PASSAGE OF ADULT FALL-RUN CHINOOK SALMON (*Oncorhynchus tshawytscha*) THROUGH A LARGE IMPOUNDMENT

by

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INTRODUCTION

One of the basic considerations in planning for fish passage at high dams is the effect of a large, deep impoundment on the upstream migration of adult salmon. If anadromous fish can pass through a large impoundment and successfully spawn, they may be passed directly over the dam into the forebay to continue their natural migration. If passage in the reservoir is impaired, it may be necessary to transport the fish around the reservoir--an operation that may be complicated by the need for separating subpopulations in the event that several tributary streams are involved.

The effect of a large impoundment on the passage of adult salmon was examined in Brownlee Reservoir on the Snake River (fig. 1). This 57½-mile-long impoundment, created in 1958, presented a potential barrier to chinook salmon (O. tshawytscha) and steelhead trout (Salmo gairdneri) on their upstream migration to spawning areas above the reservoir. Except during extreme drawdown and high river discharges, virtually no water currents exist in the impoundment, and high temperatures & low oxygen concentrations are prevalent--especially during summer and fall months.

Since the filling of Brownlee Reservoir, the number of adult salmon returning to the area has declined. There may be many factors responsible for this decline, but at the outset of these studies it was recognized that adult fish might experience difficulty in migrating through the large impoundment to spawning areas. To determine if the impoundment created problems in adult fish passage, tagging experiments with adult fall-run chinook salmon were conducted for 3 successive years by the Idaho Department of Fish & Game and by the Bureau of Commercial Fisheries.

In 1960, the Idaho Department of Fish and Game performed exploratory experiments which led to more controlled experiments in 1961. In 1962, the Bureau of Commercial Fisheries initiated a cooperative tagging experiment with the Idaho Department of Fish & Game and the Fish Commission of Oregon. Idaho Department of Fish and Game personnel tagged the fish and Fish Commission of Oregon technicians supervised a prophylactic program to minimize the transmission of disease during tagging and transportation of the fish. The fish were transported by the Idaho Power Company.

In these experiments, the ability of fall-run chinook salmon to negotiate the impoundment was determined by comparing the spawning ground recoveries of tagged fish released at two

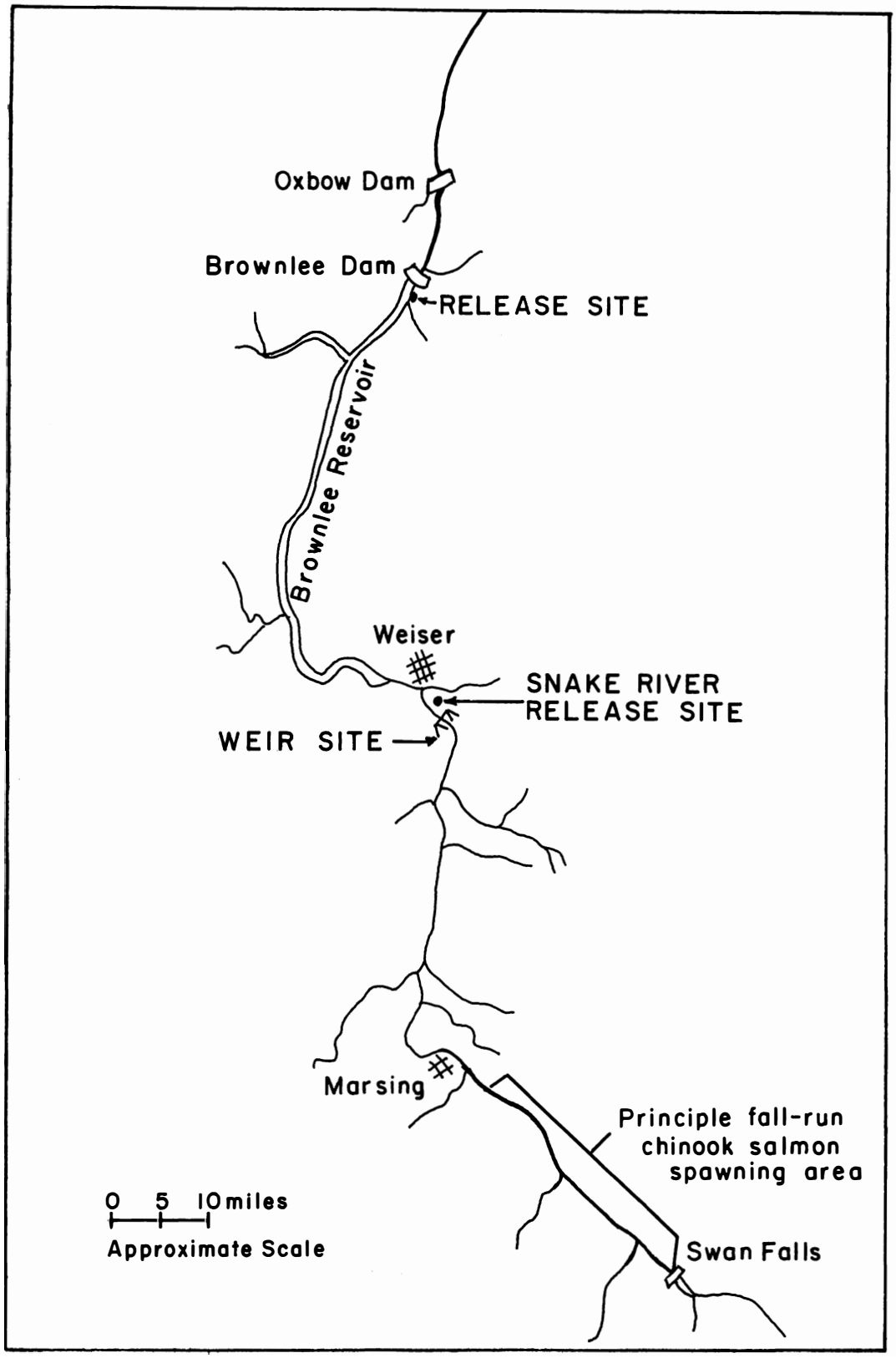

Figure 1.--Brownlee Reservoir research area showing adult salmon release sites, the weir site, and principal fall-run chinook salmon spawning area.

different sites--(1) at the lower end of Brownlee Reservoir and (2) in the Snake River above the reservoir. This report summarizes the results of the experiments.

