FISHWAY CAPACITY EXPERIMENT, 1956

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EXPLANATORY NOTE

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United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, Arnie J. Suomela, Commissioner

FISHWAY CAPACITY EXPERIMENT, 1956

by

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FISHWAY CAPACITY EXPERIMENT, 1956 1/

by

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ABSTRACT

From May 22 to September 7, 1956, eight tests were made involving the passage of varying numbers of fish through an overfall-type fishway. The fishway, which was 6 feet wide, consisted of 6 pools (1 foot rise between pools) each 16 feet long with an average depth of 6.3 feet. In the tests, from 70 to 2886 fish entered the fishway during 1-hour periods. The median passage time for fish to ascend the 6-pool fishway ranged from 12 to 35 minutes. The effect of pattern of flow and other criteria on fish passage is discussed.

INTRODUCTION

Fishery and water development interests share a mutual concern over the high costs of fishways and fish protection devices at dams and water diversion projects. As an example, the fish passage facilities at The Dalles Dam, completed in 1957, cost in excess of 18 million dollars. Outlays for fish protection structures in some instances amount to as much as 15 percent of the total cost of dam construction exclusive of fishways (U. S. Fish and Wildlife Service 1953).2/ The question arises then, "How may we seek to reduce these expenditures without impairing the safety of fish passage?" A plausible approach lies in the study of fish behavior and the principles involving in fish passage with emphasis on the application of this knowledge toward the design and construction of more efficient fish-passage facilities.

Modern fishways on the Columbia River are undoubtedly the largest and most elaborate to be found anywhere in the world. They contain a host of features which their designers felt were necessary to insure safe passage of fish beyond the man-made obstacles. There was good reason for this. Before the construction of Bonneville Dam, some people expressed serious doubt that runs of the magnitude known to migrate up the Columbia River could be effectively passed. As a result, special precautions were taken to provide ample safeguards for meeting a number of conceivable conditions (Holmes 1940). Accordingly, the total facilities finally installed may have been far more elaborate than necessary. We find that dual passage facilities (i.e., fish ladders and elevators) were provided in the event one or the other failed to pass migrants effectively. Elaborate collection systems and a complex network of auxiliary

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1/ Research financed by the U. S. Army Corps of Engineers as a part of a broad program of fisheries-engineering research for the purpose of providing design criteria for more economical and more efficient fish-passage facilities at Corps' projects on the Columbia River.

2/ A statement by the Fish and Wildlife Service in response to the request, dated November 20, 1953, of Senator Styles Bridges, Chairman, Senate Appropriations Committee, for information on the abundance, distribution, and value of the Columbia River fish runs, the effect of dams on these runs, and certain other related information. U. S. Fish and Wildlife Service, Office of the Regional Director (Region 1, Portland, Oregon), 41 pp., tables, mimeo.

water conduits were installed to provide the best known attraction and transportation facilities for fish as they approached and began their ascent over the dam. Special features were also added to assist the outmigrating fingerlings in descending from forebay to tailrace areas in their journey to the sea.

Notwithstanding early fears of possible failure, the Bonneville fishways immediately demonstrated their worthiness. Lessons learned here played an important part in the subsequent design of fishways at McNary and The Dalles Dams which are located upstream from Bonneville Dam. Despite the satisfactory operational records of the Bonneville and McNary fishways, much needs to be done to achieve increased efficiency.

Heretofore, much of our knowledge of fishway design has been derived empirically. Recently, however, various agencies and institutions have initiated vigorous research programs designed to provide basic data applicable to the solution of the many problems associated with fish passage facilities. One of the more recent developments in this new research era is the construction of the Fisheries-Engineering Research Facility, located on the Washington side of Bonneville Dam. Here, under controlled laboratory conditions, prototype fishways and allied structures can be installed and fish behavior critically examined by experimental processes.

One of the fundamental questions in fishway design which has yet to be specifically answered is "How large should a fishway be to pass effectively a known or conceivable maximum number of fish?" If we are presently constructing our fishways far larger than the maximum demand requires, then it is obvious a considerable saving might be realized merely through a reduction in their size. Not only may construction costs be reduced, but concomitant water economies may also be expected.

Initial research, seeking a basis for the solution of the problem of fishway size, began at the Bonneville facility in the spring of 1956 and was continued intermittently until early September of that year. The term "fishway capacity" was used to describe the object of these experiments and may be defined as the "maximum number of fish (size and species considered) that a fishway of given dimensions and hydraulic conditions can pass per unit time."

The purpose of this study is (1) to determine experimentally the specific capacity of a prototype overfall fishway and (2) to note factors which may influence this capacity.

The following is a report of the initial phase of our work which was confined primarily to the development of procedures and techniques whereby capacity might be measured. No attempt is made to consolidate these initial endeavors into a final determination of capacity. Several observations are made and the significance of each is discussed as it affects a measure of fishway capacity. These have been included so that they may become readily available for examination and study by those immediately concerned with the problem.

As this work is essentially preliminary, we emphasize that interpretation of the recent observations can be only tentative, pending further examination of the specific relationships which may control fishway capacity.

MATERIALS

Description of Fisheries-Engineering Research Facility

A detailed description of the Fisheries-Engineering Research Facility is in preparation by Collins.[3] Essentially the structure is a rectangualr flume 200 feet long by 24 feet wide with a maximum depth of 24 feet. The flume is a unit of a by-pass structure connecting with the Washington shore fishway. Various prefabricated structures may be installed in the flume to simulate a variety of experimental fishway conditions. An overhead traveling crane is used to install and remove the heavier structures used in the studies.

Fish for experimental purposes, diverted from the Washington shore fishway, ascend an entrance fishway to a collection

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3/ Collins, Gerald B. Research in fish passage problems, U. S. Fish and Wildlife Service. Manuscript in preparation.

pool inside the facility. From this point they are released into the experimental area where their movements are observed and recorded. They then pass into a large upper pool (flow introduction pool) and leave this area by means of an exit fishway which again joins the main ladder. A unique feature of the present experiments is that the fish are never handled or removed from their fishway environment.

Assembly and Dimensions of Experimental Fishway

The established width of experimental fishways in the Bonneville facility is 11 1/2 feet. To reduce the number of fish necessary to demonstrate capacity, the original fishway width was cut to 6 feet by installing a partition approximately in the middle of the fishway (figure 1). This created an experimental area comprised of six pools, each 16 feet long (weir center to weir center), 6 feet wide, and with an average depth of 6.3 feet. There was a one foot rise between pools (1:16 slope). Total length of the fishway was 96 feet. Weirs were 6 feet high and 7 1/2 inches thick. Weir crests were square and painted white to aid in the observation of fish during turbid water periods. All other structures were painted camouflage brown. There were no orifices in the weirs although small drains (closed during tests) were provided. A cross section view of a weir is shown in figure 2. Diagrammatic plan and side views of the experimental fishway are given in

FIGURE 1.--INSTALLING PARTITION WALL TO CREATE A 6-FOOT WIDE FISHWAY FOR THE CAPACITY TESTS.

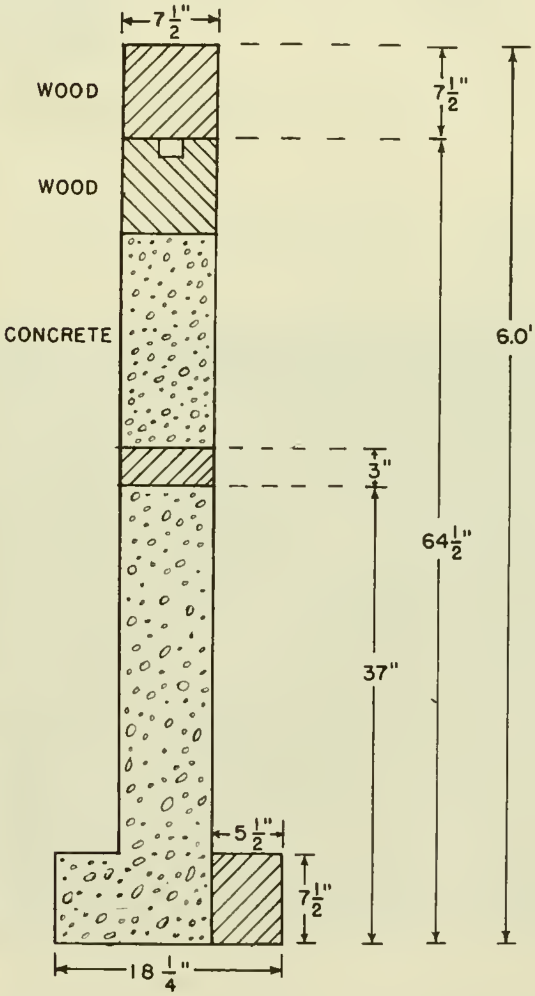

FIGURE 2.--CROSS SECTION OF WEIR USED IN TEST FISHWAY.

