FISH-PASSAGE RESEARCH PROGRAM

REVIEW OF PROGRESS 1964

VOLUME III

COLLECTION OF JUVENILE MIGRANTS FROM RIVERS AND RESERVOIRS

C O N T E N T S

Volume III Reports on Collection of Juvenile Migrants From Rivers and Reservoirs

Contents, vol. III, cont.

COLLECTION OF JUVENILE MIGRANTS FROM RIVERS

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

by

John R. Pugh

Gerald E. Monan

Jim R. Smith

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U. S. Bureau of Commercial Fisheries
Seattle, Washington

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.

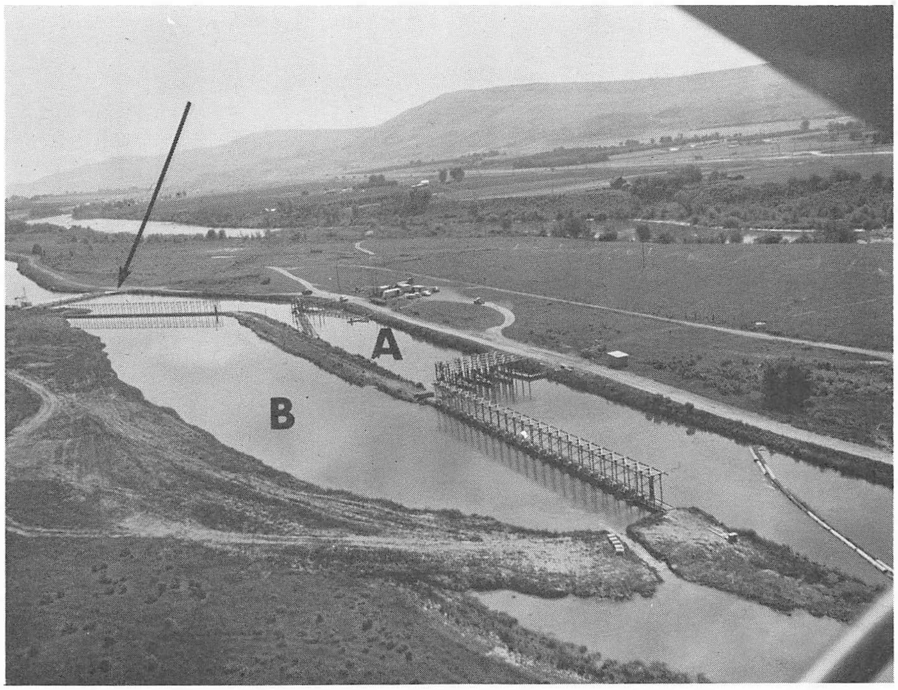


Figure 1.--Physical facilities of experimental fish guiding site at Prosser, Washington. Water flow is from right to left. Experimental canal (A) has "V" type electrode array and velocity control structure for diverting part of the flow through water-diversion channel (B). The water diversion channel 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 F.p.s.	Test cycle	Species: Chinook Percent	Coho Percent	Steelhead 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	Chinook Percent	Species 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.

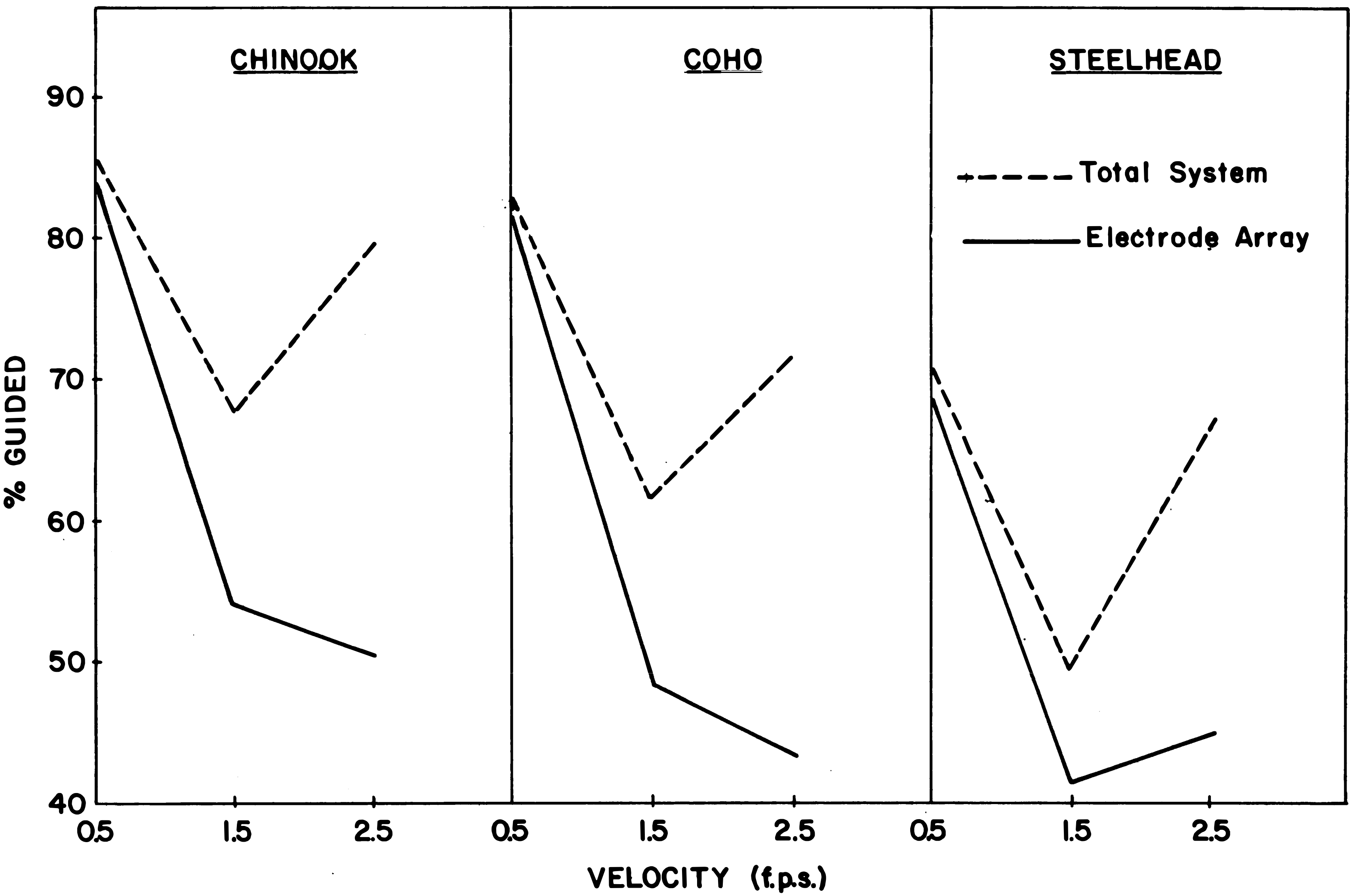


Figure 3.--Comparison of the fish collecting efficiency of the total system with the fish guiding efficiency of the electrode array alone.

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.

A FIELD TEST OF ELECTRICAL GUIDING AND LOUVER DEFLECTION COMBINED INTO A SINGLE GUIDING SYSTEM

by

Gerald E. Monan

and

John R. Pugh

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

Many techniques for deflecting or guiding downstream migrant salmonids have been tried and a wide range of results has been obtained. Among the techniques that have had some success are electrical guiding and deflection with louvers. Both systems have disadvantages which tend to limit their range of application.

Electrical guiding--which has the advantage of a minimum of equipment in the water to interfere with the flow--has shown promise, but primarily in tests with low water velocities[1/] [2/]. Contrarily, louvers have been effective at higher velocities. However, the need for rather closely spaced louver elements has made debris more of a problem and has added considerably to the overall costs. Bates (1961) reported that with a spacing of 2 inches, the fish-guiding efficiency of the louver system was 98 percent. When the spacing was widened to 10 inches, the efficiency decreased to approximately 63 percent. This decrease in efficiency has caused researchers to seek a simple method of increasing the efficiency without reducing the unobstructed space between the louver elements.

The objective of the research presented here was to determine if the fish-guiding efficiency of a louver system with widely spaced louver slats could be materially increased by applying electrical energy so that the louver slats could function as electrodes in an electrical array.

MATERIALS AND METHODS

The experiment was conducted during April and May 1962 in the Maxwell Irrigation Canal, a diversion of the Umatilla River near Hermiston, Oregon. Juvenile steelhead migrating downstream were the primary fish available during these tests.

1/ Mason, James E., and Rea Duncan. The 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.

2/ Pugh, John R., Gerald E. Monan, and Jim R. Smith. Effect of water velocity on the fish guiding effectiveness of an electrical field. Bureau of Commercial Fisheries, Fish-Passage Research Program, Seattle, Washington. Manuscript in preparation.

The Facility

The facility was the same as described by Bates (1961). The site consisted of a concrete-lined flume 50 feet long, 15 feet wide, and 5 feet deep (fig. 1). A similar but unlined section was immediately adjacent to the concrete canal. By manipulating stop logs in the test channel, all the water (or any portion of it) could be bypassed through the unlined area. The concrete canal was divided longitudinally by a wooden partition which separated the canal into two sections, one 5 feet wide and the other 10 feet wide. During this experiment the narrow section was not used. Fish that escaped through the louvers were captured by fyke nets which screened the entire flow at the downstream end of the canal. Fish deflected by the louvers passed through a 6-inch wide bypass to an inclined screen fish trap.

The Electrified Louver System

A line of vertical louvers, 30 feet long and 5 feet high was placed in the concrete flume on a 20° angle to the flow. Three louver spacings were tested: 4.75 inches, 10.00 inches, and 16.00 inches. Each louver slat was made from sheet steel approximately 0.1046 inch thick and 3 inches wide. These slats were held in position by slotted wooden cross members.

Since the metal louver slats were electrically insulated from one another by the wooden spacers, it was a relatively easy matter to connect the louvers to an electrical source and have each louver slat function as an electrode immersed in a conductive medium. The electrodes were wired alternately positive & negative and energized with pulsed direct current at a rate of 15 pulses per second. Each pulse lasted 20 milliseconds. In order to obtain relatively uniform voltage gradients, the applied voltage was varied from 60 volts at the 4.75 inch spacing to 90 volts at the 10.00 inch and 16.00 inch spacings. The electronic equipment used was the same as described by Volz (1962).

Experimental Design

In order to test the effect of the addition of electricity, the louvers were alternately tested with the power on and off. The three louver spacings (4.75 inches, 10.00 inches, and 16.00 inches) were tested in a randomized pattern during the 20-day testing period. This design allowed the data to be analyzed by analysis of variance tests.

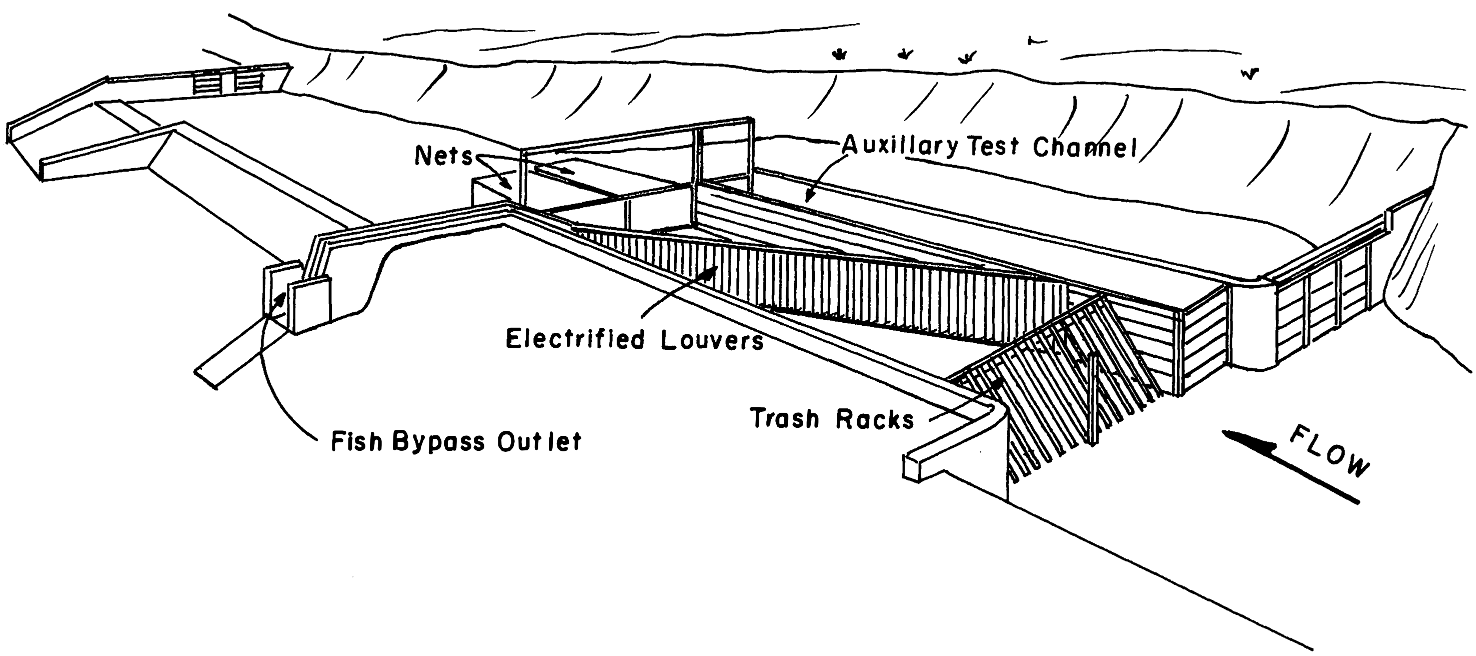


Figure 1.--Diagrammatic sketch of the facilities used in the electrified louver study in the Maxwell irrigation canal, near Hermiston, Oregon.

Experimental Procedure

Each experimental day began at 8:00 a.m. and terminated shortly after midnight. Individual fishing periods lasted 1 hour. At the end of each fishing period, all traps were blocked off and the fish removed and counted. As soon as the traps were emptied and the nets cleaned, the traps were put in fishing position and a new fishing period started. There were approximately twelve fishing periods each day. The water velocity, temperature, turbidity, and conductivity were measured and recorded every 4 hours of the experimental day. The water velocity in the test channel was maintained at approximately 2.5 feet per second throughout the experiment.

RESULTS AND DISCUSSION

During the 20-day testing period a total of 3,526 juvenile steelhead were captured. Table 1 shows the test results.

Analysis of variance tests indicated no significant difference at the 5 percent level between the fish-guiding efficiencies obtained with the power on and those obtained with the power off. However, the analysis of variance tests did indicate a significant difference between the fish-guiding efficiencies obtained at the three louver spacings tested. Water temperature, conductivity, turbidity, and weather data were examined as possible causes of the variance in efficiencies, but no strong correlations were apparent.

It is apparent from the data that the addition of electrical energy to the louvers neither consistently increased nor decreased their fish-guiding efficiency.

LITERATURE CITED

Bates, Daniel W., and Stanley G. Jewett, Jr.
1961. Louver efficiency in deflecting downstream migrant steelhead. Transactions of the American Fisheries Society, vol. 90, no. 3, p. 336-337.

Volz, Charles D.
1962. Ignitron-pulsed electric fence guides migrating salmon. Electronics, vol. 35, no. 16, p. 50-52.

Table 1.--Comparison between the fish guiding efficiencies (expressed in percent guided) of the louver spacings tested with the power on and with the power off. The total numbers of fish tested are also shown.

Louver spacing	Power condition	Efficiency[1/] Test 1	Test 2	Test 3	Test 4[2/]	Average	Number of fish tested
Inches		Percent	Percent	Percent	Percent	Percent	
4.75	On	82.9	88.5	76.6	--	82.7	471
	Off	84.3	83.9	85.0	--	84.4	408
10.00	On	74.4	82.7	80.3	--	79.1	1246
	Off	77.9	90.4	41.1	--	69.8	481
16.00	On	19.0	53.8	77.3	53.6	50.9	390
	Off	41.7	66.9	49.2	67.2	56.3	530
Number of fish tested	--	455	1936	815	320	--	3526

1/ Numbers of fish in the bypass trap divided by the total number of fish captured during each test.

2/ The 16-inch spacing was the only spacing tested four times.

EXPLORATORY RESEARCH ON GUIDING JUVENILE SALMON

by

Daniel W. Bates

October 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

Many years of research have been devoted to the problem of protecting young salmon and steelhead from destruction in rivers, streams, and canals subject to hydroelectric or irrigation developments. This has included studies, to name just a few, on the practicability of using such guiding devices as electricity (Holmes, 1948; Andrew, Kersey, and Johnson, 1955; Pugh and Monan, 1962); light (Fields, 1957); odors, traveling cables, differential velocities, and electricity (Brett and Alderdice, 1958); sound (Moore and Newman, 1956); and louvers (Bates and Vinsonhaler, 1956, and Ruggles and Ryan[1/]). The task of safeguarding each of the five species of Pacific salmon *(Oncorhynchus)* as well as steelhead *(Salmo gairdneri)* has not been simplified, because each year the complex of dams and irrigation projects becomes even more intricate.

Where effort has been made to collect downstream migrants at high-head dams, collection has been accomplished within the forebay adjacent to the dam. This applies to all high-head dams in the Columbia Basin, such as Brownlee in the Snake, Pelton in the Deschutes, North Fork in the Clackamas, and Mayfield in the Cowlitz. At Brownlee, a $3.5 million system composed of a deep, river-wide seran net and three "skimmers" on floating barges to trap downstream migrant salmon and steelhead was unsuccessfully used for 4 years. It has since been removed, but not replaced.

Another approach to downstream migrant collection at high-head dams has been used at Mayfield Dam on the Cowlitz River, where the total powerhouse flow of 12,000 c.f.s. is screened through a louver system (fig. 1).

As there is some question as to both the ability of the juvenile migrant to pass through reservoirs and the effectiveness of the migrant collection system at these high-head dams, biologists are currently carrying out investigations on these particular problems. One such study is being conducted in the Brownlee Reservoir. Present observations indicate that the downstream migrant is beset by many problems in its effort to find a way through the 57-mile-long reservoir. The evidence indicates that the length of a reservoir may be one of the factors limiting successful downstream migration.

1/ Ruggles, C. B. and D. Ryan. An investigation of louvers as a method of guiding juvenile Pacific salmon. Canadian Fish Culturist (in press).

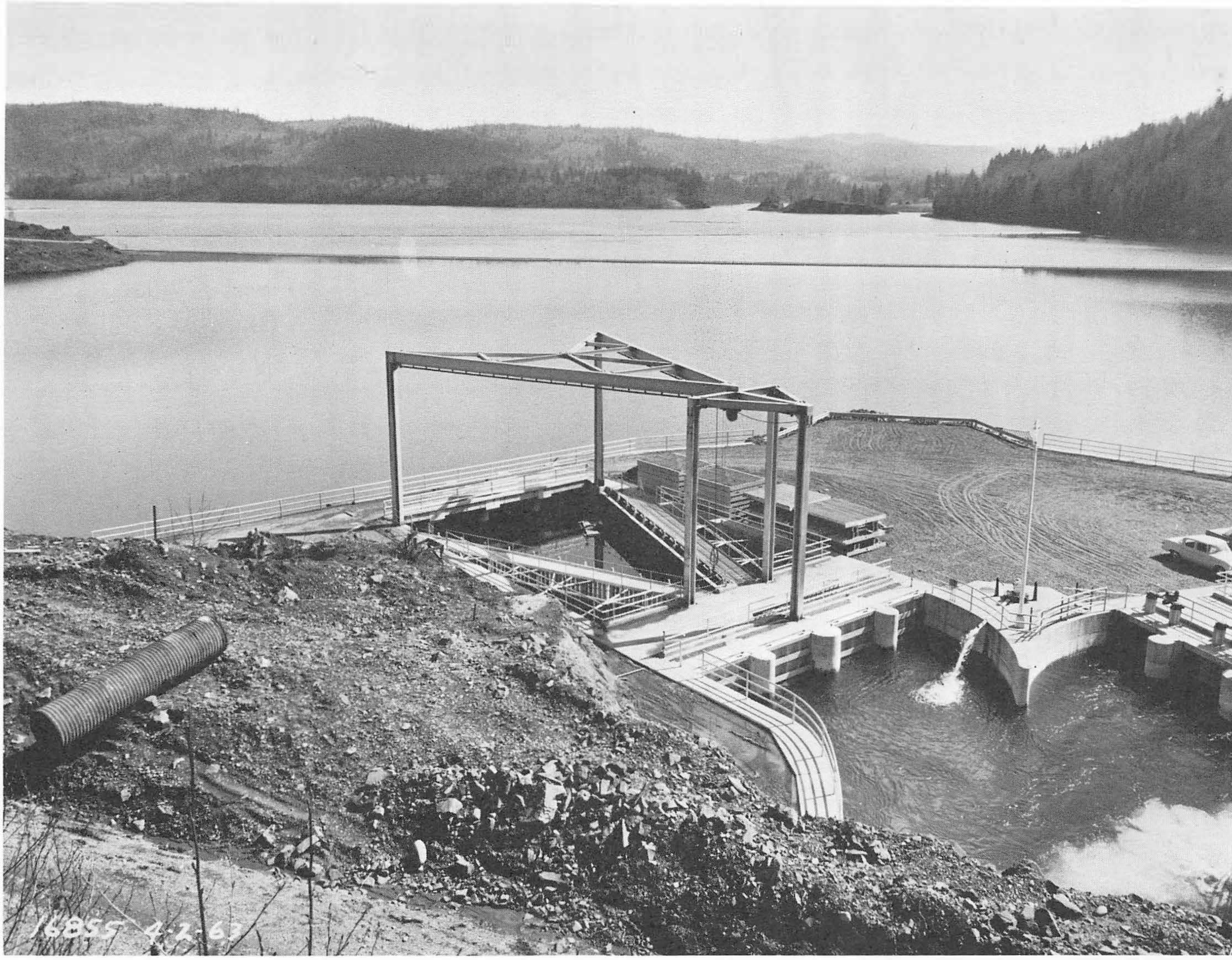


Figure 1.--Mayfield Project. Looking toward intake and trash rack, north louver structure. Fish bypass is located at juncture of louver "V." Partial view of south louver structure appears on right.

In view of the problems associated with migrant collection in the forebays of large, deep reservoirs, the scope and scale of research on methods for the collection of young migrants from rivers, streams, and canals above the reservoir have been expanded. Such studies, if successful, would eliminate the loss of migrants in reservoirs. Once collected above the reservoir, juvenile migrants could then be safely transported around the dam.

In approaching the problem, we recognized that although young salmon make regular and often precisely timed migrations (Hoar, 1953), the mechanics of the movement and behavior patterns which accompany these migrations are still undetermined. Young fish obviously respond to particular stimuli. If nature can supply such stimuli, it would be logical to employ artificial stimuli to guide the young fish into safe routes of passage. But the questions of choice and techniques and how these should be applied require investigation. The purpose of this paper is to describe some of these investigations.

Flow Deceleration Experiment
(University of Washington, 1963)

Introduction

Biologists have observed the outflow of water from fyke nets, particularly in debris-laden water where the effective open area between the mesh is reduced through clogging. When clogging occurs, entrance velocities are reduced and fish collecting efficiencies drop materially. It has been presumed that such fish response is due to the deceleration of flow immediately ahead of the net. Bates and Vinsonhaler (1956) have made observations of fish avoidance of velocity conditions existing at the entrance to a louver bypass where the bypass velocity is lower than the velocity of approach--a hydraulic condition similar to that in the clogged fyke-net example. An interesting behavior pattern has been demonstrated by stream-reared juvenile steelhead (Bates[2/]) where such a velocity relationship exists. These young fish, having stopped in their downstream movement at the entrance to the bypass, have been observed to rise and drop vertically in what would appear to be a search for a more favorable velocity condition.

2/ Bates, Daniel W. Additional studies on louver efficiency in deflecting downstream migrant steelhead. Manuscript in preparation (1964).

Extensive field studies have been carried out at Tracy, California, to determine the most efficient ratio of approach-to-bypass velocity to use in making the final collection of fish as they conclude their deflection along the louver line (Bates, Logan, and Pesonen, 1960). The results of this study (corroborated by Ruggles and Ryan[1/]) indicate that guiding efficiency for most juveniles increases with bypass accelerations up to about 145 percent of the approach velocity. The guiding efficiency dropped significantly when the bypass velocity decelerated from 100 percent of the mean approach velocity to 80 percent. Other biologists working on the problem have noted this response to velocity decelerations (Brett and Alderdice, 1958).

On the basis of these earlier experiments, we decided that there was sufficient justification for proceeding with an exploration of the feasibility of utilizing this response at the University of Washington Hydraulic Laboratory.

Description of Experimental Apparatus

To develop the desired flow deceleration conditions, a plastic model as illustrated in figure 2 was constructed and installed in a specially prepared test flume at the University. This model contained five separate canals measuring 5 inches wide, 12 inches long, and 6 inches deep--each offset to provide a deflection angle of 30°. The most downstream canal was used as a bypass.

The results of this work indicated that the velocity conditions could be secured (fig. 3), but only in part, and that there was insufficient velocity variation to consider application under actual field conditions. For this reason the project was temporarily set aside.

Resume

Based on hydraulic studies conducted in the laboratory, it was concluded that physical limitations made the extension of this design impractical.

Flow Acceleration Experiments Using Vertical Wedges, Model I (Carson Behavioral Flume, 1963)

Introduction

Following the limited success achieved in the study of the flow decelerator, we decided to direct our next investigation

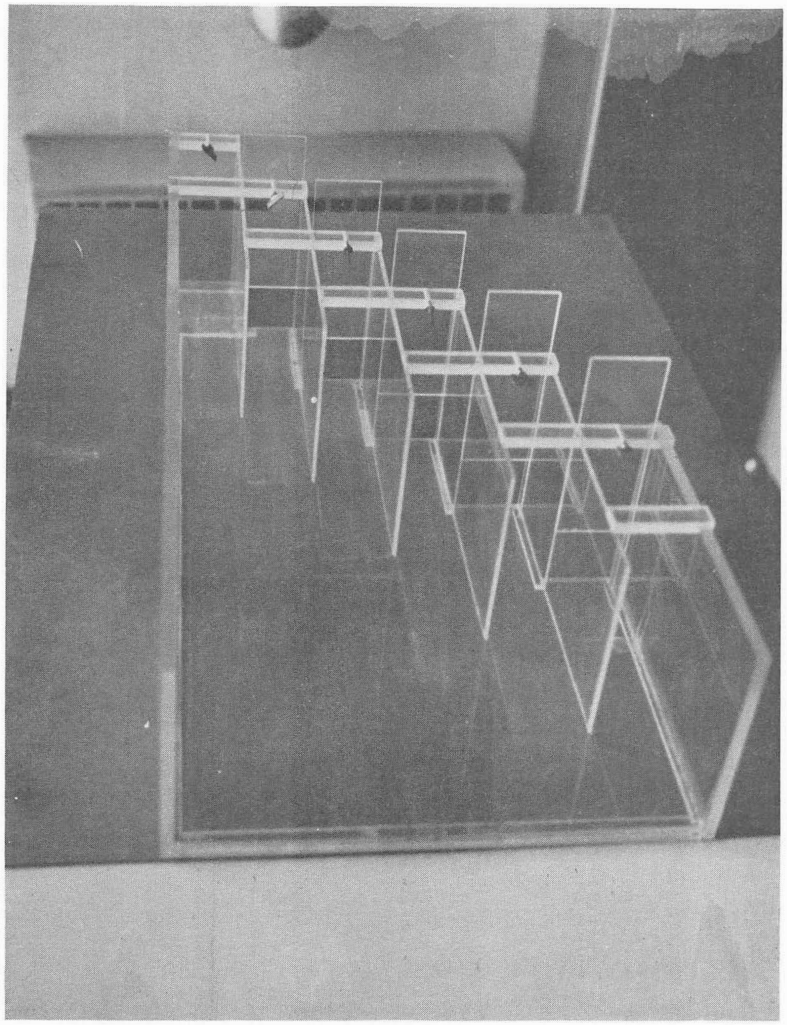


Figure 2.--Plexiglass flow decelerator hydraulic model used to study flow control methods.

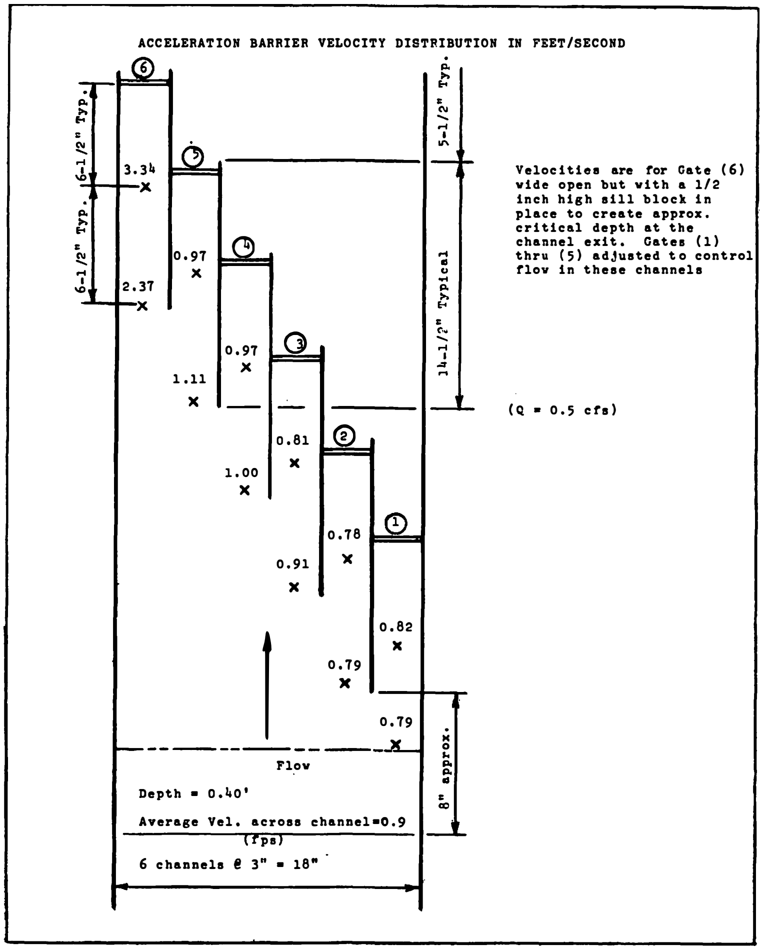


Figure 3.--Plan view sketch of the flow decelerator showing the optimum velocity relationships which could be achieved in the hydraulic model.

toward the opposite condition--the acceleration of flow. To achieve this condition, the velocity of approach would be caused to increase rapidly over relatively short lineal distance and, additionally, the canal would be gradually restricted in width up to a specific point over a specified distance. A distinction should be made here concerning the difference in this design to that of a conventional and rectangular bypass where there is no restriction or change in bypass width throughout the system. Although an acceleration of velocity exists in this type of bypass, the rate of acceleration is considerably different, and it is this difference which causes fish to accept the rectangular bypass and reject the wedge-type bypass.

Description of Experimental Apparatus

A small wooden trough measuring 5 feet long, 2 feet deep, by 1 foot wide was constructed and installed in the Carson behavioral flume. (See "Behavioral Flume at Carson," appended.) Wedges were attached near the downstream end of the trough along each side. The taper of each wedge started at the upstream end, gradually flaring out into the trough, a distance of 3 inches over a lineal distance of 8 inches. Trough width at point "A" (fig. 4) measured 12 inches, but only 6 inches at point "B."

The flow through the wedges (fig. 5) suggested that since the area was being reduced, there would be a uniform acceleration along the wedges. However, as the flow equations were solved for the acceleration, it became apparent that the acceleration depended upon the initial velocity squared and the distance from the beginning of the wedge. The acceleration at the end of the wedge might easily be five or ten times that at the beginning of the wedge. If the response of the fish is to be attributed to an acceleration effect, the comparison of responses between different wedges should be related to the acceleration curves for the wedges.

Test Procedure

Trough velocity during the experiment was maintained at 1.8 feet per second, which was generally 0.2 to 0.4 foot per second under the sustained swimming speed of the young hatchery-reared (3 to 4 inches in length) chinook salmon.

Only observations on response were made, and no attempt was made to determine any type of efficiency in remaining above point "A" (fig. 4). During any one study, only five fish were introduced into the canal immediately upstream from point "A."

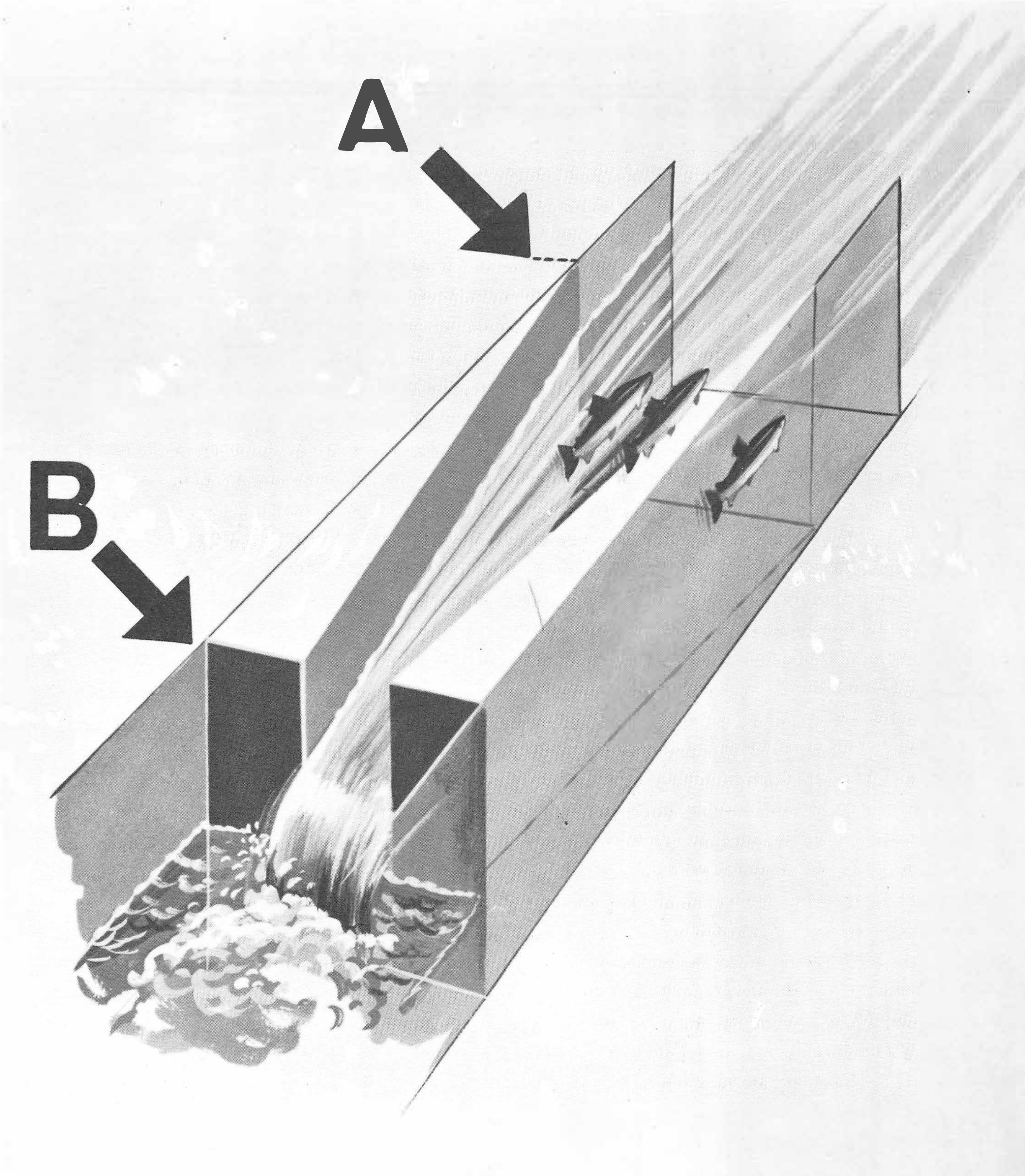


Figure 4.--Diagrammatic sketch of the flow accelerator, model I, showing wedges extending into the canal and the upstream point of flow acceleration (broken line).

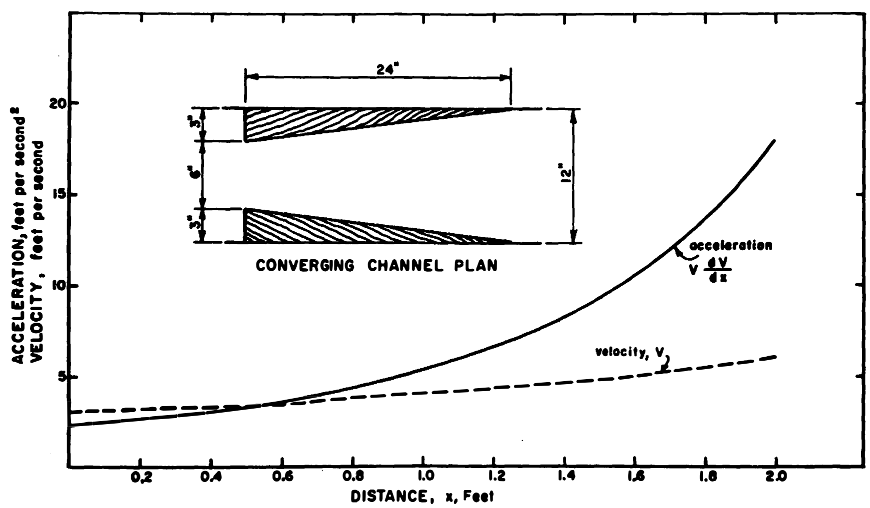


Figure 5.--Relation between velocity and acceleration plotted against the distance.

Observations

The young migrants moving downstream tail first from the upper portion of the small trough would stop in their downstream movement just as the tail portion of their bodies reached the imaginary line at point "A." On occasion, some of these fish continued downstream past "A" until they reached the area of higher velocities near point "B"; then they darted rapidly upstream, resuming their original positions between point "A" and the screen. As they maneuvered up and downstream in this area, always heading into the flow, they seldom allowed themselves to drop downstream past point "A." Also, being bounded by the flume walls, the fish were limited in their choice of movement. Fish having once rejected movement downstream past point "A" could thereafter seldom be forced downstream beyond this point.

To answer the question as to the role of vision in the response to the flow accelerator, co-workers Niggol and Gerold[3/] in 1962 carried out a series of experiments dealing with this matter.

Several hundred hatchery-reared juvenile chinook and silver salmon were blinded and held for testing. The response of these fish to the acceleration of flow was identical to that of fish with vision, indicating in this case that primary orientation was not visual, but essentially a sensory response to flow differentials.

Discussion

The pattern of behavior to the flow accelerator was similar, irrespective of species used. Of significance was the positive avoidance response by the blind fish to the unseen velocity change. The initial success in the use of this particular type of barrier was sufficient to warrant consideration of an installation composed of several acceleration barriers placed on an angle to flow to provide the downstream migrant a facility on which to guide.

3/ Niggol, Karl, and M. Gerold. Notes on the reaction of blinded fingerling salmon. Manuscript in preparation (1964).

Flow Acceleration Experiments Using Vertical Wedges, Model II (Carson Behavioral Flume, 1963)

Introduction

Following the experimental success achieved in the previous study utilizing the stimulus of flow acceleration, we decided to concentrate further investigation on a series of flow accelerators positioned on such an angle to the direction of flow that a deflection of fish could be accomplished.

Again, the intent here was to detect, where possible, unquestionable indications of acceptable deflection rather than to search for subtle differences of behavior.

Considering the use of hatchery fish, we have made no attempt to treat the data for all their statistical possibilities. One prevalent problem in this regard was that hatchery fish would swim rapidly downstream headfirst and pass through the installed facility at any open point. It was estimated that 10 to 15 percent of all fish released behaved in this particular manner.

Description of Experimental Apparatus

For the next series of experiments, the flow accelerator, modified to provide fish-deflecting capabilities (figs. 6 and 7), was installed in the behavioral flume. The assembly, consisting of five individual sets of double wedges, was placed within the behavioral flume on approximately a 25° angle to flow. Each set measured 12 inches in width at the opening, tapering to a width of 6 inches over a distance of 9.5 inches. The 1-foot-wide bypass was placed near a plexiglass view window to allow observations of fish response to certain portions of the accelerator barrier and the bypass. Velocity control was maintained at the downstream end of the flume through placement of stoplogs. Approach velocities ranged from 1.2 feet per second to 2.4 feet per second in increments of 0.2 foot per second. For all tests and all approach velocities, a ratio of approach to bypass velocity of 1.0 to 1.4 was maintained. Throughout the experiments, water depth was held generally at 18 inches.

Test Procedure

By dip-netting, fish were secured from the raceways, placed in buckets, and carried to the holding tank placed at the upstream end of the flume. The fish were then held for a period

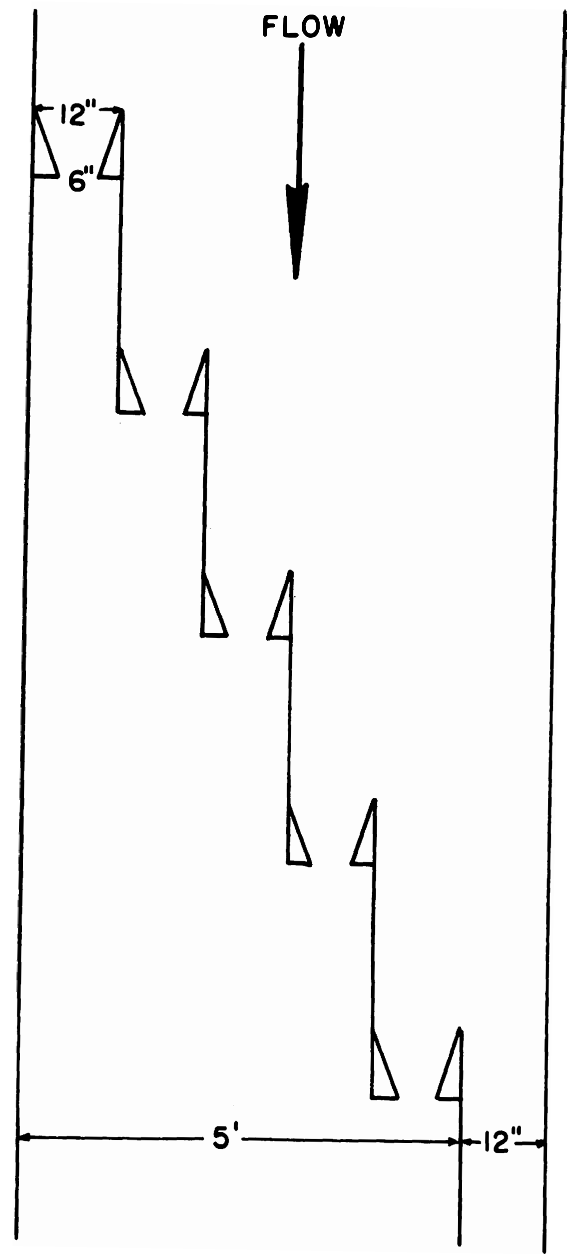


Figure 6.--Diagrammatic sketch (plan view) of the model II flow accelerator showing the individual accelerators formed on a 20° angle to flow.

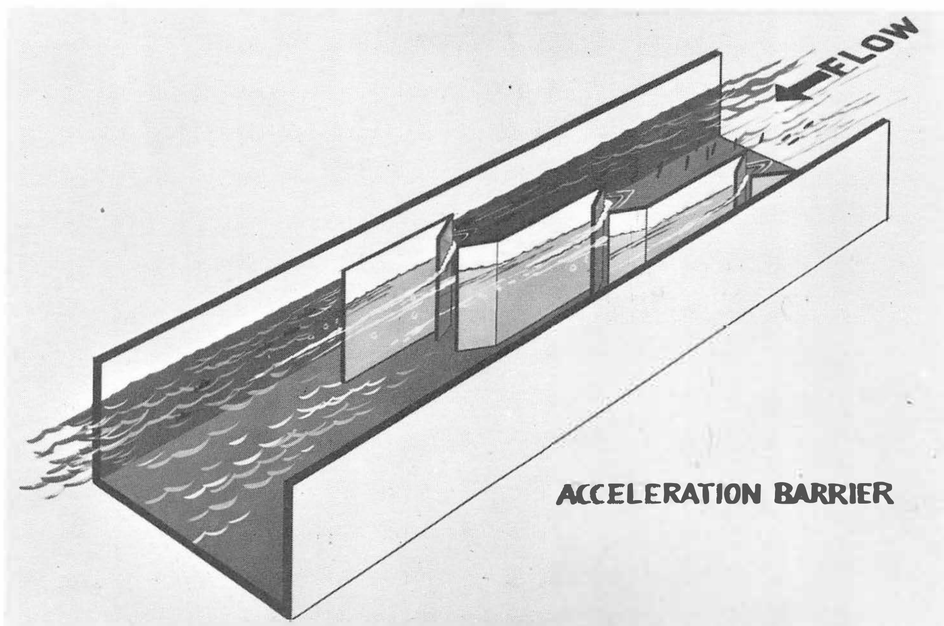


Figure 7.--Diagrammatic sketch of the flow accelerator, model II, showing a series of individual accelerators formed on a 20° angle to flow.

of 15 to 30 minutes to allow time for them to adjust to their new environment. To record fish behavior toward the various deflection devices, motion pictures were taken periodically.

Results

The results secured from the acceleration of flow created by vertically positioned wedges demonstrated that a relatively high level of deflection was possible (table 1). Young spring salmon were observed changing their direction of downstream movement in front of the barriers, moving along the entire line, and ultimately entering the bypass. In most cases, several fish would hold at the entrance to each barrier. These fish could not be driven through, even after considerable effort.

A change in the length of wedges from 9.5 to 6.7 inches did not result in any significant variation in efficiency (table 2). However, this modification of wedge lengths was relatively small. The exceedingly rapid rate at which these fish could readjust their direction of movement was surprising. This readjustment is particularly noteworthy considering the fact that as hatchery fish they never had any prior experience in avoiding obstructions, particularly at high velocities.

Discussion

One of the great disadvantages of this particular barrier design is that each individual barrier entrance creates a pocket into which a considerable number of fish will gather and hold. More desirable would be a design eliminating all pockets but providing a continuous guiding line along the complete length of structure.

Flow Acceleration Experiments Using Horizontal Wedges, Model I (Carson Behavioral Flume, 1963)

Introduction

Due to the formation of objectionable pockets created by the vertically positioned wedges, which tended to restrict the continuous downstream movement of fish along the face of the structure, a redesign was considered necessary.

Description of Experimental Apparatus

To eliminate the above problem of holdup and yet apply the principles of a flow barrier which had been developed, it was decided to place the wedges on a horizontal plane rather than a

Table 1.--Percentage deflection using vertical velocity accelerator at a deflection angle of 20°. Wedge openings tapered from upstream width of 12 inches to downstream width of 6 inches over a lineal distance of 9.5 inches, Carson behavioral flume, 1963.

Date	Time	Velocity	Recapture: Trap 1 bypass	Recapture: Trap 2	Deflection
April		F.p.s.	No.	No.	Percent
12	1020	1.2	270	94	74.1
12	1150	1.2	282	45	86.2
18	1400	1.6	210	123	63.0
18	1615	1.6	235	54	81.3
23	2105	1.8	318	120	72.6
23	2135	1.8	315	51	86.0
23	2200	2.0	234	50	82.3
24	2330	2.0	255	24	91.3
24	0910	2.2	233	21	91.7
24	1350	2.2	165	27	85.9
24	1415	2.4	196	18	91.5
				Avg.	81.2

Table 2.--Percentage deflection using vertical velocity accelerator at a deflection angle of 20°. Wedge openings tapered uniformly from upstream width of 12 inches to downstream width of 6 inches over a lineal distance of 6.7 inches, Carson behavioral flume, 1963.

Date	Time	Velocity	Recapture: Trap 1 bypass	Recapture: Trap 2	Deflection
April		F.p.s.	No.	No.	Percent
24	1630	1.8	255	27	90.4
24	1710	1.8	225	57	79.7
24	2100	1.8	289	45	80.7
24	2210	1.8	321	48	87.2
				Avg.	84.8

vertical. Such a design would provide a continuing structure along which the young fish might deflect. The new deflector (fig. 8) consisted of two horizontal wedges placed 90° to the direction of flow (no guidance provided in this first model) and installed within a 5-foot-long trough having an 18-inch depth and a 1-foot width. This in turn was positioned parallel to flow within the larger behavioral flume. The wedges which were installed near the downstream end of the trough were 3 inches high and 9 inches long, with a clear spacing of 6 inches at the downstream end. The upstream end of the small trough was screened to retain the test fish.

Although results of the initial work provided responses similar to those secured with the vertical wedges, the uppermost wedge, being made of wood, restricted observation to the extent that it was considered necessary to replace it with glass. In doing so, the length of the upper wedge was increased from 9 inches to 22 inches. At a water depth of 15 inches, point "A" of the upper wedge extended several inches upstream and beyond point "A" of the bottom wedge as shown in part "a" of figure 9.

Test Procedure

Following the pattern of procedure developed for observation of fish response to the vertical wedge design, a series of observations were made in the case of the horizontal wedges, using five juvenile chinook salmon each time. These were introduced by dip-net into the upper portion of the test trough. After a 10-minute period, those remaining were collected and returned to their respective hatchery raceway. A new group was then introduced.

Results

Although the precise hydraulic effect of having the leading edge of the upper wedge extend several inches beyond the leading edge of the lower wedge is not completely understood, there was no question as to its effectiveness. Fish were not stopped in their downstream passage. In an effort to eliminate this condition, the long glass wedge was taken out and cut to a 9-inch width to correspond in length with the lower wooden wedge as shown in part "b" of figure 9. Following this, and on retesting, the original favorable fish blocking effectiveness was obtained. No deflection efficiencies were maintained, since this test design did not provide for fish deflection possibilities, having been placed 90° to flow. Under this condition, the fish had no alternative than to move either upstream or downstream or to hold their position.

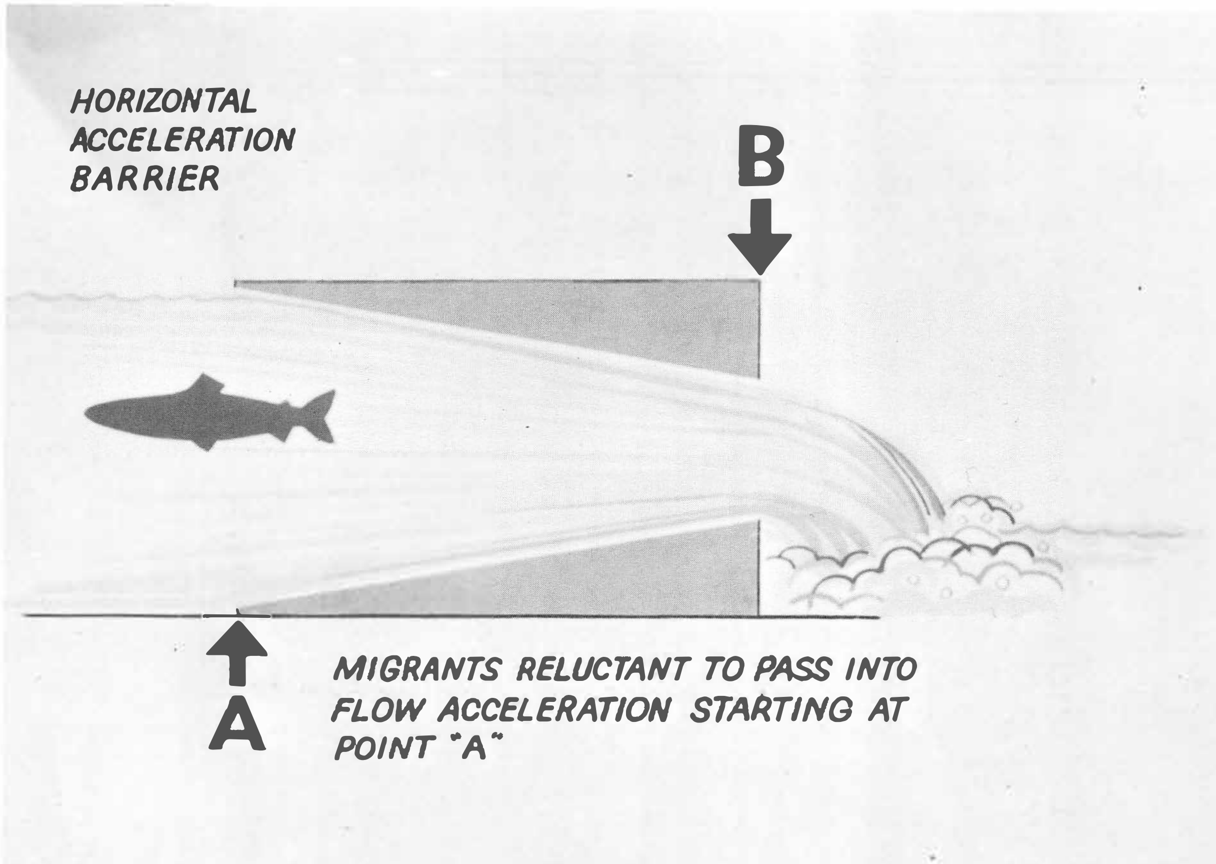


Figure 8.--Diagrammatic sketch of horizontal flow accelerator showing wedges extending into the canal and the upstream point of flow acceleration at point "A."

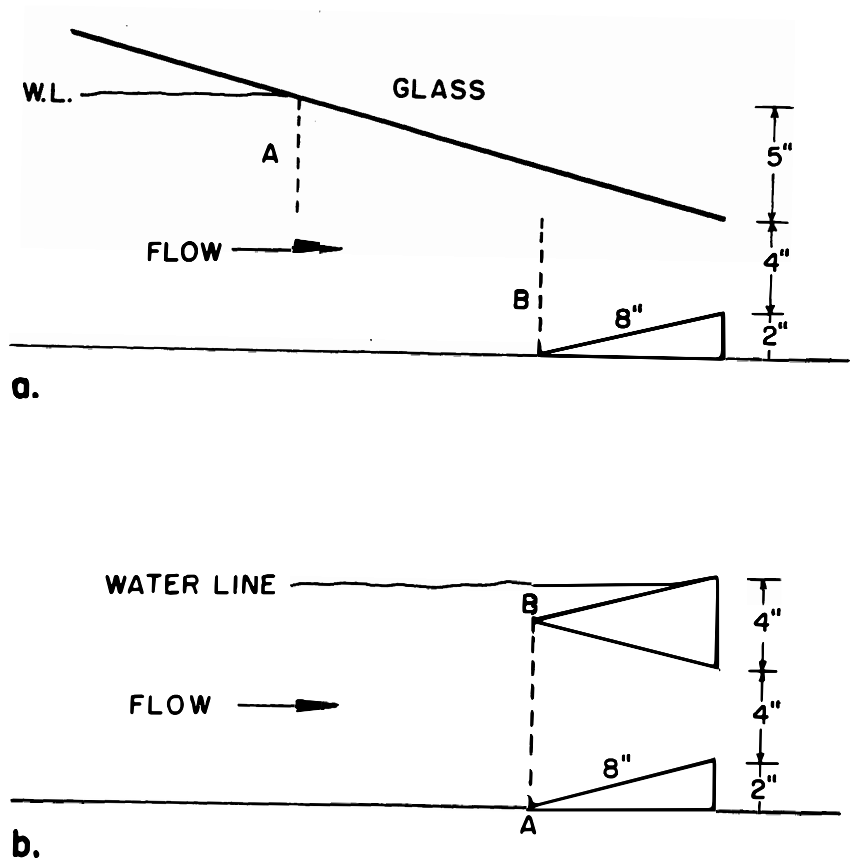


Figure 9.--Part a. Cross section of the horizontal wedge where point "A" is some distance upstream from point "B." Part b. Cross section of horizontal wedge illustrating correct position of point "B" in relation to point "A."

Resume

The basic experimental horizontal accelerator barrier, when placed 90° to flow, did show considerable potential for blocking the downstream passage of young fish.

Flow Acceleration Experiments Using Horizontal Wedges, Model II (Carson Behavioral Flume, 1963)

Following considerable measure of experimental success secured with flow acceleration created by a single unit of horizontal wedges placed 90° to flow, it was decided to redesign for a complete horizontal barrier placed on such an angle to flow as to provide for fish deflection.

Description of Experimental Apparatus

The new horizontal flow accelerator, measuring 14.6 feet in length, was placed in the 6-foot-wide canal on a 25° angle to flow (fig. 10). The individual "V" styled wedges tapered from the upstream point to a height of 6 inches over a length of 9 inches. The clear vertical distance between wedges was adjustable. The structure was designed to accommodate a water depth of 2 feet. A 1-foot-wide bypass placed near the observation window was provided at the downstream end of the horizontal barrier.

Test Procedure

As in previous tests, the fish were dip-netted from the raceways, placed in containers, and carried to the holding tank into which they were placed. Here they were held for a 30-minute adjustment period. Although the approach velocities were generally modified for each test, they did range from a minimum of 1.5 feet per second up to a maximum of 3.4 feet per second.

Two specific series of tests were conducted. The first utilized an opening of 8 inches and 2 inches, respectively, between wedges at the upstream and downstream points, and the second utilized openings of 9 inches and 3 inches.

Results

The guiding efficiencies of the horizontal wedges (table 3) were considerably less than those achieved earlier with the vertical wedges, irrespective of either a daytime or a nighttime condition. A number of blind fish were tested, with efficiencies no better than those secured with fish having full vision.

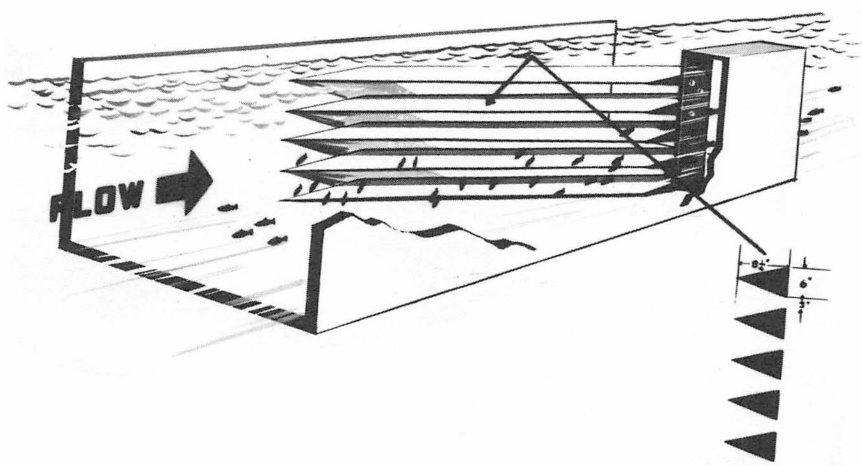


Figure 10.--Diagrammatic sketch of the horizontal accelerator barrier, model II, and bypass.

Table 3.--Percentage deflection using horizontal velocity accelerator at a deflection angle of 20°. Wedge openings tapered uniformly from upstream width of 8 inches to downstream width of 2 inches over a lineal distance of 22 inches, Carson behavioral flume, 1963.

Date	Time	Velocity	Recapture: Trap 1 bypass	Recapture: Trap 2	Deflection
April		F.p.s.	No.	No.	Percent
2	1410	2.0	99	58	63.0
2	1500	2.6	159	63	71.6
2	1540	2.6	207	72	74.1
2	1645	1.8	69	30	69.6
3	0940	1.5	302	257	54.0
3	1020	1.5	226	237	48.8
4	2100	1.8	170	165	50.7
4	2130	1.8	260	341	43.2
4	2215	2.0	197	127	60.8
				Avg.	55.6

Table 4.--Percentage deflection using horizontal velocity accelerator at a deflection angle of 20°. Wedge openings tapered from upstream width of 9 inches to downstream width of 3 inches over a lineal distance, parallel to flow, of 22 inches, Maxwell Canal flume, 1963.

Date	Time	Velocity	Recapture: Trap 1 bypass	Recapture: Trap 2	Deflection
May		F.p.s.	No.	No.	Percent
14	1045	3.0	132	106	55.4
14	1300	3.1	170	146	53.8
14	1700	2.9	71	57	55.4
14	1800	3.0	19	21	47.5
15	0900	3.0	160	182	46.7
15	1005	2.7	98	109	47.3
20	1015	3.4	36	35	50.7
20	2030	3.2	135	152	47.0
22	0645	2.8	72	88	45.0
22	0750	3.0	44	27	61.9
22	1120	3.1	60	51	54.0
22	1240	3.0	47	62	43.1
22	1355	2.9	139	123	53.1
22	1510	2.7	103	63	62.0
				Avg.	51.3

Discussion

It was apparent that the particular conditions present in the wedge system when placed at 90° to flow, which were so successful in blocking further downstream passage of the young migrants, were missing in the structure when it was placed on a 25° angle, as evidenced by the reduced deflection efficiencies. One evident difference was the restriction placed on the tendency of fish to swing laterally through the structure placed 90° to flow, whereas the horizontal accelerator barrier seemed to invite such response.

That fish could readily see through the open portions of the wedges may have been the factor contributing to their general willingness to pass through.

During the spring of 1963, the horizontal accelerator barrier was transferred to the Maxwell Canal flume and tested. Results of these tests, shown in table 4, were as unsatisfactory as those secured in the Carson behavioral flume.

Flume Experiments Using Louvers and Pickets (Carson Behavioral Flume, 1963)

Introduction

To secure further information on the response of fish to various forms of stimuli and obstacles, it was decided to determine the factors involved in the specific response of downstream migrants to louvers. This information was also required to permit the biologists to improve present louver design.

As a result of this interest, experiments using blinded fish were carried out by co-workers Niggol and Gerold[3/]. They observed that the blind fish on moving downstream and approaching a line of louvers showed no apparent recognition of the presence of the louvers until they either physically touched the louvers or felt the velocity turbulence existing in between the louver slats. On contacting the louvers with their tail sections, their response was to dart rapidly upstream or, at times, swing laterally away from the louvers. Such response indicated that the blinded fish did not recognize the presence of louvers until actual contact had been made. Yet, by contrast and based on previous experiments with the vertical-accelerator barrier, it was observed that blind fish are most responsive to certain velocity changes.

In general, it appears probable that young fish respond to various deflecting devices by means of visual perception as well as through their capacity to sense and respond to fluctuations of velocity magnitudes, and to both of these in varying degrees dependent on need and the specific conditions existing.

To find out more about the importance of vision as a factor in guiding fish, a new experiment was designed, utilizing triangular pickets placed on a 25° angle to flow, as is done with louvers.

Design of Experimental Apparatus

As will be noted in figure 11, each picket, 2 feet in height, had a 2-inch facing on each of the three sides, with spacing between pickets set as required. The upstream face of each picket was positioned parallel to the entire line of pickets which, in turn, were set on a 25° angle to the direction of flow to assist fish in deflecting. The bypass at the downstream end was 12 inches in width, with approach-to-bypass ratio set for 1 to 1.4. Collection and enumeration took place in the traps at the downstream end of the inclined screen. Fish entering the bypass were physically separated from those passing through the facility. The bypass was positioned within view of the observation window.

Test Procedure

The first and second experiments utilized pickets spaced 2 inches and 6 inches clear, respectively. (See part "a" of figure 12.) In the third experiment, the pickets remained at a clear spacing of 6 inches, but the entire area of the flume immediately downstream from the pickets was "blacked out" to reduce the downstream visibility of the fish through the opening between pickets, as shown in part "b" of figure 12. The "blacking out was accomplished by use of an opaque, black plastic covering. The floor and sidewalls were also covered with black plastic to further darken the interior area. The fourth and final test was the same as number 3, with the exception that the pickets were reset for a clear spacing of 2 inches. Velocities for each of the tests ranged from a minimum of 1.8 to a maximum of 2.2. Fish were collected, held, and released as in previous tests.

Results

As observed in earlier tests, approximately 10 to 15 percent of the fish, apparently through fright, swam headfirst through the facility without any reduction in their swimming speed.

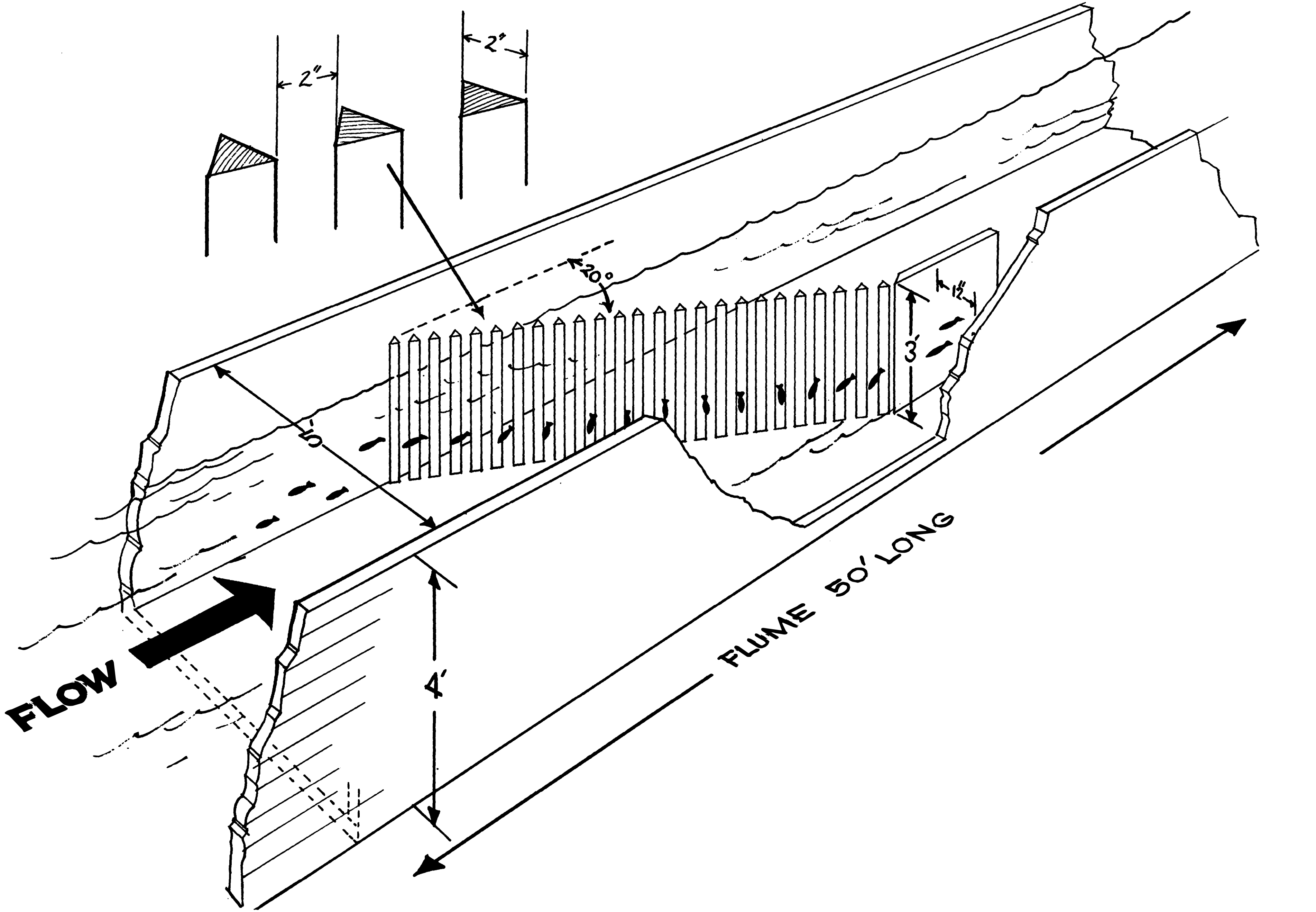


Figure 11.--Diagrammatic sketch of picket deflector with 2-inch clear spacing.

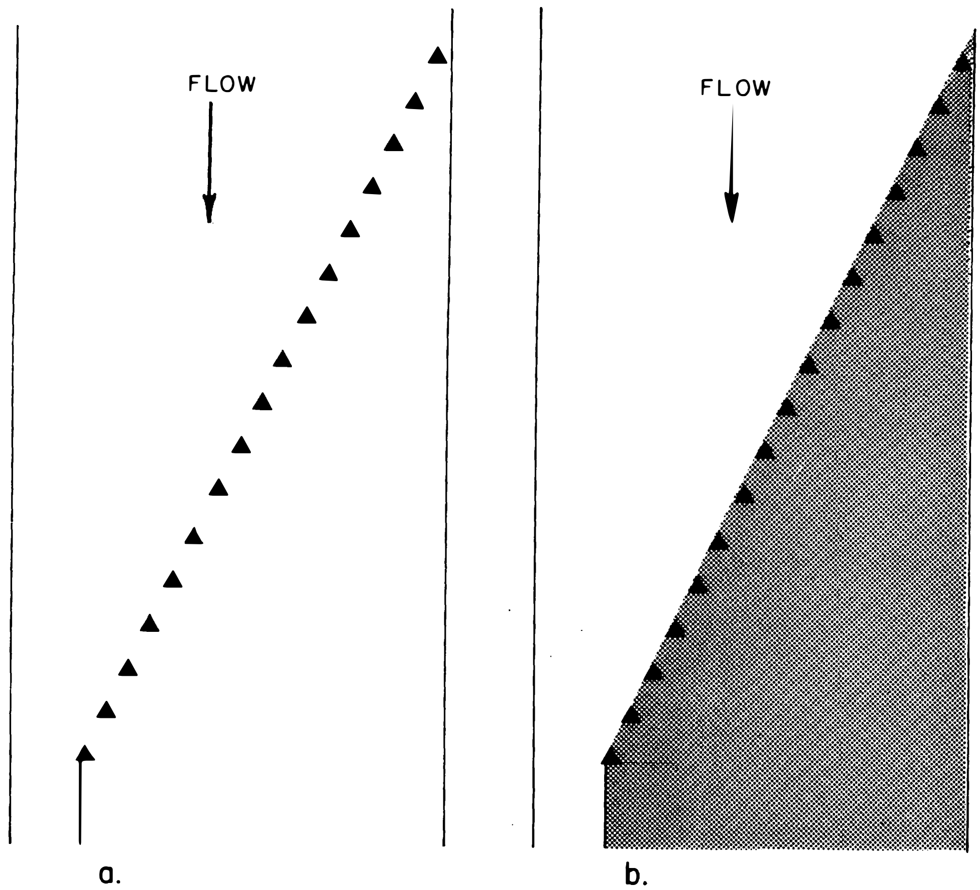


Figure 12.--Part a. Diagrammatic illustration of picket formation and placement. Bypass shown in lower left-hand corner. Part b. Same as "part a" but with the inclusion of the "blacked out" area shown immediately downstream from the pickets.

Deflection efficiencies for all tests were generally unsatisfactory, due to fish swinging laterally between the pickets. Other fish were observed to pass directly tailfirst between the pickets, indicating acceptable flow conditions.

With increased spacing between pickets, visibility improved and flow conditions between pickets became less turbulent, resulting in even greater willingness of the fish to swim through the structure. As a result, deflection efficiencies dropped radically. Although one might have anticipated some guiding effect in this particular case, the data show none. Efficiencies for tests 1 and 2 are summarized on table 5.

The results of tests 3 and 4 (table 6), although not providing a high level of deflection, show the significance of vision as a factor in area avoidance. Another point of interest is the potential shown in the learning process, as illustrated by a group of fish tested during the morning and held over until evening and run a second time (table 6). The results indicate considerable improvement in their ability to deflect. This was illustrated again by a new group tested early one morning and then rerun later that same morning.

Resume

With fish passing unhesitatingly between the pickets as they generally did, it is clear that those stimuli activating fish response to louvers are not present in the picket installation. The results also show that the pickets under certain conditions did provide some guiding, which might be improved through design modification. Use of a picket deflector demonstrated that both vision and the ability to sense changes in flow conditions are important factors to fish as they move downstream.

SUMMARY

The reactions of more than 16,000 juvenile spring chinook salmon (O. tshawytscha) to acceleration, deceleration, and changes in flow rates were tested in a fish behavioral flume constructed at the Carson Fish Cultural Station, Carson, Washington. Based on hydraulic studies conducted in both the laboratory and field on the response of fish to flow deceleration, it was concluded that physical limitations of securing desired flow conditions made application of this plan impractical. The response of fish to flow acceleration created by vertical wedges was found to be effective, with 81 percent of the fish entering

Table 5.--Percentage deflection using different intervals between vertically positioned triangular pickets at a deflection angle of 23°, Carson behavioral flume, 1963.

Date	Time	Velocity	Intervals	Recapture: Trap 1 bypass	Recapture: Trap 2	Deflection
July		F.p.s.	Inches	No.	No.	Percent
3	1120	1.8	2	159	30	84.1
3	1300	1.8	2	138	42	76.6
3	1345	2.0	2	162	117	58.0
3	2105	2.0	2	207	72	74.1
3	2200	2.2	2	210	75	73.6
8	0905	1.8	6	4	123	3.2
8	0940	1.8	6	11	240	4.4
8	1025	2.0	6	19	265	6.7
8	1110	2.0	6	13	199	6.1
8	1200	2.2	6	12	302	3.8
8	1315	2.2	6	9	276	3.2

Table 6.--Percentage deflection using different intervals between vertically positioned triangular pickets at a deflection angle of 23 with area downstream from pickets "blacked out", Carson behavioral flume, 1963.

Date	Time	Velocity	Intervals	Recapture: Trap 1 bypass	Recapture: Trap 2	Deflection
July		F.p.s.	Inches	No.	No.	Percent
8	0930	1.8	6	92	140	39.6
8	1010	1.8	6	60	161	27.1
8	1335	2.0	6	108	176	38.0
8	1415	2.0	6	157	201	43.8
8	2105	2.0	6	219	412	34.7
8	2150	2.2	6	178	264	40.3
9	0845	1.8	2	194	130	59.8 a
9	0935	1.7	2	122	106	53.5 c
9	1020	2.0	2	147	53	73.5 d
9	2145	2.0	2	226	75	75.0 b
9	2215	2.3	2	186	90	67.3
9	2255	2.3	2	205	76	72.9

"b" represents a rerun of "a" fish.

"d" represents a rerun of "c" fish.

the bypass when an appropriate combination of approach velocity spacing between wedges and angle of the total facility to flow was employed. Experimental utilization of horizontal wedges placed on an angle to flow did not provide effective cross-canal guiding. Fish exposed to louvers, as well as picket deflectors, demonstrated that vision and sensitivity to changes in flow rate are important factors in their pattern of response.

LITERATURE CITED

Andrew, F. J., L. R. Kersey, and P. C. Johnson.
1955. An investigation of the problem of guiding downstream-migrant salmon at dams. International Pacific Salmon Fisheries Commission, Progress Report No. 8, 65 p.

Bates, D. W., and R. Vinsonhaler
1956. Use of louvers for guiding fish. Transactions of the American Fisheries Society, vol. 86, p. 38-57.

Bates, D. W., O. Logan, and E. A. Pesonen
1960. Efficiency evaluation of the Tracy Fish Collecting Facility, Central Valley Project, California. U.S. Fish and Wildlife Service.

Brett, J. R., and D. F. Alderdice
1958. Research on guiding young salmon at two British Columbia field stations. Fisheries Research Board of Canada, Bulletin No. 117, 75 p.

Fields, Paul E.
1957. Guiding migrant salmon. The Scientific Monthly, vol. 85, no. 1, p. 10-22.

Hoar, W. S.
1953. Control and timing of fish migration. Biological Review, vol. 28, no. 4, p. 437-452.

Holmes, Harlan B.
1948. History, development, and problems of electric fish screen. U.S. Fish and Wildlife Service, Special Scientific Report 53, iii + 62. p.

Moore, Harvey L., and H. William Newman
1956. Effects of sound waves on young salmon. U.S. Fish and Wildlife Service, Special Scientific Report, 172 iii + 19 p., 10 figs., 2 tables.

APPENDIX

Behavioral Flume at Carson

A test flume (fig. 13) for the study of fish behavior was constructed at the Carson Fish Cultural Station in Washington, measuring 50 feet in length, 6 feet in width, and 4 feet in depth. At the upstream end, a screened release pen measuring 5 feet in length and 1 foot in width served to retain fish prior to a test. Release of fish could be accomplished through remote control. A brown stain was applied to the interior wall surfaces to minimize light reflection. However, a white paint was applied to the flume floor to facilitate fish observation. An inclined screen of perforated plate was installed at the downstream end of the flume to recapture the test fish. Individual traps were maintained to collect fish and determine deflection efficiency. In most cases, not all released fish would pass immediately downstream; those remaining upstream were not included in the deflection efficiency determinations.

A bypass was generally installed to provide for the collection of all deflected fish. A ratio of 1 to 1.4 or greater between the approach and bypass velocities was maintained. This was necessary to insure the acceptance by fish of the bypass.

A double set of stoplogs controlled the volume of flow passing through the test flume (fig. 14), diverting the stream flow either partially or completely into the flume. Additional velocity control could be secured by positioning stoplogs at the downstream end of the flume. Although an average depth of approximately 24 inches prevailed most of the time, a maximum depth of 48 inches could be created.

Any velocity up to a maximum of 7.5 feet per second, could be secured through appropriate setting of stoplogs. Velocity readings taken throughout the flume indicated a relatively uniform flow. A plexiglass window measuring 6 feet in length and 3.5 feet in height was located at the downstream end of the flume to provide a view window for the biologists.

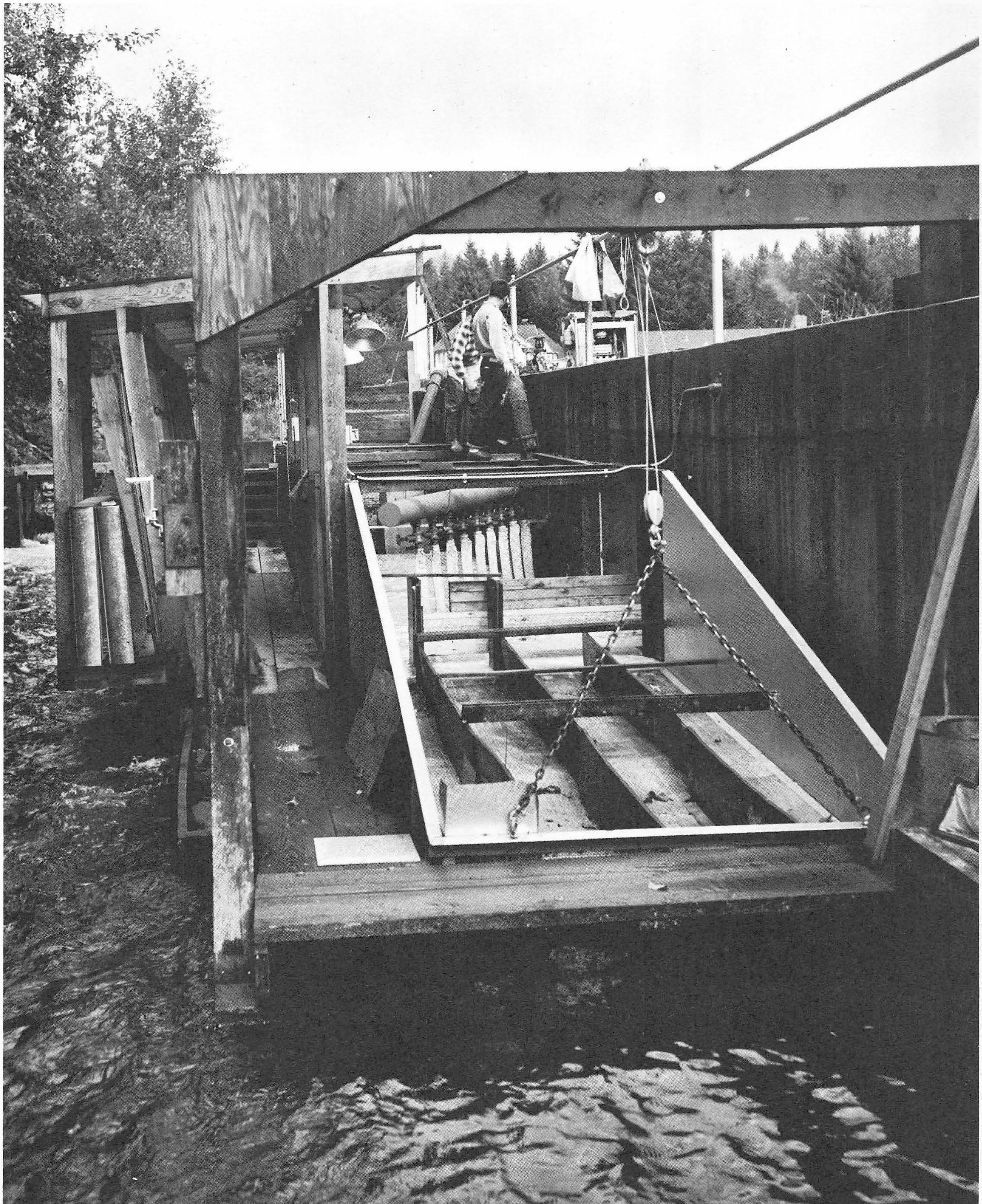


Figure 13.--Looking upstream on the Carson Behavioral Flume. The immediate foreground shows the inclined screens and fish traps.

