GOVERNMENT OF
WESTERN AUSTRALIA

Bindjareb Djilba

A plan for the protection of the Peel-Harvey estuary

Bindjareb means country and Djilba means estuary in the language of the Bindjareb Noongar people

Bindjareb Noongar baalap kaadadjan, Djilba Gabi ngalang Gabi Wonga. Nyitting yey, nidja yey, benang yey, ngalang Gabi Wonga boola moorditj. Nidja Wirrn Boodja Baalap kaadadjan, doyntj-doyntj koorl wer Noongar Dandjoo, ngalang kaaleepga. Ngalang Gabi waalang, ngalang wirrn waalang, ngalang Noongar waalang, ngalang koort waalang, ngalang kaaleepga waalang.

Bindjareb Noongar people's cultural knowledge about our estuary is our water story. From the creation time to the present time, to the future, our water story is a very amazing and important story. The interconnectedness of Spirit, Land and People brings together our cosmology, our sense of place, our homeland. Our waterway health is connected with our own health and wellbeing.

The Bindjareb Noongar people have looked after the Djilba for more than 50,000 years based on governance and lore. Bindjareb Noongar people have a continuing life commitment and cultural responsibility to the preservation of the Djilba and Bilya.

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Minister's message

The Peel-Harvey estuary is the largest and most diverse estuarine complex in south-western Australia – offering a unique and desirable lifestyle for surrounding communities as well as making it a key destination for tourism and recreation.

The Peel-Harvey Estuary Protection Plan (Bindjareb Djilba) is a whole-of-government approach to protecting the Peel-Harvey estuary and its internationally recognised values.

The proximity of the Peel-Harvey estuary to Perth has put this important asset under increasing strain over the decades, as agricultural and urban land has expanded. The estuary suffered an ecological collapse in the 1980s as a consequence of nutrient pollution, leading to a costly engineered intervention, the Dawesville Cut, to reset the ecosystem.

Good water quality and biodiverse water environments are essential precursors to sustainable urban and agricultural development.

In response to climate change and continued population growth, we all need to work together, across governments, industry and the community, to effectively manage this critically important estuary, and prevent similar environmental challenges in the future.

The Peel-Harvey Estuary Protection Plan (Bindjareb Djilba) provides a collaborative framework that will guide the protection of the system over the next 10 years.

We look forward to walking together on this journey with the Bindjareb Noongar and other estuary stakeholders as we work to protect the estuary's cultural, social, environmental and economic values.

Hon Dave Kelly, MLA
Minster for Water

Plan objective: The Peel-Harvey Estuary Protection Plan offers a blueprint of actions needed to protect and improve the water quality of the estuary so it may continue to support the community, ecology and economy of the region.

Estuary characteristics

The Peel-Harvey estuary is the largest inland waterbody in southern Western Australia, with an area of 133 km^2. It is made up of two shallow lagoons, with the deepest point (2 m) at the juncture of the two waterbodies. Shallow terraces, less than 0.5 m deep, fringe the estuary's shoreline and make up about 50 per cent of the total area. The estuary is permanently connected to the ocean via the narrow, 5 km-long Mandurah Channel and the Dawesville Cut, which was constructed in 1994.

Overview

Why do we need an Estuary Protection Plan?

The Peel-Harvey estuary is highly valued for its diverse and unique ecology, its recreational, aesthetic and tourism opportunities, its abundant fisheries and its rich cultural and spiritual connections. It is the largest and most complex estuarine system in the south-west.

In the 1970s and 1980s the estuary suffered an ecological collapse because of nutrient enrichment. The Dawesville Cut (opened in 1994 at a cost of $76 million) increased salinity in the system, making it less suitable to problem algae, and facilitated quick removal of river-delivered nutrients from the estuary. There was a dramatic improvement in water quality, leading to substantial investment in urban developments in the region. However, excess nutrients from agriculture remained unchecked. Also, large tracts of estuarine wetland habitat were lost with the development of canal estates, further reducing the ability of the estuary to process and remove nutrients. The additional pressures of urban development, intensification of agriculture and climate change continue to increase. Symptoms of poor estuary health include fish deaths, low-oxygen water and the proliferation of nuisance algae, which harms fishing, hospitality and tourism industries as well as affecting property values and the lifestyles of local communities.

It is time for a renewed focus on improving water quality in the Peel-Harvey estuary, building on the lessons of the past while exploring new and innovative ways of managing the competing demands on this system.

Taking action

This plan collates actions across the estuary and its catchment and asks for many groups to work together to protect the Peel-Harvey estuary for future generations. The plan offers an integrated approach to catchment management. It links to the 2008 Water Quality Improvement Plan (in revision), incorporates thinking from the Perth Peel @3.5 million assessments and builds on the experience delivering the Regional Estuaries Initiative. Actions are grouped into four work areas: Catchment; Estuary; Plans, Policy and Partnerships; and Measuring Progress.

Catchment actions (C) focus on reducing the loss of nutrients from the catchment. There is a suite of actions aimed at working with farmers for improved management of agricultural nutrients, both from diffuse sources (e.g. broad-scale agriculture) and point sources (e.g. feedlot effluent). We will work with industry and farmers to develop new codes of practice for intensive agriculture, horticulture and broadacre grazing that are innovative and cost-effective. The population of the Peel region is forecast to grow substantially over the coming decades, and it will be increasingly important to reduce urban nutrients entering the estuary from fertiliser application, septic systems, wastewater treatment plants, regulated industry discharge and stormwater. Larger-scale catchment actions aim to encourage revegetation and river restoration, and protect remaining patches of native vegetation and natural wetlands.

Estuary actions (E) include sustainably managing fish and crab stocks, mitigating recreation and tourism impacts and conserving foreshores and wetlands. We also need to better understand the environmental water requirements of the estuary, as well as how to best respond to the risks posed by climate change.

Plans, Policy and Partnerships actions (P) call for collective decision-making in the implementation of this plan and strategic coordination of estuary management. There is an emphasis on the link between land use planning decisions and water quality outcomes, with a suite of actions seeking to minimise the impact of future development on the estuary. The role of traditional owners is recognised, with several key actions aimed at supporting the Bindjareb Noongar people as active partners in estuary management.

Measuring progress actions (M) are based on an adaptive and iterative management framework to ensure we learn from experience and work towards continuous improvement. Investment in monitoring and science underpins our ability to evaluate the actions taken to protect the estuary. A cycle of review ensures these learnings are adopted into future plans.

The Department of Water and Environmental Regulation has led the development of this plan with a system stewardship focus – seeking to harness the capacity of all sectors to achieve long-term outcomes.

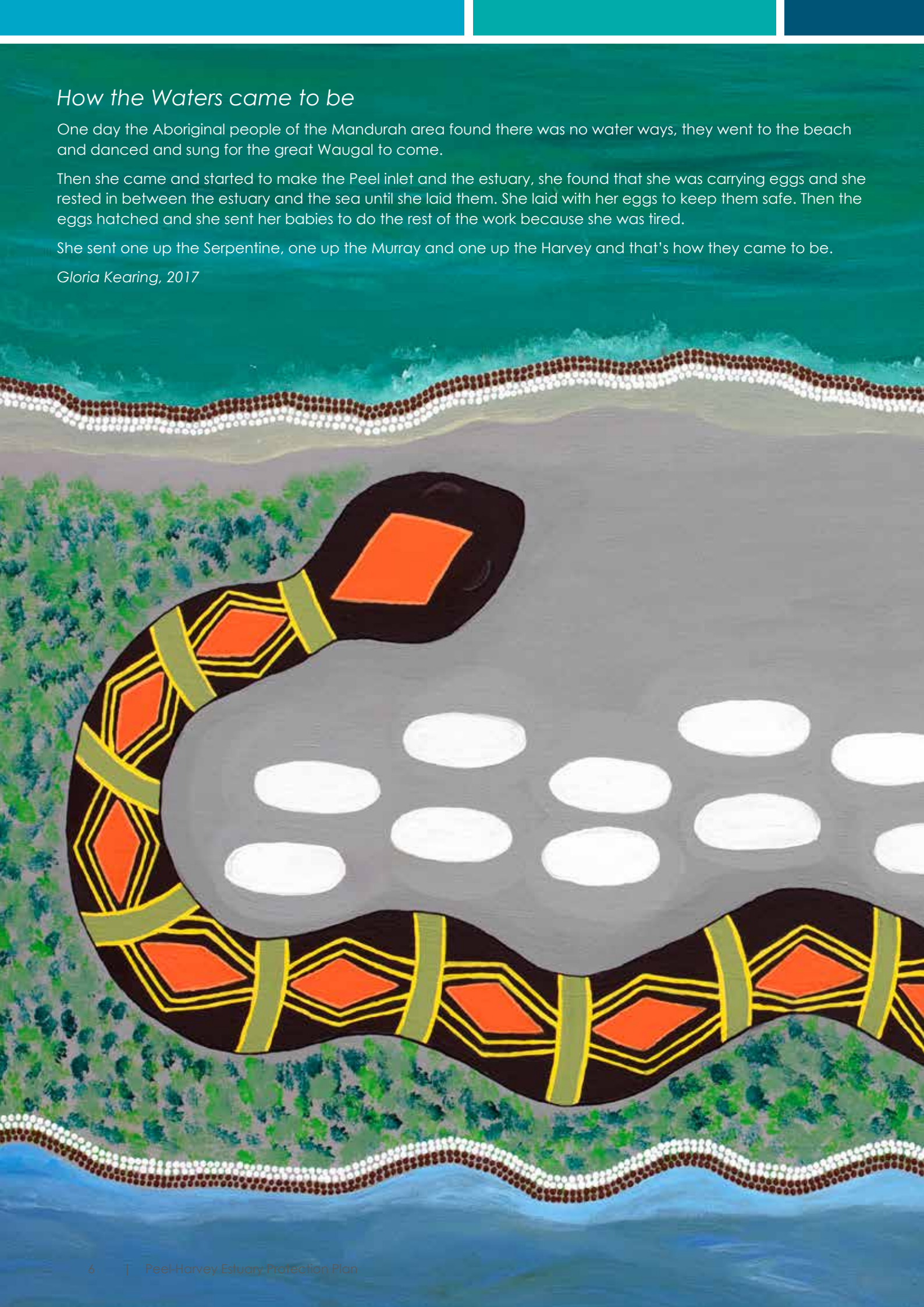
How the Waters came to be

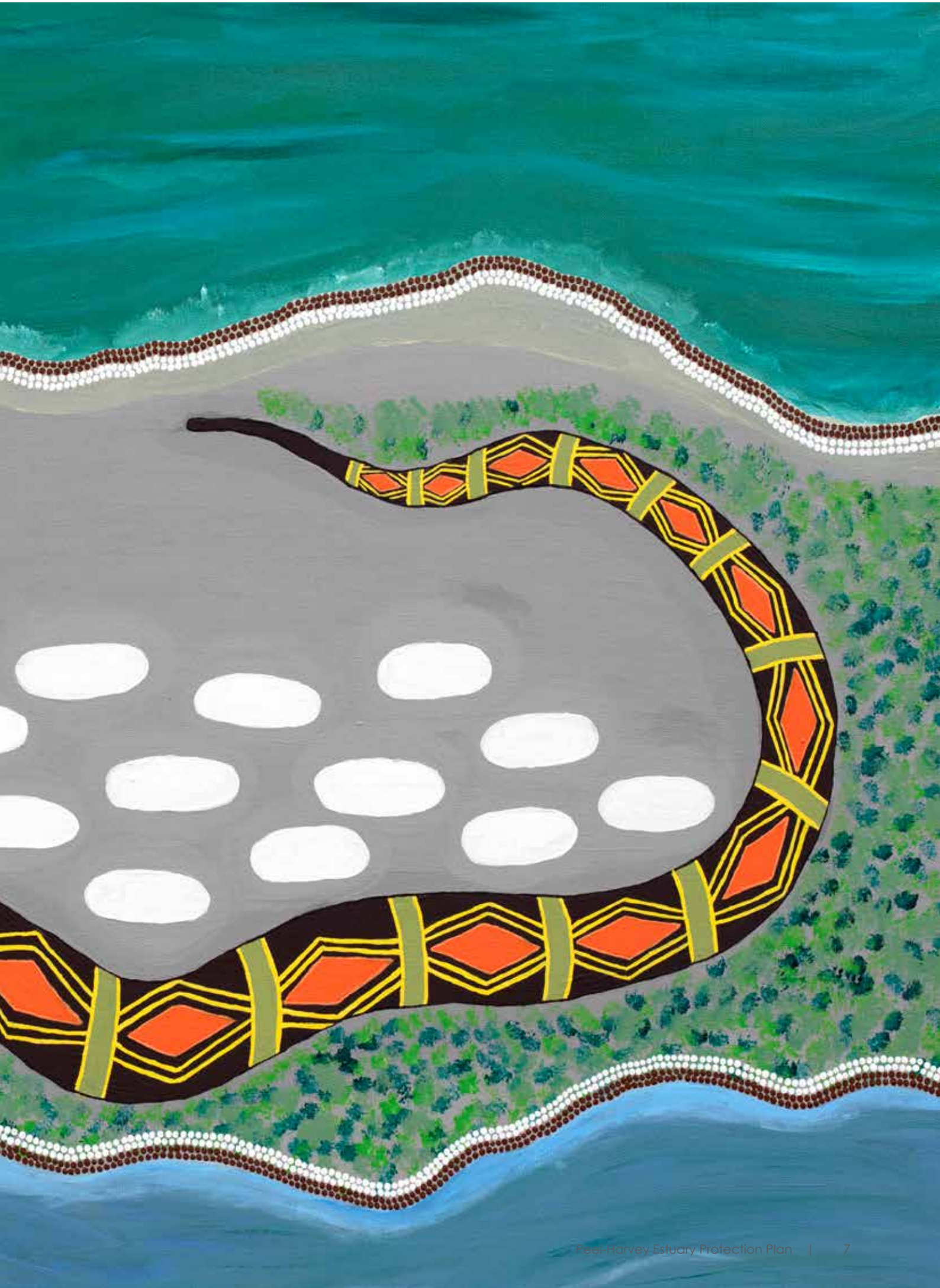
One day the Aboriginal people of the Mandurah area found there was no water ways, they went to the beach and danced and sung for the great Waugal to come.

Then she came and started to make the Peel inlet and the estuary, she found that she was carrying eggs and she rested in between the estuary and the sea until she laid them. She laid with her eggs to keep them safe. Then the eggs hatched and she sent her babies to do the rest of the work because she was tired.

