EFFECT OF WATER VELOCITY ON THE FISH GUIDING EFFECTIVENESS OF AN ELECTRIC FIELD

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INTRODUCTION

The demand for hydroelectric power in the Pacific Northwest in recent years has created serious problems for the salmon industry. Each new hydroelectric plant constitutes another obstacle to anadromous fish. Providing a method for collecting downstream migrating fish for safe passage around these dams is one of the major problems confronting fishery biologists. Various techniques such as electricity, sound, louvers, etc., have been tested as possible devices to divert fish from hazardous areas with varying degrees of success. Electricity has been tested by several investigators and shows promise[1/] but most of the successful electrical guiding experiments have been conducted in water velocities that were relatively low, usually less than 1.0 foot per second.

The objective of this experiment was to determine, under field conditions, the effect of water velocity on the fish guiding effectiveness of an electric field.

MATERIAL AND METHOD

Experimental Area

The experimental site was located near Prosser, Washington, in the Chandler Irrigation Canal. This canal is a diversion of the Yakima River. It is approximately 8 feet deep, 75 feet wide, 9 miles long, and normally carries a water flow of 1,000 to 1,200 cubic feet per second. The canal entrance is not screened and juvenile fish migrating downstream have easy access--especially during periods of low water when a large portion of the Yakima River is diverted into the canal. To cope with this problem, drum screens and a fish bypass system were installed in the canal approximately 1 mile downstream from the canal intake. The drum screens and bypass trap were utilized as the evaluation system for this experiment.

Other physical facilities (velocity control structures, bypass canal, electrode array, and array trap) required for the experiment were installed in the canal upstream from the drum screens. The arrangement of these structures is shown in figure 1.

1/ Mason, James E. and Rea E. Duncan. Development and appraisal of methods of diverting fingerling salmon with electricity at Lake Tapps. Bureau of Commercial Fisheries Biological Laboratory, Seattle, Washington. Manuscript in preparation.

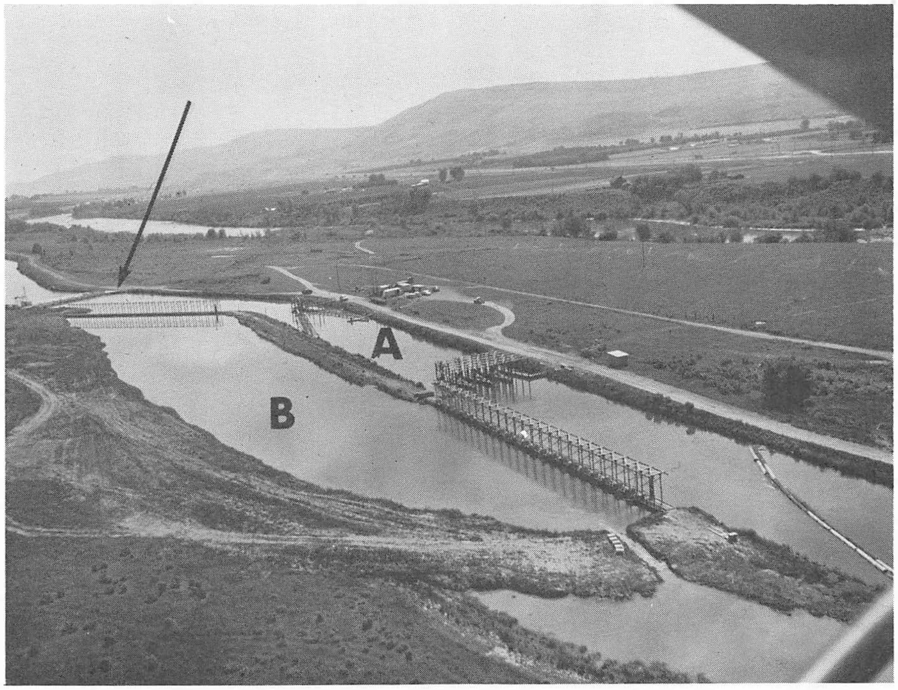

Figure 1.--Physical facilities of experimental fish guiding site at Prosser, Washington. Water flow is from right to left. Experimental canal (A) has "V" type electrode array and velocity control structure for diverting part of the flow through water-diversion channel (B). The water diversion channel carries excess flow of water around experimental area and is screened at both ends to prevent entry of fish. Arrow points to rotary drum screens used to evaluate effectiveness of electrode array. Yakima River is in background.

