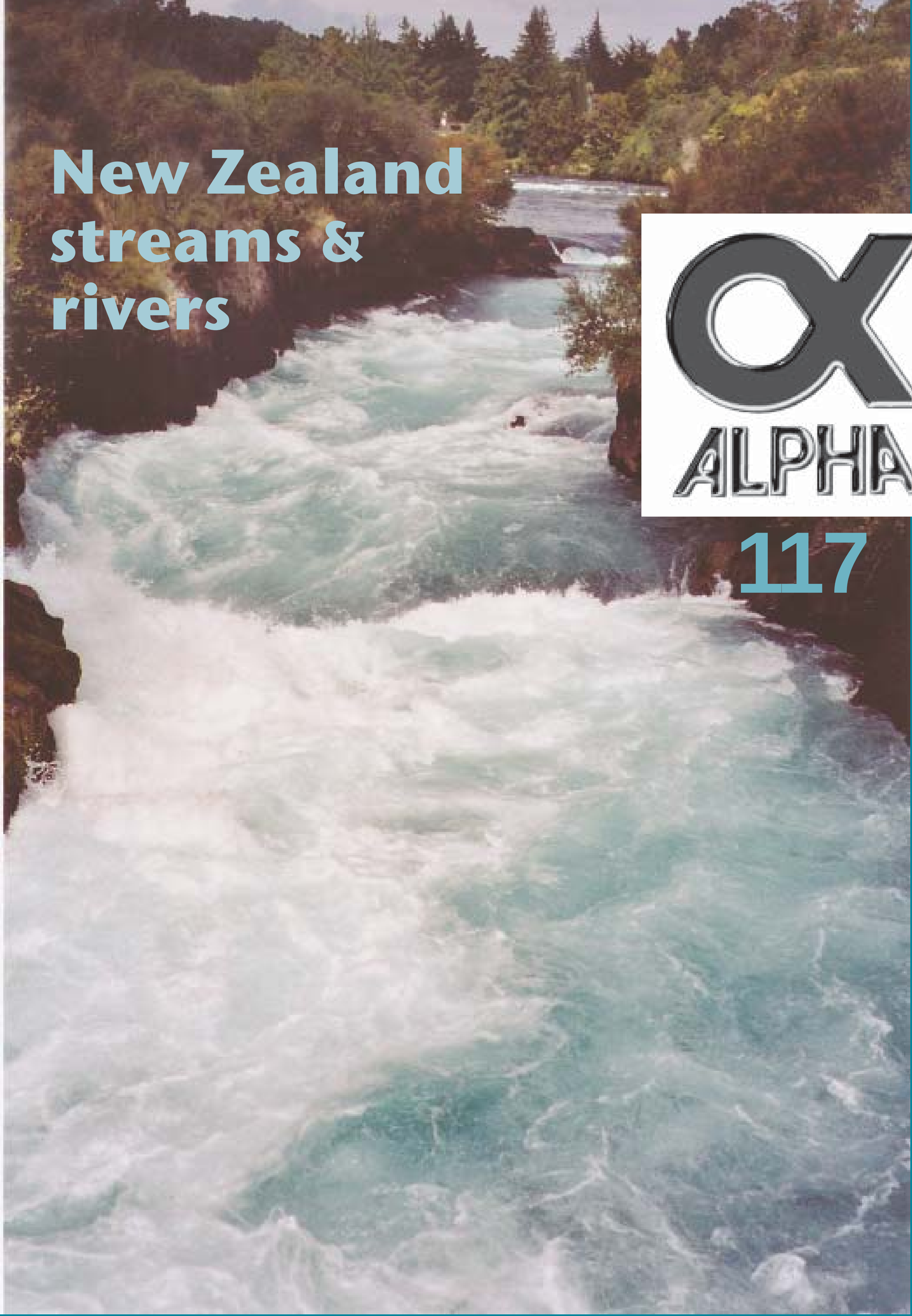
New Zealand streams & rivers



ALPHA 117

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NIWA Taihoro Nukurangi

the Royal Society of New Zealand

Introduction

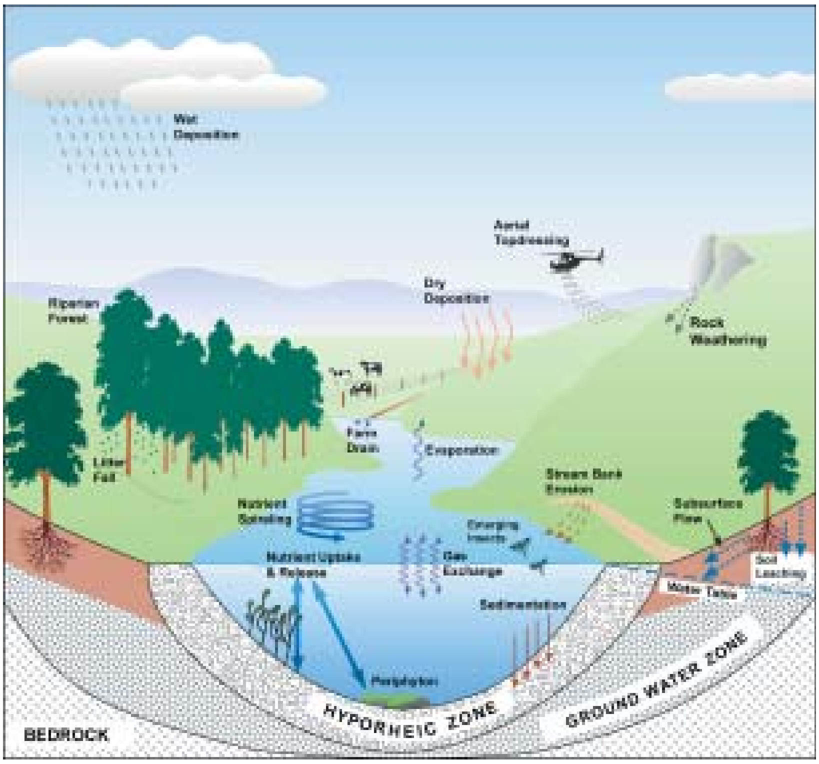

Figure 1 A stream in cross-section, showing some of the pathways that connect streams with their catchments and the atmosphere. Most pathways carry water and material to streams, but there are some that move from streams to the land (emerging insects) and from streams to the atmosphere (evaporation and gas exchange). Greg Kelly, NIWA.

Streams are *ecosystems* made up of the organisms and the water in and beneath channels, which occur in networks of many connected streams. These interact with terrestrial, atmospheric, lake and estuary ecosystems. At first glance streams seem to have distinct borders. They have banks bordered by forest, grassland or pasture. They begin at springs or lakes, and end at lakes or estuaries. However there are many pathways connecting streams to adjacent land, lakes, the atmosphere and ocean (Fig. 1). The dominant connections that most strongly affect *stream health* are between streams and their catchments. Most of the water, sediment, organic particles and dissolved material that leaves a catchment is carried by the stream. The amount of sediment and other materials in a stream are determined by climate, geology, and the way the catchment is used by humans. The ‘openness’ of stream ecosystems (Fig. 1) makes them vulnerable to changes in their catchments. Some land uses (including logging or urban growth) can cause degradation of streams and rivers. Increases in these land uses can lead to widespread degradation. Land-use patterns are changing rapidly across New Zealand. Ecologists at the National Institute of Water and Atmospheric Research (NIWA) have developed a River Environment Classification system to help identify links between land uses and the materials (including plants and animals) in streams, and to track changes over time (Fig. 2).

Managing streams

There is an urgent need to focus scientific research and land management policies on understanding the effects of human activities on catchments. If we are negligent, we face three different kinds of losses.

1) **The loss of species that live in streams and rivers**. Some species become rare or extinct without our influence but human activities often speed up the process. About 20% of the world’s freshwater fish species have become rare or extinct in the last century. The Southern Grayling (Fig. 3) is extinct, and over 60 species of New Zealand’s stream fish and invertebrates are currently threatened. Many people believe that all species have an *intrinsic value* that makes them worthy of conservation efforts.