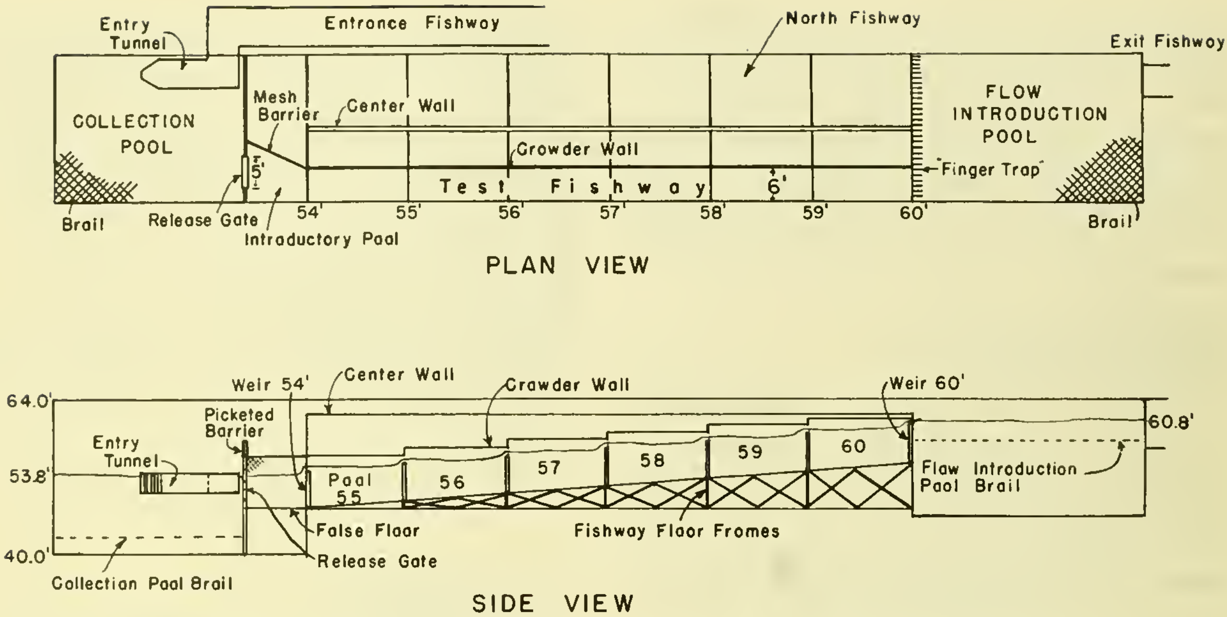

FIGURE 3.--DIAGRAMMATIC PLAN AND SIDE VIEWS OF THE TEST FISHWAY AND ASSOCIATED POOLS IN THE EXPERIMENTAL FACILITY.

figure 3. Elevations noted are relative to comparable points at Bonneville Dam. All elevations are expressed in height (feet) above mean sea level.

Collection, Introductory and Flow Introduction Pools

In addition to the test fishway proper, the flume was partitioned into several accessory pools to accommodate the fish before and after their passage through the test area. These were the collection pool, the introductory pool, and the flow introduction pool (figure 3).

Fish ascending the entrance fishway entered the flume by means of a portable entry "tunnel", passing through this structure into the collection pool. This tunnel (figure 4) was simply an extension of the entrance fishway. Its V-shaped exit was equipped with a finger trap which prevented fish from backing down into the entrance fishway after having entered the collection pool.

The collection pool provided an area in which to contain the fish prior to their release into the fishway. Pool dimensions were 30 feet by 24 feet with a water depth of 14 feet. A brail, which could be raised as desired, covered the pool bottom. A picketed barrier marked the upstream limit of the collection pool. This structure extended 8 feet above the water surface to prevent fish from jumping from the collection pool into the fishway introductory pool. A 5-foot release gate in the barrier provided access to the experimental area. Water depth at the gate entrance was 2 feet.

After fish passed through the release gate they entered an introductory pool before beginning their ascent in the test fishway. This pool was 7 feet deep, 13 feet long, and varied in width from 11 feet at the downstream end to 6 feet at its juncture with the partition wall at the first weir in the fishway.

When the fish had completed their passage through the experimental fishway, they entered the flow introduction pool which was 37 feet long and 24 feet wide. A finger trap on the upstream face of the final weir (elevation 60) permitted exit but prevented fish from drifting or swimming back into the test area once their movements had been recorded (figure 5). Water 3 to 4 inches in depth flowed over the upper surface of the finger trap.

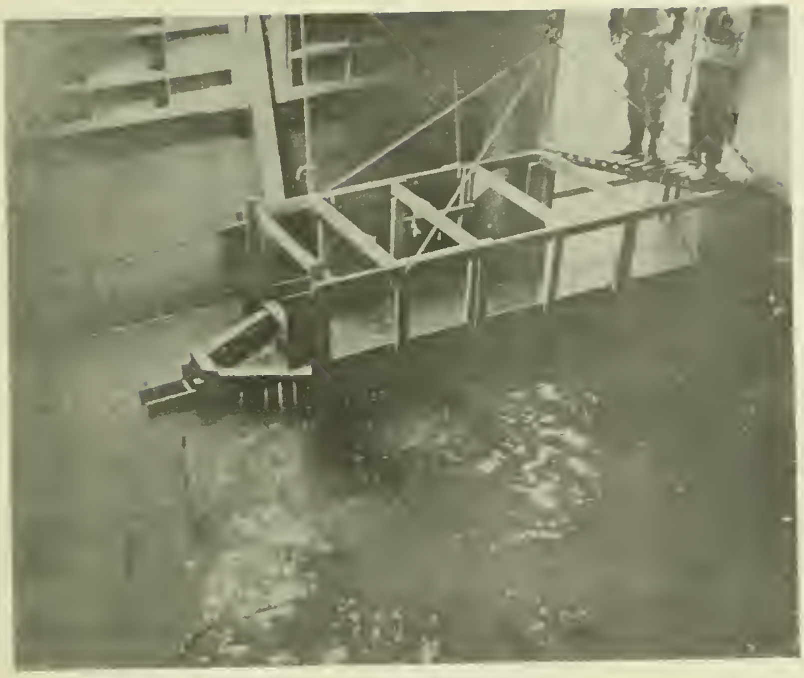

FIGURE 4.--VIEW OF ENTRY TUNNEL THROUGH WHICH FISH PASS FROM THE ENTRANCE FISHWAY TO ENTER THE COLLECTION POOL. FINGER TRAP AT EXIT PREVENTS FISH FROM LEAVING THE COLLECTION AREA.

FIGURE 5.--VIEW OF FINAL WEIR IN TEST FISHWAY SHOWING FINGER TRAP ON UPSTREAM FACE OF WEIR. NOTE STREAMING FLOW IN VICINITY OF SALMON.

A fixed brail was installed in the flow introduction pool to limit fish movement to the upper 5 feet of this pool which has a depth of 14 feet. Reduction of the pool depth served to discourage the fish from lingering unnecessarily in this area before passing outward into the exit section and back into the Washington shore fishway.

Fishway Hydraulics

Total water fall in the 96-foot fishway was 6 feet (elevation 60 feet to elevation 54 feet). Standard water flows were controlled to allow for 0.8-foot head (measured 4 feet upstream of weir) on the weir crest which was the approximate upper limit at which plunging flow could be maintained on the square-crested weir. When the fishway was filled with water, the approximate water volume per pool (accounting for the area displaced by weirs) was 585 cubic feet. Calculated discharge of the test fishway was 15.9 c.f.s.

Two sources provided water for the experiments: (1) a water supply system originating in the Bonneville Dam forebay, and (2) the exit fishway which received its water from the Washington shore fishway. Water balance within the facility was maintained by manual control of water intake and discharge valves.

Lighting

A constant light condition was established for all experiments. Sixteen 1000-watt fluorescent mercury vapor lamps were hung directly over the area in the test fishway. As a standard, all light assemblies were set arbitrarily at 6 feet above the water surface. This provided an average light intensity comparable to that which might be found in an outside fishway on a bright, cloudy day. Readings obtained directly under lights at the water surface averaged 850 foot candles. The range of incident light was 350 to 1000 foot candles.

METHODS

Experimental Approach

Our approach to the solution of the question, "What is the capacity of a fishway?" has been based on the belief that the condition can be physically demonstrated by the introduction of varying quantities of fish into a given fishway. Thus, by gradually increasing the numbers of fish introduced in each experiment, eventually an end point or boundary indicating maximum passage per unit time would be reached. Since there is no way to anticipate the particular point at which this will occur, it will be necessary, therefore, to extend the fishway beyond a hypothetical capacity in order to examine the particular reactions which might develop as a result of an overcrowded condition, if such develops. To demonstrate this condition, the first and most important requirement will be to maintain a constant supply of fish in excess of the maximum the fishway would be capable of passing per unit time--at least for a period long enough to establish that certain fundamental relationships are characteristic of a saturated or possible overcrowded fishway.

