Effect of Yolk Sac Absorption on the Swimming Ability of Fall Chinook Salmon

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ABSTRACT

Tests were made of the swimming ability of fall chinook salmon (*Oncorhynchus tshawytscha*) during and after yolk sac absorption. Two sources of fish were used: hatchery fish incubated and reared in constant-temperature well water and migrants from an incubation channel supplied with creek water of variable temperature. Two testing procedures were used: impingement tests using a fixed screen and constant water velocities with percent impinged as the measure, and stamina tests using increases in water velocities at fixed intervals with time of displacement as the measure. As the fish developed, a period of reduced swimming ability occurred shortly before complete yolk sac absorption. The slump coincided with the period of peak migration from the channel and may be a cause of migration and an important factor in survival.

INTRODUCTION

Experiments were conducted at the Salmon-Cultural Laboratory during the winter of 1965–66 to determine the swimming performance of salmon fry and first-feeding fingerlings. Swimming speed information for small fish was needed for the design of fish collection facilities and little data could be found in the literature. While conducting the swimming speed tests, it was noted that the stage of development of the fish had definite effects on their swimming ability. Additional trials were conducted during the winter of 1966–67 to more closely determine these effects. This report presents results from both years of testing.

METHODS AND TECHNIQUES

Fall chinook salmon (*Oncorhynchus tshawytscha*), from both the Abernathy incubation channel and the hatchery at the Salmon-Cultural Laboratory were used as test fish. Fish from both sources were progeny of Abernathy Creek stock. Channel fish were from green-egg plants in 1965–66 tests and from eyed-egg plants in the 1966–67 tests. A description of the Abernathy channel and the methods of experimental operation are reported by Thomas and Shelton (1968). All migrants are trapped for enumeration as they leave the channel. Groups of channel migrants were collected and held in the hatchery overnight to acclimate them to the water temperature to be used in testing. Unfed fry samples from hatchery stock were taken directly from the incubators and first-feeding fish were taken from troughs or small circular tanks.

The stamina tunnel as described by Thomas, Burrows, and Chenoweth (1964) was used for the swimming tests. Fish smaller than one gram each could not maintain themselves in the tunnel long enough to use the normal testing procedures. New techniques of testing these small fish were developed using reduced water velocities. The procedure during the 1965–66 tests was to subject groups of 50 fish to various water velocities and determine their ability to escape impingement on a fixed screen placed 90 degrees to the flow. About 3,000 fall chinook salmon were tested at stages of development from "swim-up" fry to fingerlings which had been fed as long as 50 days. The "swim up" stage occurs when the fish are first capable of maintaining themselves continuously free of the bottom. The testing period was from November 9, 1965 to February 2, 1966.

Each test began with a 5-minute orientation period with a slight, unmeasured water flow through the tunnel. The pump was then started raising the water velocity to 0.35 feet per second. This velocity was maintained for 5 minutes before being increased to the desired test level by increments of .01 fps every 5 seconds. Performance was measured by the percentage of fish which avoided impingement on the screen at the various water velocities during a 20-minute test period. If fewer than 25 percent of the fish were impinged on the screen, it was assumed that fish at that stage of development could maintain themselves against that particular water velocity. Similar samples then were tested at higher water velocities until 25% or more of the fish were impinged. Water velocities were ranged from 0.35 to 1.10 fps with the majority of the fish being tested at velocities from 0.60 to 0.90 fps.

The 1966–67 tests were similar to the normal testing procedure for fingerlings (Thomas, Burrows, and Chenoweth, 1964) except that a lower initial water velocity was used in the stamina tunnel. A total of 4,200 fish were tested in groups of 100 fish, these included 3,000 fish from the hatchery incubator source and 1,200 fish from the incubation channel. After the initial 5-minute orientation period with unmeasured flow and 5 minutes at a water velocity of 0.35 fps, the velocity was increased by increments of .01 fps each 5 seconds until 0.70 fps was reached. After 6 minutes, the velocity was again raised by .01 fps increments until 1.20 fps was reached. The 1.20 fps velocity was maintained until the test was completed. The tests were terminated when over 75% of the fish were displaced from the tunnel. A performance index was determined for each stamina test based upon the summation of the times when 25% and 75% of the fish left the tunnel and this index was used to compare the relative swimming ability of the fish at different stages of development. The testing period was from December 12, 1966 until February 10, 1967.

