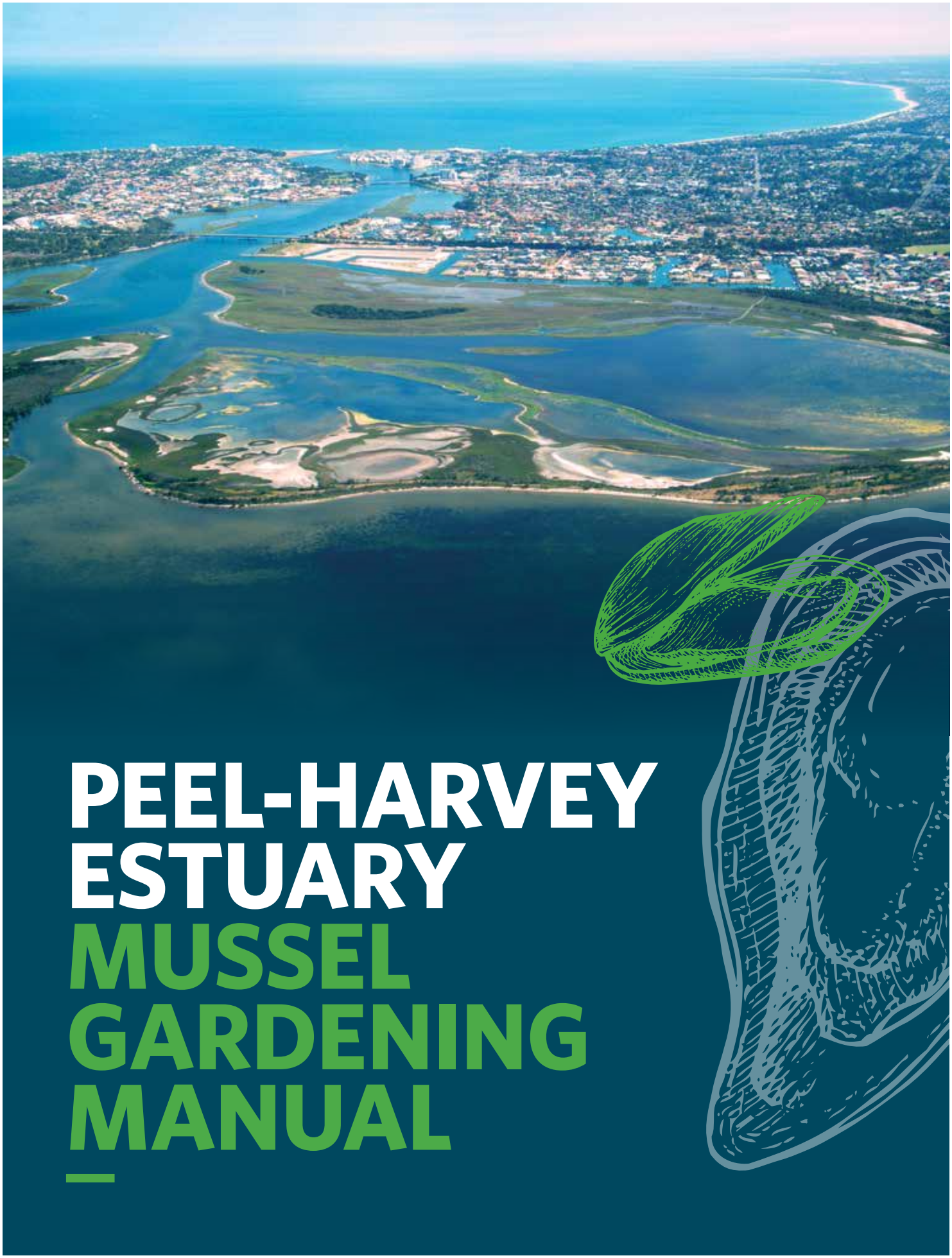


PEEL-HARVEY ESTUARY MUSSEL GARDENING MANUAL

Alcoa Foundation

The Nature Conservancy Australia

THE PEEL-HARVEY ESTUARY MUSSEL GARDENING PROGRAM AIMS TO HELP GROW MUSSEL BEDS TO BENEFIT THE LOCAL WATER QUALITY, BIODIVERSITY AND FISH STOCKS FOR EVERYONE TO ENJOY.

Wild mussels © shutterstock

OVERVIEW

Community shellfish gardening describes the process where community members volunteer to grow shellfish to help restore their local waterway ecosystems. The Peel-Harvey Estuary mussel gardening program aims to help grow mussel beds to benefit the local water quality, biodiversity and fish stocks for everyone to enjoy. As shellfish gardeners, you will be growing the mussels from juveniles into adults, which will then be 'seeded' onto new reef substrate built in the estuary.

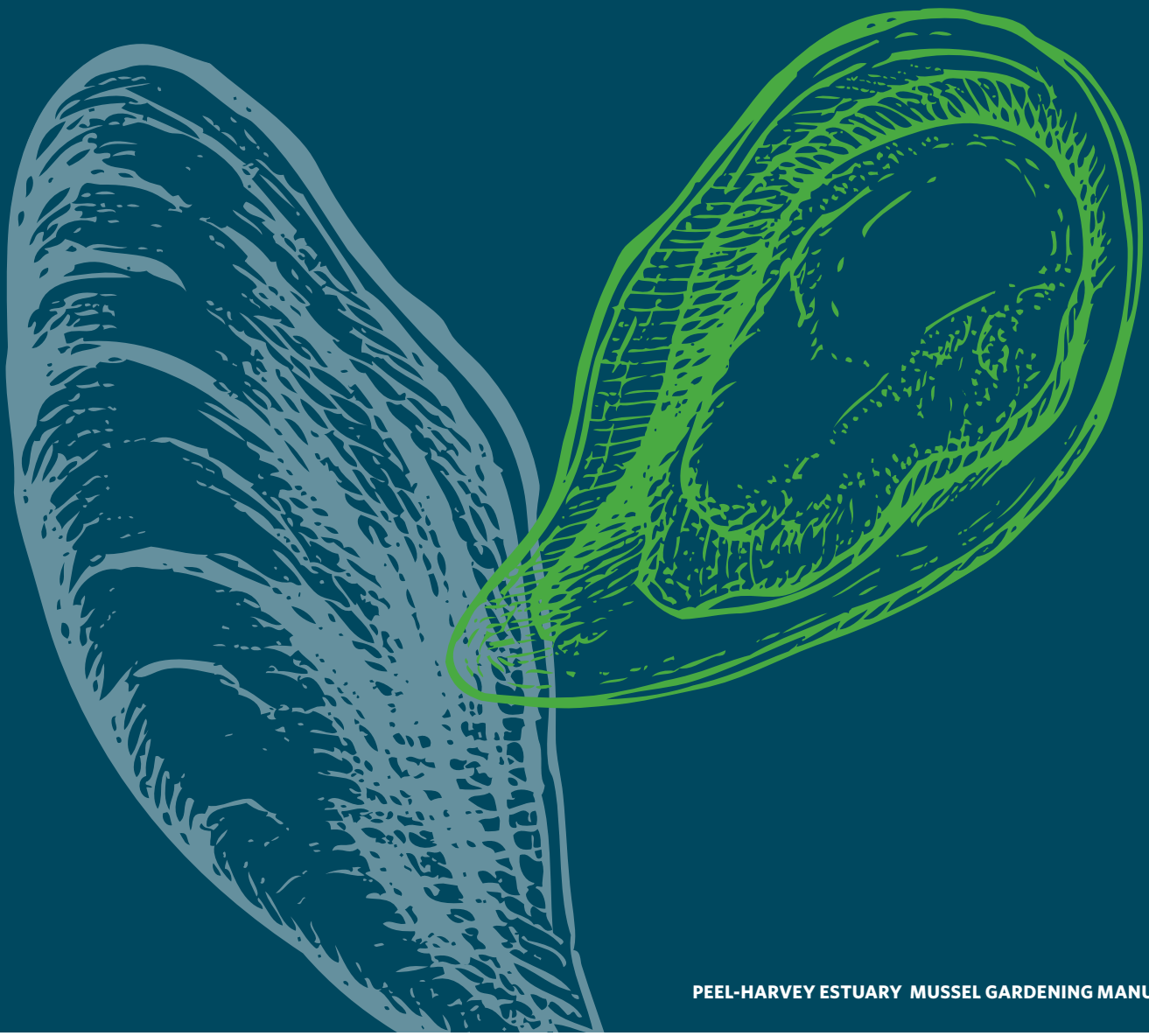
This manual is split into three sections:

1. An Introduction
2. How to establish a mussel garden, and
3. Monitoring your mussel garden.

We acknowledge the Bindjareb Nyoongar people as the traditional custodians of this land and include descriptions of the creation story of the estuary and Nyoongar seasons provided by members of the Bindjareb community.

There are two Appendices included which provide the monitoring data sheets and descriptions of the main species likely to be found growing on or living in the mussel gardens. The program also has a web site with additional material and information for further reading natureaustralia.org.au/shellfishgarden.

All gardeners will need to sign a liability waiver before participating in the program.



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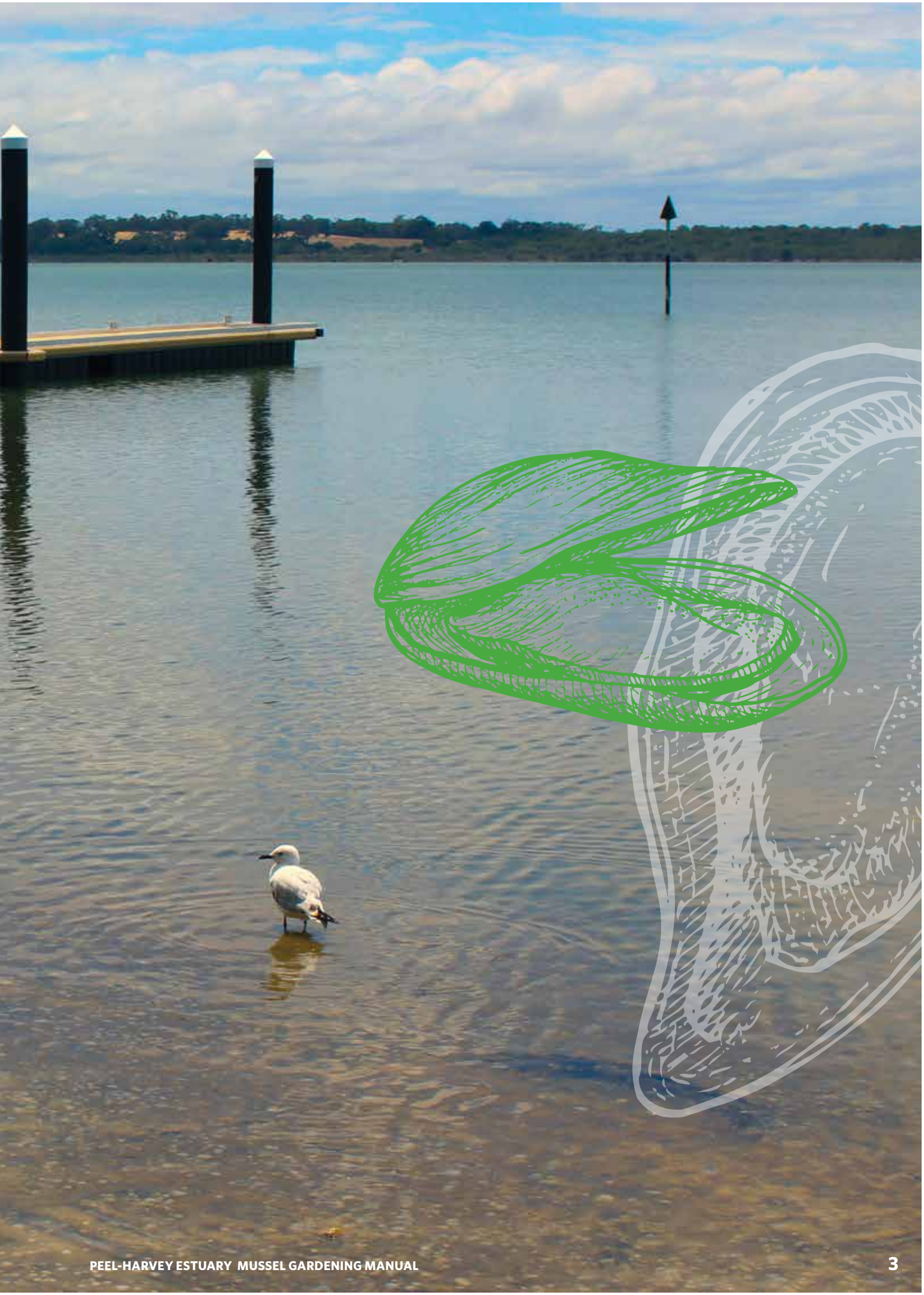
1. INTRODUCTION

