EFFECT OF SMALL IMPOUNDMENTS
ON JUVENILE SALMONIDS
1962-1964

by

OREGON FISH COMMISSION

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for

FISH PASSAGE RESEARCH PROGRAM
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CONTENTS

INTRODUCTION

One of the obstacles to predicting the success or failure of passing juvenile salmonids through a reservoir is a lack of knowledge of the relationship between the environment of the reservoir and fish behavior. The Bureau of Commercial Fisheries entered into a contract with the Oregon Fish Commission on February 20, 1962 whereby the state agency was to determine this relationship at North Fork and Pelton reservoirs. These impoundments were chosen for study since they are relatively small, possess downstream migrant collection facilities, and the populations of anadromous salmonids are adequate for study purposes.

We felt the results of our study should have practical application at future projects in deciding (1) whether downstream migrants should be collected in the reservoir or in the tributaries entering the reservoir; (2) whether collection facilities should be located at the dam or elsewhere in the reservoir; and (3) what design and operating criteria should be incorporated into collection facilities in the reservoir.

With this application in mind and with ideas developed during a preliminary study, the following objectives and methods were formulated: determine (1) timing and movements by trapping and tagging, and examination of counts at the fish facilities; (2) seasonal and diel depth distribution by the use of gill nets and SCUBA; (3) survival through marking and tagging studies; (4) the effect of age and growth on behavior by taking size composition and scale samples; and (5) the effect of environment on behavior. Additional information is available from fish facility evaluation studies on the passage of salmonid smolts through North Fork and Pelton reservoirs. These studies were conducted jointly by OFC and Portland General Electric Company. These data are supplemented by our tagging studies.

The completion of Round Butte Dam in 1964 prevented access of juveniles into Pelton Reservoir and resulted in the transfer of the behavior study from Pelton to Round Butte Reservoir.

NORTH FORK RESERVOIR

Introduction

North Fork Dam is the uppermost of a 3-dam complex on the Clackamas River in western Oregon (Figure 1). It has a hydraulic head of 138 feet and forms a reservoir 4 miles long. It is entered at the upstream end by the Clackamas River and has one small tributary. Pool fluctuations average 4 feet daily with a maximum of 19 feet. Cazadero and River Mill dams are located 2 and 7 miles downstream. Cazadero diverts water into Faraday Lake and powerhouse. Upstream migrants use an outdated fish ladder at River Mill and a modern ladder 1.7 miles long around Cazadero and North Fork. Downstream migrants may leave North Fork by one of three exits: (1) the surface collection facility, coincident with the ladder exit and with a normal attraction flow of 200 cfs; (2) the penstocks submerged 124 feet; or (3) the spillway, which handles overflow about 7.4% of the year mainly during the fall and winter. Fish collected at North Fork Reservoir are transported by the fish ladder to Cazadero Dam where they are counted and placed in a pipeline which discharges them below River Mill Dam. Spring chinook and coho leaving through the other exits pass over the spillways or through the turbines of the lower 2 projects.

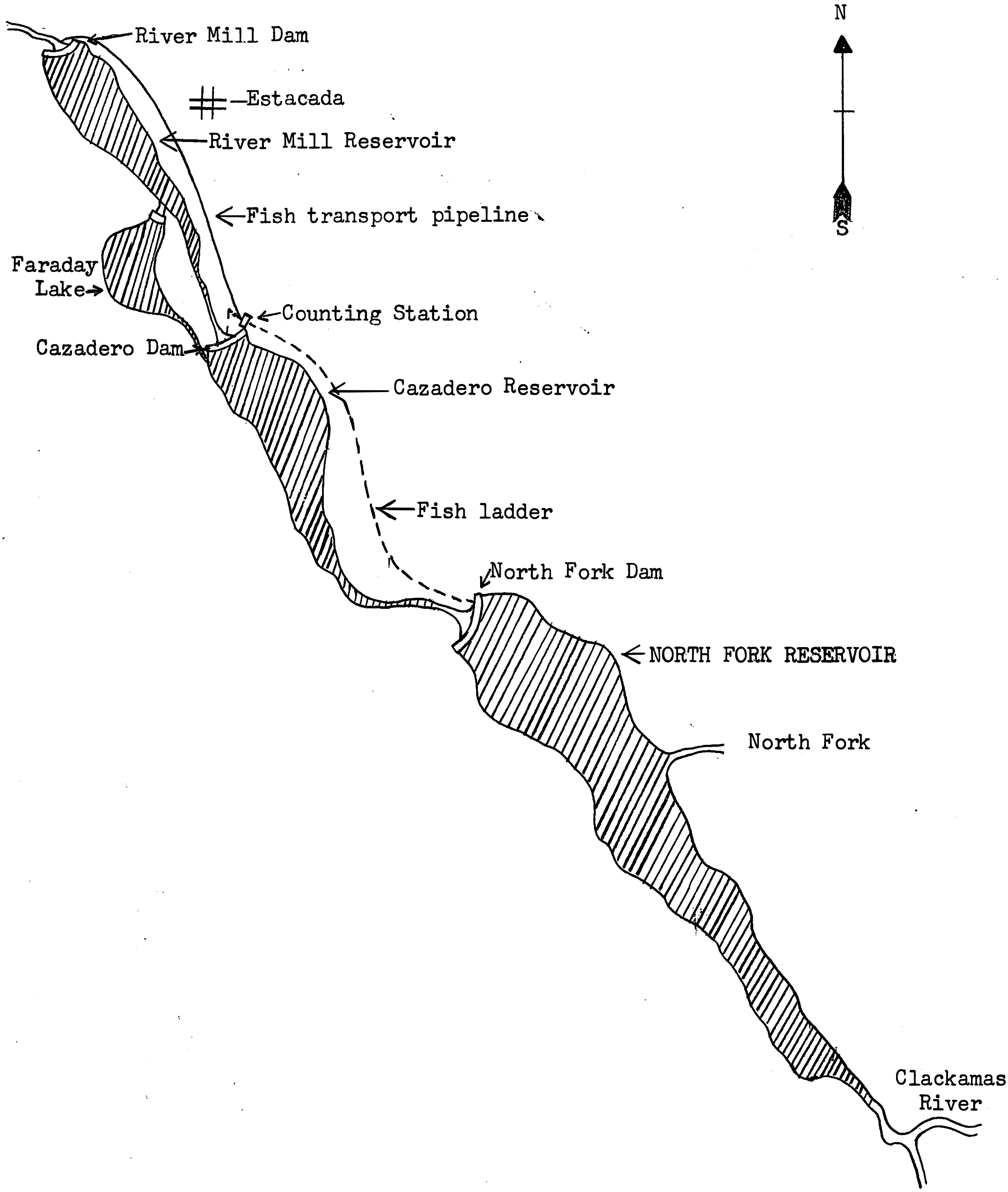

Figure 1. Diagram of Three-Dam Complex Located on the Clackamas River.

Spring chinook and coho salmon and winter-run steelhead trout are the anadromous species present. Rainbow trout are released into the reservoir during the spring and summer for an intensive sport fishery. Coarse-scaled suckers are the predominant scrapfish species and cottids are numerous.

Fish Behavior

Timing and Movements

Juvenile anadromous salmonids occurred in North Fork Reservoir during all seasons. Numerous chinook, coho, and steelhead entered as fry in February, May, and July, respectively. Migrations were not detected in the summer, but in the fall and winter, coincident with freshets, fish activity increased and intra-reservoir migrations resulted. At this time, thousands of chinook and coho entered the reservoir and left via the collection facility and spillway; some passed through the turbines. Few steelhead were observed in the reservoir between yearling and smolt stages and emigration was negligible until smoltification. Smolts of all species entered the reservoir in the spring. Peak numbers of all species migrated through the collection system in May and June, and many emigrated through the spillway when spill occurred. Steelhead emigrated first and moved only in a down-reservoir direction.

Depth Distribution

Depth distribution varied seasonally. Salmon and steelhead fry were found near the surface, close to the shoreline and cover, during the spring and early summer. As they grew they inhabited deeper water, particularly during the daylight hours. By late summer, salmon fingerlings were found to a depth of 75 feet (maximum studied) during the day and near the surface at night. Salmon remained below the stratified layer at night if surface temperatures approached 70°F. Steelhead fingerlings were always found near the surface in late summer. All species preferred a depth of 0-30 feet during the fall, when water temperatures were declining and the first freshets occurred.

In the winter,coho salmon inhabited deep water during the day and shallow water at night (Figure 2). Coho were found to a depth of 120 feet during the day, but were shallower if water visibility was 5 feet or less. Chinook and steelhead were distributed similar to coho in the winter, but data are weak. In the spring all species were found within 30 feet of the surface at all times as shown for coho in Figure 2, but some coho were found deeper.

Survival in Reservoir

Survival was determined as the per cent of marked and tagged juveniles collected at the artificial outlet as smolts. Coho, marked as fingerlings in the fall of 1962 and fry in the spring of 1963, experienced recovery rates at the collection system of 27 and 8%, respectively. Chinook fingerlings and fry, marked at the same times as the coho, showed recovery rates of 15 and 2%, respectively. Marked steelhead fingerlings evidenced a cumulative recovery of 2.1% for 1- and 2-year-old migrants. Three-year-old migrants may be captured in 1965.