2) **Wild streams and their catchments become degraded**. The great value of wilderness experiences is reflected in the popularity of our national parks and reserves (Fig. 4). Wilderness catchments are quite rare in New Zealand. About 20% of our rivers are dammed, and the catchments of most undammed rivers are used for agriculture, forestry or town supply. Of the wilderness catchments remaining, most are small and contain only *headwater streams*.

3) **Services and products that streams and rivers provide for us**. Some are obvious–food and water for drinking and irrigation; others are less so such as dilution of contaminants. Ecologists

Figure 2 An example of the River Environment Classification. The map shows streams on the South Island east coast near Kaikoura. These streams are classified according to the main land-cover in their catchments. Keri Niven, NIWA.

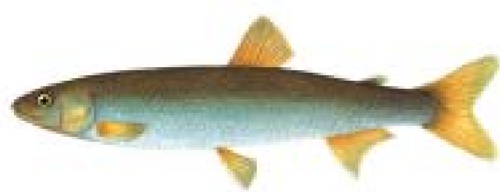

Figure 3 The Southern Grayling, now extinct. The Southern Grayling was endemic to New Zealand, meaning that it was found nowhere else. Bob McDowell, NIWA.

Figure 4 A wilderness stream in Wonderland Valley, Mount Aspiring National Park.
Lauraine Reynolds.

Figure 5 Clear-felling in forested catchments on the North Island of New Zealand.
John Quinn, NIWA.

refer to all of these as 'ecosystem services' – they cost us little or nothing yet all are invaluable. Economists have given these ecosystem services monetary values equal to the prices we would pay businesses for the same services. Rivers and lakes were valued at about NZ$17,000 per hectare (more than forests or grasslands). Researchers at Massey University recently estimated the ecosystem value of rivers and lakes in the Waikato region alone to be about NZ$2 billion.

Land-use change

About two-thirds of the world's river *runoff* reaches the sea with little direct human impact because many rivers are inaccessible to large numbers of people. The remaining runoff is accessible, and is affected by human activities. The most obvious affects of humans on rivers are dams and water removal, but land-use changes are probably responsible for most of the degradation that occurs today.

Four main land uses that affect streams and rivers

Wetland drainage. River channels near human settlements are often modified and deepened to drain adjacent wetlands and reduce flooding. Drained wetlands may be converted to agricultural land with levees and dikes, or filled to create land for development. Draining and urban development has destroyed more than half the world's freshwater wetlands in the last 100 years; of the remaining 600–900 million hectares, less than 10% have any protection status.

Figure 6 Algae growing in the Hakataramea River, near the east coast of the South Island. This mass of fast-growing algae is a sign of eutrophication, caused by nutrients that enter the river from bordering agricultural land.
Cathy Kilroy, NIWA.

Timber harvesting. Logging, particularly by clear-felling, often leads to soil erosion (Fig. 5). Removal of trees and construction of roads destabilises soils on slopes which can lead to landslides. Logging roads carry more surface runoff than the forest floor. This runoff flows into streams where it deposits sediment and causes stream banks to erode. When logging operations remove trees in *riparian zones*, the sunlight reaching stream beds increases, water temperatures often increase, and fish and invertebrates that require cooler water may be lost. Often algal growth increases, altering stream food webs. In *developed nations*, loggers are often required to leave a band of trees along stream banks to provide shade and reduce erosion. In *developing nations*, leaving trees to protect streams may be seen as an unaffordable luxury.

Agriculture. Agricultural runoff is a major source of pollutants to streams and rivers. Most of the pollutants entering these streams are eroded sediments, livestock wastes, and nitrogen and phosphorus from fertilisers. The amount of fertiliser applied to agricultural land worldwide has increased tremendously in the last century. Today, more nutrients are added to agricultural land in the form of fertiliser than are removed by crops. The excess nutrients accumulate in soils and can move into streams and rivers through groundwater, causing *eutrophication* (Fig. 6).

Urban growth. Urban growth increases the amount of catchment surface that cannot absorb rain. Much of the ground surface of a city is paved or covered by buildings, greatly reducing the amount of rainwater that soaks into the soil. An urban catchment that has 75% of the ground covered by buildings and pavement can have five times more runoff than the same area of forest. The increased runoff in urban areas causes floods to reach higher levels and peak faster. Also, urbanisation is often accompanied by removal of riparian plants, and discharge of sewage, storm drain runoff, and other wastewaters into streams. In developing nations, raw sewage is often discharged directly into streams, and can cause ecological and human health problems.