She sent one up the Serpentine, one up the Murray and one up the Harvey and that's how they came to be.

Gloria Kearing, 2017





Our values

Community values are specific characteristics or uses of the environment that are important for a healthy ecosystem or support public benefit, welfare, safety or wellbeing[1]. Community values are often interdependent and at times it may be necessary to prioritise the protection of one value over another. Ideally this is done via community consensus.

The key community values of the Peel-Harvey estuary are aquatic ecosystems, fisheries, recreation and aesthetics, and cultural and spiritual.

Management goals are measures or statements used to assess whether the community values are being protected. They should be unambiguous, measurable, and achievable and reflect the desired level of protection of the community values[1]. Management goals are underpinned by appropriate water quality and sediment condition.

VALUE

Aquatic ecosystems

The estuary will be healthy and resilient, with good water quality and sediment condition, supporting the diverse and abundant populations of plants and animals.

At a glance

- The diverse habitats of the Peel-Harvey estuary support a wide range of native plants and animals, including many threatened species.
- The estuary is part of the Peel-Yalgorup wetland system which is a 'Wetland of International Importance' under the Ramsar Convention on Wetlands.
- The estuary plays an important role in preserving the genetic diversity of plants and animals for future generations.

Management goals

- Water quality is improved, with fewer harmful or nuisance algal blooms and fewer low-oxygen events and fish kills.
- Sediment condition is maintained and improved and when sediment is disturbed (e.g. by dredging) harm is minimised.
- Key habitat types and food sources of local and migratory birds are preserved and Ramsar status is maintained
- Endemic fish populations and their habitats are protected.
- Seagrass meadows are resilient with stable or increasing areal coverage.

Commercial fisherman, Damien Bell

Sea mullet

VALUE

Fisheries

The estuary will support sustainable fisheries, for both recreational and commercial fishers.

At a glance

- Finfish have provided a valuable food source to the Bindjareb Noongar people for thousands of years. Historically the wider Noongar people would gather on the Serpentine River to trap schools of sea mullet moving up the river.[2]
- An estimated $217 million is spent annually by recreational fishers in the Peel region (of the total 2.4 billion spent in WA).[3]
- The Peel-Harvey estuary supports the largest commercial crab fishery in the south-west, with a catch ranging from 36–72 tonnes per year.[4]
- Net fishing in the Peel-Harvey estuary was first established in the mid-1800s and it is one of the oldest fisheries in Australia.[5]
- The total commercial catch of finfish in the estuary ranges from 100–130 tonnes per year, all of which is sold in Western Australia.[6]

Management goals

- The blue swimmer crab and sea mullet fishery retain Marine Stewardship Council certification.
- No health warnings to be issued for the consumption of finfish and crabs.
- Licensed fishers can maintain their livelihoods within constraints of ecological sustainability.
- Recreational fishers can continue to catch crabs and finfish.
- Traditional fishing practices remain viable.

VALUE

Recreation and aesthetics

At a glance

- There are an estimated 11,500 registered recreational boats in Mandurah.[7]
- Waterfront living is highly sought after with the premium paid for properties within one street of the estuary estimated to be in excess of $1.4 billion.[7]
- The estuary is a focus of tourism in the area, with 2.3 million visitors a year.[7]

Management goals

- Water is safe for swimming, waterskiing, and other primary contact activities.
- Water is safe for boating, fishing and other secondary contact activities.
- Visual amenity is maintained, algal blooms are minimised, there are no fish kills, water is free from floating debris and scums, and odour and colour are acceptable.

Locals and tourists will continue to be drawn to the estuary; to play, to watch, to connect.

Yakkas

As children growing up around the South Yunderup area one of our main sources of food was the long neck turtle (tortoise). The painting shows that when the water starts drying up the turtles move into the centre and that's when they start burying themselves in the mud. We knew where they were in the swamp by the different colour sand on top.
Shows then our pathway, how we moved all the way around the swamp, and the different colours represent the different family, grandmother, grandfather, mum and dad, and kids all going around, the white always represents the elders that have passed on and still do the same thing.
I believe they still follow the same pathways.
Gloria Kearing, 2019

At a glance

- Fish traps have been used by the Noongar people for thousands of years.[8]
- There are over 356 sites of Aboriginal significance in the Peel-Harvey which include sites of artefact scatter, camp sites, ceremonial sites, fish traps, skeletal remains and sites of mythological significance.[9]
- 'Bindjareb Noongar people maintain a very important relationship with the waterways today, as … (their) … ancestors have done in times past … Every generation has maintained links in some form to what the waterways have kept that is sacred. The sacredness is the same today as it has been since the Woggaal created all waterways.'[10]
- Bindjareb Noongar people have a life commitment and cultural responsibility to the preservation of waterways, the management of the waterways based on the six seasons, to identify and associate the changing seasons with the food resources and interconnectedness of all life.[11]

Management goals

- Custodial responsibilities and spiritual and cultural knowledge are preserved.
- Traditional sites and food places for hunting and gathering are preserved.
- Symbolism, special places and icons are respected and preserved.

The unique and precious link between people, spirit and the estuary is preserved for future generations.

VALUE
Cultural and spiritual

A history of water quality decline

History of development

Bindjareb Noongar custodians of the estuary

European settlement

Fertiliser mining (guano) established in WA

Highly productive estuarine fisheries

Slow and difficult period of change

First drainage bill passed

Construction of the Harvey River main drain

Large-scale land clearing begins

1820 1850 1880 19

Shallow estuary, ocean bar, densely vegetated catchment

Fishing regulations introduced in response to declining fish stocks

Environmental change

The Bindjareb Noongar people have looked after the Djilba (estuary) for 50,000 years based on governance and lore.

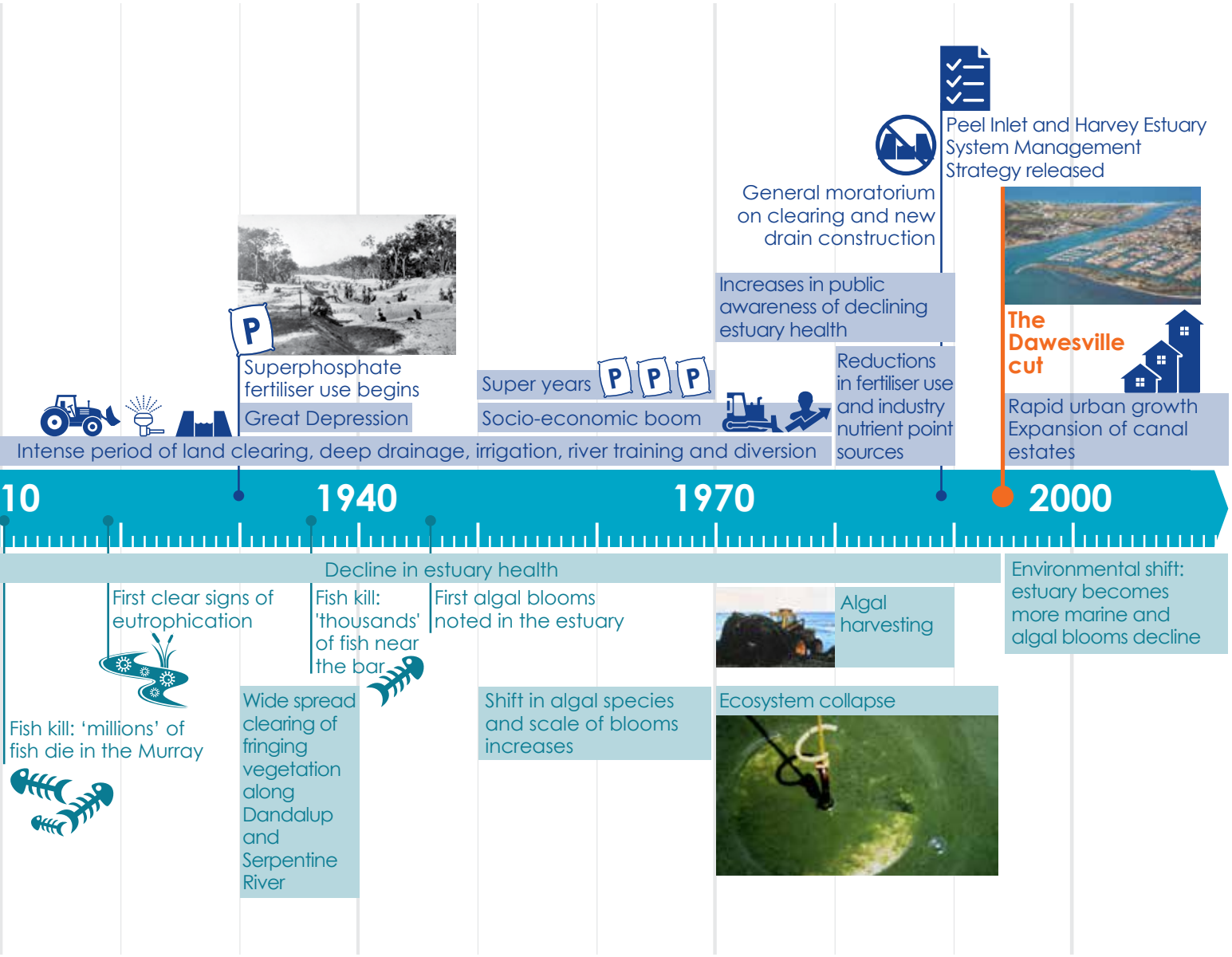
The catchment of the Peel-Harvey estuary was dramatically altered post-European settlement. Many of the rivers were dammed, and intensive drainage was constructed (from the 1890s) on the coastal plain to enable agricultural and urban development. The first large fish kill occurred in 1910 when millions of pilchard, bream, kingfish, yellowtail and whiting perished[12]. By the start of World War II many of the wetlands and rivers had suffered irreversible damage. Degradation of the catchment and eutrophication of the estuary increased during the post-World War II boom and subsequent decades.

By the late 1960s the estuary was showing clear and disturbing signs of eutrophication, in particular the loss of seagrass and the increase in green macroalgae[13, 14]. In 1978 the consequences of nutrient pollution escalated when a massive bloom of the toxic cyanobacteria *Nodularia spumigena* covered the whole Harvey Estuary and drifted into Peel Inlet, with regular blooms continuing until 1992[15]. The excessive algal growth damaged the health of the ecosystem, prevented many recreational activities and impacted on the quality of life of those living around it.

In 1989 a 'three-pronged approach to the problem' was endorsed by government[16] to:

1. reduce nutrient concentrations in runoff from the catchment
2. increase estuary flushing via the Dawesville Channel
3. continue harvesting of macroalgae as necessary.

In 1992 several water quality targets were set (mostly related to phosphorus) and outlined in a statutory Environmental Protection (Peel Inlet – Harvey Estuary) Policy 1992. During the 1980s and 1990s many rehabilitation projects were undertaken and partnerships between government and farmers worked on optimising



fertiliser application and minimising losses to waterways. Measures were taken to reduce point sources of nutrient pollution from sewerage treatment plants, piggeries and other intensive animal industries.

The Dawesville Channel more than trebled the volume of seawater exchange into the Peel-Harvey estuary, significantly improving water clarity and ameliorating blooms of *Nodularia* in the basins[15]. However, the water quality of the lower reaches of the three rivers has remained poor: nutrient concentrations remain high and increased stratification has been associated with deoxygenation events, toxic phytoplankton blooms and fish kills.

While the Dawesville Channel has treated some of the symptoms of the eutrophication, many of the causes remain. Actions to reduce nutrient losses from the catchment have been insufficient.

A drying climate has led to reduced runoff and decreased nutrient loads to the rivers; however, those nutrients persist for longer (increased residence times) and flow-weighted concentrations remain similar.

The Statement of Planning Policy 2.1 (currently under review) was written to support the Environmental Protection Policy but it was difficult to implement, leading to inappropriate siting of agriculture and urban development. The Water Quality Improvement Plan for the Rivers and Estuaries of the Peel-Harvey System[17] provided a strategy to address this; however, very little of it has been implemented because of inconsistent funding. More recently, the Regional Estuaries Initiative has invested in reducing nutrients from agricultural sources, which will be continued by Healthy Estuaries WA.

This Peel-Harvey Estuary Protection Plan builds on the lessons of the past, offering renewed focus and a clear pathway forward for improved water quality in this highly valued system.

Activities, pressures and environmental impacts

Activities in the catchment and waterways exert pressures on the estuary, which may lead to physical, chemical and biological changes (stressors) and result in adverse ecological impacts (responses)

Current condition

Estuaries are naturally productive environments that support diverse and abundent plant and animal populations. As estuaries connect land and sea, they can be highly variable environments with complex interactions between biological, physical and chemical processes.

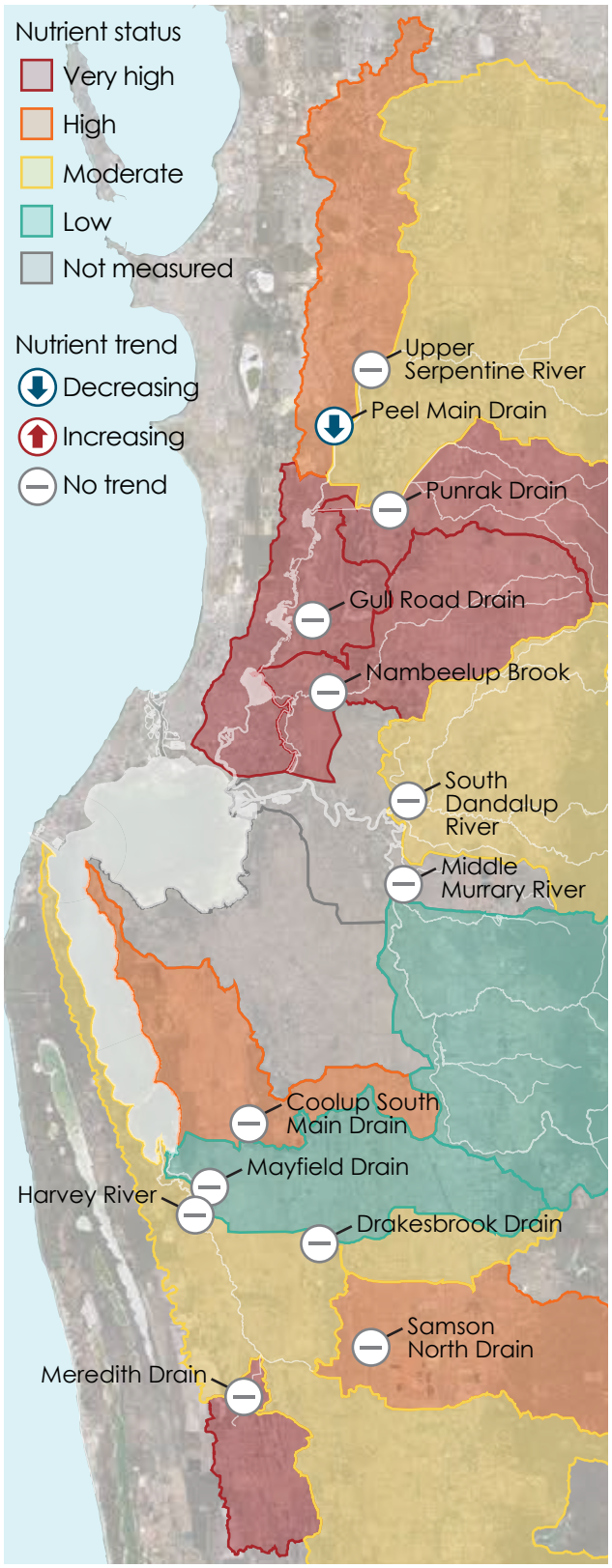
Changes in land use have substantially increased the amount of nutrients entering the Peel-Harvey estuary, which has impacted estuary health and function.

