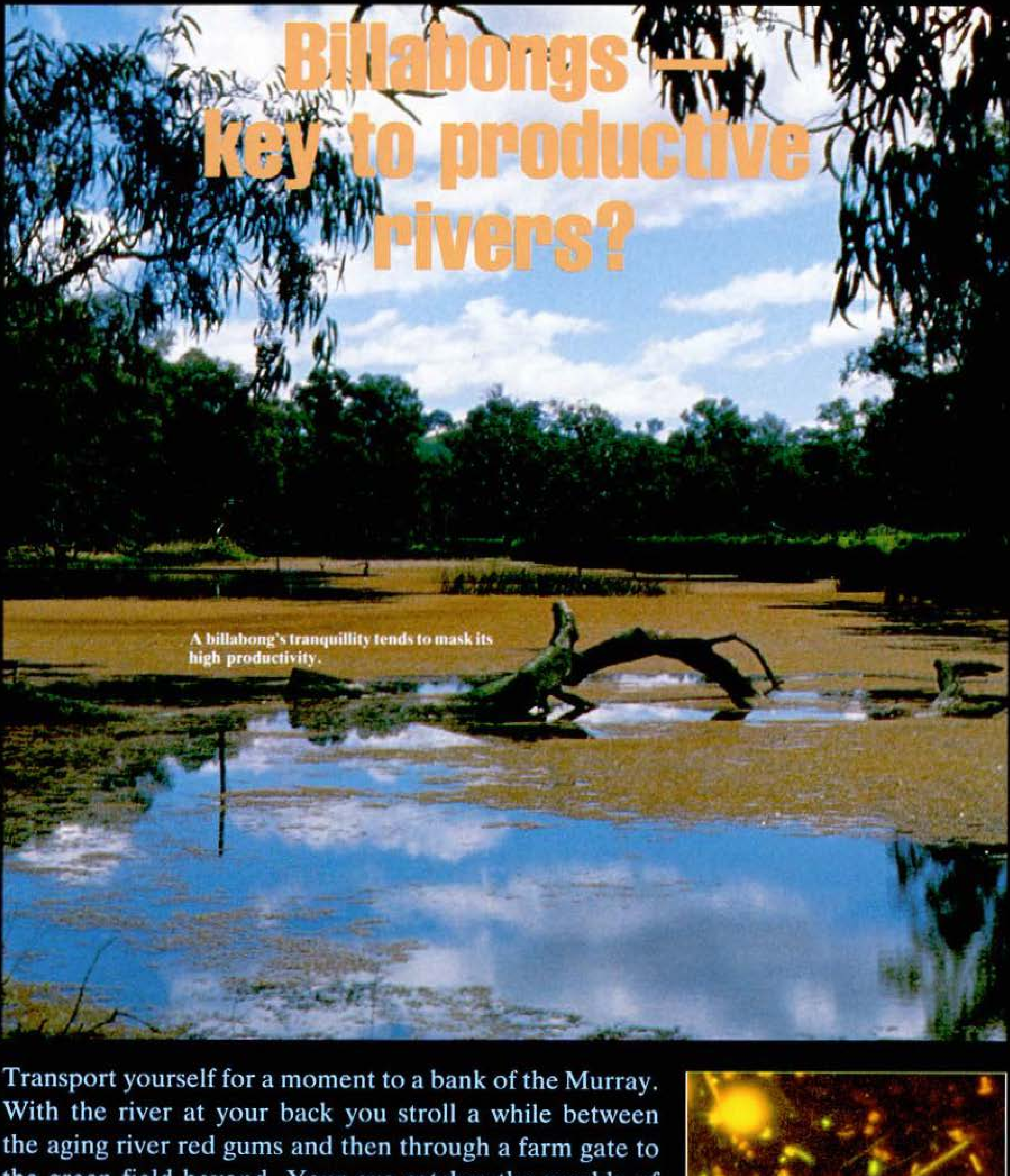
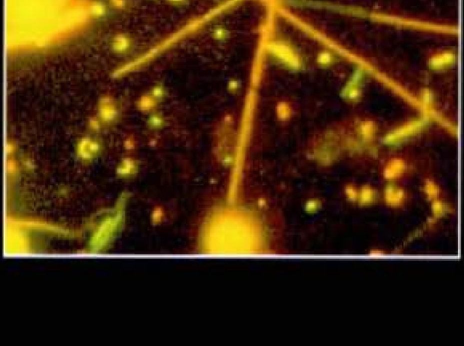
Billabongs — key to productive rivers?



