USE OF TURBINE INTAKE GATEWELLS FOR SAMPLING OF MIGRANT JUVENILE SALMONIDS

by

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INTRODUCTION

Research is needed to determine how seriously juvenile outmigrants would be affected by the series of dams and impoundments forthcoming in the Snake River. A comparison of the present magnitude and timing of individual races with that in succeeding years as the environment is changed would provide such a measure. A program of this magnitude is deemed too costly if present large scale fish-sampling equipment were to be utilized. To maintain costs within reasonable levels, more economical methods of collecting migrants must be found.

The possibility was considered of obtaining large samples of seaward migrants from turbine intake gatewells, already an integral part of the low-head dams. Fingerling salmonids have been found in the gatewells at Bonneville and McNary Dams, and samples obtained from them produced enough fish to warrant further investigation on the feasibility of using wells as collectors through an entire migrant season. If sufficient numbers of fish are caught, then the juvenile migrant sampling can be accomplished at a relatively low cost. Ice Harbor Dam, the lowermost dam in the Snake River, was selected for an exploratory study in the spring of 1964. This report summarizes the results of the first year's research.

METHODS AND MATERIALS

Ice Harbor Dam has three Kaplan turbine units through which approximately 40,000 cubic feet per second of water flows at a normal head of 93 feet. Each unit has three gatewells in which slots for both emergency and operating gates are provided to seal off the turbine from the forebay water during maintenance operations. The gatewells of each unit are designated as A, B, and C, starting from the south shore. The location and relative size of the gatewells and slots are shown in figure 1.

Fish were collected from all nine gatewells in the area between the emergency and operating gateslots. A hydraulic cylinder prevented access to the entire gatewell area, but the majority of the water mass was strained by the sampling equipment.

Downstream migrants were removed from the gatewells with a gatewell dipnet, 18-1/2 feet long by 11-1/2 feet wide, using a 6-foot bag. The net frame was constructed of tubular iron pipe which was hinged longitudinally in the center so that it could be closed as it was lowered into the gatewell. In operation, the net was lowered by a warehouse crane (fig. 1) in closed position until the desired fishing depth was reached. It was then opened and slowly raised by the crane to the water surface. At the surface, it was closed to permit withdrawal through the gate opening.

Fish were first dipnetted from the surface water of gatewells and then from successively greater depths. This was done to minimize mortalities due to crushing when large numbers of fish were present and to obtain data on the vertical distribution of fish in the gatewell. Each well was fished until less than 100 fish were captured in a sample.

A 2- by 2- by 6-foot holding tank was provided to retain the fish. Water was circulated continually through the tank to control temperature and provide aeration.

The fish were removed from the holding tank in small lots of 15 to 20 fish and anesthetized with MS-222 before processing. Approximately 25 percent of the fish collected were marked. A red fluorescent pigment tattoo and the new mark was used. (See "A thermal marking technique for juvenile salmonids", Groves and Novotny, vol. 5, Review of Progress, Fish-Passage Research Program). In accordance with laboratory findings, only fish greater than 90 mm. in length were marked. The remainder were examined for previously affixed marks, enumerated, and, at weekly intervals, fork-length measurements and scale samples were taken.

After the fish were processed, they were placed in a tank truck, in which the water was continually oxygenated, and transported to the release areas. The majority of the marked fish were taken upstream and alternately

