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FINAL REPORT

BONNEVILLE AND THE DALLES DAMS ICE-TRASH SLUICEWAY STUDIES, 1971

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Research Division

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BONNEVILLE AND THE DALLES DAMS ICE-TRASH SLUICEWAY STUDIES, 1971

INTRODUCTION

In the spring of 1969, the Fish Commission of Oregon, with funds supplied by the U. S. Army Corps of Engineers, studied the feasibility of using the ice-trash sluiceway at Bonneville Dam to pass downstream-migrant salmonids. The study was an attempt to pass migrants via the sluiceway rather than through the turbines where, as established in previous studies, significant mortalities occur (Schoeneman, Pressey, and Junge, 1961). As a result of our study, we concluded that hundreds of thousands of juvenile anadromous salmonids would pass through the ice-trash sluiceway at Bonneville Dam each year if the facility operated full time at maximum capacity throughout the spring (Michimoto and Korn, 1969). We found that fish entered the sluiceway mainly during the day and that they suffered negligible mortality.

At the conclusion of the study, we recommended full-time operation of the Bonneville ice-trash sluiceway during the spring of each year to pass downstream migrants. We also recommended that the Fisheries-Engineering Technical Advisory Committee consider the value of operating sluiceways at other main-stem dams for passing juvenile fish.

The U. S. Army Corps of Engineers agreed to operate the ice-trash sluiceways at Bonneville and The Dalles dams for fish passage beginning in the spring of 1971 and financed a study by the Fish Commission of Oregon to evaluate the operation of the sluiceways. At Bonneville Dam we compared the entry of fish into the sluiceway using overflow and submerged-orifice entrances, and determined if submerged mercury-vapor lights increased collection of fish at night. At The Dalles Dam we determined if there were operational problems associated with using the sluiceway to pass downstream migrants.

THE STUDY AREAS

The ice-trash sluiceway at Bonneville Dam extends along the forebay side of the powerhouse immediately above the penstocks and adjacent to the gate wells (Figure 1). The sluiceway is approximately 820 feet long and measures 25 feet from the underside of the deck to the bottom. The upper 15 feet of depth of the sluiceway is 14 feet wide, and the lower 10 feet tapers to a bottom width of 3 feet.

Water and trash enter the sluiceway from the forebay through one or more of 30 adjustable gates. There are three gates above each penstock. A gate across the sluiceway at its south end controls the water depth and velocity of flow. This gate, termed the sluice gate, consists of two leaves. It is opened by lowering the bottom leaf, raising the upper, or both. Water entering the sluiceway through the entrance gates travels south to beyond the sluice gate where it turns downriver and falls steeply into a concrete channel that empties into the tailrace.

The design of the ice-trash sluiceway at The Dalles Dam is basically the same as that at Bonneville. However, at The Dalles the bottom section of the sluiceway is square and there are 66 adjustable entrance gates. The sluiceway is 2,200 feet long, 16.6 feet wide, and 49 feet from the underside of the deck to the bottom. Also, the discharge spillway from the sluiceway is located adjacent and at a right angle to the powerhouse.

EQUIPMENT AND METHODS

Fish Sampling Net

We fished a fyke net in the Bonneville Dam ice-trash sluiceway to collect data on fish response during our testing period to compare overflow and submerged orifice entrances and lights versus no lights.