METHODS AND MATERIALS

Adult salmon were obtained for the experiment at the Oxbow Dam fish trap about 12 miles below Brownlee Dam and tagged with Petersen disc tags before release. In 1960, those fish that appeared to be physically healthy and vigorous were selected for the exploratory experiments and were tagged without being anesthetized, but in subsequent experiments, fish were not individually selected and were tagged under anesthesia (MS-222). In all of the tests, the fish were tagged by Idaho Department of Fish and Game personnel (fig. 2). In 1960 and 1962, the fish were tagged near the Oxbow trap before being transported to the release sites, but in 1961 the fish were transported to the release sites before being tagged and released.

Throughout the experiments untagged fish were released in the reservoir by the Idaho Power Company as a part of their usual fish passage operations. In 1962, special groups of fish were marked with adipose fin clips before release in the reservoir. These fish had been anesthetized and examined during selection for artificial spawning at the Oxbow eyeing station but were not retained for spawn-taking.

Fish were transported in circulating oxygenated water to a release site in Brownlee Reservoir about 2 miles above the dam and to another site in the Snake River about 12 miles above the impoundment. During transportation to the Snake River site, water temperatures were controlled by circulating the water through iced compartments. Transportation time to the reservoir release site was usually about 1 hour and to the Snake River release site about 3½ hours.

The prophylactic program in 1962, supervised by the Fish Commission of Oregon, included the use of tincture iodine, roccol, alcohol, and malachite green. The tagging equipment was sterilized in a solution of ethanol, and the tagging area on the fish was treated with iodine. Wounds, abrasions, and infected areas were treated with a topical application of malachite green. In addition, all fish were treated for 1 hour with malachite green while being transported to the release site. At the end of a day's operation, roccol was used to sterilize fish tanks on the hauling trucks. About 3 weeks after the start of the experiment, there was some indication that the iodine treatment might be

Figure 2.--Idaho Department of Fish and Game personnel attach disc tag to chinook salmon. Fish is partially submerged in flowing water, and the head is covered during tagging.

adversely affecting the fish. A 15 percent solution of malachite green was subsequently used. Also, on one occasion, there was high mortality due to inadequate rinsing of a fish tank after sterilization with roccol. To avoid a recurrence, malachite green at a concentration of 2 p.p.m. was substituted for the roccol.

The success of passage through the impoundment was determined by comparing the numbers of tagged fish recovered on the spawning grounds from (1) those groups released in the reservoir and from (2) those transported around the reservoir & released in the Snake River. Tagged fish were recovered during weekly surveys from late October to early January by personnel of the Idaho Department of Fish & Game and the Bureau of Commercial Fisheries. A few tagged fish that were recovered downstream of the spawning grounds by sports fishermen and from other sources were not included in the analysis.

In 1962, a weir (fig. 3) was constructed in the Snake River approximately 12 miles above the reservoir and about 1/2 mile above the release site in the river. The purpose of this structure was to obtain specific information on the immediate effect of the impoundment on fish migration. About midway through the experiment, when it became evident that the weir was delaying upstream migration, it was removed to allow free passage of adult migrants.

Bureau personnel attached sonic tags to adult chinook salmon in the fall of 1961 to examine initial orientation and behavior of fish after release in the reservoir. Individual fish were tracked in detail during this experiment. In the fall of 1962, group movements were studied with fixed monitors and portable hydrophones following release of the fish in the Snake River above the reservoir.

Information on the passage of adult chinook salmon through large bodies of water--other than impoundments created by dams--was gathered by Bureau of Commercial Fisheries personnel. The material was gleaned from discussions with biologists having knowledge of chinook salmon runs in Alaska, British Columbia, and Yukon Territory. Data were obtained on estimated size of sustained populations and size of the lakes through which the fish migrated to reach spawning areas.

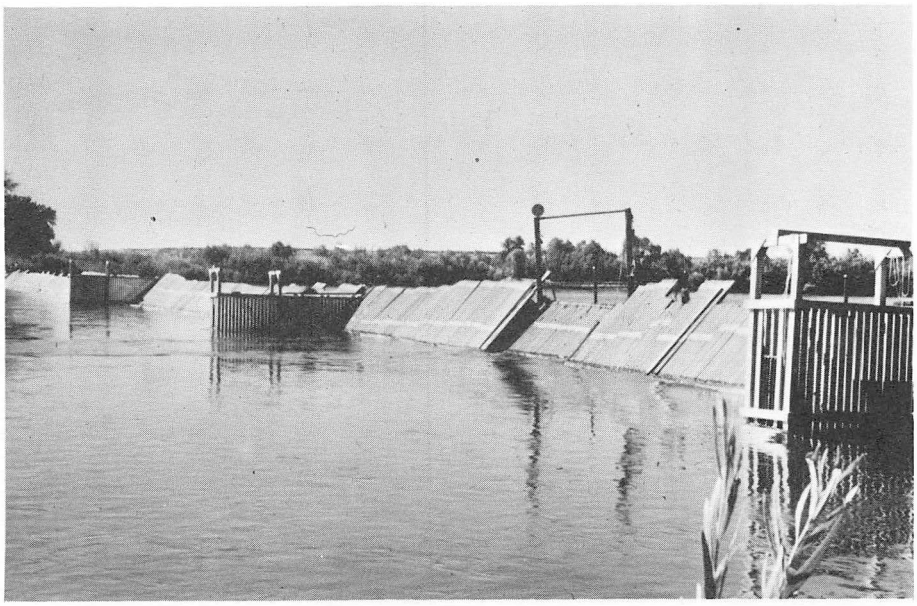

Figure 3.--Snake River weir (upstream view) with fish traps for identification and release of migrating salmon. Site is approximately 12 miles above Brownlee Reservoir.

RESULTS AND DISCUSSION

Passage through Brownlee Reservoir

Spawning ground recoveries from the various groups of tagged and untagged fish released during the experiments appear in table 1. These data show that there were no significant differences between the recoveries of tagged fish from the releases in the reservoir and in the Snake River; however, it was found that differences were evident between variously treated groups of fish released in the reservoir. Untagged fish were more successful in reaching the spawning area than either the fin-clipped or tagged fish, and the fin-clipped fish were more successful than the tagged fish.