A billabong's tranquillity tends to mask its high productivity.

Transport yourself for a moment to a bank of the Murray. With the river at your back you stroll a while between the aging river red gums and then through a farm gate to the green field beyond. Your eye catches the sparkle of the summer sun reflected on a pool of water.



Standing quietly at the water's edge, in the welcome shadow of a spreading eucalypt, you can feel the gentle breeze that moves an overhanging bough slowly to and fro. Where its leaves brush the water, they sweep a hole in the carpet of red fern that floats on the surface.

Riding the swaying limb a young cormorant, gorged on a meal of perch fingerlings, hangs out its wings to dry. Nearby, as a pair of grey teal paddle quietly through the reeds, a small squadron of swallows swoop across the water snapping at the mist of midges sharing your tree's shade.

The sudden cry of a kookaburra's laugh brings an involuntary shiver. It seems to echo the ghost of a persecuted swagman: but perhaps not. After all, there are thousands of billabongs scattered across the floodplains of the Murray and the Darling; it's not likely that you've chosen the one immortalised by Banjo Paterson.

Billabongs and the floodplain

Despite images that are firmly entrenched in our folklore, we know very little about the ecology of our billabongs, or of their role in floodplain ecosystems. In fact, we have only limited knowledge of the way in which all the various ecological components of the Murray–Darling Basin interact.

Unfortunately, our past management practices have reflected those limits. In the last few years, photographs of forlorn farmers standing in once-fertile but now salt-scarred paddocks have been striking testaments to something amiss. But change is beginning. As *Ecos* 53 reported, recent political and research initiatives are bringing hope to Australia's stressed heartland.

Since the Murray–Darling Basin Ministerial Council met formally for the first time in August 1986, it has emphasised the need for a strong research base to support improved management and planning. Its review of the Basin's environmental resources published in 1987 recognised that what we know about the ecological impact of the changes we've made over the last 70 years comes largely from anecdotal and speculative evidence.

Beginning in the early 1920s, through the construction of dams and weirs along the Murray and Darling, we've gradually changed winter and spring floods to controlled flows in summer and autumn. About the ecological effects, scientists have more questions than answers. How, for example, do aquatic fauna respond to large releases of cold de-oxygenated water during summer? How well have plants and animals adapted to a river that in many parts now resembles a series of lakes separated by weirs? What is happening to the organisms that evolved with regular flooding?

Recent concern about the declining health of the river red gums (*Eucalyptus camaldulensis*) in the Barmah Forest in the floodplain near Echuca has led to the suggestion that the trees may need occasional floods to ensure their survival: but how much water and when? Perhaps research will show that, like the suburban lawn, they will be content with a good soaking now and then. But there are already indications that other components of the floodplain will need a more sophisticated approach to management — what of the waterfowl breeding in the flooded forests, for example? What of our native fish?

Left: A recognised procedure for counting bacteria is to stain them first with 'acridine orange'.

According to scientists who attended a recent workshop on native fish management, floods appear to be closely linked with successful breeding of many species. For example, the spawning of golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanus*) is known to be flood-cued. Some fish populations certainly seem to increase a year or two after flooding (see the chart at the top of page 18).