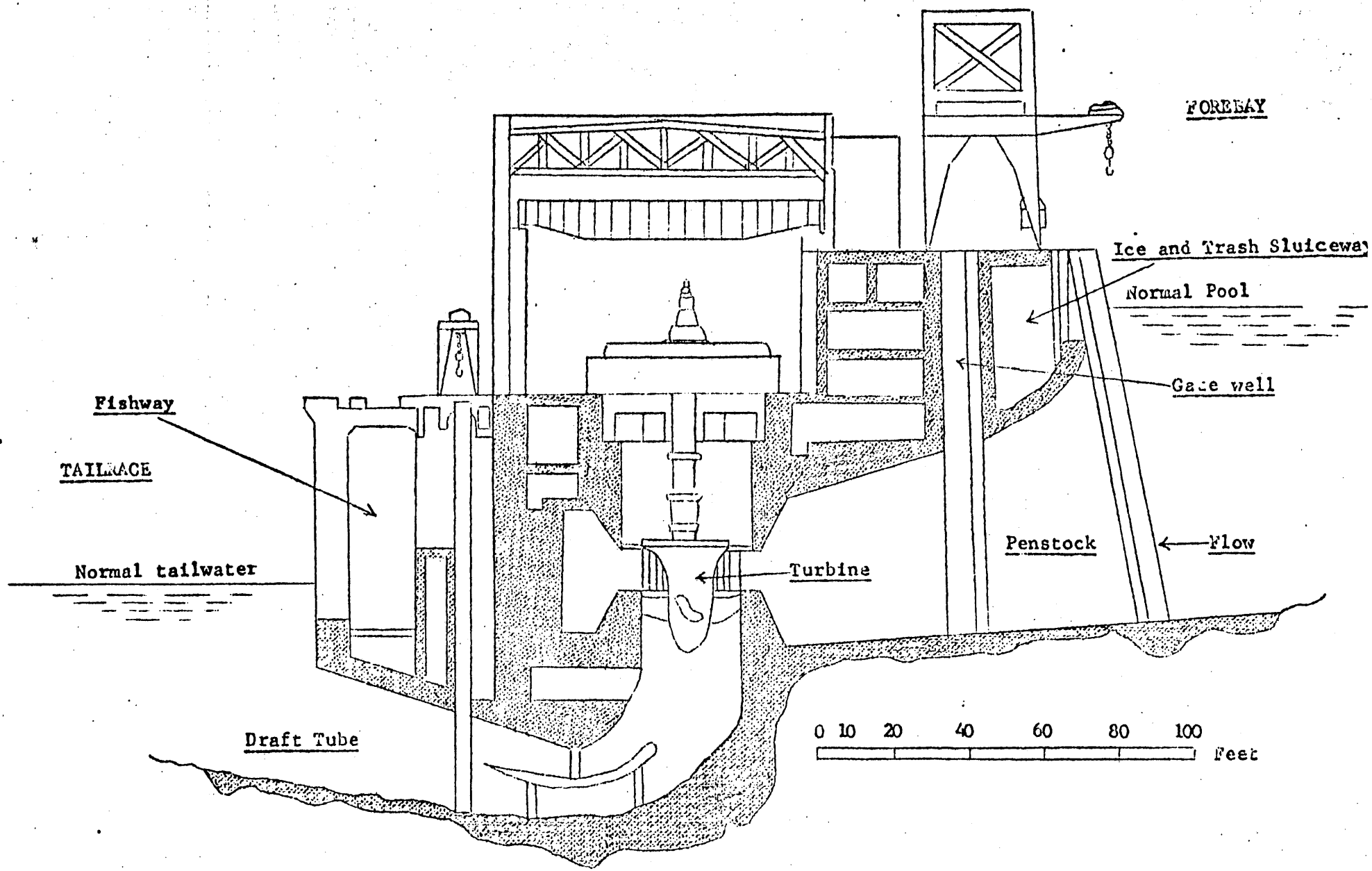

Figure 1. Cross Section of Bonneville Dam Powerhouse Showing Ice and Trash Sluiceway in Relation to Other Structures

The fyke net was two-sectioned with an overall length of 35 feet (Figure 2). The 15-foot long front section of the net was 7 feet square and composed of 2-inch stretch measure nylon webbing. The 20-foot long back section tapered to a small cod end and was composed of 1/2-inch stretch measure nylon, with the fyke located approximately 6 feet from the cod end. A stabilizing weight was attached to the bottom of the entrance frame. The net was suspended by two bridles which were hooked to cables attached to deadheads on a concrete cross wall.

Evaluation Methods

At Bonneville we systematically fished two nights each weekend, alternating the type of entrance with either overflow the first night and submerged orifice the second or vice versa. The type of entrance used first each weekend was randomly decided by tossing a coin. Each night we made several 1-hour observations with and without mercury-vapor lights. We also randomized the sequence of lights on or off. Lights were tested in submerged and above surface positions. High flows and trash prevented us from fishing on two weekends. We fished six 1-hour periods a night for the first four weekends and only four for the remaining four weekends. We fished one afternoon each weekend to determine if fish were migrating in numbers during the day. The last two weekends we fished both afternoons to determine the type of entrance fish preferred during daylight hours.

Based on catches in the gate wells in previous years, we opened entrance gates 4B, 4C, 6C, and 7A to the sluiceway. We initially tried a submerged orifice opening of 24 inches between elevations 68 and 70 feet. However, debris collected on the trash racks causing a damming

