INTRODUCED MARINE SPECIES IN WESTERN AUSTRALIA

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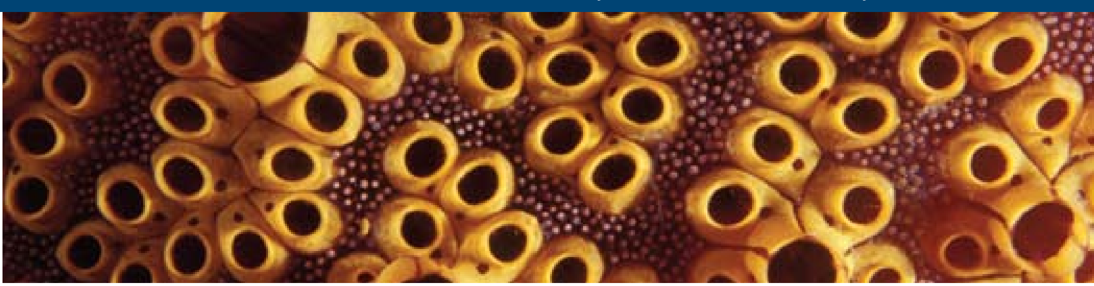

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Introduction

As the largest State in Australia, Western Australia (WA) has a long and relatively pristine coastline that stretches over 12,500 km, or over 20,700 km if the State's 3,747 islands are included. The coast ranges over 20 degrees of latitude from the temperate south coast to the northern tip of the tropical Kimberley. There are a wide variety of coastal marine habitats in this vast area. The south coast has extensive white sandy beaches interspersed with granite headlands. A diverse range of nearly 800 species of temperate marine algae, or seaweeds, occurs in the area. With 26 species, the seagrasses of the State are the most extensive in the world, covering an estimated 20,000 square kilometres. There is a rich diversity of fauna species, both invertebrates and fish, associated with these plant communities. Numerous species of whales, dolphins and sea lions live on the south coast.

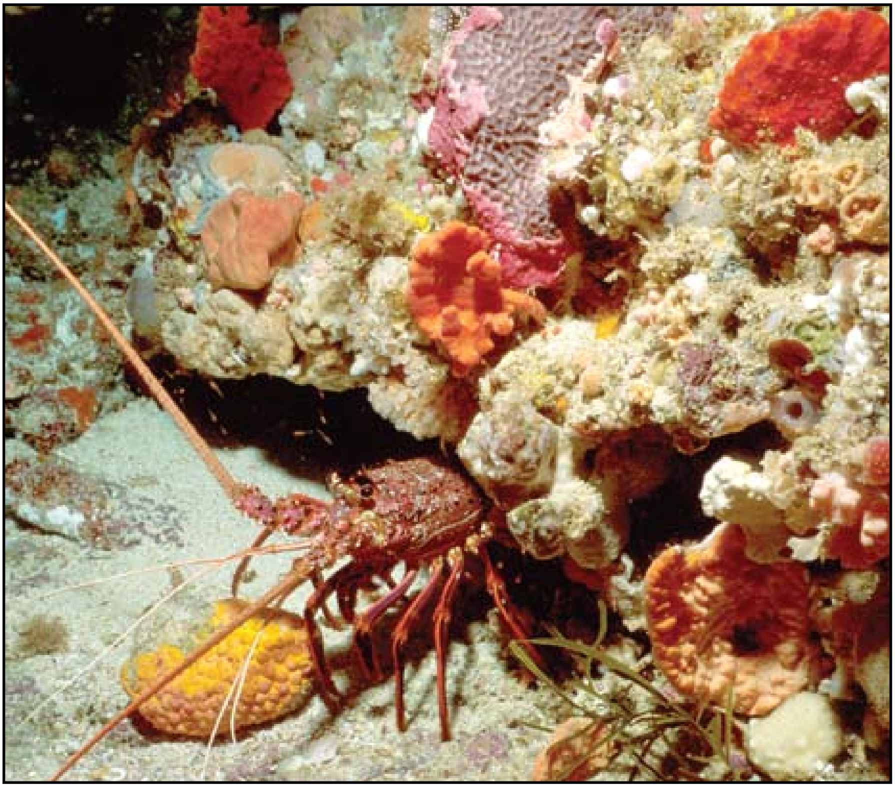
Foremost among the habitats on the north coast is Ningaloo Reef, the largest fringing reef in the world. It stretches from the tip of North West Cape 300 km south to Red Bluff. In recent years, Ningaloo has become famous as one of the best places in the world to see whale sharks. In addition, there is a fantastic variety of reef life, including large fish, which are very accessible as the reef is close to shore. There are other coral reefs in the coastal areas of the Pilbara and Kimberley. On the edge of the continental shelf, open ocean atolls are found at Rowley Shoals, Scott Reef, Seringapatam Reef, and Ashmore Reef. These reefs have a very different biota from that which occurs inshore along the continental coastline. The Pilbara has extensive mangroves, with eight species of mangrove plants and many associated animals. Further north there are much larger mangrove forests, with a total of 16 plant species.

The west coast also has a wide range of marine habitats. Shark Bay is on the World Heritage List as one of the most important marine and terrestrial areas in the world. The 12,000 square kilometres of the bay has the largest remaining population of dugongs in the world. The arid coastline has an unusual hypersaline setting where the heads of the bays reach salinities of up to 70 parts per thousand, approximately double that of normal seawater. The bay has extensive seagrass meadows, a wide variety of fish, and the dolphins that come to the shore at Monkey Mia are world famous. Closer to Perth, Rottnest Island is a favourite among West Australians. The beaches and fishing at Rottnest are a major attraction. Further south the Capes to Capes region is a national park with a beautiful open coastline. Plans are in place to develop a marine park in the area.

The population of the 2.5 million square kilometres of Western Australia has recently passed two million, 75% of whom are in the Perth metropolitan area. Perth and the southwest have high human population density, but away from these areas there are vast parts of the coast where there are very few people. Those that live outside the metropolitan area are clustered together in small towns such as Karratha, Dampier, Port Hedland, and Broome on the north coast, Albany and Esperance on the south coast, and Bunbury and Geraldton on the west coast. While activities in these marine areas, particularly large scale shipping, have increased tremendously with the recent economic boom, it is still true that human impacts on the WA marine environments largely occur near the settlements, and open areas are relatively untouched.

The importance of Western Australian marine environments was highlighted by a recent study published in *Science*. The authors analysed the worldwide distributions of 3,225 species of corals, fish, molluscs and rock lobsters that live on coral reefs throughout the world. Eighteen hotspots of coral reef biodiversity were found, including one on the west coast of Western Australia. The WA hotspot includes Ningaloo Reef, the outer islands of Shark Bay, the Houtman Abrolhos Islands and Pocillopora Reef at Rottnest Island. The international significance of the hotspot is indicated by the fact that it ranks seventh in total diversity (768 species) among the 18, second in the number of restricted range species (56) and only 15th in terms of threats from human activities.

Many of the open water habitats in Western Australia, such as this coral scene in the Houtman Abrolhos, are in excellent condition.



The western rock lobster, *Panulirus cygnus*, is the most valuable commercial and recreational species in Western Australia.

Commercial fisheries are a key component of the Western Australian economy, particularly in regional areas. The western rock lobster fishery for *Panulirus cygnus* is the largest single wild caught species fishery in Australia, with an average annual value to the fishermen of approximately $ 300 million. Many of the coastal towns on the west coast, such as Lancelin, Jurien Bay, Cervantes and Dongara originally started as fishing towns and still depend heavily on the rock lobster industry. In the north of the State, growing and harvesting the south sea pearl, *Pinctada maxima,* is one of the largest aquaculture industries in Australia. There are also valuable commercial fisheries for prawns, scallops, scalefish, and other species. Overall, commercial fisheries contribute about a half a billion dollars to the Western Australian economy.

It is critical that we maintain the Western Australian marine habitat in excellent condition for the present and future generations. Introduced marine species are a global problem, and are a serious threat to global biodiversity. Many introduced species cause no apparent harm, but some become serious pests. Among other problems, these pests can cause diseases in humans and native species, disrupt ecosystems, damage fisheries and aquaculture activities, and cause industrial problems such as fouling.

This book brings together our present knowledge of introduced marine species in Western Australia, including pest species, to provide information to anyone interested in this issue. We hope that by doing so, people will be better informed about marine pests and what we can do to minimise the risk of further introductions and their spread.

Photo: Rod Knight

The Northern Pacific Sea star, *Asterias amurensis*, has devastated the seafloor in Port Phillip Bay, Victoria.

Marine biogeography of Western Australia

Distribution patterns

Covering nearly a third of the continent, Western Australia is by far the largest state of Australia. The coastline can be divided into three biogeographical regions that are susceptible to very different threats from possible introductions of marine species.

The shallow, coastal waters of the north coast of Western Australia, from about North West Cape to the Northern Territory border, are part of the vast Indo-West Pacific marine biogeographic region. Species that occur along our north coast tend to be widely distributed. While some species occur only in a small part of this area, such as the Kimberley, most occur along the entire coastline of northern Australia to the southern end of the Great Barrier Reef in Queensland. Many of the species also occur in tropical countries to our north such as Indonesia, Papua New Guinea, Thailand, Malaysia, and the Philippines. In fact, the Indo-West Pacific Province stretches across the warm, tropical parts of the Indian and Pacific Oceans from the east coast of Africa through Southeast Asia and southern Japan as far east as the Hawaiian Islands and the South Pacific. Some individual species, such as the money cowry *Cypraea moneta,* occur over this entire range. A few Indo-West Pacific species have even been occasionally recorded along the west coast of the Americas!

A key feature of any biogeographic region is that while a species may occur in the region, it will live only in habitats that are suitable to the biology of that species. Because of this there are significant differences between species that occur along the continental coastline of the WA north coast and those that live on the coral reef atolls along the edge of the continental shelf, areas such as the Rowley Shoals, Scott Reef, Seringapatam Reef, and Ashmore Reef. Mangroves and bays with muddy bottoms are abundant along the inshore continental coastline and the water has high silt concentrations. Species living in this area are very different from those that live on the coral reefs of the offshore atolls where the ocean water is much cleaner.

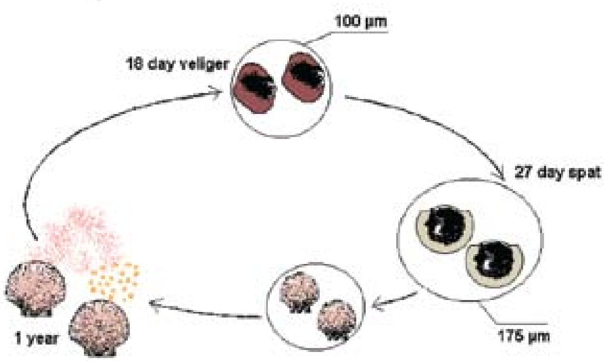
Map of Western Australia showing the shallow water marine biogeographic regions (after Wilson and Allen, 1987).

In contrast to the tropics, the shallow waters of the south coast of Western Australia are part of the Southern Australian Temperate Zone. The biota of southern Australia is almost different from that of the tropics, with a very small proportion occurring in both areas. While a few species are shared with New Zealand or southern Africa, the vast majority of south coast species are restricted to Australia. For example, about 85% of the 600 species of inshore fish are restricted to the south coast; 11% are shared with New Zealand, and 4% are a combination of circum-Australian, circum-temperate or are shared with other southern continents. The Southern Australian Temperate Zone extends from Cape Leeuwin at the southwestern tip of Western Australia across the southern shores of the continent to New South Wales. Most of the temperate species which occur along the south coast of Western Australia are distributed across the entire coastline from the South Australian Border to Cape Leeuwin. There are no major distributional barriers along the south coast. However, a few species do occur from southeastern Australia along the southern Australian coastline and have their western distributional limits in the area between Esperance and Albany.

The west coast of Western Australia, between Cape Leeuwin and North West Cape, is the Western Overlap Zone. There is a change in the shallow water biota that inhabits the Western Overlap Zone proceeding from south to north. The southern portion of the zone is inhabited by temperate species that decrease in diversity to the north. In contrast, the northern part of the zone is inhabited by tropical species that decrease going south. A key feature is the shallow water species that are endemic to Western Australia, occurring nowhere else in the world. The proportion of such species varies between taxonomic groups, being low in fish and high in echinoderms, but averaging about 10% across a wide variety of plants and animals. The ranges of individual endemic species differ: some occur on the north coast and some on the south coast; others occur from the south coast, along the entire west coast, and onto the north coast. Despite these differences, most of the species have at least some of their distribution on the west coast. Shallow water endemic species, such as the western rock lobster, can be ecologically and/or economically important. one of

Distribution mechanisms

If marine species are so widely distributed, the question is how do they do this? The answer lies in the planktonic larval stage, which occurs in the vast majority of marine animals. In its simplest form, males and females respectively spawn sperm and eggs into the water column. Fertilisation is external, and takes place in the water. The developing larvae go through a planktonic stage where they remain in the water and are carried about by of ocean currents. More advanced species have internal fertilisation. They produce fewer eggs, but there is a higher survival rate because a greater percentage of the eggs are fertilised and develop into planktonic larvae. The time spent in the plankton varies considerably. Many species live in the water for only a few days to a week. They are dependent on yolk from the egg for nutrition and do not feed in the plankton. Other species may live in the water for a year or more, providing extensive dispersal capabilities. For example, the western rock lobster goes through 15 life stages during an 11-month journey in the plankton, before the final puerulus stage settles to the bottom and moults into the juvenile form.



Life cycle of the commercial scallop *Amusium balloti*, showing the planktonic larval stage.

