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Upper Lethal Temperatures of Some British Columbia Freshwater Fishes[1]

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ABSTRACT

During the summers of 1950 and 1951 the upper lethal temperature was measured for 14 species of freshwater fishes, representing five families. The fish were captured from lakes in the southern Okanagan Valley, and the experiments were conducted in the Summerland Trout Hatchery, Summerland, B.C. The upper temperature (°C.) at which 50 per cent of the fish died in 24 hours was estimated as follows, the approximate acclimation temperature being given in brackets: *Salmo gairdneri kamloops* fingerlings, 24.0(11); *Oncorhynchus nerka kennerlyi* fry, 22(11); *Catostomus catostomus*, 27(11.5), 26.6(14); *Mylocheilus caurinus*, 27(10), 27.1(14); *Rhinichthys falcatus*, 28.3(14); *Richardsonius balteatus*, 25(9–11), 27.6(14); *Cottus asper*, 24.1(18–19); *Catostomus macrocheilus*, 29.4(19); *Micropterus salmoides*, 28.9(20–21); *Ptychocheilus oregonensis*, 29.3(19–22); *Ameiurus melas melas*, 35.0(23); *Perca flavescens*, 26.5(18), 29.2(22–24); *Lepomis gibbosus*, 28.0(18), 30.2(24); *Cyprinus carpio*, 31–34(20), 35.7(26).

INTRODUCTION

During the summer of 1950, preliminary observations were carried out on the upper lethal temperatures of five species of fishes found in Okanagan lakes (Black and Black, 1950). A correlation between the order for lethal temperatures and the carbon dioxide asphyxiation curves was noted for four of the five species. These findings prompted the extension of the investigation during the summer of 1951.

In this paper, use of the term acclimation is restricted to the exposure of an organism to temperature conditions in a laboratory, whereas the term acclimatization refers to temperature changes that are imposed by the natural habitat.

As shown by a number of workers, the upper lethal temperature relationships afford a valid clue to the abilities of and limits for fishes to tolerate environmental changes in temperature (Hathaway, 1927; Fry *et al.*, 1942, 1946; Brett. 1941, 1944, 1951; Hart, 1947, 1952). The shift in lethal temperatures with acclimation to temperature was also measured by these workers.

No direct information was gained on the interesting problem of the mechanism of thermal death in fishes. Discussions of this fundamental question will be found in the writings of Huntsman (1924), Huntsman and Sparks (1924), Battle (1926), Cameron (1930), Belehradek (1935), Heilbrunn (1943), Fry (1947), Prosser *et al.* (1950), and Hoar and Cottle (1952).

MATERIAL AND METHODS

Thirteen species of freshwater fishes of the Okanagan area were investigated during May, June and July, 1951. The common and scientific names, total numbers

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used, number used per test, weight average and range, place of capture and temperature of surface water, and duration of exposure of captured fish at 11°C. are given in Table I. The fishes were identified according to the key provided by Carl and Clemens (1948), and the identification of the fine-scaled sucker, chub, silvery-grey minnow and northern black catfish was checked by Dr. W. A. Clemens. Mr. T. Northcote confirmed the identification of the prickly sculpin.

TABLE I. Common and scientific names, total number used, usual number used for test, weight (average and range), place of capture and temperature of surface water, and duration of exposure of captured fish at 11° C., for species studied at Summerland, B.C., May-July, 1951.

Species	Total No. of fish used	Usual No. used per test	Weight (average and range)	Place of capture	Temperature of water at place of capture	Duration of exposure to 11° after capture (days)
			g.		° C.	
Kamloops trout (fingerling) *Salmo gairdneri kamloops*	40	10	26.1 14.0–54.2	Summerland trout hatchery	11.0°	Hatched and reared at 11° 8–22 days
Fine-scaled sucker *Catostomus catostomus*	36	6	44.3 32.8–60.8	Garnet valley dam	14.4°	
Coarse-scaled sucker *Catostomus macrocheilus*	60	10	19.4 2.0–48.5	Okanagan Lake at Summerland	18.9°	2–10
Carp (Lot 1) *Cyprinus carpio*	70	10	12.8 5.3–32.7	Twin Lakes	20.0°	4–15
Carp (Lot 2)	40	10	28.2 6.9–64.6	Twin Lakes	25.6°	1
Chub *Mylocheilus caurinus*	60	10	9.4 5.9–26.0	Okanagan Lake at Summerland	14.4°	5–8
Silver-grey minnow *Rhinichthys falcatus*	68	10	3.3 1.1– 7.4	Garnet valley dam	14.4°	5–8
Squawfish *Ptychocheilus oregonensis*	56	10	8.9 0.7–71.1	Okanagan Lake at Summerland	18.9° to 22.2°	4–7
Redside shiner *Richardsonius balteatus*	51	10	6.3 2.1–10.5	Garnet valley dam	14.4°	6–12
Northern black catfish *Ameiurus melas melas*	50	10	51.9 9.7–138.	Osoyoos Lake	23.3°	4–6
Yellow perch (Lot 1) *Perca flavescens*	36	6	9.8 2.0–24.8	E. Smith's pond near Oliver, B.C.	17.8°	26–32
Yellow perch (Lot 2)	70	10	8.6 2.9–50.5	E. Smith's pond near Oliver, B.C.	22.2°–24.4°	5–11
Largemouth bass *Micropterus salmoides*	28	6	52.2 5.1–127.	Shannon Lake	20.0°–21.1°	4–20
Pumpkinseed (Lot 1) *Lepomis gibbosus*	18	6	19.3 3.6–44.0	E. Smith's pond near Oliver, B.C.	17.8°	28–34
Pumpkinseed (Lot 2)	60	10	15.9 1.7–42.7	E. Smith's pond near Oliver, B.C.	22.2°–24.4°	5–10
Prickly sculpin *Cottus asper*	61	10	4.0 0.6–24.3	Okanagan Lake at Summerland	18.3°–18.9°	9–23

Not all the fishes studied are native. The following are believed to have been introduced or migrated recently through the Columbia River system from the northwestern United States: carp, northern black catfish, yellow perch, largemouth bass and the pumpkinseed (Carl and Clemens, 1948).