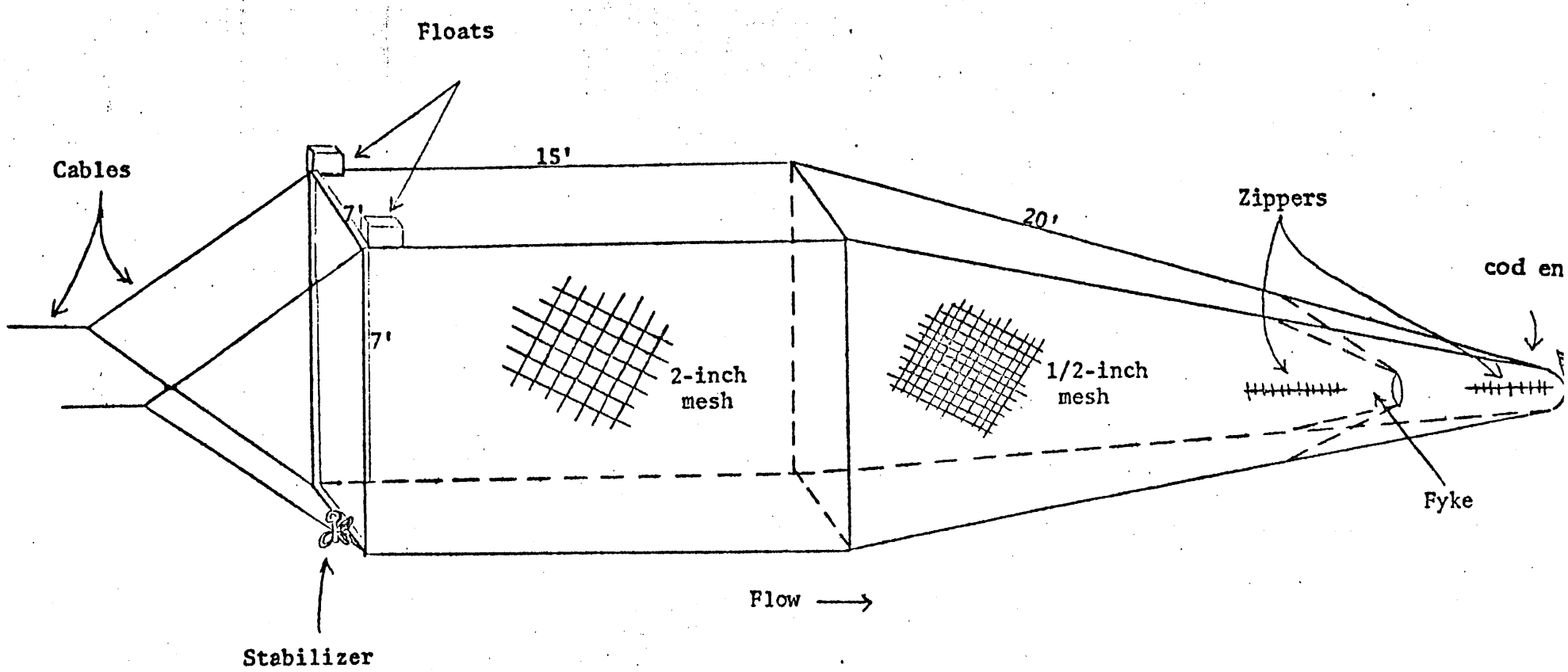

Figure 2. Schematic Diagram of Fyke Net

effect. This resulted in a reduction in water level at the entrance te to the extent that the orifice was no longer submerged. Thereafter the submerged orifice entrances were uniformly opened 12 inches between elevations 68 and 69 feet. The 68-foot elevation was the lower limit as this was the top of the concrete weir. The average forebay level during the test period was about 72.5 feet. The overflow entrance gates were lowered 18 inches the first weekend; however, the resulting flow in the sluiceway was too small. For succeeding weekends we lowered the gates 30 inches to 70-feet elevation to accommodate variations in pool level. Trash racks were placed in front of the open gates to prevent logs and other large debris from entering the sluiceway and tearing the fyke net. The Corps cleaned the trash racks an average of 1 hour each day, 5 days a week. This will not be a problem in the future since trash racks will not be needed during routine operation of the sluiceway to pass downstream migrants.

We used 400-watt mercury-vapor lights in attempts to attract juvenile salmonids to the entrance gates. On each of the first three weekends, we submerged one light 4 feet between entrance gates 4B and 4C. The fourth weekend, we submerged a light between 4A and 4B and one between 4C and 5A. On the fifth and sixth weekends, we submerged individual lights between 4A and 4B, 4B and 4C, and 4C and 5A. On the last two weekends we hung the three lights 3 feet above the water surface.

To operate the sluiceway during our tests, the upper leaf of the sluice gate was raised clear of the water allowing a 5- to 6-foot deep flow over the bottom leaf. The bottom leaf was generally lowered feet depending on the forebay level. The volume and velocity of

flow in the sluiceway depends upon forebay level and openings of the ıtrance gates and sluice gate. The flow was also complemented by leakage through some of the closed entrance gates. The mean daily flow in the sluiceway each day for the weekend sampling is shown in Table 1.

Table 1. The Mean Daily Attraction Flow Entering the Sluiceway at Bonneville Dam During Spring 1971

Date	Average Forebay Level (Elev. in Feet)	Type of Entrance	Mean Flow (cfs)
4-9 & 10	72.6	Submerged	716
4-10 & 11	72.6	Overflow	580
4-16 & 17	72.4	Overflow	1,092
4-17 & 18	72.2	Submerged	640
4-23 & 24	72.0	Submerged	600
4-24 & 25	72.0	Overflow	820
4-29 & 30	72.0	Overflow	820
-30 & 5-1	72.3	Submerged	660
5-20 & 21	72.5	Overflow	1,160
5-21 & 22	73.6	Submerged	868
5-27 & 28	72.1	Submerged	620
5-28 & 29	72.8	Overflow	1,364
6-3 & 4	72.7	Overflow	1,296
6-4 & 5	72.6	Submerged	716
6-10 & 11	72.4	Overflow	1,092
6-11 & 12	72.4	Submerged	680

At The Dalles Dam we observed the general operation of the sluiceway, flows into the sluiceway with different entrance gate settings, the relationship of the flow pattern through the sluiceway to the discharges from the gatewell orifices, flow patterns in the forebay, and discharges from the sluiceway and resulting flow patterns in the tail-

race. We used entrance gates 1-1, 1-2, 2-1, and 2-2 because past studies by the National Marine Fisheries Service showed the corresponding gatewells produced the most fish.

