NATIVE FRESHWATER FISH

Native fish survival during exposure to low levels of dissolved oxygen

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Preliminary experiments in progress at NIWA have revealed that juveniles of some of our native fish species are remarkably tolerant of low levels of dissolved oxygen.

MANY NATIVE FISH SPECIES in New Zealand undertake extensive migrations to and from the sea and, for these species, lowland streams are important migratory pathways and habitat. However, these streams often lack shade and have high nutrient loads, which can result in excessive plant growth and large daily oscillations in temperature, pH and dissolved oxygen during summer. These conditions are potentially lethal to fish.

This article outlines some of the responses observed in experiments which are examining the toxicity of low levels of oxygen to fish.

The work forms part of a larger NIWA study that is assessing plant production in lowland streams and its role in the ecology of lowland systems.

Fish respiration

Most fish acquire oxygen by pumping water across the gills. Oxygen is absorbed across the fine membranes of gill filaments into the bloodstream and is then distributed to the tissues. A reduction in external dissolved oxygen levels can result in low oxygen availability to tissues (called "hypoxia") and this may force fish to make physiological and behavioural changes to compensate. These changes include:

- leaving the water completely to respire in air ("aerial respiration");
- gulping air from above the water surface;
- surface respiration in which the fish skim the top few millimetres of water that have an appreciably higher oxygen content, even in severely deoxygenated water.
- adjustments in activity:
  - either reduced activity as energy is focused on increasing the volume of water passed over the gills to maximise oxygen extraction;
  - or increased activity that may allow the fish to escape from the low-oxygen environment.

These mechanisms may be adequate for short-term exposure to low oxygen levels, but as severity and duration increase, the costs in terms of energy expenditure and vulnerability to predation also increase.

In some species, oxygen may be absorbed across the skin to supplement oxygen absorbed at the gills. Generally, the skin of such species is relatively thin and has a good blood supply. Eels and galaxiids (whitebait) are scaleless, so are well adapted to this type of breathing.

Since most fish cannot regulate their body temperature, they are controlled by the thermal conditions of the waters in which they live. Warmer temperatures speed up fish metabolism which leads to increased oxygen demand. At higher temperatures oxygen is less soluble in water, compounding the problem of fish survival in low oxygen environments. A combination of high temperatures and low oxygen concentrations can result in fish kills.

The ability of fish to survive hypoxic conditions is therefore a function of the level and constancy of the supply of dissolved oxygen along with other environmental factors. Fish species, condition and life stage also play a part.

Experiments

The survival of juvenile smelt, torrentfish, banded kokopu, inanga and rainbow trout was determined in oxygen concentrations of 1, 3 and 5 ppm, and temperatures of 15 and 20°C (see table, below left). The experiments were conducted in a 40-litre plastic tank containing 30 litres of water. Diffusers were positioned along both sides of the tank and fed with a supply of nitrogen and air. A small submersible pump was used to ensure mixing and to maintain water flow over an oxygen probe that constantly recorded dissolved oxygen levels.

Three bins with mesh sides, each containing between seven and ten fish, were placed in the apparatus to allow the fish to acclimatise before each experiment began. During this time oxygen saturation was maintained. After 12 hours, nitrogen was introduced, and oxygen levels within the tank fell to the desired levels over 2–3 hours, and were held there for 48 hours.

Fish mortalities and position within the water column were recorded after 1, 2, 4, 8, 12, 24, 36 and 48 hours of exposure to the selected oxygen level.

Fish species and oxygen concentrations included in the study so far

Species	Mean length (mm)	Experiments at 15°C			Experiments at 20°C		
		1 ppm	3 ppm	5 ppm	1 ppm	3 ppm	5 ppm
Smelt	56.1	x	x	x	x	x	
Torrentfish	41.0	x	x				
Banded kokopu	40.7	x	x	x	x	x	
Inanga	46.8	x	x	x	x	x	x
Rainbow trout	49.1	x	x	x			