

## The Leeuwin Current - life of the West

*In the mid-1990's, Australian oceanographers participating in the World Ocean Circulation Experiment laid a trail of sophisticated ocean measuring instruments out from the shallows of the North West Shelf to depths of more than 4,000 metres.*

To be retrieved a year later by the CSIRO research vessel, Franklin, the instruments would contribute to a decade-long snapshot of the world's oceans but in particular add to the profile of one of the region's most dominant natural features - the Leeuwin Current.

Considerable research in the past four decades has clearly shown the contribution made by the Leeuwin Current to the life of Western Australia - from regional climate to fisheries and coastal development.

### The Current

The Leeuwin Current is a warm ocean current that flows strongly southwards along the Western Australian coast, before turning eastwards at Cape Leeuwin and continuing into the Great Australian Bight where its influence extends as far as Tasmania.

Its strength varies through the year, with the weakest southwards flow occurring from November to March when the winds tend to blow strongly northwards. The time of greatest flow is in the autumn and winter when the opposing winds are weakest.

Typical current speeds in the Leeuwin Current and its eddies are about 1 knot (50 cm/s), although speeds of 2 knots (1 m/s) are common, and the highest speed ever recorded by a drifting satellite-tracked buoy was 3.5 knots. The Leeuwin Current is about 300 m deep (quite shallow for a major current system, by global standards),

and beneath it is a northwards countercurrent called the Leeuwin Undercurrent.

The Leeuwin Current is quite different from the cool, northward flowing currents found along the southwest African Coast (the Benguela Current) and the long Chile-Peru Coast (the Humboldt Current), where upwelling of cool nutrient-rich waters from below the surface results in some of the most productive fisheries.

Because of the Leeuwin Current, the continental shelf waters of Western Australia are warmer in winter than the corresponding regions off southern Africa and Chile in summer. The Leeuwin Current is also responsible for the presence of true corals at the Abrolhos Islands and the transport of tropical marine species down the west coast and across into the Great Australian Bight.

The 'core' of the Leeuwin Current can generally be detected as a peak in the surface temperature with a strong temperature decrease further offshore. The surface temperature difference across the Current is about 1°C at North West Cape, 2° to 3° at Fremantle and can be over 4° off Albany in the Great Australian Bight. The current frequently breaks out to sea, forming both clockwise and anti-clockwise eddies.

The Leeuwin Current is also known to be influenced by El Niño conditions, with slightly lower sea levels along the Western Australian coast and a weaker Leeuwin Current.



*Satellite images of water temperature for the southwestern coast reveal the main ocean currents in the vicinity of Geographe Bay (courtesy of the Western Australian Satellite Technology and Applications Consortium, WASTAC). The southward-flowing Leeuwin Current (warmest water shown in red/orange, with red arrows) and the cool Capes Current (shown in blue, with blue arrows) represent the summer situation. Close inshore, the water is warmed (red) by atmospheric heating.*

### History

A century ago during a study of marine life of the Abrolhos Islands (29°S), a naturalist, William Saville-Kent, suspected that there was probably a warm southward-flowing current off Western Australia and not the expected cool northward current as those near southern Africa and South America. He based his view on observations of warm waters and tropical marine flora and fauna around the Abrolhos Islands.

Subsequent reports by fishers and scientists noted the presence of southerly currents. It was only with the advent of satellite technology in the 1970's that the existence of the southward current was finally confirmed.

During the 1970's, drifting buoys and satellite images conclusively showed a warm tropical current flowing down the West Australian coast and around Cape Leeuwin. It was named the Leeuwin Current by researchers George Cresswell and Terry Golding. The name was sourced from the Dutch merchant ship Leeuwin, meaning Lioness, which explored the south west coast of Western Australia in 1622 and was one of numerous Dutch vessels which explored coastal waters and islands of the West Coast.

Scientists working with environmental and fisheries agencies, WA universities and CSIRO have an on-going monitoring program using satellite sea surface temperature and sea surface height instruments, drifting buoys, weekly shipboard sampling and moored measurement instruments, including tide gauges. Additional measurements are being obtained by remote sensing and shipboard sampling of phytoplankton that provides the base of the marine food chain.

