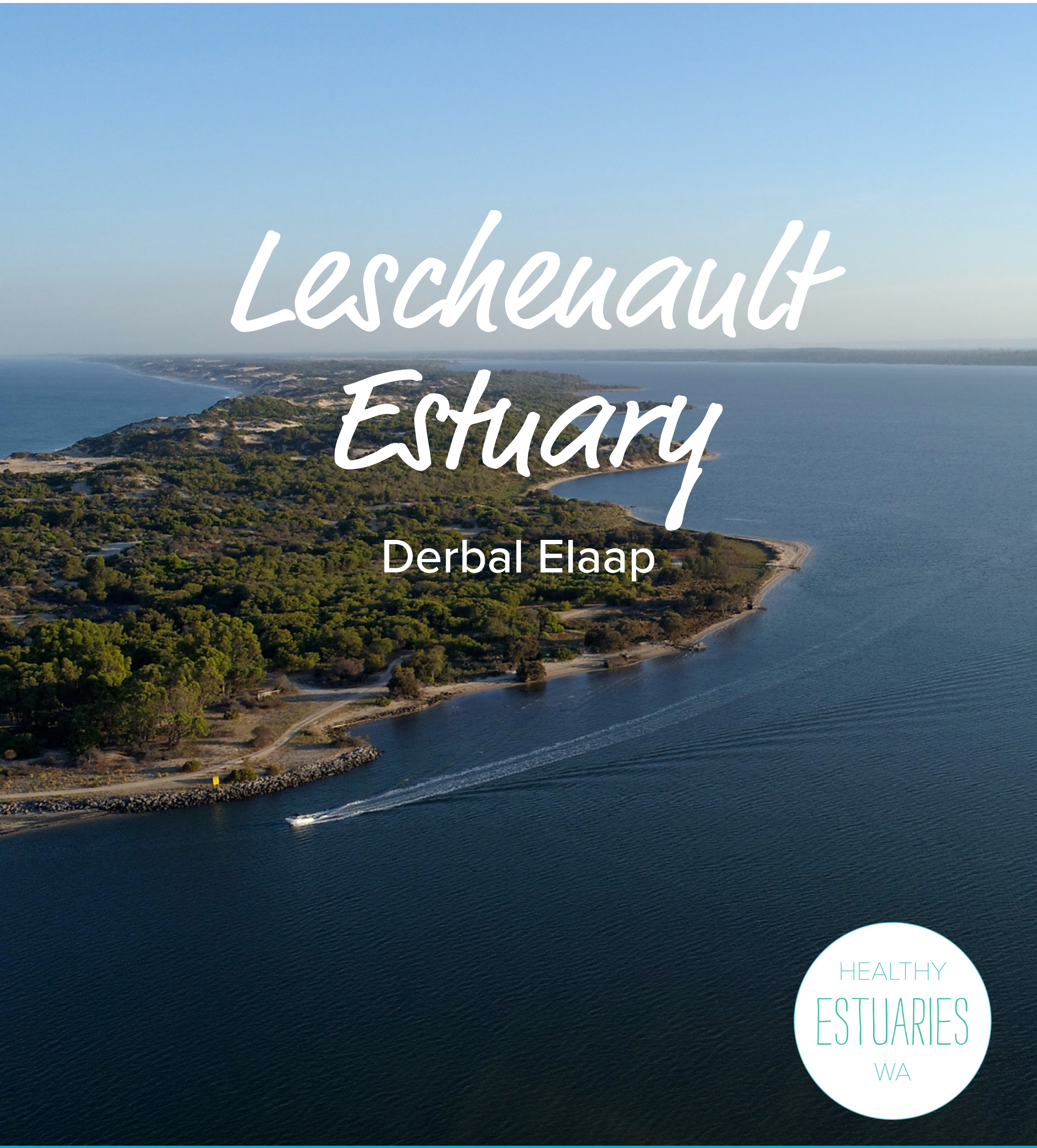
Department of **Water and Environmental Regulation**
Department of **Primary Industries and Regional Development**
GOVERNMENT OF WESTERN AUSTRALIA



Leschenault Estuary

Derbal Elaap

HEALTHY ESTUARIES WA

Condition of the estuary 2016–19

#WAestuaries

Acknowledgements

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Most photos are by Ash Ramsay, Department of Water and Environmental Regulation. Photo on p.28 of phytoplankton under the microscope is by Amanda Charles, Department of Water and Environmental Regulation.

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About estuaries


Estuaries are unique and dynamic environments where freshwater and seawater meet. They provide safe harbours and places of beauty for recreation and quiet reflection. They connect people to the natural environment, act as nurseries for recreational and commercial fisheries, provide sanctuaries for birds, and are highly productive and biodiverse ecosystems.

Estuaries face numerous pressures, primarily from excessive nutrient inputs from catchment land uses, and climate-related changes (reduced river inflows, increased temperatures, ocean acidification and rising sea levels). These pressures can diminish estuary health and consequently the social, economic and environmental values they hold.

Our vision of healthy estuaries requires collaboration with landowners, farmers, non-profit catchment and conservation groups, government agencies and local communities. The Healthy Estuaries WA program (2020–24) aims to build on the collaborative model we started through the Regional Estuaries Initiative (2016–20).

The Regional Estuaries Initiative extended scientific monitoring programs in six estuaries in the South West to provide foundational knowledge on the current ecosystem health, seasonal variation in water quality, and key drivers of estuary dynamics (for example, river flow, catchment nutrient inputs and marine exchange). This information helps us assess whether estuarine health is changing over time.

Insight into the condition of our estuaries enables more effective management. It allows, for example, for the development of targeted fertiliser practices; pinpointing of high-priority stream restoration sites; identification of public health risks and notification of the public if needed; and understanding of where more research is needed.

Report at a glance

This report summarises three years of the Regional Estuaries Initiative Leschenault Estuary water quality monitoring program (2016–19) and compares these recent results with historical data. We report on the main drivers of estuary health (flow and catchment condition, and the estuary response), the status of water quality indicators and key habitats such as seagrass.

The Leschenault Estuary is a stunning aesthetic setting for the suburbs of Australind, Eaton and Bunbury. The estuary offers recreational and tourism activities such as fishing, crabbing and water sports. It is home to dolphins and provides important habitat and refugia for breeding and migratory water birds. This ecosystem is also characterised by unique and significant vegetation, including significant seagrass beds, fringing saltmarsh and the southern-most occurrence of white mangrove.

Bunbury is one of the fastest growing regional centres in Australia. Increased urbanisation and agricultural activities combined with pressures from climate change have led to the Leschenault Estuary's declining ecosystem health, with blooms of nuisance and potentially harmful microalgal species, seagrass loss, low oxygen in bottom waters, bad odours and occasional deaths of fish, dolphins and black swans.

The estuary basin has relatively good water quality most of the time. However, the northern section is poorly flushed and vulnerable to microalgal blooms and seagrass loss.

Key points:

- the estuary basin is healthy (although the northern basin is vulnerable to hypersalinity, macroalgal blooms and seagrass loss)
- Parkfield drain has high levels of nutrients all year
- the estuarine portion of the lower Collie and Brunswick rivers continue to show signs of poor estuary health such as anoxia, excessive microalgal growth including potentially harmful species, and fish deaths
- symptoms exacerbated by low river flows, increased water temperatures and rising sea level due to climate change
- seagrass cover in the main basin shows some recovery in the last 10 years.

The estuarine reaches of the Collie and Brunswick Rivers are in agricultural subcatchments with highly modified flow regimes. The resultant poor water quality is characterised by persistent low oxygen in bottom waters, high nutrient concentrations, microalgal blooms and occasional fish kills.

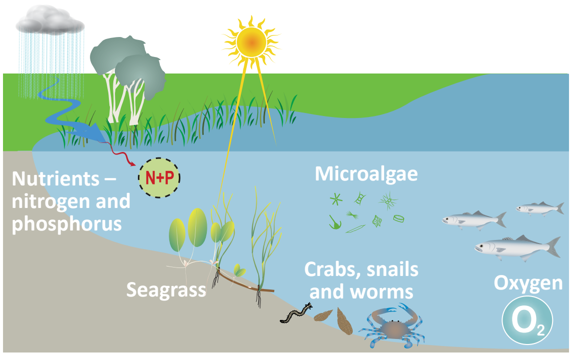
A Water Quality Improvement Plan (WQIP) was developed in 2012 to prioritise improvements to the condition of the estuary by reducing nutrient loads (nitrogen and phosphorus) from the catchment to the estuary. Given the ongoing poor water quality in the Collie and Brunswick rivers, implementation of WQIP actions is critical to improving the condition of the estuary.

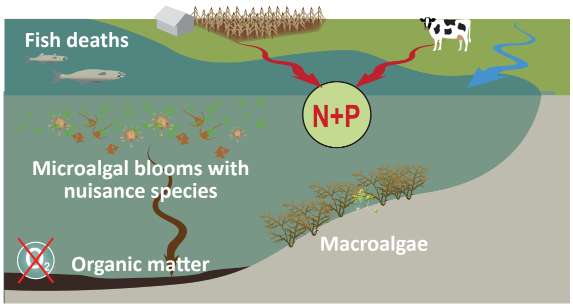
[1] Hugues-dit-Ciles J et al. 2012, *Leschenault estuary water quality improvement plan,* Department of Water, Government of Western Australia, Perth.

Estuary health refers to the ecological integrity of an estuary. Many things can compromise the ecology of an estuary: overfishing, contamination from industrial waste or the invasion of foreign species. However, for estuaries in Western Australia's South West, eutrophication is the main threat.

Eutrophication is the overgrowth of aquatic plants (usually micro- or macroalgae) caused by excessive nutrients: nitrogen and phosphorus. High algal growth (or algal blooms) leads to high organic matter decomposition rates which deplete oxygen in the water. Eutrophication can also cause fish and other fauna deaths and even lead to an ecosystem shift from a healthy seagrass-dominated system to the less desirable microalgae-dominated system.

What is estuary health?





Healthy estuaries

Estuary waters are clear, free from algal blooms, litter and turbidity. Fish are diverse and abundant. Estuary and river foreshores have healthy native trees and sedges. Small amounts of nutrients are naturally transported to the estuary by rivers and groundwater. Low concentrations of microalgae support the base of the food web. Bottom waters and sediments are well oxygenated. Seagrasses thrive in well-lit, low-nutrient waters. Seagrasses also stabilise sediments, shelter fish, provide food for birds such as swans and oxygenate bottom waters.

Unhealthy estuaries

Catchments and foreshores are extensively cleared for agriculture, urban and/or industrial land uses, leading to excessive nutrient concentrations. High nutrients fuel microalgal growth and favour macroalgae over seagrasses. Both decomposing micro- and macroalgae contribute to high levels of organic matter and oxygen consumption, while also reducing the light available to bottom-rooted seagrass, which cannot thrive in low-light environments. Microalgal communities change from healthy species to less desirable nuisance or potentially harmful species. Low oxygen and toxins from microalgae can lead to fish and fauna deaths.

What we measure

In the catchment

Flow: The volume of water per unit of time determined at hydrological gauging sites.

Temperature, dissolved oxygen, salinity, pH: Measured by an in situ probe, approximately mid-channel.

Nitrogen and phosphorus: In river concentrations, when multiplied by flow volume is an estimate of the load that enters the estuary.

In the estuary

Temperature, dissolved oxygen, salinity, pH: Measured by an in situ probe at 0.5–1 metre depth intervals.

Nitrogen and phosphorus: Concentrations measured in surface and bottom water samples. Analyses include total and dissolved nutrients (nitrate, ammonium and phosphate).

Microalgae: Chlorophyll *a* concentration in surface samples, and species identification and cell density in depth-integrated samples.

Seagrass: Mapping of spatial extent and condition assessment.

About Leschenault Estuary and its catchment

The Leschenault Estuary is located on the south-west coast of Australia, immediately north of the city of Bunbury and about 170 km south of Perth. To the east, the estuary is bounded by the suburbs of Eaton and Australind, and by the pristine sand dunes of the Leschenault Peninsula National Park to the west.