Differences in the rates of yolk sac absorption occurred between the hatchery and channel fish because of different incubating temperatures. Hatchery fish were incubated, hatched, and reared on well water at a constant 53° F. The channel water source was Abernathy Creek and water temperatures varied from the low thirties to the mid forties during testing periods. Because of the differences in incubating temperatures the rates of development were not the same. The hatchery fish were about two months more advanced than the incubator stock.

Hayes and Pelluet (1945) and Hayes, Pelluet, and Gorham (1953) demonstrated that while different water temperatures during egg and fry incubation had an unequal effect on the rate of development of certain organs, a linear relation existed between the rate of yolk sac absorption and the water temperature. Brannon (1965) found a constant rate of yolk sac absorption at a constant water temperature and no difference in the rate of absorption when water velocities were within the range of 0.5 to 75.0 mm per second. Water velocities in both the incubator and channel were within this range. Comparisons between hatchery and channel fish based on stage of yolk absorption therefore were assumed valid.

Visual estimates of the amount of yolk sac material absorbed were made daily on the channel fish and every 3 to 4 days on the hatchery fish. Preserved fish samples from throughout the testing period were measured for lengths, weights, and amount of sac exposed. Weights of live fish were found to be unreliable as a criterion due to the influence of variable amounts of food. The rate of absorption in the channel fish was slower and more variable than that of the hatchery fish because of the colder and fluctuating water temperatures. The rate of absorption of the hatchery fish on a constant 53° F water temperature appeared to be uniform at about 2.27% per day.

RESULTS

1965–66 Experiment

The swimming ability of yolk sac fry increased with the reduction in the amount of sac until an advanced stage of yolk sac absorption was reached. This increase in performance would be expected as the shape of the fish became more fusiform. A surprising slump in swimming capability occurred in both groups at about the time when the yolk sac was completely withdrawn within the body cavity. Once past this stage, the swim-

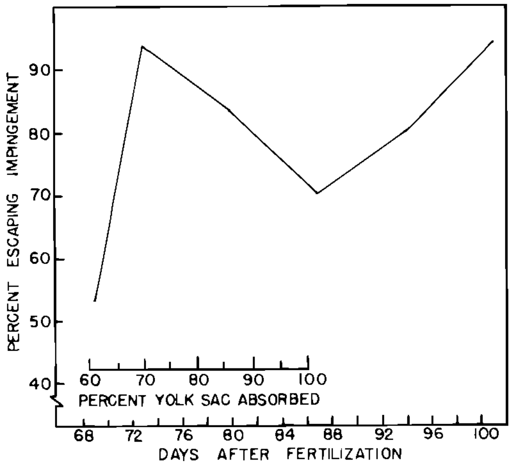

FIGURE 1.—Hatchery fall chinook salmon tested at 0.8 fps showing decrease in swimming ability during period of yolk sac absorption, 1965–66.

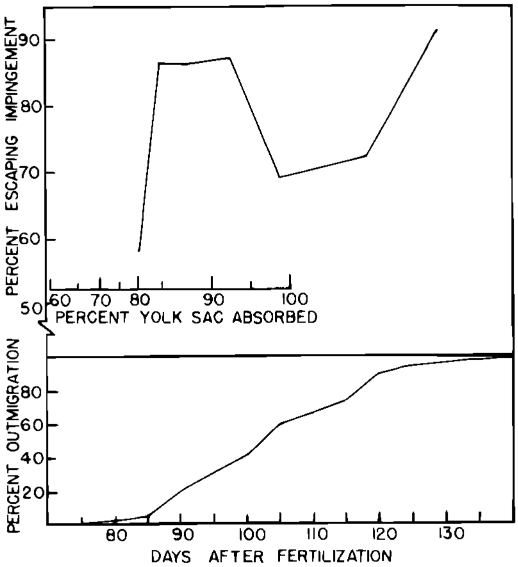

FIGURE 2.—Incubation channel fall chinook salmon tested at 0.8 fps showing decrease in swimming ability during period of yolk sac absorption and the migration pattern of fish from the channel, 1965–66.