### **Profile of a Current**

The source of the Leeuwin Current is north of North West Cape, extending from where a system of ocean currents drain the Pacific Ocean to the Indian Ocean through the Indonesian Archipelago.

Measurements across the broad continental shelf at North West Cape confirm the low-salinity Leeuwin flows along the outer North West Shelf most strongly between February and June. Strong winds to the northeast along the shelf can retard or even reverse the currents.

From North West Cape south, the Leeuwin Current is identifiable in the satellite images as a jet-like stream of warm water flowing southwards

along the edge of the continental shelf at about the 200 metre depth line. However, it periodically meanders offshore in the form of large loops and eddies which can carry the warm tropical waters over 200 kilometres away from the coast. Three or four of these 'waves' can be present at any time between Exmouth and Cape Leeuwin.

Where the continental shelf narrows along the Ningaloo Coast, the Current can be as little as 10 km off the coast. Current speeds here average between 0.5 and 1 knot.

### **From Shark Bay to Fremantle**

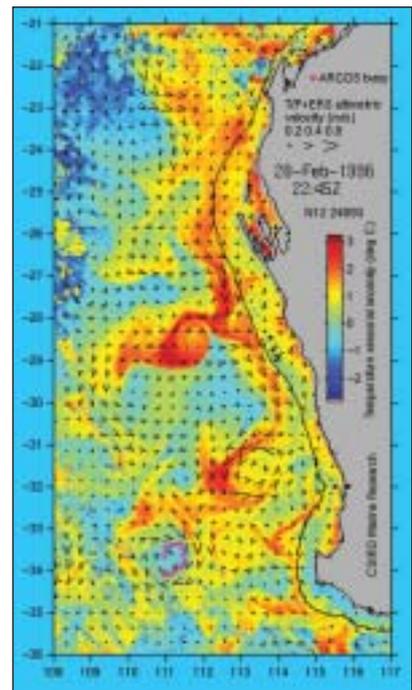
The Houtman Abrolhos Islands, situated near the edge of the continental shelf off Geraldton, are the southern-most true reef building corals in the Indian Ocean, partly because of the influence of the tropical waters of the Leeuwin Current.

Because the Leeuwin Current tends to flow along the 100-fathom line, it is generally close to the chain of islands. The strongest southward currents of up to 1.5 knots are, in fact, encountered just beyond the 100-fathom line between February and August, and the flow is weaker and more variable in direction between September and January. Large current meanders and eddies feature prominently in this area. As meanders develop and carry the warm water away from the coast, cooler offshore water can be drawn in against the shelf resulting in northward currents off the islands. Below about 250 metre depth there is often a northwards undercurrent with speeds of up to 1/3 knot.

Throughout the year there can be current reversals resulting largely from changes in the winds. The Leeuwin Current rarely flows around the eastern side of Rottnest, but it frequently bathes the western and southwestern sides, influencing the flora and fauna there. Sea temperatures in those regions in winter are several degrees higher than against the mainland coast.

### **Cape Naturaliste to Cape Leeuwin**

When the Leeuwin Current is flowing strongly during the winter months, it tends to move onto the continental shelf as it approaches Cape Naturaliste. It general flows close inshore down to Cape Leeuwin and then eastwards towards the Great Australian Bight. In late spring, however, it moves a little offshore to be replaced by a cool northwards counter-current, recently named the Capes Current. This in turn dies away in about March/April as the strengthening Leeuwin Current moves inshore again. Currents measured across the continental shelf off Cape Mentelle (34°S) show the highest speeds are almost two knots near the 100-fathom line, with weaker and more variable currents nearer the coast.



*Data from two satellite instruments is used in constructing this image of the Leeuwin Current. Sea surface temperature information comes from the US NOAA 14 satellite while the surface current velocity is derived from sea level measurements made by the satellite-borne altimeter. Sea level data from the US/French Topex/Poseidon and European ERS altimeters are combined with coastal tide gauge data to make this velocity map. To see many more images like this one, go to [www.marine.csiro.au/~griffin/WACD/](http://www.marine.csiro.au/~griffin/WACD/)*

## Cape Leeuwin into the Great Australian Bight

After rounding Cape Leeuwin, the Leeuwin Current generally flows along the outer continental shelf in its passage eastwards, at least as far as Cape Pasley near 124°E). From about this longitude, it tends to move offshore again because of the distinct northwards kink in the coastline. As on the west coast, large offshoots or meanders can carry the warm water over 100 kilometres offshore.