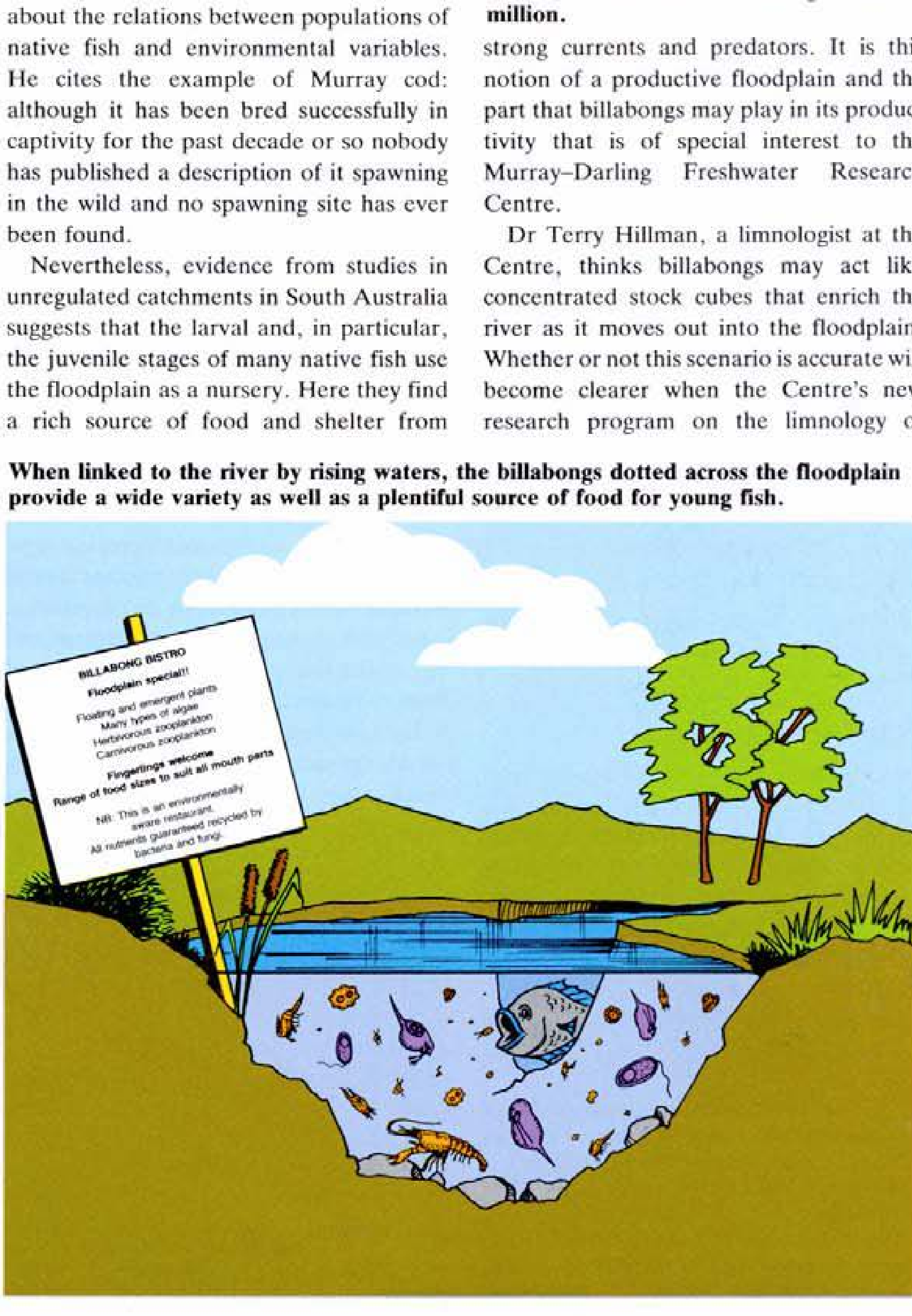
But uncertainty abounds. One of the workshop participants, Mr Sandy Morison of the Kaiela Fisheries Research Station in Victoria, says that ecologists know little about the relations between populations of native fish and environmental variables. He cites the example of Murray cod: although it has been bred successfully in captivity for the past decade or so nobody has published a description of it spawning in the wild and no spawning site has ever been found.

Nevertheless, evidence from studies in unregulated catchments in South Australia suggests that the larval and, in particular, the juvenile stages of many native fish use the floodplain as a nursery. Here they find a rich source of food and shelter from strong currents and predators. It is this notion of a productive floodplain and the part that billabongs may play in its productivity that is of special interest to the Murray–Darling Freshwater Research Centre.

The numbers of bacteria in billabong water can be very large. In the test-tube — that also contains a lot of suspended matter — Dr Paul Boon could be holding several million.