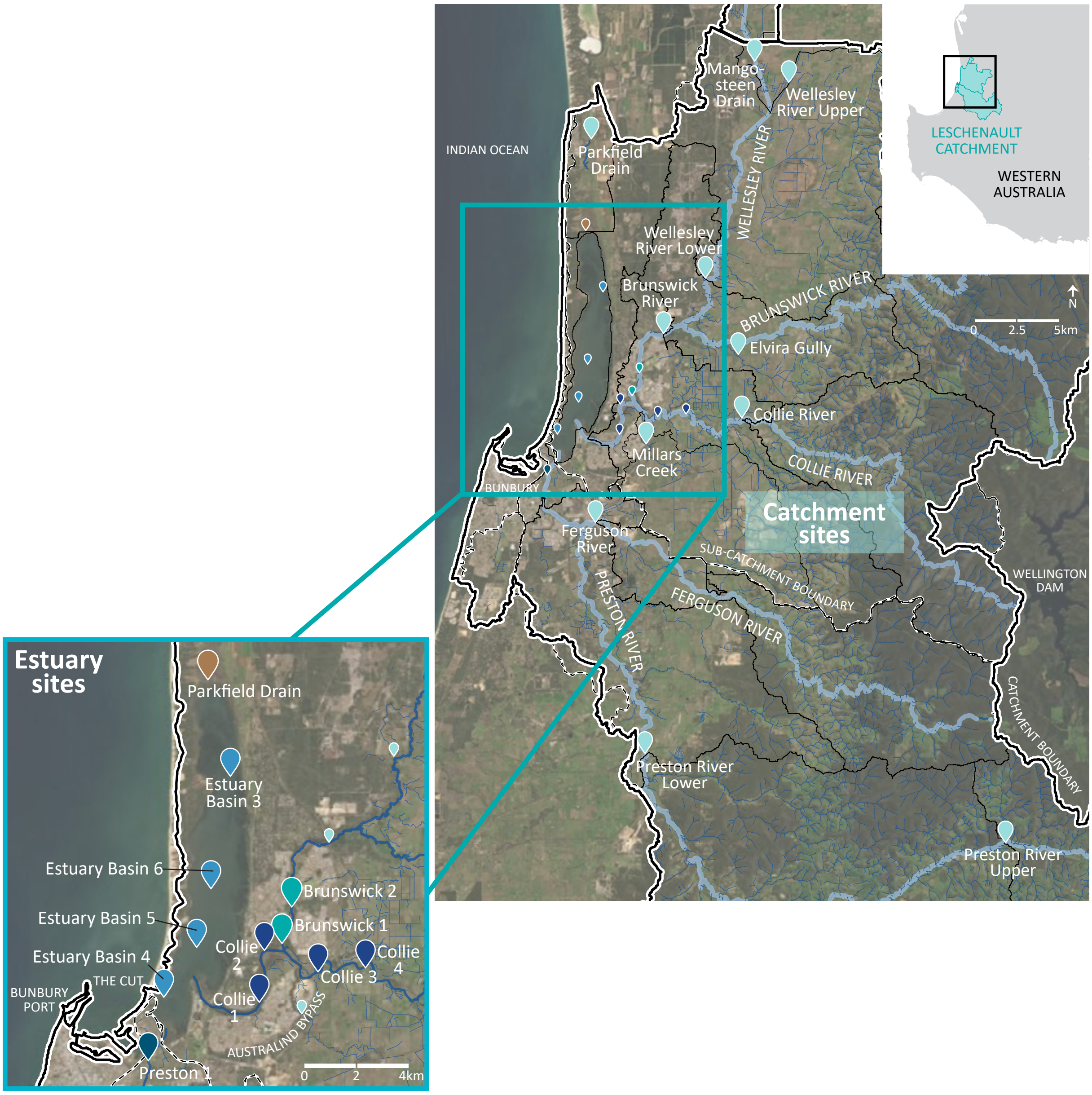
The estuary is orientated north to south, and is about 13.5 km long and 2.5 km wide, covering an overall area of 27 km^2. It is generally shallow, with an average basin depth of less than 1 m. The estuary is connected to the Indian Ocean by an artificially constructed, permanent, 180 m wide opening known as 'the Cut'. Tides are diurnal with maximum tides of 0.5–0.9 m. Marine water intrudes 10 km up the Collie and 2 km up the Brunswick rivers, so the lower river reaches are part of the 'estuarine' ecosystem.

Adjacent to the estuary, the Leschenault Inlet is home to the southern-most occurrence of mangroves along the west coast. The estuary also supports abundant fish, benthic fauna and dolphins.

Freshwater flows to the estuary are via the Collie River and its tributaries (Brunswick and Wellesley rivers), and the Preston River and its tributary (the Ferguson River). These rivers are all dammed and flow into the south-eastern part of the estuary basin. Occasionally small flows enter the northern estuary via the Parkfield drain.

The flows in the Leschenault catchment are highly modified. Downstream of Wellington Dam, the Collie River Irrigation District supports extensive agricultural interests; irrigation is via a network of open channels and pipes.

Water quality monitoring is undertaken fortnightly at 12 estuary sites, and 11 catchment sites.



Catchment sites
LESCHENAULT CATCHMENT
WESTERN AUSTRALIA
INDIAN OCEAN
Mangosteen Drain
Wellesley River Upper
Parkfield Drain
WELLESLEY RIVER
Wellesley River Lower
Brunswick River
BRUNSWICK RIVER
Elvira Gully
Collie River
COLLIE RIVER
Millars Creek
BUNBURY
Ferguson River
SUB-CATCHMENT BOUNDARY
FERGUSON RIVER
PRESTON RIVER
WELLINGTON DAM
CATCHMENT BOUNDARY
Preston River Lower
Preston River Upper
N
0 2.5 5km
Estuary sites
Parkfield Drain
Estuary Basin 3
Estuary Basin 6
Brunswick 2
Estuary Basin 5
Brunswick 1
Collie 2
Collie 4
Estuary Basin 4
Collie 3
THE CUT
BUNBURY PORT
Collie 1
AUSTRALIND BYPASS
Preston 1
0 2 4km

Historical context

Leschenault Estuary is in the boodjar (country) of the Wadandi Noongar people, and is known as Derbal Elaap.[1] 'Derbal' means estuary and 'Elaap' refers to the territory of the Elaap clan group of the Wadandi tribe or Yoongan Jarli Elaap (people of Elaap). This district was also known as home to the Cultaa Yoongan Jarli (Mullet people). Both Yellow Eye (*Aldrichetta forsteri*) and Sea Mullet (*Mugil cephalus*) use the Leschenault Estuary as a nursery area.

The Derbal Elaap is comparatively young, having formed as a dune barrier estuarine lagoon system some 7,000 years ago.

When Nicolas Baudin led a French scientific voyage to the South West of Western Australia in 1801–03, he named the estuary after the ship's botanist, Jean-Baptiste Leschenault de la Tour. The British colonised the area in the late 1830s. They used the land adjacent to the estuary for beef farming, housing and horse breeding to supply the British Army in India. The township 'Australind' reflects this association between Australia and India with its name being a combination of the two countries.

The Leschenault Peninsula on the western bank of the estuary was privately owned until the 1970s, when it was used for acid and mining effluent disposal. In the 1990s, it was revegetated and became an 'A class' conservation park.

The population growth of the greater Bunbury region was slow at first, but the discovery of gold inland and the expansion of the Bunbury Port supported the region's growth and it is now one of the main regional centres in the South West. Changes to the estuary and its catchment have been extensive over the past 80 years. Land reclamation, substantial native vegetation

[1] Information courtesy of cultural informants Zac and Wayne Webb from the Undalup Association.

clearing, urbanisation, damming and redirecting of rivers in the catchment, flood control programs, dredging and harbour reconstruction, barrier causeways, leakage of industrial wastes, and utilisation of groundwater resources have all taken their toll on the estuary.

One of the most dramatic geomorphological changes was the development of a narrow, artificial opening (the Cut) in 1951, to enhance marine water exchange and accommodate the development of Bunbury port. This changed the estuary from being predominantly brackish to predominantly marine.

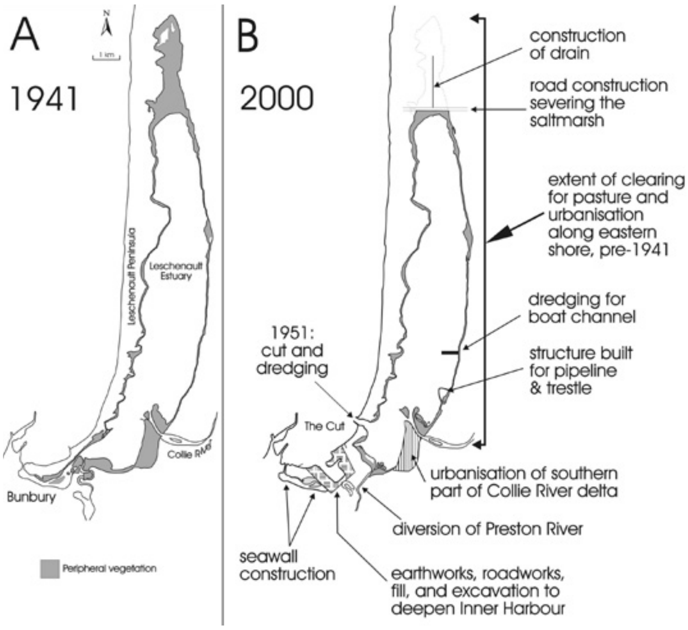
The construction of the Wellington Dam on the Collie River in 1933 supplied water to the Collie Irrigation District and reduced the flushing capacity of the lower Collie River. Parkfield drain, constructed in the 1970s, reduced the northern area of saltmarsh.

By the 1990s, only half of the original fringing vegetation around the estuary remained due to land clearing and reclamation.[3] More has been lost since.

Also, since the 1990s, due to the way the land is being used and modifications to drainage, the estuary and associated waterways have shown signs of eutrophication, such as excessive microalgal growth, low oxygen, fish kills, bad odours and a reduction in seagrass distribution.

The Leschenault Estuary has significant biodiversity and geomorphological values. The details are well documented in a special issue of the Royal Society of Western Australia's journal, based on 20 years of scientific studies on the estuarine environment.[4] In response to symptoms of water quality decline, the WQIP was developed in 2012 to improve the condition of the estuary by reducing loads of nitrogen and phosphorus from the catchment.

Today, despite the changes and declining health, the estuary and its catchment still support many ecological, social, and economic values. Activities such as mining (coal, alumina, and mineral sands), timber production, tourism and agribusinesses have created prosperity for the region, which is one of the most populous areas in the South West. Future growth and pressures from climate change will continue to stress the Leschenault estuarine ecosystem.



Source: Semenuik V, Semeniuk TA & Unno J 2000, 'The Leschenault Inlet estuary: an overview', *Journal of the Royal Society of Western Australia*, 83(4). Corrected by V Semeniuk in 2020.

[3] Pen L et al. 2000, 'Peripheral wetland habitats and vegetation of the Leschenault Inlet estuary', *Journal of the Royal Society of Western Australia,* 83: 293–316

[4] Semenuik V & Withers P (eds) 2000, 'The Leschenault Inlet Estuary special issue', *Journal of the Royal Society of Western Australia*, 83(4).

Climate change in the South West

Lower river flow, higher temperatures and rising sea level are drivers of estuary health

The South West of Western Australia has a Mediterranean climate pattern: cold, wet winters and warm, dry summers.

Rainfall plays a key role in estuary dynamics as it influences freshwater inflows. The interplay between freshwater inflows and ocean water exchange determines the salinity, flushing rate and stratification patterns in estuaries. Temperature is also important, as it strongly influences biological growth rates.

Changes in the key climate drivers in the South West are already evident and predicted to continue. The region has become warmer and drier.

Since 2000, May to July rainfall over the South West has been about 28 per cent less than the long-term average.[5] There is strong evidence to suggest that rainfall in the region will decline further in the future.[6,7] Not only has rainfall dramatically decreased in autumn and early winter, but there have also been large fluctuations in summer rainfall, which could lead to more frequent and intense storms.[5,6]

Freshwater flows have also decreased significantly by up to 70 per cent since the 1970s – a pattern which is expected to continue.[8]

Between 1910 and 2013, the average annual air temperature in the South West increased by 1.1 degrees Celsius (°C),[9] and is predicted to increase by 0.7 °C by 2030 (relative to the 1961–90 baseline).[6]

5 Bureau of Meteorology 2020, *Australia's changing climate*, available from www.bom.gov.au/state-of-the-climate/australias-changing-climate.shtml.

6 Department of Water 2015, *Selection of future climate projections for Western Australia*, Water science technical series, report no. 72, Dow, Government of Western Australia, Perth.

7 Hope P et al. 2015, *Southern and south-western flatlands cluster report, Climate change in Australia projections for Australia's natural resource management regions: cluster reports*, ed Ekström M. et al., CSIRO and Bureau of Meteorology, Australia.

8 Petrone K et al. 2010, 'Streamflow decline in southwestern Australia, 1950–2008', Geophysical research letters, Hydrology and land surface studies, 37(11), available from: agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2010GL043102.

9 Department of Primary Industries and Regional Development 2020, *Climate trends in Western Australia, Government of Western Australia*, Perth, available from: www.agric.wa.gov.au/climate-change/climate-trends-western-australia.

How will estuaries be affected?

Reductions in freshwater flows will lead to increased average salinity in most estuaries. Some areas will be prone to hypersalinity, where a lack of freshwater inflows and summer evaporation means that salt concentrates in zones with restricted ocean exchange. Hypersalinity can already be seen in parts of the Leschenault Estuary and Peel–Harvey estuary. Ecological consequences of hypersalinity are decreased microalgal diversity and restricted habitat for brackish and freshwater fish species.

Water quality may improve in some areas. For example, the zones closest to permanent openings with good connection to the marine environment will most likely see an increase in marine biodiversity and a decrease in algal activity as they become less influenced by fresh, nutrient-rich catchment inflows. Conversely, intermittently closed estuaries (common on the south coast of Western Australia) are likely to have longer periods of sandbar closure. This change in environmental conditions may reduce biodiversity and increase the effects of nutrient-rich catchment inflows.