Although the tagged fish released in the Snake River were transported about 2½ hours longer than those released in the reservoir, there was no evidence that the longer period of confinement affected the condition of the fish. Upon release, they appeared healthy and vigorous and resumed upstream migration shortly after release. There was no measure of delayed mortality due to hauling in these experiments, but other investigators have indicated that prolonged transportation appeared to have no adverse affect on adult chinook salmon. Parker (1944) transported adult fish for 2 hours and Fish and Hanavan (1948) reported hauls of about 4 hours without adverse effects. In 1961, Groves[1/], transporting fish 5 hours or more to a test area, followed by a 5-hour return haul to a hatchery, reported no mortalities directly attributable to the prolonged transportation. This information suggests that fish transported to the reservoir and to the Snake River were in comparable condition throughout these experiments. Thus, any differences between the proportions of recoveries on the spawning grounds from releases at the two sites would be attributable to environmental factors after release. Since there was no significant difference between the recoveries of fish released in the reservoir and in the Snake River, we conclude that adult salmon can pass successfully through a large reservoir such as Brownlee and reach the spawning grounds.

A high mortality of tagged fish was indicated in 1962. There was a complete lack of tag recoveries from fish released between August 27 and September 23 and only 1 recovery between

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1/ Personal communication. Alan B. Groves, Biologist, Fish-Passage Research Program.

Table 1. Recovery of fall-run chinook from spawning grounds during adult migrant tagging experiments, 1960-1962.

Year	Release site	Experimental condition	No. of fish released	No. of fish recovered on spawn. grounds	Percent recovered
1960[1]	Reservoir	Tagged	361[2]	23	6.5
		Untagged	4,282	218	5.1
	Snake R.	Tagged	267	16	6.0
1961	Reservoir	Tagged	686	70	10.2
		Untagged	3,272	467	14.3
	Snake R.	Tagged	688	83	12.1
1962	Reservoir	Tagged	444	13	2.9
		Fin-clipped	365	31	8.5
		Untagged	342	85	24.9
	Snake R.	Tagged	340	11	3.2

1/ Exploratory experiments by Idaho Department of Fish and Game.

2/ 94 fish were transported in unoxygenated water.

September 24 and 28. This lack of tag recoveries coincided with a period of constant high temperature (fig. 4 and 5) at both the reservoir and river release sites. The high temperature does not appear to be the specific cause of mortality; however, the good recovery of untagged fish (highest of 3-year study) suggests that individuals from these releases survived and reached the spawning grounds regardless of the temperatures at time of release. Possibly the stresses on fish during the tagging operation produced these mortalities.

The differential recovery of tagged and untagged fish from the reservoir releases in 1961 and 1962 also indicates a tagging mortality. Although no differences were noted in the 1960 experiments, possibly because of the selection of large healthy fish for tagging, Hauck (1961) states the data suggested decreasing recoveries with increasing temperatures.

Recoveries of fish from the fin-clipped group also give evidence of stress from handling, since these returns amount to only about one-third of those from the untagged controls. Whereas the recoveries from fin-clipped fish were higher than those from the tagged fish, even though handling procedures were about the same for both lots, it should be noted that most of the fin-clipped fish were released when temperatures were more favorable.

Initial Orientation and Behavior

Sonic tracking experiments in Brownlee Reservoir in 1961 indicated that most of the tagged fish were initially disoriented and spent considerable time in the lower reservoir before resuming upstream migration. A disoriented pattern of behavior after release is shown in figure 6, and the track of one fish that resumed upstream migration soon after release is shown in figure 7. Apparently, fish eventually become oriented and migrate upstream, as is evidenced by the number of adults observed on the spawning grounds each year.

Monitoring of groups of sonic-tagged fish released in the Snake River above the reservoir indicated that more than half of the 44 tagged fish migrated upstream to the weir (1/2 mile) in less than an hour. Other fish followed more slowly, but only a few remained in the release area up to 24 hours. The most extreme downstream migration of 1-1/2 miles was by a fish that remained there for only about 2 hours before resuming upstream movement. A typical pattern of distribution, showing the delaying effect of the weir, is given in figure 8. During three releases after the weir was removed, the fish moved past the weir site with no hesitation.