Except for the hatchery fish and the prickly sculpin, all species were captured by means of a small minnow seine. The sculpins were caught by angling, dip-net and seine. The fish were transported to the Summerland Trout Hatchery, Summerland, B.C., in fry cans and then placed in rearing troughs or cement ponds depending upon the availability and convenience of holding space. The temperature of the hatchery supply of artesian water was 11°C.

As the lake temperatures were slowly rising during the period of fish captures, the temperatures at the time of capture are considered to be uppermost till that date. Certain limnological characteristics of Okanagan lake for an earlier season were determined by Clemens, Rawson and McHugh (1939).

Temperature of the body of water in which the fish were captured was above that of the hatchery supply in all cases except for the Kamloops trout (see Table I). No allowance was made for the possibility that there may have been some selection of captured fish by transfer from higher temperature to 11°C.

Other than for the Kamloops trout, no effort was made to feed the fishes during captivity although often supplies of dead trout eggs and ground mammalian liver were liberated by hatchery attendants into the holding tanks. Usually the carp, pumpkinseed, perch, suckers and silver-grey minnows did not feed. The sculpins ate trout eggs and would occasionally feed upon their own kind. The northern black catfish ate liver. The effect of starvation on upper lethal temperatures was not determined.

Species of fish which showed signs of deterioration (external sores, etc.) during captivity were the largemouth bass, yellow perch, northern black catfish and the carp. When signs of increased mortality appeared, the experiments were abandoned or a new lot obtained for study.

The method used in determining upper lethal temperatures was that developed by Brett (1941, 1944) and Fry *et al.* (1942) which method was adapted from that used earlier by Hathaway (1927). Four to six samples of fish were placed directly from the holding tank to the experimental tank of water at the desired temperature. The upper lethal temperature was taken as the temperature at which 50 per cent of the sample survived 24 hours. Usually this point was taken from a graph constructed for the percentage of those that survived 24 hours exposure plotted against the temperature of the test bath.

Two sizes of experimental tanks were used, 61 × 61 × 17.8 cm. (24 × 24 × 7 inches) and 76 × 76 × 20.3 cm. (30 × 30 × 8 inches). The construction was of galvanized sheet metal, coated completely with aluminum paint. The tanks were filled to within an inch of the top. The water was heated by stainless-steel electrical heaters purchased from the American Instrument Company. During the first six weeks the temperature was controlled by Fenwal thermostat switches suitably covered with stainless steel. During the last five weeks mercury-in-glass thermoregulators, Elektran transformers and mercury relays purchased from the American Instrument Company were used. The water was stirred by aeration, using Thiberg aerators and stone air-breakers purchased from the General Biological Supply House. Usually three to five tanks were in operation simultaneously.

The larger-sized sheet-metal tanks were used for samples of six larger fish or ten of the fingerling size. Each tank was covered with galvanized netting

0.64 × 0.64 cm. (¼ in.) mesh to prevent escapement. The tanks were well illuminated.

The temperature was recorded from time to time during each test run using laboratory-grade mercury thermometers calibrated from −10° to 110°C. A second check was made on the temperature by using Taylor maximum-minimum thermometers. The laboratory thermometers were standardized against a certified thermometer.

Source of the hatchery water supply is from an artesian well. Temperature of the water was uniform varying only 0.5°C. from 11.0°C. While the level of dissolved oxygen was adequate, the content of free carbon dioxide was relatively high (8 mm. Hg. or 30 p.p.m.). Aerators were added as required to the lethal test tanks in order to maintain oxygenation above 100 mm. Hg. (two-thirds saturated).

Usually the fish were removed from the tank as they died so as to reduce fouling of the water. Experimental tanks were cleaned after each experiment. At the conclusion of each test, all survivors were sacrificed for sex determination and search for parasites.

As was the experience of Brett (1944) and Fry *et al.* (1946), no difficulty was encountered in recognizing the end-point of life in the upper lethal-temperature tests. An exception to this rule was the indeterminate end-point for the first lot of carp.

TABLE II. Summary of upper lethal temperature data for freshwater fishes studied at the Summerland Trout Hatchery from May to July, 1951. The data are arranged in groups according to the approximate acclimatization temperatures. The values marked * are actual readings for 50 per cent mortality.

Species	Approximate acclimatization temperature	Upper temperatures at which fish survive 24 hours		
		All	50%	None
	° C.	° C.	° C.	° C.
Kamloops trout (fingerling)	11	22.4	24.0	25.7
Fine-scaled sucker	14	26.4	26.9*	28.3
Chub	14	24.4	27.1	29.1
Silver-grey minnow	14	25.2	28.3	28.3–31.1
Redside shiner	14	22.8	27.6	30.3
Prickly sculpin	18–19	22.8	24.1	26.5
Coarse-scaled sucker	19	25.7	29.4	32.2
Largemouth bass	20–21	25.2	28.9*	30.4
Squawfish	19–22	26.4	29.3	32.0
Northern black catfish	23	34.4	35.0	36.7
Yellow perch	22–24	28.9	29.2	29.1–29.8
Pumpkinseed	24	29.2	30.2	31.0
Carp	26	34.1	35.7	36.9

RESULTS

Results are presented in summary in Tables I–III and illustrated in Figures 1–14. Complete tables of data are appended to typescript reports which are on file in the libraries of research stations of the Fisheries Research Board of Canada.

The degree of variation for the upper lethal temperatures is not given. However, the variation during the test run is discussed below. The writer contends

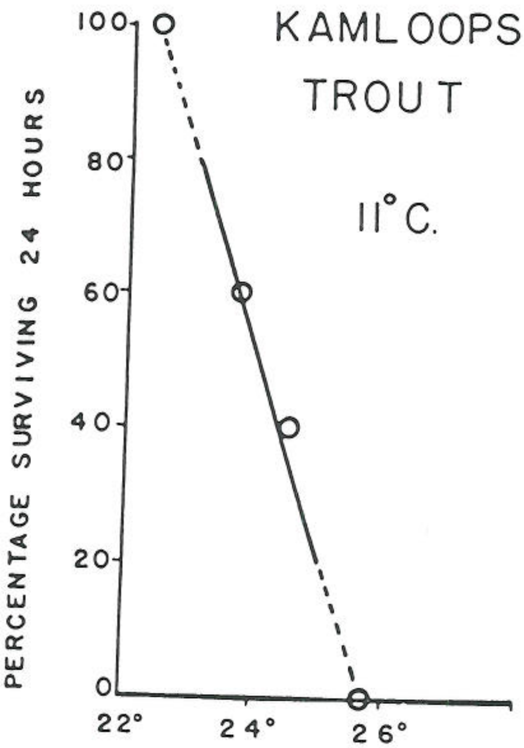

FIGURE 1. Upper lethal temperature data for Kamloops trout fingerling acclimatized at 11°C.

