EFFECT OF WATER VELOCITY ON PASSAGE OF SALMONIDS IN A TRANSPORTATION CHANNEL

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ABSTRACT

Passage times of fish at velocities of 1 and 2 feet per second were compared in a 4-foot wide transportation channel, with a water depth of 6 feet. The timing zone was about 100 feet long.

Passage times did not differ significantly between water velocities for any one of three species: chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*Salmo gairdneri*), and sockeye salmon (*Oncorhynchus nerka*). The two salmon species moved faster than steelhead trout at both water velocities.

Transportation channels for migrating adult fish are part of the fish-passage facilities at many dams. These channels vary somewhat physically, but all have the primary purpose of providing a passage area leading either to or from the fish ladders or other passage facilities. Most of the large dams on the Columbia River—Bonneville, McNary, and The Dalles, for example—have a multiple-entrance collection channel on the downstream side of the powerhouse which also serves as a transportation channel. In addition, independent channels are occasionally provided at some dams to pass fish from a single major entrance to a distant fishway. The Dalles Dam is equipped with both types (U.S. Army Corps of Engineers, 1957). These channels make it possible for one fishway to serve two or more collection points. Some channels are nearly a quarter mile long and may require up to 1,000 cubic feet per second (c.f.s.) of water for operation.

Water velocity in a transportation channel is important from the standpoint of fish passage as well as water use. Clay (1961) reported that the accepted standard velocity for ensuring continuous migration of fish through open channels is near 2 feet per second (f.p.s.). Preliminary experiments at the Fisheries-Engineering Research Laboratory at Bonneville Dam indicated that a velocity considerably less than 2 f.p.s. might be satisfactory for passage of salmonids. If so, velocity standards for transportation channels could be lowered and less water used without impeding the passage of migrating fish.

The purpose of this study [1] was to determine if salmonids would move up a transportation channel as rapidly in a water velocity of 1 f.p.s. as in 2 f.p.s.

EXPERIMENTAL EQUIPMENT

The study was made in the Fisheries-Engineering Research Laboratory at Bonneville Dam on the Columbia River. Details of the laboratory were described by Collins and Elling (1960). The experimental transportation channel (fig. 1) was 4 feet wide, 91 feet long, and operated at a water depth of 6 feet. Fish were timed over a distance of about 100 feet. (This included a short introductory area extending from a release compartment to the channel.) Water velocity was controlled by regulating the head on a weir located between the flow-introduction pool and the test channel. Headwater elevations producing velocities of 1 and 2 f.p.s. were determined before the experiment was started.

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[1] Research financed by the U.S. Army Corps of Engineers as part of a broad program to provide design criteria for more economical and efficient fish-passage facilities at Corps projects on the Columbia River.

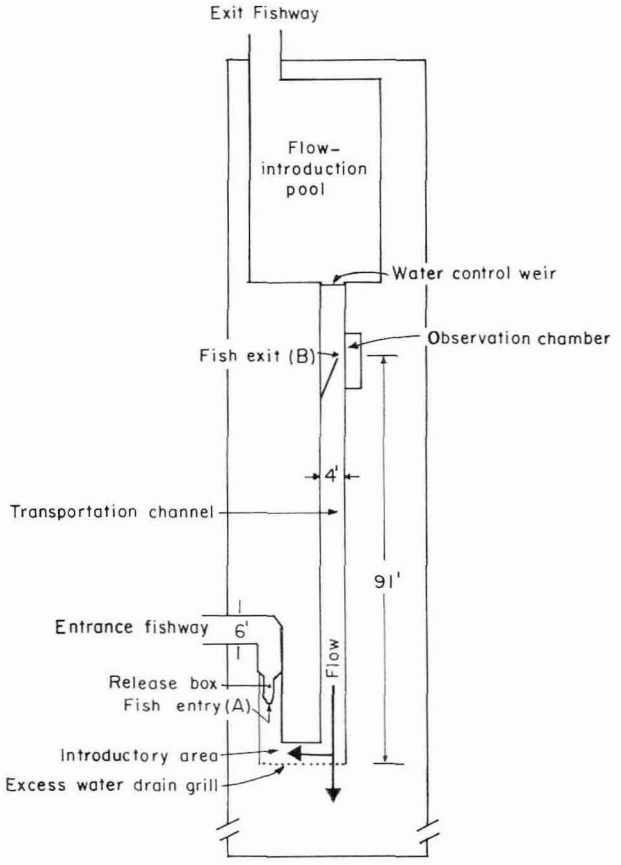

FIGURE 1.—Diagrammatic plan view of laboratory showing transportation channel and timing zone (A to B).