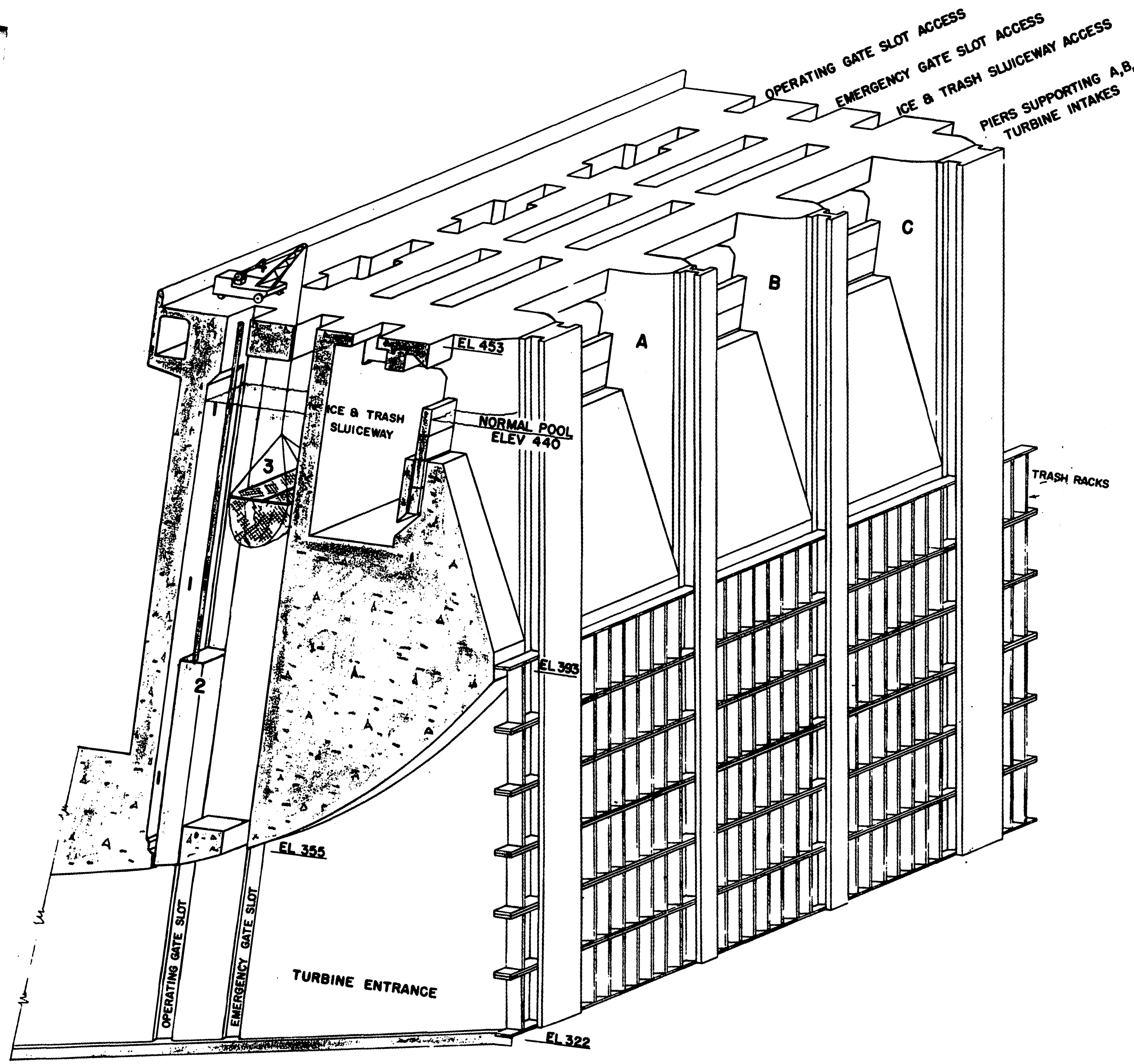

Fig I. Isometric View of Ice Harbor Dam showing:

1. Area Unavailable for Fishing
2. Operating Gate and Cylinder in Stored Position
3. Gatewell Net in Open Position
4. Warehouse Crane

released into the Snake River at Fishhook Park (south shore) and at Snake River Junction (north shore). (fig. 2). These sites were 8 and 13 miles, respectively, above Ice Harbor. The unmarked fish were transported below the dam and released in the tailrace.

The efficiency of the gatewells as collectors and the population estimates were based on the recoveries of marked fish released above the dam. Gatewell efficiency was assessed in terms of the percentage of mark recoveries, and population estimates were derived from the general formula

$$\hat{N} = \frac{nt}{s} \quad \text{(Chapman, 1948)}$$

where

$\hat{N}$ = the population estimate

n = number sampled

t = number marked

s = number recaptured

Population estimates of chinooks less than 90 mm. in length could not be made since these fish were not marked. However, the total estimate was not adversely affected since less than 10 percent of the total chinooks collected were under 90 mm.

Separate marks were used to identify fish released at the two sites. In addition, marks were changed each week. This was done to obtain a measure of mixing of marked fish within the population and to permit stratification of the data. It was assumed that, if proportionately equal numbers of fish were recaptured from each release site, then mixing did take place.

The suitability of the thermal marking technique for field use was demonstrated by comparing returns and survival of thermal marked fish and tattooed fish. Recovery percentages from the approximately 23,000 thermal marked fish released was slightly higher than for about 2,000 tattooed fish (2.5 vs. 2.0 percent). No difference in survival was noted among tattooed, thermal marked and unmarked fish held for observation for a week.

Exit rates from gatewells were explored by periodically introducing marked fish, in lots of at least 10 fish, into adjacent gatewells. Exit rate was determined by comparing numbers of marked fish remaining in a given well after periods of 1, 3, and 6 days.

To examine the effect of light intensity on fish accumulation and attraction of fish into the gatewells, tests were conducted in three gatewells of turbine unit no. 2 for a period of 2 weeks. One gatewell was used as a