Test Fish

The majority of the fish available for this experiment were wild downstream migrants of the Yakima River system. A total of 129,000 juvenile salmonids were captured. The catch was comprised of 50 percent chinook salmon (*Oncorhynchus tschawytscha*), 32 percent coho salmon (*O. kisutch*) and 18 percent steelhead (*Salmo gairdneri*). The chinooks were members of age groups 0 and I. Their average fork length was 88.74 and 132.87 mm., respectively. The majority of the cohos were members of age group I and averaged 130.68 mm. in length. The steelhead were members of the one-plus age group and averaged 198.21 mm. in length.

Electrical Conditions

The electrode array consisted of vertically suspended electrodes arranged to form a 30° "V" and was installed in the experimental canal so that each leg of the V was at a 15° angle to the water flow. Three rows of electrodes comprised each leg of the V (fig. 2). The array trap was located at the bottom of the V.

The electrodes were energized with direct current, square-wave pulses that were supplied by interrupting the output of a d.c. generator with sequential switching equipment (Volz, 1962). The pulse amplitude was 125 volts and the pulse duration was 20 milliseconds. The pulse frequency was 15 pulses per second; however, since the electrodes were wired in five groups and the groups were sequentially pulsed, each group was actually energized only three times per second (total pulse frequency divided by number of electrode groups).

Experimental Design

The experiment was conducted in accordance with a 3 x 3 Latin square design using water velocities, 3-day test cycles, and 24-hour test periods as the variables. The water velocities selected for testing were 0.5, 1.5, and 2.5 f.p.s. Each water velocity was tested four times[2/]. The electrical conditions used were those that have proved to be noninjurious to fish (Pugh, 1962).

2/ The results of the fourth test are included in the analysis of the mean percentage fish guiding effectiveness of the electrode array. However, because of the 3 x 3 experimental design, they are not included in the analysis of variance tests of the effect of the differences within each of the variables on the fish guiding efficiency of the electrode array.

Figure 2.--One leg (looking upstream) of electrode array. Upstream velocity control structure is shown in the background.

The fish guiding effectiveness of the electric field was determined for each of the three test velocities by comparing the number of fish captured in the array trap with the number taken in an evaluation trap located downstream from the electrode array. The effect of the differences within each of the variables on the fish guiding effectiveness of the electric field was determined by statistical analysis.

Experimental Procedure

At the beginning of each test the desired water velocity was obtained by manipulating stoplogs in the velocity control structures.

Each control test was started at 4:00 p.m. Both the array and the inclined-plane trap were cleared of fish prior to starting the test and then fished at regular intervals for the duration of the control period. The control period lasted for 40 hours (until 8:00 a.m. on the second day after the experiment started). The following 8 hours (8:00 a.m. to 4:00 p.m.) were used primarily for maintenance and cleanup. Promptly at 4:00 p.m., when the maintenance period ended, the power was turned on, energizing the electrode array with the pre-set electrical conditions. The power-on portion of each test also lasted for 40 hours (until 8:00 a.m. on the second day after the array was energized).

The water velocity was checked every 2 hours and controlled by manipulating stoplogs and cleaning screens. Water temperature was measured three times each day and ranged from 52.0 to 68.0°F. during the experiment. The average water temperature was 57.9°F. Turbidity and resistivity of the water were also checked three times daily. The turbidity ranged from 10 to 26 parts per million and averaged 15.6 parts per million. The conductivity ranged from 4,290 to 7,000 ohm centimeters and averaged 5,535 ohm centimeters.

The electrode array trap was fished every 2 hours (2:00 p.m. to 4:00 p.m., etc.) and the inclined-plane trap every 4 hours (4:00 p.m. to 8:00 p.m., etc.) for the duration of the experiment. Fish captured in the array trap were transferred to holding troughs where they were counted and identified. Movable partitions within the troughs made it possible to accomplish this operation without handling the fish. After the data from each group of fish had been recorded the fish were released by removing stand pipes from the troughs, allowing the water and fish within the troughs to drain into a bypass flume. From there, the fish could enter the Yakima River. Fish captured in the inclined-plane trap were also identified, enumerated, and subsequently released back into the Yakima River.