The foregoing approach will lead to the examination of the following concepts as they are applicable to the determination of capacity in an overfall, pool-type fishway:

1. The initial factor limiting the capacity of any fishway is the maximum number of fish that may enter per unit time. Among the factors which may affect maximum entry are (a) passage space, (b) entrance hydraulics, and (c) differential motivation among the fish on different days and within the same day.

2. Maximum exit per unit time (capacity) can equal maximum entry per unit time.

3. Once a maximum entry is reached and maintained, the rate at which fish ascend the fishway will govern the extent to which they will accumulate in the fishway per unit time. This accumulation will mount arithmetically as the rate of movement decreases. For instance, if entry is established at a maximum of 40 fish per minute and fish ascend the fishway at an average rate of one pool per minute, then 40 fish will be the average number present in each pool. If the average rate of movement decreases to an ascent of one pool every two minutes or one pool every three minutes, then the accumulation in each at a given minute will be 80 and 120 fish respectively. Exit in each instance will be 40 fish per minute. As long as the accumulation resulting from a particular rate of movement in combination with a fixed maximum entry rate does not impair "free"

movement in the fishway, exit per unit time should equal entry per unit time.

4. There may be a point at which the maximum entry per unit time in combination with a particularly slow rate of movement will produce an excessive accumulation of fish in the fishway. Once this condition is reached, the following may result: (a) maximum exit per unit time will decline below maximum entry per unit time, (b) entry per unit time may also decline (i.e., a given number may enter a pool each minute, but of these a certain number may drop back out of the pool, presumably because of lack of sufficient space in the pool), or (c) a further decrease in rate of movement. The latter may be difficult to define, but an excessively slow movement coupled with high density could be indicative of a crowded condition impairing movement.

Fish Collection

To accumulate a supply of fish for the capacity test, fish ascending the entrance fishway were contained in the collection pool until such time as it was felt that sufficient numbers were on hand to conduct the experiment. At the outset of these experiments, our estimates of the number of fish that would be required to fill the fishway to capacity were necessarily arbitrary. The only way to determine the number was to conduct several experiments, each time increasing the numbers collected (with due consideration for size and species of fish passed), if previous experimentation indicated that capacity had not been reached. As the experiments progressed, it became evident that several thousand or more fish would be necessary to create or exceed a capacity situation in the test fishway. A collection of this magnitude occasionally required that some fish be held in excess of 48 hours prior to release.

Sample counts were made on the hour between 8:00 A.M. to 4:00 P.M. to obtain relative estimates of the number of fish in the collection pool. These were taken by observing the fish as they passed from the entry tunnel into the collection pool.

Preparations for Release of Fish

Just before the beginning of a test, the entry tunnel was removed and a screen was inserted in its place to prevent fish from backing out of the pool. Then the collection pool brail was raised approximately 11 feet. This confined all fish within a 3-foot surface layer of the pool. The view in figure 6 (page 8) shows the concentrattion of fish in the collection pool following this operation. The purpose of the above maneuver was to create a concentration of fish similar to that which might exist in an actual fishway during periods of peak migration.

Release of Fish into Fishway

Shortly after the collection pool brail was raised, the release gate in the picketed barrier was opened to provide access to the test fishway. This was considered the start of the test. As the fish moved through the entry gate into the introductory pool and then up into the fishway, the downstream end of the brail was gradually raised higher to concentrate further the remaining fish in the vicinity of the fishway entrance. Figure 7 (page 8) presents a view of the collection pool showing the entry gate in open position and with the brail tilted.

Observation and Recording Procedure

Immediately prior to the release of fish from the collection pool, observers were stationed along the walkways at points overlooking the various weirs. Each observer was provided with a push button limit switch which recorded the passage of fish on an operations recorder (figure 8, page 9). This provided a convenient means of recording the number of fish and the time at which each passed a particular weir while the experiment was in progress.

One of our major problems in the fishway capacity experiments was to obtain an accurate tally of fish passage at each observation station. Counting errors were particularly evident in some of the initial tests before our observers had acquired proficiency in counting procedure. As the season progressed and the observers gained experience, discrepancies in counts at individual stations became less evident.

The most difficult counting period generally occurred immediately following the release of fish from the collection pool and for a period of 10 to 15 minutes thereafter. During this time, observers occasionally had to tally over 100 fish per

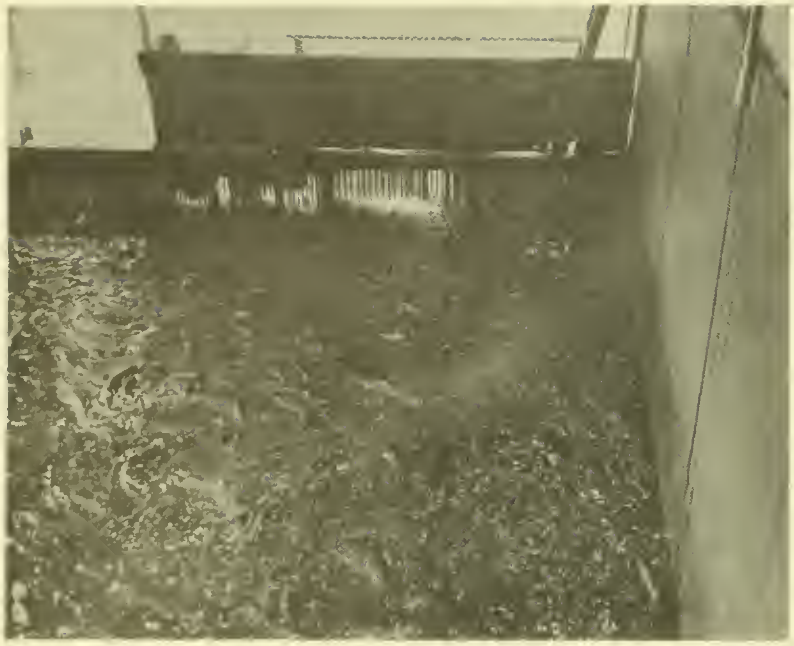

FIGURE 6.--VIEW OF COLLECTION POOL PRIOR TO RELEASE OF FISH INTO TEST FISHWAY. BRAIL HAS BEEN RAISED TO CONFINE FISH TO SURFACE OF POOL AND INDUCE MOVEMENT INTO FISHWAY.

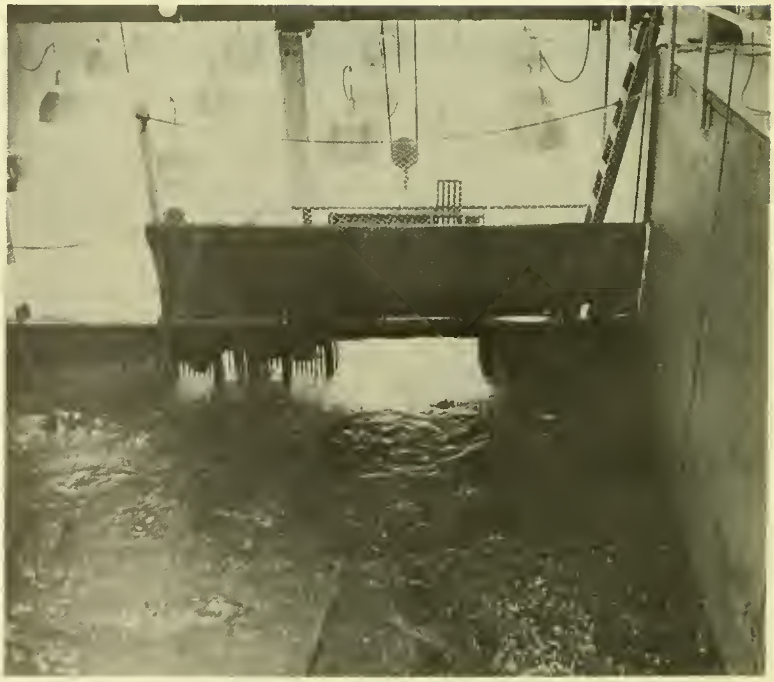

FIGURE 7.--LOOKING UPSTREAM OVER COLLECTION POOL WITH ENTRY GATE IN OPEN POSITION. POOL BRAIL HAS BEEN RAISED AND TILTED.

minute. To simplify counting, the observers were instructed to tally in groups of five until the numbers passing decreased sufficiently to permit individual tally of fish.

Size and Species Considerations

In a study of fishway capacity we must necessarily give consideration to the size and species composition of a fish population which may be expected to pass a fishway located in a given area of a river system. For instance, if a fishway is limited size, we may logically expect to pass greater numbers (per unit time) of a run in which species average 5 pounds in weight than of another run in which species average 10 pounds, other factors being equal. Further, if the smaller of the two species is capable of ascending the fishway twice as fast as the larger, then the potential difference in total numbers capable of passage per unit time may become even greater when we compare the capacity of the fishway with respect to the two species. Conversely, the opposite might be true if the larger of the two species proves to be the better swimmer. Clearly we must recognize the possible effect of these two factors--size and species performance--in our measure of fishway capacity.

