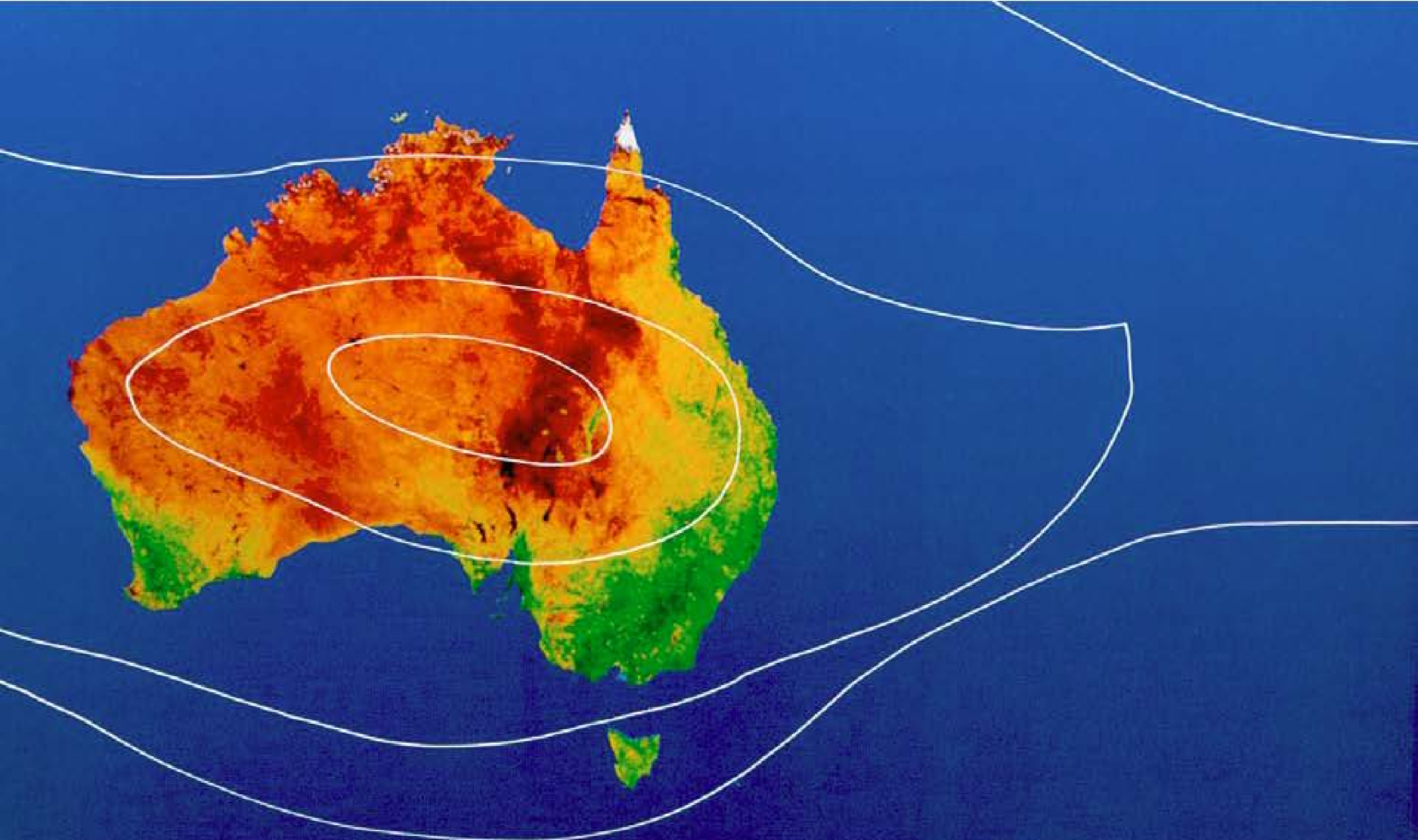


Getting drier in the WEST

Rainfall in Western Australia's south-west has declined substantially in the past 60 years; researchers are trying to find out why

The winter of 1930 was a dismal time in Western Australia. Even the weather seemed to suit the economic climate of the day. Throughout the months of June, July and August — as the unemployed of Perth gathered in street-side soup queues — it barely stopped raining. While 671 mm of rain (well above the winter average) fell, and the jobless thousands pondered the scarcities of life, the city's meteorologists no doubt pondered its plenitudes.