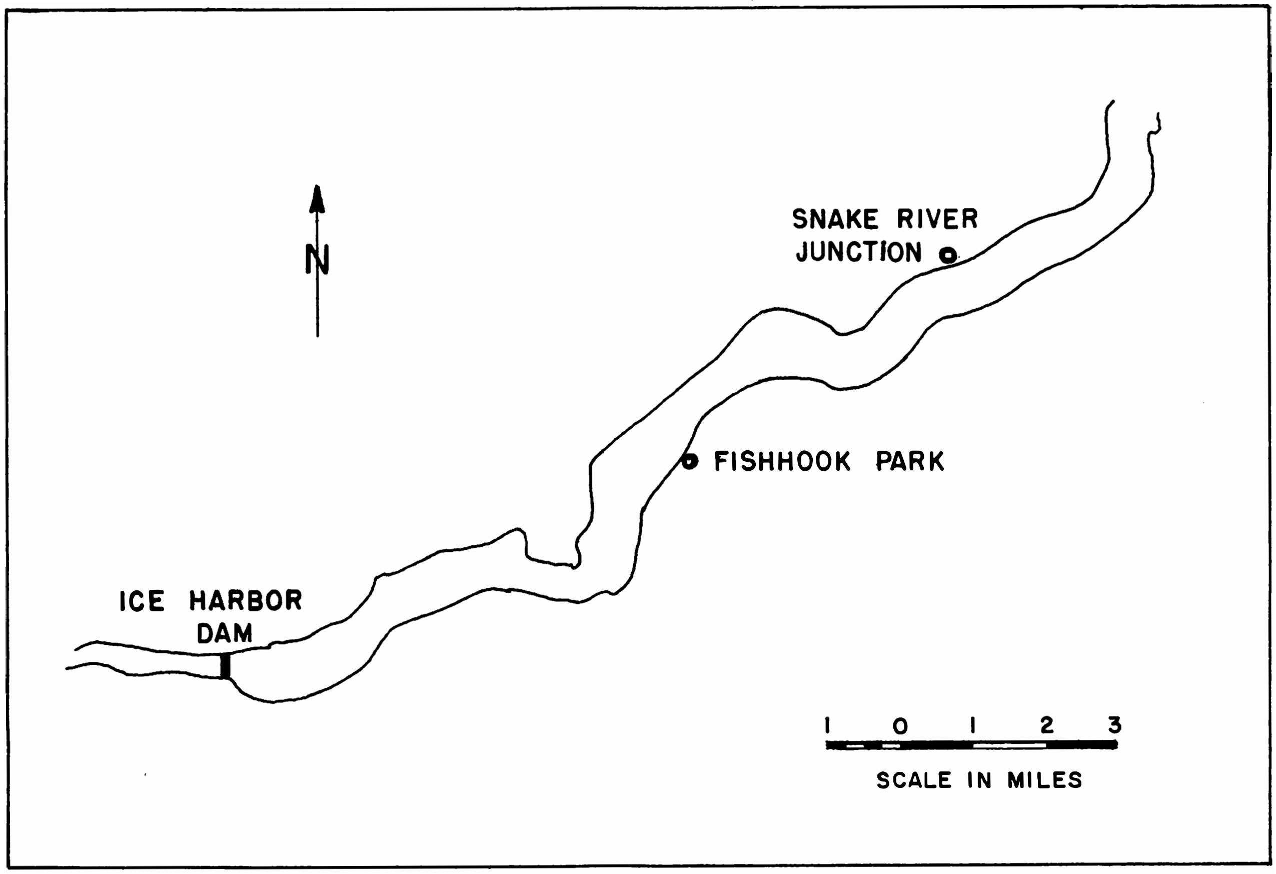

Figure 2.--Marked fish release sites at Fishhook Park and Snake River Junction upstream from Ice Harbor Dam.

control, one was completely covered with black (opaque) plastic sheeting and the third was artificially lighted with three 400-watt underwater lights. Conditions were rotated among the gatewells, usually once every 3 days in the following sequence.

Light	Dark	Control
B	C	A
A	B	C
C	A	B

Corps of Engineers activities during the experimental season prevented continuous sampling of all gatewells; unit 3 was unavailable for fishing until June 5, one month after the peak of the chinook run had passed. Therefore the results generally are based on data from units 1 and 2 only. Salmonids collected from unit 3 were, however, included in the overall totals of marked and unmarked fish.

RESULTS

Gatewell Collection Efficiency

Gatewell sampling from March 23 through June 30, 1964, resulted in the collection of 126,833 salmonid migrants: 76,350 chinook salmon (*Oncorhynchus tshawytscha*) over 90 mm. long; 6,450 chinook less than 90 mm.; 43,836 steelhead trout (*Salmogairdneri*); 106 sockeye salmon (*O. nerka*); and, 91 coho salmon (*O. kisutch*).

The gatewell collection efficiency for all salmonids throughout the season was 2.5 percent based on 644 recaptures out of 25,735 marked fish released. This percentage was obtained while fishing an average of 33 percent of the gatewells 30 percent of the time. With continuous collection, this percentage would have been substantially increased. Returns of this magnitude indicate that sufficient samples of downstream migrants can be collected from Ice Harbor gatewells to warrant expansion of the racial timing and magnitude studies.

Population Estimates

Population estimates were made for the total run and for chinook salmon and steelhead trout respectively. These estimates included only fish larger than 90 mm. passing Ice Harbor Dam between April 17 and June 10, 1964. The estimates of the population and the 95 percent confidence limits around the estimates were:

	Lower	Mean	Upper
Total population	4,172,477	4,518,521	4,888,177
Chinook salmon	2,744,596	3,036,917	3,333,614
Steelhead trout	1,270,088	1,481,604	1,664,144

In making a population estimate it is necessary to consider mortalities of marked fish and the degree of mixing of marked fish with the unmarked population between release and recapture. As the mortalities during handling and transportation were less than 1 percent, it appears the fish were released in good condition. However, if delayed mortality occurred, it may have been higher in chinook than in steelhead. Recoveries of marked steelhead amounted to 2.9 percent whereas those of chinook were 2.3 percent. If mortalities occurred, the foregoing estimates are high.

There was evidence that the marked fish became well mixed with the unmarked population since recoveries were similar from each release site (table 1).

Table 1.--Number and percent of marked fish released and recovered in relation to release site.