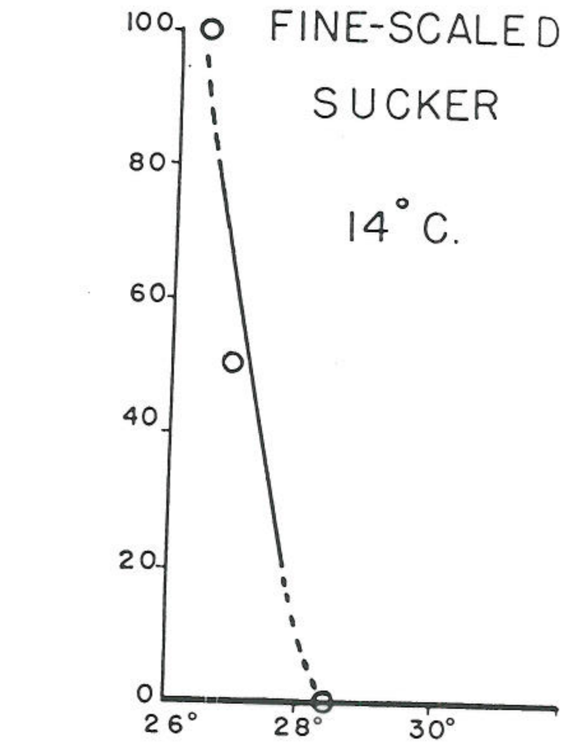

FIGURE 2. Upper lethal temperature data for fine-scaled sucker acclimatized at approximately 14°C.

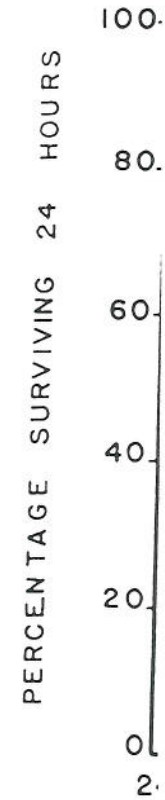

FIGURE 5
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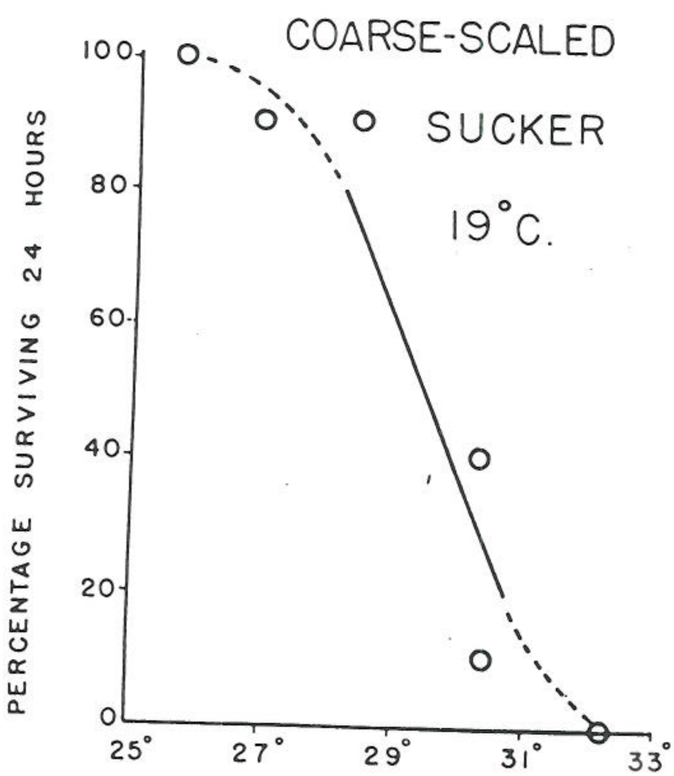


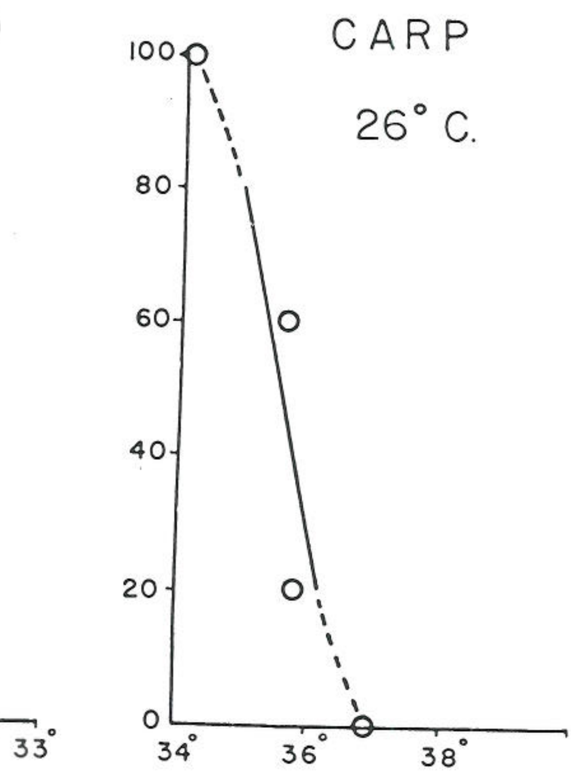
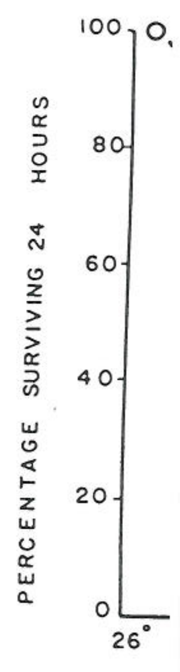


FIGURE 3. Upper lethal temperature data for coarse-scaled sucker acclimatized at approximately 19°C.