More than 60 years later, the meteorologists are still pondering Perth's weather, and with good reason. At a recent international drought conference in Melbourne, Dr Rob Allan of the Climate Impact Group at CSIRO's Division of Atmospheric Research sat listening to an American expert describing the decades-long drought in the African Sahel as a unique meteorological phenomenon. Feeling like a schoolboy with the answers to next week's exam, he resisted the temptation to put up his hand to tell the audience about the south-west of Western Australia, where the winter rainfall has been in decline for more than half a century.

A huge section of the State's south-west, midlands and southern regions — about 300 000 sq. km in area, from north of Geraldton to Albany in the south and extending east to Esperance — has steadily become drier. Since 1930, the average winter (June, July and August) rainfall over this region has dropped from 120 mm to 94 mm, a decrease of 22%. The decline has been greatest in districts north and north-east of Perth, especially near the port of Geraldton. In these areas, records show a decrease in winter rain of 4·8% per decade for the years 1913 to 1986, equal to a drop of one-third over the whole period.

What could possibly cause such significant changes in rainfall? The global climatic patterns of pressure and wind and cloud formation are based on short-lived atmospheric phenomena that live and die usually in the course of weeks and occasionally months. The idea that a weather trend might last for decades is baffling. Climatologists believe such long-term phenomena result from the interactions between the atmosphere and the ocean — which acts as a 'long-term memory' of climate. The dynamics of these interactions are yet to be resolved.

Low water in Wellington Dam near Collie.

A rainstorm in the south-west; Western Australians will be keeping a close eye on future winter rainfall trends.

Reduced rainfall may increase pressure on underground water supplies.

Photos: Bill van Aken

The need to know what is happening with rainfall in Western Australia's south-west is fairly obvious: the State's agricultural industries depend on rain, almost all of which falls in the months from May to October. The areas affected by the decline comprise about one-fifth of the nation's cropland and pastures with produce worth more than $3 billion a year.

Changes in agricultural technology and the introduction of new crops (such as lupins) make it difficult to assess whether the drier conditions experienced since the 1930s have already affected farming in the region. The State Department of Agriculture suspects not, at this stage, as the worst-affected areas tend to be on the coast where rainfall is highest. But what of the future? If the trend continues, and millions of hectares of improved pastures in the south-west receive less and less rain each decade, could the farmers continue to adjust their practices, move on to new crops and stay profitable?

Metropolitan and regional water supplies are at risk. Perth has a precarious water supply, partly due to its sandy soils. As the ground has little water-retaining capacity, much of the city's water is used to keep its lawns and gardens alive. At present, existing catchments can provide only 60% of Perth's water supply (the rest comes from the underground aquifers of the coastal plain), and new dams will be needed in the near future. The number of dams required in 50 years' time and their capacity will depend on average rainfall.

A recent statistical analysis of local rainfall history by Dr Henry Allison and Dr Greg Davis, at the CSIRO Division of Water Resources, indicates a decline in Perth's annual rainfall in the second half of the century. The researchers believe they have identified a 22-year cycle in Perth rainfall — possibly linked to the well-established 11-year solar cycle that controls sunspot activity — and suggest the city may experience a reduction in winter rainfall during the next decade. If the prediction is correct, then it is imperative policy-makers do not underestimate the city's future water storage needs.

Environmental planning issues are also at stake. The State's south-west has a rich plant life — more than 3600 native species have been described, of which it is estimated at least 70% occur nowhere else.

Dr Allan and Mr Malcolm Haylock (also in the Climate Impact Group) are trying to pinpoint the physical cause of the south-west's rainfall deficiency by studying regional atmospheric and ocean circulation features. In their work to date, they have identified at least two major atmospheric factors: a change in the extent and intensity of the winter high-pressure cells over the centre of the Australian continent; and a change in the location of the semi-permanent trough or elongated area of low pressure in the Southern Ocean to the south-west of Australia. They are also investigating a possible link with the current of warm water (known as the Leeuwin Current) that runs south along the Western Australian coast.