Frequent reversals to westward flow occur during the summer months. There can be eastward currents exceeding 3 knots in the core of the Leeuwin Current just off the continental shelf.

### Influence on marine life

Because of the tropical Leeuwin Current, the coastal waters are relatively nutrient-poor and the fisheries are correspondingly different. The Leeuwin Current therefore has an important influence on both the climate and the marine ecosystem off Western Australia, and is responsible for the presence of tropical marine organisms off the west and south coasts much further south than would otherwise be expected. It plays a major role in the life histories of (for example) the southern bluefin tuna, the western rock lobster and a number of our State's coastal commercial fisheries (including salmon).

### Rock Lobsters

Collaborative studies between CSIRO and Fisheries Western Australia during the past 30 years have confirmed the link between ocean circulation and lobster recruitment. Partially-funded by the Fisheries Research and Development Corporation and providing an aid to management, scientists have modelled surface circulation patterns to explain the variability from year to year of lobster recruitment.

Following hatching near the edge of the continental shelf in summer, millions of early-stage lobster larvae rise to the ocean surface and are

transported offshore by surface wind-driven currents. Ocean sampling from research vessels in the 1970's showed that the larvae spend the next 8 - 10 months drifting in the open ocean, as far as 1,000 kilometres from the coast. By late winter and early spring the puerulus are carried by ocean currents back to the continental shelf and inshore coastal regions.

Earlier studies have shown that settlement of lobster puerulus (small but recognisable rock lobsters) is closely linked with variations in the strength of the Leeuwin Current, which in turn is associated with El Niño - Southern Oscillation (ENSO) events as well as westerly winds.

During ENSO years, when the Leeuwin Current tends to be weak, puerulus settlement is poor. In so-called La Niña years, on the other hand, the Current tends to flow more strongly and settlement is much greater.

Satellite sensors can measure undulations in the ocean surface, of as little as 30 cm over tens of

kilometres. Although small, these 'lumps' indicate the presence of a warm-water current such as the Leeuwin. This data is simulated by scientists to trace the movement of the larvae.

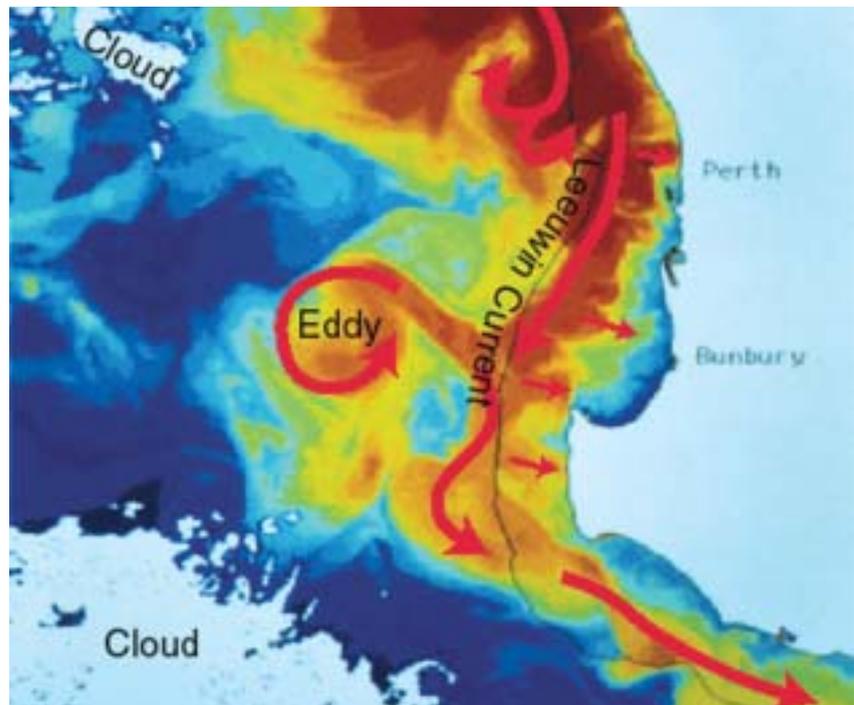
Early results of this lobster larvae simulation show that larger anti-clockwise eddies help larvae remain off south western Australia, rather than being swept away to the south, often by being temporarily trapped in the cool clockwise eddies.