FIGURE 4. Upper lethal temperature data for carp acclimatized at approximately 26°C.



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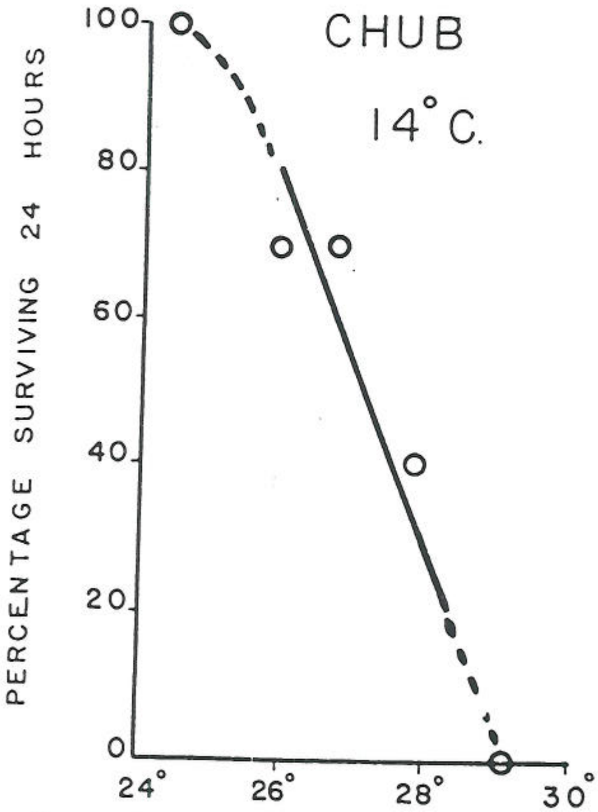


Figure 5. Upper lethal temperature data for chub acclimatized at approximately 14°C.

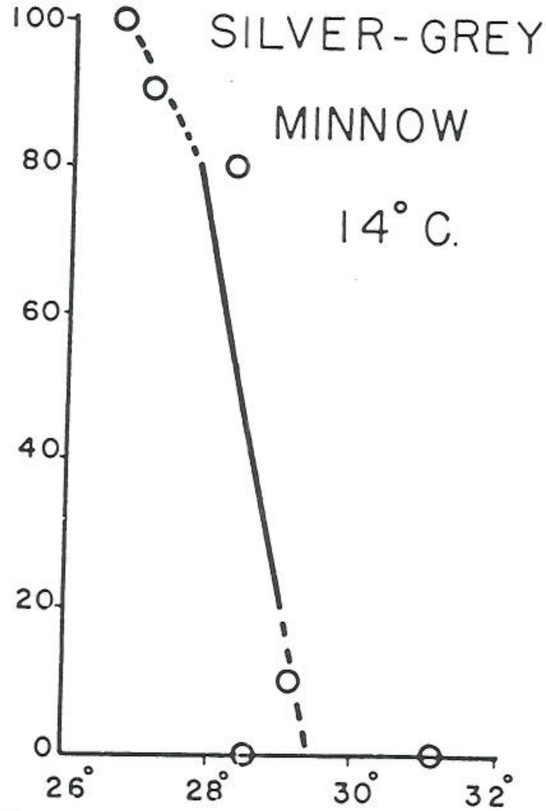
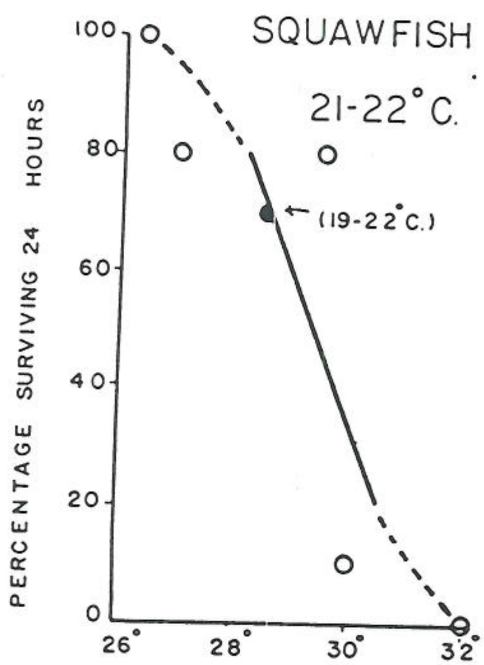
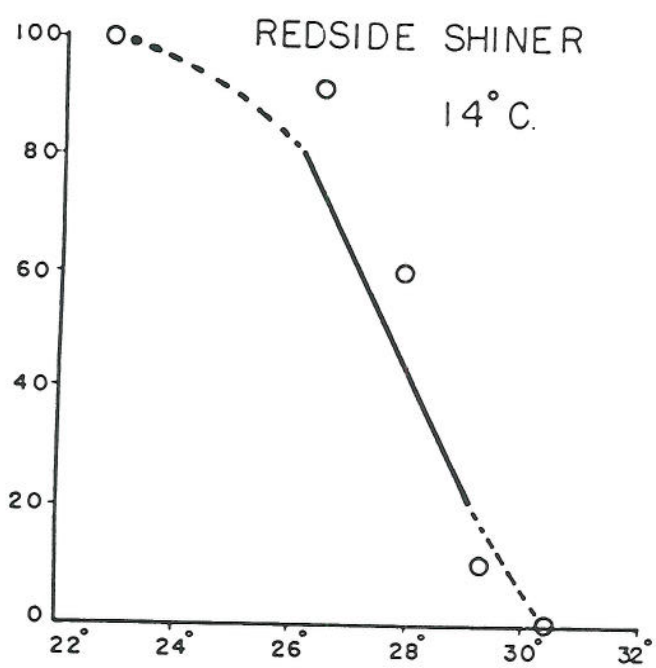


Figure 6. Upper lethal temperature data for silver-grey minnow acclimatized at approximately 14°C.





UPPER LETHAL TEMPERATURE DEGREES C.

Figure 7. Upper lethal temperature data for squawfish acclimatized at approximately 19–22°C.

Figure 8. Upper lethal temperature data for redside shiner acclimatized at approximately 14°C.