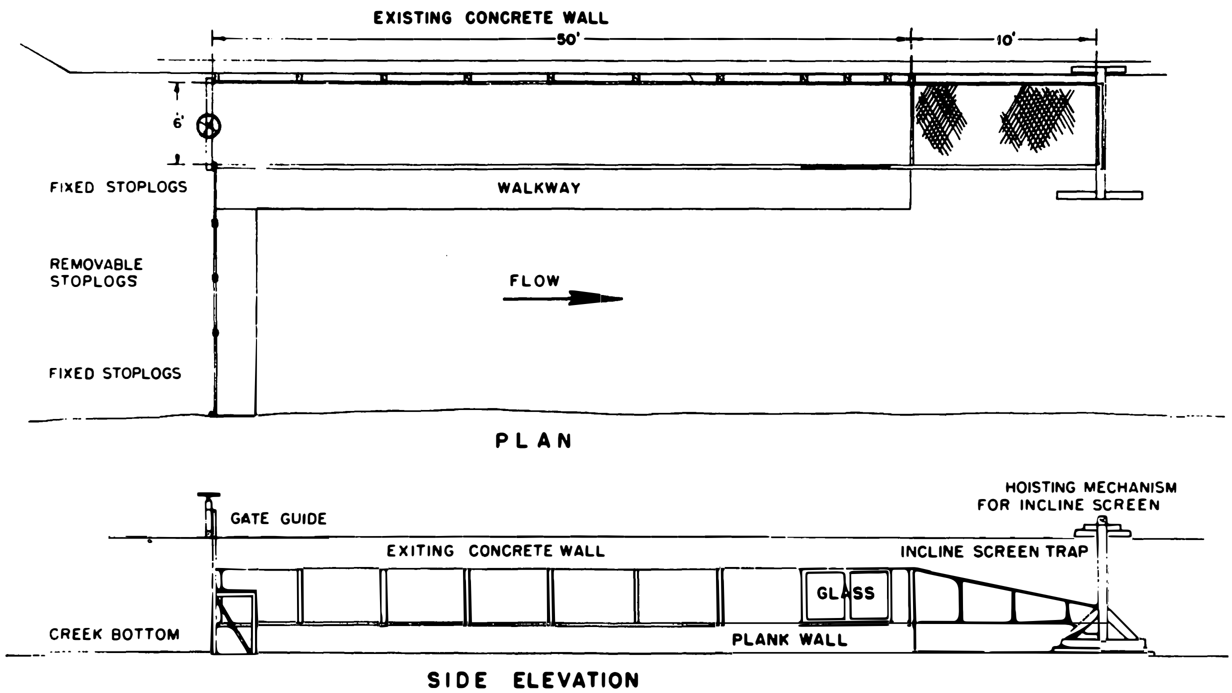


Figure 14.--Plan and elevation views of Carson Behavioral Flume.

EXPLORATORY EXPERIMENTS ON THE DEFLECTION OF JUVENILE SALMON BY MEANS OF WATER AND AIR JETS

by

Daniel W. Bates

and

John G. VanDerwalker

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

The need is urgent for an effective, low-cost method of guiding and collecting juvenile salmonids from rivers and streams. Present techniques require costly screening of flow, and where flow volumes are high a structure is both massive and expensive. In addition, the maintenance costs for such facilities are also high and continuing. It is necessary, therefore, to develop a fish guiding and collecting system, which by minimizing the problem of debris, will reduce maintenance costs.

The development of louvers was a partial advance in this direction. Research on sound, lights, air-bubble acreens, and electricity has been directed toward achieving this same end. However, the results have never been sufficiently successful to warrant field application.

The exploratory studies described here were made to determine whether or not water or air jets could meet the requirements. The investigation was carried out during the fall and winter of 1963-64 in a test flume designed specifically for this purpose and located at the Carson Hatchery Fish Cultural Station, Carson, Washington.

DESCRIPTION AND OPERATION OF FLUME

The Carson behavioral flume (fig. 1), measures 50 feet long, 6 feet wide, and 4 feet deep. The flume floor has only sufficient slope to facilitate drainage. A clear plastic window 3 feet high and 6 feet long was installed on one side near the downstream end of the flume to allow observation of fish response. Experimental devices undergoing tests were all contained within the flume, generally positioned close to the downstream end.

A continuing source of crystal-clear water for the flume was provided by Tyee Springs, originating several thousand feet away from the structure. By means of stoplogs this flow of water (45 c.f.s. maximum) could be directed completely, or in part, into the flume. Water temperatures ranged between 46° and 52° Fahrenheit.

A bypass was provided in all cases for fish guided experimentally. An inclined screen of perforated plate with trap was installed to collect all fish, guided or unguided (fig. 2). Efficient collection of guided fish requires not only a properly designed bypass but flow conditions acceptable to the young migrants. On the basis of earlier studies (Bates, et al., 1960), it has been shown that fish preparing to enter into a bypass will do so more readily if certain velocity conditions are provided. In most cases the requirement is for an acceleration of the flow approaching and entering into the bypass. This acceleration is spoken of as a percent-bypass acceleration and is expressed as a percent of the mean approach velocity. At the Carson behavioral flume a bypass acceleration of approximately 140 percent was found to be suitable[1/]. Bypass accelerations higher than 140 percent were also acceptable, but were somewhat difficult to secure. Lower acceleration rates caused the young fish to reject the bypass.

MATERIALS AND METHODS

Water-Jet Studies

To carry out the water-jet studies a gasoline-powered water pump having approximate pumping capacity of 1 c.f.s. at a maximum pressure of 110 pounds per square inch was installed adjacent to the flume. Pump pressure could be controlled to meet various test requirements. Water was passed from the pump through a transportation line (fig. 3) and into a manifold pipe. At this point it passed into a series of individual vertical pipes spaced 1.2 feet apart, each 3 feet long, jetting out through the orifices (1/32nd of an inch in diameter) spaced vertically at 1/2-inch intervals the full length of each pipe.

1/ Also expressed as a ratio of the approach flow to the bypass flow; i.e. 1:1.4.

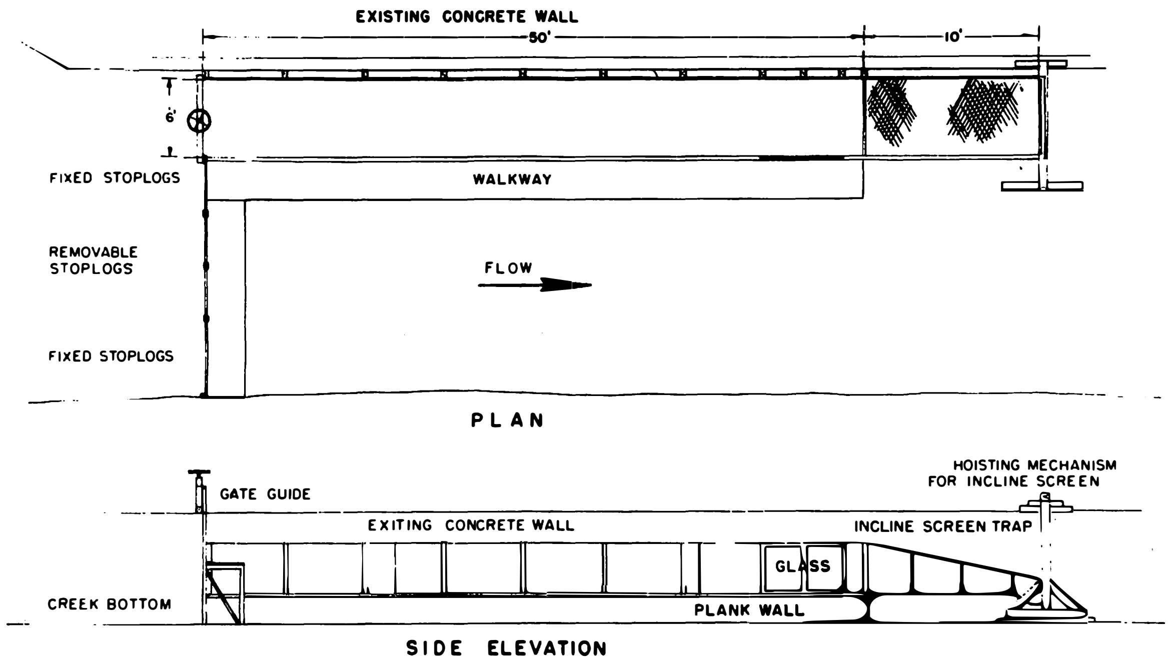


Figure 1.--Diagrammatic sketch showing both plan and elevation of Carson behavioral flume.

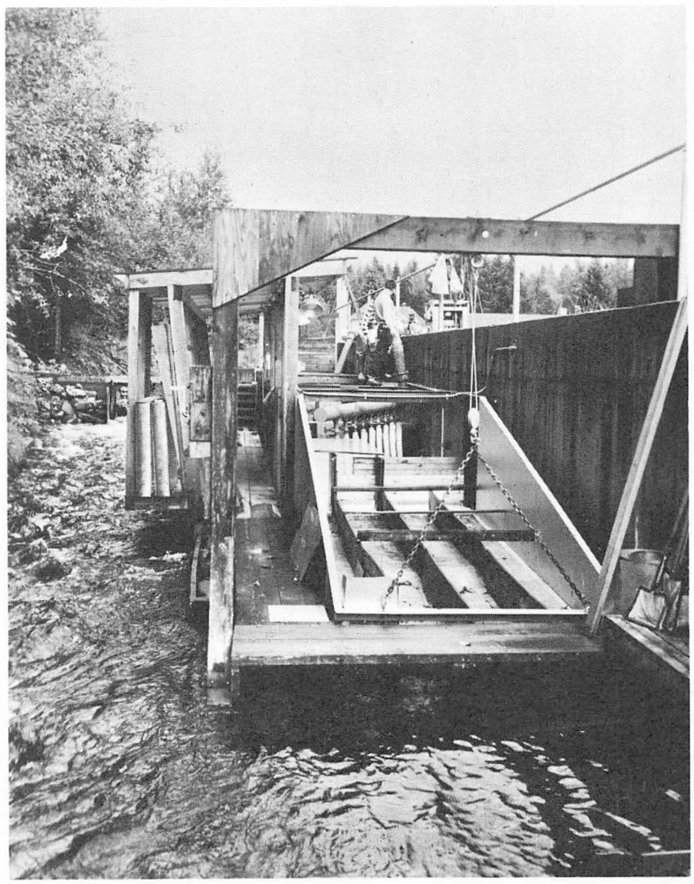


Figure 2.--The Carson flume with the inclined screen traps in foreground.

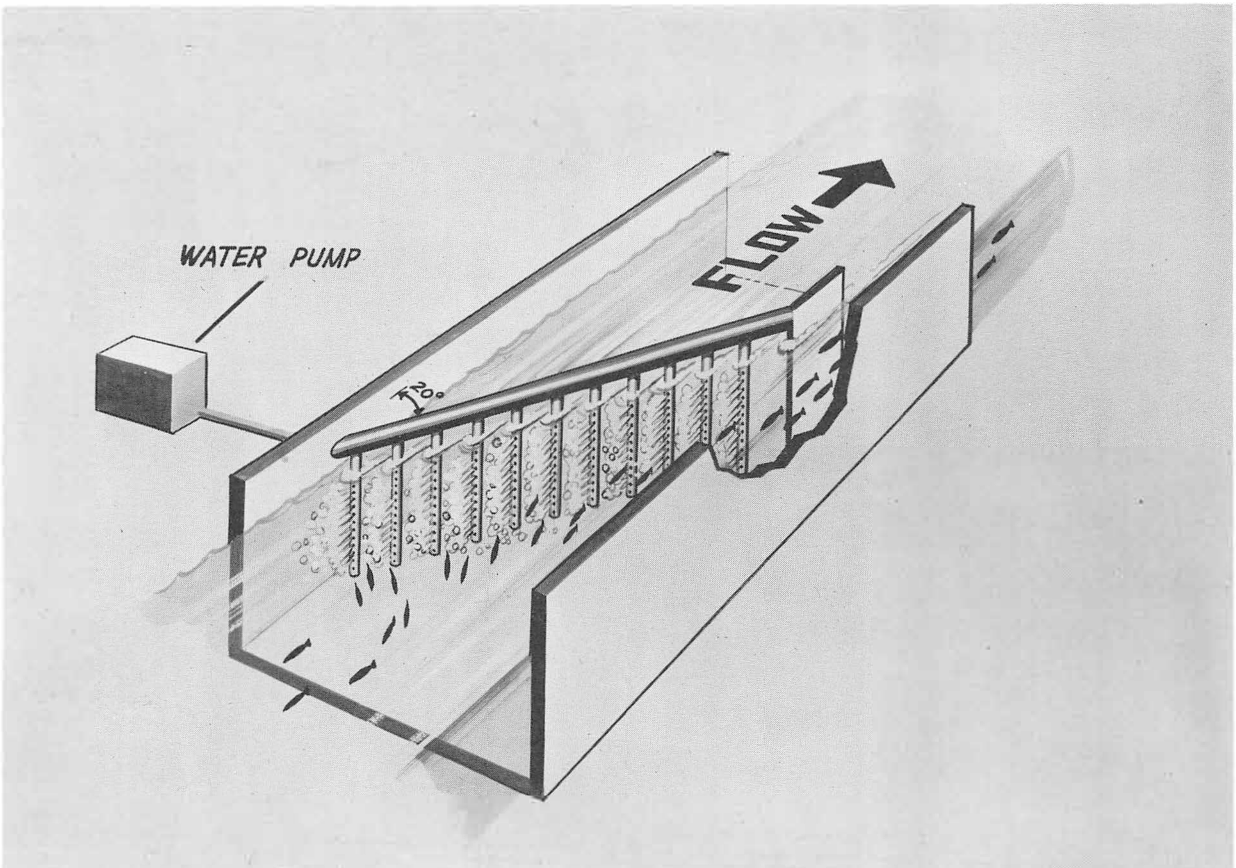


Figure 3.--Diagrammatic sketch of the water-jet system showing water pump, manifold pipe, and individual water-jet pipes in relation to flow direction.

Flow release valves were installed at the juncture of the pipe and manifold. Canvas stockings were placed completely around each pipe, covering all jet above the water line to eliminate undesirable water spray. The line of vertical pipes positioned on a 20° angle-to-flow led into a 1-foot wide bypass. Metal screw caps, originally without orifices, were used to close off the extreme end of each pipe. The caps were later drilled to provide flow after it was found that some fish had been swimming underneath the jet curtain.

Preliminary tests indicated that water pressures of 80 to 110 pounds per square inch physically disoriented the fish, forcing them, in many instances, through the jet barrier. To avoid this, two specific pressures--30 and 60 pounds per square inch--were selected. Because fish response might vary as a factor of the angle of the jet in relation to the velocity of the approach flow, three jet angles of 30°, 60°, and 90° were selected.

To determine the extent and force of the jet as a factor of (1) the approach velocity, and (2) the angle of the jet in relationship to the direction of canal flow at the three jet pressures, dye was introduced into the pump-intake line and photographs were taken of the jet flow displacement into the canal. The relationship is illustrated diagrammatically (fig. 4).

A fish-release tank measuring 30 inches high, 14 inches wide, and 4 feet long, with perforated-plate screen panels at either end was used to hold the test fish prior to each test. Each perforated-plate screen panel could be raised independently by remote control for the release of fish.

For each test, water in the flume was held at a constant 1.2-foot level. Approach velocities were varied, depending on the test requirement, between 2.5 and 3.5 feet per second.

Test fish were spring chinook salmon, hatchery-reared, ranging from 62 mm. to 105 mm. in length with a mean of 87 mm. These fish were first dip-netted from the hatchery ponds, placed in containers, and transported for release into the fish-holding tank positioned at the upstream end of the flume. Here they were held for a minimum of 15 minutes to provide time for their adjustment to the transfer prior to release into the test flume. Approach velocities, water depth, jet direction and pressure, and bypass accelerations were secured and set prior to introducing the fish into the holding tank.

Following the 15-minute (or longer) recovery period, both the upstream and downstream gates of the holding tank were raised, releasing fish into the flume. At approach velocities of 2.5 and 3.5 f.p.s., the hatchery fish would generally begin drifting tailfirst downstream immediately after release.

The results of the various tests are expressed as percentages and show the portion of the total number of fish migrating through the flume that were guided into the bypass.

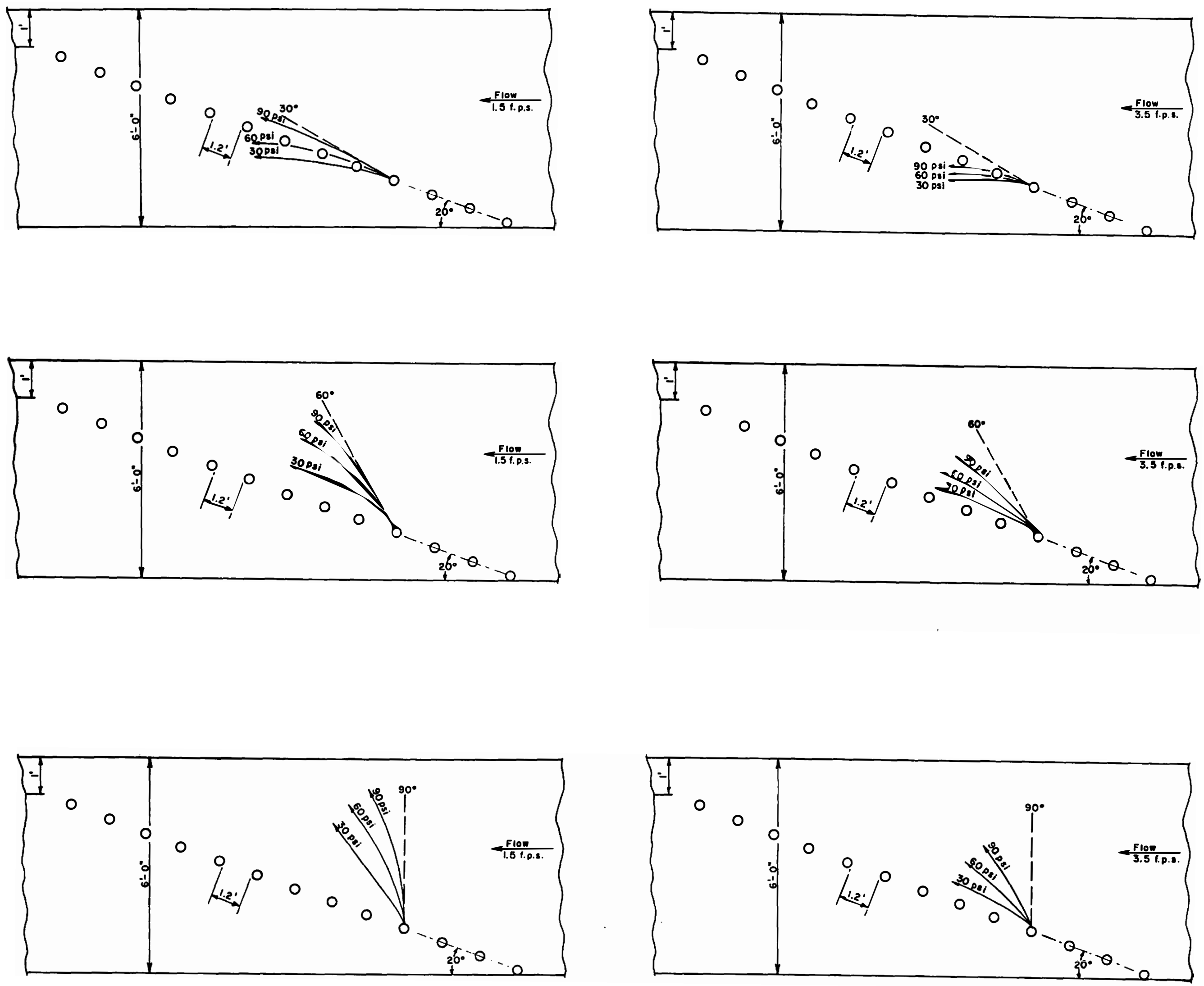


Figure 4.--Diagrammatic sketch illustrating relationship of three jet angles of 30°, 60°, and 90° and flow direction as factors of two different approach velocities.

Air-Jet Studies

The experimental apparatus (fig. 5) used for the air-bubble screen tests consisted of a 210-cubic foot air compressor which forced air through an air filter into a perforated pipe. The pipe, measuring 1 inch in diameter and 11 feet 9 inches in length, had a single line of holes 1/64 inch in diameter drilled every 1/2 inch along its entire length. The pipe extended upstream on a 25^{o} angle from the leading edge of the bypass wall, across the flume floor to the opposite wall where it was joined to a pipe leading to the compressor. Air pressure in the system was indicated by a gauge tapped into the line between the air filter and the perforated pipe. The air pressure was controlled by a valve inserted between the air filter and pressure gauge.

Within the perforated pipe, a pressure of 38 to 48 pounds per square inch was maintained. As the air passed through a single perforation, a jet approximately 3/4 inch high was formed. This jet transformed into large bubbles about 3 inches in diameter, each of which broke down into smaller and smaller bubbles. At the surface the bubbles had a diameter of 1/4 inch or less.

To begin a test, water was diverted into the flume, and the downstream stoplogs within the flume were adjusted to maintain the desired depth and velocity of water. The air-bubble screen was then developed by starting the air compressor and adjusting the pressure. Approach and bypass velocities were measured and adjusted to meet test requirements.

Following the procedure used in the individual water-jet tests, approximately 125 juvenile spring chinook (mean total length 102 mm., range 89-121 mm.) were removed from a hatchery pond and placed in the release chamber where they were held for 15 minutes. At the end of the holding period, both gates of the release chamber were raised, allowing the fish to move downstream toward the air-bubble screen.

Fish guided by the air bubbles entered the bypass and traveled over an inclined screen and into a trap. Fish penetrating the air bubbles also passed over an inclined screen and into a trap. Each of the two groups were then counted and returned to the hatchery pond. This cycle was repeated until at least 500 fish had been exposed to each particular test condition.

Efficiency determination was similar to that used in the water-jet study.

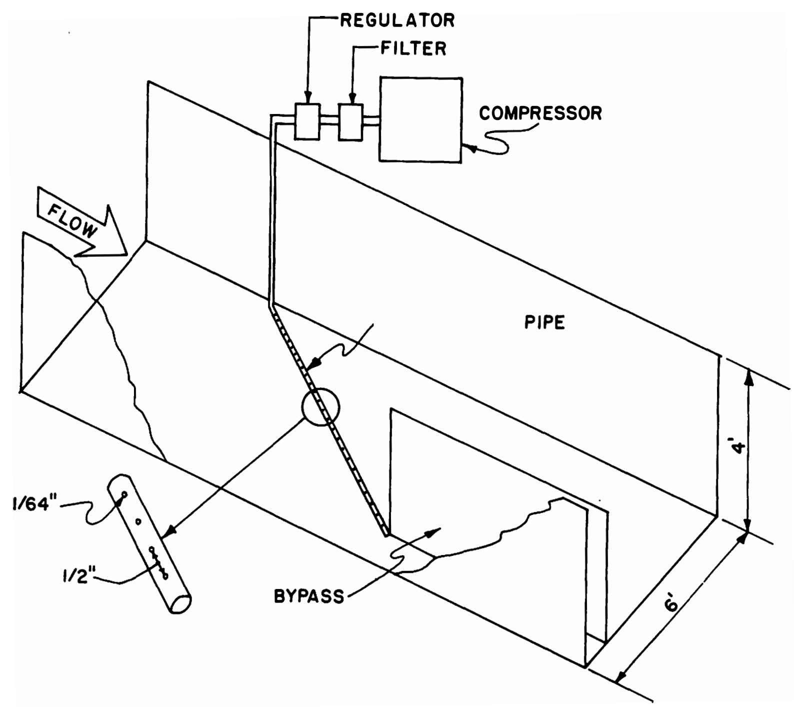


Figure 5.--Diagrammatic sketch of the air jet system showing compressor and perforated pipe layout.

RESULTS AND DISCUSSION

Water Jets

The results of the water-jet deflector demonstrated that a high level of deflection was possible (fig. 6). One factor, commonly associated with the use of hatchery fish, leads to a reduction of deflection efficiencies. Five to 10 percent of all fish within each test group, without hesitation, swam excitedly and rapidly headfirst downstream and through the jet barrier. The majority of the fish displayed a more normal response by traveling downstream tailfirst, avoiding the jet streams by lateral deflection (fig. 7).

Although the preliminary results indicate some promise in the use of water jets as a method of deflecting fish, a number of inherent limitations characterized the technique. For example, screening of a 1.2-foot depth of water 6 feet wide required approximately 1 second-foot of water. Therefore, to screen a river 15 feet deep and 500 feet wide would require a continuing flow in the magnitude of 1,250 second-feet. In addition, the jet orifices required extensive maintenance as they were continuously subject to clogging from debris and rust.

Visual response by fish to the water jet was low due to the limited contrast between the main-canal flow and the water jet. As nighttime and daytime water-jet deflection efficiencies were comparable, it might therefore be presumed that the sense of touch was more dominant than the sense of vision.

The results of the tests using an air-bubble screen are shown in figure 8. Best results were obtained during daylight hours, with an approach velocity of 1.9 f.p.s. All nighttime tests resulted in poor guiding.

The effectiveness of an air-bubble screen in deflecting downstream migrants is a function of the fish's ability to see it (fig. 9). This ability is at least limited, if not entirely absent, during nighttime periods or in areas with highly turbid water. The use of artificial lights may offer a solution to this problem; however, brief tests conducted at the end of this study indicate that the use of artificial light does not increase the efficiency during nighttime test periods. Additional night studies using different lighting techniques and exposing the test fish to light for longer periods in the release chamber may result in better guiding.

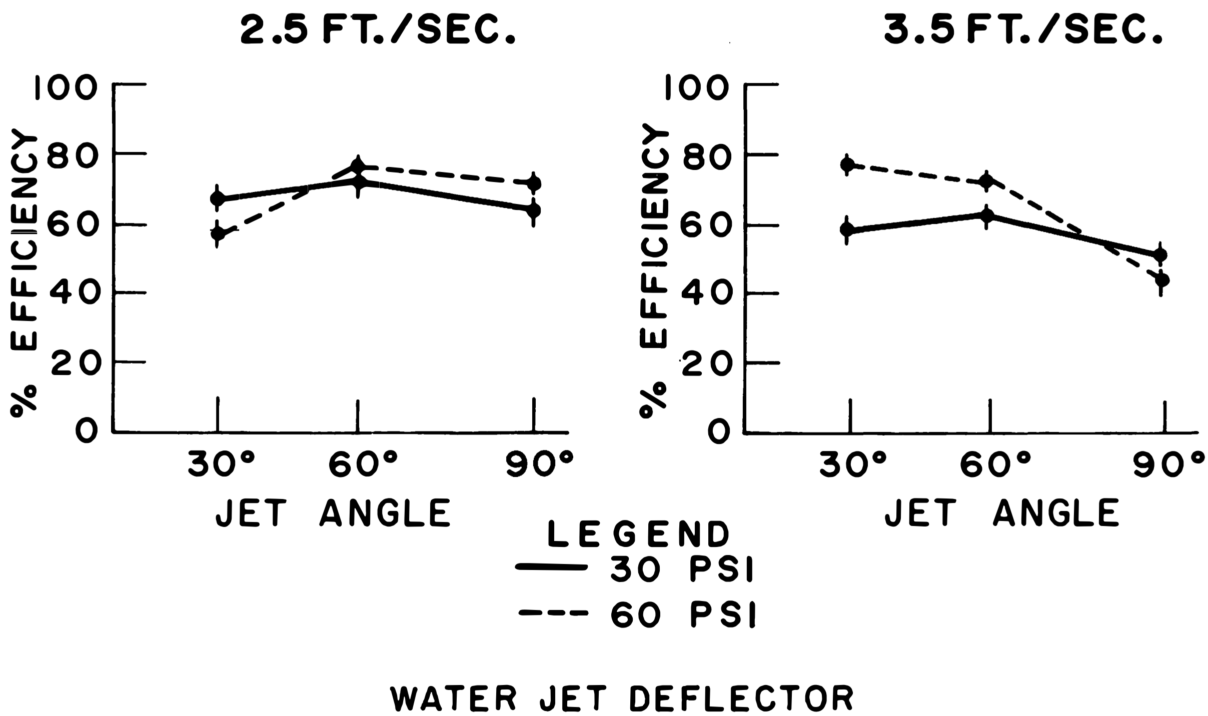


Figure 6.--Relation between rate of approach velocity and percentage deflection for jet angles of 30°, 60°, and 90° at 30 pounds per square inch and 60 pounds per 60 pounds per square inch.

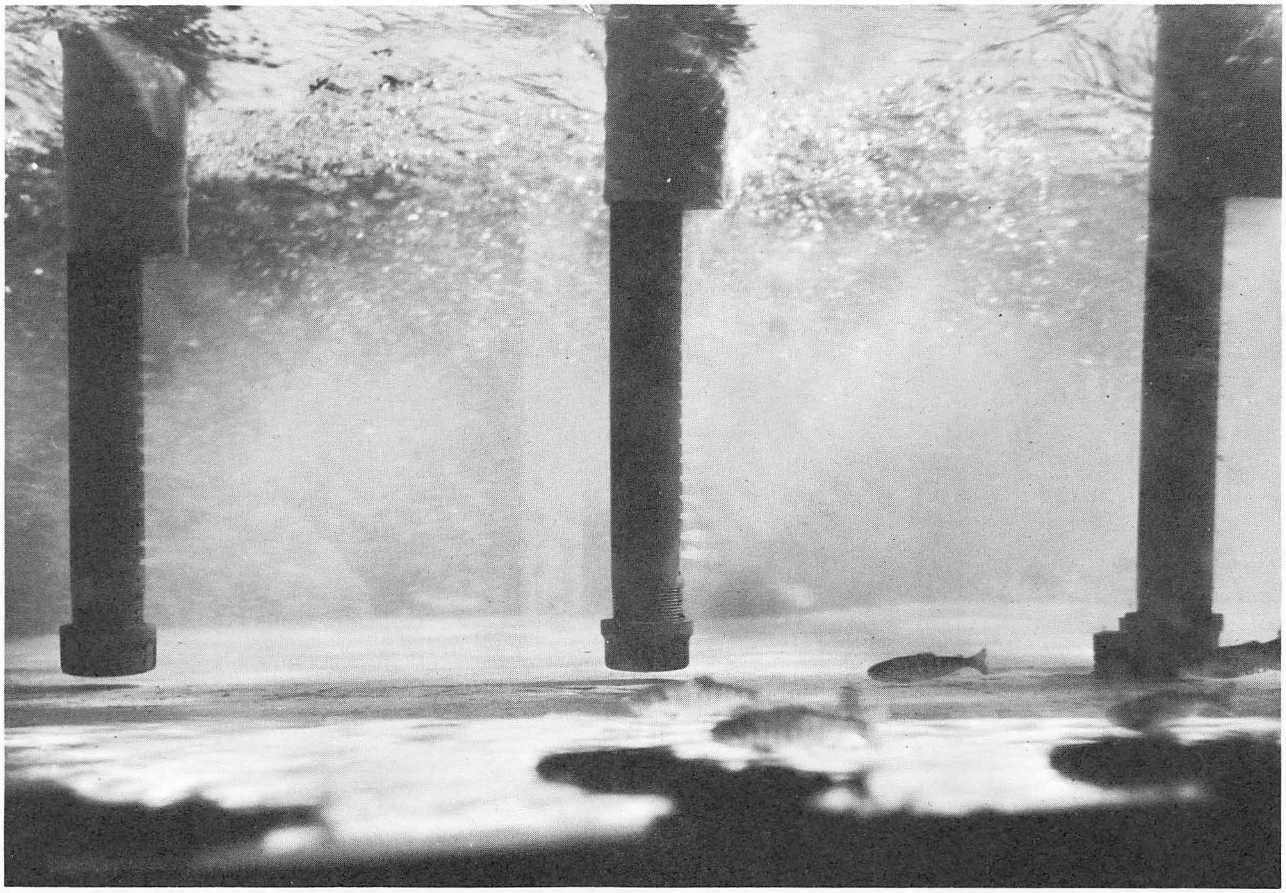


Figure 7.--Fish deflecting away from water jets.

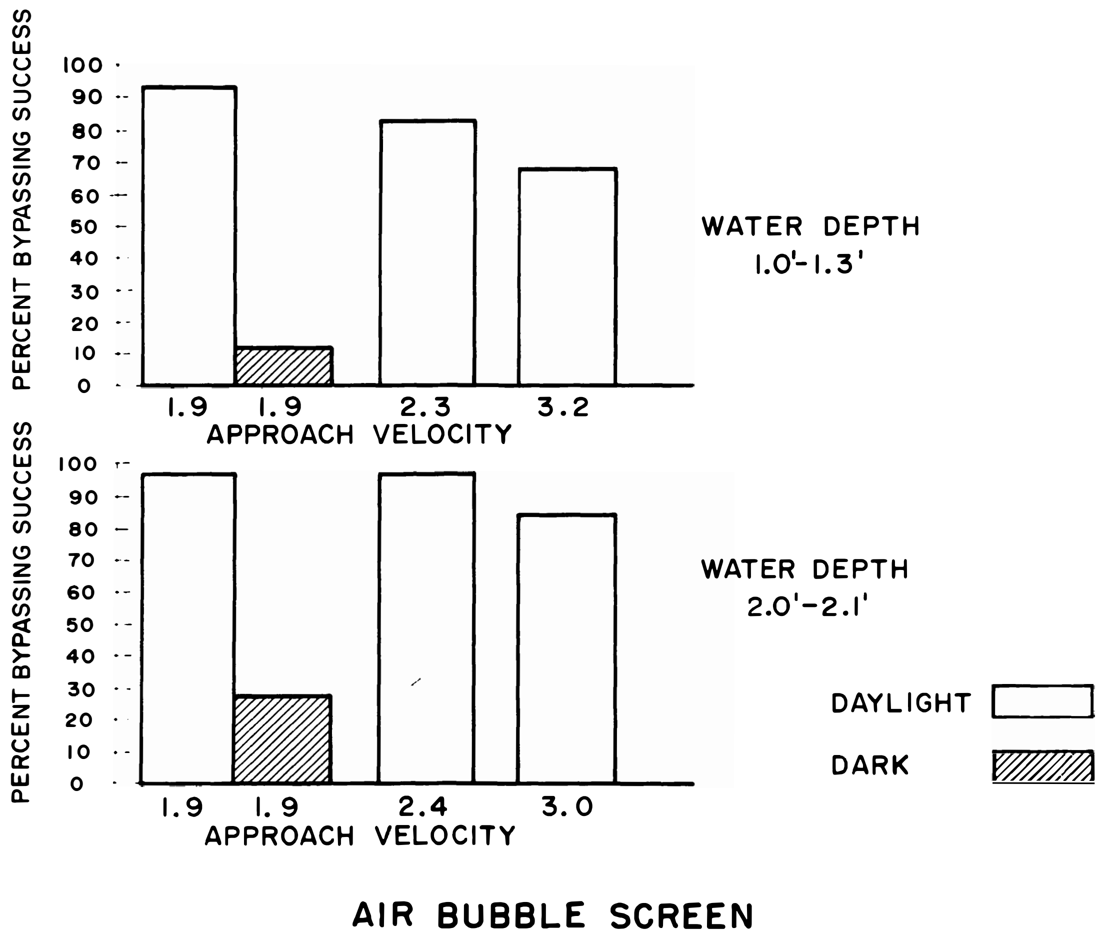


Figure 8.--Relation between rate of approach velocity and percentage deflection for two different water depths under daytime and nighttime conditions.

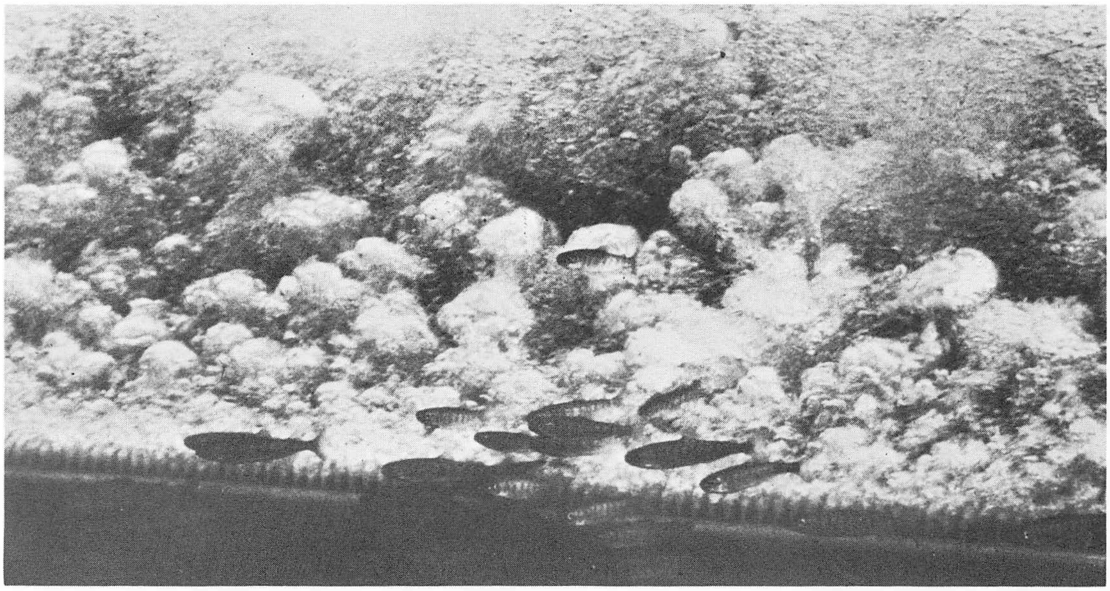


Figure 9.--Fish deflecting away from air bubble screen.

RESUME

The experimental water-jet deflector showed potentials when an appropriate combination of approach velocities, angle, and pressure of jet was employed. However, extensive maintenance and need for large volumes of water made continued consideration of this technique impractical.

Fish exposed to an air-bubble screen deflector under the described condition exhibited a definite response during daylight hours. However, the poor deflection obtained during nighttime hours precludes its use as a functional barrier to downstream migrants.

LITERATURE CITED

Bates, D. W., O. Logan, and E. A. Pesonen.
1960. Efficiency evaluation of the Tracy fish collecting facility, Central Valley Project, California. U. S. Fish and Wildlife Service.

RESPONSE OF JUVENILE MIGRANTS TO FLOW ACCELERATIONS

by

Karl Niggol

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

The collection of juvenile salmonid migrants is sometimes difficult after they have been deflected from the main portion of the stream by mechanical devices such as louvers, screens, or electrical impulses. Downstream-migrating salmonid juveniles at times are reluctant to accept the provided bypasses or confined openings (Brett, 1958; Bates, 1960).

A series of tests was carried out to determine the relationship of fish acceptance or non-acceptance to various acceleration ratios of the approach flow to the bypass flow. All tests were conducted at the Eagle Creek behavioral flume, near Estacada, Oregon, using a conventional louver array.

EAGLE CREEK BEHAVIORAL FLUME

The Flume

A flume designed for use in testing various fish guiding and collecting devices was constructed on Eagle Creek (Estacada, Oregon) during the fall of 1962. Placement of the flume in relation to Eagle Creek is shown in figure 1. Flow in excess of that required for flume operation can be diverted through control gate 2. A louver structure was installed just ahead of this control gate to guide the young migrants toward the test flume. The wooden flume, which measures 100 feet long, 6 feet wide, and 4 feet deep was so designed that the entire structure could be pivoted at the upstream end and sloped from the horizontal plane down to a maximum of 9°, providing a drop of 1.5 feet at the downstream end.

At the inlet end, control gate 1 provides security against flood flows as well as attraction to fish through use of high volume flows into the canal.

Two sections of clear plastic windows, measuring 8 feet long and 3 feet high, were installed on one side of the flume adjacent to the center and downstream end of the flume to allow observation of fish response.

A bypass was provided for fish guided by the test facility. A perforated plate screen, with 1/4-inch-diameter holes, attached to the downstream end of the flume carried all fish into a compartmented trap. Volume of flow was regulated with a steel gate (control gate 3) at the upstream end of the flume. Velocity control was secured through use of stoplogs positioned at the downstream end.

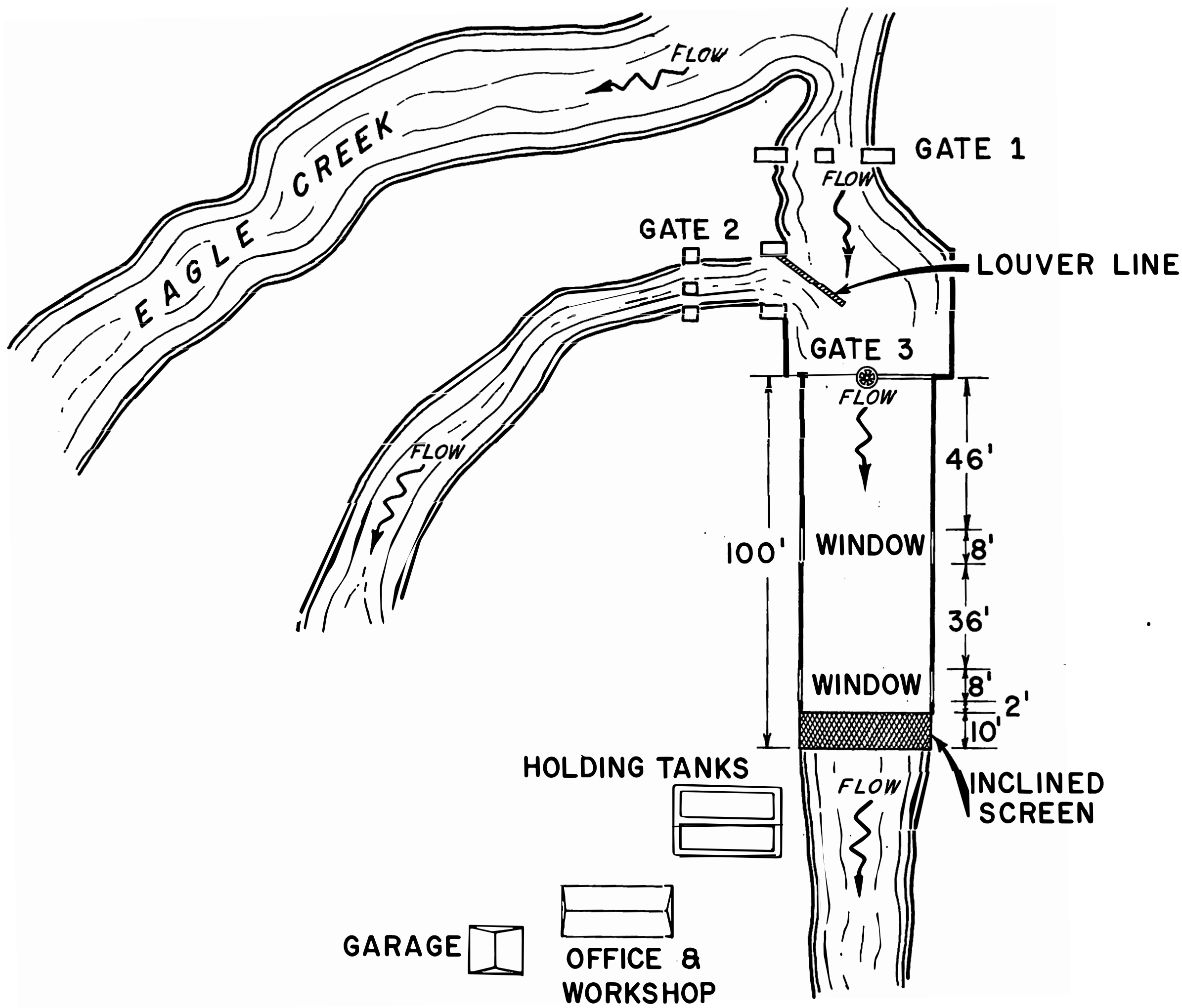


Figure 1.--Plan view of test flume area showing physical relationship of Eagle Creek, control gates, louver shunt, flume, and fish holding tanks.

Water Supply

Eagle Creek, a tributary to the Clackamas River, flows by way of the Willamette River into the Columbia River. It is capable of fluctuating rapidly in volume as a factor of precipitation within the Pacific slope of the Cascades, ranging from a maximum of several thousand second feet to as little as several hundred. At times, particularly during flood periods, the water becomes turbid, but this condition seldom lasts more than several days. During the low-water periods of summer, the main stream is completely channelized into the test flume to provide sufficient volume of flow.

EQUIPMENT AND PROCEDURE

A 2.5-foot-deep, 20-foot-long louver line angled at 20 degrees to the flow was installed in the flume. This louver terminated in an 8-inch-wide, 8-foot-long bypass (fig. 2). The transition from louver line to bypass was situated opposite a view window. Placing the test structure at the lower end of the flume took full advantage of the increased velocities created by the water spilling out of the flume and through the inclined screen. The flume gradient was adjusted to 1 percent (1-foot drop in 100 feet) to produce a higher head differential. Stoplogs at the lower end provided additional flow control.

A series of tests was conducted at approach velocities of 1, 2, 3, and 4 feet per second. For each specific approach velocity there was in turn a respective series of bypass velocities that was lower than, equal to, or higher than the initial approach velocity value.

A short pretest study of the characteristics of flow approaching the louver line and bypass showed there was no appreciable change in mean velocity values until the flows approached to within 6 feet or less of the bypass entrance (fig. 3). The flow then increased up to the bypass mouth and beyond.

Acceleration is the ratio of the mean approach velocity to the bypass velocity. The mean approach velocity was determined by averaging all measurements from the head of the louver to the point where a marked increase began. The bypass velocity used to calculate acceleration was that value measured at the mouth of the bypass. The relationship of the mean approach velocity to the bypass velocity was expressed as a percentage of approach velocity.

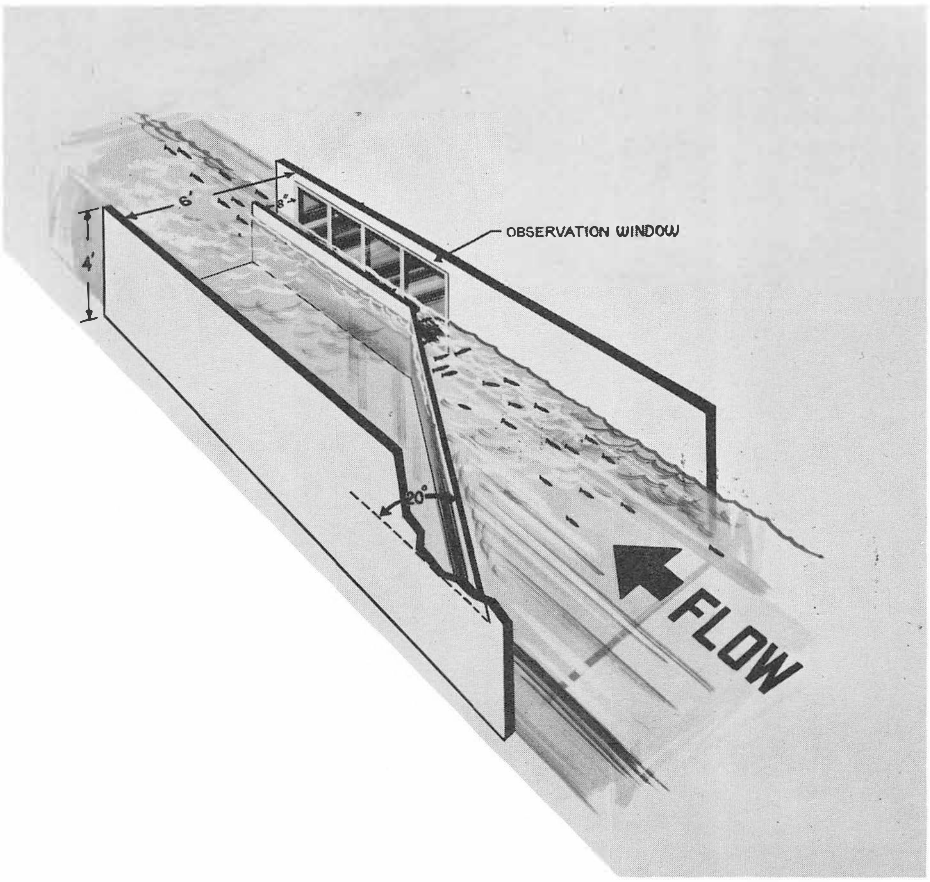


Figure 2.--Details of louver and bypass used in acceleration tests.

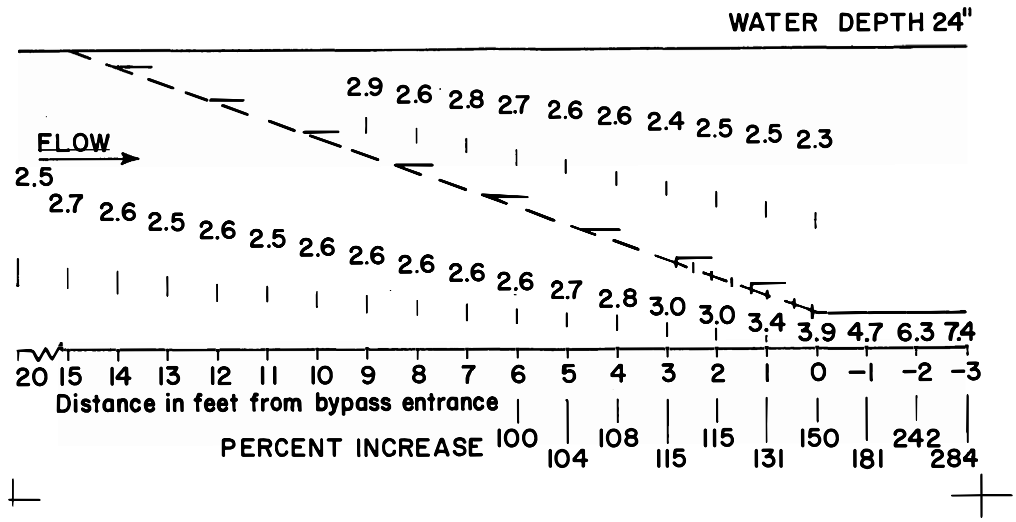


Figure 3.--Approach velocity to bypass velocity ratio of 150 percent (1:1.5) showing velocities measured at 1-foot intervals. Bypass velocity is measured at mouth of bypass (3.9 f.p.s. at 0-foot mark). Acceleration is ratio of mean approach velocity (2.6 f.p.s.) to bypass velocity (3.9 f.p.s.).

Fish used in these experiments were hatchery-reared chinook and coho salmon fingerlings 3 to 5 inches in fork length. One-hundred fish were released in each test at the upper end of the channel above the louver line and their behavior was recorded during passage through the observation area. Most tests were conducted during daytime hours, as no difference could be detected between day and night testing. Bypass efficiency was expressed as the percentage of fish accepting the bypass in relation to the total number of fish presented to the louver array.

RESULTS

The willingness or reluctance of fish to enter the louver bypass was related to both the approach and bypass velocity patterns (fig. 4). At the lowest approach velocity (1 f.p.s.), a ratio of 1. to 2.6 was necessary to achieve an acceptable bypass efficiency, whereas at an approach velocity of 4 f.p.s. a reasonably good bypass efficiency was achieved at a ratio of 1 to 1. In all cases, chinook fingerling evinced a virtually complete rejection of the bypass when bypass velocities were less than approach velocities.

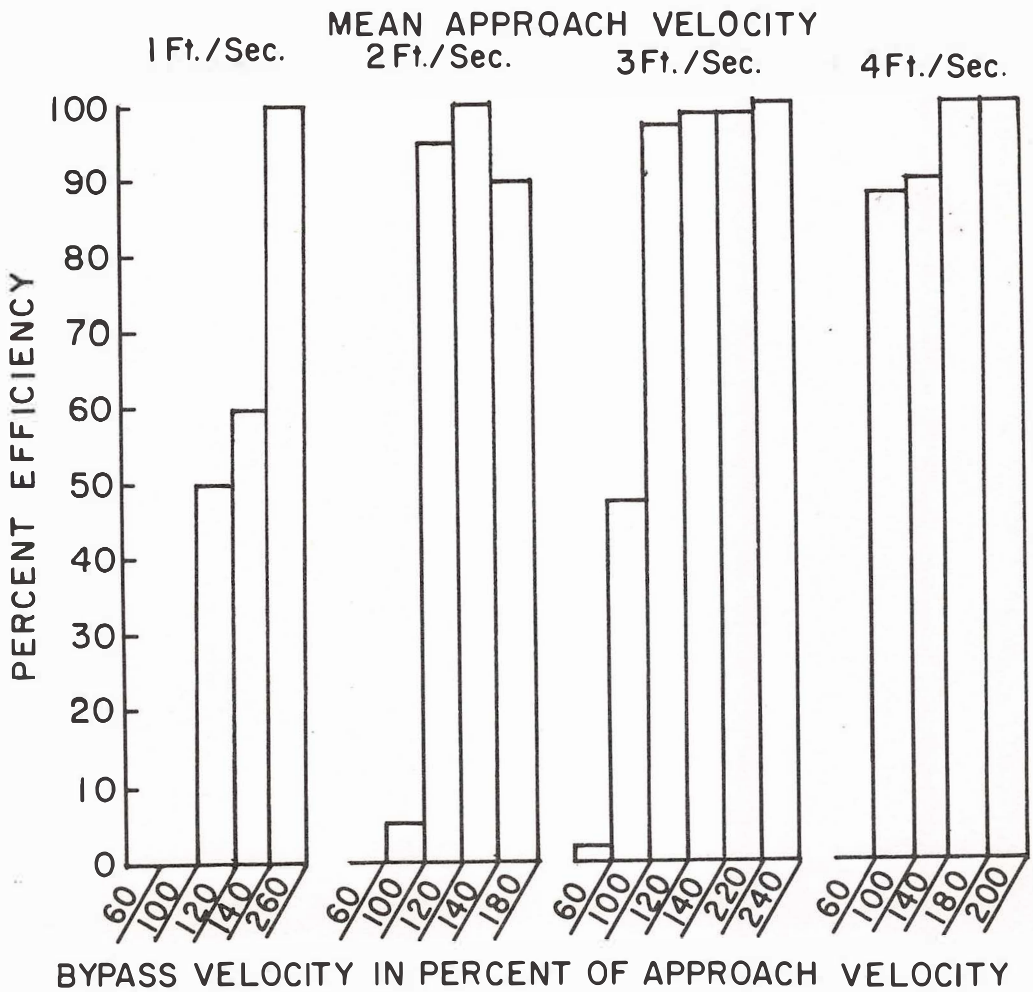


Figure 4.--Bypass efficiency in relation to bypass and approach velocities.

GUIDING SALMON FINGERLINGS WITH HORIZONTAL LOUVERS

by

Charles M. Larsen

October 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

The use of horizontal louvers at dams or other water-use projects for the purpose of guiding downstream migrants into safe bypasses may be more desirable in some instances than vertical louvers. From an economic viewpoint, the location of a fingerling bypass at or near the surface of the water, or the physical conformation of an existing dam, may indicate the need for guiding fish upwards rather than from side to side (horizontally) as is the case with vertical louvers.

If use of the louver principle is to be extended to include a wider range of environmental conditions, we need to know more of how and why fish respond to a louver array. The experiments reported here employed a horizontal-louver array with a bypass located at or near the surface. The objectives of this study were to examine the effect of light and louver color on the guiding efficiency of a horizontal-louver array.

EXPERIMENTAL SITE AND EQUIPMENT

All experiments were conducted in the Tanner Creek bypass, a special auxiliary channel providing discharges up to 60 cubic feet per second from the forebay to the tailrace of Bonneville Dam. The test area was located near the forebay entrance of the bypass. At this point, the channel is 17 feet deep and 10 feet wide. In order to create velocities sufficient for operation of the louver facility, the width of a 40-foot section of the main channel was reduced to 4 feet. The louver array and associated experimental equipment were installed in this area (fig. 1).

During initial experiments, the louvers consisted of black iron slats 1/8 inch thick, 2 inches wide, and 4 feet long. In the final experiment, the louvers were painted white. Individual slats were fitted into slotted channel irons at 90° to the direction of flow and were spaced 2-3/16 inches apart. Flow straightener vanes were installed at 1-foot intervals (fig. 2) and overlapped one another to give a continuous flow-straightening effect as described by Bates and Vinsonhaler (1957). The resulting louver array measured 4 feet wide by 10 feet long and was installed at an angle of 30° to the channel floor.

The fingerling bypass was located in a fixed position at the downstream end of the louver array (fig. 1) and operated either as a surface or a submerged collector depending on depth of water in the channel. Because of fluctuations in the forebay level, water depth varied between approximately 6 and 9.5 feet

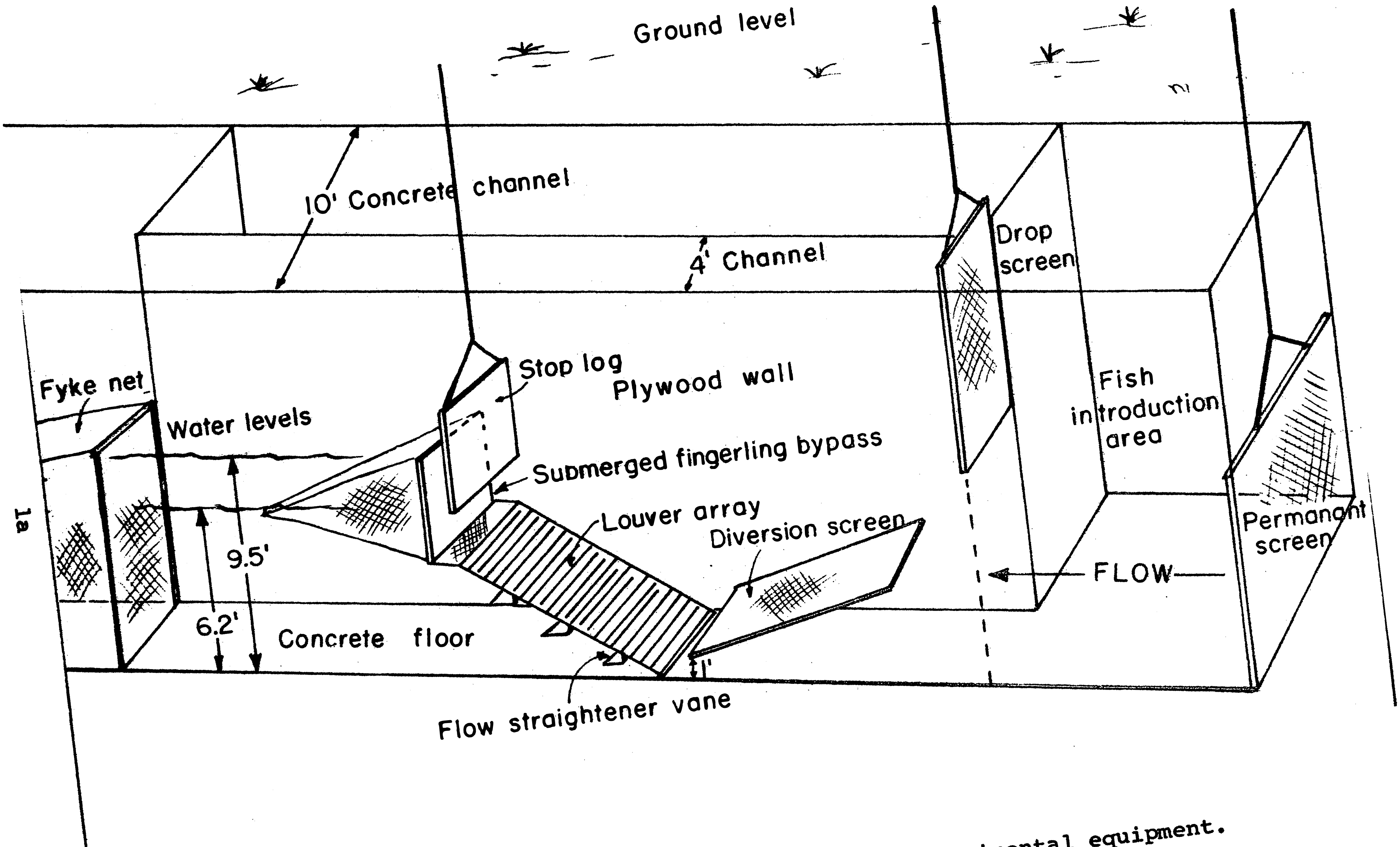


Figure 1.--Horizontal-louver test area showing experimental equipment.

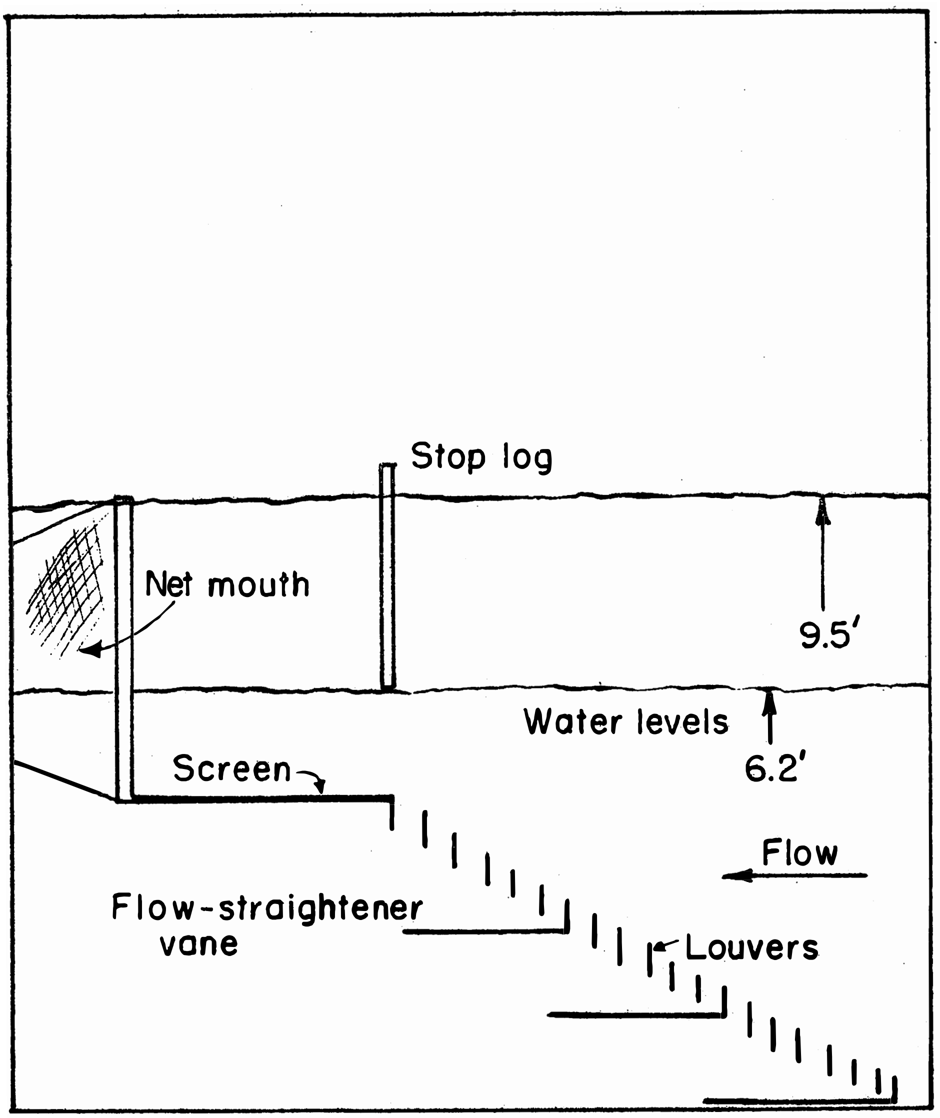


Figure 2.--Side view (diagrammatic) of horizontal-louver assembly showing flow-straightener vanes and appurtenant test facilities.

during the experiments. When the water was about 6 feet deep, the bypass was located at the surface. When the water depth exceeded 6 feet, a submerged bypass 1 foot high by 4 feet wide was created by insertion of a plywood panel. This panel was removed when the bypass operated as a surface collector.

In order to maintain control over the movement of fish in the test area, several screens (number 4 wire mesh) were installed. A diversion screen was positioned so that all fish were presented to the foot of the louver. This made it necessary for each fish to avoid virtually the entire length of the louver array to reach the fingerling bypass. A drop screen at the head of the test channel was used to prevent fish from entering the test area at the conclusion of each test. A permanent screen was installed at the channel entrance in conjunction with tests using introduced hatchery fish to prevent the fish from moving upstream into the forebay. The screen also served to keep predatory fish from moving downstream into the test area where their presence was considered detrimental to the experiment.

Two fyke nets were used to measure the guiding efficiency of the louver array--(1) a net to catch all fish that passed through the louvers and (2) a net to trap fish bypassing the louvers.

The velocity at the fingerling bypass, measured in the center of the 1- by 4-foot opening, ranged from 2 to 2.8 feet per second (f.p.s.). Approach velocities measured 5 feet upstream from the louver array varied from 1 to 1.5 f.p.s.

Turbidity of the water decreased from a Secchi disk reading of 1.1 feet in May to 6.6 feet in August. Water temperatures ranged from 50° F. in May to 68° F. in August.

METHODS AND PROCEDURES

Four experiments were conducted from May to August 1962. Each experiment consisted of eight or more tests of 9½ hours duration (4:30 p.m. to 8 a.m. the following morning). Guiding efficiency is expressed as the number of fish diverted by the louvers as a percentage of the total number of fish recovered in both nets. The two conditions of lighting were usually alternated every other test night. The brighter the illumination included naturally occurring light and some reflected artificial light. In the alternate condition light was decreased by covering the entire test area with plywood to prevent all overhead light from reaching the louver array (fig. 3).

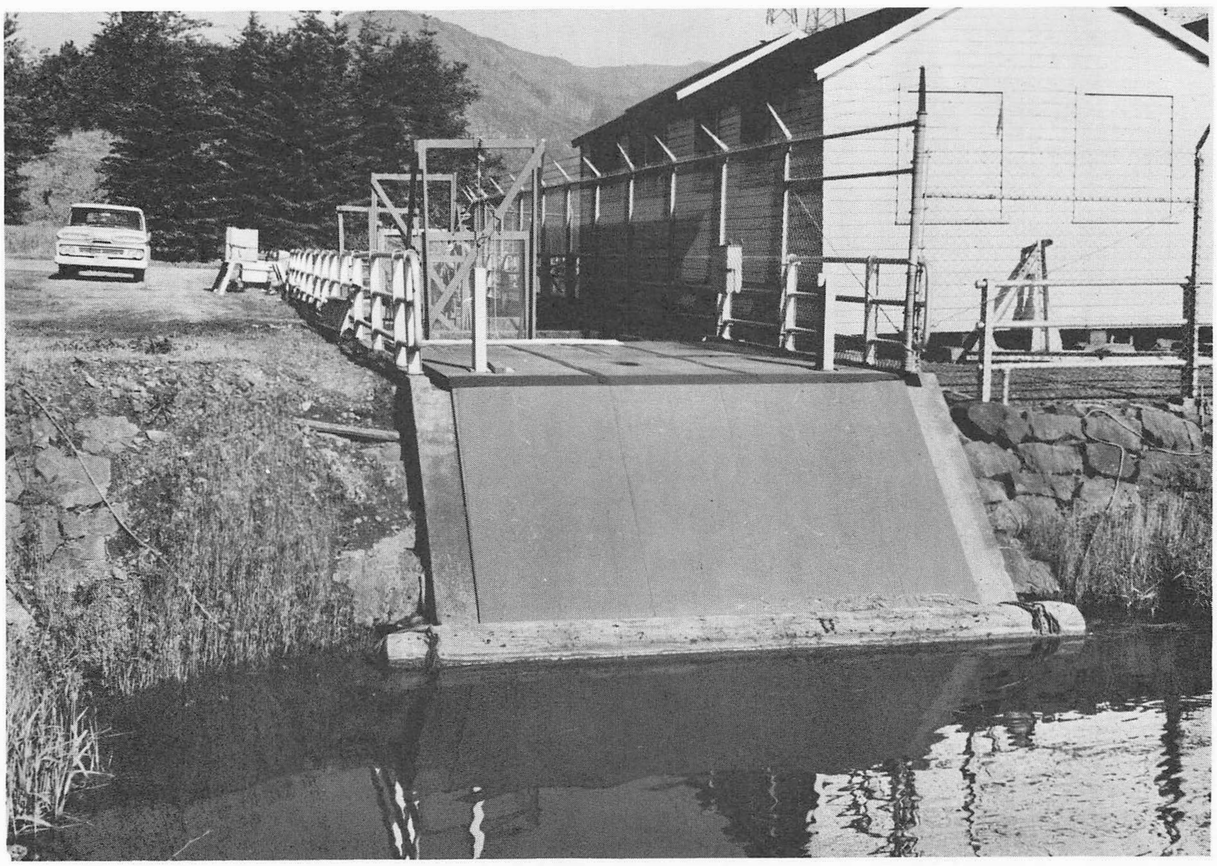


Figure 3.--Test area darkened, showing plywood cover in place.

At night, a limited amount of reflected light from mercury vapor lamps on Bonneville Dam reached the test area. The value of natural and artificial reflected light over the louver array at ground level on a clear night was approximately .15 foot-candle. Since the water surface in the channel was from 7.5 to 11 feet below ground level, light on the water surface above the louver array was undoubtedly less than that measured at ground level. In the dark condition, observations under the plywood covering indicated there was insufficient light to register in the human eye.

During experiments I and II, the water depth in the channel varied between 7.0 and 9.5 feet and the bypass was submerged from about 1 foot to about 3.5 feet. In experiments III and IV, water depth varied from 6.2 to 6.6 feet and the bypass was operated on the surface. Chinook salmon (Oncorhynchus tshawytscha) fingerlings migrating down the Columbia River were used in experiment I, and marked hatchery-reared coho salmon (O. kisutch) were used for experiments II, III and IV. In experiment I, migrants were allowed to enter and pass through the test area on their own volition. These consisted of wild migrants and fish released from hatcheries above Bonneville Dam. Total lengths of the fish ranged from 60 to 75 mm. In the remaining experiments a permanent screen was installed, and fish (120 to 140 mm. total length) were transported from nearby hatchery ponds to the test area where they were marked with an identifying fin clip and released into the area between the drop screen and the permanent screen. Fish were marked and released approximately 2 hours before the start of each test. A different fin clip was used in each test to determine if there was a holdover of fish from one test to another. Over 92 percent of the hatchery fish entered the test area on the day they were released.

In all experiments, the drop screen was raised at 4:30 p.m. to start a test and lowered at 8 a.m. on the following day to end the test. Fish were then removed from the two fyke nets, identified, and counted. The fyke net below the louvers returned to fishing position after inspection to prevent the entry of resident species (bass, squawfish, etc.) into the test area from the downstream end. The drop screen remained down until the start of the next test to prevent entry of fish into the test area from upstream.

RESULTS

Louver Efficiency Under Light and Dark Conditions

Experiments I and II were conducted to measure the effect of light on the guiding efficiency of black horizontal louvers in conjunction with a submerged fingerling bypass. Results of these experiments are given in table 1. In both experiments the fish were guided most efficiently under the lighted condition.

Guiding Efficiency, Black vs. White Louvers

Because the first two experiments showed guiding efficiency to be much greater when surface lighting prevailed, it was believed that vision might be an important factor in the reaction of fingerlings to louvers and that the visibility of the louvers could be increased by painting them white. At the time the latter experiments were carried out, the water level in the test site had dropped, making a surface bypass necessary. This permitted an evaluation of the two light conditions on the guiding efficiency of black and white horizontal louvers in conjunction with a surface bypass for fingerlings.

Referring again to table 1, a marked improvement in guiding efficiency resulted from use of white louvers under the darkened condition.

CONCLUSIONS

The experiments indicate the importance of vision in the response of salmon fingerling louvers. The guiding efficiency of black iron louvers was markedly reduced in the absence of overhead light. Conversely, efficiency increased under reduced illumination when louvers were painted white.

LITERATURE CITED

Bates, Daniel W., and Russell Vinsonhaler.
1957. Use of louvers for guiding fish. Transactions of the American Fisheries Society, vol. 86, p. 38-57.

Table 1.--Percentage of salmon fingerlings guided with a horizontal louver array under various operational conditions.

Experiment number	Bypass condition	Louver color	Turbidity (range of Secchi disc readings)	Guiding efficiency by light condition: Light	Guiding efficiency by light condition: Dark	Fish in sample
			Feet	Percent	Percent	Number
I	Submerged	Black	1.1 to 2.8	83	35	282
II	Submerged	Black	2.5 to 4.6	92	34	940
III	Surface	Black	4.0 to 5.0	91	64	914
IV	Surface	White	4.5 to 6.6	95	94	940

COMPARATIVE RESPONSE OF BLINDED AND NON-BLINDED FINGERLING SALMON TO A LOUVER BARRIER AND TO A SHARP INCREASE IN WATER VELOCITY

by

Maclyn Gerold

and

Karl Niggol

October 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

Louvers were developed as a promising fish-guiding device by Bates (1956) at the Tracy-Mendota Canal in California. In these experiments, and in literature extant at the time (Wunder, 1950), pressure wave sensing seemed to account for the response young fish exhibited toward the louvers. Tests conducted by Larsen[1/] at Bonneville Dam showed a higher degree of response to white louvers than to dark louvers when visible light was excluded as much as possible. Such differences indicated that sight, too, must have a role in the response of fish to louvers. The experiments described here compared the response of blinded and non-blinded fingerling salmon to a louver barrier and to a sharp increase in water velocity.

EQUIPMENT AND PROCEDURE

Populations of blinded and non-blinded fish were used in this experiment. Hatchery-reared spring chinook (Oncorhynchus tshawytscha) and coho salmon (O. kisutch) were blinded with an electric soldering iron and allowed a 1-week period of acclimatization to visual occlusion prior to testing for (1) their reactions to a louvered barrier, and (2) their reactions to a rapid increase in water velocity. The technique used to blind fingerlings for this experiment did not destroy their sensitivity nor capacity to detect and respond to a change in water velocity.

A cedar plank flume, 50 feet long, 6 feet wide and 4 feet high, was the facility in which the vertical louver was erected and into which a small box was affixed to create rapid water velocity increase. The experiment described here was conducted at Carson National Fish Hatchery, Carson, Washington, in January 1963.

The vertical louver consisted of a 24-inch-high black iron frame containing 1/8-inch-thick by 3-inch-wide black iron slats spaced 2 inches apart. The louver, on a 20^{o} angle across the flume with the slats seated at 90^{o} to flow, terminated at a 6-inch bypass. Water depth during the obstacle detection test was approximately 18 inches; the approach velocity to the louver was 1.5 feet per second, with an approach-to-bypass velocity ratio of 1:1.4 f.p.s.

1/ (See "Guiding salmon fingerlings with horizontal louvers," Larsen, vol. 4, Review of Progress, Fish-Passage Research Program.)

The flow accelerator (fig. 1) in which the velocity perception test was conducted was a plywood box, 60 inches long, 8 inches wide, and 12 inches high, with 0.5-inch metal mesh at the upstream end to retain the fish. Two triangular wood wedges, each forming an angle of 28° to the flow of water were nailed inside the box 6 inches from the downstream end. The 4.75-inch-long, 2.5-inch-wide, 12-inch-high wedges provided a 3.0-inch constriction within which the sudden increase in velocity occurred. Water approached the wedges at 1.3 feet per second, but increased at a high ratio between the wedges. Water depth remained quite consistent despite the almost 300 percent increase in velocity. Terminal velocity was 3.8 f.p.s.

In the obstacle detection test, water was introduced into the flume at a constant head, and the depth and velocity in the flume were controlled manually by stoplogs across the downstream end of the flume. Velocity was measured in the mid-approach area, approximately 10 feet upstream from the louver, and also measured at the bypass entrance.

Fingerling salmon were released into the approach area as individuals, by twos and threes, and by groups of approximately 15 or 20. Their response toward the louvers was observed. The test fish were recovered in a trap section of the inclined screen attached to the foot of the flume.

In the flow perception test, the accelerator device (fig. 1) was fastened to the flume floor and braced firmly to prevent the sides from bulging outward from the internal pressure. Vertical panels, angled across the flume and fitted tightly against each side of the upstream end of the accelerator, created a constant head that fed a consistent volume of water into the plywood box. Volume of water (and the subsequent velocity in the box) was controlled by allowing a sufficient amount of water to enter the flume.

Fish with vision as well as blind fingerlings were introduced by hand--one fish at a time--into the already flowing water. Their reactions, induced by the rapid increase in velocity, were observed.

RESULTS AND DISCUSSION

Behavioral patterns exhibited by chinook and coho during all phases of this experiment were quite pronounced, and very few individuals reacted differently from their class norm. Because both species behaved alike, no further reference to species is made.