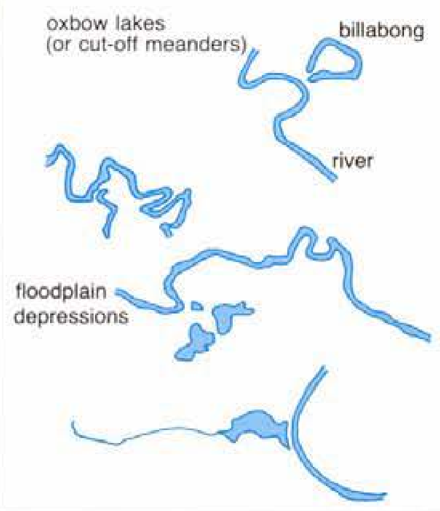
Dr Terry Hillman, a limnologist at the Centre, thinks billabongs may act like concentrated stock cubes that enrich the river as it moves out into the floodplain. Whether or not this scenario is accurate will become clearer when the Centre's new research program on the limnology of

When linked to the river by rising waters, the billabongs dotted across the floodplain provide a wide variety as well as a plentiful source of food for young fish.



What is a billabong?

Types of billabong



Billabongs cover up to 50% of some parts of the Murray and Darling floodplains, but they're not all the same. A cut-off meander or oxbow lake is the most common, although there are many other forms, including waterholes in small streams and backwater remnants of channels long-since moved. Most are filled by rising river levels moving into a network of channels, or by flood-waters moving across the plain. Some are connected to the main river by a labyrinth of porous gravel. Others are supplied by water from their own catchments, perhaps where the flow from a local stream is isolated in a cut-off meander. It can be useful to think of billabongs as a heterogeneous mosaic of habitats comparable to islands in the floodplain.

billabongs is further advanced. But some early research results give weight to the idea.

Billabong bacteria

Dr Paul Boon, a microbiologist in the team of scientists working with Terry Hillman on the program, has discovered that billabongs contain higher concentrations of bacteria — the organisms that supply some of the driving energy at the bottom of the food chain — than most fresh-water bodies elsewhere in the world.

Bacteria are important in aquatic systems for a number of reasons. Some types give concern because they cause diseases such as cholera. Others, along with some algae, produce many of the unpleasant tastes and odours in drinking water. State Health Departments undertake most of the research into the pathogenic aspects of these organisms, but research in the Centre's limnology program focuses on the way in which they contribute to the food chain as food for zooplankton and by making nutrients available for plants through recycling organic material.

Heterotrophic organisms like bacteria — they live by breaking down previously formed organic matter — are essential in aquatic systems that draw most of their carbon and nitrogen from organic detritus in the water. Submerged branches and logs — which, incidentally, are thought to be valuable habitats for many larger aquatic animals — provide some of these important organic degradation sites.

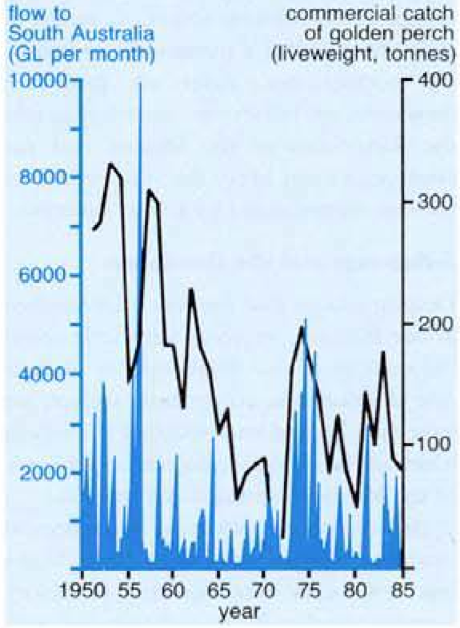
Mr Oliver Scholz, a PhD student co-supervised by Dr Boon, is attempting to quantify the rates of microbial colonisation and decomposition of submerged timber. He says that colonisation typically follows a uniform progression. Solitary bacteria attach to the wood and develop into colonies. These facilitate the colonisation by algae, first unicellular and then multicellular forms. In turn these communities support invertebrates and so on up the food chain.

