A leak from the Pacific warming the west?

That gourmet's delight, the western rock lobster of Western Australia, probably owes its existence to an ocean current that has no parallel anywhere in the world.

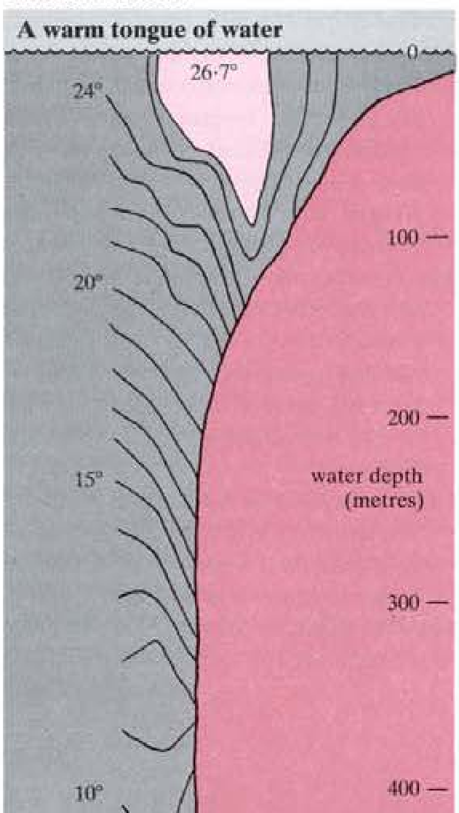
The Leeuwin Current is the world's 'odd man out', oceanographically speaking. This narrow ribbon of warm water flows rapidly southwards along the coast of Western Australia, accelerating into the prevailing winds. Then it curls into the Great Australian Bight.

This surprising behaviour differs from that found on the western sides of all the other continents. There, a combination of the earth's rotation and equator-wards winds results in a flow of water, near the surface, away from the coast. Compensating for this outflow is a second effect, an upwelling of cold, nutrient-rich water near the coast, which results in a steady decrease in the sea-surface temperature towards the coast. Finally an interaction between the near-surface outflow and the earth's rotation creates a broad, gentle current in the direction of the prevailing wind, towards the equator.

The same should be true of Western Australia, where strong steady winds blow towards the equator as they do along the other western coasts. But it is not.

Not only does the warm Leeuwin Current accelerate south into the wind, but beneath it water masses appear to sink rather than well up, and the surface temperature frequently increases at spectacular fronts as one approaches the coast.

Temperature soundings from the research vessel *Sprightly* reveal the warm waters of the Leeuwin Current near the edge of the continental shelf.



Peculiar this current certainly is, and its oddity creates far-reaching, practical consequences. First, and directly related to the western rock lobster, is the creation of a quite different fisheries environment from that found on the western sides of other continents, where cold rich waters support vast schools of anchovy and sardine. Off Western Australia, the major fishery is the succulent rock lobster, a creature that insists on warm habitats.

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With the warmness of the waters off the coast comes a second consequence — the fogs covering vast areas of ocean off the western sides of other continents do not occur off Western Australia. Even more important, if the warm waters of the Leeuwin Current were not there, it is quite likely that the winter rainfall of southern Western Australia, which comes with the westerly winds, would be substantially reduced.

Oceanographers have been puzzled for decades about this unusual current system; now two CSIRO oceanographers think they have solved the mystery, although much work remains to be done.

Early surprises

It's been known for many years that the flow patterns along the Western Australian coast are contrary. Early scientists couldn't distinguish any clear regularity in the observations of flow, but they did notice the lack of upwelling and the nutrient-poor waters. Particularly noticeable were occasional marked intrusions of warm, low-salinity tropical water into southern regions.

One observer in 1897 was surprised to see tropical marine fauna, including corals, around the Abrolhos Islands at 29°S, and now and again others would find tropical marine animals off Rottnest Island and sometimes as far south as the Great Australian Bight. Marine turtles normally found off Broome have even turned up on the western coast of Tasmania. It was noted that the waters off the shelf tended to be distinctly warmer than those next to the coast.

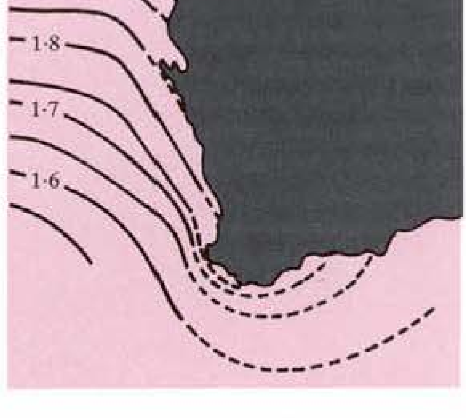
However, no identifiable current was recognized until recent times, when satellites came to the oceanographer's aid. Infra-red sensors revealed a warm tongue of water flowing south in a narrow (about 30-km) corridor just west of the continental shelf.