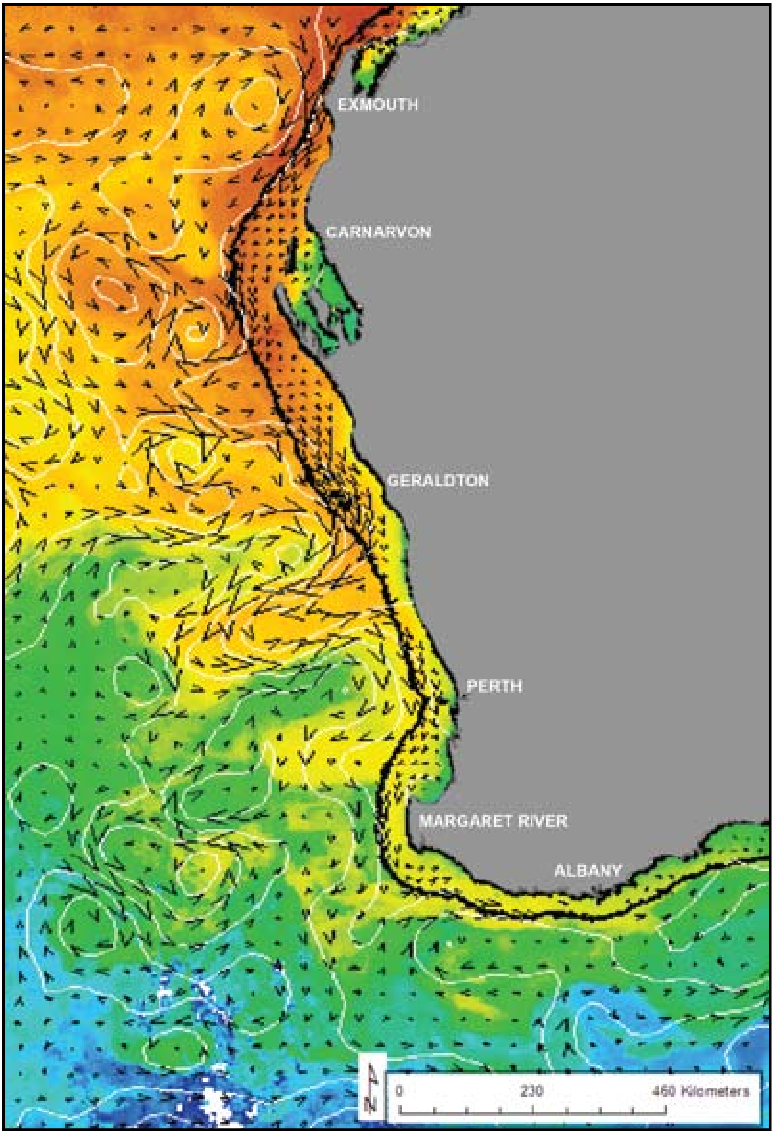
Most marine species that lack a planktonic larval stage have other means of distributing themselves over a wide area. Marine plants, such as species of the brown alga *Sargassum,* can be torn from the sea bottom during storms and then carried about by currents. The plant continues to live in the water column. Any species that is attached to the plant is also carried away. Small fish are attracted to the floating plants as they provide hiding places from predators. The fish then swim wherever the *Sargassum* is carried, and both the plant and its associated animals broaden their range. Other marine invertebrates may be attached to large mobile species such as whales and turtles. It is important to remember that a species does not have to be distributed over its entire range in the lifetime of a single individual. All that is required is that there is sufficient genetic exchange between the various populations for them to remain in contact with each other and not diverge into separate forms.

The Leeuwin Current

The famous Australian naturalist Saville Kent reported in 1897 that winter sea surface temperatures at Geraldton were several degrees cooler that those at the Houtman Abrolhos Islands to the west. He speculated that there was a south flowing current that keeps temperatures on the islands warmer than would otherwise be the case, and that the current does not reach the continental coastline at Geraldton. It was more than 80 years later, in 1980, that George Cresswell and T. J. Golding described the Leeuwin Current.

As we understand it now, the South Equatorial Current flows west from South America as part of the huge gyre that moves water about the margins of the South Pacific Ocean. As it nears Australia, the South Equatorial Current turns southward and flows down the east coast of Australia as the East Australian Current. Some of the water from this massive current flows through the Indonesian Archipelago to an area off northern Western Australia. This Indonesian through flow is thought to be the key driving force for the Leeuwin Current.

The Leeuwin Current forms north of North West Cape and flows south along the outer continental shelf of the west coast. It is strongest in winter, maintaining sea surface temperatures higher than they would otherwise be in areas such as the Abrolhos, the western end of Rottnest Island and other offshore islands. The current is a key mechanism for the distribution of tropical species down the west coast of the State.



Satellite photograph of the Leeuwin Current. Areas in red are where sea surface temperatures are greatest; those in blue are the coolest waters.

Naturally changing distributions

The distributions of individual species are not constant. Instead they vary over time. In recent geological history distributions changed with the ice ages. There are also significant variations over shorter time frames. The strength of the Leeuwin Current varies from year to year. In years when it is stronger, larvae of tropical species are distributed further down the coast than they are in years with weaker Leeuwin Currents. The mangrove crab, *Scylla serrata,* provides an excellent example of this. The crab is a tropical species that is abundant in mangroves and coastal muddy areas along our north coast as far south as Shark Bay. A strong Leeuwin Current in 1999/2000 brought larvae farther south than usual and a population developed in the Moore River at Guilderton. Suddenly fishers were collecting mangrove crabs in an area where they had never been found before. Over the next year or two crabs were also found further south, with some being caught as far south as Wilson Inlet on the south coast. These crabs reached full legal size and were fished, but conditions were not suitable for them to spawn and the population was not replenished. Over time they were fished out and the southern populations disappeared.

Another example is that in recent years the western rock lobster, *Panulirus cygnus,* has been more abundant than usual in the area near Cape Naturaliste. The enhanced catches have attracted larger numbers of rock lobster fishers to the area, creating conflicts with local surfers when the two groups are operating in the same waters.

In this time of climate change, there will be a tendency for water temperatures along the west coast to increase. As this happens, the ranges of more tropical marine species will be extended to the south, along with a contraction of temperate species.

On a larger scale, shells of three species of marine snails, *Bullia annulata, Cymatium cutaceum africanum* and *Nassarius kraussianus* were found at beaches near Augusta in the southwestern corner of the State during the 1980s. These are common South African species that had never before been found in Australian waters. Apparently they had been carried as larvae across the southern Indian Ocean to Augusta where they settled from the plankton and survived. While the animals lived, they did not reproduce, and no populations were formed.

Introduced marine species

Difficulties in identifying species

The marine flora and fauna of Australia is highly diverse with tens of thousands of species spread across dozens of phyla of marine plants and animals. Nobody knows exactly how many species occur either in Australian or Western Australian waters.

The most detailed species list for any area of Western Australia has been developed for the Dampier Archipelago and the nearby Burrup Peninsula by the WA Museum. A number of surveys have been conducted by the Museum in the Dampier region. Over 80 scientists from throughout the world, all specialists in different groups, have examined the specimens collected during these surveys. Together, they have found over 4,500 species of marine flora and fauna in the Dampier Archipelago. Many have been previously unknown to science or are new records for Australia or Western Australia.

A series of six marine biological workshops organised by the WA Branch of the Australian Marine Sciences Association in different areas of the State, including one in Dampier, have discovered more than 300 new species and 20 new genera. Many groups of animals have never been scientifically studied in the State. Two groups were examined in detail for the first time in WA at the workshops: marine mites and marine oligochaetes, the group to which terrestrial earthworms belong. Over 70 species were found in each group, most new to science. Clearly, no one person or group of people can be familiar with all these organisms. This has a significant impact on the recognition of introduced species, as the first step in establishing whether a species is introduced is to know what marine species occur naturally in an area. For most of our coastline we have little understanding of the 'naturally' occurring marine flora and fauna present.

Albany, on the south coast of Western Australia, has long been known for oysters, as indicated by the name Oyster Harbour being given to one of the three marine embayments in the area. One of the local oysters in the region is *Ostrea angasi*, which has been farmed commercially for years. A recent study, which included DNA analyses, demonstrated that in fact two species are present where it was thought there was only one! The presence of the second species, the European oyster *Ostrea edulis* had gone undetected for an unknown period.

How the European oyster arrived in Albany has not been determined, but early colonists could have brought it in as an aquaculture species shortly after the colony of Western Australia began. In the poor record keeping of the colonial days the fact that it was introduced was forgotten until the recent rediscovery. Although the two species are genetically distinct, they cannot be easily separated on external shell morphology.

On the botanical side, the marine alga *Codium fragile* ssp. *fragile* has been introduced around the globe through shellfish aquaculture, recreational boating, and transport on ship hulls. *Codium fragile* ssp. *fragile* has serious economic implications for aquaculture industries. Indeed, the tendency of this species to overgrow and smother oyster beds has earned it the nickname 'oyster thief'. In its quest for a stable substrate *Codium fragile* ssp. *fragile* will often make its home on the shells of oysters, scallops, and clams. This can cause problems because an attached adult plant can hinder the movement and feeding of the shellfish. In cases where the attached plant is relatively large and wave exposure is high, the shellfish can be swept away with the plant. The species fouls shellfish beds and causes a myriad of impacts on shellfish communities. This species also causes a nuisance to humans when it accumulates on beaches and rots, producing a foul odour.

In Western Australia we have a native species of *Codium fragile*. However, there is an invasive subspecies, *Codium fragile* ssp. *fragile*, that readily colonises new areas. As with oysters, the invasive strain of *C. fragile* ssp. *fragile* cannot reliably be distinguished by an examination of external morphology; genetic analyses are recommended.

Cryptogenic species

The great majority of marine plants and animals have evolved in the area in which they live, and they remain in that particular marine biogeographic region. However, a large number of species have been moved about by human activities over the centuries. Wooden sailing vessels were used for thousands of years. The wooden planks on their hulls provided a ready means of transport for species that could live attached or burrowed into the wood. While organisms cannot burrow into steel, the more recent use of steel ships has still allowed both marine plants and animals to adhere to their hulls, and niche areas or in internal piping. Many species have been found with clearly unnatural distributions, occurring in widely separated ports that are in very different marine biogeographic regions. One example is the nudibranch *Polycera hedgpethi.* The species was described in 1964 from California, and was originally thought to be native to the temperate west coast of North America. However, *P. hedgpethi* was found in Auckland, New Zealand in 1972. It has been recorded from several temperate Australian areas, including Albany in 1980, and also South Australia, Victoria and New South Wales. Overseas it has been found from widespread areas, including South Africa, western Africa, Spain and Japan. Clearly this is not a natural distribution pattern, but where the species originated has not been determined. Species such as these are called cryptogenic (from the Greek *kryptos* = hidden, and *genes* = born) for their uncertain origins.

Bacteria and viruses

The present handbook deals only with relatively large species, and does not include minute forms such as viruses and bacteria. This is not to say such life forms are not important, in fact they can be critically so.

For example, in March 1995 a mass mortality of pilchards occurred and resulted in dead fish washing up on the beaches of South Australia. The mortality event spread rapidly, as much as 30 km/day, and by the end of June stretched across the entire southern coastline of the continent from Carnarvon, Western Australia to Noosa Heads, Queensland. Millions of fish had died during this period. A second mass mortality occurred in 1998 when 60-70% of adult pilchards were killed in Western Australia. This resulted in closure of all of the WA pilchard fisheries. A *Herpes* virus was responsible for the deaths, but the origin of the virus could not be established.

Methods of introduction

Marine species have probably been moved from one location to another ever since humans began to move about in boats, so introduction of species into far-flung areas is nothing new. What differs now is the scale of human activity and the speed of ships and other vessels. Many modern ships can move through the water at speeds of up to 30 knots, or about 55 kilometres per hour. Such a speed means they can travel more than 1000 km in a day. This provides a ready means of moving adhering organisms from one part of the ocean to another in a few days.

Associated with vessels there are two main vectors for introduced marine species, these include ballast water and hull fouling. In the days of wooden ships, heavy rocks and other materials were used as dry ballast to ensure that the vessel floated properly in the water. When the vessel entered a port and was loaded, the ballast was simply thrown overboard or put to use on shore. A stone portico structure intended for the port entry into Jakarta was recovered from the wreck of the *Batavia* in the Houtman Abrolhos Islands. It was being used as ballast on the trip to Jakarta. Several introductions are known to have occurred through such dry ballast.

Since World War II there has been a dramatic change from using rubble and solid material to using seawater as ballast. When a vessel takes on cargo in a port the water is pumped out of the ship. The problem is that the water provides a habitat for the transfer of planktonic larvae of bottom dwelling species and larvae and adults of planktonic species that live in the water itself.

Overall, shipping is considered to have been the source of most of the introductions of marine species into new areas. However, there are many additional sources that are also important in distributing these organisms.

A major concern in northern Western Australia is hull fouling on illegal foreign fishing boats that have been found along our north coast. Many of these vessels are wooden Indonesian prahus. Like the sailing ships of old, the wood provides attachment for many species and others burrow into the wood itself. The boats are slow moving and sometimes poorly cleaned. These vessels often stay in an area for weeks, providing considerable time for any introduced species to move about into nearby areas. Many prahus have been found hidden in mangroves along the shores; the close contact with the bottom and the variety of coastal habitats giving ample opportunity for the transfer of any species that might be on the hulls. Some of the prahus that have been inspected have had the black striped mussel, *Mytilopsis sallei*, attached to their hulls. Often the vessels are deemed to be unseaworthy. If the crew is convicted of illegal fishing the boats are burned to prevent the introduction of diseases, etc into Australia.

Another opportunity for introduction of foreign marine species is presented by ocean going yachts. These vessels are in the water for considerable periods of time, allowing species to become attached to their hulls. As they move into new areas the attached organisms can then be introduced into the new area. Fishing boats are another potential source of introduced species. Like yachts, they are in the water for prolonged periods. Some, such as boats in the Northern Prawn Fishery, move widely about over the coastline. In addition, nets and other fishing gear are in close contact with the bottom. This presents opportunities for species to be caught up in the nets and be taken on board. There is increased opportunity for survival and transmission to new areas if the netting remains damp.

The early settlers to Australia brought with them many items that they found useful in the United Kingdom, including living agricultural plants and animals. The oyster *Crassostrea gigas* was introduced into Tasmania in the late 1940s for aquaculture. The species is farmed commercially in the southeast of Australia. In addition to being beneficial, *C. gigas* is also a pest species that forms feral populations that disrupt local ecosystems. Thus it is both a good and bad introduction. Often, species that have been deliberately introduced into a new area have carried with them other species, including pest species. One famous example is the introduction of the American oyster, *Crassostrea virginica,* into England in the late 1800s. Unfortunately, a predatory snail, the oyster drill *Urosalpinx cinerea*, was among the oysters and became a pest species in southern England. Fortunately, we have learned from such mistakes. Any request for the introduction of new species for aquaculture must undergo rigorous testing before it is allowed into the country.

Maintaining fish and other species such as snails, plants, etc. in freshwater aquaria is a popular hobby that has been going on for years. Unfortunately, people sometimes lose interest in the fish and discard them into nearby rivers and streams where they establish populations. These populations can be used by aquarists to replenish their fish tanks, and the populations can be spread by humans, or through natural means. In 2006 the South American cichlid *Geophagus brasiliensis* was found in the Bennet Brook/Whiteman Park area near Lockridge, WA. The species is carnivorous and can wreak havoc with local populations. The population was thought to be about three years old when it was discovered. So far attempts to eradicate the species from this area have failed.

The South American cichlid *Geophagus brasiliensis* has become established in the Bennet Brook/ Whiteman Park area near Lockridge WA.

Fortunately, saltwater aquaria are much more difficult to maintain than freshwater aquaria, so the problem of no longer wanted fish is reduced because there are fewer owners of marine aquaria. However, there are still many species that could potentially be introduced through this mechanism. That this is a real problem is illustrated by *Caulerpa taxifolia*, a marine alga that was once widely used as decoration in marine aquaria. This species is now regarded as one of the world's most invasive species.

In 1984 a small patch of a vigorous strain of *Caulerpa taxifolia* was found growing near the Monaco aquarium. *Caulerpa taxifolia* spreads by horizontally growing stolons and by 2004 the plant had spread to cover an area of 30,000 hectares – an expansion of 30 million times the original outbreak! It does not reproduce sexually, so all of the transmittal is by movement of fragments of algae that can become established in new areas. As the plants are fragile, boat anchors and fishing nets can easily break off segments. The invasive strain has a higher pollution tolerance than other plants in the area, so it is able to invade polluted environments. The invasive *C. taxifolia* came to dominate the benthic environment. Like many other algae, *C. taxifolia* produces noxious chemicals that repel species that would otherwise feed on it. The fauna of small species living in association with the alga are different, and the entire environment is changed.