Fish were tagged each month throughout the year. Figure 3 shows that coho salmon 9 cm or longer survived better (40-76%) than those 6-9 cm long (17-57%). This may mean a differential tagging mortality due to size, or a poorer survival rate for smaller fish, or both. Recovery rates of fish tagged prior to February were low because tagged fish were known to

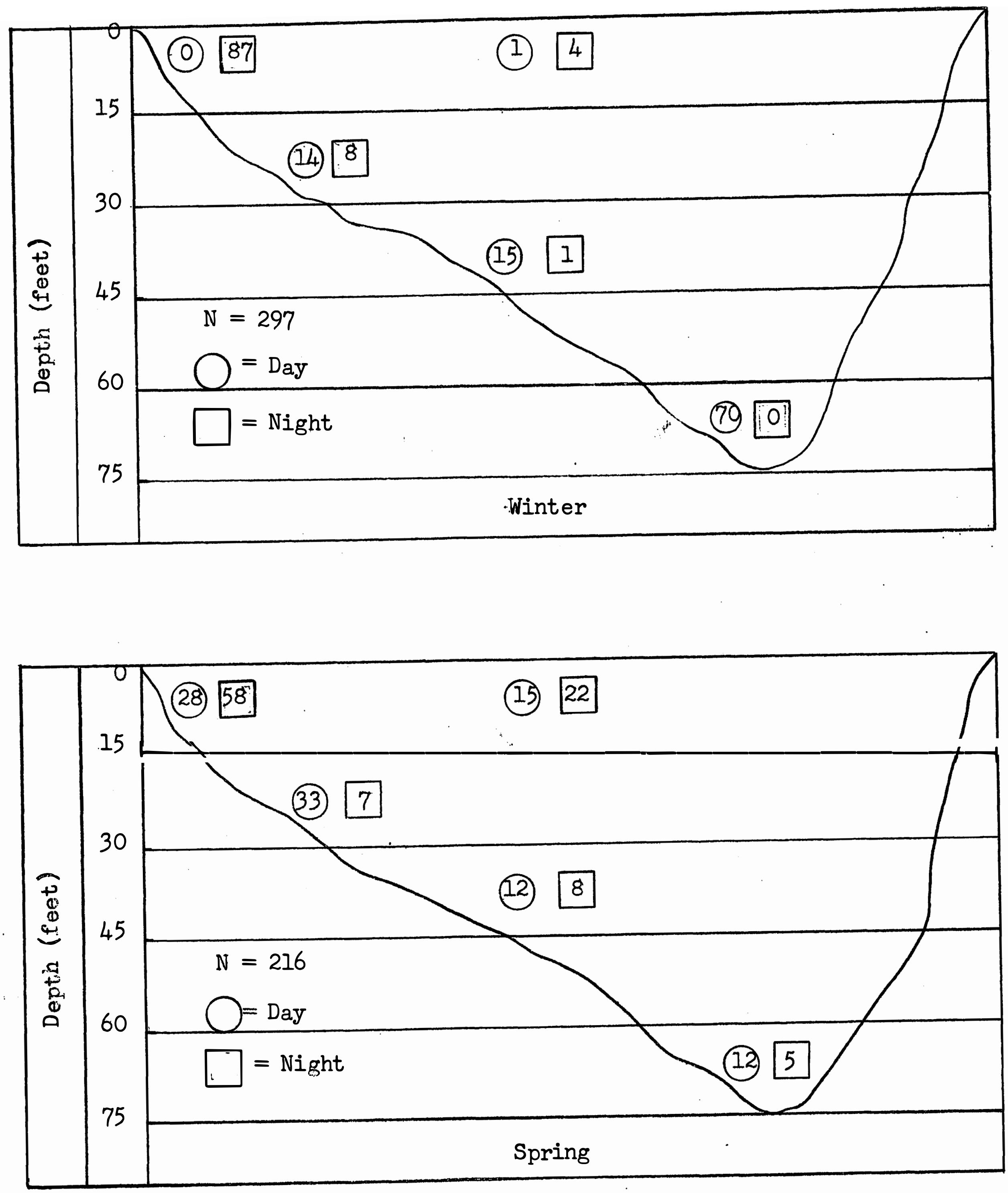

Figure 2. Depth Distribution of Coho Salmon During the Day and Night as Shown by the Per Cent of Fish Caught at Five Fishing Positions in a Cross Section of North Fork Reservoir, Winter and Spring Seasons.

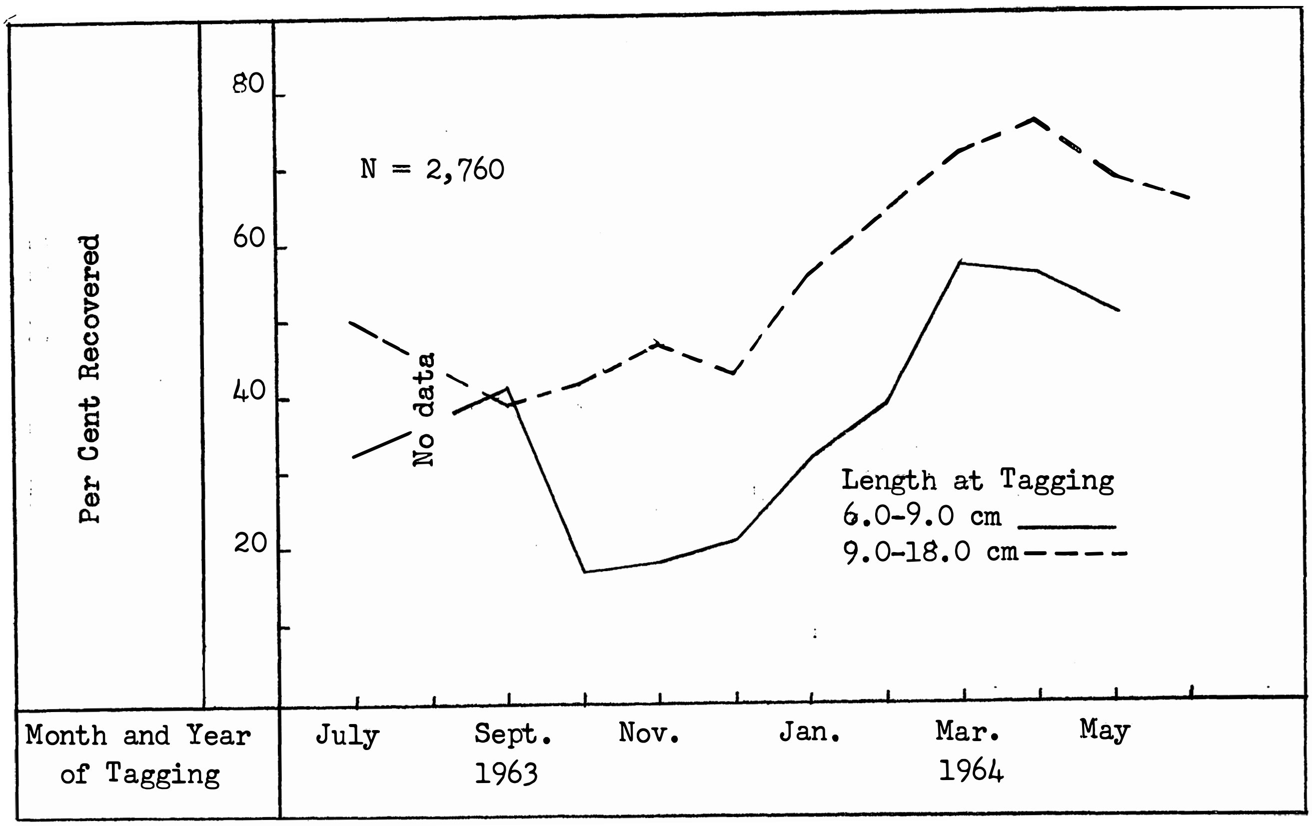

Figure 3. Per Cent Recovery at the Collection System of Two Size Groups of Coho Salmon, by Month of Tagging, North Fork Reservoir, July 1963-June 1964.

emigrate with spill. The rate of recovery for chinook ranged from 7% for fish tagged in July 1963 to 87% for those tagged in February 1964, but few were tagged. Steelhead smolts were tagged only in April and May, and 61% were recovered at the collection system.

Survival appeared good to excellent in North Fork Reservoir with coho surviving best. The most serious losses in the reservoir occurred during the fry stage for all species.

Cottids, rainbow trout, and yearling salmon preyed on fry salmonids. Coho were potentially the most serious predators as they were the most abundant.

Sport census data obtained by the North Fork Evaluation Study during the spring of 1963 showed that 18% of the fish sampled were wild steelhead smolts. Catch estimates are not available. Chinook and coho smolts were sub-legal size, but many were caught by anglers and returned to the water. SCUBA divers found numerous dead salmon and steelhead smolts on the reservoir bottom during the spring, most with hook wounds.