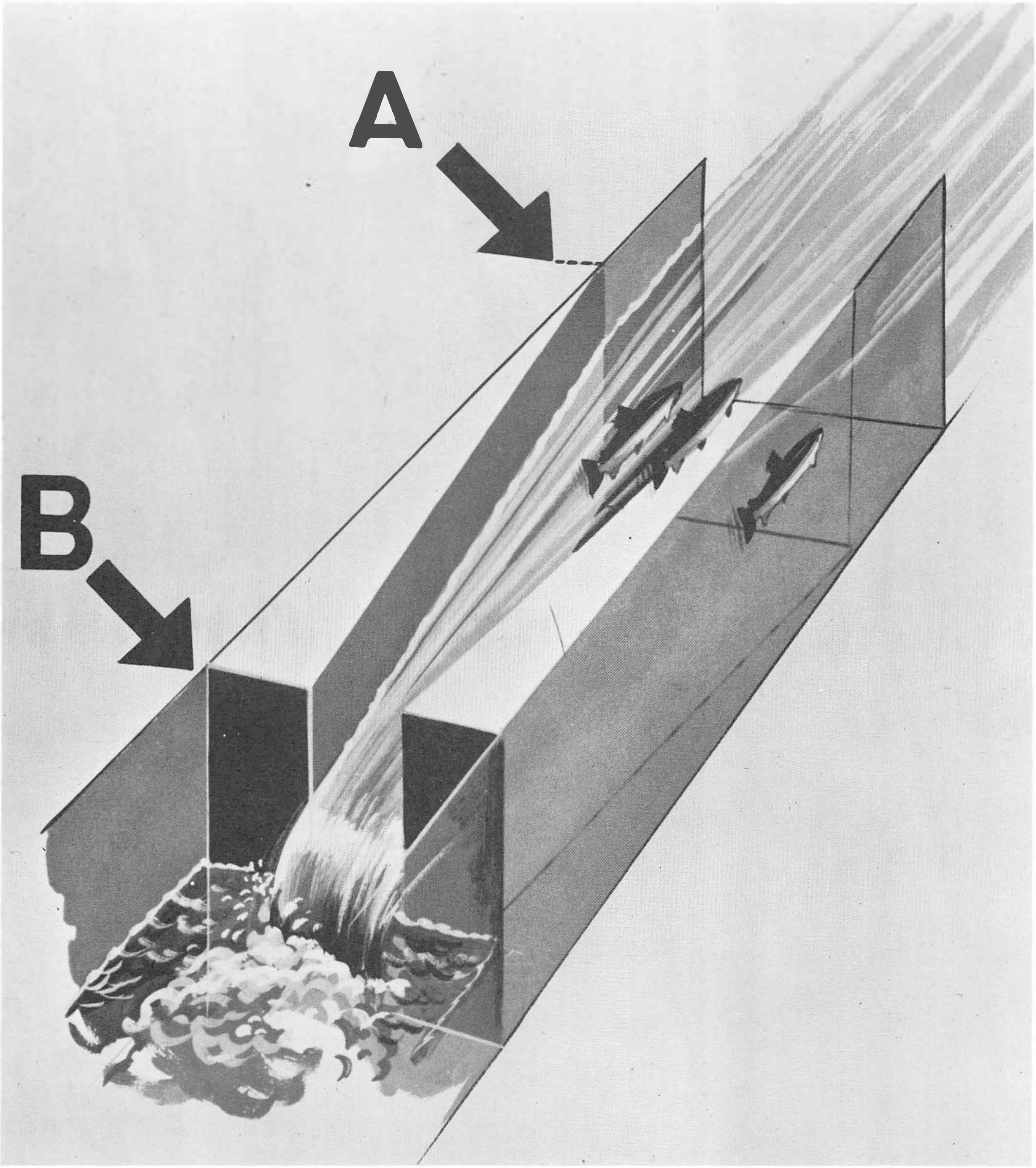


Figure 1.--Flow accelerator, a device in which blinded and non-blinded fingerling salmon were tested for their reactions to a sudden increase in water velocity. "A" indicates the mouth of the accelerator and "B" the throat. The box is 60 inches long, 12 inches high, and 8 inches wide. The constriction is 3.0 inches wide; A and B are 4.75 inches apart.

Obstacle Detection Test

During normal migration downstream, juvenile salmon generally approach a vertical louver system tailfirst, head oriented upstream against the flow of water. To avoid colliding against a louver, downstream migrants either deflect laterally without altering the linear position of their bodies, or in certain specific instances of relatively high velocity, turn as much as 90° in relation to the line of the louvers and continue downstream retaining their position until they reach the bypass (Bates, 1956).

In these experiments the behavior pattern of the fish in possession of sight was one of lateral deflection away from the louvered barrier--without linear alteration of their bodies. They came downstream tailfirst, shunned the barrier, and guided into the bypass.

The blinded fingerlings reacted quite differently toward the louver. Although these fish still passed tailfirst downstream they displayed no awareness of the louver until their caudal fins came in contact with the angular obstruction. They did not deflect laterally, or in any obvious degree, alter the linear position of their bodies as an indication of awareness.

Unlike the normal behavior of fish in possession of sight, the blinded fingerlings did one of two things in the obstacle detection test: (1) Swimming passively, they went tailfirst downstream as expected, but very frequently slipped without resistance through the 2-inch spacings between the louver slats or (2) as a consequence of physical contact against the louver, they darted immediately back upstream. The presence of the louver exerted no guiding influence upon the blinded fish unless they touched some part of the barrier.

Velocity Perception Test

Young salmon swimming downstream tailfirst often evidence unwillingness to enter areas in which there is a sudden increase in water velocity. Instead, the fish will either shear off or refuse to enter the area of accelerating velocity. Behavior of this sort is common to fluvial fish and was again demonstrated in the velocity perception test.

The majority of fish with vision responded actively to the barrier as their tails entered the inlet to the wedges (Point A, fig. 1). Most fish either swam immediately back upstream, or after only a slight pause, continued downstream into the throat of the wedge. Rejection of the barrier velocity was most pronounced at the terminal slot (Point B, fig. 1). At Point B, the fingerlings either continued on downstream and out of the box because they could not overcome the 3.8 f.p.s. velocity, or they darted back upstream toward the retaining screen.

Blinded fish also approached the wedges tailfirst, and the majority darted back upstream after contact with the area of increased velocity. In the main, the responses of these fish were no different from those of fish in possession of sight. The pronounced rejection of the sharp velocity increase was similar to the type of response the blinded fish exhibited when their caudal fins contacted the vertical louver during trials in the obstacle detection test. In the velocity perception test, the blinded fish reacted to flow acceleration as though coming into contact with a solid object.

CONCLUSIONS

Blinded fingerlings, when approaching or within proximity of an obstruction, seemingly cannot detect the object. Results of this experiment suggest that fingerlings in possession of sight may not respond to objects which they cannot see, and therefore are unlikely to be affected by fish diverters wherein the function depends entirely upon the fish maintaining a visual fix.

The behavior of blinded fingerlings toward the louvers demonstrates that the response of fish to obstacles is predominantly a function of sight.

In the event vision is denied fingerling salmon (even for reasons other than physical impairment), the sense of touch apparently assumes the dominant role in the guiding mechanism. Since fingerlings can detect changing velocities very readily, a controlled sharp increase in water velocity may very well be effective in the guiding of young salmon. Tests of a device keyed to the principle of velocity rejection would appear worth exploring.

LITERATURE CITED

Bates, Daniel W., and Russell Vinsonhaler.
1956. Use of louvers for guiding fish. Transactions of the American Fisheries Society, vol. 86, p. 38-57.

Wunder, W.
1950. Die Seitenline, ein besonders Wassersinnesorgan der Fische. Allgemeine Fischerei - Zeitschrift, Bd. 75, no. 4, p. 97-99.

PRELIMINARY TESTS WITH LOUVERS IN THE TROY LABORATORY ON THE GRANDE RONDE RIVER

by

Daniel W. Bates
Russell Vinsonhaler
and
Doyle F. Sutherland

September 1964

Fish-Passage Research Program
U. S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

The efficient and low-cost collection of juvenile salmonids has been subject to many years of intensive investigation. That there has been no relaxation in the intensiveness of the effort clearly points out present day limitations in the field of fish collection.

The purpose of the study presented here was to provide a continuation of the vertical louver tests originating at Tracy, California, and particularly to determine response differences, if any, between fish of different river systems such as the Sacramento and the Grande Ronde Rivers. This work was conducted during the spring and summer of 1964 in the newly completed Troy Laboratory (Grande Ronde test facility) constructed on the Grande Ronde River near Troy, Oregon.

DESCRIPTION AND OPERATION OF TEST FACILITY

Physical Description

The facility, designed for use in testing various fish guiding and collecting techniques under near prototype conditions, was constructed on the Grande Ronde River about 40 miles upstream from its confluence with the Sanke River (Fig. 1).

Built of reinforced concrete, the structure is 40 feet wide, 330 feet long, and 13 feet deep (Figs. 2 and 3). It is designed to provide two removable partitions which permit use as a single 40-foot wide channel, or two 20-foot wide channels. It also provides for a third combination of 20-, 11-, and 9-foot wide canals simultaneously.

An island location and a stream gradient of 6 inches per 100 feet for the 1,400 feet of stream to the point of reentry provided as good a site for the test structure as was available on the Grande Ronde River. The facility was constructed within a natural stream channel carrying approximately 40 percent of the flow. At the inlet located 750 feet downstream from the bifurcation of the stream effected by the island, the flow is routed through a trashrack (with bars 4 inches apart) into the desired channel, or channels. Entering flow is controlled by individual roller gates. A uniform channel section extends for 250 feet downstream from the gates. Three stoplog grooves spaced at 5-foot intervals provide for downstream flow control. Perforated-plate screens are used to dissipate surplus water at the flume exit. Each plate screen is 25 feet long, and has a fish trap secured to the downstream end. The screens are hinged at the attachment and at a distance of 18 feet. Geared hoists and cables provide adjustments for the screens at the 18-foot joint and the traps. A vertical drop formed by the inverted screen provides an elevation differential to compensate for the accumulated stream gradient drop between the forebay and afterbay water surfaces.

Two smooth bore hoses, 6 inches in diameter, are attached to each trap. These hoses transport fish concentrated in smaller quantities of water by gravity flow into individual holding tanks through which water is continually passing when the equipment is in use. The holding tanks are mounted upon a floating dock secured at one side of the structure exit. Elevation of the holding tanks is thus controlled by the river water surface of the afterbay.

A shunt rack, just downstream from the flume section and installed as an integral part of the structure, diverts upstream migrants through the unobstructed channel, while a floating log boom shears trees and other heavy debris away from the structure intake channel into the uncontrolled portion of the river.

Light is provided by overhead floodlights. Stoplog control operation and maintenance are expedited by a 4-ton traveling gantry crane spanning the width of the structure. Shop, warehouse, office facilities, and field laboratory, as

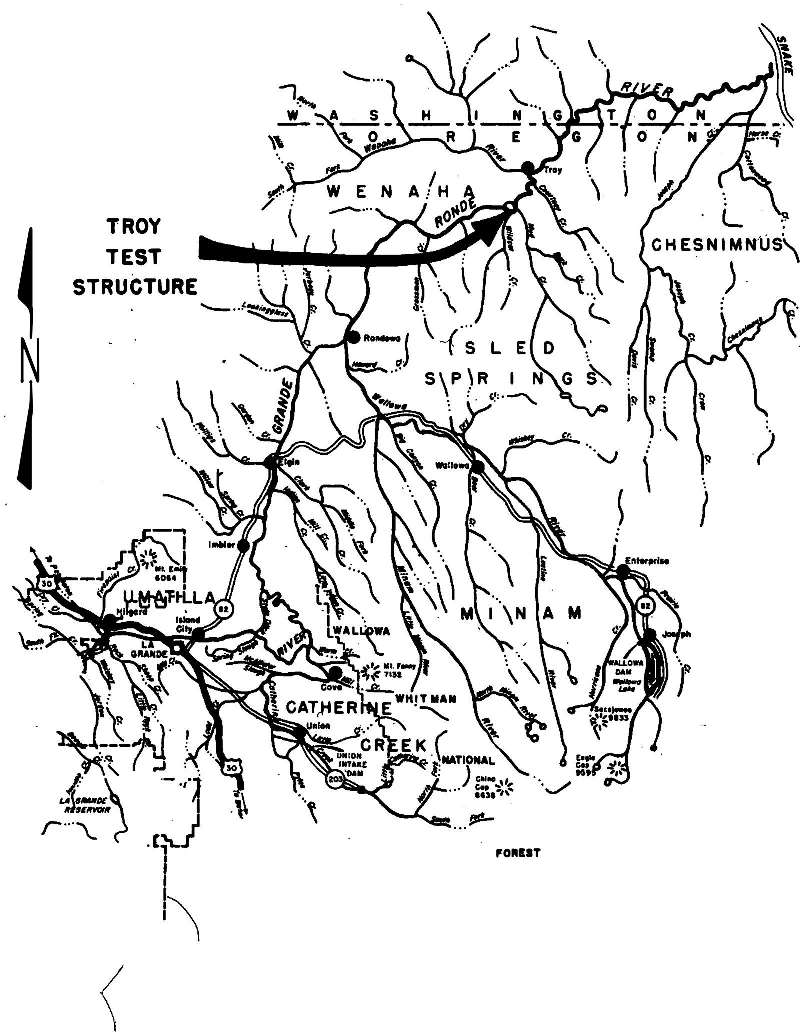


Figure 1.--Location of the Troy Laboratory on the Grande Ronde River in Northeast Oregon.

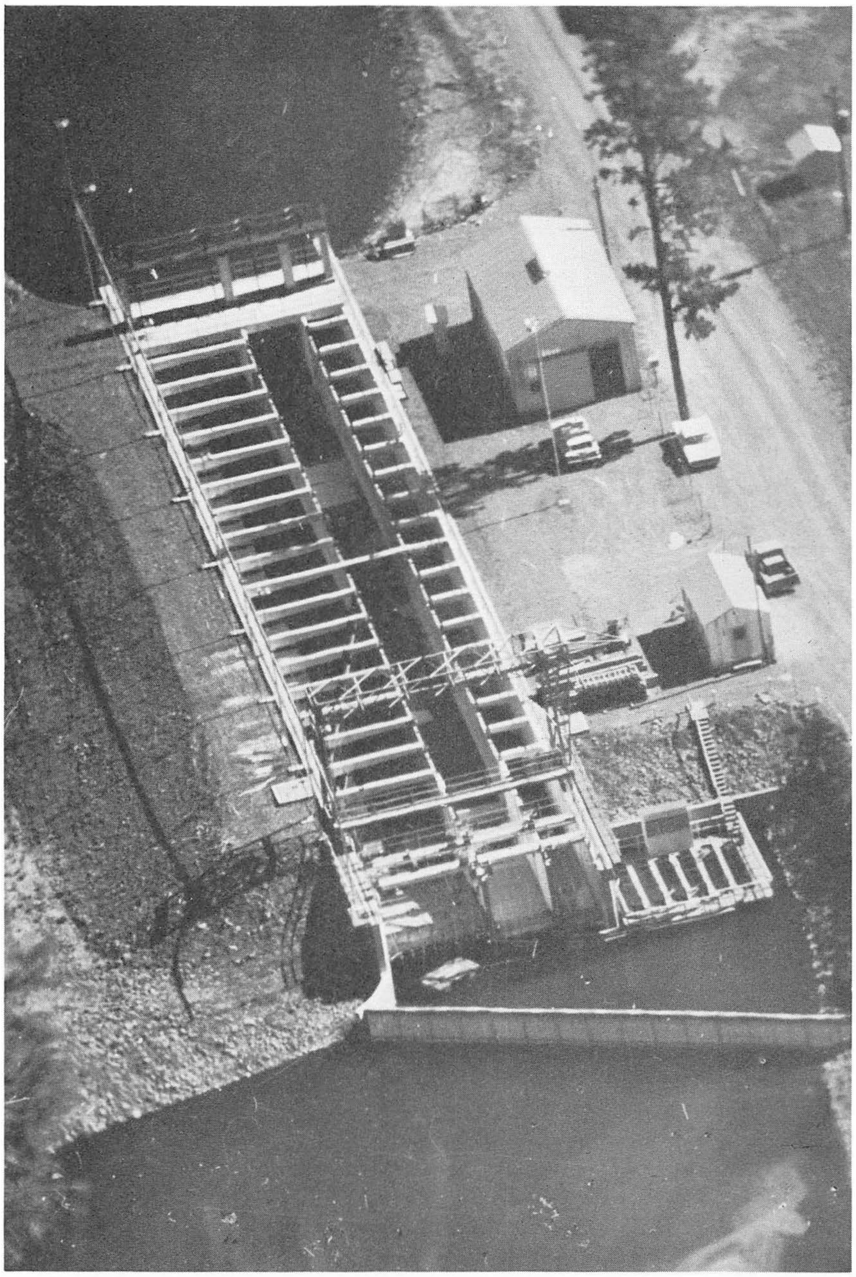
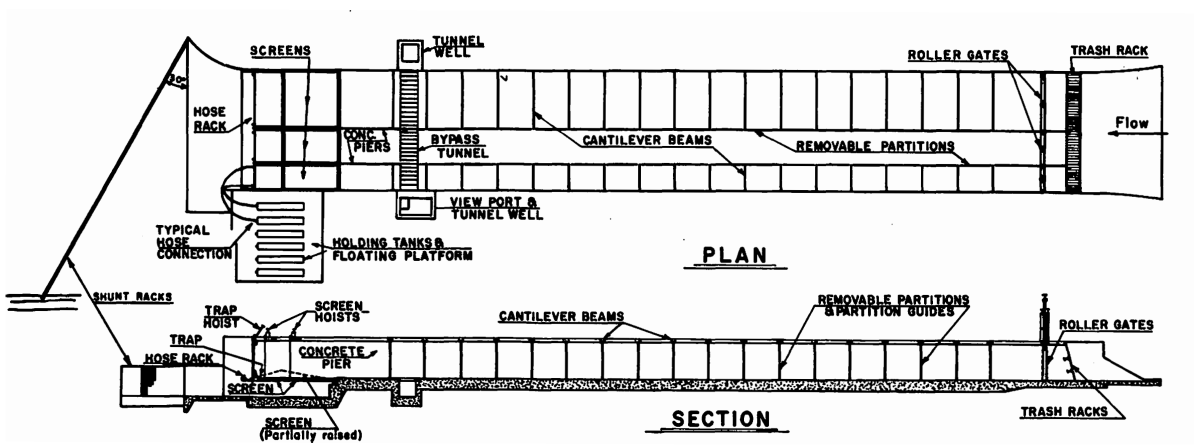


Figure 2.--Troy Laboratory (looking upstream).



DIAGRAMMATIC LAYOUT OF TROY TEST FLUME

Figure 3.--Plan and elevation of Troy Laboratory.

well as limited personnel quarters, are furnished by supplementary buildings.

Water Supply

The Troy Laboratory is a run-of-the-stream installation, and as such, cannot be radically adjusted to alter the channel geometry and hydraulic-flow patterns existing at a specified time, particularly during flood conditions. In this respect, prototype structures generally differ from models in the laboratory, or from small installations operating with superimposed controls.

In the reach of the Grande Ronde River adjacent to the test facility, stream flow is sub-critical and turbulent. During much of the year the water ranges from a definitely muddy to a slightly discolored state. Flash storms over the drainage area can cause rapid increase of flow, carrying suspended material in a degree comparable to the storm's intensity. Visibility, therefore, becomes quite limited.

The relationship between total river flow and that passing through the structure in cubic feet per second for the period of May 8 through July 22, 1964, is shown in Figure 4.

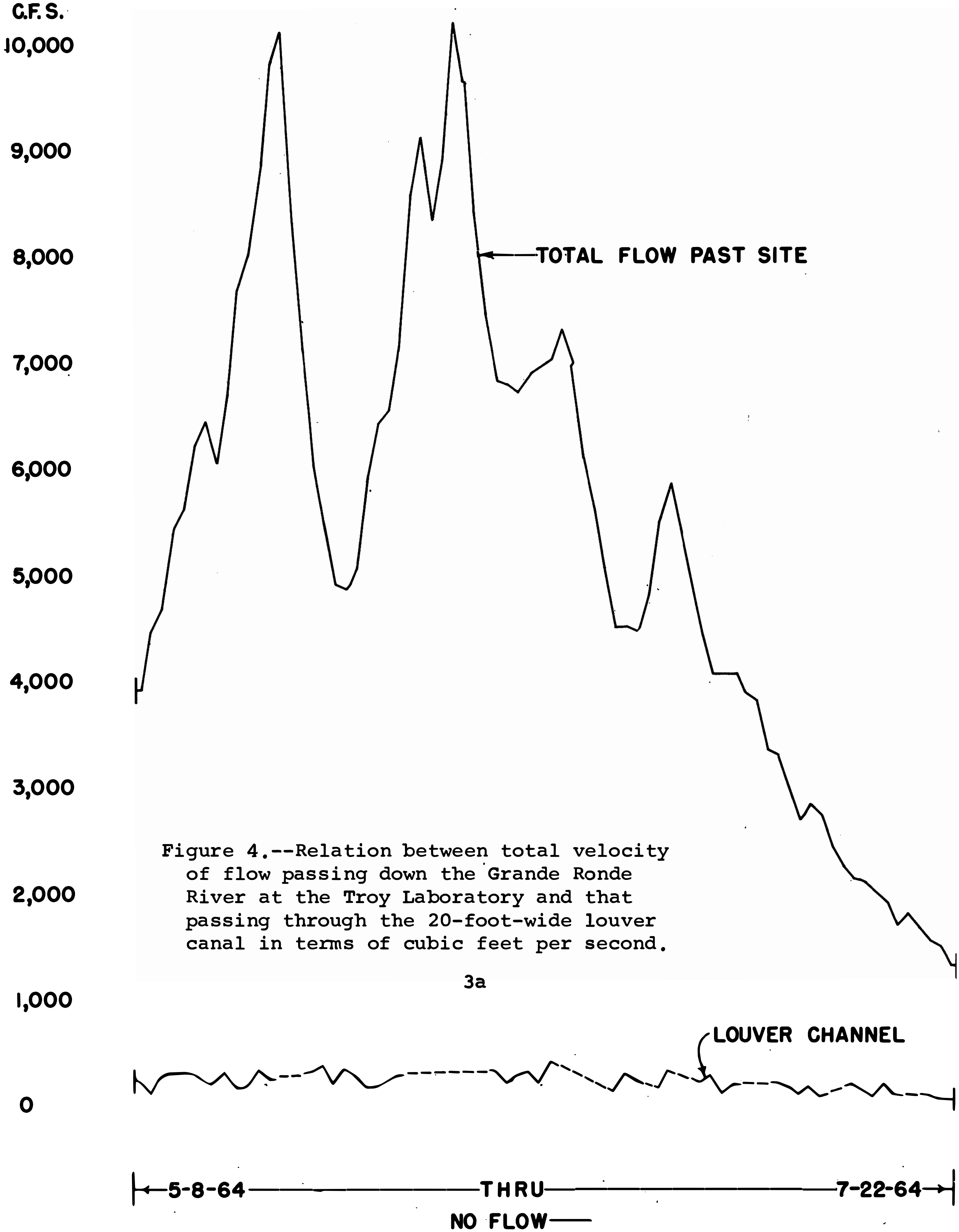


Figure 4.--Relation between total velocity of flow passing down the Grande Ronde River at the Troy Laboratory and that passing through the 20-foot-wide louver canal in terms of cubic feet per second.

VERTICAL LOUVER TESTS

Equipment and Procedure

The louver facility installed in the 20-foot flume channel was fabricated of 2 1/2-inch wide flat bars spaced at 2-inch centers. Every seventh bar was modified to provide a flow-straightening vane extending downstream to aid in channeling and dispersing the streamlines of flow. Individual louver bars were installed at 90° angles to the flow, and the face of the louver line was placed on an angle of 15° to the channel. The upstream end of the louver installation was secured to the south wall of the channel, the downstream end of the louver line being blended into a 6-inch wide bypass secured parallel to the north channel wall. It required 27 feet of vertical walled bypass to pass water and fish across the perforated-plate screen and into the trap. The width of this portion of the bypass varied from 6 inches at the inlet of the perforated-plate screen to 18 inches at the trap.

Test Fish

Spring and fall-run chinook salmon, coho salmon, and steelhead trout spawn in the mainstem and tributaries of the Grande Ronde River upstream from the Troy Laboratory. The natural run of outmigrating juvenile smolts was used in testing the louver structure. An estimate taken between the period of May 8 and July 22, 1964 of the total Grande Ronde River juvenile fish run, including non-migratory species, is shown in Figure 5. The numbers are based on flow volume relationships between main river and flume and numbers of fish caught in the test flume. Seasonal variation of juvenile salmonids is shown in Figure 6.

The size composition of the chinook and coho salmon and steelhead trout caught in the test flume from May 9 to June 23 is shown in Figure 7.

Fish were removed from the holding tanks with fine mesh dipnets and placed in an anesthetizing tank containing MS-222. Following anesthesia, the fish were carefully lifted out with a small seine-type scoop and identified. They were then transferred to a second tank to recover from the anesthesia before being released to continue downstream.

Throughout the test season, sample measurements were frequently taken and in such numbers as to give a reasonably accurate description of the size composition rather than of specific changes in composition.

Experimental Design

Louver testing for the spring of 1964 was designed to provide information on the guiding response of juvenile salmonids to louvers as a factor of color, velocity of approach flow, time of day, and segment of the season for each of

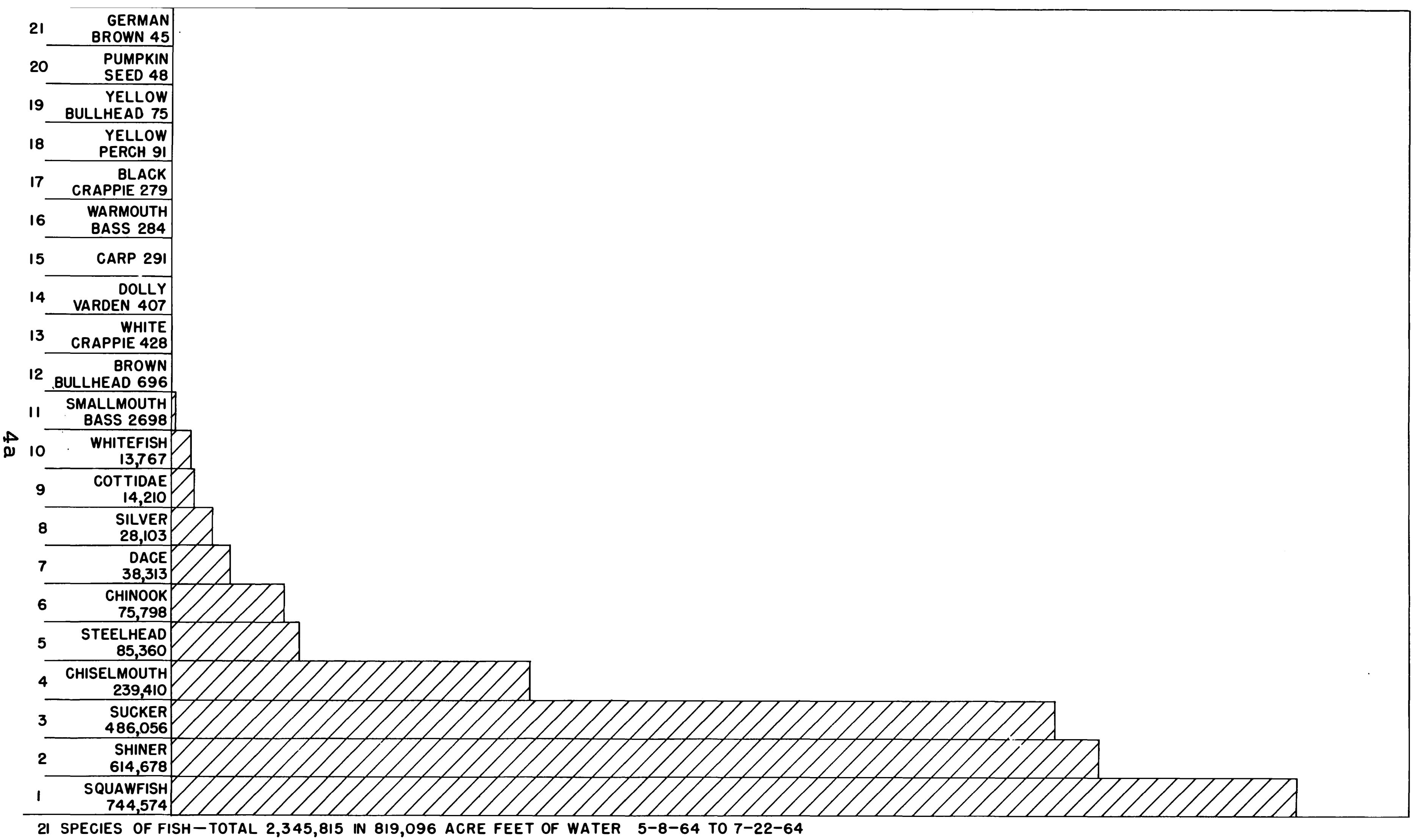


Figure 5.--Estimate of total Grande Ronde River juvenile fish run passing by the Troy Laboratory during the period of May 8 through July 22, 1964.

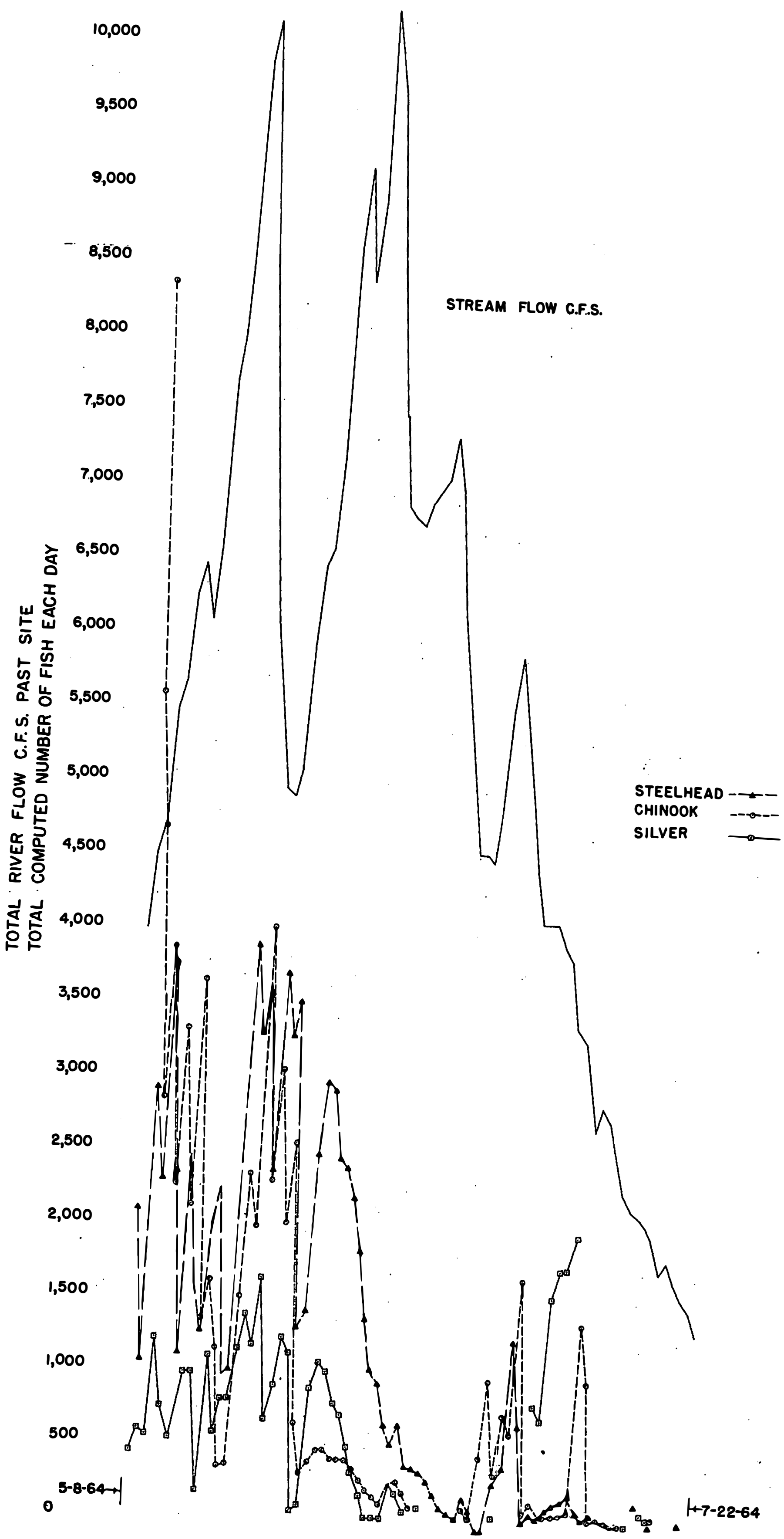


Figure 6.--Grande Ronde River seasonal variation in both flow volume and juvenile migrant salmonids at the Troy Laboratory during the period of May 8 through July 22, 1964.

4c

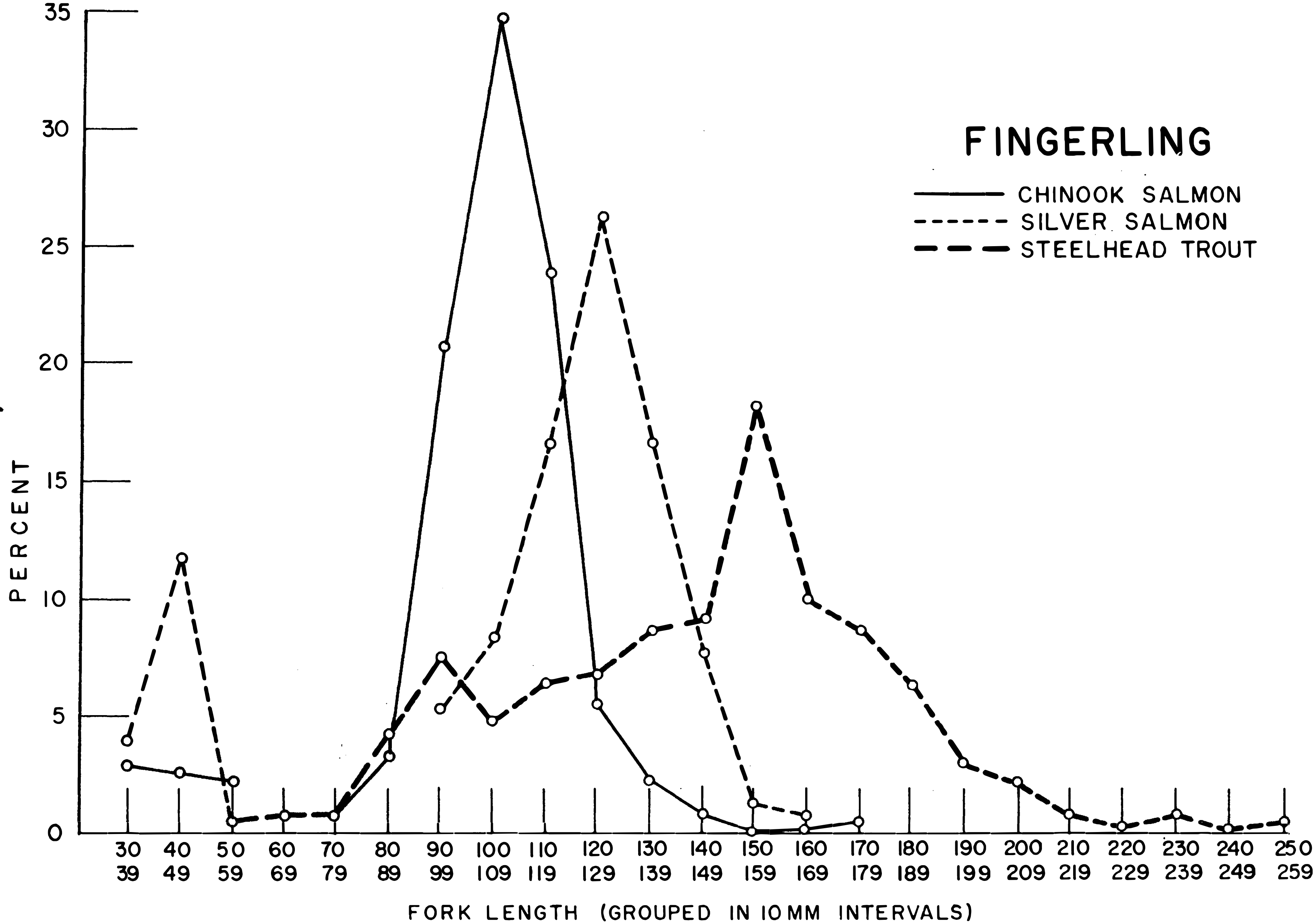


Figure 7.--Size composition of chinook and coho salmon and steelhead trout caught in the Grande Ronde River test facility (Troy Laboratory) from May 9 through June 23, 1964.

three species. The tests were conducted in an open flume under natural light that ranged in intensity from bright daylight to moonless nighttime and heavily overcast sky. Artificial light was largely excluded by shading the windows of buildings surrounding the flume and using flashlights after dark when gathering data or inspecting the flume. The floating live tanks were exposed to artificial light at all hours of darkness; however, the light source was strategically placed behind the flume wall to prevent light diffusion over the test area.

Conduct of Experiment

In preparation for a test cycle, the louvers and supporting structure were painted either black or white to a height above water level. A fast drying glossy paint was used that permitted a change of colors without interrupting the test schedule, and at least one continuous 3-day cycle was completed before changing colors.

The inclined screen was regularly adjusted to maintain a minimum differential of 21 inches between the afterbay water surface and the trap outlet hose. The differential was necessary to establish a gravity flow from the trap at the end of the screen to the live tanks. Screen angles of inclination greater than required to maintain the differential were seldom exceeded by more than a few inches, for it was observed that the porosity efficiency of the screen perforations was inversely related to the screen angle above zero. Suspended debris was considered a constant factor in this relation.

At or near zero elevation, the screen operated efficiently in relatively heavily concentrations of debris for periods of 2.5 hours or longer in approach velocities up to 3.5 feet per second. In contrast, records on June 2 showed that the screens became ineffective within 30 minutes of operation at approach velocities of 3.5 f.p.s. The debris removed from the screen on that date, following 5 hours and 55 minutes of operation, was measured volumetrically and amounted to 23 cubic feet after 7 hours of draining on a corrugated surface.

Tests were interrupted when it became apparent that the screen had to be cleaned of debris to prevent water overflowing the trap compartment. After the debris had been removed, the headgate was reopened to its previous setting, the flow was allowed to stabilize, and testing was resumed.

Water Control

Volume of flow through the flume was regulated by the upstream headgate and the downstream stoplogs. From the beginning of the experiment on May 9 until June 10 the two were used in conjunction to control depth and velocity. During this period, water depth in the approach channel exceeded 8 feet and carried large amounts of debris. To maintain the flows within the porosity capacity of the inclined screens it was necessary to limit the headgate to a partial opening.

This created a submerged weir effect, with accelerated flows beneath the gate and considerable turbulence just downstream.

The required louver approach velocity was obtained by placing stoplogs within guide slots at a point just downstream from the louvers. A spacing of 2 inches to 12 inches was provided between stoplogs and between the bottom stoplog and the flume floor.

After June 10 the operating procedure was changed to include a full headgate opening with closed stoplogs. The bottom space was continued, however, to provide an escape route for the migrants. Not only was the turmoil eliminated by this procedure but the flow pattern took on the appearance of a river-run condition. This change was made possible by a decline in forebay depth to less than 7 feet and a reduction in the amount of suspended debris.

The downstream migrants approached the test facility by an old established island channel that (prior to construction of the facility) carried approximately 40 percent of the total river flow at low-water discharge levels. A floating log boom across the channel entrance constituted the only alteration to former flow pattern except for the reduced flow volume caused by the physical presence of the facility.

Test fish passing through the louvers, or guided into the bypass, were first collected in separate traps located at the lower end of the perforated-plate screen. Guiding efficiencies were expressed as the percent of all fish migrating through the flume that entered the bypass.

Evaluation of the Grande Ronde louver array was based on 29 tests that began on May 9 and ended on June 23, 1964. At the three approach velocities, black louvers were tested for 17 days and white louvers for 12 days. An attempt was made to equalize the time of each test by starting daily at 4:30 p.m. and ending at 7:30 a.m. the following morning. This schedule, however, was frequently interrupted to make necessary adjustments in the water control and fish-collection installations.

The number of fish entering the test facility fluctuated according to natural rate of out-migration. A shortage of fish over much of the season made it impossible to relate the guiding efficiencies to environmental or procedural changes.

RESULTS

Numbers of juvenile salmonids caught during the period from May 9 through June 23 are shown in Table 1. The percentages of fingerlings guided in the tests of louver efficiency are shown in Table 2. These data were tested by four-way analysis of variance with a single observation consisting of the seasonal louver efficiency for each category.

There was a significant difference at the 5 percent level of significance between louver colors, between water velocities, between light conditions, and between species. There were no significant interactions between these main effects.

Black louvers usually were more efficient than white louvers at night as well as during the day at all water velocities for every species.

Table 1.--Numbers of fingerlings collected during period from May 8-June 24, 1964.

Louver color	Water velocity	Light Condition*	Chinook No. in bypass	Chinook No. thru louvers	Coho No. in bypass	Coho No. thru louvers	Steelhead No. in bypass	Steelhead No. thru louvers
	F.p.s.							
Black	1.5	day	50	8	12	3	31	6
		night	139	34	46	5	98	33
	2.5	day	118	8	26	1	65	9
		night	88	7	37	6	115	30
	3.5	day	139	18	52	8	97	21
		night	138	14	35	4	167	42
White	1.5	day	15	5	7	6	24	11
		night	44	15	9	5	48	26
	2.5	day	41	2	28	9	51	13
		night	80	15	31	3	69	48
	3.5	day	52	10	18	1	49	7
		night	71	20	27	13	61	52
Totals			975	156	328	64	875	298
			1131		392		1173	

*Daylight = 4:30 p.m. to 9:30 p.m. plus 5:00 a.m. to 7:30 a.m.

Night = 9:30 p.m. to 5:00 a.m.

Table 2. --Percentages of juvenile salmonids guided in tests of louver efficiency.

Louver color	Water velocity	Light condition[1]	Species Chinook	Coho	Steelhead
	F. p. s.		Percent[2]	Percent	Percent
Black	1. 5	day	86. 2	80. 0	83. 8
		night	80. 3	90. 2	74. 8
	2. 5	day	93. 7	96. 3	87. 8
		night	92. 6	86. 0	79. 3
	3. 5	day	88. 5	86. 7	82. 2
		night	90. 8	89. 7	79. 9
White	1. 5	day	75. 0	53. 8	68. 6
		night	74. 6	64. 3	64. 9
	2. 5	day	95. 3	75. 7	79. 7
		night	84. 2	91. 2	59. 0
	3. 5	day	83. 9	94. 7	87. 5
		night	78. 0	67. 5	54. 0

[1]Daylight = 4:30 p. m. to 9:30 p. m. plus 5:00 a. m. to 7:30 a. m.
Night = 9:30 p. m. to 5:00 a. m.

[2]Numbers of fish observed from May 8 to June 24, 1964 were summed and the percentages shown above were calculated from those sums. The percentages shown above were converted to arcsin values (Snedecor, 1957) which were used in a four-way analysis of variance test.

Daylight guiding was genereally better than night guiding, and water velocities of 2.5 f.p.s. produced a higher guiding effect at 3.5 f.p.s. than those at 1.5 f.p.s. Table 3 shows the average percentage guidance values that were compared for each main effect.

Steelhead Trout

Throughout the test season 714 steelhead trout were captured when the black louver structure was in place. Of those, 573 were guided into and through the bypass while 141 escaped between the louvers for a total efficiency of 80 percent. White louvers, in contrast, guided 302 out of 459 steelhead trout through the bypass for a total efficiency of 66 percent. This difference in response due to louver color exceeds the differences displayed by either chinook or coho salmon. The total efficiencies due to velocity effects were 72 percent at 1.5 f.p.s. and 75 percent at 2.5 and 3.5 f.p.s. The numbers of steelhead guided through the bypass and the numbers passing through the louver system are shown in Table 4.

The relation of steelhead trout size to louver guiding can be examined on a gross basis by comparing the size of those guided through the bypass to those passing through the louver system (Fig. 8). Of the guided fish only 30 percent were smaller than 140 mm. as compared to 60 percent of those passing through the louver system.

Fingerling Coho Salmon

Throughout the season 208 of 235 were guided by black louvers for a total efficiency of 88 percent. White louvers, in contrast, guided 120 of 157 for at total efficiency of 76 percent. The total efficiencies due to velocity effects were 80 percent at 1.5 f.p.s. and 85 percent at 2.5 and 3.5 f.p.s. The data pertaining to coho are given in Table 5.

Table 3. --Average percentages that were compared in the analysis of variance test. They can be calculated from values shown in Table 1.

		(Percent)
Louver color:	Black	86.04
	White	75.11
Water velocity:	1.5 f.p.s.	74.71
	2.5 f.p.s.	85.07
	3.5 f.p.s.	81.95
Light condition:	Day	83.30
	Night	77.85
Species:	Chinook	85.26
	Coho	81.34
	Steelhead	75.13

Table 4. --Fingerling steelhead trout guiding efficiency of the test louver structure, May 9 - June 23, 1964.

Louver color	Approach Velocity 1.5 Test no.	1.5 No. fish through Bypass	1.5 No. fish through Louvers	2.5 Test no.	2.5 No. fish through Bypass	2.5 No. fish through Louvers	3.5 Test no.	3.5 No. fish through Bypass	3.5 No. fish through Louvers
Black	1	10	6	2	80	13	4	68	26
	3	40	11	11	6	5	5	47	5
	9	12	4	12	68	18	10	23	4
	14	51	11	23	10	2	13	105	20
	22	8	6	24	16	1	21	17	5
	25	8	1				26	4	3
Total fish:		129	39		180	39		264	63
Efficiency:		77%			79%			88%	
White	8	12	2	6	43	19	7	9	15
	17	48	26	16	61	28	15	83	25
	18	12	8	19	14	12	20	16	14
	27	0	1	29	2	2	28	2	5
Total fish:		72	37		120	61		110	59
Efficiency:		66%			66%			65%	

Table 5. --Fingerling Coho salmon guiding efficiency of the Grande Ronde River louver structure, May 9 - June 23, 1964.

		Approach Velocity (f. p. s.)							
		1. 5		2. 5			3. 5		
Louver Color	Test	No. fish through Bypass	Louvers	Test	No. fish through Bypass	Louvers	Test	No. fish through Bypass	Louvers
Black	1	8	1	2	16	2	4	17	2
	3	25	2	11	9	0	4	8	4
	9	9	0	12	26	5	10	7	0
	14	14	4	23	6	0	13	53	5
	22	0	1	24	6	0	21	0	1
	25	2	0				26	2	0
Total fish:		58	8		63	7		87	12
Efficiency:		88%			90%			88%	
White	8	2	0	6	27	6	7	14	1
	17	13	11	16	28	6	15	20	7
	18	1	0	19	2	0	20	6	5
	27	0	0	29	2	0	28	5	1
Total fish:		16	11		59	12		45	14
Efficiency:		59%			83%			76%	

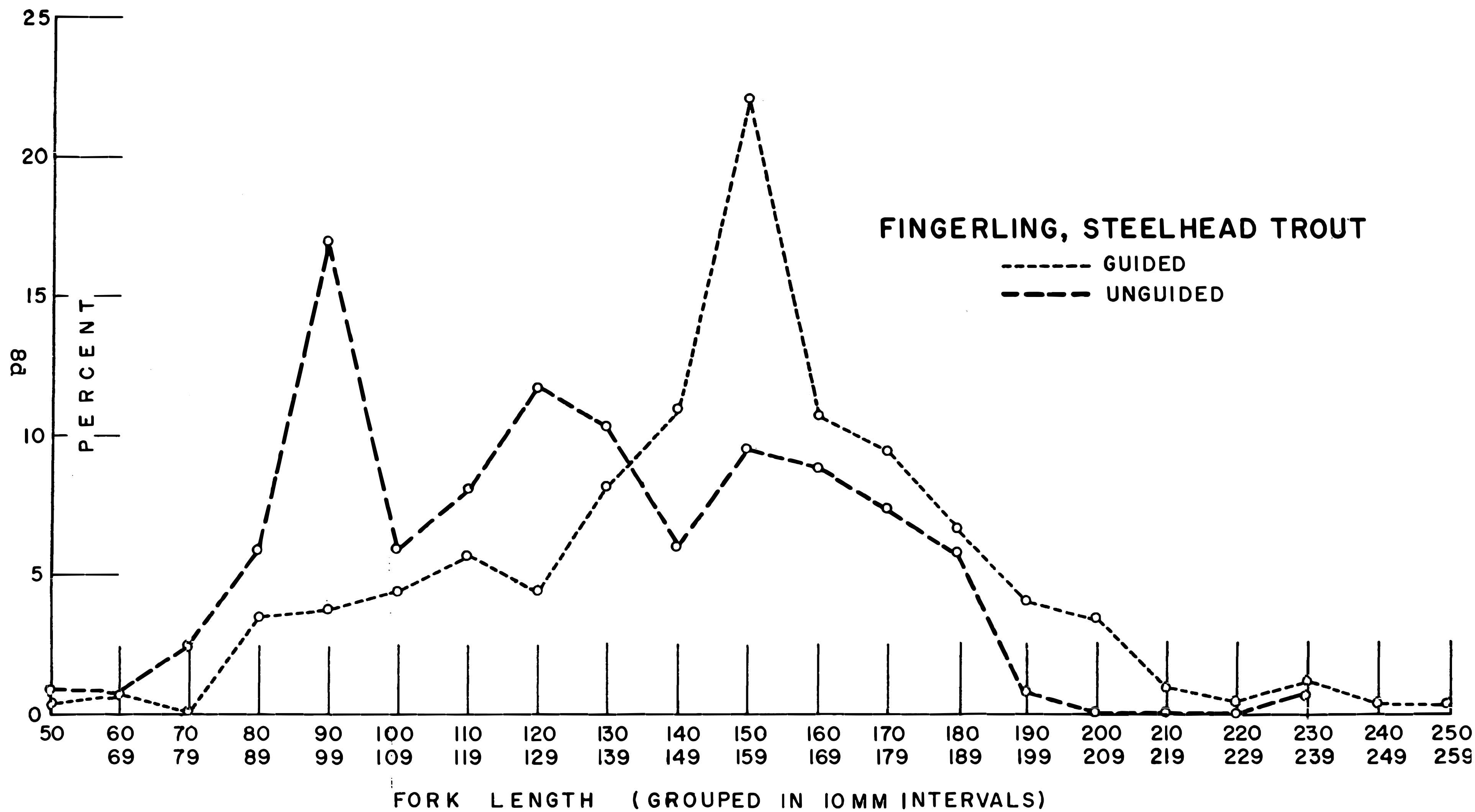


Figure 8.--Size composition of the steelhead trout tested in the louver system in the Troy Laboratory, May 9 through June 23, 1964.

A sample of 136 guided and 32 unguided fish collected intermittently throughout the test season provided the only available basis for determining the effects of size on guiding. Figure 9 shows the two groups to be bimodally distributed, with modes differeing by 10 mm. The computed mean length of the two groups were 108 mm. for the unguided fish and 118 mm. for the guided ones. Of the two samples only 19 percent of the guided fish were smaller than 100 mm., whereas 37 percent of the unguided fish were smaller than 100 mm.

Fingerling Chinook Salmon

Throughout the entire test season, black louvers guided 672 of 761 for a total efficiency of 88 percent. In contrast, white louvers guided 303 of 370 for a total efficiency of 82 percent. At 1.5 f.p.s. approach velocity, 248 of 310 were guided for a total efficiency of 80 percent. At 2.5 and 3.5 f.p.s., 727 of 821 were guided for a total efficiency of 89 percent. Table 6 presents the number of chinook fingerlings guided and not guided during the season.

Samples of 221 guided fish and 50 unguided fish taken throughout the test season provided the only basis for examining the effects of size on guiding. The mean length of the sample of guided fish was 100.03 mm. as compared to 89.28 mm. for the sample of unguided fish. Of the guided fish only 7 percent were less than 90 mm. as compared to 34 percent for those not guided (Fig. 10).

DISCUSSION

The comparisons made in this study indicate several areas in which future research might prove useful. Judging from differences established for guidance between black and white louvers and daylight and night catches, vision probably plays an important part in the response of juvenile salmoids to louvers. Examination of methods to increase the contrast between louvers and the surrounding water throughout a 24-hour period should lead to improved guiding efficiency.

The best guidance efficiency in this study was obtained for chinook and the least for steelhead. By contrast, louver tests carried out on Umatilla River with juvenile steelhead provided guiding efficiencies of over 98 percent with louvers spacing of 2 inches (Bates, 1961). The Canadian Puntlage River louver tests provided efficiencies of 86 percent with wild steelhead smolts and 98 percent with hatchery smolts (Ruggles, 1964). This indicates the possibility that the Grande Ronde River steelhead were not readily accepting the 6-inch louver bypass. For this reason the bypass width will be extended to 2 feet in future tests.

Table 6. --Fingerling chinook salmon guiding efficiency of the Grande Ronde River louver structure, May 9 - June 23, 1964.

	Approach Velocity (f. p. s.)								
	1.5			2.5			3.5		
Louver Color	Test no.	No. fish through Bypass	No. fish through Louvers	Test no.	No. fish through Bypass	No. fish through Louvers	Test no.	No. fish through Bypass	No. fish through Louvers
Black	1	67	17	2	138	12	4	91	6
	3	49	14	11	4	0	5	42	8
	9	13	0	12	50	2	10	12	2
	14	52	11	23	6	0	13	125	16
	22	3	0	24	8	1	21	5	0
	25	5	0				26	2	0
Total fish:		189	42		206	15		277	32
Efficiency:		82%			93%			90%	
White	8	12	3	6	69	6	7	43	12
	17	38	16	16	45	10	15	73	16
	18	9	1	19	5	1	20	4	1
	27	0	0	29	2	0	28	3	1
Total fish:		59	20		121	17		123	30
Efficiency:		75%			88%			80%	

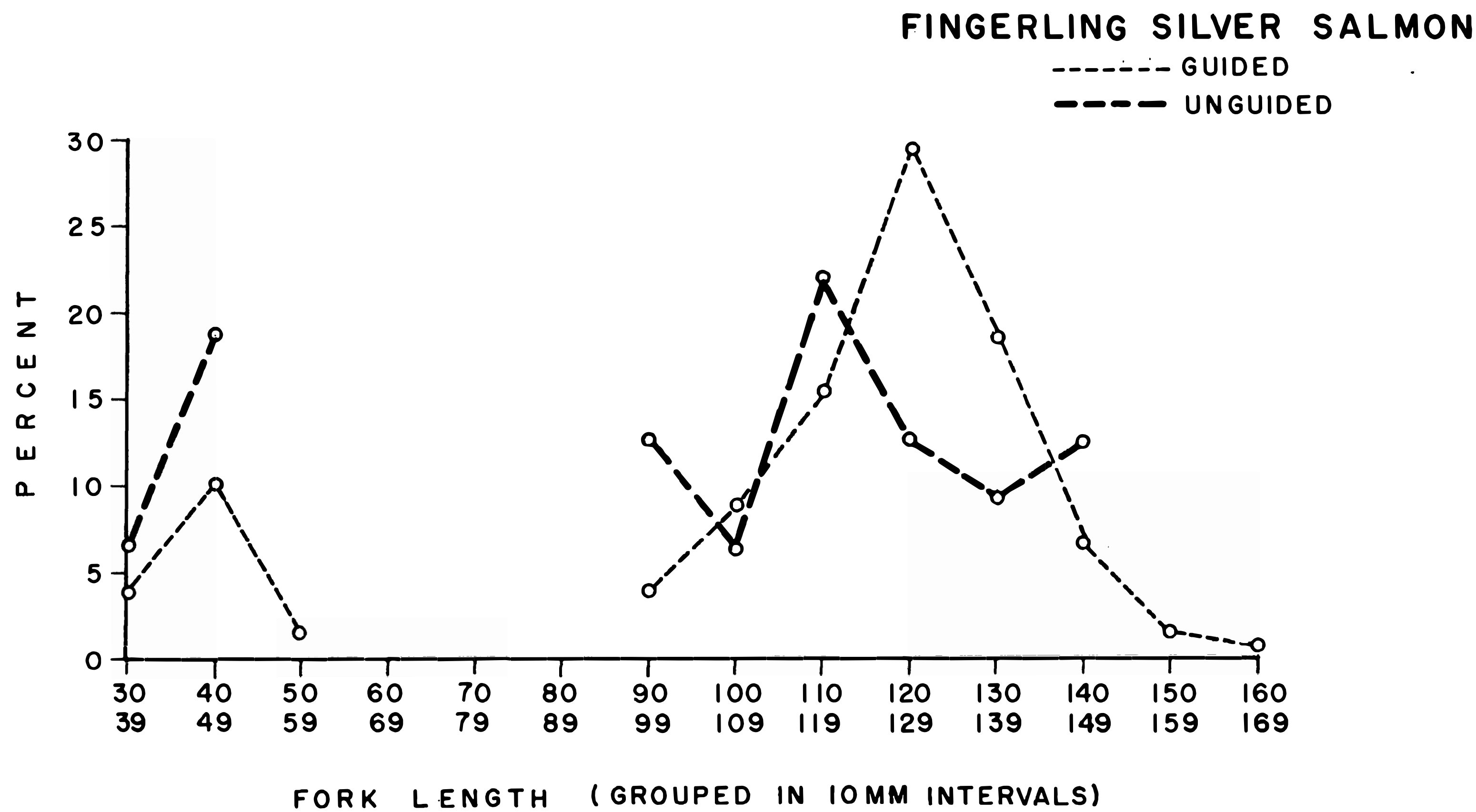


Figure 9.--Size composition of the coho (silver) salmon tested in the louver system in the Troy Laboratory, May 9 through June 23, 1964.

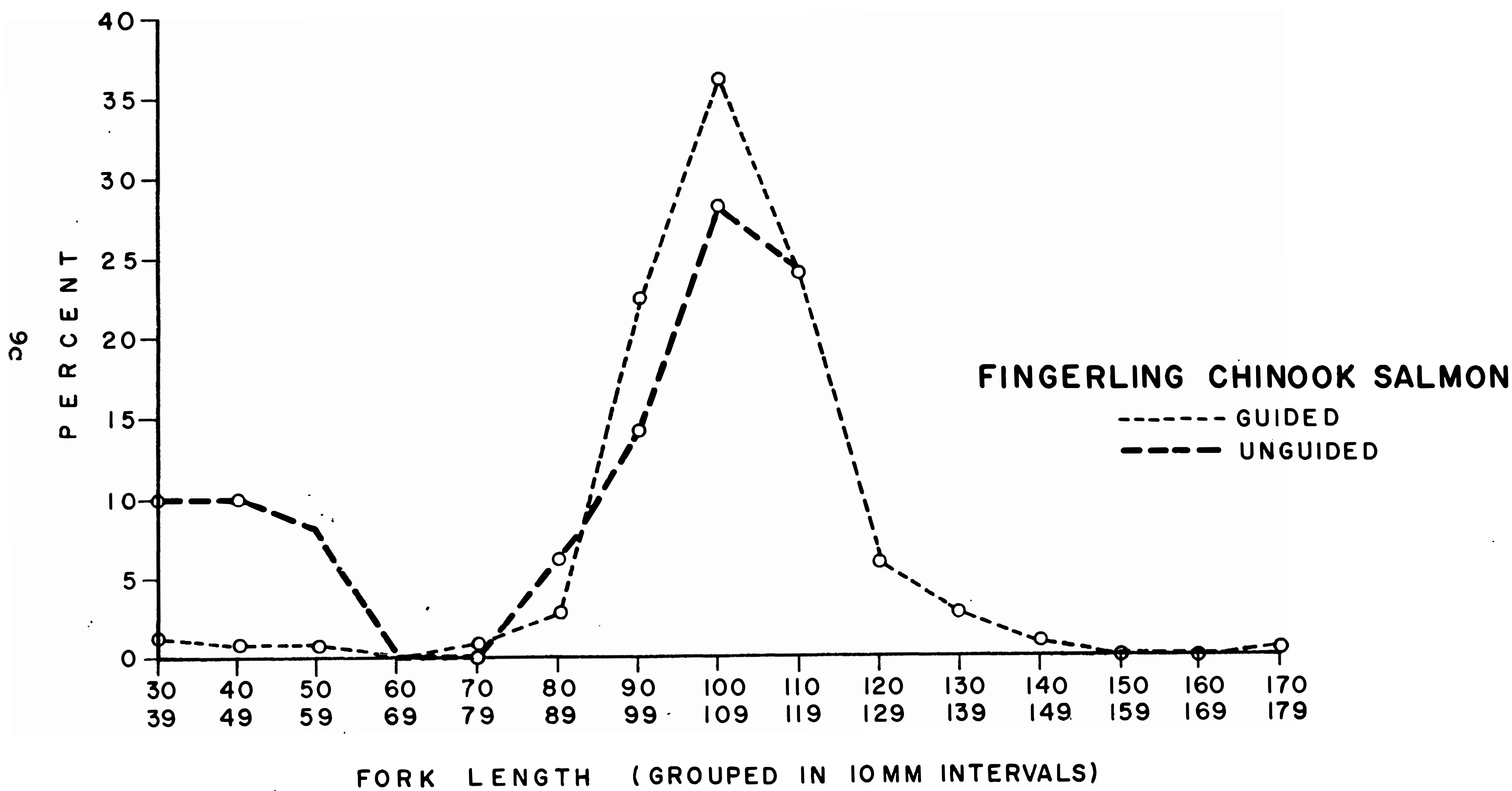


Figure 10.--Size composition of the chinook salmon tested in the louver system in the Troy Laboratory, May 9 through June 23, 1964.

LITERATURE CITED

Bates, Daniel W., and Stanley G. Jewett, Jr.
1961. Louver efficiency in deflecting downstream migrant steelhead. Transactions of the American Fisheries Society, vol. 90, no. 3, p. 336-337.

Ruggles, C. P., and Peter Ryan.
1964. An investigation of louvers as a method of guiding juvenile Pacific salmon. Department of Fisheries of Canada, Canadian Fish Culturist (February), p. 13. (In press.)

ADDENDUM

Since this report was prepared, the bypass has been enlarged from 6 inches to 24 inches. Testing during the period October 17 to 21 resulted in virtually 100 percent guidance at approach velocities of 1.5, 2.5, and 3.5 feet per second.

The testing has continued with no reduction in the efficiency. This high efficiency with a wider bypass points even more strongly to the critical nature of relationships between the bypass and approach.

EXPLORATORY TESTS OF VELOCITY SELECTION AS A MEANS OF GUIDING JUVENILE FISH

by

Russell Vinsonhaler

and

Doyle Sutherland

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

In the imaginative process of creating new methods to deflect juvenile migrants from rivers and streams, the use of a system of contrasting velocities was proposed. It was suggested that juvenile migrants would be uncomfortable within a high velocity and would seek areas of reduced velocity. The purpose, therefore, of this study was to determine if there were any basis for this conjecture. The plan was to provide a high velocity flow ranging from 5 to 15 feet per second through the central portion of a behavioral flume with a relatively low velocity of 1 to 2 feet per second along either wall.

If such a plan were found practical, it would allow for a structural design in which debris would readily sweep through the open central canal while the migrants would move out of the high central velocity and into the reduced velocity existing along the walls and ultimately into a bypass. The study was conducted during the summer of 1964 within an 8-foot canal of the Troy Laboratory, located in the Grande Ronde River, Oregon.

MATERIALS AND METHOD

Experimental Apparatus

There were no design precedents to follow. To provide the requisite refuge of low velocities along the walls, three designs were conceived and installed at the lower end of the flume. The first structure consisted of 18 vertical two-by-fours spaced on 2-foot centers in a line 2 inches off each flume wall. Fish selecting the slower velocities along the two-by-fours were collected in 6-inch wide bypasses set adjacent to each flume wall (fig. 1).

The second structure was a modification of the first. The vertical two-by-fours were installed on 1-foot centers and moved away from each wall by 6 inches. Each bypass was 20 inches wide (fig. 2).

In the third installation, only the bypass structure was left in the canal to determine fish response to the canal walls and bypasses only (fig. 3).

Test Procedure

Water velocities through both the flume and bypasses were controlled with stoplogs at the downstream end of the individual canals.

Fish used during the tests were wild downstream migrants collected from the inclined screen traps. Approximately 15 minutes prior to each test, the fish were placed in a container positioned against the trashrack at the upstream end of the flume. At the time of testing, the fish were released from the container and allowed to travel downstream through the flume. In the first and second series, fish were released in the center; in the third series the release position was varied from side to center.

Guiding efficiencies are expressed as the percent of all fish migrating through the flume that entered the bypasses.

RESULTS AND DISCUSSION

Results of the tests using the three designs are shown in tables 1, 2, and 3. It should be noted that the test fish, with the exception of three chinooks, were all non-salmonid. Therefore, the interpretations that follow are not intended at this time to apply to salmon and steelhead trout.

Collections in the 6-inch bypasses were negligible. When the bypass was widened and flow arresters changed, the slight bias to south bypass was altered but collection was still negligible. Total removal of the flow arresters did not change distribution in the north bypass, but a much larger collection in the south bypass resulted. The results of moving the release point indicate a strong bias toward the south bypass. When designs 2 and 3 are

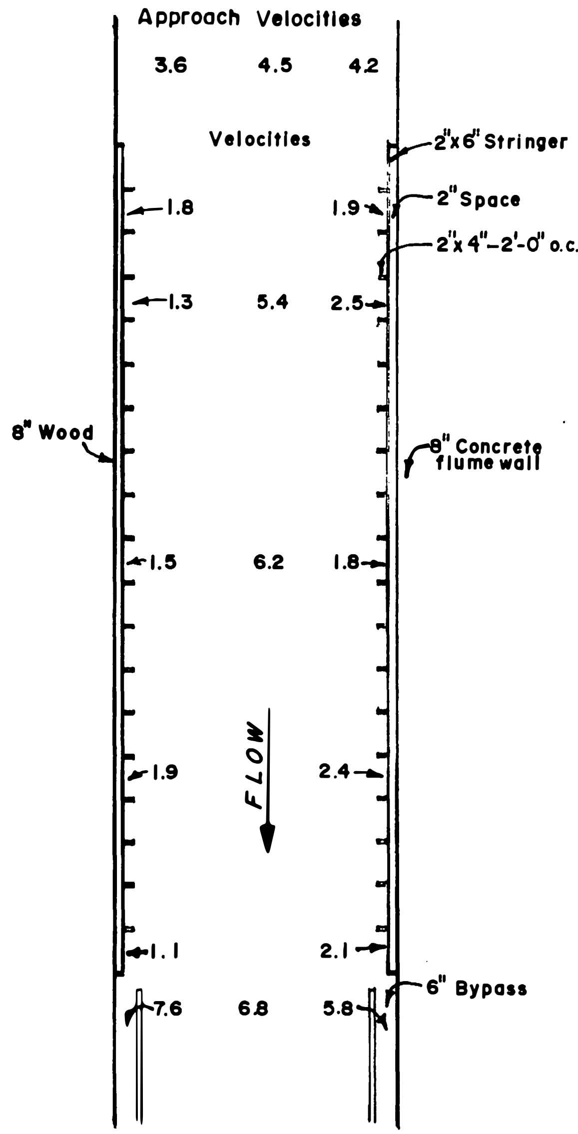


Figure 1.--Plan view showing velocity baffle arrangement in a portion of the 8-foot wide canal at the Troy Laboratory. High velocity section was 36 feet long.

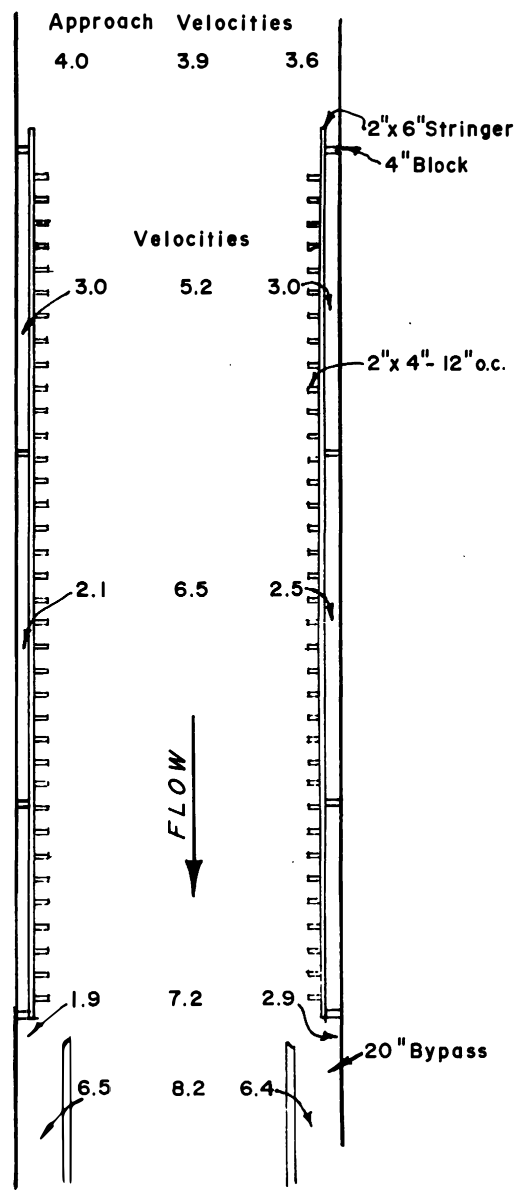


Figure 2.--Plan view showing modified velocity baffle arrangement in a portion of the 8-foot wide canal at the Troy Laboratory. High velocity section was 36 feet long.

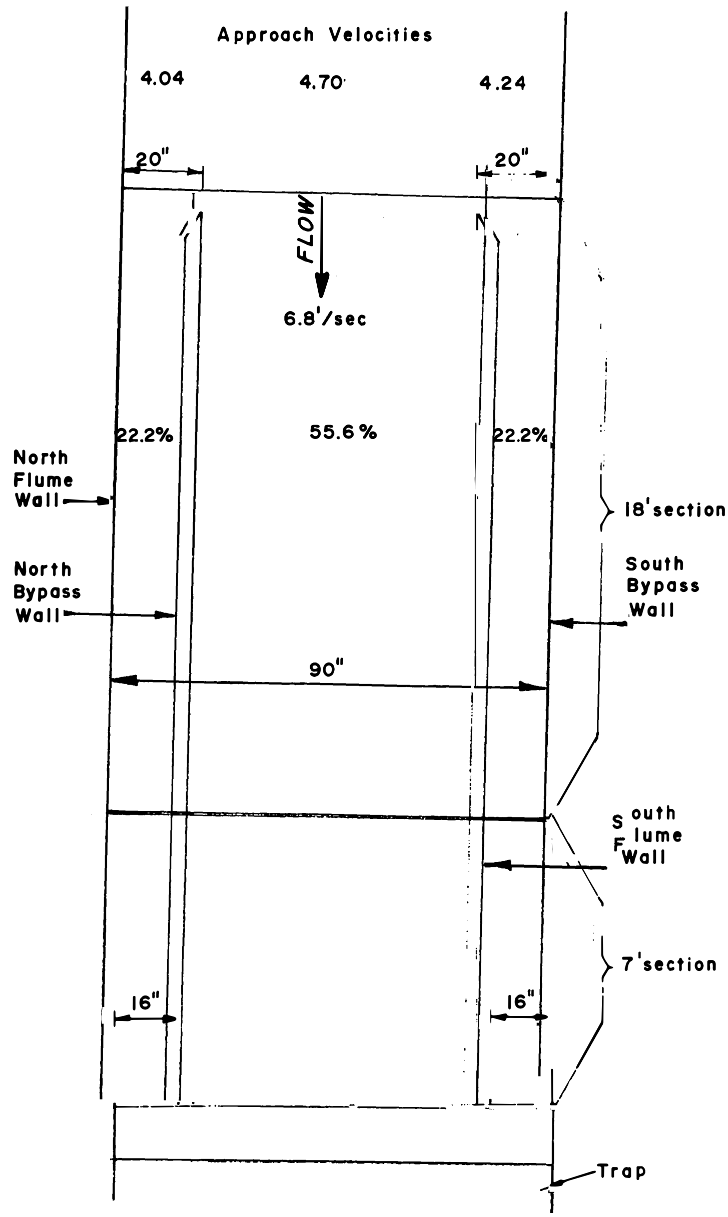


Figure 3.--Plan view showing a further modification of the velocity baffle arrangement in a portion of the 8-foot wide canal at the Troy Laboratory. High velocity section was 72 feet long.

Table 1. --Percent of juvenile fish guided into 6-inch bypass by vertical two-by-four flow arresters on 2-foot centers in a line 2 inches from each flume wall.

Test No.	Fish composition	Lateral distribution: North bypass 6.7% of flow	Center of channel 86.6% of flow	South bypass 6.7% of flow
	Species and Number	Percent	Percent	Percent
1	Chinook-3 Whitefish-45	0.0	100.0	0.0
2	Chiselmouth-3 Dace-1 Red-sided shiner-11 Bluegill-1 sucker-10	0.0	96.2	3.8
3	Whitefish-20	0.0	100.0	0.0
4	Whitefish-20	0.0	82.5	17.5
5	Whitefish-20	0.0	100.0	0.0
6	Red-sided shiner-16	0.0	100.0	0.0
7	Chiselmouth-11 sucker-5	0.0	100.0	0.0

Table 2.--Percent of juvenile fish guided into 20-inch bypass by vertical two-by-four flow arresters on 1-foot centers in a line 6 inches from each flume wall.

Test No.	Fish composition	Lateral distribution: North bypass 22.2% of flow	Center of channel 55.6% of flow	South bypass 22.2% of flow
	Species and Number	Percent	Percent	Percent
1	Red-sided shiners-20	0.0	100.0	0.0
2	Whitefish-19	0.0	100.0	0.0
3	Whitefish-18	0.0	100.0	0.0
4	Chiselmouth-18	5.6	83.3	11.1
5	Whitefish-19	0.0	100.0	0.0
6	Chiselmouth-19	15.7	68.6	15.7

Table 3.--Percent of whitefish accepting two 20-inch bypasses installed on the inclined screen in the 8-foot test flume. Fish were released on the north, center, and south side of flume entrance.

Test No.	Number tested	Release site	Lateral distribution		
			North bypass 22.2% of flow	Center of channel 55.6% of flow	South bypass 22.2% of flow
			Percent	Percent	Percent
1	18	North side	0.0	72.2	27.8
2	20	North side	0.0	94.8	5.2
3	18	Center	0.0	83.3	16.7
4	19	Center	10.5	63.2	26.3
5	19	South side	10.5	68.4	21.1
6	20	South side	0.0	80.0	20.0

compared, no contribution can be assigned to the use of the arresters.

Since the major portion of the test fish remained within the center of the flume, this may indicate that (1) they did not find the high velocities objectionable; (2) they may not have had sufficient length of structure (time) to allow their moving out of the center; or (3) the velocity-reducing baffles along each wall may have repelled rather than attracted the fish.

These tests were suspended to permit installation of a test design of higher priority.

A PRELIMINARY STUDY ON THE MAINTENANCE OF AN INCLINED SCREEN

by

Daniel W. Bates

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

Inclined screens fabricated of perforated plate or wire cloth screen have had widespread application in collecting juvenile migrants out of canals, small rivers, and streams. One of the most recent is now in use by the Bureau of Commercial Fisheries in a test facility on the Grande Ronde River near Troy, Oregon.

Notwithstanding the popularity of the inclined screen, little information was available as to how well suited such a facility might be for use as a fish screening device within a major river. There was considerable question as to just how the entire flow of a river could be passed through a screen without completely clogging the openings, or without developing a severe maintenance problem.

The purpose of this initial investigation was to explore the methods for cleaning debris from the screens in the search for the most efficient.

Studies on the effect of factors such as approach velocity, static head, screen angle, type and volume of debris and design of the plate screen upon screen efficiency are still in progress and will be reported later.

The flume was designed for a capacity of 80 cubic feet per second at a maximum velocity of 18 feet per second. Both water volume and velocity controls were built into the headwork of the flume. A series of stoplogs afforded head control, while a power-driven vertical steel gate placed several feet downstream from the stoplog section controlled flow volume.

DESCRIPTION AND OPERATION OF TEST STRUCTURE

To provide a structure in which various inclined screen tests could be conducted, a relatively small flume measuring 50 feet long, 4 feet deep, and 2 feet wide was constructed within a spillway section of the Stanfield Irrigation Canal, a diversion of the Umatilla River near Echo, Oregon.

The flume design (fig. 1) provided for the installation of four inclined screens, each measuring 2 feet by 4 feet, with a total length of 16 feet and a width of 2 feet. Slope of the total screen array could be varied in 5° increments from a minus 5° to a plus 5°.

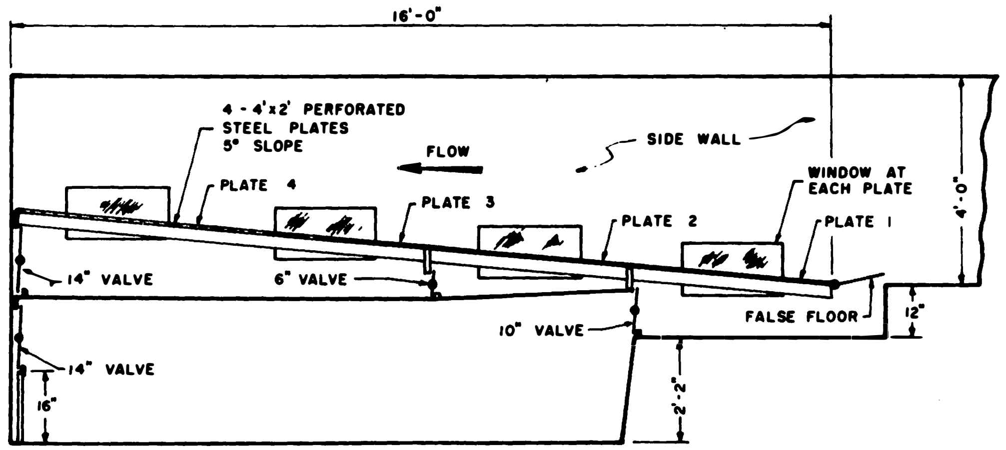


Figure 1.--Plan of the 1964 inclined screen experimental flume in the Stanfield Canal, Echo, Oregon.

Each test carried out in phases 1 and 2 used 12 gauge perforated plate screens (fig. 2) with 1/4-inch diameter holes staggered on 3/8-inch centers (40 percent effective open area) placed on a 5° slope. To allow for observation of the plates and flow through the plates, plexiglass windows--one for each plate screen--were installed along one side of the flume.

To control the static-pressure head passing through the openings of the screens, individually gated compartments were constructed directly under plates 1 and 2. Also, a single-gated compartment combining plates 3 and 4 was fitted directly between these two plates. A false door was installed several inches upstream from plate 1 (fig. 1).

Accurate water depth readings could be taken through the use of piezometers installed at specific points throughout the length of the flume.

TECHNIQUES TESTED

False Floor

The first technique used to clear the plate screens of debris involved the use of the false floor (fig. 1), which when opened for a brief period, allowed a portion of the high velocity approach flow (12 f.p.s.) to pass into the gated compartment under plate 1 and up through the plate perforations in a reverse direction.

Water Hammer

The second technique to clean the screens utilized the operating principle of the water hammer. When the relatively high velocity of flow passing through the perforations of the plate and into a compartment was interrupted by rapid closure of the compartment valve (fig. 1), the onward motion of the water was suddenly halted. As a result, inertia of the flow caused a sudden high pressure, the effect of which was like a hammer blow which set up a pressure wave moving at a high velocity in a reverse direction through the perforated plate screens. It was this reversal of flow which cleaned the screens.

Vibrators

A third technique was developed in which air-actuated vibrators were attached to the underside of plates 3 and 4 (fig.3). These devices vibrated 16,300 times per minute at 90 pounds per square inch.