The three most common salmon passing Bonneville Dam in order of abundance are (1) chinook (Oncorhynchus tschawytscha Walbaum), (2) blueback (O. nerka Walbaum), and (3) silver (O. kisutch Walbaum). Two other species, chum salmon (O. keta Walbaum) and pink salmon (O. gorbuscha Walbaum) are also known to pass the dam, the latter rarely.

Except for chinook salmon, the steelhead (Salmo gairdneri Richardson) is usually the most abundant salmonoid appearing at Bonneville Dam.

For comparative purposes, the average weights of the various species will be used as a measure of size. Weights of the above-mentioned species, particularly chinook salmon (Silliman et al. 1947) may vary considerably between and within years. The following average weights (Cleaver 1951) are presented to demonstrate characteristic size differences among salmonoids present in the Columbia River: chinook salmon, 17 [4/] to 20[5/] pounds; steelhead, 9 pounds; blueback, 3 pounds; and silver salmon, 10 pounds.

FIGURE 8.--OPERATIONS RECORDER USED TO RECORD FISH PASSAGE IN NUMBERS PER UNIT TIME. EACH PASSAGE IS NOTED IN THE FORM OF A BLIP ON THE RECORDER TAPE AT THE EXACT MOMENT OF OCCURRENCE.

Average weights obtained during September 1949 (Schoning et al. 1951) at Celilo Falls (now inundated), which was approximately 50 miles above Bonneville Dam on the Columbia River, showed that chinook salmon average 15.7 pounds; steelhead, 9.25 pounds; and silver, 7.1 pounds.

Average weights listed above apply to fish taken in commercial catches and may not, therefore, be directly applicable to the salmonoid population passing Bonneville

4/ "Spring" run average. Arbitrarily January 1 - July 31.

5/ "Fall" run average. Arbitrarily August 1 - December 31.

Dam. In the recent capacity experiments it was not possible to obtain a series of average weights of species passed. To have done so would have entailed considerable handling of the fish, a situation we particularly sought to avoid.

Therefore, in the absence of actual field measurements applicable to these tests, estimated weights were assigned to each species with respect to season, based in part on the information contained in the foregoing reports. For the tests conducted on July 13 and September 7, the average weight per fish (all species) was estimated at 3 and 13 pounds respectively.

In addition to salmonoids considerable numbers of miscellaneous species pass Bonneville Dam each year. The term "scrap" fish has come to be applied locally to the non-salmonoid fishes which have limited or no commercial value. They are generally in peak abundance during early summer, as a rule, shortly after the high water run off. Among those most frequently observed in the fishways at Bonneville Dam are the Columbia River sucker (Catostomus microcheilus), common carp (Cyprinus carpio), squawfish (Ptyocheilus oregonenis) and chiselmouth chub (Achrocheilus alutaceus). Also present, in addition to the so-called scrap fish, are the shad (Alosa sapidissima), Oregon whitefish (Prosopium oregonium), white sturgeon (Ancipenser transmontanus), and a fish-like vertebrate, the lamprey (Entosphenus tridentatus).

Scrap fish were estimated to range in weight from several ounces (small suckers and squawfish) to over 10 pounds (carp). The majority, however, probably averaged less than 1 pound. As a group they may occasionally be as abundant or more so than the salmonoids. In this regard their presence must not be overlooked since they are in competition with the salmonoids for space in the fishway.

Species Identification

As a wide variety of fish could have been present for a given test, it was important to develop a simple and yet effective method by which to identify the various species. Since all fish generally were visible only momentarily as they passed a weir crest, identification was necessarily confined to a rapid sight recognition of a salient feature. Use of the conventional fish identification key was, therefore, of little value under these circumstances. while body conformation and color were occasionally useful, we eventually found that dorsal markings provided the most reliable means for rapid field identification of the salmonoids. For instance, markings on the chinook salmon were generally large (5 to 10 mm.), oblong, blotch-like and numerous. Steelhead dorsal marks were much smaller (2 to 3 mm.), ovoid or nearly so, and numerous to very few. On the blueback salmon, dorsal markings were generally absent or extremely rare. The silver salmon more closely resembles the steelhead than any of the other species. Its markings, however, were more rectangular than ovoid, about 3 to 4 mm. long and generally quite numerous. The above descriptions apply to the Columbia River salmonoids as we observed them at Bonneville Dam and are not necessary applicable to other watersheds frequented by the Pacific salmon and steelhead. Fish other than salmonoids were summarily listed as scrap fish.

During several initial capacity trials, attempts were made to identify the species composition at each weir. This was soon found to be impracticable as water turbulence in the downstream sections of the fishway either prevented or limited the possibility of accurate identification. The crest of the last weir in the fishway was eventually chosen as the site at which to identify the various species. Here relatively smooth water flows allowed a more accurate identification. Two observers were always stationed at the final weir, one to record total count and the other to tally species. Total count by minutes was transmitted to the operations recorder while species counts were kept manually on a multiple hand-tally array.

Test Duration

Following the release of fish from the collection pool, observations at the fishway weirs were generally continued for a period of 60 minutes. The length of the testing period was again arbitrary and as the experiments progressed, we occasionally deviated from the assigned one hour test period. However, in general, the 60-minute observation period was established as a standard for comparative purposes.

Ideally, assuming that a constant, abundant supply of fish would be available for each experiment, tests might be run for continuous periods of perhaps 10 to 14 hours and thus provide us with a basis upon which to measure possible diurnal fluctuations in fishway capacity. As conditions developed experimentally, our supply generally became exhausted--or nearly so--within periods of less than 60 minutes.

Measurement of Passage Time in Fishway

Several means of measuring rate of ascent in a fishway are possible. Tauti and Miyoshi (1934) expressed rate of ascent in terms of "the number of fishes which reach the top of the fishway in unit time expressed as a percentage of the total number of fishes." While this method allows for a convenient comparison between trials, a measure expressing passage in terms of an average time required to ascend the fishway (or in time per pool) is perhaps more appropriate for the intent of these experiments. This may be conveniently expressed as minutes per pool or in minutes required to ascend the 6-pool test fishway.

The measure established for the purpose of comparing passage time in the recent capacity experiments was median elapsed time. This was derived by subtracting the time at which half of the total release had passed the lower weir (elevation 54) from the time at which half of the total entered has passed the upper weir (elevation 60). For example, in a given test the release over weir 54 in a 1-hour period is 1525 fish; the median time (763rd fish) at weir 54 is observed at minute 15; median time (763rd fish) at weir 60 occurs at minute 35; median elapsed time is 20 minutes (35 - 15 = 20) for the 6-pool fishway. This might also be expressed as a rate of one pool per 3.3 minutes.

Use of the median was particularly advantageous as applied to these experiments. For instance, it was not necessary to continue an experiment until all fish entering had completed passage through the fishway. Only an excess of 50 percent passage was necessary. Had the mean time been used as a measure of rate of ascent, all fish entering would have to be accounted for in the exit. Also, preliminary examination of passage time frequency curves (unpublished data based on the passage time of individual fish) suggests a marked skewness to the right with the majority of individuals (central values) falling in the left hand portion of the curve. Use of the median will, therefore, more adequately represent the central tendency of a sample since it is not distorted by unusual values to the right of the point of maximum frequency on the curve.

We recognize that while the median is useful from a comparative standpoint, it is open to the criticism that in pratice one is concerned with all the fish leaving a fishway, not only the first 50 percent. In these experiments from 61 to 92 percent of those entering actually left the test fishway within the test interval.

OBSERVATIONS

List of Capacity Tests

As has been noted, our measure of capacity was to be based on a series of tests beginning with trials involving relatively small numbers of fish and continuing with gradually increasing numbers introduced in each trial until capacity was reached and could be effectively demonstrated. Much of our initial effort (trials 1 through 6) was confined to the development and refinement of experimental procedure and techniques. Data obtained during these early tests were, therefore, subject to a variety of conditions which were not always comparable. However, the data are included for examination, since they provide a fund of background information which may be basic to the examination of fishway capacity.

In all, eight capacity tests were conducted during the period May 22 through September 7, 1956. A summary of these tests is given in table 1 (page 12). Total numbers released in an individual test ranged from 70 to nearly 3000 fish during a 1-hour period. The test involving the largest number of fish (July 13) was not, however, the largest when considered in terms of total weight. A conversion to estimated poundage shows the weight of the fish in the September 7 test was more than double that in the July 13 test (13 pounds x 1515 = 19,695 pounds as compared to 3 pounds x 2886 = 8,658 pounds).

