk based framework to cost effectively implement Ecosystem Based Fisheries Management (EBFM). In: Global progress on Ecosystem-Based Fisheries Management (G.H. Kruse, H.I. Browman, K.L. Cochrane, D. Evans, G.S. Jamieson, P.A. Livingston, D. Woodby, C. Ik Zhang eds.). Fairbanks: Alaska Sea Grant College Programme pp. 129-146.

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

FRDC. (2020). Nets. http://www.fish.gov.au/fishing-methods/nets. Last accessed July 14, 2020.

Froese, R., Demirel, N., Coro, G., Kleisner, K. Winker, H. (2016). Estimating fisheries reference points from catch and resilience. *Fish and Fisheries* 18(3): 506–526.

Gaughan, D., Ayvazian, S., Nowara, G. and Craine, M. (2006). The development of a rigorous sampling methodology for a long-term annual index of recruitment for finfish species from south-western Australia, Fisheries Research and Development Corporation Project 1999/153, Fisheries Research Report 154, Department of Fisheries, WA.

Haddon, M., Punt, A., Burch, P. (2018). simpleSA: A package containing functions to facilitate relatively simple stock assessments. R package version 0.1.18.

Hale, J. and Butcher, R. (2007). Ecological Character Description of the Peel-Yalgorup Ramsar Site, Report to the Department of Environment and Conservation and the Peel-Harvey Catchment Council, Perth, WA.

Hallett, C., Hobday, A., Tweedley, J., Thompson, P., McMahon, K. and Valesini, F. (2018). Observed and Predicted Impacts of Climate Change on the Estuaries of South-Western Australia, a Mediterranean Climate Region. *Regional Environmental Change* 18(5): 1357-1373.

Hallett, C., Valesini, F., Yeoh, D. (2019). Assessing the health of the Peel-Harvey Estuary through its fish communities. Balancing estuarine and societal health in a changing environment, ARC Linkage Project LP150100451. Murdoch University, WA.

Hart, A.M., Murphy, D.M., Harry, A.V. and Fisher, E.A. (2018). Western Australian Marine Stewardship Council Report Series No. 14: Resource Assessment Report Western Australian Octopus Resource. DPIRD, WA. 114 pp.

Hodgkin, E. and Hesp, P. (1998). Estuaries to Salt Lakes: Holocene Transformation of the Estuarine Ecosystems of South-Western Australia. *Marine & Freshwater Research* 49(3): 183–201

Hotbite. (2012). How to catch blue manna crabs. Last accessed 6 June 2014 from: http://www.hotbite.com.au/content/fishing_articles_wa/?artid=21&thePage=3.

Hyndes, G. A., and Potter, I. C. (1997). Age, growth and reproduction of *Sillago schomburgkii* in south-western Australian, nearshore waters and comparisons of life history styles of a suite of *Sillago* species. Environ. Biol. *Fishes* 49: 435–447.

Johnston, D., Chandrapavan, A., Wise, B., Caputi N. (2014). Assessment of blue swimmer crab recruitment and breeding stock levels in the Peel-Harvey Estuary and status of the Mandurah to Bunbury Developing Crab Fishery. Fisheries Research Report No. 258. Department of Fisheries, WA, 172 pp.

Johnston, D.J., Smith, K.A., Brown, J.I., Travaille, K.L., Crowe, F., Oliver, R.K., and Fisher, E.A. (2015). Western Australian Marine Stewardship Council Report Series No. 3: West Coast Estuarine Managed Fishery (Area 2: Peel-Harvey Estuary) & Peel-Harvey Estuary Blue Swimmer Crab Recreational Fishery. Department of Fisheries, WA. 284pp.

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

Joll, L.M. (1976). Mating, egg-laying and hatching of *Octopus tetricus* (Mollusca: Cephalopoda) in the laboratory. *Marine Biology* 36(4): 327-333.

Jones, A.A., Hall, N.G., Potter, I.C. (2010) Species compositions of elasmobranchs caught by three different commercial fishing methods off southwestern Australia, and biological data for four abundant bycatch species. Fishery Bulletin 108: 365-381.

Kailola, P.J., Williams, M.J., Stewart, P.C., Reichelt, R.E., McNee, A., Grieve, C. (1993). Australian Fisheries Resources. Bureau of Resource Sciences, Department of Primary Industries and Energy, and the FRDC, Canberra, Australia.

Krumholz, O. (2019). Macrophyte communities in the Peel-Harvey Estuary: Historical trends and current patterns in biomass and distribution. Honours Thesis, Murdoch University, WA.

Lai, E., Hall, N., Telfer, C., Eyres, J. & Wise, B. (2014). Recreational surveys of catch and effort for blue swimmer crabs in the Peel-Harvey Estuary. In: Assessment of blue swimmer crab recruitment and breeding stock levels in the Peel-Harvey Estuary and status of the Mandurah to Bunbury Developing Crab Fishery, Johnston, D., Chandrapavan, A., Wise, B. & Caputi N. (eds.), Fisheries Research Report No. 258. Department of Fisheries, WA, pp. 70-105.

Last, P.R., Stevens, J.D. (2009). Sharks and rays of Australia. CSIRO Publishing, Collingwood, Victoria.

Malseed, B.E. & Sumner, N.R. (2001) A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99. Fisheries Research Report No. 127. Department of Fisheries, WA, 48 pp.

Mandurah Licenced Fishermen's Association (MLFA) (2008). Environmental Management System: A voluntary, industry-driven, environmental initiative. OceanWatch; WAFIC; SeaNet.

McComb, A. and Humphries, R. (1992). Loss of Nutrients from Catchments and Their Ecological Impacts in the Peel-Harvey Estuarine System, Western Australia. Estuaries 15 (4): 529.

Pedretti, Y.M., Kobryn, H.T., Sommerville, E.F., Wienczugow, K. (2011). Snapshot Survey of the Distribution and Abundance of Seagrass and Macroalgae in the Peel-Harvey Estuary from November/December 2009. Report to Department of Water. Institute for Environmental Science (Report No. MAFRA 11/1), Marine and Freshwater Research Laboratory, Murdoch University.

Potter, I., Veale, L., Tweedley, J. and Clarke, K. (2016). Decadal Changes in the Ichthyofauna of a Eutrophic Estuary Following a Remedial Engineering Modification and Subsequent Environmental Shifts. *Estuarine, Coastal and Shelf Science* 181: 345-363.

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

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

Ryan, K.L., Hall, N.G., Lai, E.K., Smallwood, C.B., Taylor, S.M., Wise, B.S. (2017). Statewide survey of boat-based recreational fishing in Western Australia 2015/16. Fisheries Research Report No. 287, DPIRD, WA.

Ryan, K.L., Hall, N.G., Lai, E.K., Smallwood, C.B., Tate, A., Taylor, S.M., Wise, B.S. (2019). Statewide survey of boat-based recreational fishing in Western Australia 2017/18. Fisheries Research Report No. 297, DPIRD, WA.

Sezmiş, E. (2004). The population genetic structure of *Portunus pelagicus* in Australian waters. PhD thesis, Murdoch University, WA.

Smith, K. and Grounds, G. (2019). West Coast Nearshore and Estuarine Finfish Resource Status Report 2018. In: Status Reports of the Fisheries and Aquatic Resources of Western Australia 2016/17: The State of the Fisheries, D.J. Gaughan, B. Molony and K. Santoro (eds.). DPIRD, WA. pp. 45-53.

Smith, K. and Grounds, G. (2020). West Coast Nearshore and Estuarine Finfish Resource Status Report 2019. In: Status Reports of the Fisheries and Aquatic Resources of Western Australia 2018/19: The State of the Fisheries, D.J. Gaughan, and K. Santoro (eds.). DPIRD, WA. pp. 53-62.

Smith, K.A., Dowling, C.E. and Brown, J. (2019). Simmered Then Boiled: Multi-Decadal Poleward Shift in Distribution by a Temperate Fish Accelerates During Marine Heatwave. *Front. Mar. Sci.* 6: 407. doi: 10.3389/fmars.2019.00407

Steer, M. and Smith, K. (2018). Yellowfin whiting. In: Status of Australian fish stocks reports 2018, Carolyn Stewardson, James Andrews, Crispian Ashby, Malcolm Haddon, Klaas Hartmann, Patrick Hone, Peter Horvat, Stephen Mayfield, Anthony Roelofs, Keith Sainsbury, Thor Saunders, John Stewart, Simon Nicol and Brent Wise (eds.). Fisheries Research and Development Corporation, Canberra.

