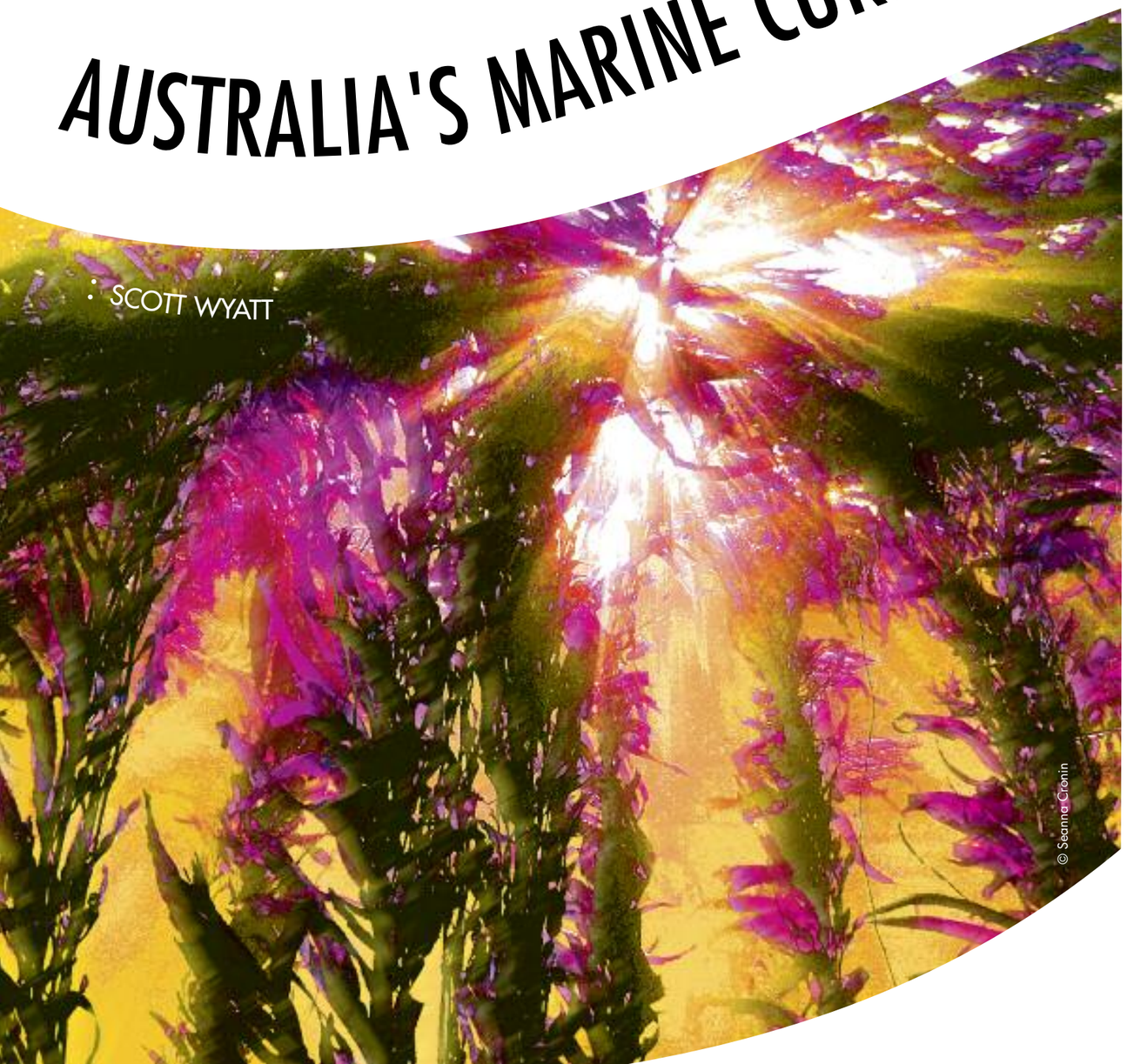
AUSTRALIA'S MARINE CURRENTS AND HOW THEY'RE CHANGING



: SCOTT WYATT

> I'VE ALWAYS BEEN CAPTIVATED BY GREAT FORCES OF NATURE – ERUPTING VOLCANOES, VIOLENT ELECTRICAL STORMS – THAT KIND OF THING.
IT'S NO SURPRISE THEN, THAT BEING PERCHED SPIDER MAN-LIKE ON A BOMMIE NEAR MILNE BAY IN PAPUA NEW GUINEA WATCHING THE BUBBLES OF THE DIVER ABOVE ME BEING SWEPT BENEATH ME WAS A RATHER GRATIFYING – IF WHITE-KNUCKLE – EXPERIENCE.

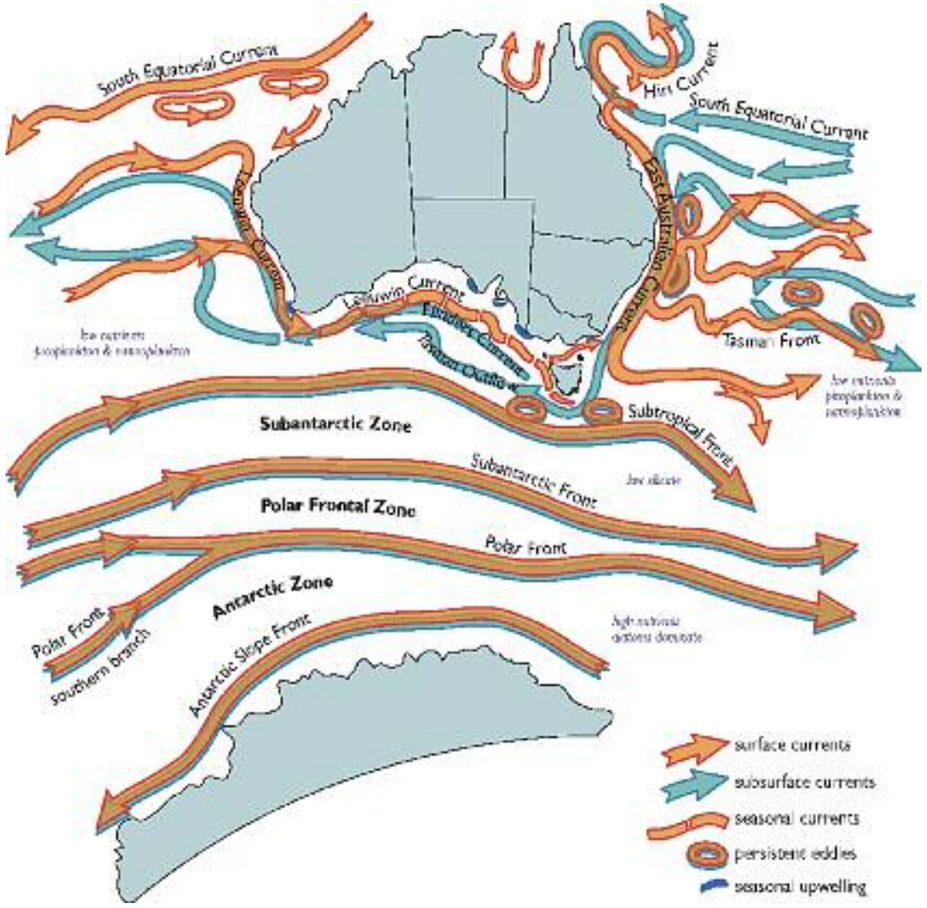
In a similar vein, every May my local dive club braves the John Young Banks off the New South Wales coast, near Jervis Bay – a serious, current-swept site. In 2009 our first day's diving was abandoned outright owing to the maelstrom beneath: despite the reef rising to around 20 metres at its shallowest, the current was boiling over the top, making even descending near impossible. Some of us made it down on the second day, but decompressing on the anchor line I did have cause to worry that the water ripping past heading for Tasmania might just filch my mask. During this almost therapeutic buffeting, I also mused that our oceans aren't static isolated bodies of water, but are pulsing, swirling and circulating with an energy and in volumes we can scarcely conceive.