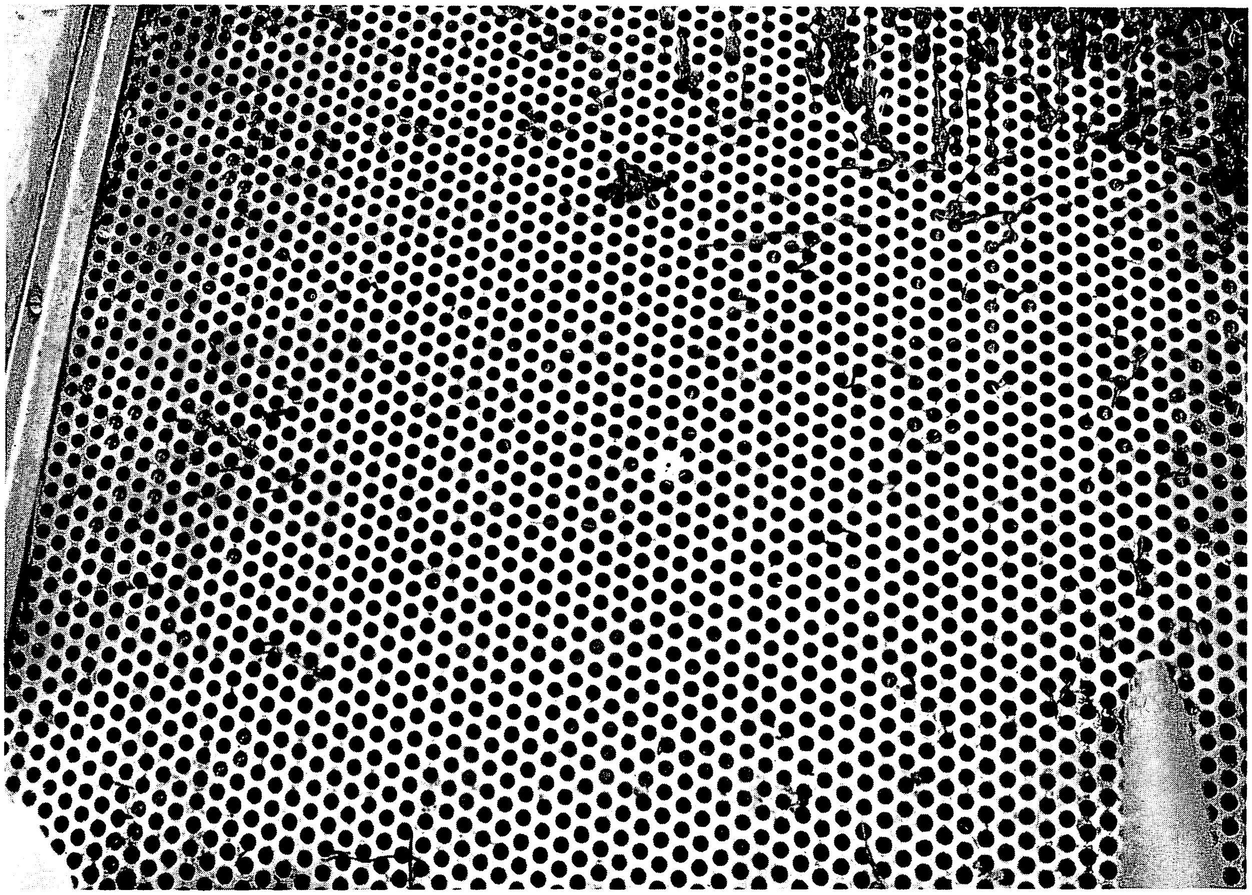


Figure 2.--Perforated plate screen with 1/4-inch diameter holes staggered on 3/8-inch centers, providing an effective open area of 40 percent.

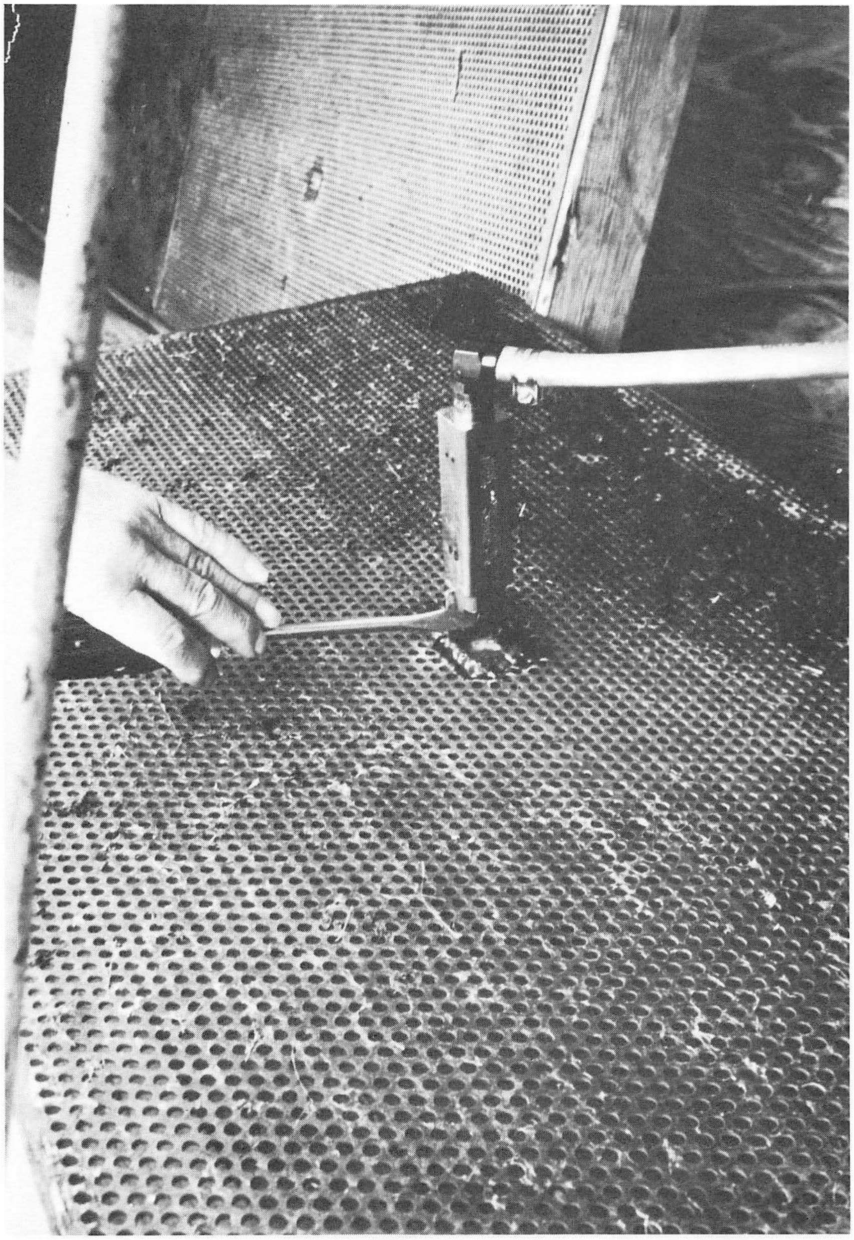


Figure 3.--Air-actuated vibrator attached to the underside of a perforated plate screen.

Water Jets

A fourth method evaluated was the use of high velocity water jets. Two different systems were used in this test. The first involved the use of water jets directed upward from the underside of the perforated plate screens (fig. 4). The jets discharged about 3/4 of an inch from the bottom of the plate screens. The entire jet assembly traveled along a track parallel to the direction of flow and beneath plates 3 and 4. A water pressure of 50 pounds per square inch through the jets was used.

The second water jet system was designed to eliminate the travel required in the first method. In this study a 6-inch diameter pipe was positioned directly underneath the plates and extended along a midline their full length. It could be readily turned to cause the 3-inch spaced spray jets to rotate in an arc of 180 degrees, sufficient to clean the entire screen width (fig. 5).

RESULTS AND DISCUSSION

Use of the false floor cleaning technique resulted in a thorough cleaning of a 12-hour accumulation of debris in approximately 1 second. The rush of water from below provided by the opened floor section instantly lifted debris free of the plate where it was swept away by the high velocity flow passing over the screen. One exception to this was when the debris included a large proportion of filamentous algae.

Results of the water hammer operation were equally favorable. It was found that debris could be instantly cleared, again with the exception of filamentous algae, from the plates within less than 1 second. It was also true with this cleaning technique--as with the false floor--that unless the screens were cleaned every 5 hours (approximately) or less, the instantaneous cleaning action was lost and that more time was required to accomplish the task. With the addition of vibrators to plates 3 and 4 there was a marked reduction in the extent of clogging when compared to similar tests conducted on the same day and for the same period of time without vibrators.

Both water jet systems thoroughly and rapidly cleaned the entire screen array, including algae. Because of the ease of operation there was considerable advantage in use of the rotating pipe system. The results of those tests dealing with various screen cleaning methods, with specific reference to use of the false floor as well as to the water hammer principle, were

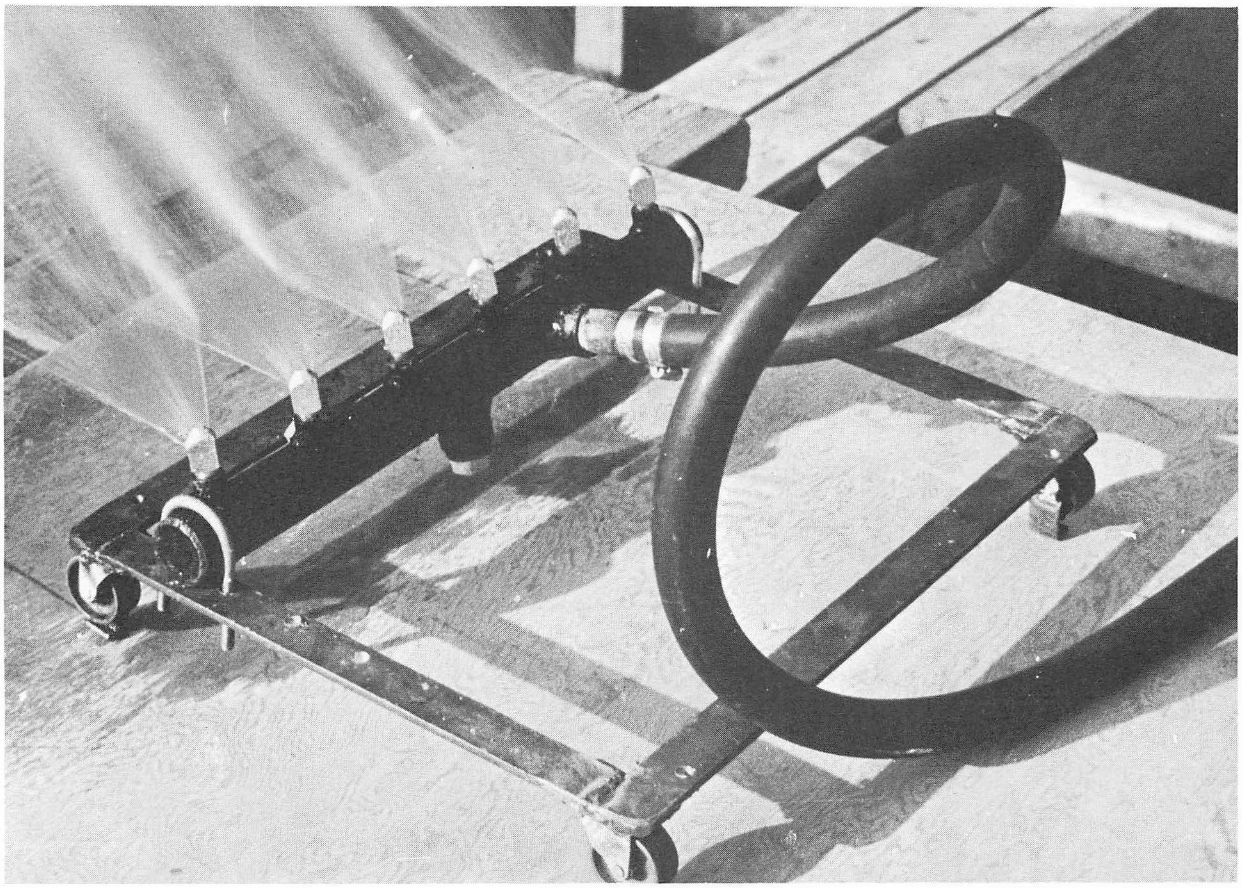


Figure 4.--Traveling water jet system used in cleaning perforated plate screens.

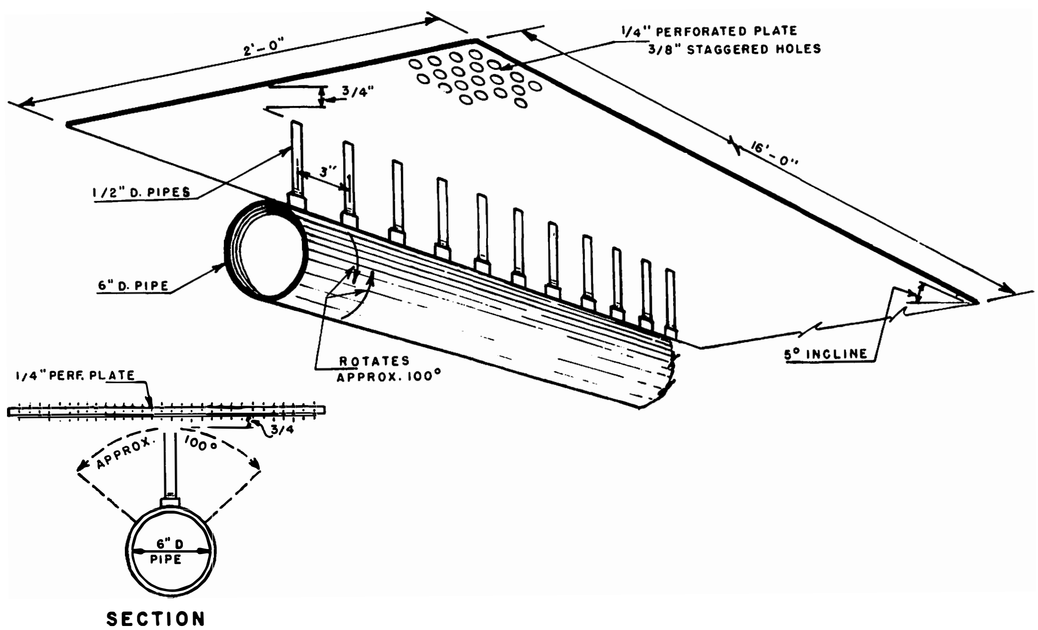


Figure 5.--A portion of the water jet pipe showing its position relative to the perforated plate screens.

satisfactory. However, it was indicated that the longer the time interval between screen cleaning periods, the more time in terms of seconds was required to accomplish cleaning. It should be noted that in the use of the water hammer principle, should the screens clog to the point of allowing little or no flow to pass through, the use of the principle is lost.

Irrespective of the cleaning system adopted, there is always the possibility of a severe debris load passing onto, and rapidly and completely clogging a screen. The immediate result would be the total engulfment of the structure by the river flow.

SUMMARY

The possible application of the inclined screen for use in deflecting juvenile salmonids from rivers, streams, and canals was examined from the standpoint of how the screens could best be cleaned. Although several systems were developed which cleaned the perforated plate screens successfully, the high pressure wash system appeared to be most promising from the standpoint of application.

Results of tests on inter-relationship of such factors as head, velocity, screen design, and type & volume of debris have not been concluded at this time.

POROUS PLATE STUDIES
(SUMMARY)

by

E. P. Richey

and

Randolph H. Murphy

Hydraulic Laboratory
University of Washington

for

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

September 1964

INTRODUCTION

This report consists of a brief summary of the work being done in connection with porous plate screens at the University of Washington. The work is being conducted with the objective of extending the present knowledge toward more definitive design criteria by a careful study of the hydraulic variables which govern the flow over such a screen. Some of the geometries for the study were chosen so as to be similar to the field installations at the Stanfield Canal at Echo, Oregon.

Before a design criteria for porous plate screens can be utilized it is necessary to know the inter-relationship of such variables as the screen porosity, screen length, and the slope angle as defined in figure 1. Although there are many field installations of screens or porous plates, the few general studies which have been made leave many design parameters only vaguely defined. A reasonably good analysis has been made only for a slope angle of 0^{o}. It is to be expected that the relationships will change as the angle is altered from that of 0^{o} to say 5^{o} or 10^{o}. The theoretical relationships involved become very cumbersome, and in order to make any use of them at all it is necessary to make a number of assumptions. The exact nature of these assumptions can be accurately made only through use of quantitative laboratory results.

For this purpose a model was constructed to simulate a porous plate screen. The model is now being tested.

DESCRIPTION OF MODEL

The model used in the study is shown in operation in figure 2. It is constructed primarily of plexiglass, to aid in visual analysis of the flow, and is attached to an existing flume of one foot width. The test section is four feet in length. The floor of the screen is made out of tee-sections constructed of 3/8-inch-thick plexiglass and 1[illegible]inch wide. These are placed in a direction transverse to the flow. The tee portion is added to provide extra strength. The present sections in use are shown in figure 3. During the second phase of the test program the downstream edge of these sections, or the upstream edge of the openings, will be rounded for reasons which will be explained. This is shown in figure 4.

There are several reasons for using the tee-sections. These floor sections slide into grooves cut in the inside of each wall and the desired opening width is maintained by spacers

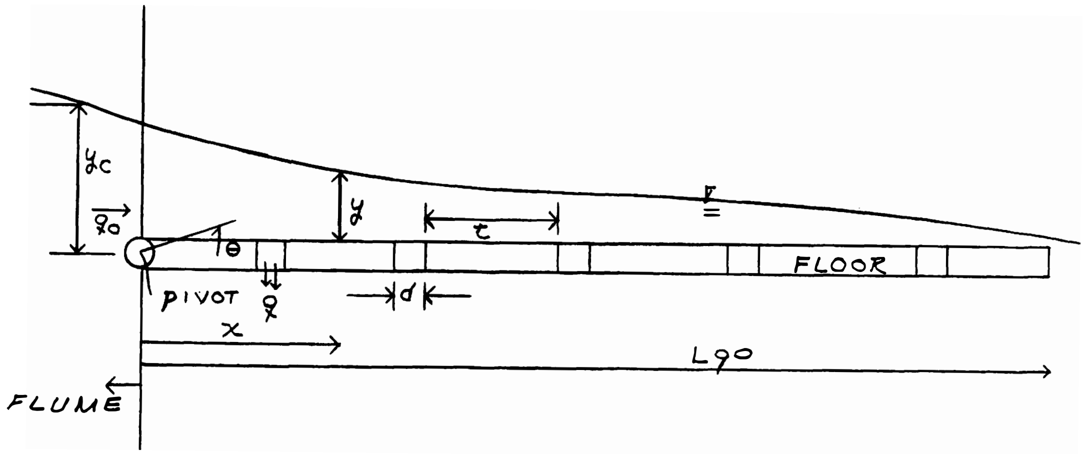


Figure 1.--Elevation view of test model.

q_o = initial flow.

q = flow through a single opening.

p = porosity = $\frac{\text{area of openings}}{\text{gross area}} = \frac{d}{t + d}$

L_{90} = length at which 90% of the initial flow has passed through the plate.

x = distance from start of plate

y = water depth

y_c = critical depth of initial flow

θ = angle of the floor with the horizontal, measured counterclockwise

C_d = discharge coefficient = $\frac{q}{A \text{ opening } \sqrt{2gh}}$ where $h = y$

t = bar width = 1"

d = opening width

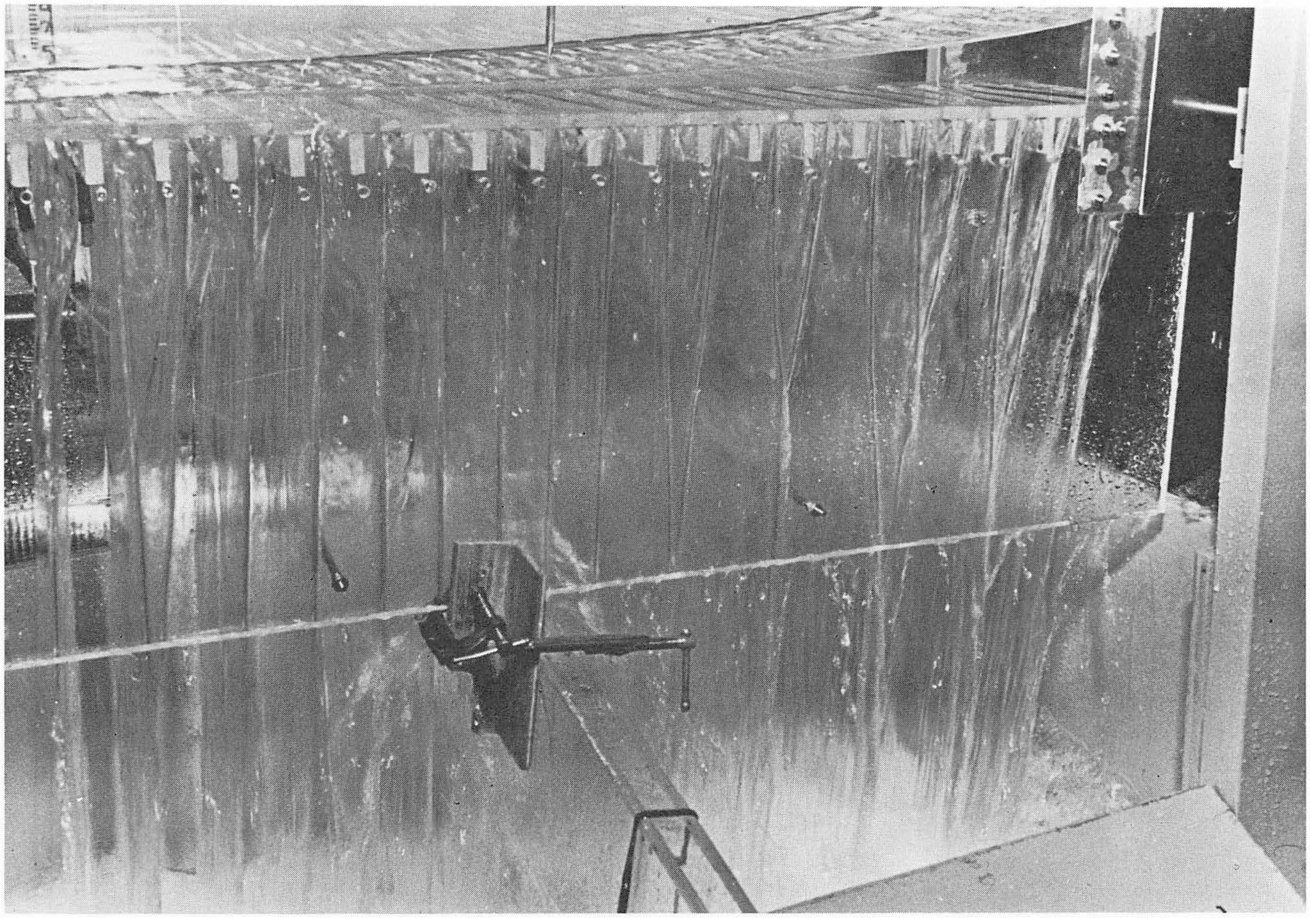


Figure 2.--View of test model in operation.

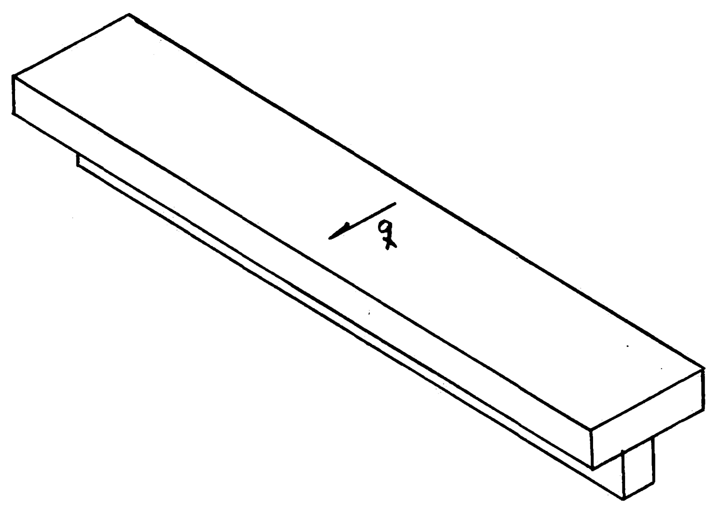


Figure 3.--Square edge tee-section.

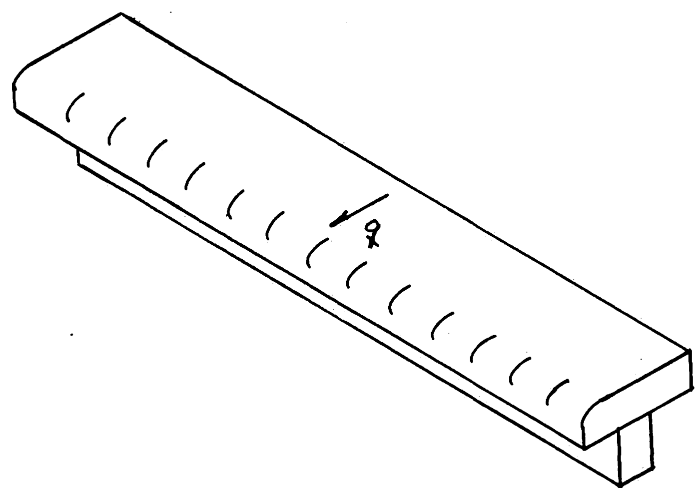


Figure 4.--Rounded edge tee-section.

which are easily changed. This arrangement enables the changing of the porosity and length. The porosities being used in the present series of tests are 0.197, 0.261, and 0.333.

Another advantage of the bar arrangement over that of a true porous plate is the relative ease with which the discharge through the openings can be defined and measured. With the punched hole openings there occurs a three-dimensional effect which leads to uncertainty in the definition of the porosity. Not only is the effective opening area of the bar arrangement more readily visualized and analyzed, but the actual opening area is more easily defined and measured.

In the present series of tests the incremental flows are being measured to enable some determination of the relationship of the discharge coefficient to some of the other variables, such as t/d, slope, depth, and initial flow.

The entire test section is pivoted so that the floor can be tested at any angle from zero to twenty degrees. By varying the number of tee-sections in use at a time the length can vary from zero to four feet. The tests run to date have been in the range of from one to three and one-half feet. The maximum available flow for the one foot of width is about 1.1 cubic feet per second.

The test program has been divided into two separate parts. The first part was run with the sharp edge sections. The second part will be run with the rounded edges on the downstream edge of the tees. It is believed that the rounded edges will increase the discharge per foot, maintain a smooth, uniform approach flow, and more nearly represent a field installation fabricated from commercial tee-sections.

The first part of the program was run to provide background information to be used to compare with existing studies and with subsequent changes in the test model. The data which has been taken includes the water surface profiles, the incremental discharge through the plate, and the pressure on the surface of the plate.

In order to compare the data from tests made with various lengths, angles, porosities, and flows, it is necessary to compare them on a dimensionless basis. The terms are defined in figure 1 with L_{90} being the length at which 90 percent of the initial flow has passed through the plate.

RESULTS

The flow over the plate can be either sub-critical or super-critical depending both upon the angle of the plate with the horizontal and the porosity. In the first phase tests have been run at 0°, 5°, 10°, and 15°. At 0° and 5° the flow was super-critical over the plate, and at the 10° and 15° angles the flow was sub-critical over the plate, at the porosities at which these angles were tested. At the angle at which critical flow occurs the flow is unstable. This angle is of course dependent upon the porosity. This region should be avoided in any field installation as the flow is highly variable and non-uniform. At the lower porosity of 0.197 this angle was found to be about 7° -8°. More testing will be done in the second phase to try to determine the influence of the parameters upon the location of the critical flow region.

Typical water surface profiles for each of the angles and porosities tested will be found in figure 5. Also, in figure 6, will be found a dimensionless representation of the discharge as a function of the dimensionless length.

Another important relationship which needs to be determined is that of the discharge coefficient. In the past this has been assumed to be constant along the length of the plate. From figure 7 it can be seen that there is considerable variation. It is interesting to note, however, that it remains more nearly constant for the sub-critical flow cases. This would tremendously simplify a design procedure for this type of flow and is one point in favor of using such angles. It is also interesting to note that the discharge coefficient does depend upon the plate porosity.

FUTURE PLANS

As stated earlier, the next step is to round the edges of the tee-sections. In the series of tests already completed most of the attention was given to flow over the plate at an angle of 0° to the horizontal. This was to compare results with the somewhat limited results presently available.

It is realized, however, that most fish screen installations would be on angles of greater than that of 0°; partially for economic reasons, as the length required to pass a given amount of water decreases rapidly as the angle with the horizontal increases.

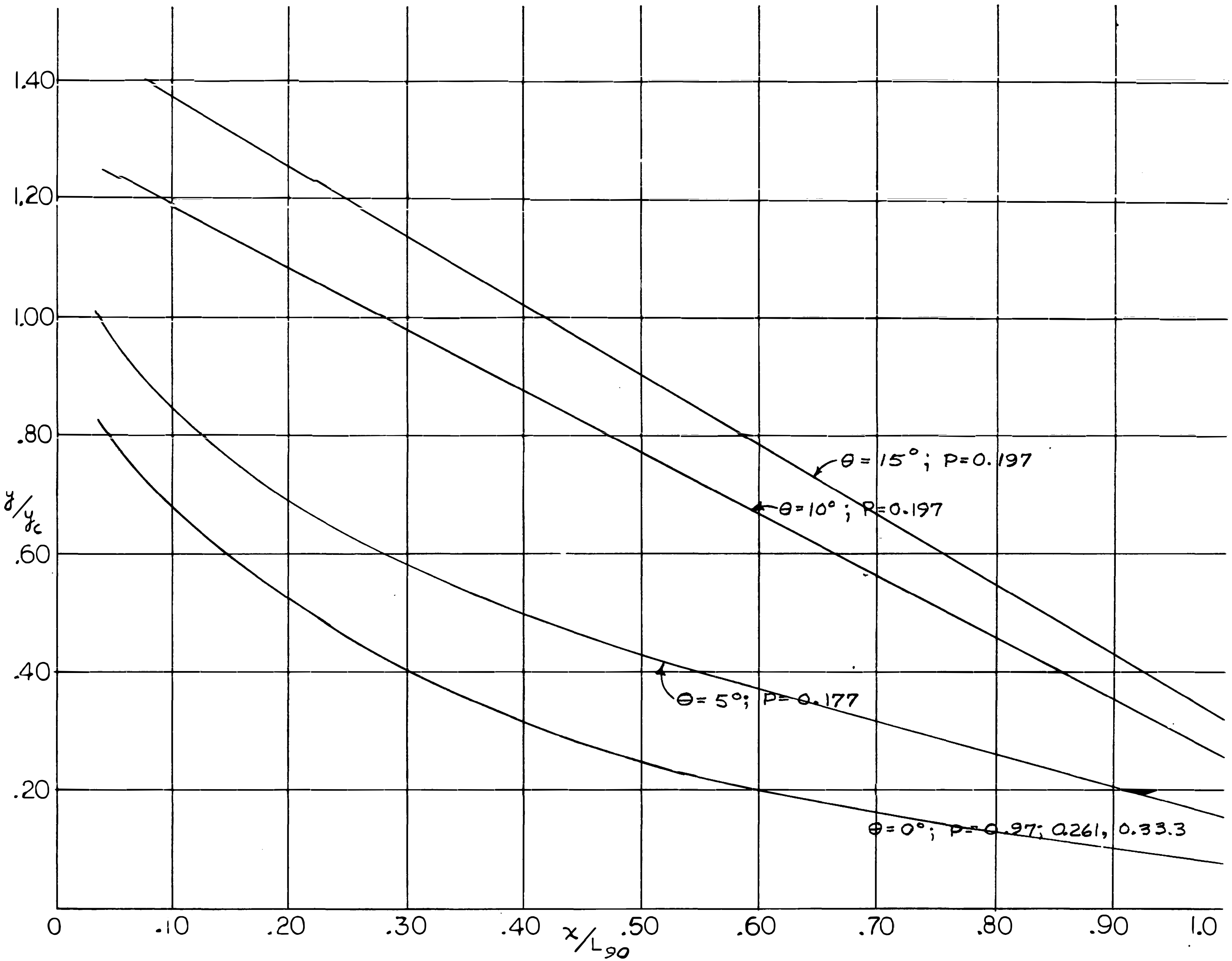


Figure 5.--Water-surface profile.

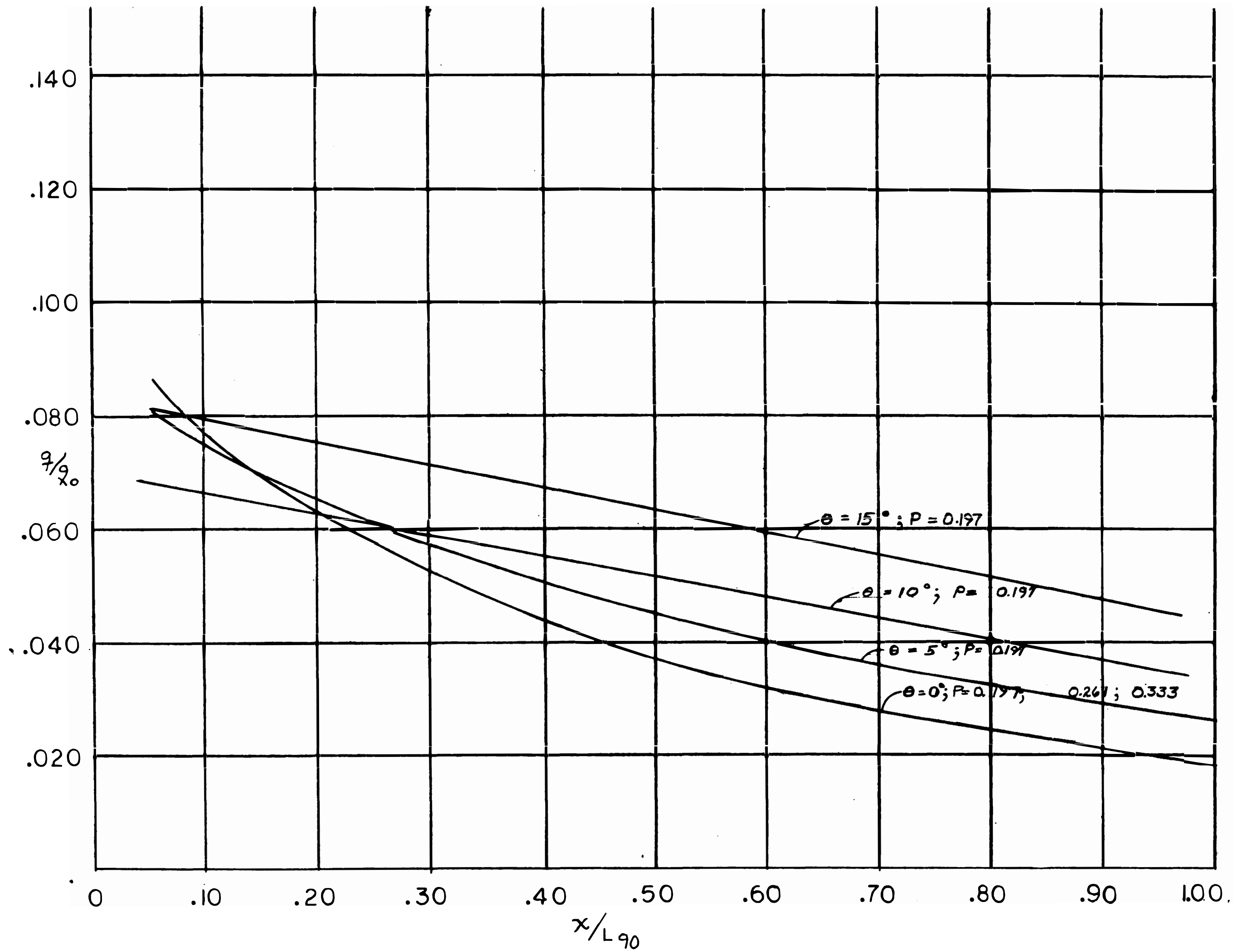


Figure 6.--Flow variation.

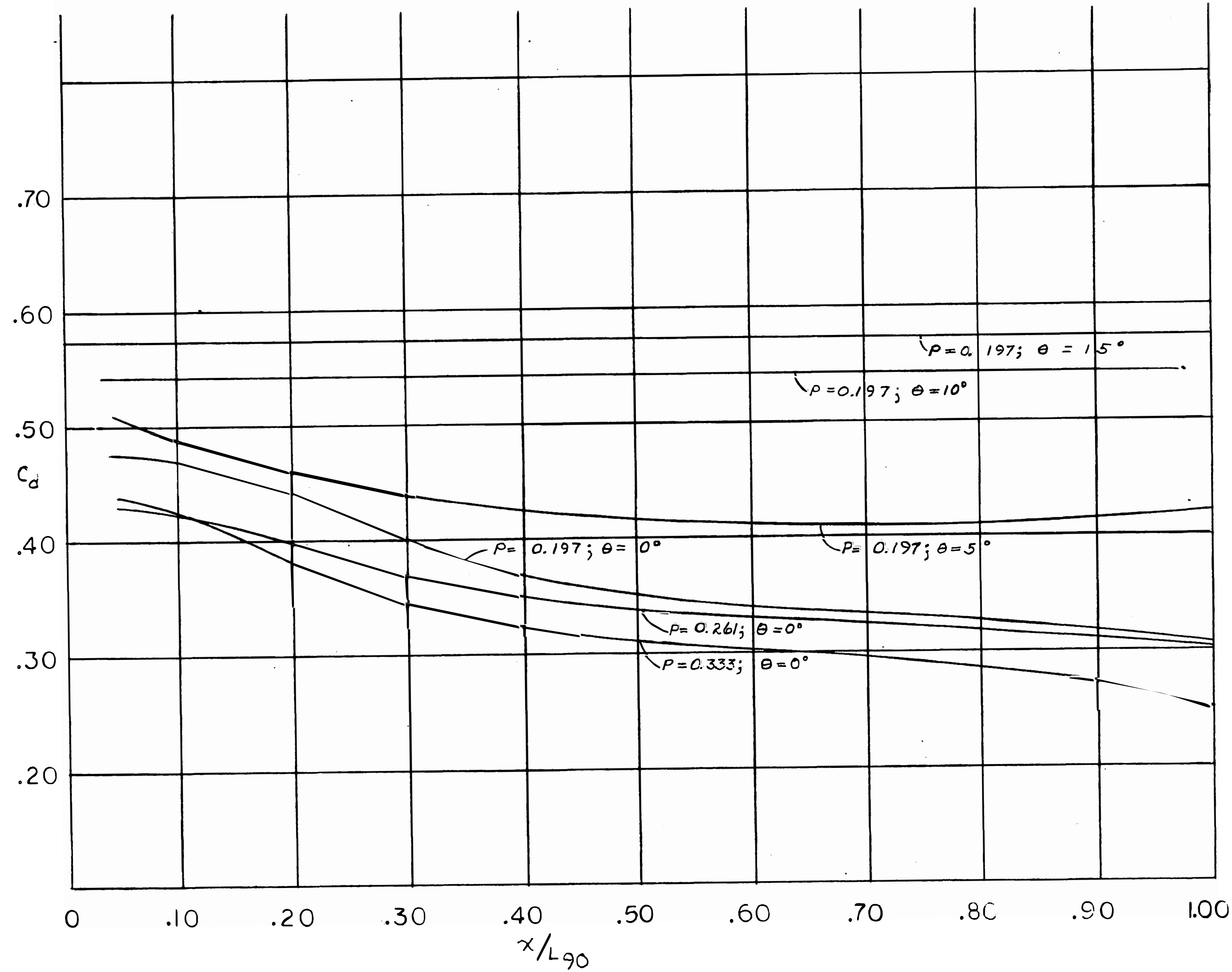


Figure 7.--Discharge coefficient.

In the next phase of the tests more attention will be given to the hydraulic characteristics at angles other than 0°, with some tests being run at 0° to compare with previous results. A number of tests will be run at 5° so that these data may be compared with that obtained at existing field installations. Also tests will be run at sub-critical flows, the advantage of the constant discharge coefficient being apparent at these angles.

TIMING, COMPOSITION, QUANTITY, AND VERTICAL DISTRIBUTION OF DEBRIS IN THE SNAKE RIVER NEAR WEISER, IDAHO--SPRING 1964

by

Robert J. McConnell

and

Gerald E. Monan

October 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

The development of a practical method for guiding and collecting downstream-migrating salmonids for safe passage around high dams may be necessary if major losses are to be avoided. A principal consideration in the design, installation, and operation of any fish guiding or collecting system is its ability to cope with debris. Because of differences in principle and design, each fish guiding or collecting system is affected differently by debris. A particular type of debris may limit the application of one system, whereas another system may not be affected or may be only slightly affected by the same material. In order to plan adequately for the collection of downstream migrants in an area, an understanding of the debris problems that will be encountered is necessary.

The objective of the research reported here was to determine the timing, composition, quantity, and vertical distribution of debris encountered in the Snake River above Brownlee Reservoir during the spring migration of downstream migrant salmonids.

MATERIAL AND METHODS

Area and Facilities

The research was conducted in the spring of 1964 in the Snake River near Weiser, Idaho, at a site where the river is approximately 500 feet wide with a relatively uniform depth of 13 feet. The study was carried out in conjunction with another research project, the objective of which was to determine the horizontal and vertical distribution of seaward-migrating juvenile salmonids in the Snake River.

The debris samples collected for this study were gathered with the same sampling nets used in the downstream migrant distribution study. The majority of the operational techniques and equipment have been described by Monan. (See "Horizontal and Vertical Distribution of Downstream Migrants, Snake River, Spring, 1964," vol. 2, Review of Progress, Fish-Passage Research Program.) Additional equipment and techniques which were used in this study are described below.

Sampling Design

The debris was sampled in a random pattern across the Snake River from April 1 to July 23, 1964. Three fyke nets, each 16 feet long with a 4- by 4-foot mouth, were used one above the other to collect the debris. Because of the vertical arrangement and size of the nets, the debris was sampled at the 0- to 4-, 4- to 8-, and 8- to 12-foot levels. The debris collected during a 1-hour sampling period once each week was separated into categories and weighed.

Sampling Procedure

The debris samples were obtained each week by placing three clean nets in one of the traps normally used to sample fish distribution and lowering them to fishing position. The nets were allowed to fish for approximately 1 hour, and then were raised clear of the water. The water velocity was measured at the mouth of each net immediately after they were lowered to fishing position and immediately before they were raised. After the nets were raised, they were labeled and taken to shore for further processing.

Each net was individually washed in a large tank fitted with a fine-mesh steel brail. After the net was cleaned, it was removed and the brail was raised from the water. The debris was then allowed to drain for 15 minutes. It was then removed from the brail, placed on a large wooden platform, and separated into five main classes: (1) woody (sticks, bark, lumber, etc.), (2) herbaceous (leaves, grass, and other soft terrestrial plants), (3) hydrophytic (moss, algae, etc.), (4) special (items that occurred in large quantities from specific sources--straw, onions, and tumbleweeds), and (5) miscellaneous (items that occurred infrequently in small quantities--silt, rocks, and manmade objects).

In order to compare the amounts of debris taken over the entire sampling period, the data were converted to pounds of debris per volume of water strained, and this information was used to determine timing, quantity, and vertical distribution.

RESULTS AND DISCUSSION

Timing

Figure 1 illustrates the debris load of the Snake River during the sampling period in relation to the river flow. The graph shows that the debris load fluctuates with the flow of the river but the peaks become less pronounced as the system is flushed by each succeeding high-water stage.

Thirty-six percent (62.0 pounds) of the total debris collected was obtained during the first sample period (April 1, 1964). This period coincides with the first high water of the of the 1964 season. Observations by other researchers working in this area indicated that the debris load of the Snake River was relatively light prior to April 1, 1964.

Composition

As previously mentioned, the debris was grouped into five categories. Table 1 shows the composition of the debris load in the Snake River for each sample day and the entire sampling period. The total debris collected during this period was approximately 20 percent woody, 41 percent herbaceous, 11 percent hydrophytic, 20 percent special, and 8 percent miscellaneous.

The items in the special category occurred in relatively abundant quantities during specific conditions caused by high flow, wind storms, or agricultural practices. For example, straw was very abundant during the first high water. Apparently, the straw had been flushed from flooded fields and gravel bars where cattle had been fed during the winter. Tumbleweeds occurred during wind storms throughout the test period. Onions were found in one sample when irrigation ditches were cleaned prior to the watering of fields.

Composition data presented here do not reflect objects that were too large to enter the nets. However, during 1½ hours of observation on April 1, 1964, several large objects such as trees, lumber, etc. floated past the sampling area. Similar large debris was recognized as being relatively abundant throughout the season. Ice is not included in this report as the main ice flow was reported to have gone out of the river during February of 1964.

Quantity

During the sixteen 1-hour sample periods, a total of 7,945,751 cubic feet of water was strained by the sampling nets. In this same period, 173 pounds of debris was collected. This represents an average of 0.2 pounds of debris for each 10,000 cubic feet of water strained.

The highest quantity of debris during any 1-hour sampling period was collected on April 1, during the first high water of 1964. During the season, the amount of debris ranged from a high of 1.17 pounds per 10,000 cubic feet of water strained to a negligible amount during the latter part of July (fig. 1).

Table 1.--The composition of the debris load in the Snake River near Weiser, Idaho, April 1 to July 23, 1964, shown by percentage of the daily sample. The overall composition for the entire sampling period is also shown.

Date of Sample		Composition of debris					
		Woody	Herbaceous	Hydrophytes	Special	Miscel- laneous	Sample weight
		Percent	Percent	Percent	Percent	Percent	Pounds
April	1	16.8	44.7	5.6	28.9	4.0	62.0
	8	21.9	34.3	40.0	0.0	3.8	10.5
	19	9.6	23.1	50.0	13.5	3.8	5.2
	26	8.5	22.1	10.6	49.1	9.7	22.6
May	3	31.4	43.8	12.4	7.6	4.8	10.5
	11	17.0	35.8	34.0	9.4	3.8	5.3
	18	29.0	59.7	6.5	0.0	4.8	6.2
	24	45.3	42.4	6.6	0.0	5.7	10.6
	31	6.1	48.4	17.2	21.2	7.1	9.9
June	11	25.0	45.8	0.0	20.9	8.3	2.4
	18	50.0	45.0	0.0	0.0	5.0	10.0
	25	22.7	42.8	0.0	5.1	29.4	11.9
July	2	12.9	67.8	0.0	16.1	3.2	3.1
	9	0.0	45.0	0.0	0.0	55.0	2.0
	17	0.0	0.0	0.0	0.0	100.0	1.0
	23	0.0	0.0	0.0	0.0	0.0	0.0
Entire sampling period		20.3	40.8	10.7	20.0	8.1	173.2

Vertical Distribution

The debris collected during the entire sampling period was taken as follows: 41 percent from the top 4 feet, 26 percent from the area between 4 and 8 feet of depth, and 33 percent from the 8- to 12-foot level.

The vertical distribution of each class of debris is shown in figure 2. The woody and special classes were found primarily in the surface net, the hydrophytes were taken mostly in the bottom net, and the herbaceous and miscellaneous classes were collected in similar amounts in all three nets.

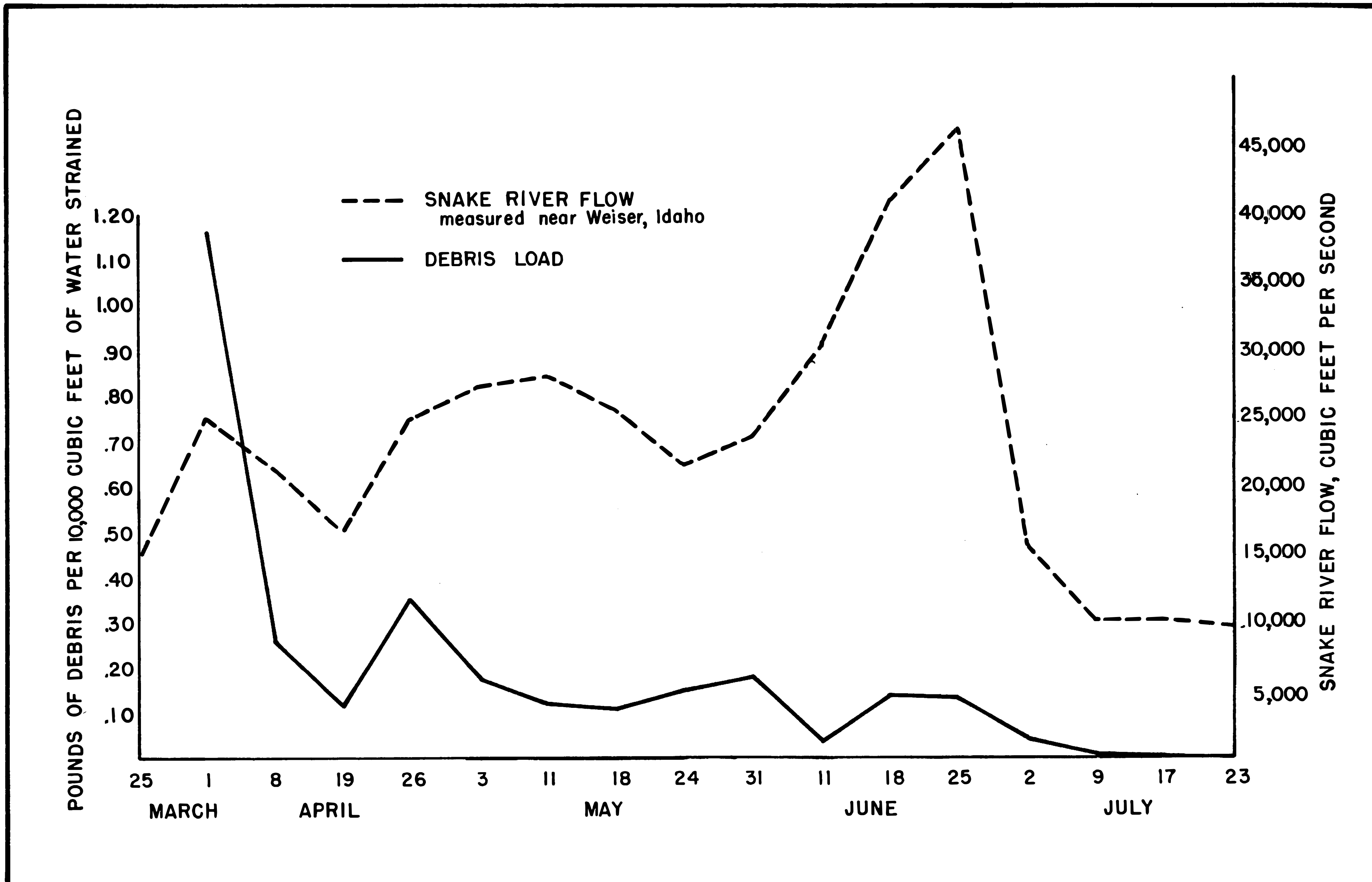


Figure 1.--The debris load in relation to the flow of the Snake River during the sampling period.

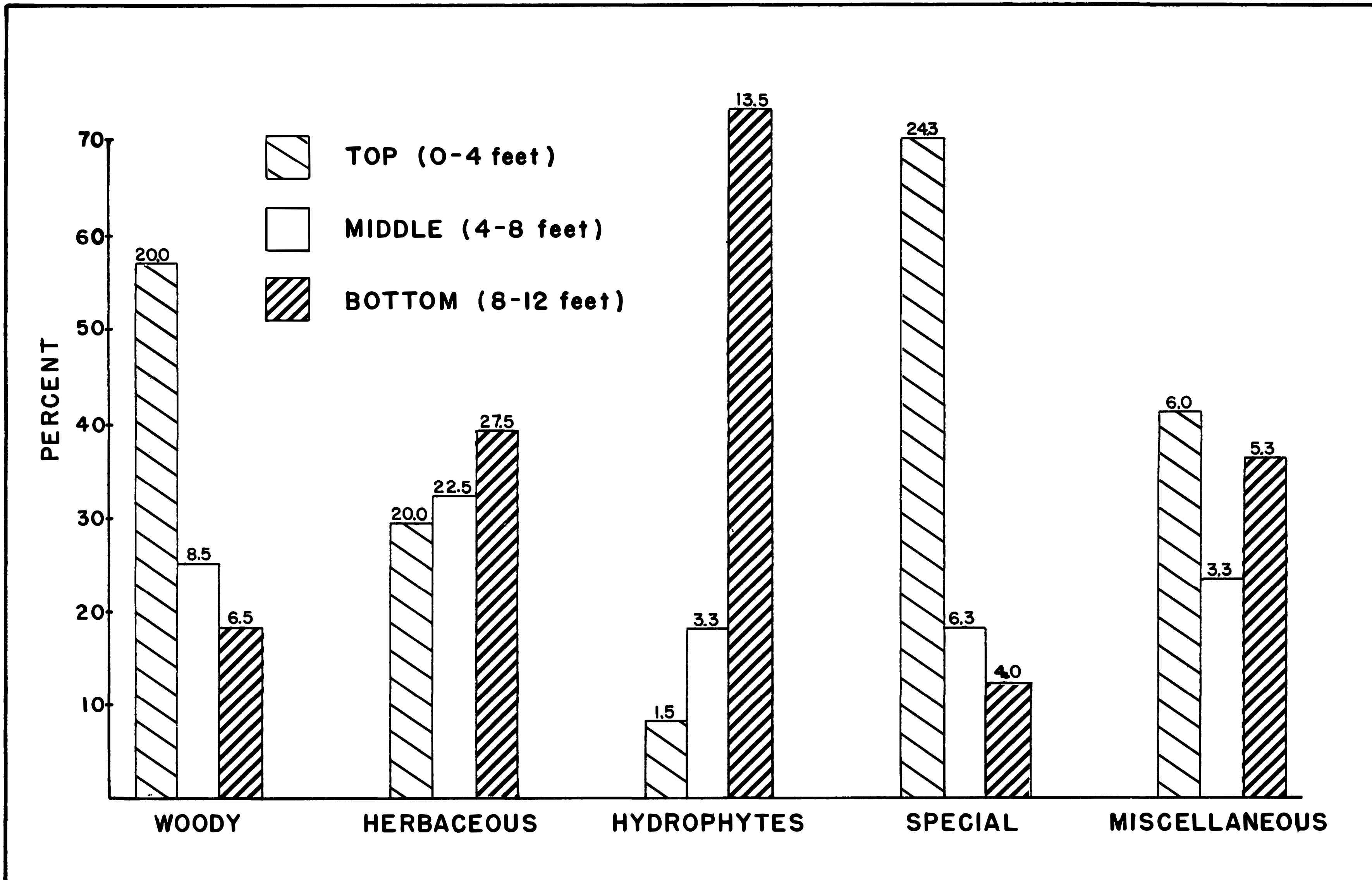


Figure 2.--The vertical distribution of each of the five classes of debris shown by percentage of season's collection. The pounds of debris (that each bar represents) is indicated by numerals above each bar.

The vertical distribution of each sample over the entire sampling period is shown in figure 3. The river flow during this period is also shown. During the early portion of the sampling period, the debris was usually most abundant near the surface in times of increasing flow, but as the flow decreased, the highest concentration of debris was near the bottom of the river. Once the major concentrations of debris were flushed from the river by the early high-water stages, the debris was generally more concentrated near the bottom of the river.

CONCLUSIONS

1. The highest concentration of debris occurs during the first high water.

2. The amount of debris fluctuates with the rise and fall of the river. The range of fluctuation decreases as the loose material along the banks is removed by each successive flushing.

3. Herbaceous material is the most common when debris in the Snake River is placed into five principal categories: woody, herbaceous, hydrophytic, special, and miscellaneous.

4. Debris in the Snake River is a representative cross section of a wide range of materials from algae to parts of buildings.

5. Agricultural practices along the Snake River have a definite influence on the composition of debris.

6. Debris is distributed throughout the water mass. However, the distribution pattern varies according to the time of year and the river flow.

7. Because of such varied conditions as weather, snow pack, agricultural practices, etc. that influence the timing, composition, quantity, and vertical distribution of debris, only general standards will hold true from year to year.

8. The flushing of debris in the middle Snake River takes place when an abundance of downstream migrant salmonids are present. For this reason, debris handling capability must be a major consideration in the design of any proposed downstream migrant guiding or collection facility for the middle Snake River.

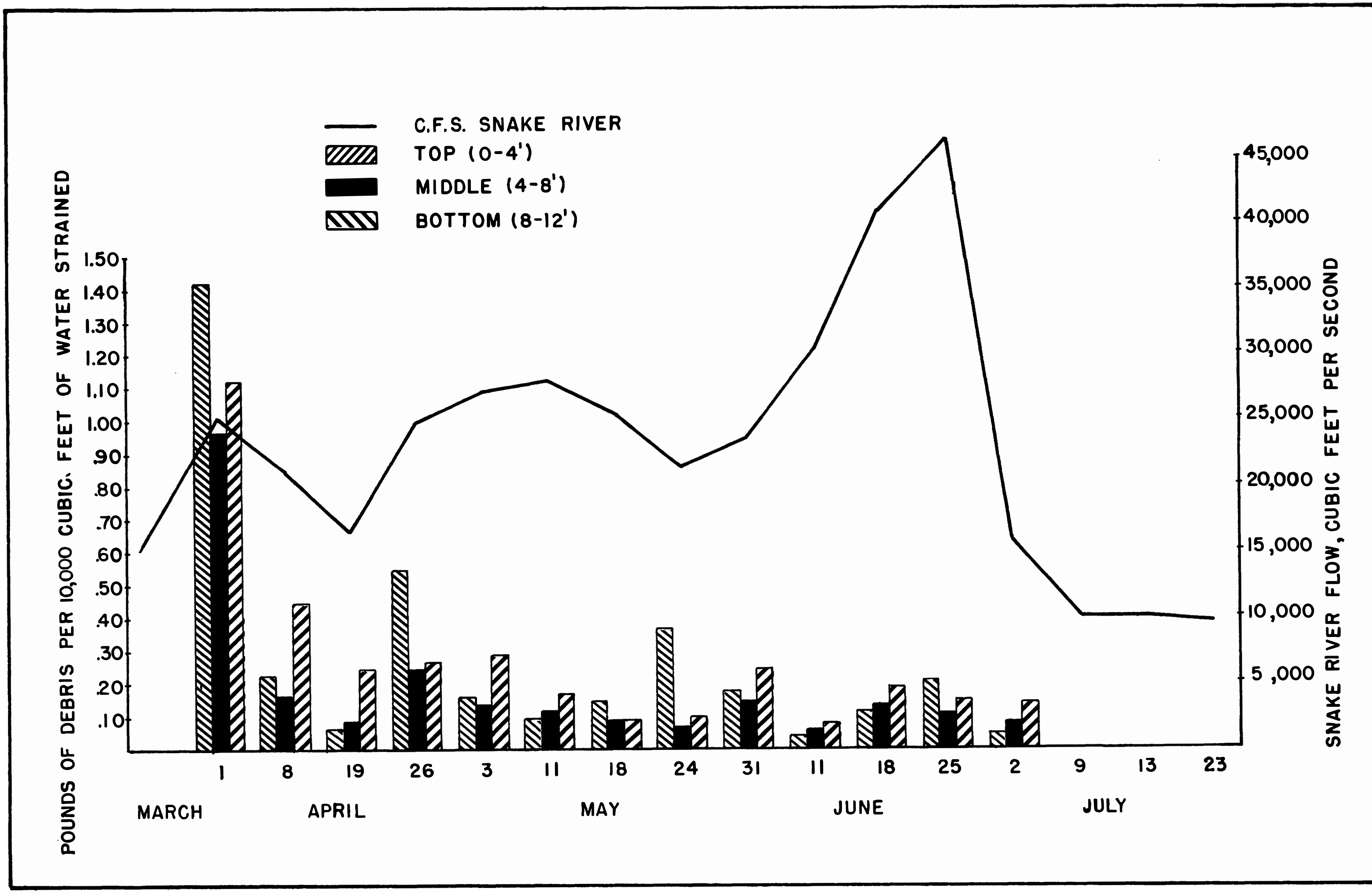


Figure 3.--The vertical distribution of debris in relation to river flow.

HORIZONTAL AND VERTICAL DISTRIBUTION OF DOWNSTREAM MIGRANTS, SNAKE RIVER, SPRING 1964

by

Gerald E. Monan

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

Research is presently being carried out on several types of guidance and collection systems for juvenile salmonids. To date, no one device has been developed that has universal application. In order to determine what type of collector may be applied in each problem area, many factors must be considered. One of the most important considerations in each potential installation is the distribution of the migrants within the water mass to be strained.

The objective of the research reported here was to determine the vertical and horizontal distribution of downstream migrant salmonids at a site in the Snake River above Brownlee Reservoir with the specific aim of locating an area where the migrants were naturally concentrated.

MATERIALS AND METHODS

The research site located near Weiser, Idaho, was chosen for two principal reasons: (1) It is in a potential collection area for migrants prior to their entry into Brownlee Reservoir, and (2) it is located at the downstream end of a sharp bend in the river where hydraulic conditions might tend to concentrate the migrants.

Three identical electrified traps were used in the study (fig. 1). Each trap has two main components: the barge and the nets. One set of electronic equipment was used to operate all three barges.

Barges

The barges were approximately 28 feet long and 11 feet wide (fig. 2). Two metal-covered styrofoam pontoons provided the flotation. The pontoons were parallel to each other and separated by a 5-foot 10-inch opening. This opening was decked over at the front and rear to provide work space and also to fasten the two pontoons together as a unit. Two 55-gallon drums of water were mounted on the downstream end of each pontoon to provide ballast. This ballast kept the front of the pontoons from sinking into the water due to the drag of the nets.

A large frame, constructed of heavy duty aluminum "I" beams, held the nets between the pontoons. The frame was approximately 27 feet high and 5 feet wide. This frame could be extended down into the water to three different depths: 8 feet, 12 feet, or 14 feet. The frame could also be pivoted forward

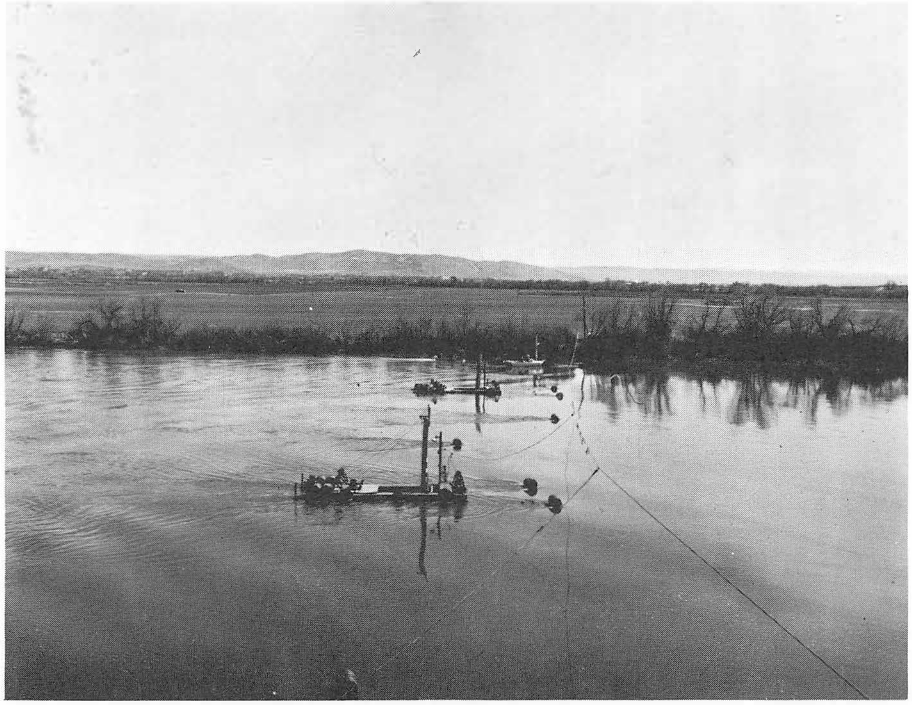


Figure 1.--Fish traps in operation during downstream migrant distribution study in the Snake River near Weiser, Idaho.

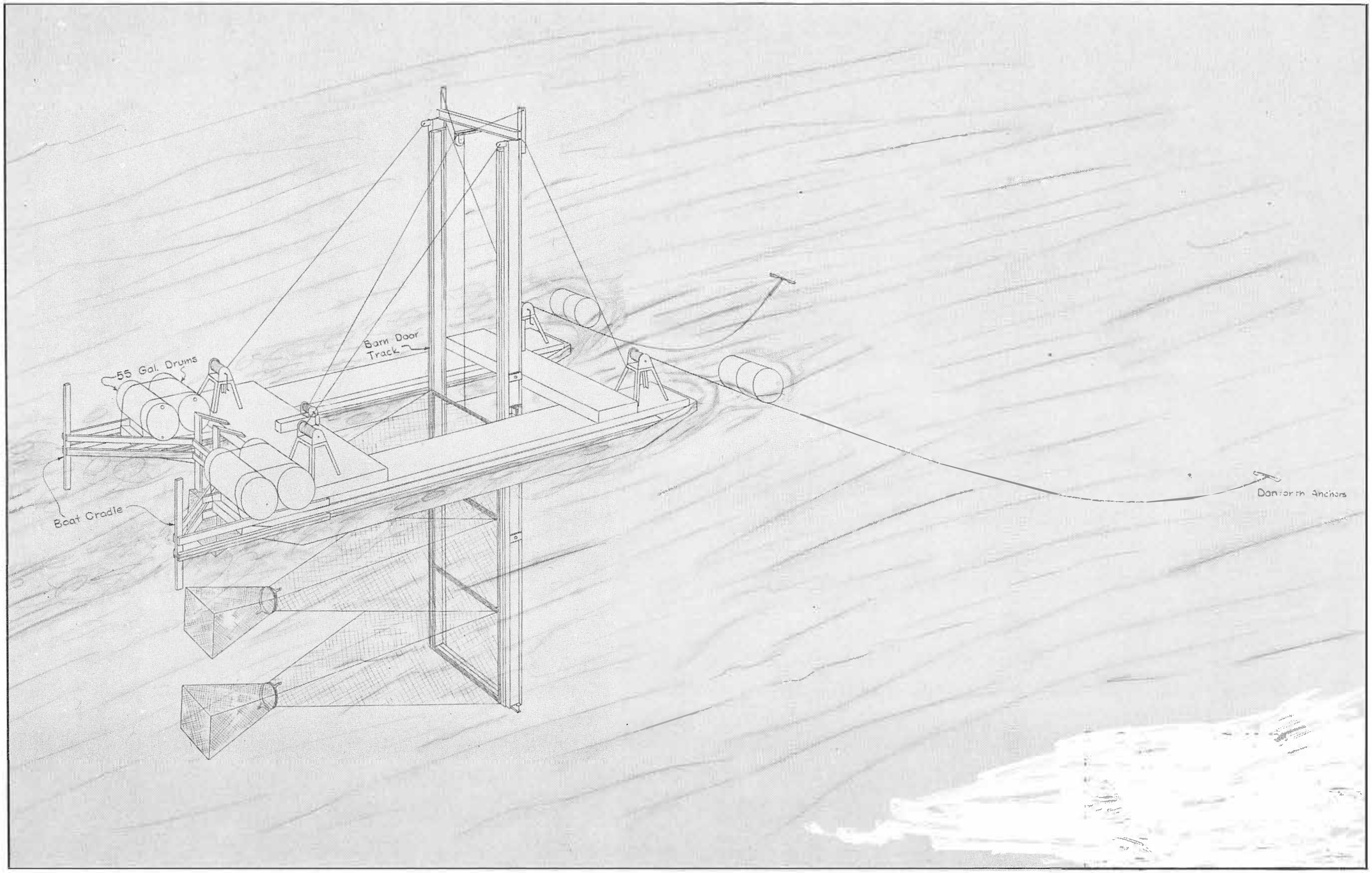


Figure 2.--An electric-fyke trap anchored in the river with its nets lowered into fishing position.

easily, so it would lie almost parallel with the water surface. In this configuration the barges had a shallow draft and presented a minimum of resistance to the flow. This was an important factor when moving the barges.

A trolley track was fastened to each leg of the frame to serve as a guide for the nets. The nets were attached to metal frames equipped with rollers that fit into the track. The nets could be lowered to, or raised from, the desired fishing level by means of a winch and cable system.

Nets

The nets were built in two sections. The front portion was made of knotted nylon webbing (7/8-inch stretched measure). This net was 4 feet square at the mouth, 12 feet long, and tapered to a 16-inch circle at the downstream end. The cod end or bag portion was made of knotless nylon webbing (1/2-inch stretched measure). It was 16 inches in diameter at the mouth, 4 feet long, and enlarged to a 2-foot by 2-foot square at the downstream end. The two nets were joined together by clamping them to an electrode unit. This made the cod ends easily removable and facilitated cleaning and fish handling.

Electrical Equipment

The electrodes were made of stainless steel plate. Each electrode was 18 inches long by 16 inches wide. They were bent to an 8-inch radius along the 16-inch dimension. The electrodes were fastened to, but electrically insulated from, a heavy metal band, 50 inches in circumference and 2 inches wide (fig. 3). The electrodes were attached to the band with the negative electrode extended upstream and the positive electrode extended downstream. While fishing, the electrodes were energized with 125 volts of rectified alternating current. The electrical field was pulsed with a frequency of 60 pulses per second with each pulse having a duration of 4-1/6 milliseconds.

The electronic pulsing equipment and power source were located on shore and the electricity was transmitted to the barges by overhead wires. A 10-kilowatt, gasoline driven generator provided the power for the electrodes and for the work lights on the rafts.

Procedure

The river at the research site was approximately 500 feet wide. The bottom was relatively uniform and the water was

Figure 3.--Cod end of the net being slipped over the electrode prior to clamping it to the lead portion. Gloved hand is grasping negative electrode in the net.

approximately 13 feet deep across the entire river. The daily mean river flow during the study ranged from 16,700 to 29,700 cubic feet per second and averaged 24,414 c.f.s. Water temperatures taken 2 feet below the surface each day at noon in the middle portion of the river ranged from 46 to 60 degrees Fahrenheit and averaged 53° F. For analyzing purposes, the river was divided longitudinally into thirds. Three sections were sampled within each third, thus giving us nine sampling stations across the river. Each barge was assigned a third of the river and moved from station to station within this third in a randomized sampling program. Ten single drum-floats were anchored in the river to provide constant anchor points for the rafts at each of the nine fishing locations.

Each sampling day began at 2:00 p.m. and continued until 11:00 a.m. the following day. At 2:00 p.m. the nets were lowered and fished for approximately 1 hour. The nets were then raised, the fish removed and processed, and the nets cleaned and prepared for the next fishing period. The cleaning and processing of all the nets took about 1½ hours. The nets were alternately fished and cleaned in this manner until approximately 11:00 a.m. the following day. Between 11:00 a.m. and 2:00 p.m. the barges were moved to their next scheduled fishing position and routine maintenance was performed in preparation for the new sampling day.

Trapping was conducted in 3-day cycles. During each cycle all nine sampling stations were fished 1 day. Each raft fished three nets, one above the other, to sample the vertical distribution at each station. The water velocity was measured at the mouth of each net immediately after it was lowered and immediately before it was raised. A measure of the conductivity, turbidity, and temperature of the water was also made for each fishing period.

RESULTS AND DISCUSSION

The distribution of the migrants was analyzed by two measures of fish abundance: (1) The numbers of fish per volume of water strained, and (2) the numbers of fish per unit of time. The distribution figures shown are based upon the combined catches of chinook salmon, silver salmon, and steelhead trout. Distribution by species and the correlations between fish distribution and the many variables such as velocity, fish size, water temperature, etc. have been programed for electronic data processing. However, the analyses have not been completed at this time.

Horizontal Distribution

The horizontal distribution of the migrants is shown in figure 4. This graph indicates the fish were distributed completely across the river with somewhat fewer fish in the middle third of the river than in each of the other thirds. This general pattern was true for all periods of the day (dawn, daylight, dusk, and dark).

Vertical Distribution

The vertical distribution of the migrants at each of the nine trap locations and for the total width of the river in this area is shown in figures 5 and 6. Figure 5 is based on the number of fish caught per unit of water strained, whereas figure 6 is based on the number of fish caught per unit of fishing time. Generally speaking, the vertical distribution was similar for all nine locations. The largest percentage of fish was located in the top 4 feet of water (approximately 60 percent) and the smallest percentage in the bottom layer of the river. Considering the overall catch for the entire width of the river, the top two nets captured approximately 84 percent of the salmonids. The general pattern of the top net catching the most salmonids and the bottom net the least was true for all periods of light (dawn, daylight, and dusk). However, there was a shift in the vertical distribution during the hours of darkness. Between 10:00 p.m. and 4:00 a.m. only 30 percent of the salmonids were captured in the top net, while 70 percent were taken in the bottom two nets (middle net--29 percent, bottom net--41 percent).

CONCLUSIONS

1. Downstream migrant salmonids were distributed throughout the river mass.

2. The majority of the downstream migrants were found in the top 4 feet of water.

3. The vertical distribution of migrants is altered by darkness. During the hours between 10:00 p.m. and 4:00 a.m. the majority of the migrants prefer the bottom 8 feet of water.

4. The salmonids were distributed somewhat evenly across the river despite the location of the site on the terminal end of a sharp bend in the river.

5. In order to efficiently collect the downstream migrant salmonids from this area of the middle Snake River, it appears that the entire water mass would need to be strained in some manner.

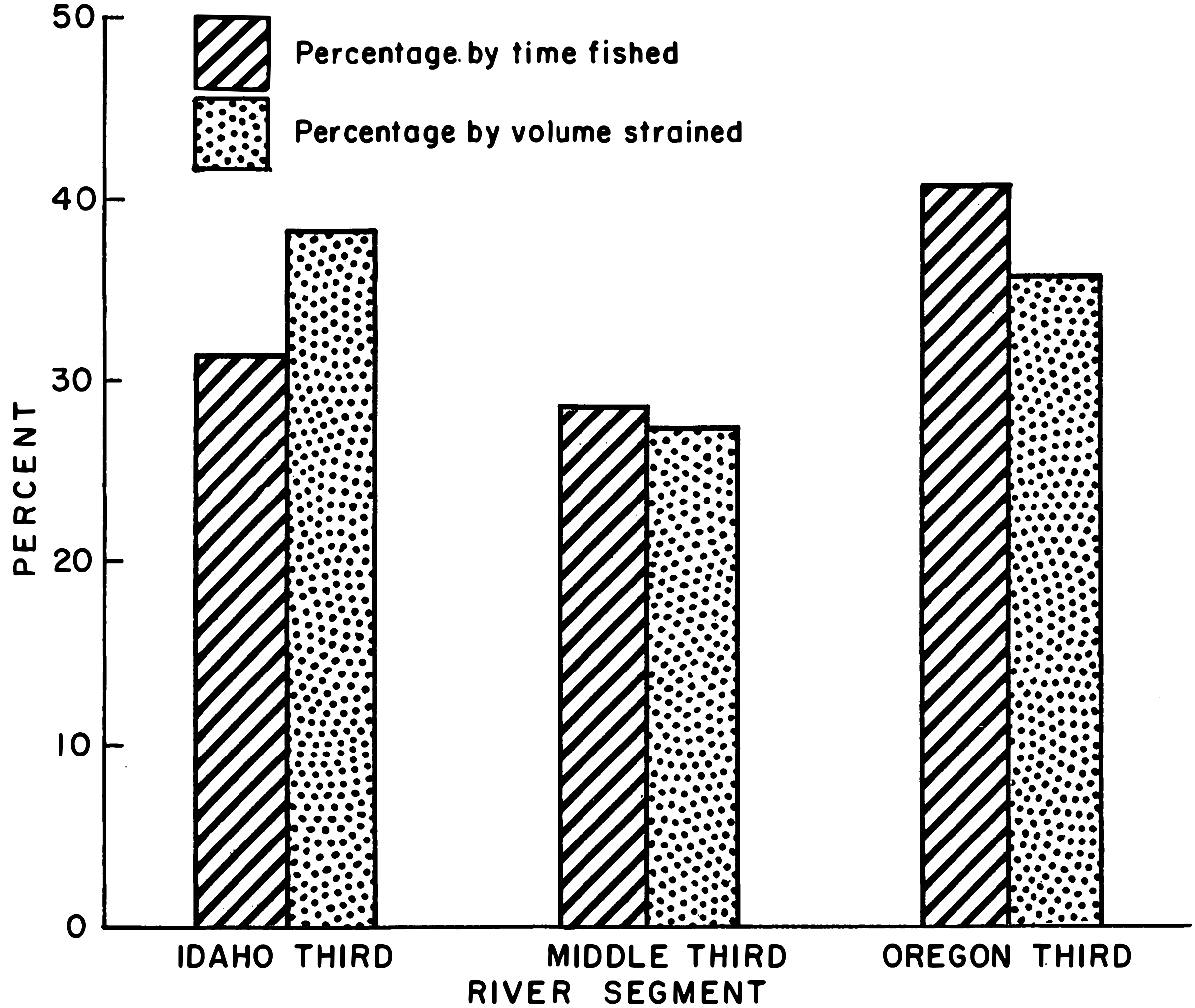


Figure 4.--Horizontal distribution of salmonids captured by electric-fyke nets, expressed in percentage.

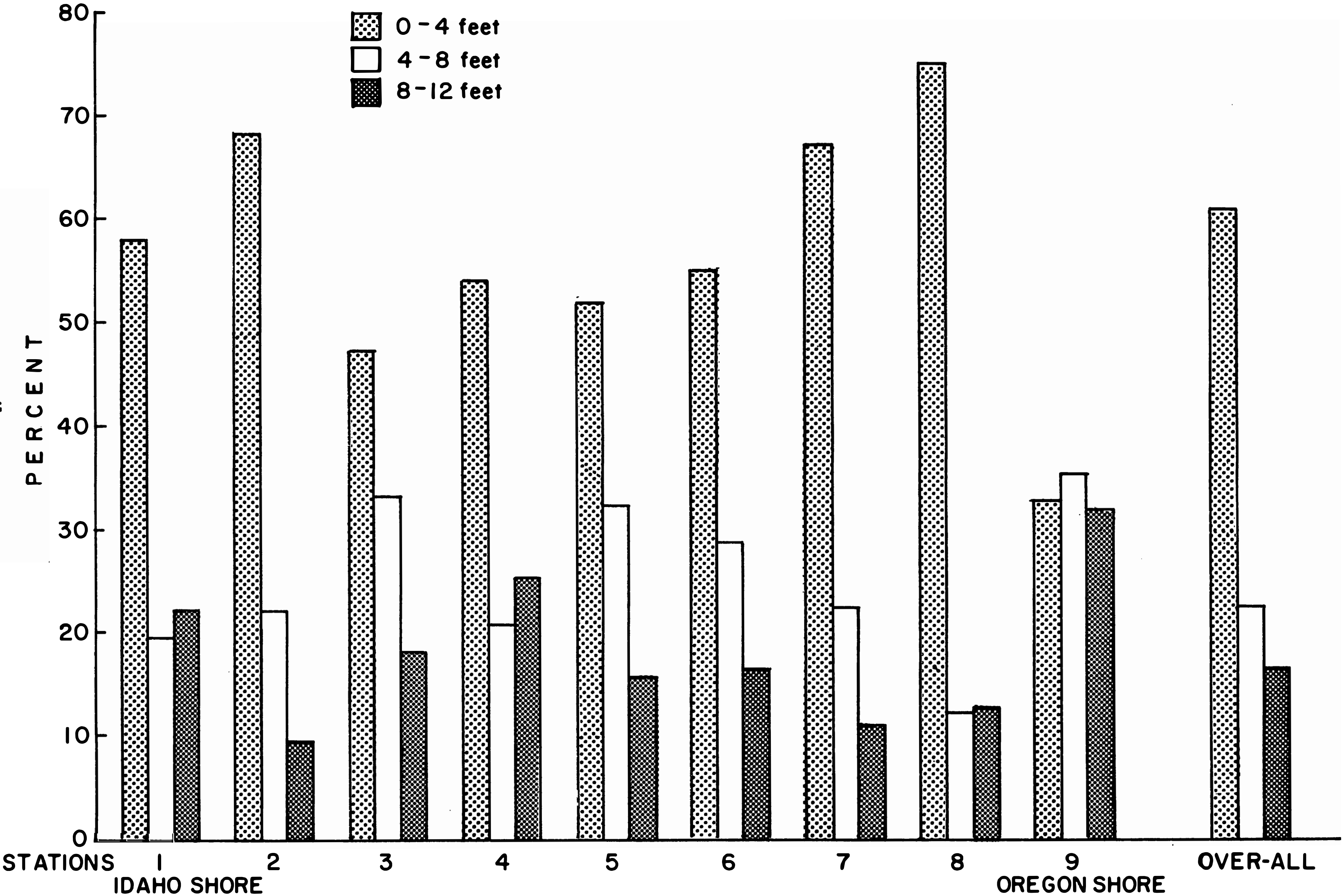


Figure 5.--Vertical distribution of the salmonids captured in electric-fyke nets at each station based on the volume of water strained and expressed in percentage.