### Other species

WA Fisheries marine biologists have made a clear association between the strength of the Leeuwin Current and the transport of pilchards (sardines) early life-history stages on the south coast region near Albany.

Data on the fishery shows a significant negative relationship between the abundance of two-year fish with the strength of the Leeuwin Current, measured two years previously during the fishes' spawning period.

Whitebait also appears to be affected by variations in the Leeuwin Current.



*September: In winter, the Capes Current is not flowing, and the strong Leeuwin Current floods across the continental shelf to the coast. Note the large eddies and offshoots extending westwards, as well as the tongues of warm water pushing onto the continental shelf towards the coast. The shallow water in Geographe Bay is cool (blue) because of heat loss to the atmosphere.*

A strong relationship exists between the annual catch variations and the strength of the Leeuwin Current during the previous year when spawning occurred. Thus, the stronger the Leeuwin Current, the greater the relative catch of whitebait in the following year.

The abundance of juvenile Australian salmon in South Australia is linked to the Leeuwin Current. Fluctuations in recruitment/catches of the west coast salmon fishery may also be associated with variations in the strengths of the Capes Current and the Leeuwin Current - when the Leeuwin Current is flowing strongly and warmer waters penetrate onto the continental shelf, it is thought that the fish may simply migrate offshore into deeper cooler waters rather than continue to migrate around the coast.

### **Inshore Currents**

Along the inner continental shelf (and inshore of the Leeuwin Current), the currents tend to be more influenced by the wind and so change direction seasonally. Because of the generally northwards winds which blow along the west coast during the summer months, there appears to be a "chain" of northwards countercurrents between say October and about March, while in winter when the Leeuwin Current is flowing strongly the coastal currents tend to flow southwards. While the summer countercurrents may be fairly continuous right along the coast, they are probably still generated by local winds and so have been given different local names.

The Capes Current commences near Cape Leeuwin and flows northwards past Cape Naturaliste and on beyond Rottnest Island; there is often an upwelling region in the lee of Rottnest Island. Similarly, a

summer countercurrent (the Ningaloo Current) has recently been identified along the Ningaloo Reef, and similar countercurrents are known to exist inshore of the Abrolhos Islands. Few current speed measurements have been made in these areas, although measurements near Perth and the Abrolhos Islands suggest mean currents of 10 to 20 cm/s and peak speeds of about 50 cm/s (1 knot), and there are frequent changes between northerly and southerly flows in sympathy with changing weather patterns.

### **Future Research**

Continued ocean observations and monitoring will allow scientists to build on one of the best-established foundations linking physical and biological conditions in the ocean with benefits for the management of sustainable fisheries and an improved understanding of the marine ecosystem.

#### **Further information: [www.marine.csiro.au](http://www.marine.csiro.au)**

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(North West Shelf Study - [www.marine.csiro.au/nwsjems/index.html](http://www.marine.csiro.au/nwsjems/index.html))

#### **Other information sources:**

"Lumps in the Leeuwin Current". Article by Alan Pearce, David Griffin (CSIRO), John Wilkin (NIWA), Nick Caputi, Chris Chubb (Fisheries WA) - Western Fisheries (Winter 2000).

"The Leeuwin Current - Yachtsman's Friend and Foe?" by Alan Pearce and George Cresswell, a chapter in Western Australian Cruising - A Yachting Guide, by Ross Brown (1997)

"Our fickle salmon fisheries" By Alan Pearce (CSIRO Marine Research) and Gabrielle Nowara, Suzy Ayvazian & Rod Lenanton (Fisheries WA) Article for the Busselton-Dunsborough Mail, March 2001

#### **Acknowledgments**

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