We seek to understand the estuary condition and monitor for change by measuring water quality in the estuary and its tributaries as well as key ecological components such as sediment, phytoplankton, seagrass and macroalgae, fish and birds.

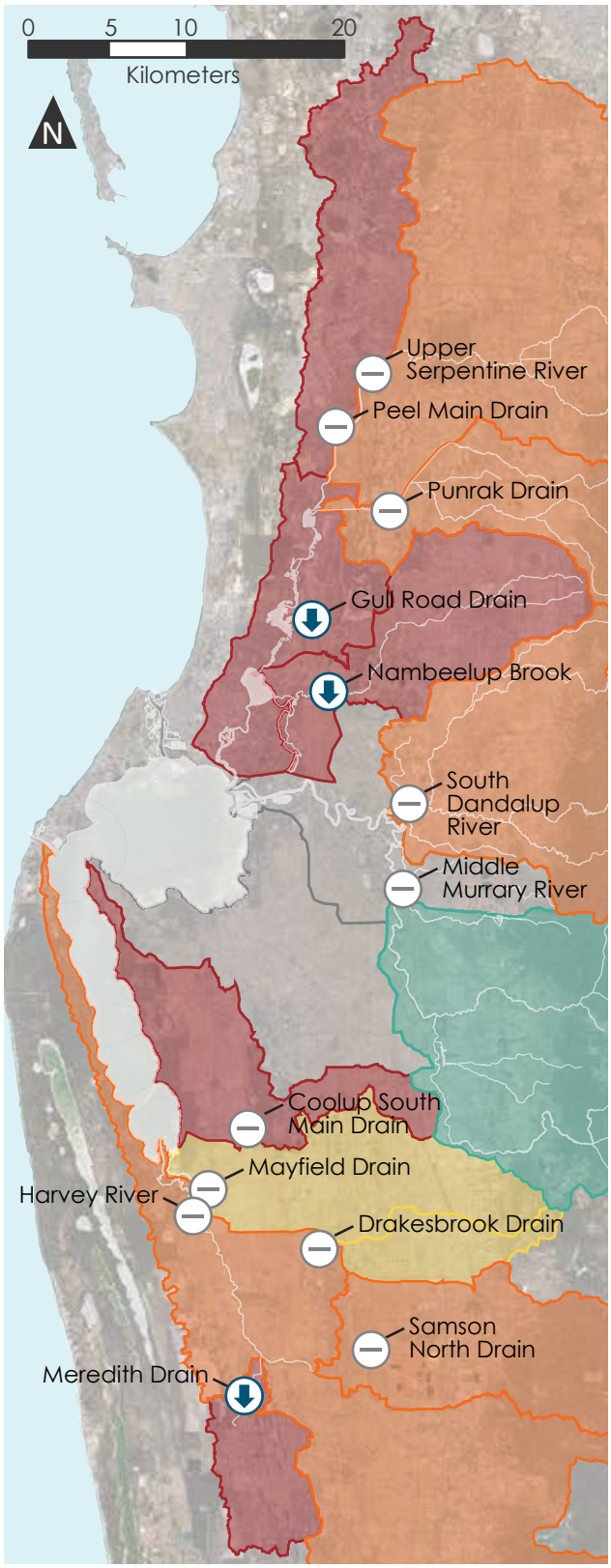
Catchment nutrient inputs

Nutrient status (2016-18) and long-term nutrient trends for total nitrogen and total phosphorus (based on 11–15 years of data up until 2018)

Total nitrogen



Total phosphorus



Nutrients applied to the catchment end up in the estuary

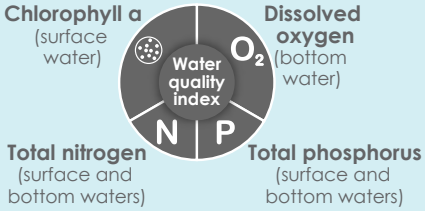
Tributaries with high nutrient concentrations are the primary cause of poor water quality in the Peel-Harvey estuary. The Peel-Harvey catchment covers an area of 9,340 km^2, extending inland over 160 km. Most of the nutrients entering the estuary originate in the coastal plain portion of the catchment and can generally be attributed to intensive land uses on poor nutrient-retaining soils and/or a high watertable that requires an extensive network of artificial drainage. Soil testing shows that in the majority of paddocks phosphorus has built up in soils to levels in excess of plant requirements, which are leeching to the estuary over time.

While a decline in rainfall and streamflow has reduced annual nutrient loads, those nutrients that do enter the estuary persist for longer (increased residence time). In the past, water quality objectives have focused on nutrient loads, but in a drying climate, this approach may falsely suggest improvements in water quality. Concentration targets for tributaries of 1.2 mg/L for nitrogen and 0.1 mg/L for phosphorus are more appropriate water quality objectives, representing acceptable nutrient concentrations in the estuary based on likely ecological responses. To meet these concentration targets, the inputs to the estuary need to be roughly halved.

Although large decreases in nutrient concentrations are required, over the past 11–15 years of monitoring, only a few catchments have shown a reduction in nutrient concentrations. Of the 13 sub-catchments where water quality is regularly monitored, seven have a high or very high nitrogen status and 10 have a high or very high phosphorus status. The nutrient-enriched surface waters across much of the catchment is a consequence of high nutrient export from many of the land uses (current and legacy) in combination with mostly poor phosphorus-retaining soils.

Water quality

The Interim Water Quality Index (WQI) has been calculated from water quality monitoring from June 2017 to May 2018.



How is the Interim Water Quality Index calculated?

The Interim Water Quality Index (WQI) is a broad measure of water quality, which has been calculated for each monitoring site in the Peel-Harvey estuary for June 2017 to May 2018. The WQI illustrates the variation in water quality across the estuary and can be compared with changes in catchment inflow and nutrient loads.

The WQI combines scores for four key water quality indicators – chlorophyll *a*, dissolved oxygen, total nitrogen and total phosphorus. Indicators are compared with 'trigger values' (agreed values that when exceeded suggest that an indicator is moving away from the desired condition) and 'worst expected values' (derived from an analysis of the past 10 years of data).

The WQI is reported as a grade ranging from A to E. A grade of 'A' suggests good water quality which is likely to support healthy communities of fish and seagrass. A score of 'E' suggests poor water quality that may be associated with fish kills and harmful or nuisance algal blooms.

The Interim WQI reported here is still in development, and scores for the Peel-Harvey may change as it is adapted for consistent application across similar estuaries in the south-west.

Water quality varies across the estuary

Good water quality underpins all the community values and is necessary to maintain key ecological processes. Water quality is monitored fortnightly at 12 sites across the Peel-Harvey estuary, which gives us an understanding of current estuary condition, enables longer-term patterns to be identified and contributes to decision support tools that facilitate better future management of the estuary.

The Water Quality Index for 2017-18 reflects differences in water quality across the estuary, ranging from very good in the more saline basin sites and very poor in the lower reaches of the Serpentine and Murray Rivers (complete results of the monitoring program can be found in the Estuary Condition Report: Peel-Harvey 2016-2019). Sites close to the Dawesville Channel (A) have good water exchange with the ocean and tend to be well-oxygenated, with low nutrient concentrations and low chlorophyll *a* activity throughout the year.

In the Peel Inlet (A) average salinities were slightly less than marine, because of freshwater inflow from the Murray and Serpentine rivers. The waters were well-oxygenated and had good water clarity. Nutrients and chlorophyll *a* concentrations were mostly below guidelines, except after a significant summer rainfall event in February 2017 which delivered high loads of nitrogen, primarily from the Murray River (see below).

The Harvey Estuary (A to B) had salinities slightly above marine levels, reflecting mild hypersalinity in summer and autumn because of low freshwater inputs and summer evaporation. Bottom waters were well-oxygenated and had good clarity allowing for light penetration. Nutrients and chlorophyll *a* concentrations were mostly below relevant guidelines. The lower grade (B) in the southern end of the Harvey was because of higher chlorophyll *a* and nutrient concentrations. *Dinophysis acuminata*, a harmful algal species, was frequently observed in this part of the Harvey (see Phytoplankton section).

The lower reaches of the Murray River estuary (B to C) had persistent salinity stratification with poor oxygen status in the bottom waters. Harmful algal species (generally dinoflagellates and diatoms) are often present. Fish kill events (about one every year) are associated with inflows from the catchment, salinity stratification, low oxygen and sometimes high densities of harmful phytoplankton.

The Serpentine River (B to D) is shallower and has less flow than the Murray, with extreme fluctuations in salinity from fresh to hypersaline at the end of summer. Sites on the Serpentine River had the highest nutrient and chlorophyll *a* concentrations, and harmful algal species are often observed (predominantly blue-green algae or cyanophytes, see Phytoplankton section).

Sediments

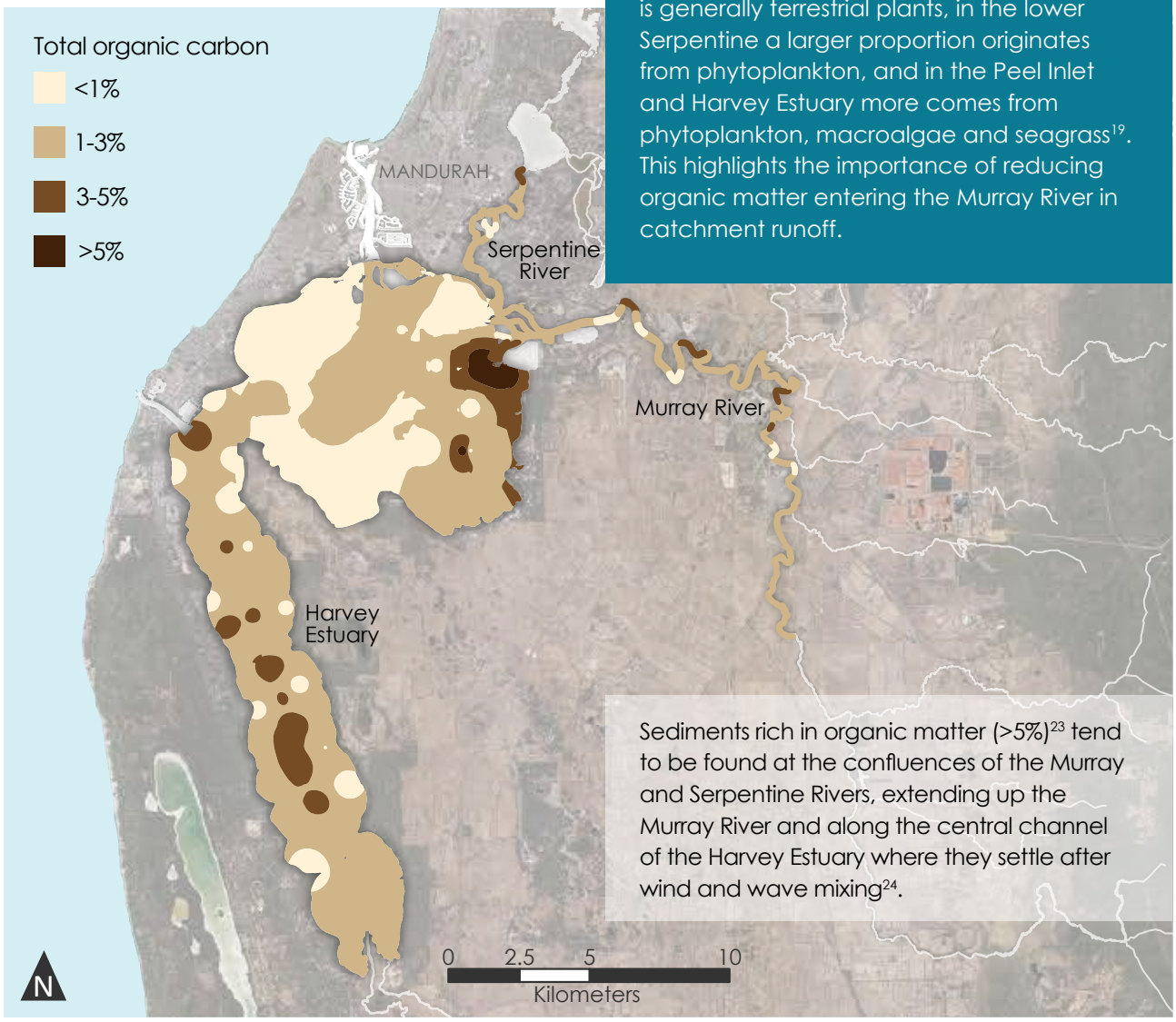
The sediments in estuaries, as with the soils on land, are crucial to the health of the plants and animals that live in or around them. Grain size, sediment chemistry and composition (including the amount of nutrient-rich organic matter) are key characteristics that influence how the sediment interacts with the surrounding environment. The grain size of the Peel-Harvey sediments varies from coarse sands to fine-grained muds with thick fluid-like sediments in the dredged channel of the basins and the central channel of the Murray River[18, 19]. As with soils, sediments can act as a source or sink of nutrients. Microbes in the sediment convert organic matter to nutrients, which may be released into the overlying water and exacerbate problematic algal blooms.

How have sediments changed?