Velocities were measured with a cup-type current meter.

The channel was lighted by 1,000-watt mercury-vapor lights placed 6 feet apart and suspended 6 feet above the water. Light readings at the surface averaged about 700 foot-candles, which approximates light intensity on a bright cloudy day.

PROCEDURE

Salmonids used in these tests were diverted from the Washington shore fishway at Bonneville Dam. They ascended a short entrance fishway to the laboratory. Varying numbers of fish were used in each test, depending on seasonal abundance of the different species. Each fish entering the laboratory was tested only once. After a fish had completed passage through the test facility, it left the laboratory through a small exit fishway and entered the main fishway about 200 feet upstream from the laboratory.

Fish of all sizes were used; however, on a few occasions, fish were rejected because of severe cuts or other obvious physical injuries. No distinction was made as to sex.

EXPERIMENTAL DESIGN

A 2 by 2 Latin Square design used in these tests allowed 4 days (2 days at each velocity) for each test. The experiment consisted of four separate tests—two with chinook salmon (*Oncorhynchus tshawytscha*) and one each with steelhead trout (*Salmo gairdneri*) and sockeye salmon (*Oncorhynchus nerka*).

TIMING FISH

Fish entered a release compartment (fig. 2)

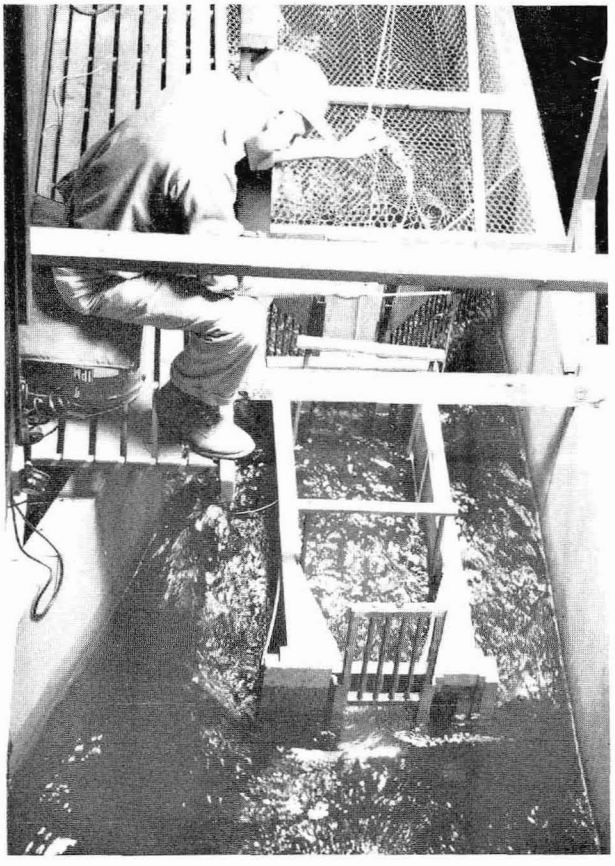

FIGURE 2.—Release compartment. Operator has raised gate (foreground) to allow fish to enter test area.

where they were identified as to species and released individually into the test area. Only one fish was permitted in the channel at any one time.