Release site	Chinook Salmon			Steelhead		
	Released	Recaptured	Percent recaptured	Released	Recaptured	Percent recaptured
Fishhook Park	8,210	203	2.47	3,634	109	3.00
Snake River Junction	9,530	203	2.13	3,632	101	2.78
Totals	17,740	406	2.29	7,266	210	2.89

Migration Rates and Timing--Chinook and Steelhead

The recapture of marked fish released in this study indicated an elapsed time of 1 to 2 days from the release sites to the dam. Additional migration rates in the Snake River were obtained from the recapture of 31 tagged fish released in the Brownlee-Oxbow Dam area. Five of these fish were from a group of 150 chinook fingerlings collected in Eagle Creek and transported and released below Oxbow Dam. The average migration rate of these fish was 15 miles per day for the 270 miles to Ice Harbor Dam. The remaining 26 fish had been released within Brownlee Reservoir, and since the proportion of time spent in the Brownlee Reservoir and the river is unknown, the river migration rates cannot be established. It is of interest, however, that these fish passed through both Brownlee and Oxbow impoundments and arrived in excellent condition at Ice Harbor Dam.

The magnitude and timing of salmonid migration is shown in figure 3. While some fish were caught as early as March, the main migration of chinooks began about April 17, and peaked about May 11. The steelhead migration started later and peaked about 10 days after the chinook. The peak of the chinook outmigration occurred about 30 days before the main flood. This agrees with results obtained by the Washington Department of Fisheries at Central Ferry (Mains and Smith, 1956). Migration peaks did not appear to be related to water turbidity and temperature.

Length and Age Composition

Fork lengths of 90 percent of the steelhead trout measured were between 140 and 190 mm. and averaged about 170 mm. throughout the season. By contrast, 90 percent of the chinooks collected were between 70 and 140 mm. Average lengths varied throughout the season (fig. 4).

Initial sampling of the gatewells in late March revealed a sizeable group of chinook salmon averaging 205 mm. (8 + inches). Analysis of scale samples indicated that these fish were mostly in their second year and that they showed extensive fresh water growth. These data on timing, size, and scale patterns were similar to data obtained from winter outmigrants from Brownlee Reservoir.

Two size ranges, averaging 43, and 117 mm., were observed in the first half of April. The smaller fish were believed to be the progeny of the 1963 brood-year fall-run chinook spawning in the Snake River system. The larger fish were considered the progeny of the 1962 brood of spring and summer chinook spawning in the tributary streams.

During the last half of April and the first half of May, a unimodel size range was observed. These fish averaged 117 mm. in length. While fish of this size dominated the picture most of the month, a group of fish averaging 75 mm. in length was observed entering the catch in the last 10 days of the month.

During June, this 75-mm. size group range continued to increase in numbers and by the middle of the month, 66 to 90 mm. fish dominated the catch. It is possible that this group could have originated from the Oxbow rearing facility as the timing of release at Oxbow and subsequent recovery at

