H. M. BISHAI

UPPER LETHAL TEMPERATURES FOR LARVAL SALMONIDS

EXTRAIT DU JOURNAL DU CONSEIL INTERNATIONAL
POUR L'EXPLORATION DE LA MER
VOL. XXV. No. 2. 1960

Upper Lethal Temperatures for Larval Salmonids

By

H. M. Bishai

Dove Marine Laboratory, Cullercoats, England*

Introduction

Although much work has been carried out on the effect of temperature on fish, very little has been done on their early larval stages. BRETT (1956) gave a brief account on the thermal requirements of fish and the effect of temperature on their distribution. He pointed out the importance of the study of the thermal requirements during the early stages of development. The present work deals with the effect of high temperatures on larval salmonids, i. e., the early larval stages just after hatching.

Material

The fish used in these experiments were the larvae of salmon (*Salmo salar* L.), sea trout (*Salmo trutta*), and brown trout (*Salmo trutta* f. *fario*). The fish were reared at the Dove Marine Laboratory, Cullercoats, North Shields, England. Artificial fertilization was carried out either at the Laboratory or at the fish hatcheries.

Methods and Apparatus

Experiments and acclimation were carried out in 6 litre glass tanks, 8·5″ long, 7″ wide, and 15·5″ high. Thermostatically controlled glass covered electric heaters maintained temperatures within ±0·5°C. The water was continuously aerated by compressed air and occasionally changed either by siphoning and replacing, or by introducing a continuous flow, or simply by transferring the fishes to other tanks brought to the same temperature. Salmonid larvae could live in such water for at least a fortnight without changing the water and experiments showed that at 5°C these larvae survived for three days (duration of experiment) at 3·5% oxygen saturation (BISHAI, 1959). The fish larvae used in all the experiments were reared at 5° to 6°C. Incubation of the eggs took place at an average temperature of 7·5°C.

* Present address: Zoology Department, Faculty of Science, University of Khartoum, Sudan.

Effect of slow rise of temperature to upper lethal levels

Ten fish of each species (salmon, sea trout, and brown trout) were introduced into the experimental tanks. The water was heated slowly from 6°C to the desired temperature which lay between 20° to 30°C. The limit of 20°C was chosen after preliminary experiments, which showed that the larvae of the three species can live for at least one week at that temperature without any apparent ill effects.

The rise of temperature from 6°C to the desired temperature took place in 4 to 6 hours, after which the temperature was kept constant. The time at which the fish died was taken from when the desired temperature was reached. Experiments were continued either until all fish were dead or until the experiment has been running for 5 to 7 days.

Acclimation experiments

As pointed out by various authors (HUNTSMAN, 1942; HART, 1947; BRETT, 1956) acclimation increases the resistance of fish and so produces a higher figure for the lethal temperature. Some acclimation experiments were carried out on larvae in which the yolk-sac was not completely absorbed, as when the fish reaches the fry stage other factors such as the availability of food will affect the results. Consequently acclimation had to be limited to periods not longer than 7 days. Larvae at 5°C were acclimated at 10°C and 20°C. They were held at 10°C for five days, and at 20°C for five days (two days at 10°C, two days at 15°C, and one day at 20°C). After acclimation fish were subjected to high temperatures from 22°–26°C. Tests were performed at 1°C higher temperature until two temperatures were found at one of which more than half and at the other less than half of the species tested survived. The upper lethal temperature is taken as the highest temperature that 50% of the population can withstand for 7 days (the duration of the experiment).

Experimental Results

(i) *Slow heating without previous acclimation*

The results of these experiments are shown in Table 1.

The results show that brown trout is the most resistant, salmon and sea trout less so.

(ii) *Quick transfer to higher temperatures following varying conditions of acclimation*

The results are summarized in Table 2 which again shows that brown trout is more resistant than salmon and sea trout. The median resistance time which represents 50% mortality increases with increase of acclimation temperature.

Discussion

The effect of high temperature on the survival of fish may be a direct one by being lethal. The death of fish from heat stroke was observed in nature for salmonids and other stream fishes by HUNTSMAN (1942, 1946) and BAILEY (1955). Experiments showed that salmon (*Salmo salar*), sea trout (*Salmo trutta*), and brown trout (*Salmo trutta* f. *fario*) alevins die if subjected to temperatures

Table 1

Resistance of salmon, sea trout, and brown trout alevins to high temperatures

Age: newly hatched larvae. Initial temperature 6°C (local tap water used). Fish brought to the final temperature in 6 hours period. Maximum duration of experiment: 16 days (384 hours).

