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THE EFFECT OF SMALL IMPOUNDMENTS ON THE BEHAVIOR OF JUVENILE ANADROMOUS SALMONIDS

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RESEARCH DIVISION

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THE EFFECT OF SMALL IMPOUNDMENTS ON THE BEHAVIOR OF JUVENILE ANADROMOUS SALMONIDS

INTRODUCTION

One obstacle to predicting the success or failure of passing juvenile anadromous salmonids through a reservoir is a lack of knowledge of the relationship between the environment of the reservoir and the behavior of the fish. On February 20, 1962, the Bureau of Commercial Fisheries signed a contract requiring the Fish Commission of Oregon to determine this relationship at North Fork and Pelton reservoirs, two hydropower projects owned by Portland General Electric Company. These sites were chosen for study since they were relatively small, possessed facilities for counting upstream and downstream migrants, and were located in areas with different climates. Round Butte Dam, completed in 1964 by PGE, blocked the downstream migration of juvenile fish into Pelton Reservoir. The behavior study was subsequently transferred from Pelton to Round Butte Reservoir.

We felt the results of our study should have practical application at future impoundments in deciding (1) if passage should be attempted, (2) whether downstream migrants should be collected in the reservoir or in the tributaries entering the reservoir, (3) whether collection facilities should be at the dam or elsewhere in the reservoir, and (4) what design and operating criteria should be incorporated into collection facilities in the reservoir. With this application in mind, we formulated specific objectives. These were to determine:

1. the timing of migrations and intra-reservoir movements of juvenile fish in the reservoirs;
2. seasonal, diel distribution of fish, by depth, through a cross-section of each reservoir;
3. survival of fish in the reservoirs;
4. efficiency of collection at the fish passage facilities;

5. the influence of age and growth on behavior; and
6. the relationships between environmental conditions and behavior of fish.

Funds totalling $291,000 were made available to the Fish Commission under the Accelerated Fish Passage Research Program. Field studies were completed by June 30, 1965. An additional 18 months was needed to analyze data and prepare this final report and publications.

STUDY AREAS

North Fork Reservoir

Description of area

North Fork Dam is the uppermost of a three-dam complex on the Clackamas River in western Oregon (Figure 1). It is 29 miles upstream from the confluence of the Clackamas with the Willamette River, a major tributary of the Columbia River. The dam has a hydraulic head of 134 feet and forms a reservoir 4 miles long with a surface area of 330 acres and a storage capacity of 18,630 acre feet. The Clackamas River and one small tributary flow into the reservoir. The project operates on a peaking schedule, and the pool fluctuates about 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 240 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 that enter the collection system must swim down the fish ladder to Cazadero Dam where they are counted and placed in a pipeline which discharges them below River Mill Dam. Juvenile salmonids leaving through the other exits pass over the spillways or through the turbines of the lower two projects.