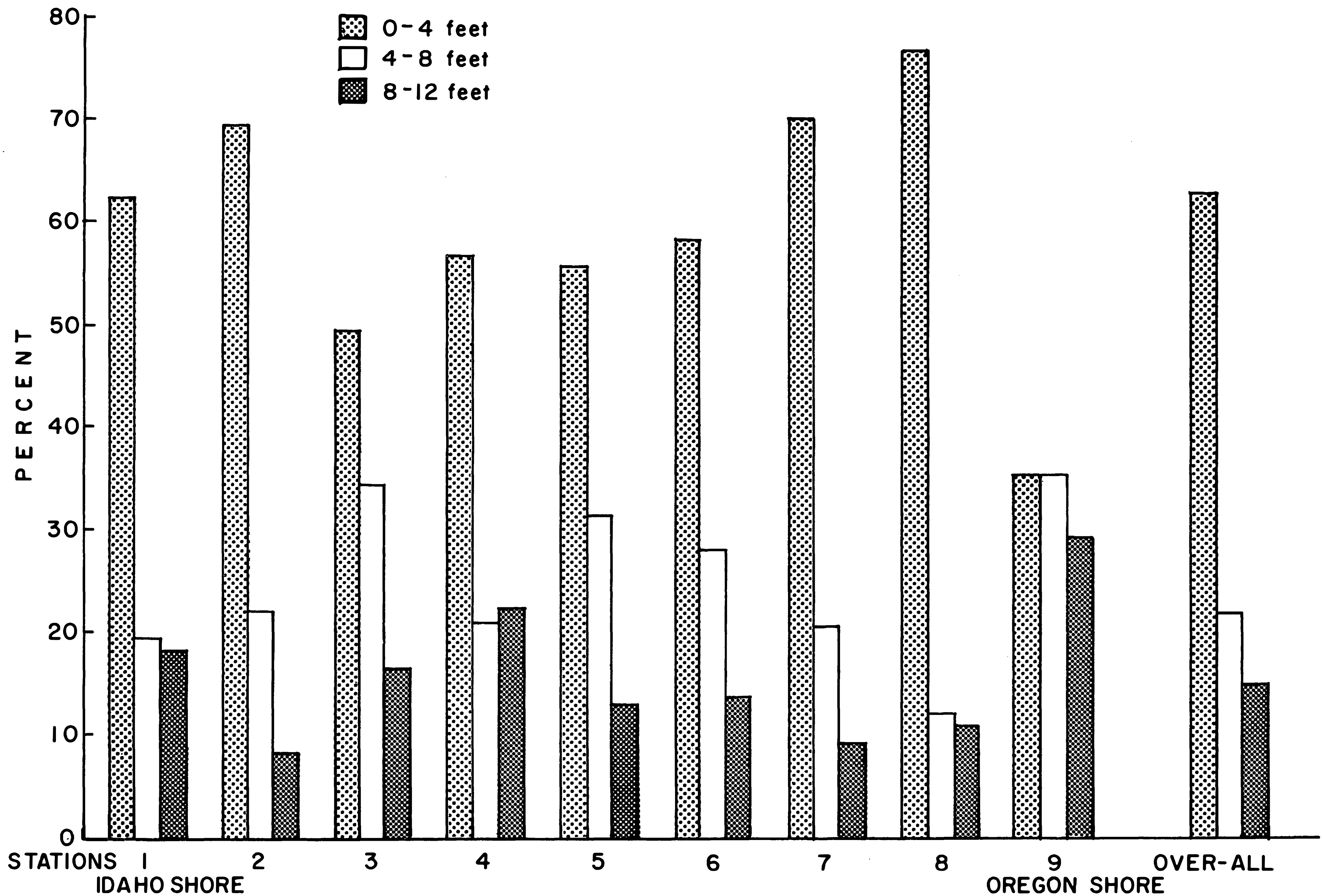


Figure 6.--Vertical distribution of the salmonids captured in electric-fyke nets at each station based on fishing time and expressed in percentage.

VELOCITY MATCHING TRAVELING SCREENS FOR JUVENILE MIGRANT COLLECTION

by

Daniel W. Bates

and

John G. VanDerwalker

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

In the search for a practical method for collecting juvenile salmonids from rivers and streams, many plans have been conceived and tested. None of these, however, have been able to cope successfully with the high flows and debris of a major river in flood without excessive cost. In an attempt to eliminate the need for expensive structures capable of withstanding high flow velocities, a method of guiding fish by the use of suspended velocity-matching visual references was proposed by Long[1/]. The system would utilize moving visual references traveling diagonally across the stream similar in concept to those described by Brett (1958) but moving in a downstream direction at a rate equal to the downstream velocity of the stream. The velocity-matching aspect of the system would actually permit the guiding of fish in stream velocities greater than the maximum swimming speed of the fish.

Because the degree of guiding efficiency that might be expected with moving visual references in turbid, turbulent water was questionable, the velocity-matching concept was extended by the authors for use with a traveling screen that appeared to give promise of greater guiding effectiveness. The following account describes the fabrication and operation of two velocity-matching traveling screens that were installed for test purposes in the behavioral flume at Carson, Washington; reports on the guiding efficiency obtained; and discusses future potential of the method.

EQUIPMENT AND PROCEDURE

Experimental Flume

The Carson behavioral flume (fig. 1) measures 50 feet long, 6 feet wide, and 4 feet deep. The flume floor has only sufficient slope to facilitate drainage. To allow observation of fish response, a clear plastic window 3.5 feet high and 6 feet long was installed on one side near the downstream end of the flume.

At the downstream end of the flume a perforated plate inclined screen and trap (fig. 2) were installed to recapture

---

1/ Long, Clifford W. The use of velocity-matching visual references in guiding fish. Manuscript in preparation.

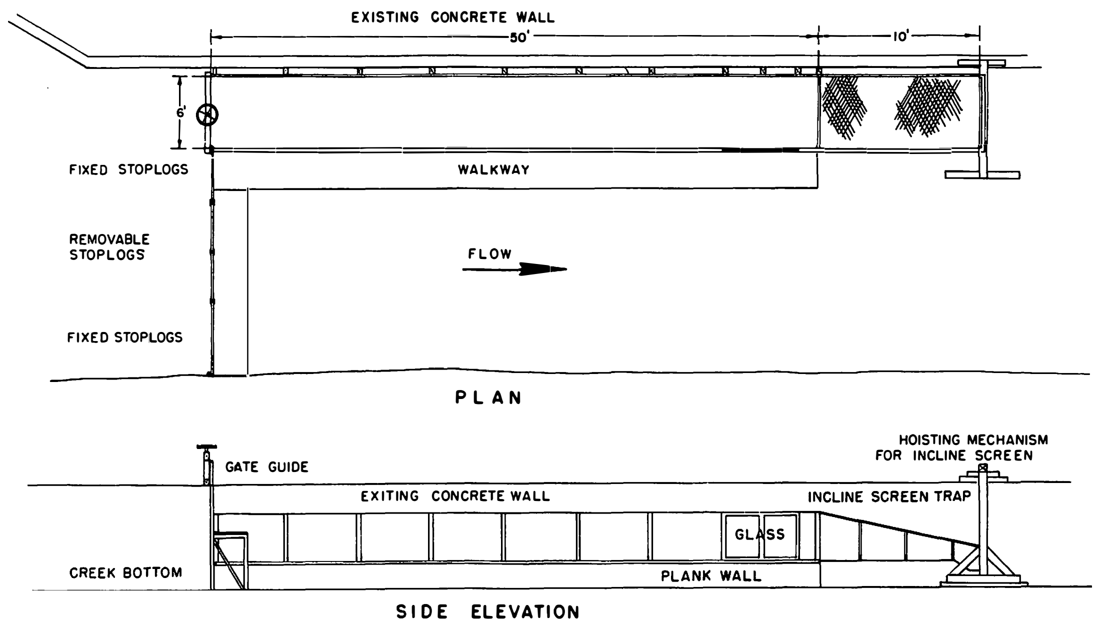


Figure 1.--Diagrammatic sketch showing both plan and elevation of Carson behavioral flume.

Figure 2.--The Carson flume with inclined-screen traps in foreground.

test fish from which a deflection efficiency could be determined. In most cases all released fish would pass immediately downstream; those remaining upstream were not included in the deflection efficiency determination. A bypass was provided for fish guided by the facility.

A continuing source of crystal-clear water for the flume was provided by Tyee Springs originating several thousand feet away from the structure. By means of stoplogs this flow of water (45 c.f.s. maximum) could be directed completely, or in part, into the flume. Water temperatures ranged between 46° and 52° F.

Velocity was controlled by means of stoplogs positioned at the downstream end of the flume. Although an average head of approximately 24 inches prevailed most of the time, a maximum head of 36 inches could be developed. Any velocity up to a maximum of 3.2 feet per second could be secured through appropriate setting of the stoplogs. Velocity readings taken throughout the flume indicated a relatively uniform flow.

Experimental Apparatus

Two different designs of velocity-matching traveling screens were tested in the Carson flume. Each system was composed of four main parts: the drive unit, the suspension or tracking unit, the stationary screen supports, and an endless screen belt.

The drive unit (fig. 3) was made up of a variable speed d.c. motor and reduction gear, pocket sheaves, and a drive chain. A 1-horsepower motor with a reduction gear which allowed a range of 10 to 170 revolutions per minute was used in both systems. A pocket sheave with a 22¼-inch circumference which accommodated a 17/64-inch hand chain was mounted on the drive shaft of the reduction gear. The maximum speed attained by the chain using this drive unit was 5 f.p.s.

The pocket sheave on the drive shaft, along with all other sheaves used in the installation had two notches cut in the bottom rim to allow the hangers which supported the screen to pass around them. Figure 3 shows the pocket sheaves and chain with hangers for mounting the screen. These hangers were made by welding a 5/16-inch eye bolt to every 10th and 22nd link in the chain.

A track was provided to guide and support the chain as it traveled between the sheaves. Figure 4 shows the track with the chain fitted into it. During operation these tracks were liberally greased to allow the chain to slide smoothly over them.

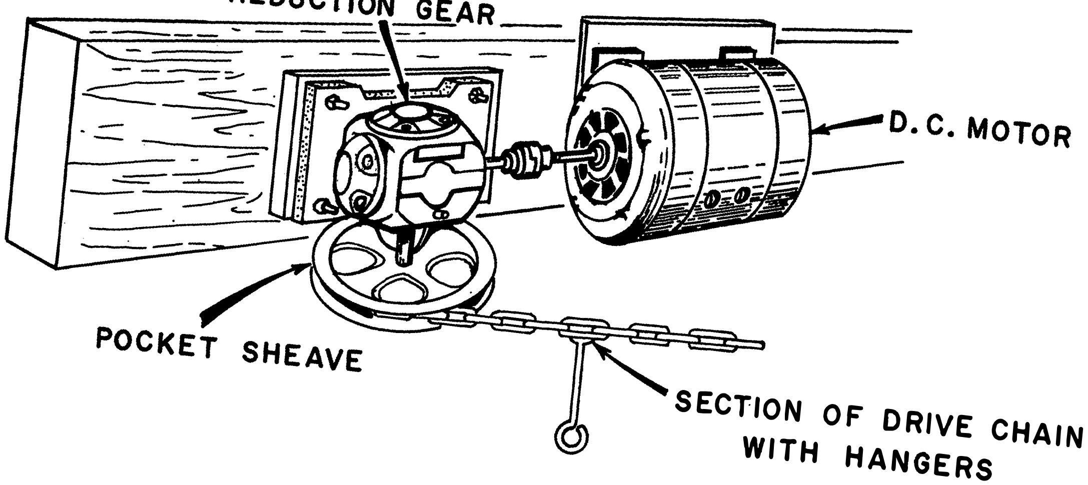


Figure 3.--Sketch of variable-speed d.c. motor and reduction gear drive assembly.

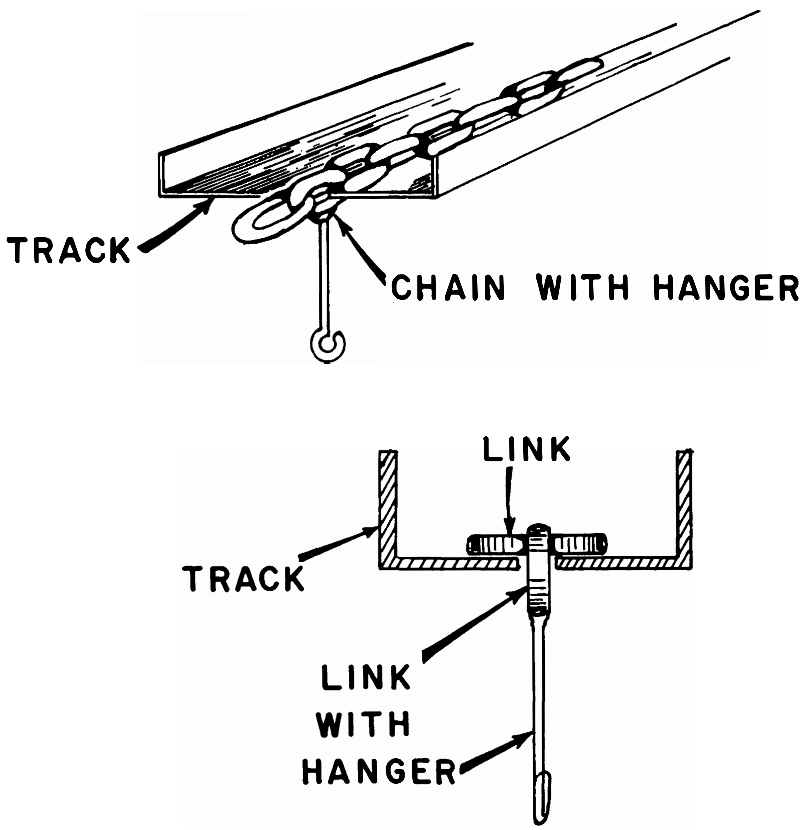


Figure 4.--Sketch of drive chain support and guide.

The screen was a 36-inch wide endless belt constructed of 1/4-inch round spiral-weave screen (commonly used in fireplace screening) and 1/8-inch by 1-inch flat-bar steel brackets (fig. 5). The brackets were bolted to the top edge of the screen at intervals which corresponded to the hangers on the chain. These brackets had a hole drilled in the top so they could be attached to the drive chain with "S" hooks. To make a more flexible joint, these "S" hooks were later replaced with size 14 brass single-jack chain loops. Every fourth bracket extended to the bottom of the screen to serve as support to stiffen the screen and prevent it from sagging.

Additional support for the screen was provided by constructing two stationary rails, or curbs, on the downstream side parallel to the leading face of the screen (fig. 5). These curbs, constructed of 1-inch strap iron, prevented the screen from being swept downstream and away from the floor by the water current. The bottom curb, located on the floor, also prevented fish from passing under the screen in case it was not in contact with the bottom at all times. The ends of the curbs were rounded so they would not snag the screen as it traveled around them.

<u>Model I.--A</u> plan view of the first velocity-matching traveling screen is shown in figure 6. The continuous belt screen traveled from the upstream end (A) to the entrance of the bypass (B) on a 20^{o} angle to flow (ABE). This portion of the screen which was supported by the two stationary rails moved at approximately the same speed as the water.

As the screen traveled from B to C it passed a rubber seal which rested against it, forming a flexible joint between the bypass wall and the screen (fig. 7). This seal prevented any fish loss at this point. To form the screen as it passed from B to C and to hold it against the rubber seal, two 7-inch pulleys mounted on a vertical shaft were placed on the side of the screen opposite the seal. This shaft also had the downstream pocket sheave attached to it.

After passing through the downstream seal, the screen traveled upstream against the current to point D. There was no support for this portion of the screen and it tended to be swept up off the floor by the water current. From D the screen went around the upstream sheave to A where it passed by another seal similar to the downstream one. At the top traveling speed of 5 f.p.s., any point on the screen could make a complete circuit in 5.5 seconds.

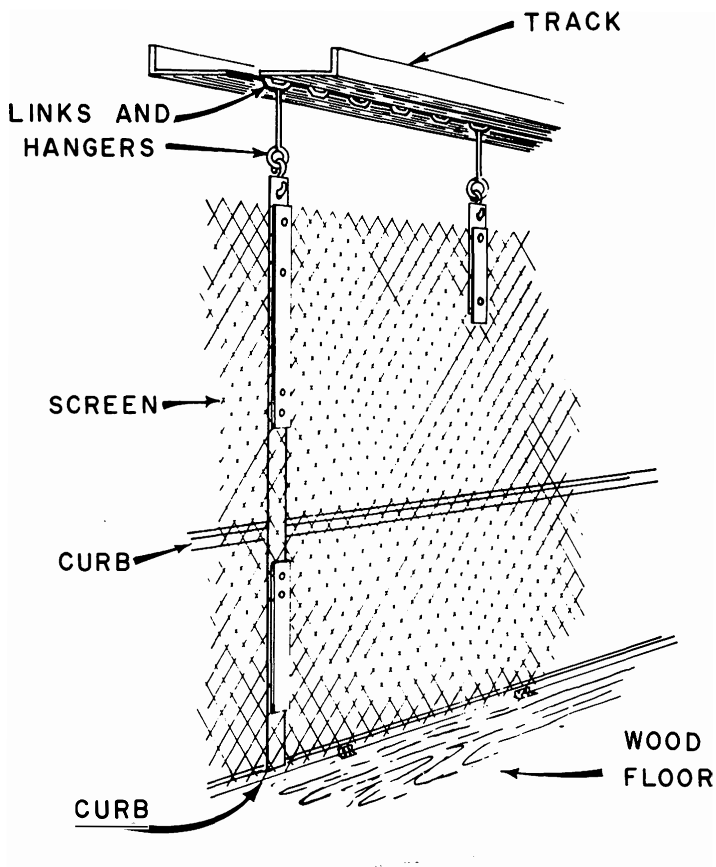
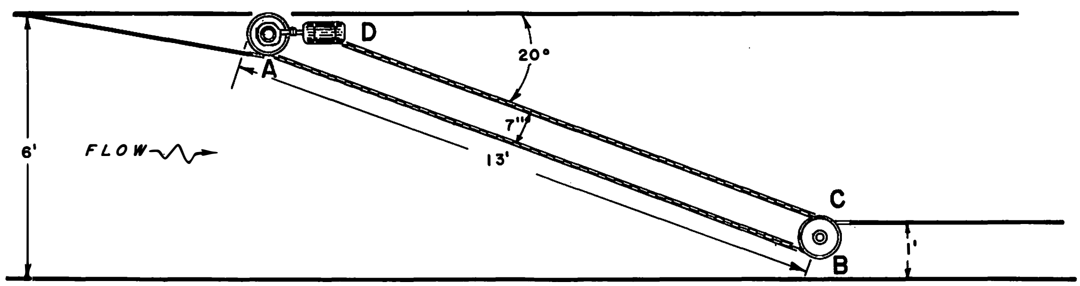


Figure 5.--Sketch of screen and 1-inch flat bar bracket attachments.



6

Figure 6.--Diagrammatic sketch of Model I velocity-matching traveling screen.

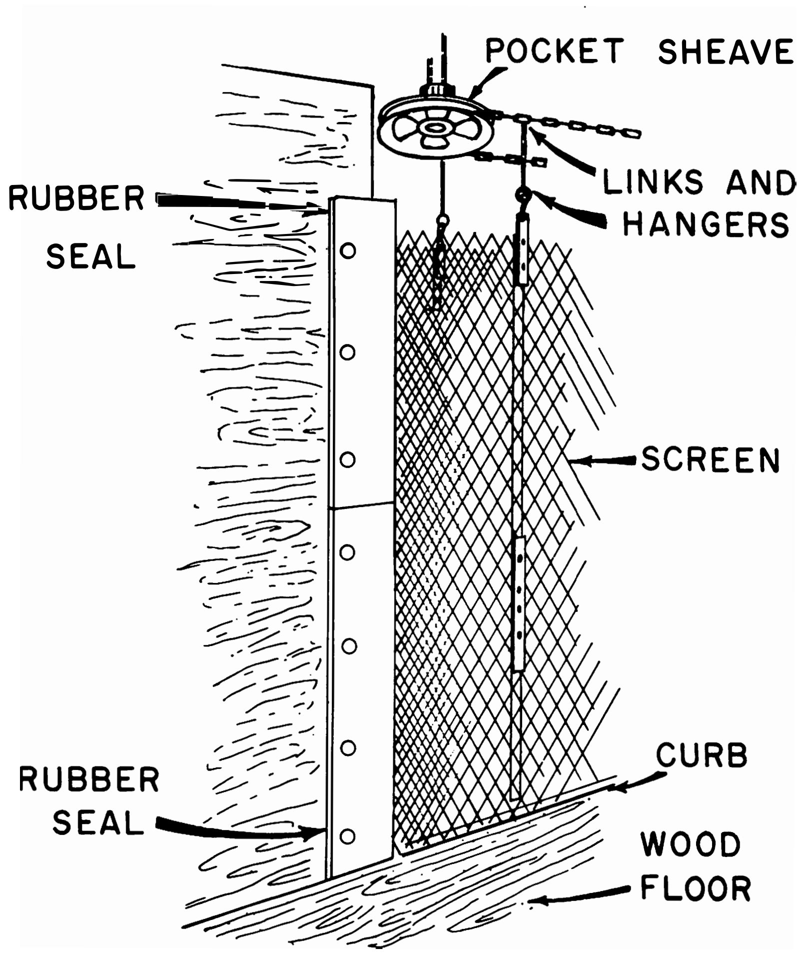


Figure 7.--View of sealing fabrication at juncture of screen and bypass.

Model II.--A second traveling-belt screen was designed to eliminate the drag that developed when the screen traveled upstream, as it did in Model I (that portion of the screen between C and D; see fig. 6). This was accomplished by lifting the screen out of the water as it traveled upstream.

A schematic drawing of Model II is shown in figure 8. The screen traveled from the upstream end (F) to the downstream sheave (G) on a 20^{o} angle to flow (FGK). At point G the screen went around a sheave and turned into the flume at a 20^{o} angle. The screen also began rising at an angle of 22^{o}. By the time the screen reached point (H) it had been lifted 2 feet up off the flume floor. The screen traveled at this height from H to J where it began descending. By the time it reached F, the bottom of the screen was in contact with the floor.

The leading face of the screen was supported with the same type of stationary curbs as used in Model I. An upstream seal, F, was also installed. Since Model II was designed to illustrate the principle of raising the screen out of the water, and not to guide fish, no seal was installed at point G.

Basically, Model II was built and operated in the same way as Model I. The major difference was that the drive unit and the tracking structure had to be tipped to allow the screen to come out of the water on the upstream trip. All of the sheaves and track were laid on the same plane, which was on a 22^{o} angle to the floor.

Bypass

With louvers, it is extremely important that a correct relationship between the approach and bypass velocity be maintained to prevent fish from refusing the bypass and swimming back upstream along and possibly through the louvers. Through the use of a continuous screen curtain, provided the seals at at either end and along the bottom are well fitted, there should be no fish loss. It is therefore probable that the bypass flow conditions can be less stringent. Bypass width at Carson was arbitrarily set at 1 foot.

Test Procedure

Test fish were spring chinook salmon 3.5 to 6 inches in length and coho salmon 2 to 3 inches in length. These fish were dip-netted from a raceway, placed in containers, and transported for release into the upstream end of the flume.

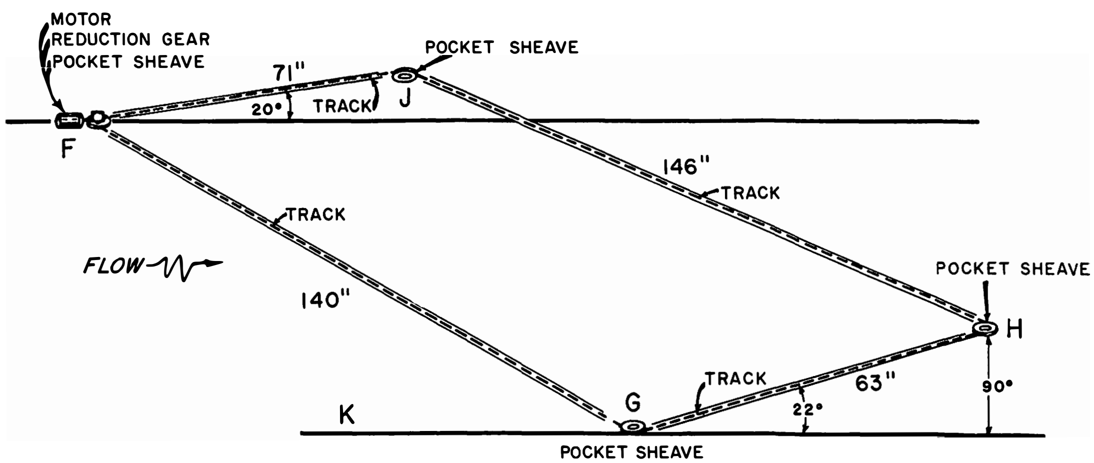


Figure 8.--Schematic drawing of velocity-matching traveling screen, Model II.

Several hundred fish were released per test into specific velocities of 1.5, 2.5, and 3.2 f.p.s. The fish which migrated down the flume were guided by the screen into the bypass and swept over an inclined screen into a trap. Numbers of fish tested and numbers of tests performed at each velocity are listed below:

Species	Water velocity		
	1.5	2.5	3.2
	F.p.s.	F.p.s.	F.p.s.
Chinook salmon			
Number of tests	4	8	5
Number of fish	1,537	2,326	1,790
Coho salmon			
Number of tests	6	9	5
Number of fish	1,838	2,140	1,407

RESULTS AND DISCUSSION

One-hundred percent efficiencies were achieved for both chinook and coho salmon at approximate velocities of 1.5, 2.5, and 3.2 f.p.s. The high efficiencies are understandable (1) as the effective open area of screen mesh was of such size as to preclude fish passing through and (2) as the sealing system at either end and along the canal floor was well fitted.

Head loss across the screen of both models was held to a minimum owing to the motion of the screen across the canal. Head loss was higher on the Model I screen, due to the screen being dragged back through the flow on its return.

Debris in the form of moss, leaves, twigs, and grass was continuously passing downstream. Due to the matching travel rate of screens and flow, debris not only impinged gently onto the screens but also washed off readily. Although no large volumes of debris were passing downstream, that which did pass provided indication that cleaning would not be difficult. Even though the two systems operated efficiently, it is recognized that many design modifications will be required when considering a prototype facility.

Placement of the traveling screen units on a small (20°) angle to flow provided two advantages: First, the young fish could readily deflect even at higher velocities; and second, travel rates of screens to match the approach flow are proportionately less at the smaller angles. For example, with an approach velocity of 5 f.p.s. and a structure angle of 20°, the screens--to match the approach velocity--must travel at 5.3 f.p.s. However, with a screen angle of 45° and without changing the approach velocity, required screen travel would be 7.0 f.p.s.

The considerations for angular placement of traveling screens within a canal, with the exception of cost, are not the same for louvers. To effectively guide along the louver, it is important for fish to be able to swim continuously. This requires suitable approach velocities and a structure angle sufficiently low to allow young fish to readily deflect. With the traveling screen, this does not appear too important. If fish are unable to maintain control and impingement results, the impinging force is gentle and the period of impingement brief due to the continuous travel of the screens.

FUTURE INVESTIGATIONS

Since the traveling screen plan is new and relatively undeveloped, many questions have arisen which will require additional consideration:

1. Relative degree of drag of screens of various material, open area, and design. These are currently being studied.

2. Relationship of screen mesh size to size of the juvenile migrant as a factor in possible fish loss. This will be explored at the Carson behavioral flume.

3. Need for a positive wash system to prevent development of clogging and resultant head.

4. Adjustment of the sealing system to insure high fish collection efficiency. A rubber or neoprene bumper attached to the bottom of the screen could be used to make contact with the sill and absorb wear. Supports installed immediately behind the screens to hold them in a vertical position and prevent their billowing would increase the effectiveness of the bottom seal.

5. Screen inspection. This may be desirable to provide an alternate method for inspection.

6. Screen repair. To accomplish this, the use of replaceable screen panels is being considered.

7. Need to match the velocity of stream flow. The debris load of a river and the swimming ability (as affected by size, species, and condition) of the migrants may determine how critical this is.

8. Carrier system. One design would provide a modified monocable tramway as used at ski resorts (fig. 9). Such a plan would allow for long unhindered spans across rivers. The other plan suggests the use of an engineered beam capable of a long span free of sag.

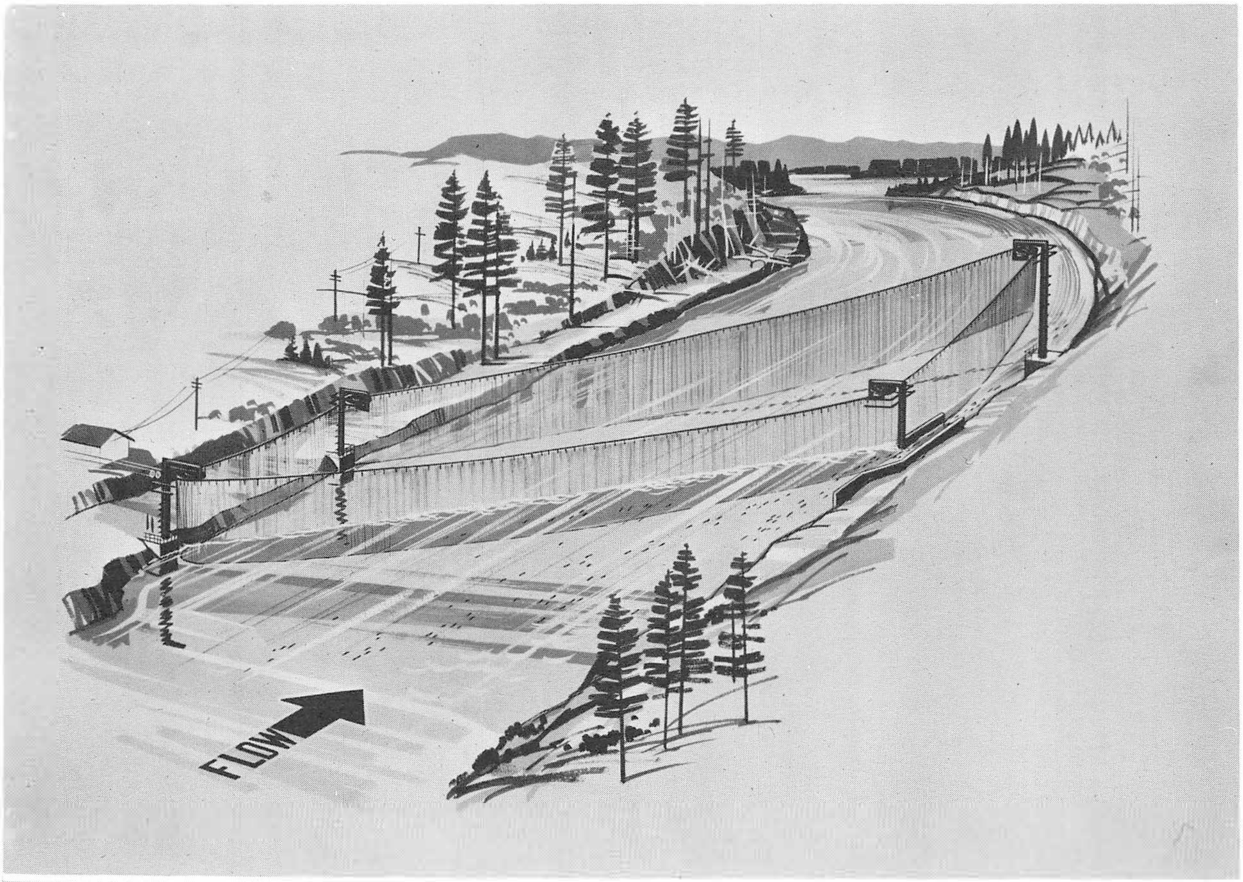


Figure 9.--Artist's concept of the monocable tramway traveling screen carrier.

STUDIES OF THE RESPONSE OF FISH TO LOW FREQUENCY VIBRATIONS

by

John VanDerwalker

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

Studies of the response of salmonids to sound have been conducted by Moore and Newman (1956), and Burner and Moore (1953). Those studies did not describe any response that could be used to attract or repel any particular species.

The most positive results have been obtained by the California Department of Fish and Game (Painter[1/]), using a sound generator invented by Mr. Ernie Murphey. Using this type of generator at the Granlee Canal in the Sacramento Valley, they were able to obtain guiding efficiencies of 74 to 100 percent with downstream migrating salmon.

This paper reports the results of field studies on the responses of salmonids to random noise in the low frequency range using a generator similar to the California type. Also reported are preliminary results of laboratory studies on the response of fish to discreet vibration frequencies.

FIELD TESTS

Equipment and Procedure

Carson Flume Tests

The first tests were conducted in the Carson behavioral flume located at the Carson National Fish Hatchery, Carson, Washington. The tests were conducted in a wooden flume 50 feet long, 6 feet wide, and 4 feet deep. The sound, or vibration barrier (fig. 1) was located at the downstream end of the flume. The barrier consisted of five vibrating plates 3 feet by 4 feet, of sixteen-gauge steel sheets installed in a vertical position parallel to flow. Plate no. 1 was mounted 10 inches away from the flume wall. Each succeeding plate was mounted 10 inches away from the preceeding plate and staggered 12 inches downstream.

The first, third, and fifth plates had a 3/4-inch Cleveland Air Vibrator[2/] (a device similar to the Murphey generator) attached to the lower front corner of the plate

---

1/ Painter, Richard. Personal communication describing tests of sound studies conducted in the Cosumnes River area.

2/ Trade names referred to in this publication do not imply endorsement of commercial products.

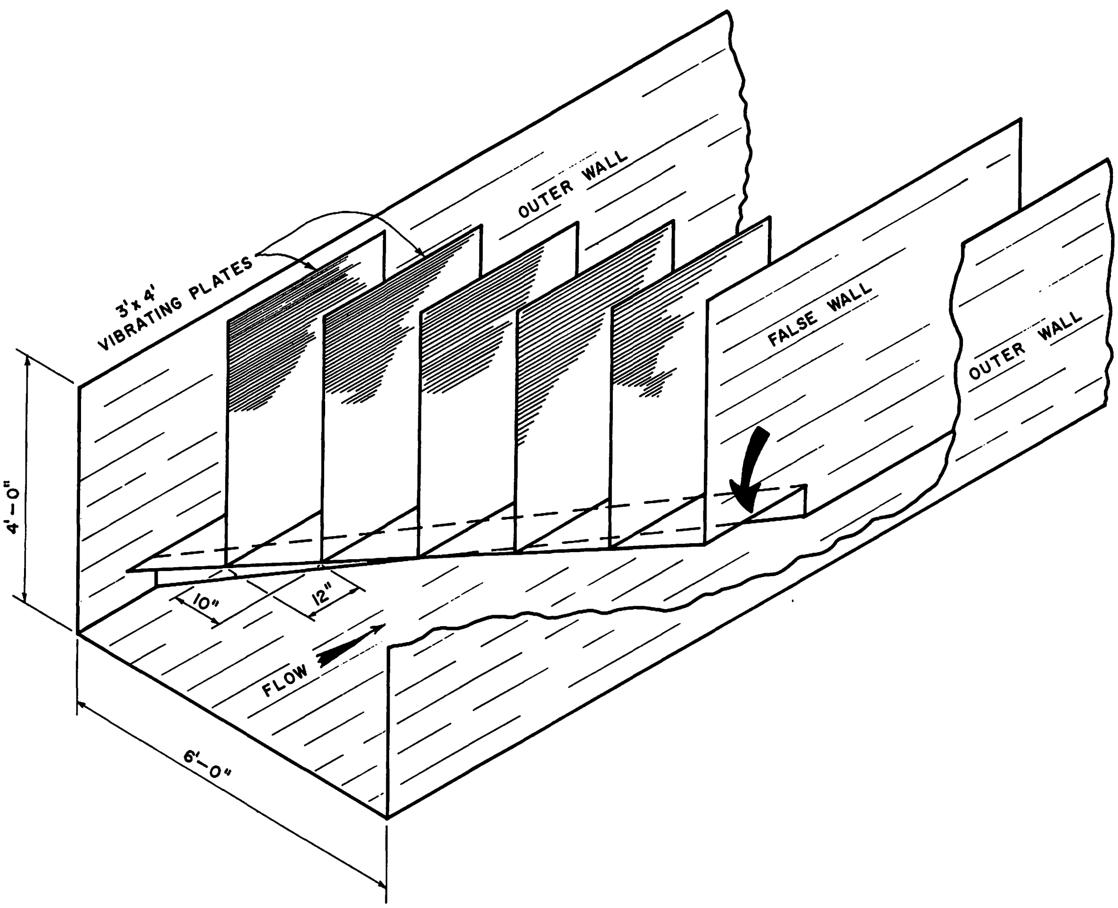


Figure 1.--Diagrammatic view of sound barrier showing vibrating plates. Note horizontal bypass (arrow) angled across floor and leading into side bypass.

(fig. 2). These vibrators were actuated by 80 pounds of compressed air supplied by a portable air compressor. At this pressure the vibrator had a vibration rate of 270 cycles per second.

Horizontal and vertical bypasses (fig. 1) were installed to allow the fish to migrate through the flume without traveling through the sound barrier.

For testing, the flume was filled with water, the depth and velocity were adjusted, and the vibrators actuated. Juvenile spring chinook (Oncorhynchus tshawytscha) 3 to 5 inches in total length were taken from one of the hatchery raceways and placed in the flume at the upstream end. The response of these fish to the vibration barrier was observed for periods of 1 to 6 hours.

Maxwell Canal Tests

Following the Carson tests the study was transferred to the Maxwell test site near Hermiston, Oregon. These tests were to investigate further the possibility of using the vibration techniques developed at the Carson site. The experimental area was considerably larger than that at the Carson facility and the water was more turbid. Wild migrant steelhead were used in these tests.

Maxwell Canal is an integral part of the irrigation project that diverts water out of the Umatilla River near Hinkle, Oregon, for distribution to farms in the Hermiston, Oregon, area. The canal is of earthen construction, approximately 25 feet wide and 4 feet deep. Downstream migrating steelhead (Salmo gairdneri) from 5 to 10 inches in length enter the canal in May and June. These migrants are diverted back into the river at a facility located about 3 miles downstream from the diversion dam. A plan view of this facility, which was used as the test site, is shown in figure 3.

The facility consists of two channels, one 10 feet wide, the other 5 feet wide. Within each of these channels there is a louver line which guides fish to a bypass and into a trap. At the downstream end of each channel, a recovery net was installed to catch any fish which might go through the louver lines during the testing periods.

The vibration barrier located upstream in front of the 10-foot channel was similar to the one used during the Carson studies. It consisted of ten 3-foot by 4-foot plates, with vibrators driven at 270 c.p.s. attached to alternate plates.

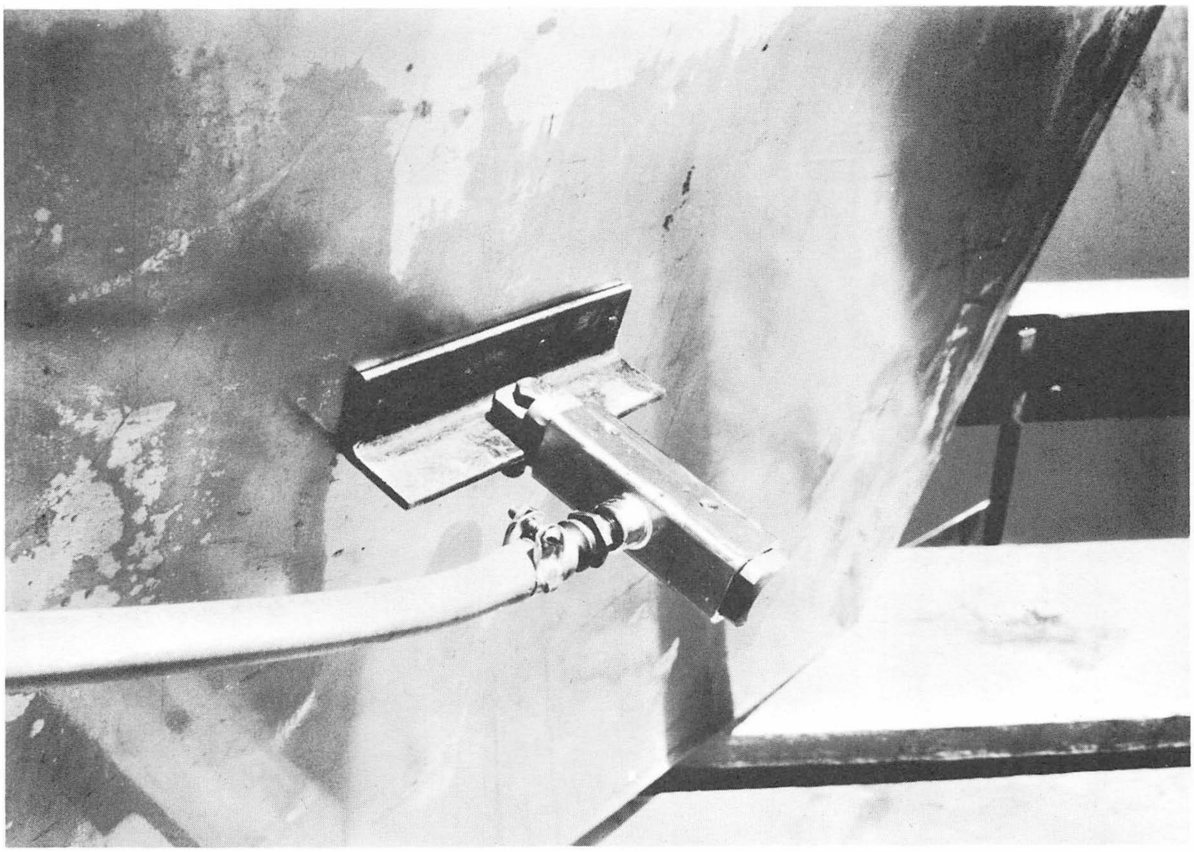


Figure 2.--Portion of vibrating plate with vibrator attached.

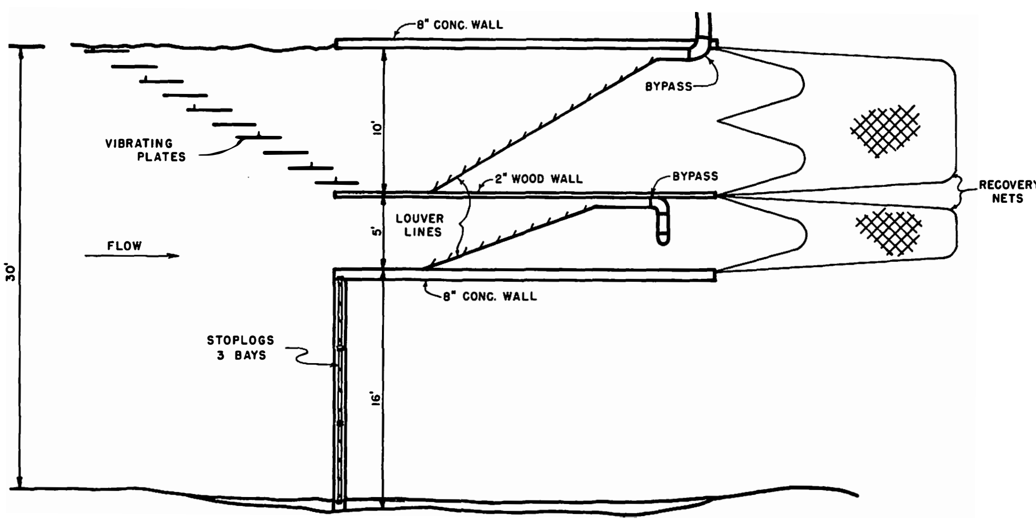


Figure 3.--Plan view of Maxwell Canal test site.

The water approached the vibration barrier at a velocity of 1.3 to 1.7 feet per second. The water depth varied between 30 and 48 inches. Although Secchi disc readings fluctuated over a wide range they were generally around 2 feet.

As fish migrating down the canal approached the test structure, they had the choice of entering the 10-foot channel by passing through the sound barrier, or of going around it and migrating through the 5-foot channel.

Before the vibration equipment was installed at Maxwell, the percentages of the migrating population entering the 5-foot and 10-foot channels were established with the aid of the louver lines and recovery nets. Approximately 11 percent of the fish entered the 5-foot channel, the balance passing through the 10-foot channel. After the plates were installed but not actuated, approximately 32 percent of the fish entered the 5-foot channel.

Results and Discussion

Carson Flume Tests

Fish used in the Carson tests tended to avoid the vibrating barrier. Of the first groups placed in the channel, several hundred moved directly downstream, dived below the barrier, encountered and followed the angled sill (horizontal bypass), and passed into the vertical bypass. During subsequent tests, this response no longer appeared. Fish that moved downstream while the barrier vibrated did not appear to choose the bypass. Fish placed in the flume when the barrier was not vibrating would migrate through the array without hesitation.

Soon after the first group of test fish had been placed in the flume, it became evident that they could feel the influence of the vibrations throughout the flume. Apparently the vibrations from the plates were transmitted to the floor and walls of the flume which then became a source of vibration the fish could detect. Fish introduced into the upper end of the flume would generally depress and stay within a few inches of the floor. Almost every fish stayed at least 12 inches away from the walls. After long periods of exposure, some fish would drift down the flume and through the plates, or the 1-foot bypass.

While these tests were being conducted, approximately 5,000 of the Carson reared fish which had been released from the hatchery, took up residency in a pool immediately above the flume entrance. During the sound tests small numbers of these fish would enter the flume. When the barrier vibrated, these fish would remain at the upper end of the flume; as soon as the sound was turned off they would migrate through the flume.

If an efficient deflector using high intensity vibration can be developed, the possibility of injuring fish exposed to it must be considered. Preliminary tests in which groups of fish were held within 2 feet of a vibrating plate for 45 minutes showed no visible harm to the fish. These fish were held in a pond for an observation period of 48 hours and no mortality was noted.

Maxwell Canal Tests

The percentage of the fish migrating down the canal which entered the 5-foot channel increased from 32 percent with a non-operating barrier to 77 percent with vibration. A total of 221 fish migrated through the site during the testing period of this group--171 entered the 5-foot channel.

The results of the Carson tests and of those conducted by the California Department of Fish and Game indicated that salmon approaching the barrier tended to deflect downward. The turbidity of the water at Maxwell precluded any observation of the steelhead as they approached the barrier. Assuming they would react in a way similar to the behavior of the migrant salmon, it is possible that a bypass located under the barrier along its entire length would have caused higher deflection efficiencies at the Maxwell site.

No attempt was made to determine if the barrier was discouraging the migrants from moving into the test area. Because of the mud banks of the canal and the greater dimensions of the site, it was assumed that the reverberation experience at Carson was not a problem during the Maxwell study.

Having found that sound of some unknown frequency and force would cause fish to respond, field studies were discontinued in favor of laboratory studies where more precise determination could be made on the nature and effect of sound.

LABORATORY TESTS

Equipment and Procedure

Equipment

After the Maxwell tests, studies were initiated at the Boeing Developmental Center Vibration Laboratory, Seattle, Washington. The purpose of these studies was to define the response of juvenile migrant salmonids to discreet vibration frequencies between 10 and 500 cycles per second. This study, still in progress, will determine the critical frequencies and levels required to accomplish efficient deflection of downstream migrating salmonids.

The experimental apparatus consisted of two main parts: the vibration chamber, and the electromagnetic vibrator with its various electronic controls (fig. 4). The chamber, measuring 18 inches by 18 inches by 6 inches, was constructed of aluminum and plexiglass. Plexiglass was used in the construction of the chamber to allow observation of the fish during the testing period. A 2-inch hole in the top of the tank was used for filling and emptying the chamber. A threaded plug with a stopcock was used to close this hole during the tests.

Pressure sensing transducers, one in a plexiglass side and one in an aluminum end of the chamber, constantly monitored the pressure inside the chamber. The G-level force exerted in the chamber during the testing periods was measured with an accelerometer attached to its base.

The chamber was bolted to a 2-inch-thick magnesium plate that rested on a slippery table. A thin layer of grease was spread on top of the table to allow the plate to slide freely. The magnesium plate, bolted to the vibrator, transmitted the vibrations from the vibrator to the test chamber. The vibrator was a Ling Model 246 electromagnetic exciter. For the purposes of this study it vibrated at frequencies from 10 to 500 cycles per second at a maximum G level of 5.

Handling Procedure for Test Fish

The fish used in the Boeing vibration studies were juvenile spring chinook, 3 to 5 inches in length, held at the Behavior and Physiology Laboratory in Seattle, Washington. At the beginning of each test day, approximately 50 fish were removed from a holding tank and placed in a plastic bucket containing 3 gallons of water, and 8 cubic centimeters of MS-222 (5 percent solution). At this concentration the fish were in a deep anesthesia in a few seconds. As soon as the fish were anesthetized they were transferred from this bucket to a commercial-type chest containing 20 gallons of water. The water temperature in this chest was maintained at the same level as the water temperature in the holding tank. The dissolved oxygen concentration was 8 p.p.m. or greater.

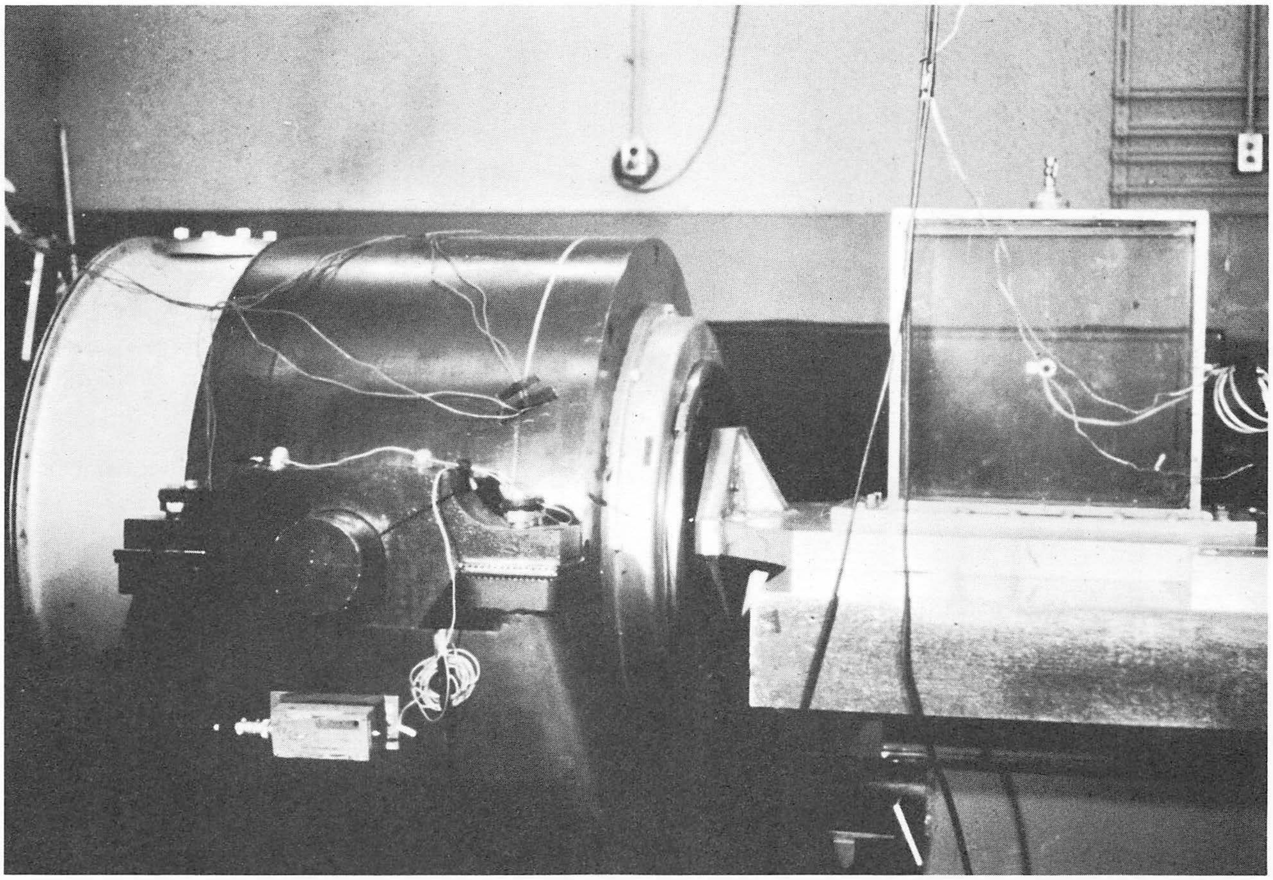


Figure 4.--Sound test chamber mounted on slippery table. Electromagnetic exciter is seen on left hand side.

After the fish were placed in the chest, it was sealed and transported to the Boeing Development Center. Upon arrival the chest was opened and an air stone was placed in the tank to provide oxygen during the test day. The water was maintained at the initial temperature by the addition of ice when needed. In order to keep the fish quiet and allow handling without an undue amount of stress, a low concentration of MS-222 was used in the chest. The lid of the chest remained open during the testing period to allow the test fish to acclimate to the light present in the laboratory. At the completion of the test, all fish were returned to the ice chest which was then sealed and transported back to the Behavior Laboratory. There, the fish were held in separate tanks for an observation period of at least 3 weeks.

Test Procedure

To conduct a test, the chamber was filled with water of the same temperature as the water in the fish holding tank. The air bubbles which were trapped against the top of the chamber were removed by a vacuum tube and the stopper was placed in the top of the tank. The chamber was then filled to the top and the stopcock turned to the "off" position. The fish were allowed to remain in the test chamber for approximately 15 minutes before the beginning of vibration to provide time for them to recover from prior use of the anesthetic. After this recovery period, the test was started and the fish responses to the various vibrations were noted. At the completion of a test, the chamber was opened and the fish were anesthetized. This made it possible to remove the fish from the tank with a minimum amount of disturbance and injury. As soon as the fish were removed, the tank was drained, and refilled with fresh water and the next test was started.

RESULTS

Two types of response were noted during the study period. The first was a loss of equilibrium, interrupted by short periods of erratic swimming. The second response was an escape action in which the fish swam very rapidly around the chamber. Fish exhibiting this response often ran head first into the walls, or into other fish.

The loss of equilibrium occurred at a frequency of 60 cycles per second at the 3-G level. This response was also evident at the 30 and 180 c.p.s. frequency at the 3-G level. The escape response was noted at several frequencies and G levels. However, the most violent reaction was obtained in the 80 and 180 c.p.s. range at a G level of 3 or greater.

DISCUSSION

The responses at the 60-, 80-, and 180-c.p.s. range were all obtained at a 3-G level exerted on the tank. This is not necessarily the force that was experienced by the fish. The resonant frequency of the chamber may have amplified the force two or three times. Another factor that varied independently of the frequency was the pressure within the tank. Figure 5 shows the pressure within the tank at the various frequencies between 15 and 500 c.p.s. The pressure fluctuations occurring at 60 cycles, and to a lesser degree at 30 and 180 cycles, may account for the loss of equilibrium exhibited by the fish at these frequencies. The pressure fluctuated over a 1.5 pounds per square inch range approximately 100 times per minute at 60 cycles, smaller fluctuations occurring at 30 and 180 cycles. These fluctuations also occurred to a lesser degree at 80, 120, and 240 cycles, but no loss of equilibrium was exhibited by the fish at these particular frequencies.

The escape response was noted at several of the vibration frequencies. The frequency at which the fish gave the most positive and consistent response was in the 70- and 88-cycle range at an acceleration level of 3 G's. At this frequency the fish would frantically swim around the tank, seeking an escape from it. This reaction would continue as long as the chamber was vibrated at this frequency. As soon as the vibration ceased the fish would settle to the bottom of the tank and remain nearly motionless. If the vibration was resumed, the fish would again begin searching for a way out.

No loss of equilibrium was observed during tests at 70 to 88 cycles. As can be noted on figure 5 there was no appreciable amount of pressure fluctuation over this frequency range. No significant mortality of test fish occurred in the 3-week observation period following the tests.

The results of the preceding tests demonstrate the need for eliminating the pressure fluctuations to prevent them from affecting the response of the fish to the vibration. This will be accomplished by modifying the present test chamber to maintain a 0.25 pound per square inch of pressure in the chamber at all frequencies. Following this modification, tests similar to those already completed will be conducted to single out those frequencies resulting in the most positive escape response. Using this information, a sound transducer will be designed and built for use in the Carson flume.

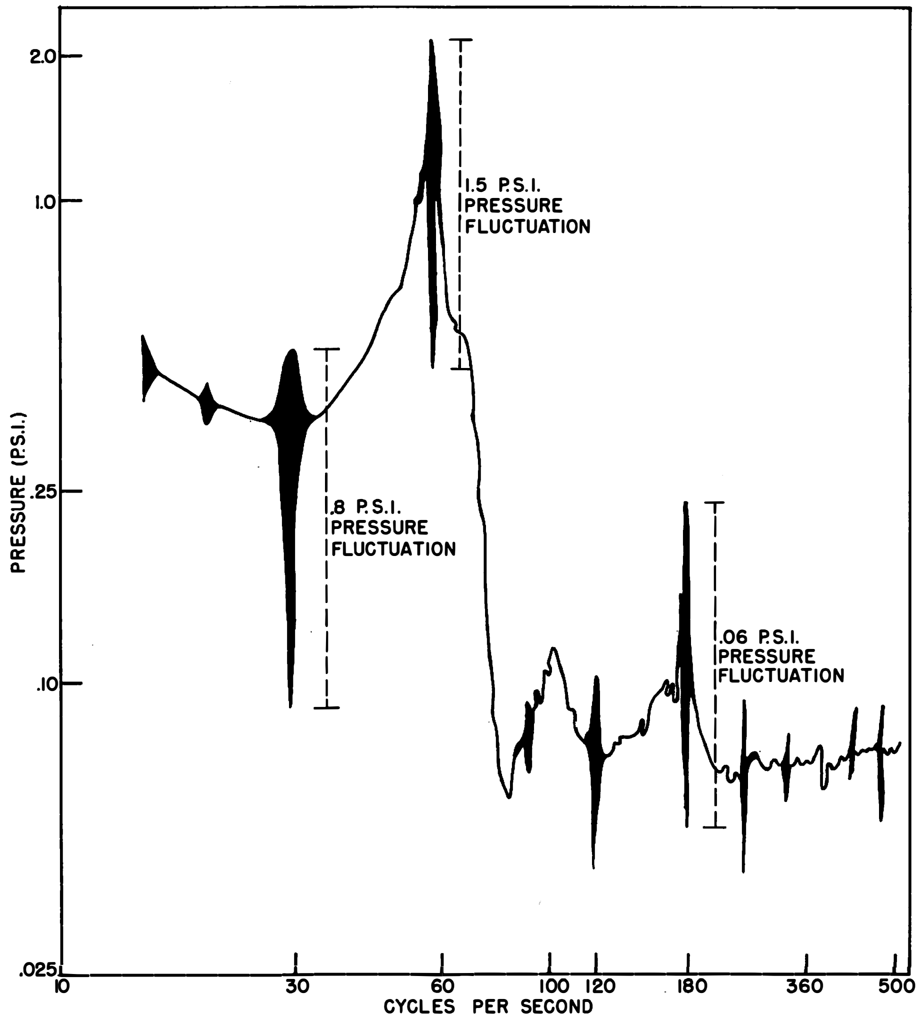


Figure 5.--Pressure within test chamber at frequencies from 15 to 500 cycles per second. Note fluctuation around 30, 60, and 180 cycles per second.

BIBLIOGRAPHY

Burner, Clifford J. and Harvey L. Moore.
1953. Attempts to guide small fish with underwater sound. U.S. Fish and Wildlife Service, Special Scientific Report No. 111, 38 p.

Moore, Harvey L. and H. William Newman.
1956. Effects of sound on young salmon. U.S. Fish and Wildlife Service, Special Scientific Report No. 172, 19 p.

COLLECTION OF JUVENILE MIGRANTS FROM RESERVOIRS

LAKE MERWIN JUVENILE FISH COLLECTOR STUDY

by

Richard Allen

State of Washington
DEPARTMENT OF FISHERIES

for

FISH-PASSAGE RESEARCH PROGRAM
U. S. Bureau of Commercial Fisheries
Seattle, Washington

September 1964

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Washington Department of Fisheries and other fisheries agencies have been working for many years to develop a downstream migrant collector which will successfully collect and bypass downstream migrants around dams. One of the many problems encountered in this field is the extreme fluctuation in forebay levels encountered at some dams which precludes the use of a juvenile fish collector attached to or made part of the dam structure proper.

In 1955 work conducted by the Department of Fisheries at the Lower Baker Dam in northern Washington demonstrated that an artificial surface current could be created by pumping. In 1957 the Department designed and tested a floating juvenile fish collector which could be used in reservoirs which experienced heavy drawdown. The structure, which utilized a current created by pumping to attract fish, successfully collected fish at Mud Mountain Dam in western Washington but the louver guidance system proved unsatisfactory (Regenthal and Rees 1957). Later that year experimentation in various louver type systems was carried out at the University of Washington Hydraulics Laboratory. Following this work a prototype floating juvenile collector employing a horizontal louver bank for fish guidance and water separation was constructed on Lake Union near the Fisheries College. In 1958 a production model was installed at the lower dam on the Baker River. The success of this unit led to the development of an improved version which was installed at Upper Baker Dam in 1960. These units have been used since to collect and bypass migrants around the two dams on the Baker River.

The Baker collectors as designed, although successfully passing fish, allow for little flexibility in operation. An experimental unit was desired to test the effectiveness of the collector at another reservoir and to determine the optimum attraction flows into the collector and the internal water velocities and depths required for the most efficient passage of fish. The determination of these factors could then effect a cost savings in the design of future floating collectors.

In 1962 the Department of Fisheries and the U.S. Bureau of Commercial Fisheries entered into an agreement which provided the Department with the funds to design, construct, and test a floating downstream migrant collector as part of the Accelerated Fisheries Research Program being conducted by the Bureau.

Lake Merwin located in southwest Washington was chosen as the test site. This reservoir has been under study since 1958 through a co-operative program by the Department of Fisheries, Pacific Power and Light Company, and the Cowlitz County P.U.D. to determine if the reservoir can be used as a natural rearing area for coho salmon (*Oncorhynchus kisutch*). As part of this investigation fixed downstream migrant collectors of the skimmer type were employed and evaluated at Merwin Dam in 1957, 1958, and 1959. None of the devices tested were considered successful. The selection of this site then provided for testing the experimental floating collector at a reservoir similar in size to the Baker reservoirs, at one in which other collection devices had not been successful, and at a site where related reservoir research was currently in progress.

DESCRIPTION OF LAKE MERWIN

Lake Merwin was formed by the construction of Merwin Dam in 1932 by Pacific Power and Light Company of Portland, Oregon. The dam is on the North Fork Lewis River in southwestern Washington, about 13 miles upstream from the community of Woodland. The reservoir (Figure 1) is about 12 miles long and at full pool contains 422,000 acre feet of water. Merwin Dam is approximately 1,400 feet long and has three-turbine units. The intakes for these are 180 feet below maximum pool. The maximum depth of the reservoir is 200 feet. Two other dams, Yale and Swift, completed in 1954 and 1958 respectively, are located upstream from Merwin Dam. Yale Dam provides the principal inflow to Lake Merwin.

METHODS AND MATERIALS

Description of the juvenile fish collector

The Lake Merwin juvenile fish collector is 70 feet long and 36 feet wide. It resembles a floating drydock in that it can be raised or lowered to desired depths.

Inflow into the collector is created by four electrical pumps, two 75 h.p. and two 10 h.p. Fish entering with the attraction water pass into the primary flume, where they are separated from the bulk of the water, and then into a secondary separation system, where more of the water is removed (Figure 2). The excess water is ejected from the sides of the collector. The fish and the small remaining amount of water pass on into two collection baskets.

The two larger pumps evacuate water through the primary flume and discharge it into the primary sump located 10 feet below the surface near the middle of the collector. Regardless of which pump is in operation, the design of this sump provides for the simultaneous ejection of water from both sides of the collector. One of the pumps is a two-speed unit; the other can only be operated at its maximum pumping rate. If only these two pumps are in operation, attraction flows in the amount of 86, 190, 254, or 305 cubic feet per second can be drawn into the main flume (Table 1). When the two secondary pumps are operated at their maximum pumping rates an additional 20 cfs is added to the inflow.

Table 1. Attraction flows into the Lake Merwin juvenile fish collector created by the two primary pumps.

Left Pump Speed	Right Pump Speed	cfs
Half	Off	86
Full	Off	188
Off	Full	192
Half	Full	254
Full	Full	305

Fish entering the main flume with the attraction water are screened out by a system of louvers before the water enters the pumps. The louvers are arranged

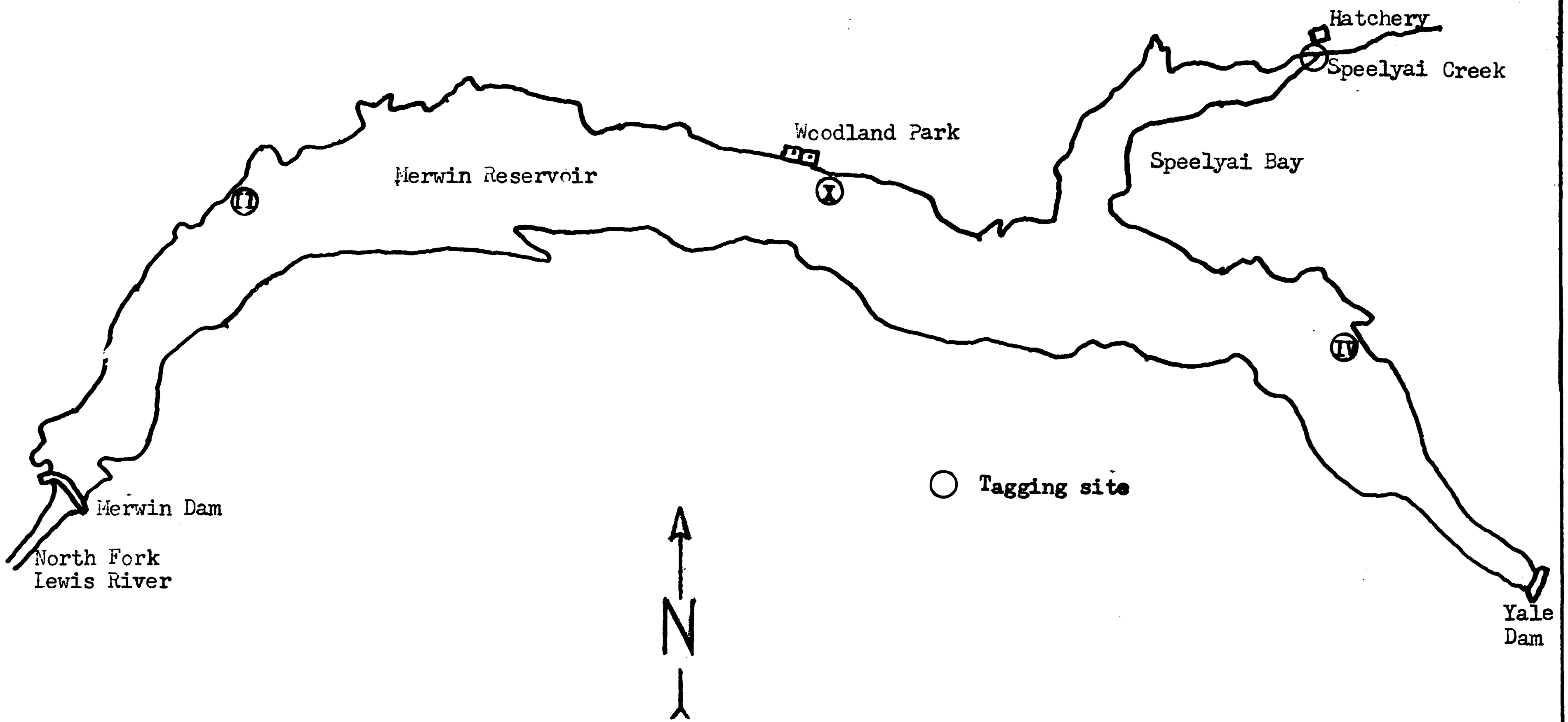


Figure 1. - Merwin Reservoir (Scale: One inch - approximately one mile)

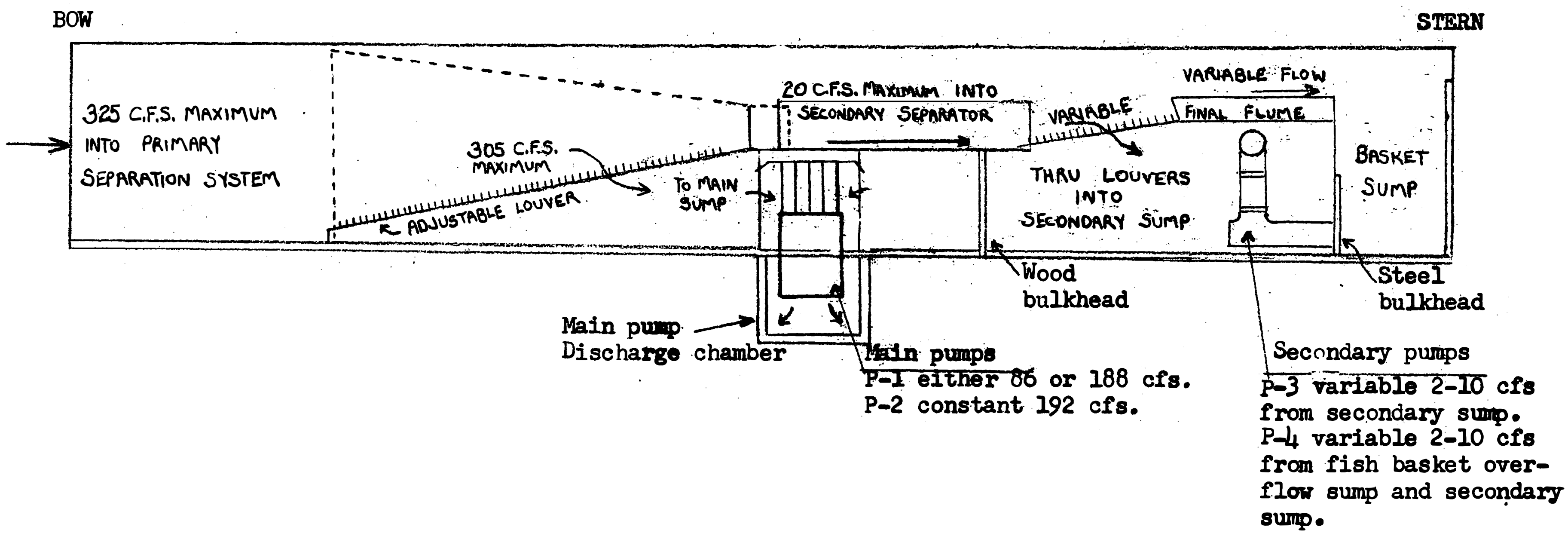


Figure 2. - Diagram of the fish separation and collection systems of the Lake Merwin juvenile fish collector. Small arrows denote directions of water flow. (From an original drawing prepared by the Andersen - Bjornstad - Kane consulting engineering firm).

horizontally and vertically across the flume to provide a sloping, gradually tapering ramp that guides the fish into the secondary separation channel. These louvers are fir, spaced 1.5 inches apart. The vertical louvers taper from the 15 foot width of the primary flume to the four foot width of the secondary separator (Plates 1 and 2) over a distance of 21.5 feet. The horizontal louvers rise a maximum of 6.5 feet over the same distance. Two hydraulic jacks, located at the junction of the two separation systems, are used to adjust the slope of the louvers and control the depth of the water entering the secondary channel.

The secondary separator has an overall length of 23 feet. This channel is constructed of galvanized sheet metal and is divided into three over-lapping components. The first section is a rectangular flume 15 feet long and 30 inches deep. The rear section is 8 feet long and 18 inches deep and empties into the collection baskets. The center section is 8 feet long and the floor is a louvered area of aluminum grating backed with 18 gauge hardware cloth. The draw-down from the left secondary pump into the secondary sump is through these metal louvers, creating a further separation of the fish and water. Three hydraulic jacks independently raise or lower the front and rear sections, controlling the slope of the louvered area.

The right secondary pump can evacuate water both from the secondary sump and from the collection basket sump; however, it is primarily used to pump water from the latter. Both secondary pumps are variable speed and their combined pumping rates, together with the slope of the louvers in the secondary channel, control the amount of water entering into the collection baskets. Maintaining the water level in the collection basket sump below the floor of the channel prevents fish from swimming back into the secondary separator.

The sides of the two collection baskets (Plate 3) are constructed of No. 18 gauge hardware cloth, (No. 4 mesh); the bottoms and frames are galvanized sheet metal. The larger basket is 5 feet 4 inches long, 3 feet 4 inches wide, and 4 feet 1 inch deep. The smaller basket has identical length and depth dimensions but it is only 2 feet 4 inches wide. The baskets are raised to a height of about six feet above the work deck by a small electrically operated hoist. At this point the water remaining in the baskets has a maximum depth of 10 inches. The fish are transferred from the baskets to live boxes through a 6-inch flexible hose which attaches to the bottom of the baskets.

The entire collector can be raised or lowered nine feet (Plates 4 and 5). In operating position the 22 ballast tanks, which are 13.5 feet high and 5 feet in diameter, are filled with water. To raise to the maintenance (highest) position the top nine feet of these tanks are filled with air. Styrofoam blocks under the work deck aid the 28 sealed floatation tanks in preventing the collector from sinking below eight inches freeboard. Ten stabilizer tanks prevent the collector from raising violently when water is evacuated by the pumps. The collector is moored in position by one-half inch steel cables mounted on five-ton "Beebe" winches.

Attraction light at night is provided by 13 mercury vapor lamps. Three of these lights are on pivoted posts over the primary flume, the others are mounted singly or in pairs over the secondary flume (Plates 2 and 4).

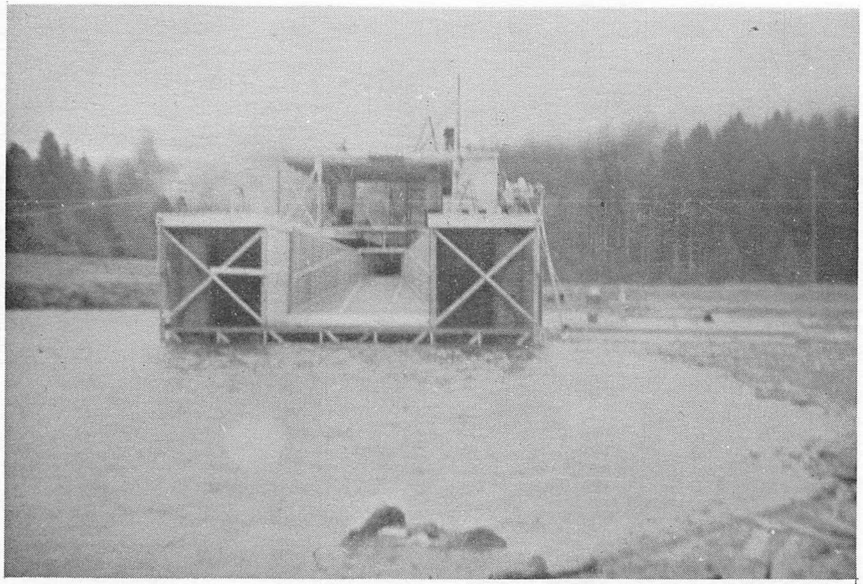


Plate 1.

Bow of juvenile fish collector and entrance to main flume.

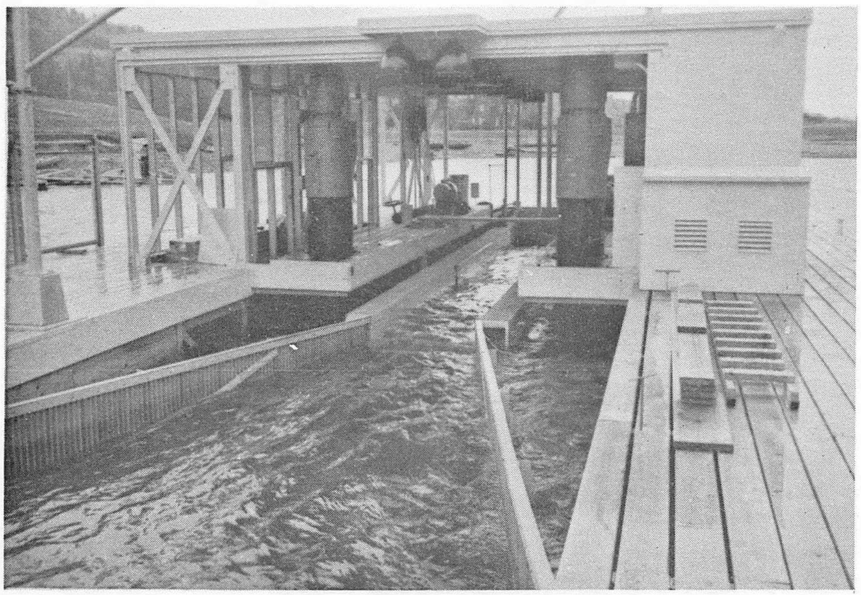


Plate 2.

Interior of the collector showing vertical louvers of main flume, secondary separation channel and the two primary pumps.

Plate 3.

Discharge into the two fish collection baskets from end of the secondary separator.

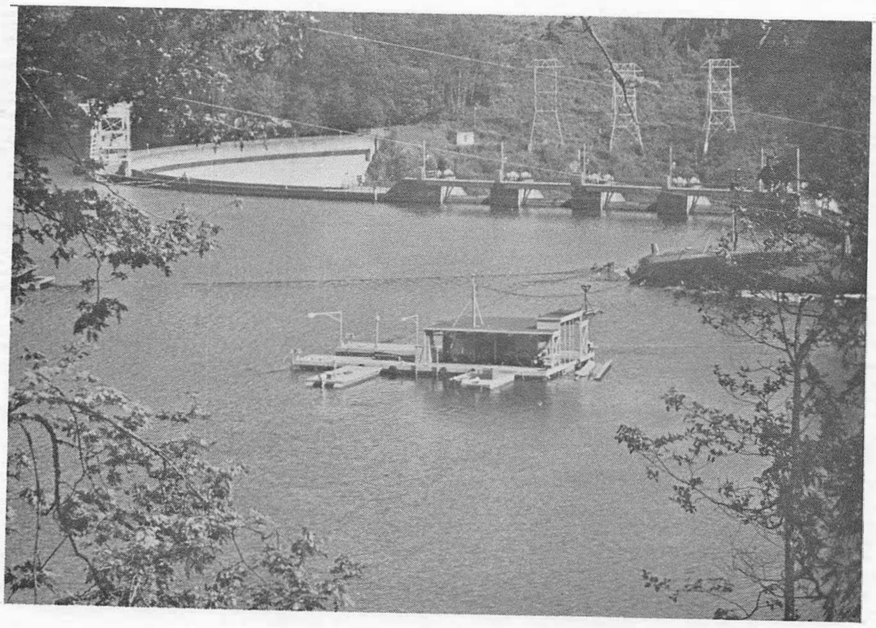


Plate 4.