The state of the world's waterways

Many consequences of land-use change come under the general heading of "water quality". Water quality refers to the chemical and physical conditions in a stream or river, and the suitability of water for drinking, fishing, and supporting a healthy ecosystem. When stream ecologists examine water quality they usually assess nutrients, suspended sediment, temperature, toxins and biodiversity.

Nutrients. Nitrogen and phosphorus are the nutrients that most often lead to eutrophication. Massive lifeless areas called "dead zones" have developed in some rivers and coastal oceans of Europe, Asia and North America where eutrophication has reduced oxygen levels. Eutrophication can also favour growth of toxic algae. The development of agricultural and urban areas often causes nutrient levels in streams to increase as the quantity of fertiliser, sewage, manure, and eroded soil entering streams increases.

Sediments. Stream sediments are produced by erosion in the catchment, even in pristine regions. This is not necessarily harmful to streams, as sediments create habitats for stream organisms. But problems may develop when sediment enters streams at high rates as it can clog the gills of fish and invertebrates, interfere with feeding by visual predators, and reduce light levels. Sediment deposits can also degrade habitat for fish and invertebrates that feed or spawn in streams.

Temperature. Water temperatures affect the *metabolism* of organisms, and the amount of dissolved oxygen in streams. Dissolved oxygen levels increase as water temperatures decrease so fish and invertebrates with high oxygen requirements are restricted to cool water. The removal of riparian plants reduces shade and increases solar heating. Streams in developed catchments where riparian forests have been removed often have higher summer temperatures than streams in undeveloped catchments. A common practice in stream restoration is to plant riparian trees, thereby reducing water temperatures.

Toxins. Contamination due to metals, pesticides and other toxins is often a problem for streams in developed catchments. In agricultural catchments, herbicide, fungicide and insecticide residues may reach streams and groundwater. Wood pulp, paper wastes, and wood preservatives such as chromated copper arsenate can contaminate streams in catchments used for forestry. In urban catchments, hydrocarbons and metals from street runoff, garden fertilisers, paints and other household contaminants are carried in storm drains to streams. Industrial and mine discharges can introduce many contaminants such as metals, solvents, coal dust, pesticides and detergents.

Biodiversity. Generally, healthy rivers have high biodiversity. When aquatic insects, algae, and the species living on the stream channel and in *hyporheic* zones are accounted for, a healthy river and its tributaries may support hundreds of species. When plants, birds and insects in riparian zones are included, the number of species may increase several times. (There are exceptions: Antarctic rivers, geothermal

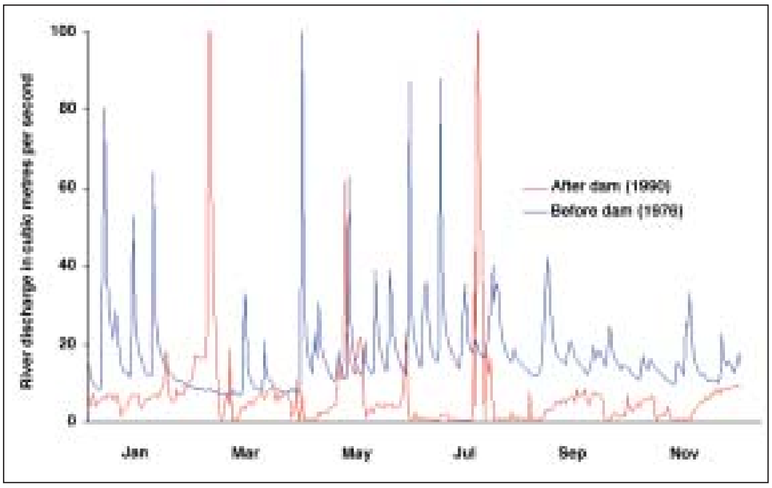

Figure 7 Hydrographs for the Tongariro River near Lake Taupo, showing the flow during years before and after construction of the Rangipo Dam. Note that baseflow was reduced and medium-size floods were eliminated after the dam was built. Kathy Walter, NIWA.

streams, and other extreme environments may be naturally species-poor). Biodiversity in cool, middle latitude stream ecosystems can be as high as it is in rainforests.

