[science:un:covered]

Western Australia – a unique but under-explored marine environment

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The intertidal limestone platform at Cape Vlamingh is at the extreme western end of Rottnest Island.

Western Australia – a unique but underexplored marine environment

Western Australia's coastline is vast, beautiful and often inaccessible. It is also unique with many species endemic to its marine ecosystems. But in this idyllic paradise, there are warning signs that all is not well with its molluscs. Curtin University's Professor Marthe Monique Gagnon and Dr Fred Wells tell *Aether* of the catastrophic population declines they have been recording.

Profile: Marthe Monique Gagnon

Professor Marthe Monique Gagnon is a teaching and research academic in Ecotoxicology at Curtin University, working primarily on sublethal effects of industrial pollution on marine organisms. She is involved in multiple projects from monitoring impacts of oil spills on fish health to measuring trace metals in individual snake scales and long-term monitoring of marine invertebrates.

Profile: Fred Wells

Dr Fred Wells is an Adjunct Professor in the School of Molecular and Life Science at Curtin University in Perth, Western Australia. His research has concentrated on discovering the marine biodiversity and ecology of Western Australia and nearby countries. In recent years he has been particularly involved in issues related to marine invasive species.

A vast land

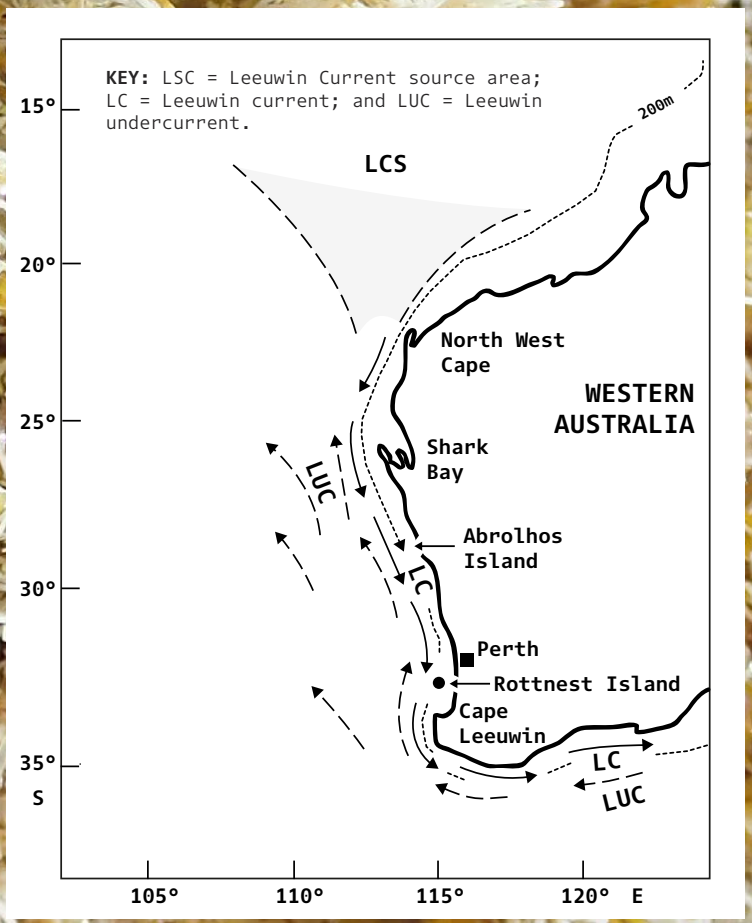
Occupying the western third of the island continent of Australia, Western Australia (WA) is truly huge: its land mass is over 2.5 million square kilometres, and the coastline is over 20,000km long. Yet there are very few people in this vast land – just under 2.7 million, 80% of whom live in Perth on the southwest corner of the state. By comparison, WA is over ten times the size of the United Kingdom, but the UK has more than 25 times as many people. In American terms, California has the largest population, about 39 million, but is less than a sixth of the size of WA.

With such a large size and so few people, it is not surprising that there are many exciting marine environments waiting for discovery. The vast WA coastline can be divided into three shallow water marine biogeographic regions: a tropical north coast extends from North West Cape across northern Australia and is part of the vast Indo-West Pacific. The south coast, heading east from Cape Leeuwin, is part of the southern Australian warm temperate region. The west coast, between North West Cape and Cape Leeuwin, is an over-lap zone where tropical species dominate in the north and temperate species in the south. Superimposed on this is a small, but significant, group of Western Australian endemic species that occur nowhere else in the world. Depending on the group, 5 to 10% of the species are endemic to WA. These are concentrated on the west coast overlap zone.