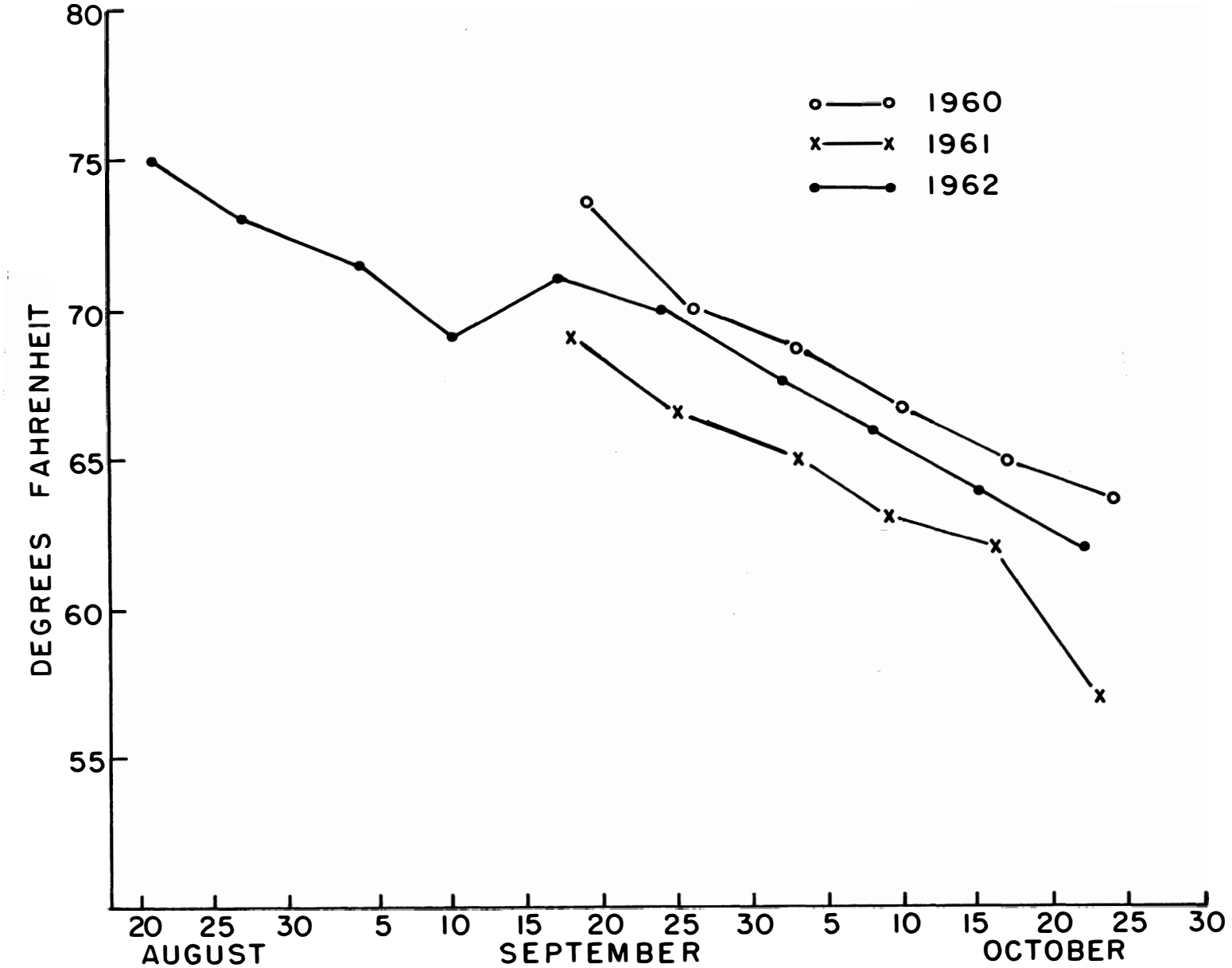

Figure 4.--Brownlee Reservoir surface water temperatures taken by Idaho Power Company personnel at center barge of skimmer net during adult tagging studies.

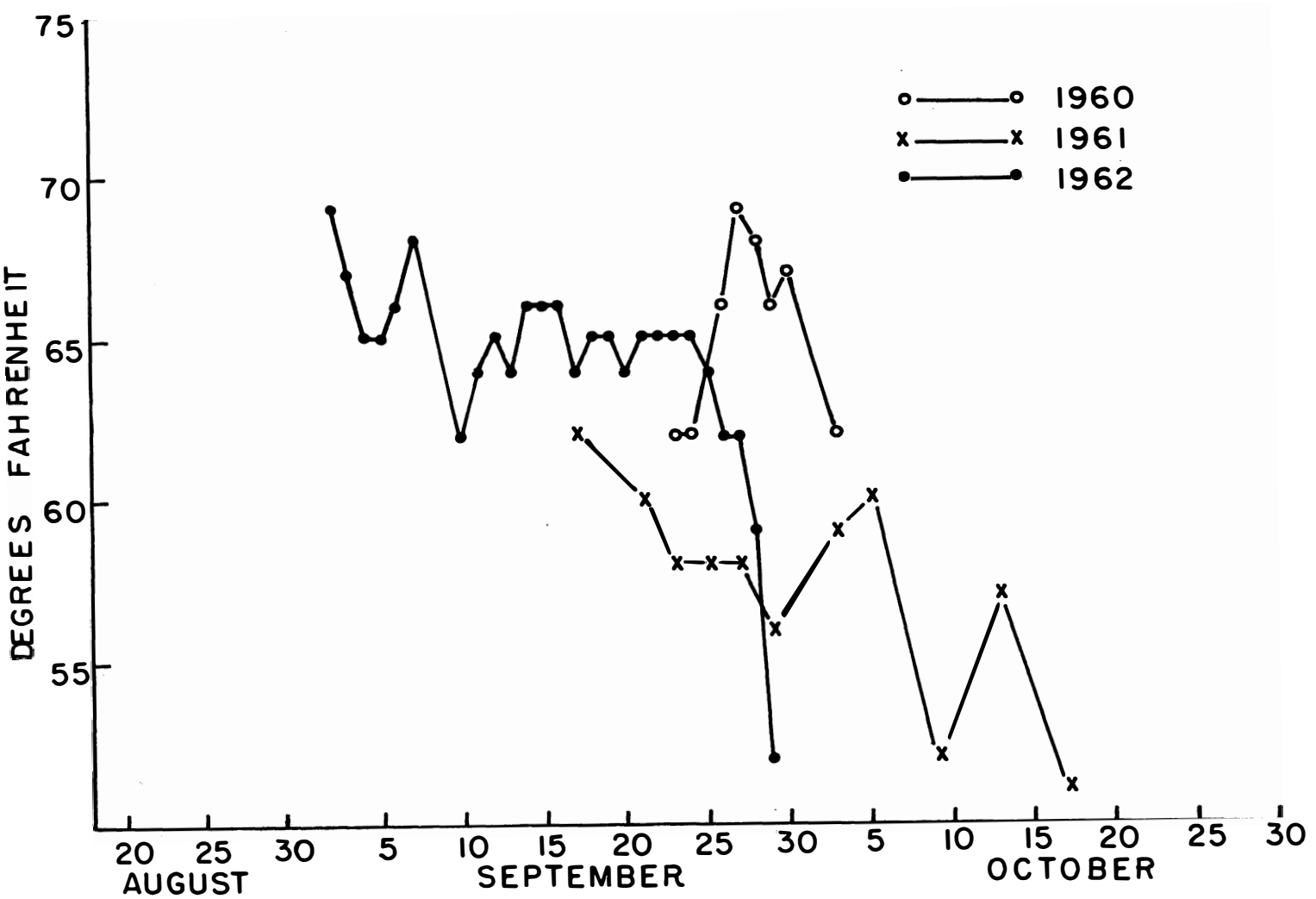

Figure 5.--Snake River surface water temperatures at river release site at time of release.