A snapshot comparison of sediments from 1998 (just after the Dawesville Cut) to studies conducted in 2006, 2009 and 2016 suggests that the percentage of organic carbon has reduced in the Peel Inlet, the Harvey Estuary and the lower Serpentine River. However, there has been an increase in the percentage of organic carbon in the Murray River [18, 19, 20, 21, 22].

Where does the organic carbon come from?

The organic carbon in estuarine sediments was originally plant material, washed into the estuary from the land (as plant matter or manure) or grown in situ in the form of seagrass, algae or bacteria. Isotopic analysis can be used to identify the primary sources of organic matter; in the Murray it is generally terrestrial plants, in the lower Serpentine a larger proportion originates from phytoplankton, and in the Peel Inlet and Harvey Estuary more comes from phytoplankton, macroalgae and seagrass[19]. This highlights the importance of reducing organic matter entering the Murray River in catchment runoff.

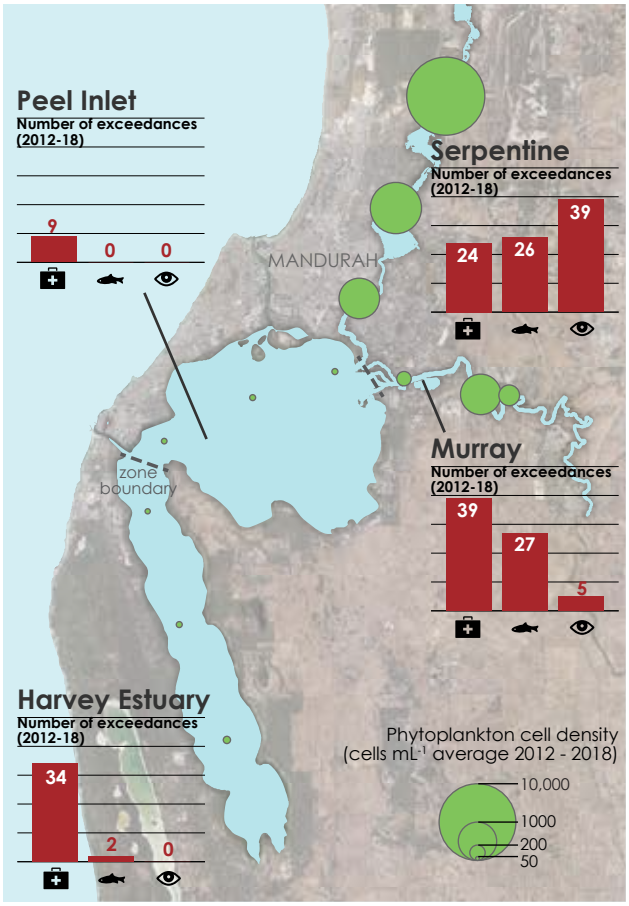


Sediments rich in organic matter (>5%)[23] tend to be found at the confluences of the Murray and Serpentine Rivers, extending up the Murray River and along the central channel of the Harvey Estuary where they settle after wind and wave mixing[24].

Phytoplankton

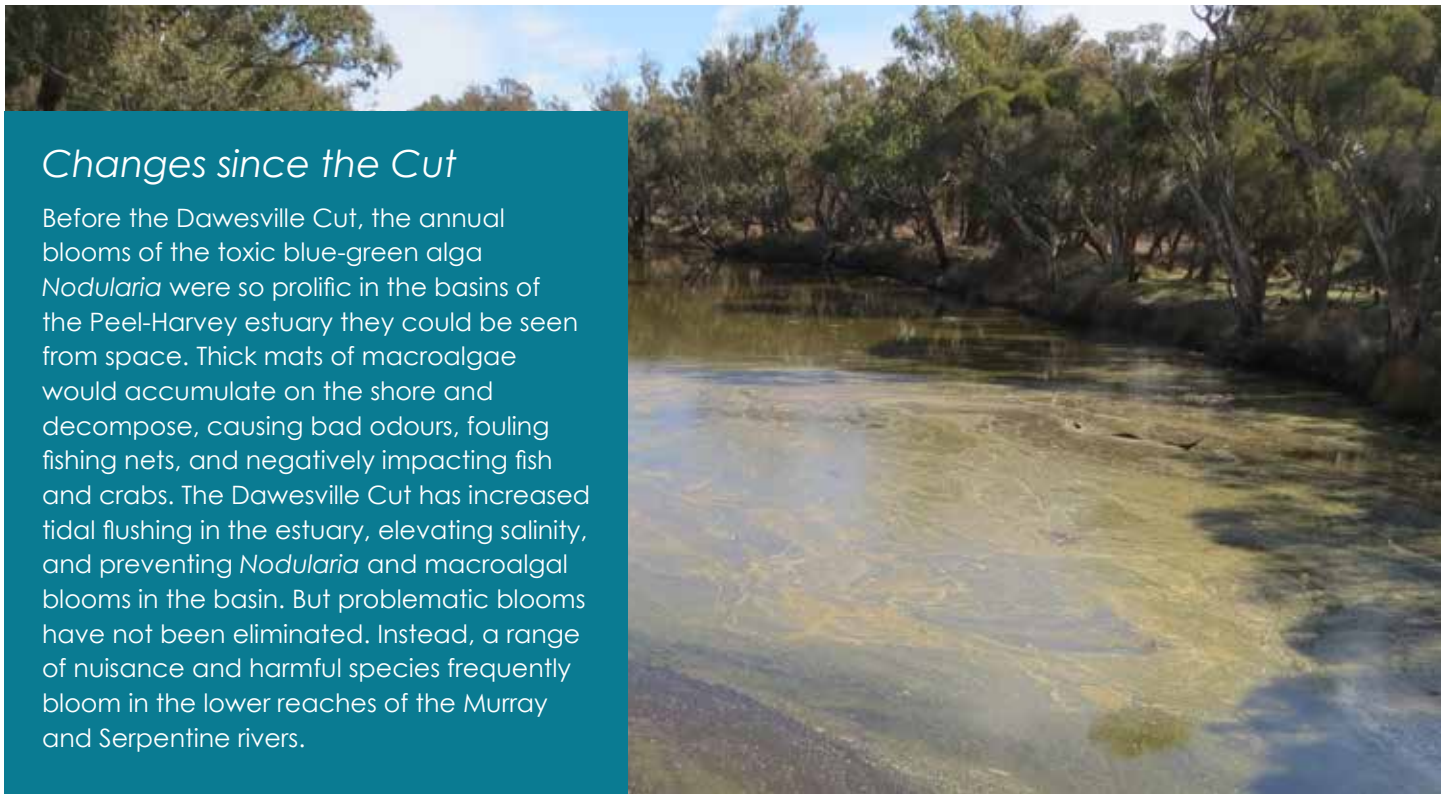
Phytoplankton are either single-celled algae or cyanobacteria; naturally occurring photosynthetic organisms that float freely in water. A microscope is needed to see individual phytoplankton cells but at high numbers they can become visible throughout the water column as discolouration, or scum on the surface of the water. Phytoplankton are an essential component of aquatic ecosystems and are the foundation of the food chain for many aquatic animals. However, excessive nutrients can lead to persistent phytoplankton blooms, surface scums, bad odours, extreme fluctuations in dissolved oxygen and anoxia. While some species of phytoplankton produce toxins that may be harmful to humans and wildlife at low cell densities, most species are only problematic at very high cell densities.

The Department of Water and Environmental Regulation monitors the density and composition of phytoplankton across the Peel-Harvey estuary on a fortnightly basis, and reports against nationally established or local interim guidelines. From 2012-18, the most guideline exceedances were observed in the lower Serpentine River but there was also a concerning number of exceedances in the lower Murray.



Exceedance category

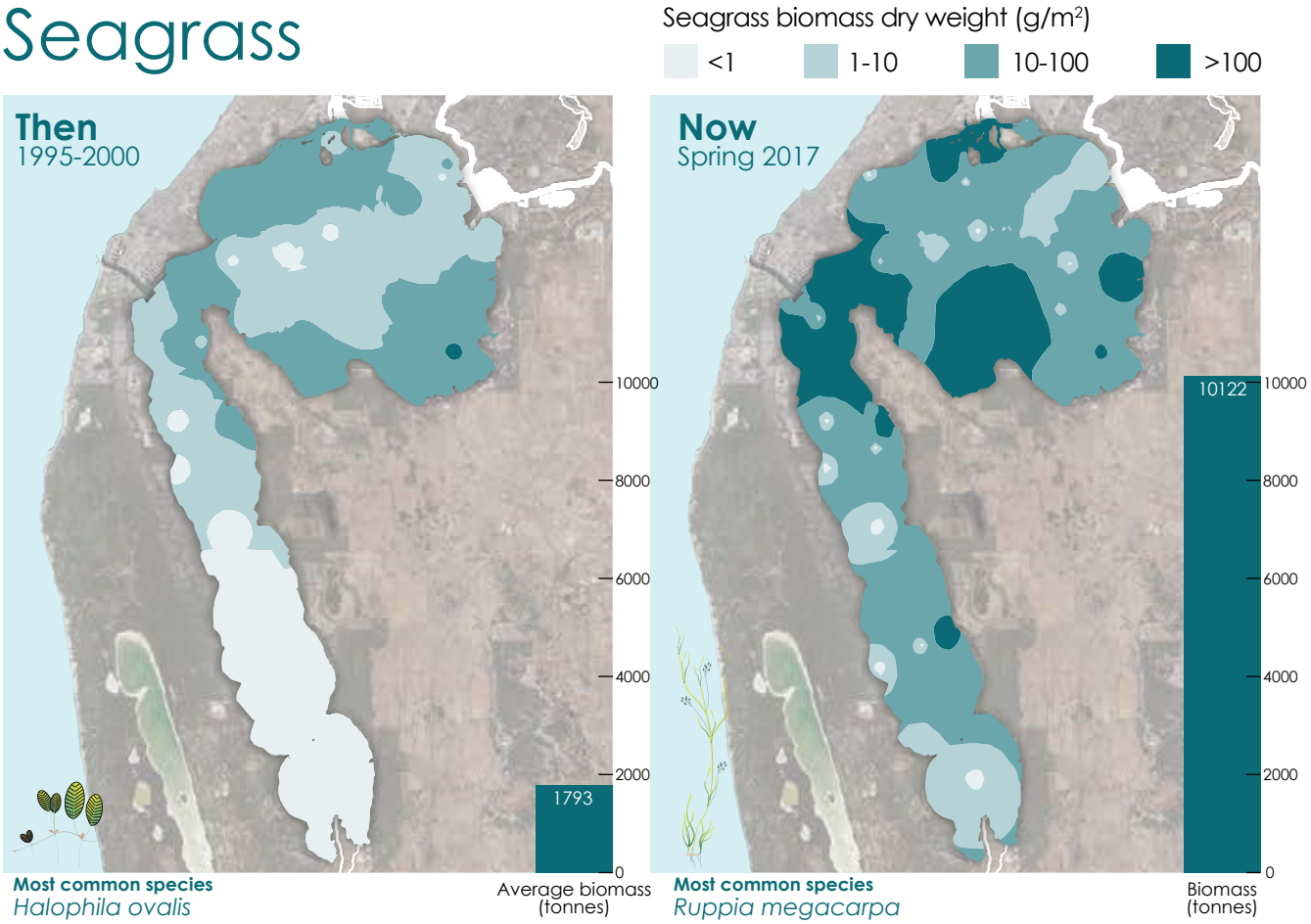
- **Human health** - presence of species at cell densities that may cause irritation with contact or illness related to the consumption of wild shellfish.
- **Fish health** - presence of species at cell densities that pose a risk to fish health because of the release of toxins or a decline in gill function.
- **Aesthetic decline** - cell densities suggest a risk of discolouration or scum.



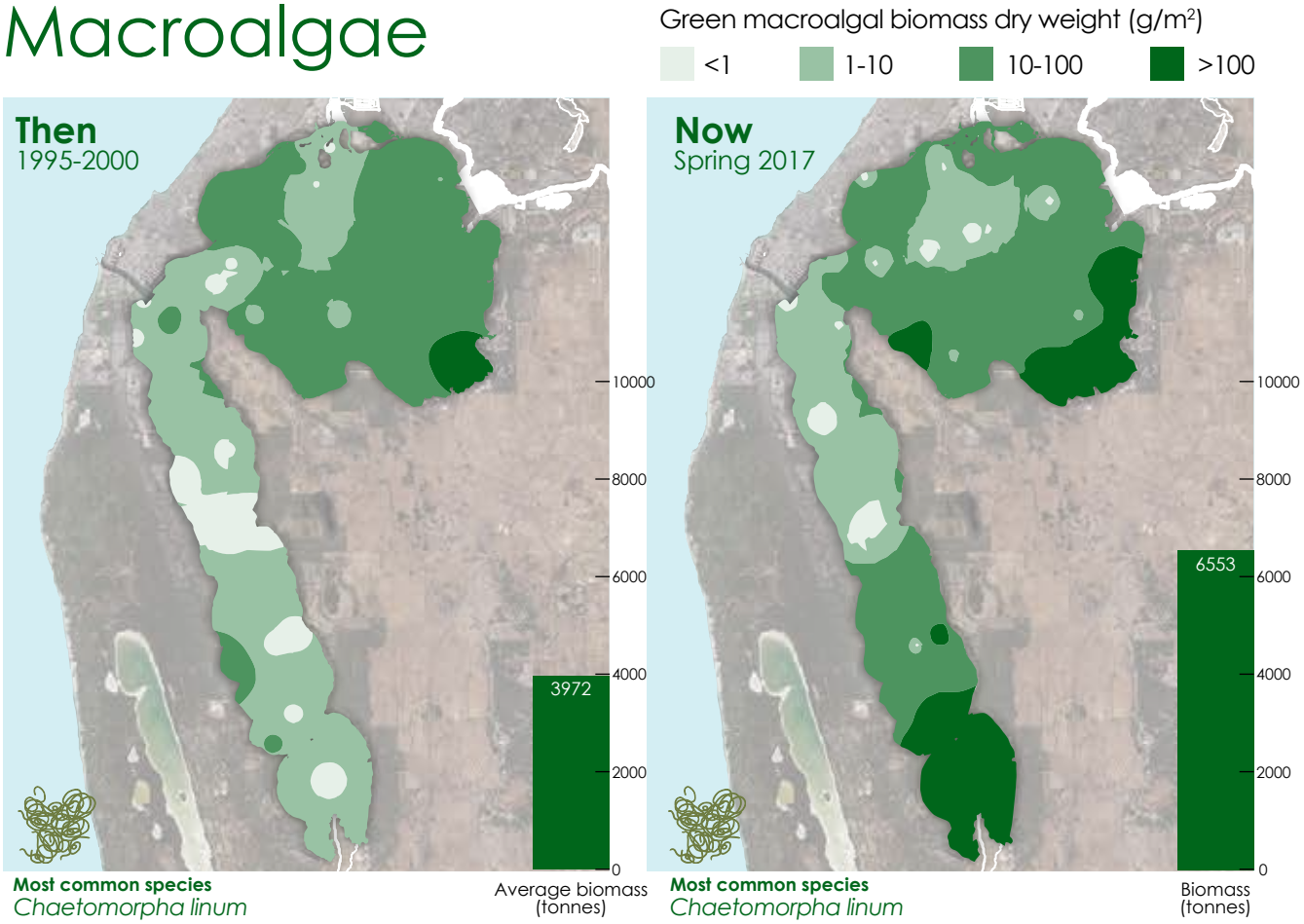
Changes since the Cut

Before the Dawesville Cut, the annual blooms of the toxic blue-green alga *Nodularia* were so prolific in the basins of the Peel-Harvey estuary they could be seen from space. Thick mats of macroalgae would accumulate on the shore and decompose, causing bad odours, fouling fishing nets, and negatively impacting fish and crabs. The Dawesville Cut has increased tidal flushing in the estuary, elevating salinity, and preventing *Nodularia* and macroalgal blooms in the basin. But problematic blooms have not been eliminated. Instead, a range of nuisance and harmful species frequently bloom in the lower reaches of the Murray and Serpentine rivers.