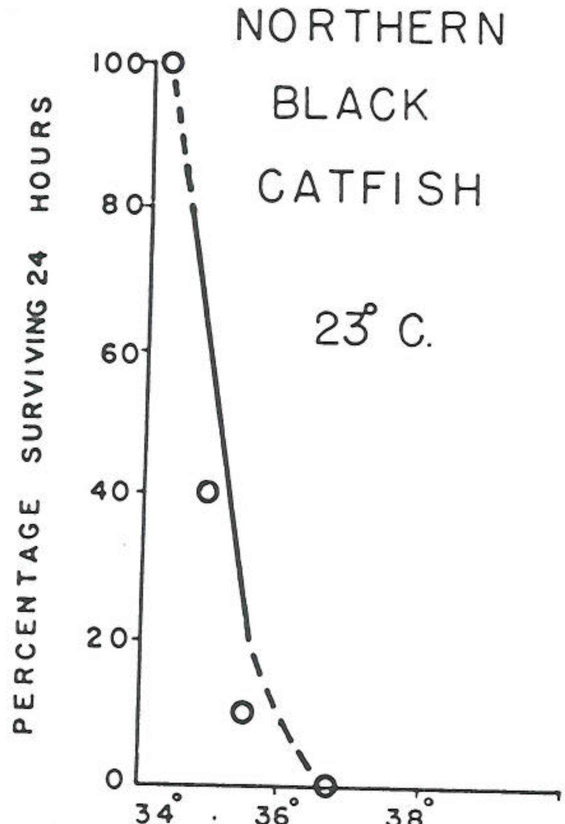


FIGURE 9. Upper lethal temperature data for northern black catfish acclimatized at approximately 23°C.

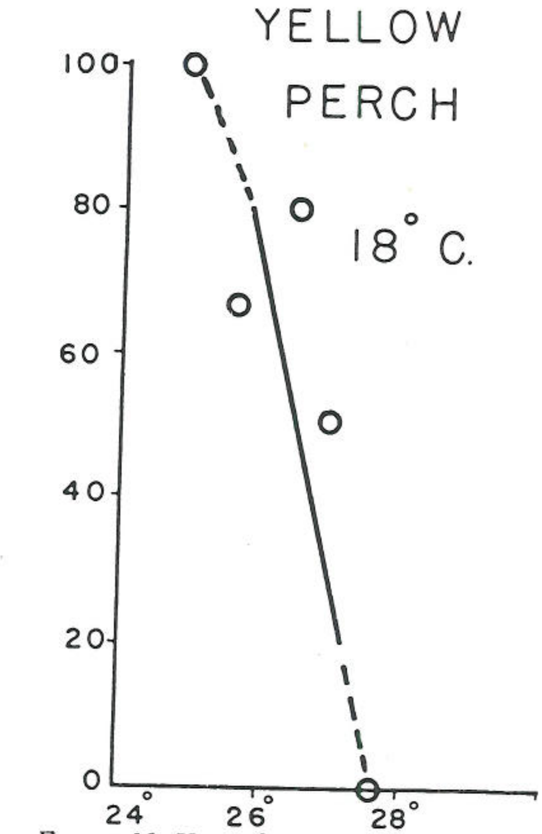
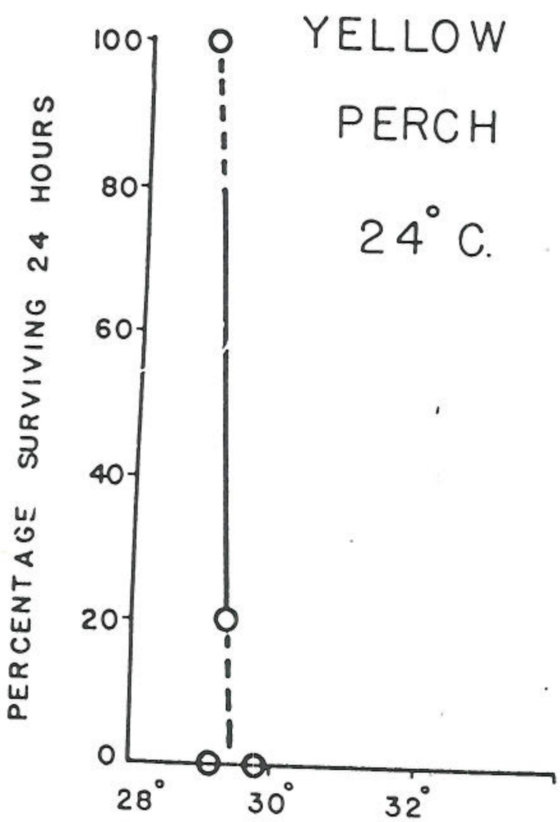
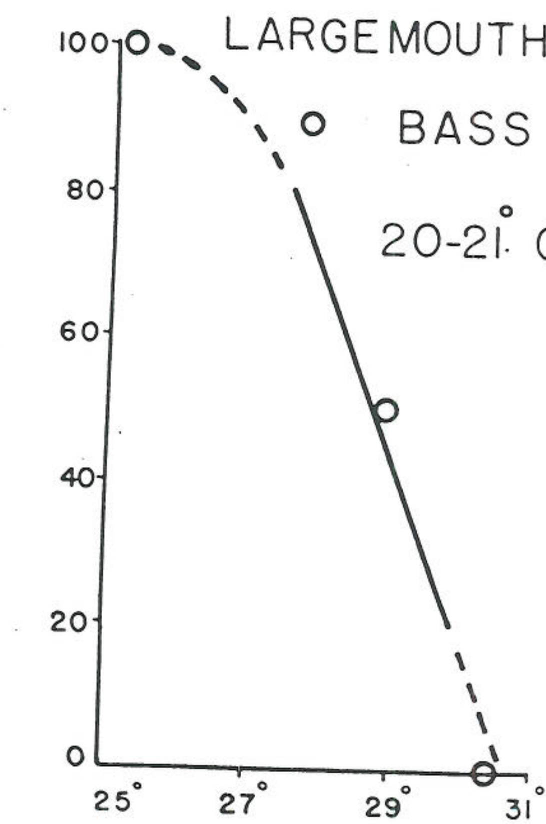


FIGURE 10. Upper lethal temperature data for yellow perch acclimatized at approximately 18°C.