Stratification patterns will change as low flows cannot fully flush estuarine waters in winter; rather, smaller freshwater flows sit as a layer above the saline bottom waters and may persist for longer periods of time. This can result in depleted oxygen (known as hypoxia) and the release of sediment-bound nutrients, which can fuel undesirable algal blooms (discussed in more detail later). Nutrients from catchment inflows could become retained in the estuary rather than being flushed out to sea. This can lead to adverse impacts such as increased algal activity and low light conditions for seagrasses. The estuarine river reaches of many South West estuaries already show these patterns of extended periods of low oxygen status due to high nutrient loads and persistent stratification.

Shallow estuaries will be particularly vulnerable to warming conditions. Higher temperatures favour microalgal growth and estuaries may have greater microalgal productivity as a result, which subsequently affects the overall food web. Extreme heat waves also have negative impacts on some fauna and flora, such as important seagrasses. Rising sea levels and more frequent summer storm events could increase the occurrence of coastal inundation events.

The synergistic impact of these various stressors is difficult to predict, and recent studies show that these effects are happening at rates faster than those predicted by climate change models.[10]

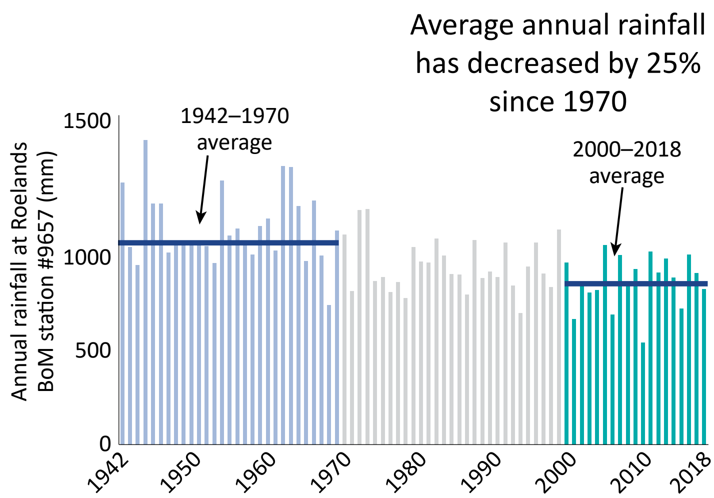
[10] Scanes E, Scanes PR & Ross PM (2020), 'Climate change rapidly warms and acidifies Australian estuaries', *Nature Communications* 11(1803), available from https://www.nature.com/articles/s41467-020-15550-z.

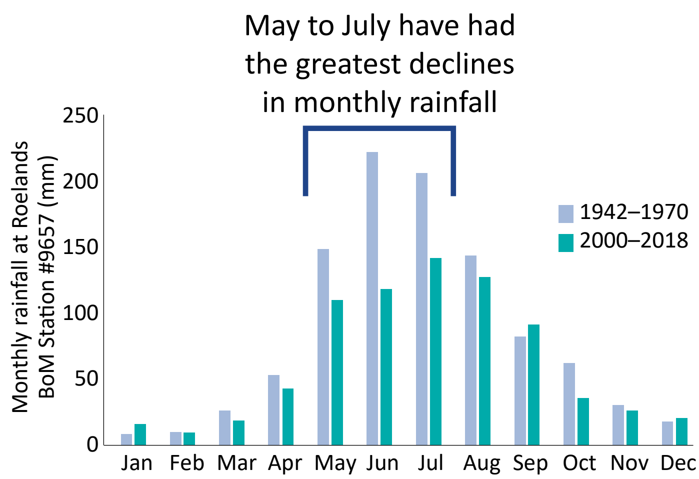
Rainfall and flow

In the Bunbury region, the average rainfall from 2000–18 was 763 mm, a 25% decline since the 1942–70 annual average of 1014 mm. The greatest decline in rainfall in the South West region was in May to July: from 2000 to 2018 the autumn-winter average was 36 per cent less than that from 1942 to 1970.[11]

Key points:

- rainfall in the Leschenault Estuary region has decreased by 25% since 1970 due to climate change
- in recent years, the highest rainfall period has occurred between June and August and lowest between November and February.



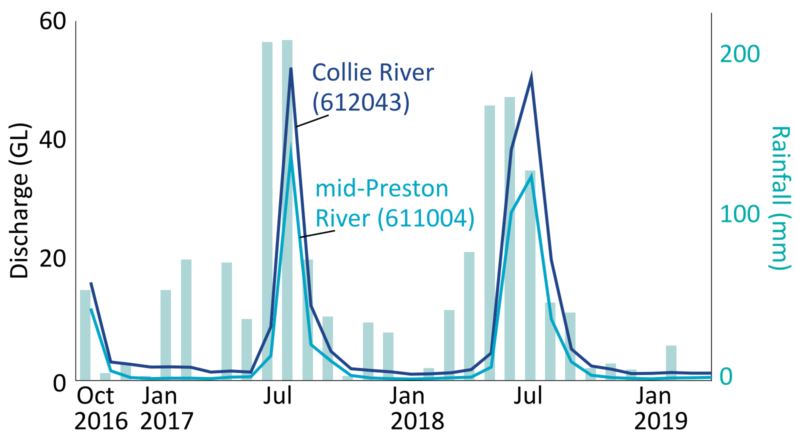


[11] Bureau of Meteorology 2018, *Australia's changing climate*, available from www.bom.gov.au/state-of-the-climate/australias-changing-climate.shtml.

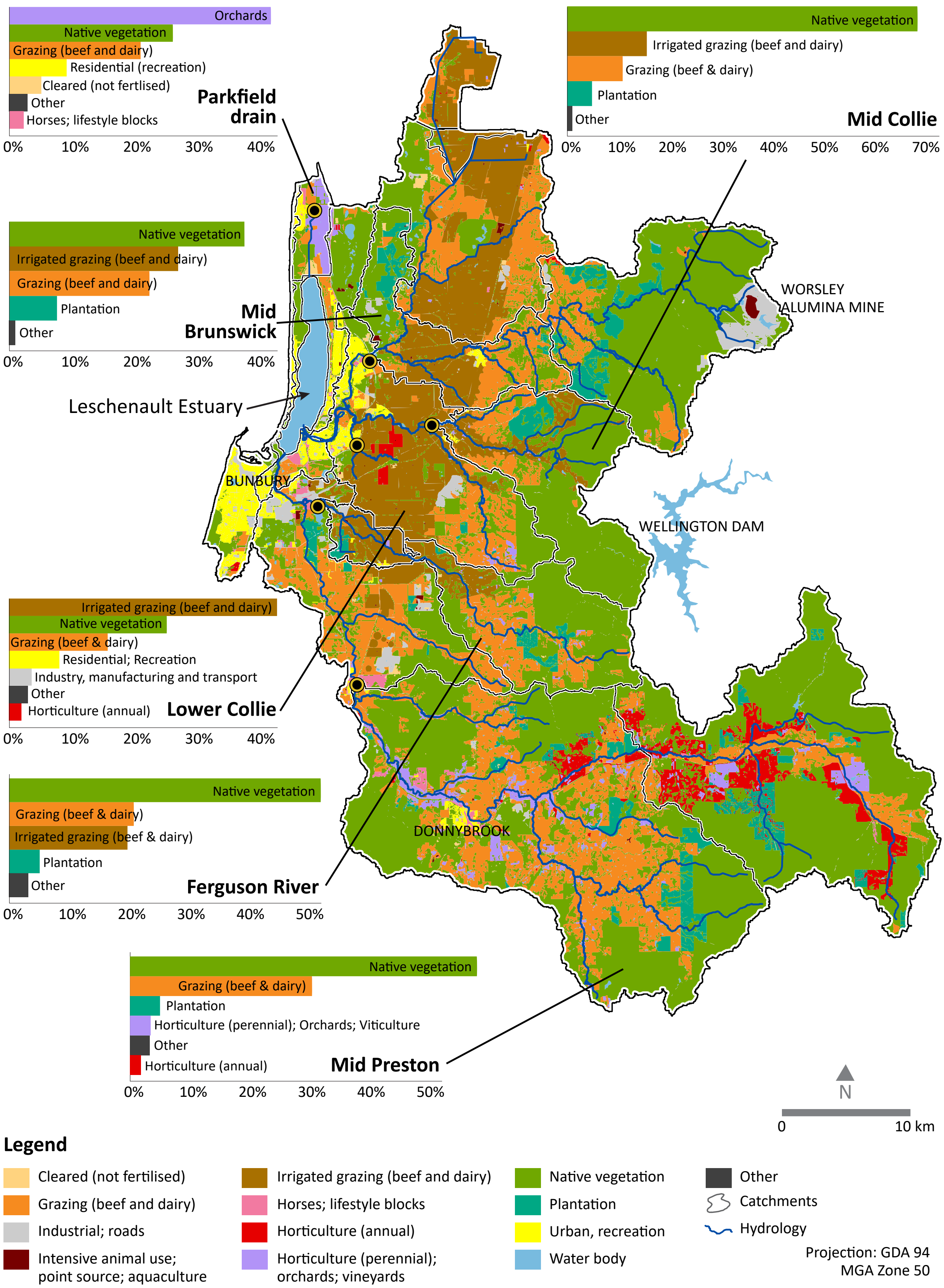
Burekup Weir on the Collie River. Water is released to the Collie River Irrigation District from October to April.

River flows are important for an estuary's condition as they directly influence the transport and concentration of nutrients, as well as ecological processes. River flows and rainfall follow a similar pattern: for example, years with high annual river flows (2000, 2005, 2013 and 2014) are generally associated with years of high rainfall. The same is true for low annual river flows (2001, 2006, 2010 and 2015). Yet, similar annual rainfall values do not consistently produce the same annual river flows, as observed in 2011 and 2012, for instance. The river flow is affected by the intensity of the rainfall event, the period between events and the location of the rainfall within the catchment. Dry periods between rainfall events in the wet season result in drying of the catchments, which then take time to get sufficiently wet again for the next rainfall to run as river flow. This highlights the complexity of such dynamic systems and the need for ongoing environmental monitoring.

The Collie and Preston River flows are similar in seasonal pattern and magnitude. Flows, particularly in summer, are controlled for irrigation and therefore summer rainfall events do not always result in increased flows. (Rainfall from BOM station #9657)



Catchment land use



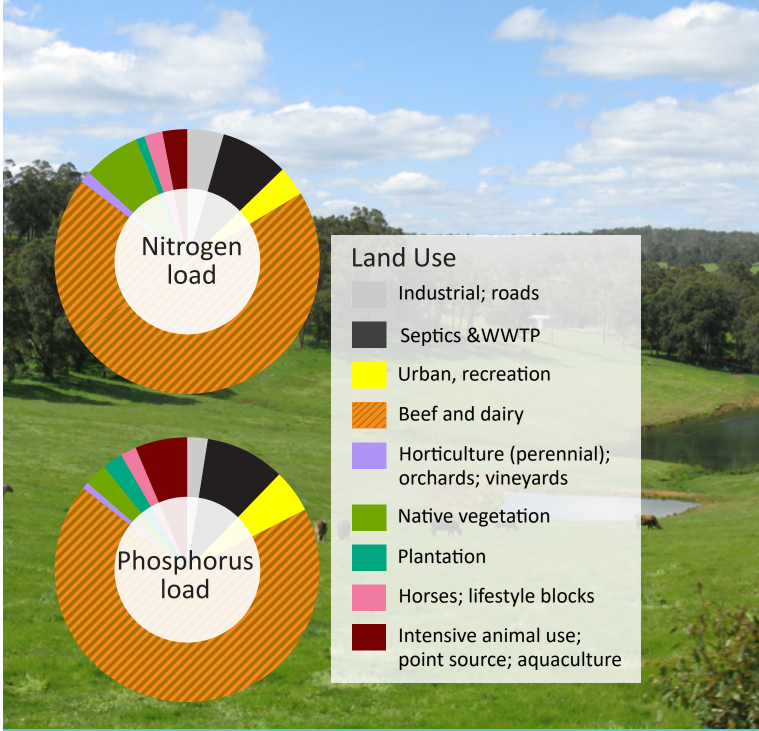
Catchment nutrient sources

The catchment of the Leschenault Estuary covers 1,981 km^2 and extends to Harvey in the north, Donnybrook in the south and about 40 km east to Wellington Dam. Approximately a third of the total catchment has been cleared for urban or agricultural purposes.[12] If we exclude the eastern upper Collie catchment, which is above the Wellington Dam, close to 50 per cent of native vegetation has been cleared. Twenty-one per cent of the eastern part of the catchment, in the Darling scarp, has been cleared.

Modelling completed as part of the WQIP detailed the sources of nutrients to the Leschenault Estuary with respect to land use. Beef and dairy grazing contributed the largest proportion of nutrient loads, together accounting for nearly 70 per cent of both nitrogen and phosphorus loads.

Significant diffuse nutrients also come from horticulture, viticulture, horses and lifestyle blocks. The relative contribution varies between subcatchments. For example, 40 per cent of the Parkfield drain subcatchment is dedicated to horticulture, while dairy sheds dominate the Wellesley and mid-Brunswick subcatchments. Septic tanks concentrated around the eastern Leschenault foreshore provide significant urban nutrient load contributions.

Soils vary in their capacity to bind phosphorus. In the South West, areas on the coastal plains with grey sands tend to have poor phosphorus-binding capacity. Phosphorus applied as fertiliser can move relatively quickly to drains, streams and groundwater. Sustainable farming in the South West can be achieved through improving soil structure, which will help reduce nutrient losses (mostly phosphorus) from farmland.