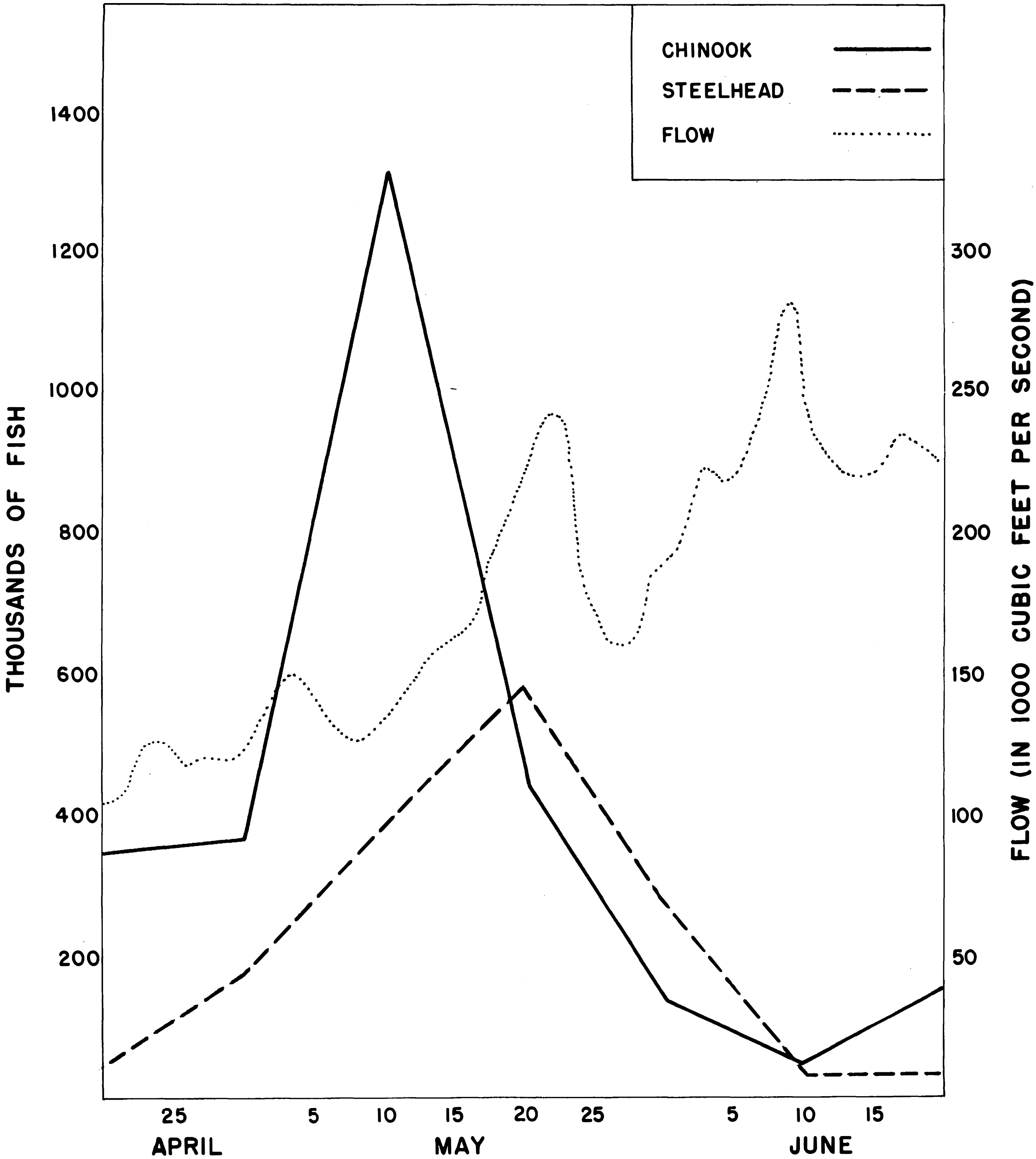

Figure 3.--Timing of downstream migration of chinook salmon and steelhead trout in relation to water flow at Ice Harbor Dam, 1964.

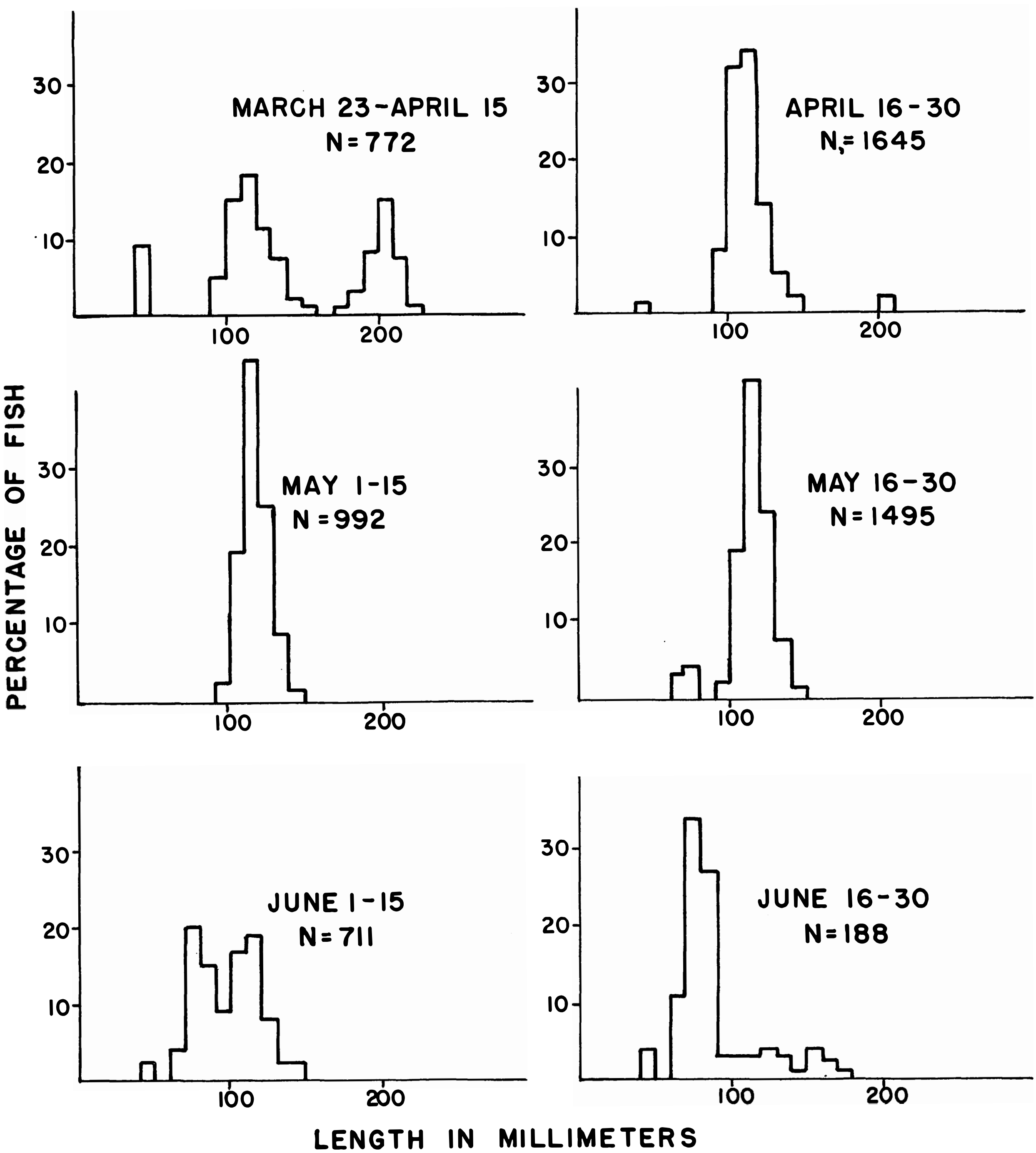

Figure 4.--Length frequencies of migrant chinook salmon, Ice Harbor Dam, March 23 - June 30, 1964.