Passage Through Reservoir

The ability of salmonid smolts to pass through North Fork Reservoir and enter the collection system was measured by the evaluation study through the release of marked wild and hatchery fish at the head of the reservoir. Preliminary results indicate 70-90% of the salmon and steelhead smolts entering the reservoir were recovered at the collection system trap. These passage efficiencies are adequate to perpetuate the runs.

Age and Growth

All species of salmonids grew rapidly after entering North Fork Reservoir as fry. Chinook, coho, and steelhead, of the zero age group, had modes of 15-16, 10-11, and 9 cm, respectively, by October. The first fall freshets transported large numbers of small stream-reared fish into the reservoir. This reduced the modal sizes of the three species in the reservoir to 9-10 cm for chinook, 7-8 cm for coho, and 7 cm for steelhead. Fish of all sizes left the reservoir via the collection facilities and spillway during the fall. Salmonids did not grow during the late fall and winter months. In the spring, chinook and coho yearlings grew rapidly, and at emigration the modal length was 12 and 11-12 cm, respectively. Steelhead smolts did not evidence growth in the reservoir.

Most chinook and coho left North Fork Reservoir as sub-yearlings and yearlings. Steelhead emigrated as 1-, 2-, and 3-year-olds; preliminary scale analysis indicates most left after their second year. There was no indication of residualism in the reservoir for any species.

Limnology

Physical Factors

Water temperatures were compatible with salmonid survival and passage through the reservoir. Temperatures at the water surface seldom exceeded 73° F during the summer, and frequently remained in the 60's. A weak thermocline between the surface and a depth of 15 feet formed during extreme summer temperatures. A profile taken August 7, 1963, when maximum surface water temperatures prevailed that summer, showed stratification but no thermocline (Figure 4). Water temperatures declined rapidly in the fall, and the reservoir became isothermal in October. This condition persisted until the following April, when warming occurred. The temperature profile taken May 20, 1964 (Figure 4) is typical of those obtained during the migration season of 1962-64, and shows the water mass cool with weak stratification.

Flows recorded below River Mill Dam give a rough indication of inflow and outflow at North Fork Reservoir. In 1962 the minimum flow of 325 cfs occurred in October with the maximum of 14,000 cfs in November. This was typical in that rain-caused freshets seldom occurred prior to November. The mean daily flow during the spring migration period ranged between 3,000 and 4,100 cfs for the past 3 years. Spill occurred 1-5 times each year, mainly in the fall and winter and occasionally in the spring.

Water clarity was adversely affected by occasional phytoplankton blooms in the summer, and freshets during the fall and winter. Secchi disc water visibility was often less than one foot after a large freshet, and exceeded 25 feet when surface water temperatures were in the low 60's in late summer.

Surface water currents were generally in a down-reservoir direction during the spring migration period. Velocities ranged between 11 and 32 feet per minute depending on area of the reservoir, water flow, and wind direction and velocity. Up-reservoir surface currents occurred with strong upstream winds and relatively low flows.

Chemical Factors

Dissolved oxygen concentrations were adequate for salmonid life throughout the past year with minimal values approximately 8 ppm. Total alkalinity values were low and indicated poor productivity. This is indirectly corroborated by the absence of large resident fish. The pH range was within the limits necessary for fish life. Table 1 shows selected seasonal values of oxygen, total alkalinity, and pH taken near the dam from the surface, middle of the thermocline, and bottom of the reservoir.

Biological Factors

Zooplankton and bottom samples, and stomach samples from gill-netted salmonids were taken to determine if diel depth distribution of fish was affected by their feeding habits. The relationship between these factors has not been analyzed.

Meteorological Factors

Collection of meteorological data included barometric pressure, moon phase (in conjunction with SCUBA observations), cloud cover, and wind direction and velocity. These data have not been analyzed.

PELTON RESERVOIR

Introduction

Pelton Dam is the lower of two dams on the Deschutes River in central

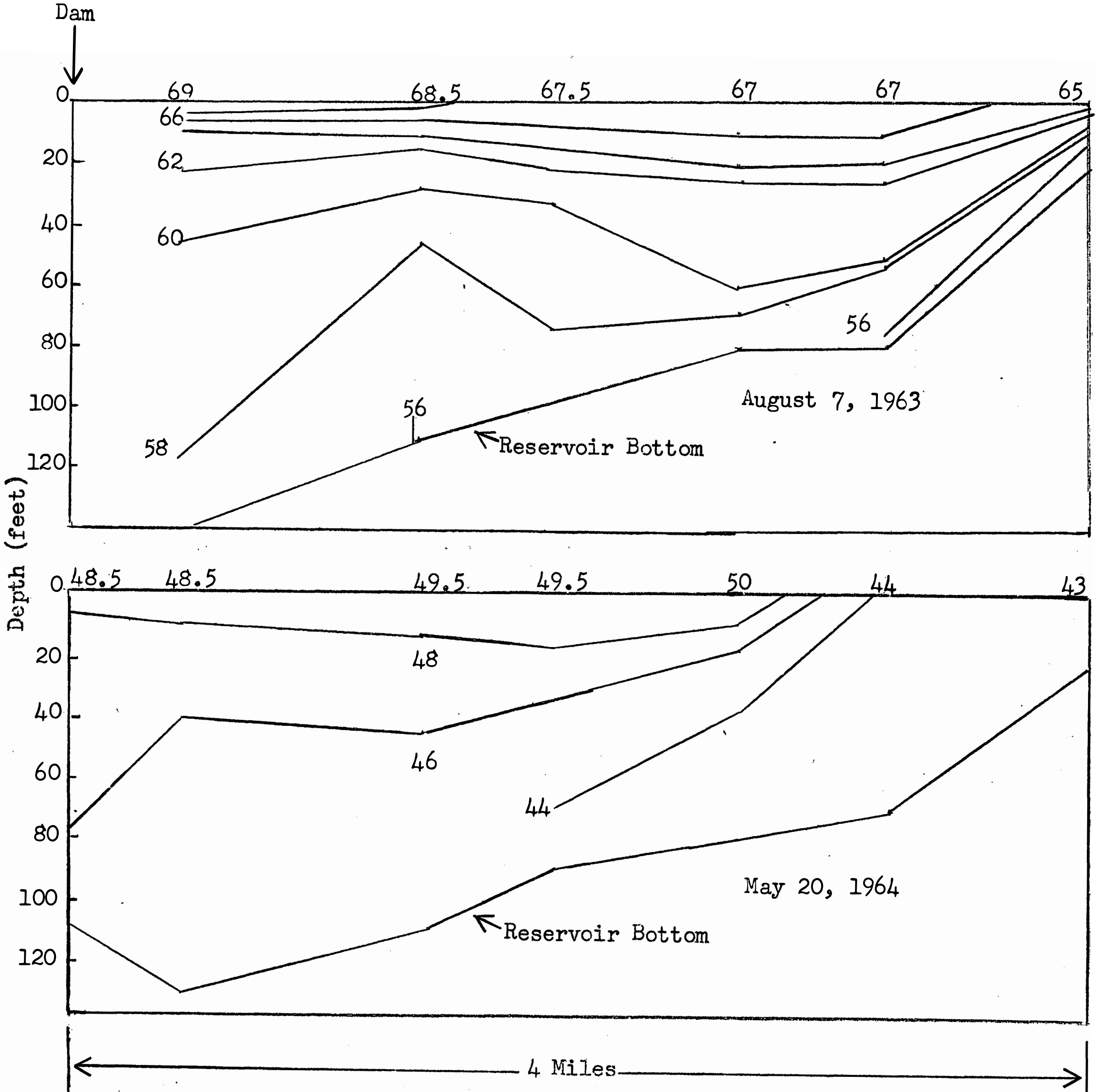

Figure 4. Temperature Profiles, North Fork Reservoir, August 7, 1963 and May 20, 1964. Isotherms: 2° F.

Table 1. Chemical Data, Area G, North Fork Reservoir, 1963-64.

Depth	Chemical Determination	Season: Winter	Spring	Summer	Fall
Surface	Dissolved Oxygen	13.0	11.5	9.5	9.5
	Total Alkalinity	24	20	24	32
	pH	7.50	7.25	7.25	7.50
Thermocline	Dissolved Oxygen	-	12.0	9.5	9.0
	Total Alkalinity	-	20	24	32
	pH	-	7.25	7.25	7.50
Bottom	Dissolved Oxygen	12.5	11.5	9.5	9.5
	Total Aklalinity	25	21	25	32
	pH	7.50	7.25	7.25	7.50

Oregon (Figure 5). It has a hydraulic head of 152 feet and forms a reservoir approximately 8 miles long, originally entered at the upstream end by the Deschutes and Metolius rivers. This condition is now changed by construction of Round Butte Dam which encroaches approximately ½ mile into Pelton Reservoir. Pool fluctuation averages 5 feet daily with a maximum of 7 feet anticipated. Downstream migrants may leave the reservoir by one of 4 exits: (1) the collection facility, provided specifically for this purpose; (2) the exit from the fish ladder which opens into the reservoir near the downstream migrant collection facility; (3) the penstocks submerged 142 feet; or (4) the spillway, with use not probable. Spring chinook and sockeye salmon and summer-run steelhead were present above Pelton at the outset of the study. Coho salmon were released for study purposes. Resident species include rainbow trout, Dolly Varden, brown trout, bass, sunfish, carp, suckers, squawfish, and chiselmouth.