The timing zone (A to B, fig. 1) extended from the release compartment (A) to the exit area (B) at the upper end of the channel. A deflecting grillwork (fig. 3) directed fish toward an observation

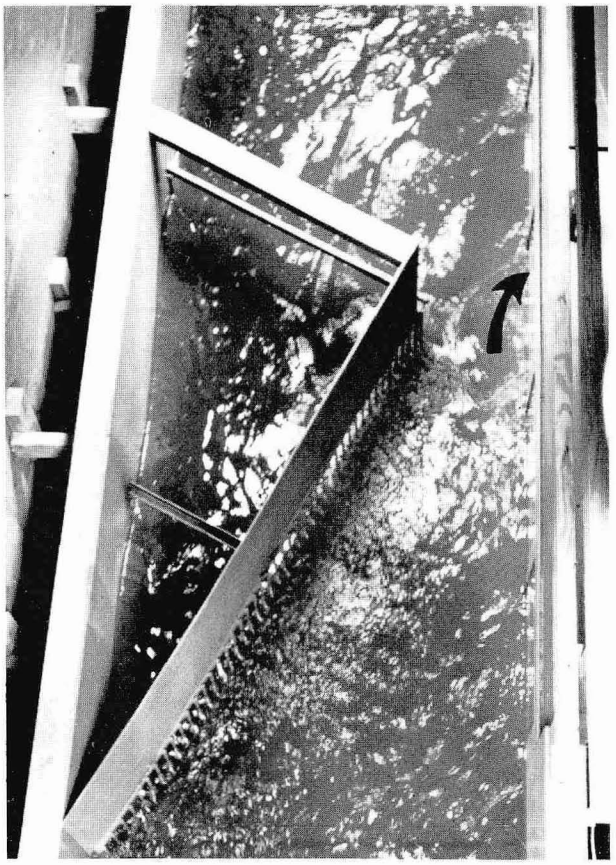

FIGURE 3.—Exit area of test channel viewed from above. Grill on left foreground deflects fish toward viewing area (arrow) of submerged observation chamber. Flow is toward foreground.

window at the point of exit. This arrangement ensured accurate observation and timing of the fish when visibility was limited owing to turbid water. The time of entry and exit for each fish was registered on a special time-event recorder. If a fish had not completed passage of the channel within 45 minutes after time of entry, it was removed and another fish was introduced.

ANALYSIS OF PASSAGE TIME

The effect of water velocity on fish passage was determined by measuring the time required for the fish to pass through the channel. Ninety-five percent confidence intervals about the median (Dixon and Massey, 1957) were applied to test for significance of differences between passage times at the two velocities. As used here, the median is the passage time of the median fish of all fish tested in each group, including those fish that failed to complete passage within the arbitrary 45-minute time limit. Computations of the mean passage time include only those fish that completed passage of the test channel within 45 minutes.

PASSAGE TIME IN RELATION TO WATER VELOCITY

Comparisons of time required to pass through the test channel at the two velocities are given by species in the following subsections.

CHINOOK SALMON

Tests with chinook salmon were made during two periods—May 8–11 and June 12–15, 1962. Fish in the early period are normally called spring-run and those in the latter period, summer-run chinook salmon. Median passage times in the May test at water velocities of 1 and 2 f.p.s. were 3.4 and 3.9 minutes, respectively (table 1). Results of the June test were similar. Median passage times in the two velocities did not differ significantly between velocities or between tests. Mean passage times, given for comparison, suggest similar trends. In both tests, however, chinook salmon took slightly more time to pass through the channel at 2 f.p.s. than at 1 f.p.s. (fig. 4). This difference corresponds with observations by Weaver (1963), who found that chinook salmon moved more slowly as velocity increased in the range of 2 to 8 f.p.s.

TABLE 1.—*Median and mean passage times of chinook salmon in an experimental transportation channel at Bonneville Dam at water velocities of 1 and 2 f.p.s., May and June 1962*

Test period	Water velocity	Fish tested	Passage time			
			Median	Lower limit[1]	Upper limit[1]	Mean
	F.p.s.	*Number*	*Minutes*	*Minutes*	*Minutes*	*Minutes*
May 8–11	1	37	3.4	2.7	5.5	4.7
	2	44	3.9	3.2	4.5	[2]4.9
June 12–15	1	45	3.1	2.5	4.4	4.8
	2	75	3.6	2.7	4.2	5.3

[1] 95-percent confidence intervals about the median.

[2] One fish failed to complete passage within the 45-minute time limit and was not included in computation of the mean.