Ice Harbor followed in logical sequence.

An analysis of chinook scale samples showed a general relation between size and age. 0 age fish were usually less than 90 mm.; yearlings ranged from 75 mm. to 214 mm.; and 2 year old fish ranged from 160 to 240 mm. The variation in time of the formation of annuli and numbers of circuli suggests the presence of several races of chinook.

Distribution in Gatewells

Sampling for vertical distribution of fish in the gatewells indicated that 84 percent of the chinook salmon were concentrated in the upper 20 feet of the gatewells, whereas only 50 percent of the steelhead trout were captured in the same area. This assumes that the net efficiency was the same for both species and that efficiency did not vary with depth.

The horizontal distribution of fish in the gatewells of an individual turbine unit revealed that Gatewell A consistently contained more fish than well B, and that well C produced far less fish than either A or B wells. Figure 5 shows this distribution in relation to the velocities taken at the emergency gate slots of each turbine intake. By inspection, it may be seen that the catches in the respective intake wells were in some degree related to velocity within these intakes; i.e., the higher the velocity the higher the catch. Since the gatewells in turbine unit no. 3 throughout most of the season were unavailable for fishing, this relationship could not be expanded across the powerhouse section.

Exit Rate from Gatewells

Exit rate tests during various times of the season showed that an average of 58 percent of the chinook and steelhead remained in the gatewells after one day, 45 percent after 3 days, and 36 percent after 6 days. However, the data suggest that exit rate is related to species and time of migration. The chinook exit rate appeared to be faster earlier in the run than just prior to the peak. Steelhead showed the reverse of this trend. A test conducted 3 weeks after the peak was of special interest; 87 percent of both chinook and steelhead had not exited after 3 days.

Lateral Movement in Gatewells

The lateral movements of 12 out of 300 marked chinook and steelhead placed in A and B gatewells of turbine unit 2 on April 7 and 9 are shown in figure 6. To accomplish this movement, fish had to sound 84 feet to leave the gatewell and then swim 35 to 40 feet upstream through the turbine intake to the forebay where they must have moved laterally and passed downstream into another gatewell (fig. 1). Under normal load, velocities at the gateslot of A or B intakes were in excess of 5.9 f.p.s. Powerhouse operation records during this period showed unit 2 operated under full load for all but one 6-hour