Fish Behavior

Construction of Round Butte Dam prevented normal entry of juvenile salmonids into Pelton Reservoir, and created conditions which interfered with observations. As a result, limited information was obtained during the 2 years of study. Conditions in Pelton prior to, during, and after construction of Round Butte differ. The following description of fish behavior for Pelton Reservoir generally will not apply to future runs.

Timing and Movements

Chinook fry were observed in Pelton Reservoir in the spring during all years of study, but were less abundant after construction of Round Butte cofferdam. Hatchery coho fry were released into Pelton Reservoir in April 1963. Time of entry of rainbow-steelhead fry into Pelton Reservoir was not determined. Few were observed above Round Butte cofferdam in early summer, but by late summer and fall the population had increased substantially. Rainbow-steelhead in their second year were commonly caught above and below Round Butte cofferdam.

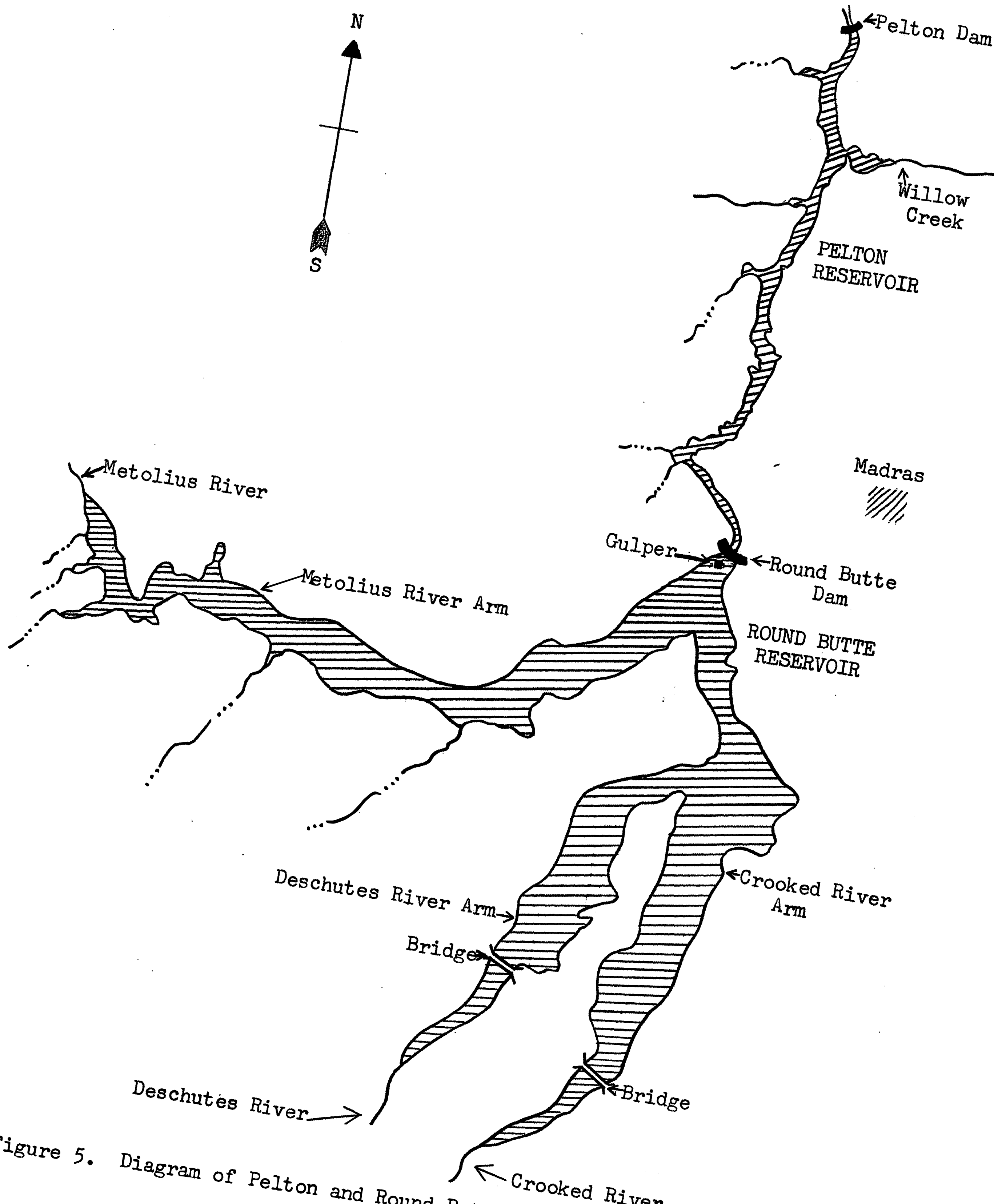

Figure 5. Diagram of Pelton and Round Butte Reservoirs.

It was not known if this group included steelhead.

Chinook fingerlings entered Pelton Reservoir from the Round Butte cofferdam, and left via the collection facilities with freshets or turbid water during the winter. Prior to construction of Round Butte, smolts entered Pelton Reservoir in the spring. Peak emigrations occurred through the collection system in April and May for chinook and May and June for steelhead. In 1964 the peak chinook emigration occurred in January, but closure of the Round Butte diversion tunnel in January prevented the normal entry of smolts in the spring. Coho liberated into Pelton as fry in 1963 emigrated mainly in April and May 1964.

Depth Distribution

Because of small catches, data on depth distribution are presented for 24-hour periods. Chinook and coho fry inhabited the surface, shoreline areas in the spring. Both species showed preference for depths of 15-30 feet during the summer when the water stratified and surface temperatures were 70° F or higher. In the winter, most chinook were captured between the surface and a depth of 15 feet. Some were found to a depth of 75 feet (Figure 6). Coho evidenced similar distribution. In the spring migration period, chinook smolts were found near the surface and away from the shoreline (Figure 6). Steelhead smolts also preferred the surface, but they were found inshore as well as offshore. Data are not available for coho smolts. Nets were not fished deeper than 75 feet.

Survival in Reservoir

Based on recovery rates at the skimmer of marked and tagged fish released into Pelton Reservoir, survival was poor. In April 1963, 400,000 unmarked and 8,000 marked coho fry were released into the reservoir, and experienced recovery rates at the collection facility of 0.5 and 0.4%, respectively, the following year. The survival of unmarked fish was maximal because recoveries may include coho planted in the Metolius River above Round Butte Dam.

Tagging of juvenile chinook in the winter and spring of 1963 (195 tagged) and 1964 (124 tagged) resulted in similar recovery rates of 15 and 14.5% respectively. The highest recovery rates were obtained from fish tagged in the winter, and more fish were tagged during that season. A total of 237 coho was tagged in 1963-64, and 13.5% were recovered at the collection facility. As with chinook, most fish were tagged in the winter and recovery rates were best from this group. The recovery rates of steelhead smolts tagged from April through June 1963 declined progressively from 50 to 20%. Of 491 steelhead smolts tagged, 28% were recovered at the skimmer. Survival as determined by recovery rates at the collection system was minimal because some fish may have passed through the turbines and fish ladder exits. Few fish leave by these routes as determined by the Pelton evaluation study.

Data on predation are limited, however several predatory species are present. Some predation occurred in the floating traps, but results may not be applicable to the reservoir environment. For the 2-week period following the release of coho fry in 1963, extensive predation was noted by Dolly Varden, brown and rainbow trout, suckers, squawfish, chiselmouth, and yearling chinook salmon.