Globally, land-use changes, pollution, habitat loss, introduced species, and *water abstraction* have caused major reductions in stream biodiversity. In developed countries surveys show that populations of many fish, invertebrate and plant species have been reduced or lost. Unfortunately, in developing countries resources for conducting surveys are scarce, and species may be lost without our knowledge.

The New Zealand river scenario

About 300 km^3 of water flow down our streams and rivers every year. About 100 km^3 per year are used for generating electricity. This is reflected in the large area of river catchments affected by hydro dams. Almost 20% of New Zealand's land area is composed of the catchments of dammed rivers. Many rivers have more than one dam; some have six or seven, separated by artificial lakes and stretches of river. Dammed rivers have highly-altered flow patterns (Fig. 7). At sites where water is diverted and runs through power stations outside the river channel, *baseflow* downstream of the diversion is reduced. Intakes of most hydro dams are large enough to cope with small to medium-sized floods, so the effects of these floods are reduced downstream. The braided rivers of the South Island that remain undammed have wide gravel *floodplains* and multiple channels separated by low islands. These channels continually migrate across the floodplains in response to floods, removing some islands and creating new ones. Floods keep the gravels unstable and remove silt deposits and accumulated plants and algae. Following dam construction or water diversion, some flooding is eliminated, channels and islands become semi-permanent, and gravel beds become stable. This promotes algal growth and allows plants to colonise floodplains and islands. Nesting birds and native plants that require sparsely vegetated islands may lose habitat. In some dammed rivers, such as the Waiau River in Southland, intentional water releases ("*environmental flows*") have been used to simulate floods and improve conditions for the aquatic ecosystem.

Land-use change in New Zealand.

Before colonisation, about 80% of New Zealand's land area was forested. Today, over 50% of the land area is in pasture and cropland, 5–10% is exotic forest (mostly radiata pine) and 10–15 % is native forest. Urban areas covered less than 1% of the land area 30 years ago; today, they cover about 3%. Agricultural land has not expanded a great deal over the same period, but agricultural practices have changed rapidly. Low-impact grazing has grown little or declined, while high-intensity dairy and crop farming have increased. These changes have major implications for water quality and biodiversity.

Figure 8 Streams in catchments with three different land uses in and around the Whatawhata Research Centre near Hamilton.

John Quinn, NIWA.

Water quality in New Zealand

Agriculture

High-intensity agriculture requires much more water and fertiliser than low-intensity grazing. The amount of nitrogen fertiliser applied to farmland in New Zealand has more than tripled since 1990, and dairy cattle numbers have increased by 40%. The amount of farm wastewater sprayed on pastures has also increased. As a result, nutrient levels in streams and rivers in agricultural catchments are almost certain to increase in the near future.

Smaller-scale effects of common land uses in New Zealand are studied by NIWA researchers (Fig. 8). Here, the focus is on water quality in small catchments that are dominated by one of three land uses – grazing, pine forestry, and native forest. NIWA research has shown that sediment, nitrogen and phosphorus move from pasture catchments into streams at high rates, especially during wet winters. Streams in native forest catchments had lower sediment and nutrient concentrations than streams in pasture or pine forest catchments.

Residues of pesticides have been detected in some streams in agricultural catchments. Chemicals used to control insect pests of livestock and crops pose particularly high risks, as they may be toxic to stream invertebrates. To minimise these risks, some regional councils prohibit sheep dipping and other insecticide applications within 25–50 m of a stream.

Urban streams

Many urban streams in New Zealand are contaminated with metals, pesticides and other toxins. This may be because of recent discharges and industrial spills or the contamination may have occurred years ago, but the toxins remain. Although leaded petrol was phased out in 1996, lead levels are high in many urban streams. Such persistent toxins highlight the need to protect streams today in order to prevent problems in the future. Researchers in a NIWA programme called StormWater And Transport (SWAT), are examining the effects of contaminants on urban streams and looking for ways to minimise their toxicity. One focus of their research is the use of stream plants to minimise toxic effects – as plants decompose, they produce dissolved compounds that bind and detoxify many contaminants.