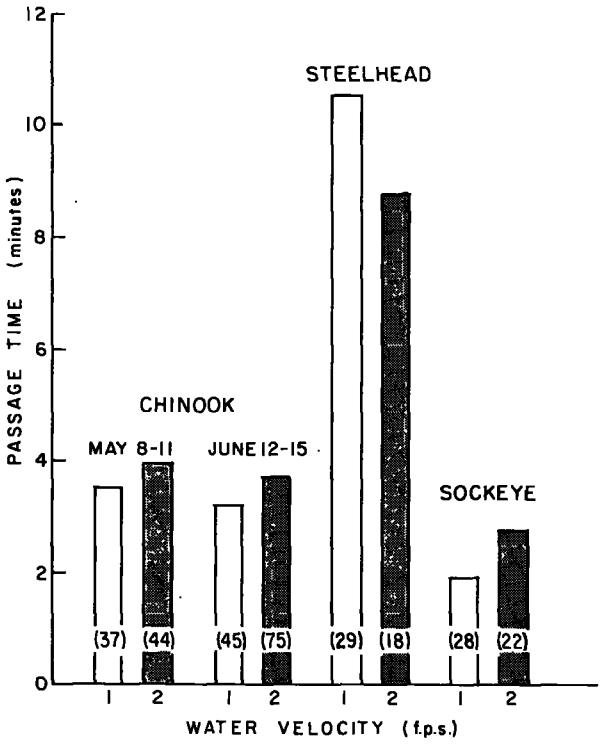

FIGURE 4.—Median passage times of chinook salmon, steelhead trout, and sockeye salmon in a transportation channel at water velocities of 1 and 2 f.p.s., 1962. Numbers of fish tested are shown in parentheses near the base of each bar.

STEELHEAD TROUT

Median passage times of steelhead trout at water velocities of 1 and 2 f.p.s. were 10.6 and 8.8 minutes, respectively (table 2). This difference was not statistically significant. Mean passage times were similar to the medians. Steelhead trout moved somewhat faster at the higher velocity, in contrast to the difference in chinook salmon (fig. 4). Weaver (1963) observed similar performances among steelhead trout, i.e., faster movement as water velocity increased.

In comparison with the other species tested, steelhead trout obviously spent considerable time in the test channel. Given suitable hydraulic conditions, steelhead trout frequently remain in favored pools or runs for varying periods of time before proceeding upstream. This characteristic possibly accounts for the relatively slow passage times of this species in the present tests.

SOCKEYE SALMON

Performances of sockeye salmon at the two water velocities were similar to those of chinook salmon. Both the median and mean passage times (table 3) give evidence of a slightly faster passage at the lower velocity. The difference between median passage times, however, was not significant.

TABLE 2.—*Median and mean passage times of steelhead trout in an experimental transportation channel at Bonneville Dam at water velocities of 1 and 2 f.p.s., July 30–August 2, 1962*

Water velocity	Fish tested	Passage time			
		Median	Lower limit[1]	Upper limit[1]	Mean
F.p.s.	*Number*	*Minutes*	*Minutes*	*Minutes*	*Minutes*
1	29	10.6	5.4	15.0	[2]9.6
2	19	8.8	3.0	11.0	[3]8.1

[1] 95-percent confidence intervals about the median.
[2] Four fish failed to complete passage within the 45-minute time limit and were not included in computation of the mean.
[3] Excludes one fish that did not complete passage within 45 minutes.

TABLE 3.—*Median and mean passage times of sockeye salmon in an experimental transportation channel at Bonneville Dam at water velocities of 1 and 2 f.p.s., July 10–13, 1962*

Water velocity	Fish tested	Passage time			
		Median	Lower limit[1]	Upper limit[1]	Mean
F.p.s.	*Number*	*Minutes*	*Minutes*	*Minutes*	*Minutes*
1	28	1.9	1.5	3.3	3.1
2	22	2.7	2.0	5.7	[2]4.1

[1] 95-percent confidence intervals about the median.
[2] One fish failed to complete passage within the 45-minute time limit and was not included in computation of the mean.

CONCLUSION

A water velocity of 1 f.p.s. is as suitable as one of 2 f.p.s. for the passage of chinook salmon, steelhead trout, and sockeye salmon in a transportation channel.

ACKNOWLEDGMENTS

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