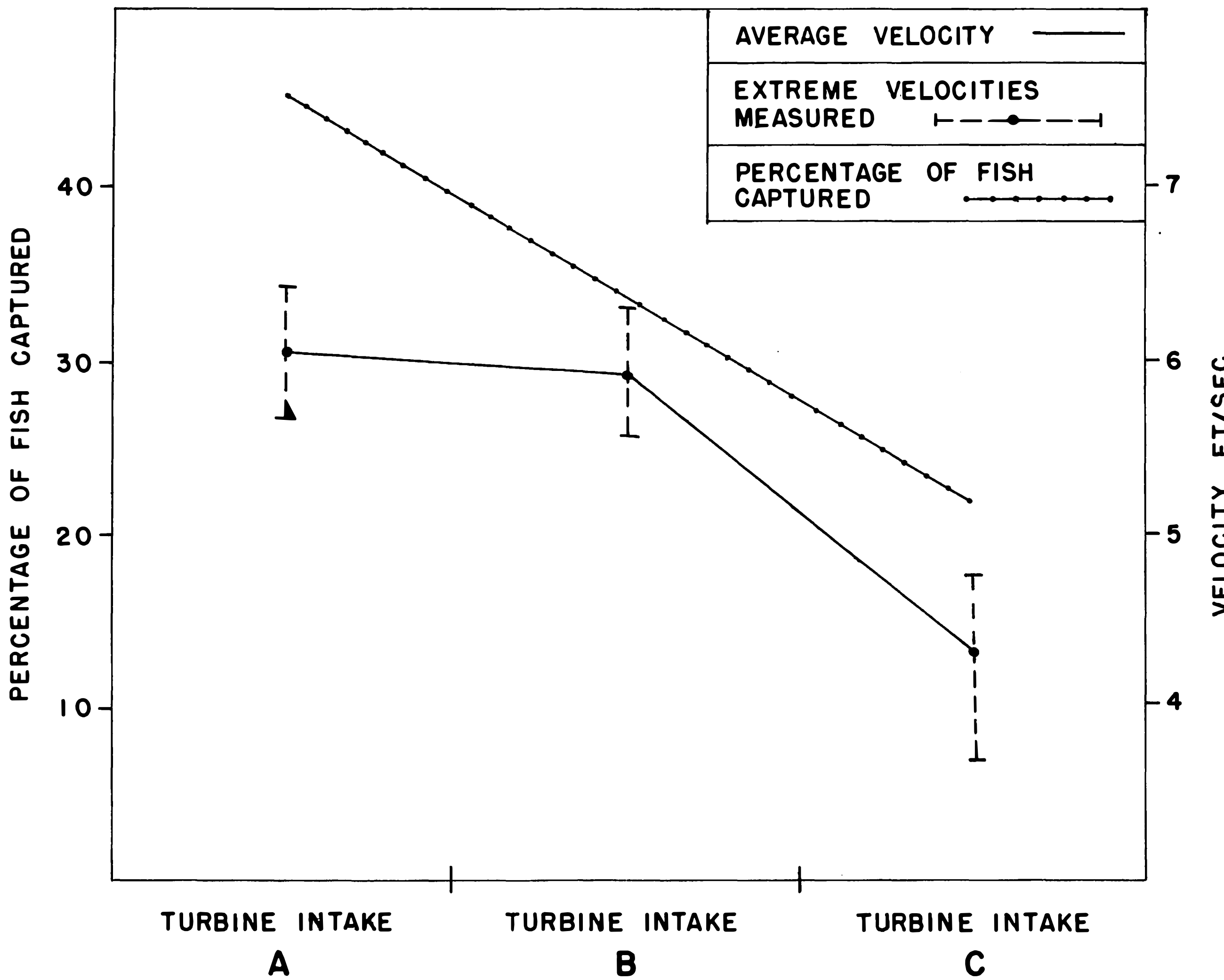

Figure 5.--Proportion of fish in gatewells A, B, and C in relation to velocities measured at the emergency gateslots within each gatewell.

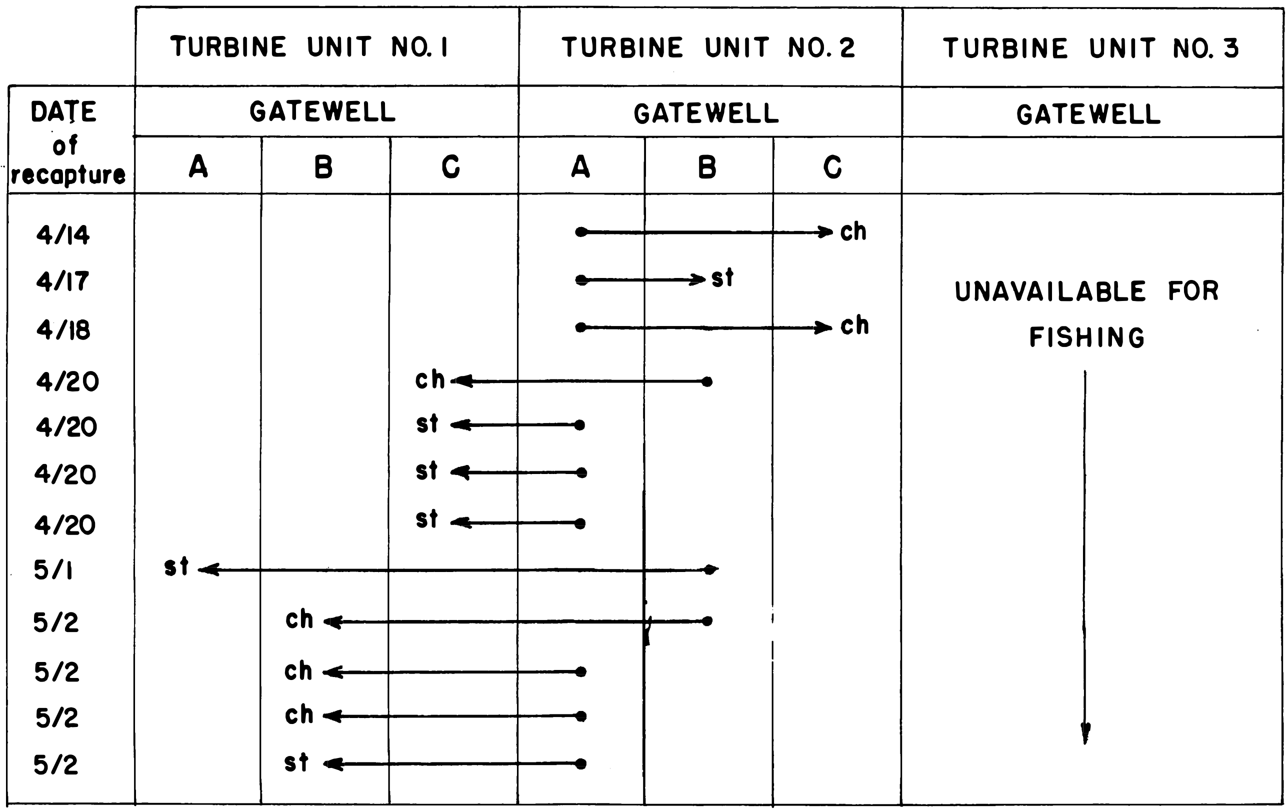

Figure 6.--Lateral movement of 12 salmonids released in A and B gatewells of turbine no. 2 on April 7 and 9.

period on May 1 when the turbine was off the line.