The role of bacteria in the recycling process is of particular interest to Dr Boon. For a year, at 17 river and billabong sites in the Murray–Darling Basin, he has been studying relations between decaying algal blooms and the subsequent regeneration of nutrients in the system. He has found that a key part of the process in billabongs, but not in the river, is the remarkable rate of bacterial productivity.

In fresh-water environments around the world, populations of bacteria usually reach about 1000 million per litre — the number that Dr Boon regularly found in his samples of river water — but billabong populations can reach 100 000 million per litre. To illustrate the immensity of the numbers involved he likes to compare these aquatic bacterial populations with human communities. For example, in a teaspoon of river water the bacteria roughly equal the number of people in south-eastern Australia whereas those in a teaspoon of billabong water nearly match the population of China.

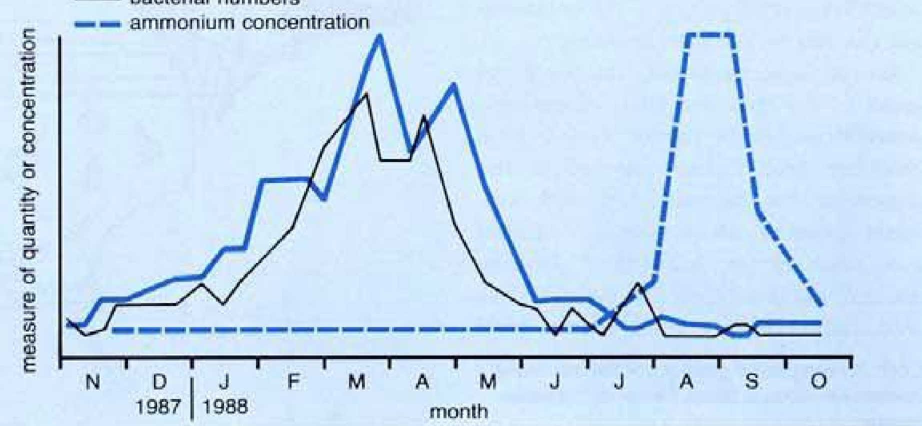
Paul Boon found that the number of bacteria closely followed the growth of phytoplankton, as measured by the concentrations of chlorophyll in the billabong. Through regular sampling, he also tracked the link between the autumnal algal and bacterial blooms and the subsequent mid-winter production of an inorganic form of