Harvey Estuary near Mandurah, WA © shutterstock



THE PEEL-HARVEY ESTUARY

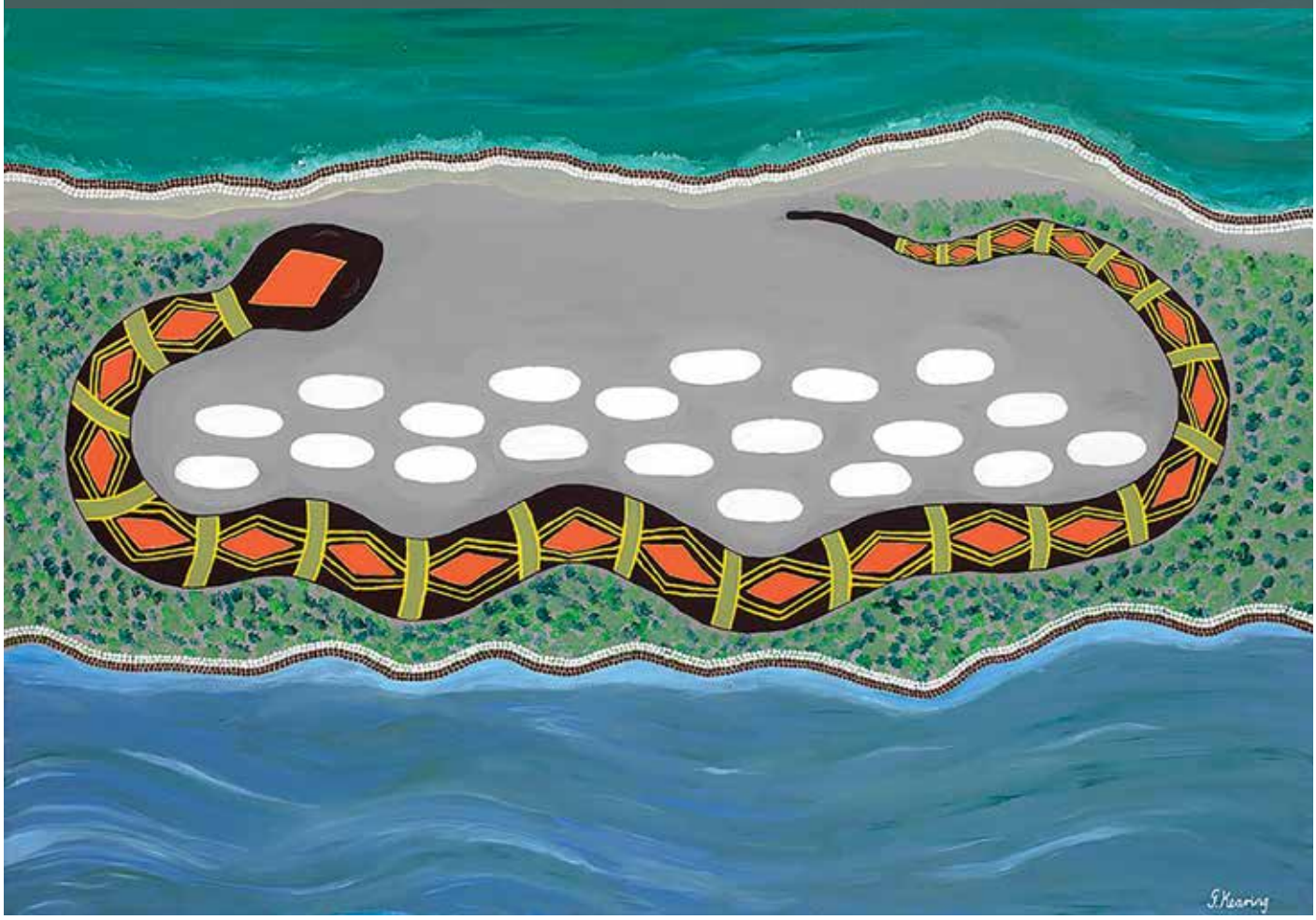
Creation

When Bindjareb Nyoongar people first came to the Mandurah area many thousands of years ago, it was during the time of a great drought. The Bindjareb people went to the beach and danced to get guidance from the Waugal or rainbow serpent (a mythological creature that helped to create landscapes in the South West of Western Australia) and ask for help for the tribe.

The Waugal sent one of its babies to help the people with their problem. It came from the ocean and started by making the Peel Inlet, curling itself up making a round depression into the ground (Figure 1). It then went a little further to the south and made a long depression into the earth, which is now known as the Harvey Estuary. Exhausted from all of the work, she rested there for a while to recover.

Soon after, she had some babies who then left their mother, spreading out everywhere and creating many wetland depressions and waterways, with three of them moving towards the scarp, creating the three rivers known as the Serpentine, Murray and Harvey rivers. The rivers and estuary they created allowed water to flow and became a great food source for the Bindjareb people then, as it still is to this day.

Figure 1: An artwork by Gloria Kearing depicting the Waugal protecting her babies in the Peel-Harvey Estuary.



Estuary and Catchment

The Peel-Harvey Estuary, near the City of Mandurah in Western Australia, is approximately 70 km south of Perth. It is a shallow permanently-open estuary, with an area of ~130 km² comprising two main basins, the Peel Inlet in the north and Harvey Estuary in the south (Figure 2).

The estuary receives runoff from a 1,173,620 ha catchment comprising the Serpentine, Murray and Harvey river sub-catchments (Figure 2a). It is connected to the ocean via two channels, the Mandurah Channel to the north of the Peel Inlet and the man-made Dawesville Cut at the top of the Harvey Estuary (Figure 2b), which was created in the mid-1990s.

The Peel-Harvey Estuary is home to many species of plants and animals. The shallows and surrounding wetlands provide excellent habitats for wading shorebirds, which is one of the reasons why the broader Peel-Yalgorup wetland system (which includes the estuary) is recognised as a Wetland of International Importance under the Ramsar Convention.

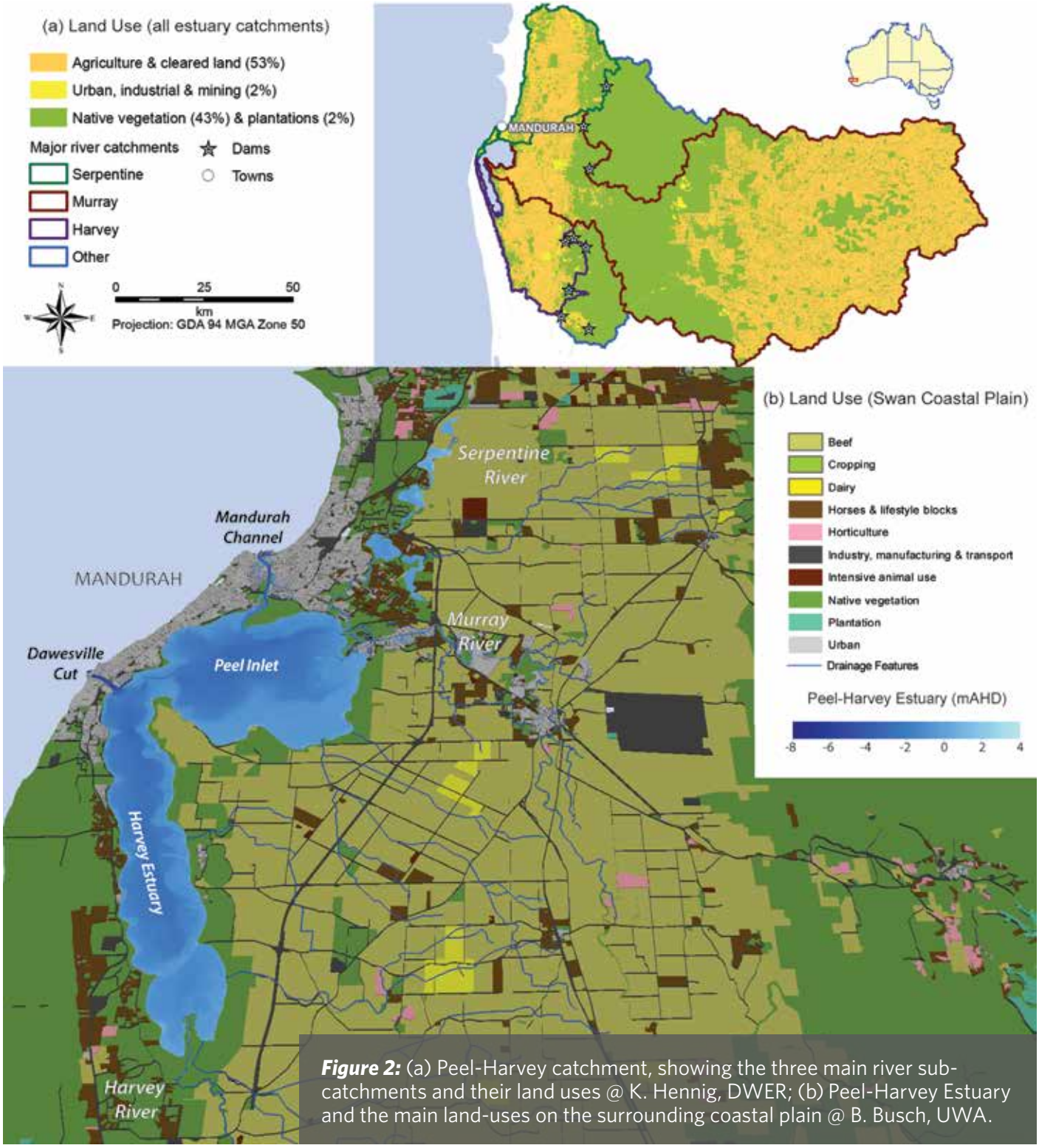


Figure 2: (a) Peel-Harvey catchment, showing the three main river sub-catchments and their land uses @ K. Hennig, DWER; (b) Peel-Harvey Estuary and the main land-uses on the surrounding coastal plain @ B. Busch, UWA.

Fishing

The Peel-Harvey Estuary has long been a very productive system for marine life including fish, crabs and submerged plants. These rich fishing grounds have been a major drawcard for the region and have provided people with a reliable source of food for many thousands of years. The Bindjareb people used Mungah, or fish traps in the lower reaches of the Serpentine River to trap and collect fish through an ingenious process of placing closely spaced sticks across the channel and guiding fish into an area where they could easily be caught by hand and thrown up onto the bank. When the fish were running, large gatherings of tribes from other parts of the South West took place to enjoy the abundance of fish caught with the Mungah. These gatherings formed the origin of the term Mandjar, meaning 'meeting place', which was later to form the basis for the name Mandurah.

Commercial fishing operations in the Peel-Harvey Estuary commenced with canning of fish for export from as early as 1878, with several processors operating by the end of the 1800s. It was not until after the second World War that refrigeration and transport would support the sale of fresh fish to the markets of Perth and beyond. Today, there are several commercial fishers operating in the estuary, with the Peel-Harvey being the most significant commercial crab fishery in the South West. Recreational fishing is also highly popular, targeting Blue swimmer crabs and finfish including King George whiting, Yellowfin whiting, Black bream, Sea mullet, Herring and Cobbler, among others.

History of Modifications

In the early 20th century, the coastal plain portion of the catchment was extensively cleared to make way for agriculture (Figure 2a). A large network of drains was constructed to allow farming enterprises to thrive, including along large sections of the Harvey and Serpentine Rivers (seen as the grid criss-crossing the plain in Figure 2b). However, this soon led to the mobilisation of sediment into the estuary basins, smothering the bottom habitats. Along with sediment, large loads of nutrients also made their way into the estuary, eventually resulting in very high nutrient concentrations (eutrophic conditions) and the growth of nuisance algal blooms, including the toxic microalgae *Nodularia spumigena* in the 1970s and 80s. The constant 'boom and crash' tendencies of algal blooms also led to severe depletion of oxygen (anoxia) as the algae decomposed at the bottom of the estuary, which in turn caused large fish kills.

These eutrophic conditions were alleviated in the mid-1990s through the construction of the Dawesville Cut, an artificial channel connecting the northern Harvey Estuary to the ocean (Figure 2b). The 'Cut' was built to allow increased tidal flushing of the estuary, which greatly reduced algal growth by flushing nutrients out to sea and creating more marine-like conditions in the estuary. Catchment-wide efforts have also helped to stem the flow of nutrients, however the improvement is slow and gradual. The creation of more consistent and marine conditions within the Peel-Harvey Estuary has led to the opportunity to establish mussel habitats to help improve its ecosystem health.

WHY RESTORE MUSSEL HABITATS IN THE PEEL-HARVEY ESTUARY?

Shellfish reefs support a range of ecosystem health benefits for coastal waterways. They help improve water quality by filtering algal particles from the water and create excellent habitat for fish and other marine species. This not only increases fish production and boosts fishing opportunities, but also enhances biodiversity at the local scale.