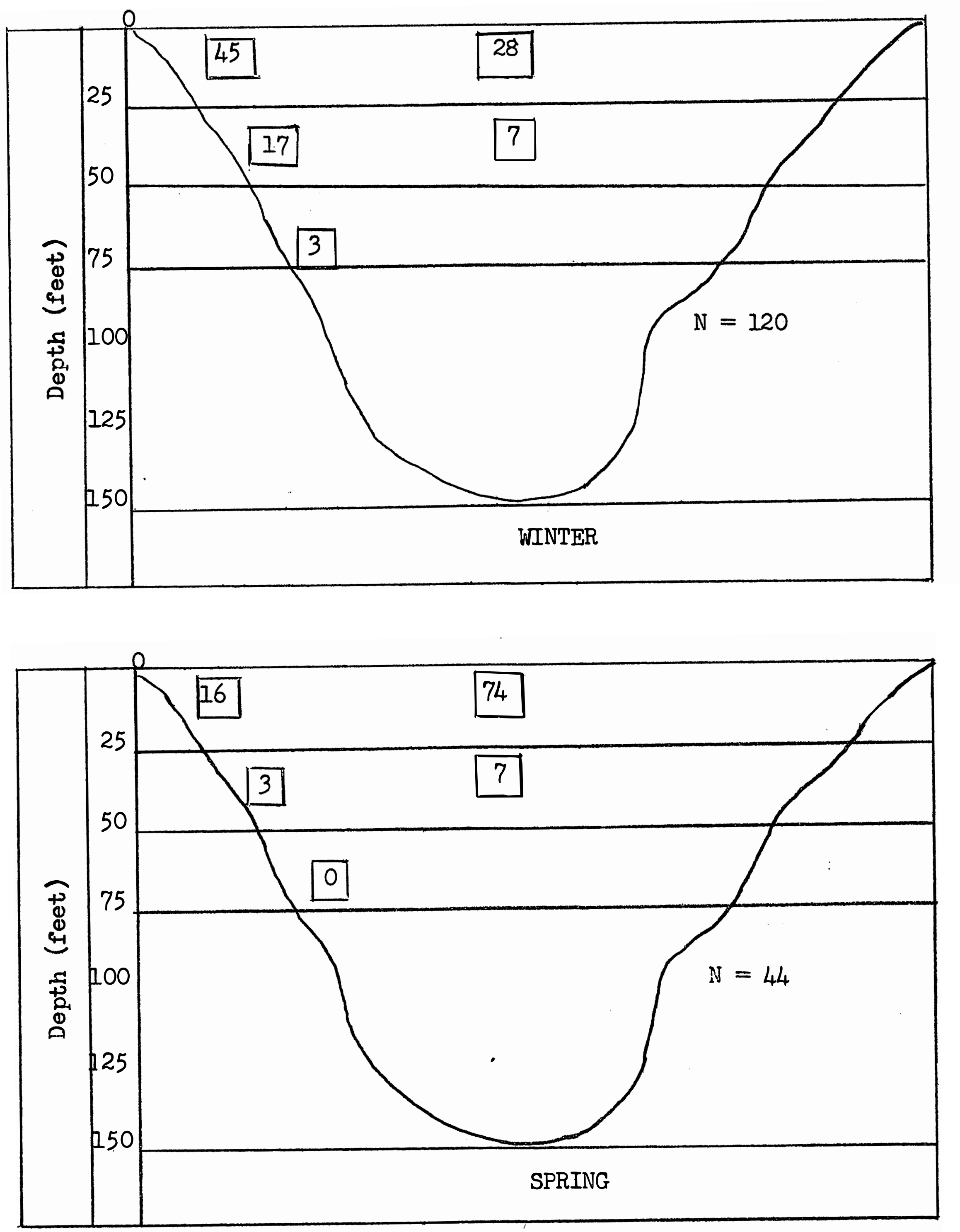

Figure 6. Depth Distribution of Chinook Salmon for a 24-hour Period as Shown by the Per Cent of Fish Caught at Five Fishing Positions in a Cross Section of Pelton Reservoir.

Sport catches of wild steelhead in the reservoir were estimated by the Bureau of Sport Fisheries and Wildlife as 3,390 in 1960 and 3,153 in 1961. Comparison of these catches with the respective counts at the fish facility of 10,355 and 4,267 fish indicated the sport fishery had a significant effect on the steelhead runs.

Passage Through Reservoir

The Pelton evaluation study measured the ability of salmonids to pass through the reservoir and enter the collection facility by releasing marked wild and hatchery fish into the Metolius and Deschutes rivers. Passage efficiency between the 2 years of the study differed for each species as follows: chinook-1960: 54-69%, 1961: 21-30%; steelhead-1960: 35-44%, 1961: 13-44%. Only 19% of a release of marked hatchery chinook in 1963 entered the collection facilities possibly due to the influence of Round Butte cofferdam.

Age and Growth

The apparently small populations of salmonids in Pelton Reservoir resulted in variable-sized samples and poor size and growth data. Coho salmon, released as fry in April 1963, grew rapidly that spring and summer and exhibited average and extreme sizes of 16.5 and 20.0 cm, respectively, by March 1964.

Chinook salmon, entering the collection facility during the fall and winter, had size modes at 11.0-11.5 and 19.0-21.0 cm. Age composition of the larger fish was not determined, but were thought to include 1- and 2-year olds. In the spring, chinook emigrants had one mode at 11.0-13.0 cm, and appeared to be stream-reared yearlings.

Steelhead smolts did not grow in Pelton Reservoir, although some were present for over 2 months. Multiple age groups of steelhead seemed probable, but scale analysis is incomplete.

Limnology

Physical Factors

Water temperatures at Pelton Reservoir appeared compatible with salmonid survival, and generally were not extreme during the spring downstream migration period. Temperatures at the water surface seldom exceeded 75° F during the summer, and usually remained near 70° or slightly lower. The August 10, 1964 profile in Figure 7 is typical for summer at Pelton Reservoir. The highest surface water temperatures usually occurred near the upper end of the reservoir, while those at the dam were generally several degrees cooler. A thermocline formed in the upper reservoir between the surface and a depth of 15 feet, but stratification was weaker in the lower reservoir.

Water temperatures declined in late August, and were isothermal by the last of October. Pelton Reservoir warmed at a faster rate than North Fork during the spring and by May 13, 1964 surface temperatures near the dam were in the mid-50's (Figure 7). Weak stratification occurred.

Mean daily discharge was recorded at Pelton Dam. Discharge is considered an accurate measure of inflow since pool fluctuation was slight. In 1963 the minimum flow of 3,600 cfs occurred in December and the maximum flow of

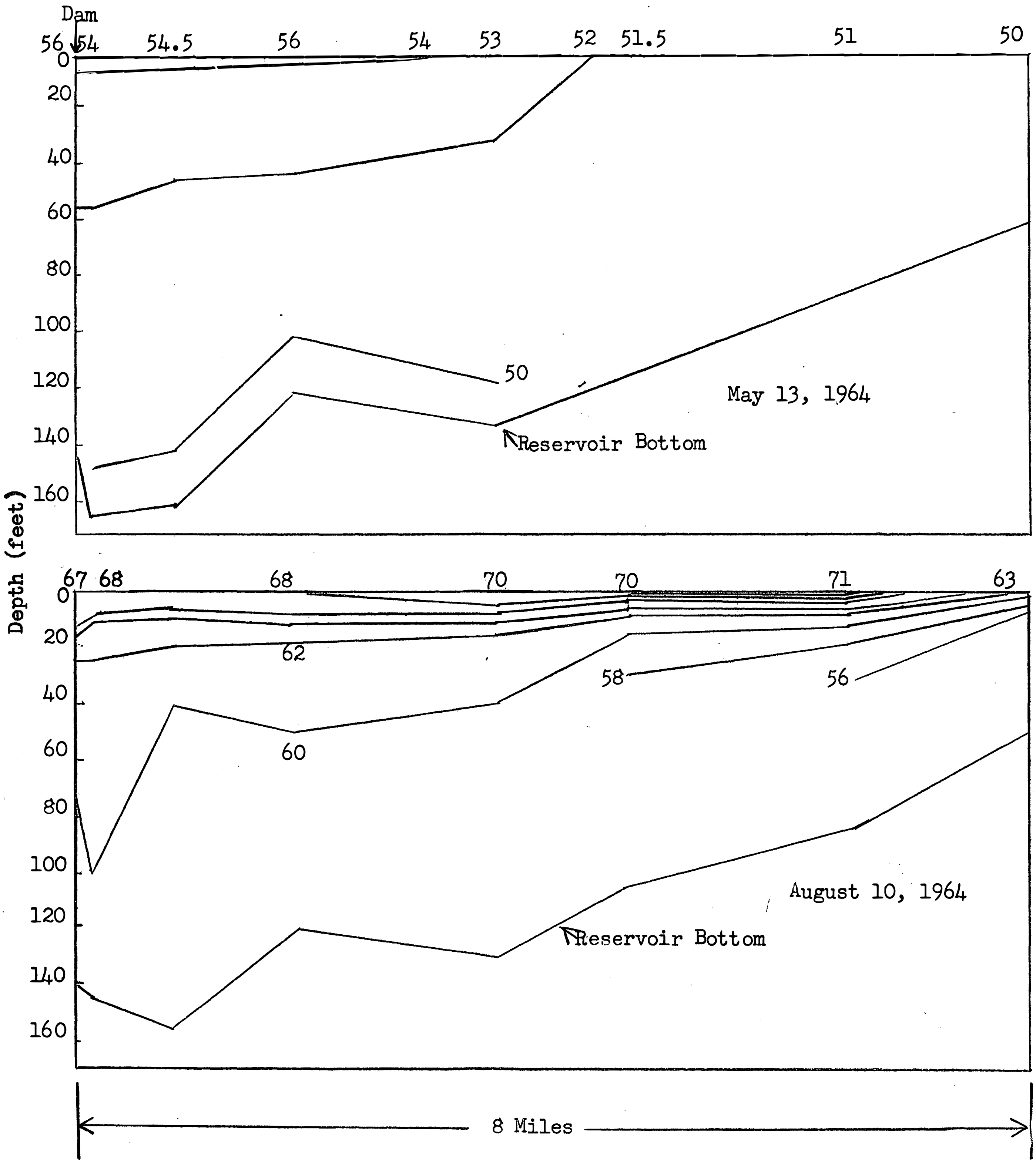

Figure 7. Temperature Profiles in Pelton Reservoir, May 13 and August 10, 1964.
Isotherms: 2° F.