Table 1.--Summary of fishway capacity tests, 1956

Date	Time of day	Number of fish		Percent completing fishway	Median elapsed time in fishway 1/ (minutes)	Species composition (percent)				
		Entering fishway	Leaving fishway			Chinook 2/	Blueback	Steelhead	Silver	Scrap
5/22	3:27-4:27 P	70	61	87.1	15.42	100.0	--	--	--	--
6/19	3:45-4:30 P	180	166	92.2	15.21	95.0	--	5.0	--	--
6/28	3:15-4:15 P	343	291	84.8	24.01	26.6	47.2	1.9	--	24.3
6/29 3/	10:20-11:20 A	459	420	91.5	11.56	37.5	57.5	5.0	--	4/
7/2	2:00-3:00 P	484	445	91.9	12.34	10.8	87.5	1.7	--	4/
7/5 3/	8:50-9:50 A	797	723	90.7	17.08	10.1	85.0	4.9	--	4/
7/13 3/	10:20-11:20 A	2886	2417	83.7	20.20	8.3	33.6	10.1	--	48.0
9/7	9:20-10:20 A	1515	930	61.4	34.55	64.8	--	29.7	5.1	0.4

1/ Fishway -- 6 pools, each 16 feet long, 6 feet wide and 6.3 feet deep with a 1 foot rise between pools. Head on weir -- 0.8 foot. Flow-plunging unless otherwise noted.

2/ Includes Jacks (arbitrarily all chinook 20" long and under).

3/ Streaming flows developed at 1 or more weirs in fishway.

4/ Scrap fish present but not included in counts.

Note is made here of the respective sizes of the above experiments as a subsequent discussion will consider the possibility that capacity may have been achieved in the September 7 trial while there was no clear evidence that maximum passage was reached in the July 13 trial. The inference is, of course, that numbers alone are not a valid measure of test magnitude. Size of fish within the test must be considered if each test is to be evaluated properly with respect to gross content.

Effect of Changing Hydraulics on Fish Passage

If there is to be a sound comparison between tests, comparable physical conditions must prevail. One of the major difficulties encountered in our recent experiments resulted from our inability to control the established flow pattern in the fishway. We have previously noted that the established flow over weirs at the beginning of each test was plunging. Some time after fish had been introduced into the fishway, their presence apparently disturbed the flows sufficiently to change the pattern from plunging (submerged motion) to streaming (surface motion). This phenomenon usually commenced at the uppermost weir (60) and was successively established at succeeding downstream weirs. During several trials streaming flows failed to develop. Characteristically, once streaming flow was established, it continued in effect for the balance of the test.

Undoubtedly, hydraulic conditions at the beginning of a test were approaching the upper limit at which plunging flows could be maintained. Use of a broad crested weir (7 1/2 inches wide) and the fact that 0.8-foot head was in effect on the weir attest for the critical nature of the hydraulics. Any disturbance of the flow, such as may have been produced by fish passing over the crest, could have created the streaming flow conditions.

Our concern with this development was because of its effect on the movement of fish. Figure 9 presents passage curves obtained at two weirs in the capacity test of July 5, 1956. Passage per unit time over weir 54 produced a curve which was essentially unimodal. Plunging flows obtained at this weir during the entire

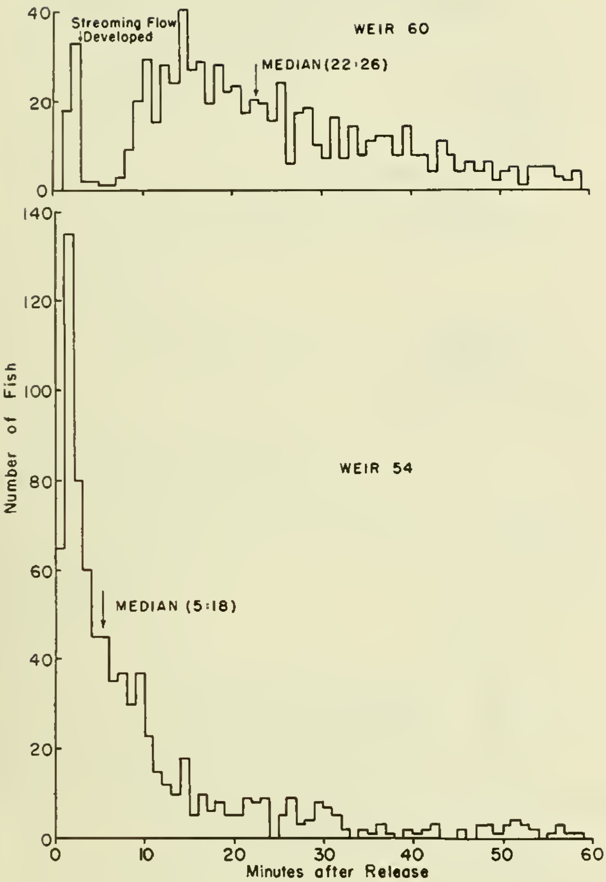

FIGURE 9.--COMPARISON OF FISH PASSAGE AT UPPER AND LOWER WEIRS OF FISHWAY IN THE JULY 5, 1956 CAPACITY TEST. STREAMING FLOW DEVELOPED AT UPPER WEIR (60) AT END OF MINUTE 3. PLUNGING FLOW IN EFFECT DURING ENTIRE 60-MINUTE PERIOD AT LOWER WEIR (54).

60-minute test period. By contrast, the passage curve at weir 60 is clearly bimodal. The abrupt decline in numbers passing per unit time directly coincides with the inception of streaming flow at this weir.

The striking feature in the passage of fish at weir 60 is that movement was virtually halted for approximately 5 minutes (minute 4 through 8) during the initial period that streaming flow was in effect. (See table 2 in the Appendix.) Thereafter, the migrants apparently gradually became conditioned to the change in flow and continued their ascent out of the fishway.

In measuring the possible effect of streaming flow on rate of movement, we may examine the position of the median passage time at the two weirs (54 and 60). At the lower weir (54) half of the group had entered the fishway in approximately 5.3 minutes (figure 9) while half had ascended the fishway at 22.4 minutes after the start of the test. Thus, the median elapsed time in the fishway was 17.1 minutes (22.4 - 5.3). Conceivably, had streaming flow failed to develop at weir 60, the median time at this weir might have been reached several minutes earlier with a resultant decrease in the median elapsed time. This is based on the assumption that all passage to the right of minute 9 would be proportionately repositioned to the left, filling in the depression in the passage curve caused by streaming flow.

Comparison of the capacity trials held on July 2 and 5 (table 1) gives interesting support to the above. These trials were virtually identical as regards species composition. A principal difference in the tests is that streaming flows did not develop in the July 2 trial. Significantly, the median elapsed time for the July 5 trial (streaming flows in effect) was approximately 4.5 minutes in excess of that observed in the July 2 test (17.1 - 12.6).

Examination of Entry Rate into Fishway

One of the means by which we expected to recognize whether capacity were reached or exceeded was to examine the entry rate 6/ into the fishway. Conceivably a peak entry rate (the maximum number of a given size which could enter a fishway 6 feet wide in unit time) would be reached, and provided that the supply could be maintained at this point, we would expect the net entry to stablize at a given level (assuming fish size remained constant). During the first seven experiments (May 22 to July 13

6/ As applied here, the entry rate is net entry per minute; i.e., the total number of fish entering a pool in a given minute minus the number of fish dropping downstream out of the pool in the same minute. A subsequent section will be devoted to "fallbacks" which we have termed those fish which move downstream from one pool to another.

inclusive) this condition was never clearly demonstrated.

Chief among the difficulties in producing and maintaining a maximum entry was our inability to provide an ample, sustained supply of fish for the tests. A typical entry rate achieved in the initial tests is shown in figure 10. Depicted is the passage of fish over the various weirs in the July 13 experiment. The entry into the fishway is shown in the passage over weir 54. This may be seen to rise rapidly to a peak (350 fish per minute) shortly after the release and then decline almost as rapidly as it had risen. At this stage of the investigations the assumption is that the supply was not adequate to sustain a constant maximum entry. Also, a major portion of the initial supply would always be required to saturate the fishway which was void of fish at the start of a test. By the time a point of saturation was being approached, the supply had become virtually exhausted. Thus, it was becoming apparent that the present experimental condition of limited supply was to be an obvious deterrent to a realistic determination of capacity.

Realization of the existing experimental limitations led us to conclude that our initial approach to a determination of capacity would undoubtedly have to come from an examination of conditions in the lower pools of the fishway. This reasoning was based on the belief that the greatest surge of fish would undoubtedly occur at the point of entry into the fishway and that the lower pools would be the first and perhaps the only areas in the fishway which would become sufficiently saturated for any period of time. The approach may not appear to be in keeping with our stated purpose of determining the maximum number of fish that a fishway can pass since passage implies that the measure should be based on the exit from the fishway (last pool). It is probable, however, that capacity may in fact be controlled at a particular point in the fishway, and that this point might well be in the first pool or one of the lower pools. Later in the text, data will be presented which lend some support to this assumption.