The development of shellfish reefs elsewhere in Australia (including Oyster Harbour in Albany, WA, Gulf St Vincent in South Australia and Port Phillip Bay in Victoria) and internationally (including the USA, Asia and Europe) has seen some significant improvements in the health of the estuaries and coasts where they have been built.

With the support of the Alcoa Foundation, The Nature Conservancy (in partnership with the Peel-Harvey Catchment Council, Nyoongar leaders, local and State Government, universities, commercial and recreational fishing groups and community groups) are planning to construct shellfish reefs in the Peel-Harvey Estuary to help improve its ecosystem health. This will be achieved by creating reef bases at suitable sites then seeding them with Blue Mussels *(Mytilus galloprovincialis)* grown locally in 'shellfish gardens' and from aquaculture leases.

In 2019, The Nature Conservancy (TNC) led a feasibility study in partnership with Murdoch University and the University of Western Australia with funding support from Alcoa. This study showed that mussels and some oyster species are likely to thrive within the Peel-Harvey Estuary and highlighted some potential locations suitable for reef development. There is also some evidence that mussels and some oysters are naturally present within the system, and that historically, these shellfish may in fact have been far more extensive prior to changes that occurred over the past 100 years.

Water quality within the canal estates along the Dawesville Cut and Mandurah Channel is considered ideal for the growth of Blue Mussels, being essentially marine and containing abundant food. These areas provide many opportunities for landholders to undertake community shellfish gardening activities and contribute to reef development. With the added assistance of schools and local businesses engaging in shellfish gardening activities, the size and numbers of shellfish deployed onto the reef will provide a big boost to the success of the project.

NYOONGAR SEASONS

Unlike the traditional four seasons of Western or European culture, the Nyoongar people of the Bindjareb region (Peel) live their lives following six seasons, which are considered to be a more accurate reflection of the weather conditions and how they influence the rhythm of life in the region (Figure 3).

These seasons form the cornerstone of the people and places that were camped, farmed or lived because of the food and shelter available at those times of the year. These seasons let the people know what food can be hunted and collected and where the food and shelter are best at all times.

The Nyoongar seasons not only accurately reflect the weather conditions experienced at that time of year in the Peel Region, but also the reproduction cycle of many of the plants and animals and the Bindjareb people themselves.

Figure 3: Six Nyoongar seasons @ Australia's South West (www.australiassouthwest.com/south-west-inspo/six-seasons-south-west) and images of the seasonal totems (pages 8-9) @ T. Kearing, TNC.

Birak (December to January) – The season of the young

This period is usually dry and hot and is a season when burning country in mosaic patterns is done. Regular easterly winds in the mornings followed by sea breezes in the afternoons helped with managing these burns. Djildjit (fish) and Yurenburt (berries) are plentiful at this time of year from around the waterways and estuary.

Bunuru (February to March) – The season of adolescence

The hottest part of the year with little to no rain. This period was usually spent near the coast and estuary chasing Djildjit (fish). White flowering gums such as Kardan (Marri) and Jarrah are in full bloom during this time of year. Many of the young animals in the region are starting to mature.

Djeran (April to May) – The season of adulthood

Cooler weather begins, with cooler nights and dew forming an indicator of the season. Lighter winds mainly from the southerly directions are present during this season. Red flowers and banksias are blooming during this time of year. River Djildjit (freshwater fish), Kooboolong (frogs) and Yarkan (turtles) are the main foods collected.

Makuru (June to July) – The season of fertility

The coldest and wettest season of the year with more frequent gales and storms. As waterways and wetlands started to fill, moving about became easier and Bindjareb people moved inland for shelter and food. Yonga (Kangaroo) were hunted for food as well as skin for clothing and sinew and bones were used for tools. Animals were busy preparing for breeding. Blue and purple flowers dominate the flora landscape.

Djilba (August to September) – The season of conception

Most animals are starting to mate at this time, so their young are born in warmer times with plenty of food and water available. A mixture of wet days with increasing numbers of clear cold nights and pleasant warm days. Plants with yellow and cream flowers come to the fore with some vivid blue flowers coming out as well. Yonga, Waitj (emu) and Koomal (possum) were hunted in this period.

Kambarang (October to November) – The season of birth

This period is typified by longer dry periods and an abundance of wildflowers. Acacias continue to flower, along with some of the Beera (banksias) and many small flowering plants including Kurilbrang (kangaroo paw) and orchids. Two of the most striking plants to flower at this time are the Balga (grass trees), especially if they have been burned in the past year, and Mooja (Australian Christmas Tree) that develops bright orange/yellow flowers that continue to bloom until the end of the year. Waugal (snakes) and other reptiles start to emerge as they come out of hibernation and many birds will be hatching chicks.

The Bindjareb people spent most of the time in the hottest part of the year near the coast and estuary where it was cooler and spent the coolest time of the year in the hills where more shelter is available.

The main seasons for hunting in the Peel-Harvey Estuary were, and still are, Kambarang, Birak and Bunuru (October to March), which is the best time of the year for fishing and finding berries in the area as well as collecting delicacies like mussels, Karil (crabs) and lobster.

SHELLFISH – WHO NEEDS 'EM?

Shellfish (specifically bivalve molluscs such as mussels and oysters) were once important habitat builders along Australia's southern coast, forming extensive beds and reef habitats.

Shellfish, much like corals, are known as 'Ecosystem Engineers' because they create an entire ecosystem that depends on the structure that they provide. While corals build reefs in the tropics, it's the mussels, oysters and a few other bivalves that become the dominant reef builders as we move away from the tropics. Available in large quantities, these important shellfish have been a staple for the Traditional Owners of coastal areas throughout Australia, although less so in south-western Australia.

Unfortunately for the shellfish, but fortunately for early European colonists, the southern Australian oysters and mussels look very similar to (and are closely related to) the European species, resulting in a readily recognised, tasty and accessible food source for the growing colonies. As such, they were recognised as valuable fisheries and rapidly became the focus of extensive fishing which drastically reduced the amount of these shellfish and the habitats they create.

Shellfish habitats are not just important because of the shellfish that create them. Mussel beds and oyster reefs become homes for large numbers of other plants and animals (Figure 4). They also provide important benefits, or ecosystem services, to human communities (Figure 5). Benefits such as filtering the water, removing some of the nutrients that cause low dissolved oxygen events and fish kills, stabilising the sediment and producing large numbers of fish that rely on these habitats.

Some further information on these benefits can be found at www.natureaustralia.org.au/what-we-do/our-priorities/oceans/ocean-stories/oyster-reef-habitat/.

Mussels filter the water to feed on the single celled plants called phytoplankton that grow suspended in the water (Figure 6). This helps to reduce the density of phytoplankton and the amount of oxygen consumed by the bacteria that feed on these algae when they die. However, filter feeders like mussels don't just remove the phytoplankton.

Figure 4: Restored Blue Mussel bed in Port Phillip Bay, Victoria @ J. Boord , Streamline Media

They tend to remove all the floating particles (within a certain size range), including non-living particles like mud and sand. They eat what they need, and the rest gets ejected as 'biodeposits' (pseudofaeces which are the inorganic particles and unwanted food stuck together by a mucous thread, and faeces), which sink to the bottom. In this way, most of the particles in the water are removed and added to the sediment, clearing the water and allowing light to penetrate.

The light helps seagrass beds, another very important habitat in our coastal waterways, and the biodeposits are used by small animals (e.g. worms) that become food for juvenile fish, increasing the fish populations. A 5 cm Blue Mussel can filter 5 litres of water per hour, with a typical reef having tens of millions of mussels and other filter-feeding animals such as scallops and sponges. This ecosystem collectively helps remove excess nutrients and keeps water quality in balance.

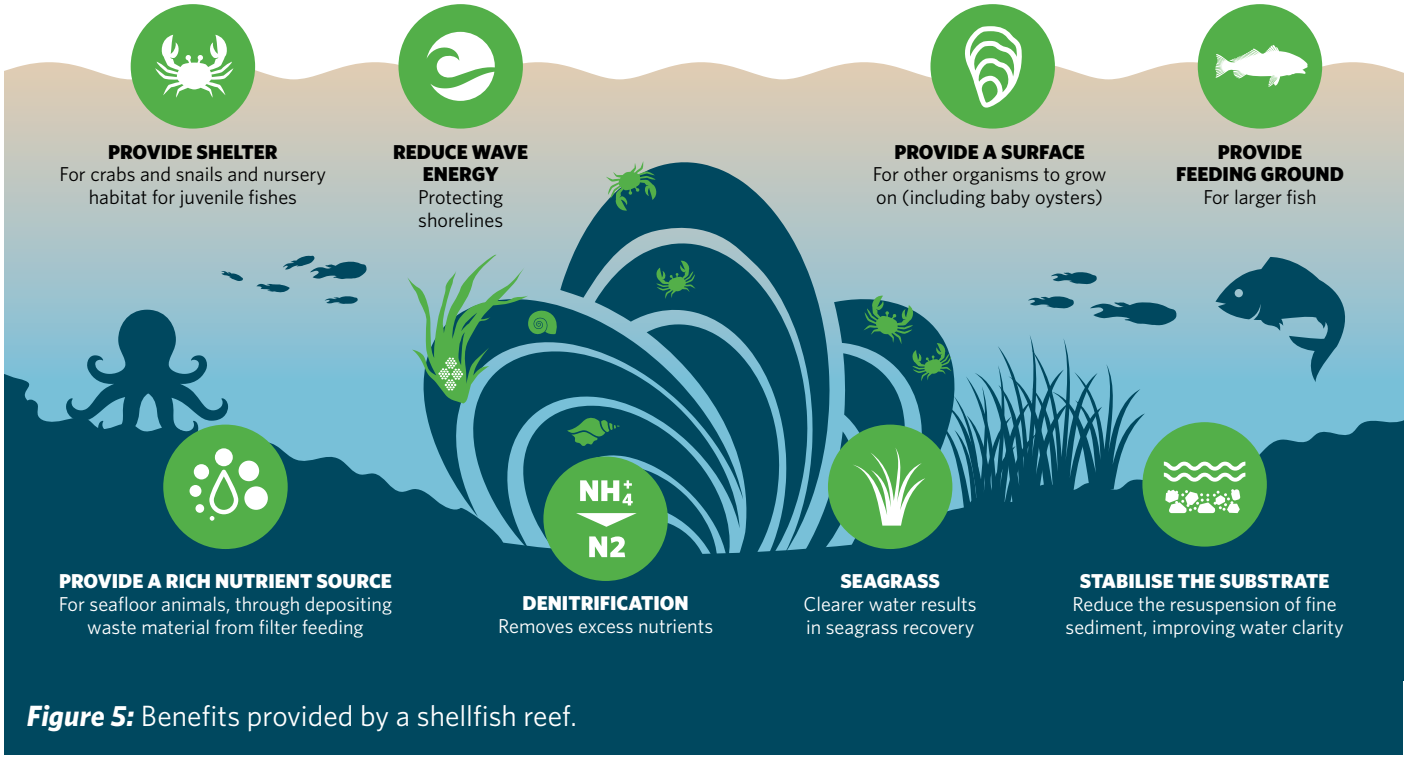


Figure 5: Benefits provided by a shellfish reef.

Figure 6: The filtering power of shellfish. Both tanks were filled with seawater, limestone and algae. The tank on the left also contained some Blue Mussels and Flat Oysters. Over the course of a few hours, the shellfish in the left tank consumed all of the algae by filtering it out of the water column @ A. Hams, TNC

BLUE MUSSELS – THEIR HABITATS AND LIFE-CYCLE

Blue mussels can create reef ecosystems on different surfaces. Typically, people notice small reefs created on hard surfaces such as on jetty pylons or rock platforms, particularly in the intertidal zone. However, they can also form 'beds' below the water on the seafloor, usually on sand or mud (Figure 7). These subtidal mussel beds can occupy large areas from tens of metres to hectares in size. Because of their potential size, these beds can provide more biodiversity and water quality benefits and are often prioritised for restoration.

BUILDING A MUSSEL BED

In a subtidal mussel bed, the juveniles settle among the adults and attach with their 'byssal threads' (Figure 8). Note that these threads and the gland that produces them are important for the survival of mussels (see the 'Cleaning your mussels' section).

To restore these beds, a layer of substrate is first laid over the bare sediment for the mussels to attach to. Many hard substrates could be used, but recycled shells or limestone rubble are common. Once a bed of mussels has formed, juveniles will settle amongst the substrate and other live mussels.

Figure 7A: Subtidal mussel beds restored in Okiwi Estuary, New Zealand (*Perna canaliculus* @ I. McLeod, JCU).

Figure 8: Blue Mussel with byssal threads (the 'beard') that attach to hard substrate © R.Swainston/ANIMA.fish

Figure 7B: Subtidal mussel bed restored in Port Phillip Bay, Victoria (*Mytilus galloprovincialis* @ P. Hamer, TNC).

Figure 9: Mussels being grown on long-lines in Cockburn Sound (left), and a mature long-line (right) @ R. Michael, Harvest Road Oceans

Next, the substrate needs to be seeded with mussels. Juvenile mussels are more vulnerable to being eaten than larger older animals so when starting a bed, it is an advantage to have older animals to seed onto the substrate.