RESULTS AND DISCUSSION

Preliminary analysis indicated that the electrode array trap captured a relatively high percentage of fish due to its placement and size (located in the center of the canal and screened approximately 34 percent of the flow) even when the electrode array was not energized. Therefore, the results are presented in a manner that distinguishes between the fish collecting efficiency of the total system, i.e., electrode array plus the array trap and the fish guiding efficiency of the electric field for each of the three test velocities and for each species (tables 1 and 2).

In computing the fish collecting efficiency for the entire system, the proportion--

$$\frac{\text{Array trap catch}}{\text{Array trap catch + inclined-plane trap catch}} = \text{Percent Efficiency}$$

--was used because it eliminated the necessity for delivering a constant number of migrants to the electrode array for each test condition.

Table 1.--Percentage fish collecting efficiency of the total system (electrode array plus array trap) for each test velocity, test cycle, and species.

Velocity	Test cycle	Species		
		Chinook	Coho	Steelhead
F.p.s.		Percent	Percent	Percent
0.5	1	88.2	82.0	71.3
	2	81.2	82.8	74.3
	3	78.2	86.0	75.9
	4	93.9	82.0	64.0
	Average:	85.4	83.2	71.4
1.5	1	77.1	77.9	43.3
	2	79.7	82.3	64.2
	3	72.6	60.5	59.8
	4	39.9	24.6	28.9
	Average:	67.3	61.3	49.0
2.5	1	88.2	76.2	74.9
	2	87.5	75.5	70.2
	3	86.4	76.1	72.2
	4	57.3	59.4	49.5
	Average:	79.8	71.8	66.7

Table 2.--Percentage fish guiding efficiency of the electric field for each test velocity, test cycle, and species.

Velocity F.p.s.	Test cycle	Species Chinook Percent	Coho Percent	Steelhead Percent
0.5	1	87.4	81.5	70.0
	2	79.0	81.0	70.7
	3	77.0	85.4	75.4
	4	93.6	81.5	63.6
	Average:	84.2	82.4	69.9
1.5	1	67.7	59.8	32.0
	2	70.9	76.8	58.4
	3	64.0	51.2	57.1
	4	14.3	3.4	13.3
	Average:	54.2	47.8	40.2
2.5	1	71.5	19.2	52.4
	2	71.1	55.3	46.2
	3	61.3	57.1	54.0
	4	0.0	39.4	26.5
	Average:	51.0	42.8	44.8

The fish guiding effectiveness of the electric field was determined by mathematically eliminating the proportion of fish from the electrode array trap catch which the control (power-off) tests indicated the array trap would capture whether the power was on or off.

Figure 3 presents a comparison of the fish collecting efficiency of the entire system with the fish guiding efficiency of the electric field and shows that the percentage of fish guided was a function of water velocity and that in general the fish guiding effectiveness of the electric field decreased as the water velocity increased. The figure also shows that there were differences in fish guiding efficiency among the three species with chinooks being diverted the most effectively, cohos second, and steelhead the least effectively.

Statistical examination revealed that the differences in fish guiding efficiency that could be attributed to the differences among the test velocities and among the species were significant at the 5-percent level. Differences within each of the other test variables--3-day test cycles and 24-hour test periods--did not result in significant differences in fish guiding effectiveness.