7,100 cfs was in February. Less variation in flow will probably occur in the future because of Round Butte Dam. The mean daily flow during the spring was 4,600 cfs in 1963; it was 3,500 cfs in 1964 and will be similar to this in future years because of the Round Butte operating schedule. Spill occurred twice since construction of Pelton Dam, but was not caused by high water.

Construction of Round Butte Dam adversely affected water clarity in Pelton Reservoir during the past 2 years. In the past year, Secchi disc water visibility varied from 2.0 feet in January 1964, when restriction of the tunnel gate at Round Butte created turbulent inflow conditions at Pelton, to 32.0 feet in December 1963. The highest water visibilities occurred in the winter, during periods of cold weather and relatively low flow. Phytoplankton blooms reduced water clarity during the summer.

Water currents were not measured during the spring migration season. Measurements were made in July 1964, after formation of a thermocline between the water surface and a depth of 10 feet. Most currents measured moved in a down-reservoir direction, but in the area below the shearline, surface currents moved up-reservoir. These and other measurements indicated the thermocline may affect direction of water currents.

Chemical Factors

Dissolved oxygen concentrations at all depths in Pelton Reservoir were adequate for salmonid life throughout the past year. Total alkalinity was 2-3 times greater than that measured at North Fork, and may have a bearing on productivity since fish at Pelton attained larger maximum sizes. Values of pH appear compatible with fish life. Table 2 shows selected seasonal values of oxygen, total alkalinity, and pH taken near Pelton Dam from the surface, thermocline, and bottom of the reservoir.

Biological Factors

Zooplankton and bottom samples, and stomach samples from gill-netted fish were taken as at North Fork. Samples were not obtained from Pelton throughout the year since all fish behavior activities were transferred to Round Butte Reservoir in the spring of 1964.

Meteorological Factors

Collection of meteorological data at Pelton Reservoir was similar to that at North Fork. The data have not been analyzed.

ROUND BUTTE RESERVOIR

Introduction

Round Butte Dam is located at the upper end of Pelton Reservoir. It forms an impoundment composed of the Metolius, Deschutes, and Crooked River arms, which at full pool will be 12, 8.5, and 6 miles long, respectively (Figure 5). At maximum pool the dam will have a hydraulic head of 365 feet. Pool fluctuation will average 1 foot daily with a maximum of 85 feet anticipated.

Downstream migrants will leave the reservoir by one of 4 exits: (1) the permanent collection facility at the dam which will operate through a pool

Table 2. Chemical Data, Area I, Pelton Reservoir, 1963-64.

Depth	Chemical Determination	Season			
		Winter	Spring	Summer	Fall
Surface	Dissolved Oxygen	11.0	14.0	10.0	10.5
	Total Alkalinity	63	60	68	68
	pH	7.75	8.50	8.75	7.75
Thermocline	Dissolved Oxygen	-	14.0	9.5	-
	Total Alkalinity	-	59	61	-
	pH	-	8.50	7.75	-
Bottom	Dissolved Oxygen	11.0	11.0	8.5	10.0
	Total Alkalinity	63	60	59	71
	pH	7.75	8.00	7.75	7.75

fluctuation of 22 feet, (2) a floating collection facility or "gulper" which may be moved to any point in the reservoir, (3) the penstocks, submerged to 219 feet, or (4) the spillway. Spill is predicted to occur once in 100 years. In 1964 the by-pass tunnel was also available for fish passage, but was located below a depth of 200 feet during most of the spring migration period. Round Butte Reservoir should contain the same species of fish as are found in Pelton.

Closure of Round Butte Dam occurred in January 1964 and the water level during most of the spring migration period was 70-80 feet below full pool. As a result the only exits available to salmonid migrants were the gulper; the penstocks, located at depths in excess of 100 feet and operated intermittently during this period; and the by-pass tunnel.

Fish Behavior

Timing and Movements

Hatchery coho, released into the upper Metolius River, and wild chinook salmon entered the Round Butte cofferdam pool as fry in the spring of 1963. Chinook fry were also observed in the Metolius River arm of Round Butte Reservoir in the spring of 1964. Large numbers of coho remained in the river through March, and appeared in the upper Metolius arm of the reservoir as smolts in mid-April 1964. Time of entry of chinook and steelhead smolts into Round Butte was not learned.

Emigration of salmonids from Round Butte Reservoir was described by catches made at the gulper during the spring of 1964. Some fish emigrated through the penstocks or by-pass tunnel after closure of Round Butte Dam, but counts at the Pelton collection facility indicate passage by those outlets was not significant. Chinook and coho smolts peaked at the gulper in late May and early June, respectively. Steelhead smolts were not caught in significant numbers by this facility. Downstream migration ceased in early July even though large numbers of smolts of each species remained in the reservoir. The fish gradually lost the smolt appearance thereafter.

Intra-reservoir migrations of salmonid smolts in the spring indicated the fish did not readily find the gulper. All species congregated in the upper Metolius arm of the reservoir, where the coldest water temperatures occurred. Up-reservoir surface water currents in this arm may have been a contributing factor. Some coho and marked hatchery chinook salmon, which originated entirely in the Metolius River, migrated to the Deschutes and Crooked River arms of the reservoir, and to the gulper. A few chinook and coho migrated to the gulper from all tagging points in the reservoir, but several remained in the upper Metolius arm where they were tagged. Steelhead smolts, which appeared the most confused, originated mainly in the Deschutes River; but large numbers were trapped in the upper Metolius arm of the reservoir. Tagging showed that steelhead moved predominantly from the Deschutes arm to the Metolius arm where they remained throughout the spring migration period (Figure 8). Few tagged steelhead were recovered at the gulper.

In early June all available Fish Commission traps were placed in the upper Metolius arm of Round Butte Reservoir to aid in the collection of salmonid smolts for transport below the dam. Many juveniles were collected and transported, but data on intra-reservoir migrations were curtailed.

Depth Distribution

Limited depth distribution data are available since emphasis was placed on trapping and tagging and observations were only in the spring. Coho fry, released directly into the reservoir, were observed near the water surface; and smolts of all species were found distributed from the surface to the maximum depth of 45 feet in the upper Metolius arm of the reservoir.

Survival in Reservoir

Data on survival of salmonids in Round Butte Reservoir were poor, because work did not commence until spring and many smolts did not enter the collection facilities. Totals of 8,000 marked coho fry and 2,900 tagged coho fingerlings were released into the Metolius River in 1963, and recovery rates from all collection gear in the reservoir were 1.0 and 2.0%, respectively. Because of the residualism problem, these are minimum rates of survival of fish primarily stream-reared with varying amounts of reservoir life after January 1.

A total of 1,200,000 coho fry, including 120,000 marked fish, was released into Round Butte Reservoir in February 1964. This experiment will measure survival of coho during the first year of reservoir existence, providing collection of migrants is successful next spring. Predation occurred on the coho fry by Dolly Varden and mergansers.

Estimates of sport fishing mortality were not made. Chinook and coho have remained in the sport fishery since the season opened this spring. Sport fishermen reported the capture of 3.0% of the tagged steelhead in the reservoir. Many recoveries probably were not reported since the tags were inconspicuous and tagging was not highly publicized.