These survive better and can provide additional protection for the juveniles that settle amongst them as well as producing new juvenile mussels themselves. Juvenile mussels will be sourced from Harvest Road Oceans Mussel Farm in Cockburn Sound. These come from the natural settlement of mussel larvae onto ropes suspended from long-lines on the surface (Figure 9).

It is important to source the seed mussels from the local area so that we reduce the chance of accidentally transferring invasive species attached to the mussels or ropes, or diseases that may be inside the mussels.

As part of the project, TNC has a permit from the Department of Primary Industries and Regional Development (Fisheries) to translocate mussels from Cockburn Sound to the Peel-Harvey, which includes several conditions that need to be followed. A TNC Project Coordinator will guide you through these requirements.

As mussel gardeners you will be helping us develop techniques to restore these reef habitats in the Peel-Harvey Estuary.

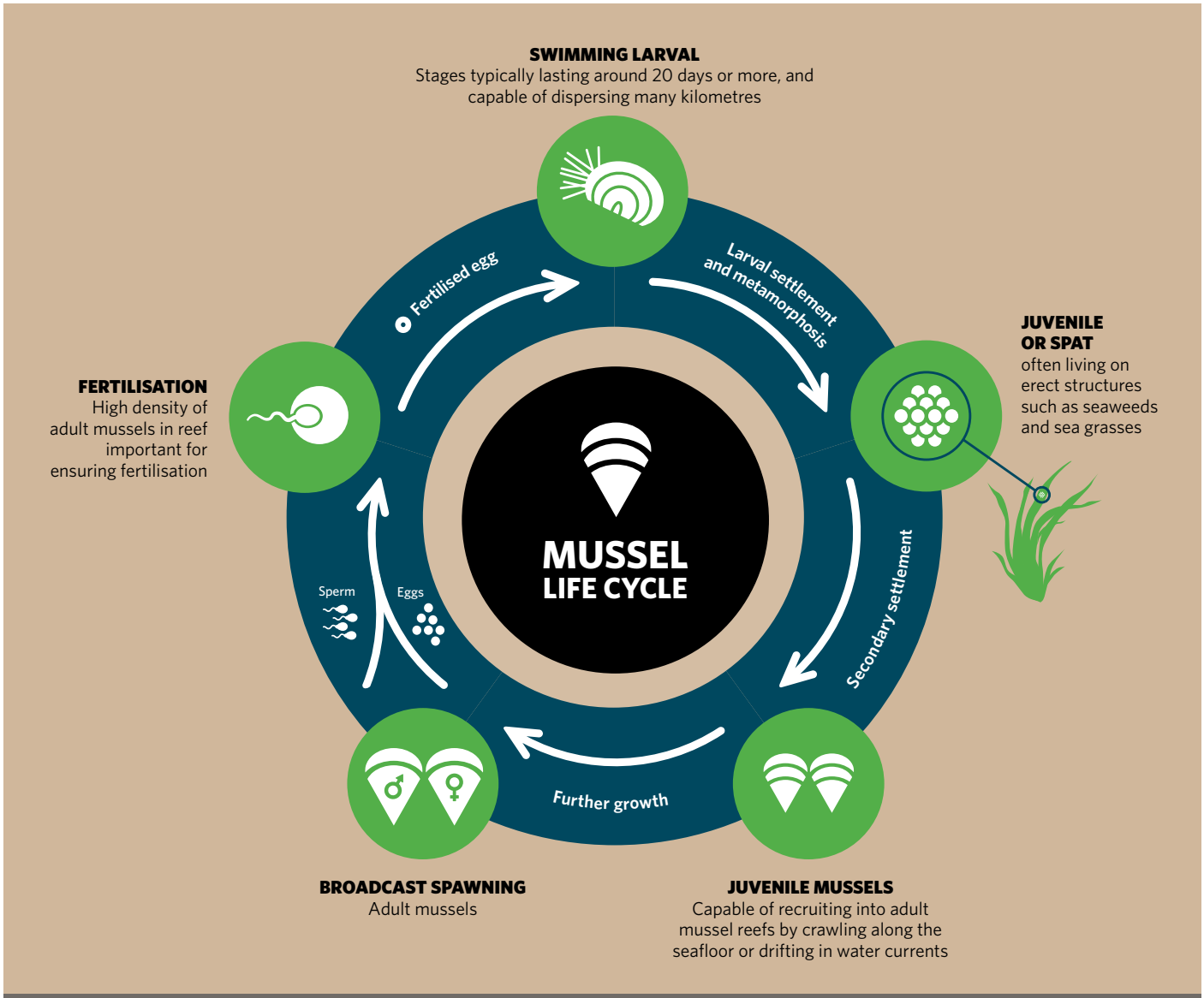


Figure 10: The mussel life-cycle.

Mussel Life Cycle

Mussels belong to a large group of marine animals that are broadcast spawners. The male and female mussels release eggs and sperm directly into the water where fertilisation takes place (Figure 10). For effective fertilisation, the egg and sperm need to come into contact within a short period, so the adults need to be close together and spawning must occur at the same time. The fertilised egg develops into a free-swimming larva, which means the baby mussel can travel with the currents for up to 100s of kilometres. After about three weeks, the larvae actively begin looking for a good home to settle onto and attach, generally somewhere with other mussels. They attach via one or more tough fibres called byssal threads that are produced by the Byssal Gland at the base of the 'foot'. The cluster of byssal threads that attach older mussels to the substrate is also called the 'beard' (Figure 8).

Mussels can move short distances by using these byssal threads, more commonly when they are relatively small and light, up to about 25 mm. To do this, mussels will extend the foot beyond the shell and attach a byssal thread. They then pull themselves up on the thread, reach out to attach another, and release the old thread before pulling themselves up on the new one. They can also use this movement to distribute themselves around the inside of the grow-out basket.

The growth, age at maturity and lifespan of mussels varies depending on the environment. Blue Mussels grow fast and generally mature towards the end of their first year. They can live for 15 to 20 years, though the lifespan is more often only a few years.

2. MUSSEL GARDENING

Wild mussels © shutterstock

As mussel gardeners, you will be growing the mussels from juveniles collected from Cockburn Sound into adults to be seeded onto the new reef substrate that will be built in the Peel-Harvey Estuary.

You will also be able to provide information on the growth and survival of mussels in your location, as well as the other plants and animals that settle on the mussels and equipment (often called 'biofoul'). Mussel growth and survival data are important for identifying the best mussel gardening areas, and recording the fouling organisms gives information on the changes in this community over time and also on how often the baskets need cleaning in different areas of the estuary.

THE MUSSEL GARDENING TIMETABLE

The general timeline of activities from acquiring the juvenile mussels to growing the mussel reefs is summarised below and in Figure 11.

July – October

- Mussels settle onto ropes in Cockburn Sound
- Gardeners sign up for the program and initial program meeting
- Schedule delivery of mussels and gardening equipment (kits)

October – November

- Section of mussel rope and kits delivered to mussel gardeners

November – June

- Mussels from rope grow in baskets, gardeners clean and monitor

June – July

- Adult mussels seeded onto reef substrate

July – September

- Mussels spawn and new larvae settle and grow on the mussel bed, TNC monitor the mussel bed and collect more mussels to grow for another year (subject to funding).

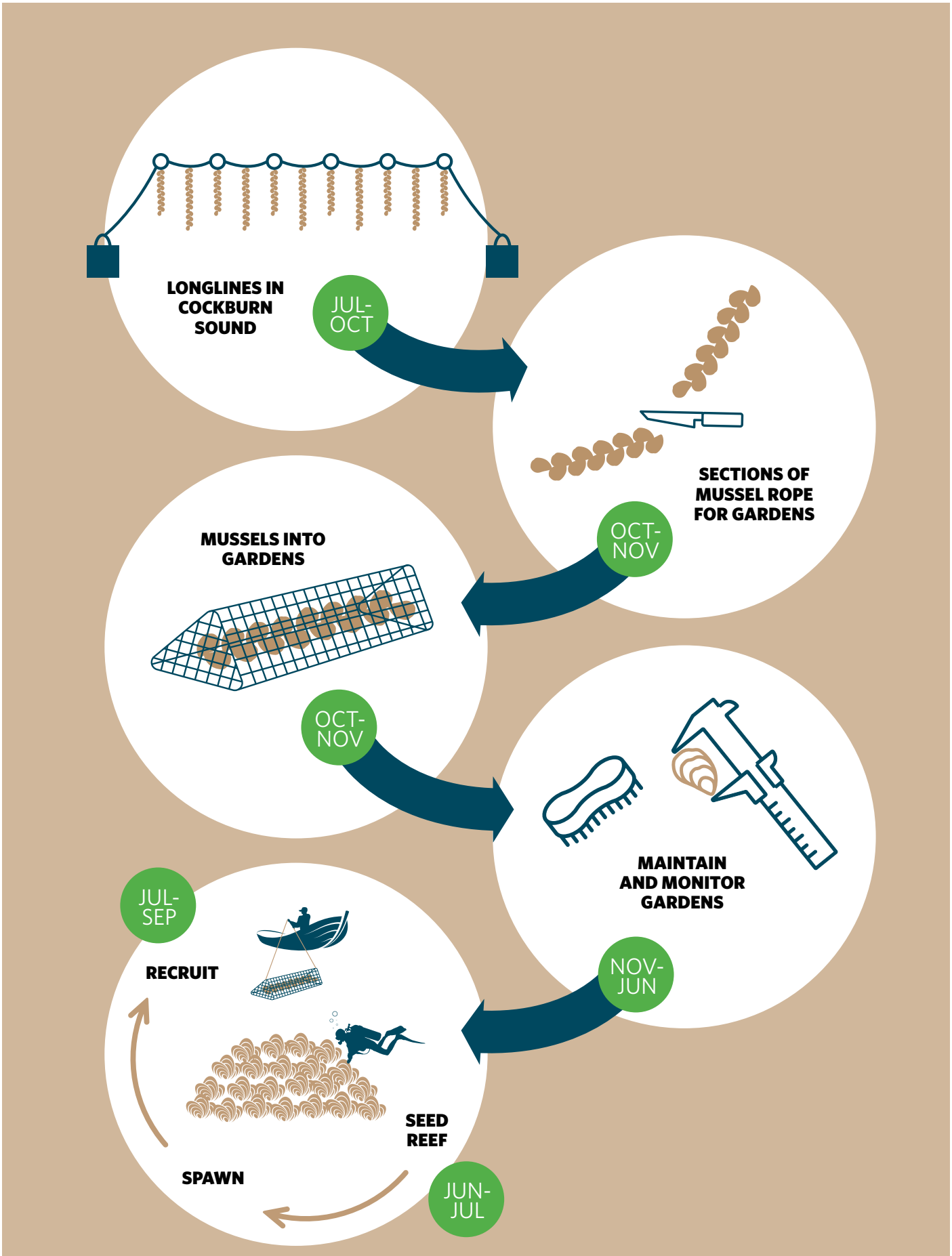


Figure 11: The mussel gardening timeline.

GETTING STARTED

Permits

Any aquaculture (growing fish or shellfish) or movement of fish/shellfish from one area to another in WA requires permits from the Department of Primary Industries and Regional Development (DPIRD-Fisheries) in order to manage disease, invasive species and any impacts of such operations on the local surroundings and estuary users.

To make it easier for Shellfish Gardeners, TNC is taking care of those approvals for you, however there may be some specific instructions you will need to follow to ensure we comply with permit conditions. A TNC Project Coordinator will explain any particular conditions with you when you receive your garden materials and work though what needs to be done for each mussel garden.

Site Suitability

Any of the canal estates in close proximity to the Mandurah Channel or Dawesville Cut are considered to be suitable for Shellfish Gardens containing Blue Mussels (Figure 12). The essentially marine waters present in these areas provide suitable conditions, including salinity and temperature ranges and food availability.

THE MUSSEL GARDEN

After you have registered for the program, an initial meeting or workshop will be arranged by TNC staff and a time scheduled to deliver your mussels and gardening equipment.

Your mussel garden will be a plastic basket (Figure 13) where you will maintain a small population of mussels and monitor their progress until they mature at the end of their first summer. You will be provided with the following basic equipment that you will need to care for and monitor your mussels.

Equipment

- Plastic tray/crate – for cleaning and monitoring mussels
- Basket(s) – to contain the mussels during grow-out
- Rope – to secure your basket to a jetty
- Gloves
- Cable ties
- Scrubbing brush – for cleaning your basket
- Paint scraper – for cleaning your basket and cutting byssal threads (Note: if you have a general-use utility knife at home, this will also be useful for cutting byssal threads)
- Monitoring equipment (see Monitoring section)

Figure 12: Suitable Blue Mussel shellfish gardening areas in the Peel-Harvey Estuary @ Google Maps, 2020.

