NEW ZEALAND FRESHWATER FISHERIES MISCELLANEOUS REPORT

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TEMPERATURE STUDES ON BROWN AND RAINBOW TROUT: LITERATURE SURVEY

CONFIDENTIAL

ISSN 1170-2001

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by

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MARCH
1989

NEW ZEALAND FRESHWATER FISHERIES MISCELLANEOUS REPORTS

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ISBN 0-477-08393-5

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TEMPERATURE STUDIES ON BROWN AND RAINBOW TROUT

LITERATURE SURVEY

Salmonids are amongst the most thermally sensitive fish species, and there is considerable information available on the thermal biology of rainbow (*Salmo gairdneri*) and brown (*Salmo trutta*) trout. Much of this literature, however, is contradictory. Further confusion is introduced by the many authors who omit, misquote or wrongly interpret other authors' work.

The temperature which trout can withstand depends on several factors, including the rate of temperature change, the duration of exposure and the animals' previous thermal history. Non-thermal factors such as the animals' genetic makeup, size, state of starvation, circadian rhythms, social and biotic interactions, stresses, infections, as well as toxic chemicals, oxygen level, photoperiod and currents, all can affect thermal responses (Alabaster & Welcomme 1962, Reynolds 1977).

The two most important factors affecting temperature preferences are the acclimation temperature and duration of exposure. These factors have been studied extensively for rainbow trout. Recently, the biochemical effects of the acclimation and test temperatures have received much attention.

Temperature Preference

In nearly all species, including brown trout, the preferred temperature bears a positive relationship to increasing acclimation temperature (Cherry *et al.* 1977, Spigarelli *et al.* 1983). However, conflicting results of studies on rainbow trout have indicated that increasing the acclimation temperature either increased (Cherry *et al.* 1975), decreased (Garside & Tait, 1958), or had no effect (Stauffer *et al.* 1984) on the preferred temperature of that species.

Final Preferendum

The final preferendum is that temperature towards which a fish will finally move, regardless of its previous thermal history. At the final preferendum, preferred and acclimation temperature are equal (Garside and Tait 1958).

There appear to be two groups of final preferred temperature reported for rainbow trout. Values below 15 °C are quoted by Garside & Tait (1958), McCauley *et al.* (1977), Spigarelli & Thommes (1979) and Stauffer *et al.* (1984); estimates by other authors are considerably higher (Table 1). Although similar discrepancies are reported for brown trout, its temperature preference appears to be lower than that of rainbow trout (Table 1).

Avoidance Temperature

Avoidance temperature is defined as the temperature avoided by fish when acclimated to their final preferendum (Coutant 1975). Problems in interpretation arise if an "avoidance temperature" is determined for a fish acclimated to any temperature, since differing responses are obtained for fish acclimated to different temperatures (e.g. rainbow trout avoided 18, 24 or 27 °C when acclimated to 6, 18 or 24 °C respectively (Stauffer et al. 1984)).

Upper and Lower Preferred Temperature

These apparent threshold values are the temperature preferences at the highest and lowest possible acclimation temperatures. They are not avoidance temperatures as trout have been known to move into waters at temperatures higher than the upper preferred temperature, notably in thermal plumes (Spigarelli et al. 1983).

Lethal Temperature

The upper lethal temperature is the temperature at which fish become severely stressed. Prolonged exposure at these levels result in death. Values that have been reported for brown and rainbow trout are given in Table 2.

The upper lethal temperature is dependent on the acclimation temperature and duration of exposure (Table 3). It is probable that if trout were acclimated to high temperature that high lethal temperature would be obtained (Stauffer et al. 1984). Indeed, in experiments in which the acclimation temperatures have been gradually raised, the lethal levels obtained were close to 30 °C for salmonids (Spaas 1960).

Frost & Brown (1967) report that trout can survive short periods at temperatures above 26.8 °C but add that trout do not survive long above 25.3 °C and that temperature tolerance markedly decreases if dissolved oxygen falls. These authors also report that exposure to high temperature has cumulative effects unless the fish can spend periods of several hours at temperatures below 21 °C.