It originates near North-West Cape and travels towards Cape Leeuwin, the south-western tip of the State. (In 1622, the *Leeuwin* was the first Batavia-bound Dutch ship to explore into the Great Australian Bight after making its Australian landfall from South Africa.)

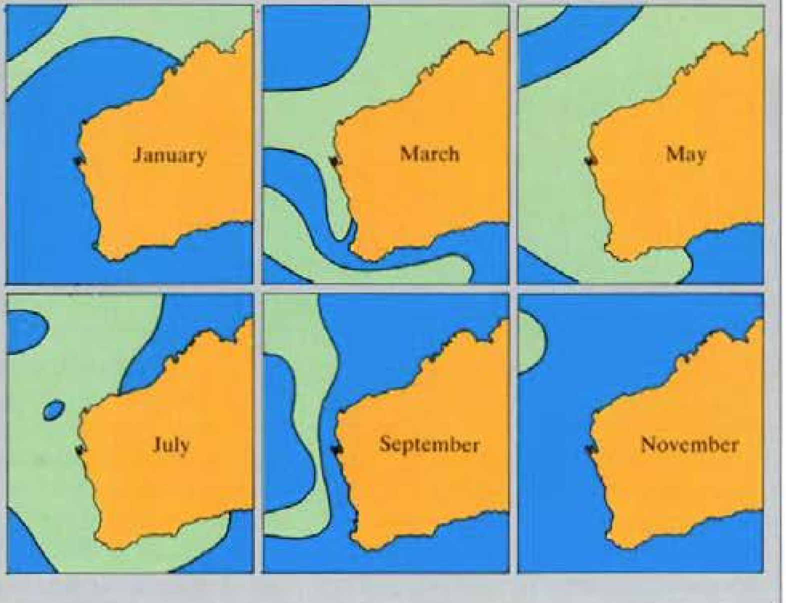
Oceanographers Dr George Cresswell and Mr Terry Golding, of CSIRO, named the flow the Leeuwin Current in 1980. It surges around Cape Leeuwin and into the Bight, ending a journey of some 2000 km in a knot of whirlpools.

What prevented navigators recognizing the current earlier was its narrowness, its seasonal character, and the surrounding vigorous eddies that camouflage it. Nevertheless, its strength is appreciable, with drifting buoys recording speeds of up to one metre per second.

The contour lines show the annual average height (in metres) of the sea surface, derived from temperature and salinity soundings, and referred to an arbitrary level. The Leeuwin Current apparently results from water running 'downhill' to the south.



The Leeuwin Current comes and goes



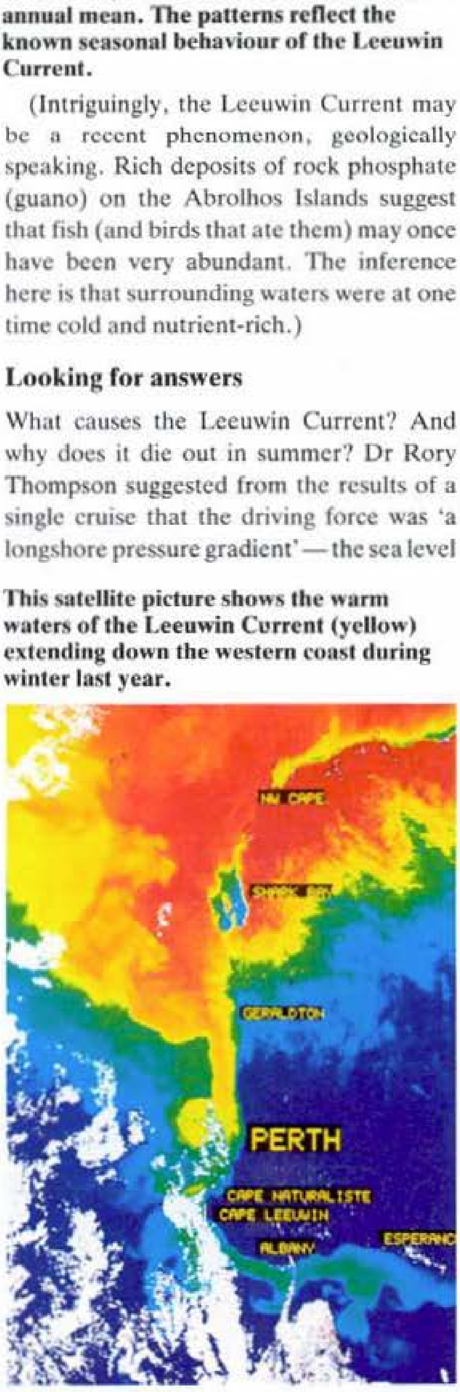
The green areas show, for the month concerned, where the sea level is above the annual mean. The patterns reflect the known seasonal behaviour of the Leeuwin Current.