Mussel Baskets

Your mussels will be housed in a sturdy 'basket' of the same type that commercial shellfish farmers use on their aquaculture leases (Figure 13). The baskets, which are made from a sun-resistant plastic, are triangular in shape, 20 cm high, 35 cm wide, 87 cm long and open length-ways. This will allow you to have easy access to your mussels and make it easier and safer to clean and remove any other plants or animals growing on the inside or outside of your baskets.

The baskets weigh less than 1 kg when clean and dry. The mesh size in these baskets is variable, with smaller mesh (<10 mm) used initially while the mussels are juveniles, and larger mesh used as they grow (>10 mm). You will need to swap baskets when the mussels are big enough to be contained by the larger mesh, within a month or two of starting your gardens. You may also need to split your mussels into two or possibly three baskets to ensure they are not over-crowded.

Depending on your shellfish gardening environment, your basket will need to be suspended in the water column using ropes that are tied to a jetty or floating pontoon (Figure 14). If fixed to a solid structure such as a jetty, the basket will need to be set at a depth where it is not exposed at low water on a spring tide. If fixed to a floating pontoon, the basket should be about 50 cm below the surface and needs to be at least 30 cm above the sediment on a low spring tide. If the baskets are secured under the structure they will be out of the way and the shade will slow the growth of algae and seaweed on the baskets.

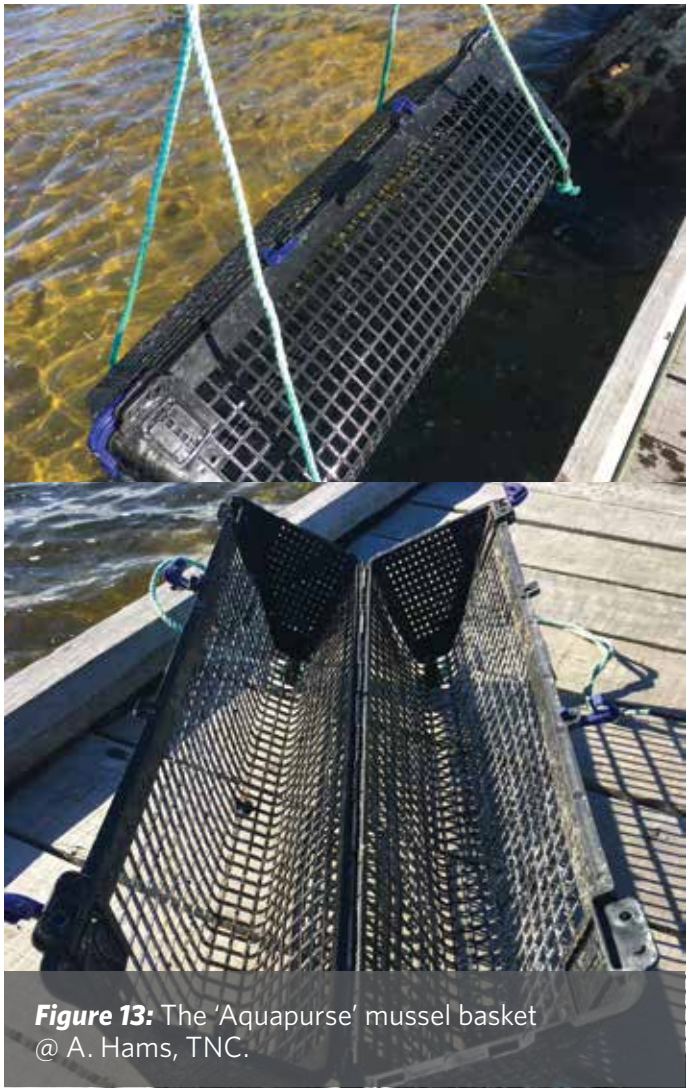


Figure 13: The 'Aquapurse' mussel basket @ A. Hams, TNC.

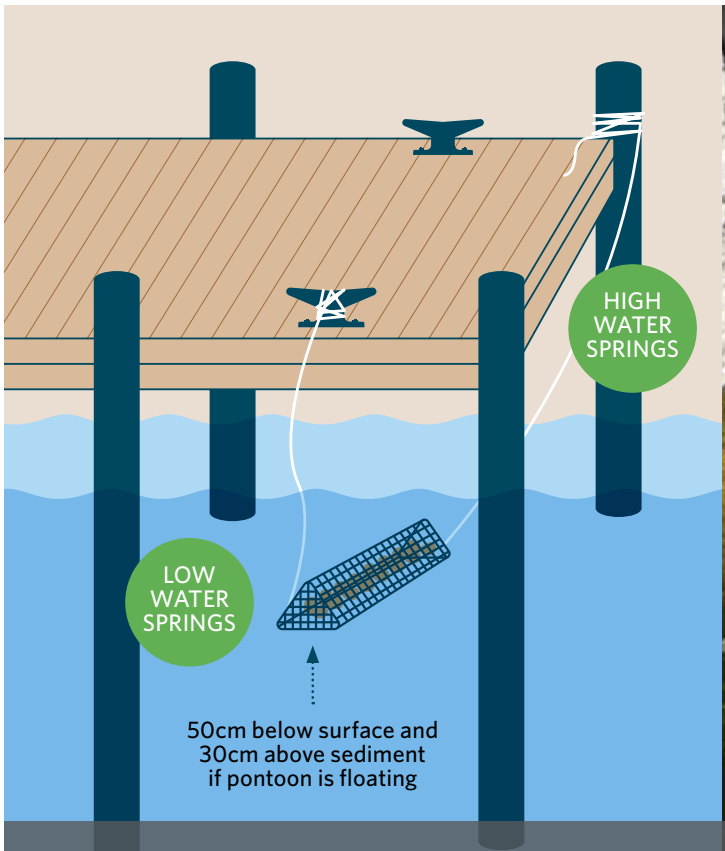


Figure 14: One option for securing a basket beneath a jetty © A. Hams, TNC

SAFETY FIRST

The first consideration with the mussel gardening process is your safety and the safety of those with you.

From the time that the mussels are first delivered to the time they are removed to be seeded to the reef base, there are safety considerations to be mindful of. Gloves must be worn any time the gardens are being handled. Potential dangers can be divided into a few categories.

Bites, stings and squirts

The animals that may occur in your mussel garden that you need to keep an eye out for include **Blue ringed octopus!** While these may not be common in the Peel-Harvey (Figure 15), they are common along the Mandurah shoreline and can occur in the estuary. They are small, excellent at hiding and love shellfish! While they are not at all aggressive, an unnoticed small octopus can bite to defend and protect itself.

They only flash the blue rings when they are feeling threatened. Remember, a bite is toxic and can kill. If you see one, use a tool to place it back into the water. They are surprisingly strong for their size and can hang on. **If you think you may have been bitten call for assistance immediately!**

Other animals to be aware of are larger crabs, cobbler and the spines of other fish (even if they aren't poisonous like the cobbler). Even the ascidians or 'sea squirts' can squirt salt water into your eyes if they are squeezed.

Figure 15: Blue ringed octopus. These small animals are highly venomous and can be deadly to humans. Do not aggravate or handle the animal. **If bitten, call 000 immediately**
© R.Swainston/ANIMA.fish

Lifting and Conditions

The gardens can get heavy as the mussels and fouling growth attached to the baskets grow. Care should be taken when lifting and seek assistance if necessary. Avoid working with your gardens during inclement weather, if you can hear thunder or see lightening you should leave your gardening site. In summer, you will need to be aware of the risk of heat-related stress, both to yourself and your mussel garden. Work in the shade, early morning, or late afternoon, avoiding the hottest times of the day.

Cuts and Scratches

All surfaces will have the potential to cause cuts and scratches. Particularly once barnacles have set to the equipment. Gloves and care are required when handling any equipment. If scratched or cut, apply an antiseptic wash to avoid infection and seek medical attention.

Ultimately, you are your best safety rule:
IF IT DOES NOT FEEL RIGHT, STOP!

If you are unsure of anything, **STOP**, and contact us with your question.

Eating Shellfish can Make You Sick

The mussel gardening program is growing mussels for restoration, not consumption, so **PLEASE DO NOT EAT YOUR MUSSELS.**

The Department of Health also cautions against eating shellfish from waters that may become contaminated (healthywa.wa.gov.au/~/media/Files/HealthyWA/Original/WildShellfishCollection.pdf).

Because shellfish feed by filtering food from the water, they can accumulate harmful substances in their flesh if the water quality is not good, e.g. bacteria, viruses, metals, and algal toxins. These microorganisms and toxins can make you sick if you eat shellfish that have been contaminated. Symptoms of food poisoning may range from diarrhoea and/or vomiting to severe respiratory and neurological problems, and occasionally even death.

Harmful microorganisms and toxins are often present in waterways due to run-off from the land, especially following heavy rainfall, and are more likely to occur in areas surrounded by urban or agricultural development. It is impossible to guarantee the safety of wild shellfish without having a comprehensive monitoring program that tests the waterway regularly. Shellfish that are commercially available are managed through an accredited quality assurance program, which includes routine testing of the product and the environment they grow in to ensure shellfish are safe to eat.

INSTALLING AND MAINTAINING THE GARDEN

There are three steps in the mussel gardening timeline (Figure 11) that occur at the gardener's site.

1. Deploying the garden;
2. Routine monitoring and maintenance; and
3. Harvest for seeding onto the reef base.

The steps do not require the same input of your time. Most of the time is spent with monitoring and maintenance, but all three steps include measuring a sub-sample of mussels. A detailed description of measuring a sub-sample of mussels is included in the section on Monitoring below.

Step 1: Deploying the Garden

When your mussels are delivered by the TNC Program Coordinator (around October) they will be attached to a short section of mussel rope from Cockburn Sound. The coordinator will have done the initial measurements to estimate the number of mussels you receive.

The coordinator will help or guide you with the initial installation of your basket for the first time. This will involve:

- Placing your rope in the basket with any live mussels that have come loose; and
- Securing the basket for the first time.

Please note: The basket should be attached with two ropes. This allows the basket to be oriented horizontally in the water. It also gives a level of insurance in case a knot fails or a rope chafes through and breaks. The forces of waves and tides causes the mussel garden to move continuously. Lines and cables attached to the mussel garden will continuously scrape against any hard structure they are touching. This slow steady friction can cut through lines and cables surprisingly quickly.

To avoid losing your basket to the bottom, check your lines every time you inspect your garden, making sure both are in good condition. Especially after stormy weather, it's a good idea to go check your mussel garden. In places that look at risk of chafing, the rope can be pushed through a conduit of old garden hose to make a protective sleeve. If any serious abrasion is seen, the rope should be replaced altogether. Where possible, secure an eye bolt or hook to the jetty to secure your baskets.

Step 2: Routine Monitoring and Maintenance of your Mussel Garden

Once installed your mussel garden will need regular attention. This falls into 3 categories;

A. Maintenance of the equipment

B. Monitoring:
   a. the mussels;
   b. the plants and animals growing on the basket (fouling growth or mussel garden predators and associates, Appendix 2); and
   c. water temperature.

C. Cleaning the mussel garden.

All tasks need to be done once a month and where possible, done at the same time each month. The exception may be checking the basket for damage or excessive fouling (see 'Maintenance of the equipment'). After a strong storm or any event that you think may have caused damage, pull the basket from the water and do an additional inspection. During summer, fouling will increase due to warmer waters, so additional checks and maintenance may be required.

Step 3: Harvesting for seeding onto the reef base

Once the mussels are mature and the reef base has been built, the mussels from your gardens will be collected by the TNC Program Coordinator then deployed directly onto the reefs by divers. The mussels will reattach to the reef base with their byssal threads, and help contribute to a self-sustaining mussel reef ecosystem.