Facts and figures

Catchment area	1,981 km^2
Per cent cleared area (2018)	50% (excluding Upper Collie above Wellington Dam)
Inflows	Collie, Brunswick, Wellesley, Preston, Ferguson rivers and Parkfield drain
Annual flow (2018)	155 GL (excluding Brunswick River)
Main land use (2018)	Beef and dairy farming, horticulture

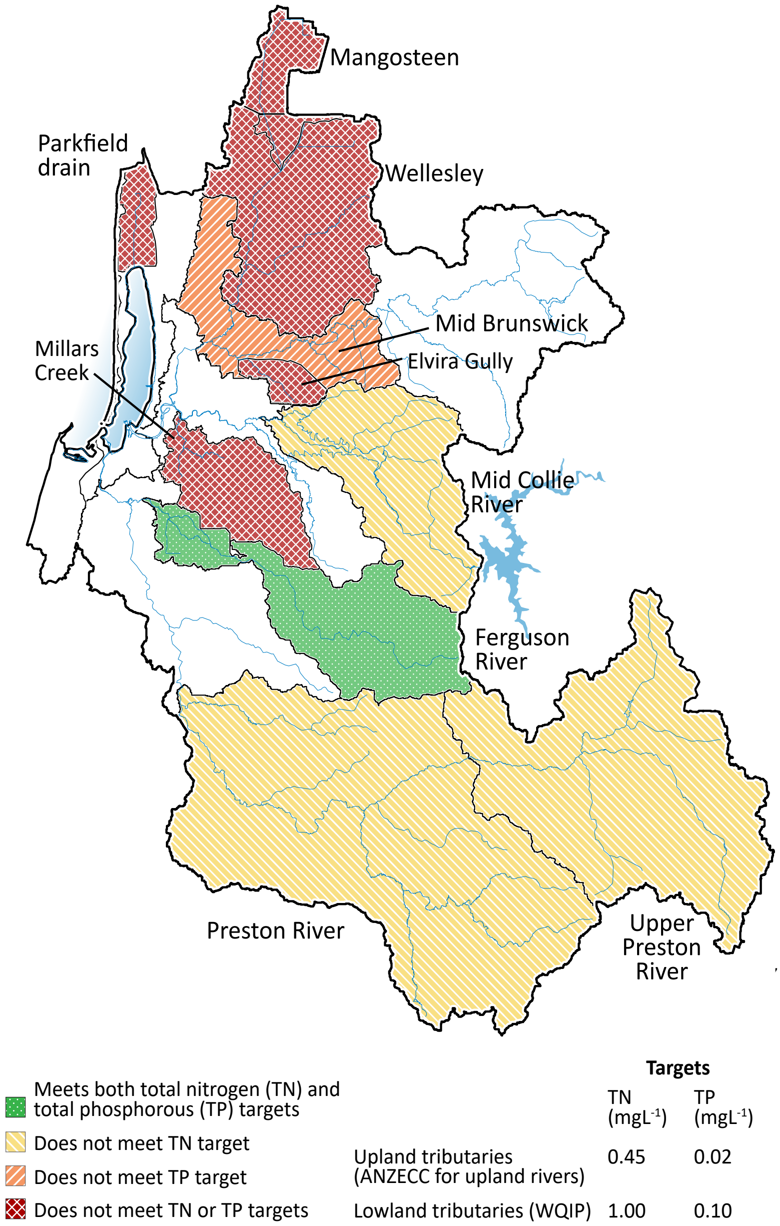
Different land use types vary in the amount of nitrogen and phosphorus they export to receiving waters such as estuaries. Land covered by native vegetation exports the least. Pig, beef and dairy farms tend to export the highest amount of nutrients, and this reflects the amount of nutrients applied as well as the total area of the land use type. Urban garden fertiliser use, septic tanks and wastewater treatment plant discharges can also cause eutrophication. Land use mapping and knowledge of the nutrient status of the major flows within the catchment help us to identify areas that currently have (or potentially may have) a negative impact on estuary health. This information is used to guide investment in mitigating land use impacts in large, diverse catchments.

[12] Hugues-dit-Ciles J et al. 2012, *Leschenault estuary water quality improvement plan*, Department of Water, Government of Western Australia, Perth.

Catchment nutrient concentrations

During the 2016–19 monitoring period, nutrient concentrations were measured about mid-channel in surface water samples every fortnight, in the major river or stream within each subcatchment. Winter median nutrient concentrations were compared to the WQIP total nitrogen (TN) and total phosphorus (TP) concentration targets for the Leschenault Estuary: TN 1.0 mgL^{-1}, TP 0.1 mgL^{-1} (lowland); and TN 0.45 mgL^{-1}, TP 0.02 mgL-1 (upland).[13] Nutrient concentration targets are used to establish the nutrient status of the catchment. They help determine what management actions need to be implemented and act as a value against which progress can be measured. The WQIP classified subcatchments as being either 'upland' or 'lowland'. Concentration targets for the upland subcatchments are the same as the Australian and New Zealand Environment and Conservation Council's (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) guidelines for south-west upland rivers.[14] In this instance, we compared recent data to the concentration targets, but acknowledge this is not a rigorous compliance testing analysis for which longer-term data is required.

The map shows if the subcatchment total nitrogen and phosphorus winter median concentrations in 2016–19 were above or below the concentration targets. For nitrogen, the winter median concentrations were higher than the concentration targets in all subcatchments except the mid-Brunswick and Ferguson River. Winter median total phosphorus concentrations



	Targets	
	TN (mgL^{-1})	TP (mgL^{-1})
Upland tributaries (ANZECC for upland rivers)	0.45	0.02
Lowland tributaries (WQIP)	1.00	0.10

Key points:

- throughout the monitoring period, nitrogen concentration targets were exceeded in most subcatchments
- phosphorus concentration targets were also exceeded in most of the coastal (lowland) subcatchments
- nutrients are highest in the subcatchments with large areas of agricultural (beef and dairy farms) and horticultural land use in the coastal (lowland) subcatchments

exceeded the concentration targets in the Wellesley and Brunswick subcatchments, Millar's Creek (Collie River subcatchment) and the Parkfield drain.

Overall, the pattern of high nutrient status in the lowland subcatchments and moderate nitrogen status in both the lowland and the upland subcatchments is reflected in the current monitoring results and largely comparable to the results reported in the WQIP.

There are, however, some differences between the WQIP catchment nutrient status and the data within the 2016–19 monitoring period:

- Ferguson River was below the WQIP's nutrient concentration targets in 2016–19, where it previously exceeded both the TN and the TP targets
  - it is worth noting, however, that previously it only just exceeded the targets, and the current results show it fell just below the targets, so this is not a significant variation
- Parkfield drain nutrient concentrations were below the TP target and above the TN target in the WQIP, but exceeded both in the 2016–19 monitoring
  - the monitoring site has shifted in recent years, however, as the earlier site was tidally influenced; therefore, direct comparisons between these two sites are not valid.

Detailed catchment water quality monitoring results are reported annually for individual subcatchments. Due to gaps in the data, it was not possible to calculate water quality trends for the Leschenault subcatchment sites as a minimum of five years of data is required.

[13] Hugues-dit-Ciles J et al. 2012, *Leschenault estuary water quality improvement plan*, Department of Water, Government of Western Australia, Perth.

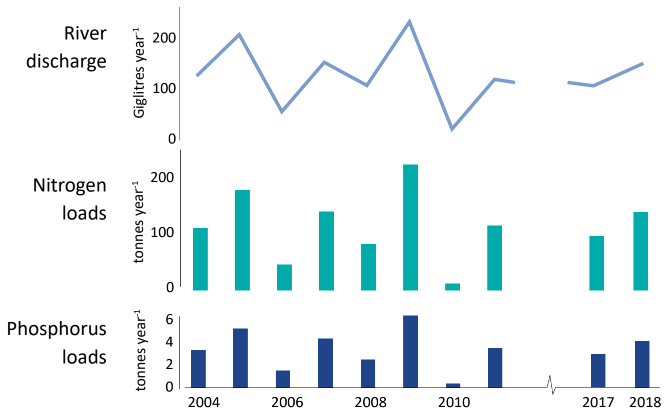
[14] ANZECC & ARMCANZ 2000, *Australian and New Zealand guidelines for fresh and marine water quality*, vol 1: the guidelines, available from https://www.waterquality.gov.au/anz-guidelines/resources/previous-guidelines/anzecc-armcanz-2000. The default guideline values for lowland rivers in the south-west provide a concentration above which there may be a risk of an adverse impact on water quality.

Flows and loads to the estuary

The total amount (or load) of nutrients entering the estuary is estimated by multiplying nutrient concentration by the flow volume. There is a strong relationship between river flow and the amount of nutrients entering the estuary. The pattern of high interannual fluctuations in nutrient loads represents natural (or climate-change influenced) fluctuations in river discharge. Ideally, nutrient load reduction targets would be normalised for flow.

In 2017 and 2018, flow and nutrient loads were within the range recorded from 2004 to 2011.

Given the effect of flow on nutrient loads, trends in nutrient concentrations are a more useful measure of change. Such analyses will be possible once more than five consecutive years of monitoring data is collected.



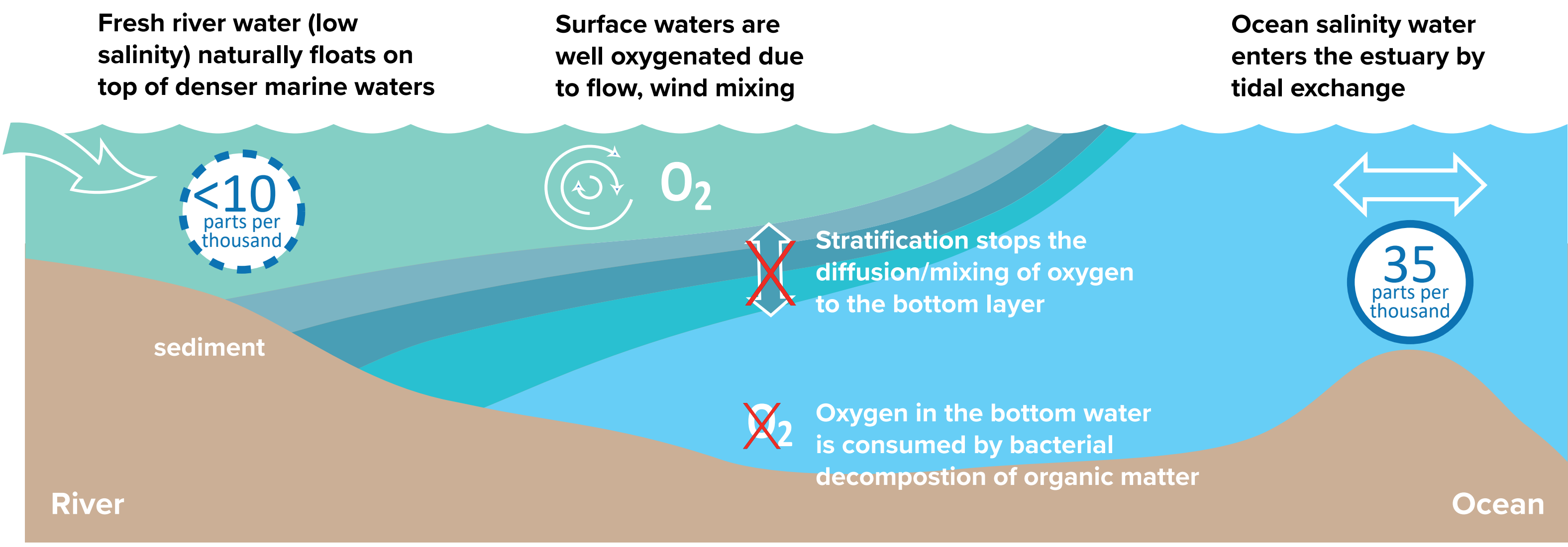
In the estuary:

the importance of stratification

Stratification in water is an important feature of most estuaries. It relates to vertical differences in salinity: freshwater from the rivers tends to sit at the surface because of its lower density, while the denser marine water entering from the ocean makes up the bottom layers. These layers require energy to mix, either from wind, currents or shear due to movement between the two layers. The strength and persistence of stratification varies seasonally and even daily within an estuary, depending on the river flow, tidal conditions and distance from the ocean entrance.

Stratification greatly influences estuarine chemistry and biology, especially the oxygen status of bottom waters. Strong stratification causes a physical barrier to the diffusion of oxygen from the surface to the bottom waters.

In estuaries with significant microalgal productivity, the bottom layer also has a large amount of organic matter which is decomposed by oxygen-consuming bacteria. Oxygen can be depleted rapidly and when stratification persists, low oxygen (hypoxic) or no oxygen (anoxic) conditions emerge. These conditions are inhospitable to bottom-dwelling animals, and no oxygen in the bottom waters gives rise to rotten-egg-smelling hydrogen sulfide gas, which is also toxic. Sediment chemistry is altered by anoxia, releasing sediment-bound nutrients and adding to eutrophication problems.