In the final test of the season (September 7) there is indication that a sustained entry rate finally may have been achieved. Figure 11 presents the numbers of fish passing per unit time at 5 of 7

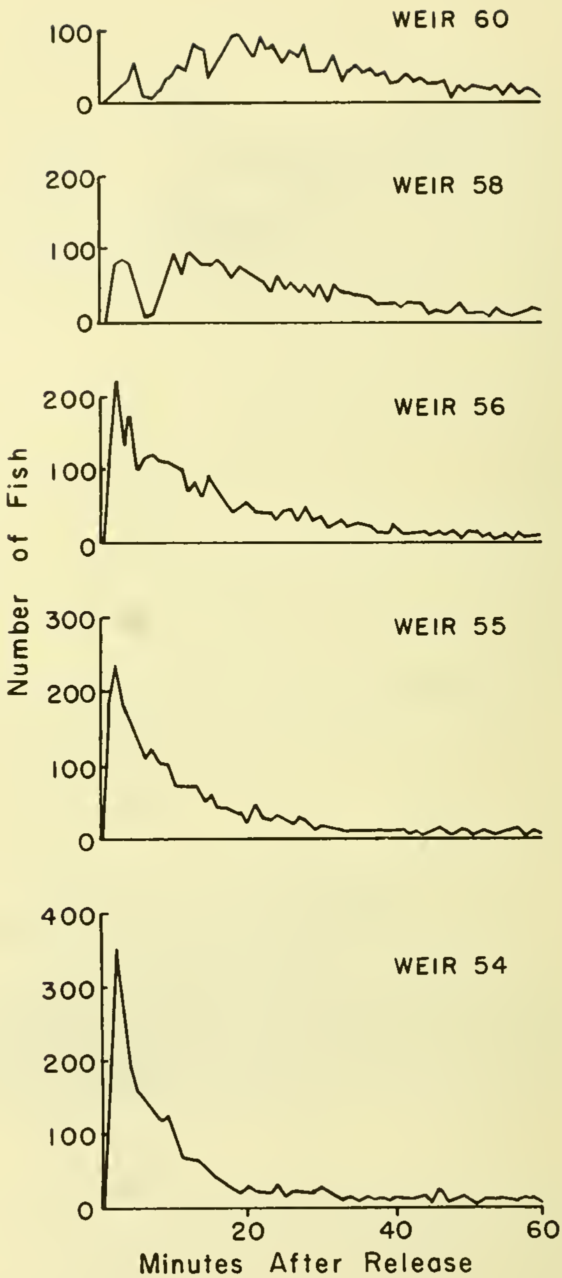

FIGURE 10.--PASSAGE PER MINUTE OVER WEIRS 54, 55, 56, 58 AND 60 DURING CAPACITY TEST OF JULY 13, 1956.

weirs in the fishway. Entry rate into the fishway is given in the passage curve shown at weir 54. The maximum observed entry per minute was 75 fish and this occurred in both the 2nd and 5th minute after release. From the 6th to the 22nd minute, the entry held relatively constant, fluctuating between 40

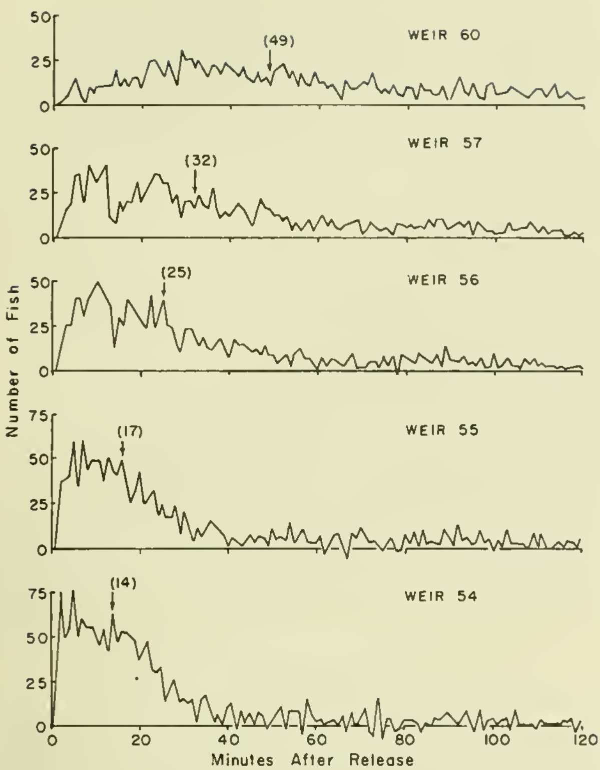

FIGURE 11.- PASSAGE PER MINUTE OVER WEIRS 54, 55, 56, 57 AND 60 DURING CAPACITY TEST OF SEPTEMBER 7, 1956.

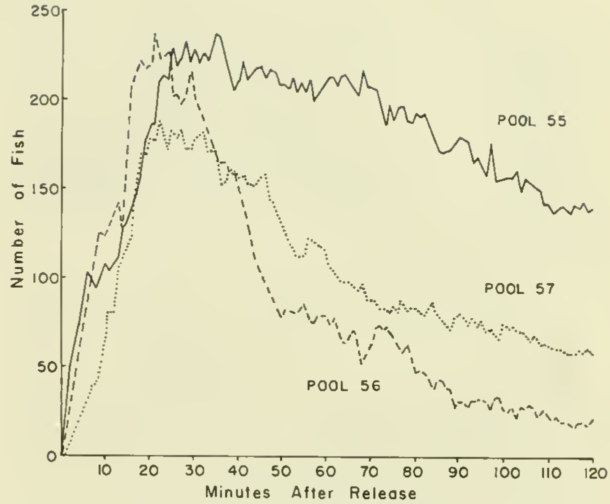

FIGURE 12.--NUMBERS OF FISH PRESENT IN POOLS 55, 56 AND 57 DURING A GIVEN MINUTE IN THE SEPTEMBER 7, 1956 CAPACITY TEST.

and 60 fish per minute. The average for the 17-minute period was 51 fish per minute. (Table 3, Appendix.)

The fact that the entry rate in the September 7 trial did not appreciably decline after rising to a peak as was typical in all previous tests, but instead rose to and then sustained a maximum level for a number of minute, leads us to believe that we may have achieved a condition (maximum entry) which might demonstrate the existence of capacity. Since this was the only test in which a sustained entry was demonstrated, a conclusion regarding the foregoing must await the conduct of further tests in which conditions of maximum entry can again be repeated for a sustained period.

Pool Residence Per Minute, September 7 Test

Given in figure 12 are curves showing the number of fish present in each of the three lower pools (55, 56, and 57) in a given minute during the September 7 capacity test. During the test, it became evident that fish were not moving through the fishway as rapidly as they had in previous tests. For this reason, the usual 60-minute trial period was extended for an additional hour to allow for a continued observation of movement in the fishway. The maximum number of fish observed in a single pool in a given minute was 239. This occurred in both pools 55 and 56, reaching a maximum in minute 35 in the former, and minute 21 in the latter. The maximum number of fish in the fishway (6 pools) was 948, reached 28 minutes after release. (For complete data on the foregoing, refer to table 4 in the Appendix.)

A striking feature in the comparison of pool residence in the three lower pools is the continued long residence in pool 55, the first pool in the fishway. After reaching a peak of 239 fish in the 35th minute, numbers present in this pool did not fall below 200 fish until the 80th minute. By contrast, residence in pools 56 and 57, after reaching a peak density, declined far more rapidly than in pool 55. At the conclusion of the 2-hour test a total of 82 fish remained in pools 56 and 57. Almost double this number was present in pool 55 at the end of the test.

From the foregoing it may be concluded that there must have been an accumulation of slow fish in the lower pool of the fishway. If there is a tendency for slow-moving fish to accumulate in the lower pool(s) of the fishway (further experimentation will be necessary to verify this) then the restriction on capacity will be determined by the residence in a single pool and not on an average residence for all pools.

Whether the phenomenon was a natural occurrence or the result of experimental procedure remains to be determined. Should the relationship persist in subsequent experiments in which varying release techniques are employed, it may be possible to demonstrate that a natural accumulation of slow fish develops in the lower section of a fishway under crowded conditions, and that resultant spatial restrictions will undoubtedly influence passage (capacity) through the fishway. If this be true, the suggestion has been made that some of the lower fishway pools could be constructed considerably larger than succeeding upstream pools to provide additional space for the slow fish and at the same time allow sufficient passage area for the other migrants which proceed up the fishway more rapidly.

Fallbacks

In some of the initial capacity tests involving the release of relatively small numbers of fish, a few fish in each trial were observed to enter a pool and then drift back downstream into the pool below. Fish exhibiting this particular behavior were called "fallbacks". As the number of fish introduced in each test was increased, the number of fallbacks also increased. The frequency leads us to speculate that the phenomenon might be a possible indicator of a capacity condition.