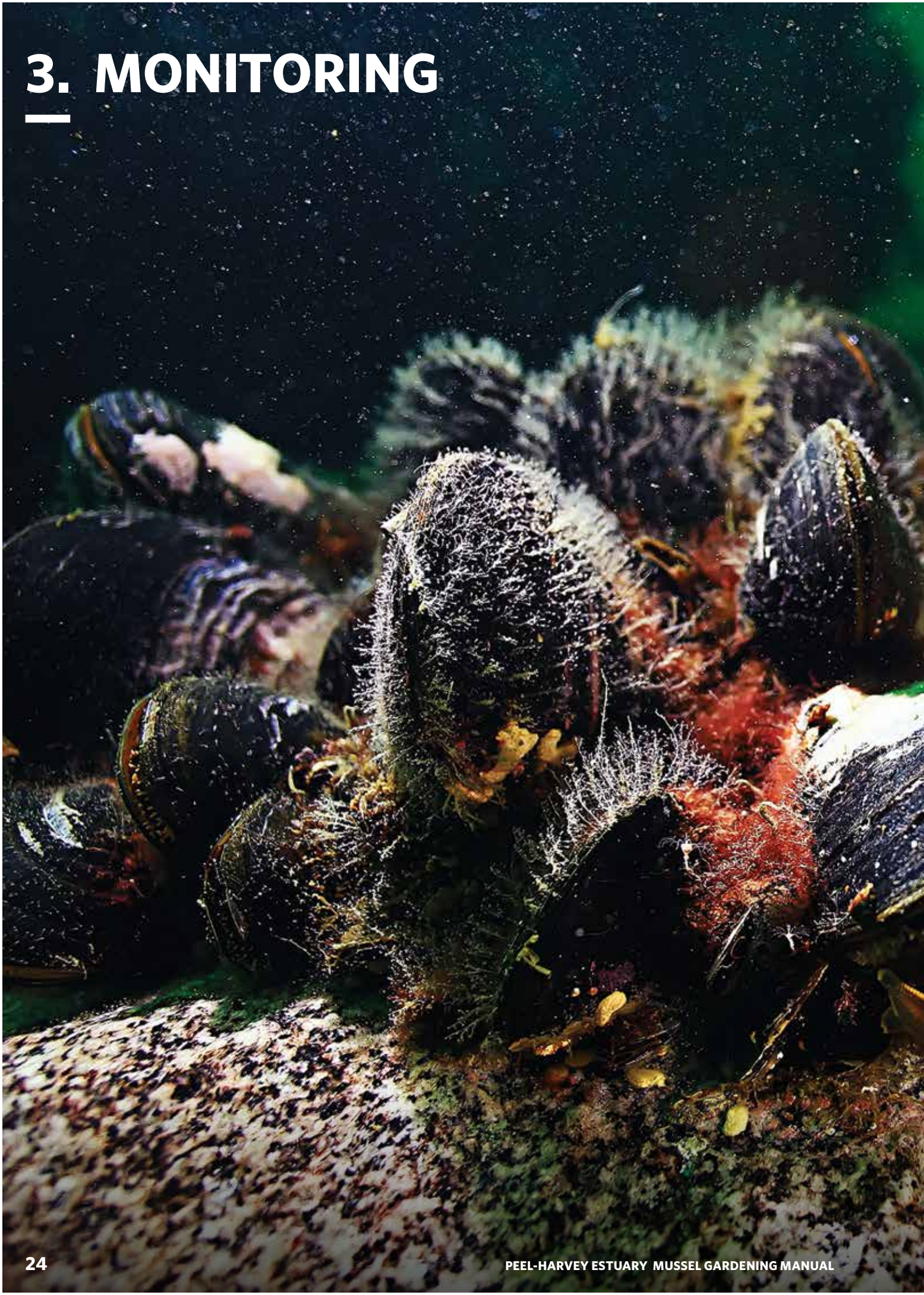
MAINTENANCE OF THE EQUIPMENT

Baskets should be inspected and maintained in person by an adult at least every four weeks. Before disturbing the basket take a minute to observe any predators or associated species on the outside of the basket.

The maintenance routine includes:

- Observe predators and associates on or around the basket and record your observations on your data sheet (see Monitoring below).
- Haul the basket out of the water and onto a stable platform (jetty, pontoon or shore depending on your location).
- Inspect the basket thoroughly for damage or weakness. If the basket appears to be damaged or is weakening, contact your TNC Project Coordinator to discuss the damage and a replacement basket.
- Inspect the knots to ensure they are secure and inspect the lines for any damage or abrasion. Replace any lines as necessary.

3. MONITORING



Mussel reef © shutterstock

The growth and survival of mussels can vary substantially between sites separated by small distances (hundreds of metres). The community of species that settle and grow on the garden can also vary. These may vary by location, the time of year that they appear, or between years. In addition to providing larger mussels to seed onto the reef base, the mussel gardening program would like your help in understanding how different areas in the gardening program perform. The monitoring data will help us understand this variation.

Observations and measurements from the routine monitoring are recorded on the data sheet. The data sheets are provided in Appendix 1 of this manual. You can also print them from The Nature Conservancy's shellfish gardening webpage natureaustralia.org.au/shellfishgarden. You are only required to submit one data sheet per month. On the same web page, you can find other interesting information about mussels and the reefs they will be deployed onto. If it appears that a large amount of mussels have died or if you are concerned about a situation that is unexpected, please contact the TNC Project Coordinator at shellfish.gardens@tnc.org to discuss and decide if further investigation is warranted.

Equipment

- Gloves
- Calipers
- Monitoring Data sheet (Appendix 1) and pen
- Your phone or camera (to take photos)
- Thermometer
- Bucket with rope lanyard
- Species ID sheets (Appendix 2).

Associates and Predators

There will be various small marine organisms moving around your mussels, such as worms, amphipods, crabs, shrimp, small fish and maybe even a Blue ringed octopus. These species will begin to emerge and appear as you retrieve your basket from the water. **Be careful and wear your gloves at all times as not all things may be visible immediately**. Consider tipping the contents of your basket onto a plastic tray or crate to better view your living associate organisms. It is important to monitor the main fauna associated with your garden when you pull up your basket as they will not be able to survive out of water for long periods.

Begin by identifying and recording the abundance of species that you see. You can use the Species Identification Sheets provided in Appendix 2 to help with identifying common groups of organisms. There may be lots of the small invertebrates (e.g. amphipods, glass shrimp, gastropods, small crabs, etc.).

If so, estimate the number in categories.

- 10 to 20
- 20 to 50
- 50 to 100
- 100 to 500
- Over 500

When an organism is unknown, take a photo and send to your TNC Project Coordinator at shellfish.gardens@tnc.org. The fouling community and other associates and predators will be recorded separately on your data sheet but practically, observations of the outside of the basket are made before opening the basket and observing the species within.

Associates and predators

- Identify any of the main mussel associates and predators both before disturbing the garden and after you have opened it to empty its contents.
- Record all organisms observed in the 'Associates and predators' section of your monitoring data sheet.

Fouling Community

Estuaries are productive environments and an abundance of marine organisms will colonise your basket, similar to those living on jetties or piers. During the summer months, when water temperatures are warmest, you will notice maximum fouling. It is important to keep this fouling growth to a minimum to allow water to flow through the basket so the mussels can feed.

The most common fouling organisms that will grow on your basket are barnacles, sponges, seaweeds (macroalgae), bryozoans and sea squirts. Check the Identification Sheet for examples of groups of fouling species (Appendix 2). You might even find some mussels attached to the outside of the basket. If you do, cut the byssal threads and place them with your other mussels in the basket. Remember your gloves. Some bryozoans have a mild sting.

Fouling community

- Determine the groups of organisms growing on your basket
- Estimate the extent of cover on the basket (as percent cover)
- Record each in the space on your data sheet.
- Open the basket and observe.

Mussel Growth

Before the mussel garden was installed, baseline measures were taken to determine the overall number of mussels and the average height of at least 30 mussels. These measures are repeated monthly to track growth and mortality (Figures 16 and 17). To select a sample to measure for growth, identify an area of the basket (or length of rope) that contains at least 30 mussels (see 'Why Random Sampling is Important' box).

If it is possible to measure ALL the mussels in this area without removing them then mark the area and proceed. Alternatively cut the mussels from the basket (or rope) and place in a container for measuring. Measuring the heights of more than 30 mussels does provide additional information, but the data from 30 to 60 mussels is sufficient.

Please take all measurements in millimetres. Data from these measurements will be submitted to The Nature Conservancy by emailing to shellfish.gardens@tnc.org, where it will be incorporated with data from all other mussel gardening sites within the estuary. In summary:

- select a group or area of at least 30 mussels to measure.
- to remove the mussels, cut the byssal threads carefully. Measure the height of all the mussels in that group or area with the calipers provided. See Figure 17 for details on how to measure mussel height.
- retain the measured mussels to be returned to the basket before closing. You may need to do some cleaning of fouling growth inside the basket before returning the loose mussels (see 'Cleaning your Mussel Garden', page 29).

You may need to remove the mussels from the basket to measure them. Gently pulling a mussel off the surface that it is attached to usually breaks the byssal threads without damaging the mussel, but it can also pull out the byssal gland. If the whole byssal gland is removed the mussel will no longer be able to reattach and is unlikely to survive. It is important to avoid removing the byssal gland. If you can grip the threads themselves then you will be able to break them without damaging the mussel. If not, it may be easier, and safer for your mussels, to cut the byssal threads. Running a knife between the mussel shells and the edge of the basket or rope it is attached to will cut the threads. If the byssal gland is intact the mussels will reattach within an hour.

Mortality

The byssal threads attach the soft tissue of the mussel to the substrate, not the shell. This means that when a mussel dies, the shell may come loose and collect at the bottom of the basket. Others may remain attached to other mussels. All dead mussels within your basket are to be counted and the total number of dead mussels recorded on your data sheet. A mussel is dead if the shells remain open when you take it out of the water. If the shells of dead mussels are still wedged among the other mussels, you may need to gently shake the rope and basket to make them come loose or cut the threads attaching them to other mussels. If you happen to clean your basket more than once a month, then please keep a tally of dead mussels so that you can combine the total mortality on your monitoring datasheet. If the hinge has broken so there are individual shells (valves) in the basket, just count these and divide by two for the number of dead mussels. In summary:

- gently shake the basket
- count all dead mussels and remove them from your basket so they are not counted twice
- count any separated shells and divide by two before adding to the count of dead mussels
- remove dead mussels from the basket (where possible).

Water Temperature

Temperature is a major driver for many biological processes that affect the Peel-Harvey Estuary. Mussels are adapted to cooler southern waters so maintaining a temperature profile of the mussel gardening areas will help us understand changes in growth, mortality and the fouling community. As a guide, Blue Mussels prefer temperatures between 10°C and 20°C, but can tolerate between 0°C and 26°C.

- Using the bucket with rope attached, dip a full bucket of water from the area around the basket.
- Hang or hold the thermometer in the bucket away from the sides or bottom of the bucket to minimise temperature drift.
- Wait for the probe or thermometer to stabilise.
- Record your reading.

Monitoring should only take about 30 minutes to complete. At the end of each month, send your monitoring datasheets to shellfish.gardens@tnc.org.

Why Random Sampling is Important

It can be difficult to get a random, or representative, group of mussels to measure and it can be tempting to select the bigger mussels in your basket to measure. Even if you are trying to select mussels that reflect the range of sizes in the basket, it is likely to be a biased sample. It is important to try and avoid doing this and instead select mussels randomly to eliminate bias in the growth measures. You can sample randomly by selecting a representative clump of mussels. To do this, locate a small area that contains approximately 30-60 mussels and measure all mussels in that clump or area.

Figure 16: Measuring the height of a mussel © F. Valesini, TNC.

How to Measure a Mussel

Before measuring any mussels, check that the calipers read zero when closed. If the closed position is not reading zero, turn the dial so that the pointer is pointing to the zero mark. Using the calipers, measure mussels for height (the distance from the hinge axis to the distal margin of the shell) to the nearest millimetre (see Figure 17). Mussels are returned to the basket only after all mussels in the selected area have been measured. Record your height measurements to the nearest millimetre in the space provided on your datasheet. If you would like to track the average growth of your mussels, calculate the average height for each sampling period (add all heights then divide by the number of mussels measured) and compare the results from month to month.

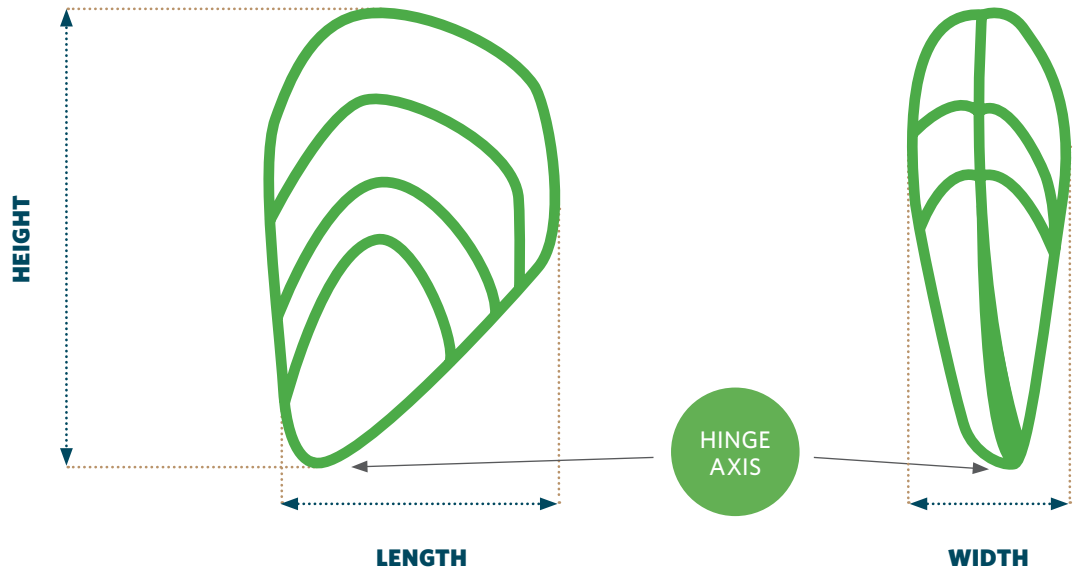


Figure 17: Measurement guide for bivalve shellfish.

