# IMPLICATIONS OF THE GREENHOUSE EFFECT FOR NATIVE FRESHWATER FISHES IN NEW SOUTH WALES

**J.J. Burchmore**
Habitat Management Unit
NSW Agriculture and Fisheries
PO Box K220
Haymarket NSW 2000

Many freshwater fishes live in restricted and enclosed environments, and therefore climatic changes can have immediate impacts on them. Unlike Europe and North America, Australia has a natural climatic cycle of droughts and floods, and native freshwater fishes have evolved to survive these harsh climatic extremes. Many native freshwater fishes such as golden perch, silver perch, Murray cod and Australian bass require flood events to stimulate spawning and/or migration. Inundated floodplains also provide vital spawning and nursery areas for many native freshwater fish species (Geddes & Puckridge 1989).

Despite this certain degree of inbuilt adaptability to changing environmental conditions, the populations of many freshwater fish species are in decline (Cadwallader 1978). Of the 189 native freshwater fishes found in Australia, the conservation status of 59 (i.e. over 30%) is in some way threatened or in doubt (Harris 1987).

Some of the reasons for this decline are set out in Table 1 and many of these reasons are related to the modification of fish habitats. Past water management practices have been very damaging, particularly irrigation schemes, river "improvement" works and the construction of dams and weirs. In the vast Murray-Darling Basin, over fifty percent of the available surface water is used for irrigation (Jacobs 1989).

* Water management practices - irrigation, flood mitigation, river "improvement" (including de-snagging and channelisation), dam and weir construction.
* Land clearing for agricultural purposes.
* Forestry activities.
* Dredging, reclamation and extractive industries.
* Road and bridge construction.
* Diffuse and point source pollution.
* Competition with introduced species, e.g. trout, carp, redfin.
* Disease, which is often spread by introduced species.

Table 1. Reasons for population declines in native freshwater fishes.

What effect then will the projected climatic changes due to the Greenhouse effect have on these already environmentally stressed freshwater fish species?

It is hard to make generalisations as each native species has a different conservation status and a different set of environmental requirements. However, some possible effects of both direct and indirect climatic change are listed in Table 2.

| DIRECT CHANGES | POSSIBLE EFFECTS |
|---|---|
| Temperature rise of 2-4°C | * Spawning seasons possibly earlier and longer |
| Rainfall increase (of ~50%) in spring, summer and autumn | * Beneficial for spawning and recruitment (floodplain inundation).<br>* Increased siltation which covers spawning and feeding substrates and fills refuges. |
| Rainfall decrease (of ~20%) in winter | * Less aquatic habitat available.<br>* Adverse effect on winter spawners, e.g. Australian bass. |

| INDIRECT CHANGES | POSSIBLE EFFECTS |
|---|---|
| Operation of irrigation storages - more frequent releases; higher flood mitigation use. | * Benefits to downstream habitats if suitable water released.<br>* Adverse effects if released water too cold or of poor quality.<br>* Adverse effects if more irrigation licences granted or water quotas increased. |
| Shift in temperate zone to semi-arid areas | * Benefits to maintenance of fish habitats.<br>* Adverse effects if more irrigation, land clearing, etc. |
| Increase in groundwater salinity | * Adverse effects due to loss of riparian vegetation and available fish habitats. |
| Increase in abundance of pests | * Adverse effects if more pesticides sprayed. |
| Alteration of tidal limit | * Less habitat available for coastal freshwater fish. |

Table 2 Climatic changes and possible effects on native freshwater fishes.

Even very closely related species, such as the golden perch (*Macquaria ambigua*), the Macquarie perch (*Macquaria australasica*) and the Australian bass (*Macquaria novemaculeata*), all members of the family Percichthyidae, may differ in their responses to projected Greenhouse climatic changes.

Golden perch generally inhabit warm, sluggish inland rivers throughout the Murray-Darling Basin (fig. 1) and are well adapted to fluctuating water temperatures (range 4-37°C) and river heights. Golden perch spawn in spring and summer when water temperatures reach approximately 23-26°C, and they lay non-adhesive, pelagic eggs (Llewellyn & MacDonald 1980). This species could thus be regarded as "environmentally robust" and will probably not be adversely affected by Greenhouse climatic changes.

Macquarie perch, on the other hand, are found mainly in the upper reaches of the Murray-Darling River System in only a few isolated localities and prefer cool, clear waters (fig. 1). They spawn when water temperatures reach 16°C in shallow streams with silt-free gravel substrata and lay adhesive, demersal eggs (Llewellyn & MacDonald 1980). The populations of this "environmentally sensitive" species are already in decline and may decline even more sharply with Greenhouse climatic changes.

The Australian bass occurs in coastal drainages and is a catadromous species migrating from freshwaters to estuaries in the winter months for breeding, which is usually associated with a flood event. Spawning usually occurs from June to September when water temperatures are between 14-20°C (Llewellyn & MacDonald 1980). This species has already been placed under stress by the construction of weirs and dams on coastal streams, which hinder its seasonal movements. A Greenhouse related reduction in winter rainfall may adversely affect this winter migrating species.

Simplistically, it may appear that more water would be beneficial for native freshwater fish in general. Close (1988) pointed out that average rainfall in the Murray-Darling catchment over the past 30 years was higher than during the previous 30 years, with a concomitant increase in streamflows. These increased flows, however, have not been passed on to the environment. Our past has shown that more water probably means increased security of supply to water users and more intensive water management involving increased irrigation and increased construction of dams and weirs and other flood mitigation structures. Until fish and their important habitats, such as wetlands, are regarded as legitimate "water users" and environmental allocations of water are set aside for them in binding legislation, native freshwater fish populations will continue to decline.