Salinity and oxygen concentrations

The complex geomorphology of the Leschenault Estuary creates a variety of hydrodynamic zones:

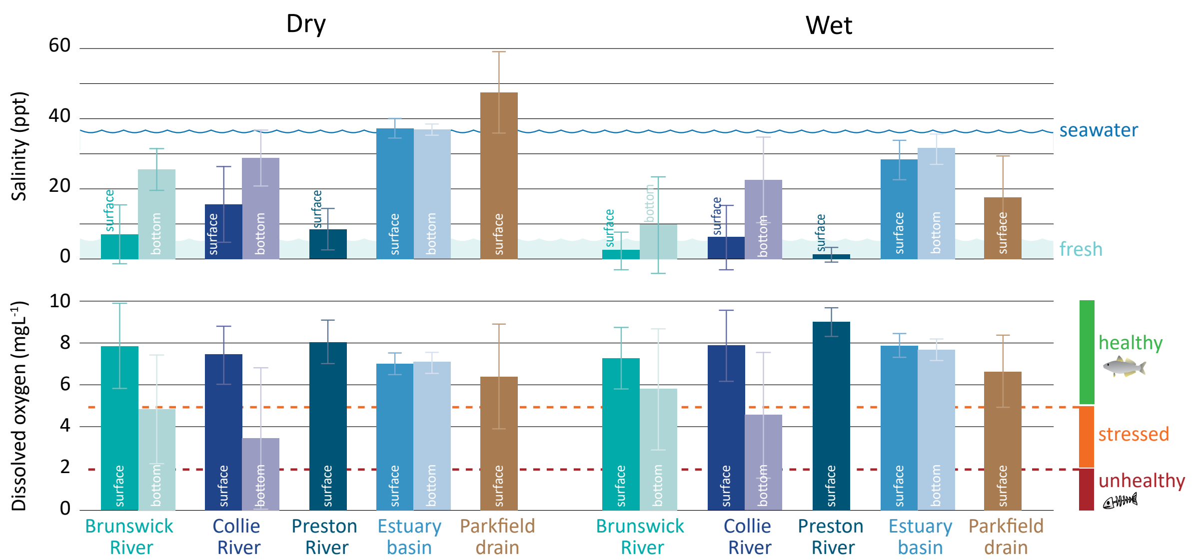
Brunswick River
The estuarine part of the river is often stratified in terms of salinity. When stratified, bottom water oxygen concentrations are consistently low, with the lowest oxygen concentrations recorded during the dry season.

Collie River
The salinity differences between surface and bottom waters in both wet and dry seasons show that the waters are rarely flushed with freshwater from the rivers and stratification is persistent. Like the Brunswick River, bottom water oxygen concentrations were consistently low in 2016–19, especially in the dry seasons.

Preston River
Surface waters were fresh to brackish. Unlike the Brunswick and Collie River systems, the waters in the Preston had a healthy oxygen concentration. This is probably because the river is shallow and does not have excessively high organic loads (which can consume oxygen).

Estuary basin
During the monitoring period, there was a small decrease in winter salinity averages in the estuary basin to below seawater levels, showing the influence of the freshwater river inputs. However, the estuary is strongly influenced by tidal exchange and in summer the limited freshwater input to the northern basin leads to hypersaline conditions. The oxygen status of this system was good in both seasons.

Parkfield drain
This area is often hypersaline, particularly during the summer (up to 1.5 times as salty as marine water), due to high evaporation rates and poor flushing. Because of the shallow depth of this system, only surface oxygen concentrations were measured, and showed elevated values all year. While high oxygen concentrations are generally good, excessive concentrations in day-time values can also indicate algal bloom activity.



Dry = November to May; Wet = June to October

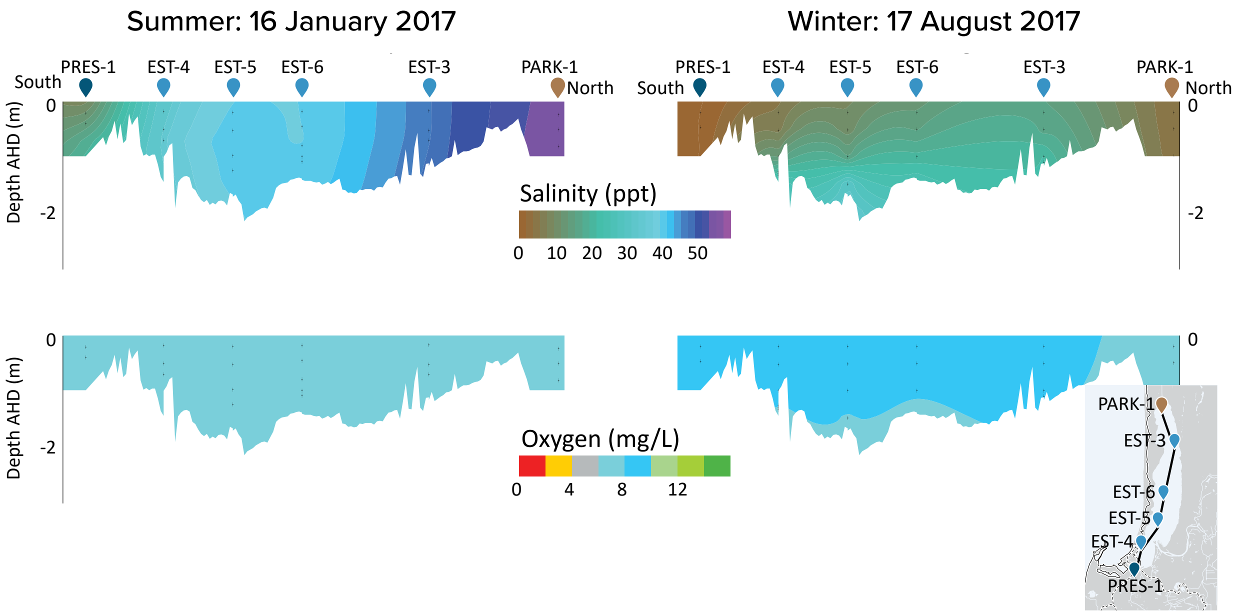
Seasonal patterns:

salinity and oxygen dynamics

Salinity and dissolved oxygen concentrations were measured fortnightly across the estuary basin and Collie River. The plots below represent typical conditions for the summer dry and winter wet seasons.

In the estuary basin, the water was more saline during the dry season, with the northern part of the basin becoming hypersaline. A mild salinity stratification was observed during the wet season; however, no oxygen stratification was observed.

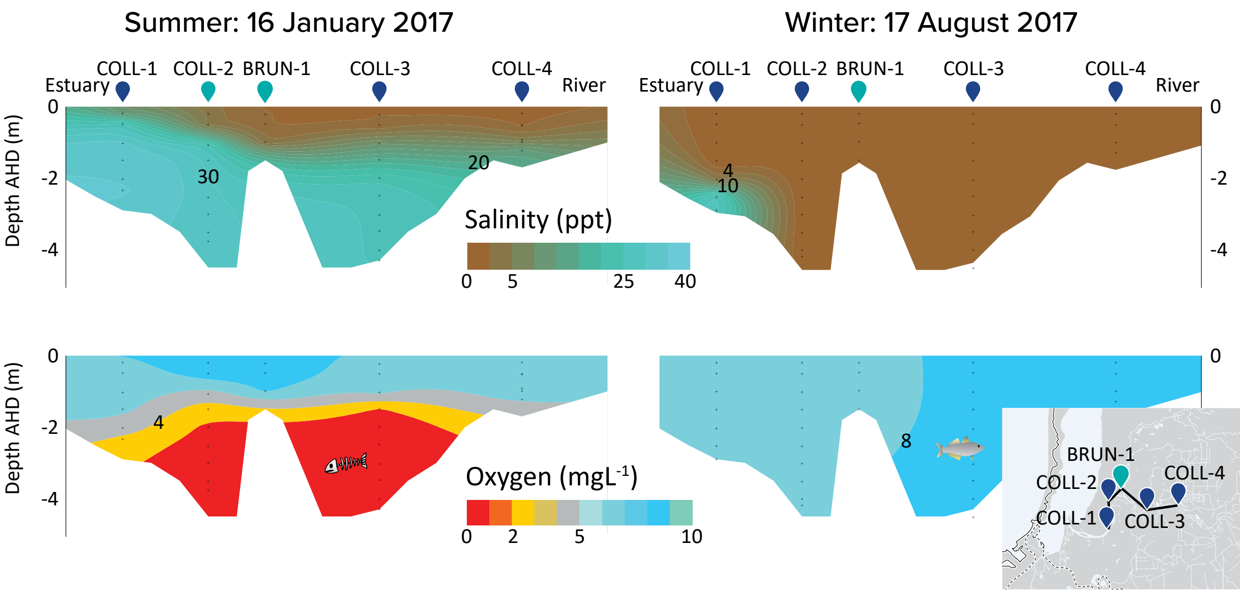
Estuary main basin – hydrodynamics



In the Collie River, during the dry season there was a clear salinity stratification of the water, with freshwater at the top and seawater at the bottom. Due to restricted exchanges between the surface and bottom waters, the deeper waters had less oxygen than those above, and there was a total absence of oxygen in the bottom waters. During the wet season, however, freshwater was almost exclusively present throughout all the layers. The lack of stratification led to more water being exchanged and therefore healthy oxygen levels in the river.

In the Collie and Brunswick rivers, prolonged periods of stratification can lead to unhealthy conditions for aquatic fauna. During the monitoring period, strong summer salinity stratification was associated with extremely low oxygen conditions, typically in regions deeper than two metres, as shown in the contour plots from 16 January 2017.

Collie River – hydrodynamics



In the estuary:

nutrient and chlorophyll concentrations

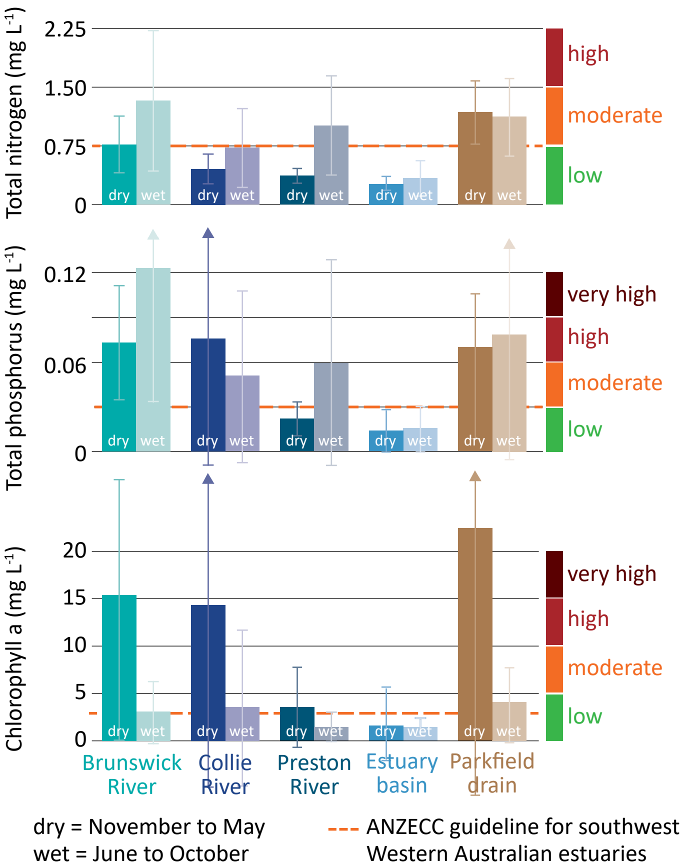
Nitrogen and phosphorus are the most important nutrients for plant growth. They exist in many forms. The dissolved inorganic nutrients – such as ammonium, nitrate and phosphate – are immediately available for plants and algae to use. Other nutrient forms (organic or particulate) are not immediately available and must be remineralised first.

As discussed earlier, catchment inflows are a key source of nutrients to most estuaries. Sediments can also be a significant source of dissolved nutrients where there is persistent stratification and large amounts of organic matter. By measuring the seasonal pattern of nutrient concentrations in surface and bottom water samples, we can determine whether these nutrients are likely to come from catchment inflows, sediments or both.

The first response of an estuary to higher nutrient concentrations is usually increased microalgal activity. We monitor this by measuring the concentration of chlorophyll *a*, a plant pigment, in water.