ming ability again began to increase. A difference was found, however, in the rate of recovery between the two groups of fish. Fish from the hatchery source recovered more rapidly and had regained their original level by 15 days after complete yolk withdrawal. Channel fish did not regain their original level until 22 days after complete yolk withdrawal at which point nearly all migrants had left the channel. Once the original level of proficiency was reached, performance of fish from both sources continued to increase.

Swimming tests were conducted at velocities ranging from 0.45 to 1.2 fps from the time when 60% of the yolk sac was withdrawn until well beyond complete sac absorption. The maximum water velocity tested at which the fish could maintain their performance level throughout the period of yolk sac absorption was 0.6 fps. For this report, the 0.8 fps velocity was selected as the one best showing the full range of fish performance during and after yolk sac absorption. Figure 1 shows results with hatchery fish at 0.8 fps where the slump started when 70% of the yolk was withdrawn and continued to decline until the entire sac was absorbed. At the low point of the slump, the fish performed about as well as groups having about 35% exposed yolk sac.

The plots are based on averages of two tests for each stage of development investigated and represent the percent of fish swimming after 5 minutes at 0.8 fps. In tests conducted 15 days after yolk sac absorption, the fish showed continued improvement in swimming ability. Figure 2 shows the results of the channel fish tests at 0.8 fps plotted to coincide with the migration of fish from the channel. The slump in performance of the channel fish did not begin until after 90% sac absorption. About 62% of the fish had migrated from the channel by the time the yolk sac was completely absorbed. Over 95% of the migrants had left the channel before the peak swimming ability was regained and surpassed. The rate of development of the fish was slowed down soon after 85% of yolk was absorbed due to an extended period of cooler water temperatures.

1966–67 Experiment

In the 1966–67 trials, five stamina runs of 100 fish each were conducted with hatchery fish and three stamina runs of 100 fish with channel fish for each sampling period. Attempts were made to test fish samples at nearly equal stages of development. Figure 3 shows the results of this testing on hatch-

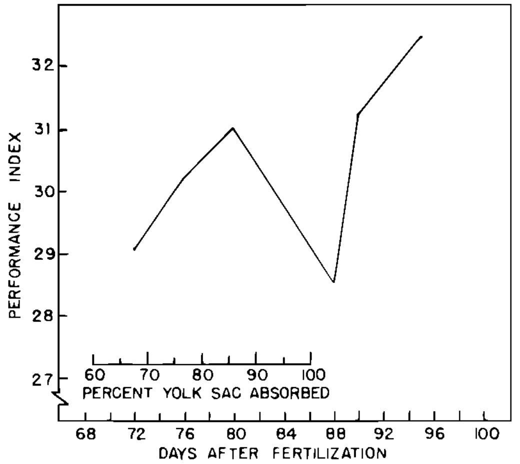

FIGURE 3.—Effect of yolk sac absorption on the performance index of hatchery fall chinook salmon, 1966–67.

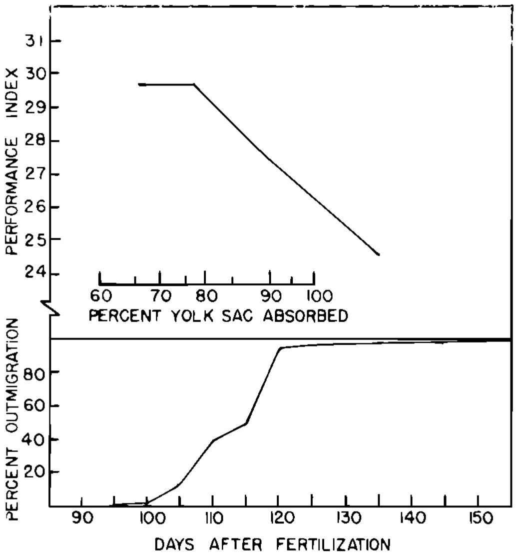

FIGURE 4.—Effect of yolk sac absorption on the performance index of incubation channel fall chinook salmon and the migration pattern of fish from the channel, 1966–67.