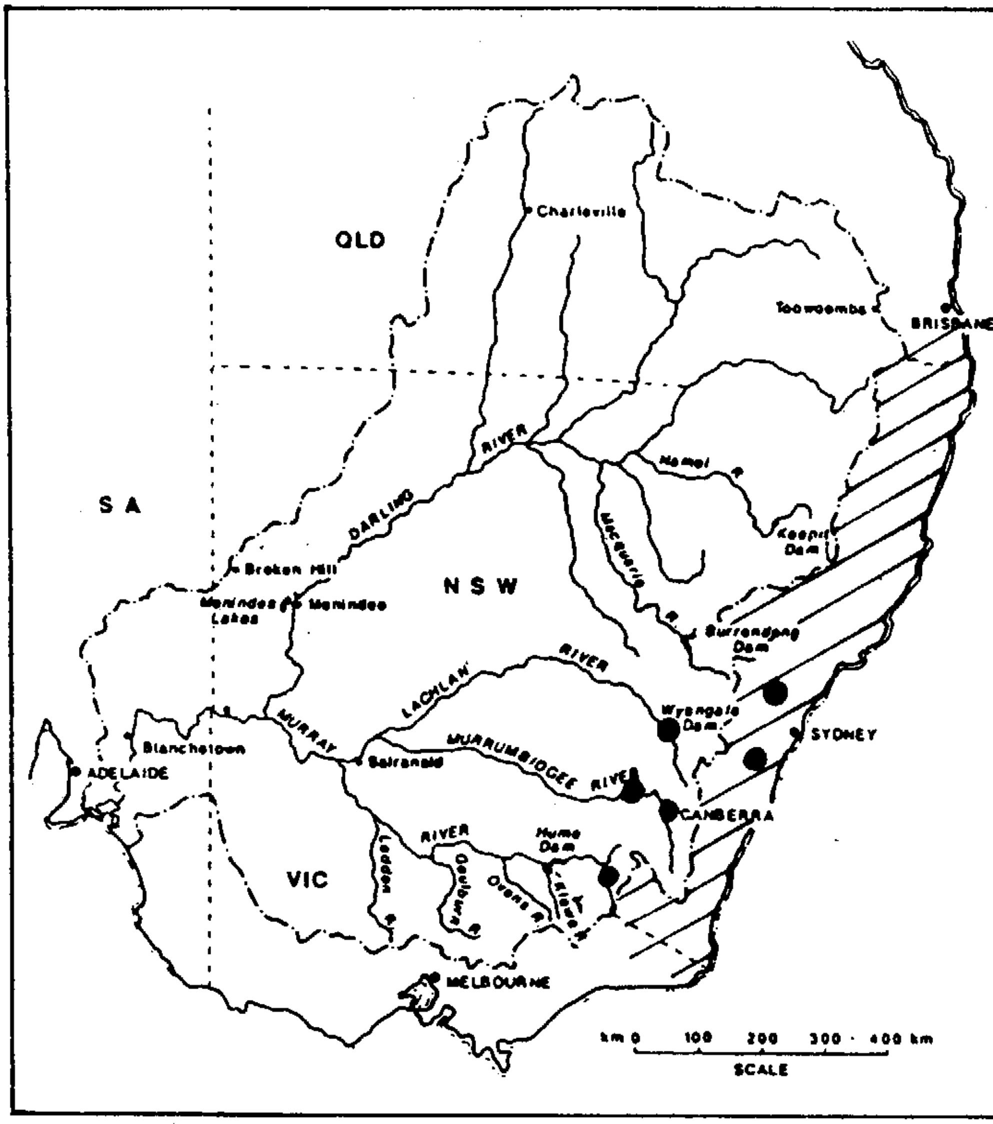


Figure 1 Present distributions of golden perch (------), Macquarie perch (•) and Australian bass (///) in New South Wales waters.

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

**R.A. Faragher**
Fisheries Research Institute
PO Box 21
Cronulla NSW 2230

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.

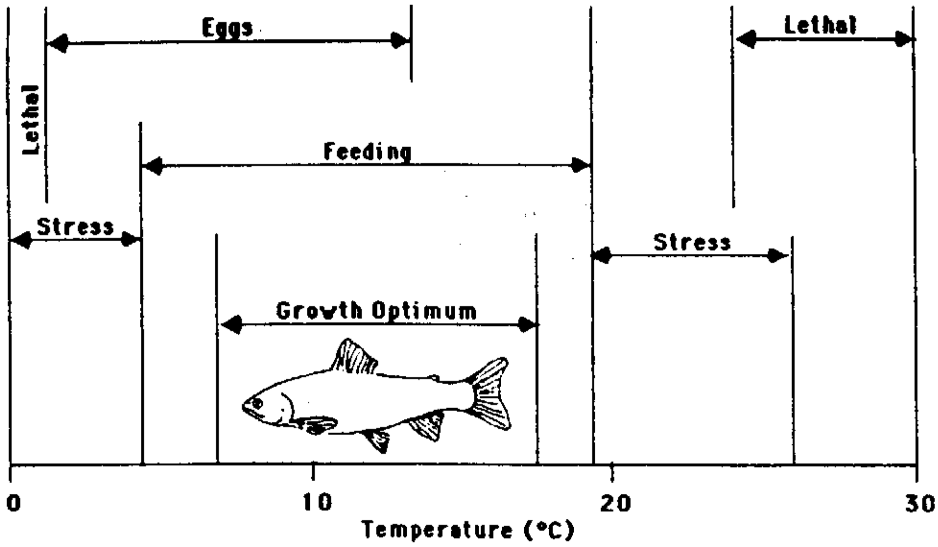


Figure 1 Thermal requirements for different life cycle stages in brown trout (after Elliot 1981).

| 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.<br>Can increase erosion and siltation and washout of redds and eggs.<br>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.<br>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.<br>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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