Besides the tides, water movement around the oceans is driven by two major factors:
1. Wind
2. density differences arising from variations in the sea's saltiness and temperature. The Earth's spin also plays a crucial role through the Coriolis effect. Ocean currents, like the weather above, disperse the heat energy from the tropics towards the Poles. Currents affect how the earth's climate will respond to rising greenhouse gas levels, and themselves change as the planet warms and cools. In fact, the top few metres of the oceans contain more heat than the entire atmosphere. Ocean currents matter – they are an integral component of the earth's climate system and a key element in the distribution and abundance of life on earth. Some of the world's most productive fisheries are underpinned by upwellings bringing nutrients into the sunlit zone where phytoplankton grow. And the life cycle and dispersal of many a marine critter hinges on catching a lift on some current or other.

BUSY COASTLINES
Australia is essentially bounded by two important currents. The Leeuwin Current runs southwards down the coast of Western Australia and hooks under the south of the continent towards Tasmania. As its name suggests, the East Australia Current (EAC) runs down the east coast.

The EAC has its origins in the tropical Pacific's southeasterly trade winds, which drive the South Equatorial Current westwards. Part of this current hits the Australian coast from just north of Cooktown to just south of Townsville, and splits to form the Hiri Current which heads north, and the EAC to the south (see diagram). The EAC then splits again midway down the New South Wales coast to form the Tasman Front, which meanders into the Tasman Sea and is one of the reasons you'll find a flourishing coral reef at Lord Howe Island – the world's most southerly. The rest of the EAC keeps heading towards Tasmania.

There's very strong evidence that the EAC has strengthened, bringing warmer, saltier water some 350 kilometres further south over the last 60 years. Ozone layer depletion affects wind patterns and is thought to be one ultimate cause of the stronger EAC. Furthermore, scientists from CSIRO are moderately



confidant that the current will strengthen further under climate change – up another 20% by 2100.

To the south of Australia, lies the eastward flowing Antarctic Circumpolar Current. This monster stretches right down to the sea floor and connects the major ocean basins in the south. A part of the Antarctic Circumpolar Current collides with southern Patagonia and heads north, generating the Humboldt Current up the west coast of South America. Once this reaches the tropics, the southeast trade winds push the water westward towards Queensland, and the cycle begins again. These great circular systems or 'gyres' are replicated throughout the world's oceans in the two hemispheres.

SO MUCH WE DON'T KNOW...

In flowing polewards, the Leeuwin is unusual for an eastern ocean basin boundary current and its origins are still being investigated. Sea water density differences generate an enormous, deep, global cycling of the oceans, sometimes called the Great Ocean Conveyor, which takes about one thousand years to turnover. Part of this exchange, along with other climatic factors, delivers water in a southwestward direction through the Indonesian archipelago, and this phenomenon, known as the Indonesian Throughflow, is part of the Leeuwin's story. However, CSIRO's Ken Ridgway and his colleagues have now discovered that seasonal winds 'pile' water up in the southeast of the Gulf of Carpentaria; this water then sloshes back as the winds abate, acting as a further driver of this non-conformist current.

The array of tools and measures being employed to piece together ocean currents is impressive. Satellites record variables like sea surface temperature, and satellite altimetry can record sea surface slope (the sea is not flat) to within one centimetre from a thousand kilometres in space. Ordinary commercial vessels, or 'ships of opportunity', provide physical and biological samples while under way and dedicated moorings, autonomous underwater vehicles and gliders sample variables like water velocity, chlorophyll, oxygen, salinity and turbidity. And thousands of Argo floats have been deployed around the world by 24 countries. These ingenious, self-operating devices last around five years. Once released, they're programmed to sink to 1000 metres, drift for nine days, then sink to 2000 metres, then rise continuously while taking measurements. Data is uploaded via satellite before the next cycle.

