IMPLICATIONS OF THE GREENHOUSE EFFECT FOR TROUT HABITATS AND FISHERIES IN NEW SOUTH WALES

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Brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) have a distribution in NSW which generally reflects their temperature requirements, occurring along the higher parts of the Great Dividing Range from the tributaries of the Clarence and Macleay Rivers in the north to the Snowy River in the south. Since trout are also stocked in most areas in which they now occur their distribution does not necessarily reflect an ability to spawn in the wild throughout this entire area.

Water flow and thermal requirements for trout vary with the size and life cycle stage of the fish, and there are optimal temperatures for growth, feeding and egg development (fig. 1). Lethal temperatures quoted in the literature vary (Crisp 1989, Coutant 1977) and depend on both the acclimatisation temperature of the experimental fish and the oxygen saturation of the water. The upper lethal temperature tends to be about 25°C for both species of trout. However, it is both the upper lethal and avoidance temperatures (the latter c. 19°C) which limit trout distribution in NSW, as most lowland streams exceed the avoidance temperature in summer.

The numerous interrelated factors contributing to stream temperature regime include flow, source and groundwater influences (Ward 1985, Crisp 1989). All of these are expected to change with the climatic changes associated with the Greenhouse effect. Changing rainfall patterns and therefore flow regimes will affect habitat in many ways (Table 2) and although Australian rivers are noted for their highly variable flow (Williams 1981) this variability will become even more pronounced. One of the most significant changes would be increased rainfall, which would increase siltation and spawning redd washout, and thus affect both survival of juveniles and food production. Increased rainfall could, conversely, have a positive contribution to cooling in those rivers having elevated temperatures under low flow summer conditions.

A rise in mean temperature of 2-4°C will, at best, shrink the area suitable for trout, but a large number of areas already close to the thermal maxima may also become unsuitable for trout. In most areas an increase of altitudinal range is not possible because the fish already inhabit the highest areas, except in the Snowy Mountains.

The other stages of the trout life cycle which are vulnerable to temperature rises occur during the spawning migrations and egg/larval development. Temperature ranges suitable for egg development and young fish are, as for other species of fish, far narrower than for adult fish (fig. 1, Table 1) (Elliott 1981, Brett 1956). Spawning migrations of trout occur over a range of temperatures, and Davies and Sloane (1987) reported that temperature optima for migration were 6-10°C and 9-14°C for brown and rainbow trout, respectively. This, together with upper lethal limits for egg development (Table 1) will further restrict suitable spawning areas. This is compounded by the prediction of less winter rainfall and a decrease in snowfall, and thus snowmelt, a precursor for rainbow trout spawning in some areas and particularly the Snowy Mountains. Brown trout spawn in low flow conditions in late autumn/early winter, while rainbow trout spawn in high flow conditions in early spring when temperatures are rising (Davies & Sloane 1987).

The effects will not be sudden, but likely events include an increased incidence of summer fish kills, parasites and diseases (Pickering 1989). These will be noticed first in trout hatcheries, where fish are crowded and more prone to stress. Those areas where trout production is now limited by occasional high summer temperatures will become decreasingly viable for trout production.

SPECIES	LETHAL TEMPS		OPTIMAL TEMP. RANGES	SPAWNING TEMPS	SPAWNING FLOWS
	Adults	Eggs			
Brown trout	c.25°C	c.13°C*	4-19°C	Optimum 6-10°C# Range 4-15°C	Intermittent low flows
Rainbow trout	c.25°C	>20°C*	10-22°C*	Optimum 9-14°C# Range 5-16°C	Stable high flows

* Elliott 1981; # Davies & Sloane 1987.

Table 1 Flow and thermal requirements of brown and rainbow trout.

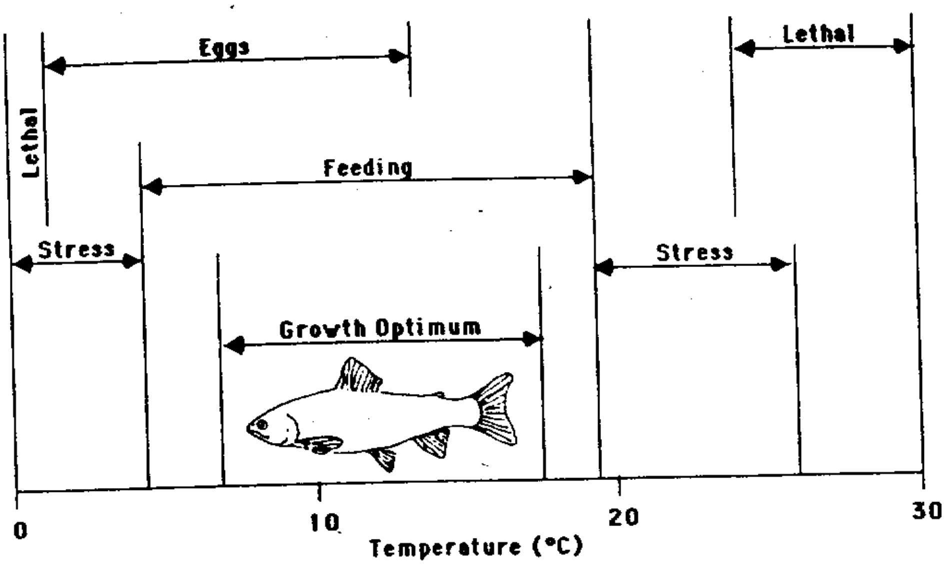

Figure 1 Thermal requirements for different life cycle stages in brown trout (after Elliot 1981).

PROBABLE CHANGES	POSSIBLE EFFECTS
Mean annual temperature rise of 2-4°C, greatest in south and in winter.	Will exceed optimal and lethal temperatures in some areas. Will exceed optimal spawning temperatures and affect larval development. Most hatcheries will experience more disease, parasite and mortality problems.
Rainfall increase of 50% in spring, summer and autumn. Daily maximum rainfall increase of the order of 20-30% with some change in the frequency and distribution of the rainfall.	Reduction of refuges. Can increase erosion and siltation and washout of redds and eggs. Possible cooling of water may influence survival of juveniles.
Rainfall decrease of 20% in winter south of 36°S.	Effects on spawning migrations, particularly of brown trout. Shift in time of spawning possible.
Snowline rise of 100 m per 1°C rise in temperature.	Snowmelt runoff changes. Effects on spawning and egg/larval development caused by changing temperatures and flows.
Increased summer and decreased winter electricity demand.	Altered storage dynamics of impoundments. Fluctuating levels and rapid replacement of water will affect food production.

Table 2 Possible effects of climatic changes on trout (to the year 2030).

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