Stewart, J., Prosser, A., Smith, K. (2018). Sea mullet. In: Status of Australian fish stocks reports 2018, Carolyn Stewardson, James Andrews, Crispian Ashby, Malcolm Haddon, Klaas Hartmann, Patrick Hone, Peter Horvat, Stephen Mayfield, Anthony Roelofs, Keith Sainsbury, Thor Saunders, John Stewart, Simon Nicol and Brent Wise (eds.). Fisheries Research and Development Corporation, Canberra.

Taylor, S.M., Blight, S.J., Desfosses, C.J., Steffe, A.S., Ryan, K.L., Denham, A.M. and Wise, B.S., (2018). Thermographic cameras reveal high levels of crepuscular and nocturnal shore-based recreational fishing effort in an Australian estuary. I*CES Journal of Marine Science* 75(6): 2107-2116.

Valesini, F., Coen, N., Wildsmith, M., Hourston, M., Tweedly, J., Hallett, C., . . . and Potter, I. (2009). Relationships between fish faunas and habitat type in south-western Australian estuaries. FRDC Final Report Project 2004/045. Murdoch University, WA.

Valesini, F., Hourston, M., Wildsmith, M., Coen, N., Potter, I. (2010). New quantitative approaches for classifying and predicting local-scale habitats in estuaries. *Estuarine, Coastal and Shelf Science* 86: 645-664.

Valesini, F., Hallett, C., Hipsey, M., Kilminster, K., Huang, P. and Henning, K. (2019). Peel-Harvey Estuary, Western Australia. In: Coasts and Estuaries. The Future, Wolanski, E., Day, J., Elliott, M. and Ramachandran, R. (eds.), pp. 103–120. Burlington: Elsevier

Veale, L. J., (2013). Inter-period comparisons of the ichthyofaunas of two nearby, modified estuaries and the biology of *Pelates octolineatus* (Terapontidae). PhD thesis, Murdoch University, WA. 260 pp.

Walker, T. I., Stevens, J. D., Braccini, J. M., Daley, R. J., Huveneers, C., Irvine, S. B., Bell, J. D., Tovar- Ávila, J., Trinnie, F. I., Phillips, D. T., Treloar, M. A., Awruck, C. A., Gason, A. S., Salini, J., and Hamlett, W. C. (2008). Rapid assessment of sustainability for ecological risk of shark and other chondrichthyans bycatch species taken in the Southern and Eastern Scalefish and Shark Fishery. Final report to Fisheries Research and Development Corporation Project No. 2002/033. (July 2008.) 354 + v pp. (Fisheries Research Brand: Queenscliff, Victoria, Australia)

Wildsmith, M., Harvey, M., Valesini, F., McDonald, A., Bivoltsis, A. (2008). Classifying shallow water benthic habitats in the Swan Marine Region. Final Report. Murdoch University, WA. 60 pp.

Wilson, C., Hale, J. and Paling, E. (1999). Macrophyte Abundance, Distribution and Composition of the Peel-Harvey Estuary: Comparison before and after the Opening of the Dawesville Channel (July 1985 to June 1999). MAFRA 99/5. Murdoch University, WA.

Wise, B.S. and Molony, B.W. (Editors). 2018. Australian Herring and West Australian Salmon Scientific Workshop Report, October 2017. Fisheries Research Report No. 289 Department of Primary Industries and Regional Development, WA. 158 pp.

Young, G. and Potter, I. (2003). Do the characteristics of the ichthyoplankton in an artificial and natural entrance channel of a large estuary differ? *Estuarine, Coastal and Shelf Science* 56: 765-779.

Young, G. (2000). The fish fauna of two south-western Australian estuaries: influence of an artificial entrance channel and of hypersalinity and prolonged closure. PhD Thesis, Murdoch University, WA.

Appendix A

Retained catches in the commercial haul and gill net fishery (separated by method)

Table 1. Retained catches (tonnes) in the Peel-Harvey Estuary haul net fishery between 2015 and 2019, and proportions of the total retained catch.

Species	Retained catch (tonnes)						% of total retained
	2015	2016	2017	2018	2019	Average	
Sea Mullet	79.9	84.6	95.4	100.4	80.7	88.2	70%
Yellowfin Whiting	26.4	19.0	12.2	11.6	15.7	17.0	13%
Yelloweye Mullet	4.9	11.1	10.7	10.4	9.6	9.3	7%
Australian Herring	2.6	3.1	3.8	5.4	6.3	4.2	3%
Tailor	6.2	1.3	1.1	2.6	2.3	2.7	2%
Perth Herring	2.5	2.8	3.3	2.5	1.9	2.6	2%
King George Whiting	0.4	0.8	0.1	1.6	1.8	0.9	1%
Whitings, other	0.1	0.8	0.4	0.3	1.4	0.6	0.5%
Trevallies	1.1	0.8	0.4	0.3	0.2	0.5	0.4%
Estuary Cobbler	0.4	0.3	0.1	0.5	0.2	0.3	0.2%
Australian Sardine	0.2	0.1	0	0	0	0.1	0.04%
Common Silverbiddy	0.02	0.1	0.002	0.01	0.04	0.03	0.02%
Silver Trevally	0.08	0	0	0	0	0.02	0.01%
Flatheads	0.01	0.01	0.02	0.01	0.02	0.01	0.01%
Black Bream	0	0.02	0.003	0.02	0	0.008	0.01%
Southern Garfish	0.005	0	0	0	0.002	0.001	<0.01%
Squid	0	0	0	0	0.01	0.001	<0.01%
General Fish	0	0	0.005	0	0	0.001	<0.01%
Leatherjackets	0	0	0	0	0.005	0.001	<0.01%
Flounders	0	0	0	0	0.003	0.001	<0.01%
Total	124.7	124.8	127.4	135.6	120.2	126.5	

Table 2. Retained catches (tonnes) in the Peel-Harvey Estuary gill net fishery between 2015 and 2019, and proportions of the total retained catch.

Species	Retained catch (tonnes)						% of total retained
	2015	2016	2017	2018	2019	Average	
Sea Mullet	11.1	1.8	5.2	2.4	0.8	4.2	55%
Estuary Cobbler	0.9	0.9	1.8	1.2	0.01	0.9	12%
Yelloweye Mullet	0.9	0.3	2.0	0.8	0.0	0.8	11%
Yellowfin Whiting	3.2	0	0.5	0.1	0.1	0.8	10%
Perth Herring	0.0	0	1.1	1.0	0	0.4	5%
Australian Herring	0.1	0	0.4	0.7	0.2	0.3	4%
Tailor	0.1	0	0.04	0.8	0.02	0.2	3%
Black Bream	0.01	0	0.03	0	0	0.1	0.1%
Flatheads	0	0	0.01	0	0	0.002	0.03%
King George Whiting	0.01	0	0.005	0	0	0.002	0.03%
Trevallies	0.01	0	0	0	0	0.001	0.01%
Flounders	0	0	0	0.002	0	0.0004	0.01%
Total	16.3	3.0	11.1	6.9	1.1	7.7	

Appendix B

Exploration of area use by waterbirds in the Peel-Harvey Estuary

E.A. Fisher

August 2020

Introduction

The Peel-Harvey Estuary, as part of the broader Peel-Yalgorup system, is listed as a Ramsar wetland of international importance (Hale and Butcher 2007). The listed site covers more than 26,000 hectares, including the shallow estuarine waters of the Peel Inlet and Harvey Estuary, and a number of adjacent saline, brackish and freshwater lakes and marshes (Peel-Harvey Catchment Council 2009). Although large sections of the shoreline have been cleared for agriculture and urban developments, parts remain fringed by samphire vegetation, rushes and sedges (Hale and Kobryn 2009). The wetlands support a large number of waterbirds, including many migratory shorebird species (Hale and Butcher 2007). Some of these populations are showing signs of decline globally, with habitat loss in key stopover areas in the Yellow Sea identified as a key threat to several species (Bamford et al. 2008; Studds et al. 2017).

Resident waterbird species can be observed in the Peel-Harvey Estuary all year round, with more than 10 species recorded breeding within the system (Hale and Butcher 2007). Migratory species visit the region during summer after undertaking a journey of many thousands of kilometres from their breeding grounds in Siberia, along the East Asian-Australasian Flyway (EAAF, Figure 1). They typically arrive at staging areas in northern Australia around September before dispersing across coastal and freshwater wetlands (Weller and Warren 2017). The highly productive Peel-Yalgorup system provides vital feeding and roosting habitats to more than 20 species of migratory shorebirds during their non-breeding season, enabling them to build sufficient energy reserves needed for their northbound return migration in March. Human-induced disturbance resulting from recreational activities, including boating and fishing, has the potential to impact roosting birds and prevent effective foraging (e.g. Paton et al. 2000; Lilleyman et al. 2016; Melville et al. 2016).

