THE EFFECT OF TEMPERATURE ON INCUBATING EGGS, JUVENILE, AND ADULT SALMON

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Note:
Only a partial survey of literature was possible due to limited time available.

THE EFFECT OF TEMPERATURE ON YOUNG AND ADULT SALMON

Temperature acts in a variety of ways. It may kill, reduce activity, interact with other environmental factors, confine reproduction, effect sex products carried in pre-spawning adults, and be a directing agent where a gradient exists. The study of the effect of water temperature has been much more extensive on eggs and young salmon than on adults.

Eggs and Young Salmon

Combs and Burrows (1957) found that the optimum temperature range for developing chinook salmon eggs was between 42-1/2°F. to 57-1/2°F. These were for constant temperatures. Eggs from Entiat and Skagit River spring chinook salmon were used. However, Seymour (1954) found that there was some loss in growth of fingerling reared above 55°F. Therefore, I have noted the optimum range as between 42-1/2° to 55° F. (See figure 1). Donaldson (1954) found that by varying the temperature during certain stages of egg development that the tolerance of eggs to temperature exposure varies for the stages of development. The stages during which the greatest percentage mortalities occurred were: the time until closure of the blastophore, the period just previous to and during hatching, and the period when the fry are adapting to feeding. Donaldson also observed that as the temperature increases from 63° to 67°F. the time necessary to kill a certain percentage of the eggs in any one lot decreases. Exposuresto 67°, 65° and 63° F. for 2, 5, and 13 days respectively resulted in a 10 percent kill of the eggs by the end of the hatching period. It required 6.5, 14, and 22 days at the same respective temperatures to kill 50 percent of the eggs by the same time.

Olson and Foster (1957) studied the temperature tolerance of eggs and young of chinook salmon which spawn in the Columbia River below Priest Rapids Dam. Approximately 5,800 eggs were taken and fertilized in the field and brought to the laboratory. These investigators observed that eggs could initially be incubated at temperatures as high as 61°F. without significant loss. The eggs that were incubated in the early stages above this temperature suffered mortalities in the fry and fingerling stages. Total mortalities of 79 percent were found in the group reared at 65° initial temperature even though the temperatures during the period after the first three weeks were below 60° and the temperatures during the majority of the incubation period was from 55° to 42°. Mortalities of the other controls were from 7.5 to 16.1 percent. These fish were held to the early fingerling stages and were generally in the 800 to 900 fish per pound stage. This mortality pattern is strong indication of early embryological damage which was not manifested until the later stage of development. Johnson and Brice (1953) found that chinook salmon eggs incubated in Dorena Reservoir water at temperatures over 60°F. suffered excessive mortality and that the adverse effect at these high water temperatures continued to be reflected in the mortality data through the fry and early fingerling stages. "Coagulated yolk " disease caused much of the mortality during the feeding period.

Seymour, (1954) observed the growth of fish held at certain temperatures. The number of fish per pound for the 45°, 50° and 55°F. lots was 138, 36, and 25 respectively. For growth rate at temperatures above 55° an experiment was started during the 19th week using fish from a lot that previously had been reared at city water temperatures. At the end of the experiment there were no survivors in the lot at 74°F. and the number of fish per pound for the 60° and 67°F. lots was 41 and 61 respectively. The fish that he used in these experiments were Green River ~~River~~ fall chinook, ~~stock which are fall chinook~~. Seymour also found that egg mortality was nominal, averaged 5 percent at temperatures from 40° to 57-1/2° but increased to 29 percent at 60°, 81 percent at 62-1/2° and 100 percent at higher temperatures.

Brett (1952) found that for the five species of young salmon acclimatized to temperatures of 10° to 20° centigrade that their lethal temperatures were as follows:

Spring (chinook) 25.1°C. (77.2°F.)

Coho - 25.0°C. (77.0°F.)

Sockeye - 24.4°C. (75.9°F.)

Pink - 23.9°C. (75.0°F.)

Chum - 23.8°C. (74.8°F.)

Brett also found that the lower lethal temperatures for salmon acclimati~~ons of~~zed at 23°C.:

Spring - 7.4°C. (45.3°F.)