The invasive strain, which originally came from southern Queensland, has been transported around the world via the aquarium trade and further escapes have occurred in New South Wales, South Australia and the west coast of the United States. This alga was previously sold in aquarium shops around Perth and was freely traded; it is extremely fortunate that no escapees occurred. It could easily survive in WA's water temperatures. *Caulerpa taxifolia* is now banned from sale, but it is likely that remnant plants are being maintained in home aquaria.

Although the idea would not occur to most people, human food is another potential source of marine species introductions. There is an increasing demand for fresh fish and other marine species that are sold live in markets and restaurants. While these species are usually sourced from within Western Australia, some are imported. Occasionally the animals may be discarded into the Swan River or the local marine environment where they have the potential to survive and establish new populations.

Not all introductions survive

Not all species that are transmitted from one area to another survive. Arriving in a new location is simply the first step to colonising an area. When species arrive they must have the right environment in which to live. Temperature and salinity levels are perhaps the greatest constraint to an introduced species successfully occupying a new area; if the temperatures or salinity levels are too extreme a species will simply not survive. For example, a fish coming from the tropical waters of Indonesia will have a much greater chance of surviving in the warm water areas of the WA north coast than in the cooler waters of the south coast. Similarly an estuarine species adapted to low salinities may not survive in the high salinity environments of the open coast, and a rocky shore species may not adapt to a muddy bottom area. Even if the physical environment is suitable, there are a host of relationships with other species that may prevent the new arrival from surviving, such as predation, competition, parasitism, and many others.

There have been two grand "experiments" in inadvertently changing marine distributions on a large scale, with very different results.

In 1969 the Suez Canal was opened. The 163 km long canal connects the high diversity Red Sea with the low diversity eastern end of the Mediterranean Sea.

The Suez Canal is essentially a channel cut through the sand. It is a sea level canal, meaning there are no locks or other obstructions. Ships are able to move from one end to the other. The canal was dug through a region known as the Bitter Lakes where salinities were much higher than the 35 parts per thousand of normal seawater. In the early decades after the canal was opened, the high salinity in the middle was a barrier to the movement of species from one end to the other. However, salinity became more uniform over time and the barrier disappeared. Over a hundred species have since spread from one end of the canal to the other. Such spread may have occurred by a progressive stepwise extension of populations or by one-off migration or transport by ships. Most of the species have spread from the Red sea to the Mediterranean, presumably because there are move vacant niches in the low diversity Mediterranean. The introductions have resulted in profound changes to the marine biology of the eastern Mediterranean, with as much as 10% of some groups of animals being introduced species.

The Panama Canal, opened in 1914, connects the Atlantic Ocean with the Pacific Ocean at the narrowest part of the Central American isthmus. At 80 km from deep water to deep water, the Panama Canal is only half as long as the Suez Canal. Yet in contrast, there have been fewer than a dozen documented movements of species from one side to another over the last century. The reason is simple – the Panama Canal is a lock canal. To minimise digging through a low lying mountain chain, the Chagres River was dammed, creating what was at the time the third largest man made lake in the world. Vessels entering the canal on one side are raised a total of 29 m through a series of three locks. They then sail through the fresh water of Gatun Lake to the other side and are lowered back to sea level. The average of eight hours spent in freshwater presents an effective barrier that has prevented all but a few species from moving from one ocean to the other.

Where introduced species come from

It is likely that most of the species in the Indo-West Pacific that could colonise the north coast have arrived here over the millennia and survived if the right habitats occurred in the north. However, there are invasive species such as the Asian green mussel, *Perna viridis,* which have the potential to become pest species in the north.

The marine biota of other tropical areas, such as the eastern Pacific, Caribbean Sea or eastern Atlantic, is largely distinct from that which occurs on the north coast of Australia. If species from one of these areas were to reach our tropical shores, there is a significant possibility of it surviving. While such a transfer appears unlikely, it can happen. The black striped mussel, *Mytilopsis sallei,* is thought to have originated in the Caribbean Sea. It has been distributed to many tropical ports, including Fiji, India, Japan, Taiwan, Indonesia, and Hong Kong. Any of these stepping-stones can provide a source population for the species to reach Australia. The species was established in three small marinas in Darwin in the late 1990s. It was thought to have been carried to Darwin on one or more yachts, and rapidly spread in the harbours. Fortunately, this is one of the few marine species to be successfully eradicated.

Temperate southern Australian habitats are considered by many to be at greatest risk from introduced marine species. The south coast of Australia has been separated for geological eons from the flora and fauna of the temperate North Pacific by the extensive temperature barrier of the tropical Indo-West Pacific region. There is little natural exchange of species between the two areas, and they have evolved separately. The advent of modern shipping has provided a means of rapidly transiting through the tropics and transporting species in ballast water or on the hulls. Many species have made the transition, including the destructive Northern Pacific sea star, *Asterias amurensis*, and the mussel *Musculista senhousia.* The Japanese seaweed *Undaria pinnatifida*, also known as 'wakame' in Asian cuisine, has been introduced to Tasmania and Victoria. The issue is not simply with the North Pacific. Species can also be transported from southern hemisphere areas, such as the mussel *Perna perna* from southern Africa. There have also been well-publicised introductions of the crab *Carcinus maenus* and the fanworm *Sabella spallanzanii* from Europe.

Although often not considered, the Eastern Australian overlap zone is also a potential source of introductions into Western Australia. Again, the east coast has species which have evolved independently of the west and which have no natural means of extending their distribution. However, interstate shipping now provides a vector. The scallop *Scaeochlamys lividus* is one such species that has been distributed from eastern Australia into the Fremantle marine area: the lower Swan River, Fremantle Harbour and Cockburn Sound. It has also recently been found in more exposed areas of the adjacent open coast.

It is interesting to note that the flow of introduced species is not all one way, into Australia. Just as species are introduced into Australia, so our marine environment can be a source for introductions into other parts of the world. Genetic testing has shown that the two species of *Caulerpa*, *C. taxifolia* and *C. racemosa* var. *cylindracea*, that are now causing major problems in the Mediterranean and elsewhere, originated from, respectively, southern Queensland and south-western Australia. Other introductions of marine species include the barnacle *Balanus modestus* into the United Kingdom and the snail *Bedeva paivae* into South Africa.

Concentrated in port areas

While we know that introduced species are concentrated in port areas, the reasons for this are not fully understood. Certainly most of the transmittal vectors are concentrated in the marine areas near major towns and cities where ports occur. Most types of vessel movements, from large ships through the fishing boats, recreational boats, and other users are concentrated in protected marine areas. Thus it is natural that species occur in these parts of the coast. However, once they arrive, relatively few species are able to expand their range outside these restricted areas. Dredging, construction of ports, small boat jetties, moorings, roads and breakwaters along the shoreline, buildings, and the myriad of other human activities all disrupt the coastal marine environment and local ecosystems, creating opportunities for introduced species to colonise and survive.

On the one hand, this is good, as it tends to mean that the problem of introduced species is restricted to relatively small areas. On the other hand, those species that expand outside the harbours can create a disproportionate amount of damage and become widespread pests.

Risks posed by different vessel types

Different types of vessels provide very different risks for the introduction of marine species. At the low end of the risk spectrum are ships such as liquefied natural gas (LNG) tankers. They are generally operated by the company producing the LNG and are dedicated for that purpose, operating between a tropical port on the north coast of Australia and a temperate Asian port. There is low biogeographic risk of introductions because temperature shock will kill most species. The vessels are well maintained and are routinely cleaned and anti-fouled. In addition to being good environmental practice, it is in the company's interest to have the vessels as clean as possible, as fouling organisms will slow the vessel and add to fuel costs. When ships are in port it is for a minimum period to load cargo, then they depart. There are many vessels in this category that operate in Western Australia.

The high-risk vessels are generally those that are slow moving, have numerous spaces where marine species can gain purchase, and come in close contact with the sea bottom. Some of these vessels stay in a single area for months, enhancing the opportunities for species to settle at the source and then be introduced to new regions. Vessels in this category include dredges, supply boats and drilling rigs, and some fishing boats. Other high-risk ships include some of the flag of convenience carriers that are low cost operators with poorly maintained vessels.

Minimising risk of introductions

With such a myriad of species that can be introduced, a wide range of potential distribution mechanisms, and a variety of available habitats, management of introduced species is a very complex problem. The key is preventing introductions as a first line of defence; it is by far easier to prevent the arrival of a species than to eradicate it once it has arrived. Successful marine pest eradications are rare worldwide and the costs are substantial. With the massive amount of shipping that is moving around the world, there will always be species that slip through. The goal is to minimise the arrival of new species and to prevent them from becoming established once they are here.

Ballast water

Large vessels use extensive amounts of ballast water to maintain their correct position in the water. Simply put, there are a number of tanks on large ships which can be filled with water when the ship has a light load. These add weight, sometimes thousands of tonnes, to the vessel, allowing it to settle to the waterline at which it should be operated. When a vessel enters a port the ballast water is discharged and the vessel rises in the water. It then takes on a cargo that makes it heavier, returning it to the waterline. This is an efficient system that allows vessels to be operated safely. The unfortunate part is that the thousands of tonnes of water in the ballast tanks provide an ideal habitat for some species of plankton to live inside the ship. Some of these may be species that live permanently in the water column, while others are larval stages that settle and become benthic organisms; either in the ballast tank or after the ballast water is discharged. Seawater taken on as ballast contains sediment, which tends to settle to the bottom of the ballast water tanks, forming a muddy bottom. This can become a habitat for benthic species that live on, or in, soft sediment, or highly resistant resting cysts of some toxic phytoplankton. The walls of the ballast water tank can be a habitat for species that require a hard bottom. Material in the ballast water forms the basis of the food webs within the tank.

Vessels coming into Australia from overseas are required to undertake one of two methods to exchange high-risk ballast water at sea if the water is to be discharged in port. One option is to empty the tank completely (some sea water will still be in the bottom and cannot be drained) and refill the tank with water well away from the coast. The other option is to pump seawater into one part of the tank and out the other side until three times the volume of the tank has been pumped. This substantially reduces the concentration of organisms in the tank. Neither method is perfect. The idea is that the open sea has few nutrients and very low densities of holoplanktonic species, those that live in the water column for their entire life cycle. Meroplanktonic species, the larval stages of species with bottom living adults, are concentrated in coastal areas and are depauperate in the open sea. When the vessel arrives in port it is inspected by the Australian Quarantine and Inspection Service (AQIS) checks the records of the ballast water pumps to check that they have been used if ballast water is to be discharged. Having an empty ballast water tank at sea can be a danger to the vessel and its crew. If the captain determines that it is too dangerous to exchange ballast water, such as in a storm, the requirement is waived.

A major anomaly occurs in handling ballast water – the rules are different for vessels operating entirely within Australian waters. For example, AQIS inspects the ballast water pump records for a ship coming to Western Australia from a foreign port such as Cape Town, South Africa. However, if that same ship went from Cape Town to Melbourne, then to WA, it would not be inspected on the voyage between Australian ports. Yet, there are many introduced species in Melbourne, and there are native species there that do not occur in Western Australia. To overcome this, all Australian States (except New South Wales), the Northern Territory, and the Commonwealth have signed an Intergovernmental Agreement to ensure that ballast water is handled consistently across the country, whether it originates overseas or in a different Australian port. Methods for implementing the agreement are now being developed.

Biofouling

Biofouling or hull fouling as it is more commonly known is the other major source of introductions of species by vessels. In contrast to ballast water, which is an issue only on commercial trading vessels, bio fouling can occur on any vessel, from the smallest boat to the largest ship. Basically on any part of a vessel or its equipment in contact with seawater provides a surface on which marine plants and animals can settle and grow. If the vessel is wooden, many species can burrow into the wood. As it grows, the developing fouling community provides an increasing number of complex habitats for other species to occupy. There are two major mechanisms for combating the spread of species through hull fouling:

regular cleaning and the use of antifoulants. Hull cleaning is relatively simple, and can be done whenever a vessel is in dry dock or removed from the water.

Starting in the late 1960s, tributyltin (TBT) became the most widely used antifoulant chemical. When painted on a vessel the TBT leaches out and inhibits species from adhering to the vessel. TBT is very toxic and effective. Initially it was thought to be environmentally benign. However, adverse consequences soon became apparent in a wide variety of marine organisms. The best known is a phenomenon of imposex, which has now been recorded in over 120 species of marine snails worldwide. Many groups of marine snails are dioecious, having separate males and females. When TBT is present in minute quantities (parts per billion) females start to develop male characteristics, a vas deferens and/or a penis. The rate at which this happens and the degree of change is directly proportional to the TBT concentration; the more TBT there is in the environment the faster imposex will develop and the more severe the effect. In the most severe cases, the female aperture is sealed over. The female is unable to spawn, but eggs continue to develop. Eventually the female dies. Females never become functional males. There are no known effects in males.

The first case of imposex was found in Western Australia at Rottnest Island in 1991. Professor Alan Kohn of the University of Washington, Seattle was working on snails of the genus *Conus* at the first International Marine Biological Workshop at Rottnest. Professor Kohn found 80% of the individuals of six different species had imposex. The striking fact was that most of the animals were collected at the west end of Rottnest, where TBT concentrations were only 1% of their levels in some small boat harbours in Cockburn Sound. Other studies subsequently showed that levels of imposex in Fremantle Harbour and Cockburn Sound were higher than at Rottnest. Following the report of imposex, and a study by the then Department of Environment on TBT levels in sediments, the use of TBT on vessels smaller than 25 m was banned and the rate at which it could leach from the paint on larger vessels was reduced.

The partial bans in Western Australia were part of a worldwide trend to reduce the use of TBT. The half-life of TBT in the water column is a few days, so concentrations fall rapidly. However, TBT can persist for up to 20 years in the soft sediment of harbours. In recent years there have been reports of high TBT levels in predatory species at the peaks of food webs, such as mammals. TBT is now being phased out in favour of other methods of providing antifouling, primarily copper based chemicals.

The ultimate goal of the Intergovernmental Agreement for minimising marine pest introductions is to develop nationwide protocols for both ballast water and hull fouling.

Illegal fishing vessels

For years, the Australian and Western Australian Governments have been concerned about illegal fishing in our northern waters. Not only does illegal fishing damage fish stocks, but the boats also bring disease and pest risks with them. A number of Indonesian prahus have been found hidden in coastal mangroves. The close contact between the wooden vessel and the wood of the trees and the nearby sea bottom provides a real risk of transmitting introduced marine pests. A number of the prahus have been found to be carrying the black-striped mussel, *Mytilopsis sallei,* a potentially high-risk species if it colonises Western Australia. Some of the prahus have been declared unseaworthy, their crews removed from the boats and the boats destroyed at sea. Others have been towed to port and their crews arrested. When convicted, the boats are forfeited and are destroyed by burning.

Construction and Dredging

Large-scale construction projects require assessment under the *Environmental Protection Act 1986.* Often the high-risk vessels involved are dredges. If dredging is approved, the Minister for the Environment, on advice from the Environmental Protection Authority, attaches a series of Ministerial Conditions to ensure the dredging is undertaken in a manner that minimises effects on the environment. Increasingly, if a dredge is being brought into Western Australia for a dredging program, one of the conditions is that it be surveyed for introduced pest species before it is allowed to dredge.

Eradications

As indicated above, the key to managing introduced marine species is to minimise their chances of arriving in Western Australia. There have only been two successful instances in Australia in which a marine introduction was eradicated.