Australia has some of the most comprehensive shorebird monitoring within the EAAF (Weller and Warren 2017) and surveys have been undertaken regularly in the Peel-Yalgorup region since the mid-1970s (Lane and Pearson 2002). More recently, Australian shorebird monitoring has been coordinated by Birdlife Australia through the Shorebird 2020 program (Weller and Warren 2017). Bird counts are mostly undertaken by experienced volunteers, with professional support provided for education, training and database maintenance. Across Australia, there are more than 3000 count areas aggregated into 464 broader shorebird areas (Weller and Warren 2017). The Peel-Yalgorup represents one of these shorebird areas, in which an annual summer count has been undertaken since 2008.

To ensure adequate protection of the habitats within the Peel-Yalgorup system and minimise the impact on shorebirds of disturbance by recreational activities, there is a need to better understand how different species use these areas. The key aims of this study were to explore the broad patterns of habitat use by shorebirds and identify any areas of particular importance to these species in the Peel-Harvey Estuary, which is a popular destination for recreational boating, fishing and crabbing.

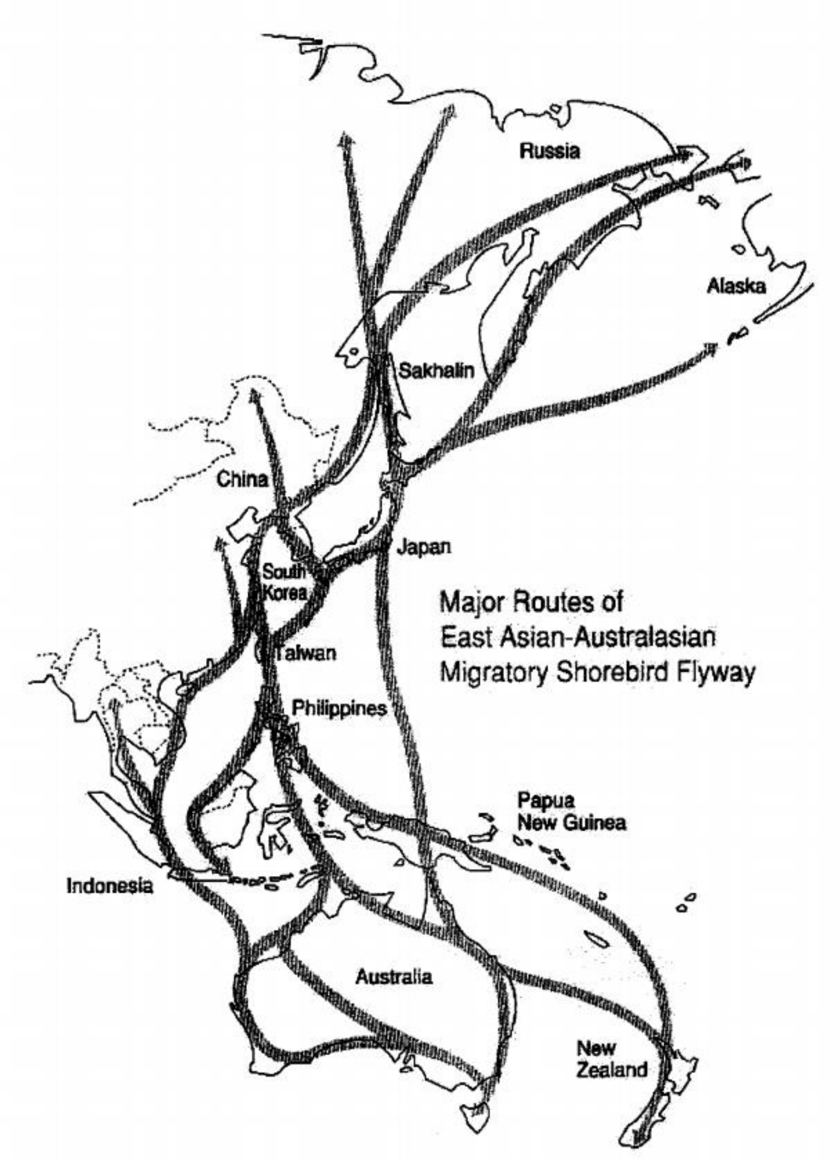


Figure 1. The East Asian-Australasian Flyway (Source: Milton 2003).

Methods

Shorebird 2020 count data for the Peel-Yalgorup system were acquired from Birdlife Western Australia's Peel Branch. The data comprised annual counts of waterbirds between 2008 and 2019, typically undertaken in January or February at a number of fixed sites (count areas) within the system. As movements of migratory shorebirds to other non-breeding sites during this time are likely minimal, the counts are considered to provide a reasonable representation of the number of birds available for detection in the Peel-Yalgorup.

Bird counts in most of the areas within the Peel-Yalgorup system have been conducted on the same day or within a couple of days in each year to minimise the effect on counts of any local movements between roosts. However, as the counts in some areas have occasionally been undertaken up to a few weeks after the other areas were counted, the total number of individuals of each species counted annually need to be interpreted with caution. Also, as the tidal and weather conditions on count days can influence the number of birds present, any observed changes in abundance of species between years may not provide an accurate indicator of population trends. As such, the data were mainly used in this study to explore any patterns in the spatial distribution of waterbirds across the different count areas over the 12-year sampling period.

The different count areas within the Peel-Yalgorup data set were largely consistent between years, although some have not been sampled annually. In the majority of years, bird counts have been conducted in 28 areas, of which 16 are within the Peel-Harvey Estuary (Table 2, Figure 2). Some of the count areas have been slightly modified over time since the survey started in 2008. For example, bird counts in Area 2B have recently been separated into ‘west’ and ‘islands’ but were grouped together in most earlier sampling years. To ensure consistency, count data from these smaller sub-areas were merged into the broader count area prior to analysis.

Table 2. Areas in which bird counts were organised for analyses. See also Figure 2.

Area	Name	Habitat type	No. of years sampled
1A	Point Robert	Estuary (Coastal)	12
1B	Manjar Bay	Estuary	10
2A	Soldiers Cove	Estuary	9
2B	Mandurah Channel & Estuary Islands	Estuary	12
2C	Creery Wetlands	Estuary	11
3	Coodanup to Nairns	Estuary	12
4	Erskine	Estuary	10
5	Yunderup	Estuary	9
6A	Austin Bay	Estuary	12
6B	Boggy Bay	Estuary	9
7A	Roberts Bay	Estuary	10
7B	Point Grey	Estuary	5
8	East Harvey (Mealup Point to Herron Point)	Estuary	11
9A	Bouvard (East Port north to Dampier Avenue)	Estuary	11
9B	West Harvey (Island Point north to Dawesville Cut)	Estuary	8
10A	Herron Point South	Estuary	10
10B	Harvey River Delta to Island Point	Estuary	11
11A	Lake Mealup	Inland – Freshwater	8
11B	Lake McLarty	Inland – Freshwater	6
12	Yalgorup Northern Lakes	Inland – Saltwater	11
13	Yalgorup Middle Lakes	Inland – Saltwater	9
14A	Lake Preston West	Inland – Saltwater	10
14B	Lake Preston East	Inland – Saltwater	9
14C	Lake Preston South	Inland – Saltwater	1
15A	Goegrup Lake	Inland – Freshwater	11
15B	Black Lake	Inland – Freshwater	11
16	Nambeelup	Inland – Freshwater	12
17	Barragup Swamp	Inland – Freshwater	5

Figure 2. Approximate location and boundaries of individual count areas in the Peel-Harvey Estuary and adjacent lakes within the northern part of the broader Peel-Yalgorup wetlands system. See also Table 2.

To obtain a broad overview of the shorebird species found in the Peel-Yalgorup wetlands and better understand the importance of the different areas within the system to these birds, the total counts of species recorded in the data set were first summarised. Secondly, the spatial distributions of waterbird species across the different count areas were evaluated, with particular focus on the Peel-Harvey Estuary (Areas 1A to 10B, see Table 2).

As it was not feasible in this study to plot the spatial distribution of each bird species that has been counted in the Peel-Yalgorup system since 2008, the second component of analyses focused on 22 key species considered of most interest (Table 3). This selection was initially based on 14 species where at least 1% of the total population is supported by the Peel-Yalgorup system; a benchmark used by Bamford and others (2008) in a report on migratory shorebirds in the EAAF. It also represents a criteria considered by the Ramsar Convention when classifying wetlands as internationally important (Hansen et al. 2016). A number of less abundant migratory species were later added to the list, including the common greenshank, eastern curlew, bar-tailed and black-tailed godwits and four migratory plover species.

Table 3. Key waterbird species considered in analyses of spatial distribution patterns within the Peel-Yalgorup wetlands, and their current global and Australian conservation status.