Coho - 6.4°C. (43.5°F.)

Sockeye - 6.7°C. (44.1°F.)

Chum - 7.3°C. (45.1°F.)

Brett observed that young salmon were very sensitive to low temperatures. Among the four species tested the coho and sockeye salmon could not tolerate long exposure (four days) to 0°C. even when taken from holding temperatures as low as 5°C.

On the effect of cruising speed of young sockeye and coho salmon Brett (et al 1958) discovered that the optimum cruising speed for sockeye was 15°C. (59°F.) and 20°C. (68°F.). Maximum sustained swimming levels fell mainly between 1.0 and 1.5 feet per second. The swimming speed increased as temperatures from 0.5°C. to 15°C. for sockeye and 5°C. to 20°C. for coho. After reaching the maximum speed a rather rapid decrease in swimming ability was found as the temperature increased to the upper lethal temperature of approximately 25°C. (77°F.)

According to Rucker, columnaris disease becomes a problem to fingerling chinook salmon at 60° and above.

In conclusion, I would like to stress that the temperature at which eggs are initially incubated is very critical. If we could lower the temperatures below 60° in the Snake and Columbia River during the fall when spawning starts the latent mortalities, which Foster and Johnson have found, would be reduced. This would benefit the fish which had high mortalities due to temperatures above 60° during some years. Hatcheries and spawning channels planned for the main stem Columbia and Snake River spawners need temperature control. During the incubation period if the optimum range can be realized, 42.5 to 57.5°F. better production should be possible.

Adult Salmon

The optimum range for adult or sub-adult salmon during their existence in the sea is probably within the optimum range for the young salmon. However, observations are difficult and no literature was found to support this theory. As the adult spring-migrating salmon migrates upstream to spawn he is confronted with the warming trend of temperature. A fall-migrating salmon for the most part are proceeding during the decline of temperature. The increased virulency of columnaris disease was found by Ordal (1958) at temperatures above 60°F. Wood has observed (personal communications 1963) that the occurance and severity of furunculosis disease increases as water becomes warmer.

Groves (personal communication 1963) noted at Bonneville Dam that acclimatized spring and fall chinook salmon showed reduced swimming abilities at temperatures above 65°.

Ridgeway (personal communication 1963) has noted that there is some evidence of an adverse effect on the sex products contained in adult salmon when they are exposed to high temperatures during the pre-spawning period. Temperatures which he has reference to are probably in the upper 60's and up to 75°.

Cramer and Hammack (1952) found that the Sacramento River King salmon when transferred to Deer Creek in temperatures of 81° to 82°, high mortalities occurred. They concluded that this was the lethal temperature. I am a little skeptical of this conclusion as the deaths may have been due to stress caused by handling or hauling.

Lethal temperatures for adults are dependent upon so many variables that a definite temperature has not been established but I would certainly agree that temperatures above the high 70s are potentially lethal. The condition of the fish (as to disease or progress of maturity) and the length of exposure to the high temperatures are probably the most important factors.

Evidence that rapidly decreasing temperatures hastens spawning activity has been observed by the author in the case of two runs of blueback or sockeye salmon. The Wenatchee and Okanogan runs were intermingled with each other during the Grand Coulee salvage program. The Wenatchee run spawns from early September and to about the third week of September. The Okanogan River blueback does not start spawning until about the third week in September and lasts until about the end of October.

Temperatures in the spawning area of the Wenatchee are about 57° to 47° while they are from 65° to 50° in the Okanogan. The temperatures are descending as the spawning season progresses.

I have appended a chart showing the optimum range and the gradations of temperatures ascending and descending from this range. Also appended is a list of references pertinent to the subject.

Burroughs has also observed that cooler water hastens the spawning activity of Entiat River chinook salmon. He found however, that shortening the number of hours of daylight had a more pronounced effect than temperature. Apparently, salmon have a "built in mechanism" for the protection of the race. If changes are brought about in its environment due to transplantation or change in temperature of a stream, the fish has an endocrine system which is affected by the environmental change to a certain extent. Warm water delays maturation while cool water hastens it. This is the opposite to what one would expect to happen but I regard it as another marvelous adaptation found in nature.