RESULTS

Bonneville Dam

Effect of Lighting. The mercury-vapor lights were submerged adjacent to the gate openings in one phase of our testing and hung 3 feet above the water surface in the other phase. Studies at Green Peter and Fall Creek dams indicated that lights submerged adjacent to the fish horns significantly increased passage of fish from the lighted forebay area to the dark interior of the collection horns.

We were limited to fishing gear in the sluiceway only 2 days each week throughout the spring. This schedule would not have provided an adequate number of samples for analysis if we located the lights in more than two positions. However, the manufacturing schedule of the three mercury-vapor lights was such that we received our lights one at a time during the testing period. As a result we began our tests using only one light and added each of the other two on the fourth and fifth weekends of testing, respectively. For this reason and because we changed the position of the lights during the last two weekends, our analysis became complicated. We are therefore presenting our data by species and by each lighting arrangement for overflow and submerged orifice entrances (Tables 2 to 4).

The relatively small numbers of fish caught during each of these tests did not appear to justify use of statistical analysis. However, in my opinion, the numbers of fish caught under the presence or absence

Table 2. Numbe. of Juvenile Chinook Salmon Caug in the Ice-Trash Sluiceway, Bonneville Dam, 1971

Lighting Arrangement and Weekend	Catch			
	Overflow Entrance		Submerged Orifice Entrance	
	Lights On	Lights Off	Lights On	Lights Off
One submerged light				
4-9 to 11	8	3	6	9
4-16 to 18	4	5	13	7
4-23 to 25	3	1	4	4
Subtotal	15	9	23	20
Two submerged lights				
4-29 to 5-1	14	10	8	18
Subtotal	14	10	8	18
Three submerged lights				
5-20 to 22	10	8	10	11
5-27 to 29	3	5	5	3
Subtotal	13	13	15	14
Three surface lights				
6-3 to 5	1	1	2	1
6-10 to 12	9	1	0	2
Subtotal	10	2	2	3
Grand Total	52	34	48	55

Table 3. Number of Juvenile Coho Salmon Caught in the Ice-Trash Sluiceway, Bonneville Dam, 1971

Lighting Arrangement and Weekend	Catch			
	Overflow Entrance		Submerged Orifice Entrance	
	Lights On	Lights Off	Lights On	Lights Off
One submerged light				
4-9 to 11	34	36	56	48
4-16 to 18	23	33	90	65
4-23 to 25	47	25	64	45
Subtotal	104	94	210	158
Two submerged lights				
4-29 to 5-1	72	72	42	78
Subtotal	72	72	42	78
Three submerged lights				
5-20 to 22	29	21	22	38
5-27 to 29	10	15	5	3
Subtotal	39	36	27	41
Three surface lights				
6-3 to 5	3	6	2	2
6-10 to 12	2	4	1	1
Subtotal	5	10	3	3
Grand Total	220	212	282	280

Table 4. Number of Juvenile Steelhead Trout Caught in the Ice-Trash Sluiceway, Bonneville Dam, 1971

Lighting Arrangement and Weekend	Catch			
	Overflow Entrance		Submerged Orifice Entrance	
	Lights On	Lights Off	Lights On	Lights Off
One submerged light				
4-9 to 11	7	5	8	6
4-16 to 18	13	14	28	25
4-23 to 25	16	13	21	16
Subtotal	36	32	57	47
Two submerged lights				
4-29 to 5-1	21	8	18	16
Subtotal	21	8	18	16
Three submerged lights				
5-20 to 22	75	69	45	56
5-27 to 29	35	34	11	10
Subtotal	110	103	56	66
Three surface lights				
6-3 to 5	42	38	16	12
6-10 to 12	6	11	1	4
Subtotal	48	49	17	16
Grand Total	215	192	148	145

of lighting were similar in most cases and indicates that lights did not aid the collection of fish. We did not catch many fish at night in the sluiceway with or without lights.

After reviewing the results of the tests and becoming satisfied that the responses to lighting for all tests were generally similar, we combined all data by species to show the total number of fish caught during each of the four conditions of lighting and entrance locations (Table 5). The small difference in the total numbers of fish caught when lights were used and when they were not used reveals that lighting had little, if any, influence upon the migration of fish into the sluiceway. High water and turbidity (Secchi disc readings ranged from

1.5 to 2.0 feet) during the testing period may have decreased the effectiveness of the lights. High turbidity is common in the Columbia River, especially during the spring when run-off and downstream migration of fish coincide.