Common Name	Species Name	Global status (IUCN)	Australian status (EPBC)
Australasian shoveler	*Anas rhynchotis*	Least Concern	Not Assessed
Australian shelduck	*Tadorna tadornoides*	Least Concern	Not Assessed
Banded stilt	*Cladorhynchus leucocephalus*	Least Concern	Not Assessed
Bar-tailed godwit*	*Limosa lapponica menzbieri*	Near Threatened	Critically Endangered
Black-tailed godwit*	*Limosa limosa*	Near Threatened	Not Assessed
Black-winged stilt	*Himantopus himantopus*	Least Concern	Not Assessed
Common greenshank*	*Tringa nebularia*	Least Concern	Not Assessed
Curlew sandpiper*	*Calidris ferruginea*	Near Threatened	Critically Endangered
Eastern curlew*	*Numenius madagascariensis*	Endangered	Critically Endangered
Eurasian coot	*Fulica atra*	Least Concern	Not Assessed
Fairy tern	*Sternula nereis*	Vulnerable	Vulnerable
Greater sand plover*	*Charadrius leschenaultii*	Least Concern	Vulnerable
Grey plover*	*Pluvialis squatarola*	Least Concern	Not Assessed
Grey teal	*Anas gracilis*	Least Concern	Not Assessed
Hooded plover	*Thinornis rubricollis*	Vulnerable	Not Assessed
Lesser sand plover*	*Charadrius mongolus*	Least Concern	Endangered
Musk duck	*Biziura lobate*	Least Concern	Not Assessed
Pacific golden plover*	*Pluvialis fulva*	Least Concern	Not Assessed
Red-capped plover	*Charadrius ruficapillus*	Least Concern	Not Assessed
Red-necked avocet	*Recurvirostra novaehollandiae*	Least Concern	Not Assessed
Red-necked stint*	*Calidris ruficollis*	Near Threatened	Not Assessed
Sharp-tailed sandpiper*	*Calidris acuminata*	Least Concern	Not Assessed

* Listed as migratory species under the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA), and the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)

A review of the available literature and the Shorebird 2020 data was undertaken to summarise the conservation status, distribution and ecological characteristics of each key waterbird species to better understand their potential vulnerabilities to disturbance by fishing activities within the Peel-Harvey Estuary. This review considered the broader distribution and abundance of the species, the importance of the Peel-Harvey Estuary, with regards to the numbers counted annually, estuary use (relative to areas outside the estuary) and spatial distribution within the estuary.

Results

Overview of data

More than 530,000 waterbirds have been counted in the broader Peel-Yalgorup system as part of the Shorebird 2020 program between 2008 and 2019 (Table 5). Over the 12 years of sampling, 84 different species have been recorded, with between 45 and 61 species observed each year. Just under a third of the species observed in the system over this time are listed as migratory shorebirds. The remainder comprise a wide range of resident waterbird species, including ducks, grebes, pelicans, cormorants, herons, egrets, gulls and terns.

Based on the total number of birds counted in all areas and years, the most commonly observed species in the Peel-Yalgorup between 2008 and 2019 were the banded stilt, grey teal, red-necked stint, silver gull, Australian shelduck and the black swan (Table 5). *These six species collectively comprise 67% of birds observed during the survey period.* Most of the species recorded in the survey have only been observed occasionally, with 66 of the 84 species collectively representing only 4.5% of the total bird counts in the data set.

Although not all individual count areas in the broader Peel-Yalgorup system were surveyed in all years (see Table 2), approximately half (54%) of all birds counted over the sampling period were observed within the Peel-Harvey Estuary (Areas 1A-10B), with the remainder counted in the inland freshwater and saline lakes to the south and east of the estuary (Table 6). Bird counts in the Peel-Harvey Estuary comprised 76 different species, with eight species only counted outside the estuary.

The most important area in terms of total bird counts was the eastern Peel Inlet, with 25% of birds observed in Austin Bay (Area 6A) and Boggy Bay (Area 6B) (Table 6). Other important areas within the Peel-Harvey Estuary include the Harvey Estuary Delta (Area 10B) and the Mandurah Channel and nearby Estuary Islands (Area 2B), constituting 7 and 5% of total counts, respectively. Outside the estuary, the most important areas included the Yalgorup Lakes (Areas 12 and 13; 16% of counts), Lake Preston (Areas 14A-C; 15% of counts) and Lake McLarty (Area 11B; 7% of bird counts).

Table 5. Total counts of waterbird species observed in the Peel-Yalgorup system between 2008 and 2019, and their relative contribution to the overall bird count.

Common name	Species name	Total number of birds counted (2008-2019)	Percentage of total bird count
Banded stilt	*Cladorhynchus leucocephalus*	98,318	18.3%
Grey teal	*Anas gracilis*	57,110	10.6%
Red-necked stint	*Calidris ruficollis*	54,292	10.1%
Silver gull	*Chroicocephalus novaehollandiae*	52,833	9.8%
Australian shelduck	Tadorna tadornoides	49,778	9.3%
Black swan	*Cygnus atratus*	49,313	9.2%
Black-winged stilt	*Himantopus himantopus*	26,801	5.0%
Sharp-tailed sandpiper	Calidris acuminata	25,211	4.7%
Pacific black duck	*Anas superciliosa*	19,663	3.7%
Little pied cormorant	*Microcarbo melanoleucos*	13,726	2.6%
Red-capped plover	*Charadrius ruficapillus*	12,521	2.3%
Australian pelican	*Pelecanus conspicillatus*	12,324	2.3%
Little black cormorant	*Phalacrocorax sulcirostris*	11,077	2.1%
Pied cormorant	*Phalacrocorax varius*	9,380	1.7%
Red-necked avocet	*Recurvirostra novaehollandiae*	5,528	1.0%
Hoary-headed grebe	*Poliocephalus poliocephalus*	4,315	0.8%
Australian white ibis	*Threskiornis moluccus*	3,113	0.6%
White-faced heron	*Egretta novaehollandiae*	2,804	0.5%
Common greenshank	*Tringa nebularia*	2,633	0.5%
Eastern great egret	*Ardea modesta*	2,097	0.4%
Caspian tern	*Hydroprogne caspia*	1,997	0.4%
Crested tern	*Thalasseus bergii*	1,790	0.3%
Fairy tern	Sternula nereis	1,443	0.3%
Little egret	*Egretta garzetta*	1,279	0.2%
Australian wood duck	*Chenonetta jubata*	1,235	0.2%
Australasian darter	*Anhinga novaehollandiae*	1,112	0.2%
Yellow-billed spoonbill	*Platalea flavipes*	994	0.2%
Eurasian coot	*Fulica atra*	860	0.2%
Musk duck	*Biziura lobate*	856	0.2%
Australasian shoveler	*Anas rhynchotis*	767	0.1%
Hooded plover (western)	Thinornis rubricollis tregellasi	677	0.1%
Grey plover	Pluvialis squatarola	617	0.1%
Red-kneed dotterel	*Erythrogonys cinctus*	565	0.1%
Bar-tailed godwit	Limosa lapponica	516	0.1%
Pink-eared duck	*Malacorhynchus membranaceus*	472	0.1%
Curlew sandpiper	*Calidris ferruginea*	376	0.1%
Pied oystercatcher	*Haematopus longirostris*	351	0.1%
Straw-necked ibis	*Threskiornis spinicollis*	344	0.1%
Unidentified		*4,547*	*0.9%*
Other species		*3,119**	*0.6%*
Total		536,754	

*Cumulative count of all other species, each which comprised <0.1% of total counts.

Table 6. Total counts of waterbirds in each count area of the Peel-Yalgorup system between 2008 and 2019. Note that not all areas have been counted in all 12 sampling years (see Table 2).