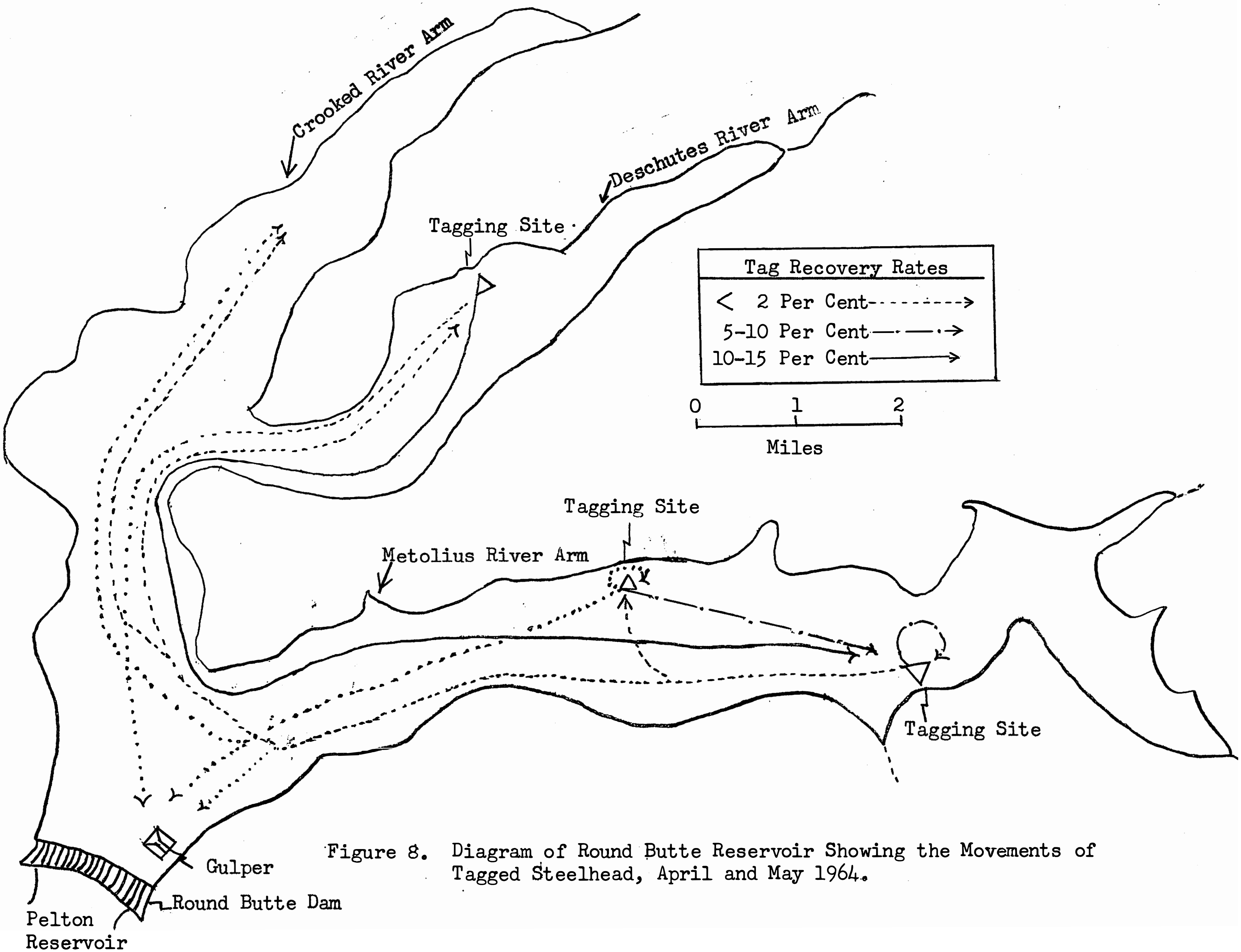

Figure 8. Diagram of Round Butte Reservoir Showing the Movements of Tagged Steelhead, April and May 1964.

Passage Through Reservoir

The release of tagged salmonid smolts into the reservoir and their subsequent recovery rates at the gulper showed passage efficiency at Round Butte was poor. Tagged chinook, coho, and steelhead experienced recovery rates of 11.0, 12.5, and 1.0%, respectively.

Marked hatchery yearling chinook, released into the upper Metolius River on April 1, 1963, exhibited a recovery rate at the gulper of only 1.5%. These fish behaved abnormally and did not enter the reservoir in substantial numbers until late May.

Age and Growth

Coho salmon released into the reservoir as 4.0-cm-long fry in February 1964 averaged 8.5 cm by June. For a similar period, coho fry released into the Metolius River were about 3 cm smaller. Coho tagged and released into the reservoir in April, and recovered in early June, grew an average of 1.5 cm. In June coho in the reservoir showed two modes at 8.0 and 14.0 cm.

Chinook salmon caught in traps during March had modes of 11.5 and 15.5 cm, while those entering the gulper in May showed a single mode at 13.0-13.5 cm. Tagged chinook smolts evidenced little growth in the reservoir during the spring of 1964.

The size of most steelhead smolts caught in Round Butte Reservoir during the spring of 1964 ranged from 14.5-26.5 cm with no mode evident. A few fish exceeded 30.0 cm. Tagged steelhead smolts showed little growth in the reservoir.

All coho and most chinook emigrants were yearling fish in the spring of 1964. Age data for steelhead were not analyzed.

Limnology

Only physical and chemical data were collected at Round Butte Reservoir in early 1964. Biological samples will be collected in conjunction with gill netting beginning in September 1964.

Physical Factors

Temperature stratification occurred in Round Butte Reservoir in January 1964, shortly after closure of the diversion tunnel (Figure 9). The Metolius arm is shown, but similar patterns existed in all 3 arms. Stratification in the winter was caused by the layering of the Metolius, Deschutes, and Crooked rivers with water temperatures of 40°, 42°, and 52.5° F, respectively. The stratified layer gradually moved upstream as the reservoir filled.

In May, when smolts were migrating, surface water temperatures of the Metolius River arm were about 54° F; and the Metolius River was 44.0° F (Figure 10). By July 24, after downstream migration terminated, the reservoir was strongly stratified (Figure 10); and water temperatures reached 71.5° F in the Metolius River arm, and 68.5° at the dam. The Metolius River was 48° F.

Discharge from Round Butte was similar to that at Pelton in 1964. Inflow

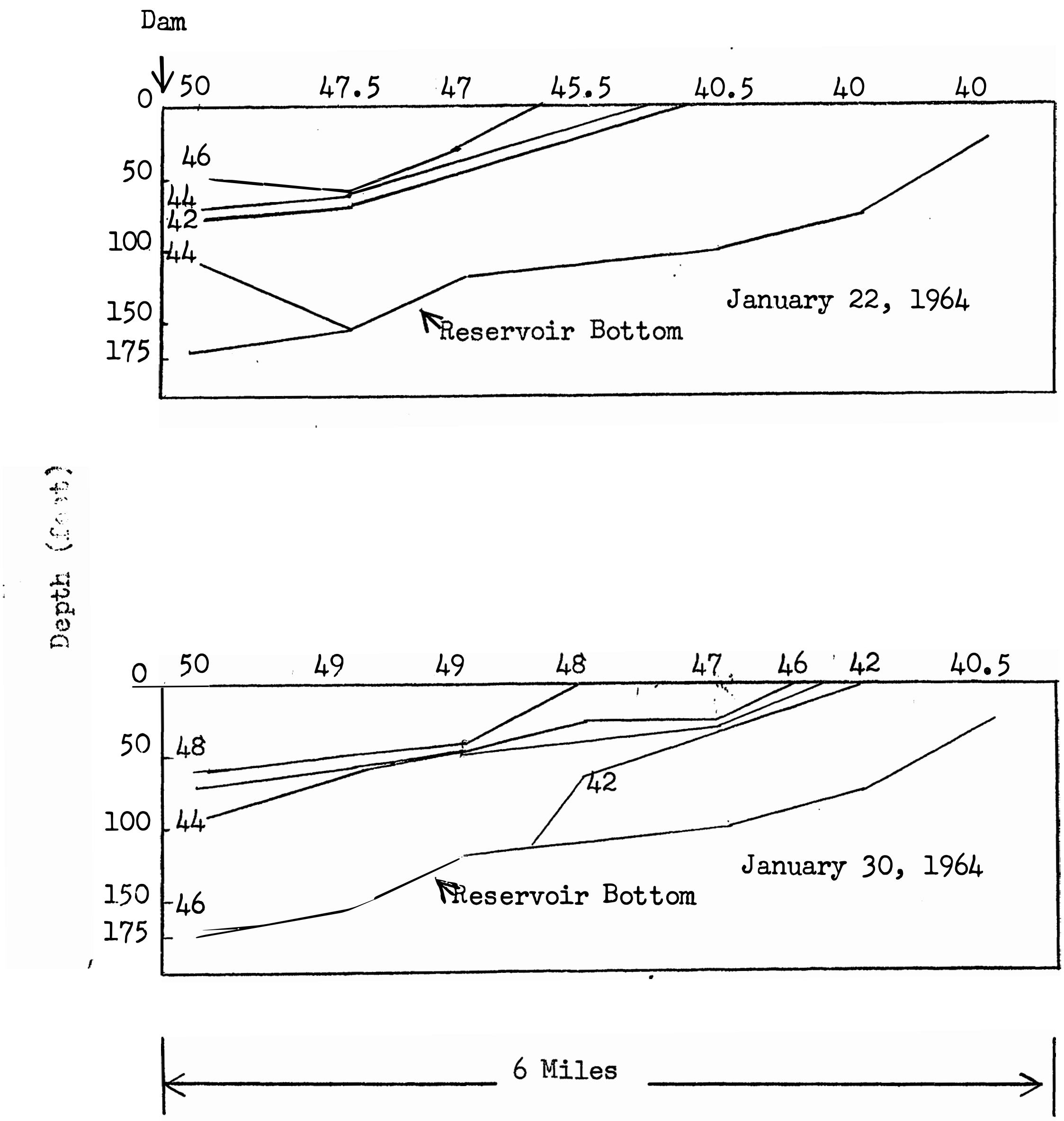

Figure 9. Temperature Profiles in Metolius River Arm of Round Butte Reservoir, January 22 and 30, 1964. Isotherms: 2° F.