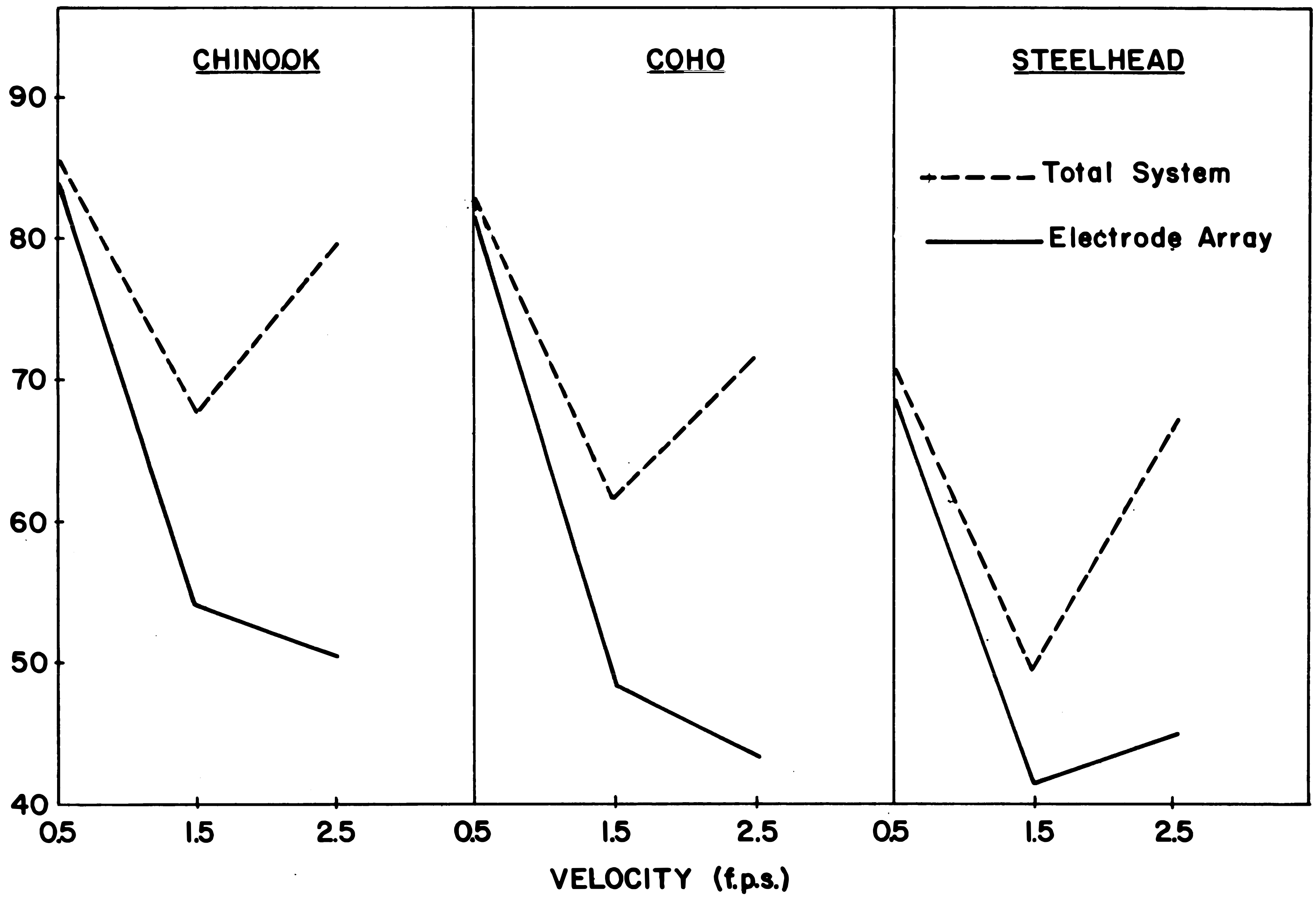

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Figure 3.--Comparison of the fish collecting efficiency of the total system with the fish guiding efficiency of the electrode array alone.

SUMMARY AND CONCLUSIONS

A field experiment was conducted in the Chandler Irrigation Canal to determine the effect of water velocity on the fish guiding effectiveness of an electric field using three water velocities.

The majority of the fish utilized in the experiment were wild downstream migrating chinook and coho salmon and steelhead trout of the Yakima River system. Approximately 129,000 juvenile salmonids were captured during the experiment.

In general, the highest fish guiding efficiency was achieved at 0.5 f.p.s., the second was at 1.5 f.p.s., and the lowest was at 2.5 f.p.s. Of the three species tested, chinooks were the most readily guided, cohos second, and steelhead were the least effectively guided. Statistical analysis showed that the differences in fish guiding efficiency that could be attributed to velocity differences, and to species differences were significant at the 5-percent level. The differences in fish guiding effectiveness that could be attributed to differences within each of the other variables--3-day test cycles and 24-hour test periods--were not statistically significant.

The major conclusions reached are:

1. The effectiveness of an electric field to guide downstream migrating salmonids appear to be limited by the water velocity. In the velocities tested, the fish guiding efficiency of the electrode array generally decreased as the water velocity increased.

2. The fish guiding efficiency of an electric field varies with different species. Of the three species of fish tested, chinooks were guided the most effectively, cohos second, and steelhead the least effectively guided.

3. The use of the electric field to divert downstream migrating fish in environments such as the Snake River, where water velocities often exceed 5.0 f.p.s., does not appear to be practical.