Aside from expeditionary surveys, studies of WA marine biology really began in the late 1940s with the appointment of the first marine biologist, Dr Ernest P Hodgkin, to The University of Western Australia. The Perth shoreline is essentially one long sandy beach broken up by small intertidal limestone platforms that range in width from a few metres to over 100m.

Hodge and one of his first students, Loisette Marsh, began examining the invertebrates of Perth metropolitan platforms in the early 1950s and compared them with similar platforms at the west end of Rottnest Island, about 27km offshore. Their early studies showed that the platforms are small-scale biodiversity hotspots. Over 130 species of molluscs alone have now been recorded on the platforms. The marine biota of Rottnest is a complex mixture of tropical, temperate and WA endemic species. Incredibly, at a latitude of 32°S, there is a small coral reef, Pocillopora Reef, on the south side of the island. An amazing 26 species of coral and over 90 fish species have been recorded from

Conus dorreensis, named after Dorre Island in Shark Bay, occurs only in Western Australia. It was still present in 2021.



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The nudibranch *Dendrodoris nigra* is another species known from the platforms that was not found in 2021.

Rottnest. The tropical species are concentrated on intertidal platforms at the western end of the island, Radar Reef and Cape Vlamingh.

Ocean currents

All of the world's oceans have massive currents that form gyres along their margins. The gyres are clockwise in the northern hemisphere but anticlockwise in the southern hemisphere. For example, in the South Pacific, the East Australian Current flows south along the east coast of the continent. When it meets the Roaring Forties the current moves eastward as the West Wind Drift. Part of the water then moves north along the west coast of South America as the Humboldt Current. The South Equatorial Current completes the circle, flowing westward across the South Pacific to northern Australia. Similar current patterns are found in the South Atlantic and Indian Oceans.

Under this scenario, temperate species would be moved northwards along the west coast of Western Australia by the West Australia Current, so the marine biota of the Perth region, including Rottnest Island, would be mostly temperate. Given this, how can tropical species be distributed so far south to the west end of Rottnest Island?

In his 1897 book *The Naturalist in Australia*, William Saville Kent commented on the large number of tropical species occurring in the Houtman Abrolhos Islands, 400km north of Perth. Saville Kent reported that sea surface temperatures were significantly warmer at the Abrolhos than they were 60km inshore at Geraldton on the continental coastline. He speculated that there was a southwards-flowing current in the area.

Over the following decades, additional supporting information was provided by a number of studies, including those of Hodgkin and Marsh, but it was not until 1980 that the Leeuwin Current was formally described by George Cresswell and Terry Golding of the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO). We now know that the Leeuwin Current is the longest unidirectional current in the world, explaining why tropical species are found on the west end of Rottnest Island.

Flowing across the vast Pacific Ocean, the South Equatorial Current moves a huge volume of seawater. As it turns south to form the East Australian Current, a portion of the water is forced westward through the islands of the Indonesian Archipelago. This makes the sea surface off the north coast of WA 0.5m higher than at Cape Leeuwin. While this sounds insignificant it is enough to drive the Leeuwin Current down the west coast of WA along the outer continental shelf. South of Cape Leeuwin the current is driven east into the Great Australian Bight, weakening as it mixes with the temperate waters off the south coast. Traces of the Leeuwin Current have even been detected off Tasmania in southeastern Australia.

The Leeuwin Current is strongest in July and August, the Austral winter, raising sea surface temperatures during the coldest months of the year. The south-flowing current provides a mechanism for delivering tropical species from northerly locations to southern areas on the WA coast where they would not otherwise occur, and the warmer temperatures provided by the current allow many species to survive and develop populations.

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The sea hare (*Bursatella hirsute*) is sometimes abundant at North Point, Rottnest Island, outside the direct influence of the Leeuwin Current. An estimated 600,000 individuals were at North Point at the same time as the declines in molluscs at Radar Reef and Cape Vlamingh were recorded.

This beautiful tailed slug (*Chelidonura hirundinina*) previously occurred in small numbers at both Radar Reef and Cape Vlamingh, but was not found in 2021.

Marine molluscs

Shortly after the Leeuwin Current was described, marine molluscs were examined to document the effects of the current on the west end of Rottnest Island. Mollusc collections of the Western Australian Museum were examined in 1981 for species occurring at the west end of Rottnest, bathed in the Leeuwin Current, and the east end of the island and the Perth metropolitan coastline, neither of which receives the current.