ery samples. Performance increased until about 86% of the yolk sac had been absorbed. A distinct slump occurred after this point with the lowest stamina level being reached just after 100% absorption. The slump began at a slightly later stage of development than it did in the hatchery fish in the impingement study (Figure 1), but was similar to the channel group (Figure 2). Recovery was rapid and occurred soon after complete yolk sac absorption.

The results of tests of the channel group as correlated with migration are shown in Figure 4. The slump in swimming ability began at a slightly earlier stage of development than in the hatchery samples. The decrease in performance continued far below levels for the hatchery fish and no recovery was demonstrated. Almost the entire migration from the channel occurred during the period of reduced swimming ability. Tests beyond 15 days after yolk sac absorption could not be conducted on channel fish as too few fish were migrating to provide adequate samples. The few fish remaining in the channel did increase in size and had obvious stamina improvements.

The patterns as shown by Figures 3 and 4 are generally similar to those of Figures 1 and 2 even though the results were obtained using two different testing procedures.

DISCUSSION

The decrease in swimming ability during yolk sac absorption may be of little importance in the survival of hatchery fish which are normally reared under protected conditions to a much larger size before being released. The lower swimming performance of migrating channel-reared fish, however, could reduce their ability to escape predators and to find food.

The water velocity through the channel varies from nearly 0 to 1.6 fps. Fish emerging from the gravel are not necessarily displaced by their inability to cope with the current. Some other stimuli may cause them to move into water velocities in which they cannot maintain themselves. Numbers alone can cause displacement in that the preferred areas become overcrowded. The search for food can cause the fish to venture into areas of high velocity resulting in downstream displacement. Phototaxis can have a similar result. A rise in stream flow reduces the number and areas of low velocity causing downstream movement. Other responses not directly traceable to displacement are undoubtedly factors in the downstream movement of fish. In channels, however, the close correlation between reduced swimming ability and the outmigration is no coincidence. The inability of the fish to maintain itself in static or increased water velocities appears to be one of the principal factors causing the outmigration.

Other species of salmon were not tested, but a similar reduction in swimming ability correlated with yolk sac absorption may exist and, where downstream displacement occurs, may be a factor in the timing of migration.

SUMMARY

Tests to determine the effects of yolk sac absorption on the swimming ability of fall chinook salmon were made during the winters of 1965–66 and 1966–67.

Fish tested were from hatchery and incubation-channel sources. Hatchery fish were incubated and reared on well water at a constant temperature of 53° F. The incubation channel was supplied with creek water which varied in temperature from the low thirties to the high sixties. Comparisons were made between fish at similar stages of yolk sac absorption.

The 1965–66 impingement tests measured the ability of chinook fingerlings to escape impingement on a fixed screen placed at a 90° angle to flow. Water velocities used varied from 0.35 to 1.10 fps. Individual tests involved 50-fish samples submitted to a constant flow for a 20-minute period. Only results from tests at 0.8 fps are reported.

The 1966–67 tests used a first-gear stamina tunnel procedure of increased water velocities at fixed time increments. Water velocities used varied from 0.35 to 1.20 fps. A performance index was determined for each group of 100 fish.

The testing period extended from when about 60% of the yolk sac was absorbed until about 3 weeks after absorption. In all tests, a slump or period of reduced swimming ability occurred shortly before complete yolk sac absorption. The lowest point occurred at or shortly after complete sac absorption. The lowered performance coincided with the period of peak migration from the channel. This reduced swimming ability may be an important factor in the time of migration and the survival of migrants from channels.

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