Plausibly, the decline in rainfall may be due to one or more of three possible causes: natural long-term variations in the climatic system governing rainfall in that region; a random fluctuation in rainfall patterns; and climatic change resulting from global warming or the enhanced greenhouse effect. As evidence of the global warming currently represents the elusive Holy Grail of climate research, it is not surprising that Dr Allan and others have closely considered this possibility. If the deficiency is due to natural long-term variations, then it should be predictable and possibly forms part of a quasi-regular pattern. If it's a random event, then rainfall (already a notoriously capricious phenomenon) is even less predictable than scientists currently believe.

In order to examine the possible impact of the enhanced greenhouse effect, the researchers had to look at long-term records — preferably extending back in time to when the concentration of greenhouse gases in the atmosphere was significantly lower than today. With the assistance of the Bureau of Meteorology, the two assembled monthly rainfall readings from weather stations throughout the south-west for the past 115 years. Combining the data, they confirmed the decline in regional rainfall since the 1930s (see the graph), but also found evidence suggesting that a similar period of declining rainfall occurred late last century.

Finding a cause behind these two declines (if they were indeed related) meant the researchers initially had to establish a correlation between the long-term rainfall data and other meteorological data that had been gathered for over a century. It didn't take long. As Dr Allan had previously worked on the El Niño phenomenon using long-term air-pressure data, it was easy to look first at trends in mean sea-level pressure at Perth.

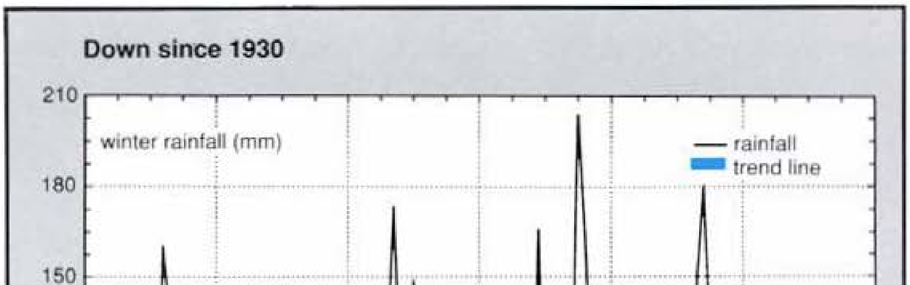
Before long the data revealed a possible link — a strong inverse relationship between south-western rainfall and the monthly average air pressure at sea level in Perth during the months of June, July and August. The most striking feature is that the air-pressure data display periods of up to a decade of high or low values, and a marked upward trend since the 1960s, mirroring the period of steepest decline in local winter rainfall. Later work showed a statistically significant link between south-western rainfall and mean sea-level pressures over much of the Australian continent, particularly in the south and south-west.

To better understand the processes involved, the scientists constructed maps using sea-level air-pressure data selected to accentuate the differences between years of high and low rainfall. During 'wet' years (see the maps), the region of high pressure or anticyclone centred over much of the continent weakens and contracts eastwards to central and southern Australia, while the semi-permanent low pressure trough to the south-southwest of Western Australia becomes less intense. The opposite occurs during 'dry' years. Other studies of the Southern Hemisphere using weather balloons suggest a similar relationship applies at an altitude of about 5·5 km. Further analysis of pressure patterns over the Australasian region shows that anomalous or unusual westerly air flows occur over south-western Australia during 'wet' years, mirrored by anomalous easterly air flows during 'dry' ones.