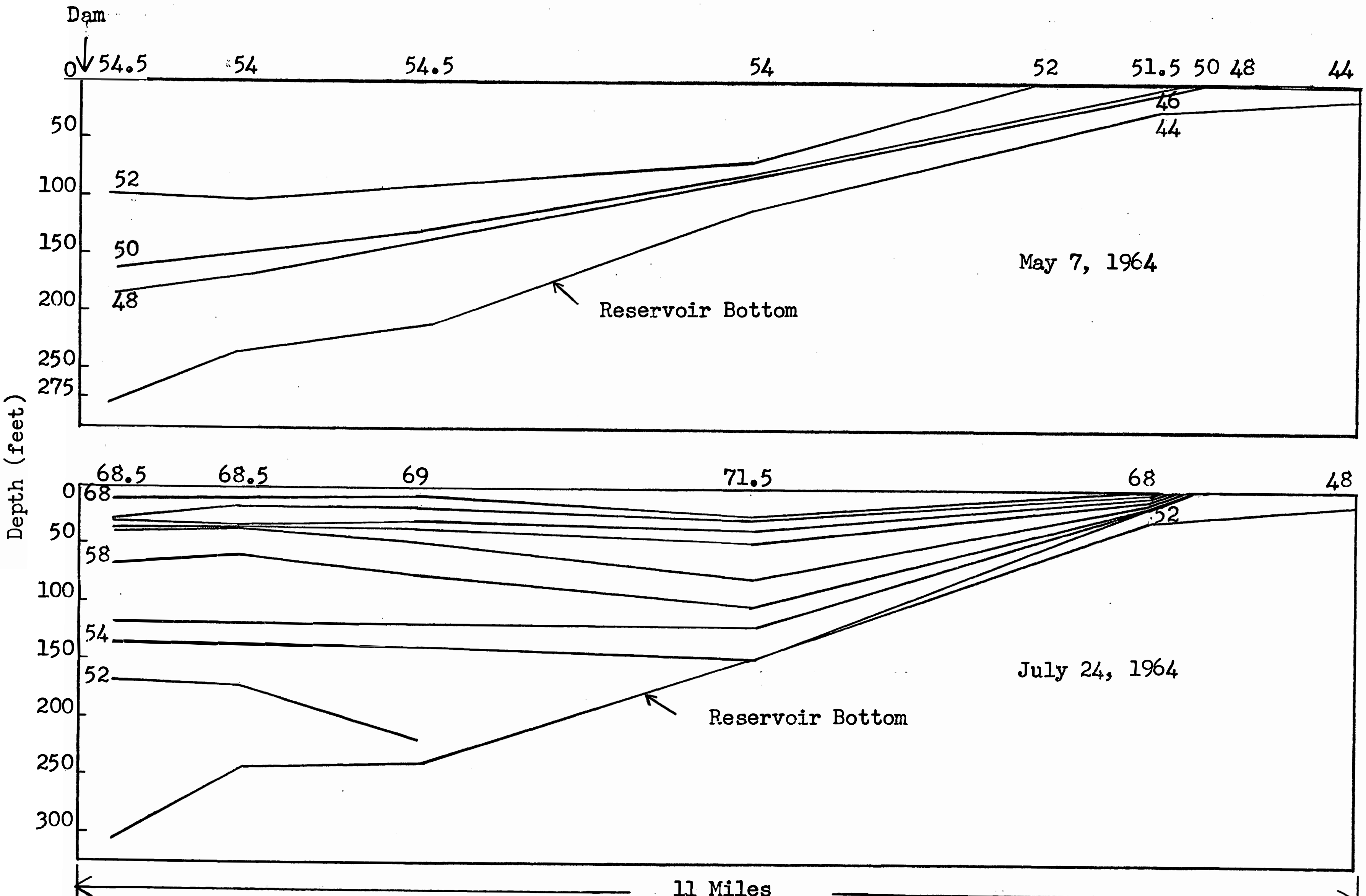

Figure 10. Temperature Profiles in Metolius River Arm of Round Butte Reservoir, May 7 and July 24, 1964. Isotherms: 2° F.

was not determined.

Water clarity was generally poor in the reservoir throughout the spring due to phytoplankton blooms in all areas except above the shearline in each arm.

Prevailing winds blew down the Deschutes arm of the reservoir and up the Metolius arm during most of May. Water between the surface and a depth of 20 feet moved in the same direction as the wind.

Chemical Factors

Dissolved oxygen in Round Butte Reservoir was generally adequate for fish life from January-July 1964, but some oxygen deficiencies occurred in the Crooked River arm at depths below 150 feet in June and July. Total alkalinity was highest in the Crooked River and lowest in the Metolius River. Table 3 shows selected seasonal values of oxygen, total alkalinity, and pH taken near the dam from the surface, middle of the thermocline, and bottom of the reservoir. Data for the fall of 1963 were obtained from the cofferdam pool. Occasional pH values of 9 were found in the surface waters of the reservoir, and may be due to phytoplankton.

Table 3. Chemical Data, Area II-F, Round Butte Reservoir, 1963-64.

Depth	Chemical Determination	Season			
		Winter	Spring	Summer	Fall (1963)
Surface	Dissolved Oxygen	10.0	15.0	9.0	10.5
	Total Alkalinity	84	79	86	79
	pH	8.0	8.75	8.25	7.75
Thermocline	Dissolved Oxygen	-	9.0	8.0	10.5
	Total Alkalinity	-	77	84	64
	pH	-	8.25	8.25	7.75
Bottom	Dissolved Oxygen	10.6	6.5	7.0	11.0
	Total Alkalinity	64	59	54	57
	pH	7.75	8.25	7.75	7.75

DISCUSSION

This study has resulted in some generalizations on the behavior of juvenile salmonids and characteristics of the environment in North Fork, Pelton, and Round Butte reservoirs. Some of the most important similarities and differences in fish behavior at the 3 projects are as follows:

1. Some fish of all species entered the reservoirs as fry. Migration of smolts began first at Pelton and started with chinook. Steelhead

migrated earlier at North Fork than at Pelton.

2. Movement in all reservoirs was stimulated by freshets and muddy water. Steelhead and salmon smolts moved directly through North Fork, but wandered in Pelton and Round Butte.

3. Smolts were found at similar depths in the spring in all 3 reservoirs.

4. Survival of all species was very good at North Fork and poor at Pelton. Data are lacking on survival at Round Butte.

5. Smolts passed successfully through North Fork Reservoir. Passage efficiency at Pelton was about one-half that of North Fork, and was even less successful at Round Butte.

6. Essentially no smolts remained in North Fork beyond the normal time of emigration, but some smolts did not migrate at Pelton and large numbers remained in Round Butte after the spring migration.

7. Species composition differed in that squawfish and spiny rayed fish are found in Pelton (and presumably Round Butte), but not in North Fork. Their presence may indicate predation and perhaps an environmental difference.

8. Smolts and holdover juveniles concentrated in the upper Metolius arm of Round Butte Reservoir, and this was peculiar only to this area.

Since the anadromous species are similar at these reservoirs, differences in behavior very possibly are related to differences in the environment. The environments differed in the following ways:

1. Pelton and Round Butte warmed earlier in the spring, and maximum temperatures were a few degrees higher than at North Fork.

2. North Fork was least alkaline of all the reservoir areas, and the Metolius arm was less alkaline than other areas of Round Butte.

3. The pH was highest at Round Butte and lowest at North Fork.

4. Up-reservoir currents were more prominent and deeper in the Metolius arm of Round Butte than other reservoir areas tested.

5. Spill occurred only at North Fork.

6. The ratio of river flow to reservoir capacity indicates that replacement of water in the reservoirs is most frequent at North Fork and least frequent at Round Butte.

7. The climate is wet at North Fork and arid at Pelton and Round Butte.

In addition to the biological and limnological observations, physical characteristics also show an interesting relationship. North Fork is the smallest reservoir and Round Butte the largest from the standpoints of length, surface area, and depth.

The significance of these differences in behavior and environment is how they have affected the status of the stocks passing above each of the projects. The status of the runs can best be determined by examining records of counts of fish at the passage facilities. Relationships of the counts show trends of numbers of adults and juveniles, production in terms of smolts counted at the dam for each parent spawner, survival of smolts from emigration until return to the project as adults, and a comparison of the number of returning adults to the number of parent spawners.

Stocks at North Fork appear in good condition. Trends in counts of adults are generally upwards. Counts of juveniles vary annually in accuracy due to the frequency and timing of spills. Increases in the number of adults returning from their parent year have occurred for all species in all years except one. The increase is probably influenced by a passage facility constructed as part of the North Fork project which by-passes juveniles around the 3-dam complex. Passage downstream was formerly through the turbines of the lower two dams except when spill occurred. Spill rarely occurred during the spring migration season.

The stocks at Pelton show a steady decline. In all years returning adults of all species are fewer than the number of parents. Based on the numbers of smolts counted per adult and other data, failure to maintain the level of the runs appears due to factors above Pelton Dam.

Since Round Butte is upstream and adjacent to Pelton, stocks at these two dams are affected similarly. Counts at both Pelton and Round Butte indicate severe passage problems for downstream migrants in 1964 in Round Butte. Temporary passage facilities currently at Round Butte will be supplemented by the permanent collector in the spring of 1965 if the reservoir is filled at this time.

It is concluded on the basis of fish counts, passage efficiency, survival, and lack of holdover smolts that the environmental and biological phenomena of North Fork Reservoir are compatible with the life cycles of spring chinook, coho, and winter steelhead, but conditions at Pelton and Round Butte reservoirs have adverse effects upon the runs passing these projects. Some clues are evident as to the reasons why juvenile salmonids are successful or unsuccessful in migrating through a reservoir, but confident prognostication of passage success at future reservoirs cannot be made without additional study.