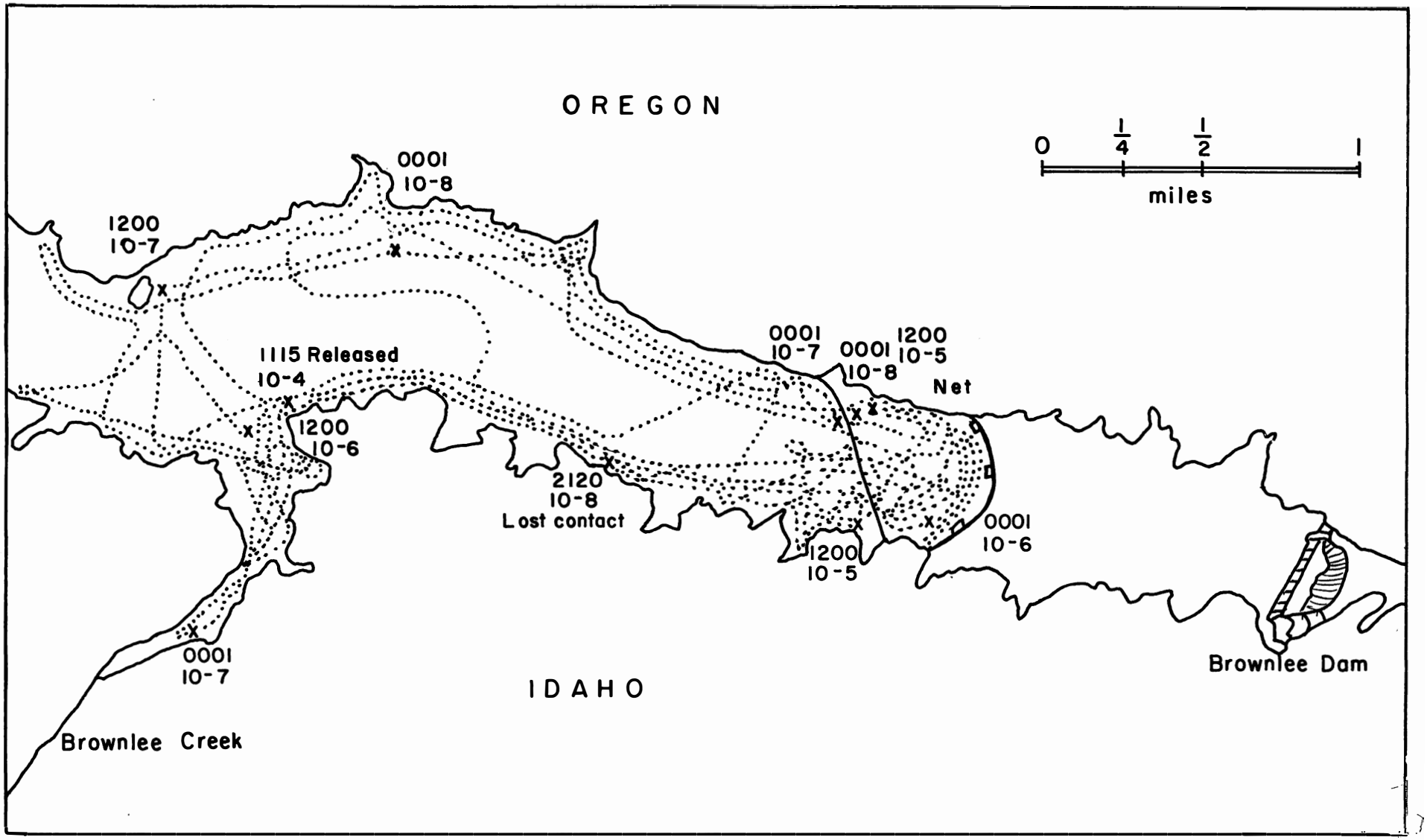

Figure 6.--Disoriented behavior pattern of adult chinook salmon released in Brownlee Reservoir. This fish, tracked for 106 hours, moved almost continuously day and night and travelled about 50 miles, all within 2 miles of the release point.

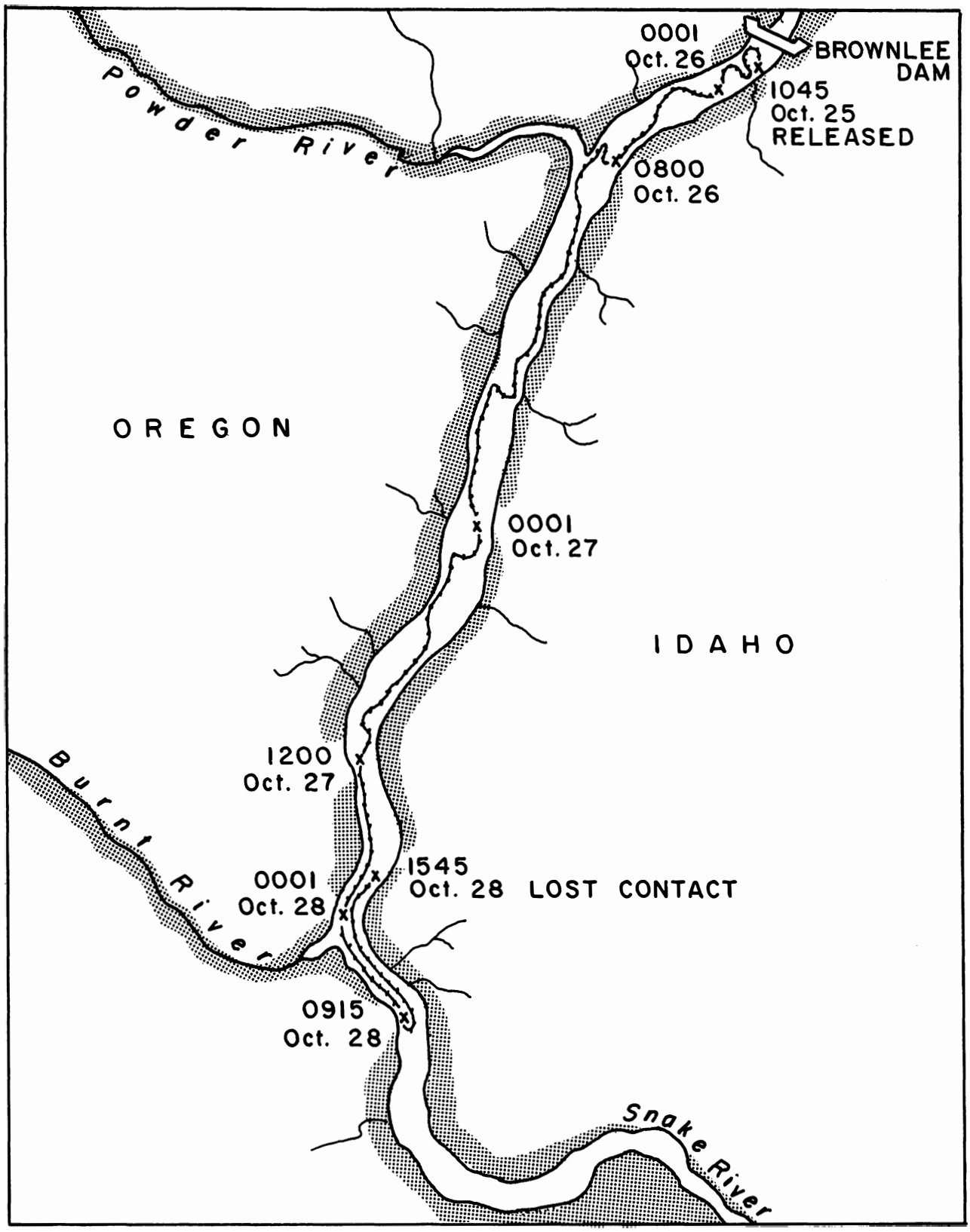

Figure 7.--Chronological record (diagrammatic) of a 77-hour track of an adult salmon moving 50 miles upstream in Brownlee Reservoir.