Urban streams in New Zealand are often *channelised* and cleared of plants to reduce flooding risk, and their banks are often reinforced with concrete or wood to prevent erosion. These changes reduce habitat for stream organisms and increase water velocity and temperatures. The combination of poor water quality and habitat loss can eliminate species that are sensitive to degradation, such as stoneflies and mayflies. Other symptoms of degradation in New Zealand's urban streams include low dissolved oxygen, mats of algae, and large areas of exotic stream plants.

Urban stream restoration projects are underway throughout New Zealand. In Christchurch, the wooden culvert of a 300–m long stream channel was removed and replaced with a natural meandering bed. Native riparian and aquatic plants were planted (Fig. 9), and the stream is being monitored closely to see if they become established and whether native invertebrates and fish colonise the area.

Figure 9 A NIWA ecologist plants native aquatic plants in a restored urban stream in Christchurch. Scott Larned, NIWA.

Mining

Both coal and gold mining operations have affected water quality in New Zealand streams, primarily in Westland and the Coromandel Peninsula. Acidic water draining from mines into streams is often high in sediment and heavy metals. Invertebrate diversity and abundance are often lower in these streams. When a mine closes down, the streams that receive its runoff may be at risk of pollution for many years. Ensuring that closed mines do not degrade streams is a high-priority research area for our stream ecologists.

Biodiversity and exotic species. More than 200 exotic aquatic plant and animal species have become established in New Zealand rivers and lakes. Some, such as salmon and trout, were introduced to establish permanent populations, but most exotic introductions and their later dispersal are accidental – by boats, boat trailers, bait tanks, fishing nets, and other vectors. Studies of exotic species are at an early stage, but it is clear that many have negative effects. Mosquitofish, introduced to New Zealand from the United States, kill the native dwarf inanga, a threatened fish. In some Canterbury rivers, salmon redds (depressions in river gravels created by spawning salmon) have fewer aquatic insect species than adjacent gravels. On a larger scale, willow and poplar trees planted for erosion control have created dense riparian forests where none existed previously (Fig. 10). These forests reduce aquatic habitat, artificially stabilise stream banks, and prevent native riparian plants from colonising.

Figure 10 Dense riparian forest of non-native willows along the Waitaki River near Oamaru, South Island.

Michal Tal, University of Minnesota

Success stories – restoring streams and rivers

The Thames River in England and the Cuyahoga River in Ohio, United States are widely-publicised cases of the effects of pollution – and the effects of restoration. In the mid–1950s, the Thames near London was highly contaminated and depleted in oxygen. Only eels could tolerate these conditions. Twenty years later, pollution controls had improved conditions substantially and more than 60 fish species inhabited the Thames. In the 1960s, the Cuyahoga was so polluted with oil and debris that the river's surface caught fire several times and there were few fish. Today, after 30 years of pollution control and restoration, water quality in the Cuyahoga has greatly improved and the river supports 70 fish species.

Many stream and river restoration efforts have been made in New Zealand and more are underway. A habitat enhancement project by the Christchurch City Council has resulted in large increases in native fish species and a greater diversity of habitats in urban streams. In the North Island, baseflow was restored to the Moawhango River below a hydro-power dam in 2001, 20 years after baseflow was diverted. The level of restored baseflow, 600 litres per second, was intended to provide habitat for a diverse community of aquatic invertebrates. After less than two years of restored flow, the invertebrate community below the dam is similar to that above the dam, and to other lake-fed rivers.

Several regional councils in New Zealand have undertaken *riparian retirement* and planting projects. Many of these projects have reduced sediment and nutrient levels in streams, reduced streambank erosion, and increased diversity. Guidelines for restoring and managing riparian zones of rural streams are available from the Ministry for the Environment and the Department of Conservation.

You can help!

Do you want to learn about streams and their catchments, help with restoration projects, and monitor the ecological health of local streams? Joining a community organisation that focuses on streams and wetlands is a good way to start. Get a copy of the free magazine *The Volunteer Monitor* online at www.epa.gov/volunteer/summer02/volmon.pdf.