(Intriguingly, the Leeuwin Current may be a recent phenomenon, geologically speaking. Rich deposits of rock phosphate (guano) on the Abrolhos Islands suggest that fish (and birds that ate them) may once have been very abundant. The inference here is that surrounding waters were at one time cold and nutrient-rich.)

Looking for answers

What causes the Leeuwin Current? And why does it die out in summer? Dr Rory Thompson suggested from the results of a single cruise that the driving force was 'a longshore pressure gradient' — the sea level drops by some 40–50 cm between North-West Cape and Cape Leeuwin and the Leeuwin Current literally 'falls down' the drop. (This drop has no analogue on the eastern sides of other oceans.)

This satellite picture shows the warm waters of the Leeuwin Current (yellow) extending down the western coast during winter last year.



Dr Stuart Godfrey and Mr Ken Ridgway, of the Division of Oceanography, have examined this idea further by working on records of all oceanographic cruises carried out off Western Australia. Their results showed that this sea-level drop varies strongly with the seasons, being greatest in May when the Leeuwin Current is strongest, thereby tending to confirm Dr Thompson's hypothesis.

(Oceanographers estimate sea level indirectly, using measurements of water density as a function of depth. When the water is warm and light, sea level stands higher than when it is cold and dense. Sea-level gradients of, say, 40 cm in 1000 km can be measured accurately using this technique.)

Dr Godfrey has advanced a somewhat controversial theory to explain why this longshore pressure gradient occurs along the Western Australian coast, but not along the eastern boundaries of other oceans. He suggests there may be an outpouring of perhaps ten million cubic metres per second from the Pacific Ocean through the deep channels between Indonesia's islands, into the 'South Equatorial Current' and then westwards at about 12°S across the Indian Ocean.

Because of the earth's rotation, sea level has to be higher on the southern side of this through-flow than on the northern side, which tends to raise sea levels off north-western Australia.

Dr Godfrey suggests that it is this bank of high water that drives the Leeuwin Current southwards — and that if a hypothetical wall were built across the channels from the Pacific to the Indian Ocean then Western Australia would revert to a normal, cold, fogbound, eastern ocean boundary.

The reason this idea is controversial is the size of the through-flow required: previous estimates were only one to three million cubic metres per second, and it is hard to understand how such a large flow of ten million cubic metres per second could have been missed by ships' navigators over the centuries.

However, substantial indirect evidence is accumulating to support Dr Godfrey's hypothesis, and he points out that the Leeuwin Current itself was not picked up by ships' navigators.

Only careful (and expensive) observations designed to measure accurately the Pacific–Indian through-flow will resolve this point. Some American researchers are formulating plans to install current meters in the Timor Sea region; if their plans come to fruition, they should settle the question of whether the through-flow indirectly causes the Leeuwin Current.

The wind's effects

But why does the Leeuwin Current vary so much through the year? The answer, it seems, lies with the blowing of the wind.

Dr Godfrey and Mr Ridgway examined the prevailing winds over all areas traversed by the Leeuwin Current. They conclude that monsoon winds in northern Australia cause autumn increases in the water heights off North-West Cape.

At the same time as this sea-level increase effectively doubles the Current's driving force, headwinds from the south slacken. As a result, the Current, which runs against the prevailing wind, reaches its maximum strength then.

More about the topic

The large-scale environment of the poleward-flowing Leeuwin Current, Western Australia: longshore steric height gradients, wind stresses and geostrophic flow. J.S. Godfrey and K.R. Ridgway. *Journal of Physical Oceanography*, 1985, **15** (in press).

The Sverdrup relation in the Indian Ocean, and the effect of Pacific–Indian Ocean through flow on Indian Ocean circulation and on the East Australian Current. J.S. Godfrey and T.J. Golding. *Journal of Physical Oceanography*, 1981, **11**, 771–9.

Observations of the Leeuwin Current off Western Australia. R.O.R.Y. Thompson. *Journal of Physical Oceanography*, 1984, **14**, 623–8.

Leeuwin Current revealed. *Ecos* No. 22, 1979, 21–2.