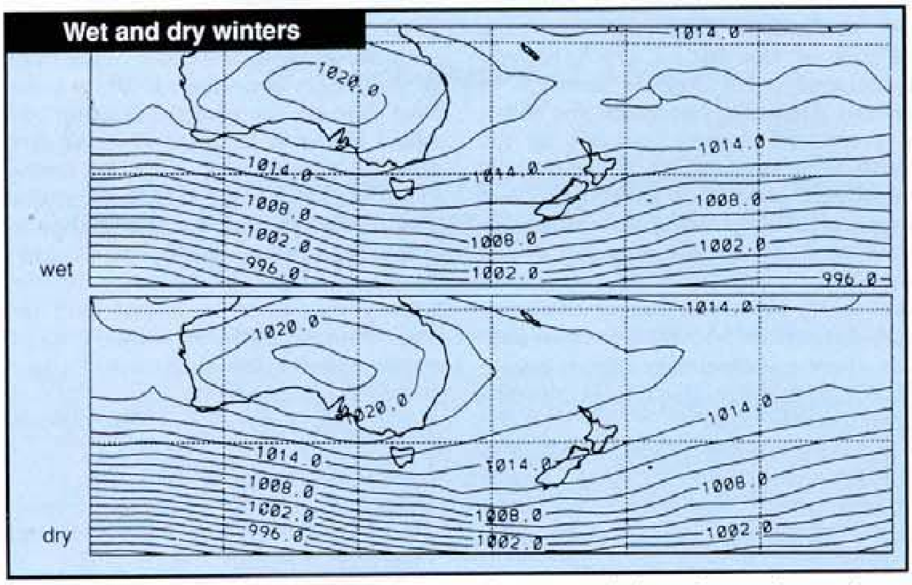
The findings give some indication of what happens when winter rainfall is below average. During these years, it appears the anti-cyclone expands westwards to cover much of Western Australia (hence the higher air pressure in Perth), pushing the trough centred over the Southern Ocean further south. As this trough (more properly known as a long-wave trough) has a major influence on the activity of cold fronts passing over the southern margin of the continent, its position and intensity affect rainfall here. In the 'dry' years, the trough has a lower air pressure and is at a higher latitude than average, diverting the path of the cold fronts southward. In 'wet' years, when the opposite occurs, the fronts can penetrate further north, where they bring rain to south-western Australia.

Air-pressure data obtained from Antarctica appear to confirm the link. Mean sea-level pressure readings from weather stations on the Antarctic coast (from Halley Bay to Dumont d'Urville) show that the trough has maintained its position near Casey station (at 110·5°W) since at least 1957, varying only in intensity. During 1966–71 and again in 1975–89, it became more intense (lower air pressure), broadly coinciding with drier episodes in the Australian winter.

While the relationship between the rainfall deficiency and atmospheric



Winter (June, July and August) rainfall trends in Western Australia's south-west.



Compared with wet winters, dry ones show an expansion of the high over central Australia and southward movement of the low pressure trough over the Southern Ocean. The maps show composite pressure patterns (pressures in hectopascals) for six relatively wet years and eleven relatively dry ones since 1950.

circulation patterns such as the long-wave trough is an important piece of scientific evidence, scientists are still trying to understand why such patterns may persist for decades and then quickly change. Research examining a possible link between the rainfall changes and the enhanced greenhouse effect has been inconclusive.

A CSIRO-developed computer model of global circulation has been used to simulate pressure changes over a 10-year period, at the current atmospheric CO_2 concentration and at double the current concentration. The computer simulation has to date only poorly matched observed changes in pressure fields, so the model, until it is improved, cannot be considered a reliable guide to what may happen to rainfall in the region as greenhouse gases accumulate.

Evidence of a link between rainfall and the climatic influence of the warm Leeuwin Current running south along the margin of the Western Australian continental shelf looks promising, although the researchers suspect the relationship may be relatively localised and not the driving force behind the decades-long trends in pressure and rainfall.

Tropical cyclones — an ENSO link

Cyclones are a mixed blessing for Western Australia's north-west, as they are in coastal areas of the Northern Territory and northern Queensland. Two or three times a year, during the tropical wet season from November to May, these violent and destructive storms form over warm water in the Timor Sea and quickly head south-west towards the Western Australian coast between Onslow and Broome. 'The Great Blow' of 1887 took 140 lives, and more lives have been lost since.

Some cyclones fade away while well to sea, but most (about two-thirds) head inland, accompanied by winds of up to 200 km per hour, occasionally wreaking havoc on the towns of the north-west. Industrial stoppages due to cyclone activity near mining operations and off-shore oil and gas facilities are also costly. However, despite the threat they present to the people of the Pilbara and surrounding regions, cyclones are generally beneficial, because of the heavy rain they usually bring to the parched sheep and cattle stations. Without them, the north-west's pastoral industry would scarcely be viable.

Knowing, then, how often tropical cyclones are likely to form and what path they may follow is valuable information. Those off the Western Australian coast chiefly result from large regions of low pressure in the tropics — known as monsoon troughs — where the prevailing winds favour cyclonic activity. Within a trough, the heat from the surface of a warm sea and an inflow of moist air can combine to form a tropical cyclone, where the creation of towering clouds releases tremendous amounts of energy into the atmosphere.