Figures represent the time for 100% mortality in hours taken from when the desired temperature was reached.

Species	Temperature, °C 28	26	25	24	23	22	20
Salmo salar	2	3	15	144	192	216	No mortality
Salmo trutta	2	3	15	144	180	288	No mortality
Salmo trutta f. *fario*	5	7	15	144	200	384	No mortality

Figures represent the time for 50% mortality in hours.

Species	Temperature, °C 28	26	25	24	23	22	20
Salmo salar	1	2	10	65	120	188	No mortality
Salmo trutta	1	2	8	17	96	168	No mortality
Salmo trutta f. *fario*	1	5	12	65	144	288	No mortality

Table 2

Resistance of salmon, sea trout, and brown trout alevins to high temperatures

Age: 30 days after hatching (yolk-sac partly absorbed). Alevins transferred directly from rearing tanks to the experimental tanks (local tap water used). Duration of experiment: 7 days (168 hours).

Fish	Acclimation temp. °C	Time in hours for 50% mortality and 100% mortality (in parentheses) at different temperatures 26	25	24	23	22.5	22
Salmon	5	–	1 (1·5)	2 (14)	3 (24)	6 (30)	*
	10	1 (5)	2 (10)	12 (30)	*	*	*
	20	10 (12)	12 (14)	48 (144)	*	*	*
Sea trout	5	–	1 (1·5)	17 (62)	24 (96)	24 (125)	*
	10	1 (10)	3 (12)	48 (72)	*	*	*
	20	7 (29)	14 (35)	60 (144)	*	*	*
Brown trout	5	–	1 (3)	62 (86)	100 (126)	130 (*)	*
	10	12 (15)	24 (48)	72 (94)	*	*	*
	20	24 (144)	36 (168)	86 (168)	*	*	*

* indicates that 50% or 100% mortality was not reached before the end of the experiment.

higher than 25°C. The upper lethal limit of temperature of salmonid alevins reared at 5° to 6°C and heated slowly was barely above 23°C. EMBODY (1921) found that trout lived at 25°C for 10 days and at 26·7°C for three days. RUSHTON (1929) observed that 80% of salmon and brown trout fry died at temperatures not higher than 25°C. MCGONIGLE (1932) found that brook trout fingerlings die at 29°C if heated slowly. BRETT (1952) working on salmonids (*Oncorhynchus*) found that the upper lethal temperature of the fry acclimated at 5°C was 21·2°C–22·9°C. Moreover many investigators pointed out that young fish have a greater heat tolerance than do the adults (HUNTSMAN, 1942; HART, 1952, 1954; BAILEY, 1955, etc.).

Acclimation of salmon, sea trout, and brown trout increases their resistance to high temperatures. The upper lethal temperature for salmon reared at 5°–6°C was 22°C but when acclimated at 10°C and 20°C it was 23°C. The results of acclimation experiments are summarized in Table 3.

Table 3

Upper lethal temperatures (°C) of salmonid alevins at different acclimation temperatures

Acclimation temperature	Upper lethal temperature (50% living for 7 days) 5°–6° C	10° C	20° C
Salmo salar	22	23	23
Salmo trutta	22	23	23
Salmo trutta f. *fario*	22·5	23	23

This table shows that by raising the acclimation temperature by 15°C (from 5°–20°C) there is a 1°C rise in the upper lethal temperature. FRY, BRETT, and CLAWSON (1942) working with goldfish, found that for every 3°C rise in acclimation temperature the upper lethal temperature rose by about 1°C. Yearling speckled trout (*Salvelinus fontinalis*) showed a smaller change; a 7°C rise in acclimation was required to produce 1°C change in the upper lethal temperature (FRY, HART, and WALKER, 1946). This increase in the resistance to high temperatures after acclimation has been observed by many investigators (HATHAWAY, 1928; SUMNER and DOUDOROFF, 1938; BRETT, 1941, 1944, 1946, 1952, 1956; FRY, BRETT & CLAWSON, 1942; FRY, HART, and WALKER, 1946; HART, 1947, 1952).