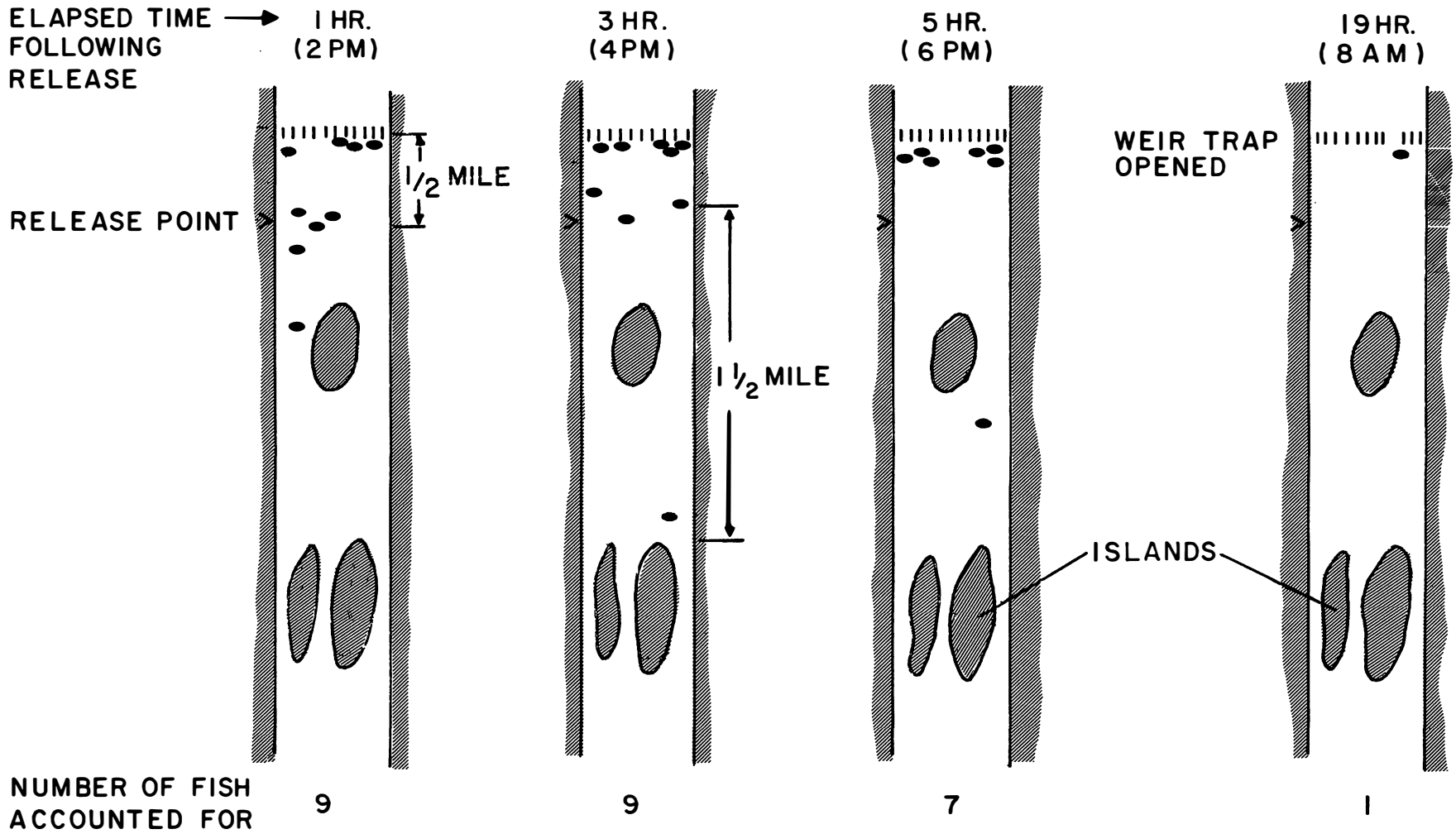

Figure 8.--Changing distribution of a group of nine sonic-tagged salmon. No trace was found of any fish dropping downstream further than 1½ miles. Two fish presumably passed undetected through the weir between 4 and 6 p.m. During the afternoon following opening of the weir trap, five fish were located from 1 to 10 miles above the weir with portable detection equipment. Others probably were undetected in unchecked sloughs and channels.

Rates of Movement

Before the weir was removed from the Snake River, five fish that were tagged and released in the reservoir were identified as they passed the weir. The total elapsed time from release to identification at the weir ranged from 76.0 to 236.9 hours, an average elapsed time of 160.5 hours or 6.7 days. The average rate of upstream movement from release to passage through the weir was 10.5 miles per day. It is possible that the extended elapsed times were due to disorientation in the reservoir and to delay at the weir.

Thirteen of the fish released at the Snake River site were observed passing through the weir. Total elapsed times from release to identification varied between 2.2 and 159.5 hours, an average of 67.3 hours or 2.8 days. The extended elapsed times for these fish can be attributed to delay at the weir. Sonic monitoring observation showed that fish began moving upstream shortly after release, but few fish passed the weir until it was opened.

Selection of Spawning Streams

Spawning ground surveys and catches of juveniles in downstream migrant traps indicate that adult salmon migrants select specific tributaries for spawning. Spring-run chinook salmon and steelhead trout enter the Powder River about 18 miles above Brownlee Dam and migrate into Eagle Creek (fig. 1) where they spawn. Substantial numbers of juveniles are captured as they migrate into the impoundment.

Spring chinook and steelhead trout also negotiate the entire reservoir and enter the Weiser River and possibly other tributaries of the Snake River. Progeny from these adult populations have been captured by Idaho Department of Fish & Game and by Bureau of Commercial Fisheries downstream migrant trapping activities.

Fall-run chinook salmon swim through the reservoir and continue about 75 miles upstream in the Snake River where they spawn in the Swan Falls area. Large numbers of adults have been observed on this spawning ground and many of their progeny have been captured as they migrate downstream.