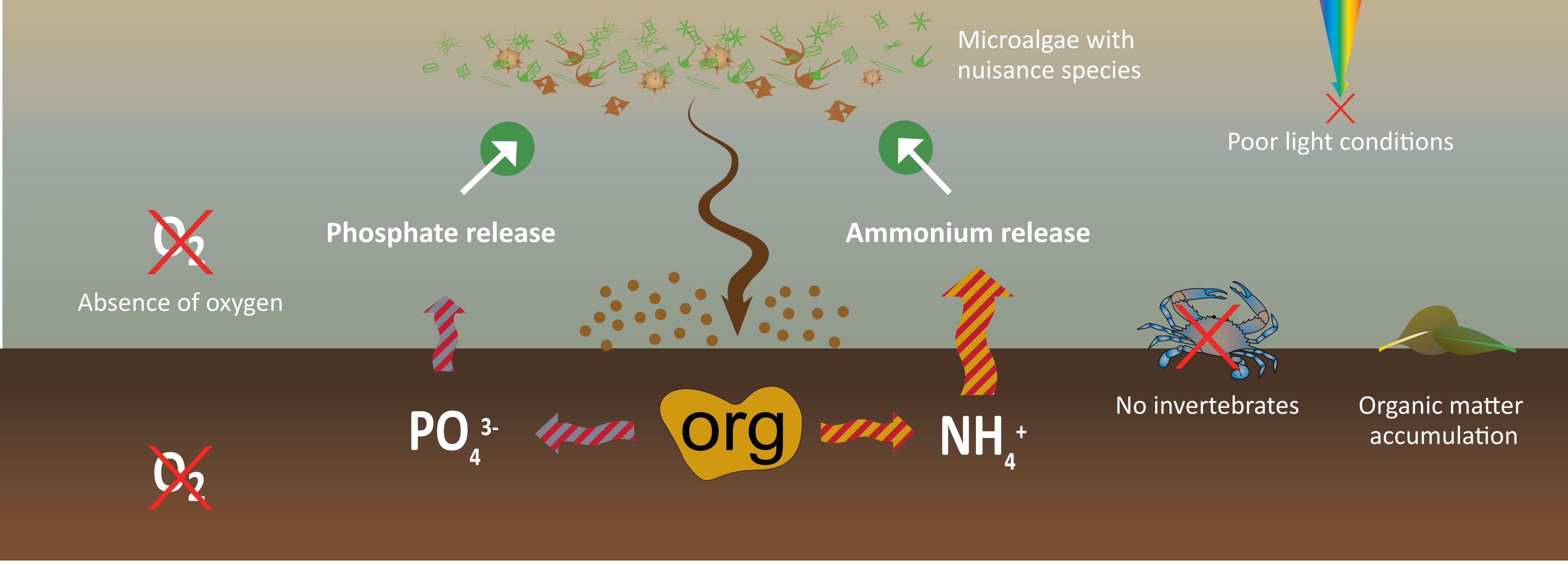
Spatial and seasonal patterns

In the estuarine region of the Brunswick, Collie and Preston rivers, total nitrogen concentrations were higher in the wet season than the dry, particularly in the Brunswick River. Comparatively, the mean total nitrogen concentrations were low in both the dry and wet seasons in the estuary basin, but were among the highest average levels (about one and a half times the guideline levels) in Parkfield drain.



The mean phosphorus level followed a similar spatial pattern, with higher concentrations in the rivers and Parkfield drain compared with the estuary basin. The average phosphorous level in the Brunswick River during the wet season was four times the guideline value. This is probably due to high phosphorus loads coming from fertiliser and animal waste related to agricultural land use in the Wellesley catchment. In the case of the Collie River, average phosphorus levels in the dry season were higher than the wet season. This suggests that we have an in-estuary source of phosphorus in the Collie River, likely derived from sediment release of nutrients caused by high organic loads and persistent stratification.

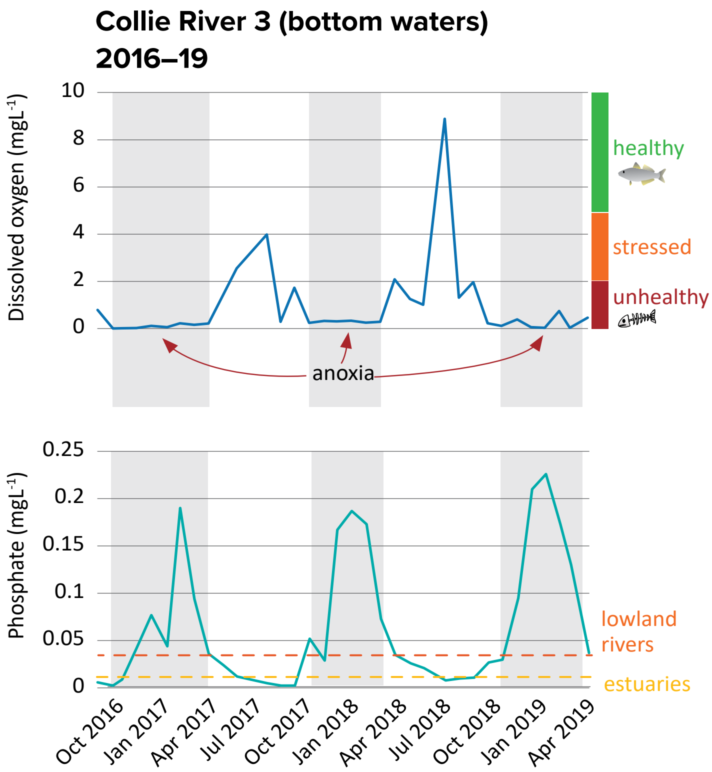
Chlorophyll *a* levels were high to very high in the dry season in the Brunswick and Collie rivers. They were very high in Parkfield drain: poor flushing and high nutrient inputs from the Parkfield drain catchment create the perfect conditions for microalgal growth. In the wet season in the two rivers and drain, high nutrient concentrations but low chlorophyll *a* levels and therefore low microalgal activity tell us that other factors were limiting microalgal growth, such as low temperatures, regular flushing of the waters and low light penetration.



Low oxygen and nutrient release

Stratification of the water column can lead to unhealthy, low-oxygen bottom waters. It is important to note that, under such conditions, nutrients are being released from the sediment. Specifically, when oxygen levels are very low, a build-up of ammonium (NH_4+) can occur, increasing concentrations of nitrogen in the water. In addition, under such oxygen-restricted conditions, phosphate bound to sediments will also be released, further enriching the phosphorus content of the water.

This can be seen in the figure below from one of the sampling sites from the Collie River (Collie River 3). A decline in oxygen levels in 2017 and 2018 led to a rise in phosphate concentrations in the bottom waters. Therefore, persistent stratification is not only threatening to organisms who require oxygen to survive but also contributes to further increases in nutrient concentrations in the water.

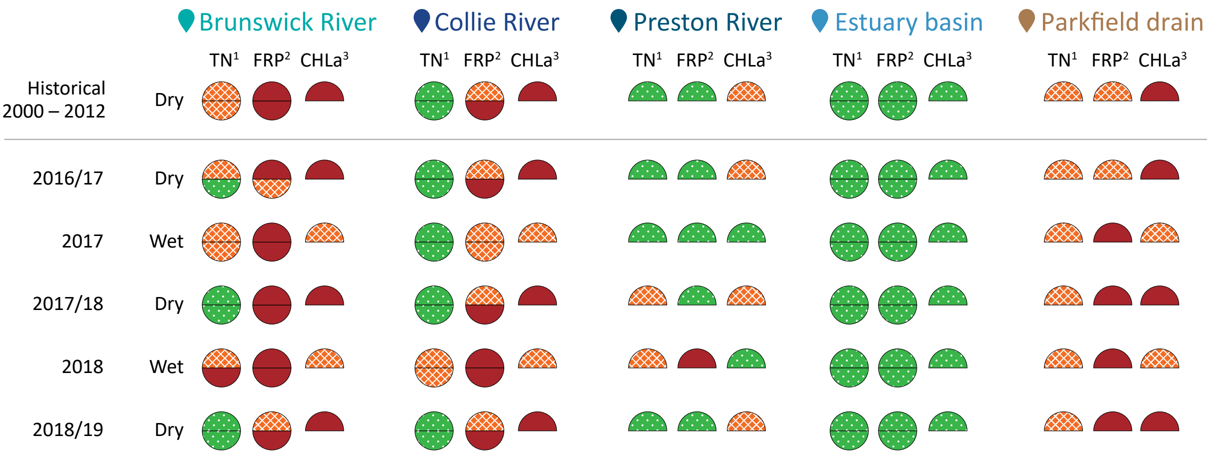


Dashed lines are the ANZECC guidelines for south-west Western Australian estuaries and lowland rivers.

Comparison with historical data

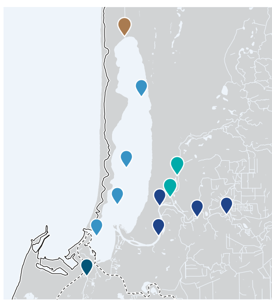
Prior to the Regional Estuaries Initiative, water quality monitoring in Leschenault Estuary was inconsistent and rarely occurred during the wet season. However, of the data available for the dry seasons between 2000 to 2012, the mean nutrient and chlorophyll *a* concentrations followed a similar pattern to the recent (2016–19) dry seasons, with a few points of difference. Total nitrogen concentrations, for example, were low in the Brunswick River in recent dry seasons compared with the historical data where they were moderate. Phosphorus concentrations in Parkfield drain were high in recent dry seasons, while they were only moderate in the historical data.

In broad terms, the similarity of the results, especially the high chlorophyll *a* activity in the estuarine river reaches (Brunswick and Collie) and Parkfield drain in the dry seasons since 2012, would suggest that little improvement has occurred. However, sustained low nutrient and chlorophyll *a* activity in the estuary basin is positive.

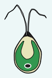


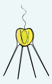
		[1]Total nitrogen (mgL^{-1})	[2]Phosphate (mgL^{-1})	[3]Chlorophyll a (μgL^{-1})
surface / bottom				
high		>1.5	>0.01	>6
moderate		0.75 - 1.5	0.005 - 0.01	3 - 6
Low		<0.75*	<0.005*	<3*

* ANZECC trigger values for southwest estuaries

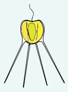


Phytoplankon groups


Chlorophytes are a large and diverse group of green algae, with over 7,000 species. Like land plants, green algae contain chlorophylls *a* and *b*.

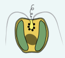

Chrysophytes, are known as golden-brown algae due to their pigment. In the Leschenault Estuary, this group is represented predominantly by the genus *Pseudopedinella*.


Cryptophytes are algae which occur in freshwater and marine habitats. Their unique characteristic is the presence of ejectosomes, two coiled springs which release under stress and propel the cells in a zig-zag fashion.


Cyanophytes, also known as cyanobacteria, are primitive, single-celled organisms, often blue-green in colour. Cyanobacteria in estuaries indicate poor water quality, when abundant.


Diatoms are single-celled or chain-forming microalgae and generally indicate healthy aquatic flora.


Dinophytes use their flagella to move through the water column, and many are also mixotrophic, meaning they can photosynthesise and/or ingest prey for growth. Dinophytes contribute to many of the world's nuisance microalgal species and are sometimes toxic.


Haptophyte algae are a dominant marine microalgal group in the oceans.

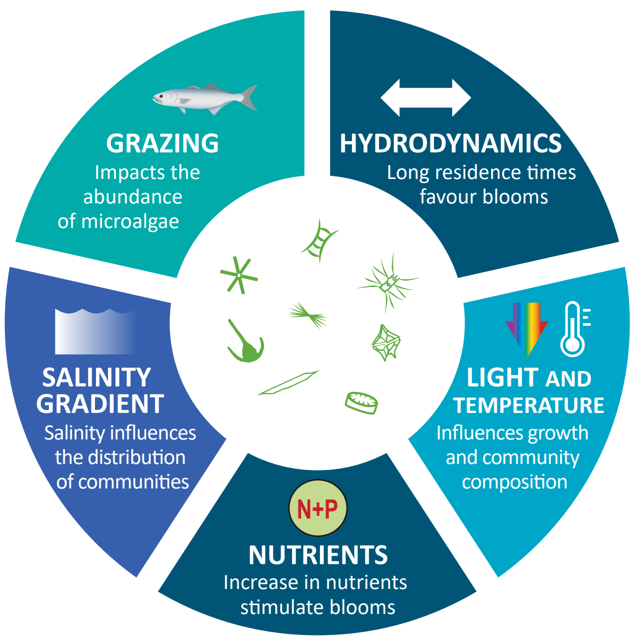

Raphidophytes encompass marine and freshwater species of algae. Their cells tend to be large with two flagella. *Heterosigma akashiwo* is the most notorious of this group and can form toxic algal blooms.

Microalgae dynamics

Microalgae, also known as phytoplankton, are tiny photosynthetic organisms which play a huge role in removing carbon dioxide from the atmosphere and generating the oxygen we breathe. As key components of healthy ecosystems, they provide food for invertebrates and fish. During the day, they photosynthesise, which oxygenates the water. However, excessive nutrients, warmer water temperatures and reduced water movement can lead to a rapid increase in the cell numbers of microalgae, promoting the occurrence of blooms. These blooms can be detrimental to aquatic ecosystems: they can reduce light availability to seagrasses; rapidly remove oxygen from the water when they decompose, causing fauna deaths; and certain species can produce toxins, which can be harmful to fauna such as fish, crabs and dolphins, as well as humans.

Chlorophyll *a*, as mentioned, is a universal indicator of microalgal activity. However, to further understand microalgal dynamics in estuaries, we also identify and assess the density of each type of microalgae. Analogous to studying plant communities on land, we investigate whether there is a community of desirable and diverse species, or whether it is dominated by undesirable plants such as weeds. This can tell us if the microalgal community composition is healthy or unhealthy.