Juvenile fish collector in position No. 2 in Merwin Dam forebay, 1963.

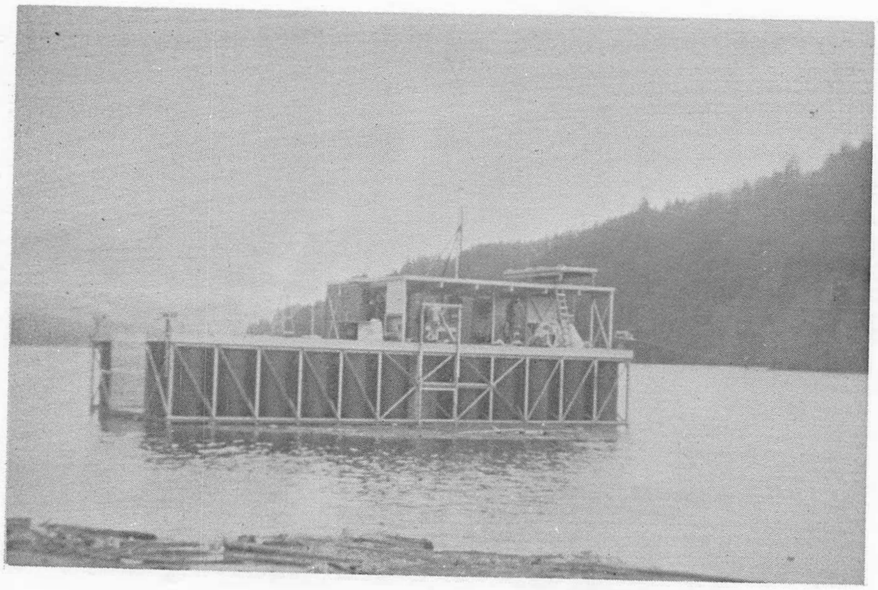


Plate 5.

Collector raised to the maintainence (highest) position.

Collector modification for the 1964 season

The Lake Merwin floating juvenile fish collector was constructed in early 1963 and operated during the spring downstream migration period with disappointing results. The recovery rate of lake-reared yearling coho, based on a population estimate, was only 10.2%. The recovery rate of fish tagged upon egress from Speelyai Creek, approximately eight miles uplake from the dam (Figure 1) was 13.7%. The highest recovery rate, 20.5%, was obtained for fish transplanted from the Baker River system in late May 1963 (Allen, 1963).

Analysis of the 1963 catch data indicated that the low catch in the collector was related to the size and/or the vertical distribution of the coho. During the winter of 1963 the collector was modified to enable it to draw water from greater depths.

The primary flume of the collector is only ten feet deep, therefore most of the attraction into the unit in 1963 was obtained from a surface inflow. In 1964 an addition to the collector was constructed, which enabled the inflow to be brought up vertically from depths as great as 28 feet.

The addition is essentially a "floating well" which attaches to the primary flume of the collector (Figure 3). The main floatational support is afforded by cedar logs, covered by a work deck of 2-inch by 12-inch fir planks. The deck is about 12 feet wide and supports a framework of steel macomber beams (Plate 6) which serve as guides for the raising and lowering of 91 plywood panel units, each 4 feet by 8 feet. These panels are constructed of 2-feet by 4-feet wood frames, covered with one-half inch exterior marine plywood on one side and coated with cement on the other side to reduce their buoyancy. The panels form the front and side walls of a rectangular underwater box 43 feet long, 25 feet wide, and 28 feet deep, open only at the bottom. The fourth wall consists of a large plywood panel which fits around the main flume of the collector and between the two side walls.

Net leads were employed in both seasons to guide fish to the collector. In 1963 leads were extended from each side of the primary flume to shore or from the center of the primary flume to shore depending on the fishing location. These sites are described in the following section. The leads were 30 feet deep and up to 700 feet long. Regardless of location the nets did not provide a barrier from surface to bottom and fish could sound and pass beneath them.

In 1964 net lead, extending from surface to bottom, was installed from the front of the addition to shore. Net walls were attached to each side of the addition and extended from the surface to the lake bottom. These walls were also attached to a herring web wall which extended from the bottom of the primary flume to the lake floor. Fish following along the lead from shore to the collector were thus prevented from passing beneath the collector (Figure 4).

The 1963 and 1964 fishing sites

During the 1963 season the collector was fished at three different sites in the Merwin Dam forebay; however, movement of the unit was limited by the length of the electrical cable, and the locations were very close together.

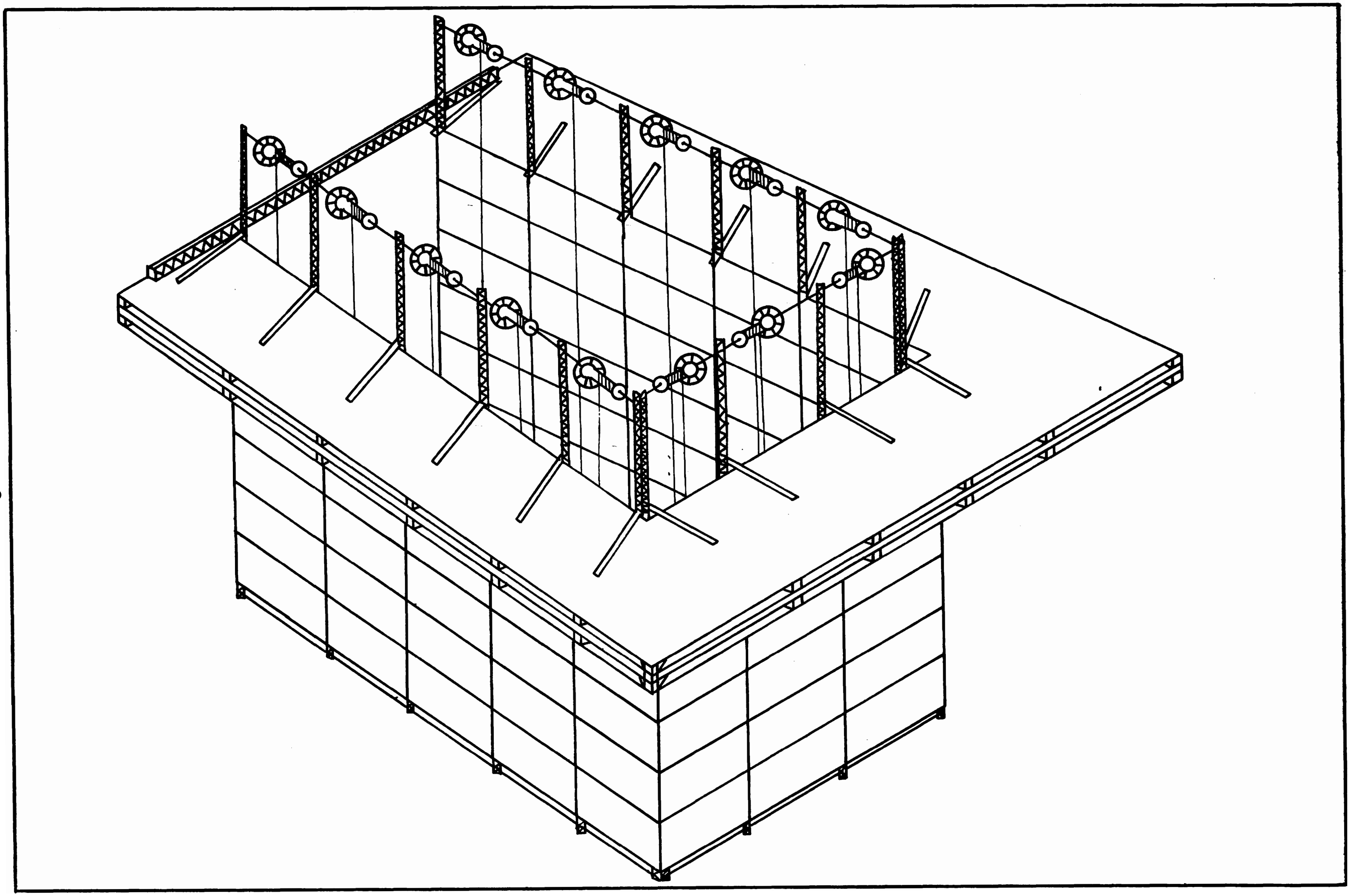


Figure 3.--Diagram of the well addition to the juvenile fish collector.

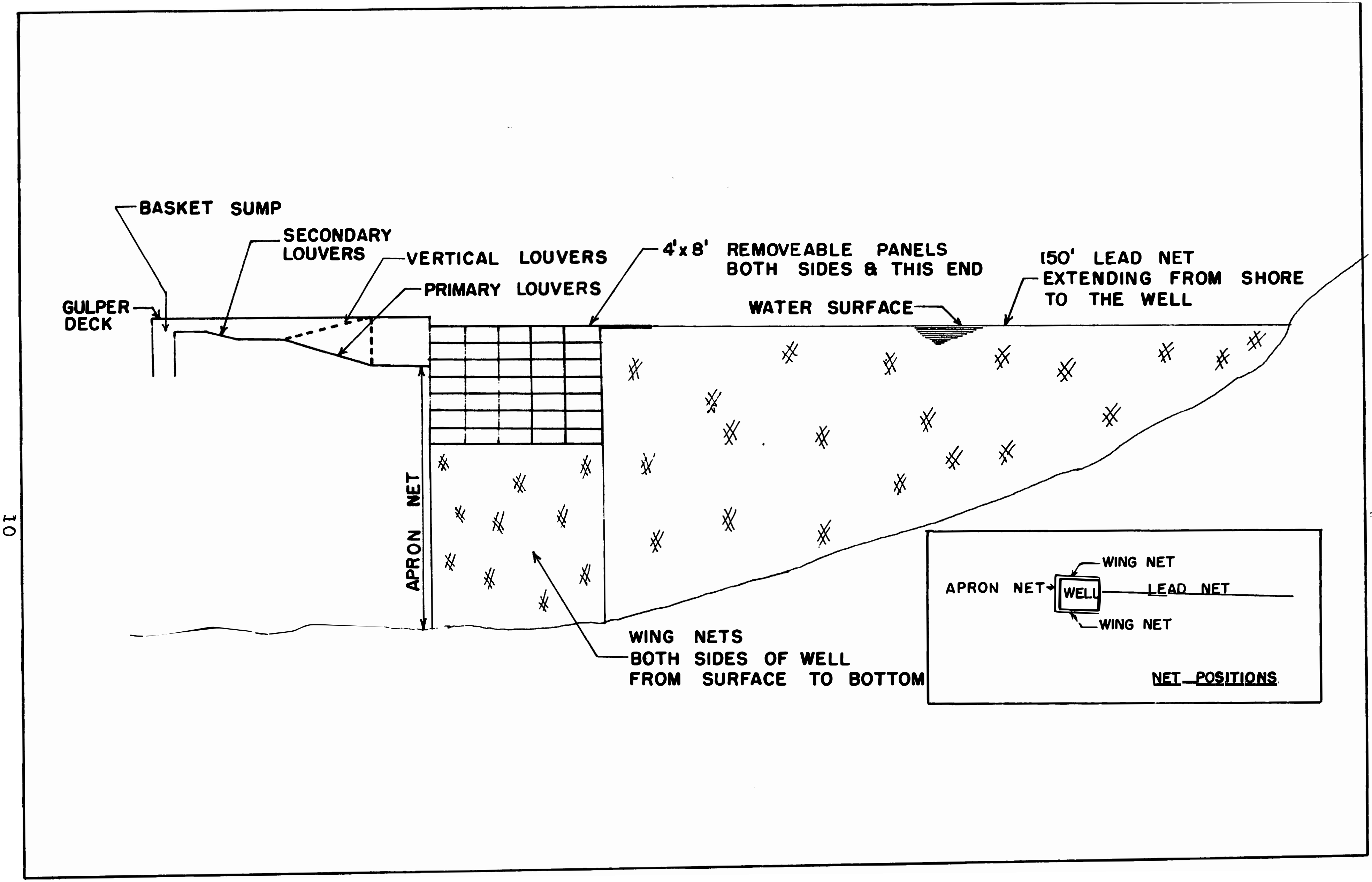


Figure 4.--Diagram of the 1964 fish concentration and collection facilities.

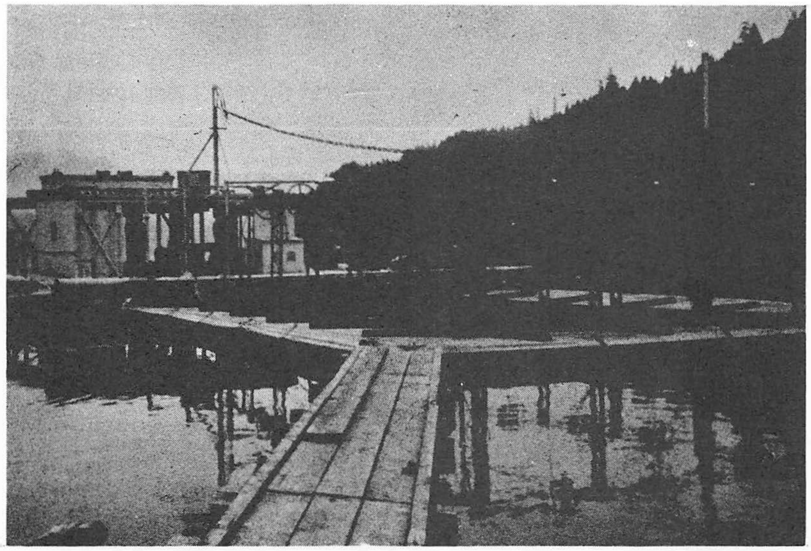


Plate 6. 1964 well addition to the juvenile fish collector in fishing position.

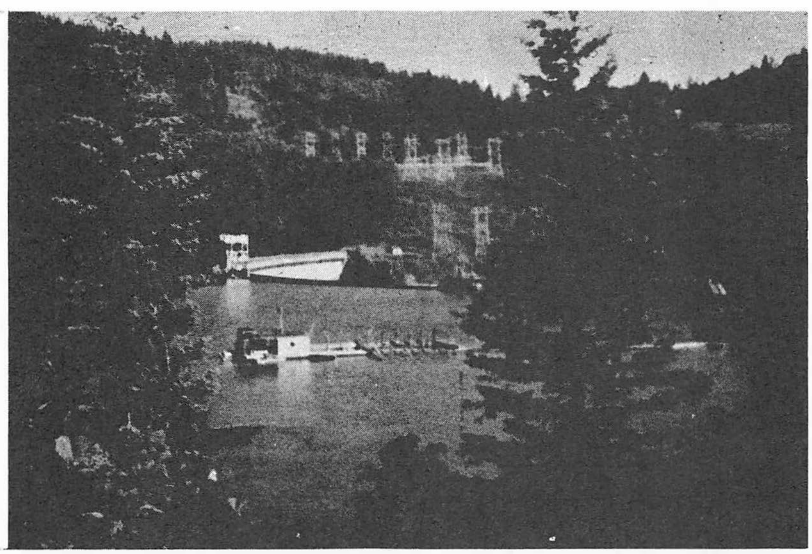


Plate 7. Juvenile collector 1964 fishing site in relation to Merwin Dam.

At the first two sites the primary flume of the collector was facing uplake, (Plate 4) but in the last position the collector was turned around and pointed towards shore. The primary reason for the latter change was the successful fish sampling with "Lake Merwin" floating traps that were fished at the site previously. This third site, about 100 yards above the dam (Plate 7) was the location of the collector during the 1964 season.

When attached to the collector, the anterior most part of the 1964 well addition was approximately 150 feet offshore. The water depth below the addition was about 50 feet and there was a gradual increase to 70 feet in depth below the stern of the collector. At the other two fishing sites utilized in 1963, the collector was fished closer inshore and the water depth was approximately 30-40 feet.

Operation of the collector

The construction and initial testing of the collector was completed in April 1963, with routine operation of the collector commencing on April 16. On April 25 mechanical failure of the right secondary pump necessitated a 34-hour shutdown for repairs. On May 24 the right secondary pump again ceased functioning and operations were not resumed until June 1. The collector was then operated until June 29 when the migration appeared over.

The collector was also operated in October and November 1963 to determine if there was a full migration but only 19 coho were taken in 220 hours of operation.

In 1964 the collector addition was constructed at Merwin Dam during February and March. Operation of the collector on a part-time basis began on March 23. The first catch of fish occurred on March 27 and operation of the collector on a continuous basis began April 1. The operation was continued through June 28, 1964 when the migration appeared to have ceased.

Mechanical difficulties, apparently resulting from an improperly aligned shaft, were experienced with the right secondary pump of the collector on two different occasions. The collector was inoperative for 21 hours on April 14 and 15 while new bearings were installed in the pump. When this failed to correct the problem, the collector was raised to its maintenance position on April 16-20, and was inoperative for 127 hours while repair work continued on the pump. On May 13 the pump again behaved adversely but this was corrected with a loss of only seven hours fishing time. This latter repair work apparently resolved the mechanical problem, as the pump ran normally the remainder of the 1964 season.

Operational procedures

For the initial operation of the collector, it was decided to approximate the conditions at the Baker collectors as closely as possible. Therefore standard operating conditions of approximately 200 cfs into the main flume and a weir crest height (initial depth of water in the secondary separation channel) of about 20 inches were created. From these standards it was intended to test the collector under other conditions to determine optimum operation criteria.

Catches were tabulated by two-hour periods, although the collection baskets were raised and emptied whenever fish were seen in them in order to minimize possible injury from the turbulence.

All salmon captured in the collector were measured; tagged yearlings and 1962 brood coho were returned to the lake. All of the untagged yearling (1961 brood) coho were marked as part of the Lake Merwin research program. These latter fish were then barged into the beach and transferred to a 200-gallon aerated tank mounted on a pick-up truck for transportation to a release area in the river approximately one-quarter mile below Merwin Dam.

In 1964 it was desired to run further tests on the wide range of internal water depths and velocities possible in the collector, in order to determine optimum conditions for fish attraction, but it was first considered more important to test the effect of the new addition. An attraction flow of approximately 190 cubic feet per second into the collector had appeared most favorable during the 1963 operation but the inflow was set at 254 cfs during the initial 1964 operation to provide increased current inside the addition. The 1963 results indicated fish passage over the primary flume weir crest was aided by increasing the depth of water over the crest. Consequently in 1964 it was decided to retain a maximum amount of water over the crest and, in practice, this depth was generally about 27 inches.

During the 1963 season various combinations of the mercury vapor lights were employed for fish attraction at night. To standardize the 1964 operation, only the three lamps over the primary flume were used during all hours of darkness for fish attraction. All other lights on the collector, excepting fluorescent fixtures required for fish handling, remained off.

Except for changes in the enumeration of the catch and in handling the tagged coho, the fish processing procedures were similar to those followed in 1963. In enumeration the catches were tabulated in four-hour intervals in contrast to every two hours as had been done in 1963. This allowed the entire catch for a 24-hour period to be held in only six separate live boxes and enumeration of the catch was not necessary at night. Tagged coho were also released into the river instead of being returned to the lake as was done in 1963.

THE LAKE MERWIN RESEARCH PROGRAM

The Washington Department of Fisheries and Pacific Power and Light Company conducted tagging studies in 1961 and 1963 to enumerate the yearling coho salmon populations and to study the distribution and movement of these fish in the reservoir. Hamilton and Rothfus (1963) demonstrated that Lake Merwin reared coho moved to the vicinity of the dam during the normal spring migratory period. A similar tagging study was also conducted in the spring of 1964; however, its primary purpose was to enumerate the coho population, Hamilton et al (1964).

Identical tagging sites, at approximate distances of 2, 6, and 10 miles above the dam (Figure 1) were utilized for both the 1963 and 1964 studies. Lake Merwin floating traps, units of gear very similar in design to the floating traps used commercially in Alaska to capture adult salmon, were used to capture the uplake coho for tagging. In both years a Lake Merwin trap, referred to as

Trap 1-A, was utilized as recovery gear at the dam. The primary function of this trap was to serve as an indicator of the relative abundance of coho in the area. In 1963 a second Lake Merwin trap (Trap 1) was fished at the dam during the period of major breakdown of the collector near the end of May.

Fish available to the collector

On August 21-22, 1962 a plant of fingerling, 1961 brood, coho salmon was made at Speelyai Bay, about eight miles uplake from Merwin Dam, as part of the regular Lake Merwin program. These fish had been reared in holding ponds at the Speelyai hatchery. In the spring of 1963 the previously mentioned tagging study demonstrated a population of 28,452 yearling coho in the lake. The 1964 tagging study indicated 4,894 of these fish were present in the lake as two-year-old fish.

To determine if stream reared fish would utilize the collector to a greater extent than those which were lake reared, 949 migrant coho from Speelyai Creek were tagged and released into the lake from March through June 1963. This experiment was repeated the following season and 742 tagged Speelyai migrants were released in the lake from April 13 through June 3, 1964.

On April 3, 1963, 102,000 unfed Lewis River chinook salmon fry (1962 brood) were released at the Woodland Park resort, about five miles uplake from the dam, to determine if this species would migrate through the reservoir and utilize the collector.

On May 27, 1963, 682 yearling coho and 116 yearling sockeye salmon, obtained from the Lower Baker Dam collector, were released into Speelyai Bay. Recognizing that the additional factors of handling and placing the fish in a different environment were being introduced, this experiment was designed to test possible differences in behavior patterns between these fish and the Lake Merwin yearling coho.

Also during the spring of 1963, a plant of unfed coho fry was made in Speelyai Bay. These 1962 brood fish were reared in the lake and migrated in the spring of 1964, at which time their population was estimated at 12,229 fish.

Other salmonoid fish present in the lake in unknown numbers included land-locked sockeye salmon or kokanee, and rainbow and cutthroat trout.

RESULTS

Catches during the 1963 and 1964 spring migrations

The total number of yearling coho obtained in the collector in 1963 was 2,525. This total includes 2,269 Lake Merwin yearlings, 130 Speelyai Creek migrants, and 126 Baker River stock. The catch of 1962 brood salmon was 383 coho and 38 chinook. None of the Baker River sockeye salmon were caught in the collector. The incidental fish catch was 166 trout and two kokanee (Table 2).

The collector was operated for a total of 1,482 hours, the yearling coho catch amounting to only 1.7 fish per hour over the entire 1963 season. During the five weeks of highest catches in the collector, May 12 to June 22, the yearling catch was 3.0 fish per hour.

The peak yearling coho catch in the collector occurred during the week ending June 8 when 900 fish were obtained. The highest daily catch was 283 coho yearling on June 2. Catches in recovery Trap 1-A, utilized as an indicator of fish abundance at the dam, reached a peak during the last week in May when the collector was inoperative due to mechanical failure of one of the pumps. However, due to tests to determine its affect upon catches in the collector, this trap was fished only part time during the period June 1-10.

Table 2. Weekly catches in the Lake Merwin juvenile fish collector, 1963.

Week Ending	Lake Merwin	1961 Brood Coho Speelyai Creek	1961 Brood Coho Baker River	1962 Brood Coho	1962 Brood Chinook	Kokanee	Trout
April 20	2	0	0	2	0	0	0
27	6	0	0	0	0	0	0
May 4	6	0	0	0	0	0	1
11	60	0	0	0	0	0	1
18	279	0	0	0	0	0	5
25	152	0	0	0	0	0	11
June 1	Not operating						
8	853	24	23	0	0	0	48
15	625	49	50	5	0	1	51
22	235	44	39	13	0	0	30
29	58	14	14	63	7	0	19
July 10-19	2	1	0	300	31	1	0
Season Totals	2,278 1/	132 2/	126	383	38	2	166

1/ Includes 9 multiple tag recoveries.
2/ Includes 2 multiple tag recoveries.

The total number of coho obtained in the collection baskets in 1964 was 9,598. This total includes 2,088 coho of the 1961 year class; 7,054 lake reared yearling coho, and 456 Speelyai Creek migrants. The catch of other species was 94 chinook salmon, 22 kokanee, and 718 trout (Table 3). The trout catch includes at least 41 multiple tag and mark recoveries; the salmon totals are individual recoveries only.

Table 3. Weekly catches in the Lake Merwin juvenile fish collector, 1964.

Week Ending	Tagged coho recoveries: Lake 1961 Brood	Lake 1962 Brood	Speelyai Creek	Untagged coho 1961 Brood	Untagged coho 1962 Brood	1962 Chinook	Kokanee	Trout
March 28	0	0	0	21	1	0	0	0
April 4	1	0	0	121	7	0	0	2
April 11	14	0	0	366	19	0	0	9
April 18	18	0	0	206	29	0	0	1
April 25	3	3	0	98	60	0	0	2
May 2	83	27	0	436	412	6	0	10
May 9	43	115	0	310	1,269	6	1	22
May 16	8	121	2	110	1,250	6	4	32
May 23	29	216	13	168	1,695	31	3	68
May 30	5	137	51	32	617	16	3	100
June 6	0	92	101	12	397	13	9	121
June 13	0	58	156	2	221	8	2	101
June 20	0	21	93	1	140	2	0	148
June 28	0	5	40	1	142	6	0	102
Totals	204	795	456	1,884	6,259	94	22	718

The collector was operated for a total of 2,000 hours; the coho catch amounting to 4.80 fish per hour over the entire 1964 season. During the five weeks of highest catches in the collector, April 26 - May 30, the coho catch was 8.6 fish per hour.

The peak coho catch occurred during the week ending May 23 when 2,048 fish were collected (Figure 5). The highest daily catch was 617 coho on May 18, 1964.

Size composition of the coho catches.

As a result of rearing in the highly productive lake environment, the Lake Merwin yearling coho were considerably larger than either the Speelyai Creek or the Baker River stocks. The Lake Merwin yearlings captured in the collector in 1963 averaged 205.9 mm in fork length as compared with 167.5 mm for the Speelyai Creek fish and 159.9 mm for the Baker River coho (Figure 6). There were probably

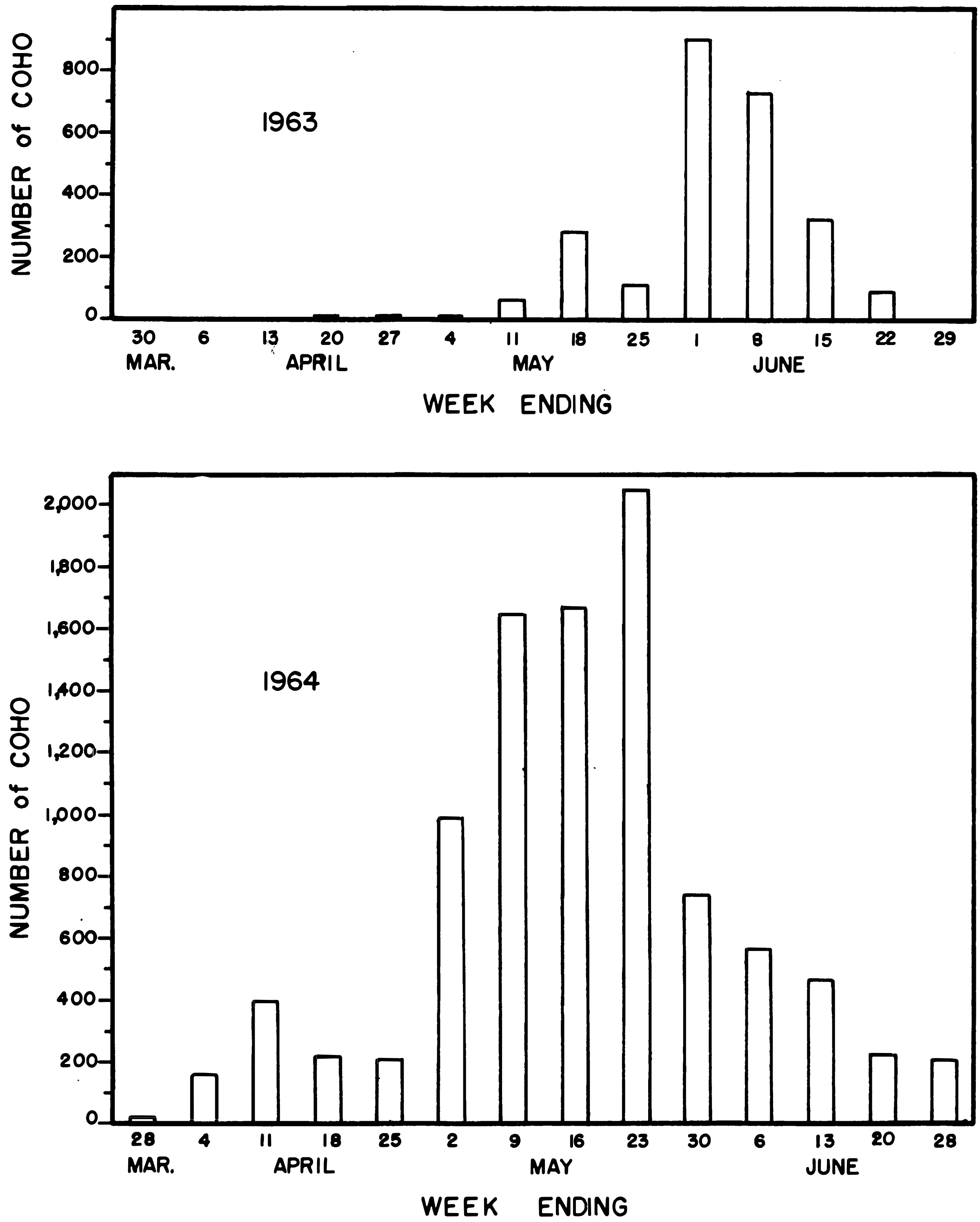


Figure 5.--Weekly catches in the Lake Merwin juvenile fish collector, 1963 and 1964.

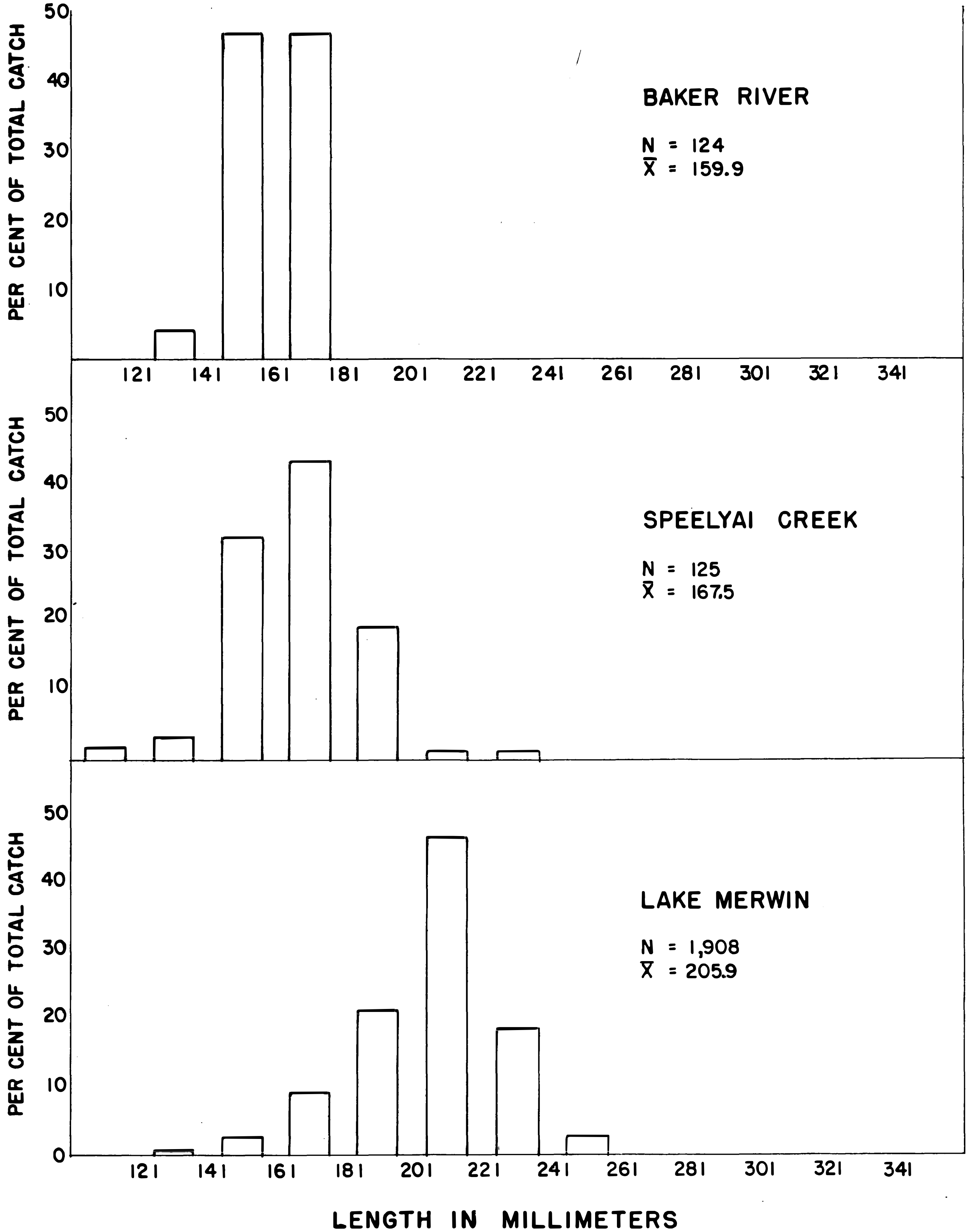


Figure 6.--Length frequencies of yearling coho salmon obtained in the Lake Merwin juvenile fish collector, 1963.

a few two-year-old coho in the lake in 1963 but their numbers were considered insignificant and no attempt was made to separate them from the yearling catch.

In 1964 scale readings and length frequencies were examined to determine the year class of coho obtained in the collector. These findings indicated that an overlap in lengths of the 2-year classes occurred in the size range from 240-280 mm during the season. It appeared that 260 mm could be effectively utilized as the separation point of the two-year classes (Hamilton et al ibid). On this basis the 1961 year class formed the bulk of the coho catch during the first four weeks of operation (March 23 to April 18, 1964), but the catch was primarily yearling (1962 brood) fish during the remainder of the season (Figure 7).

The Speelyai Creek tagged fish began appearing in the collector catch in fairly large numbers during the last week of May 1964. These fish averaged 161 mm in fork length when obtained in the unit. A large number of untagged coho of the approximate size of the Speelyai tagged fish was also obtained in the collector in June, and it is believed that some of these fish might have been escapees from Speelyai Creek.

Efficiency of the collector.

In order to determine the 1963 efficiency of the juvenile collector on lake reared coho, the number of fish captured in the two Lake Merwin Program recovery traps must be deducted from the population estimate to obtain the actual number of lake yearlings available to the collector. Trap 1-A fished throughout the season and captured 2,898 unmarked yearling coho. Trap 1 fished for approximately two weeks and captured 3,386 unmarked yearlings. The number of yearling coho available to the collector was 28,452 minus 6,284 or 22,168. Of this number the collector captured 2,268 or 10.2% (Table 4).

The efficiency of the collector slightly improved upon the Speelyai Creek fish. Of 949 migrants released into the lake over a period of approximately three months, the collector captured 120 fish (13.7%).

Of the 682 yearling Baker River coho released into the lake, 66 were removed by the two traps, leaving a total of 616 available to the collector. The collector captured 126 Baker yearlings for a recovery rate of 20.5%.

It should be noted that the results of live box tests to determine handling mortality and tag loss for the Lake Merwin fish involved in the population enumeration and the Speelyai Creek migrants were unavailable during the preparation of this report. The application of a correction factor for mortality and tag loss would undoubtedly decrease the number of fish available to the collector and increase the efficiency. Similarly, live box tests to determine the effects of transporting and handling the Baker River fish were not conducted, and the physical condition of these fish was judged to be poor at the time of their release into the lake.

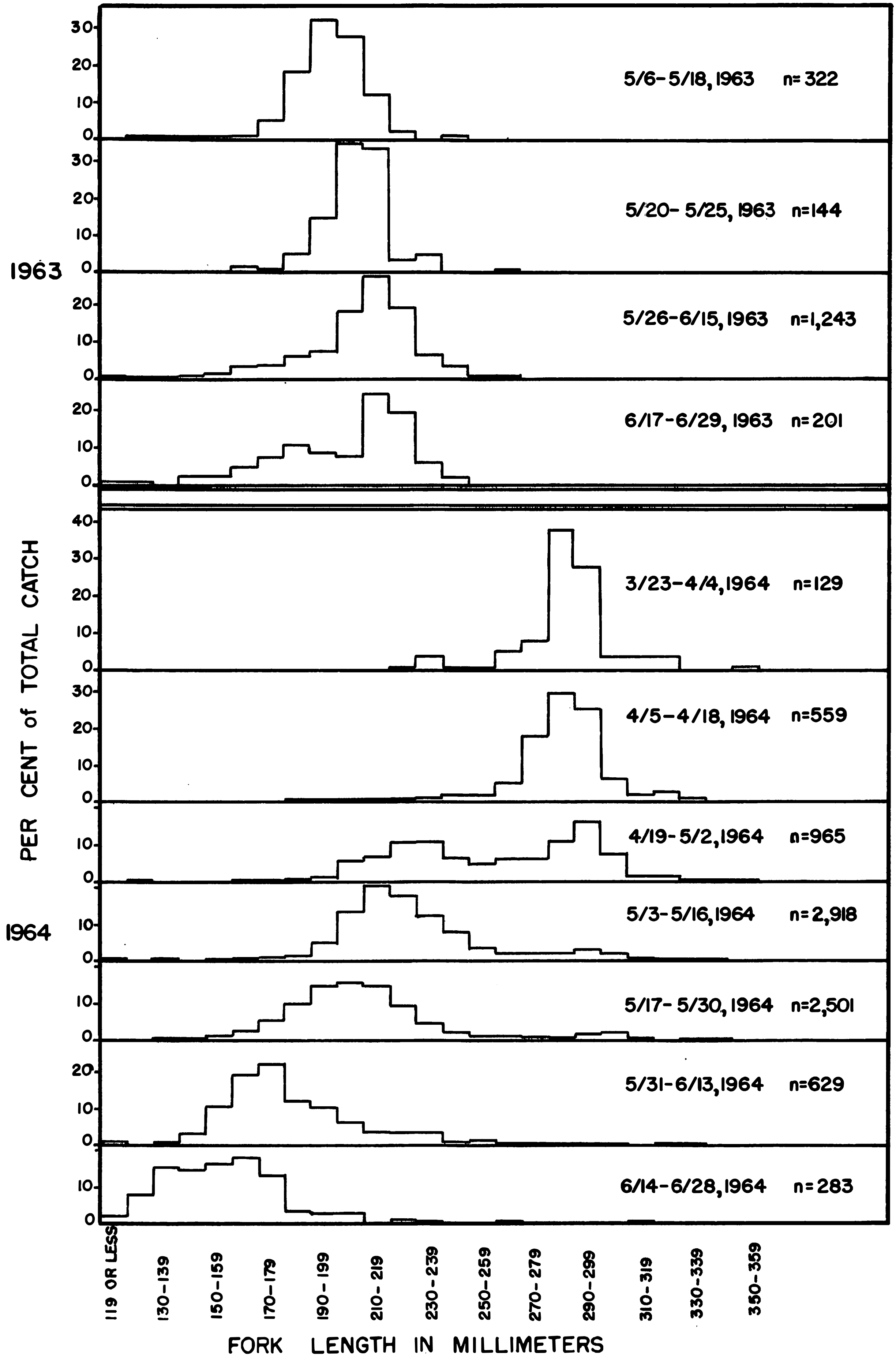


Figure 7.--Coho salmon length frequencies by two week fishing intervals, Lake Merwin juvenile fish collector, 1963 and 1964.

Table 4. Yearling coho salmon recovery rates, Lake Merwin juvenile fish collector, 1963.

Source of fish	Number available to collector	Number recovered	Per cent recovered
Lake Merwin	22,168	2,269	10.2
Speelyai Creek	949	130	13.7
Baker River	616	126	20.5

In addition to the coho obtained in the collection baskets, fish removed from the lake population by four other types of recovery gear during the period of operation of the collector must be considered when computing the efficiency of the unit for 1964. These other gear are (1) the nets over the discharge from the collector, which recovered fish passing through the louvers in the main flume, (2) the previously mentioned recovery Trap 1-A which was fished at the dam from March 30 through June 11, (3) the gill net vertical distribution study which coincided with the operation of the collector, and (4) the sport fishery in the lake, April through June 1964.

Most of the fish recovered in the discharge nets and in the gill nets were either dead or injured too badly to be returned to the lake population and all coho recovered in Trap 1-A were released into the river with the collector fish. Consequently, the affect of these three units of gear upon the total population is a known factor. An evaluation of the sport fishery was not made, and its effect on the total coho population, particularly on 2-year-old fish, is known. The fishery was monitored on a few occasions and voluntary tag returns were incurred, but the unknown sport tag recoveries would in effect reduce the population estimates and increase the calculated collector efficiency.

The known number of yearling coho removed from the lake population by the discharge nets, gill nets, Trap 1-A, and the sport fishery was 1,445. Deducting these fish from the population estimate resulted in a total of 10,784 yearlings available to the collector in 1964 and the efficiency rate was $\frac{7054}{10784}$ or 65.4%.

The known number of 2-year-old coho removed from the lake population was 953 and the efficiency of the collector on these fish was $\frac{2088}{3941}$ or 53%.

The efficiency of the collector was also computed on the basis of tag recoveries only. In Table 5 the recoveries of all tags in all types of recovery gear are listed by year class and origin of the fish. The combined results (Table 6) show a recovery rate in the collector of 65.6% of the tagged lake yearlings, 53.1% of the tagged 2-year olds and 66.2% of the tagged Speelyai Creek yearlings. The 1964 efficiency figures again are minimal values only, as a tagging mortality factor was unavailable at the time of preparation of this report.

Table 5. 1964 Lake Merwin coho tag recoveries by type of gear and origin of the fish.

Origin of fish	Brood year	Number tagged	Recoveries				
			Collection baskets	Discharge nets	Trap 1-A	Gill nets	Sport fishery
Lake Merwin	1961	497	204	3	64	11	35
Lake Merwin	1962	1,345	795	15	86	22	10
Speelyai Cr.	1962	742	456	12	30	11	0

Table 6. Combined 1964 Lake Merwin tag recoveries by year class.

Coho year class	Number tagged	Discharge nets, Trap 1-A, gill net and sport fishery recoveries	Available to collector	Collector recoveries	Collector per cent recovery
1961 Lake Merwin	497	113	384	204	53.1
1962 Lake Merwin	1,345	133	1,212	795	65.6
1962 Speelyai Cr.	742	53	689	456	66.2

Pump discharge net tests.

Nets were fished in 1963 and 1964 in the discharges from the two main pumps of the collector to determine the number of fish passing through the louvers of the main flume. The net frames raise and lower in metal guides which position them exactly over the egress from the primary sump, and the entire discharge from the pumps passes through the nets. In 1963 the nets were fished May 14 - June 29, while in 1964 they were fished continuously from April 3 through the remainder of the 1964 season and captured 249 coho, 2 chinook, and 142 trout (Table 7).

The total coho catch in the collection baskets from April 3 to June 28 was 9,566. Therefore the number of coho passing through the louvers was 2.6% of the number entering the baskets. This figure is almost exactly the same as was obtained during the shorter 1963 test (Table 8). The percentage of trout passing through the louvers in 1964 as compared with the collection basket catch was much higher at 19.8% (Table 7).

Table 7. Pump discharge net catches for the Lake Merwin juvenile fish collector, 1964.

Period	Coho salmon catch: Collection baskets	Coho salmon catch: Discharge nets	Coho salmon catch: Nets/baskets	Trout catch: Collection baskets	Trout catch: Discharge nets	Trout catch: Nets/baskets	Other species: Chinook salmon	Other species: Sculpins
April 3-18	774	16	2.1%	11	4	36.4%	0	2
April 19-May 2	1,203	13	1.1%	12	1	8.3%	1	0
May 3-16	3,320	111	3.3%	54	10	18.5%	1	0
May 17-30	2,787	71	2.5%	168	21	12.5%	0	0
May 31-June 13	1,043	31	3.0%	222	54	24.3%	0	0
June 14-28	439	7	1.6%	250	52	20.8%	0	4
Totals	9,566	249	2.6%	717	142	19.8%	2	6

Table 8. Pump discharge net catches for the Lake Merwin juvenile fish collector, 1963.

Week	1961 Brood coho: Collection baskets	1961 Brood coho: Side nets	Net/baskets	1962 Brood coho	1962 Brood chinook	Trout	Sculpins	Suckers
May 14-24	333	7	2.0 %	1	0	2	0	0
June 1-7	900	11	1.0 %	0	0	3	1	1
June 8-14	724	15	2.0 %	0	0	8	1	1
June 15-21	318	8	3.0 %	7	3	15	0	1
June 22-29	86	15	17.0 %	7	0	8	0	0
Total	2,358	56	2.4 %	15	3	36	2	3

The year class was obtained for 197 of the 249 coho captured in the discharge nets in 1964; the other 52 fish were mutilated too badly for accurate measurement. Those measured included 28 of the 1961 brood and 169 of the combined 1962 lake and Speelyai Creek broods. Of the 9,566 coho obtained in the collection baskets (1964) during the period the nets were also fished, 2,057 were 1961 brood and 7,509 were 1962 brood. Therefore, the ratios of net catches to basket catches for the identified coho were 1.36% for the 1961 brood and 2.25% for the 1962 brood, indicating the louvers were slightly more efficient in guiding the larger coho.

Catch in the collector as related to flow.

The original intent during the 1963 season was to test the four basic attraction flows into the collector and the wide range of internal water velocities and depths, with the view of determining which combination provided optimum operating conditions. Tests were set up when the collector first began operating in mid-April, but all combinations tried were equally unsuccessful, although catches in Trap 1-A indicated that there were yearling coho in the area. For this reason the emphasis was shifted to increasing the catch, rather than testing, with the assumption testing could be resumed when the catch increased. The addition of net leads was one part of the attempt to increase catches and the movement of the collector was another. However, even during the period of greatest catches in the collector in 1963, June 1-16, the schools of fish entering the main flume were small and scattered and adequate testing conditions were not met. Therefore the original operating criteria, as adopted from the Baker collectors, were utilized throughout most of the season. As a general rule, the two primary pumps were operated singly and the initial depth of water in the secondary flume was 20-24 inches. Table 9 presents the catch in the collector by flow, but these results are misleading because 86 and 305 cfs were not tried during the periods of greatest fish abundance.

Observations on fish behavior were hampered early in the season by the turbidity of the water. However, all indications suggested fish behavior to be most satisfactory at 190 cubic feet per second. This amount of inflow apparently produced smoothly accelerating velocities from the main flume into the collection baskets. At 86 cfs there did not appear to be a sufficient attraction flow. Head differences on either side of the vertical louvers were experienced at 254 and 305 cfs. (The above rates of flow do not include the additional 10-15 cfs which is normally contributed to the inflow by the two secondary pumps.)

Table 9. Yearling coho salmon catch by flow, Lake Merwin downstream migrant collector, 1963. (Weir crest set at 20-24 inches).

	Flow in cubic feet per second							
	86		190		254		305	
Month	Hours run	Catch	Hours run	Catch	Hours run	Catch	Hours run	Catch
April	22	0	211	7	48	0	20	0
May	0	0	465	459	51	27	0	0
June	14	5	440	1,508	181	520	30	14
Totals	36	5	1,116	1,974	280	547	50	14
Pct. of totals for season	2.4	0.2	75.3	77.7	18.9	21.5	3.4	0.6

Catches during daylight and dark hours.

Mercury vapor lights were used at night during both seasons to attract fish since catches made during hours of darkness in 1963 with all lights off were negligible. Most of the yearling coho caught prior to May 12, 1963 and all of the 1962 brood coho caught during the period July 10-19, 1963 were taken at night with the lights on. However, 76.6% of the yearlings captured over the entire 1963 season were taken during daylight hours (Table 10).

The 1964 results found the catch spread more uniformly over a 24-hour period with only 58.6% occurring during daylight hours (Table 10). However, 1200-1600 hours was the most productive period in both years.

Table 10. Coho salmon catches in the Lake Merwin juvenile fish collector by four hour intervals, 1963 and 1964.

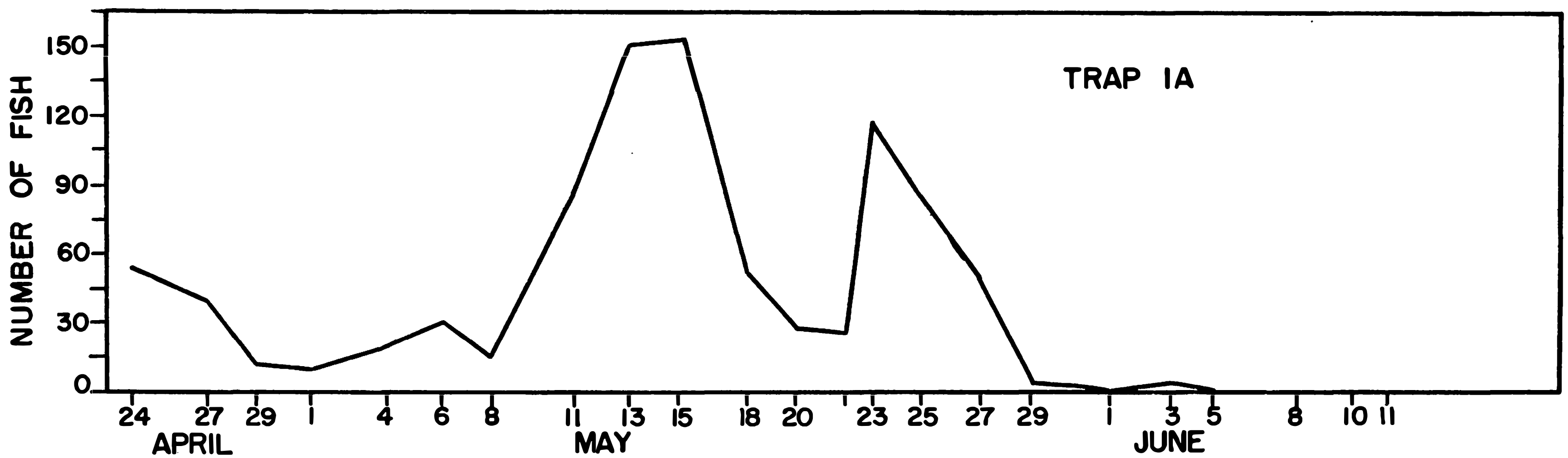
	Hourly time periods						
	0000-0400	0400-0800	0800-1200	1200-1600	1600-2000	2000-2400	Totals
1963 catch	322	229	511	724	575	175	2,536
Per cent of total	12.7	9.0	20.2	28.5	22.7	6.9	100.0
1964 catch	1,605	1,164	1,429	2,310	1,454	1,636	9,598
Per cent of total	16.7	12.1	14.9	24.1	15.2	17.0	100.0

Tests of the well addition to the collector.

Testing of the well on the collector began in late April and was continued through June 16, 1964. This consisted of comparing catches in the collector with panels in the front end of the addition set at 0, 14, and 28 feet in depth. (Throughout the tests the side panels were in place to a depth of 28 feet.) With the panels removed from the front, fish in the surface layers of the lake could enter directly into the well. Under this condition the inflow into the collector was very similar to that of 1963. With the front panels set at 14 or 28 feet in depth, however, fish in the surface water layers were required to sound and enter the well from below. Under these conditions the collector was drawing water from greater depths than in 1963.

During the testing the panels were generally set at the desired depth for 72 or 96 hours before being changed. Longer testing periods were prevented by the shortness of the migratory season and shorter periods were undesirable because of the sporadic pattern of catches in the collector. All tests began and ended at 1600 hours except for May 13 when the unit was shut down earlier for repairs.

Since catches in the gill net distribution study indicated the fish were concentrated in the surface layers (Erho, 1964) the panels were left out of the front section until April 27. However, the installation of all panels on this date (28 foot depth) resulted in an immediate increased catch in the collector, although the Trap 1-A catch did not indicate an increase in abundance of fish (Figure 8). In the 96-hour period preceding the installation of the panels, the



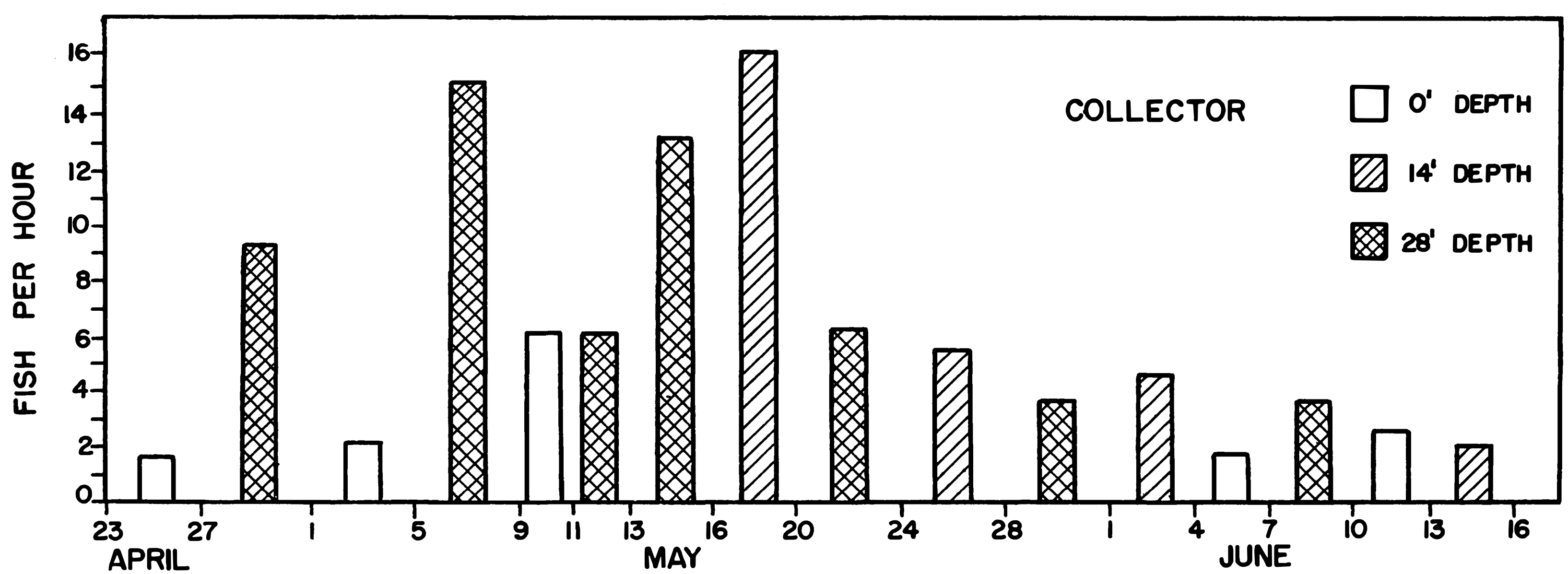


Figure 8.--Coho salmon catches in the juvenile fish collector and in trap I-A during the testing of the 1964 addition to the collector.

collector recovered 147 coho. After the panels were installed the catch was 887 coho in 93 fishing hours.

When the front panels were removed on May 1, the collector caught 232 coho in 94 fishing hours; and the installation of all panels on May 5 resulted in a catch of 1,454 fish in the following 96 hours. During the period May 9-13, the recovery rates were 296 coho in 48 fishing hours with the front panels removed and 252 coho in 41 fishing hours with all panels installed. These latter results were possibly affected by mechanical failure of the collector on the 13th.

Following repair work on the unit, testing was continued at the 28 foot depth until May 16 when the front section was set at 14 feet. Because of a time limitation on the testing, this series of tests was considered to commence on May 12, and in the following 89 hours the collector recovered 1,296 coho. From May 16-20, with the front section at 14 feet, the recovery was 1,540 coho in 96 fishing hours. On May 20 the panels were reset at maximum depth and a catch of 588 fish occurred in 94 hours. During the 96-hour period of May 24-28 with panels at 14 feet, the catch was 531 coho. From May 29 - June 4 the collector recovered 264 coho in 72 hours at maximum fishing depth and 337 coho in 72 hours with the front section at intermediate depth.

During June it was planned to conduct tests comparing all three depths, but this was curtailed by a decrease in abundance of fish. By combining the results of tests at 14 and 28 feet, however, a measure of the effect of panel installation can be obtained.

From June 4-7 the catch was 124 coho in 72 fishing hours with all front panels removed. On June 7 fishing was resumed at the 28 foot depth and 266 coho were obtained in the following 72 hours. All front panels were again removed on June 10 and 190 coho were recovered in another 72-hour test. On June 13 the panels were set at 14 feet and a catch of 133 coho occurred in the ensuing 68-hour test period.

The results of the three series of tests indicated that the panel installation to a depth of 28 feet during the period April 23 - May 13 effectively increased the catch in the collector. With all front panels removed from the addition the collector recovery rate was 2.84 fish per hour; with these panels set at 28 feet in depth, the recovery rate was 11.27 fish per hour (Table 11). During the period of May 12 through June 4, catches at the 14 and 28 foot panel depths were somewhat similar. With the panels set at 14 feet in depth, the coho recovery rate was 9.12 fish per hour and at the 28 foot depth the recovery rate was 8.42 fish per hour.

During June the presence of the panels did not appear to greatly increase the catches. The recovery rate with all front panels removed was 2.18 fish per hour, while 2.85 fish per hour was obtained with the panels at 14 or 28 feet in depth.

Table 11. Coho salmon catches in the Lake Merwin juvenile fish collector with the front section of panels in the well set at 0, 14, and 28 feet.

Period	Panel depth	Fishing hours	Coho catch	Period	Panel depth	Fishing hours	Coho catch
April 23-27	0	96	147	April 27-May 1	28	93	887
May 1-5	0	94	232	May 5-9	28	96	1,454
May 9-11	0	48	296	May 11-13	28	41	252
		238	675			230	2,593
Fish per hour = 2.84				Fish per hour = 11.27			
May 12-16	28	89	1,296	May 16-20	14	96	1,540
May 20-24	28	94	588	May 24-28	14	96	531
May 29-June 1	28	72	264	June 1-4	14	72	337
		255	2,148			264	2,408
Fish per hour = 8.42				Fish per hour = 9.12			
June 4-7	0	72	124	June 7-10	28	72	266
June 10-13	0	72	190	June 13-16	14	68	133
		144	314			140	399
Fish per hour = 2.18				Fish per hour = 2.85			

It should be noted that the Trap 1-A catches presented in Figure 8 are used only as an indicator of the relative abundance of coho near the dam. Although this trap was located approximately 300 yards uplake from the collector, all indications were that the latter had the more preferable fishing site and fish moving to the dam were more likely to encounter the collector first. Therefore daily fluctuations in the trap catches could have been partly influenced by the catches in the collector.

It should also be noted that the testing periods per each panel depth were not selected randomly, but followed one another in orderly sequence. Extreme fluctuations in catches occurred within the individual testing periods at one particular depth and the apparent increase in catch due to panel position might have been primarily due to fish abundance. To determine if the observed differences in catches at the three panel depths were significant, a statistical analysis was performed on the catch data.

The first step in the analysis was the calculation of fish per hour values for each 24-hour fishing interval within the various testing periods listed in Table 11. These values were summed to obtain one fish per hour total for the entire period (Table 12). The combined results produced six periods of comparisons of catches with the panels set at depths of 0 feet and 28 feet, six comparisons at 28 feet and 14 feet, and four comparisons of panels "in" versus panels "out" in June.

Table 12. Coho catches in fish per hour during the 1964 testing of the well addition to the Lake Merwin juvenile fish collector.

Testing Period	Panel 0 ft	Depths 28 ft	Testing period	Panel 28 ft	Depths 14 ft
April 23 to May 1	2.6	9.3	May 12 to May 20	10.4	5.4
	1.7	6.1		13.8	35.3
	0.1	16.1		16.8	16.4
	1.8	6.6		16.0	7.1
Subtotals	6.2	38.1		57.0	64.2
May 1 to May 9	1.0	16.6	May 20 to May 28	3.9	3.7
	4.4	11.4		12.0	2.7
	1.4	11.7		5.7	10.4
	2.9	21.0		3.4	5.3
Subtotals	9.7	60.7		25.0	22.1
May 9 to May 13	3.7	3.1	May 29 to June 4	4.3	7.5
	8.7	10.4		3.3	6.1
				3.5	0.5
Subtotals	12.4	13.5		11.1	14.1

Testing Period	Panel 0 ft	Depth 14 or 28
June 4 June 10	1.9	1.5
	2.8	7.0
	0.5	2.6
Subtotals	5.2	11.1
June 10 June 16	0.5	3.3
	1.5	2.3
	5.9	0.4
Subtotals	7.9	6.0

The testing periods for the computed panel depths were arranged in a one way analysis of variance design and the hypothesis that catches were equally as good at each depth was tested at the 95% level of significance. The hypothesis was rejected for the series of tests with the panels at 0 feet and 28 feet, but it was accepted for the other two types of comparisons (Table 13). [The tabled distribution of F is from Snedecor (1956) Table 10.5.3, p. 246.]

Table 13. Analysis of variance table for comparisons of catches with the panels set at 0, 14, and 28 feet.

A. Analysis of variance table for 0 versus 28 feet in depth, April 23-May 13, 1964

Source	Sum of squares	Degrees of freedom	Mean square	F value	Tabled distribution of F
Between classes	496.74	5	99.35	7.92	2.96
Within classes	175.50	14	12.54		

B. Analysis of variance table for 28 versus 14 feet in depth, May 12-June 4, 1964

Source	Sum of squares	Degrees of freedom	Mean square	F value	Tabled distribution of F
Between classes	526.43	5	105.29	2.41	2.85
Within classes	698.94	16	43.68		

C. Analysis of variance table for 0 versus 14 or 28 feet in depth, June 4-16, 1964

Source	Sum of squares	Degrees of freedom	Mean square	F value	Tabled distribution of F
Between classes	6.88	3	2.29	0.45	4.07
Within classes	40.48	8	5.06		

To further define the source of variability in the catches at 0 feet versus 28 feet, a two-way analysis of variance test was performed. When the observations were arranged as in Table 14 below, it can be seen that the proportional numbers model is appropriate (Snedecor, 1956). The analysis of variance for these observations is given in Table 15.

Table 14. Observation table obtained from the totals of each testing period in Table 12.

Testing period	Observations at 0 ft	Observations at 28 ft	Totals for testing periods
April 23 to May 1	n = 4 + = 6.2	n = 4 + = 38.1	n = 8 + = 44.3
May 1 to May 9	n = 4 + = 9.7	n = 4 + = 60.7	n = 8 + = 70.4
May 9 to May 13	n = 2 + = 12.4	n = 2 + = 13.5	n = 4 + = 25.9
Subtotals	n = 10 + = 28.3	n = 10 + = 112.3	n = 20 T = 140.6

Table 15. Analysis of variance table (proportionate analysis)

Source	Sum of squares	Degrees of freedom	Mean square
Testing period	44.11	2	22.06
Panel depth	352.80	1	352.80
Interaction	99.83	2	49.92
Error	175.50	14	12.54

The hypotheses tested were (1) no significant differences in catches due to testing periods, (2) no significant differences in catches due to panel positions, and (3) no interaction between the panel positions and testing periods.

For (1) $F = \frac{22.06}{12.64} = 1.76$ Since F (d.f. 2.14) = 3.74, this hypothesis is accepted.

For (2) $F = \frac{352.80}{12.54} = 28.13$ Since F (d.f. 1.14) = 4.60, this hypothesis is rejected.

For (3) $F = \frac{49.92}{12.54} = 3.98$ Since F (d.f. 2,14) = 3.74, this hypothesis is rejected.

The interpretation of the interaction between panel positions and testing periods is that catches with the panels at 28 feet were significantly greater for the periods April 23 to May 1 and May 1 to May 9, but not for the period May 9 to May 13 (Table 7). It is suspected that this latter is at least partly due to mechanical malfunctioning of the collector during this period.

Water temperature.

The temperature of the inflow to the collector was monitored by a recording thermometer throughout the 1963 and 1964 seasons. Also, from late April through the remainder of the 1964 season, daily surface to bottom water temperature readings were taken inside the addition and off the stern of the collector. The spring of 1964 was extremely cool and water stratification in the vicinity of the collector was minor throughout the entire migration season (Figure 9). In 1963 stratification was evident in the vicinity of the collector in June (Figure 10). The temperature of the inflow to the collector did not reach 60 F until the last day of the 1964 operation, and during the period of highest catches it was 45-50 F. These later values compare with a temperature of about 58 F during the period of highest catches in 1963. In the latter part of the 1964 season the surface water temperature was slightly warmer off the stern of the collector than inside the well addition, probably due to the upwelling of water inside the addition.

Observations on fish behavior in and around the collector.

In 1963 the fish were generally observed entering the main flume in small groups (10-20 fish). Once inside the flume they would normally drift slowly backwards, working laterally just above the horizontal louvers, until reaching a point approximately five feet in front of the weir crest. Here they apparently became disturbed and would swim out towards the entrance again. This maneuver would often be repeated several times before some or all of the fish crossed the weir crest and entered the secondary channel, or else the entire group would leave the collector. A few larger groups of fish (50-70) entered during the first two weeks in June and these fish appeared more willing to accept the collector. Also, the 1962 brood coho which were captured in July, averaging 129 mm in length, appeared more willing to accept the collector than had the smaller groups of yearlings.

Fish which crossed the weir crest and entered the secondary channel would normally pass on into the collection baskets. However, they would often remain in the channel several minutes before passing through the drawdown from the secondary separator.

In general the behavior of the fish inside the primary flume of the collector in 1964 was similar to that observed during the 1963 season. The one behavior difference noted between the two years was that in 1964 the fish appeared less hesitant to cross the weir crest and enter into the secondary separation channel, although it was not unusual for them to make repeated passes through this area before entering the baskets. On several occasions during the season large groups of coho (50-70 fish) were observed to pass over the crest and drift back in the secondary channel until reaching the louvered area. Here they would congregate for a short period of time, with perhaps a few entering the collection baskets. The remaining fish eventually swam entirely out of the collector and momentarily disappeared from view inside the well addition before re-entering the primary flume and repeating the cycle. This maneuver would often be repeated several times before the majority of the originally sighted group entered the baskets.

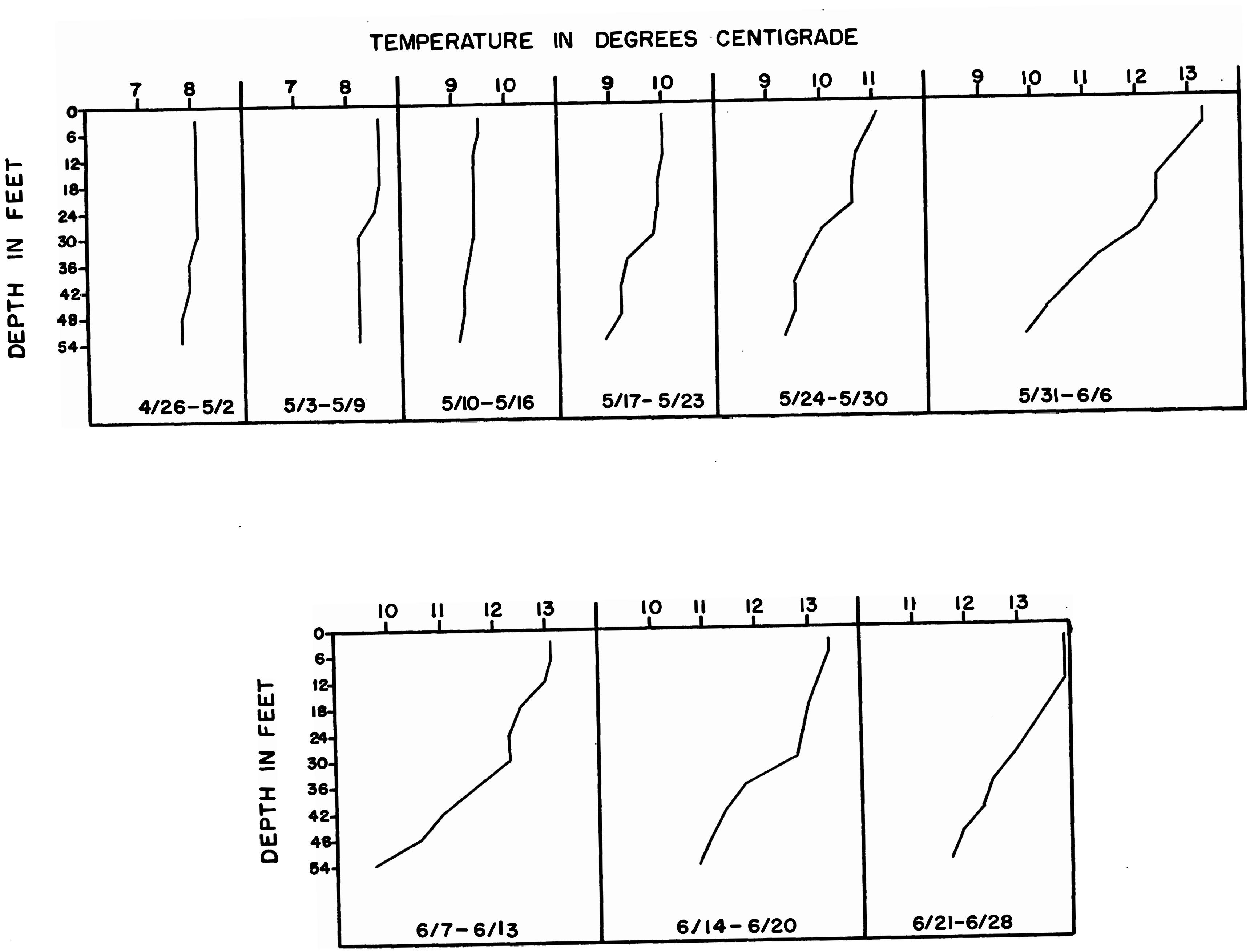


Figure 9.--Average weekly water temperatures at six foot intervals in depth inside the well addition to the juvenile fish collector.

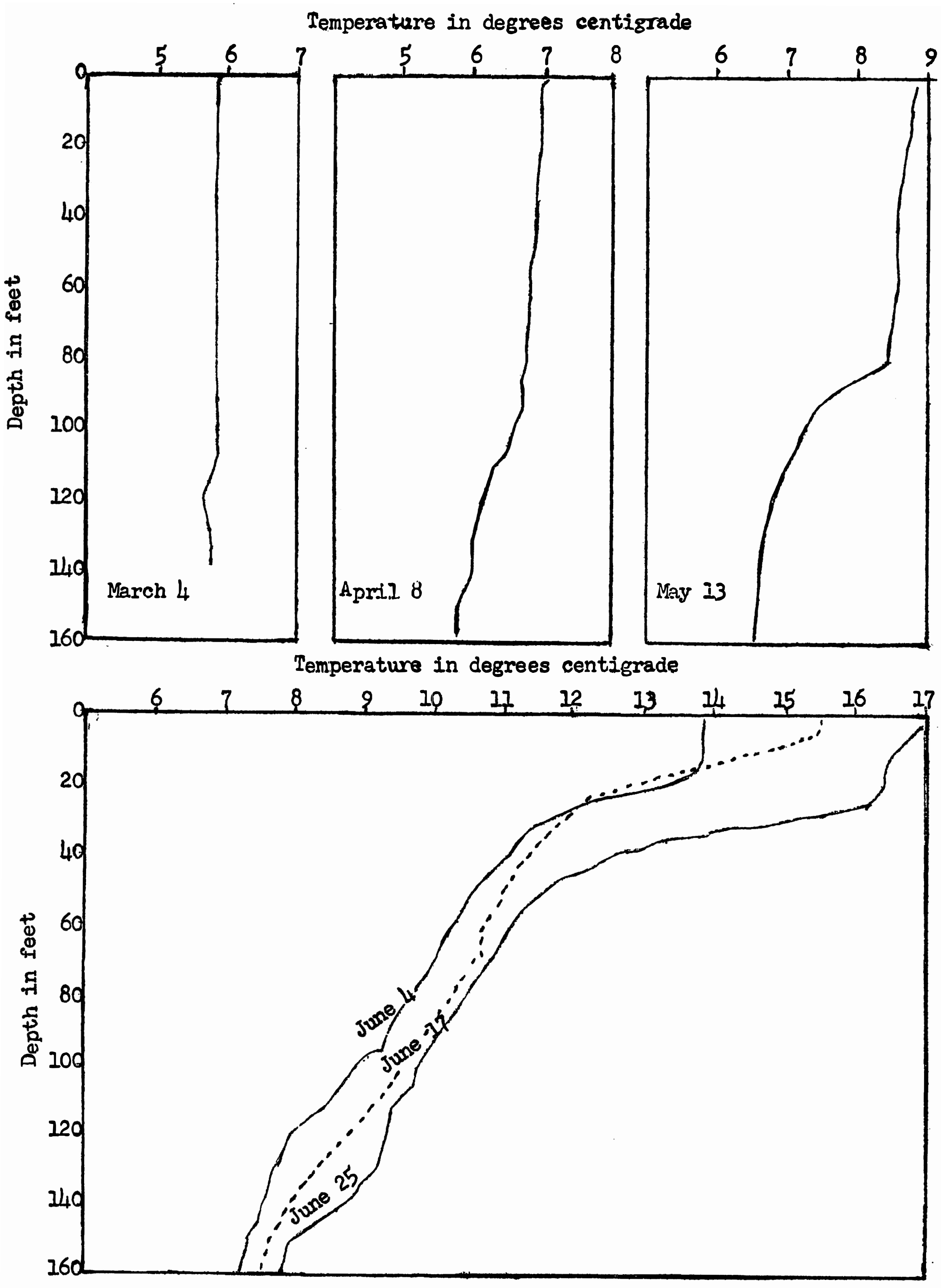


Figure 10 – Temperature profiles at Merwin Dam, 1963. (Unpublished data obtained from the Reservoir Limnological Study Program).

DISCUSSION

The results of the 1963 operation of the juvenile collector were extremely poor and the reason or reasons for this were thought to be related to the vertical distribution of the coho due to size of fish, water stratification, or other unknown factors. Of three stocks of fish available to the collector, the recovery rate was highest on the smaller fish (the Baker River and Speelyai Creek groups). Significant numbers of the larger lake-reared coho were approaching the floating Lake Merwin traps, as evidenced by the catches, and these traps were fishing to a depth of 30 feet as compared with 10 feet for the collector (Allen, ibid). Consequently, in 1964 a well addition to the collector was created which changed the maximum fishing depth from 10 to 28 feet.

The catch in the collector in 1964 improved appreciably despite the fact that the coho population was smaller than in the previous season. Based on the population estimate, the 1964 efficiency of the collector on yearling coho was calculated at 65.4%, as compared with 10.2% in 1963. Recoveries of coho tagged and released throughout the season uplake from the collector were 65.6% for Lake Merwin yearlings, 53.1% for lake two year olds, and 66.2% for Speelyai Creek migrant yearlings. The fish per hour value for 1964 over the entire season was 4.8 as compared with 1.7 fish per hour for 1963. During the five weeks of highest catches in the collector in each of the two seasons, the coho catch was 8.6 fish per hour in 1964 and 3.0 fish per hour in 1963.

The reason or reasons why the collector was more efficient in 1964 was not entirely due to the construction of the well addition. Tests of this structure were conducted during the season to determine its effect on the coho catch. With the front panels removed, inflow to the collector was considered to be drawn from the surface water layers similar to that in depth distribution of 1963. The 1963 catch during the period of highest recovery in the collector was 3.0 fish per hour. The 1964 catch during the period of highest recovery, April 23 - May 11, was 2.84 fish per hour with all panels removed from the front end (Table 11). When the panels were set at their maximum depth of 28 feet the catch increased to 11.27 fish per hour. Subsequent tests in May indicated it made little difference whether the panels were set at 14 or 28 feet in depth. During June the testing indicated no significant difference in catches, regardless of whether the front panels were in or out.

The panel testing was limited due to the shortness of the migratory season. In particular, 14 feet, or some other intermediate depth, should have been tried during the early testing period and all panels should have been removed during the mid-May incidence of highest catches in the collector. Although it does appear that the well addition in itself was an important contributor to the more successful 1964 catch, particularly in the early part of the season, the June panel testing results suggest some other factor was also important in the improved 1964 catch.

As mentioned previously a system of nets designed to concentrate the fish near the collector was also installed prior to the 1964 season. This system consisted of a net lead, extending from the water surface to the lake bottom, from the front of the addition into shore, and net walls which extended to the lake bottom from the floor of the primary flume of the collector and the two sides of the well addition. Fish sounding or following the lead below the 28 foot maximum depth of the addition were thus still entering a three-sided enclosure formed by the nets. Net leads were used to some extent in 1963 but they were not designed to concentrate the fish near the collector and the fish could sound below the unit. The 1964 net complex was in place during the entire season and its individual effect on the catch is unknown, but it could have been a very important factor.

The 1964 fishing site, the most successful location for Lake Merwin traps previously, may also have contributed to the improved catch. Although catches in 1963 did not materially improve when the collector was moved into this position, the move was not made until late in the migratory season when fish abundance was decreasing.

In 1963 the average length of 1,908 untagged yearling coho obtained in the collector was 205.9 mm. The following season the unit recovered 6,259 untagged yearlings and their average length was 210.1 mm. The average length of Speelyai Creek fish recovered during the two seasons was 167.5 mm in 1963 and 161.0 mm in 1964. Although in 1963 the size of fish was considered as a possible contributor to the low catch, there was no major difference in average size of coho in the two seasons. Size of fish alone did not appear to be an important factor in the 1964 catch. The recovery rates for tagged coho in the collector were 65.6% for lake-reared yearlings and 66.2% for the smaller Speelyai Creek fish. The recovery rate on tagged two-year-old coho was only 53%, but this could have been due to a large number of these fish being taken in the lake sport fishery during the season.

The average size of the recovered coho was also compared with the fishing depth of the collector. During the series of tests with the panels at either 0 or 28 feet in depth, the average size of the recovered coho was 233.0 mm at 0 feet and 244.1 mm at 28 feet. When the catches at 14 feet versus 28 feet are compared the average coho size at 14 feet was 211.6 mm in length and at 28 feet, 217.6 mm in length. The average size of the coho recovered in June was 169.7 mm in the catches with all panels removed and 176.9 mm with the panels at either 14 or 28 feet. Although a slight increase in average size occurred with increased fishing depth (Table 16) this difference may be too minor to be of significance.

Table 16. Average size of coho recovered during the 1964 tests of the Lake Merwin juvenile fish collector addition.

Period	Panel depth (feet)	Total coho	Average size (mm)
April 23 - May 11	0	675	233.9
April 27 - May 13	28	2,593	244.1
May 16 - June 4	14	2,408	211.6
May 12 - June 1	28	2,148	217.6
June 4 - June 13	0	316	169.7
June 7 - June 16	14 or 28	399	176.9

Since catches earlier in the season improved with the fishing depth of the collector, it might be assumed that the coho at the dam were initially at greater depths and then appeared in the surface layers more frequently later in the season. However, the 1964 gill net distribution study indicated that the majority of the fish were present in the 0-20 layer during the entire season (Erho, 1964).

It is proposed that part of the success of the 1964 addition was due to an "imprisonment" of the fish inside the well addition which kept them concentrated near the collector for a period of time. If the majority of the fish were in the surface layers, as the gill net study indicated, they were required to sound to enter the well addition when all panels were in place. In theory then they followed rising inflow to the collector and became concentrated inside the walls of the addition, in front of the main flume of the collector. It has been previously noted that fish were observed entering the collector almost to the collection baskets, then swimming back out into the addition to be lost from view, before eventually being captured. If these fish had become frightened upon their initial entree into the collector and retreated into the addition, they might have been turned by the panels and again returned to the primary flume. With the front panels removed they could have departed the vicinity of the collector without again sounding below the well addition.