The black-striped mussel, *Mytilopsis sallei,* was found in Darwin in 1999. Only six months previously a survey for introduced marine pests had not found any evidence of the species. The mussel was present by the millions in one small boat marina, and in much smaller numbers in two other marinas. It is believed to have already spawned twice during the six months. Because of the high tidal range in Darwin the marinas are separated from the sea by locks. Water is allowed to enter the lock from the marina until the two levels are equal and the boat can enter or leave the marina. The black-striped mussel was restricted to the marinas and had not colonised the adjacent open ocean. The Northern Territory government made the decision that the artificial marinas were of low environmental value and used chemicals to totally eliminate the mussels. An intensive program was then instituted to locate and inspect all vessels that had been in the marinas. Fortunately, the black-striped mussel had not spread out of the marinas. There is now a continuous monitoring program in place to provide early warning if the black-striped mussel or another species invades the harbour.

In a similar incident, the invasive strain of the marine alga *Caulerpa taxifolia* invaded West Lakes in Adelaide. The entire four kilometre length of West Lakes was sectioned off from the Port River and turned from marine to freshwater by diverting a creek into a stormwater system. Although this appears to have been successful in West Lakes, it is of course impossible to undertake in open areas. In Adelaide additional infestations of *C. taxifolia* have been found and their eradication is an ongoing battle.

However, compared to these two successful eradications, there are many unsuccessful attempts.

What we can do to help

The Biosecurity Group of the Department of Fisheries is the section responsible for undertaking of any emergency activities in response to reports of a marine pest species in Western Australia. Once a report is received, it is investigated to check that the species of concern is in fact a pest species. As indicated above, many potential pest species are closely related to species that occur naturally in Western Australia. If a pest is present, a survey must be conducted to determine the extent of the infestation and an assessment made of whether eradication can be attempted. If eradication is thought possible, it must be undertaken as soon as practical. If not, there may be measures to minimise the impacts of the infestation and to reduce the chances of it spreading. The Consultative Committee on Introduced Marine Pest Emergencies (CCIMPE), which has representation of the Commonwealth and State/Territory governments, must be informed. CCIMPE has access to resources on a national scale that can be used for emergencies.

While the task of minimising introductions of marine species may seem to be daunting there are two things individuals can do to help.

Western Australians have a close affinity for the sea and one of the highest rates of private boat ownership in the world. The Swan River, Cockburn Sound, Rottnest Island, and many other coastal environments near the major towns and cities are all popular with small boat owners. Most people thoroughly wash their boats with fresh water after taking them out of the water to remove salt and any debris. This is good basic maintenance practice. As the boat is cleaned it should be checked to ensure that there are no living organisms, plants or animals, remaining. If there are, they should be removed. Nooks and crannies, wet ropes, nets, and other such gear provides a relatively protected habitat in which species can be transported from one part of the State to another by people going on fishing or camping trips. A few minutes spent checking the boat will ensure that this does not happen. Given that most boats are transported on trailers there is a distinct risk that non-indigenous species can be translocated from one region to another. An example of this occurred in Canada. The invasive water flea was transported from one lake to another by boats on trailers. This flea led to the decline of local invertebrate and fish species.

Many people now dive or snorkel as a hobby, becoming familiar with a wide range of plants and animals that occur in their local area. As with boats, dive equipment should be thoroughly washed in freshwater and dried before using it in another area. If something unusual is seen during the dive it should be reported to the Biosecurity Group at the Department of Fisheries. Early detection of an introduced species is the key to having any chance of preventing it from becoming established, so the earlier an invasion is found, the better the chance of managing it.

Known introduced marine species in Western Australia

Sixty species are known to have been introduced into Western Australia and are established here. Most are cool water, temperate species (37 species) that occur from Geraldton south; only 6 are tropical species that occur from Shark Bay north; 17 introduced species occur in both the southern and northern halves of Western Australia. The preponderance of temperate species is in agreement with most studies in other areas.

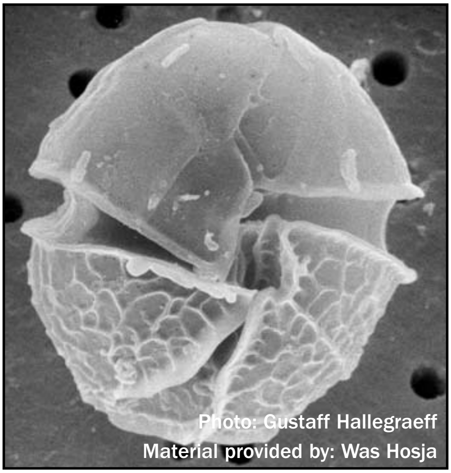
Because most of the introduced species are temperate, it follows that southern marine areas have more known introduced marine species than northern areas. The greatest concentration is in the southwest corner of Western Australia: the Fremantle marine area (including Cockburn Sound and the lower Swan River) has 46 introduced species. Fremantle is also the port with the largest number of vessel movements. Albany (25 introduced species), Bunbury (24 introduced species) and Esperance (15 introduced species) are all smaller marine areas with fewer vessel movements and fewer introduced marine species. In addition to the high vessel activity in the Fremantle marine area, there is also considerable habitat diversity (both natural and artificial), which provides a large variety of niches for introduced species to occupy. In this regard, the Albany area also has a wide variety of habitats in close proximity to one another and the port, so the large number of introduced species might be expected. Esperance has lower habitat diversity; so fewer species would be expected in that area. Bunbury stands out in this regard. The marine area is small and habitat diversity is low, so it would be expected to have relatively few introduced species. Instead, at 24, the number of introductions is high.

The fact that most introduced species are temperate does not mean the problem is confined to the southern part of the State. In fact there are invasive species, such as the black-striped mussel, *Mytilopsis sallei,* and the Asian green mussel, *Perna viridis,* which could be easily introduced to our north coast.

In the pages that follow we present information on a selection of species that have been introduced into Western Australia. The introduced species have been chosen to represent a wide range of plant and animal groups.

Dinoflagellates

Dinoflagellates are microscopic, single-celled organisms that are protists, a group that is neither plant nor animal. While some occur in freshwater, 90% of dinoflagellates are marine. The marine group is split fairly evenly between photosynthetic species and those that consume other organisms, including other dinoflagellates. Some species live in the tissues of other organisms, such as sponges, corals and jellyfish. The host does not consume the dinoflagellate, but instead provides shelter and nutrients. In turn the dinoflagellate uses photosynthesis to produce energy used by the host. A single species of dinoflagellate (*Alexandrium minutum*) has been introduced into Western Australia.



Alexandrium minutum

Common name: Toxic dinoflagellate.

Distribution: In Western Australia, *Alexandrium minutum* is known from Bunbury, Geographe Bay, Mandurah, Peel Inlet, Cockburn Sound and the Swan River. Elsewhere it occurs in southeastern Australia, the Mediterranean, New Zealand, the east coast of the USA, and southeast Asia

Habitat: It is a planktonic species that is mostly found in the water column. If it is in bloom it can cause a discolouration of the water. Like other dinoflagellates, *Alexandrium minutum* has a benthic cyst stage that can live on the surface of sediments for years.

Identification features: Accurate identification of most dinoflagellates is a difficult process best left to experts. Like many others, *Alexandrium* forms small spherical cells with an outer casing composed of plates. The arrangement of these plates serves to distinguish the species. Cells have two flagella (tail like structures), one trailing behind and the second encircling the cell and lying in a groove.

Notes: This species is recorded sporadically in Western Australian waters, either as the swimming, flagellated stage or as benthic cysts. In other areas of the world, these species form dense toxic blooms in shallow lagoons and brackish marine embayments that may be accompanied by mortality of fish and shellfish and in outbreaks of paralytic shellfish poisoning. No such blooms have been reported in WA and monitoring is routinely undertaken of commercial mussel and oyster farming areas.

Primary vector: The primary vector for translocating this species is via ballast water.

Marine algae

The Western Australian marine benthic flora includes numerous species that are widely distributed, particularly so in tropical areas where many of the taxa have a broad Indo-West Pacific distribution. These species could be regarded as cryptogenic (i.e., potentially introduced but their origins presently obscure due to their widespread distribution). None have ever shown pest tendencies and are no cause for concern. There are, however, at least three known recent introductions. None of these has reached large densities but all three should be monitored closely. In total five species of marine algae have been introduced into Western Australia:

- *Codium fragile* ssp. *fragile*
- *Elachista orbicularis*
- *Grateloupia imbricata*
- *Pseudocodium devriesii*
- *Stictyosiphon soriferus*

Codium fragile ssp. *fragile*

Common name: Dead Man's Fingers, Oyster Thief and many others.

Distribution: Originally from Japan, *Codium fragile* ssp. *fragile* has spread throughout Europe, the Mediterranean Sea, western North Atlantic, Pacific Coast of North America, South Africa, New Zealand and southeastern Australia.

Habitat: *Codium fragile* ssp. *fragile* grows on rocks in the mid to lower intertidal down to about 2 m depth.

Identification features: Plants are large, medium to dark green and are dichotomously (in series of two) branched. The branches have a spongy texture. Many native species have a similar appearance and microscopic features are used to confirm identifications. In *Codium fragile* ssp. *fragile*, the surface has what appear to be small spines. These are outgrowths from the plant's utricles (the inflated cell-like structures that make up the surface). Moreover, only plants with utricles of a certain size range are classified as this species. Given this, identification requires significant taxonomic expertise.

Notes: This invasive species was previously know as *C. fragile* subspecies *tomentosoides*, but is now known to be the same as the subspecies *C. fragile* ssp.

fragile. The various subspecies of *C. fragile* are very difficult to distinguish from each other and require an examination of internal structures. DNA sequencing can also be used. Several native species of *Codium* also look similar to *C. fragile*. This alga has recently been collected from Albany, but the extent of the population has not yet been determined.

Primary vector: The primary vector for translocating this species is via hull fouling, although gametes may be transported in ballast water and plant fragments can be transported via vessels and their equipment.

Grateloupia imbricata

Common name: Forked Grateloup's Weed.

Distribution: In Western Australia *Grateloupia imbricata* is known from a rocky groyne at Cottesloe and from Albany. It is apparently not found elsewhere in Australia. The species was described originally from Japan in 1896 but has since been reported as an introduction to the Canary Islands.

Habitat: *Grateloupia imbricata* grows attached to rock in the lower intertidal.

Identification features: Plants of this red alga are cartilaginous and slightly slippery to touch, with flattened branches that are regularly dichotomously divided. Internally the plants have a loose construction of sparse filaments. This is a feature that serves to distinguish this species from the superficially similar *Rhodymenia sonderi*, which has a structure of densely packed cells.

Notes: Species of *Grateloupia* are well known as introduced and pest species (e.g. *Grateloupia turuturu* in the Mediterranean and recently recorded from Tasmania). *Grateloupia subpectinata* is a cryptogenic species that is common in the Perth region.

Primary vector: The primary vector for translocating this species is via hull fouling.

Pseudocodium devriesii

Common name: False Codium.

Distribution: In Western Australia, this species is known only from the vicinity of Cottesloe, Rous Head, Fremantle, and Cockburn Sound. It was originally described from South Africa and is common there.

Habitat: *Pseudocodium devriesii* grows on rocks associated with sandy substrata, at depths of around 5-10 m.

Identification features: This species looks like a small *Codium* ('dead man's fingers'). It grows to about 5 cm tall and has forked branching. Plants are generally a bright green colour. When the surface is examined closely, polygon shaped facets can be seen.

Notes: *Pseudocodium devriesii* has only recently been recognized in Western Australia. DNA sequence studies have shown a very close relationship to populations in South Africa. This, along with its local distribution in the Fremantle area, suggests the species is introduced.

Primary vector: The primary vector for translocating this species is believed to be via hull fouling.

Hydroids

While they look like plants, hydroids are actually cnidarian animals, the group that includes jellyfish and corals. Many marine species have a complex life cycle that alternates between an asexual benthic stage that is familiar to divers and a planktonic medusa stage that looks like a jellyfish. The Portuguese man of war, *Physalia physalis,* and the By the Wind Sailor, *Velella velella,* both resemble jellyfish, but are actually hydroids. Hydroids are carnivorous, using stinging cells (nematocysts) to kill their prey. Six species of hydroids have been introduced into Western Australia:

- *Antennella secundaria*
- *Ectopleura crocea*
- *Eudendrum carneum*
- *Gymangium gracilicaule*
- *Halecium delicatulum*
- *Obelia dichotoma*
- *Sarsia eximia*

Photo: Karen Gowlett-Holmes

Gymangium gracilicaule

Common name: Hyroid.

Distribution: *Gymangium gracilicaule* is widely distributed in the tropical and subtropical Indian Ocean and the Indo-West Pacific. It has been recorded in Western Australia from the Houtman Abrolhos Islands and Port Hedland.

Habitat: The species lives on coral rock and rubble.

Identification features: *Gymangium gracilicaule* is up to 70 mm high and lives attached to the substrate. There are several major stolons (low-lying branch like structures), each with branches, and small polyps. The stolons connect the polyps of a colony. Each tiny polyp resembles a sea anemone in that it has a central sac with a mouth at the end surrounded by tentacles.

Notes: Specimens in the Abrolhos Islands were found attached to coral rock and rubble in shallow water and had another hydroid species (*Salacia desmoides*) attached to them. There are literally dozens of marine species of hydroids found in Western Australia. A specialist taxonomist is required to identify the various species.

Primary vector: The primary vector for translocating this species is believed to be via hull fouling.

Polychaetes

Together with earthworms and leeches, the polychaetes are included in the phylum Annelida, the group of segmented worms. Polychaetes are characterised by leg-like parapodia that have bristles (chaete) on their ends. The name polychaete actually means "many bristles". Eight thousand of the 9,000 species of annelids are polychaetes. All polychaetes are marine or estuarine and many can be found in incredible numbers on intertidal sand and mudflats. Sexes are separate, and there is a planktonic larval stage. Some species can reproduce asexually by budding. There are two major groups of polychaetes: tubeworms (Sedentaria) and those that can crawl about on the sea floor (Errantia). Four species of polychaete have been introduced into Western Australia:

- *Alitta succinea*
- *Boccardia proboscidea*
- *Ficopomatus enigmatica*
- *Sabella spallanzanii*


Photo: Karen Gowlett-Holmes


Photo: Justin McDonald

Sabella spallanzanii

Common name: European fan worm.

Distribution: *Sabella spallanzanii* has a native range from the Mediterranean Sea and the Atlantic east coast of Europe to the English Channel. It has been introduced to

Victoria and South Australia, and overseas to North Africa, Brazil and Southeast Asia. The species has been recorded in all Western Australian marine areas associated with ports from Fremantle to Esperance.

Habitat: On debris, rocks, rubble etc. associated with the seafloor and attached to jetty piles.

Identification features: *Sabella spallanzanii* is one of the largest species in the family Sabellidae with a leathery tube and spiral-feeding fan that can reach 10 to 15 cm in diameter. The fan is composed of two lobes, only one of which is spiralled, the other lobe forming a semi-circle.