Spawning Success

Passage through Brownlee Reservoir does not appear to affect the ability of fall-run chinook to complete their spawning

activities. From observations by the Idaho Department of Fish and Game (Pirtle & Keating, 1955, and Richards, 1956-1962) during their annual spawning ground surveys, there does not appear to be any significant change in the totally spent fish (fig. 9) before and after Brownlee Dam was closed in 1958.

Passage Through Lakes

Evidence of adult chinook salmon migration through large lakes suggests that the size of a body of water may not be a critical factor influencing upstream migration. In Alaska, chinook (king) salmon have been observed in the upper Wood River Lakes, some 60 miles upstream of the lowermost lake. About 5,000 adults are estimated to enter and spawn in tributaries to Naknek Lake. Some of these fish reached Brooks Lake weir, which is about 30 miles above the outlet of Naknek Lake.

In British Columbia, 500 to 1,000 adult chinook pass through 50-mile-long Harrison Lake into the Birkenhead River, and about 5,000 migrate through 15-mile Kamloops Lake and continue on for 45 miles through Shuswap, Eagle, and Mara Lakes to spawn. Some fish pass 50 miles through Quesnel Lake into the Mitchell River. Before Coulee Dam was constructed, large runs of chinook were reported to have migrated through the lower Arrow Lake (45 miles) and upper Arrow Lake (35 miles) to spawn below Windemere Lake, 80 miles further upriver.

Over 3,600 chinook are estimated to enter LaBerge Lake in Yukon Territory. A small number enter a tributary about half way through the 35-mile lake, but the majority of fish continue through the lake to the Takhini and McKlintock rivers. Another run of 2,000 fish migrates up the Teslin River and continues 45 miles into Teslin Lake before entering the Nisutlin River.

CONCLUSIONS

1. Adult fall-run chinook salmon can pass successfully through a large impoundment such as Brownlee Reservoir.

2. Passage through Brownlee Reservoir has not affected the ability of fall chinook to spawn successfully.

3. Fall chinook migrants were initially disoriented when released in the reservoir but recovered and resumed migration to spawning areas.

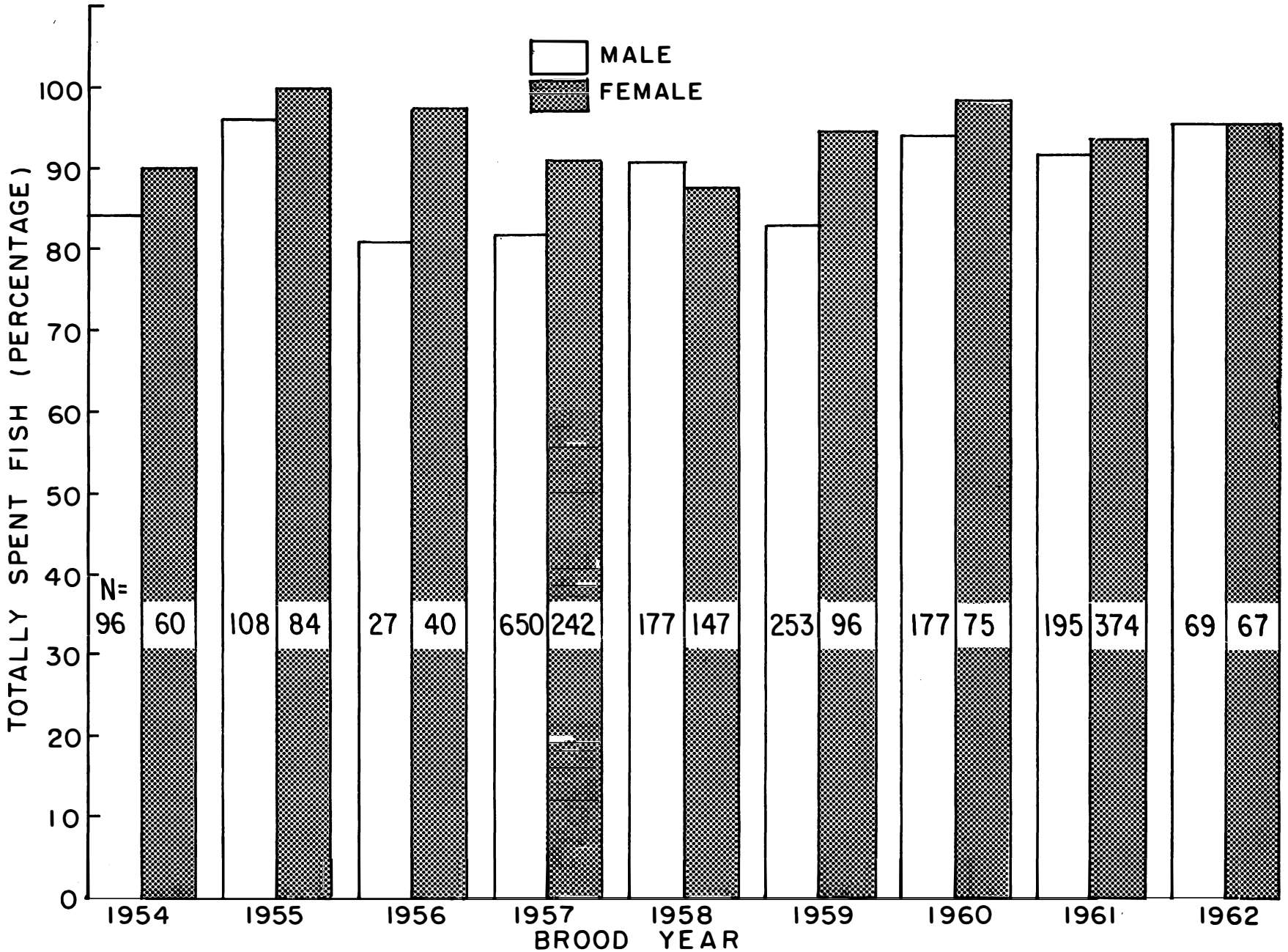

Figure 9.--Percentage of totally spent fall-run chinook salmon recovered on spawning ground surveys in the Swan Falls area, Snake River.