In spite of a growing body of knowledge, considerable gaps in our understanding of currents remain. In contrast to a likely additional strengthening of the EAC, the Leeuwin Current might weaken under climate change, but scientists are less confident about changes in the Leeuwin than in the EAC. Of course, the Leeuwin is a different beast anyway, illustrated by the fact that it is strongest in winter, whereas the EAC hits its peak in summer.

WHAT BRINGS YOU HERE?

Many marine organisms, including plenty of fishes, disperse during a mobile planktonic larval stage. The EAC's enormous footprint means that tropical and sub-tropical species appear much further south than you might otherwise expect. In fact, summer and autumn dives on the New South Wales south coast will often reveal fishes, especially juveniles, you'd be more accustomed to seeing in the likes of the Solomon Islands, Papua New Guinea or the Great Barrier Reef. Species such as cleaner wrasse, butterfly fish, Moorish idols, yellow box fish and others commonly turn up. I've occasionally been flummoxed, unable to identify a fish using a southern Australia field guide, only to find it immediately in one covering the tropical Indo-Pacific!

Warming waters and a stronger EAC will see the ranges of some tropical and sub-tropical fishes pushing southwards. That's assuming that the fishes' other physical and biological requirements are met. In work published this year, ecologists Will Figuera and David Booth have been exploring just this question. As might be expected, winter temperatures represent a barrier to southward range extension of fishes more used to tropical climes, but the incidence of overwinter survival has certainly increased at some study sites, and it's logical that we may see even more tropicals turning up well out of the tropics, and even persisting if winter temperatures rise over time.

THE IMPACTS OF OCEANIC CURRENTS

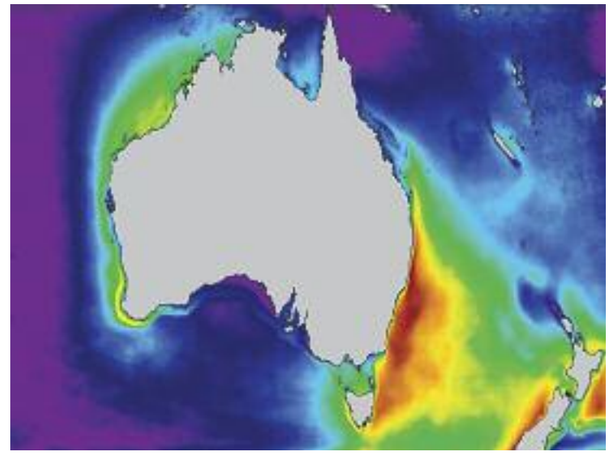
UNDERWATER FORESTS

A stronger EAC, against a background of rising sea surface temperatures has led to pronounced warming off south-east Tasmania and this is affecting the island's *Macrocystis pyrifera* kelp forests. The warmer waters and strengthening current has seen the establishment of the habitat-modifying sea urchin *Centrostephanus rodgersi* in Tasmania from New South Wales. First detected in 1978, the range of this sea urchin in Tasmania has been ever encroaching onto previously kelp-dominated reef. On top of the expansion of this new rapacious herbivore, the warmer, nutrient poor waters are in themselves not favoured by the kelp. There are still some great areas of giant kelp to see, but at a fraction of their former range.