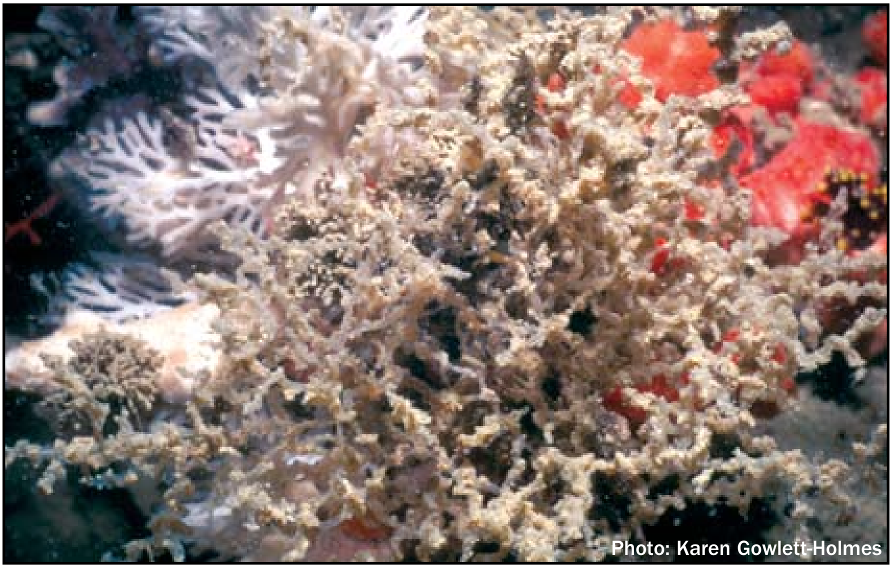
Notes: The tube of *Sabella* can protrude up to 40 cm above the sediment and bury as deep as 10 cm into the sediment. *Sabella* commonly forms clumps of two or more individuals, creating a canopy of feeding fans that stretches over the sediment. It is not known to be preyed upon by native fish and in any case has a high tolerance to wounding to the extent of being capable of regenerating from fragments.

Primary vector: The primary vector for translocating this species is via hull fouling.

Bryozoans

Bryozoans are colonial filter-feeding animals. Bryozoan colonies can be encrusting, arborescent (branching, and tree-like), or even free living. Individuals within colonies are referred to as zooids. These zooids may have specialised functions, such as brood chambers for young, feeding apparatus or may have spines or pincers to prevent other organisms from settling. Zooids of most species are enclosed in a protective tunic made from either chitin (a tough protein also found in insect exoskeletons) or calcium carbonate. This exoskeleton has an opening, through which the lophophore is extended into the water column for feeding. In some species, the orifice is covered by an operculum (lid or covering which closes over the opening). Fifteen species of bryozoans have been introduced into Western Australia:

- *Amathia distans*
- *Amathia vidovici*
- *Bowerbankia gracilis*
- *Bugula flabellata*
- *Bugula neritina*
- *Bugula stolonifera*
- *Conopeum seurati*
- *Cryptosula pallasiana*
- *Savignyella lafontii*
- *Schizoporella errata*
- *Schizoporella unicornis*
- *Tricellaria occidentalis*
- *Watersipora arcuata*
- *Watersipora subtorquata*
- *Zoobotryon verticillatum*



Amathia distans

Common name: Bryozoan.

Distribution: The native range is uncertain, but *Amathia distans* is thought to be native to the warmer waters of the western Atlantic Ocean. The species also occurs in the eastern Atlantic. It has been introduced to France, the Mediterranean and Red Seas, the Atlantic coast of the Americas, west coast of North America, Indonesia, New Zealand, and eastern Australia, from Queensland to South Australia. In Western Australia, *A. distans* has been reported from Port Hedland and the lower west coast.

Habitat: The species grows on a wide variety of surfaces, including other bryozoans, algae, seagrasses, oyster valves, sandstone boulders, dock, pilings, breakwaters, and man-made debris.

Identification features: *Amathia distans* is a stoloniferous bryozoan found as fragile, erect colonies with many free branches. The colony has dichotomous branching (in series of two), a thin stolon (stalk), and usually grows to about 4 or 5 cm high. Zooids are arranged in paired clusters that run spirally around the stolon. It forms pale-yellow/brown transparent colonies.

Notes: There have been no recorded predators of this species, however nudibranchs commonly feed on bryozoans.

Primary vector: The primary vector for translocating this species is via hull fouling.

Bugula flabellata

Common name: Bryozoan.

Distribution: *Bugula flabellata* is believed to be native to Atlantic and Mediterranean coasts of Europe. It has been widely introduced into tropical and temperate seas. In eastern Australia the species occurs from New South Wales to Victoria, and in Western Australia from Albany to Fremantle.

Habitat: This species lives on a variety of substrata, including stones, shells, and other bryozoans. *Bugula flabellata* is a major fouling bryozoan in ports and harbours, particularly on vessel hulls, pilings and pontoons. It has also been reported from offshore oil platforms. Quite often it is found growing with other erect bryozoan species such as *Bugula neritina* or growing on encrusting bryozoans.

Identification features: *Bugula flabellata* forms an erect broad, branched colony between 2-5 cm in height. Colonies are pale pink in colour. Each branch is broad, flat and wedge shaped with 3-6 rows of zooids. Zooids have spines in the central area that often cover the opening from which the zooid extends its feeding structure (the lophophore). Avicularia (modified beak-like structures with a defensive role) are only found on the marginal zooids, and resemble a bird's head. They are stalked and have a strongly decurved beak.

Notes: Many species of nudibranch have been recorded feeding on this species of bryozoan.

Primary vector: The primary vector for translocating this species is via hull fouling.

Bugula neritina

Common name: Bryozoan.

Distribution: *Bugula neritina* is widely distributed in most tropical and temperate areas. It also occurs widely in southern Australia from New South Wales to South Australia, including Tasmania. In WA it is found from Esperance to Port Hedland.

Habitat: This is a serious and common fouling organism that grows on a wide variety of natural and artificial substrata. It can even grow heavily in ship's intake pipes and condenser chambers. In Australia, it occurs primarily on artificial substrata, such as jetty pylons.

Identification features: *Bugula neritina* is an erect, arborescent, red-purple-brown bryozoan. Branching is dichotomous (in series of two) and zooids alternate in two rows on the branches. Unlike all other species of *Bugula*, *B. neritina* has no avicularia or spines. Ovicells (reproductive structures) are large, globular and white in colour. Ovicells often appear in such high numbers that they resemble small snails or beads.

Notes: Nudibranchs have been recorded as feeding on *B. neritina*.

Primary vector: The primary vector for translocating this species is via hull fouling.

Schizoporella errata

Common name: Bryozoan.

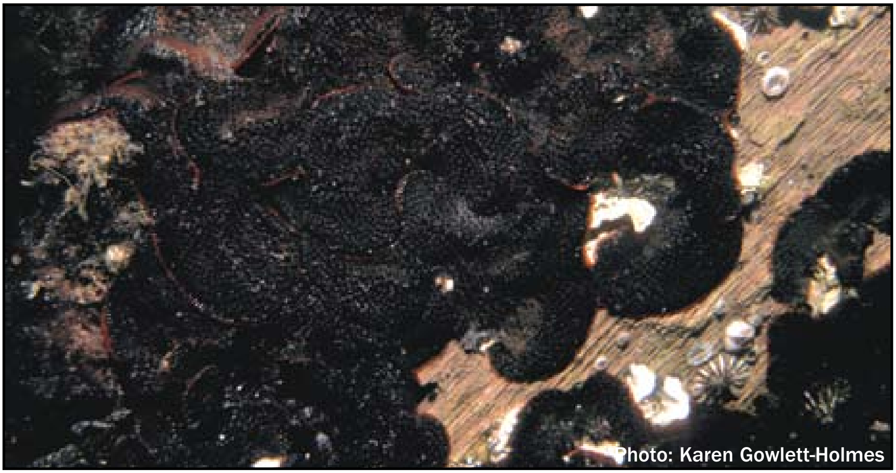
Distribution: *Schizoporella errata* is widespread in warm temperate to subtropical seas, and occurs in Australia from South Australia to Victoria. In WA it has been recorded from Esperance to Shark Bay.

Habitat: The species is most often found in shallow water in ports and harbours on hard substrates (pilings, hulls, coral rubble, etc.) and reefs.

Identification features: *Schizoporella errata* is typically dark brick red with orange-red growing margins. This species has many forms, from flat encrusting, multi-laminar to erect branching structures, depending on the surface it is colonising. The frontal surface of the exoskeleton housing of individual zooids is porous with a wide semicircular aperture. Avicularia (beak-like structures) occur in varying density on colonies, with one per zooid.

Notes: This is a well-known fouling species and is known to inhibit the growth of adjacent species.

Primary vector: The primary vector for translocating this species is via hull fouling.



Watersipora arcuata

Common name: Bryozoan.

Distribution: *Watersipora arcuata* is widely distributed in warm seas. In eastern Australia it has been introduced to Queensland and New South Wales. In southwestern Australia it occurs from Esperance to Fremantle.

Habitat: This is an important marine fouling species in ports and harbours where it is found on vessel hulls, pilings, and pontoons. This species can also be found attached to rocks and seaweeds. They form substantial colonies on these surfaces, typically around the low water mark.

Identification features: Colonies range from dark red-brown to black in colour, with a thin bright red margin. Cellular parts of the zooids are orange-red, which explains this colour on the margin. *Watersipora arcuata* has no spines, avicularia or ovicells (reproductive structures). Zooids are elongate, rectangular or subhexagonal in shape, and are typically arranged in rows of about five. The aperture of the zooid is black, with a semicircular distal margin and a concave proximal margin - a key distinguishing feature of this species.

Notes: *Watersipora arcuata* is an abundant fouling organism and is resistant to antifouling paints. It can therefore spread rapidly on vessel hulls and provide an area for other species to settle upon. This in turn has an impact on vessel maintenance and speed, as many more organisms are able to foul the hull. There have been no recorded predators of this species.

Primary vector: The primary vector for translocating this species is via hull fouling.

Photo: Karen Gowlett-Holmes

Watersipora subtorquata

Common name: Bryozoan.

Distribution: *Watersipora subtorquata* has been widely recorded from Brazil, West Indies, Bermuda, Cape Verde Islands, Japan, Mediterranean Sea, and New Zealand. In Australia the species has been recorded from Torres Strait to South Australia, including Tasmania. In WA it is found from Albany to Shark Bay.

Habitat: *Watersipora subtorquata* is most common in lower intertidal and shallow subtidal areas, though it grows to depths of at least tens of meters. This species grows on a wide variety of solid substrata including rocks, shells, docks, vessel hulls, pilings, debris, kelp holdfasts, and other bryozoans.

Identification features: The colony is usually a bright to dull orange or red. The opercula are black or dark brown, and the lines marking the boundaries between zooecia are usually black. The central and older parts of older colonies are often black; in some cases, virtually the entire colony is black, with only the outermost growing edge showing orange or red.

On flat surfaces smaller colonies, up to several centimeters in diameter, are flat and roughly circular. As a colony grows larger it becomes more lobed and may overgrow itself in places. In protected waters where growing conditions are good, colonies may become quite large and grow outward from the substrate (which is often the side of a dock) in lobes and frills, forming a striking, cauliflower-like mass up to 25 cm in height.

Notes: *Watersipora subtorquata* has often been reported from vessel hulls. It is less sensitive to copper than many fouling organisms, and is therefore less affected by copper based anti-fouling paints.

Primary vector: The primary vector for translocating this species is via hull fouling.

The photographs of *Watersipora arcuata* and *W. subtorquata* provide an excellent example of some of the issues encountered in working with introduced marine pests. There are 10 species recognised worldwide in the genus, but only specialists can determine the identity of the various species. The two species shown here are both introduced to Australia, but it is very difficult to tell them apart.

Zoobotryon verticillatum

Common name: Bryozoan.

Distribution: *Zoobotryon verticillatum* is widely distributed in warm waters, including the Mediterranean and Adriatic Seas. In Australia it has been recorded from several locations from New South Wales to South Australia. It is known from Shark Bay and Port Hedland in Western Australia.

Habitat: This is a common fouling species in warmer waters that can grow on virtually any hard subtidal surface. It is common in ports and harbours.

Identification features: Colonies are arborescent, with trifurcately (in threes) branching stolons of approximately 0.5 mm in diameter. Zooids measure approximately 0.4 – 0.6 mm in height and are sac-like, arranged along 2 sides in rows. The lophophore has a diameter of approximately 0.3 mm, and bears 8 tentacles. Young colonies have transparent stolons. The calcium carbonate found in other species is absent in exoskeletons of this species.

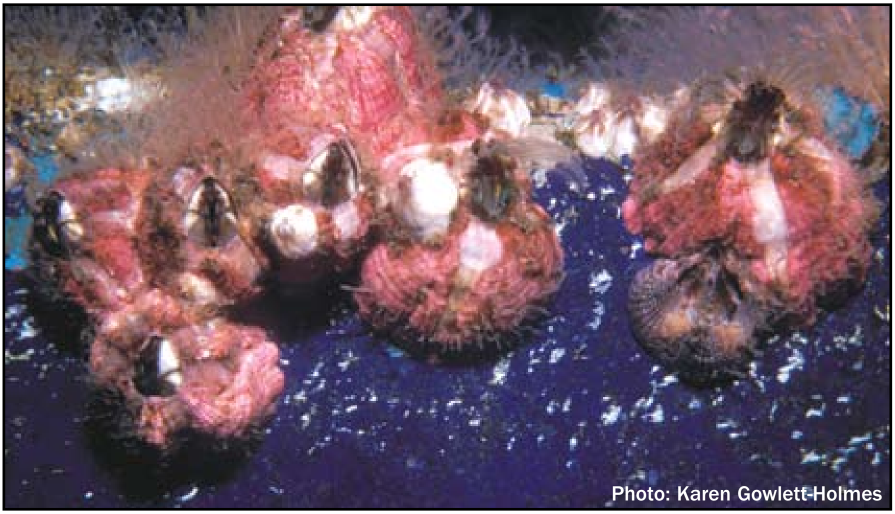
Notes: It is highly unlikely that many organisms feed directly on *Z. verticillatum* as colonies produce bromo-alkaloids, a class of chemical compounds related to drugs like nicotine, morphine, and cocaine. These secondary metabolites are likely to protect zooids in the colony by discouraging predation, preventing settlement of other organisms, and preventing bacteria or viruses from invading. Only a few species of nudibranch molluscs are known to feed directly on *Z. verticillatum*.

Primary vector: The primary vector for translocating this species is via hull fouling.

Crustaceans

With over 50,000 species, crustaceans are one of the most diverse groups in the animal world. The group includes such familiar animals as crabs, lobsters, shrimp, and barnacles. Most of the species are marine, but there is a substantial proportion of freshwater species. Some, such as the slaters commonly found under dead wood in the garden, have adapted to living on land. An interesting feature is the chitinous exoskeleton that protects the soft parts of the body of the animal. While it provides important protection, the exoskeleton also prevents growth of the animal. Thirteen species of crustaceans have been introduced into Western Australia:

- *Amphibalanus amphitrite*
- *Amphibalanus reticulatus*
- *Cirolana harfordi*
- *Paracerceis sculpta*
- *Paradella dianae*
- *Sphaeroma serratum*
- *Megabalanus ajax*
- *Megabalanus rosa*
- *Megabalanus tintinnabulum*
- *Monocorophium acherusicum*
- *Monocorophium insidiosum*
- *Monocorophium sextonae*
- *Tesseropora rosea*



Megabalanus rosa

Common name: Acorn barnacle.