Get your school involved with the National Waterways Project (NWP).

For further information contact:

Katherine Hicks, ph:(04) 470 5760 fax: (04) 473 1841

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Further reading

Allan, J. D. 1995. Stream ecology: structure and function of running waters. Chapman & Hall.

Boulton, A. J.; Brock, M. A. 1999. Australian freshwater ecology: processes and management. Gleneagles Publishing.

Collier, K. J. 1994. Restoration of aquatic habitats: selected papers from the second day of the New Zealand Limnological Society 1993 Annual Conference. Department of Conservation, Wellington, New Zealand.

Websites

National Institute of Water and Atmospheric Research
www.niwa.co.nz
New Zealand Journal of Marine and Freshwater Research
www.rsnz.org/publish/nzjmfr/
The State of New Zealand's Environment www.mfe.govt.nz/about/publications/ser/ser.htm

Note: more references and websites are listed in the Teacher notes and student activities that accompany this Alpha

Glossary

Baseflow – Sustained flow in a stream that comes from groundwater discharge or seepage.

Biodiversity – The variety of plant and animal life in a particular habitat.

Catchment – Source area for water that drains to a stream (or a lake or wetland, in areas without streams). All of the land surfaces on the earth are in catchments.

Channelisation – Straightening stream channels, reinforcing stream banks, or otherwise altering stream channels, usually as a flood-control measure.

Developed nations – Nations that are wealthy, usually industrialised, and which invest money in environmental quality and conservation.

Developing (and underdeveloped) nations – Poorer nations, with economies often based on raw materials such as timber, minerals, and oil. (Little money is invested in environmental quality and conservation).

Discharge – Volume of water flowing in a stream per unit of time. Discharge in New Zealand streams is usually given in cubic metres per second (m^3/s).

Ecosystem – An ecological unit consisting of the living organisms in an area, and the physical and chemical environment they inhabit.

Environmental flow –Water released into regulated rivers that is intended to meet both human and ecological needs.

Eutrophication (ū-trō-fi-cā-shun) – Fertilisation of stream, estuary or ocean water with nutrients that are rare under natural conditions. Nitrogen and phosphorus are the nutrients that most often lead to eutrophication.

Evapotranspiration – Moisture loss to the atmosphere from plants. Water is transported from soils through plant surfaces by transpiration, to the atmosphere by evaporation.

Floodplains – Areas of flat land adjacent to streams that are inundated with water during large floods. Sediment and plant debris may be deposited on floodplains by receding flood waters.

Headwater streams – Streams at the source of a river, which have no tributaries.

Hydrograph – A plot of stream or river discharge against time. Hydrographs are useful for showing flood frequency and magnitude, duration of baseflow, and the effects of droughts.

Hyporheic zone (hī-pō-rē'-ik) – Zone below and alongside streambeds in which water flows through the sediments. Water moves back and forth between the stream channel and the hyporheic zone. Hyporheic water is not the same as groundwater, which generally flows in one direction, to the stream.

Intrinsic value – Value of a species without regard for its usefulness to humans. Intrinsic values may be based on the roles a species plays in a community of species or an ecosystem.

Land use – The way in which, and the purposes for which, humans use land and its resources (for example, farming, mining, forestry and recreation).

Macronutrients – Nutrients required by organisms in large amounts. A few macronutrients (nitrogen, phosphorus, silicon, carbon) receive great attention from aquatic ecologists because demand for them is high, while their availability can be quite low.

Metabolism – Chemical processes that occur inside living organisms including digestion, respiration and photosynthesis.

Riparian zone – Vegetated land that borders and directly interacts with streams and rivers.

Riparian retirement – Exclusion of livestock from riparian zones to promote the restoration of soils, forest and wildlife habitat.

Runoff – Water that runs off the surface of the land and flows into waterways.

Stream health – A measure of how closely a stream's habitat, water quality and living community match historical conditions (before the stream was affected by humans).

Water abstraction – Removal of water from a stream for human uses such as irrigation.

Written by Scott Larned, National Institute of Water and Atmospheric Research (NIWA). Sponsored by NIWA

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