Area	Name	Total number of birds counted (2008-2019)	Percentage of total bird count
6A	Austin Bay	107,147	20.0%
13	Yalgorup Middle Lakes	67,229	12.5%
14A	Lake Preston West	52,939	9.9%
11B	Lake McLarty	38,721	7.2%
10B	Harvey River Delta to Island Point	36,266	6.8%
6B	Boggy Bay	27,388	5.1%
2B	Mandurah Channel & Estuary Islands	25,840	4.8%
14B	Lake Preston East	23,734	4.4%
15A	Goegrup Lake	19,765	3.7%
12	Yalgorup Northern Lakes	19,650	3.7%
8	East Harvey (Mealup Point to Herron Point)	12,954	2.4%
2C	Creery Wetlands	12,557	2.3%
3	Coodanup to Nairns	12,122	2.3%
15B	Black Lake	11,998	2.2%
4	Erskine	11,022	2.1%
10A	Herron Point South	10,715	2.0%
7A	Roberts Bay	8,935	1.7%
5	Yunderup	7,538	1.4%
11A	Lake Mealup	6,123	1.1%
14C	Lake Preston South	5,594	1.0%
16	Nambeelup	3,648	0.7%
1B	Manjar Bay	3,437	0.6%
9A	Bouvard (East Port north to Dampier Avenue)	2,764	0.5%
9B	West Harvey (Island Point north to Dawesville Cut)	2,679	0.5%
7B	Point Grey	2,405	0.4%
2A	Soldiers Cove	1,717	0.3%
1A	Point Robert	1,664	0.3%
17	Barragup Swamp	203	0.04%
Total		536,754	

Spatial distribution of key waterbirds

The banded stilt, grey teal and red-necked stint were the most commonly-counted of the key waterbird species within the Peel-Harvey Estuary (Areas 1A-10B) over the 12-year sampling period (Table 7). Conversely, the Australasian shoveler, musk duck and the Eastern curlew were among the least commonly-encountered waterbirds in the estuary, with no hooded plovers counted within the estuarine waters during the sampling period (Table 7). While some of the rarer species (Eastern curlew and godwits) were almost exclusively counted within the Peel-Harvey Estuary, others (Australasian shoveler and musk duck) were more commonly counted in areas outside the estuary (Table 7).

The spatial distribution of the key waterbirds within the Peel-Harvey Estuary varied among species (Figures 3, 4). While the majority of species occurred in most areas around the estuary, others appeared more restricted in their habitat use. Examples of species that were primarily counted within the estuary but were relatively rare and were found in only a few areas of the estuary included the curlew sandpiper and Eastern curlew (Table 7; Figure 3).

Review of potential vulnerabilities of key waterbird species to fishing

A summary of the review undertaken to better understand the potential vulnerabilities of the key waterbird species to disturbance by fishing activities within the Peel-Harvey Estuary is provided in Table 8.

Table 7. Percentage of overall counts of key waterbird species/groups (Table 5) observed within the estuary (Areas 1A-10B) and the total counts these species in the Peel-Harvey Estuary between 2008 and 2019. Species or groups with species listed as migratory are highlighted in grey.

Common Name	Species Name	Percentage of overall counts in the Peel-Harvey Estuary	Total count of birds in the Peel-Harvey Estuary (2008-2019)
Australasian shoveler	*Anas rhynchotis*	0.4%	3
Australian shelduck	*Tadorna tadornoides*	27%	13,588
Banded stilt	*Cladorhynchus leucocephalus*	44%	43,521
Black-winged stilt	*Himantopus himantopus*	52%	14,006
Common greenshank	*Tringa nebularia*	87%	2,299
Curlew sandpiper	*Calidris ferruginea*	67%	252
Eastern curlew	*Numenius madagascariensis*	100%	108
Eurasian coot	*Fulica atra*	20%	170
Fairy tern	*Sternula nereis*	76%	1,091
Bar-tailed godwit	*Limosa lapponica,*	99%	513
Black-tailed godwit	*Limosa limosa*	74%	34
Grey teal	*Anas gracilis*	53%	30,377
Hooded plover	*Thinornis rubricollis*	0%	-
Musk duck	*Biziura lobate*	6%	50
Plovers, migratory	*Pluvialis fulva*, *P. squatarola*, *Charadrius leschenaultia,* *C. mongolus*	95%	757
Red-capped plover	*Charadrius ruficapillus*	38%	4,718
Red-necked avocet	*Recurvirostra novaehollandiae*	39%	2,147
Red-necked stint	*Calidris ruficollis*	45%	24,494
Sharp-tailed sandpiper	*Calidris acuminata*	77%	19,462

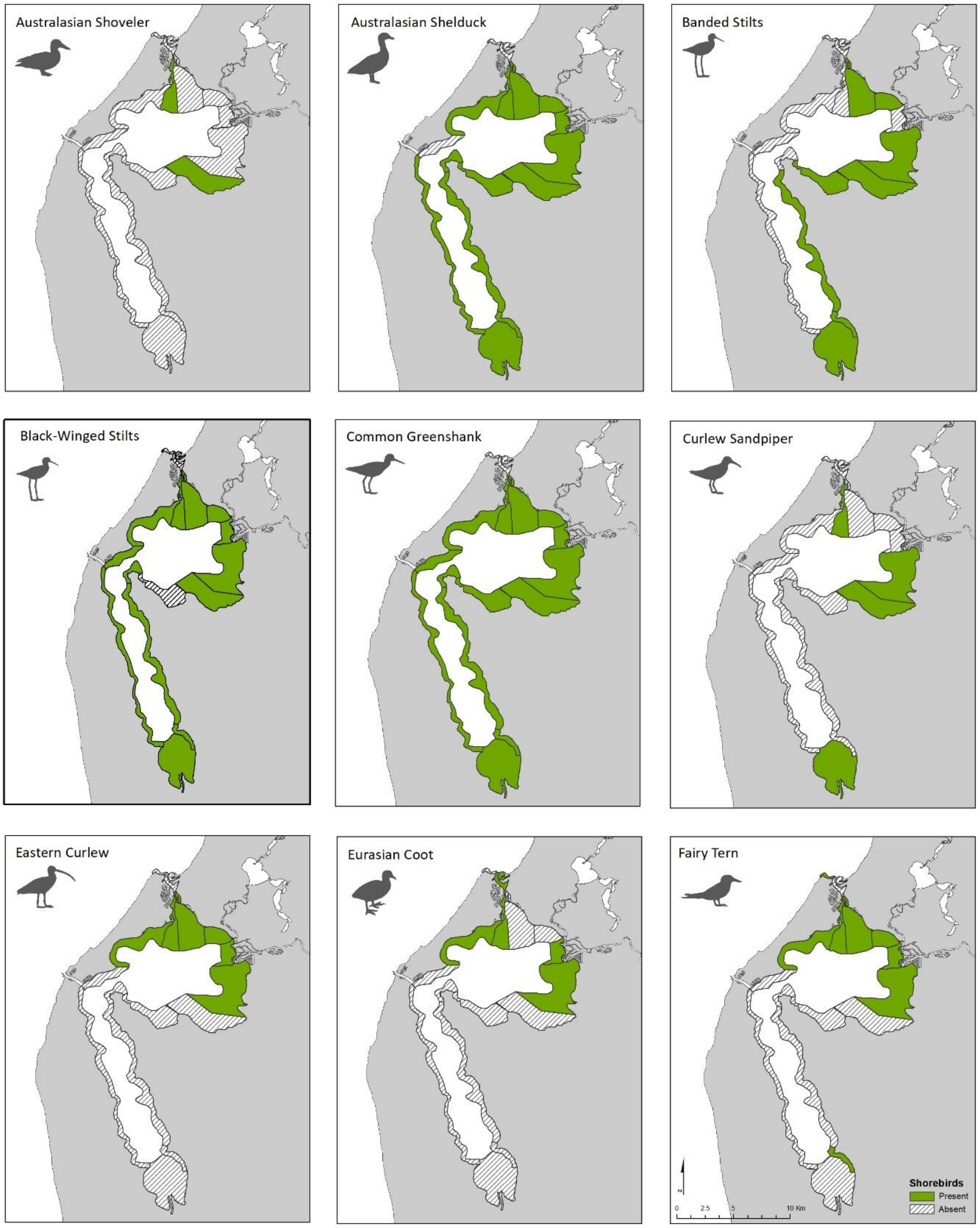


Figure 3. Areas (in green) in which key waterbird species and groups have been counted in the Peel-Harvey Estuary during the annual Shorebird 2020 surveys undertaken between 2008 and 2019. Note, the remainder of the species are shown in Figure 4.