Table 5. Total Numbers of Juvenile Salmonids Caught in the Bonneville Ice-Trash Sluiceway at Night With and Without Lights and With Overflow and Submerged Orifice Entrances, 1971

Species	Entrance	Lights On	Lights Off	Total
Chinook Salmon	Overflow	52	34	86
	Submerged	48	55	103
	Total	100	89	189
	1. Interaction X^2_{1df} = 3.62 not significant			
	2. Lights vs. no lights X^2_{1df} = 0.64 not significant			
	3. Overflow vs. submerged X^2_{1df} = 1.53 not significant			
Coho Salmon	Overflow	220	212	432
	Submerged	282	280	562
	Total	502	492	994
	1. Interaction X^2_{1df} = 0.05 not significant			
	2. Lights vs. no lights X^2_{1df} = 0.10 not significant			
	3. Overflow vs. submerged X^2_{1df} = 17.00 > 3.84 SIGNIFICANT			
Steelhead Trout	Overflow	215	192	407
	Submerged	148	145	293
	Total	363	337	700
	1. Interaction X^2_{1df} = 0.36 not significant			
	2. Lights vs. no lights X^2_{1df} = 0.96 not significant			
	3. Submerged vs. overflow X^2_{1df} = 18.57 > 3.84 SIGNIFICANT			

The negative results we obtained in attempting to attract juvenile almon with lights at the Bonneville sluiceway contrasted with the positive results obtained by Fields (1966) at McNary Dam. However, Fields' results cannot be directly compared to ours since he found that downstream migrants entered the sluiceway at McNary mainly at night while we found that fish entered the sluiceway at Bonneville predominantly during the daylight hours. We collected small numbers of fish at night in the Bonneville sluiceway with or without lights.

Effect of Overflow and Submerged Orifice Entrances. Since we were limited to using a 12-inch opening for the submerged orifice, this type of entrance could not pass as much water as the overflow (Figure 3). The flow at the overflow entrance during the first weekend was low because we were seeking the desired gate setting. Thereafter, flows were consistently higher with overflow entrances in use than with submerged rifices.

Examination of catches showed appreciable differences existed between the numbers of fish of each species collected at night with overflow and submerged orifice entrances to the sluiceway. When the data are combined for all species the totals collected with overflow and submerged orifice entrances were similar, 925 and 958 fish, respectively. However, when the data are considered by species, significantly more coho were collected when the entrance was submerged while steelhead were collected better with the overflow entrance (Table 5). Differences in the numbers of chinook caught with the two types of entrances were not significant.

Examination of the data suggest the difference in species preference for the two types of entrances were due more to timing of their migrations