Seagrass



Macroalgae



Why are seagrasses and macroalgae important?

Seagrasses and macroalgae are both aquatic plants. However, key differences in their physiology and growth patterns mean they respond differently to changes in water quality. In the Peel-Harvey estuary the presence of seagrass is generally considered to indicate healthy conditions, while an overabundance of macroalgae indicates poor conditions.

Seagrasses are true flowering plants, with leaves, roots, and rhizomes. As they are rooted in the sediment they need good water quality and sediment conditions to thrive. In contrast, the macroalgae in the Peel-Harvey estuary tend to be free-floating, taking up nutrients directly from the water with minimal dependence on sediment quality. They may be filamentous, leaf-like or clumping, and will be moved around the estuary by wind and waves.

Both seagrasses and macroalgae are important parts of the ecosystem. As photosynthetic organisms they form the base of the food chain, which ultimately supports fish, birds and crabs. They also take up nutrients, store carbon and provide habitat. However, excessive nutrients can result in the proliferation of some species of quick-growing green macroalgae (termed 'nuisance algae') which may clog waterways, accumulate in wracks on beaches and smother seagrass. The proliferation of nuisance algae in the 1970s and 1980s led to the construction of the Dawesville Cut.

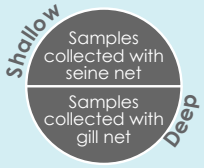
Seagrass and macroalgae have recently increased in Peel-Harvey

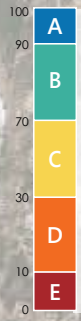
Changes in the distribution and amount of seagrass and macroalgae can indicate changes in estuary health. Immediately after the Dawesville Cut, macroalgae decreased from about 15,000 tonnes in 1994 (spring)[25] to a spring average of 3,972 tonnes by 1995-2000, being most abundant in the lower Harvey and the eastern Peel Inlet (dominated by Chaetomorpha)[26]. A general increase in seagrass was observed after the Cut and 1,793 tonnes (spring average) was present in 1995-2000[26]. The most common species was paddleweed (*Halophila ovalis*), which was most abundant in the main basin of the Peel Inlet[26].

Seagrass and macroalgae were far more abundant in 2017 than in 1995-2000 – with more than five times more seagrass (10,322 tonnes) and 65 per cent more macroalgae (6,553 tonnes)[26]. The increase in biomass may reflect the environmental conditions of that year (rainfall, temperature, sunshine) as annual variability of this magnitude is evident in the historical data. The most dominant species of seagrass was *Ruppia megacarpa*, which was favoured by the large inflows of freshwater over the proceeding summers (2016, 2017) and whose growth form also tends to lead to greater measures of biomass. The relatively high abundance of macroalgae in 2017 is concerning and may suggest a slide back towards a more eutrophic state. The most abundant species was *Willeella brachyclados*, a nuisance green macroalgae that was prevalent in large free-floating mats pre-Cut. It collects in the southern Harvey Estuary and eastern Peel Inlet, where it can utilise the high concentrations of nutrients entering the estuary from the rivers.

Fish communities

The Fish Community Index, developed by Murdoch University, scores key characteristics of the fish community from 2017-18 and integrates these into an overall measure of fish community health[27].





Healthy fish communities have a greater species diversity, and a balance of specialists (those with distinct habitat and feeding requirements) and generalists.

In less-healthy communities, there tends to be less diversity, a larger proportion of detritivores (those that feed on decaying plant and animal matter), generalists, and an over-representation of species tolerant to poor water quality.

Mandurah Channel

Whitebait
Yellow-eye mullet (kalkada)
Ogilby's hardyhead
Presbyter's hardyhead

Shallow: D

Serpentine

Shallow: C
Deep: D

Whitebait
Yellow-eye mullet (kalkada)
Elongate hardyhead

Perth herring
Roach

Peel Inlet (western)

Long-finned goby
Gobbleguts
Western striped grunter
Presbyter's hardyhead
Elongate hardyhead

Shallow: D

Yellow-eye mullet (kalkada)
Australian herring

Deep: B

Murray (lower)

Shallow: C
Deep: D

Sea mullet (kalkada)
Yellow-eye mullet (kalkada)
Roach

Perth herring
Roach
Black bream (djilba)

MANDURAH

zone boundary

Harvey (northern)

Yellow-eye mullet (kalkada)
Gobbleguts
Western striped grunter
Presbyter's hardyhead
King George whiting

Shallow: C

Tailor (bila)
Perth herring
Australian herring

Deep: B

Murray (upper)

Shallow: B
Deep: D

Sea mullet (kalkada)
Yellow-eye mullet (kalkada)
Wallace's hardyhead
Southwestern goby

Sea mullet (kalkada)
Perth herring
Black bream (djilba)

Harvey (southern)

Whitebait
Gobbleguts
Presbyter's hardyhead
Elongate hardyhead

Shallow: C

Blowfish
Perth herring
Tailor (bila)

Deep: C

Peel Inlet (eastern)

Shallow: D
Deep: D

Yellow-eye mullet (kalkada)
Gobbleguts
Blowfish
Presbyter's hardyhead
Elongate hardyhead

Tailor (bila)
Southern eagle ray
Australian herring

N

0 2.5 5 10

Kilometers

Why are fish important?

Changes in fish communities often reflect less visible changes in estuary health, driven by human activities, climate changes and other pressures. Fish communities underpin many of the community values of the Peel-Harvey estuary and are essential to the criteria that justify its Ramsar listing[28]. Fish are a critical component of the estuary's foodweb, linking primary consumers (such as tiny polychaetes and crustaceans) to predators such as birds and dolphins. Fish communities support a mixed commercial and recreational fishery and are essential in preserving the traditional fishing methods of the Bindjareb Noongar people. More broadly, fish communities support fishing-related and eco-tourism industries, including bird and dolphin watching.

The fish of the Peel-Harvey estuary

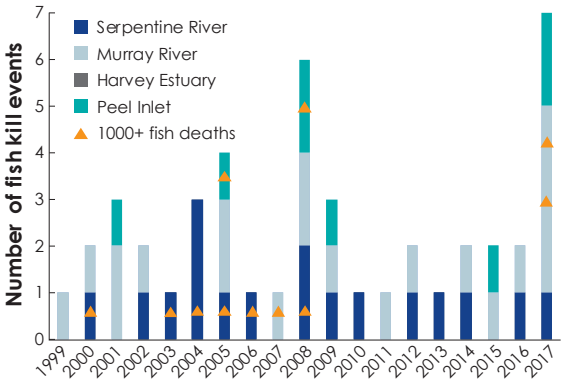
About 70 marine and estuarine species of fish currently reside in the Peel-Harvey estuary[29]. They include marine species such as whiting, mullet (kalkada), tailor (kila) and whitebait, and estuarine species such as black bream (djilba)and estuary cobbler (nyola).

However, when sampled in 2017-18 and assessed with the Fish Community Index the estuary generally performed poorly. Fish community condition was worst in the shallower waters of the Peel Inlet, the Mandurah Channel and the deeper waters of the eastern Peel, Serpentine and Murray rivers (scoring a D). Condition was slightly better in the Harvey Estuary and shallower regions of the Serpentine and lower Murray River (scoring a C). The deeper regions of the western Peel Inlet, the northern Harvey and the shallow waters of the upper Murray had the highest index of fish community condition (scoring a B).

Unless there is an improvement in water quality, fish community condition will remain poor in the deeper parts of the lower rivers. And while water quality in the basins is relatively good, the poor Fish Community Index in much of the basins suggests that other factors may be limiting condition, such as the loss of nursery and feeding habitat such as saltmarsh[30].

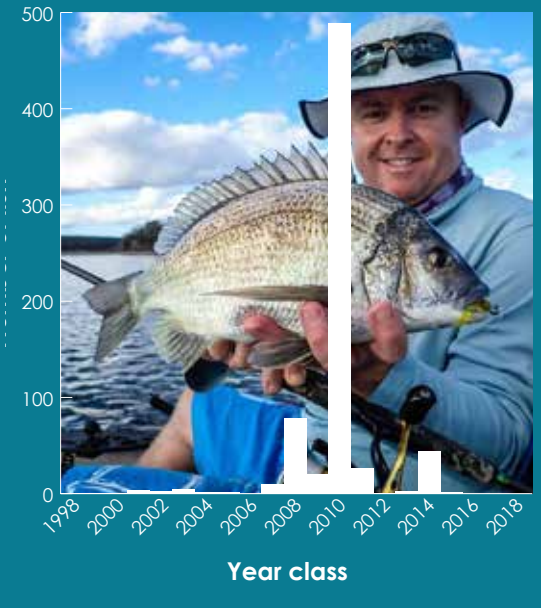
Fish kill events

Fish kill events are a particularly visible symptom of poor water quality in the Peel-Harvey estuary. From 1999–2017 there was at least one fish kill each year, often comprising thousands of fish and most commonly occurring in the lower Murray and Serpentine, followed by the Peel Inlet. Fish kill events may result from low dissolved oxygen, exposure to toxicants or physical irritants (often associated with algal blooms) or a combination of these factors. Large-scale fish kills have the potential to wipe out viable fish populations as well as result in a loss of amenity.



Black bream an indicator species

Fish community health can also be gauged by studying key indicator species. An example is black bream (djilba) which completes its life cycle in the estuary and is a favourite with recreational fishers. Besides one good breeding year in 2010, there have been very few observations of young Black Bream throughout the past 17 years[31]. In two years of extensive sampling from 2016-18, very few adults were caught, possibly a reflection of poor water quality in the rivers[31]. Without recruitment, the future of black bream is under threat.



Fisheries

Jason, Viky, Ben and Eli Stokes fishing for Blue Swimmer Crabs

The Peel-Harvey estuary supports important commercial and recreational fisheries

Recreational fishers in the Peel-Harvey estuary target crabs by hand, scoop net and drop net, while line fishers target a suite of near-shore species including yellowfin whiting, tailor (bila) and herring. There are seven commercial licenses to take finfish and prawns (yala). Six of these may also take crabs (karil). The total number of commercial licenses has been reduced in recent times to reallocate a greater share of the crab catch to the recreational sector.

Fishing for blue swimmer crabs and finfish is managed under legislation and in accordance with two publicly available harvest strategies (updates in draft): *Blue Swimmer Crab Resource of the Peel-Harvey Estuary Harvest Strategy 2015-2020*, and *Finfish Resources of the Peel-Harvey Estuary Harvest Strategy 2015-2020*. The harvest strategies set out the management objectives, performance indicators and associated monitoring and assessment framework, and importantly the reference levels and control rules to inform management.

In 2016 the commercial sea mullet (kalkada) fishery, and commercial and recreational blue swimmer crab fisheries were certified as sustainable by the Marine Stewardship Council (MSC). Catches of sea mullet have increased in recent years which triggered a review of stock sustainability. While both the standardised commercial catch rate and the annual catch for blue swimmer crabs are within the target ranges, the Department of Primary Industries and Regional Development undertook a strategic review of the south-west blue swimmer crab resource to improve protection of the breeding stock across the entire resource and increase the resilience and reliability of the fishery it supports.

As an outcome of this review, in 2019 the Minister for Fisheries introduced a three-month (1 September to 30 November) seasonal closure of the south-west crab resource and all crab fisheries, extending from the Swan and Canning rivers to Minninup Beach in Geographe Bay (including the Peel-Harvey estuary), halved the bag limit in the Swan and Canning rivers and introduced a maximum of five female crabs per bag limit in Geographe Bay.

In addition, a buyback has been established for commercial crab fisheries in Cockburn Sound, Warnbro Sound and the Mandurah to Bunbury commercial fisheries before their permanent closure. This will benefit the broader south-west blue swimmer crab resource, including the Peel-Harvey crab fishery.

The stock status of other near-shore and estuarine finfish species is assessed against the finfish harvest strategy annually as part of the MSC accreditation process. Recent commercial catches of yelloweye mullet (kalkada), yellowfin whiting, tailor (kila) and cobbler (nyola) are all within threshold levels.

A stock assessment of Australian herring in 2017 demonstrated it was in recovery phase after management changes to reduce fishing pressure were implemented in 2015. These measures will be maintained until the stock has recovered. Catches of Perth herring exceeded threshold levels in 2016, which has triggered a review of the sustainability of the stock.

A wetland of international importance

The Peel-Harvey estuary is part of the Peel-Yalgorup Ramsar Site, an integral component of the East Asian-Australasian Flyway. The estuary provides migratory shorebirds with food (fish, invertebrates and macrophytes), vegetation for shelter, and a quiet place to breed – away from humans and domestic animals.

Djilba Gabi (Peel-Harvey estuary) djerab (birds)

Over thousands of years, local Bindjareb Noongar families have observed the diverse and unique bird populations of the Djilba Gabi (Peel-Harvey estuary). Observation was an important part of how Bindjareb people in Mandjoogoordap survived and lived successfully according to the Six Noongar Seasons, and looking at the activities of the bird life was part of a very complex threading and network of a wider knowledge base. The waterbirds were given Noongar names and became part of culture and language.