Fluctuating temperatures increase the heat tolerance and median resistance times of juvenile rainbow trout (Thrader & Houston 1983).

For free swimming brown and rainbow trout, the upper lethal temperature seems to range between 22-28 °C (Gardner 1926, Phillips 1929, Hobb 1948, Charlon et al. 1970, Y. & J. Stark pers. comm.).

Optimum Temperature for Growth

Biotic and abiotic factors influence growth, and genetic factors are likely to affect growth rate (Frost & Brown 1967, McKay et al. 1984, Allen 1985). The maximum temperature at which a population of rainbow trout can maintain its initial weight for 40 days is a constant temperature of 23 °C or a fluctuating mean (±3.8 °C) of 21 °C (Hokanson et al. 1977). In wild populations, of brown trout, growth continued at temperatures of at least 20 °C (Allen 1951, Nichols 1957 cited in Frost & Brown 1967). Elliot (1975), however, maintains that growth of brown trout can be expected to occur only in the temperature range of 3.8-19.5 °C.

Effect of Temperature on Activity

For rainbow trout there is much supporting evidence to set the optimum temperature for physiological performance and activity at 16-18 °C (Hokanson et al. 1977). Temperatures above 20 °C significantly decreased swimming performance of rainbow trout (Schneidert & Connors 1982). Studies of enzymes in the rainbow trout found that the optimum temperature for activity was around 20 °C (Sato et al. 1984, Guibbolini & Lahlou 1987).

Effect of Temperature on Distribution

Several studies have reported that the distribution of rainbow trout in lakes was limited by temperatures over 20-21 °C (e.g. Horak & Tanner 1964, Overholtz et al. 1977, May & Gloss 1977 cited in Rowe 1986, Spigerelli & Thommes 1979).

In a survey of streams in Ontario, Canada, Barton et al. (1985) found that streams with trimean weekly maxima of less than 22 °C had trout, but that warmer streams, at best, only had small trout populations.

Although fish are poikilotherms, they are able to seek out thermal regimes which optimise their physiological processes. Thus fish can maintain a body temperature that fluctuates less than the ambient water temperature (Stauffer et al. 1984).

Emigration of rainbow trout from streams has been associated with receding water levels and rising water temperature (Kaya et al. 1977, Kwain 1983). Similar movements of trout have been recorded in Lake Rotorua and elsewhere when surface water temperatures exceeded 20-21 °C. During such hot periods, trout are known to move into, and often ascend, the colder in-flowing streams, sometimes in densities high enough to create concern about overfishing (Rowe 1984). Coutant (1987) notes however that following thermal gradients to a preferred zone does not necessarily lead a fish to beneficial habitats; the exact opposite may occur.

Trout, temperature and the Wanganui catchment

On the basis of the data just discussed, it is not possible to propose a definitive temperature regime that would promote the trout fishery of the Wanganui catchment. Only an in depth study of the catchment and of the temperature requirements of the trout strains present there could provide the material necessary to make such management decisions.

If the objective is to produce the best conditions for trout, then temperatures should be maintained close to that which promote maximum growth. From Table 2, omitting the extreme values, maximum growth seems to occur between 7 and 20 °C for brown trout, and between 11 and 22 °C for rainbow trout. Thus, maintaining temperatures below 20 °C should maximise growth of both brown and rainbow trout. It is, however, unlikely, even under a natural flow regime, that this temperature could be maintained in the Wanganui catchment during low summer flows.

From the upper lethal temperature figures available, temperatures of 23 to 26 °C are likely to cause severe stress to both trout species. It would thus be desirable to maintain temperatures below 23 °C at all times.

There is much evidence to suggest that the best means of controlling temperature in streams is by improving bank-side vegetative cover (e.g. Lynch et al. 1984, Barton et al. 1985, Theurer et al. 1985). Since much of the upper Wanganui catchment is forested, it is unlikely that this method could markedly improve conditions.

Trying to alter temperatures by flow releases in a controlled river has been shown to affect temperatures for only a short distance below the point of release (Larson 1984). Furthermore, in the Wanganui catchment under the present flow restrictions, no consistent relationship has been found between discharge and water temperature (Richardson & Teirney 1982).