CLEANING YOUR MUSSEL GARDEN – MAINTAINING GOOD WATER FLOW

Mussels are hungry animals. To support the rapid growth during their first year, and high egg production (fecundity) in following years, mussels need to feed.

Mussels filter their food from the water, so this means that they need good water flow moving past them. Caging your mussels keeps them safe from large predators such as crabs, fish and birds, but if the holes in the baskets become covered with 'fouling' growth (Figure 18) your mussels will starve. Maintaining a good water flow by cleaning your baskets is essential.

During the growing season, there will be waves of other seaweed and animals that settle on your baskets. If they are allowed to grow too thick, they will cover the holes in the basket and stop the water getting through. Giving the outside of the baskets a good scrub with a stiff bristled scrubbing brush at regular intervals will keep the growth under control for a while. Scrubbing doesn't remove all the animals and may not remove the base or 'holdfast' of the seaweed, which is the point where the growth begins. If the growth does not come off with scrubbing and builds up, you may need to use a metal paint scraper or butter knife.

Figure 18: A highly fouled basket from the Peel-Harvey Estuary. Growth of this type will starve mussels by restricting water flow through the basket © A. Cottingham, Murdoch University

HARVEST FOR SEEDING

Once the substrate has been deployed to form the base of the new reefs, you will be contacted by the TNC Project Coordinator who will collect the mussels you have been growing and place them onto the reef bases.

This will most likely be in June or July when your mussels will be getting large and hopefully ready to spawn themselves.

For more in-depth reading about reef development, please consult our web page; www.natureaustralia.org.au/shellfishgarden.

APPENDIX 1: DATA SHEETS

Mussels ready for harvesting © shutterstock.

MUSSEL GARDENING MONITORING DATA SHEETS

INSTRUCTIONS

Record your mussel garden monitoring data and observations each month, then email it to shellfish.gardens@tnc.org. Photograph anything you are not sure of and submit with the data sheet. Electronic versions of this data sheet are available at natureaustralia.org.au/shellfishgarden.

Name:		
Site No/Address:		
Date:	**Time:**	**Water temperature:**
Describe any damage to the basket:		
Other noteworthy observations or concerns:		

Measuring Growth: Measure the **height** of at least 30 live mussels (mm). Keep a tally of dead mussels as you measure.

1		21		41	
2		22		42	
3		23		43	
4		24		44	
5		25		45	
6		26		46	
7		27		47	
8		28		48	
9		29		49	
10		30		50	
11		31		51	
12		32		52	
13		33		53	
14		34		54	
15		35		55	
16		36		56	
17		37		57	
18		38		58	
19		39		59	
20		40		60	
				Average Height:	mm

Mussel Mortality: Count all dead mussels in your basket. Remove shells after counting.

Number of dead mussels:	

Fouling Community
Fouling of the basket: Record the % of the plastic mesh of the basket that is covered by biofoul.
Comment

Use the Species Identification Sheets in Appendix 2 to identify the fouling plants and animals found attached to the outside or inside of your mussel garden. Estimate the % of the basket covered by each group.

Species/Name	Approximate %	Notes
Barnacles		
Sponges		
Seaweeds		
Sea squirts		
Other group*		
Other group*		
Other group*		
Other group*		

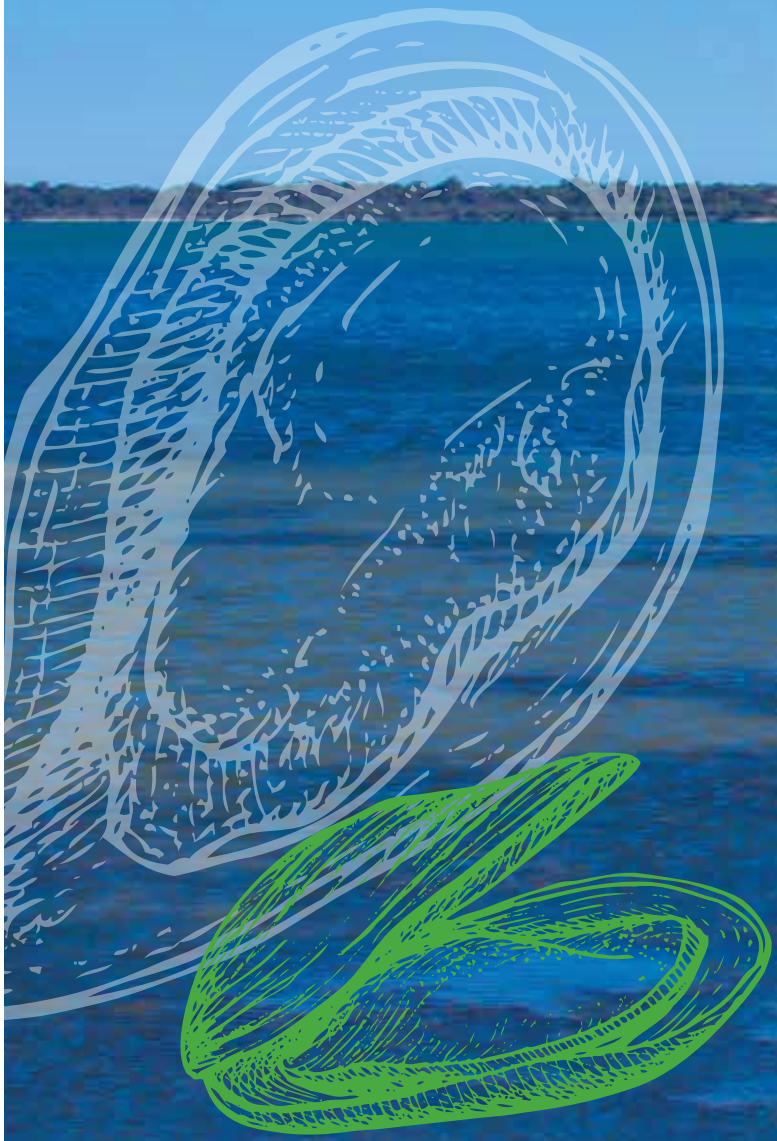
*identify if known, otherwise take a photo and send with the datasheet.

Associates and Predators
Other shellfish, invertebrates or fish observed on the outside or inside of your baskets: Use the Species Identification Sheets in Appendix 2 to identify the main associate or predator species found in or around your mussel garden. For abundant species, estimate the number category, 0-9, 10-20, 20-50, 50-100, 100-500, >500.

Species/Name	Approximate No.	Notes
Amphipods		
Glass shrimp		
Worms (polychaetes)		
Gastropods		
Small crabs		
Other*		
Other*		
Other*		

*identify if known, otherwise take a photo and send with the datasheet and we will identify it for you.

APPENDIX 2:
FOULING ORGANISMS, ASSOCIATES AND PREDATORS



Peel Inlet and Harvey Estuary catchment © shutterstock.

Aside from Blue Mussels, there are several other plant and animal species that are likely to be attracted to your shellfish gardens.

Some may rapidly colonise the mussel basket, rope or the mussel shells themselves. Several can become a nuisance by **'fouling'** the mesh of the basket and starving your mussel garden, especially if not removed regularly.

Other animals are likely to be attracted to the fouling organisms, either for food or shelter. These **'associates'** may include small invertebrates like shrimp or worms, or otherwise small fish. You might also find other types of bivalve shellfish (e.g. oysters) growing on or in your baskets.

Of course, other species will be attracted to your shellfish gardens because they like to eat mussels, i.e. **'predators'**.

Following is a brief list and description of potential shellfish garden fouling organisms, associates and predators – you are likely to uncover others. If you encounter a species that is not listed, and you are confident of the ID, then please add it. If you are not confident of what it is, please take a few photos and submit it with your data sheet to shellfish.gardens@tnc.org. Most species listed below are abundant in both coastal waters and the more marine parts of estuaries in south-western Australia and beyond.

Please note that some of these species can be harmful to people, which is indicated at the bottom of the species information tables, along with the following simple colour-coding system.

HARMFUL TO HUMANS?	**No**
HARMFUL TO HUMANS?	**May cause temporary discomfort or minor injuries if handled, e.g. minor abrasions, spikes or nips**
HARMFUL TO HUMANS?	**Venomous or poisonous and potentially deadly**

A similar coding system has been applied to whether species are harmful to mussels, either because they are predators or have other ways of directly impacting mussel survival.

HARMFUL TO MUSSELS?	**No**
HARMFUL TO MUSSELS?	**Potentially, though are unlikely to cause a major impact**
HARMFUL TO MUSSELS?	**Voracious predator**

A SPECIAL CASE

PLEASE BEWARE! One animal you may find hiding in your shellfish basket is a Blue ringed octopus. These small animals are highly venomous and can be deadly to humans. Do not aggravate or handle the animal. If bitten, call 000 immediately.

COMMON NAME	**Blue ringed octopus**
SCIENTIFIC NAME	*Hapalochlaena maculosa*
ABOUT ME	Blue ringed octopus belong to the same wider group (Phylum) of animals as your mussels, i.e. they are both molluscs. However, octopus lack the shell that most other molluscs have, their head has become joined to their foot, and they have 8-10 arms with rows of strong suction discs. They are also super intelligent and complex in the world of marine invertebrates. They can learn and adapt quickly, have excellent eyesight and can flatten their bodies to squeeze into tight spaces. They also have a special outer body layer that can quickly change colour and pattern to blend with their environment, attract mates or ward off enemies. Which is how the Blue ringed octopus gets its name – the electric blue rings that light up on its otherwise pale body when threatened. These small animals (up to ~10 cm long) are not aggressive and like to hide under rocks or inside crevices during the day, including empty shells or discarded bottles. They eat small crustaceans (e.g. shrimps or crabs), other invertebrates or fish, which they catch with their tentacles, bite with their 'beak' (near the mouth) and then paralyse them by injecting venom, which is an **extremely powerful nerve toxin. It is also highly toxic to humans, and can result in a range of effects including paralysis, respiratory arrest and heart failure.**
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**Yes – Highly venomous and potentially deadly within minutes of being bitten. If you encounter a Blue ringed octopus, do not aggravate or handle the animal.**

© R.Swainston/ANIMA.fish

FOULING OR COLONISING PLANTS AND ANIMALS

You are likely to find many different types of plants and animals growing attached to your shellfish basket or attached to the shells of the mussels, which can become a nuisance and starve your mussels if not cleaned off regularly. Like mussels, many of these fouling or colonising animals are filter feeders, so are competing for the same food sources. Additionally, fouling plants and animals can block water flow through your baskets, and hence reduce food supply to your mussels. However, they can also provide good food and habitats for a range of other animals, which are listed in the following 'associates' section.

COMMON NAME	**Barnacles**
SCIENTIFIC NAME	Cirripedia sp.
ABOUT ME	Barnacles are a type of crustacean (the same group of animals as crabs and prawns) and live only in marine waters. While their early life stages (larvae) are free-swimming, they then settle on to hard structures such as rocks, jetty pylons and boat hulls, and possibly the shells of your mussels! They attach themselves head down using cement glands, then transform their bodies to suit a stationary life-style. For example, they lose their head, transform their limbs into long, feathery appendages (called 'cirri'), and develop a shell made up of a series of connected plates that protects the soft-bodied animal inside. The cirri can be extended out of their shells to filter food (plankton and detritus) from the water and draw it towards their mouth. It is common to find large clumps of adult barnacles growing together where planktonic food is abundant.
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**Be careful of sharp shell plates, which can cause cuts and grazes.**

@ A. Cottingham, Murdoch University

COMMON NAME	**Sea squirts**
SCIENTIFIC NAME	Ascidiacea sp.
ABOUT ME	Adult sea squirts are often attached to substrates such as reefs, rocks or shells. The bodies of these animals are surrounded by a tube-like 'tunic' (from which these animals derive their broader name, 'tunicates'), which can range from thin and delicate to thick and tough and vary widely in colour. Although they may not look like it, the early life-stages of sea squirts (which are free-swimming and look a little like a tadpole) actually contain the basic characteristics of vertebrates. This includes the very beginnings of a backbone, a tail and nerve cord running along their back, but they lose most of these features as adults. Most sea squirts feed on plankton, which they capture by drawing large volumes of water in through one pipe or 'siphon' on one side of their bodies, filtering it through a sieve-like structure (their 'pharynx') to remove their food, then squirting the cleaned water out of a second siphon to another side of the body.
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**No**