Distribution: Known from Japan, China and Taiwan. In eastern Australia it is found in New South Wales. In WA, the species is widespread from Cockburn Sound to Cockatoo Island in the Kimberley.

Habitat: This is a fouling species that lives on jetty pilings and readily colonises the hulls of ships.

Identification features: *Megabalanus rosa* has six smooth lateral plates that are generally pinkish rose-red to reddish purple (occasionally entirely white) coloured. It grows to no more than 50 mm in height. The orifice is usually greater than half the basal diameter. The detail of the scuta and terga (operculum) of *M. rosa* is used to identify the species. As many of this group display similar characteristics they are regarded as very difficult to identify. This species belongs to a group of 'pink barnacles' that are currently under taxonomic review.

Notes: In its native range *M. rosa* is classified as an open sea species. However it is often found on wharf pylons, vessel hulls and other artificial structures. It is recorded to a depth of 300 m, and from waters ranging in temperature from 15-28 °C.

Primary vector: The primary vector for translocating this species is via hull fouling.

Molluscs

Molluscs are the seashells group. They are the most diverse group in the sea. While the total number of species is not known, it may be in the range of 100,000 species. There are a wide variety of body shapes and sizes, from small animals that reach a maximum of only a few millimetres to the largest of the giant squid. There are a number of classes, or major groups, of molluscs, including cephalopods (squids, octopuses and cuttlefish), chitons (coat of mail shells), gastropods (snails and seaslugs), bivalves (scallops, mussels and oysters), and tusk shells. Most of the species have an external shell composed of calcium carbonate. Some groups, such as seaslugs, have lost the shell in evolution. However, shell-less groups can still be recognised as molluscs through other characters such as the radula (a ribbon of teeth) and the mantle (a unique external tissue). Both of these occur only in molluscs. Nine species of molluscs have been introduced into Western Australia. Most of the invasive marine molluscs are bivalves, though there are also some gastropods and one chiton in this group:

- *Godiva quadricolor*
- *Musculista senhousia*
- *Mytilus edulis planulatus*
- *Okenia pellucida*
- *Ostrea edulis*
- *Polycera hedgpethi*
- *Scaeochlamys lividus*
- *Theora lubrica*
- *Velacumantus australis*

Godiva quadricolor

Common name: Aeolid nudibranch.

Distribution: This is a South African species. Isolated individuals were found in Cockburn Sound and Fremantle in 1980, 1983 and 1997. It has also been recorded in New South Wales.

Habitat: On jetty pilings in protected waters such as harbours.

Identification features: This is a long, narrow species of aeolid that is brownish in colour and reaches 20 mm in length. The body tapers to a long, narrow tail. There is a pair of long tentacles on the front of the head, with a smaller pair at the back. Numerous long, narrow cerata are clumped along the side of the body. The cerata are brown for much of their length, but the tips have blue, orange and yellow colouring.

Notes: This is not an invasive pest species. However it is reported to be a voracious carnivore that feeds on other nudibranchs.

Primary vector: The primary vector for translocating this species is via hull fouling.


Photo: Bill Rudman

Okenia pellucida

Common name: Nudibranch.

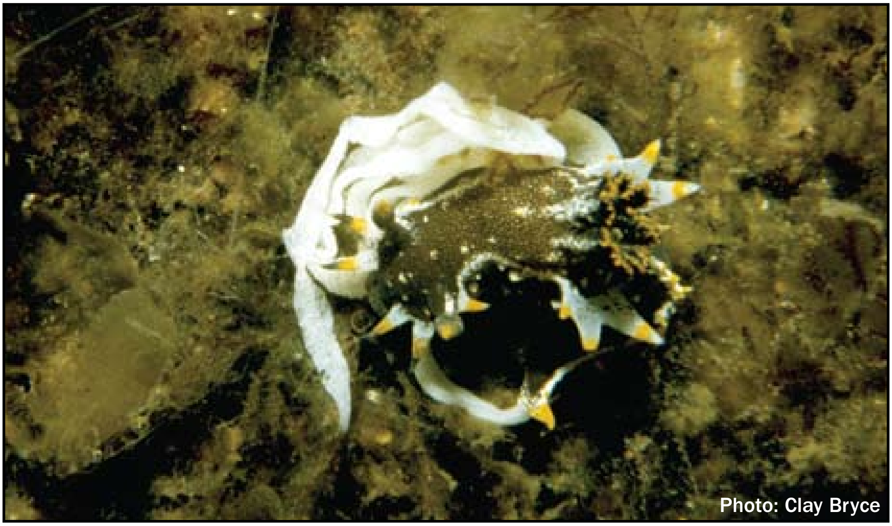
Distribution: Uncertain. This is a species that has become widespread through shipping. It has been reported from Hawaii, Japan, Palmyra Atoll, Malaysia, and the United Arab Emirates. In eastern Australia it occurs from New South Wales and Queensland. In WA it has been recorded only from Fremantle.

Habitat: *Okenia pellucida* lives on jetty pilings.

Identification features: The body is up to 20 mm long, and resembles a sea hare in shape. The animal is white with thin brown lines scattered over the surface. The head is separate from the body, with triangular oral tentacles. The body has 10-12 long, narrow elongations (papillae) on each side. The gills are at the back, bipectinate and surround the anus.

Notes: *Okenia pellucida* lives and feeds on the introduced bryozoan *Zoobotryon verticillatum*.

Primary vector: The primary vector for translocating this species is via hull fouling.



Polycera hedgpethi

Common name: Hedgpeth's dorid.

Distribution: This species was thought to be an introduction from California, where it was originally described. However, the natural distribution of the species is obscure. Specimens were known from New Zealand prior to the original species description and the species was recorded in Australia only nine years later. It has been reported from California, the Caribbean, Mediterranean, South Africa, New Zealand, Japan, and the Iberian Peninsula. In Australia *P. hedgpethi* is known from New South Wales to South Australia. In WA it has been recorded from Albany and Rockingham.

Habitat: The species lives on jetty pilings in harbours in shallow water.

Identification features: This is a small nudibranch that reaches only 15 mm in length. The body is slender, dark brown, with whitish spots. The head has a frontal veil of four to six long narrow extensions that are yellowish on the base, black near the tips, and whitish on the tips themselves. The gills, on the back of the body near the centre, are dark brown, almost black. They are surrounded by appendages with the same colouring as the extensions on the head.

Notes: In Western Australia the species was originally recorded from jetty pilings at Quaranup, Princess Royal Harbour at Albany in February 1980. No further specimens have been recorded from Albany despite several searches at Quaranup.

Primary vector: The primary vector for translocating this species is via hull fouling.

Photo: Helen Cribb, Northern Territory Government

Musculista senhousia

Common name: Asian date mussel.

Distribution: *Musculista senhousia* is native to North Asia. This is an invasive species that has been recorded in a wide variety of areas, including the Mediterranean, United States, India, and New Zealand.The taxonomy of this species is uncertain – there may in fact be more than one species. It has been introduced to Victoria, Tasmania and South Australia. In Western Australia the species is limited to the lower Swan River and Fremantle Harbour.

Habitat: *Musculista senhousia* lives in the intertidal and shallow subtidal region of bays and estuaries. While the species can live on hard or soft bottom, soft sediments are the preferred habitat. Numerous byssal threads that project from the anterior end of the shell are used to construct a cocoon that protects the shell. When there are numerous animals living close together the cocoons form a mat that smothers the underlying surface.

Identification features: The shells of this mussel are small, being from 10 to 25 mm long and up to 12 mm wide. The shell is smooth, thin, and olive green to brown in colour; with dark radial or zigzag markings.

Notes: *Musculista senhousia* was discovered in the Swan River in the early 1980s, and within a few years was one of the most common shells washed up on the beach. Densities of up to 2,600 individuals per square metre were recorded in the lower Swan River in the 1990s. Populations appear to have been decimated by an intense summer rainfall event in 2000. A survey of the Swan River, Fremantle Harbour, Rous Head, and Cockburn Sound in October 2007 failed to find any living individuals of this species.

Primary vector: The species can be translocating via hull fouling or in ballast water.

Mytilus edulis ssp. *planulatus*

Common name: Blue mussel.

Distribution: New South Wales to Western Australia. Common in harbours from Esperance to Fremantle.

Habitat: Abundant on jetty pilings and rocks in shallow water.

Identification features: This is a large (up to 10 cm) mussel, with black or purple shells and a white terminal umbo. Numerous concentric growth lines extend to the rounded end of the shell. The periostracum (horny outer covering) is brown. The inside of the shell is light near the umbos and becomes progressively darker near the opposite margins.

Notes: Blue mussels are widely used for aquaculture in southern Australia, including the Albany harbours, Warnbro Sound and Cockburn Sound, Western Australia under the name *M. edulis*. The taxonomy of this species is confused. Australian specimens were first collected by Francois Péron on the exploratory voyage of the French corvette *Géographe* in 1798. The specimens were later described as described as *Mytilus planulatus* by Lamarck in 1819. *Mytilus planulatus* is now generally considered to be a subspecies of *M. edulis*. In fact they may be descended from mussels brought to Australia by early European exploratory ships. *Mytilus galloprovincialis* is an almost identical species, which can only be separated genetically. The two species can co-occur and be intermingled. Like most species listed in this publication they have not been studied in detail in Western Australia.

Primary vector: The primary vector for translocating this species is via hull fouling.


Photo: David Roberts

Ostrea edulis


Photo: Clay Bryce

The oyster *Ostrea angasi* is on the left and *O. edulis* is on the right.

Common name: European flat oyster.

Distribution: This species is native to Europe. It has been recorded in Western Australia at Oyster Harbour, Albany.

Habitat: *Ostrea edulis* lives on intertidal rocky shores and in shallow water where it is attached to a hard substrate.

Identification features: This is a large (up to 10 cm), oval or pear shaped oyster. It is attached to the bottom by the concave left valve. The smaller right valve is flat and sits inside the left valve. Its upper surface may be scaly with concentric growth lines. The shell is off-white to cream, with the internal shell being a glossy white.

Notes: Vancouver named Oyster Harbour in 1798 because of the abundance of oysters (*Ostrea angasi*) in the area. However, it was recently found that there are actually two species in Oyster Harbour, the native *O. angasi* and the European *O. edulis*. It is not known when or how the European species was introduced, but it could have been quite some time ago.

Primary vector: The primary vector for translocating this species is via hull fouling.

Scaeochlamys livida

Common name: Scallop.

Distribution: This species is native to the east coast of Australia, from New South Wales to southern Queensland. In WA it has been recorded from Fremantle Harbour, Cockburn Sound, and the adjacent open coastline as far south as Mandurah and as far north as Hillarys.

Habitat: *Scaeochlamys livida* lives attached to jetty piles and rocks in shallow water.

Identification features: The shells of *Scaeochlamys livida* are up to 7 cm high, slightly unequal, with the left valve more convex. The auricles (projections where the shells meet) are unequal. There is a pronounced gape in the shell where the byssal threads emerge. The shells are colourful, often brown or purple, or orange, yellow, or white, but in life they are often covered by an encrusting sponge. There are 10 to 12 very strong, low, flattened radial ribs on left side with flat, translucent scales. The scales are much stronger near the shell margin. The right valve has 20 to 25 ribs, but they are lower than those on the left valve.

Notes: This species is unusual as it is an introduction from eastern Australia rather than from overseas. It is widespread in the waters off the Perth metropolitan area. Although it is not classed as a pest species, *Scaeochlamys livida* appears to have largely replaced the local species *Mimachlamys asperrima* locally.

Primary vector: The primary vector for translocating this species is via hull fouling.


Photo: Clay Bryce

Theora lubrica

Common name: Bivalve.

Distribution: The native distribution of this species is the east coast of Asia, from Japan south to Singapore and Indonesia. It has been introduced in Australia from New South Wales to eastern South Australia, including Tasmania. In Western Australia, it is known only from the Swan River, Rockingham and Bunbury.

Habitat: *Theora lubrica* lives in shallow, muddy environments and can be found in depths to 50 m.

Identification features: The shell is small, up to 15 mm long, elongate, almost transparent, with fine concentric growth lines. The shell gapes at both ends.

Notes: The above photo is actually *Theora fragilis*, but the shells are very similar and it would takes significant taxonomic skill to tell them apart. Both species are deposit feeders, using their siphon to suck small particles of detritus off the sediment surface.

Primary vector: The species is believed to be translocated via ballast water and hull fouling.

Velacumantus australis

Common name: Mudwhelk.

Distribution: This snail is widespread in eastern Australia, from southern Queensland to South Australia, and also lives in Tasmania. It is thought *V. australis* introduced into the lower Swan River and the Woodman Point area of Cockburn Sound many years ago.

Habitat: *Velacumantus australis* lives in sandy environments, including some with macroalgae and seagrasses, in shallow water.

Identification features: This is a small snail, up to 4 cm long, with a high spire, and a pronounced suture, or indententation, between the whorls. There is a beaded appearance on the body whorl and the upper whorls of the shell are very knobbly. The shell is usually dark brown, with a dark brown opening. Some shells have a distinct white band.

Notes: Thousands of years ago *Velacumantus australis* was widespread across southern Australia, including southern Western Australia, but over time its range became restricted to the east coast. It was recorded from Albany in the 1960s, but the specimen turned out to be a subfossil.

Primary vector: Transport of larvae in ballast water is a possible source of the species in WA. However, it was sufficiently common in the Swan River in the 1960s to be the subject of a series of scientific papers, so it may have already been in WA for a period of time. Ballast water came into widespread use after World War II, and *V. australis* may have been introduced earlier through individuals being brought across in wet ropes or as biofouling.

Tunicates

Tunicates, or sea squirts, are actually chordates because their planktonic larvae have a notochord, dorsal nerve cord, pharyngeal slits, and a post anal tail. The Chordata is the group to which all of the vertebrates, including fish, mammals, birds, amphibians, and reptiles belong. However, tunicates lack a backbone and are thus invertebrates. The body plan of adults is simple: there is essentially a chamber with two openings. Water enters one opening, food is filtered out, and the water leaves through the other opening. Despite this simple body plan there are many variations and numerous species. Planktonic salps resemble jellyfish, but are actually tunicates. Bottom dwelling sea squirts are common as fouling organisms on jetty pilings, ships' hulls and other structures. A number of species have been introduced to Western Australia.

Five species of ascidians have been introduced into Western Australia:

- *Ascidiella aspersa*
- *Botryllus schlosseri*
- *Ciona intestinalis*
- *Styela clava*
- *Styela plicata*

Botrylloides leachi

Common name: Colonial ascidian.

Distribution: *Botrylloides leachi* is widespread in the Northeastern Atlantic, Mediterranean Sea, Adriatic Sea, Black Sea, Indonesia, western Indian Ocean, Red Sea, South Africa, New Zealand, and along all Australian coasts. In Western Australia it occurs from Albany to the Dampier Archipelago and is even found at the offshore Rowley Shoals.

Habitat: *Botrylloides leachi* is an encrusting species, growing on both natural and artificial substrata. It is often seen on seagrasses. It is found in the lower intertidal and shallow subtidal zones.