The reason many cyclones may form one year and not the next appears to be linked with the El Niño–Southern Oscillation (ENSO) phenomenon, which is recognised as a strong factor in climatic variability from year to year. In years when ENSO is active, summertime sea surface temperatures north-west of Australia are unusually high, encouraging cyclone development. During years when the opposite is occurring — anti-ENSO events — cyclone activity is suppressed.

In an effort to better understand the dynamic relationships between ENSO and tropical cyclone activity, Dr Jenni Evans and Dr Robert Allan, of CSIRO's Division of Atmospheric Research, have compared wind data during January and February (the months of the Australian summer monsoon) between different years. They found more tropical cyclones in the north-western Australian region in 1966, 1973, 1983 and 1987 — that is, recent ENSO years — than in the anti-ENSO years of 1971, 1974, 1976 and 1989.

They suspect the variation relates to a change in the position of the monsoon trough. In anti-ENSO years, much of the trough is located over land in Western Australia's north-west, where cyclones cannot form. In ENSO years, it moves closer to the Equator, and therefore lies more over the warmer parts of the ocean.

The oceanward shift favours more cyclones; moreover, in those years the winds during the cyclone season have less tendency to change with altitude, thereby weakening their ability to disrupt an emerging cyclone.

In their analysis of the paths followed by the cyclones, the researchers found 'a westerly bias' in the motion of most storms during the ENSO years, leading to more coastal crossings in Western Australia and the Northern Territory and, correspondingly, fewer in Queensland. In anti-ENSO years, the wind flow that steers the cyclones is weaker and less coherent. In this case, it is more likely for the storms to track offshore from the Western Australian coast and persist further south.

The findings suggest that ENSO, while it may spell drought in eastern Australia, may herald a greater number of storms and more rain in the north-west of the continent.

El Niño/Southern Oscillation modification to the structure of the monsoon and tropical cyclone activity in the Australasian region. J.L. Evans and R.J. Allan. *International Journal of Climatology*, 1992, **12** (in press).

Dr Allan believes the cause of the drying trend may be part of 'a near-global effect' resulting from changes in the El Niño–Southern Oscillation (ENSO) phenomenon. Largely responsible for drought in the eastern two-thirds of Australia, ENSO has become the most important and best-studied climatic anomaly in modern meteorology, linking atmospheric and oceanic changes in the Indian and Pacific Oceans (see *Ecos* No. 49). It is possible, Dr Allan suggests, that fluctuations in the propagation of the features heralding the onset of an ENSO event (such as the weakening of the easterly trade winds in the western equatorial Pacific) may be the key behind the observed changes in the continental anticyclone and the long-wave trough.

At present, ENSO is not considered to have a strong influence on the State's south-western rainfall, but that might not have always been the case. The strength of an ENSO event is commonly measured by the Southern Oscillation Index (SOI), which is often taken to be the difference in pressure between Darwin and Tahiti — the two 'poles' of the oscillation. Greater-than-average values of the index are strongly associated with higher rainfall in eastern Australia; but when the index is compared against rainfall in the south-west in the last 50 years, the correlation is poor. In particular, there appears to be little or no correlation between Darwin's air pressure at sea level and the rainfall in the south-west since 1915. However, during an earlier period, from 1876 to 1914, the two data sets show a statistically significant inverse relationship during the months from June to October.

Further analysis shows that significant correlations between Darwin pressure and mid-winter to early spring rain were dominant from the beginning of records until the 1930s. Thereafter, the relationship weakened and became statistically insignificant. Such a shift would help explain why Western Australia experienced a severe drought during the 1877–78 ENSO event but remained largely unaffected by the slightly more severe ENSO-related drought of 1982–83 that devastated agriculture in eastern Australia.

According to the researchers, the evidence suggests the cause of the rainfall deficiency is unlikely to be, as some have claimed, the result of clearing and other land-use changes in Western Australia's south-west. 'What I'm seeing so far is a large-scale phenomenon that seems to be part of a wider change in ENSO in the Indian and Pacific Oceans', Dr Allan said. He believes the deficiency may even be linked with the same climate patterns thought to be responsible for the long-term drought in the African Sahel.