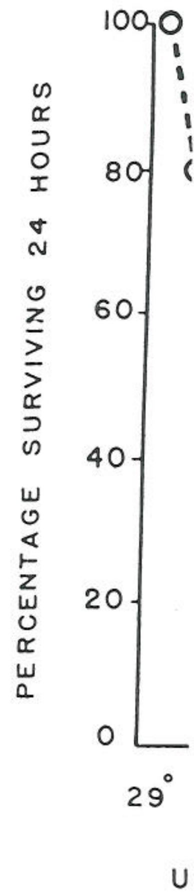




UPPER LETHAL TEMPERATURE DEGREES C.

FIGURE 11. Upper lethal temperature data for yellow perch acclimatized at approximately 24°C.

FIGURE 12. Upper lethal temperature data for largemouth bass acclimatized at approximately 20–21°C.



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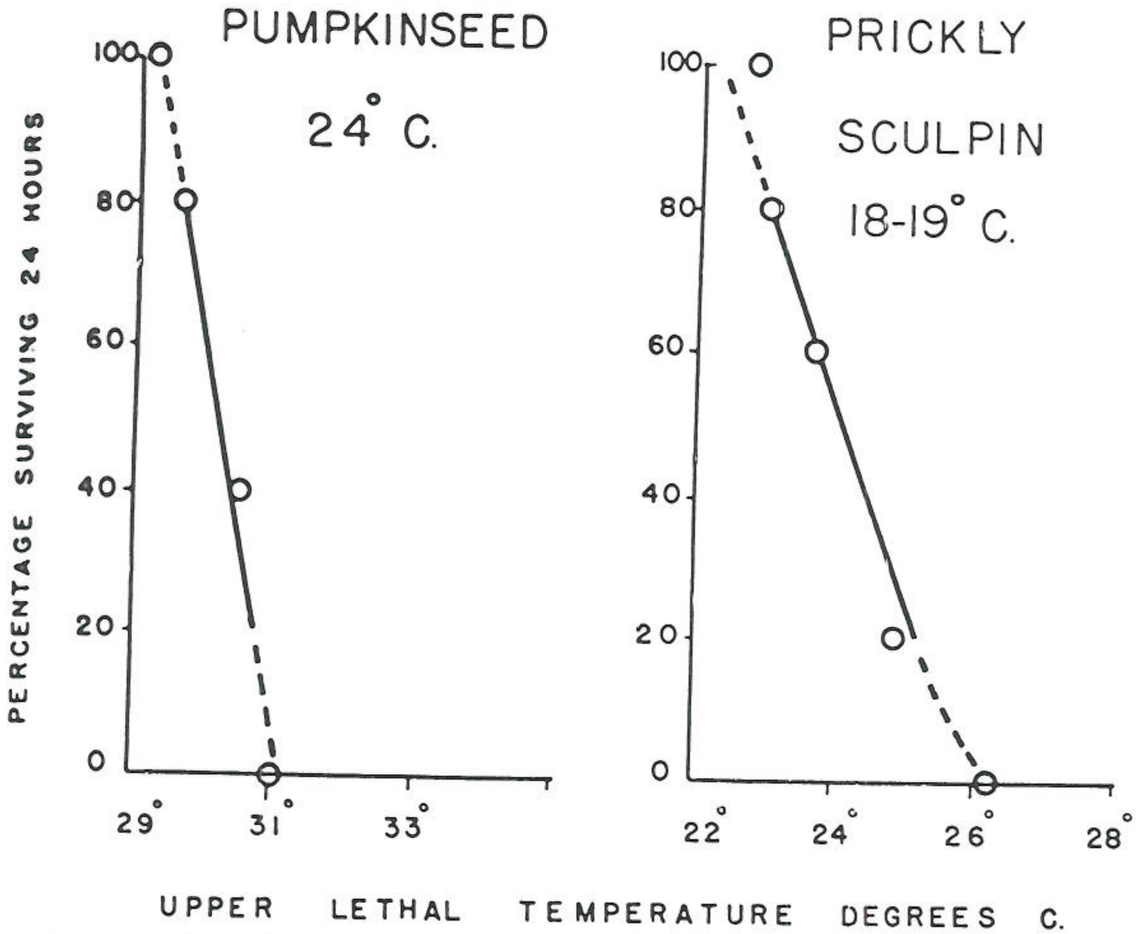

FIGURE 13. Upper lethal temperature data for pumpkinseed acclimatized at approximately 24°C.

FIGURE 14. Upper lethal temperature data for prickly sculpin acclimatized at approximately 18–19°C.

that insufficient data are available to warrant placing limits upon the upper lethal temperatures. Possibly the most reliable limits would be the temperature at which all survive 24 hours exposure as the lower limit, and the temperature at which none survive within 24 hours as the upper limit (Table II). For a complete discussion of the implications of temperature variations, the reader is referred to the comprehensive discussions by Fry (1947) and Hart (1952).

DISCUSSION

Sources of Error

For a systematic consideration of the sources of error encountered in determining lethal temperatures in fishes, the reader is referred to the recent works of Brett (1951) and Hart (1952).

From the publications of Hathaway (1927), Doudoroff (1942, 1945), Brett (1944, 1951), Fry *et al.* (1942, 1946) and Hart (1947), it is manifest that the greatest single factor bearing upon the validity of the lethal temperature data is the temperature of acclimation or acclimatization. In this study only an approximation of the acclimatization temperature can be given, except for the Kamloops trout, which were raised in the hatchery at a constant temperature. The value given for the acclimatization temperature for the other species is the daylight surface temperature for the time that the species was captured. Often temperatures were taken simultaneously at depths of 1–2 meters from the surface, but in no instance was the temperature at this depth more than 2°C. colder than that obtained at the surface. It is probable that the fish inhabited water the average temperature of which was lower than the daylight surface temperature. However as the temperature-acclimation rate is about 20-fold faster in the upward direction than downward (Brett, 1946; Doudoroff, 1942), the upper temperature affords the safer index to the acclimatization temperature.