Identification features: *Botrylloides leachi* is an ascidian composed of many individual zooids growing together to form colonies. Zooids are small, up to 2 mm long but the entire colony can be quite large and greatly variable in colour from grey, red-brown to purple and orange. Colonies are thin, irregular in shape and have a smooth, even surface. Zooids are crowded together in long curving and branching double-row systems with a common exhalent (atrial) siphon between them.

Notes: *Botrylloides leachi* can be a dominant competitor, overgrowing and excluding many other epibiont species. Fouling on aquaculture structures can decrease water flow as well as compete for food with suspension feeding aquaculture species. Various nudibranch, gastropod and flatworms are reported to feed on this colonial ascidian.

Primary vector: The primary vector for translocating this species is via hull fouling.

Ciona intestinalis

Common name: Solitary ascidian.

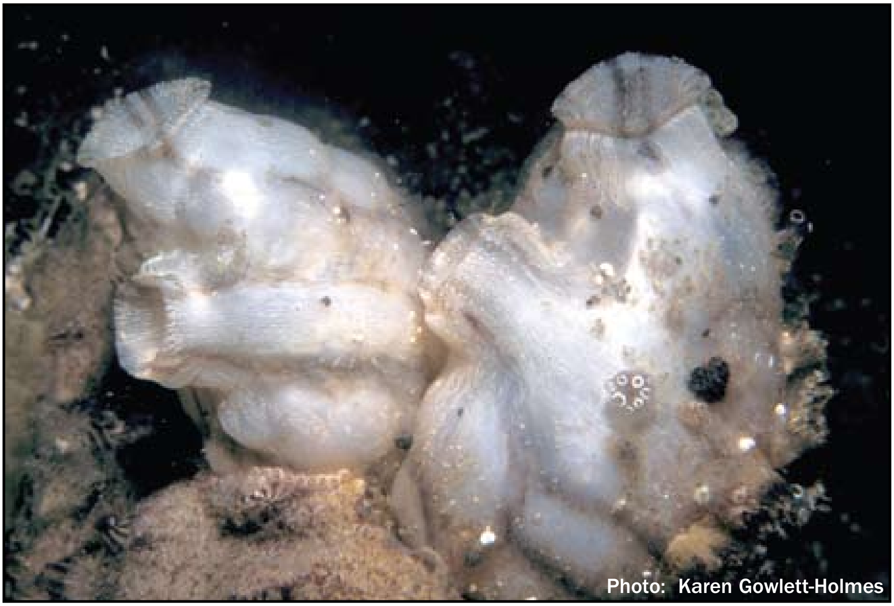
Distribution: This species is native to the North Atlantic, but has been introduced to North and South America, Hong Kong; China Sea, Indonesia, and New Zealand. In eastern Australia it occurs from southern Queensland to South Australia and Tasmania. In WA, it occurs from Esperance to Fremantle.

Habitat: *Ciona intestinalis* is a solitary ascidian but is commonly found in dense aggregations on rocks, algal holdfasts, seagrass, shells, and artificial structures such as pylons, buoys and ships' hulls. It is found in enclosed and semi-protected marine embayments and estuaries. While it occurs in the low intertidal and shallow subtidal zones, C. intestinalis clearly decreases in abundance with depth.

Identification features: *Ciona intestinalis* usually hangs vertically upside-down in the water column. It is cylindrical, 100-150 mm in length and ends with a cone-shaped branchial (inhalant) siphon. There are 8 lobes on the branchial siphon and 6 on the atrial (exhalent) siphon. The siphon openings may have yellow margins and orange/red spots. The body wall is generally soft and translucent with the internal organs visible, however, the animals may be hard and leathery due to heavy fouling.

Notes: Juveniles are eaten by snails such as *Mitrella*, *Hydrobia* and *Littorina*. Fish such as sticklebacks also consume juvenile ascidians. Jellyfish are known to feed on eggs and larvae in the water column.

Primary vector: The primary vector for translocating this species is via hull fouling.



Styela plicata

Common name: Solitary ascidian.

Distribution: The native range of *Styela plicata* is unknown. It is cryptogenic in widespread locations in the Mediterranean and warmer parts the Pacific, Indian and Atlantic Oceans. It has been introduced to the Atlantic coast of South America and is probably Australia-wide. *Styela plicata* is widespread in WA from Esperance to the Monte Bello Islands.

Habitat: *Styela plicata* is a fouler of ships, boats, docks and aquaculture facilities, attaching to hard substrates. It is usually covered with non-ascidian flora and fauna, which can 'travel' on the tunicate and add more non-indigenous species to aquatic ecosystems.

Styela plicata competes with other organisms, excluding them from the space it occupies. Its larvae are capable of invading occupied space and growing to a large size in a relatively short period of time, attached to other organisms. *Styela plicata* then sloughs off because of its large size, often taking other marine organisms with it. This sloughing destabilises the marine community.

Identification features: *Styela plicata* is an ovular, greyish to tannish white benthic tunicate. This solitary sessile invertebrate is cloaked in an un-stalked tunic that is large, tough, warty and ridged.

Notes: The first WA specimens were collected in Cockburn Sound in 1928. Snails, crustaceans, sea stars and fish have been known to prey on *S. plicata*. Specifically, the species *Linatella caudata* preys upon *S. plicata*.

Primary vector: The primary vector for translocating this species is via hull fouling.

Fish

There are literally thousands of species occurring along the coasts of Western Australia, but only three have been introduced to the State:

- *Acentrogobius pflaumi*
- *Sparidentex hasta*
- *Tridentiger trigonocephalus*


Photo: Mark Maddern

Acentrogobius pflaumi

Common name: Streaked goby.

Distribution: The species is native to the area including Japan, Taiwan, Korea, and the Philippines. It has been introduced to New Zealand, and into Sydney Harbour and Botany Bay, New South Wales, and Port Phillip Bay, Victoria. In Western Australia it is known only from Cockburn Sound and the Swan River in the Fremantle marine area.

Habitat: In WA *Acentrogobius pflaumi* lives in soft sediment, silty areas. In its native area the species lives in protected marine embayments and brackish areas.

Identification features: *Acentrogobius pflaumi* is a small, slender goby, with the eyes very close together. There are two dorsal fins and the anal fin has 10-segmented rays. The body is grey to brown with five dark blotches along each side. The last blotch is at the base of the tail. There are bright electric blue spots on many of the scales.

Notes: *Acentrogobius pflaumi* lives in close association with a small alpheid shrimp, and shares its burrow.

Primary vector: The primary vector for translocating this species is through ballast water.

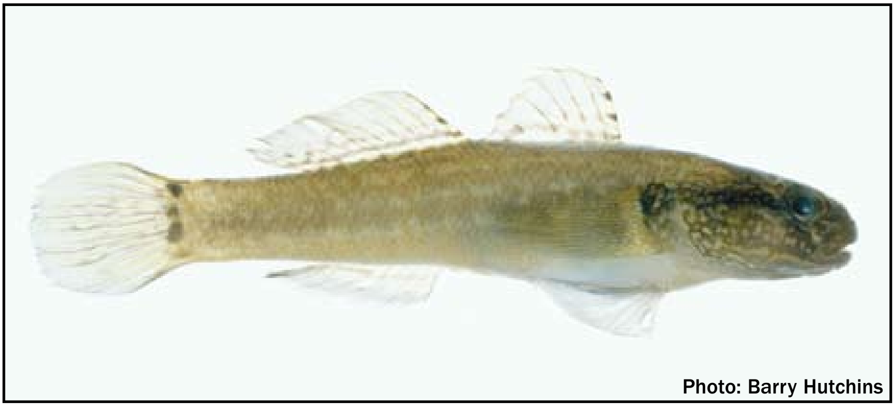


Photo: Barry Hutchins

Tridentiger trigonocephalus

Common name: Chameleon goby.

Distribution: This species is native to the northwest Pacific (Japan, China and Korea). It has been introduced to California and in New South Wales and Victoria in eastern Australia. In WA it has been introduced into Bunbury and the Fremantle marine area (Fremantle Harbour, Swan River and Cockburn Sound).

Habitat: This species lives on the bottom in estuaries and other protected areas where it occurs near rocks, in holes and crevices, and other places where it can hide.

Identification features: *Tridentiger trigonocephalus* has a typical goby shape. The key feature is two black stripes along the body from behind the eye to the tail. As the common name implies, the fish can change its colour from silvery to brown, sometimes obscuring the stripes. There are two dorsal fins and a pale band at the base of the pectoral fin.

Notes: This species is thought to compete with native species sharing the same habitat and general ecology.

Primary vector: The primary vector for translocating this species is through ballast water.

Potential introductions to Western Australia

With the wide range of habitats in Western Australia, there are thousands of potential species that could inhabit our shorelines if they were able to arrive in the State. The list of potential introduced species is almost endless, particularly when vessels come from unexpected sources. Any risk assessment of possible species that could be introduced in to Western Australia would seem unlikely to include species from the Caribbean Sea, yet that is exactly where the *Leonardo da Vinci* came from on its way to Geraldton in 2002. While it was on a very unusual route, the dredge *Leonardo da Vinci* arrived in Geraldton virtually directly from the Caribbean. When it arrived in Western Australia an inspection of the vessel revealed a number of Caribbean species, including pest species, on the stern and in tanks near the stern that were open to the sea. Fortunately, steps were immediately undertaken to minimise the chances of Caribbean species becoming introduced into Geraldton. So far, no such introductions have been recorded.

Hull fouling on the bottom of the Leonardo da Vinci.

The National Introduced Marine Pest Coordination Group

The Australian and New Zealand governments have recognised the importance of monitoring for introduced marine pests. Working collaboratively they developed the national introduced marine pest monitoring strategy. This strategy has at its core a set of minimum requirements for marine pest monitoring and the collection of monitoring data from marine environments. The National Introduced Marine Pest Coordination Group (NIMPCG) also compiled a list of introduced species that should be monitored for, consisting of 55 species that are known pests, or are considered to be likely to become marine pests if they are introduced into Australia. A selection of the 55 listed and potential next pest species are detailed in this section.

Target species list developed by the National Introduced Marine Pest Coordination Group (2008)

Dinoflagellates
Alexandrium catenella
Alexandrium monilatum
Alexandrium tamarense
Dinophysis norvegica
Gymnodinium catenatum
Pfiesteria piscicida
Diatoms
Chaetoceros convolutus
Chaetoceros concavicornis
Pseudo-nitzschia seriata
Macroalgae
Bonnemaisonia hamifera
Caulerpa racemosa
Caulerpa taxifolia
Codium fragile ssp. fragile
Grateloupia turuturu
Sargassum muticum
Undaria pinnatifida
Womersleyella setacea
Comb jellyfish
Beroe ovata
Blackfordia virginica
Mnemiopsis leidyi
Polychaete worms
Hydroides dianthus
Marenzelleria spp.
Sabella spallanzanii
Seastar
Asterias amurensis
Ascidians (sea squirts)
Didemnum spp. (exotic invasive only)

Crustaceans
Acartia tonsa
Balanus eburneus
Balanus improvisus
Callinectes sapidus
Carcinus maenas
Charybdis japonica
Eriocheir spp.
Hemigrapsus sanguineus
Hemigrapsus takanoi
Pseudodiaptomus marinus
Rhithropanopeus harrisii
Tortanus dextrilobatus
Molluscs
Corbula amurensis
Crassostrea gigas
Crepidula fornicata
Ensis directus
Limnoperna fortunei
Musculista senhousia
Mya arenaria
Mytilopsis sallei
Perna perna
Perna viridis
Rapana venosa
Varicorbula gibba
Fish
Neogobius melanostomus
Siganus luridus
Siganus rivulatus
Tridentiger bifasciatus
Tridentiger barbatus

Undaria pinnatifida

Common name: Wakame.

Distribution: *Undaria* currently occurs on the east coast of Tasmania and in several bays in Victoria. Based on its wide temperature tolerance, it could spread to other areas. The species is native to *Japan, China and Korea*.

Habitat: *Undaria* grows on hard surfaces from the intertidal to depths of about 20 m (e.g., reefs, rocks, shells, ropes, wharf piles, and ship hulls). It can form dense stands in sheltered areas. It does not grow well in areas of high wave energy or where native seaweeds are abundant.

Identification features: This species is a kelp that grows to 1-3 m in height. Plants are a golden brown colour and consist of a holdfast, cylindrical stipe (stem) and flattened, branched blade, with the stipe extending as a mid-rib through the blade. Fertile plants produce frilly sporophylls (leaves that produce spores) on the stipe.

Notes: *Undaria* is thought to have spread to, and within, Australia in ballast water and by hull fouling.

Caulerpa taxifolia (invasive strain)

Common name: Aquarium Caulerpa

Distribution: The origin and natural distribution of *Caulerpa taxifolia* (invasive strain) is difficult to assess, as it is morphologically similar to a widespread, non-invasive strain. An algal taxonomist is required to correctly identify the invasive strain of this species, however it is recommended that positive identification be made using molecular techniques. It is likely that the invasive strain originated in Queensland, from where it was distributed worldwide via the aquarium trade. Escapees were first noted in the Mediterranean near Monaco, and outbreaks have also occurred in California. In Australia, the invasive strain is known from Queensland, New South Wales and South Australia.

Habitat: This species grows on a range of substrata, including rocks, sand, mud and seagrasses. Its usual depth range is from 3 to 35 m, but in the Mediterranean it has been recorded from 100 m depth. It can grow successfully in a variety of conditions and water qualities.

Identification features: *Caulerpa taxifolia* is a green seaweed that has creeping stems (stolons) that meander across the sea bottom, from which upright fronds arise. Stems of the upright fronds are unbranched or sparsely branched, compressed, and grow to approximately 20-60 cm in height. They produce small lateral branchlets that are 5-9 mm long and arise in one plane. The branchlets are slightly flattened, unbranched, sickle-shaped, straight or upwardly curved. There is a slight constriction at the base of the branchlets and a small gap between adjacent branchlets.

Notes: Accurate identification of the invasive strain of *C. taxifolia* can be problematic, particularly in tropical areas (including northern Western Australia) where the non-invasive strain occurs naturally. Vigorously growing populations in colder waters, however, will almost certainly be the invasive strain.

Myxicola infundibulum

Common name: Slime feather duster worm.

Distribution: This species is native to northern Europe, where it is widespread from France and the British Isles to Scandinavia. It is also widespread in cold and temperate waters throughout much of the world. CSIRO document the species as being cryptogenic in southern Australia, including southern WA, but there are no records of the species in WA.

Habitat: *Myxicola infundibulum* lives in shallow sandy and muddy environments to a depth of about 30 m.

Identification features: This is a tubeworm. The mucilaginous tube is up to 20 cm long. Except for the opening, the tube is buried in the sediment. The animal has up to 100 segments, and lives in the tube, withdrawing when threatened by a predator. The body is dark yellow-brown. When the animal emerges there is a crown of purple and brown tentacles extending from the tube.