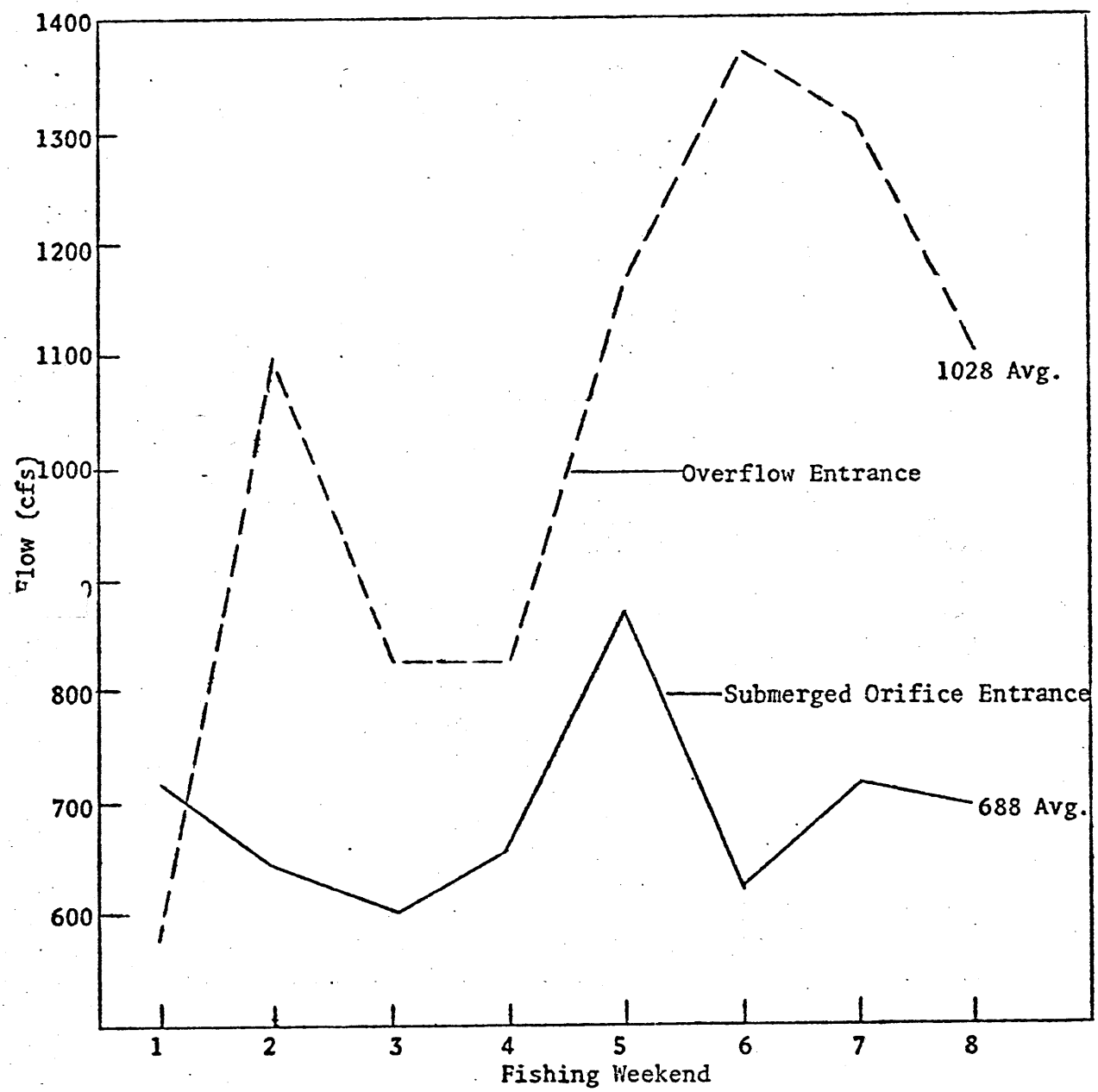

Figure 3. Flow Through the Bonneville Dam Ice-Trash Sluiceway for Each Weekend Period of Fishing, 1971

than to other behavioral factors. We combined all species for each weekend, including day and night fishing, and divided the total collected with the overflow entrance by the total caught with the submerged orifice entrance. After converting the resulting ratios to their common logarithms, we plotted them by time (Figure 4). This showed that preference for the entrance position for all species combined tended to shift from submerged orifice to overflow during the course of the experiment. The increased scatter of the ratios in Figure 4 towards the end of the experiment is probably due to the small numbers of fish caught at the time. Because the bulk of the steelhead migrated late in the experiment when the overflow entrance was apparently preferred by all species, the results for the entire experiment show that more steelhead use the overflow entrance than they do the submerged. The reverse holds true for coho which mostly migrated during the first few weeks of the experiment.

The factors associated with the change in preference of type of entrance were not controlled or measured during the experiment. Consequently, it is impossible to say which type of entrance would provide the best results over the entire fish migration.

The only useful data collected to determine the effectiveness of the overflow and submerged orifice entrances during the daylight hours were obtained on the last two weekends of the study. At that time, the overflow entrance was obviously more effective for chinook (Table 6). We collected small numbers of coho and steelhead during that period apparently because their migrations were terminating. Therefore, the comparison in numbers collected using overflow and submerged orifice entrances was not reliable for these species. However, for both coho