Birds

The Peel-Harvey supports diverse and unique bird populations

The bird (djerap) species that reside in and around the estuary can be divided into seven main types with different habitat and food requirements – ducks (yerderap) and small grebes; macrophyte-eating; fish-eating; Australian shorebirds; international shorebirds; large-bodied waders; and other wetland-dependent birds. These seven groups have been represented by 104 species since the 1980s[32].

Monitoring the bird species, numbers, and evidence of breeding in the Peel-Yalgorup site allows comparison to specific Ramsar criteria to check that the site is still in good ecological condition for a wetland of international importance.

Total bird numbers from 1995-2019 have been relatively stable; however, there has been a notable decline in international shorebirds in recent years. From 2015-19, the species of waterbirds observed at the site have met the Ramsar criteria and their abundance is above expected numbers. Breeding has been recorded at least once every two years for key species including the Australian fairy tern (kaldjirkang), Australian pelican (booladaalaang), hooded plover, red-capped plover, little pied cormorant (kakak) and little black cormorant (karbanga). Observations of bar-tailed godwit, eastern curlew, great knot, red knot and greater sand plover were frequent enough to meet the Ramsar requirement related to threatened species. The Australian fairy tern (kaldirkang) was more abundant than that required by Ramsar criteria.

The diversity and abundance of birds in the Peel-Yalgorup site and the importance of this area for breeding highlights the need to protect and manage the Peel-Harvey estuary as the largest waterbody within the Ramsar site.

Bird Group	Description	Number of species
Ducks and small grebes 	Ducks (yerderap) and small grebes that typically are omnivorous and shallow or open-water foragers.	14
Macrophyte-eating (herbivores) 	Black swans (maali), hens (kwiyaloom) and coots (kidjibroon) that have a vegetation diet.	6
Fish-eating species 	Gulls, terns (kaldirkang), cormorants, petrels (nekayit), shearwaters and grebes with a diet mainly of fish	20
Australian shorebirds 	Australian resident shorebird species that feed in shallow inland waters or mud and sand flats mainly on invertebrates.	12
International shorebirds 	Palaearctic shorebird species that breed in the northern hemisphere and migrate to the southern hemisphere to feed.	31
Large wading birds 	Long-legged wading birds with large bills, feeding mainly in shallow water and mudflats.	14
Other wetland-dependent birds 	Other birds that are wetland dependent such as birds of prey (white-bellied sea eagle, swamp harrier), reed warblers and the orange-bellied parrot	7
Total		**104**

Actions

This plan collates actions across the estuary and its catchment and asks for many groups to work together to protect the Peel-Harvey estuary for future generations. The plan offers an integrated approach towards catchment management, grouping actions into four work areas: Catchment (C), Estuary (E), Plans, Policy and Partnerships (P) and Measuring Progress (M).

Action: Catchment

These actions focus on reducing the loss of nutrients from the catchment to the estuary – leading to poor estuary condition. There is a suite of actions aimed at working with farmers for improved management of agricultural nutrients, which have been divided into those aimed at diffuse sources (e.g. broad-scale agriculture) and point sources (e.g. feedlot effluent). The population of the Peel region is forecast to grow substantially in coming decades, further increasing the importance of actions to reduce urban nutrients entering the estuary from fertiliser application, septic systems, wastewater treatment plants, prescribed premises and stormwater. There are several actions aimed at improving drainage water quality. Larger-scale catchment actions aim to encourage revegetation and river restoration and protect remaining patches of native vegetation and natural wetlands.

Improved management of diffuse agricultural nutrients

C1 Reduce nutrient losses to waterways by optimising fertiliser use to agronomic need through soil testing, agronomic advice and extension in partnership with farmers and the fertiliser industry.

C2 Improve phosphorus retention in sandy soils used for intensive and broad-scale agriculture through the use of soil amendments, including:

a. expanding on-farm trials using mining by-products and other materials that retain phosphorus, and making the results available to industry

b. investigating how changes to regulation may facilitate wider use of soil amendments where appropriate.

C3 Expand the development of slow-release phosphorus fertilisers and other new fertiliser formulations appropriate to Western Australian soils and promote uptake through demonstration trials.

C4 Develop new best management practices for broad-scale agriculture, including those to:

a. reduce fertiliser losses and reduce erosion through improved whole-of-farm management practices in conventional, broad-scale agriculture

b. encourage regenerative agriculture and holistic management techniques that improve soil health, use water

efficiently, and maintain soil cover through farm-scale trials that may be adopted at a sub-catchment scale.

C5 Develop horticulture best management practices suited to high nutrient leaching environments, such as innovative closed-loop agricultural systems and autonomous vertical smart farms.

C6 Conserve water and reduce nutrient runoff from irrigated agriculture by requiring Nutrient Irrigation Management Plans (NIMPs) as part of planning approvals and water licensing processes.

C7 Assist farmers and other landowners to exclude stock from rivers, streams and drains to reduce erosion and the input of sediment and organic matter to the estuary and its tributaries.

Improved management of point source agricultural nutrients

C8 Extend partnerships with industry groups and farming enterprises to fast track adoption of best management practices in intensive agriculture, including the management of effluent from dairy sheds, piggeries and feedlots, to national standards or better, as appropriate for the Swan Coastal Plain.

Reduce diffuse and point sources of urban nutrients

C9 Assist householders to improve water use efficiency in urban gardens and minimise nutrient export risk through Waterwise education programs (aligned with Waterwise Perth).

C10 Public open space managers to reduce the application of nutrients (fertiliser and others) and export risk and improve water efficiency in public open space (aligned with Waterwise Perth).

C11 Public open space managers to evaluate the use of soil amendment to reduce phosphorus losses.

C12 Upgrade existing stormwater systems in priority areas according to water-sensitive design principles (aligned with Waterwise Perth).

C13 Increase training and development opportunities for local government and the stormwater management industry to adopt water-sensitive design principles.

C14 Increase the reuse of treated wastewater from wastewater treatment plants (WWTPs) on woodlots, golf courses and other green spaces where there is low risk of leaching into waterways. Identify opportunities and barriers for wastewater reuse within the industrial and agricultural sectors.

C15 Encourage replacement of septic systems with a connection to a reticulated sewerage scheme where available. If reticulated sewerage is not available, encourage installation of a secondary treatment system with nutrient removal.

Improve drainage water quality

C16 Improve the water quality of drainage waters that discharge to the Peel-Harvey estuary and its tributaries:

a. Implement the drainage partnering agreement between the Water Corporation, Department of Water and Environmental Regulation and Peel-Harvey Catchment Council. Identify actions to improve water quality in priority Water Corporation drains such as those draining to the Harvey Estuary.

b. Investigate, develop and evaluate the use of innovative materials for phosphorus removal in drains, including phosphorus-binding clays.

c. Evaluate other approaches (such as in-drain vegetation) to improve water quality in drainage waters that discharge to the Peel-Harvey estuary and its tributaries. Implement approved approaches in the prioritised drains.

d. Install stock-exclusion fencing and appropriate in-drain structures, such as sediment traps in key drains.

Biodiversity-focused measures

C17 Reinstate the ecological function of key rivers and streams through river restoration works and revegetation of the river and stream margins.

C18 Develop and implement a strategic revegetation and restoration plan, identifying opportunities for revegetation with deep-rooted endemic plant species with consideration to co-benefits such as increases in biodiversity:

a. Develop and fund a plan.

b. Implement the plan.

Actions that make a difference

What is a catchment-scale water quality model and why is it useful?

Catchment-scale water quality models have become important tools for water quality management, planning and reporting worldwide. They are developed to determine the source, transformation, transport and delivery of nutrients in the catchment and receiving water bodies.

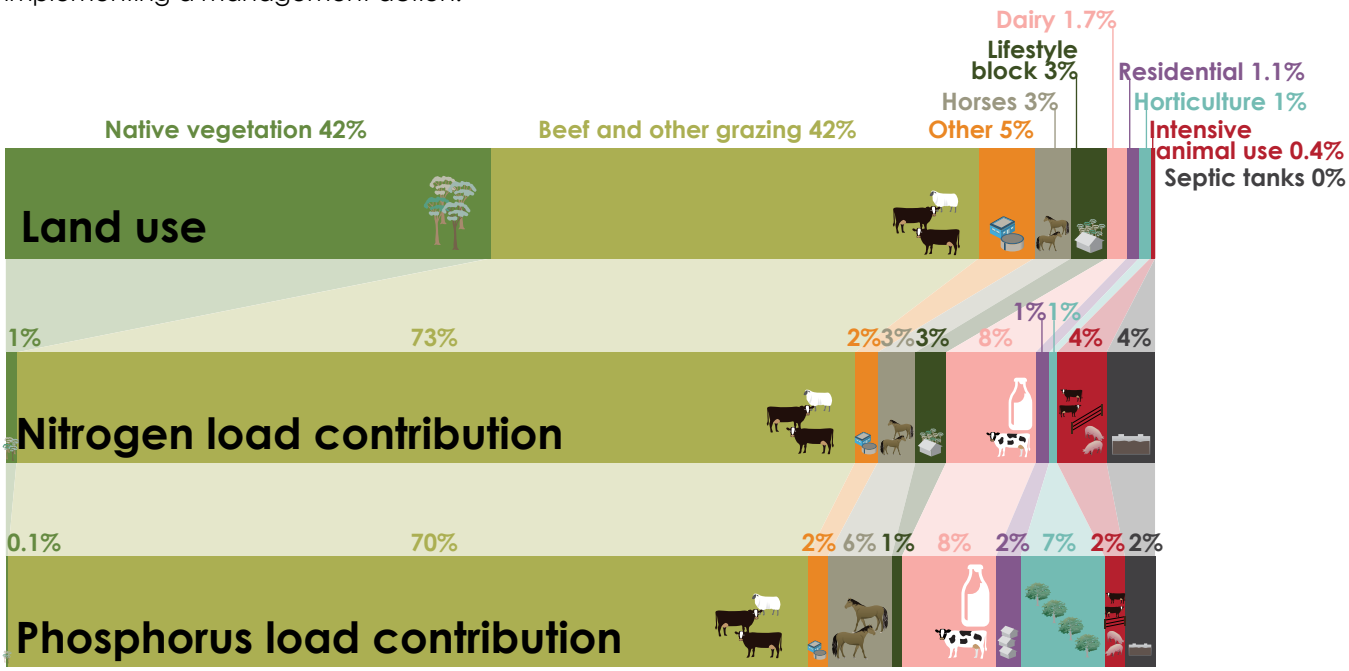
The Department of Water and Environmental Regulation developed a catchment model for the Peel-Harvey estuary using a range of inputs including: land use and drainage mapping; fertiliser and feed inputs from surveys; soil testing data; climate data; and data relating to point sources and septic tanks. It was calibrated using flow and nutrient data from monitoring programs to ensure modelled outputs closely match measured data. The model uses the eWater Source framework and is supported by finer-resolution paddock-scale models.

The model is used to determine the nutrient loads delivered from each of the subcatchments to the Peel-Harvey estuary and the relative proportion of nitrogen and phosphorus contributed by each land use type. It calculates nutrient load reduction targets to meet the nutrient concentration targets that have been set for the tributaries. It predicts changes in nutrient load that would be expected from a change in land use, a climate shift or implementing a management action.

'Lag time' is the period between a management change and a related improvement in water quality in a downstream waterbody; an important consideration when planning management measures. Lag time is site and system dependent but is likely to range from years to decades for excessive phosphorus levels in agricultural soils on the coastal plain of the Peel-Harvey catchment.

Sources of nutrient loads

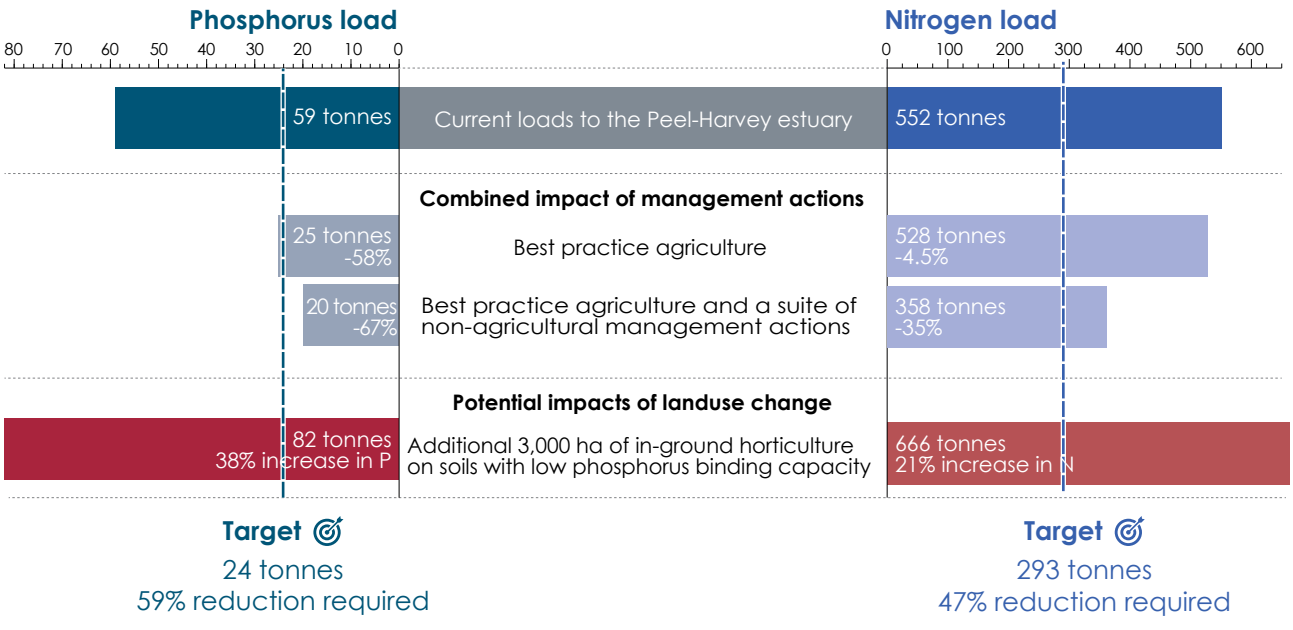
The land use that contributes the highest nutrient load is grazing (primarily for beef), which contributes over 70 per cent of the nitrogen and phosphorus loads to the estuary. This is followed by dairies which contribute 8 per cent of the total load for both nitrogen and phosphorus. Horticulture is particularly important for phosphorus export, which contributes about 7 per cent of the load but comprises only 1 per cent of the catchment area. Urban land uses (including septic tanks, lifestyle blocks and urban residential) contribute 8 per cent of nitrogen load and 5 per cent of phosphorus load, which may be particularly significant in summer months, where small rain events will produce outflows in urban landscapes but not in rural areas.