Hamilton and Rothfus (1963) in their tagging studies found that the interval between time of tagging of coho uplake and time of their initial recovery at the dam increased as the migration season progressed. If this is an indication of increased speed of migration, then it might be assumed that they would accept the collector more readily as the season progressed. The "imprisoning" effect of the addition could then have become less important in the recovery rate later in the season, resulting in the almost equal catches in June during the "in" versus "out" panel tests.

During the 1963 season it did not appear that the low coho catch was directly attributable to water temperature. However, it appeared possible that vertical distribution of fish, particularly late in the season, could have been influenced by water stratification.

Lake Merwin is under limnological study under a separate contract with the Bureau of Commercial Fisheries Accelerated Research Program, and an intensified sampling of the forebay area was conducted during the 1964 migration season to determine the possible effect of stratification. A complete analysis of the results is not yet available but it is known that stratification was weaker in 1964 than during the previous season. If stratification is an important factor in the vertical distribution of fish near the dam, then its effect on the efficiency of the collector in 1964 was less than in 1963.

SCUBA observations upon the behavior of fish entering the well addition were hampered by the murkiness of the water and the relatively small numbers of fish in the area at one time. It was unfortunate that time did not allow the testing of the well without the net lead and walls to determine the effect of the latter upon the catches. Of primary importance, however, was the determination that the juvenile collector could be successfully utilized for fish passage at a reservoir other than those on the Baker River system, although some modifications or additions to the basic structure may be necessary.

SUMMARY

1. The Lake Merwin juvenile fish collector was constructed at the lake in early 1963 and operated during the normal spring downstream migration period for yearling coho salmon.

2. The catch during the 1963 season was very low, possibly due to the size and/or the vertical distribution of the lake-reared yearling coho.

3. A well addition structure designed to increase the fishing depth of the Lake Merwin juvenile fish collector, was constructed prior to the operation of the unit during the 1964 spring downstream migration season. A system of nets, designed to lead and concentrate the fish near the primary flume of the collector, was also installed.

4. The collector recovered 9,598 coho in 2000 hours of operating the catch amounting to 4.80 fish per hour over the entire 1964 season. This was an increase from 2,525 total coho and 1.7 fish per hour in 1963.

5. On the basis of the population estimate obtained by a tagging study conducted under a separate research program, the 1964 efficiency of the collector was calculated at 65.4% for the lake reared yearling coho population. In 1963 this efficiency value was 10.2%.

6. Recoveries of tagged coho in the collector in 1964 amounted to 53.2% of the 2-year-old lake reared fish, 65.6% of the lake reared yearlings, and 66.2% of the Speelyai Creek yearlings.

7. The percentage of fish passing through the louver guidance system in 1964, as compared with the collection basket catch, 2.6%, was very similar to that obtained in 1963.

8. Less than 60% of the total 1964 coho catch occurred during daylight hours, as compared with a 76% daylight catch in 1963. This change was apparently due to improved catches during the earlier part of the migration season.

9. Catches in the collector early in the 1964 season significantly improved when the well addition was set at the maximum fishing depth of 28 feet. Later in the season however, the fishing depth of the collector did not appear in itself to be the only reason for the increase in the efficiency in 1964.

10. Water stratification in the Merwin Dam forebay was weaker in 1964 than in 1963, which could have contributed to the improved catch.

11. The primary reasons for the improved catch were probably due to the 1964 fishing site and concentrating the fish in front of the collector by the well addition and the net leads.

12. It is concluded that the juvenile collector could be successfully utilized for fish passage at reservoirs other than those on the Baker River system, although some modifications or additions to the basic structure may be necessary and the fishing site could be critical.

ACKNOWLEDGEMENTS

Operation of the collector at Lake Merwin was made possible by the excellent co-operation of Pacific Power and Light Company. Messrs. William Rees, Russell Webb, Ronald Westley, and Elmer Quistorff of the Washington Department of Fisheries were instrumental in the design of the well addition. Dr. J.A.R. Hamilton of Pacific Power and Light Company did the scale readings to determine the coho year classes. Dr. Gerald Paulik of the University of Washington College of Fisheries suggested the statistical model for the tests of the addition. Special thanks are due to Mr. Lloyd Rothfus of the Washington Department of Fisheries for helpful suggestions on the operational procedures of the collector and on the preparation of this report.

LITERATURE CITED

Allen, Richard
1963. Progress Report July 1, 1962 to June 30, 1963 Lake Merwin Juvenile Fish Collector. Unpublished manuscript, Wash. Dept. Fish.: 29 p.

Hamilton, J.A.R., L. O. Rothfus, J.D. Remington and M. Erho
1964. Unpublished data, Wash. Dept. Fish. and Pacific Power and Light Co.

Hamilton, J.A.R. and Lloyd Rothfus
1963. A Summary Report on Lake Merwin Investigations. Unpublished manuscript, Pacific Power and Light Company and Wash. Dept. Fish.: 40 p.

Snedecor, George A.
1956. Statistical Methods, Fifth Edition Iowa State College Press, Ames. xiii,: 534 p.

THE VERTICAL DISTRIBUTION OF COHO SMOLTS IN THE FOREBAY OF MERWIN DAM IN 1964

by

Mike Erho

State of Washington
DEPARTMENT OF FISHERIES

for

FISH-PASSAGE RESEARCH PROGRAM
U. S. Bureau of Commercial Fisheries
Seattle, Washington

September 1964

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

THE VERTICAL DISTRIBUTION OF COHO SMOLTS NEAR THE DOWNSTREAM MIGRANT COLLECTION FACILITIES AT MERWIN DAM IN 1964

The vertical distribution of juvenile coho salmon (Oncorhynchus kisutch) in the forebay of Merwin Dam was examined during the 1964 downstream migration. Of particular interest was the relationship of coho distribution to the successful operation of a floating downstream migrant collector at Merwin Dam. This migrant collector was provided for testing at Merwin Reservoir under the Accelerated Fish Passage Research Program sponsored by the Bureau of Commercial Fisheries. The collector was completed prior to the 1963 downstream migration and tested during the spring of the year. Results of the first year's operation showed a collection efficiency much lower than anticipated (Allen 1963). The vertical distribution and the size of Lake Merwin coho migrants appeared to be possible causes for the low collector efficiency. For this reason a limited coho distribution study was conducted concurrent to the operation of the collector during the 1964 downstream migration.

METHODS

Three gill net stations were established in the forebay area of Merwin Dam (Figure 1). Tests conducted during the first week of sampling demonstrated the inability of the nets to capture numbers of coho during daylight hours. Subsequent tests also indicated that the majority of coho caught entered the nets between dusk and dawn. Therefore, the sampling schedule usually consisted of setting gill nets in the late afternoon and removing them the following morning. At times it was necessary to leave the nets in for a full 24-hour day although in all cases the sampling period encompassed the dusk to dawn hours.

Each net consisted of three panels each of 1-inch and $1\frac{1}{4}$-inch, and $1\frac{1}{2}$-inch stretch measure multifilament nylon. A finished net measured 75 by 10 feet and could be fished horizontally at any depth. This was accomplished by using SCUBA divers to add or remove weights or corks while the nets were in fishing position. Once a given net was made to fish properly it was always used at the same level. Underwater examinations were conducted periodically to determine if changes in floatation were occuring which would affect the fishing position of the nets. The nets were supported between pairs of gill net suspension floats of the type described by Korn and Gunsolus (1962) (Figure 2). A maximum of three nets could be supported by a single pair of floats which necessitated the installation of a pair of adjacent floats in the areas where more than three depth intervals were sampled. On each set of suspension floats, nets were separated by 10-foot spacerlines on each end to minimize the possibility of fish encountering a net at a given level and moving on a vertical plane along the net to become entangled at a different level. The position of each net in relation to the water surface and the shorelines is shown in the cross sectional sketch of the forebay in Figure 3. Coho distribution by 10-foot intervals to the 50-foot depth was sampled at Stations AB and DE. At Station C near the center of the forebay only the surface to 10-foot and 20- to 30-foot intervals were sampled. Occasional sets made at depths greater than 50 feet throughout the season failed to catch any coho and are not treated in this report. All of the fish collected were measured to the nearest millimeter fork length. Scale samples were taken to aid in age determination for separating 1962 brood yearling and 1961 brood residual coho.

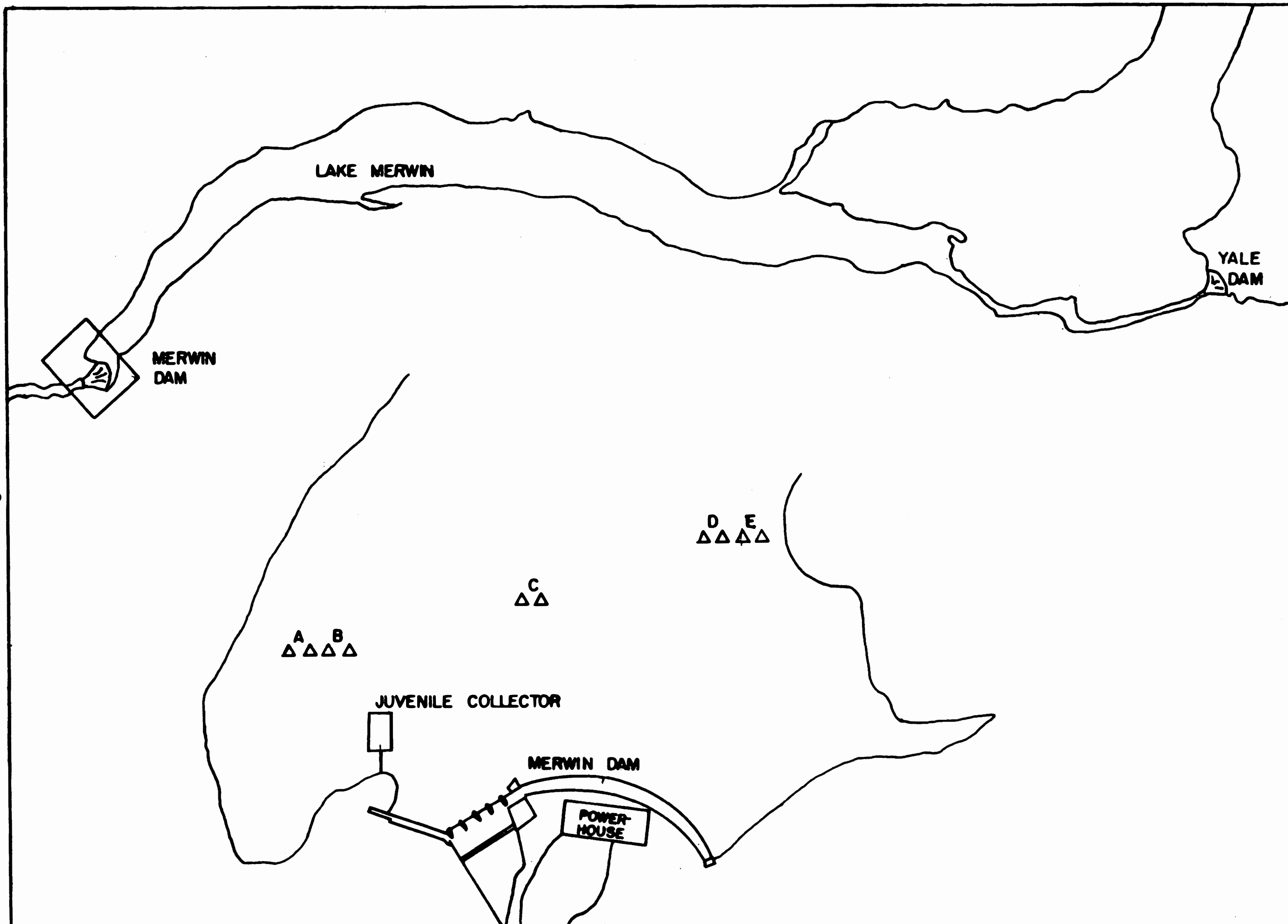


Figure 1.--Location of sampling stations and collection facilities--Merwin Dam, 1964.

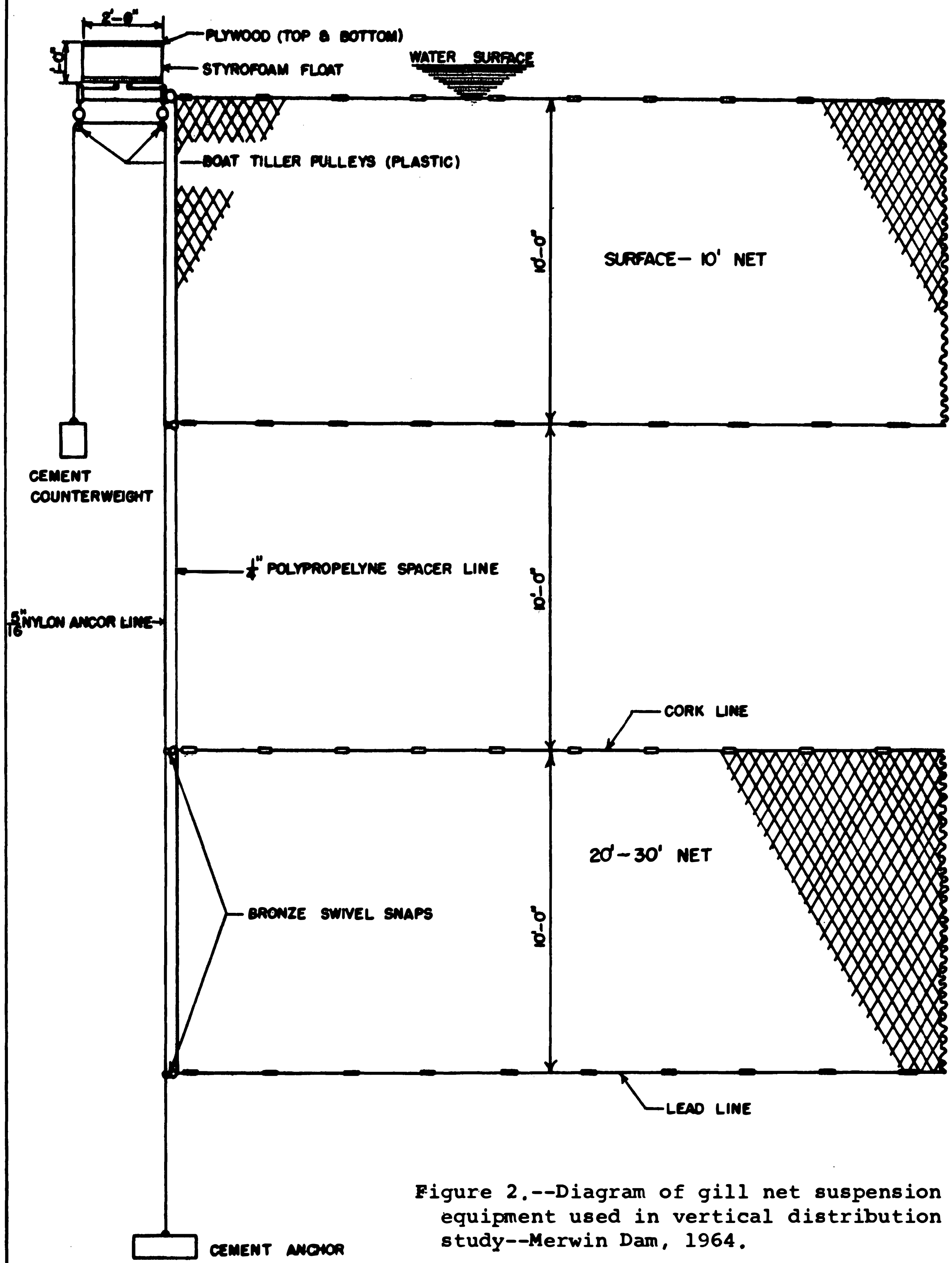


Figure 2.--Diagram of gill net suspension equipment used in vertical distribution study--Merwin Dam, 1964.

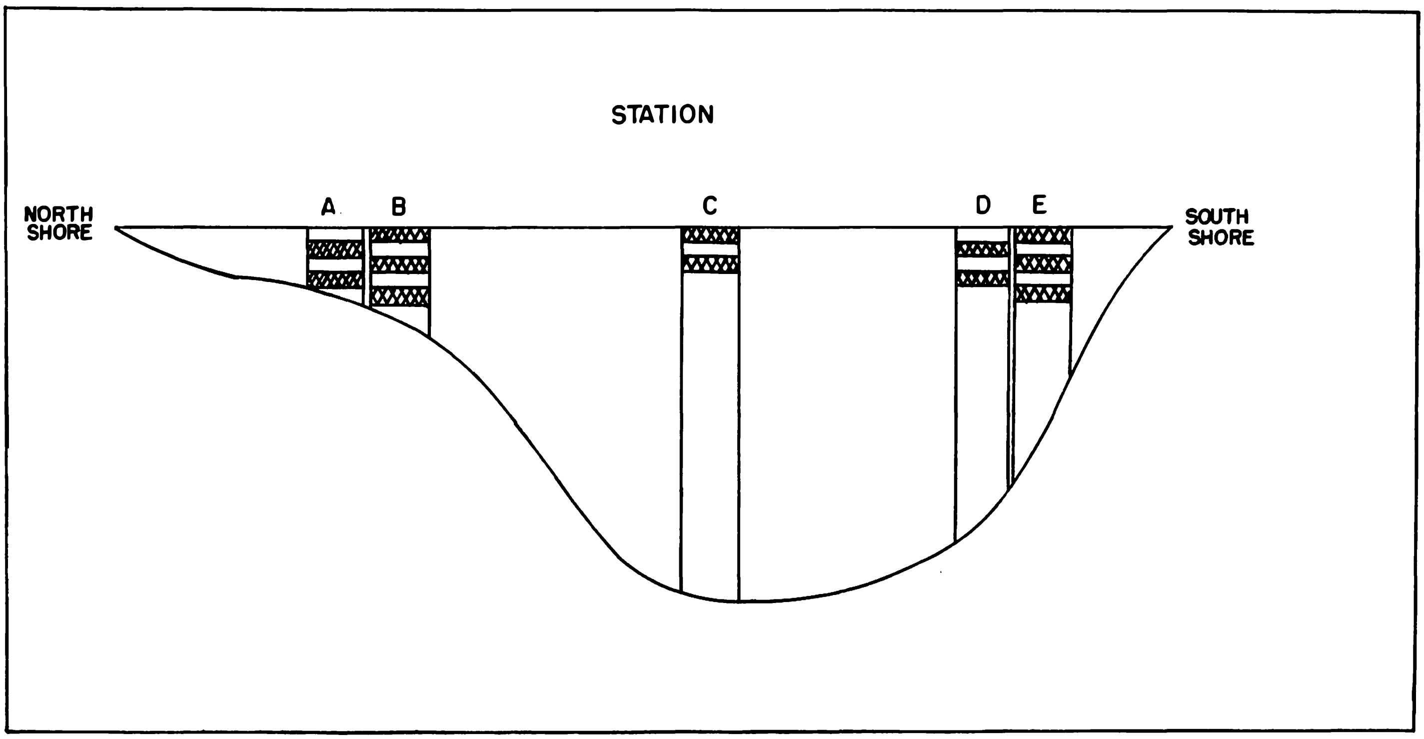


Figure 3.--Cross-sectional sketch of Merwin Dam forebay showing placement of gill nets, 1964.

RESULTS

Total catch

The total coho catch during the period of investigation, March 30 through June 27, was 306 fish. A tagging study, conducted concurrently as a facet of the co-operative Lake Merwin Research Program involving the Washington Department of Fisheries and Pacific Power and Light Company, resulted in a coho population estimate (yearling and residual) of approximately 17,000 fish during the migration period. Low catches in the gill nets probably reflects the low coho population present in the lake. The coho catch by two-week periods in each net is shown in Table 1.

Table 1. Gill net coho catch by 2-week intervals - Lake Merwin 1964.

	Station and depth (ft)												
	AB					C		DE					
Date	Surface 10	10-20	20-30	30-40	40-50	Surface 10	20-30	Surface 10	10-20	20-30	30-40	40-50	Total
3-29 to 4-4	12	6	0	0	-	5	-	24	-	1	-	-	48
4-5 to 4-18	13	4	1	0	0	8	1	16	3	0	0	0	46
4-19 to 5-2	5	2	2	0	1	5	0	12	6	0	1	0	34
5-3 to 5-16	39	13	1	0	1	5	0	23	6	0	0	-	88
5-17 to 5-30	18	10	1	0	0	0	0	8	1	0	0	-	38
5-31 to 6-13	10	4	4	0	0	2	0	3	3	4	2	-	32
6-14 to 6-27	7	2	2	0	0	4	0	2	3	0	0	-	20
Total	104	41	11	0	2	29	1	88	22	5	3	0	306

These figures have not been adjusted for net hours fished. More coho were collected in the surface to 10-foot nets than any of the other depth intervals fished. No attempt was made to interpolate catches for the 10- to 20-foot interval at Station C but it is likely that the relationship of coho abundance to depth would be similar to Stations AB and DE.

Adjusted catch and catch per unit of effort by depth interval

The predominance of coho in the 30 surface feet of the forebay can be seen in Table 2. Catch totals have been adjusted here for net hours fished and differ slightly from the previous table.

Table 2. Adjusted coho catch and catch per hour by 10-foot depth intervals - Lake Merwin - 1964

	Surface 10 ft.		10-20 ft.		20-30 ft.		Less than 30 ft.	
Date	Catch	Catch per hour	Catch	Catch per hour	Catch	Catch per hour	Catch	Catch per hour
3-29 to 4-4	41	.325	6	.143	1	.012	0	-
4-5 to 4-18	37	.171	7	.058	2	.009	0	-
4-19 to 5-2	22	.075	8	.041	2	.007	2	-
5-3 to 5-16	67	.176	19	.075	1	.003	1	-
5-17 to 5-30	26	.107	11	.050	1	.004	0	-
5-31 to 6-13	15	.040	13	.052	8	.022	2	-
6-14 to 6-27	13	.025	10	.027	2	.004	0	-
Total	221	.167	74	.061	17	.014	5	

Over 72% of the total coho catch came from the surface to 10-foot depth interval. Catch per unit of effort at this depth ranged from .325 to .025 coho per net hour study period. The nets fished at the 10-20 and 20-30-foot intervals caught 20.6 and 5.6% of the total coho catch respectively. Catch per unit of effort ranged from .143 to .027 coho per net hour at 10 to 20 feet compared to a range of .022 to .033 per net hour at 20 to 30 feet. Only five coho or 1.6% of the total were caught below the 30-foot level. Catch per unit of effort averaged .002 per net hour below 30 feet.

Percentage distribution by depth

Although 72% of the coho catch was taken in the surface to 10-foot nets, the incidence of coho in deeper nets increased as the season progressed. The percentage of the total coho catch, taken in the surface to 10-foot depth interval, during each two 2-week period declined from over 85% for the period March 27 - April 4 to 39.5 and 52% in June (Figure 4). Conversely, catches in

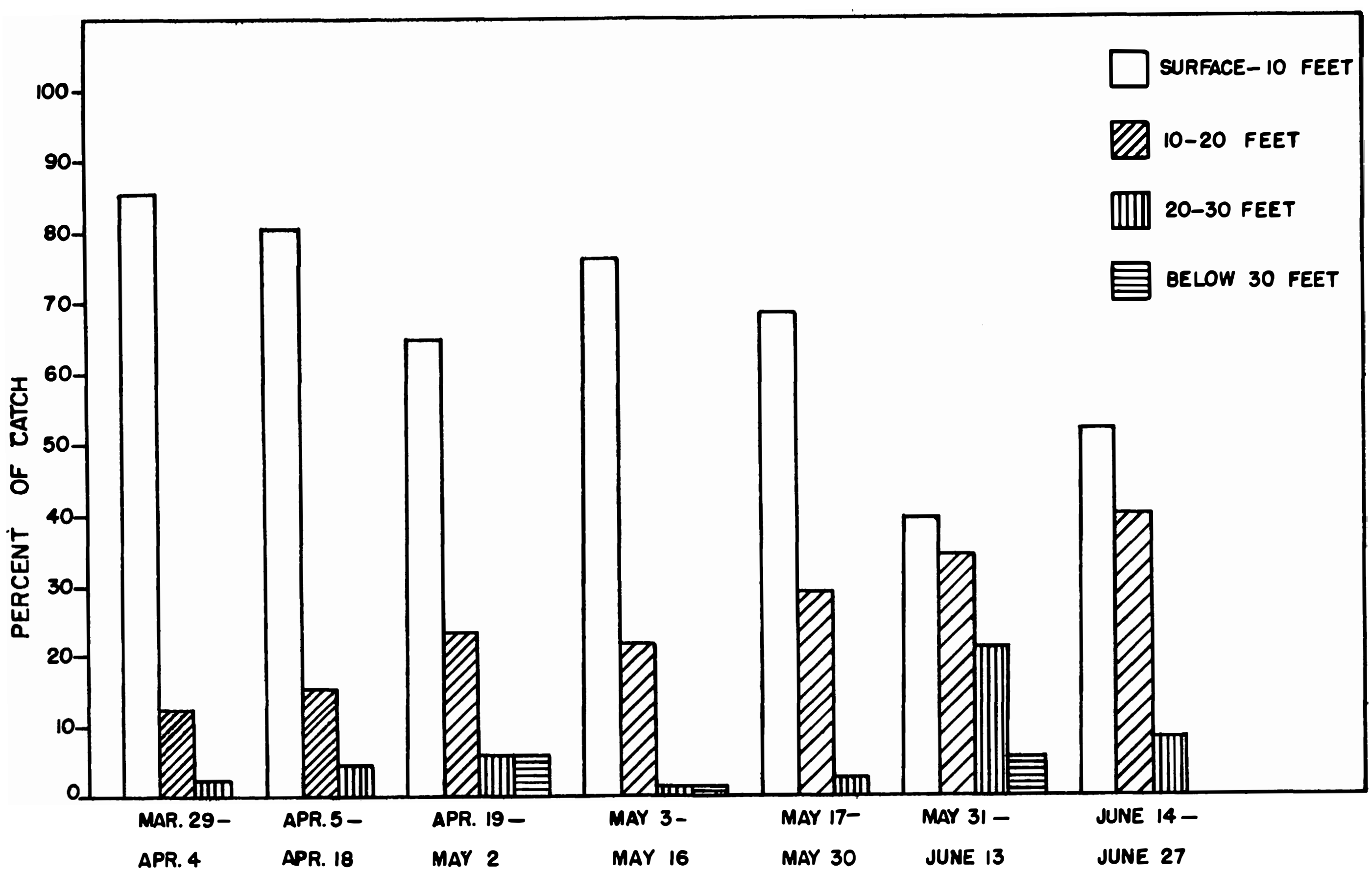


Figure 4.--Percent distribution by depth interval of gill net caught coho, Lake Merwin, 1964.

the 10- to 20-foot depth interval increased from 12.5% through April 4 to 40% of the total for the period ending June 27. The percentage catch taken in the 20-to 30-foot interval and below 30 feet was erratic due to the smaller number of fish caught at these depths. However, the percentage taken at these depths appears to be higher in June than previous months.

The reasons for this change in coho distribution during the migration period are not well defined. One factor may have been warming of the surface layer in the forebay during this period. The surface temperature rose from 5.6 C on March 30 to 14.7 C on June 10. Although the maximum temperature is well within the accepted tolerance range for coho smolts, there may have been factors associated with rising water temperatures which indirectly affected coho distribution. For example, rising water temperatures may have resulted in an increase in the subsurface abundance of zooplankton, the most important food form for Lake Merwin coho (Hamilton and Rothfus, 1963).

Water transparency, another possible factor in coho depth distribution, was measured at least once every other week in the forebay at Merwin Dam near the gill net locations. Comparison of secchi disk readings at this location revealed little change in water transparency from early April to the end of June. Therefore, it is doubtful that water transparency alone was responsible for the increasing percentage of coho in the subsurface depth intervals.

Preference of coho for the surface layer of Baker reservoir during the migration period was shown by Rees 1957. Lake Merwin coho demonstrate this same preference during the migration period and the increase in percentage of the catch in the subsurface layers may actually be a function of the relative abundance of migrating and non-migrating fish. The highest percentage catch in the 10- to 20-foot depth interval occurred during June after the peak of the downstream migration. By this time approximately 90% of the coho migrants captured at Merwin Dam had already been removed from the reservoir. This decrease in percentage of coho in the surface 10-foot nets may have been a result of the removal of migrating fish from the reservoir during the period of investigation.

Comparison of coho depth distribution at Stations AB and DE

A comparison of the depth distribution at Station AB, located in close proximity to the migrant collector, and Station DE located near the south shore of the forebay is shown in Table 3. A correlation coefficient (r) of .96 shows a definite correlation between the vertical distribution of coho caught at these two stations. This correlation discounts the possibility that the vertical distribution of coho at Station AB was affected by the currents associated with the subsurface discharge of the collector.

Table 3. Comparison of coho depth distribution at Stations AB and DE by 2-week intervals - Lake Merwin - 1964

	Depth (ft) and station							
	Surface - 10		10-20		20-30		Below 30	
Date	AB	DE	AB	DE	AB	DE	AB	DE
3-29 to 4-4	12	24	6	0	0	1	0	0
4-5 to 4-18	13	16	4	3	1	0	0	0
4-19 to 5-2	5	12	2	6	2	0	1	1
5-3 to 5-16	39	23	13	6	1	0	1	0
5-17 to 5-30	18	13*	10	2*	1	0	0	0
5-31 to 6-13	10	3	4	3	4	4	0	2
6-14 to 6-27	7	2	2	3	2	0	0	0
Total	104	93	41	23	11	5	2	3

* Adjusted for net hours fished.

Size of fish

Prior studies conducted under a joint Department of Fisheries and Pacific Power and Light Lake Merwin research program have demonstrated an extremely rapid growth rate and large migration size of coho reared in the reservoir [1/]. The average length of 1959 brood year coho collected at Merwin Dam in 1961 was 196 mm while the 1961 brood coho collected in 1963 averaged 210 mm fork length. During both years the catch was composed primarily of yearling migrants. Coho collected during the 1964 downstream migration included both 1961 and 1962 brood year fish.

1/ Washington Department of Fisheries and Pacific Power and Light Company, unpublished data.

Examination of scale samples provided the basis for separating the two year classes. It was concluded that coho over 260 mm fork length were predominantly 1961 brood while those under 260 mm were from the 1962 brood year (Hamilton etal, 1964). Overlap in the 240 to 280 mm range prevents exact separation of the two groups. The size range of migrants in the downstream collection facilities in 1964 was 85 to 357 mm.

Gear selectivity

Coho caught in gill nets during the migration season ranged from 119 to 344 mm fork length. The size range was similar for each mesh size but there were certain differences in distribution with the size range (Figure 5). A larger percentage of coho over 250 mm was caught in the 1-inch mesh than in the $1\frac{1}{4}$-inch mesh (60% compared to 35 and 32% respectively). Rees (ibid) found that coho gilled in the 1-inch mesh at Baker Lake were predominantly 110 to 130 mm in length. Since very few fish at Merwin were within this size range, the majority of coho caught in the 1-inch mesh were entangled in the mesh by their teeth. It is possible that large fish, over 250 mm, are captured more readily in this manner than fish under 250 mm. Coho over 250mm did not gill in the $1\frac{1}{4}$- or $1\frac{1}{2}$-inch mesh either but the fact that fish as large as 200 mm did gill in these mesh sizes could account for the percentage difference between the 1- $1\frac{1}{4}$- and 1-inch mesh.

Size composition by depth interval

The length frequency of coho caught in the gill nets at each depth interval was examined to determine if the size and/or age composition of the catch was a factor of depth distribution. No appreciable difference was noted in size composition of coho collected at intervals from the surface to 30 feet (Figure 6). Catches below 30 feet were omitted from the analysis due to the small numbers of fish involved. Residual coho over 260 mm accounted for 37.6% of the coho caught in the surface nets compared to 34.5% at the 10- to 20-foot interval and 33.4% at 20 to 30 feet.

In considering the relationship of gill net coho distribution to the distribution of fish in the immediate vicinity of the migrant collector, it is necessary to determine if the gill net caught coho were representative of the available coho population. The length frequencies of gill net and migrant collector coho were examined by two-week intervals for comparison of size composition throughout the migration (Figure 7). A definite similarity existed between gill net and collector coho during the period of investigation, supporting the belief that the gill net catch was representative of the coho caught in the collector.

The length frequencies in Figure 7 show a decrease in the size composition of both gill net and migrant collector coho during the migration period. Residual coho, in this case 1961 brood year fish, migrate early in the spring prior to the peak of the yearling migration. A definite break between the migration of residual and yearling fish occurs in late April or early May. Following the peak of the yearling lake-reared coho migration, the size composition of the catch continues to decline. The bulk of the catch at that time includes stream-reared coho which escaped from Speelyai Creek.

Direction of movement

The directional orientation of 281 gill net captured coho was noted during the course of the study (Table 4). It was found that most of the coho (68.7%) were traveling in a downlake direction when they entered the nets. The downlake movement was more pronounced at Stations AB and DE near the north and south shores than at Station C near the center of the forebay as evidenced by 70.2% at Stations AB and DE and only 55.2% at Station C. Only 8.5% of the coho captured at Baker Lake travel in an uplake direction when they entered the nets (Rees, ibid). The difference in directional orientation between Baker and Merwin

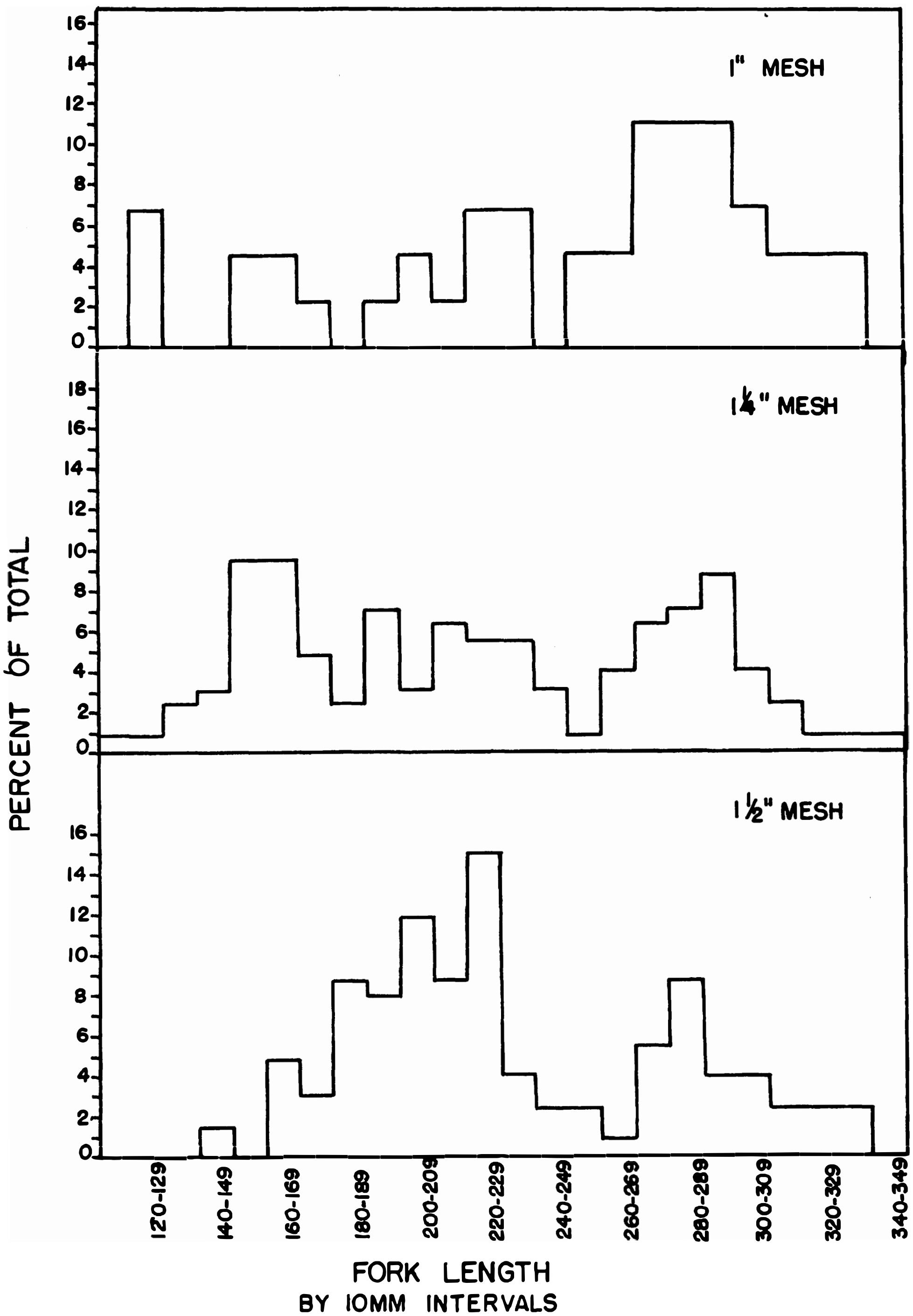


Figure 5.--Length frequencies of Lake Merwin Gill net coho by mesh size, 1964.

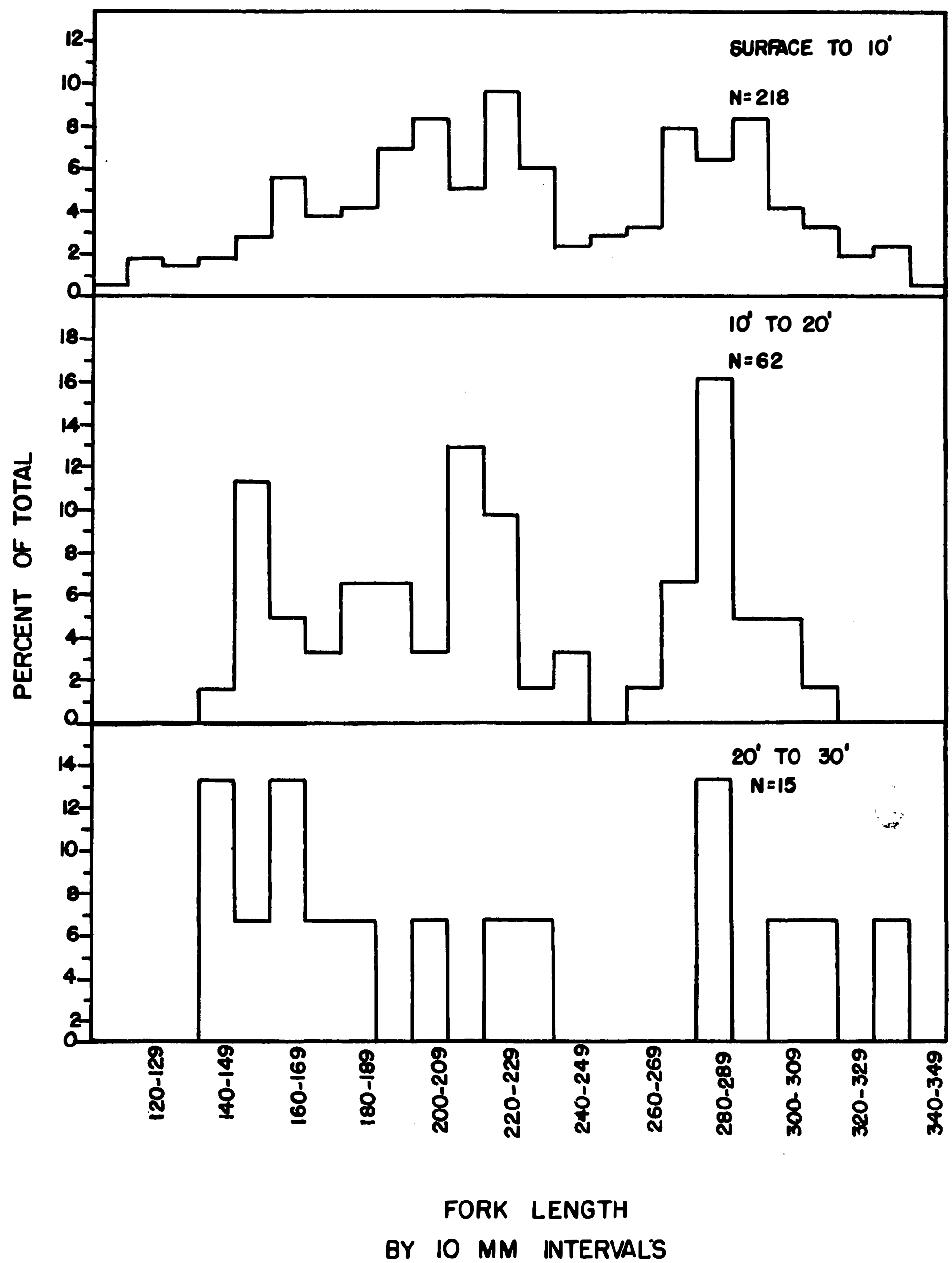


Figure 6.--Length frequencies of Lake Merwin gill net coho by depth interval, 1964.

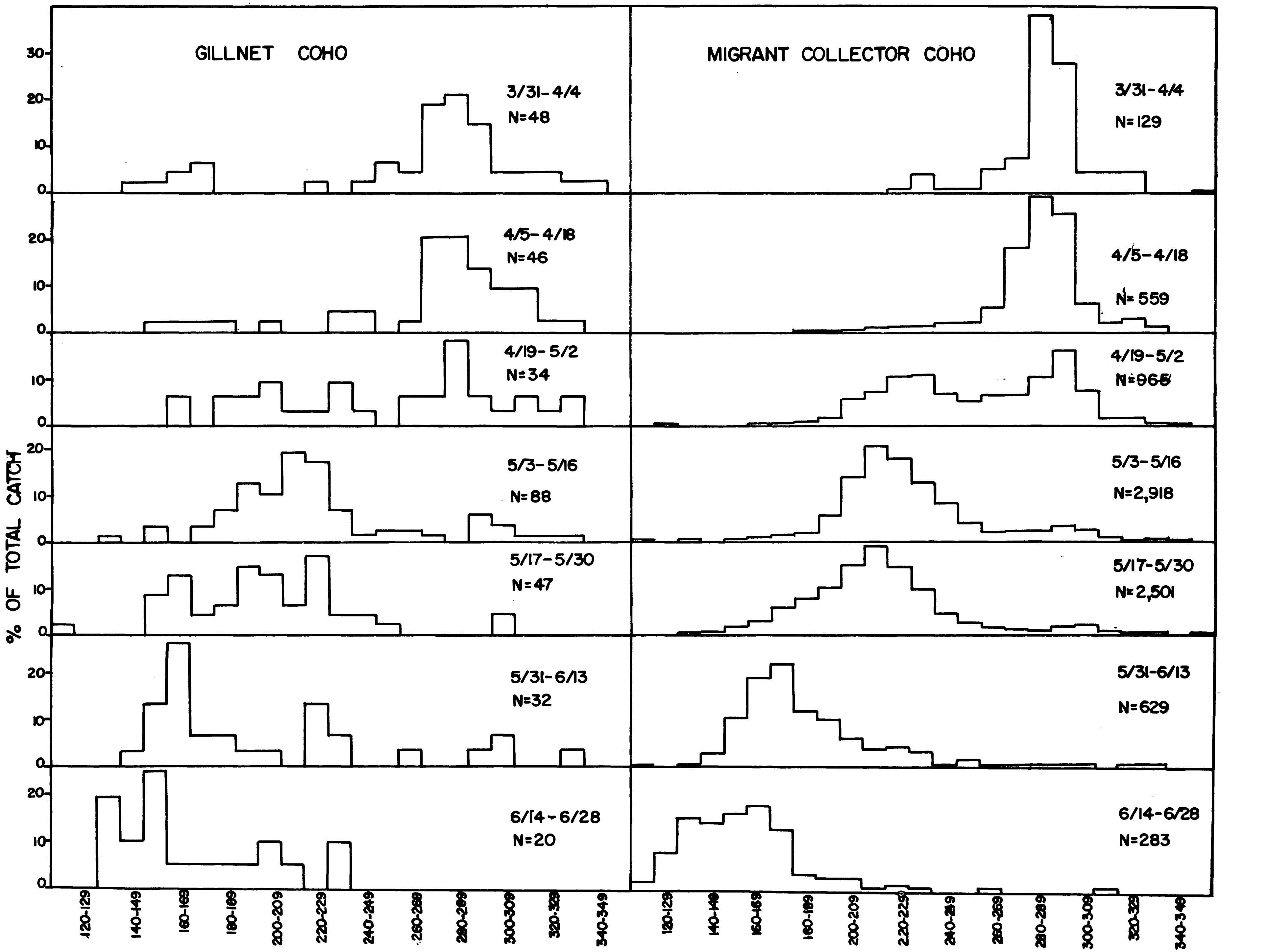


Figure 7.--Comparison of length frequencies of gill net and migrant collector caught coho, Lake Merwin, 1964.

coho may be due to a tendency of Lake Merwin fish to mill in the vicinity of the dam during the migration period. Hamilton and Rothfus (1963) found that the majority of tagged coho released from a recovery trap near Merwin Dam in 1961 were recaptured in the same trap. This indicates that the tagged coho remained in or returned to the vicinity of the dam.

Table 4. Percentage of coho traveling in a downlake direction when entering shoreline and center - forebay gill nets by 2- week intervals - Merwin Reservoir 1964

	Period ending							
Location	April 4	April 18	May 2	May 16	May 20	June 13	June 27	Total
Shoreline	57.9	70.2	79.3	71.1	71.1	66.7	73.3	70.2
Center of forebay	25.0	56.7	60.0	60.0	-	100.0	50.0	55.2
Total	52.2	67.4	76.5	70.5	71.1	68.8	65.0	68.7

Incidental fish catch

In addition to coho salmon (Onchorhynchus kisutch) six other species were caught in the distribution study gill nets (Table 5). These included, in order of numbers caught, rainbow trout (Salmo gairdnerii), squawfish (Ptychocheilus oregonensis), sockeye salmon or kokanee (O. nerka), chinook salmon (O. tshawytscha), sculpins, (Cotus sp.), and dolly varden (Salvelinus malma). The incidence of these species in the gill nets increased during the season and reached a peak during the month of June when 116 or 55.8% of total catch was taken.

The chinook salmon collected in the gill nets were yearling fish which had failed to migrate after release into the reservoir in the spring of 1963. Kokanee (sockeye) enter Merwin reservoir through surface spill or turbine discharge from Yale Dam located immediately upstream. The vertical distribution of these species has not been analyzed.

Table 5. Incidental gill net caught fish - Lake Merwin 1964.

Species	3/29-4/4	4/5-4/8	4/19-5/2	5/3-5/16	5/17-5/30	5/31-6/13	6/14-6/27	Total
Chinook		1	1	1	1	2		6
Sockeye (Kokanee)		2		1		6	3	12
Rainbow trout	4	12	4	15	12	41	27	115
Squawfish	1	2	5	14	15	12	23	72
Dolly Varden						1		1
Sculpins				1		1		2

SUMMARY

1. A Gill net study was conducted in the forebay of Merwin Dam during the 1964 downstream migration to determine the vertical distribution coho smolts in the vicinity of the downstream migrant collector.

2. Coho distribution by 10-foot depth intervals was sampled at the 3 sampling stations established in the forebay area. Two stations were sampled to a depth of 50 feet while the other station was sampled to a maximum depth of 30 feet.

3. The majority (72%) of the 306 coho captured during the study were caught in the surface to 10 foot depth interval while the 10-to 20-, 20-to 30-, and below 30-foot intervals accounted for 20.6, 5.6, and 1.6% of the total respecively.

4. The percentage distribution of coho in the surface layer dropped from a high of 85% in early April to a low of 39.5% in June while the percentage in the deeper layers increased gradually throughout the migration.

5. The size range of coho caught in each mesh size was similar although the percentage of fish over 250 mm was highest in the 1-inch mesh.

6. No significant difference was noted in size composition of the coho catch by depth interval.

7. The similarity between gill net and migrant collector coho length frequencies indicates that the gill nets and migrant collector were operating on the same population.

8. Over 68% of the gill net caught coho were traveling in a downlake direction when they entered the nets. The percentage was higher at the stations near the shorelines than at the station in the center of the forebay.

9. Rainbow trout and squawfish were the most numerous incidental species captured in the gill nets.

ACKNOWLEDGEMENTS

The author wishes to thank the Pacific Power and Light Company for their consideration in making this study possible. The personnel of the co-operative Lake Merwin Research Program and the Lake Merwin Juvenile Collector Program provided assistance when needed. Special thanks are due Dr. J.A.R. Hamilton, who analyzed the coho scales for age determination. Lloyd Rothfus of the Washington Department of Fisheries assisted in outlining the study program and offered valuable advice during the course of the study.

LITERATURE CITED

Allen, Richard
1963. Lake Merwin Juvenile Fish Collector Progress Report July 1, 1962 to June 30, 1963. Unpublished manuscript, Wash. Dept. Fish: 29 p.

Hamilton, J.A.R., and Lloyd Rothfus
1963. A Summary Report on Lake Merwin Investigations. Unpublished manuscript, Pacific Power and Light Company and Wash. Dept. Fish.: 40 p.

Hamilton, J.A.R., Lloyd Rothfus, Jack D. Remington, and Mike Erho
1964. Unpublished data, Pacific Power and Light Company, and Wash. Dept. Fish.

Korn, Larry and Robert T. Gunsolus
1962. Final Report. The Development and Testing of Techniques for Studying the Behavior of Juvenile Salmonids in Reservoirs, Fish. Comm. Ore. Manuscript: 90 p.

Rees, William H.
1957. The Vertical Distribution of Seaward Migrant Salmon in the Forebay of Baker Dam. Fish. Res. Pap., Wash. Dept. Fish.: 2 (1) 5-17.

HORIZONTAL AND VERTICAL DISTRIBUTION OF YEARLING SALMONIDS IN THE UPPER END OF MAYFIELD RESERVOIR

by

John R. Pugh

and

Jim R. Smith

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

Research has indicated that when a typically fast flowing river or stream is changed (by the construction of dams) to a reservoir-type environment, the migration rate of juvenile salmonids is sometimes appreciably delayed. There is also evidence that many young fish fail to pass through these reservoirs.

Until recently, most of the effort to pass young fish safely at high dams has been based on collection bypass systems located at the lower end of reservoirs. Under these conditions, even the most efficient collection system would not serve its purpose if the bulk of the young migrants fail to reach the lower end of the reservoir. Faced with this possibility, fisheries agencies are now considering the feasibility of collecting downstream migrants before they pass beyond the upper end of a reservoir.

In order to determine the type of collection equipment best suited for this purpose, an investigation is currently underway at the upper end of Mayfield Reservoir on the Cowlitz River in southwestern Washington. The purpose of this study is to determine, a seasonal basis, the horizontal and vertical distribution of migrating juvenile salmonids.

MATERIALS AND METHODS

Experimental facilities

The experimental site (fig. 1) was located approximately 6 miles above Mayfield Dam, directly in front of the Washington State Gam Department's Mossyrock Fish Hatchery, where the reservoir is approximately 800 feet wide with depths to 102 feet.

The sampling nets were constructed of monofilament nylon. Each net was comprised of three panels each measuring 12 by 20 feet. The webbing sizes of the three panels by stretched measurement were 7/8-inch, 1-1/8 inches, and 1-3/8 inches. The twine sizes of these panels were 0.15 mm., 0.15 mm., and 0.20 mm. respectively. The panels were sewn together in ascending order by mesh size, forming nets that were 12 feet deep and 60 feet long. Each net was equipped with a lead line to make it hang properly with just enough flotation to make the buoyancy slightly positive.

A 1-inch-diameter polyropylene hawser was stretched across the reservoir perpendicular to the water flow. This hawser served as a visual reference to insure that the sampling nets were always fished in the same reservoir cross section.

An opening was provided in the middle of the hawser to facilitate the passage of boats. The hawser was marked off in 60-foot intervals, the length of each of the sampling nets, and a styrofoam float was attached to the hawser at each mark (fig. 2). A concrete anchor, weighing approximately 100 pounds, was positioned on the bottom of the reservoir directly beneath each

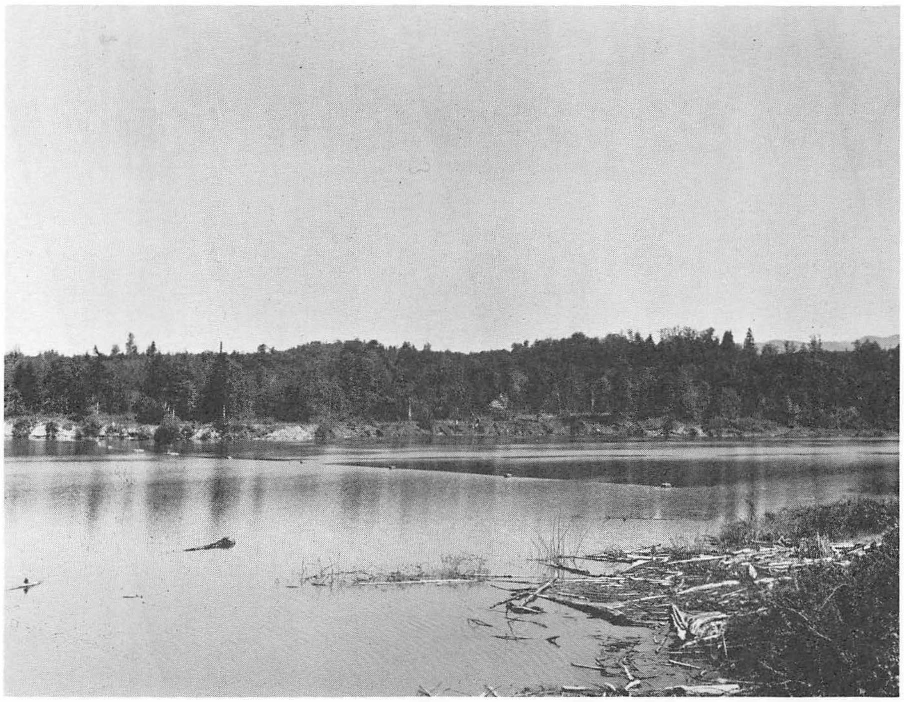


Figure 1.--Experimental site of Mayfield Reservoir (Cowlitz River) distribution study. Buoys are spaced at 60-foot intervals completely across the reservoir. The space between the buoys comprised the 12 horizontal fishing positions.

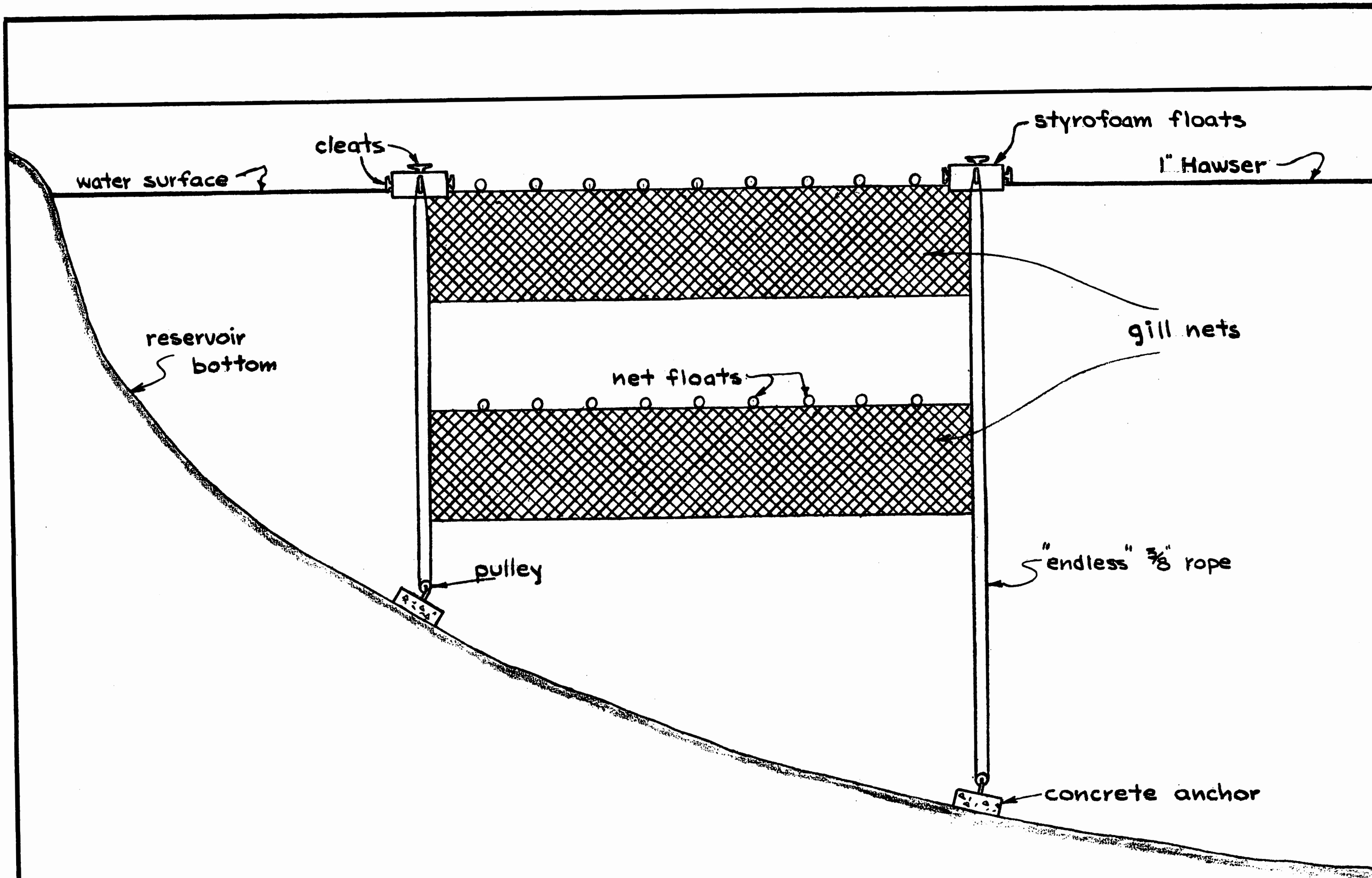


Figure 2.--Diagrammatic sketch of net suspension system used in the Mayfield Reservoir distribution study.

float and each anchor was fitted with a 3/8-inch pulley. At each styrofoam float, a 3/8-inch diameter nylon rope was run from the surface down through the anchor pulley and back to the surface, forming an endless loop. The surface portion of each loop was secured to one of the styrofoam floats. One-half of each loop was marked by knots tied at 12-foot intervals--the depth of the sampling nets. These endless ropes and the positioning of the concrete anchors made it possible to fish the sampling nets at any desired position in the reservoir cross section.

The space between the styrofoam floats constituted the fishing positions. These positions were numbered from 1 through 12 from the right bank (north shore) to the left bank (south shore). Vertically, the fishing positions were assigned letter designations. The number of vertical fishing positions depended upon the depth.

Test fish

The test fish were wild downstream migrants of the Cowlitz River system. Approximately 7,000 juvenile salmonids were captured. The catch was comprised of 73.5 percent silver salmon (*Oncorhynchus kisutch*), 16.8 percent chinook salmon (*O. tshawytscha*), and 9.7 percent steelhead (*Salmo gairdenerii*). The silver and chinook salmon were members of age group 1 and averaged 136.24 and 132.54 mm. in length respectively. The steelhead were members of age groups 1-plus and averaged 175.93 mm. in length.

Experimental design

The experiment was designed to operate on a 6-day test cycle. Two days were spent sampling the surface layer of water, two day the mid-depths, and two days the bottom area. At least one sampling net was fished on the surface (north shore) every day to monitor fish movement through the experimental area. The number of nets fished daily varied from 5 to 10, depending upon the depth being sampled.

Fishing position 12 (south shore) was always very shallow and so encumbered with briars and sunken debris that it was not feasible to sample the area with the relatively fragile and expensive gill nets. Therefore, after the reservoir was filled later in the season, the position was sampled daily with a sturdy 3 by 3 by 12 foot, 1/2-inch stretched mesh hoop net with a 30-foot lead. Although numerous scrap fish were captured in this fishing position, no salmonids were every taken. Consequently, reference to fishing position 12 has been omitted in the discussion that follows.

Experimental procedure

Setting the sampling nets required two men and two boats. Each man handled one end of each net. One man would tie one end of a net lead line to a knot on one of the endless ropes, and the second man would tie the other end of the lead line to a corresponding knot on an adjoining endless rope. Each man would then rotate the endless rope he was handling to the next knot and in doing this would pull the net lead line to a depth of 12 feet. The men would then secure each end of the net float line to the knot of their respective endless ropes on the surface and the net would be set. In the deeper portions of the experimental cross section, the investigators would rotate the endless ropes, submerging one net to a previously selected depth. They would then attach more nets between the same pair of endless ropes as desired. The nets were always fished with at least 12 feet of space between them vertically with a maximum of three nets fished in one column of water. In the horizontal plane, the nets were normally fished at least 60 feet apart.

The sampling nets were placed in fishing position each afternoon at 2 p.m. They were allowed to fish through the evening, night, and early morning and were removed at 8 a.m. on the following day. The nets were always set with the smallest mesh (7/8-inch) closest to the shore to enhance the chance of capturing small migrants moving along the bank.

After removal of each net from the water, it was placed in a separate plastic bucket that was numbered to correspond with the position where the net had been fished. When all the nets had been removed from the water they were taken to the shore where they were individually stretched across fiberglas covered railings (fig. 3). This enabled the researchers to observe and record the total number of fish captured, the species of each fish, the position (mesh size) in the net where each fish was captured, and the direction (upstream or downstream) in which each fish was swimming when captured. After removal from the net, each fish was measured and the fork length recorded.

The turbidity of the water was checked daily at three positions across the reservoir. Secchi disk readings ranged from 0.5 to 17.0 feet. The water temperature was also measured daily. The surface temperature ranged from 39 to 52 degrees Fahrenheit.

A series of water velocity readings were taken at the experimental site on July 23, 1964. The readings were taken at 60-foot intervals across the reservoir and at 12-foot intervals of depth. The number of vertical readings was limited by the length of the velocity meter lead cable to a depth of approximately 50 feet. The water velocity across the entire cross section was less than 0.25 f.p.s. On the south shore (fishing positions, 9, 10, and 11), no velocity was detected.

RESULTS AND DISCUSSION

The horizontal and vertical distribution of downstream migrants in Mayfield Reservoir is still being sampled on an intermittent basis. However, sufficent data have been collected and analyzed to indicate certain distribution patterns. It is anticipated that the sampling will continue for at least 1 year

Figure 3.--Mayfield Reservoir sampling net. Nets were stretched across fiberglass-covered railings where investigators could observe the exact position of each fish, species, and direction of travel before removing the fish for measurement.

and it is possible that the distribution of the migrants might change as seasonal environmental changes occur. Therefore, the results as reported here represent the horizontal and vertical distribution of the downstream migrants for the spring (April 6 to June 9, 1964) outmigration period only.

Figure 4 represents a cross section of the experimental site. It shows the horizontal and vertical distribution by percentage, of the three species combined. Approximately 71.0 percent of all the fish captured were taken in the top 12 feet and 91.0 percent were taken in the top 24 feet. The horizontal and vertical distribution of each of the three species present is shown in figures 5, 6, and 7.

Apparently the downstream migrants were milling about in the experimental area, since 51 percent of the fish captured were headed downstream and 49 percent were headed upstream.

The water temperature was quite uniform at the test site during the experimental period with the surface temperature never exceeding 52° F. Consequently, fish distribution was probably not affected by temperature. Observations indicated that the turbidity of the water did not affect fish distribution; however, turbidity did affect the effectiveness of the sampling nets. Considerably larger catches were taken on days when the water was turbid than on days when the water was clear.

CONCLUSIONS

1. The majority (approximately 91 percent) of the yearling downstream migrants in the upper end of Mayfield reservoir are concentrated in the top 24 feet of water.

2. The downstream migrants are distributed completely across the reservoir with a slightly higher concentration near the shores than in the middle of the reservoir.

3. Juvenile salmonids mill around considerably in the reduced velocities of the upper end of Mayfield Reservoir.

SUMMARY

Gill nets were systematically fished in the upper end of Mayfield Reservoir, near Mossyrock, Washington from April 6 to June 9, 1964, to determine the horizontal and vertical distribution of juvenile salmonids in this area of the reservoir.

Monofilament gill nets of three mesh sizes were used. Each net included one panel of 7/8-inch stretched mesh, one of 1-1/8-inch mesh, and one of 1-3/8-inch mesh. The panels were 12 feet deep and 20 feet long and sewn together to form nets that were 12 feet deep and 60 feet long.

The number of nets fished each day varied from five to ten, depending upon the depth being fished. The experiment was operated

DEPTH	FISHING STATION 11	10	9	8	7		6	5	4	3	2	1	VERTICAL DISTRIBUTION
Feet							Percent recovered						Percent
0-12	15.8	6.5	5.0	1.9	2.5	Boat Passage	1.0	2.6	7.5	5.4	9.7	13.4	71.3
12-24			0.6	1.9	1.6		3.4	1.1	5.5	0.6	4.6		19.3
24-36	South shore		0.0	0.1	0.2		0.3	0.3	1.7	1.0	1.5	North shore	5.1
36-48							0.3	0.3	0.7	0.5	1.2		3.0
48-60							0.1	0.0	0.2	0.3			0.6
60-72								0.1	0.0				0.1
72-84									0.6				0.6
84-96									0.0				0.0
HORIZONTAL DISTRIBUTION	15.8	6.5	5.6	3.9	4.3		5.1	4.4	16.2	7.8	17.0	13.4	100.0

Figure 4.--Horizontal and vertical distribution (by percentage) of the three species (silvers, chinook, steelhead) combined in the upper end of Mayfield Reservoir (Cowlitz River) from April 6 to June 9, 1964.

DEPTH	FISHING STATION 11	10	9	8	7	6	5	4	3	2	1	VERTICAL DISTRIBUTION
Feet	Percent recovered											Percent
0-12	12.6	6.5	4.1	1.4	1.9	1.0	2.6	9.0	5.4	11.2	13.5	69.2
12-24			0.7	2.2	1.4	3.7	1.2	6.7	0.2	5.5		21.6
24-36				0.0	0.1	0.3	0.3	2.2	1.0	1.6		5.5
36-48						0.3	0.2	0.5	0.4	1.2		2.6
48-60						0.1	0.0	0.2	0.2			0.5
60-72							0.1	0.0				0.1
72-84								0.5				0.5
84-96								0.0				0.0
HORIZONTAL DISTRIBUTION	12.6	6.5	4.8	3.6	3.4	5.4	4.4	19.1	7.2	19.5	13.5	100.0

South shore — Boat Passage (between stations 7 and 6) — North shore

Figure 5.--Horizontal and vertical distribution (percentages) of juvenile silver salmon in the upper end of Mayfield Reservoir (Cowlitz River) from April 6 to June 9, 1964.

DEPTH	11	10	9	8	7	Boat Passage	6	5	4	3	2	1	VERTICAL DISTRIBUTION
							FISHING STATION — Percent recovered						
Feet													Percent
0-12	25.3	7.9	5.5	1.8	3.4		0.7	1.7	2.8	4.3	4.6	13.9	71.9
12-24			0.6	1.2	2.4		3.0	0.7	3.3	1.6	2.7		15.5
24-36	South shore			0.4	0.5		0.1	0.1	1.0	1.4	1.3	North shore	4.8
36-48							0.3	0.6	0.9	1.0	1.8		4.6
48-60							0.2	0.0	0.6	0.9			1.7
60-72								0.4	0.0				0.4
72-84									1.1				1.1
84-96									0.0				0.0
HORIZONTAL DISTRIBUTION	25.3	7.9	6.1	3.4	6.3		4.3	3.5	9.7	9.2	10.4	13.9	100.0

Figure 6.--Horizontal and vertical distribution (percentages) of juvenile chinook salmon in the upper end of Mayfield Reservoir (Cowlitz River) from April 6 to June 9, 1964.

DEPTH	11	10	9	8	7	6	5	4	3	2	1	VERTICAL DISTRIBUTION
Feet						Percent recovered						Percent
0-12	24.2	5.8	10.6	5.0	4.3	1.2	4.4	3.5	7.5	7.9	11.3	85.7
12-24			0.0	1.1	1.4	1.1	0.6	1.1	0.6	2.1		8.0
24-36				0.0	0.2	0.2	0.8	0.4	0.6	0.6		2.8
36-48						1.1	0.2	0.5	0.2	0.5		2.5
48-60						0.3	0.0	0.0	0.0			0.3
60-72							0.2	0.0				0.2
72-84							0.0	0.5				0.5
84-96								0.0				0.0
HORIZONTAL DISTRIBUTION	24.2	5.8	10.6	6.1	5.9	3.9	6.2	6.0	8.9	11.1	11.3	100.0

South shore

Boat Passage

North shore

Figure 7.--Horizontal and vertical distribution (percentages) of steelhead in the upper end of Mayfield Reservoir (Cowlitz River) from April 6 to June 9, 1964

on a 6-day cycle. Two days were utilized to sample the surface layer of water, 2 days to sample the mid-depths, and 2 days to sample the bottom area. Each sampling period consisted of approximately 18 hours.

The results indicate that during the spring out-migration period, approximately 91 percent of the fingerling migrants are concentrated in the top 24 feet of water, and a slightly higher percentage are concentrated nearer the banks than in the middle of the reservoir. There appears to be extensive milling in the upper end of Mayfield Reservoir, since 51 percent of the fish were swimming downstream when captured and 49 percent were headed upstream.

The distribution of yearling salmonids in the upper end of Mayfield Reservoir will be sampled on an intermittent basis until April 1965 to determine if seasonal environmental changes affect fish distribution. In the spring of 1965, small mesh trawls will be employed to sample the distribution of age group 0 (less than 90.0 mm.) fish.

GUIDING JUVENILE SALMONIDS WITH LONG LEAD NETS AT THE UPPER END OF BROWNLEE RESERVOIR

by

John R. Pugh

and

Gerald E. Monan

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

Mounting evidence of failures to pass fish at high dams points to the need for collection and bypass systems that will assure the safe passage of young salmonids around these barriers.

Most of the efforts to collect downstream migrants have been in the lower end of reservoirs. Recent observations indicate that downstream migrants sometimes fail to negotiate large reservoirs and consequently are not available to collection equipment located at the downstream end. This suggests that collecting efforts may have to be shifted to the upper end of reservoirs, or possibly to reservoir tributaries.

In the spring of 1963 members of the Fish-Passage Research Program conducted an experiment in the upper end of Brownlee Reservoir, taking advantage of a surface concentration of downstream migrants, to explore the feasibility of collecting downstream migrants at the upper end of a reservoir with long lead nets.

MATERIAL AND METHODS

The experimental area was located approximately 40 miles upstream from Brownlee Dam (fig. 1) in an area where the reservoir is about 1/4 mile wide with depths to 80 feet at normal full pool (2,077 feet elevation).

The experimental collection equipment consisted of two floating fingerling traps with long lead nets fabricated of 3/4-inch stretched-measure knotless nylon. One trap--a Lake Merwin type--was anchored 200 feet from the Idaho shore (fig. 2) and connected to the bank by an inner lead net that was 30 feet deep. An outer net, 975 feet long by 20 feet deep, extended upstream into mid-reservoir at about a 45° angle to the flow and was moored at the terminal end to an anchored buoy. The second trap (fig. 3) was located approximately 1/2 mile downstream near the Oregon shore. This unit employed similar leads that were attached to an automatic trapping device called a migrant dipper.

After the experimental collection equipment was installed in the reservoir, it was fished continuously from May 9 to June 15, 1963. During this period, there were short intervals each day when the nets were cleaned and repaired, the mechanical devices lubricated and repaired, or the pot of the Lake Merwin trap was emptied of fish.

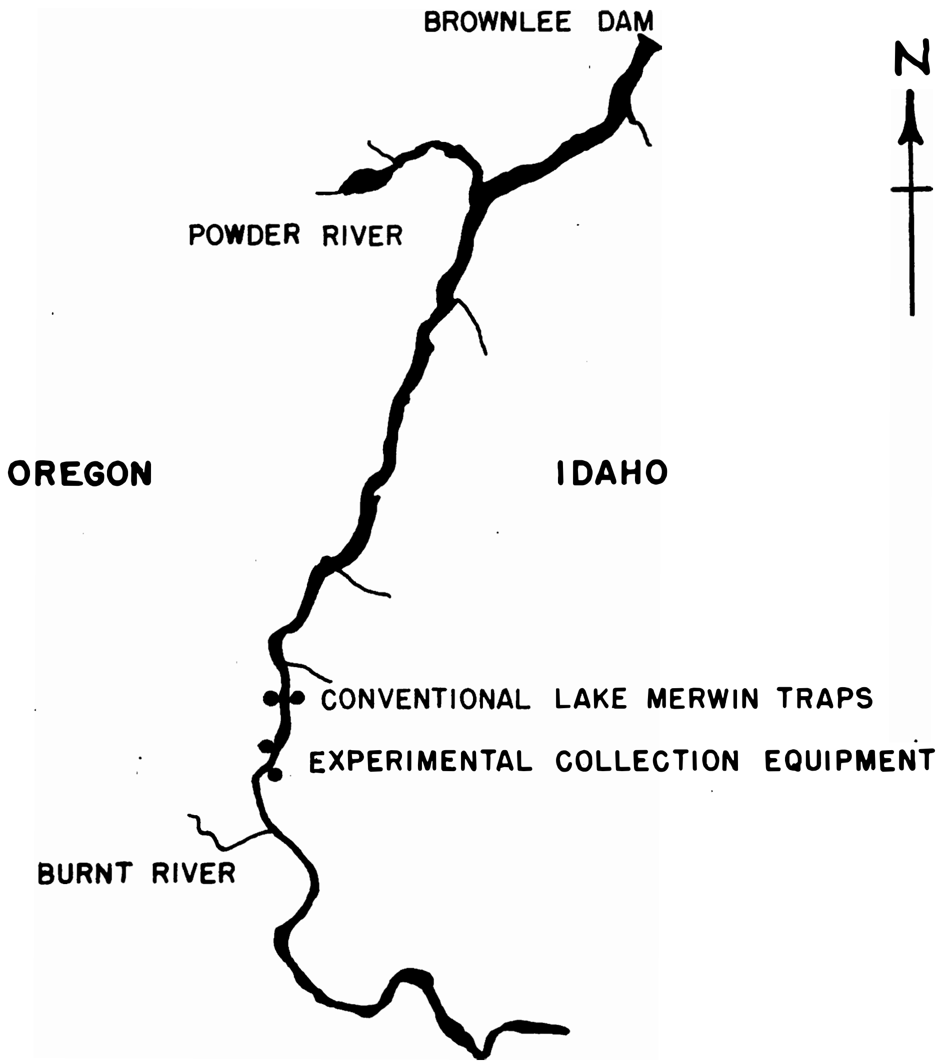


Figure 1.--Diagrammatic sketch of Brownlee Reservoir showing relative location of collection equipment.

Figure 2.--Floating Lake Merwin-type trap and lead nets viewed from Idaho shore, Brownlee Reservoir. Shore lead is 200 feet long by 30 feet deep; outer lead is 975 feet long by 20 feet deep.

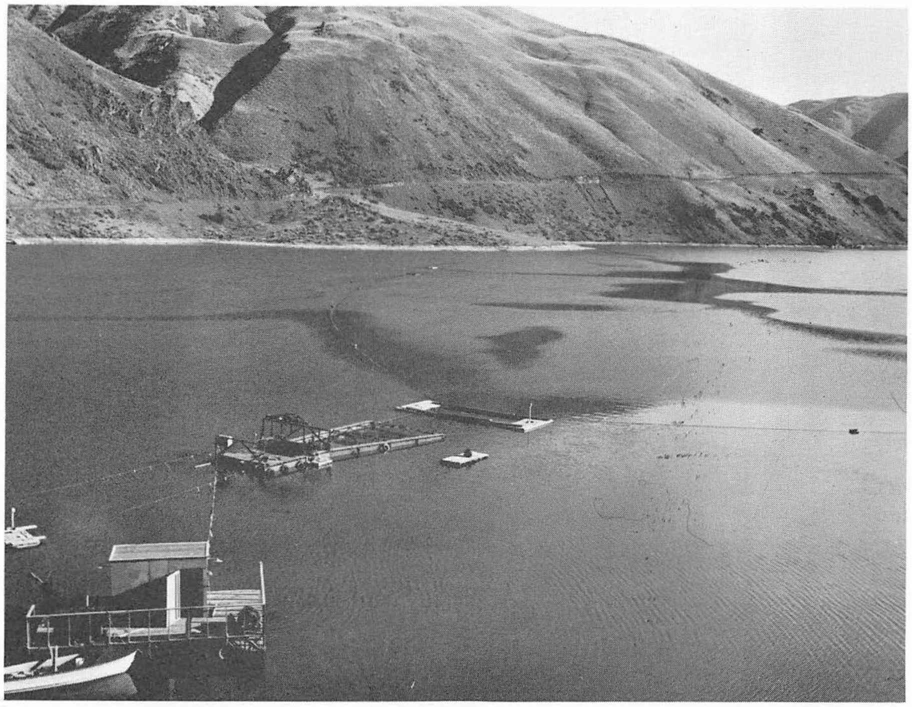


Figure 3.--Migrant dipper trap and lead net extensions as seen from Oregon shore, Brownlee Reservoir.

All of the fish captured in both traps were marked with either a jaw tag or a tattoo, depending upon the size of the fish, and then released back into the reservoir. The marks provided a means of identifying fish that were recaptured by the experimental collection equipment or by other research projects in the area.

RESULTS

Total salmonid catches of the experimental collection equipment and of conventional (no long outer lead net) Lake Merwin traps fished in the same general area are shown in the table below. The sampling period was from May 9 to June 15, 1963.

Collection equipment	Location	Species: Chinook	Species: Steelhead	Total
Experimental:				
Lake Merwin trap	Idaho shore, Res. mile 40.0	1,023	463	1,486
Migrant dipper	Oreg. shore, Res. mile 39.5	1,891	452	2,343
Total:		2,894	915	3,829
Conventional:				
Lake Merwin trap	Idaho shore, Res. mile 37.0	1,124	948	2,072
Lake Merwin trap	Oreg. shore, Res. mile 37.0	808	1,585	2,393
Total:		1,932	2,533	4,465

DISCUSSION AND CONCLUSIONS

The long outer lead nets apparently failed to enhance the collection of fingerlings. The experimental collection equipment did not catch significantly more fish than conventional Lake Merwin traps.

Although the reservoir is about 80 feet deep in this area, gill net catches revealed that the majority of the fish were migrating within the top 20 feet of water--the layer screened by the lead nets. However, a few fish were captured as deep as 40 feet, suggesting that some of the downstream migrants might have escaped beneath the lead nets.

Large quantities of debris necessitated the cleaning of the nets daily. At times the debris would become so plentiful it would raise the lead line of the nets to the surface, and consequently, the fish guiding effectiveness of the nets would be lost.

It was almost impossible to hold the nets in fishing position in water velocities over 0.5 f.p.s. In order to keep the nets in such reduced flows, it was necessary to move them approximately 11 miles downstream from the head of the reservoir. In these reduced velocities the fish appeared to be milling about rather than migrating downstream. This milling about apparently contributed to the ineffectiveness of the nets in guiding fish.