REFERENCES

Brett, J. R.
1959. Thermal requirements of fish - three decades of study, 1940-1970. Reprint, trans. of second seminar on Biological Problems in Water Pollution, April 20-24 1959. U. S. Public Health Service, Robert A. Taft, Sanitary Eng. Cent. Cinncinnati 26, Ohio.

Brett, J. R.
1958. Implications and assessments of environmental stress. pp. 69-83 in: H. R. MacMillan Lectures in Fisheries, A symposium held at the University of British Columbia, April 29 and 30, 1957. Edited by P. A. Larkin, Institute of Fisheries, Univ. Brit. Columbia, Vancouver, 111 p. 6 figs.

Brett, J. R.
1952. Temperature tolerance in young Pacific salmon, Genus, *Oncorhynchus*. J. Fish. Res. Bd. Can. 9(6) 265-323.

Brett, J. R. and D. F. Alderdice.
1958. The resistance of cultured young chum and sockeye salmon to temperatures below 0°C. J. Fish. Res. Bd. Canada, 15(5): 805-813. 4 figs., 2 tables. September.

Brett, J. R., M. Hollands and D. F. Alderdice
1958. The effect of temperature on the cruising speed of young sockeye and coho salmon. Jour. Fish. Res. Bd. Canada 15(4) 587-605.

Combs, Bobby D. and Roger E. Burrows
1957. Threshold temperatures for the normal development of chinook salmon eggs. Prog. Fish-Culturist 19(1): 3-6.

Cramer, Fred K. and David F. Hammack
1952. Salmon research at Deer Creek, California, U.S. Fish & Wildlife Service, Sp. Sc. Rept. F. #67, 16 pp.

Donaldson, John R.
1954. Effect of variation of temperatures on eggs. Northwest Fish Cultural Conference, Seattle, Washington, December 2 and 3, 1954: 47. Mimeographed.

Donaldson, John R.
1954. Experimental studies on the survival of the early stages of chinook salmon after varying exposures to upper lethal temperatures. Wash. St. Dept. Fish., Annual Report to U. S. Army Corps of Engineers, 1954. Part II. Army Engineers Contract No. DA 35026 - Eng. 20572. 101 p. 42 figs., 16 tables.

Donaldson, L. R. and F. J. Foster
1941. Exp. Study of the effect of various water temperatures on the growth, food utilization, and mortality rate of fingerling sockeye salmon. Trans. Am. Fish Soc. 70: 339-346.

Johnson, Harlan E. and R. F. Brice
1953. Effects of transportation of green eggs, and of water temperature during incubation on the mortality of chinook salmon. Prog. Fish-Culturist 15 (3): 104-108.

Keenleyside, Miles H. A., and William S. Hoar.
1954. Effects of temperature on the responses of young salmon to water currents. Behaviour, 7 (2/3): 77-87. Illus. (Biol. Abst. #7018, 30(3). 1956.)

Mattson, Chester K.
1948. Spawning ground studies of Willamette River spring chinook salmon. Oregon Fish. Comm. Res. Briefs, vol. 1, no. 2, pp. 21-32.

Olson, P. A. and R. F. Foster
1957. Temperature tolerance of eggs and young of Columbia River chinook salmon. Trans. Amer. Fish. Soc. 1955, 1957. 85: 203-207. 8 figs., 8 tables.

Ordal, E. J. and R. E. Pacha
1959. Research and investigations on Diseases Affecting the Fisheries Resources of the Columbia River Basin. Pt. I and II. Special Report - not processed.

Seymour, Allyn
1959. Effects of temperature upon the formation of vertebrae and fin rays in young chinook salmon. Trans. Amer. Fish. Soc., 88(1): 58-69. 7 figs., 4 tables. (Biol. abst. #7509, 35(3), February 1960.)

Seymour, Allyn H.
1954. Effect of high constant temperatures upon the mortality and growth of chinook salmon eggs, fry and fingerlings. Northwest Fish Cultural Conference, Seattle, Washington, December 2 and 3, 1954: 45. mimeographed.