How effective are management actions at reducing nutrients?	Reduction in N		Reduction in P	
	tonnes	%	tonnes	%
Optimal fertiliser use on all beef and dairy farms	0.0	0%	23.4	40%
All beef and dairy farms using soil amendments to bind phosphorus	0.0	0%	20.9	35%
All dairy operations applying the Dairy Code of Practice for effluent management	2.3	0%	1.0	2%
All piggeries, feedlots and holding yards minimising discharge to waterways	22.6	4%	1.0	2%
Removal of septic tanks that are in close proximity to the estuary (1,074 units)	3.6	1%	0.2	0%
Stock exclusion and revegetation of 1,394 km of streams and drains	99.8	18%	2.0	3%
Targeted revegetation (24,770 ha of land currently used for grazing replanted with deep-rooted native species)	84.5	15%	19.6	33%
All urban areas retrofitted with WSUD	4.3	1%	0.7	1%

Why it is important to have controls on new developments?

Land use intensification in the catchment is a constant pressure. Population growth is driving the demand for new housing developments while still protecting priority, existing horticultural areas to service the Greater Perth Region. Some intensive land uses such as in-ground annual horticulture and free-range piggeries and poultry have the potential to significantly increase nutrient loads to the estuary because of nutrient inputs that are orders of magnitude higher than grazing cattle of beef cattle. Special planning controls are recommended for new developments of this type to ensure they are not in areas with sandy soils that readily leach phosphorus – which makes up much of the Peel-Harvey coastal plain catchment. We must match land uses to soil capacity in these landscapes to prevent significant declines in water quality as a result of land use change.



Action: Estuary

These actions address sustainably managing fish and crab stocks, mitigating recreation and tourism impacts and encouraging conservation partnerships. Improved knowledge is also required to better understand the environmental water requirements of the estuary, as well as how to best respond to the risks posed by climate change.

Fisheries management

E1 Manage the Peel-Harvey crab and finfish resources in line with harvest strategies that aim to maintain stocks at sustainable levels.

E2 Maintain sustainable populations of sea mullet and blue swimmer crabs through Marine Stewardship Council (MSC) certification which provides an oversight and reporting mechanism.

E3 Reduce fishing pressure via the voluntary Fisheries Adjustment Scheme which provided for the buyback of a portion of commercial fishing licenses.

E4 Support management measures which improve the protection of the blue swimmer crab breeding stock within the estuary including periodic closures, bag limit reductions and license buyback across the whole resource.

Recreation and tourism

E5 Develop a plan for recreation and tourism management on the estuary, which defines the recreational carrying capacity and guides acceptable management of boat wash, jetties, pump-out facilities and moorings.

Conservation and estuary restoration measures

E6 Support The Nature Conservatory to deliver projects that improve estuary condition (for example the installation of living shorelines and habitat restoration) and our understanding of the value of associated estuarine ecosystem services.

Improving knowledge to support management

E7 Undertake an environmental water requirements study for the estuary to inform water licensing and abstraction decisions.

E8 Assess estuary response to climate change and identify adaptation strategies.

E9 Use the Peel-Harvey estuary response model to scale and prioritise management actions to improve estuary condition.

Action: Plans, policy & partnership

These actions call for collective decision-making in the implementation of this plan and strategic coordination of estuary management. There is an emphasis on the link between land use planning decisions and water quality outcomes, with a suite of actions seeking to minimise the impact of future development on the estuary. The role of traditional owners is recognised, with several key actions aimed at supporting the Bindjareb Noongar people as active partners in estuary management.

Strategic coordination of estuary management

P1 Establish a coordinating committee to:

- guide the implementation of the plan
- share information on land development and planning proposals
- collaborate with key stakeholders to support implementation of the specific actions of this plan.

Stronger environmental protection

P2 Implement a contemporary statutory framework to achieve water quality improvements in the Peel-Harvey estuary by revising the current Environmental Protection (Peel Inlet – Harvey Estuary) Policy 1992 or replacing with an appropriate alternative.

Planning processes to minimise the impacts of future development on the estuary

P3 Ensure appropriate siting of 'agriculture – intensive' and 'animal husbandry – intensive' land uses, and premises with livestock numbers in excess of recommended stocking rates. These land uses (particularly in-ground horticulture, poultry farms, piggeries and feedlots) should not be in areas prone to nutrient export unless it can be demonstrated that they will be closed agricultural systems.

a. Implement:
   - relevant State Planning Policy
   - Peel Region Scheme, Priority agriculture and rural land use policy (DPLH and WAPC 2017), particularly paragraph 5.8, 5.9, 5.10, 5.11
   - Environmental Protection (Peel Inlet-Harvey Estuary) Policy 1992.

b. In areas prone to nutrient export, support the transition to closed agricultural systems with zero discharge of nutrient-rich liquid or solids to the immediate environment.

P4 Develop guidance material for agricultural and animal husbandry activities to align and integrate with: relevant State Planning Policy; Peel Region Scheme, Priority agriculture and rural land use policy (DPLH and WAPC 2017); and Environmental Protection (Peel Inlet – Harvey Estuary) Policy 1992.

P5 Implement the sewerage provisions contained in the government sewerage policy and other relevant State Planning Policy and guidelines, particularly connection to reticulated sewerage. Where connection to reticulated sewerage is not practicable, residential development should be serviced by secondary treatment systems with nutrient removal capabilities.

P6 Apply water-sensitive design in new urban and industrial developments to ensure all changes in land use will reduce nutrients entering the estuary (aligned with Waterwise Perth). Implement:

a. relevant State Planning Policy
b. *Better urban water management*[33]
c. *Stormwater management manual for Western Australia*[34]
d. decision process for stormwater management in WA[35].

P7 Review regulation of point source discharges from agricultural activities (e.g. dairy sheds, piggeries, feedlots) to ensure treatment to national best practice before discharge to the environment.

P8 Reduce or eliminate discharges to waterways through review and update of licensing requirements of prescribed premises.

P9 Protect waterway vegetation (e.g. samphire flats, sedges and paperbarks):

a. Identify and map remnant waterway vegetation as critical estuary habitat.
b. Identify and protect waterway foreshore areas consistent with the Operational policy; identifying and establishing waterway foreshore areas.[36]
c. Protect water quality by providing an additional separation distance between intensive land uses and waterways where required.
d. Investigate ways to restrict new canal developments in the Peel-Harvey estuary.

P10 Protect wetlands, including their hydrology, water quality and habitats:

a. Identify and map wetlands.
b. Develop new wetland buffer guidelines to clarify planning requirements and improve protection of those wetlands identified as having ecological values.
c. Apply wetland buffer guidelines which are protective of wetland values.
d. In addition to wetland buffers, provide a further separation distance between potentially polluting land uses and wetlands to protect water quality.

P11 Protect and conserve remnant vegetation in the catchment:

a. Develop and apply policy specific to the Peel-Harvey estuary to identify and protect priority areas of native vegetation and encourage revegetation with deep-rooted perennial species that improve water quality.
b. Consider incorporating areas of remnant vegetation into regional parks and conservation reserves.

Bindjareb Noongar people to be active partners in estuary management

P12 Work with elders to develop an agreement for Aboriginal participation and partnering in waterways planning and management of Bindjareb Boodja (Bindjareb country).

P13 Develop and implement a plan (Bindjareb Gabi Wonga) to communicate Aboriginal creation beliefs, values and management goals and guide actions for improved and collaborative management of the Djilba (estuary).

P14 Support initiatives that strengthen Bindjareb Noongar partnerships in water planning and management to preserve traditional sites and food places by:

- implementing an Aboriginal ranger program for Bindjareb boodja to look after special places
- developing and implementing the Bindjareb Waterways Assessment Program
- developing and implementing waterways protection and restoration projects in partnership with Aboriginal people to improve the health of the Djilba (estuary) and Bilya (its rivers).

Action: Measuring progress

These actions are based on an adaptive and iterative management framework to ensure we learn from experience and work towards continuous improvement. Investment in monitoring and science underpins our ability to evaluate the actions taken to protect the estuary. A cycle of review ensures that these learnings are adopted into future plans.

M1 Report progress on implementing the Peel-Harvey Estuary Protection Plan to the community annually and evaluate the plan every four years.

M2 Evaluate estuary condition, and report to the community on observed changes, with consideration to M3, M4, M5, M6 and M7 as appropriate, with key findings published at least every four years.

M3 Conduct fortnightly water quality sampling, including phytoplankton and nutrients, with reporting against the Water Quality Index at least every four years.

M4 Continue monitoring the streams and drains that flow into the Peel-Harvey estuary. Publish nutrient status and trends relative to the water quality objectives of 1.2 mg/L N and 0.1 mg/L P annually.

M5 Undertake seagrass and macro-algal surveys as a key component of ecological monitoring.

M6 Undertake fish community surveys and report on changes using comparative tools such as the Fish Community Index (developed by Murdoch University).

M7 Undertake periodic surveys of sediment condition and benthic invertebrate communities as indicators of changing environmental conditions.

M8 Undertake required reporting against Ramsar Limits of Acceptable Change.

M9 Measure the effectiveness of management practices at an appropriate scale to improve model predictions and the understanding of the response time between a management action and the measured improvement in water quality (i.e. lag-time).

Implementation

This plan highlights the need to increase efforts to improve water quality to protect estuary condition. It integrates the collective experience of the many people who have managed and studied the estuary and its catchment, as well as those who work and live locally. Our plan asks for many groups to work together for the collective benefit of the Peel-Harvey estuary, particularly given the pressures of a growing population and the likely effects of climate change.

Actions presented in this plan span a range of scales, from broad enabling actions to specific on-ground works and improved targeted management practices. Working at different scales allows for more immediate outcomes to be realised while making progress towards long-term goals.

The overarching policy, people and partnership actions create an environment conducive to responding to regional challenges in a coordinated and effective manner. Since the way we use the land surrounding estuaries has a large influence on their health, many of our on-ground actions target the major land-uses in the catchment. Estuary actions will help minimise pressures and improve science-based management within the Peel-Harvey estuary itself. We also recognise the need to measure our progress in implementing the plan and to continue to use science to understand how the health of the estuary is tracking over time.

This plan provides an agreed pathway to improved water quality and condition of the Peel-Harvey estuary. A subsequent implementation strategy will be developed to specify where actions are best situated in the landscape, and the requisite timeline. The implementation strategy is the next step in creating meaningful progress towards the goal of a healthy estuary that continues to support community values and ecological integrity for future generations.

Catchment		Lead	Support
Improved management of diffuse agricultural nutrients			
C1	Reduce nutrient losses to waterways by optimising fertiliser use to agronomic need through soil testing, agronomic advice and extension in partnership with farmers and the fertiliser industry.	DPIRD, DWER	PHCC
C2	Improve phosphorus retention in sandy soils used for intensive and broad-scale agriculture through the use of soil amendments, including: a. expanding on-farm trials using mining by-products and other materials that retain phosphorus, and making the results available to industry b. investigating how changes to regulation may facilitate wider use of soil amendments where appropriate.	DPIRD, DWER	PHCC
C3	Expand the development of slow-release phosphorus fertilisers and other new fertiliser formulations appropriate to Western Australian soils and promote uptake through demonstration trials.	DPIRD, DWER	Industry groups
C4	Develop new best management practices for broad-scale agriculture, including those to:		
	a. reduce fertiliser losses and reduce erosion through improved whole of farm management practices in conventional, broad-scale agriculture	DPIRD, DWER	PHCC
	b. encourage regenerative agriculture and holistic management techniques that improve soil health, use water efficiently, and maintain soil cover through farm-scale trials that may be adopted at a sub-catchment scale.	DWER	DPIRD PHCC
C5	Develop horticulture best management practices suited to high nutrient-leaching environments, such as innovative closed-loop agricultural systems and autonomous vertical smart farms.	DPIRD	PDC
C6	Conserve water and reduce nutrient runoff from irrigated agriculture by requiring Nutrient Irrigation Management Plans (NIMPs) as part of planning approvals and water licensing processes.	DWER, LGAs	DPIRD
C7	Assist farmers and other landowners to exclude stock from rivers, streams and drains to reduce erosion and the input of sediment and organic matter to the estuary and its tributaries.	PHCC	DWER, Water Corporation, private landholders
Improved management of point source agricultural nutrients			
C8	Extend partnerships with industry groups and farming enterprises to fast track adoption of best management practices in intensive agriculture, including the management of effluent from dairy sheds, piggeries and feedlots, to national standards or better, as appropriate for the Swan Coastal Plain.	DWER	DPIRD, Industry Associations

Catchment		Lead	Support
Reduce diffuse and point sources of urban nutrients			
C9	Assist householders to improve water use efficiency in urban gardens and minimise nutrient export risk through Waterwise education programs (aligned with Waterwise Perth).	DWER	PHCC, LGAs, Water Corporation
C10	Public open space managers to reduce the application of nutrients (fertiliser and others) and export risk and improve water efficiency in public open space (aligned with Waterwise Perth).	LGAs	DWER, PHCC, Water Corporation
C11	Public open space managers to evaluate the use of soil amendment to reduce phosphorus losses.	DWER & LGAs	PHCC
C12	Upgrade existing stormwater systems in priority areas according to water-sensitive design principles (aligned with Waterwise Perth).	LGAs	DWER, PHCC, Water Corporation
C13	Increase training and development opportunities for local government and the stormwater management industry to adopt water-sensitive design principles.	DWER	
C14	Increase the reuse of treated wastewater from wastewater treatment plants (WWTPs) on woodlots, golf courses and other green spaces where there is low risk of leaching into waterways. Identify opportunities and barriers for wastewater reuse within the industrial and agricultural sectors.	DWER	Water Corporation
C15	Encourage replacement of septic systems with a connection to a reticulated sewerage scheme where available. If reticulated sewerage is not available, encourage installation of a secondary treatment system with nutrient removal.	LGAs	DWER, Water Corporation
Improve drainage water quality			
C16	Improve the water quality of drainage waters that discharge to the Peel-Harvey estuary and its tributaries:		
	a. Implement the drainage partnering agreement between the Water Corporation, Department of Water and Environmental Regulation and Peel-Harvey Catchment Council. Identify actions to improve water quality in priority Water Corporation drains such as those draining to the Harvey Estuary.	PHCC	Water Corporation, DWER
	b. Investigate, develop and evaluate the use of innovative materials for phosphorus removal in drains, including phosphorus-binding clays.	DWER	Industry
	c. Evaluate other approaches (such as in-drain vegetation) to improve water quality in drainage waters that discharge to the Peel-Harvey estuary and its tributaries. Implement approved approaches in priority drains.	DWER/ PHCC	Water Corporation,
	d. Install stock-exclusion fencing and appropriate in-drain structures, such as sediment traps in key drains.	Water Corporation	PHCC, DWER LGAs