The limitations to using the daylight surface temperature are shown in Table III. The upper lethal temperature for the chub was found to be 27°C. in 1950 and 1951, yet the daylight surface temperature at the time of capture was 10°C. on June 19, 1950, and 14°C. on June 17, 1951. A similar situation holds for the fine-scaled sucker, where the upper lethal temperature (27°C.) is the same for both years and yet the daylight surface temperature at the time of capture was 11.5°C. on May 25, 1950, and 14°C. on May 23, 1951. However, the upper lethal temperature for the redside shiner was found to be 25°C. during 1950 when the fish were captured at 9–11°C. on May 19–25, and 27.6°C. for a daylight surface temperature of 14°C. when captured on May 22–30, 1951. Again, the upper lethal temperature for Kamloops trout fingerlings was 24°C. at an actual acclimatization temperature of 11°C. for both years.

TABLE III. Summary of upper lethal temperatures for fishes studied at the Summerland Trout Hatchery during the summers of 1950 and 1951. The data for 1950 are taken from unpublished results of Black and Black (1950). The values marked * are actual readings for 50 per cent mortality.

Species	Year	Approximate acclimatization temperature	Upper lethal temperature (temperature at which 50% of fish survive 24 hours)
		° C.	° C.
Chub	1950	10	27
	1951	14	27.1
Redside shiner	1950	9–11	25
	1951	14	27.6
Kokanee (fry)	1950	11	22
Kamloops trout (fingerling)	1950	11	24
	1951	11	24.0
Fine-scaled sucker	1950	11.5	27
	1951	14	26.9*
Silver-grey minnow	1951	14	28.3
Yellow perch	1951	18	26.5*
		22–24	29.2
Pumpkinseed	1951	18	28.0
		24	30.2
Prickly sculpin	1951	18–19	24.1
Coarse-scaled sucker	1951	19	29.4
Largemouth bass	1951	20–21	28.9*
Carp	1951	20	31–34
		26	35.7
Squawfish	1951	19–22	29.3
Northern black catfish	1951	23	35.0

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A second limitation to the study is the fact that the fish were held at a temperature of 11°C. from the time of capture till the time the lethal temperature experiments were carried out. Two influences may be operative to invalidate the reliability of the acclimatization state. In the first place there is the possibility that the hatchery temperature of 11°C. may be lethal at the lower level to some species plunged into the cooled fry cans and later transferred to the hatchery trough. In this case the sample of fish would constitute a selected sample. However, the mortalities immediately following capture were insignificant except for the yellow perch and pumpkinseed. From Hart's (1947) data it would appear that the lower lethal temperature for the yellow perch is below the temperature used here, namely 11°C.

Another possible influence following the transfer of the captured fishes to the hatchery water is that downward acclimation may have occurred before the lethal tests were completed. It would appear from the first set of data for the carp that such a process may have taken place. However the samples of pumpkinseed and yellow perch captured at different acclimatization temperatures appear to be stable. This appearance of stability for the latter two species may be deceptive, and merely reflect selection provided by the initial mortalities when the fish were first brought in from the field after capture.

A different limitation to the study is the possible adverse effect of the high level of free carbon dioxide content of the hatchery water supply, especially to fishes known to be sensitive to carbon dioxide. The dissolved carbon dioxide would be minimal in the test tanks which were always aerated previous to and during the test run.

When the results obtained at Summerland for the yellow perch at acclimatization temperatures of 18° and 22–24° are compared with those of Hart (1947), it would appear that the combined effects of exposure to holding in water of relatively high free carbon dioxide concentration and lowered temperature did not seriously impair the results. This contention implies that the stock of fish used by Hart in Ontario and the author in British Columbia were identical, and further, that the fish were in the same condition, factors which obviously are not known. The possible influences of free carbon dioxide and duration of preliminary exposure to lowered temperatures on the upper lethal temperature characteristics remain to be determined.

In a recent paper Brett (1951) has emphasized the place of proper feeding prior to lethal temperature test runs for members of the genus *Oncorhynchus*. This is possible for fish that will feed under the conditions of captivity. As mentioned earlier, none of the fish appeared to feed except the Kamloops trout, the prickly sculpin and the northern black catfish. The only published evidence on the possible effects of starvation on lethal temperature has been that of Brett (1944) for the brown catfish where no effect could be demonstrated. This evidence does not preclude the possibility that starvation may influence the lethal temperature runs for other species.

The effects of sex, size and age upon upper lethal temperatures were not determined in this study. Hart (1947) reported that there was no correlation between size or age and the order of death at a given temperature. Later Hart (1952) found small differences in lethal temperatures associated with differences in age and size for three of 15 species studied.

The length of time that observations were carried out in each test was 24 hours, provided there were survivors. Fry *et al.* (1942) used a 14-hour period; Brett used a 12-hour period for work published in 1944 and a 48-hour period for much of his work reported in 1951, although periods up to seven days were also used. Hart (1947) used periods up to 8,000 minutes for upper lethal tests. No efforts were made in the study reported here to determine the least time which would approximate "infinity" so far as survival is concerned.

During most lethal test runs the temperature varied considerably as compared with the fine margin of variation (within ±0.1°C.) for the experiments of Brett (1944, 1951), Fry *et al.* (1942, 1946) and Hart (1947, 1952). For the data reported here, 75 per cent of the readings showed variations of ±0.7°C. or less. In 7 per cent of the readings the temperature was +1.0° to +1.4°C. Seven per cent of the readings showed variation between −1.1° and −1.2°C. Two readings showed variations of −2.0° to −2.3°C. A maximum-minimum thermometer was used in most cases as a check on the control of temperature. In most instances, the readings are concordant with the observation for the laboratory thermometers after the corrections had been applied to the latter. The total spread for 49 readings was 2.3° or less; 7 at 2.6° to 2.9°; 4 at 3.3°; 1 at 4.4°; and 1 at 4.5°C.

Acclimatization Temperature and Upper Lethal Temperature

As noted above, the upward shift of the upper lethal temperature with increased temperature has been demonstrated by earlier workers (Doudoroff, 1942, 1945; Fry *et al.*, 1946; Brett, 1944 and 1951; Hart, 1947, 1952). In limited studies made this year on field acclimatization, the yellow perch, pumpkinseed and carp show higher lethal temperatures for fish captured at higher environmental temperatures later in the summer (Table II). Hart (1947) noted that the upper lethal temperature for yellow perch acclimatized to 25° was 29.7°, and implied that this was the upper limit to which this species could be acclimated. The upper lethal temperature reported in this paper for the yellow perch is 29–30°C. for an approximate acclimatization temperature of 22–24°C. Brett obtained 30.9° as the upper lethal temperature for the same species acclimatized to 25–26° in the field.