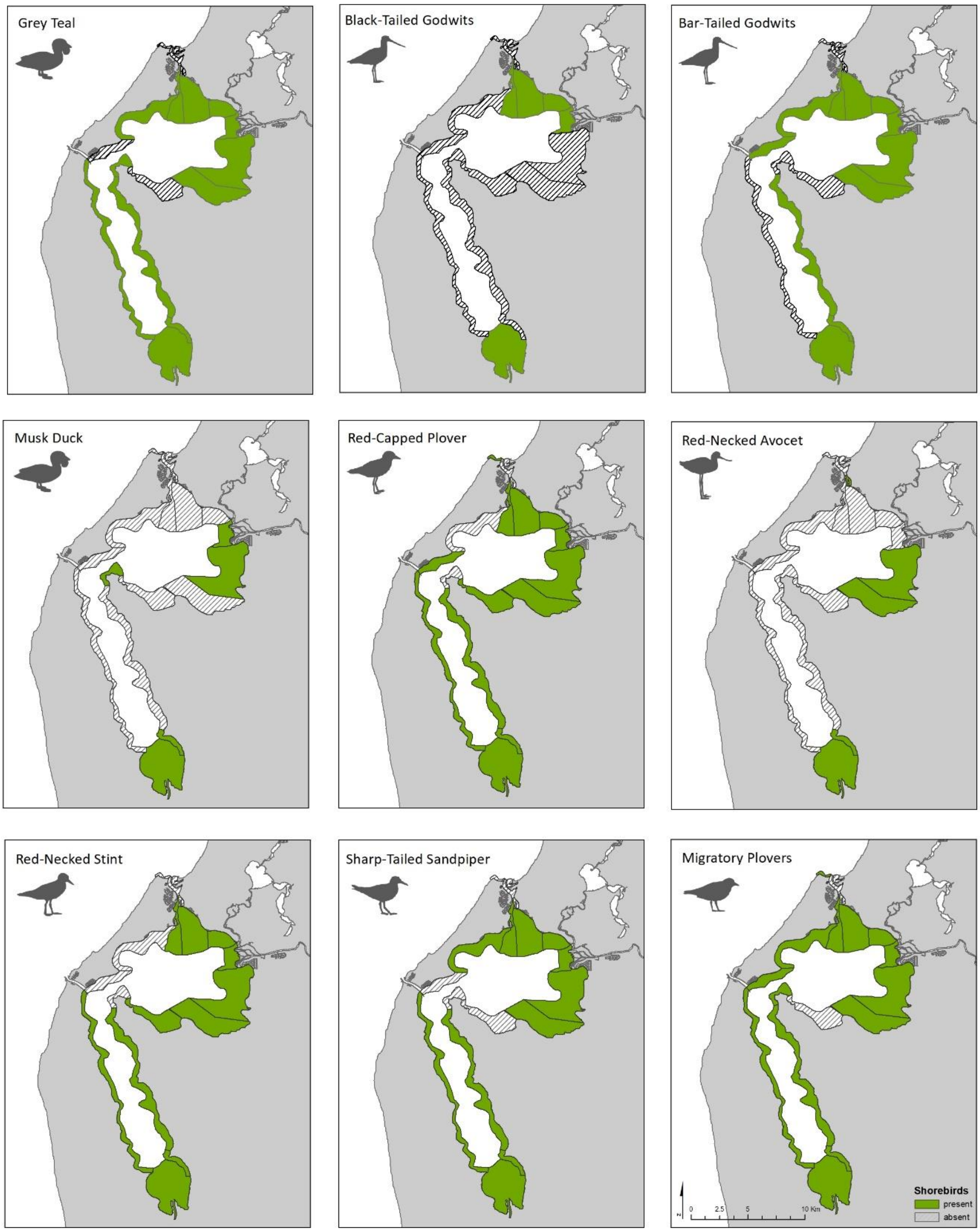


Figure 4. Areas (in green) in which key waterbird species and groups have been counted in the Peel-Harvey Estuary during the annual Shorebird 2020 surveys undertaken between 2008 and 2019. Note, the remainder of the species are shown in Figure 3.

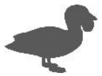
Table 8. Summary of information for determining the impact of disturbance of recreational boating and fishing activities in the Peel-Harvey Estuary on key waterbird species. Footnotes with relevant references are listed below the table.

Species	Population distribution and abundance	Ecological characteristics (in Australia)	Annual count range in Peel-Yalgorup (2008-2019)	Reliance on estuary within Peel-Yalgorup	Spatial distribution within estuary
Migratory, threatened shorebirds					
Bar-tailed godwit 	325,000 estimated in the EAAF, of which close to 190,000 migrate to Australia[1]. Occur along the coast, especially in the north and east[2].	Occur on muddy coastlines, in estuaries, inlets, mangrove-fringed lagoons and sheltered bays[2]. Feed on annelids, bivalves and crustaceans[2].	5-133 individuals	99% in estuary	Counted in 11 of areas, mostly in 3, 2B and 10B
Curlew sandpiper 	90,000 estimated in the EAAF, of which close to 70,000 spend non-breeding season in Australia[1]. Most abundant in far south-east and north-west[2].	Inhabits coastal brackish lagoons, mud and sand flats, estuaries, saltmarshes and inland[2]. Feeds on small marine invertebrates, especially polychaete worms[2].	0-135 individuals	67% in estuary	Counted in 4 of areas, mostly in 6A
Eastern curlew 	35,000 estimated in the EAAF, of which 26,000 spend non-breeding season in Australia[1]. Widespread in coastal regions of the north-east and south, including Tasmania, and scattered in other coastal areas[2].	Found in estuaries, mangroves, saltmarshes and intertidal flats, often with beds of seagrass[2]. Feed on marine invertebrates, especially crabs and molluscs[2].	3-14 individuals	100% in estuary	Counted in 7 of areas, mostly in 2B, 2C and 6A
Greater sand plover 	200,000-300,000 estimated in EAAF, of which 120,000 migrate to Australia[1]. Occur along all the Australian coast, especially in north[2].	Found on sheltered sandy, shelly or muddy beaches or saltmarshes[2]. Feed on marine invertebrates such as molluscs, worms and crustaceans[2].	0-41 individuals	78% in estuary	Counted in 4 of areas, mostly in 10A and 6A
Lesser sand plover 	Estimated 180,000-275,000 in EAAF, of which 27,000 migrate to Australia[1]. Occur along the Australian coast in summer, particularly in the east[2].	Inhabit mud and sand flats of coastal bays and estuaries, feeding on insects, crustaceans, molluscs and polychaete worms[2].	0-2 individuals	100% in estuary	Counted in 2 of areas; 6A and 8

Species	Population distribution and abundance	Ecological characteristics (in Australia)	Annual count range in Peel-Yalgorup (2008-2019)	Reliance on estuary within Peel-Yalgorup	Spatial distribution within estuary
Migratory, non-threatened shorebirds					
Black-tailed godwit 	Estimated 160,000 in EAAF, with 47,000 estimated to migrate to Australia[1]. Non-breeding birds occur throughout Australia, especially along the coasts in the north[2].	Inhabit sheltered bays, estuaries, lagoons and coastal wetlands[2]. Feed on invertebrates such as worms, insects and crustaceans[2].	0-14 individuals	74% in estuary	Counted in 5 of areas, mostly in 3 and 2B
Common greenshank 	Estimated 110,000 in EAAF, with around 20,000 migrating to Australia[1]. Common throughout in Australia in summer[3]. Sites of particular importance in WA include Eighty Mile Beach, Roebuck Bay and Wilson Inlet[4].	Occurs both on the coast and inland, in estuaries and mudflats, mangroves and lagoons[3]. Feed on insects, worms, molluscs, small fish and crustaceans[3].	70-400 individuals	87% in estuary	Counted in 15 of areas, mostly in 6A and 6B
Grey plover 	Estimated 80,000 in EAAF, of which 12,000 migrate to Australia[1]. Occurs around coastal Australia, with large numbers at sites in both south and north[2].	Inhabits intertidal mud and sand flats, saltmarshes and beaches, feeding on polychaete worms, molluscs and crustaceans[2].	21-97 individuals	96% in estuary	Counted in 13 of areas, mostly in 10B and 2B
Pacific golden plover 	Estimated 120,000 in EAAF, of which 9,000 migrate to Australia[1]. Widespread along the Australian coast[5].	Occur on muddy, sandy and rocky wetlands, shores, saltmarshes, estuaries and lagoons[5]. Feed on molluscs, worms and crustaceans[5].	0-35 individuals	94% in estuary	Counted in 4 of areas, mostly in 2C and 2B
Red-necked stint 	Estimated 475,000 in EAAF, of which 270,000 migrate to Australia[1]. Widely distributed along Australian coast[6].	Inhabit sheltered bays, inlets, lagoons, estuaries and intertidal mudflats[6]. Feed on seeds, insects, small vertebrates, plants, molluscs, gastropods and crustaceans[6].	1,881-6,191 individuals	45% in estuary	Counted in 11 of areas, mostly in 6A and 10B
Sharp-tailed sandpiper 	Estimated 85,000 in EAAF, of which most (74,000) migrate to Australia[1]. Common especially to the south-east[7].	Inhabits muddy edges of shallow, fresh or brackish wetlands[7]. Occupy coastal mudflats once terrestrial wetlands have dried out[7]. Feeds on seeds, worms, molluscs, crustaceans and insects[7].	146-6,015 individuals	77% in estuary	Counted in 11 of areas, mostly in 6A and 6B