Temperate species were 67.3% of total mollusc species inshore and at the east end of Rottnest Island (Table 1); at the west end of Rottnest temperate species were only 51.7% of the total. WA endemic species ranged from 13.4 to 15.8% at these three locations. The difference in temperate species was made by tropical species, which increased from 17.6% at the east end of Rottnest to nearly double at 32.5% at the west end of the island.

Location	Tropical (%)	Temperate (%)	WA Endemic (%)	Total (%)
Inshore	19.3	67.3	13.4	100.0
East Rottnest	17.6	67.3	15.1	100.0
West Rottnest	32.5	51.7	15.8	100.0

Table 1. Distribution patterns of molluscs in the collections of the Western Australian Museum based on number of species.

While these are solid figures, they may be misleading. Both the general public and museum staff might be more likely to collect and deposit unusual species, leading to higher percentages of WA endemics and tropical species at the eastern end of Rottnest and inshore. To test this, quantitative transects were made at Radar Reef and Cape Vlamingh at the west end of Rottnest Island and the metropolitan platforms at Trigg Point and Cottesloe.

The results demonstrated very high diversities of molluscs on all platforms, ranging from 32 species at Radar Reef to 44 at Cape Vlamingh (Table 2). Total mollusc density varied from 130.8/m2 at Radar Reef to 1838.6/m2 at Cottesloe. Temperate species comprised 99.8% of the total mollusc density inshore at Trigg Point and Cottesloe. The data were very different at Rottnest: tropical species were 22.8% of the total mollusc density at Cape Vlamingh and 63.0% at Radar Reef. Thus, the Leeuwin Current was having a considerable impact in distributing tropical species to the west end of Rottnest Island at Radar Reef and Cape Vlamingh.

The surveys were repeated in 2007 with similar results: much greater proportions of total mollusc density occurred at the west end of Rottnest Island than on the inshore platforms. The total number of species recorded on each platform was lower, but this was because sampling had been reduced to minimise the workload and environmental effects. At Rottnest total mollusc density increased at Radar Reef, but declined at Cape Vlamingh. Inshore density decreased at both Cottesloe and Trigg Point, due to lower densities of the tropical mussel species *Brachidontes sculptis*.

Location	Number of species			Density (no./m2±SE)			
	1982/83	2007	2021	1982/83	2007	2021	Decline/increase 2007 to 2021
Rottnest Island							
Radar Reef	32	27	11	130.8±17.9	197.5±37.1	3.2±0.6	-98.4
Cape Vlamingh	44	43	17	135.0±14.8	51.9±7.1	7.4±2.8	-85.7
Perth coastline							
Cottesloe	36	31	30	1574.0±49.8	77.6±10.1	160.8±5.0	+107.2
Trigg Point	34	31	28	1838.6 ± 208.0	1028.0± 388.0	2416.9± 141.8	+135.1

Table 2. Comparison of number of mollusc species and total mollusc density on intertidal rock platforms at Rottnest Island and on the Perth coastline in 1982/83, 2007 and 2021.

The surveys were repeated in the summer of 2021, with similar results expected. However, there had been a catastrophic decline in mollusc (and echinoderm) populations at the west end of Rottnest – molluscs species were down from 27 to 11 at Radar Reef and from 43 to 17 at Cape Vlamingh. Densities crashed by 98.4% at Radar Reef and 85.7% at Cape Vlamingh. In contrast, species numbers remained high, and densities increased by over 100% at both inshore platforms. How can this be explained?

Global warming? Marine heat-waves?

Located just offshore from Perth with its population of 2.1 million people, Rottnest is a favourite holiday destination, with about 780,000 visitors annually. The island is a class A reserve, the highest level of natural protection. Most visitors remain in small settlements on the eastern corner of the island. There are paths down the cliffs to Radar Reef and Cape Vlamingh and the biota on the platforms is totally protected. There are no known pollutants on the platforms on in their surroundings.

Global warming is one possibility. The Perth region is a hotspot for rising sea surface temperatures, which have risen rose by ~0.6°C since 1950. However, this effect would have occurred both at Rottnest and inshore. Additionally, extensive research on the inshore platforms has demonstrated no major changes in mollusc species composition since the first quantitative studies in 1982.

The most likely cause of the drastic decline of molluscan populations at the west end of Rottnest Island is short-term marine heatwaves. There have been several heatwaves on the WA west coast in recent years. The most intense occurred in 2011 when sea surface temperatures rose up to 3°C for three months; shorter increases were recorded of up to 5°C. The 2011 heatwave is known to have had substantial effects all along the 1200km WA coastline between North West Cape and Cape Leeuwin. Many species and in fact entire ecosystems have been moved south by the heatwaves, and the effects may be permanent.