The results of these experiments show that brown trout alevins are the most resistant to temperature changes as compared to both salmon and sea trout. Thus migratory fish seem to have less resistance to high temperatures than is indicated by lake or stream-dwelling ones. FRY, HART, and WALKER (1946) and BRETT (1952, 1956) pointed out that sea migratory forms (*Oncorhynchus*) have considerably less resistance to low temperature than is indicated by lake or stream-dwelling char (*Salvelinus fontinalis*).

Acknowledgements

This work was carried out at the Dove Marine Laboratory Cullercoats, England. I am very grateful to Dr. H. O. BULL, the Deputy Director, for his valuable advice, continuous help and reading the manuscript. My thanks are due to the Northumberland and Tyneside River Board and Mr. G. L. TATHAM of Welham Park Fish Hatchery, Melton, Yorkshire for giving me facilities to carry out the artificial fertilization and supplying me with running fish.

Summary

1. The upper lethal temperature for salmon, sea trout, and brown trout alevins reared at 5°–6°C when heated slowly was 23°C. At 24°C, 50% lived for 5 days and at 20°C they could live without ill effects and without any mortality for at least 16 days.

2. Experiments showed that brown trout and sea trout are more resistant to high temperatures than salmon.

3. Acclimation to higher temperatures increases the upper temperature tolerance. The resistance of salmonid alevins with the yolk-sac appeared not to change with age.

References

BAILEY, R. M., 1955. "Differential mortality from high temperature in a mixed population of fishes in southern Michigan". Ecology, **36**: 526–28.

BISHAI, H. M., 1959. "The effect of gas content of water on larval and young fish". Z. wiss. Zool., **163**: 37–64.

BRETT, J. R., 1941. "Tempering versus acclimation in the planting of speckled trout". Trans. Amer. Fish Soc., **70**: 397–403.

BRETT, J. R., 1944. "Some lethal temperature relations of Algonquin Park fishes". Univ. Toronto Stud., biol. Ser., 52, Publ. Ont. Fish Res. Lab., 63: 5–49.

BRETT, J. R., 1946. "Rate of gain of heat tolerance in goldfish (*Carassius auratus*)". Univ. Toronto Stud., biol. Ser., 53, Publ. Ont. Fish. Res. Lab., 64: 9–28.

BRETT, J. R., 1952. "Temperature tolerance in young pacific salmon, genus *Oncorhynchus*". J. Fish. Res. Bd. Can., **9**: 265–323.

BRETT, J. R., 1956. "Some principles in the thermal requirements of fishes". Quart. Rev. Biol., **31**: 75–87.

EMBODY, G. C., 1921. "Trout and high water temperature". Trans. Amer. Fish. Soc., **51**: 58–61, and Salm. Trout Mag., 1944: 290–91.

FRY, F. E. J., BRETT, J. R., & CLAWSON, G. H., 1942. "Lethal limits of temperature for goldfish". Rev. Can. Biol. **1**: 50–56.

FRY, F. E. J., HART, J. S., & WALKER, K. F., 1946. "Lethal temperature for a sample of young speckled trout, *Salvelinus fontinalis*". Univ. Tronto Stud., biol. Ser., 54, Publ. Ont. Fish. Res. Lab., 66: 9–35.

HART, J. S., 1947. "Lethal temperature relations of certain fish of the Toronto region". Trans. roy. Soc. Can., **41**: 57–71.

HART, J. S., 1952. "Geographic variations of some physiological and morphological characters in certain fresh water fish". Univ. Toronto Stud., biol. Ser., 60, Publ. Ont. Fish. Res. Lab., 72: 1–79.

HATHAWAY, E. S., 1928. "Quantitative study of the changes produced by acclimatisation in the tolerance of high temperatures by fishes and amphibians". Bull. U.S. Fish Comm., 43: 169–92.

HUNTSMAN, A. G., 1942. "Death of salmon and trout with high temperature". J. Fish Res. Bd Can., **5**: 485–501.

HUNTSMAN, A. G., 1946. "Heat stroke in Canadian Maritime stream fishes". J. Fish Res. Bd Can., **6**: 476–82.

MCGONIGLE, R. H., 1932. "Some effects of temperature and their relation to fish culture". Trans. Amer. Fish Soc., **62**: 119–25.

RUSHTON, W., 1926. "Biological notes". Salm. Trout. Mag., 45: 377–85.

SUMNER, F. B., & DOUDOROFF, P., 1938. "Some experiments upon temperature acclimatisation and respiratory metabolism in fishes". Biol. Bull. Woods Hole, **74**: 403–29.

ANDELSBOGTRYKKERIET I ODENSE