Species	Population distribution and abundance	Ecological characteristics (in Australia)	Annual count range in Peel-Yalgorup (2008-2019)	Reliance on estuary within Peel-Yalgorup	Spatial distribution within estuary
Other resident shorebirds					
Banded stilt 	Endemic to Australia, found mainly in the south and inland[16]. May move to the coast or nearby when the arid inland is dry[16]. Population range and size is large and appears stable[17].	Found mainly in saline and hypersaline (very salty) waters of the inland and coast[16]. Feed on crustaceans, molluscs, insects, vegetation, seeds and roots[16]. Breed only in the arid inland, after rain or flooding[16].	0-39,202 individuals	44% in estuary	Counted in 9 of areas, mostly in 6A and 6B
Black-winged stilt 	Has a large global range and population size[18]. Widespread on the Australian mainland[18].	Inhabit freshwater and saltwater marshes, mudflats and the shallow edges of lakes and rivers[19]. Feed mainly on aquatic insects, as well as molluscs and crustaceans[19]. Nest may comprise a simple shallow scrape on the ground or a mound of vegetation placed in or near the water[19].	225-4,355 individuals	52% in estuary	Counted in 14 of areas, mostly in 6A, 2C and 10B
Fairy tern 	Occurs in Australia, New Zealand and New Caledonia[8]. Found along the Australian coast from the Dampier Archipelago in the north-west, southward to Tasmania and Victoria[8]. Most common in WA where there are around 3,000 mature individuals[9].	Inhabits coastal beaches, inshore and offshore islands, sheltered inlets, sewage farms, harbours, estuaries and lagoons[8]. Feeds mostly on fish caught by plunging into shallow water[8]. Breeds in colonies, with the nest a shallow scrape in sand[8].	0-307 individuals	76% in estuary	Counted in 9 of areas, mostly in 2B, 2C and 6A
Hooded plover 	Endemic to Australia, with relatively small populations in the south-west and south-east[10]. A census in 1995 found around 2,000 birds in WA, of which half were found on the Esperance Lakes[11].	Occurs on ocean beaches and next to inland lakes[2]. Nests on upper levels of beaches, sand dunes and on lake shores[2]. Feed on polychaetes, molluscs and crustaceans[2].	7-107 individuals	0% in estuary	Not counted in estuary

Species	Population distribution and abundance	Ecological characteristics (in Australia)	Annual count range in Peel-Yalgorup (2008-2019)	Reliance on estuary within Peel-Yalgorup	Spatial distribution within estuary
Red-capped plover 	Most common and widespread of Australia's beach-nesting shorebirds[26]. Distributed along the entire coastline and also occur inland, especially around salt lakes[26]. Estimated population size is very large, however, trend is uncertain[27].	Found on wide, bare sand and mudflats at the margins of saline, brackish or freshwater wetlands[26]. Feed on molluscs, small crustaceans as well as vegetation[26]. Nest site is a shallow scrape on a beach or stony area close to water[26].	214-1,811 individuals	38% in estuary	Counted in 13 of areas, mostly in 6A and 6B
Red-necked avocet 	Endemic to Australia, where it is widely distributed throughout the mainland[28]. Breeds mainly in the south-western interior[28]. Estimated population size very large but appears to be fluctuating[29].	Forage in shallow wetlands on aquatic insects and their larvae, crustaceans and seeds[28]. Breeds in loose colonies, with nests comprising shallow scrapes lined with water vegetation[28].	2-1,984 individuals	45% in estuary	Counted in 5 of areas, mostly in 10B and 6A
Other resident waterbirds (e.g. ducks)					
Australasian shoveler 	Distributed along the central and southern coasts of WA and most of eastern Australia, as well as New Zealand[12]. Population size is uncertain but appears stable[12].	Occur in all types of wetlands, preferring large undisturbed heavily vegetated freshwater swamps[13]. Filter feeds on insects, crustaceans and a variety of plants from the water[13]. Breeds in arid parts of the continent, synchronised with flooding rains[13].	0-484 individuals	<1% in estuary	Counted in 2 of areas; 2B and 6B
Australian shelduck 	Abundant in the south-western and south-eastern parts of Australia, as well as New Zealand[14]. The population size is very large and appears to be increasing[14].	Prefers freshwater habitats[15]. Feeds on green grass on land or in shallow water, and also eats algae, insects and molluscs[15]. Nest in a large tree hollow, well lined with down[15].	1,547-10,877 individuals	27% in estuary	Counted in 14 of areas, mostly in 6A and 10B
Eurasian coot 	Widely distributed from Eurasia to Indonesia, New Guinea and Australia. Found across Australia, but less common in the north and in the more arid regions[20]. Estimated population size is large (several millions) and appears to be increasing[21].	Found in vegetated lagoons and swamps, where they feed primarily on vegetable matter[20]. Breed at any time conditions are favourable, with nests either a floating raft of vegetation or built on tree stumps or logs surrounded by water[20].	0-270 individuals	20% in estuary	Counted in 5 of areas, mostly in 2B

Species	Population distribution and abundance	Ecological characteristics (in Australia)	Annual count range in Peel-Yalgorup (2008-2019)	Reliance on estuary within Peel-Yalgorup	Spatial distribution within estuary
Grey teal 	Abundant throughout Australia and capable of travelling vast distances in search of water[22]. Population size is estimated to be large (around 1 million) but appears to be decreasing[23].	Common to all sheltered fresh, brackish and salt water areas, feeding on dry land plants, aquatic plants, seeds, crustaceans, and insects and their larvae[22]. Most breeding takes place around inland waterways, with nests placed on the ground, in rabbit burrows or in tree hollows[22].	165-13,498 individuals	53% in estuary	Counted in 12 of areas, mostly in 6A, 6B and 10B
Musk duck 	Endemic to Australia, where it is distributed along the south-west and south-east coasts as well as inland areas[24]. Population size may be moderately small to large and appears to be decreasing[25].	Feed on animals, including aquatic insects, crustaceans, snails, shellfish, fish, frogs and ducklings[24]. Nest in a large cup of trampled vegetation, hidden in dense reeds[24].	0-318 individuals	6% in estuary	Counted in 5 of areas, mostly in 6A and 10B

[1] Hansen et al. (2016)
[2] Garnett et al. (2011)
[3] Birdlife (2020a)
[4] Watkins (1993)
[5] Birdlife (2020b)
[6] Birdlife (2020c)
[7] Higgins and Davies (1996)
[8] Australian Museum (2020)
[9] Birdlife International (2016a)
[10] Birdlife International (2019a)
[11] Birdlife (2020d)
[12] Birdlife (2020e)
[13] Birdlife International (2018)
[14] Birdlife International (2016b)
[15] Newbey (1996)
[16] Birdlife (2020f)
[17] Birdlife International (2016c)
[18] Birdlife (2020g)
[19] Birdlife International (2016d)
[20] Birdlife International (2016e)
[21] Birdlife (2020h)
[22] Birdlife International (2016f)
[23] Birdlife (2020i)
[24] Birdlife (2020j)
[25] Birdlife International (2019b)
[26] Birdlife (2020k)
[27] Birdlife International (2016g)
[28] Birdlife (2020l)
[29] Birdlife International (2016h)

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References

Australian Museum (2020). Banded stilt. https://australian.museum/learn/animals/birds/banded-stilt-cladorhynchus-leucocephalus/. Accessed 30 July 2020.

Bamford, M., Watkins, D., Bancroft, W., Tischler G., Wahl, J. (2008). Migratory Shorebirds of the East Asian - Australasian Flyway: Population estimates and internationally important sites. Department of the Environment, Water, Heritage and the Arts, Canberra.

Birdlife (2020a). Common greenshank. http://www.birdlife.org.au/bird-profile/common-greenshank. Accessed 30 July 2020.

Birdlife (2020b). Pacific golden plover. http://www.birdlife.org.au/bird-profile/pacific-golden-plover. Accessed 30 July 2020.

Birdlife (2020c). Red-necked stint. http://www.birdlife.org.au/bird-profile/red-necked-stint. Accessed 30 July 2020.

Birdlife (2020d). Black-winged stilt. http://birdlife.org.au/bird-profile/black-winged-stilt. Accessed 30 July 2020.

Birdlife (2020e). Fairy tern. http://www.birdlife.org.au/bird-profile/fairy-tern. Accessed 30 July 2020.

Birdlife (2020f). Red-capped plover. http://www.birdlife.org.au/bird-profile/red-capped-plover. Accessed 24 August 2020.

Birdlife (2020g). Red-necked avocet. http://www.birdlife.org.au/bird-profile/red-necked-avocet. Accessed 24 August 2020.

Birdlife (2020h). Australasian shoveler. http://birdlife.org.au/bird-profile/australasian-shoveler. Accessed 30 July 2020.

Birdlife (2020i). Australian shelduck. http://www.birdlife.org.au/bird-profile/australian-shelduck. Accessed 30 July 2020.

Birdlife (2020j). Eurasian coot. http://birdlife.org.au/bird-profile/eurasian-coot. Accessed 24 August 2020.