In the September 7 trial, fallbacks were recorded at each of the four lower weirs with respect to time. The following totals were observed during the 2-hour test period: at weir 54 - 566 fish, weir 55 - 392, weir 56 - 82, and weir 57 - 35. Total numbers of fallbacks observed do not necessarily imply the actual number of individual fish involved since a single fish may have been responsible for several fallback observations. Apparent in these observations is the progressive decline in fallbacks as the fishway is ascended. Also, fallbacks were first observed at the lowermost weir and were subsequently noted at successive upstream weirs with respect to time (table 3, Appendix). Initial fallback activity in each pool appeared to commence at about the time considerable numbers of fish had collected in that pool (tables 3 and 4, Appendix).

However, aside from the actual number of fish involved in a given test, other factors may have influenced the frequency of fallback activity. For instance, we observed that streaming flows could very well have been responsible for a considerable number of fallbacks since the fish would orient to the surface area of the pool rather than in the subsurface levels as was generally the case when plunging flows prevailed. This surface alignment of fish during streaming flows increases the possibility of drifting back downstream over the weir crest and into the pool below.

We also observed that steelhead appeared to be more inclined to fallback activity than the other salmonoids. Consequently, the species composition in a given test might well affect the number of fallbacks.

Fallbacks were also observed in other experiments at the Bonneville facility in which individual fish or small groups (30 or less) of fish were being timed up the fishway. Here the implication was that fallback activity was not the result of crowding but due to some other factor. Continued study on the nature of fallback activity will be necessary to establish the import of this phenomenon as it may be related to fishway capacity.

DISCUSSION

Certain limitations must be considered when using results obtained under the present experimental technique. The very nature of the experiments requires that large numbers of fish be readily available for use in the tests. Since it was not possible to supply sufficient numbers instantaneously, the method required that fish be collected and held until a presumed ample supply was on hand for an experiment. It is not known what effect the collection period may have had on the eventual motivation of the fish once they were released.

Due consideration must also be given to the fact that our experimental subjects were diverted from a large 1:16 slope fishway approximately 35 feet wide into a narrow by-pass fishway 6 feet wide having a 1:8 slope. From this point they entered a large collection pool and were then released to enter a 1:16 slope test fishway of a 6-foot width. We assumed that performance in the test fishway was independent of the changing entry conditions.

Plans for succeeding experiments call for reduction in fishway width and a change in weir crest design. By decreasing the present fishway width to 4 feet we expect to reduce the total fish requirement necessary to measure capacity. The change in weir crest is intended to eliminate the unstable hydraulic condition which developed in the recent tests due to use of a 7 1/2-inch square-crested weir.

SUMMARY

Initial experiments were undertaken to measure the capacity (maximum number of fish passed per unit time) in an overfall-type fishway which was 6 feet wide and consisted of 6 pools, each 16 feet long (weir center to weir center) with an average depth of 6.3 feet. There was a 1-foot rise between pools and approximately 0.8-foot head on the weirs which were square crested and 7 1/2 inches thick. The calculated discharge was 15.9 c.f.s.

The following is a summary of operations and observations made in the 1956 capacity tests:

1. Eight tests in which releases varied in magnitude from 70 to 2886 fish in a 1-hour period were conducted from May 22 through September 7, 1956.
2. In numbers, the largest release during a 1-hour period totalled 2886 fish. Estimated average weight of fish in this test was 3 pounds. The total estimated weight of all fish in the test was 8658 pounds.
3. In a test adjudged to be the largest release in terms of gross weight, 1515 fish, averaging an estimated 13 pounds per fish, entered the test fishway in a 1-hour period. The total estimated weight of fish in this release was 19,700 pounds.
4. A maximum entry rate of 350 fish per minute was observed in the test in which fish averaged approximately 3 pounds in weight. This high entry level could not be sustained, possibly because of rapid depletion of the original supply of fish.
5. Maximum entry in the test in which fish averaged 13 pounds, was 75 fish per minute. For a period of 17 minutes (minute 6 through 22) the entry ranged from 40 to 60 fish per minute, averaging 51 fish per minute. This was the only trial among the eight conducted in which a sustained entry was observed, suggesting that a limiting level may have been reached.
6. Among the eight trials, the median elapsed passage time required to ascend the 6-pool test fishway ranged from 12 to 35 minutes.
7. During some tests the action of fish in the fishway appeared to cause the flow pattern to change from plunging to streaming. The change in flow markedly deterred fish passage. While the delays in passage were temporary, there is evidence that the overall passage time in the fishway was materially affected, possibly slowed as much as 5 minutes or longer.
8. Numbers present each minute in a given pool were obtained for the three lower pools (55, 56, and 57) in the season's final test when the estimated average weight was 13 pounds per fish. A maximum residence of 239 fish was observed in each of the two lower pools. Maximum residence in the third pool was 189 fish. The maximum number present in the 6-pool fishway was 948 fish. Residence in the first pool (55) remained at a high level while residence in

succeeding upstream pools declined rather markedly as the experiment progressed in time.

9. Fallbacks were observed to occur in greatest numbers at the downstream weir of the fishway and become progressively less numerous as the fishway was ascended.

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Table 2.--Salmonoid passage by minutes over weirs 54 and 60 during July 5, 1956 capacity test. Streaming flow developed on weir 60 at end of minute 3 and continued for remainder of test.

Weir 54				Weir 60			
Minute	No. of fish	Minute	No. of fish	Minute	No. of fish	Minute	No. of fish
1	65	31	7	1	0	31	7
2	135	32	5	2	18	32	16
3	80	33	2	3	33	33	7
4	60	34	0	4	2	34	14
5	45	35	2	5	2	35	8
6	45	36	1	6	1	36	11
7	35	37	3	7	1	37	12
8	37	38	1	8	3	38	12
9	30	39	0	9	9	39	8
10	37	40	2	10	20	40	14
11	23	41	1	11	29	41	8
12	15	42	2	12	15	42	8
13	12	43	3	13	28	43	4
14	10	44	0	14	24	44	11
15	18	45	0	15	40	45	8
16	5	46	2	16	27	46	4
17	10	47	0	17	29	47	6
18	6	48	3	18	19	48	4
19	8	49	3	19	28	49	6
20	5	50	1	20	22	50	2
21	5	51	3	21	23	51	4
22	9	52	4	22	17	52	5
23	8	53	3	23	20	53	1
24	9	54	2	24	19	54	5
25	0	55	0	25	15	55	5
26	5	56	1	26	24	56	5
27	9	57	3	27	6	57	3
28	3	58	1	28	17	58	2
29	4	59	1	29	18	59	4
30	8	60	0	30	10	60	0
		Total:	797			Total:	723

Table 3.--Count over weirs and fallbacks per minute.
Capacity test September 7, 1956.

Minute	Weir 54		Weir 55		Weir 56		Weir 57		Weir 60 1/
	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry
1	16	-	6	-	1	-	1	-	0
2	75	-	35	-	15	-	10	-	1
3	50	-	40	-	25	-	15	-	5
4	55	1	40	-	25	-	20	-	10
5	75	-	60	-	40	-	35	-	15
6	50	-	35	-	40	-	35	-	5
7	60	-	60	-	30	-	20	-	0
8	55	-	65	-	40	-	40	-	10
9	55	-	45	-	45	-	35	-	5
10	55	2	50	1	50	-	30	-	10
1	45	-	50	1	45	-	35	-	10
2	55	1	50	1	40	-	40	-	10
3	45	3	40	1	35	-	10	-	10
4	65	1	50	-	15	2	5	-	20
5	50	3	45	2	30	-	20	-	10
6	55	1	45	3	25	-	15	-	15
7	55	2	50	1	40	-	20	-	10
8	55	4	40	1	35	-	20	-	15
9	50	3	30	4	30	-	30	-	15
20	45	6	35	3	30	1	20	-	10
1	50	7	45	2	25	1	25	-	20
2	55	6	30	5	45	2	30	-	25
3	40	9	30	3	75	1	35	-	25
4	35	5	40	8	30	-	35	-	20
5	40	7	20	3	40	-	30	-	15
6	25	10	25	-	25	-	30	-	25
7	30	7	20	2	25	1	20	1	15
8	30	4	20	3	15	2	25	1	10
9	21	7	25	1	10	-	10	-	30
30	17	2	15	6	25	1	20	-	25
1	21	7	25	4	25	1	20	-	25
2	19	4	16	5	17	-	15	-	20
3	15	13	10	6	14	-	25	1	30
4	19	4	15	4	20	1	19	-	25
5	19	2	12	7	14	1	16	-	15
6	16	8	16	4	13	1	27	-	22
7	10	8	17	1	16	-	15	-	20
8	12	6	13	1	17	-	12	2	17
9	9	8	15	5	12	-	14	-	24

Table 3 (cont'd.) Capacity test September 7, 1956.