@ F. Valesini, TNC

COMMON NAME	**Bryozoans**
SCIENTIFIC NAME	Bryozoa sp.
ABOUT ME  *@ A. Cottingham, Murdoch University*	Bryozoans are tiny invertebrate animals (~1 mm long) that mostly live in large colonies. Their colonies can have a variety of forms, including encrusting sheets, plant-like masses or fan-like structures, and are sometimes mistaken for corals or algae. The minute animals that make up the colony (called 'zooids') have a crown of tentacles used to filter plankton out of the water. The zooids are not fully independent, but instead work together for the good of the colony. The main types of zooids are responsible for feeding and removing wastes, while others help with reproduction or protection. Some bryozoans can form very large aggregations and become a nuisance in some areas by fouling fishing gear, blocking outfall pipes or outcompeting other species. They can also produce compounds that make them unappetising to many potential predators.
HARMFUL TO MUSSELS?	**No, but their tissues may contain compounds that can prevent settlement of mussel larvae.**
HARMFUL TO HUMANS?	**No, though some bryozoans have a mild sting.**

COMMON NAME	**Sponges**
SCIENTIFIC NAME	Porifera sp.
ABOUT ME  *@ F. Valesini, TNC*  *@ A. Cottingham, Murdoch University*	Sponges are very basic animals that attach themselves to hard structures. Their bodies, which can vary greatly in size, shape and structure, are made of a jelly-like material often strengthened by 'spongin' (collagen fibres) and/or 'spicules' (small rods made of calcium carbonate or silica). Sponges are designed to maximise water through-flow so that they can obtain food (very small floating particles) and oxygen and remove wastes. They draw in water through many pores on the outside of their body, then expel it out the top of the body through a central hollow cavity. They have a range of cell types that each have specialised functions, such as driving water flow (cells with beating whip-like 'tails'), obtaining food, making parts of the skeleton, or reproduction.
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**No. While the spicules of some sponges make them very rough and can be abrasive if handled, the small often jelly-like sponges common in the Peel-Harvey Estuary and shallow coastal waters are not harmful.**

COMMON NAME	**Macroalgae (red, brown or green)**
SCIENTIFIC NAME	Rhodophyta sp. (red algae), Phaeophyta sp. (brown algae), Chlorophyta sp. (green algae)
ABOUT ME  *@ F. Valesini, TNC*  *@ S. Cronin-O-Reilly, Murdoch University*	This diverse group of predominantly marine aquatic plants are common wherever there is enough light to support photosynthesis. They differ from seagrasses in several important ways – whereas seagrass have distinct roots, leaves and stems, produce flowers and have specialised tissues, macroalgae only have a 'holdfast' for attaching themselves to substrates, lack distinct leaves and stems, do not have flowers and are relatively unspecialised. Despite their simplicity, they can vary widely in form from huge kelps (a type of brown algae) to tiny 'epiphytic' algae that grows on the surface of seagrass leaves. Their colour groupings can also be a little confusing, given that some red algae look brown, some brown algae look greenish etc. Instead, these broad groupings of macroalgae mainly reflect their types of photosynthetic pigments. Macroalgae play several important roles in aquatic ecosystems, such as providing essential 'nursery' habitats for many fish species, capturing carbon and producing oxygen. However, they can also grow extremely rapidly in waters with lots of available nutrients and cause a range of negative effects, such as clogging waterways and smothering seagrasses.
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**No**

COMMON ASSOCIATES

Many other types of invertebrate animals and fish are likely to be inhabiting the area around your shellfish gardens, seeking food and/or shelter amongst the other plants and animals colonising the baskets. Some commons ones are below, but you are likely to find many others.

COMMON NAME	**Amphipods**
SCIENTIFIC NAME	Amphipoda sp.
ABOUT ME	Amphipods are small crustaceans (usually < 0.5 cm long) with segmented bodies that are flattened from side-to-side and often have a curved back. Their front legs are larger than the others and often have obvious claws, which are used to grasp food. Amphipods are very abundant and play important roles in many aquatic ecosystems. For example, many species are scavengers and help to consume detritus that accumulates in aquatic environments. Others graze on algae. They are also very important prey for many larger invertebrates, fish and birds.
	 *@ S. Cronin-O'Reilly, Murdoch University*
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**No**

COMMON NAME	**Snails**
SCIENTIFIC NAME	Gastropoda sp.
ABOUT ME	This highly diverse group of animals contains those with a single shell that houses a slug-like body, e.g. sea snails, periwinkles, whelks, abalone, limpets. The shell is coiled or spiraled, except in cases like the limpets which have a coiled shell as juveniles but develop a conical shell as adults. Unlike mussels or oysters which have two joined shells ('bivalves'), marine snails have only one shell ('univalves'). The slug has a highly muscular foot that is used for crawling (or in some cases digging or swimming), and a well-developed head with tentacles that are used for 'seeing' or smelling. Many aquatic species can also close the opening of their shells with a 'lid' (called an 'operculum') to protect themselves from predators or from drying out if they are exposed to the air. Marine snails can feed on algae, detritus or other animals.
	 *© F. Valesini, TNC*
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**No, not those common in the Peel-Harvey Estuary and nearby coastal waters. The venomous Cone Shell (*Conus striatus*) is more at home in the tropics.**

COMMON NAME	**Glass shrimps**
SCIENTIFIC NAME	Palaemonidae sp.
ABOUT ME	Glass shrimps, like their name suggests, are pale and translucent. They grow to ~5-6 cm and have noticeable pincers on their first two pairs of legs. They are omnivores and will consume various types of algae, detritus, and in turn, are prey for a range of fish species.
	 *@ S. Cronin-O'Reilly, Murdoch University*
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**No**

COMMON NAME	**Worms**
SCIENTIFIC NAME	Polychaeta sp.
ABOUT ME	Worms, or polychaetes, have obviously segmented bodies and many small 'paddles' and spines projecting from their sides. The fleshy paddles can be used for feeding, locomotion or breathing. Polychaetes are very diverse in their forms and habits, with some being free-living and others dwelling inside tubes that they build. They often live close to (or within) the sediment, though some swim freely through the water column. Tube-building polychaetes can make their homes from hard shell-like material, others are leathery in texture, while others are made from mucous. Polychaetes play important roles in coastal waterways by recycling and reworking the sediments and detritus. They are also a rich and nutritious food source for many fish and birds.
HARMFUL TO MUSSELS?	No
HARMFUL TO HUMANS?	No

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COMMON NAME	**Gobbleguts**
SCIENTIFIC NAME	*Ostorhinchus rueppellii*
ABOUT ME	Easily identified by: • The large mouth • Line of black spots on the side of the body. Often found in large schools in both sandy and seagrass habitats. These small fish grow to maximum lengths of ~10 cm and feed on small crustaceans, worms and small fish. The males brood the eggs in their mouth, incubating them until they have hatched.
HARMFUL TO MUSSELS?	No
HARMFUL TO HUMANS?	No

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COMMON NAME	**Hardyheads**
SCIENTIFIC NAME	Atherinidae sp.
ABOUT ME	'Hardyheads' is a general name for a family of small silvery fish that often occur in very large schools in shallow waters and are sometimes used as fishing bait. Three to four species are common in the more marine parts of estuaries and can be difficult to tell apart. Hardyheads have a stripe of differing colour (e.g. silver, copper or gold) along the middle of their body, and are mainly silver-coloured on their lower half. They are often less than 10 cm in length, but can grow to ~15 cm. Hardyheads are common in sandy habitats where they are well camouflaged, but also occur over seagrass. They mainly eat small bottom-dwelling worms and crustaceans or planktonic crustaceans.
HARMFUL TO MUSSELS?	No
HARMFUL TO HUMANS?	No

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COMMON NAME	**Western striped grunter**
SCIENTIFIC NAME	*Pelates octolineatus*
ABOUT ME	Easily identified by: • 5-8 dark stripes along sides of body. • Short head Western striped grunter grow up to ~28 cm in length and live in seagrass/algal habitats. They are omnivores, feeding on algae and small invertebrates.
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**No**

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COMMON NAME	**Devilfish or Soldierfish**
SCIENTIFIC NAME	*Gymnapistes marmoratus*
ABOUT ME	Easily identified by: • Mottled appearance with brown/black patches over body and fins • Strong spines on the front part of the dorsal fin, which are often raised when threatened Devilfish, which are often less than 10 cm in length in estuaries but can grow to ~20 cm, are common in weedy habitats where they are well camouflaged. They are ambush predators (lie and wait for their prey and then strike) and feed mainly on crustaceans (e.g. shrimps and small crabs) and other fish.
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**Yes – venomous spines on the head and dorsal fin**

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OTHER SHELLFISH

Other types of bivalve shellfish, including several species of oysters or perhaps scallops, may also start to grow on your shellfish gardens. Like mussels, they are also filter feeders.

COMMON NAME	**Flat oyster or Mud oyster**
SCIENTIFIC NAME	*Ostrea angasi*
ABOUT ME	The Flat oyster has one shell (or valve) which is cup-shaped and one flat shell which sits within it. The shell surfaces have a layered, flaky appearance. Juveniles grow attached to hard surfaces including other oysters or rocks, while adults (which can grow up to 18 cm long) can grow on soft sediment, cemented together with other oysters to form an oyster reef, or as part of a mixed reef. While they occur in intertidal areas, they are naturally more abundant in the subtidal zone. The Flat oyster is valued as an edible oyster, and is commercially cultured on a small scale in Australia. Like other bivalves, oysters are filter feeders, and filter phytoplankton and detritus from the water column. This species is also an ecosystem engineer that is being restored for the valuable ecosystem native oyster reefs support.
	 © R.Swainston/ANIMA.fish
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**No**

COMMON NAME	**Hooded oyster**
SCIENTIFIC NAME	*Saccostrea cucullata*
ABOUT ME	The Hooded oyster has thick valves, one of which is convex and the other of which is flat. The valves often have pleated or wavy edges, and are commonly a purple-brown colour. It cements itself to rocks and other hard structures in shallower waters, including the shells of other molluscs.
	 @ B. Hancock, TNC
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**No**

COMMON NAME	**Sydney rock oyster**
SCIENTIFIC NAME	*Saccostrea glomerata*
ABOUT ME	Sydney rock oyster is common in the intertidal waters on the south-east coast of Australia, but despite its name, is also found along the south-west Australian coast. It is highly prized as an edible oyster and is commercially farmed. They grow to 10 cm long in the wild and have a smooth thick shell that is roughly oval in shape and chalky in colour, sometimes with patches of purple or brown.
	 © R.Swainston/ANIMA.fish
HARMFUL TO MUSSELS?	**No**
HARMFUL TO HUMANS?	**No**

PREDATORS

BINJAREB NAME	Karil
COMMON NAME	**Blue swimmer crab**
SCIENTIFIC NAME	*Portunus armatus*
ABOUT ME	Easily identified by: • The flat 'paddles' on the hind legs, which are using for swimming. • Nine horns along the sides of their shell (or carapace). Blue swimmer crabs live in sandy, muddy and seagrass habitats. During the day, they often slightly bury themselves in the sand and hide. At night, they become more active, swim around to find food. They are excellent hunters and scavengers, feeding on small fish, molluscs, worms and crustaceans (including other Blue swimmer crabs). In WA, they can grow up to 25 cm wide across their shell. They are the most sought-after species by recreational fishers in WA, and the Peel-Harvey Estuary is a highly popular fishing spot. The crab fishery in the estuary is part of the world's first combined recreational and commercial Marine Stewardship Council certified fishery.
HARMFUL TO MUSSELS?	**Yes, though mainly juvenile mussels**
HARMFUL TO HUMANS?	**Be careful of my strong claws!**

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COMMON NAME	**Tarwhine or Silver bream**
SCIENTIFIC NAME	*Rhabdosargus sarba*
ABOUT ME	Easily identified by: • Silvery body with yellow/gold stripes along sides of body. • Yellow fins on bottom of body Tarwhine can grow to a total length of ~50cm in the Perth region and are sometimes targeted by fishers. They can be confused with Black bream (Binjareb name 'Djilba' and scientific name *Acanthopagrus butcheri*, also pictured opposite), but the latter lack the yellow/gold stripes and are found more commonly in the brackish to fresher waters of estuaries. Tarwhine mainly eat crustaceans and molluscs, though also consume seagrass and algae, especially as they increase in size. Black bream, which are usually found in the tidal parts of the rivers of estuaries, can sometimes venture down to the more marine reaches. They are opportunistic feeders, and will also consume bivalve molluscs as part of their diet.
HARMFUL TO MUSSELS?	**Yes, though mainly juvenile mussels**
HARMFUL TO HUMANS?	**No**

Tarwhine

Black bream

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COMMON NAME	**Blowfish**
SCIENTIFIC NAME	*Torquigener pleurogramma*
ABOUT ME	Easily identified by: • The dark stripe along the body and across the cheek. • Ability to inflate abdomen when threatened Blowfish are very common over both sandy and seagrass habitats, and can form large schools. They are highly opportunistic carnivores, eating a range of bottom-dwelling invertebrates, such as worms, small crustaceans and bivalve molluscs. While they are often less than 10 cm in length in estuaries, they can grow to over 20 cm in length.
HARMFUL TO MUSSELS?	**Yes, though mainly juvenile mussels**
HARMFUL TO HUMANS?	**Flesh is poisonous – do not consume**

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