Some fish thrive after floods

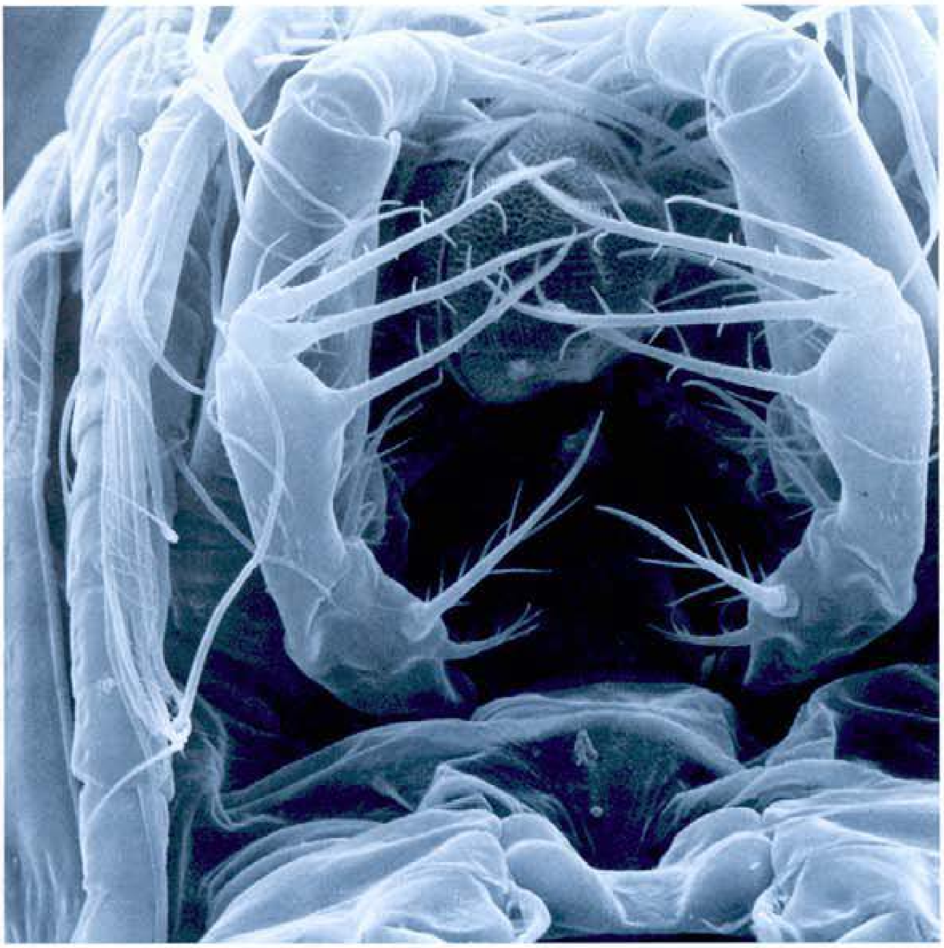


Golden perch is one species whose numbers appear to increase after flooding. The graph links catch figures recorded by the South Australian Department of Fisheries with water-flow data from the Murray–Darling Basin Commission.

Bacteria — key to nitrogen recycling



High concentrations of inorganic nitrogen are found at the end of a chain of events following algal blooms (shown as high chlorophyll concentrations). Concentrations of the enzyme (aminopeptidase) and amino acids that closely follow and mirror the numbers of bacteria are not shown here.



A hapless *Peridinium* (a dinoflagellate alga) falls prey to a *Mesocyclops* (a microcrustacean).

nitrogen essential for the growth of both microscopic plankton and larger plants (see the lower chart on page 18).

As the algal population declines, the amount of aminopeptidase increases. The activity of this exoenzyme — an enzyme that is secreted by bacteria, and in this case one that breaks down algal proteins — is closely followed by high concentrations of amino acids and, via their breakdown, the production of nitrogen in the form of ammonia (NH_4). By contrast, at his study sites in the river, he found no measurable interaction between microbial populations and inorganic nitrogen.

Underwater grazing

Other members of Terry Hillman's team are analysing billabongs for plant nutrients, major ions, heavy metals, and various physical parameters, as well as studying the ecology of zooplankton and larger invertebrates. For example, Dr Russ Shiel has been studying zooplankton to build up a picture of the relations between the bacterial, algal, and animal components in various parts of the floodplain.

According to Dr Shiel, the ecology of protozoa, rotifers, and microcrustaceans in the Northern Hemisphere fresh waters is relatively well known, but not so in Australia. Only in the last 10–15 years have scientists carried out any intensive study into the microfauna of the waters of the Murray–Darling. Early European naturalists concentrated mainly on the continent's unique vegetation, varied bird life, and curious marsupials; they paid some attention to Australia's coastal freshwater systems, but largely ignored the aquatic habitats of our inland.

And yet, beneath the surface of our billabongs are immensely rich communities of animals whose species diversity parallels that of the Amazon rainforests. With a net towed through the open water of a billabong Dr Shiel regularly catches 60–70 species of microfauna at densities of 20–30 000 per litre. Towed through a stand of water milfoil (*Myriophyllum* species), his net may gather more than 100 species living on or around the plant's finely divided leaves. By contrast, in comparable tows through the open water of a reservoir he rarely collects more than 20 species: river tows collect even fewer.

Many of these animals are too small to be seen without the aid of a hand lens. Protozoa are usually less than 0·2 mm long, while rotifers — named after their waving rings of cilia that look like rotating wheels — are usually less than 0·4 mm (although one giant grows to 2 mm). Of the 2000 rotifer species identified world-wide, more than a quarter are found in the Murray–Darling Basin: 200 occur in one billabong near Albury. (In fact, more than half of the known zooplankton of the Murray–Darling have a restricted distribution. Some are found only in a single billabong.)

Most rotifers appear to be generalist feeders but, in laboratory studies using a video camera looking down a powerful microscope, Dr Shiel has obtained the first evidence of species-specific grazing on particular components of the algal community. For example, the rotifer *Ascomorphella volvocicola* is found only in association with colonies of a unicellular alga called *Volvox*. After chewing through the colony wall the rotifer lays several eggs that, after hatching, promptly eat the colony from the inside before moving to the next. In billabongs without *Volvox*, *Ascomorphella* does not occur.