Given this background, we would have expected a decrease in temperate species at Radar Reef and Cape Vlamingh and an increase in tropical species. However, this did not happen. Instead, all biogeographic components of the molluscs crashed: tropical, temperate and endemic.

Time will tell whether the molluscs at the west end will be able to recover. On a positive note, while there have been no comparable quantitative data, the available information suggests the crash was limited to the two western platforms.

As far as we know, mollusc populations on intertidal platforms at the eastern end of Rottnest and on nearby islands are in good condition and might eventually provide larvae to repopulate the mollusc populations at Radar Reef and Cale Vlamingh.

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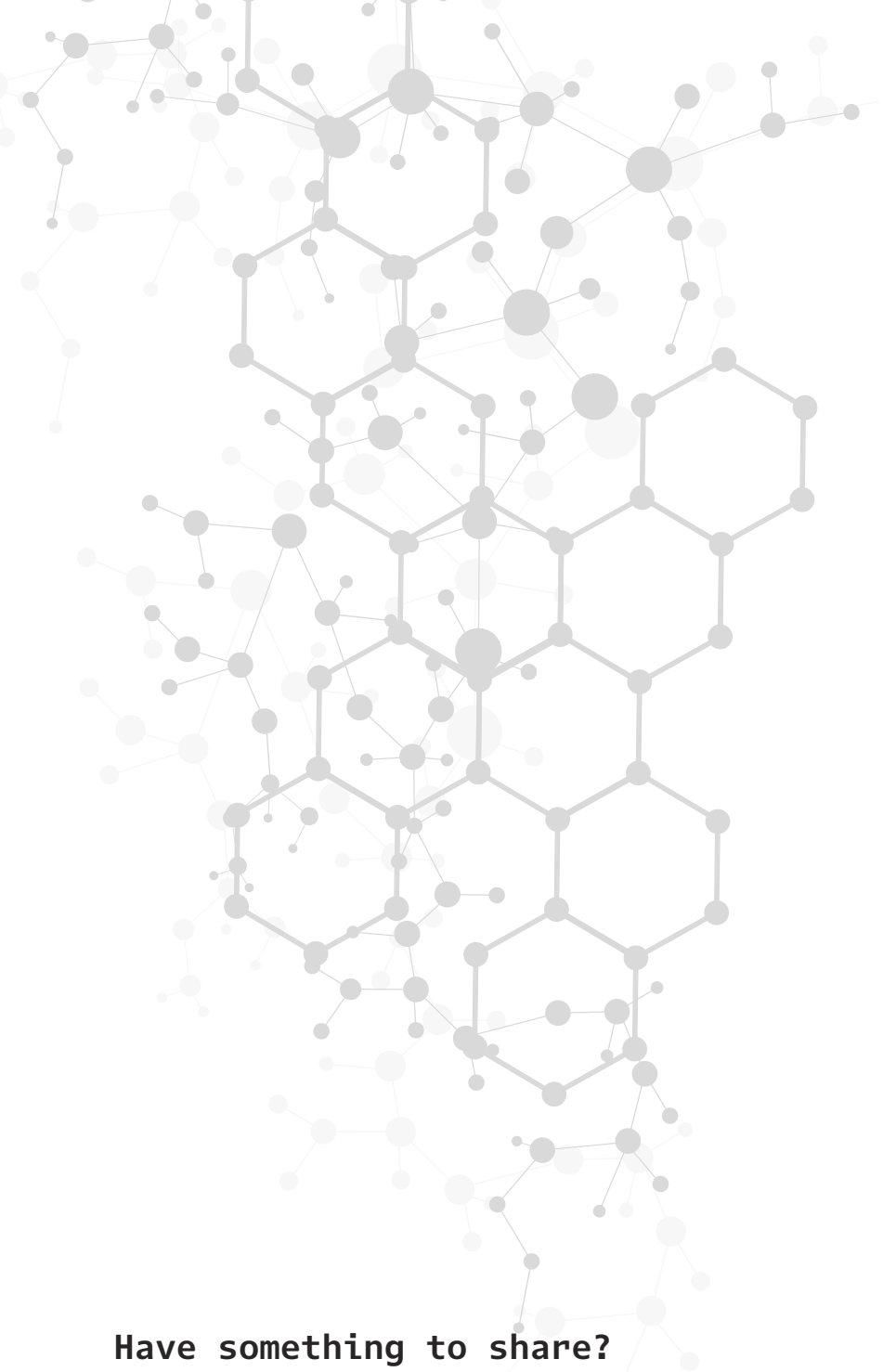

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