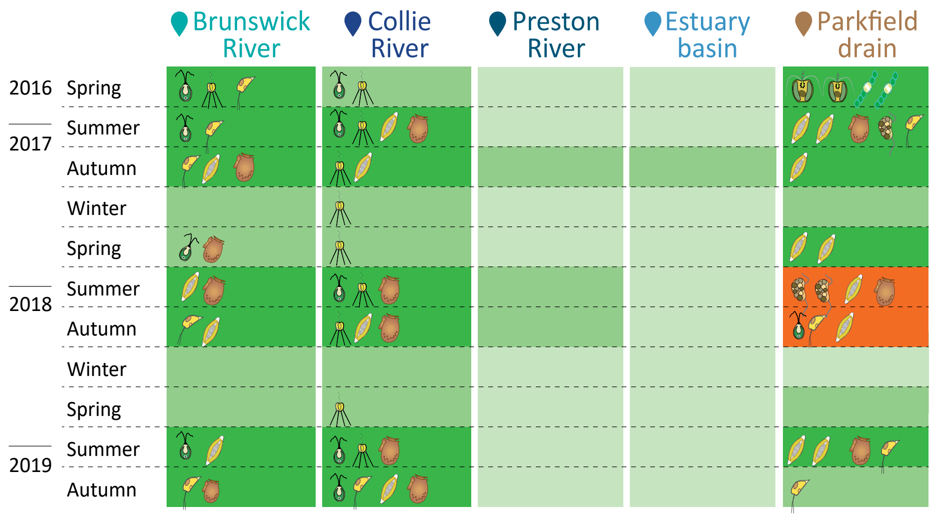
The composition of microalgal communities depends on a combination of factors which affect the algae's distribution. In estuaries, these factors include hydrodynamics, grazing, light availability, salinity gradient and nutrient availability. The groups listed in the table below are just some varieties present in estuarine microalgal communities.

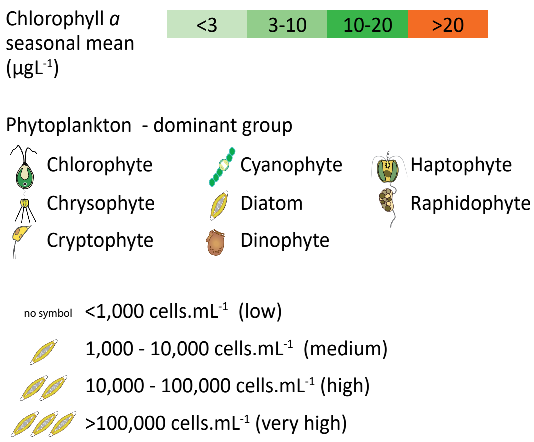


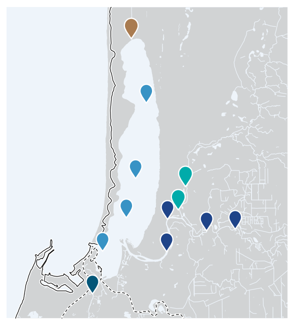
Microalgae:
seasonal patterns

Key points:

- microalgal activity was low in the estuary basin in all seasons
- potentially harmful microalgal species exceeded guidelines most frequently in the Collie-Brunswick River confluence and in Parkfield drain.







Estuary basin and Preston River

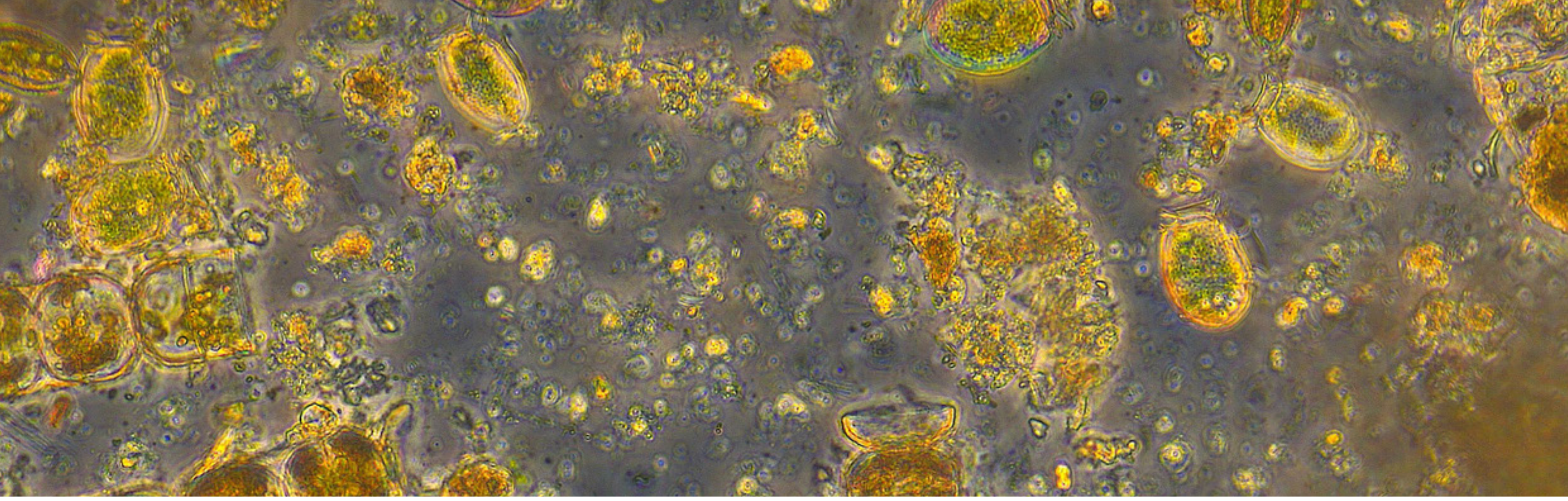
Microalgal densities were low throughout the monitoring period, which suggests the system is healthy or not suffering symptoms of eutrophication.

Brunswick and Collie rivers

Medium densities of chlorophytes, diatoms and dinophytes occurred in spring, summer and autumn. Chrysophyte densities were medium in the Collie River throughout the year, while medium densities of cryptophytes occurred in the Brunswick River, mostly in autumn.

Parkfield drain

High cell densities were observed in Parkfield drain during summer, likely associated with nutrient inputs from agricultural land runoff, and frequent stagnant water in the shallow system. Medium-to-high densities of haptophytes, diatoms, *Oscillatoria* (cyanophyte) and the red-tide associated raphidophyte, *Heterosigma akashiwo*, were recorded.

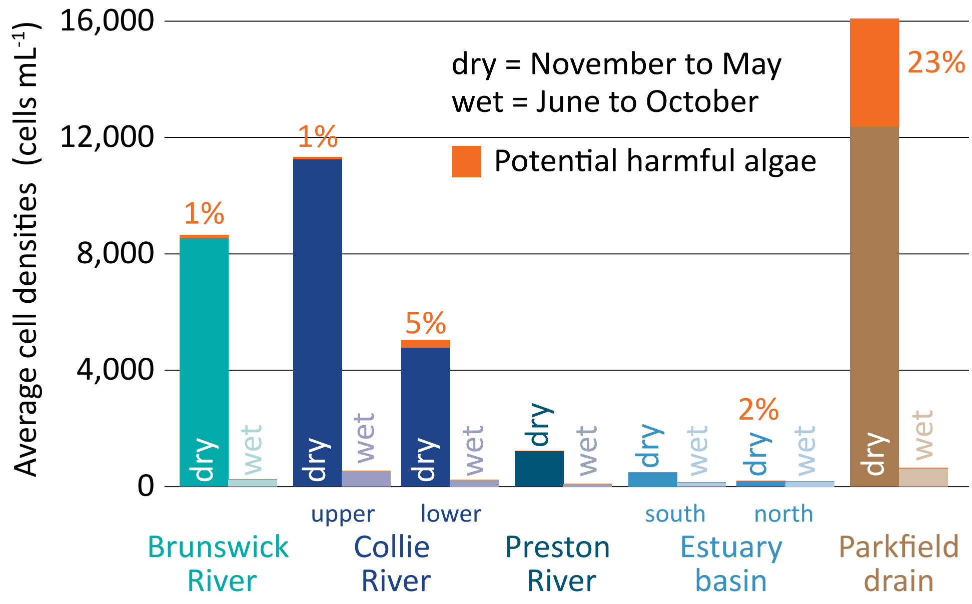


Potentially harmful microalgal blooms

Harmful microalgal blooms are a response to eutrophication in coastal and inland waters worldwide. They can be a threat to human health, fish, marine mammals and birds. Our monitoring and analysis program includes the identification and enumeration of all microalgal species, including the potentially harmful ones.

To assess the occurrence of potentially harmful microalgae, we compare our data against the Department of Water and Environmental Regulation's interim ecological trigger values, which were derived from international and national guidelines, where available, and expert local knowledge.

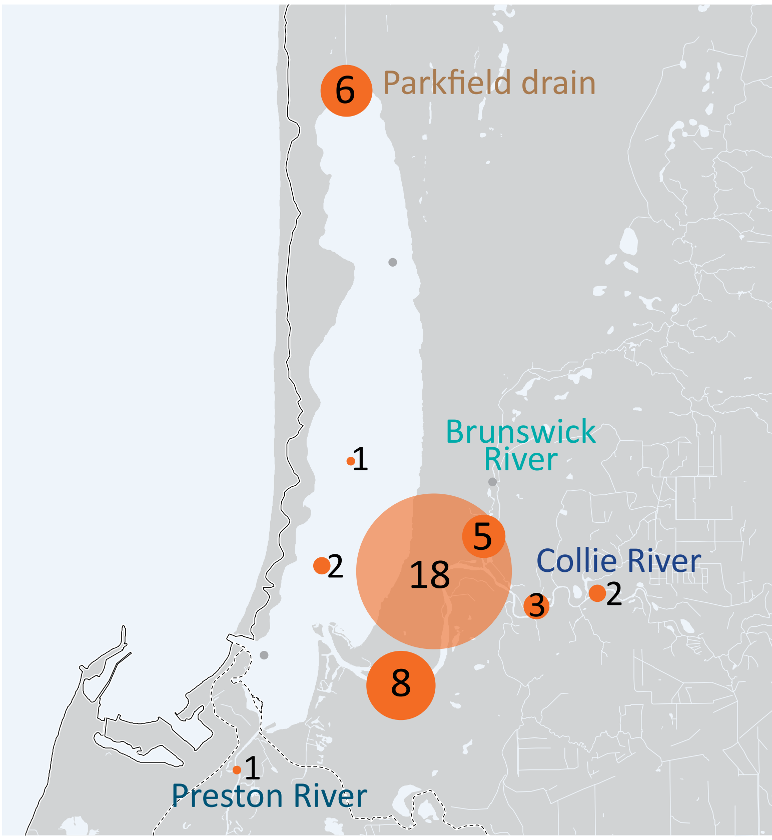
Total microalgae | 2016–19



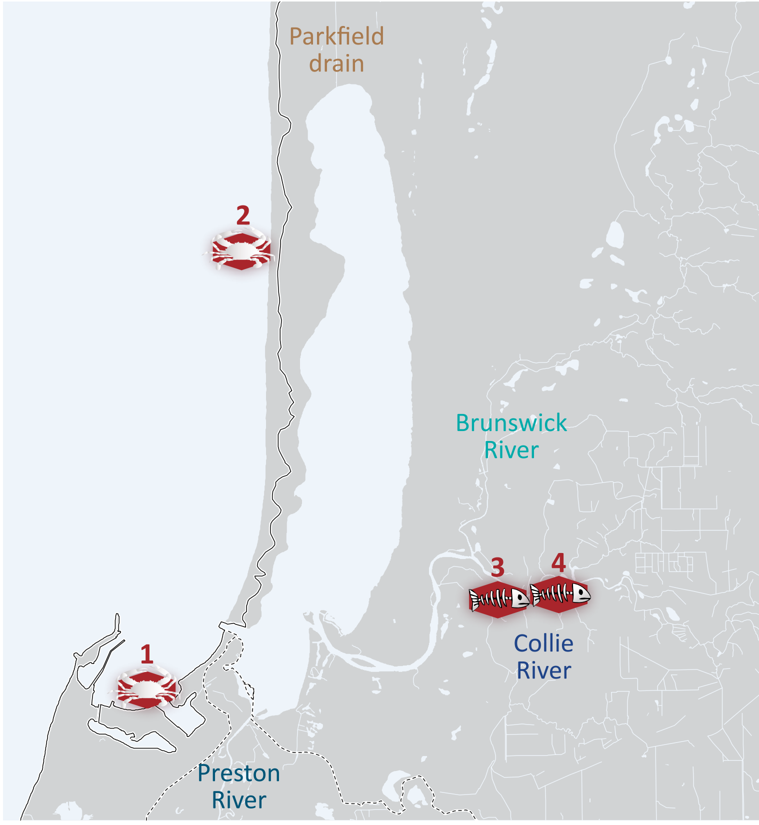
Exceedances of microalgal trigger values

Exceedances of microalgal ecological trigger values in 2016–19 were highest in the lower Brunswick and Collie rivers. Eighteen exceedances occurred just downstream of the Brunswick–Collie confluence, again highlighting the poor water quality in this region. Exceedances were most frequently observed in summer and autumn.

The lower Brunswick and Collie river exceedances were dominated by dinophytes (*Alexandrium* spp., *Dinophysis* spp. and *Karlodinium* spp.) and a raphidophyte (*Heterosigma akashiwo*). The Parkfield drain exceedances were predominantly associated with the occurrence of *Heterosigma akashiwo*.