And using the same technique, Dr Shiel has established that bacteria are heavily grazed by rotifers and ciliates. His research team is also studying another major zooplankton group that occurs in billabongs — the microcrustaceans. At the moment they know very little about these animals except that, along with other microfauna, they form the vital link between the bacterial and algal communities and the larger invertebrates and fish fry.

Management implications

Before river flow was regulated by dams and weirs, the Murray and Darling flowed out across their floodplains in two of every three years, linking backwaters and inun-

The Centre

The Murray–Darling Freshwater Research Centre, located at Albury, N.S.W., is supported financially and in other ways by the Australian Water Research Advisory Council, the Murray–Darling Basin Commission, the Albury–Wodonga Development Corporation, and CSIRO.

The Centre provides the main base for the Murray–Darling Limnological Research Program — a collaborative research effort involving the Centre, the CSIRO Division of Water Resources at Griffith, N.S.W., and several other research institutions. The research described in the article is part of this program, which aims at increasing our understanding of the surface water resources of Australia's most productive, yet most environmentally troubled, catchment.

To stay healthy, how much water do the Barmah Forest river red gums need?

dating broad expanses of forest, bringing native fish ready to spawn. Blooms of plankton and their associated microfauna — their rapid development assisted perhaps by the potent billabong communities — meant that food was available after the eggs hatched.

Many of the floodplain organisms are survivors of a long evolutionary history during which they have developed the ability to cope with the environmental extremes that come with flooding. Built into their life cycles are opportunistic strategies that help them respond rapidly to sudden habitat changes — in days, hours, or even less.

Dr Hillman accepts that, while the notion of a relatively unproductive stream winding among highly productive billabongs provides an intuitively appealing scenario, the reality is much more complicated and needs a great deal more research before ecologists fully understand it. One thing is certain: preserving these unique riverine ecosystems will require new water-management strategies. Obviously, we can't go back to the days when the rivers ran free; but we have other options, such as the ideas canvassed at last year's workshop on native fish management.

We can make small adjustments to the present river-control procedures, involving little or no loss of water; for example, we can extend the periods of minor flooding downstream of weirs, or lengthen the time that regulators are open. Another option, albeit a more expensive one, is to construct new drainage systems that will enable us to re-route water when levels are low; this could be coupled, perhaps, with the construction of new fish ladders that provide passage past the weirs. A third more controversial idea proposes that the Murray–Darling Basin Commission create an environmental allocation of water that would allow artificial floods or diversion to suitable nursery or breeding sites.

Nevertheless, early research suggests that keeping the rivers confined by their banks could also be costly. The price of denying our unique fresh-water fauna regular access to their floodplain larders may be a decline in their health and productivity and a continued decline in the rivers' value for humans.

David Brett

More about the topic

Organic matter degradation and nutrient regeneration in Australian fresh-waters: I. Methods for exoenzyme assays in turbid aquatic environments. P.I. Boon. *Archiv für Hydrobiologie*, 1989, **115**, 339–59.

'Proceedings of the Workshop on Native Fish Management.' (Murray–Darling Basin Commission: Canberra April, 1989.)

'Murray–Darling Basin Environmental Resources Study.' (Murray–Darling Basin Ministerial Council: Canberra 1987.)

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So near, yet...

Studies at the Murray–Darling Freshwater Research Centre show that, even though the two environments are often very close together, waters in billabongs support quite different communities of animals from those in the main stream. Many closely related species specialise in living in either one or the other.

Scientists at the Centre have selected several of these pairs for detailed study — for example, the river mollusc *Alathyria jacksoni* and dragonfly larva *Hemianax papuensis*, paired with the billabong species *Velesunio ambiguus* (mollusc) and *Austropetalia patricia* (dragonfly larva), all shown here. They are noting development times, responses to temperature, and food preferences as well as taking physical measurements. This knowledge will help in the evaluation of future management measures (notably those involving flow regulation).

Species from river (left) and billabong.