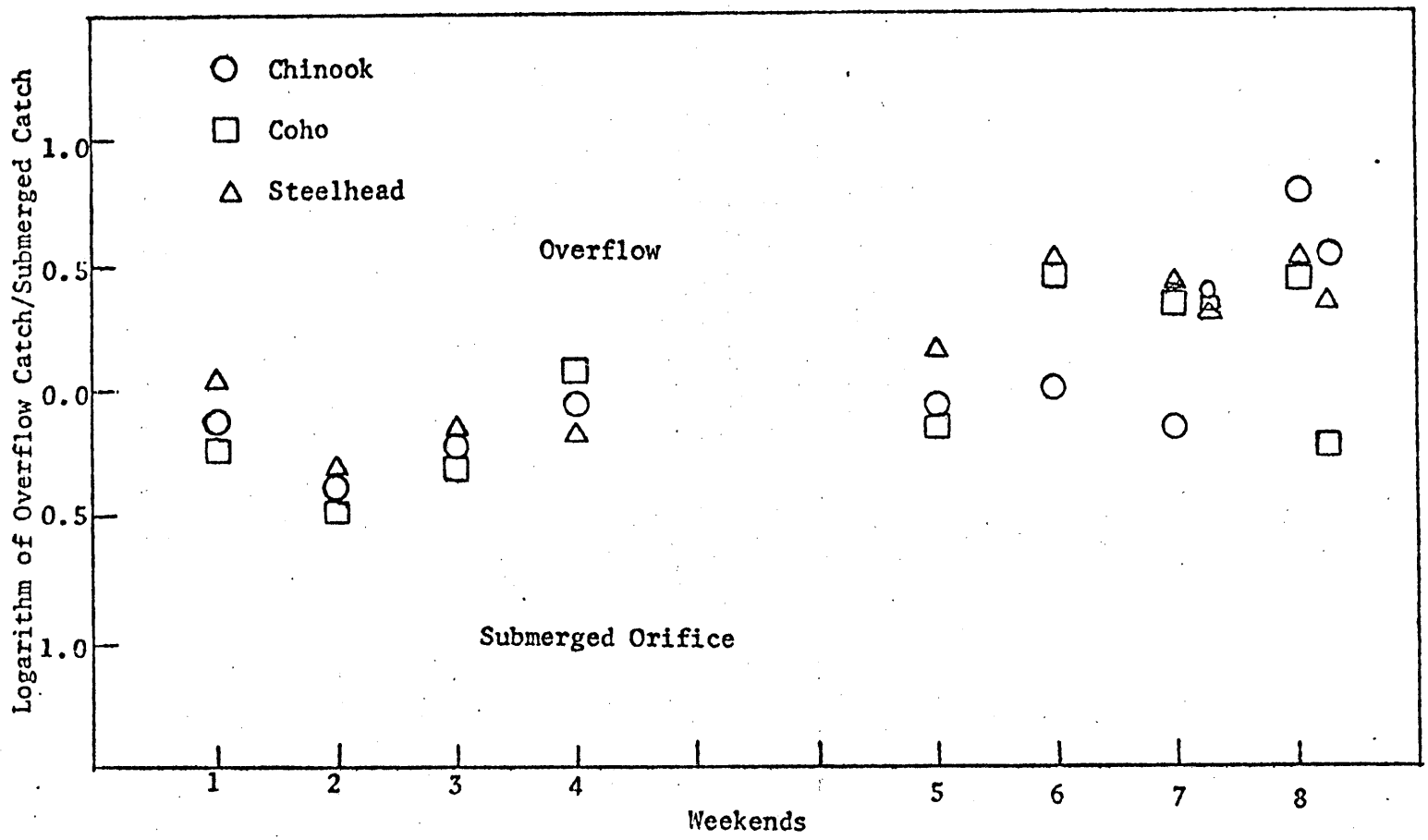

Figure 4. Logarithm Ratio of Overflow Catch/Submerged Catch Plotted by Fishing Week for Each Species, 1971

and steelhead, the combined data for the two weekends show that more fish migrated when the overflow entrance was provided.

Table 6. Number of Juvenile Salmonids Collected Using Overflow and Submerged Orifice Entrances to the Ice-Trash Sluiceway, Daylight Hours, 1971

	Overflow			Submerged Orifice		
Weekend	Chinook	Coho	Steelhead	Chinook	Coho	Steelhead
6-3 to 4	224	29	34	95	14	17
6-10 to 11	298	9	7	84	12	3
Total	522	38	41	179	26	20

The Dalles Dam

At The Dalles Dam sluiceway, the four gates used were operated as overflow entrances and opened 3 feet each for about 1 week. These gate settings produced a flow through the sluiceway of about 1,400 cfs. Average forebay elevation during the spring months is 159 feet. We did not observe fluctuations in forebay level during the few observations made that week; however, according to the Chief of Operations at the project, the forebay has substantial daily fluctuations. Large fluctuations in forebay elevation might necessitate daily adjustment of overflow gates. The same four gates were opened 12 inches as submerged orifice entrances between elevations 152 and 153 feet for the next 3 weeks. These gate settings also produced about 1,400 cfs. During the fifth and last week of observation at The Dalles Dam, we had two gates opened 3 feet as overflow entrances and two gates opened 2 feet as submerged orifices. These gate settings yielded 2,050 cfs through the sluiceway. The flows produced by all gate settings looked good for passing fish through the ice-trash sluiceway. The entrance gates that we used are near the

sluiceway exit. The only apparent potential problem in these operations is that fish passing through the gatewell orifices into the sluiceway may become trapped upstream of the turbulence caused by water entering the sluiceway. However, we do not believe this is a serious problem.

The discharge into the tailrace from the ice-trash sluiceway may attract adult salmon although we did not see any in the water or jumping in this vicinity. Observations were difficult because of high water, turbidity, and turbulence.

CONCLUSIONS

1. The use of mercury-vapor lights, both submerged and above the surface of the water, did not influence the collection of downstream-migrant salmon and steelhead at night in the sluiceway at Bonneville Dam.

2. The submerged orifice entrance was more effective in collecting fish early in the season and the overflow entrance collected fish better late. However, this may have been due more to species preference than timing. This is because coho preferred the submerged entrance and they were mainly caught early, while steelhead preferred the overflow entrance and they mainly migrated late in the season.

RECOMMENDATIONS

We recommend that the Corps of Engineers continue to operate the ice-trash sluiceway at Bonneville Dam full time with maximum possible flow from March 1 to June 30 of each year to aid safe passage of downstream migrants. Based on our study of 2 years ago (Michimoto and Korn, 1969), several hundred thousand fish will safely pass the dam mainly during daylight hours each spring; relatively small numbers will enter the sluiceway at night. If the Corps does not have a preference regarding

the type of entrance gate used to attract fish to the sluiceway, we ecommend using submerged orifices during the coho migration and overflow entrances during the steelhead migration.

If the Corps decides to use submerged orifice entrances, the gates should have a minimum opening of 24 inches between elevations 68 and 70 feet. If the overflow entrance is selected, the gates should be lowered a minimum of 2-1/2 feet below the average forebay elevation to compensate for fluctuations in pool level. Regardless of type of entrance, a minimum of four entrance gates should be used. We prefer gates 4B, 4C, 6C, and 7A.