Comparison of Upper Lethal Temperatures for the Okanagan Species

The effect of the temperature history is so important to an evaluation of lethal temperature data that only limited comparisons are possible.

From 1950 data (Black and Black, 1950), the kokanee fry showed the lowest upper lethal temperature at 22° when acclimatized to 11°C. At the same approximate acclimatization temperature, the upper lethal temperatures for the

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Kamloops trout, redside shiner, fine-scaled sucker and chub were 24°, 25°, 27° and 27°C. respectively.

The largemouth bass acclimatized to 20–21°C. has an upper lethal temperature of 28.9°C.

The squawfish acclimatized to 19–22°C. has an upper lethal temperature of 29.3°C.

In the acclimatization range of 22–24°C. the upper lethal temperatures for the yellow perch, pumpkinseed and northern black catfish are 29.2°, 30.2° and 35.0°C. respectively.

The highest acclimatization temperature was 26° for the carp, under which conditions this species showed the highest upper lethal temperature at 35.7°C.

TABLE IV. Comparison of upper lethal temperatures for some fishes studied in Ontario by Brett (1944), Fry *et al.* (1946), and by Hart (1947, 1952) in Ontario and the United States, with results reported for British Columbia freshwater fishes by Black and Black (1950) and in this paper. Values marked * were interpolated from graphs.

Family and species	Approximate acclimatization temperature	Upper lethal temperature	Authority
	° C.	° C.	
Family SALMONIDAE			
Kokanee fry (*Oncorhynchus nerka kennerlyi*)	11	22	Black & Black (1950)
Kamloops trout fingerlings	11	24.0	This paper
Speckled trout fingerlings (*Salvelinus fontinalis*)	11*	24*	Fry *et al.* (1946)
Family CATOSTOMIDAE			
Fine-scaled sucker	14	26.9	This paper
Coarse-scaled sucker	19	29.4	This paper
Common sucker (*Catostomus commersoni*)	20	30.0	Hart (1947)
	25–26	31.2	Brett (1944)
Family CYPRINIDAE			
Carp	26	35.7	This paper
Goldfish (*Carassius auratus*)	26*	36.6*	Fry *et al.* (1942)
Silver-grey minnow	14	28.3	This paper
Black nose dace (*Rhinichthys atratulus*)	15	29.6	Hart (1947)
Family AMEIURIDAE			
Northern channel catfish (*Ictalurus lacustris*)	20	32.7	Hart (1952)
	25	33.7	Hart (1952)
Brown catfish (*Ameiurus nebulosus*)	22.6	35*	Brett (1944)
Northern black catfish	23	35.0	This paper
Family PERCIDAE			
Yellow perch (summer)	25–26	30.9	Brett (1944)
(summer)	22–24	29–30	This paper
(summer)	25	29.7	Hart (1947)
(winter)	25	32.5	Hart (1952)
Family CENTRARCHIDAE			
Largemouth bass (B.C.)	20–21	28.9	This paper
Largemouth bass (Florida)	20	31.8	Hart (1952)
Largemouth bass (Ohio)	20	32.5	Hart (1952)
Pumpkinseed	25–26	34.5	Brett (1944)
	24	30.2	This paper
Bluegill (*Lepomis macrochirus*)	20	31.5	Hart (1952)
	30	33.9	Hart (1952)

Comparison of Upper Lethal Temperatures of Some Okanagan and Southern Fishes Studied in Ontario and Eastern United States

The Kamloops trout and speckled char (Fry *et al.*, 1946) have the same upper lethal temperature at 24°C., while that of the kokanee is somewhat lower at 22°C. (Table IV). The data for the three species of suckers are concordant when the acclimation (acclimatization) temperatures for the respective values are considered.

While data have been secured for more than four species of minnows, only values for the carp and the goldfish (Fry *et al.*, 1946), which are a degree apart, and two species of *Rhinichthys* are given. The upper lethal for *R. atratulus* (Hart, 1947) is 1.3°C. higher than *R. falcatus* when the acclimation temperature is only 1° higher than the acclimatization temperature (Table IV).

Values for the two species of catfish *Ameiurus nebulosus* (Brett, 1944) and *A. melas melas* are the same at 35° for a difference in acclimatization (acclimation) temperature of 0.5°, while the upper lethal temperature of *Ictalurus lacustris* (Hart, 1952) would appear to be a degree lower (Table IV).

Observations on the yellow perch obtained by the three authors are very close, differing by 1–2° at most (Brett, 1944; Hart, 1947, 1952).

Hart (1952) found that the upper lethal temperature for the largemouth bass exhibited the greatest spread in geographic variation. The value reported in this paper is lower than either value listed by Hart for an equivalent temperature history (Table IV).

The reading for the Ontario pumpkinseed obtained by Brett (1944) is 4.3° higher than that for the Okanagan sample for an increase in acclimatization temperature of 1–2°. Values obtained by Hart (1952) for *Lepomis macrochirus* studied in Florida rest between the above figures. (Table IV).

CONCLUSION

As stated in the introduction, the purpose in undertaking this study was to make possible a comparison of upper lethal temperatures with carbon dioxide asphyxiation data for the same batch of each species studied in the Okanagan when acclimated to the same temperature. This comparison will be made and discussed in another paper on carbon dioxide asphyxiation of fishes.

The lethal temperature data are presented in the belief that, despite the limitations and deficiencies of the study, the results may be of interest and use to ecologists and physiologists. Exposures for periods up to 24 hours at upper lethal temperatures afford useful data in characterizing the viability of species. These data also provide first approximations of upper lethal temperatures for comparisons on taxonomic and geographic bases, and for physiological purposes.

Within the limitations, the data confirm the level of results obtained by other workers for three species. In addition, comparisons at the same acclimatization or acclimation temperatures for kindred members of six families studied by workers in Ontario and the United States of America showed similarities in upper lethal temperatures to species studied in British Columbia.

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