How were these fish able to perform the feat? One possibility is that velocities may be lower in certain areas of the turbine intake such as near the ceiling. Velocities within the upper foot of the intake could not be measured. Temporary accumulations of debris against the trash rack could create areas of reduced flows that might be traversed by these fish. However this movement took place 45 days prior to the flood when the debris load was low.

Lightened vs. Darkened Gatewell

Numbers of salmonids entering gatewells A, B, and C of turbine unit no. 2 under the different light conditions are shown in table 2.

Table 2.--Numbers of chinook salmon and steelhead trout captured in A, B, and C gatewells of turbine unit no. 2 under light, dark and control conditions.

	Chinook			Steelhead		
Test No.	Light	Dark	Control	Light	Dark	Control
1	131	72	132	301	278	338
2	170	133	147	454	248	276
3	99	104	233	215	293	350
4	93	22	57	66	62	100
5	147	51	52	44	22	27
6	53	100	45	67	144	44
	693	482	666	1147	1047	1135

Although more chinook salmon were recovered from both the control and lightened gatewells than from the darkened gatewells, statistical analysis showed no significant differences. No significant differences were observed in the steelhead catches. These results are in contrast to those observed by Fields, et al. (1964). They found at McNary Dam, that there was a significantly larger catch in each of the lightened gatewells than in unlightened wells, and that only one-tenth as many downstream migrants were obtained from the A, B, and C gatewells having solid covers as from the B well with steel grill covers.

Predation in Gatewells

Evidence of predation by steelhead was observed in gatewells at Ice Harbor Dam. Predation was predominantly on the smaller chinook salmon (less than 90 mm.) in gatewells where fish had been allowed to accumulate for several weeks.

Potential Use of Gatewells for a Fingerling Bypass

When it became apparent that large numbers of fish were utilizing the gatewells, an attempt was made to estimate the percentage of fish entering the turbine intakes that would be potentially available to a collector within a gatewell. If it could be demonstrated that sufficient numbers of fish would become available, then attention might be given to installing bypasses in gatewells to divert fingerling migrants safely around turbine areas of future dams.

During the migration period, an average of 40 percent of the total flow of the Snake River passed through the turbines. If the numbers of fish were in proportion to the flow of water, then approximately 2,000,000 fish entered the turbine intakes in the spring of 1964. Based on fishing effort, exit rate tests, and marked fish recoveries in this experiment, it was estimated that between 400,000 to 500,000 fish entered the gatewells. Thus, an estimated 20 to 25 percent of those fish entering the turbine intakes were available for diversion. With slight modifications in the design of gatewells in future dams, this percentage might be increased considerably.

SUMMARY

Turbine intake gatewells at Ice Harbor Dam were sampled with a specially designed dipnet during the spring of 1964 to determine the feasibility of utilizing such collectors for economically monitoring the Snake River juvenile outmigration.

During the period between March 23 and June 30, 126,833 salmonids were collected. This total included 76,350 chinook over 90 mm. and 6,450 less than 90 mm.; 43,830 steelhead; 106 sockeye; and 91 cohos. A mark and recovery program yielded the following results:

1. Gatewell collection efficiency was approximately 2.5 percent based on 644 recaptures out of 25,735 marked chinook and steelhead released upstream.

2. The Snake River spring outmigration for salmonids larger than 90 mm. was calculated to be 4,518,521. Of this total, 3,036,917 were chinook salmon and 1,481,604 were steelhead trout.

3. Salmonids averaged 4 to 13 miles per day in the Ice Harbor reservoir. Recoveries of fish marked in the Brownlee-Oxbow area indicated a migration rate of 15 miles per day in the 270 miles of river and reservoir between Oxbow and Ice Harbor Dams.

4. The peak of the chinook migration occurred on about May 11, 30 days ahead of the main flood. Steelhead peaked 10 days later on May 21.

5. Chinooks averaged 117 mm. in length, with 86 percent ranging from 70 mm. to 140 mm. Steelhead averaged 170 mm., with 90 percent ranging from 140 mm. to 190 mm.

6. Preliminary estimates of the exit rates from gatewells showed that, on the average, 58 percent of the fish remained after 1 day, 45 percent after 3 days, and 36 percent after 6 days. The length of time fish remained in the gatewells varied with the species and time of season.

7. There was evidence that fish moved from one gatewell to another. Since each well is a separate unit, not connected with adjoining units, these fish had to swim out of the wells and return upstream through the turbine intake to the forebay before entering an adjoining intake and gatewell. These occurrences were of interest because the fish were required to swim upstream through intake velocities approaching 6 f.p.s.

8. Artificial lighting in the intake wells did not appear to attract or hold more fish in the wells.

9. Vertical distribution studies in the gatewells indicated that the majority of the chinook (84 percent) were in the upper 20 feet.

10. Steelhead preyed on young chinook (less than 90 mm.) in the gatewells.

11. If fish passed through the spill and turbines in proportion to volume of water, 40 percent of the total run entered the turbine intakes. Based on fishing effort, exit rate tests, and mark returns, it was estimated that 20 to 25 percent of the fish entering the intakes passed up into the gatewells.

CONCLUSIONS

1. Turbine intake gatewells provide a convenient area in which to economically sample downstream migrant populations.

2. The large number of fish observed in gatewells suggests that these areas might well be incorporated into a bypass system that would divert substantial numbers of fish out of the turbines.

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