Echinoderms

Echinoderms are one of the most common groups in shallow waters; other species can be found in the deepest depths of the oceans. The 7,000 known species of echinoderms are all marine. There are five groups: seastars, brittle stars, sea urchins, sea cucumbers, and crinoids. Feeding mechanisms vary between the groups, with some of the seastars being voracious carnivores. While most species have bilateral symmetry at some stage in their life, adults have radial symmetry, often with appendages in groupings of five. Sexual reproduction involves external fertilisation and a planktonic larval stage in almost all species. One interesting feature of echinoderms is the ability to replace lost organs. Seastars can even regenerate an entire new individual from only a single arm with a part of the central disc. This regenerative capacity was clearly demonstrated by *Asteria amurensis* in Tasmania. The species was detected in Tasmania in the mid 1980s when a visiting scientist was examining collections in the Tasmanian Museum. *Asterias amurensis* was in the collections but had gone unrecognised. A quick examination of the nearby Hobart waterfront showed the species was already in plague proportions. In an effort to remove this species from local waters a 'hunt' was coordinated to collect *A. amurensis*. During this 'hunt' over 33,000 animals were collected. Unfortunately many animals were cut in half, believing they would die, and thrown back. These animals regenerated and numbers are believed to be higher than the initial population. To date no echinoderms are known to have been introduced into Western Australia.


Photo: Karen Gowlett-Holmes

Asterias amurensis

Common name: Northern Pacific sea star.

Distribution: *Asterias amurensis* is native to northeast Asia, including Japan. It is present in Alaska and western Canada, but it is not known whether this is part of the natural range or if it has been introduced. The species was introduced into Tasmania, and later spread to Victoria.

Habitat: *Asterias amurensis* occurs in the lower intertidal and subtidal in protected areas on soft bottoms and rocks. It also occurs on jetty piles.

Identification features: A large, up to 40 cm in diameter, five armed seastar with long, tapering arms. There are numerous low spines on the upper surface. The base colour of the upper surface is yellowish with deeper purple and red. The underside is a uniform yellowish. A key identifying feature of this species is the distinct upturned tips to the arms.

Notes: This species is an active carnivore that will feed on a variety of molluscs (including mussels, oysters, and other bivalves and snails) and crabs and barnacles.


Photo: Karen Gowlett-Holmes

Carcinus maenus

Common name: European shore crab.

Distribution: The native distribution of *Carcinus maenas* is widespread along the coast of Western Europe south to the west coast of Africa, and Iceland and southern Greenland. The species has been widely introduced into the east and west coasts of North and Central America, the Caribbean Sea, Brazil, Argentina, the east and west coasts of southern Africa, and Japan. In eastern Australia *C. maenas* has been introduced from New South Wales to South Australia and Tasmania.

Habitat: *Carcinus maenas* lives in a wide range of habitats, including sand, mud and seagrass beds, in protected bays and estuaries.

Identification features: This is a medium sized crab, with a carapace width of up to 8 cm. There are five distinct spines on the carapace to the outside of each eye. Adults are green on the upper carapace but the underside may be reddish-orange.

Notes: A single specimen collected in the Swan River in 1965 is in the Western Australian Museum, but there have been no further records of the species in WA. A detailed survey of the Swan River, Fremantle Harbour, Rous Head, and Cockburn Sound in October 2007 did not find any individuals.

Carcinus maenas is a voracious predator that attacks shellfish beds and disrupts coastal ecosystems.

Perna perna

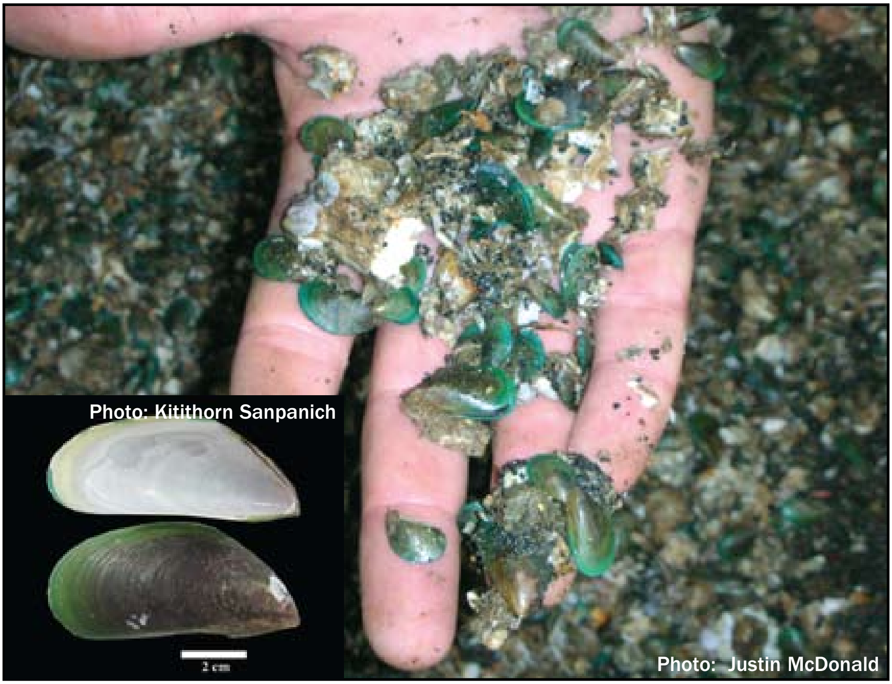
Common name: Brown mussel.

Distribution: *Perna perna* occurs from southern Africa from Mozambique to South Africa and also the east coast of South America. It was introduced into the Gulf of Mexico, including Texas.

Habitat: Like other mussels, *Perna perna* attaches to hard substrates in shallow water. The species has a wide range of temperature and salinity tolerances, so it can invade a range of areas.

Identification features: This is a large (up to 12 cm) mussel with a smooth brown shell. It is characterised by the inside of the shell having a distinctive scar made by a divided posterior retractor muscle.

Notes: This is another mussel species that could readily invade Western Australia, but it has not yet been recorded from Australia.



Perna viridis

Common name: Asian green mussel.

Distribution: *Perna viridis* is native throughout tropical Asia. It has been introduced to the Caribbean Sea and the east coast of the United States.

Habitat: This mussel lives in the intertidal and shallow subtidal, where it attaches to hard surfaces in coastal areas.

Identification features: There are only two other species in the genus, *P. perna* and *P. canaliculus*. As the common name implies the outer covering of the shell (the periostracum) of the Asian green mussel is greenish in young specimens, though as the animal grows it may become darker. The Asian green mussel most commonly reaches 8-10 cm in shell length, though there are reports of individuals up to 16.5 cm. It has a pronounced downturn at the end of the shell. There are interlocking teeth at the tip of the shell – one on the right valve and two on the left.

If the species were introduced into Western Australia, it would most likely be on the tropical north coast. The closest species in WA would be the blue mussel of the south coast.

Notes: The species has been accidentally introduced into Cairns, where it has been reported to be reproducing. It has been found on ships arriving in Dampier, but to date mechanisms employed to prevent its introduction have been successful.

Like the Pacific oyster, the Asian green mussel is both a pest species and an important aquaculture species. As a pest, it also grows rapidly and out competes other species, including mussels, and alters the ecological balance on coastlines. The species can foul industrial structures, jetties, the hulls of ships and their internal pipes. It has been widely distributed by hull fouling and in ballast water, and in a limited way through aquaculture.

The Asian green mussel is a major food species in Asia. According to the FAO, wild capture peaked at about 160,000 tonnes in 1971. By the late 1990s this had declined to a fairly stable level of just over 20,000 tonnes. The loss of wild stocks has been more than replaced by increasing aquaculture production, which is now near 300,000 tonnes per year.

Photos: Helen Cribb, Northern Territory Government

Mytilopsis sallei

Common name: Black-striped mussel.

Distribution: The origins of *Mytilopsis sallei* are uncertain. Some publications give a range of the tropical Pacific coast of Central America, but others attribute the species to the Caribbean. It has become widespread in the Indo-West Pacific, including India, Singapore, Taiwan, Hong Kong, Japan and Indonesia.

Habitat: *Mytilopsis sallei* can attach to virtually any hard surface. The species is unusual in being able to detach from the bottom and reattach itself with new byssal threads. It lives in estuarine areas and can tolerate a wide range of temperatures and salinities.

Identification features: *Mytilopsis sallei* is in fact not a true mussel (Family Mytilidae); it is in the family Dresseinidae. A key characteristic is that the two shells are not equal; one is slightly larger and overlaps the other. This is a small mussel that reaches a length of only 25 mm. The shell is smooth, dull grey, and may have darker zigzag lines that give it the common name "black-striped mussel".

Notes: *Mytilopsis sallei* is prolific and fast growing. Individuals mature within a month of spawning, when they have reached a length of only 8-10 mm. They live for about a year, though some individuals live nearly twice that. Their environmental tolerances are high, which allows *M. sallei* to rapidly colonise new areas and rapidly reach plague proportions.

In 1999, *Mytilopsis sallei* was found in three small marinas in Darwin, where it reached incredible densities in a few months. The marinas were artificial habitats with very low 'natural' conservation values. The Northern Territory Government made a rapid decision to use chemicals to essentially poison everything in the marinas to eradicate the mussels. The eradication was successfully undertaken with intensive effort over a short period and is one of very few examples of an introduced marine species being successfully eliminated. Since then *M. sallei* has been detected on a number of illegal foreign fishing vessels in Australian waters. These vessels were inspected before reaching port and were destroyed. So far, to the best of our knowledge the species has not been reintroduced to Australia.

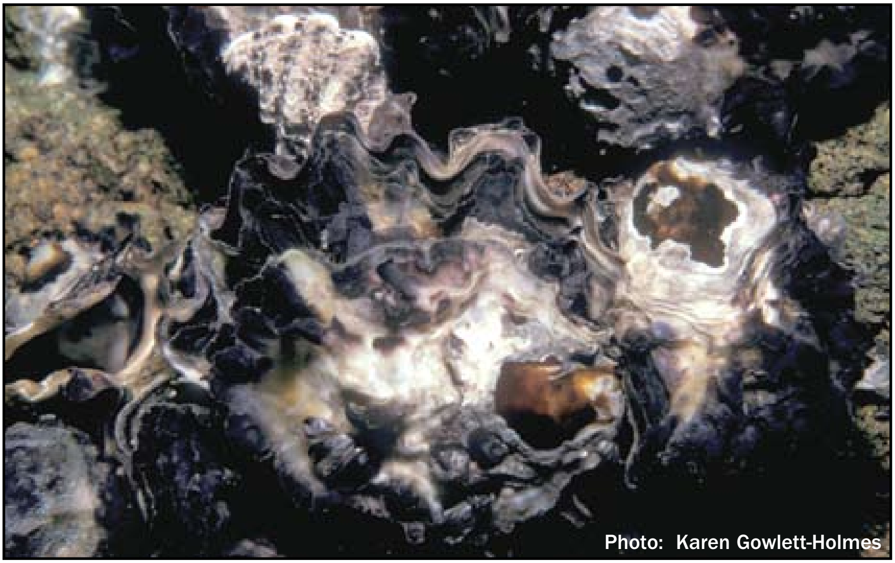


Photo: Karen Gowlett-Holmes

Crassostrea gigas

Common name: Pacific oyster.

Distribution: Asian North Pacific, including Japan.

Habitat: Intertidal rocks and jetty pilings.

Identification features: Oysters are very difficult to identify. They live on rocks and jetty pilings, and other such hard bottoms. The shape of the structure to which they are attached partly determines the shape of the oyster. Individuals are often crowded together, with the shape of adjoining individuals changing that of the ones around them. The key feature of *C. gigas* is its size, often between 15 and 20 cm, but there are unconfirmed reports of animals up to 40 cm long. Another feature is the deeply crenulated shell margins. One valve is deep and cup-shaped while the other is smaller and slightly convex. The outer shell is often off-white to brown.

Notes: Just after World War II an attempt was made to introduce this species into Oyster Harbour, Western Australia and Tasmania. The animals were in poor condition after a month at sea and consequently did not survive once introduced into Australian waters. Two years later the species was successfully introduced into Tasmania by transporting the broodstock by air. It was later introduced into Victoria (1953) and South Australia (1969). The species was not legally introduced into New South Wales, but it is believed there were illegal introductions. Fortunately, there was no second attempt to introduce the species into Western Australia. *Crassostrea gigas* has been extensively introduced into temperate seas worldwide, including the west coasts of North and South America, Europe, west coast of Africa, and Australasia. It is the most widely farmed shellfish species worldwide, with production of 4.4 million tonnes in 2006.

In Australia the species is a commercially exploited introduced species. It is widespread in estuaries in New South Wales, where it is considered noxious, but at the same time there is an important aquaculture industry at Port Stephens worth $ 1.8 million annually. The species contributes tens of millions to the South Australian and Tasmanian economies. The oyster is a concern because it settles in dense numbers, grows rapidly, and crowds out other species, including other oysters.

Glossary

Anti-fouling: the process of removing the accumulation, or preventing the accumulation of microorganisms, plants, algae, and animals on submerged structures, especially ships' hulls.

Arborescent: branching or tree-like.

Avicularia: modified zooids with a defensive role.

Ballast: material taken onto a vessel to allow it to retain the proper level in the water. Most ships use seawater for ballast.

Benthic: relating to the sea bottom

Biomass: the weight of a plant or animal.

Bipectinate: divided into two.

Carapace: a bony or chitinous shield, test, or shell covering some or all of the dorsal part of an animal.

Cerata: outgrowths on the sides and top of the body of aeolid nudibranchs.

Chaeta: bristle or seta, especially of an annelid worm.

Chitin: a hard material found in the shells of crabs, molluscs and other animals.

Cnidaria: a phylum of animals that includes jellyfish and corals.

Cryptogenic: species that have become so widespread over a long period of time that their natural ranges cannot be determined.

Endemic: species that are restricted to a particular area.

Epibionts: an organism that lives on the surface of another organism.

Exoskeleton: an external covering or integument, especially when hard, as the shells of crustaceans.

Lophophore: the ring of ciliated tentacles encircling the mouth.

Mantle: outgrowth of the body wall that lines the inner surface of the valves of the shell.

Moult: a process by which groups such as crabs shed their shell, grow rapidly, and then develop a new shell.

Oligochaetes: a group of worms. Most live in freshwater or terrestrial habitats, but some are marine.

Ovicells: an opening in the body wall of bryozoans in which the eggs sometimes undergo the early stages of development.

Plankton: species that live in the water column and are not strong swimmers. They cannot swim against a sustained current. Holoplanktonic species live in the water column throughout their lives while meroplanktonic species live in the water column as larvae and settle to the bottom for their juvenile and adult stages.

Parapodia: paired lateral extensions from the body.

Perahu: an Indonesian fishing boat.

Periostracum: the horny outer layer found on the shells of many species of molluscs.

Pharyngeal: pertaining to, or situated near the pharynx (throat).

Protists: a group of microscopic, single-celled organisms that are neither plant nor animal.

Puerulus: a larval stage in the western rock lobster and other crustaceans.

Radula: A specialised ribbon of teeth found only in molluscs.

Retractor muscle: the muscle that pulls a snail or bivalve animal back into its shell.

Salinity: the amount of salts in water. The average salinity of seawater is about 35 parts per thousand, or 3.5%.

Stolon: horizontal shoots which grow on the surface or just below the sediment in plants. There are similar structures in animals such as hydroids.

Trifurcate: divided into three.

Tunic: covering or membrane

Umbo: beak of a bivalve shell; the protuberance of each valve above the hinge.

Zoecium: secreted exoskeleton housing of individual zooids.

Zooids: One of the distinct individuals forming the colony of animals such as bryozoans and hydrozoans.

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