Minute	Weir 54		Weir 55		Weir 56		Weir 57		Weir 60 1/
	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry
40	15	5	11	5	10	1	13	-	20
1	17	4	13	12	18	1	15	-	19
2	8	11	9	3	14	-	19	-	15
3	9	1	8	4	15	-	17	1	22
4	14	11	8	6	15	3	11	-	15
5	14	8	6	1	11	-	7	1	13
6	8	7	8	1	14	2	11	-	18
7	9	2	8	5	8	-	22	-	13
8	10	4	12	5	15	1	18	1	15
9	8	9	9	3	10	1	16	-	11
50	9	8	7	6	9	1	14	1	19
1	13	6	15	5	6	2	13	-	21
2	17	6	9	4	6	-	10	1	23
3	9	10	10	4	10	2	12	-	15
4	14	5	8	4	4	1	4	-	19
5	15	6	19	5	10	-	8	-	10
6	13	4	8	5	12	-	4	-	17
7	7	12	10	4	8	1	7	-	11
8	18	3	11	1	7	-	10	-	10
9	11	4	11	8	5	2	6	2	18
60	12	7	7	5	4	3	10	-	12
1	10	6	11	9	8	1	12	-	13
2	8	8	8	2	5	2	8	2	8
3	10	8	5	9	8	2	10	-	11
4	9	5	8	5	6	-	7	2	5
5	12	12	9	3	6	2	5	1	2
6	16	10	12	4	4	1	8	2	14
7	8	10	7	5	8	3	6	-	9
8	17	9	4	10	10	-	9	1	9
9	11	11	13	4	3	1	9	-	11
70	11	7	11	6	4	2	2	-	13
1	11	1	14	2	4	2	6	2	11
2	4	7	15	8	7	2	9	-	18
3	10	16	5	2	6	1	5	-	9
4	17	1	7	4	5	3	6	2	5
5	4	12	6	5	9	1	6	1	9
6	11	6	6	7	6	3	4	-	6
7	14	10	10	6	8	-	3	1	11
8	8	10	9	4	2	3	9	2	5
9	9	10	6	7	9	-	7	-	4

Table 3 (cont'd.) Capacity test September 7 , 1956.

	Weir 54		Weir 55		Weir 56		Weir 57		Weir 60 1/
Minute	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry
80	7	3	2	3	7	-	6	-	9
1	7	3	8	1	5	-	7	-	9
2	6	2	8	5	6	2	6	-	2
3	9	7	9	1	10	-	6	-	13
4	2	7	7	6	7	-	5	-	7
5	4	2	12	2	6	1	10	-	8
6	3	3	4	2	4	-	6	-	5
7	6	1	5	1	8	-	10	-	5
8	7	3	6	3	3	-	10	-	10
9	11	4	4	2	13	-	4	-	3
90	11	3	11	1	6	-	6	1	3
1	7	3	8	3	6	1	7	-	10
2	5	4	4	2	6	1	8	-	15
3	6	2	13	1	8	-	5	-	6
4	12	4	6	2	4	-	9	-	5
5	3	3	7	1	5	-	3	1	12
6	2	5	4	3	3	-	9	-	4
7	12	3	5	3	8	1	6	-	3
8	5	6	12	2	3	1	6	2	10
9	7	3	7	4	4	1	4	-	11
100	6	1	8	3	10	-	3	-	5
1	6	5	6	7	4	2	3	-	6
2	6	2	9	5	3	-	3	-	6
3	7	2	5	4	6	-	8	-	10
4	3	5	11	1	3	-	4	-	7
5	8	-	7	5	3	-	4	-	6
6	6	5	6	3	2	1	5	-	5
7	4	3	5	2	7	-	5	-	4
8	3	3	5	4	4	-	8	-	5
9	5	4	10	1	6	-	6	-	8
110	1	3	5	5	3	-	3	-	8
11	5	1	8	1	4	-	6	-	4
12	3	2	3	3	3	-	3	-	6
13	2	-	2	2	4	1	5	1	11
14	3	2	5	3	2	-	4	-	4
15	4	3	5	2	4	1	4	-	4

Table 3 (cont'd.) Capacity test September 7, 1956.

	Weir 54		Weir 55		Weir 56		Weir 57		Weir 60 1/
Minute	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry	Fall-backs	Gross entry
116	5	1	3	3	2	-	2	1	6
17	3	-	4	-	3	1	1	-	4
18	6	1	5	2	3	1	3	-	3
19	3	7	2	2	4	1	2	1	3
120	8	2	5	-	2	1	2	-	4
21	8	2	7	4	3	-	8	-	7
Total:	2236	568	1921	396	1585	82	1482	35	1379
Net Entry 2/	1668		1525		1503		1447		1379

1/ Finger trap at weir 60 prevented fallbacks.

2/ Net Entry -- Total entry minus fallbacks.

Table 4.--Number of fish in pools by minutes. Capacity test, September 7, 1956.

Minute	Pool 55	Pool 56	Pool 57	Pools 58, 59 & 60	Total in fishway
1	10	5	0	1	16
2	50	25	5	10	90
3	60	40	15	20	135
4	74	55	20	30	179
5	89	75	25	50	239
6	104	70	30	80	284
7	104	100	40	100	344
8	94	125	40	130	389
9	104	125	50	160	439
10	108	124	70	180	482
1	104	128	80	205	517
2	109	137	80	235	561
3	112	141	105	235	593
4	126	178	113	220	637
5	130	191	123	230	674
6	142	208	133	230	713
7	146	217	153	240	756
8	158	221	168	245	792
9	179	217	168	260	824
20	186	220	177	270	853
1	186	239	176	275	876
2	210	221	189	280	900
3	214	224	178	290	906
4	212	226	173	305	916
5	228	203	183	320	934
6	218	203	178	325	924
7	223	197	183	329	932
8	232	201	172	343	948
9	222	215	172	323	932
30	228	200	176	318	922
1	221	197	180	313	911
2	225	191	182	308	906
3	223	181	171	303	878
4	227	173	171	297	868
5	239	165	168	298	870
6	235	165	153	303	856
7	221	165	154	298	838
8	215	160	161	291	827
9	206	158	159	281	804

Table 4.--(cont'd.) Capacity test, September 7, 1956.

Minute	Pool 55	Pool 56	Pool 57	Pools 58, 59 & 60	Total in fishway
40	210	155	155	274	794
1	222	139	157	270	788
2	213	131	152	274	770
3	217	120	151	268	756
4	218	110	152	264	744
5	219	104	157	257	737
6	213	99	158	250	720
7	217	94	144	259	714
8	216	87	141	261	705
9	209	84	134	266	693
50	209	77	129	260	675
1	206	83	120	252	661
2	212	82	117	238	649
3	205	80	113	235	633
4	210	81	112	220	623
5	205	85	114	218	622
6	211	76	122	205	614
7	200	75	122	201	598
8	205	78	119	201	603
9	209	78	118	187	592
60	212	79	109	185	585
1	214	74	104	184	576
2	208	77	101	182	568
3	214	67	97	181	559
4	215	64	98	181	558
5	209	66	98	183	556
6	207	71	95	175	548
7	203	68	94	172	537
8	217	52	96	171	536
9	208	59	89	169	525
70	207	62	89	158	516
1	205	72	87	151	515
2	195	74	83	142	494
3	186	72	83	138	479
4	199	73	81	137	490
5	190	66	84	133	473
6	196	62	83	131	472
7	196	58	89	122	465
8	189	64	81	124	458
9	189	54	83	127	453

Table 4.--(cont'd) Capacity test, September 7, 1956

Minute	Pool 55	Pool 56	Pool 57	Pools 58, 59 & 60	Total in fishway
80	194	46	84	124	448
1	191	48	82	122	443
2	192	47	80	126	445
3	186	45	84	119	434
4	180	39	86	117	422
5	172	44	81	119	416
6	170	42	79	120	411
7	171	38	77	125	411
8	172	38	70	125	405
9	177	27	79	126	409
90	175	31	80	128	414
1	174	31	78	125	408
2	173	28	75	118	394
3	165	32	78	117	392
4	169	32	73	121	395
5	163	33	76	111	383
6	159	31	70	116	376
7	166	26	71	119	382
8	155	34	69	113	371
9	156	34	68	106	364
100	156	29	75	104	364
1	158	26	74	101	359
2	158	27	74	98	357
3	162	22	72	96	352
4	150	29	71	93	343
5	156	28	70	91	345
6	154	30	66	91	341
7	152	26	68	92	338
8	151	23	64	95	333
9	143	26	64	93	326
110	141	23	64	88	316
1	138	26	62	90	316
2	139	23	62	87	311
3	141	20	61	80	302
4	140	20	59	80	299
5	138	20	58	80	296
6	142	18	59	75	294
7	141	20	60	72	293
8	143	21	59	72	295
9	139	18	61	70	288
120	140	22	60	68	290
1	143	22	55	69	289

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