Catchment		Lead	Support
Other water quality and biodiversity measures			
C17	Reinstate the ecological function of key rivers and streams through river restoration works and revegetation of the river and stream margins.	PHCC	Harvey River Restoration Trust, DWER, LGAs
C18	Develop and implement a strategic revegetation and restoration plan, identifying opportunities for revegetation with deep-rooted endemic plant species with consideration to co-benefits such as increases in biodiversity:		
	a. Develop and fund a plan.	PHCC	DBCA, DWER, DPIRD, LGA's, DPLH
	b. Implement the plan.	PHCC	LGA's

Estuary		Lead	Support
Fisheries management			
E1	Manage the Peel-Harvey crab and finfish resources in line with harvest strategies that aim to maintain stocks at sustainable levels.	DPIRD	Recfishwest, Industry Associations
E2	Maintain sustainable populations of sea mullet and blue swimmer crabs through Marine Stewardship Council (MSC) certification which provides an oversight and reporting mechanism.	DPIRD	Recfishwest, Industry Associations
E3	Reduce fishing pressure via the voluntary Fisheries Adjustment Scheme which provided for the buyback of a portion of commercial fishing licenses.	DPIRD	Recfishwest, Industry Associations
E4	Support management measures which improve the protection of the blue swimmer crab breeding stock within the estuary including periodic closures, bag limit reductions and license buyback across the whole resource.	DPIRD	Recfishwest, Industry Associations
Recreation and tourism			
E5	Develop a plan for recreation and tourism management on the estuary, which defines the recreational carrying capacity and guides acceptable management of boat wash, jetties, pump-out facilities and moorings.	DWER	DoT LGAs
Conservation and estuary restoration measures			
E6	Support The Nature Conservatory to deliver projects that improve estuary condition (e.g. the installation of living shorelines and habitat restoration) and our understanding of the value of associated estuarine ecosystem services.	TNC	PDC, DWER, DBCA, PHCC, Industry
Improving knowledge to support management			
E7	Undertake an environmental water requirements study for the estuary to inform water licensing and abstraction decisions.	DWER	
E8	Assess estuary response to climate change and identify adaptation strategies.	LGAs, DWER	
E9	Use the Peel-Harvey estuary response model to scale and prioritise management actions to improve estuary condition.	DWER	

Plans, policy & partnership	Lead	Support
Strategic coordination of estuary management		
P1 Establish a coordinating committee to: • guide the implementation of the plan • share information on land development and planning proposals • collaborate with key stakeholders to support implementation of the specific actions of this plan.	DWER	DPLH, DPIRD, DBCA, PHCC, Bindjareb Noongar
Stronger environmental protection		
P2 Implement a contemporary statutory framework to achieve water quality improvements in the Peel-Harvey estuary by revising the current Environmental Protection (Peel Inlet – Harvey Estuary) Policy 1992 or replacing with an appropriate alternative.	DWER	EPA
Planning processes to minimise the impacts of future development on the estuary		
P3 Ensure appropriate siting of 'agriculture – intensive' and 'animal husbandry – intensive' land uses, and premises with livestock numbers in excess of recommended stocking rates. These land uses (particularly in-ground horticulture, poultry farms, piggeries and feedlots) should not be in areas prone to nutrient export unless it can be demonstrated they will be closed agricultural systems.		
a. Implement: • relevant State Planning Policy	DPLH/WAPC and LGAs	DWER, DPIRD, technical advisory groups
• Peel Region Scheme, priority agriculture and rural land use policy (DPLH and WAPC 2017), particularly paragraph 5.8, 5.9, 5.10, 5.11	DPLH/WAPC and LGAs	DWER, DPIRD, technical advisory groups
• Environmental Protection (Peel Inlet-Harvey Estuary) Policy 1992	DWER	DPIRD, DPLH/ WAPC, technical advisory groups
b. In areas prone to nutrient export, support the transition to closed agricultural systems with zero discharge of nutrient-rich liquid or solids to the immediate environment.	DPIRD & DWER	DPLH, LGAs
P4 Develop guidance material for agricultural and animal husbandry activities to align and integrate with: relevant State Planning Policy; Peel Region Scheme, Priority agriculture and rural land use policy (DPLH and WAPC 2017); and Environmental Protection (Peel Inlet – Harvey Estuary) Policy 1992.	DWER	DPIRD, DPLH

Plans, policy & partnership		Lead	Support
P5	Implement the sewerage provisions contained in the government sewerage policy and other relevant State Planning Policy and guidelines, particularly in connection to reticulated sewerage. Where connection to reticulated sewerage is not practicable, residential development should be serviced by secondary treatment systems with nutrient-removal capabilities.	DPLH/WAPC	LGAs, DWER, DoH
P6	Apply water-sensitive design in new urban and industrial developments to ensure all changes in land use will reduce nutrients entering the estuary (aligned with Waterwise Perth). Implement:		
	a. relevant State Planning Policy	DPLH/WAPC and LGAs	DWER
	b. *Better urban water management* (WAPC 2008)	DPLH/WAPC and LGAs	DWER
	c. *Stormwater management manual for Western Australia* (Department of Water and Swan River Trust 2004-07)	DWER	Advice to DPLH, LGAs
	d. decision process for stormwater management in WA (DWER 2017).	DWER	Advice to DPLH, LGAs
P7	Review regulation of point source discharges from agricultural activities (e.g. dairy sheds, piggeries, feedlots) to ensure treatment to national best practice before discharge to the environment.	DWER	
P8	Reduce or eliminate discharges to waterways through review and update of licensing requirements of prescribed premises.	DWER	
P9	Protect waterway vegetation (e.g. samphire flats, sedges and paperbarks):		
	a. Identify and map remnant waterway vegetation as critical estuary habitat.	DWER	DBCA
	b. Identify and protect waterway foreshore areas consistent with the Operational policy: Identifying and establishing waterway foreshore areas (Department of Water 2012).	DWER (advice to planning authorities)	
	c. Protect water quality by providing an additional separation distance between intensive land uses and waterways where required.	DWER (advice to decision makers[1])	
	d. Investigate ways to restrict new canal developments in the Peel-Harvey estuary.		

1 Decision-makers include authorities under the Planning and Development Act 2005, DWER under the RIWI Act or Part V of the EP Act or the EPA under Part IV of the EP Act).

Plans, policy & partnership		Lead	Support
P10	Protect wetlands, including their hydrology, water quality and habitat:		
	a. Identify and map wetlands	DBCA, DWER	
	b. Develop new wetland buffer guidelines to clarify planning requirements and improve protection of those wetlands identified as having ecological values.	DPLH, DWER, DBCA	
	c. Apply wetland buffer guidelines which are protective of wetland values.	DPLH/WAPC	DBCA, LGAs, DWER
	d. In addition to wetland buffers, provide a further separation distance between potentially polluting land uses and wetlands to protect water quality.	DWER (advice to decision makers[2])	DBCA, DPLH
P11	Protect and conserve remnant vegetation in the catchment:		
	a. Develop and apply policy specific to the Peel-Harvey estuary to identify and protect priority areas of native vegetation and encourage revegetation with deep-rooted perennial species that improve water quality.	DWER	PHCC, DBCA, DPIRD
	b. Consider incorporating areas of remnant vegetation into regional parks and conservation reserves.	DBCA	WAPC/DPLH
Bindjareb Noongar people to be active partners in estuary management			
P12	Work with elders to develop an agreement for Aboriginal participation and partnering in waterways planning and management of Bindjareb Boodja (Bindjareb country).	Bindjareb Noongar, DWER	PHCC
P13	Develop and implement a plan (Bindjareb Gabi Wonga) to communicate Aboriginal creation beliefs, values and management goals and guide actions for improved and collaborative management of the Djilba (estuary).	Bindjareb Noongar, DWER	PHCC
P14	Support initiatives that strengthen Bindjareb Noongar partnerships in water planning and management to preserve traditional sites and food places by: • implementing an Aboriginal Ranger Program for Bindjareb boodja to look after special places • developing and implementing the Bindjareb Waterways Assessment Program • developing and implementing waterways protection and restoration projects in partnership with Aboriginal people to improve the health of the Djilba (estuary) and Bilya (its rivers).	Bindjareb Noongar, DWER	PHCC

Measuring progress		Lead	Support
M1	Report progress on implementing the Peel-Harvey estuary Protection Plan to the community annually and evaluate the plan every four years.	DWER	
M2	Evaluate estuary condition, and report to the community on observed changes, with consideration to M3, M4, M5, M6 and M7 as appropriate, with key findings published at least every four years.	DWER	Universities, Research Providers
M3	Conduct fortnightly water quality sampling, including phytoplankton and nutrients, with reporting against the Water Quality Index at least every four years.	DWER	
M4	Continue monitoring the streams and drains that flow into the Peel-Harvey estuary. Publish nutrient status and trends relative to the water quality objectives of 1.2 mg/L N and 0.1 mg/L P annually.	DWER	
M5	Undertake seagrass and macro-algal surveys as a key component of ecological monitoring.	DWER	Universities, Research Providers
M6	Undertake fish community surveys and report on changes using comparative tools such as the Fish Community Index (developed by Murdoch University).	Murdoch University	DWER
M7	Undertake periodic surveys of sediment condition and benthic invertebrate communities as indicators of changing environmental conditions.	DWER, Universities	
M8	Undertake required reporting against Ramsar Limits of Acceptable Change.	PHCC, DBCA	Peel-Yalgorup Ramsar Techinical Advisory Group
M9	Measure the effectiveness of management practices at an appropriate scale to improve model predictions and the understanding of the response time between a management action and the measured improvement in water quality (i.e. lag-time).	DWER	DPIRD, PHCC

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Acknowlegement of images

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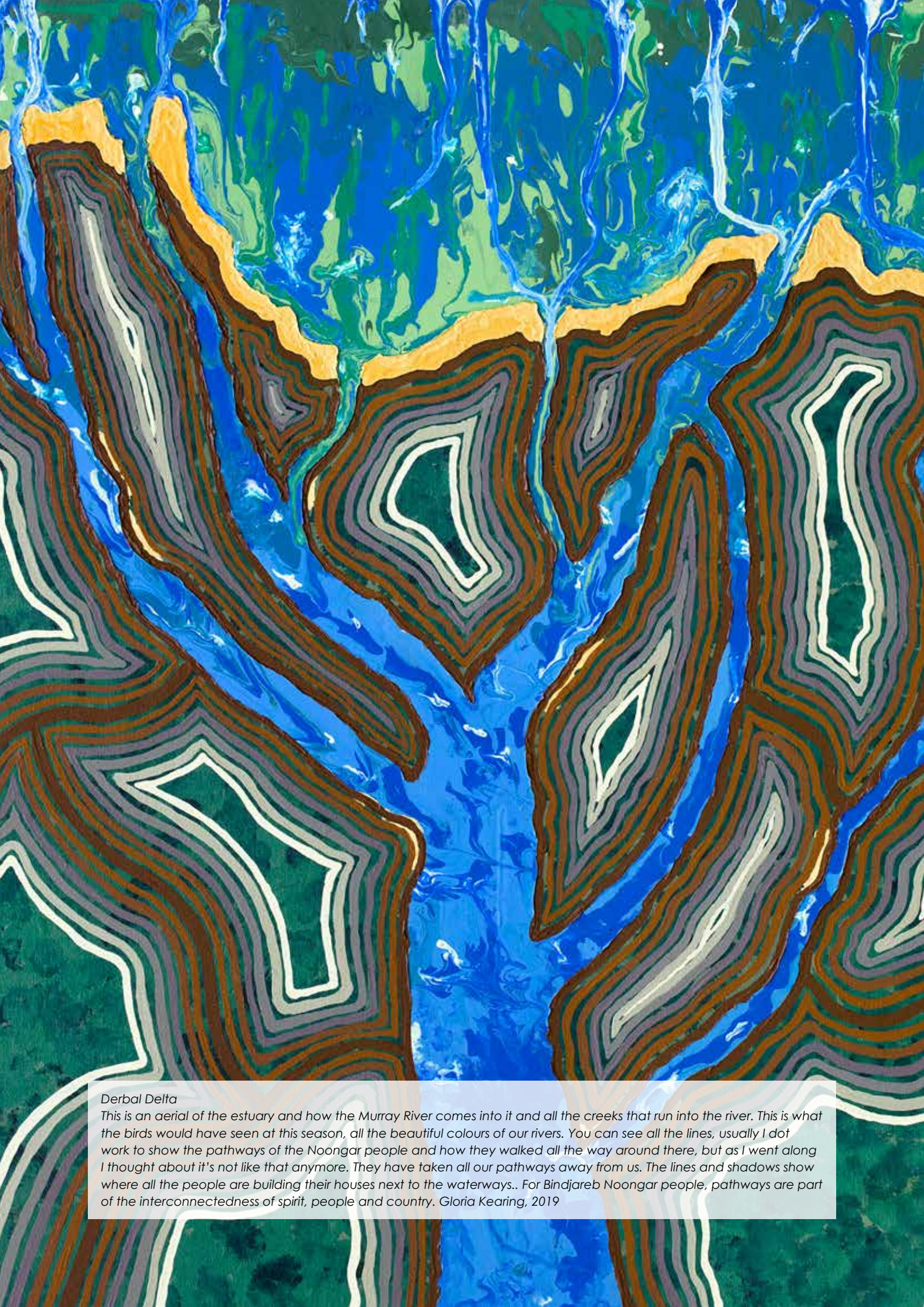
Artwork (page 6, 13, 60) by Bindjareb Elder Gloria Kearing. Much or her artwork is based on the movements of her family around the Peel-Harvey estuary, its rivers and the ocean.



Derbal Delta

This is an aerial of the estuary and how the Murray River comes into it and all the creeks that run into the river. This is what the birds would have seen at this season, all the beautiful colours of our rivers. You can see all the lines, usually I dot work to show the pathways of the Noongar people and how they walked all the way around there, but as I went along I thought about it's not like that anymore. They have taken all our pathways away from us. The lines and shadows show where all the people are building their houses next to the waterways.. For Bindjareb Noongar people, pathways are part of the interconnectedness of spirit, people and country. Gloria Kearing, 2019