Birdlife (2020k). Grey teal. http://www.birdlife.org.au/bird-profile/grey-teal. Accessed 24 August 2020.

Birdlife (2020l). Musk duck. http://www.birdlife.org.au/bird-profile/musk-duck. Accessed 24 August 2020.

Birdlife International (2016a). *Cladorhynchus leucocephalus.* The IUCN Red List of Threatened Species 2016. https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22693709A93418535.en. Downloaded on 30 July 2020.

Birdlife International (2016b). *Thinornis cucullatus.* The IUCN Red List of Threatened Species 2016. https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22693883A93429190.en. Downloaded on 30 July 2020.

Birdlife International (2016c). *Charadrius ruficapillus.* The IUCN Red List of Threatened Species 2016. https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22693832A93425838.en. Downloaded on 24 August 2020.

Birdlife International (2016d). *Recurvirostra novaehollandiae.* The IUCN Red List of Threatened Species 2016. https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22693720A93419069.en. Downloaded on 24 August 2020.

Birdlife International (2016e). *Spatula rhynchotis.* The IUCN Red List of Threatened Species 2016. https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22680243A92852551.en. Downloaded on 30 July 2020.

Birdlife International (2016f). *Tadorna tadornoides.* The IUCN Red List of Threatened Species 2016. https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22680011A92838835.en. Downloaded on 30 July 2020.

Birdlife International (2016g). *Anas gracilis.* The IUCN Red List of Threatened Species 2016. https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22680271A92853108.en. Downloaded on 24 August 2020.

Birdlife International (2016h). *Biziura lobata.* The IUCN Red List of Threatened Species 2016. https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22679830A92831295.en. Downloaded on 24 August 2020.

Birdlife International (2018). *Sternula nereis*. The IUCN Red List of Threatened Species 2018. https://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T22694691A132568135.en. Downloaded on 30 July 2020.

Birdlife International (2019a). *Himantopus himantopus* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2019. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T22727969A155440465.en. Downloaded on 24 August 2020.

Birdlife International (2019b). *Fulica atra.* The IUCN Red List of Threatened Species 2019. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T22692913A154269531.en. Downloaded on 24 August 2020.

Garnett, S.T., Szabo, J.K. & Dutson, G. (2011). The Action Plan for Australia Birds 2010. Birds Australia, CSIRO Publishing, Melbourne.

Hale, J. and Butcher, R. (2007). Ecological Character Description of the Peel-Yalgorup Ramsar Site, Report to the Department of Environment and Conservation and the Peel-Harvey Catchment Council, Perth, WA.

Hale, J. and Kobryn, H. (2009). Peel-Yalgorup Ramsar wetlands monitoring: littoral and fringing vegetation mapping.

Hansen, B.D., Fuller, R.A., Watkins, D., Rogers, D.I., Clemens, R.S., Newman, M., Woehler, E.J., Weller, D.R. (2016) Revision of the East Asian-Australasian Flyway Population Estimates for 37 listed Migratory Shorebird Species. Unpublished report for the Department of the Environment. BirdLife Australia, Melbourne.

Higgins, P.J. and Davies, S.J.J.F. (eds.) (1996). Handbook of Australian, New Zealand and Antarctic Birds. Volume Three - Snipe to Pigeons. Melbourne, Victoria: Oxford University Press.

Lane, J.A.K. and Pearson, G.B. (2002). Waterbirds of Peel-Harvey Estuary in the Mid 1970s. Western Australian Department of Conservation and Land Management, Perth.

Lilleyman, A., Franklin, D.C., Szabo, J.K., Lawes, M.J. (2016). Behavioural responses of migratory shorebirds to disturbance at a high tide roost. *Emu* 116: 111-118.

Melville, D.S., Chen, Y. & Ma, Z. (2016). Shorebirds along the Yellow Sea coast of China face an uncertain future – a review of threats. *Emu* 116: 100-110

Milton, D. (2003). Threatened shorebird species of the East Asian-Australasian Flyway: significance of Australian wader study groups. *Bulletin* 100: 105-110.

Newbey, B.J. (1996). Report on hooded plover project. June 1994 to March 1996 RAOU (WA Group). Supplement to Western Australian Bird Notes No. 79, September 1996.

Peel-Harvey Catchment Council (2009). Peel-Yalgorup Ramsar Site Management Plan, Peel-Harvey Catchment Council, Mandurah.

Paton, D.C., Ziembicki, M., Owen, P. & Heddle, C. (2000). Disturbance Distances for Water Birds and the Management of Human Disturbance with special reference to the Coorong region of South Australia. Final report for the National Wetlands Program, Environment Australia, May 2000. By the Department of Environmental Biology, University of Adelaide, Adelaide.

Studds, C.E., Kendall, B.E., Murray, N.J., Wilson, H.B., Rogers, D.I., Clemens, R.S., Gosbell, K., Hassell, C.J., Jessop, R., Melville, D.S., Milton, D.A., Minton, C.D.T., Possingham, H.P., Riegan, A.C., Straw, P., Woehler, E.J., Fuller, R.A. (2017.) Rapid population decline in migratory shorebirds relying on Yellow Sea tidal mudflats as stopover sites. Nature Communications 8:14895, DOI: 10.1038/ncomms14895

Watkins, D. (1993). A national plan for shorebird conservation in Australia. RAOU Report Series. 90.

Weller, D.R. and Warren, C.V. (2017) Migratory Shorebird Conservation Action Plan, Birdlife Australia unpublished report, September 2017.

Appendix C

LIKELIHOOD LEVELS

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

CONSEQUENCE LEVELS

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

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

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

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

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

Appendix D

ERA workshop stakeholders

Invited

Guy Leyland	WAFIC
Don Nicholls	Southern Seafood Producers Association
Meegan Watts	Commercial fisher, President MLFA
Andrew Rowland	Recfishwest
Steve Fisher	Peel Harvey Catchment Council
Tom Lerner	Shire of Murray
Brett Brenchley	City of Mandurah
Malcolm Robb	DWER
Kerry Trayler	DBCA (Estuaries)
Alan Kendrick	DBCA (Marine Science)
Adrian Parker	Peel Development Commission
George Walley	Bindjareb Noongar Community Leader
Vicki Stokes	Birdlife WA
Neil Loneragan	Murdoch University
Matt Hipsey	UWA
Paul Lavery	Edith Cowan University
Nic Dunlop	Conservation Council of WA
Fiona Valesini	The Nature Conservancy
Matt Watson	MSC
Matt Robinson	Mandurah Cruises
Brent Wise	DPIRD (Aquatic Science and Assessment)
Lynda Bellchambers	DPIRD (Aquatic Science and Assessment)
Emily Fisher	DPIRD (Aquatic Science and Assessment)
Danielle Johnston	DPIRD (Aquatic Science and Assessment)
Rodney Duffy	DPIRD (Aquatic Science and Assessment)
Cameron Desfosses	DPIRD (Aquatic Science and Assessment)
Steve Taylor	DPIRD (Aquatic Science and Assessment)
Mat Hourston	DPIRD (Aquatic Science and Assessment)
Kim Smith	DPIRD (Aquatic Science and Assessment)
Tim Nicholas	DPIRD (Aquatic Resource Management)
Nick Blay	DPIRD (Aquatic Resource Management)
Shirree Blazeski	DPIRD (Aquatic Resource Management)
Ryan Smith	DPIRD (Compliance)
Jaymon Tonkin	DPIRD (Compliance)

Attended

Damien Bell	Commercial fisher
Aaron Moses	Recfishwest
Steve Fisher	Peel Harvey Catchment Council
Brett Brenchley	City of Mandurah
Frances D'Souza	DWER
Adrian Parker	Peel Development Commission
George Walley	Bindjareb Noongar Community Leader
Vicki Stokes	Birdlife WA
Neil Loneragan	Murdoch University
Brent Wise	DPIRD (Aquatic Science and Assessment)
Lynda Bellchambers	DPIRD (Aquatic Science and Assessment)
Emily Fisher	DPIRD (Aquatic Science and Assessment)
Danielle Johnston	DPIRD (Aquatic Science and Assessment)
Rodney Duffy	DPIRD (Aquatic Science and Assessment)
Cameron Desfosses	DPIRD (Aquatic Science and Assessment)
Steve Taylor	DPIRD (Aquatic Science and Assessment)
Mat Hourston	DPIRD (Aquatic Science and Assessment)
Kim Smith	DPIRD (Aquatic Science and Assessment)
Tim Nicholas	DPIRD (Aquatic Resource Management)
Nick Blay	DPIRD (Aquatic Resource Management)
Shirree Blazeski	DPIRD (Aquatic Resource Management)
Ryan Smith	DPIRD (Compliance)
Jaymon Tonkin	DPIRD (Compliance)