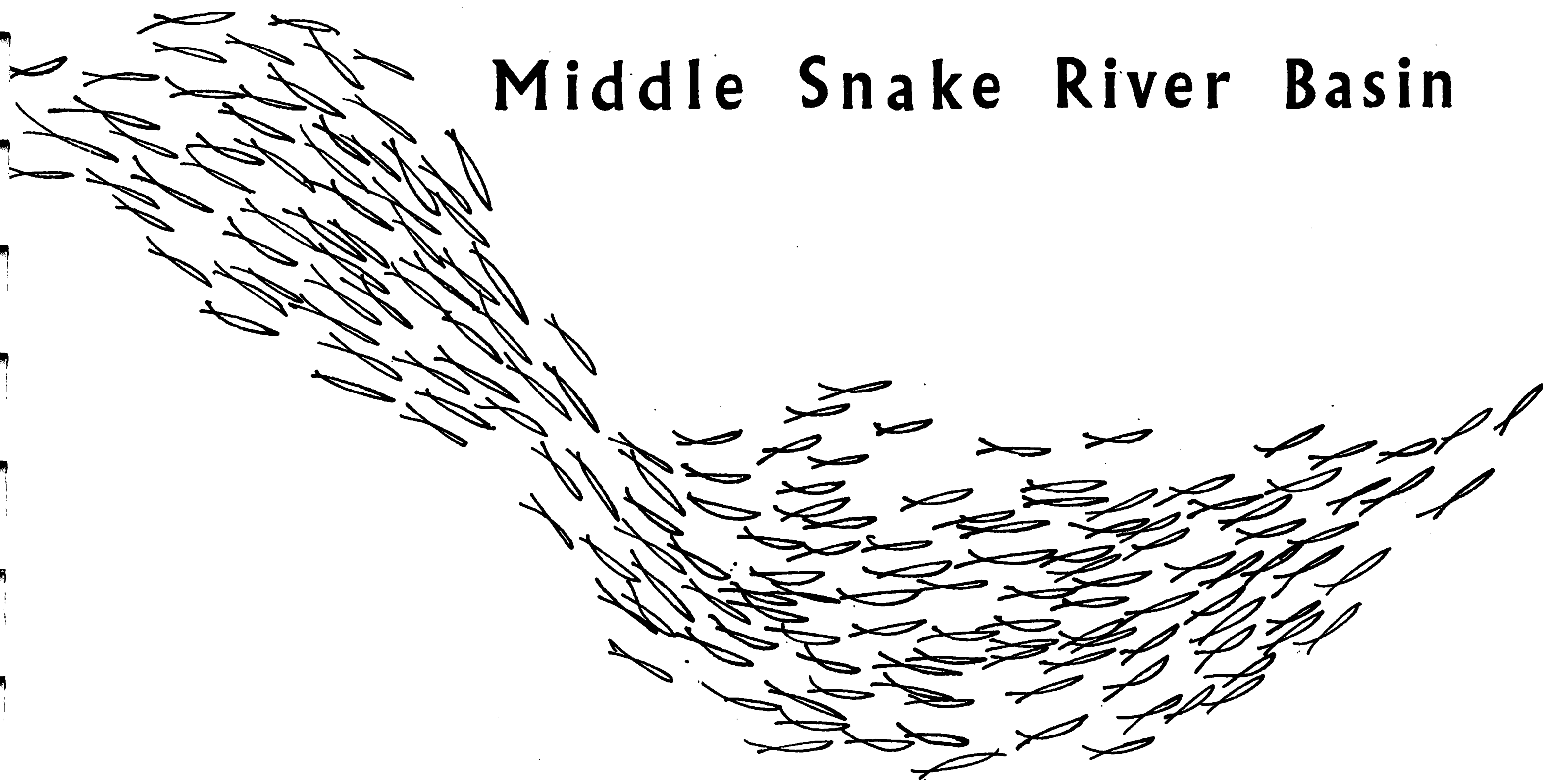
The water was also very turbid during the entire experiment. The lead nets might have diverted fish more effectively if the visibility had been better.

In conclusion, long lead nets did not prove to be a suitable method for diverting downstream migrating salmonids in the upper end of Brownlee Reservoir.

TRANSPORTATION OF JUVENILE MIGRANTS

Comparison of Alternative Fish Hauling Costs

Middle Snake River Basin



Prepared for

Fish Passage Research Program
United States Department of the Interior
Fish and Wildlife Service
Bureau of Commercial Fisheries

Consulting Services Corporation

A COMPARISON OF ALTERNATIVE FISH HAULING COSTS

IN THE MIDDLE SNAKE RIVER BASIN

Prepared For

Fish Passage Research Program
United States Department of the Interior
Fish and Wildlife Service
Bureau of Commercial Fisheries

October 1964

Consulting Services Corporation
768 Dexter Horton Building
Seattle, Washington 98104

TABLE OF CONTENTS

A COMPARISON OF ALTERNATIVE FISH HAULING COSTS IN THE MIDDLE SNAKE RIVER BASIN

INTRODUCTION

The Oxbow and Brownlee Dams are located 270 and 287 miles, respectively, from the confluence of the Columbia and Snake Rivers. Located in the Middle Snake River Basin, they form a total barrier to the migration of salmon and steelhead fish on the Snake River. The upstream migrating adult salmon and steelhead are currently trapped and transported around this dam system by the Idaho Power Company. When Hell's Canyon Dam is completed (its construction has just begun), the barrier to salmon migration will be moved further downstream--and still further downstream upon completion of High Mountain Sheep Dam just below the mouth of the Salmon River. In each case, it is expected that a trapping and transport system for adult fish will be operated at each dam.

For the downstream migrating young salmon, the dams also constitute barriers. Only here it is not the dams themselves but rather their reservoirs which constitute the effective block to the migrants. Consequently, it has become necessary to catch the young fish in the streams above the reservoir and transport them for release below the dams. As the Hell's Canyon and High Mountain Sheep Dams are added to the Middle Snake River Basin complex, it will become necessary to transport the fingerling salmon and steelhead still further downstream. The purpose of this report is to estimate, by stages, alternative hauling costs for the transportation of fingerlings from their collection points to the furthest downstream dam currently anticipated.

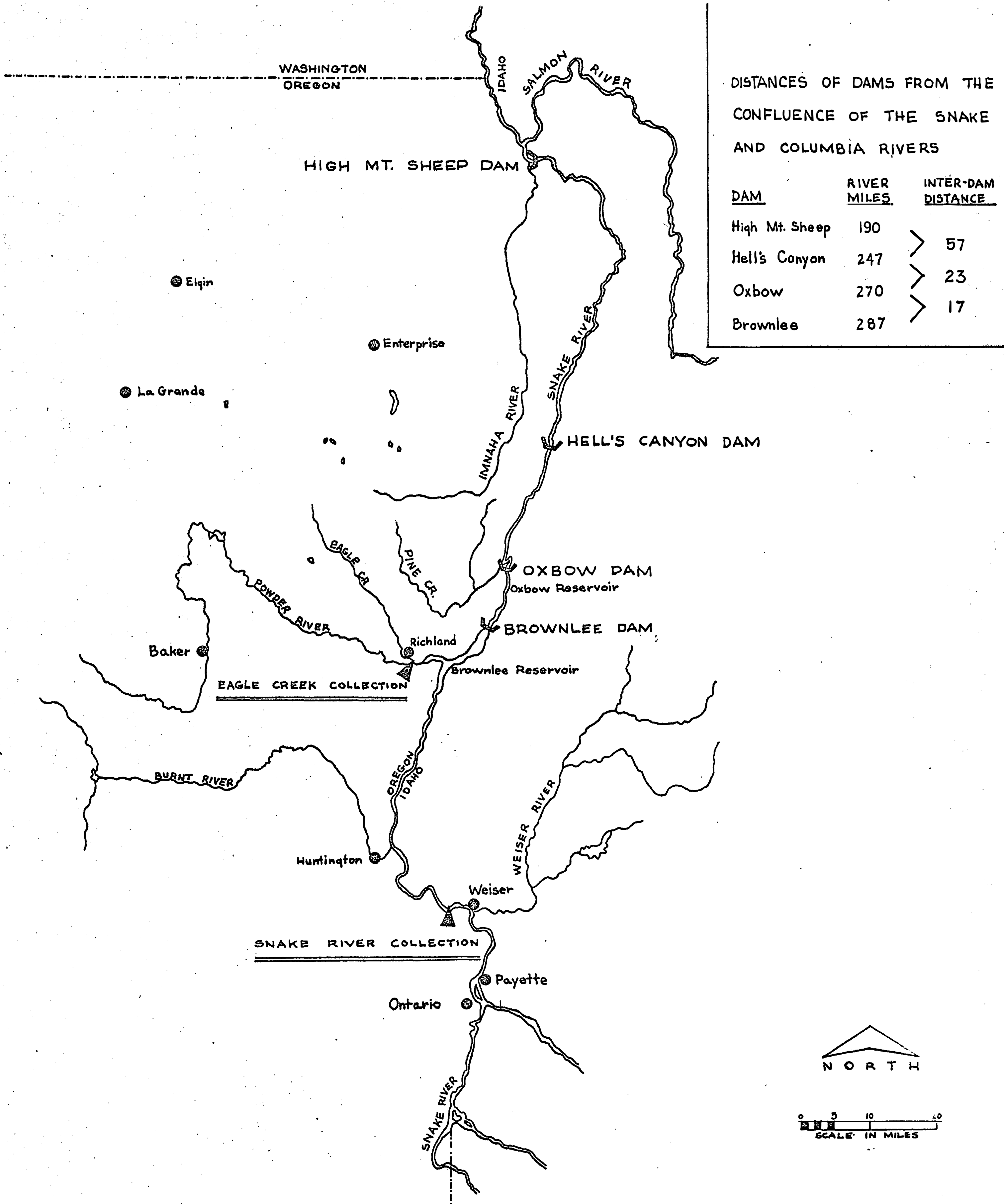


Figure 1
Dam Complex and Fish Collection Points
Middle Snake River Basin

SUMMARY OF FINDINGS AND CONCLUSIONS

Findings

The following findings are drawn from the data and analysis contained in subsequent sections of this report:

1. The current fish population has two peak run periods. The first occurs during October at the Eagle Creek station, and the second occurs during May primarily at the Snake River station.

2. Using a 3/4-ton pickup truck with a portable 150-gallon tank, the hauling cost per pound of fish is approximately 14.5¢ for the trip to Oxbow Dam, 17.5¢ to Hell's Canyon Dam, and 66.66¢ to High Mountain Sheep Dam.

3. Using a 3-5 ton stake truck with a portable 800-gallon tank, the hauling cost per pound of fish is approximately 8¢ for the trip to Oxbow Dam, 11¢ to Hell's Canyon Dam, and 40¢ to High Mountain Sheep Dam.

4. Using a 3-5 ton stake truck with a portable 800-gallon tank for peak-load hauling and a 3/4-ton pickup truck with a portable 150-gallon tank for hauling off-peak loads reduces hauling costs per pound of fish to approximately 7¢ for the trip to Oxbow Dam, 9¢ to Hell's Canyon Dam, and 35.5¢ to High Mountain Sheep Dam.

5. The cost per pound of fish for air freight hauling is approximately 19¢ for the trip to Oxbow Dam, 26¢ to Hell's Canyon Dam, and 33¢ to High Mountain Sheep Dam.

Conclusions

1. Given the existing fish population, the use of a 3-5 ton stake truck with a portable 800-gallon tank for peak-load hauling and a 3/4-ton pickup truck with a 150-gallon portable tank for off-peak hauling would be the minimum cost system for hauling fish to both Oxbow Dam and Hell's Canyon Dam.

2. For the trip to High Mountain Sheep Dam, air freight would be the minimum cost means of hauling.

3. For the estimated potential salmon population (fall chinook), air freight transportation is the minimum cost means of hauling when a 5% survival rate is assumed.

4. If a 15% survival rate is assumed for the potential salmon population, the minimum hauling cost means of transportation is a 3-5 ton stake truck with a portable 800-gallon tank.

BASIC ASSUMPTIONS

The complete transportation process actually involved three conceptually distinct activities: (1) The holding of the fish after their collection; (2) the handling of the fish in getting them first from the holding area to the hauling equipment and then back into the river; and (3) the actual hauling.

While there is reason to believe that wild fingerlings can be held for relatively long periods of time when sufficiently large holding areas, temperature control systems, and aeration systems are used, the exact costs associated with each of these holding problems could not be accurately estimated at the time of this study. It was our further understanding that several experimental collecting and holding methods were currently being tested. Until the most efficient of these methods is ascertained, precise cost estimates could contain such wide margins of potential error as to be virtually meaningless. Consequently, we have assumed throughout this report a maximum holding period of three and one-half days (i.e., a minimum of two hauling trips a week). Under this assumption, holding costs were considered identical for all methods of fish hauling and were not explicitly analyzed in the material presented in this report.

Much the same sort of assumption, and for generally the same reasons, was made with respect to the handling aspects of the transportation process. Two additional assumptions were made, however. First, the fish would not be fed during the period of time they were retained in the holding area and consequently the collection of fish excrement in the holding tanks would probably not be necessary. Second, it was assumed that the fingerlings would be anesthetized and/or tranquilized during movement, and no predation would occur in the hauling tanks. In general, it was assumed throughout the report that sufficient care would be taken in the handling of the fingerlings to either minimize or eliminate injuries and fatalities. Since the problems involved in handling the fish were considered to be roughly comparable for all of the hauling methods investigated in this report, they were not considered to account for the differential costs of fish transportation--and in consequence were not explicitly considered.

Our analysis of alternative hauling costs (which is discussed in the main body of this report) was predicated upon certain further assumptions. The first of these was that, regardless of the type of tank used, an average maximum of two pounds of fish per gallon of water could be hauled for trips of two hours or less. For trips over two hours, but under four hours, it was assumed that the average maximum capacity of the tank was one and a half pounds of fish per gallon of water. For trips in excess of four hours, but less than ten hours, the assumed average maximum capacity of a tank was one pound of fish per gallon of water.

It was further assumed, following discussions with Messrs. Tuttle, Kennedy, and Smith of the Bureau of Sports Fisheries and Wildlife, that neither the water conditions in the Snake River nor the length of trips to be made would require extensive use of refrigeration systems during the hauling operation. Occasional exceptions to this assumption might occur when the river temperature is too high to allow for optimum tank hauling conditions. Should this occur, however, it was assumed that the water temperature in the tanks would be lowered through the use of ice and that this operation would involve sufficiently small costs that they could be ignored in our analysis of the entire hauling process.

THE CURRENT FISH POPULATION

The current population of fingerlings to be hauled around existing and prospective dam sites consists of chinook salmon and steelhead. Numerically, there are more salmon than steelhead; however, the larger average size of the steelhead fingerlings gives them a larger poundage to be hauled. Salmon are estimated to vary between 61 mm. to 128 mm. (or from 110 fish per pound to 22 fish per pound), while the steelhead vary from 147 mm. to 285 mm. (or from 15 fish per pound to approximately one fish per pound).1/

The chinook run has two distinct phases. The first of these occurs at the Eagle Creek collection point and extends from the end of September through the latter part of June. The majority of chinooks recorded at the Eagle Creek station are collected during the first eight weeks of the run. During this period, the estimated average daily number of pounds of salmon per week varies from a low of approximately 13 pounds to a peak of approximately 212 pounds. Over the next thirty weeks, the salmon continue to migrate past the Eagle Creek station but in very small numbers--during only one of these thirty weeks does the average daily run of fish exceed five pounds per day.

During the last eight to ten weeks of activity at the Eagle Creek station, a second large run of salmon fingerlings occurs at the Snake River collection point (approximately five miles downstream from Weiser). This second run of salmon varies from a weekly average of about 15 to 20 pounds of fish per day during the first part of April to a high of over 240 pounds per day during mid and late May. It then drops off rapidly and remains quite small except for the second week of July when it reaches a second--but smaller--peak of approximately 70 pounds per day (see table 1 and figure 2).

Steelhead fingerlings are also collected at both the Eagle Creek and Snake River stations. In this case, however, the peak runs at both stations roughly coincide. Measured in average daily pounds of fish per week, the Eagle Creek station shows a Fall peak of approximately 35 pounds per day during the

1/ See note at end of section.

TABLE 1

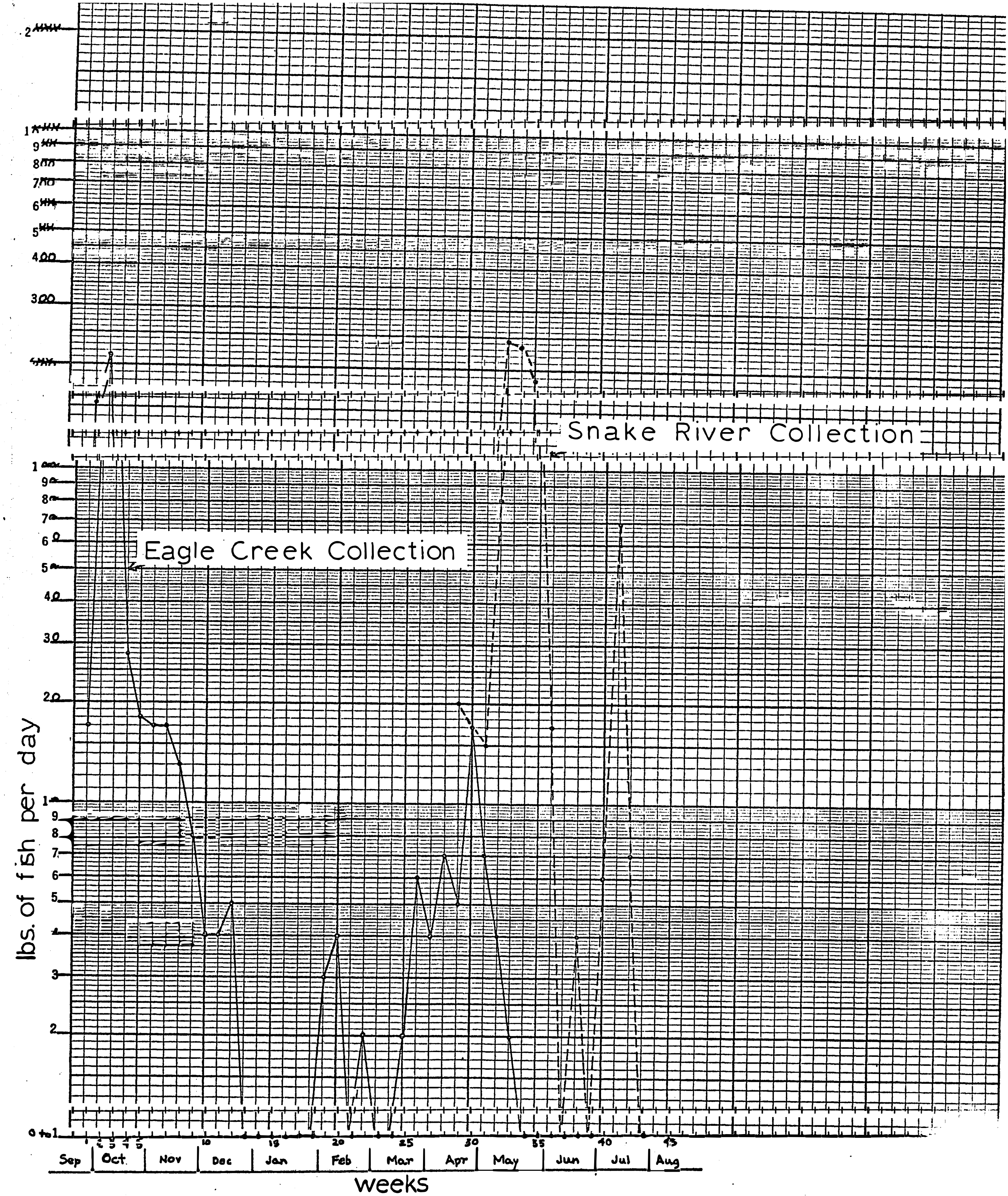
TOTAL FINGERLING SALMON RUN ON MIDDLE SNAKE RIVER: Sept. 1962-July 1963
(Eagle Creek and Snake River Stations)

Week of Run	Week No.	Estimated Total Number of Fingerling Salmon*	Estimated Total Pounds of Fingerling Salmon	Est. Average No. of Pounds of Fingerling Salmon Per Day Per Week
9/30-10/6	1	3,966	120	17
10/7 -10/13	2	37,721	1,143	163
10/14-10/20	3	48,859	1,481	212
10/21-10/27	4	6,517	197	28
10/28-11/3	5	4,060	123	18
11/4 -11/10	6	3,849	117	17
11/11-11/17	7	4,001	121	17
11/18-11/24	8	2,995	91	13
11/25-12/1	9	1,895	57	8
12/2 -12/8	10	842	26	4
12/9 -12/15	11	1,018	31	4
12/16-12/22	12	1,193	33	5
12/23-12/29	13	82	3	0.4
1/1 - 1/5	14	240	5	0.7
1/6 - 1/12	15	68	1	0.1
1/13- 1/19	16	0	0	0
1/20- 1/26	17	0	0	0
1/27- 2/2	18	0	0	0
2/3 - 2/9	19	1,043	20	3
2/10- 2/16	20	1,330	25	4
2/17- 2/23	21	505	10	1
2/24- 3/2	22	562	11	2
3/3 - 3/9	23	240	5	0.7
3/10- 3/16	24	458	9	1
3/17- 3/23	25	700	13	2
3/24- 3/30	26	2,063	39	6
3/31- 4/6	27	1,466	28	4
4/7 - 4/13	28	2,568	48	7
4/14- 4/20	29	5,092	175	25
4/21- 4/27	30	3,560	133	34
4/28- 5/4	31	5,203	154	22
5/5 - 5/11	32	38,170	597	85
5/12- 5/17	33	123,662	1,720	246
5/18- 5/24	34	122,092	1,657	236
5/25- 6/1	35	92,357	1,311	187
6/2 - 6/8	36	7,843	128	18
6/9 - 6/15	37	1,795	35	5
6/16- 6/27	38	480	7	2
6/28- 7/4	39	400	5	1
7/5 - 7/11	40	1,000	39	6
7/12- 7/18	41	10,700	480	69
7/19- 7/25	42	1,100	46	7
7/26- 8/1	43	200	9	1

(*) Salmon varied from 61 mm. (110 fish/lb.) to 128 mm. (22 fish/lb.).

Figure 2

Fingerling Salmon Run - Middle Snake River Basin 1962-1963



middle of October. After this, it rapidly diminishes and does not go above ten pounds per day until early May of the following year. During this latter period, a four-week peak period is reached where the average daily number of pounds of fish per week continuously exceeds ten pounds per day, reaching a peak of almost 110 pounds per day. At roughly the same period of time, the peak run at the Snake River station is occurring. During the week of April 14, 1963, an average of over 1,100 pounds of fish per day migrated past this point; and during the succeeding six-week period, the average daily run only once dropped below 200 pounds per day. The run falls off very sharply thereafter, and by the second week in June is less than 15 pounds per day, which is reduced to zero by the beginning of July (see table 2 and figure 3).

Note

1/ Current collections include many hatchery plants that are presumably catchable rainbow trout, not sea-going trout (i.e., steelhead). Therefore, the average weights for steelhead listed in the text may well be somewhat higher than those for wild, migrant steelhead. For purposes of this report, however, all fish other than salmon were classified as "steelhead" and considered transportable.

TABLE 2

TOTAL FINGERLING STEELHEAD RUN ON MIDDLE SNAKE RIVER: Sept. 1962-July 1963
(Eagle Creek and Snake River Stations)

Week of Run	Week No.	Estimated Total Number of Fingerling Steelhead*	Estimated Total Pounds of Fingerling Steelhead	Est. Average No. of Pounds of Fingerling Steelhead Per Day Per Week
9/30-10/6	1	1,180	118	17
10/7 -10/13	2	2,160	216	31
10/14-10/20	3	2,440	244	35
10/21-10/27	4	160	16	2
10/28-11/3	5	60	6	1
11/4 -11/10	6	140	14	2
11/11-11/17	7	0	0	0
11/18-11/24	8	260	26	4
11/25-12/1	9	60	6	1
12/2 -12/8	10	0	0	0
12/9 -12/15	11	0	0	0
12/16-12/22	12	40	4	1
12/23-12/29	13	0	0	0
12/30- 1/5	14	80	5	1
1/6 - 1/12	15	20	1	0
1/13- 1/19	16	0	0	0
1/20- 1/26	17	0	0	0
1/27- 2/2	18	0	0	0
2/3 - 2/9	19	280	19	3
2/10- 2/16	20	500	33	5
2/17- 2/23	21	100	7	1
2/24- 3/2	22	80	5	1
3/3 - 3/9	23	40	3	0
3/10- 3/16	24	20	1	0
3/17- 3/23	25	20	1	0
3/24- 3/30	26	20	1	0
3/31- 4/6	27	360	24	3
4/7 - 4/13	28	730	49	7
4/14- 4/20	29	8,220	8,015	1,142
4/21- 4/27	30	4,080	4,005	571
4/28- 5/4	31	3,150	2,077	297
5/5 - 5/11	32	5,800	2,253	322
5/12- 5/17	33	12,190	1,746	250
5/18- 5/24	34	2,830	1,589	227
5/25- 6/1	35	2,400	1,840	263
6/2 - 6/8	36	1,570	851	121
6/9 - 6/15	37	580	132	19
6/16- 6/27	38	240	109	15
6/28- 7/4	39	100	100	14
7/5 - 7/11	40	0	0	0
7/12- 7/18	41	0	0	0
7/19- 7/25	42	0	0	0
7/26- 8/1	43	0	0	0

(*) Steelhead varied from 147 mm. (15 fish/lb.) to 285 mm. (1 fish/lb.).

Figure 3

Fingerling Steelhead Run - Middle Snake River Basin 1962-1963

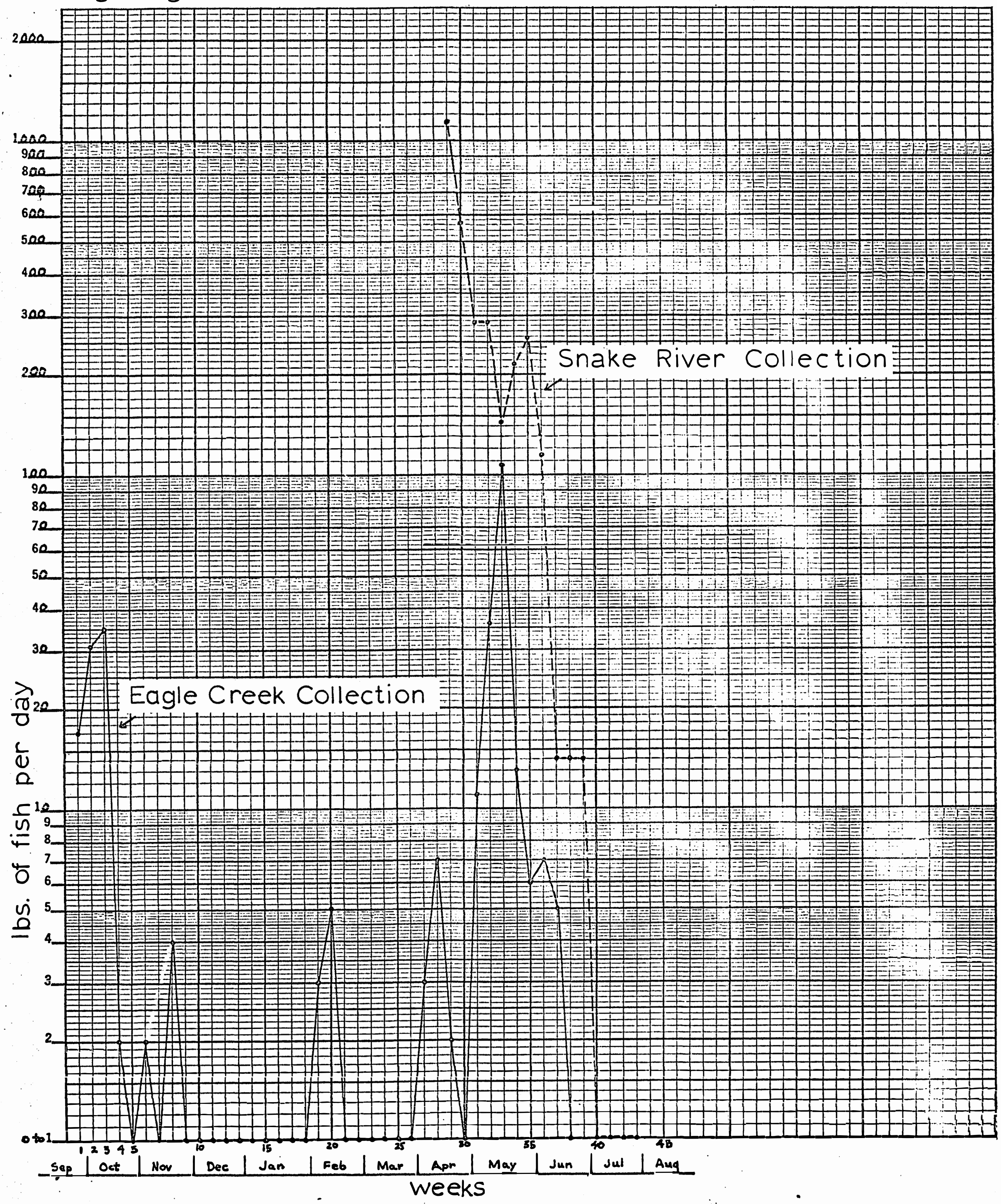
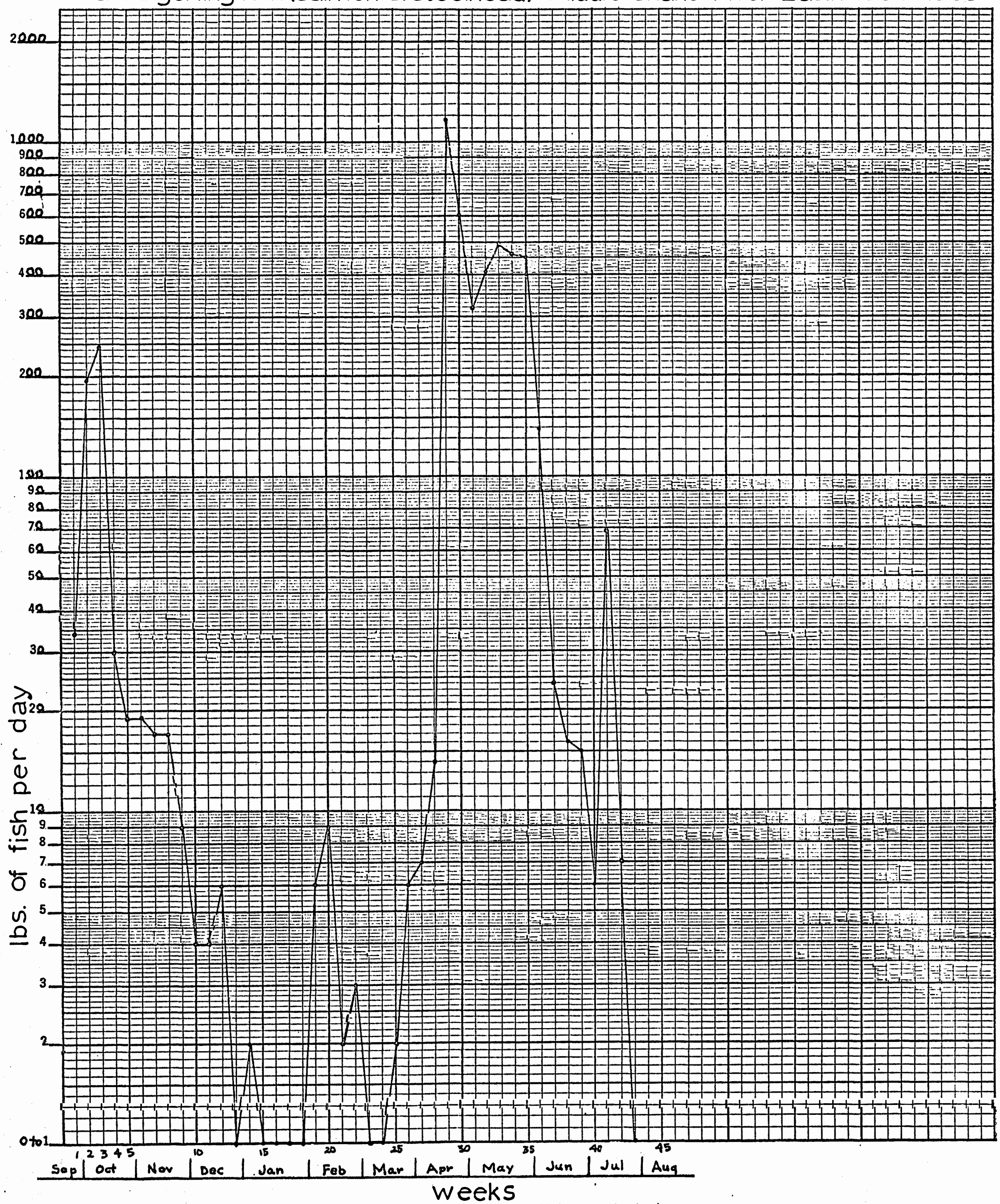


Figure 4

Total Fingerling Run (Salmon & Steelhead) - Middle Snake River Basin 1962-1963



THE COSTS OF ALTERNATIVE HAULING SYSTEMS

1. Light Truck with Portable Tank

The first method of fish hauling investigated was a small tank and light truck. The costs incurred by this method of hauling were estimated in the following manner.

The costs of acquiring and operating a 3/4-ton, 4 x 2 pickup truck were estimated from the General Service Administration's "Motor Vehicle Service Rates for Interagency Motor Pools, Region X." These rates include fuel, lubrication, maintenance, tires and, if required, storage for the vehicle. The rate for such a truck varies between 8.5¢ per mile for the first 1,000 miles driven per month to 8¢ per mile thereafter. In our report, we used an average figure of 8.25¢ per mile for cost of truck operation.

The costs of a 150-gallon tank, including all auxiliary equipment, were obtained from the article, "Fish Planting Tank for 3/4-Ton Pickup Truck" in the October 1950 Progressive Fish Culturalist. The costs were updated to current value 1963 dollars by use of the "Implicit Price Deflators for Producers Durable Equipment" as reported by the U. S. Department of Commerce. On the basis of an assumed ten-year life expectancy and the average number of miles which the tank would be covering each year, we estimated the average cost of the 150-gallon tank to be 0.45¢ per mile.

The final cost considered was that of the vehicle's driver. On the basis of the most recent joint United States Army-Air Force wage survey of the Spokane Metropolitan Area, we estimated a prevailing wage of $2.70 per hour for light truck driver. While this wage is slightly below that existing in the Puget Sound Region (Seattle Metropolitan Area), it is probably reasonable for the wage which would have to be paid for a driver operating along the Snake River (if anything, it is on the high side). Preliminary findings of the U. S. Bureau of Labor Statistics study, as reported in the Weekly Federal Employees News Digest, indicate that government fringe benefits average about 23% of the hourly wage. Consequently, the total hourly labor cost for a driver including his hourly wage and non-wage compensation was estimated to be $3.32 per hour. It was assumed that an average of ten minutes per hour of driving time was spent by the driver in waiting for the loading and unloading of his tank. Allowing for this waiting time brings the total labor costs to $3.70 per hour for every hour of actual driving time. Assuming an average truck speed of 42 miles an hour over an entire trip, average total driver costs per hour were estimated to be 8.98¢ per mile.

Summing these three costs, the total cost per mile for a 3/4-ton pickup truck carrying a 150-gallon tank was estimated to be 17.68¢.

The total number of miles which will be traveled in hauling the fingerlings during each stage of the Middle Snake River Basin's dam complex was estimated in the following manner. The average number of pounds of fish per day (both steelhead and salmon) was estimated by week for both the Eagle Creek and Snake River collection stations. These figures were summed to get the total number of pounds of fingerlings per day, by week, to be hauled (see table 3, end of text). Under an assumed average speed of 42 miles an hour, the maximum load which could be carried in a 150-gallon tank was: 300 pounds of fish for trips of 82 miles or less; 225 pounds of fish for trips of 83 to 168 miles; and 150 pounds of fish for trips in excess of 169 miles.

On the basis of this assumption, the number of trips required by a 150-gallon tank, 3/4-ton pickup truck going from Eagle Creek to Oxbow Dam, Hell's Canyon Dam, and High Mountain Sheep Dam were estimated. During the period of overlapping runs at the Eagle Creek and Snake River stations, the estimated number of miles traveled were based on a trip originating at the Snake River station, proceeding to Eagle Creek for a second collection, and then proceeding to the final destination. When collections were made only at the Snake River station, the estimated number of trips required was based upon the most direct route from Weiser to the point of final destination (see table 4, end of text).

The road distances for each of these types of trips were estimated by Consulting Services Corporation from measured inches taken from a road map and converted, according to scale, to miles traveled. The round trip distance required per trip was then multiplied by the number of trips required for each of the three possible routes discussed above to give the total number of miles per year covered by the truck. This figure was multiplied by the average total cost per mile of operating the truck (discussed above) to give a total annual operating cost for hauling the fish. The total number of pounds of fish hauled per year (from the existing population) was then divided into this estimated annual total cost to derive a cost per pound of hauling fish. In the case of the 3/4-ton pickup truck equipped with the 150-gallon tank, these costs varied from approximately 14.45¢ per pound for the trip to the Oxbow Dam; to 17.59¢ per pound for the trip to Hell's Canyon Dam; and 66.68¢ per pound for the trip to the High Mountain Sheep Dam.

3/4-Ton Truck Equipped with 150-Gallon Tank

	Total Miles Per Year	Total Costs Per Year	Total Pounds Per Year	Cost Per Pound
Eagle Creek & Snake River to Oxbow Dam	27,680	$ 4,893.82	33,859	$.1445
Eagle Creek & Snake River to Hell's Canyon Dam	33,680	$ 5,954.62	33,859	$.1759
Eagle Creek & Snake River to High Mountain Sheep Dam	127,700	$22,577.36	33,859	$.6668

2. Medium Truck with Portable Tank

The second hauling system to be investigated was a 3-5 ton stake truck equipped with an 800-gallon portable tank. Using the same sources of data as before, the estimated cost of the truck was taken as 20.50¢ per mile. The price of an 800-gallon tank, fully equipped, was estimated for Consulting Services Corporation by the Bureau of Sports Fisheries and Wildlife office in Portland. Dividing an assumed 15-year tank life by the estimated number of miles which the tank would cover over its lifetime gave us a figure of about one-tenth of a cent (0.13¢) per mile as the tank cost. From the same sources discussed above, the average hourly wage of a truck driver for a 3-5 ton truck was taken as $2.78 per hour; and the total labor cost (including waiting time) of the driver was estimated to be $3.42 per hour. Dividing by an estimated speed of 42 miles an hour over the entire length of the trip gave an estimated total labor cost of 9.45¢ per mile. Thus, the total operating and capital cost for a 3-5 ton stake truck and 800-gallon, fully equipped, tank was estimated to be 30.08¢ per mile.

Through the Portland office of the Bureau of Sports Fisheries and Wildlife, data were obtained for eight stations which used 800-gallon tank trucks for hauling from hatcheries to final distribution points. These data were available for both 1963 and 1964. Four of the stations engaged in trips involving distances that were either so small (e.g., four miles per round trip in one case) or so large (e.g., 379 miles per trip) that direct comparisons were not useful. For the remaining four stations, the average operating and capital costs per mile were estimated for 1963 and 1964. The years were appropriately weighted and averaged to arrive at an average figure for similar equipment over the two-year period. The data thus derived varied from the estimated cost per mile used in this report by less than 1.25%.

The same procedures used to determine the number of miles per year driven when hauling with a 3/4-ton pickup (as discussed earlier) were also used here to determine the total number of miles per year which would be covered by a 3-5 ton stake truck equipped with an 800-gallon tank (the pounds of fish varying by the length of the trip, however, from a maximum of 1,600 pounds to a midpoint of 1,200 pounds and a low of 800 pounds). Once the total miles per year were estimated, the total cost was derived by multiplying these miles by the average cost per mile of operating the equipment. Dividing this total cost through by the total pounds of fish hauled during the year produced an estimated cost per pound of fish hauled.

The estimated cost of hauling fingerlings by this type of equipment varied from a low of 8.88¢ per pound for the trip to Oxbow Dam, to a midpoint of 11.19¢ per pound for the trip to Hell's Canyon Dam, and a high of 40.02¢ per pound for the trip to High Mountain Sheep Dam.

3-5 Ton Stake Truck Equipped with 800-Gallon Tank

	Total Miles Per Year	Total Costs Per Year	Total Pounds Per Year	Cost Per Pound
Eagle Creek & Snake River to Oxbow Dam	9,990	$ 3,004.99	33,859	$.0888
Eagle Creek & Snake River to Hell's Canyon Dam	12,600	$ 3,790.08	33,859	$.1119
Eagle Creek & Snake River to High Mountain Sheep Dam	45,050	$13,551.04	33,859	$.4002

3. Combination 3/4-Ton Truck and 3-5 Ton Stake Truck

Because of substantial differences in pounds of fish per day (and consequently average maximum loads per week) which exist over the fingerling run, it was next assumed that a 3/4-ton truck carrying a 150-gallon tank would be used during the non-peak periods; and that a 3-5 ton stake truck with an 800-gallon tank would be used during the peak periods.

To avoid the costs of continually installing and taking off the various tanks from the different trucks, the system was designed to have the 3/4-ton pickup truck handle all hauls for approximately the first 28 and last four weeks of the run. The intervening two and a half months' period (the peak period) was assumed to be handled by the 3-5 ton stake truck. In effect, then, all of the hauls departing from either the Eagle Creek or the Snake River collection points and proceeding directly to their destination were handled by the 3/4-ton truck. Alternately, those trips originating at the Snake River station and proceeding to Eagle Creek prior to their final destination were serviced by the larger equipment.

The total costs per mile of operating the two types of equipment were the same as those derived in the earlier sections. Likewise, the same procedures discussed earlier were again used to derive the total number of miles and total number of trips required for each type of equipment. Using these data, the average cost per pound of hauling fish was estimated for a system utilizing different equipment for peak and non-peak periods. These costs varied from a low of 7.33¢ per pound for the trip to Oxbow Dam, to a midpoint of 9.20¢ per pound for the trip to Hell's Canyon Dam, and a high of 35.31¢ per pound for the trip to High Mountain Sheep Dam.

Combination 3/4-Ton Truck with 150-Gallon Tank and 3-5 Ton Stake Truck with 800-Gallon Tank

	Total Miles Per Year	Total Costs Per Year	Total Pounds Per Year	Cost Per Pound
Eagle Creek & Snake River to Oxbow Dam	10,340	$ 2,481.59	33,859	$.0733
Eagle Creek & Snake River to Hell's Canyon Dam	13,280	$ 3,116.70	33,859	$.0920
Eagle Creek & Snake River to High Mountain Sheep Dam	52,200	$11,956.96	33,859	$.3531

4. Air Freight Transportation

To estimate the air freight costs of hauling fingerling fish, Consulting Services Corporation requested two air service companies from the Lewiston, Idaho, area to submit cost estimates for transporting fish from the two collection points to the destination points for each stage of the dam system. Both of the air service companies contacted promptly replied, and from the data contained in their replies combined with Consulting Services Corporation's knowledge of the air transportation and air freight industry, we derived the following estimates of air hauling costs.

When shipping by air, the largest costs are associated with short hauls, where take-off and landing approaches are sufficiently close to prevent the maintenance of cruising speeds for any substantial periods of time. Consequently, based upon our own knowledge and the two estimates referred to above, we estimated that the average cost per 100 gallons of water of air freight would be 60¢ per air mile flown for trips of 80 miles or less and 45¢ per air mile flown for trips of 80 miles or more. The air miles to be flown were calculated between the Eagle Creek and the Snake River collection points and the final points of destination, under the assumption that either single engine (maximum capacity, 100-gallon tanks) or double engine (maximum capacity, 400-gallon tanks) light planes would be used for the air hauling and that these planes would be able to land in the immediate proximity of the collection points. The average number of air miles per trip was then multiplied by the number of trips required from each collection point to derive the total air miles flown to each destination.

Based upon the number of miles covered in each trip (or each leg of each trip), the appropriate costs per air mile were multiplied by the total miles flown to derive the total costs of air transportation. These total costs were then divided by the total pounds of fish hauled per year to arrive at an estimated average cost per pound of fish hauled. These costs vary from a low of 18.89¢ per pound to Oxbow Dam, to a middle cost of 26.16¢ per pound to Hell's Canyon Dam, and a high of 33.14¢ per pound to High Mountain Sheep Dam.

Hauling Costs by Air Freight

	Total Miles Per Year	Total Costs Per Year	Total Pounds Per Year	Cost Per Pound
Eagle Creek & Snake River to Oxbow Dam	10,659	$ 6,395.40	33,859	$.1889
Eagle Creek & Snake River to Hell's Canyon Dam	14,763	$ 8,857.80	33,859	$.2616
Eagle Creek & Snake River to High Mountain Sheep Dam	23,220	$11,220.75	33,859	$.3314

These hauling costs were estimated under the assumption that land based planes would be used and that the fish would be released by free fall dumping. If float planes were to be used, the hauling costs per pound would rise by approximately 10%.

Comparison of Alternative Hauling Costs

The major determinants of the various systems' hauling costs per pound were (a) the number of miles covered and (b) the size of the average load hauled. With respect to the first of these, as the distance between pickup and final destination points increases, the relative advantage of air freight increases. Conversely, where the distance between pickup and the destination is quite small, air transportation costs per pound are exceedingly high vis-a-vis other transportation systems. On the other hand, if the average size of the hauls is quite small, a 3/4-ton pickup truck with a 150-gallon tank provides the most inexpensive means of hauling. Conversely, where average load sizes are quite large, costs per pound of hauling with this type of equipment become very expensive.

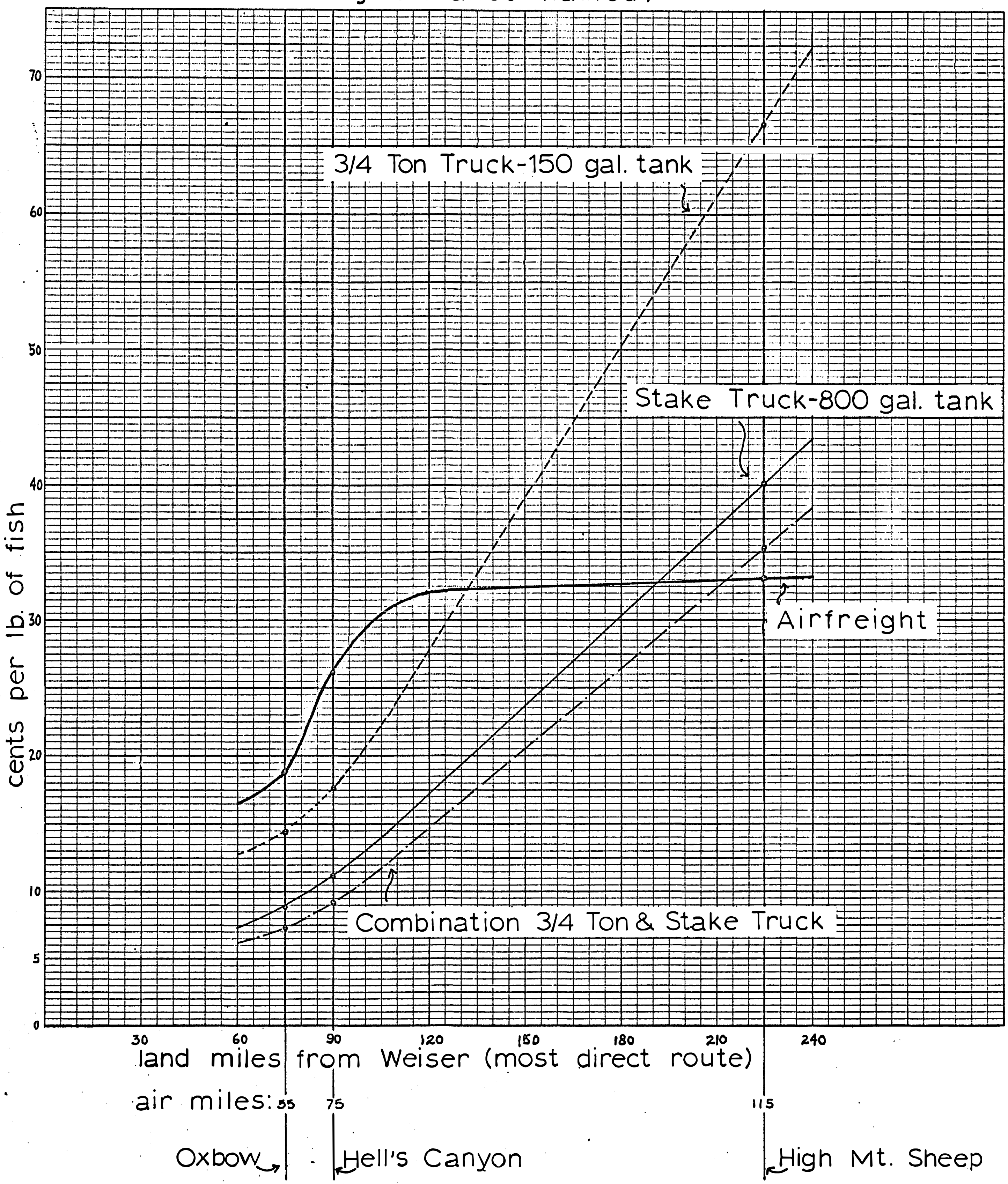
For the existing fingerling population, minimum transportation costs to both Oxbow and Hell's Canyon Dams would be achieved by using a combination 3/4-ton pickup and a 3-5 ton stake truck (as described in the previous text). On the other hand, as the full dam complex becomes developed and it is necessary to haul the fish beyond High Mountain Sheep Dam, air freight appears to be the cheapest method of hauling fish.

The advantages of air freight shipping for long distances, however, are predicated upon two assumptions. The first is that whatever air freight carrier contracts to do the work, he will have available to him equipment for hauling both 100 and 400 gallon tanks. The second assumption is that the amount of inclement weather capable of forcing cancellation of a flight following pickup of the fish but prior to their release will be negligible. The first of these assumptions is a very safe one to make, for if any particular air service firm does not have all of the equipment required, it is almost always easily available to him. The second assumption, however, requires an analysis of the weather conditions during the months of the run. Such a meteorological investigation, of course, lies beyond the scope of this present study.

One final comment on relative costs of hauling fish seems to be in order. During a relatively large number of the weeks covered by this study, the number of pounds of fish to be hauled is very small. If as a general rule, fingerling fish collected at a rate of less than ten pounds per day were released instead of being hauled, the reduction in the number of pounds of fish hauled over the year would be approximately 1.5% (i.e., 98.5% of the total run, measured in poundage, would be hauled). This reduction of approximately 1.5% in the number of fish hauled would produce a cost saving estimated to run between 12% and 14%.

Figure 5

Differential Hauling Costs for Fingerlings
(by distance hauled)



ESTIMATING COST OF TRANSPORTING POTENTIAL POPULATIONS

From data supplied to us by the Fish Passage Research Program of the U. S. Bureau of Commercial Fisheries, the costs of transporting chinook salmon and steelhead fingerlings in the future were estimated. This process primarily involved an estimation of the number of trips required by various types of fish transportation equipment, for the cost per mile of each type of equipment is expected to remain constant in terms of current value dollars (i.e., dollars having their current purchasing power).

The potential adult salmon population (25,000 fish), however, is estimated to be over four times the existing population (6,000 fish). If the potential fingerling population is distributed over the entire run period according to the distribution of the 1962-1963 run for which we have data, exceedingly high peak load hauls would occur. However, with only one year's data available, it was not possible to arrive at a reasonable distribution that would allow for both an increase in peak loads and a relative increase in average loads over the entire run. Consequently, the only cost estimates that could be derived were those predicated upon the assumption that future distributions of the run would be the same as the existing distribution.

A better guide for the future would be the realization that as the fish population increases simultaneously with the completion of the entire dam complex, both the average length of haul and the average number of pounds per haul will increase. We would thus expect future costs per pound to reach a maximum of those reported in the main body of this study for the trip to High Mountain Sheep Dam. As the average size of a haul gets larger and it becomes feasible to use larger equipment, it is expected that the economies of such large-scale equipment would come into play and a reduction in the cost per pound of hauling the fish would occur. It is, therefore, expected that the most econonical means of transporting the fish will be by either air freight or the use of a 3-5 ton stake truck carrying an 800 (or larger) gallon tank.

By the time the problem of hauling the potential population becomes a pressing one, however, it is assumed that additional years of data on the distribution of the fingerling runs will be available. From such future data, a more precise determination of costs per pound and total costs can be made.

However, in order to allow generalized comparisons to be made between current and future hauling costs, an illustrative set of data has been calculated for the existing and future costs of hauling fall chinook salmon. These data are presented in the appendix to the report.

RECOMMENDATIONS FOR FUTURE RESEARCH

1. At such time as more precise data on the means of collecting, holding, and handling fish is available, the cost per pound of each of these stages in the transportation process can be determined with some degree of accuracy. We would fully expect that the cost of collection will probably be fairly uniform regardless of the size of the run or the length of time the fish are held. On the other hand, we would equally expect that the cost of holding and handling would rise fairly substantially as the length of time the fish are held increases. Particularly during off-peak periods, however, increased holding times allow for larger average load sizes and fewer trips; consequently, they also allow for greater economy of scale in the hauling phase of the transportation process.

   With these two costs (those of holding and handling and those of hauling) moving in opposite directions, it is possible to determine the optimum holding period and the optimum load size which would allow for a minimization of costs over the entire year. This can be done along lines already well developed in the field of linear programming. Consequently, we would recommend that upon the development of relatively precise data on the holding, handling, and collection costs associated with the transportation of the fish, a linear program be developed for the entire transportation process.

2. Assuming an average life expectancy of 100 years for the dams being constructed in the Middle Snake River system, it is our opinion that the construction of a fixed installation system which allows for the automatic transportation of fish would reduce the total transportation costs over the lifetime of the dams--even though the cost of erecting such a facility would be larger than any one year's hauling cost.

On the basis of a highly preliminary investigation of the subject, we are of the opinion that a suspended capsule system could be devised, utilizing existing high-voltage electric towers and incorporating an automatic loading and releasing system at each end, which would be feasible from an engineering point of view and which would result in substantial cost savings over the lifetime of the dam system. We consequently recommend that this, or some similar, type of automatic transportation system be investigated for its feasibility and its immediate adoption.

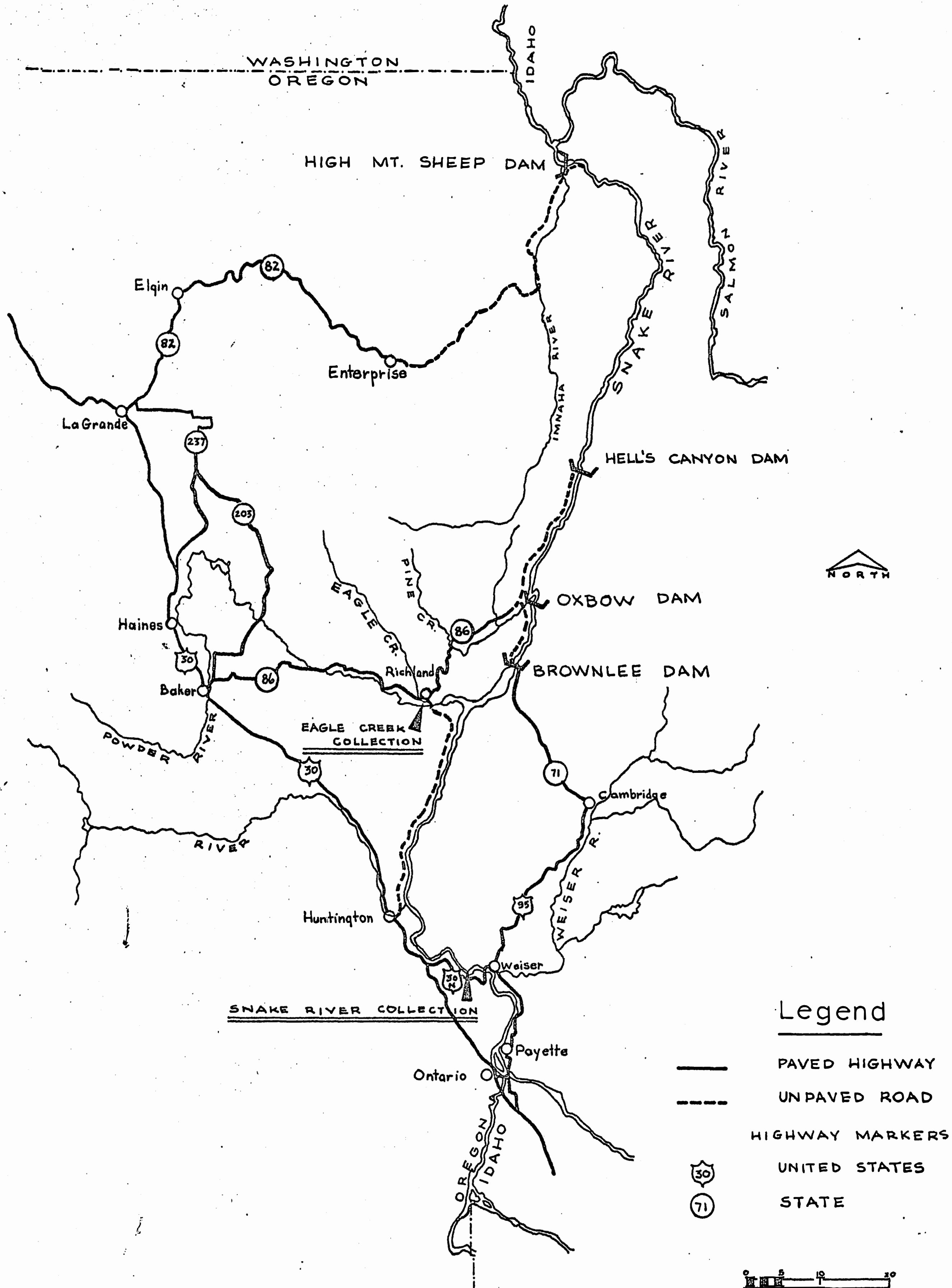


Figure 6
Road Transportation Network
Middle Snake River Basin

TABLE 3

TOTAL POUNDS OF FISH TO BE HAULED FROM MIDDLE SNAKE RIVER BASIN
(By Collection Station)

	Eagle Creek Collection			Snake River Collection			
Week of Run	Avg.Lbs. Salmon/Day	Avg.Lbs. Steelhead per Day	Average Total Lbs./Day	Avg.Lbs. Salmon/Day	Avg.Lbs. Steelhead per Day	Average Total Lbs./Day	Average Total Lbs. Fish/Day Both Stations (Col. 4 + 7)
9/30-10/6	17	17	34	-	-	-	34
10/7 -10/13	163	31	194	-	-	-	194
10/14-10/20	212	35	247	-	-	-	247
10/21-10/27	28	2	30	-	-	-	30
10/28-11/3	18	1	19	-	-	-	19
11/4 -11/10	17	2	19	-	-	-	19
11/11-11/17	17	0	17	-	-	-	17
11/18-11/24	13	4	17	-	-	-	17
11/25-12/1	8	1	9	-	-	-	9
12/2 -12/8	4	0	4	-	-	-	4
12/9 -12/15	4	0	4	-	-	-	4
12/16-12/22	5	1	6	-	-	-	6
12/23-12/29	0	0	0	-	-	-	0
12/30- 1/5	1	1	2	-	-	-	2
1/6 - 1/12	0	0	0	-	-	-	0
1/13- 1/19	0	0	0	-	-	-	0
1/20- 1/26	0	0	0	-	-	-	0
1/27- 2/2	0	0	0	-	-	-	0
2/3 - 2/9	3	3	6	-	-	-	6
2/10- 2/16	4	5	9	-	-	-	9
2/17- 2/23	1	1	2	-	-	-	2
2/24- 3/2	2	1	3	-	-	-	3
3/3 - 3/9	1	0	1	-	-	-	1
3/10- 3/16	1	0	1	-	-	-	1
3/17- 3/23	2	0	2	-	-	-	2

TABLE 3 (Continued)

TOTAL POUNDS OF FISH TO BE HAULED FROM MIDDLE SNAKE RIVER BASIN
(By Collection Station)

Week of Run	Eagle Creek Collection: Avg. Lbs. Salmon/Day	Eagle Creek Collection: Avg.Lbs. Steelhead per Day	Eagle Creek Collection: Average Total Lbs./Day	Snake River Collection: Avg.Lbs. Salmon/Day	Snake River Collection: Avg.Lbs. Steelhead per Day	Snake River Collection: Average Total Lbs./Day	Average Total Lbs. Fish/Day Both Stations (Col. 4 + 7)
3/24- 3/30	6	0	6	-	-	-	6
3/31- 4/6	4	3	7	-	-	-	7
4/7 - 4/13	7	7	14	-	-	-	14
4/14- 4/20	5	2	7	20	1,140	1,160	1,167
4/21- 4/27	17	1	18	17	570	587	605
4/28- 5/4	7	11	18	15	286	301	319
5/5 - 5/11	4	36	40	81	286	367	407
5/12- 5/17	2	107	109	244	143	387	496
5/18- 5/24	0	13	13	236	214	450	463
5/25- 6/1	0	6	6	187	257	444	450
6/2 - 6/8	1	7	8	17	114	131	139
6/9 - 6/15	1	5	6	4	14	18	24
6/16- 6/27	0	1	1	1	14	15	16
6/28- 7/4	0	0	0	1	14	15	15
7/5 - 7/11	0	0	0	6	0	6	6
7/12- 7/18	0	0	0	69	0	69	69
7/19- 7/25	0	0	0	7	0	7	7
7/26- 8/1	0	0	0	1	0	1	1
							4,837
				Annual Total Pounds of Fish (4,837 x 7)			33,859

Note: Collection at the Snake River station began the week of April 14th.

TABLE 4

TYPES OF TRIPS AND NUMBERS OF TRIPS REQUIRED TO HAUL FISH DOWNSTREAM
IN MIDDLE SNAKE RIVER BASIN -- ALTERNATIVE EQUIPMENT
(Per Week)

Week of Run	Average Total Lbs. Fish/Day To Be Hauled	Type of Trip Required*	Air Freight No. Trips	3/4 Ton Pickup with 150 Gal. Tank — Number Trips Assuming Fish/Gallon Water: 2 Lb.	1.5 Lb.	1 Lb.	3-5 Ton Stake Truck with 800 Gal. Tank — Number Trips Assuming Fish/Gallon Water: 2 Lb.	1.5 Lb.	1 Lb.
9/30-10/6	34	E	2	2	2	2	2	2	2
10/7 -10/13	194	E	7	5	7	10	2	2	2
10/14-10/20	247	E	9	6	8	12	2	2	3
10/21-10/27	30	E	2	2	2	2	2	2	2
10/28-11/3	19	E	2	2	2	2	2	2	2
11/4 -11/10	19	E	2	2	2	2	2	2	2
11/11-11/17	17	E	2	2	2	2	2	2	2
11/18-11/24	17	E	2	2	2	2	2	2	2
11/25-12/1	9	E	2	2	2	2	2	2	2
12/2 -12/8	4	E	2	2	2	2	2	2	2
12/9 -12/15	4	E	2	2	2	2	2	2	2
12/16-12/22	6	E	2	2	2	2	2	2	2
12/23-12/29	0	E	0	0	0	0	0	0	0
12/30- 1/5	2	E	2	2	2	2	2	2	2
1/6 - 1/12	0	E	0	0	0	0	0	0	0
1/13- 1/19	0	E	0	0	0	0	0	0	0
1/20- 1/26	0	E	0	0	0	0	0	0	0
1/27- 2/2	0	E	0	0	0	0	0	0	0
2/3 - 2/9	6	E	2	2	2	2	2	2	2
2/10- 2/16	9	E	2	2	2	2	2	2	2
2/17- 2/23	2	E	2	2	2	2	2	2	2
2/24- 3/2	3	E	2	2	2	2	2	2	2
3/3 - 3/9	1	E	2	2	2	2	2	2	2
3/10- 3/16	1	E	2	2	2	2	2	2	2
3/17- 3/23	2	E	2	2	2	2	2	2	2

TABLE 4 (Continued)

TYPES OF TRIPS AND NUMBERS OF TRIPS REQUIRED TO HAUL FISH DOWNSTREAM
IN MIDDLE SNAKE RIVER BASIN -- ALTERNATIVE EQUIPMENT
(Per Week)

Week of Run	Average Total Lbs. Fish/Day To Be Hauled	Type of Trip Required*	Air Freight No. Trips	3/4 Ton Pickup with 150 Gal. Tank — Number Trips Assuming Fish/Gallon Water: 2 Lb.	1.5 Lb.	1 Lb.	3-5 Ton Stake Truck with 800 Gal. Tank — Number Trips Assuming Fish/Gallon Water: 2 Lb.	1.5 Lb.	1 Lb.
3/24- 3/30	6	E	2	2	2	2	2	2	2
3/31- 4/6	7	E	2	2	2	2	2	2	2
4/7 - 4/13	14	E	2	2	2	2	2	2	2
4/14- 4/20	1,167	E & S	42	28	37	55	6	7	11
4/21- 4/27	605	E & S	21	15	19	28	3	4	6
4/28- 5/4	319	E & S	11	7	10	15	2	2	3
5/5 - 5/11	407	E & S	14	10	13	19	2	3	4
5/12- 5/17	496	E & S	17	12	16	24	3	3	5
5/18- 5/24	463	E & S	16	11	15	22	3	3	5
5/25- 6/1	450	E & S	16	11	14	21	2	3	4
6/2 - 6/8	139	E & S	6	4	5	7	2	2	2
6/9 - 6/15	24	E & S	2	2	2	2	2	2	2
6/16- 6/27	16	E & S	2	2	2	2	2	2	2
6/28- 7/4	15	S	2	2	2	2	2	2	2
7/5 - 7/11	6	S	2	2	2	2	2	2	2
7/12- 7/18	69	S	3	2	3	4	2	2	2
7/19- 7/25	7	S	2	2	2	2	2	2	2
7/26- 8/1	1	S	2	2	2	2	2	2	2

(*) E = Trip directly from Eagle Creek station to destination.
S = Trip directly from Snake River station to destination.
E & S = Trip originating at Snake River station and stopping at Eagle Creek station to take on additional loads before going to destination.

APPENDIX

ILLUSTRATIVE ANALYSIS OF HAULING COSTS FOR POTENTIAL SALMON POPULATION ON THE SNAKE RIVER

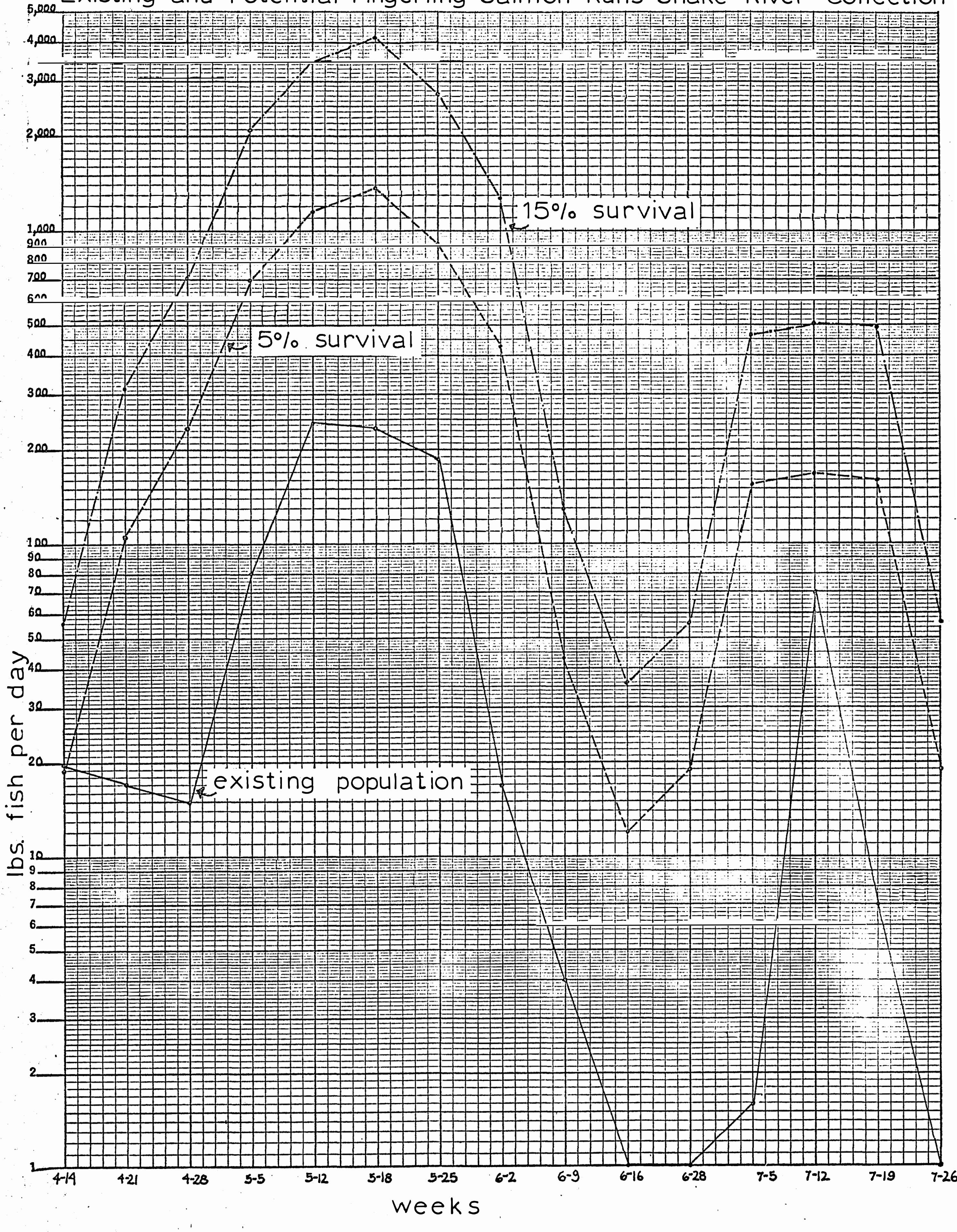
In order to provide an indication of the problems and costs associated with hauling the potential fingerling population in the Middle Snake River Basin, an illustrative analysis was conducted for the run of fall chinook salmon collected at the Snake River station. From data provided to us by the Fish Passage Research Program of the U. S. Bureau of Commercial Fisheries, the potential adult population was estimated at 12,500 females. Each female was assumed, on the average, to spawn 4,000 eggs--giving a total of 60,000,000 eggs. Two survival rates were assumed for the fingerlings: one of 5% and the other of 15%. Under the 5% survival rate, an estimated 3,000,000 fingerling salmon would constitute the potential population to be hauled from the Snake River station. Under the 15% survival rate, the fingerling population would be 9,000,000. Finally, the mean length of the fingerlings was assumed to be the same for the potential and the existing populations. Consequently, a mean length of 72 mm. was used, which would mean approximately 78 fingerlings per pound.

In order to distribute the two potential populations over the length of the run, the following procedure was used.

A three week moving average was taken of the weekly distribution (by pounds) of fingerling fall chinook salmon reported for 1963 at the Snake River station. Once this average was derived, the percentage distribution, by week, for the smoothed out fingerling run was computed. This percentage distribution was then applied to the estimated potential populations to distribute them over the length of the run. A comparison of the actual 1963 fall chinook run (as reported at the Snake River station) and the two estimated potential populations is presented in figure 7.

Figure 7

Existing and Potential Fingerling Salmon Runs-Snake River Collection



Once both the potential fingerling populations and their distributions over the length of the run were estimated, it was next possible to derive the cost of the hauling operation. These costs were computed for air freight (assuming the use of a twin engine light plane with a 400-gallon tank), a 3-5 ton stake truck with a portable 800-gallon tank, and a 1,000-gallon tanker-truck. The costs of using each type of hauling equipment were derived in a manner identical to that discussed in the main body of the text. The results of these cost calculations are presented in table 5. To allow for a comparison of the current and future hauling costs for fall chinook fingerlings, these same calculations also were made for the existing run and are also presented in table 5.

In general, total hauling costs rise very substantially as the size of the fingerling population increases. On the other hand, cost per pound of hauling diminishes sharply. For example, the existing population (approximately 6,340 pounds of fingerling salmon) would cost roughly $3,300 to haul, giving an average cost per pound of about 52¢. The potential population, assuming a 5% survival rate (roughly 38,500 pounds) would cost just over $6,600 to haul--although the cost per pound would fall to roughly 17¢. With a 15% survival rate, the fingerling population would be approximately 115,400 pounds, and the total cost of hauling would rise to approximately $14,600--although the cost per pound will have declined to approximately 13¢.

In making the cost estimates for hauling the potential fall chinook runs, the same type of equipment as discussed in the main body of the report was assumed to be used for the air freight and 800-gallon portable tank hauling. The 1,000-gallon tanker-truck hauling costs were estimated for the first time for this appendix. The method of estimating these costs was similar to the method used to develop costs for the other transportation equipment. Our conclusion is that for a 5% survival rate air freight hauling would show a slight advantage over any other form of transportation. This conclusion rests on the assumption that the size of the tank used in the air freight hauling would remain constant at 400 gallons. This assumption was maintained to allow full comparability between cost estimates in this appendix and the main part of the text. For the 15% survival rate, on the other hand, a truck with a portable 800-gallon tank would have the advantage.

However, should an adequate landing facility be available at Weiser for larger sized planes, and it becomes possible to use 600 to 800 gallon tanks, it is expected that air freight costs would again become less than any alternative form of hauling.

Figure 8

Total and Unit Cost of Hauling Fingerling Salmon
Existing and Estimated Potential Populations
(Weiser to High Mt. Sheep Dam)

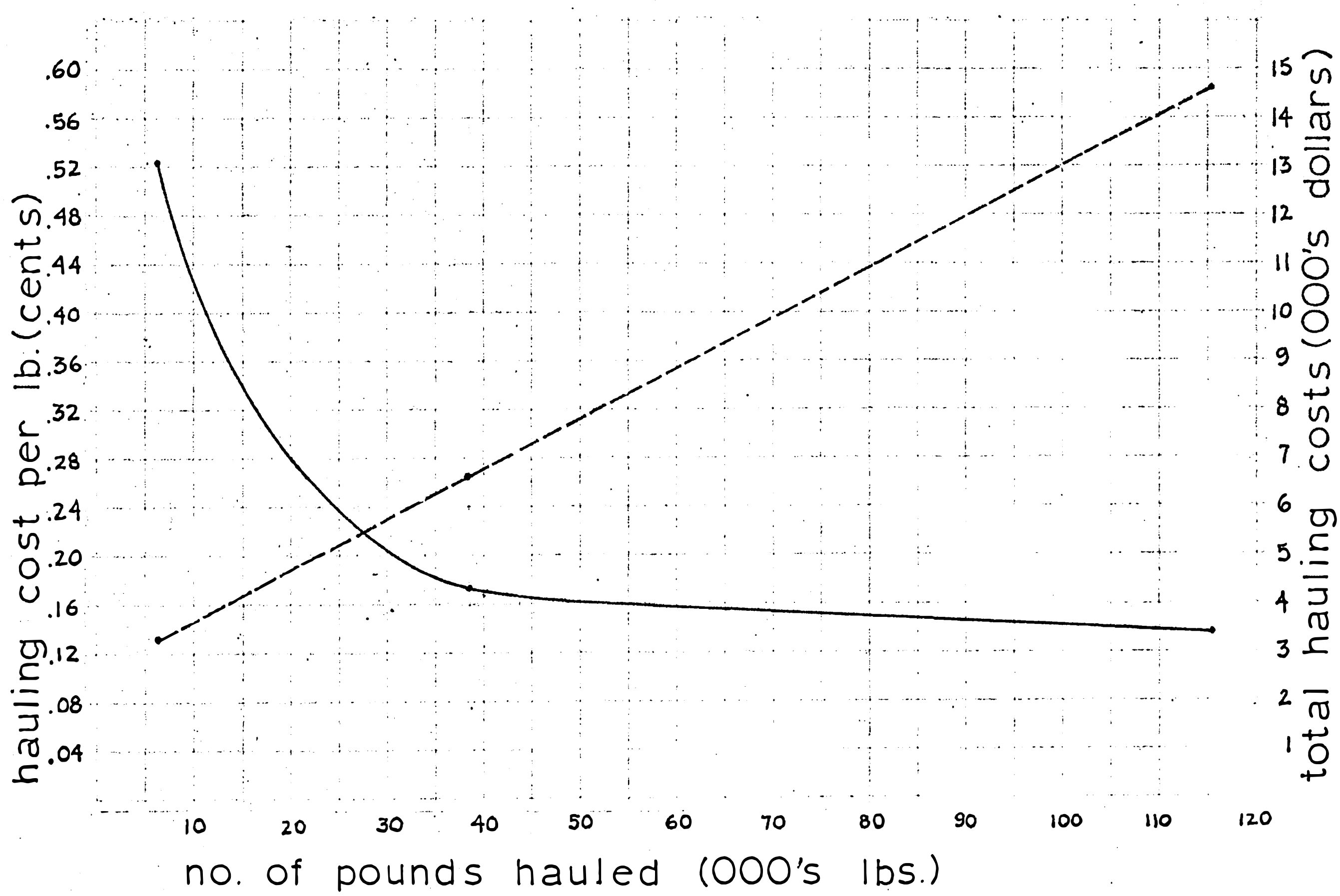


TABLE 5

COST OF HAULING EXISTING AND POTENTIAL FINGERLING SALMON POPULATION
SNAKE RIVER STATION TO HIGH MOUNTAIN SHEEP DAM

Total Miles Traveled*			Total Costs*			Pounds Fish Hauled*			Cost per Pound*		
Current#	5%	15%	Current#	5%	15%	Current#	5%	15%	Current#	5%	15%
Air Freight											
7,360	14,720	35,880	$3,312	$6,624	$16,146	6,342	38,458	115,374	$.5222	$.1722	$.1399
Stake Truck with 800-Gallon Tank											
- -	22,050	48,600	- -	$6,633	$14,619	- -	38,458	115,374	- -	$.1725	$.1267
Tanker-Truck with 1,000-Gallon Tank											
- -	19,800	40,950	- -	$9,563	$19,779	- -	38,458	115,374	- -	$.2487	$.1714

(*) 5% and 15% refer to assumed survival rates.

(#) Current costs calculated for air freight only to allow for direct comparisons between total cost data in text (where air freight was determined to be minimum cost hauling technique between Weiser and High Mountain Sheep Dam).

TABLE 6

POTENTIAL RUN OF FALL CHINOOK FINGERLINGS*
SNAKE RIVER STATION

Week of Run	Number of Chinook Fingerlings#		Pounds of Chinook Fingerlings#		Pounds/Day Chinook Fingerlings#	
	5%	15%	5%	15%	5%	15%
4/14-4/20	10,200	30,600	131	392	19	56
4/21-4/27	57,300	171,900	735	2,204	105	315
4/28-5/4	128,100	384,300	1,642	4,927	235	704
5/5 -5/11	381,300	1,143,900	4,888	14,665	698	2,095
5/12-5/17	630,900	1,892,700	8,088	24,265	1,155	3,466
5/18-5/24	749,100	2,247,300	9,604	28,812	1,372	4,116
5/25-6/1	496,200	1,488,600	6,362	19,085	909	2,726
6/2 -6/8	232,800	698,400	2,985	8,954	426	1,279
6/9 -6/15	23,700	71,100	304	912	43	130
6/16-6/27	6,600	19,800	85	254	12	36
6/28-7/4	10,200	30,600	131	392	19	56
7/5 -7/11	84,300	252,900	1,091	3,242	154	463
7/12-7/18	91,500	274,500	1,173	3,519	168	503
7/19-7/25	87,600	262,800	1,123	3,369	160	481
7/26-8/1	10,200	30,600	131	392	19	56
	3,000,000	9,000,000	38,463	115,384	5,494	16,482

(*) For distribution and size of current run see table 3.
(#) 5% and 15% refer to the assumed survival rates.