We also recommend full-time operation of the ice-trash sluiceway at The Dalles Dam with maximum flow from March 1 to June 30 of each year. Submerged orifices should be used early in the run and overflow entrances in the latter part of the season providing this procedure does not interfere with the Corps' operation of the project. If submerged orifices are selected, the gates should have a minimum opening of 24 inches between elevations 152 and 154 feet. If overflow entrances are used, the gates should be lowered a minimum of 3 feet below the average forebay elevation to compensate for fluctuations in pool level. Regardless of entrance type, a minimum of four entrance gates should be used. We prefer gates 1-1, 1-2, 2-1, and 22-3. Gate 22-3 was chosen to create a flow throughout the length of the facility. This is needed to prevent fish which pass from the gatewells into the sluiceway from being trapped upstream of the turbulence caused by water entering the facility through the other gates. The sluiceway should also be flushed out once every 2 weeks on the possibility that some fish may be trapped.

SUMMARY

During the spring of 1971, the Fish Commission of Oregon studied the ice-trash sluiceways at Bonneville and The Dalles dams with funds provided by the U. S. Army Corps of Engineers. At Bonneville Dam we compared overflow and orifice type entrances to the sluiceway and tested submersible mercury-vapor lights as a means of increasing collection of fish at night. At The Dalles Dam we observed the operation of the sluiceway as a downstream-migrant collection system to determine if there were apparent problems.

The ice-trash sluiceway at each dam extends along the forebay side of the powerhouse. Debris is removed from the forebay by passing it through the sluiceway to the tailrace.

At Bonneville we uniformly opened four gates to the sluiceway with an overflow or orifice entrance. We tested the two types of entrances by alternating their use on different days. The flow into the sluiceway was largely dependent upon forebay level and manipulation of the sluice gate.

We submerged one to three 400-watt mercury-vapor lights 4 feet to attract juvenile salmonids to the entrance gates at night during the first six weekends of study. On the last two weekends, we hung the lights 3 feet above the water surface.

We fished a fyke net as sampling gear to collect migrants in the ice-trash sluiceway during our tests. We sampled six 1-hour periods each night during the first four weekends and four 1-hour periods the last four weekends. We fished one afternoon each weekend to determine if fish were migrating downstream in numbers during the day. On each

of the last two weekends we fished both afternoons to determine the type of entrance fish preferred during daylight hours.

Lights did not attract downstream migrants into the ice-trash sluiceway. The type of entrance used at night did not influence the number of fish entering the ice-trash sluiceway if we considered the total catch for all species. However, in examining the data by species, we collected a significantly greater number of coho with a submerged orifice and a greater number of steelhead with an overflow entrance. Similar numbers of chinook were collected by the two types of entrances.

The difference in species preference for the two types of entrances may have been due more to timing of their migrations rather than other behavioral factors. All three species tended to prefer submerged orifices early in the season and overflow entrances in the latter part of the migration. However, coho predominated in the catch during the first few weeks of the study when all species preferred the submerged orifices while steelhead was the main species collected late in the study when the overflow entrances were preferred by all species. As a result, we could not determine if the preferences shown were due to variations by species or to changes in behavior of all species with time.

We fished only the last two weekends to determine if fish preferred one type of entrance over the other during daylight hours. At that time all species, especially chinook, preferred the overflow entrance.

At The Dalles Dam we used entrance gates 1-1, 1-2, 2-1, and 2-2 into the ice-trash sluiceway with 3 feet of overflow for a week and 12-inch submerged orifices for the next 3 weeks. In the fifth week, we had gates 1-1 and 1-2 opened with 3 feet of overflow and gates 2-1 and 2-2 with 24-inch submerged orifices. Our observations indicated all three

sets of gate settings produced good flows into and through the ice-trash sluiceway for passage of downstream migrants. Because of pool fluctuations, overflow gate settings might have to be adjusted daily. Another possible problem is that fish exiting from the gatewell orifices into the sluiceway may be trapped upstream of the turbulence caused by water entering through the gate openings. Adult salmonids may be attracted to the sluiceway discharge although no fish were seen. Observations in the tailrace were difficult because of turbidity and turbulence.

We recommend full-time operation of the ice-trash sluiceways at Bonneville and The Dalles dams with maximum flow from March 1 to June 30 of each year to aid in passage of downstream migrants. If feasible, submerged orifice entrances should be used during the coho migration and overflow entrances during the steelhead migration. We prefer to use gates 4B, 4C, 6C, and 7A at Bonneville and gates 1-1, 1-2, 2-1, and 22-3 at The Dalles.

ACKNOWLEDGMENTS

The U. S. Army Corps of Engineers personnel in the Portland District office and at Bonneville Dam provided valuable advice and help in fishing our fyke net in the ice-trash sluiceway. Personnel at The Dalles and Bonneville dams were helpful in manipulating the entrance gates of the ice-trash sluiceways as requested.

Portland General Electric Company loaned the Fish Commission the fyke net needed in the conduct of the study.

Louis Fredd, FCO Biometrician, designed the program and analyzed the data. John Koroloff, environmental science graduate student at Portland State University, helped fish the fyke net.

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