During periods of high water temperature, trout have been shown to seek cooler refuges. It would be important to determine if such migrations occur in the Wanganui catchment and if there are any means of enhancing these refuges and their access.

Under the present temperature conditions, it may also be possible to improve the trout fishery of the Wanganui catchment by stocking it with a trout strain more suited to the temperature regime of the catchment. It must nevertheless be remembered that water temperature is not the only factor affecting fish in a system.

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Table 1. Summary of data on final preferendum and upper and lower avoidance temperature of brown and rainbow trout from field and laboratory studies.

Species	Age	Avoidance Temp. (°C) Upper	Lower	Final Preferendum	Location	Source
Rainbow	A			13	Lab.	Garside & Tait 1958 *
	A			19-21	Lake	Horak & Tanner 1964 *
	J			18-22	Lab.	Javaid & Anderson 1967 *
	J	22	14	18-19	Lab.	McCauley & Pond 1971 *
	A	19	13	18	Lab.	Cherry _et al._ 1975
	A			16.5	Lake	Spigarelli 1975
	A	27	12	19.7	Lab.	Cherry _et al._ 1977
				11.3		McCauley _et al_ 1977
	A			15	Lake	Spigarelli & Thommes 1979
	J			19	"	" " " "
	A			18.1	Lab.	Gregory & Anderson 1984
	A	20-21			Lake	Rowe 1984
	J	27		14.7	Lab.	Stauffer _et al._ 1984
Brown				12	Lake	James 1931 *
	J			17.6	Lab.	Tait (in Ferguson 1958) *
		20			Lab.	Alabaster & Downing 1966 *
	A			14-16	Lake	Spigarelli 1975
	J	21	12	17.4	Lab.	Cherry _et al._ 1977
				11.5	Lake	Haynes & Nettles 1983
		16-17		12	Lake	Spigarelli _et al._ 1983
				18-19	Field	Nyman 1975 (in spigarelli _et al._ 1983)

A = adult   * = cited in Coutant (1977)
J = juvenile

Table 2. Growth optimum and upper lethal temperatures (°C) for brown and rainbow trout.

Species	Growth optimum	Upper lethal	Source
Rainbow			
		25.7	Black 1953 *
	12-16		Garside & Tait 1958 *
		27	Craigie 1963 *
		22.5-25.3	Frost & Brown 1967
	16-22		Javaid & Anderson 1967
		25-26	Bidgood & Berst 1969
	12-19	24.9	Bell 1973 *
	12-22	>24	Cherry <u>et al.</u> 1975
	19	24	USEPA 1976 *
	16.5		Wurtsbaugh & Davis 1977 !
	17.2	25.7	Hokanson <u>et al.</u> 1977 !
	10-13		McCauley <u>et al.</u> 1977 *
	14-22	>24	Cherry <u>et al.</u> 1977
	11-18		Kwain & McCauley 1978 *
	14.7		Paterson <u>et al.</u> 1979 *
		25.7-26.2	Kaya 1978
	18.3		Platts 1981 *
		26.7	Stauffer <u>et al.</u> 1984
Brown	18-20	25	Gardner 1926 *
		>25.6	Phillips 1929 *
	10		Pentelow 1939 !
	15.5		Wingfield 1940 !
	7-19	25	Brown 1946 *
		>25	Hobbs 1948 *
	18-20	25.5	Spaas 1960 *
	12		Swift 1961 !
		22.5-29	Jones 1964 *
	10-13		Hunt & Jones 1972 *
		26.4	Alabaster & Downing 1966
	7-19	22.5-25.3	Frost & Brown 1967 *
	4-21	23.8	Bell (1973) *
	13		Elliot 1976 !
	12-19	>23	Cherry & al. 1977

* = cited in Richardson & Teirney 1982.
! = cited by McCauley & Casselman 1981.

Table 3. Temperature (°C) at which 50% of brown trout fry survive 1 000 and 100 minutes after acclimation at a lower temperature (Alabaster 1963).

Acclimation temperature (°C) 6		15		20	
1000	100	1000	100	1000	100
23.2	23.9	26.0	27.4	26.4	28.2
24.3	-	25.9	-	-	26.7