Brett Wright

More about the topic

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Drought in Africa. M.H. Glantz. *Scientific American*, 1987, **256**, 34–50.

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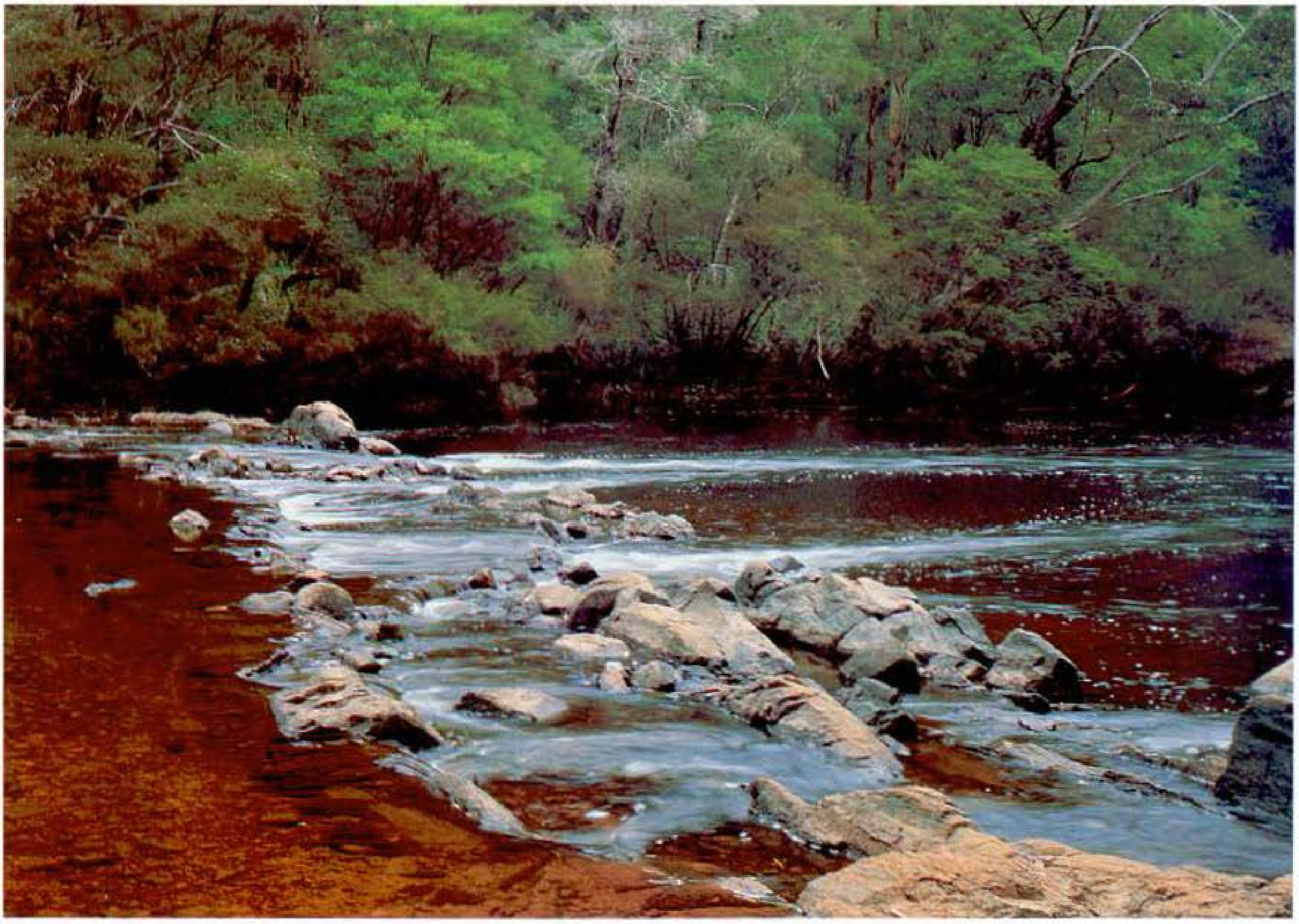

No sign of a water shortage here: the Warren river in the far south-west.