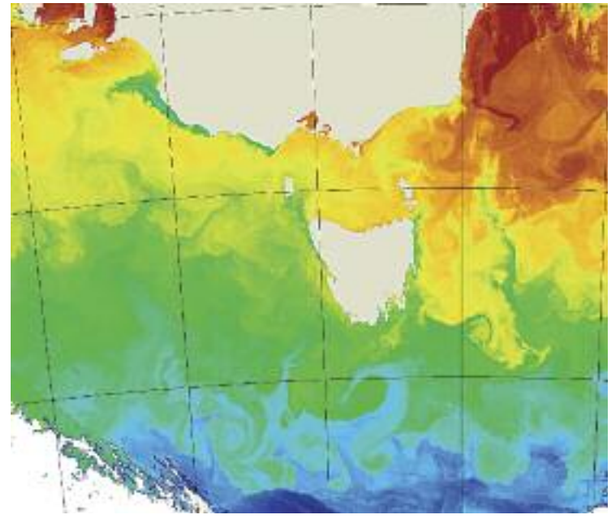
I was determined to take the opportunity to have a look at some of the remaining kelp beds during a recent Tassie jaunt. A bracing onshore wind made for less than ideal conditions for a long surface swim into the middle of Fortescue Bay, but finning into a 'wall' of kelp at 18 metres is really quite something. The sheer mass of the stuff brought home why, growing up to 50 centimetres a day, this kelp ecosystem is around 100 times more productive than the urchin barrens replacing them.

Clearly, important ecosystems may be affected by changes in both current systems. Notably, Australia's most valuable catch, the western rock lobster *Panulirus cygnus* is an animal whose recruitment is intimately linked to the vagaries of the Leeuwin Current.

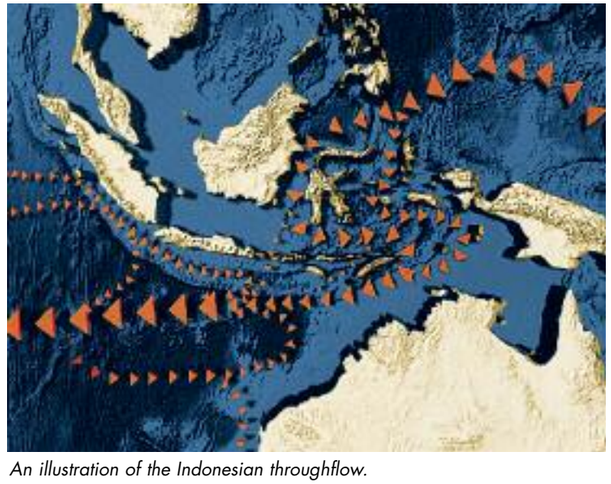
Lastly, it's important to point out that the EAC and Leeuwin Current alike are highly variable across



The deviation from what you'd 'expect' sea surface temperature to be for a given latitude, averaged for the year. Both the Leeuwin and EAC are strikingly clear, although the EAC typically carries four times the volume of water than the Leeuwin.



Warm waters off the east coast of Tasmania, brought down with the EAC.



An illustration of the Indonesian throughflow.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space and time. Both also spin off large eddies. These can be up to 300 kilometres across, last for over a year, and have a cold or warm core depending on which way they rotate. And eddy formation isn't just interesting from an esoteric oceanographic point of view. They might offer an explanation when you're diving around Montague Island off the south coast of New South Wales in late summer and you find your 5mm is offering little protection against the 12 degree water temperature...

Back in Tasmania, as I navigated my way to the boat ramp along the kelp gardens and sands on the bottom of Fortescue Bay, I couldn't help but think of a comment Dr Ridgway had made to me. The Tasman Peninsula, where I was diving, marks the point where the signature of both the EAC and Leeuwin can be detected – remarkable stuff.

Top: A weedy seadragon commonly found in Tasmania's kelp forests
Left: Macrocystis pyrifera

ABOUT THE AUTHOR
Scott Wyatt works as an Environment, Energy, Fisheries and Forestry Advisor with the Delegation of the European Union in Canberra. He has dived extensively throughout the Indo-Pacific and is an experienced writer. His writing aims to inspire others about nature and conservation, and to communicate interesting and often complex contemporary research in an engaging way.

All diagrams and maps used in this article were provided by the CSIRO.
>For more information on Australia's ocean currents visit: www.csiro.au/resources/AustralasianOceanCurrents.htm