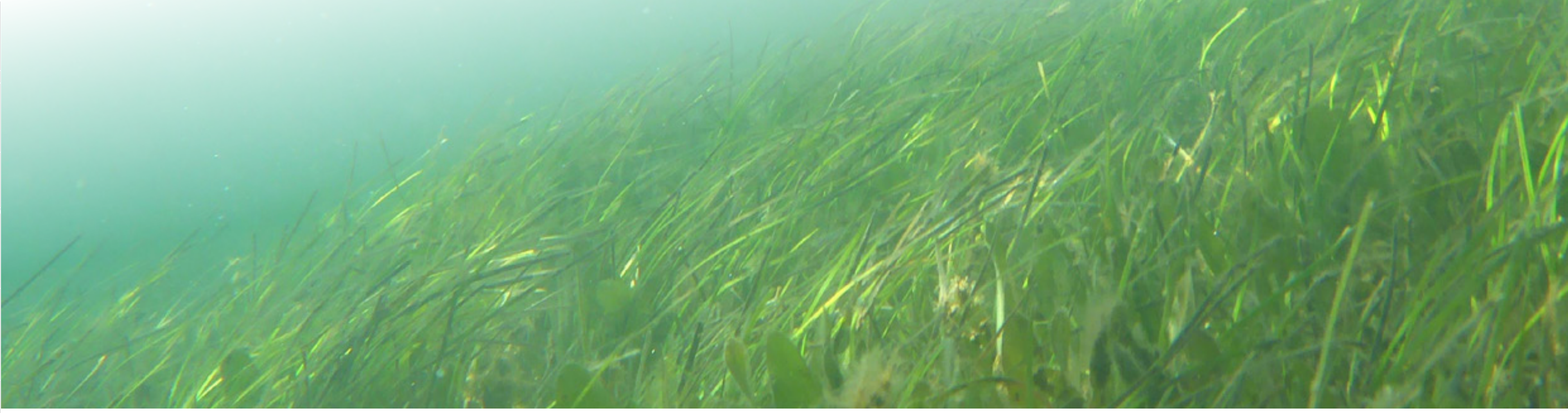
Fish kill reports



Since 2000, there has been on average close to one fish kill event every year in (or associated with) the Leschenault Estuary. In the 2016–19 period, there were four fish/crab kill events.

The crab death event on 24 August 2017 followed the highest discharge of estuarine water from the Collie and Brunswick rivers since 2016. In the preceding months, the lower Collie River (sites 3 and 4) had salinity levels from brackish to marine (~30ppt) at the bottom with persistent anoxia (dissolved oxygen <1mgL^{-1}). The routine monitoring preceding the report of crab deaths, on August 18, showed the salinity was low (equivalent to fresh water) from the surface to the bottom (see Collie River salinity profile, winter 17 August 2017, page 21). This was due to high rainfall and subsequent flows which pushed the brackish, anoxic waters from the river into the basin, then out through the Cut to the ocean. It is highly likely that the anoxic waters from the Collie and Brunswick rivers, carrying high organic loads and possibly carrying other contaminants, caused the crab deaths.

	Date	Event	Possible cause
1	12 December 2016	A few dead blue swimmer crabs near a jetty.	Possibly linked to bacterial outbreak affecting crabs in Bunbury harbour.
2	24 August 2017	About 500 dead blue swimmer crabs washed ashore on Belvidere Beach, on the ocean side of the Leschenault peninsula, 20 km north of Bunbury.	High flow river discharge, anoxia and/or contaminants.
3	17 May 2018	About 5 dead bream at Mill Bridge, lower Collie River.	Coincided with autumn rainfall/flows, possible anoxia and/or runoff contaminants.
4	30 May 2018	About 5 dead bream in Collie River, near Forrest Hwy bridge and a few 100 m upstream.	Coincided with autumn rainfall/flows, possible anoxia and/or runoff contaminants.

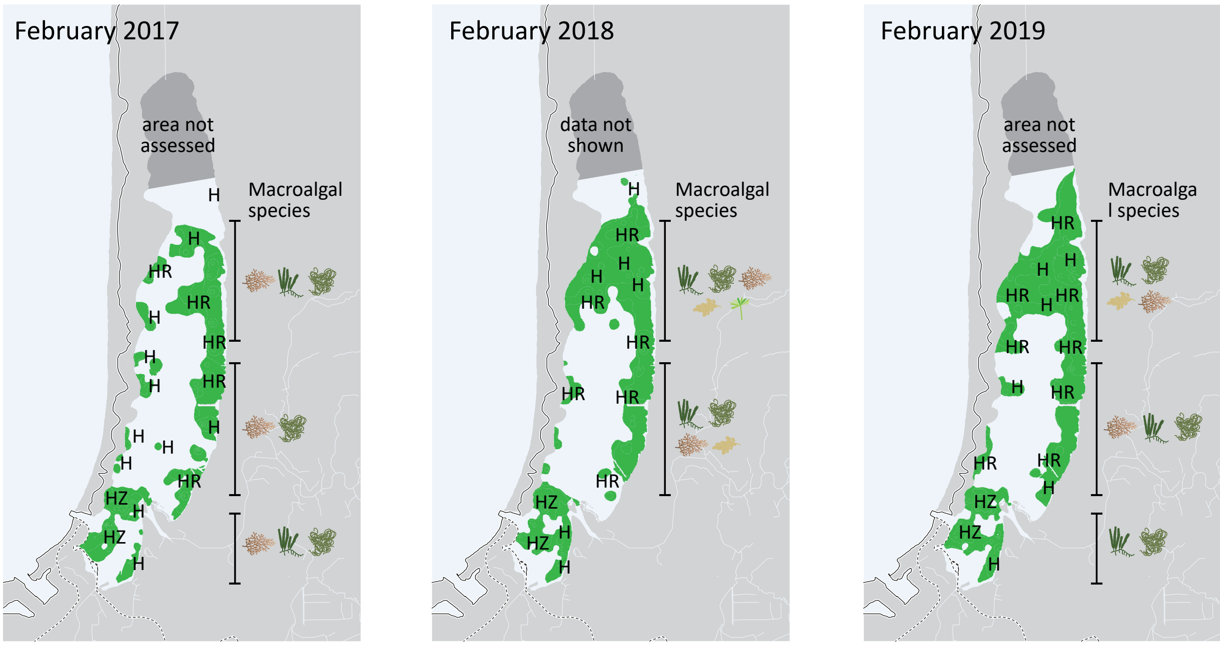


Seagrass and macroalgae

Despite a 60 per cent decrease in the area covered by seagrasses from 2009 to 2019 (1741 ha to 1059 ha), seagrass cover has recently recovered, increasing by 17 per cent from 2017 to 2019.

Seagrasses are flowering plants that have evolved from land plants and adapted to live underwater in estuarine or marine environments. They are important components of aquatic ecosystems, providing habitat and food for fish, birds and crustaceans. Seagrasses also contribute to maintaining healthy estuaries with good water and sediment quality.

Macroalgae, or seaweed, should not be confused with seagrass, even though they can look quite similar. Despite being known as 'weeds', macroalgae are an important and natural part of estuarine and marine ecosystems. However, an overabundance of macroalgae can be problematic. Excess nutrients in the water can cause prolific 'nuisance' algal growth, which can smother seagrasses, reduce oxygen in the water and produce foul odours when they decompose.



Seagrass extent   Seagrass species *Halophila ovalis* (H) *Ruppia megacarpa* (R) *Zostera muelleri* (Z)

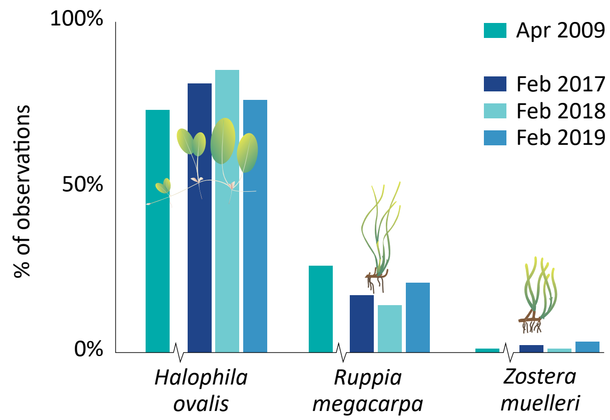
Macroalgal species *Chaetomorpha* sp. *Caulerpa* sp. *Caulocystis uvifera* *Laurencia* sp. *Acetabularia* sp.

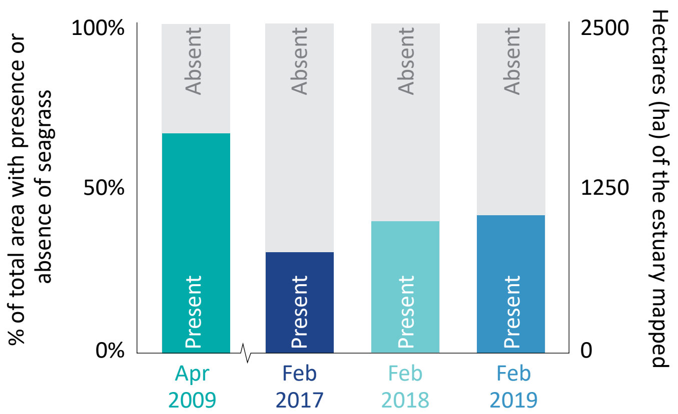
Measuring the abundance and types of seagrasses and macroalgae can provide a valuable insight into estuarine health.

In the Leschenault Estuary, three species of seagrass are present: *Halophila ovalis, Ruppia megacarpa* and *Zostera muelleri*. *Halophila* is the most common species, found throughout the estuary basin. *Ruppia* is found along the eastern shallows and has started to colonise the shallow western banks in recent years. *Zostera*, which favours marine conditions, can be found near the Cut.

Throughout the monitoring period, we observed diverse macroalgae. Macroalgae are usually classified by the colour of the photosynthetic pigments used by different species – red, green or brown. The most common types of macroalgae observed in the Leschenault Estuary were *Chaetomorpha* (green), *Caulocystis* (brown) and *Laurencia* (red).

The area covered by seagrasses increased between 2016–2019 from 899 to 1059 hectares. However, the recent coverage is only about 60 per cent of what it is estimated to have been in 2009. Although the cause of seagrass loss is not well understood (as no monitoring took place from 2009–15), these recent surveys show a promising recovery.[15] Seagrasses in the estuary are vulnerable to propellor damage, decreased light conditions caused by algal blooms, dragging anchors, and marine heatwaves.





15 Bennett K et al. 2021, *Seagrasses in four estuaries in Western Australia's south-west*, Water science technical series, report no. 86, Department of Water and Environmental Regulation, Government of Western Australia, Perth.

Outlook

In 2012, the Department of Water published the Leschenault Estuary WQIP, a long-term strategy for improving water quality in the Leschenault Estuary through the reduction of nutrient and organic matter pollution. The plan suggested that a reduction of nutrients delivered from the catchment – 38 per cent for phosphorus and 32 per cent for nitrogen – was needed to improve water quality. Best management practices proposed to achieve this nutrient reduction included the optimisation of fertiliser use across the catchment, the reduction of effluent contamination from dairy farms, the protection and restoration of fringing vegetation and the connection of septic systems to the deep-sewerage system.

Threats to estuary health include:

- long-term loading of nutrients into the estuary
- warmer, drier climate, reducing flow
- increasing stratification
- increasing microalgal blooms

The WQIP detailed which catchment management actions would drive the biggest improvement in water quality, taking into consideration cost, feasibility and community values. Recent water quality monitoring in the catchment and estuary shows that the WQIP's recommendations remain valid. Investment, planning and implementation of recommended catchment actions are the critical next steps towards improving the water quality in the Leschenault Estuary and catchment.

Monitoring data and estuary catchment models developed by the Regional Estuaries Initiative will enable us to measure the success of implemented actions.

For Bunbury, Eaton and Australind, there are numerous lifestyle and tourism benefits associated with healthy estuarine environments. This means we need to adopt the best management practices on farms and in gardens in these areas, so that fertilisers are used effectively and don't result in excessive nutrients flowing to our rivers and estuaries.

More information

The Regional Estuaries Initiative started in 2016 and continues as the Healthy Estuaries WA program. We work with local partner organisations to improve the health of the Leschenault Estuary. Our focus has been on reducing nutrients entering waterways from their source in the catchment, removing nutrients once they have entered waterways and building scientific understanding of the catchment and estuary to inform management decisions.

This has included:

- **restoring** stream function and moving stock away from waterways in partnership with the Leschenault Catchment Group
- **reducing** nutrient runoff from farms through improved fertiliser management practices in partnership with the Department of Primary Industries and Regional Development, farmers, industry and Leschenault Catchment Group
- **supporting** the scientific monitoring of the Leschenault Estuary and its catchments.

For more information on Healthy Estuaries WA and the Leschenault Estuary visit estuaries.dwer.wa.gov.au/estuary/projects/

What you can do

Farmers

Base fertiliser management decisions on soil test results.

Fence streams from livestock and restore native vegetation.

Homeowners

Adopt best fertiliser practice in your gardens.

Plant natives.

Local communities

Stay informed through the estuaries website.

Join your local catchment group.

Report algal blooms and unusual fish deaths.

Find out how at estuaries.dwer.wa.gov.au/participate

#WAestuaries

HEALTHY ESTUARIES WA