SUMMARY

Tagging experiments were conducted from 1960 to 1962 in Brownlee Reservoir to examine the effect of a large impoundment on the migration of adult fall-run chinook salmon. Some of the migrants captured at the Oxbow Dam trap, about 12 miles below Brownlee Dam, were tagged and released near the lower end of Brownlee Reservoir, whereas others were tagged and transported around the reservoir and released in the Snake River about 12 miles above the reservoir. Untagged fish were released in the reservoir throughout the experiments. In 1962, special lots of fish were marked with an adipose fin clip before release in the reservoir. These fish had been examined at the Oxbow spawning facility but were not used in the spawn-taking activities. Success of passage through the reservoir was determined by comparing the numbers of tagged fish recovered on the spawning ground from the two release sites.

The results indicate that adult fall-run chinook salmon can successfully pass through a large impoundment such as Brownlee Reservoir. Approximately equal proportions of fish were recovered from the releases in the reservoir and in the river above the reservoir. Comparisons of the recoveries of tagged and untagged fish released in the reservoir indicate that tagged fish were subject to additional stresses and reached the spawning grounds in smaller proportions than the untagged lots. This was especially true in 1962 when a high tagging mortality was observed during the early part of the run.

Tracking of sonic-tagged fish indicated that those released in the reservoir were initially disoriented but eventually resumed their migration to the spawning ground. Fish released in the Snake River resumed upstream migration shortly after release. Few fish moved downstream from the release site.

In 1962, a few fish were identified as they passed through a weir in the Snake River about 12 miles above the impoundment. Limited data indicated an average rate of passage of about 10.5 miles per day from the lower reservoir to the weir.

Evidence that migrating salmon and steelhead trout select specific areas for spawning is substantiated by spawning ground surveys and downstream migrant trapping activities. Populations of spring chinook salmon and steelhead trout have maintained their identity in widely separated spawning areas even after construction of Brownlee Dam. Spring chinook and steelhead are found in Eagle Creek, which is about 20 miles from the dam, and in the Weiser

River, which enters the Snake several miles above the reservoir. Fall-run chinook have continued to utilize their accustomed spawning grounds in the Swan Falls area, which is approximately 140 miles above Brownlee Dam.

Passage through the reservoir does not appear to affect the ability of fall-run chinook salmon to spawn. The percentages of totally spent fish before and after the closure of Brownlee Dam show no significant differences between 1954 and 1962.

The ability of adult chinook salmon to pass through large lakes suggests that the size of an impoundment may not be a critical factor in upstream migration.

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RECRUITMENT OF JUVENILE SALMONIDS TO BROWNLEE RESERVOIR (SUMMARY)

by

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SUMMARY AND CONCLUSIONS

Data on fingerling recruitment to Brownlee Reservoir were obtained with floating fingerling traps (migrant dippers and floating louver extensions) in the Snake River and with a stationary louver facility in Eagle Creek (Powder River system). Progeny of native runs of spring-run chinook salmon and steelhead trout were present through 1964 in both areas, but few fall-run chinook progeny were present in the Snake River in 1964, since only a token number of adults were passed during the previous fall.

Snake River

Supplementary plants of approximately 250,000 0-age chinook and 375,000 yearling cohoes were made in the Snake River in the late winter and early spring of 1964. These fish were the progeny of lower Columbia River stocks.

Fall-run chinook progeny have predominated in the Snake River system. The following are estimates of the annual recruitment from the principal populations in the Snake River above Brownlee Reservoir with brood years in parentheses:

Migration Period	Snake River fall chinook	Weiser River spring chinook	Rainbow-steelhead all sources	Hatchery Plants	
				Chinook	Coho
1962	529,000 ('61)	122,000 ('60)			
1963	390,000 ('62)	34,000 ('61)	22,000		
1964	1,000 ('63)			175,000 ('63)	92,500 ('62)

Peaks of migrations from the Snake River system have occurred in mid-May for all species. A second movement of chinook, falling within the general size range of spring-run progeny, has been observed in late June and early July. The origin of this run has not been fully established. Of interest here is the fact that catches during this late period have included marked fish from Eagle Creek. These fish apparently migrated up the reservoir, entered & ascended the Snake River, and were captured as they returned downstream.

Daily peaks of migration have occurred from 7:00 to 11:00 a.m. and from 3:00 to 7:00 p.m. Lowest catches were made from 10:00 p.m. to 4:00 a.m.

Fall-run chinook salmon progeny migrate downstream in the Snake River as 0-age fish, and the spring-run progeny move out primarily as yearlings (age-group I). Rainbow-steelhead are comprised of five age groups.

Lengths of 0-age chinook have ranged from 30 to 103 mm., whereas the yearlings have ranged from 106 to 142 mm. In late April 1964, the size ranges of natural spring-run salmon progeny merged with the size ranges of the planted fall-run chinook salmon. Rainbow-steelhead have fallen within a range of 90 to 480 mm.

Average collection efficiency of the floating fingerling traps in 1963 was 11.5 percent for fish over 103 mm. and 8.1 percent for fish under this size. In 1964, efficiencies averaged 15.7 percent and 7.9 percent respectively for the large and small size groups.

Eagle Creek

Migrations from Eagle Creek of the Powder River system have consisted of spring-run chinook salmon and rainbow-steelhead trout progeny.

Progeny of chinook salmon begin migration out of Eagle Creek with the first increase in runoff during the fall. This run is comprised of 0-age fish (55 to 120 mm. fork length) and continues until freezeup in early winter. Peak migrations have occurred in October and November. A second, smaller migration begins during warmup in late winter or early spring and continues until June. Fish in this migration are nearly all age-group I (70 to 135 mm. fork length).

Rainbow-steelhead trout migrate out of Eagle Creek in the spring. Peak catches of migrants have occurred in May, but high water levels during the spring have handicapped trapping efforts, making it difficult to fully assess the extent of this migration. Five age groups are indicated and lengths range from 70 to 283 mm.

The following estimates of recruitment from Eagle Creek (brood years in parentheses) were obtained during the 1962-63 and 1963-64 runs:

Migration period	Chinook	Rainbow-steelhead
1962 fall	117,000	22,000
1963 spring	16,500	
Total:	133,500 ('61)	
1963 fall	24,000 1/	
1964 spring	7,000 2/	2,800
Total:	31,000 ('62)	

1/ Includes 3,000 0-age fish taken in spring of 1963.

2/ Estimate to May 17, 1964.

The efficiency of the louver trap in the 1962-63 period was 10.2 percent, with selectivity toward larger fish. In 1963-64, the efficiency of the louver facility was improved. Average efficiency was 55.2 percent (range, 37-65 percent), and there was no evidence of selectivity on the basis of fish size.