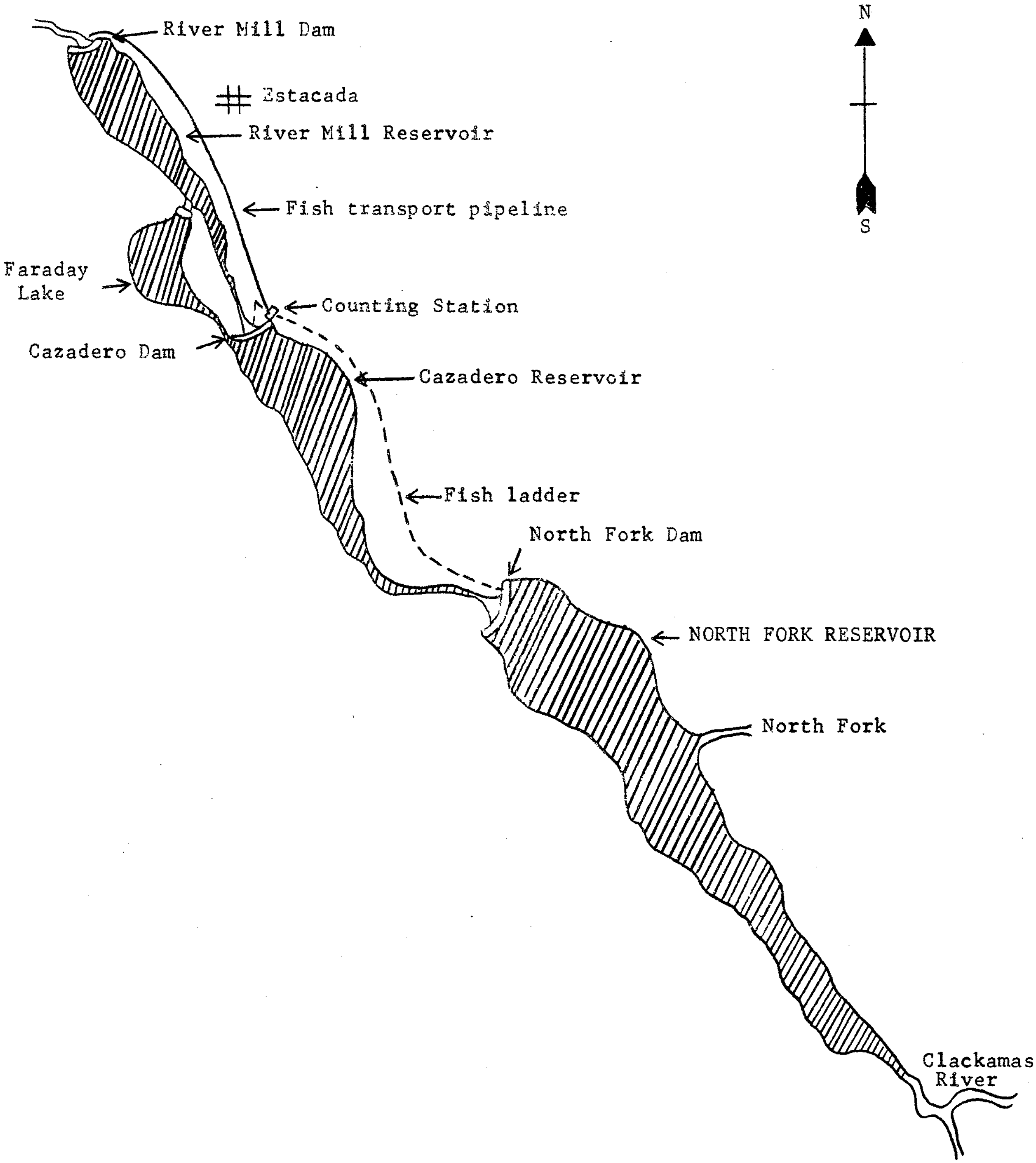


Figure 1. Diagram of three-dam complex located on the Clackamas River.

Spring chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) salmon and winter-run steelhead trout (Salmo gairdneri) 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 and dace are numerous.

History of fish runs

Cazadero and River Mill dams were constructed early in this century, and the lack of a fish ladder at the former prevented the migration of adult salmon and steelhead past that point for almost 35 years. An inadequate facility constructed in 1938 allowed some fish to migrate into the upper watershed. Counts of adult salmonids passing River Mill Dam from 1950 to 1955 (Table 1) indicate the numbers of anadromous fish available to pass the North Fork site during those years, but some of these fish spawned in the area between Cazadero and River Mill dams.

Table 1. Annual counts of upstream-migrant salmonids, River Mill Dam, 1950-55. 1/

Year \ Species	Chinook	Coho 2/	Steelhead
1950	170	--	--
1951	366	416	1,484
1952	496	751	1,952
1953	627	1,378	1,559
1954	536	1,124	1,625
1955	407	1,155	950

1/ Jacks included.
2/ Counts of coho extend from October of one year to February of the following year. The counts are listed after the year migration ended.

Annual counts of adult salmon and steelhead at North Fork Dam since its completion in 1959 indicate the project has aided passage (Table 2). The total annual counts for each species at North Fork are generally equal to or better than the counts made previously at River Mill, even though some fish

Table 2. Annual counts of upstream-migrant salmonids at North Fork Dam including a comparison of adults with parent runs, 1958-66.

Species and year	Total counts 1/	Adults	Parent adult 3 years previously	Parent adult 4 years previously	Parent adult 5 years previously
Chinook					
1958	475(88)	387	--	--	--
1959	578(279)	299	--	--	--
1960	287(110)	177	--	--	--
1961	370(145)	225	--	--	--
1962	666(96)	570	--	387	--
1963	616(82)	534	--	299	387
1964	450(104)	346	--	177	299
1965	511(204)	307	--	225	177
Coho 2/					
1959	522(213)	309	--	--	--
1960	1,330(284)	1,046	--	--	--
1961	2,185(1,516)	669	--	--	--
1962	2,189(740)	1,449	309	--	--
1963	3,121(454)	2,667	1,046	--	--
1964	1,879(1,366)	513	669	--	--
1965	2,475(599)	1,876	1,449	--	--
1966	3,936(625)	3,314	2,667	--	--
Steelhead					
1958	1,648	1,648	--	--	--
1959	556	556	--	--	--
1960	1,148	1,148	--	--	--
1961	2,204	2,204	--	--	--
1962	4,365	4,365	--	1,648	--
1963	2,242	2,242	--	556	1,648
1964	1,889	1,889	--	1,148	556
1965	1,551	1,551	--	2,204	1,148

1/ Numbers of jacks in parentheses are included in totals.

2/ Counts of coho extend from October of one year to February of the following year. The counts are listed after the year migration ended.

counted at River Mill spawned in the area between the two projects. With one exception, the counts of adult chinook and steelhead for each year from 1962 to 1965 at North Fork were higher than those of their parents 4 or 5 years previously; and, again with one exception, more adult coho returned each year than adult parents 3 years earlier.

Pelton and Round Butte Reservoirs

Description of area

Pelton Dam is the lower of two dams (Figure 2) on the Deschutes River, about 95 miles upstream from its confluence with the Columbia River, near Madras in central Oregon. It has a hydraulic head of 152 feet. The reservoir is 7-1/2 miles long with a surface area of 611 acres and a storage capacity of 37,300 acre feet. Peaking at this project causes pool fluctuations averaging 5 feet daily with a maximum of 7 feet anticipated. Downstream migrants may leave the reservoir by one of four 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, seldom used. The Deschutes and Metolius rivers originally entered the upstream end of the impoundment, but this condition was changed by construction of Round Butte Dam which encroaches approximately 1/2 mile into Pelton Reservoir.

Round Butte Dam forms an impoundment composed of the Metolius, Deschutes, and Crooked River arms, which at full pool are 12, 8-1/2, and 6 miles long, respectively (Figure 2). At maximum pool level the dam has a hydraulic head of 365 feet, and the reservoir has a surface area of almost 4,000 acres and a storage capacity of 525,022 acre feet. The pool fluctuates about 1 foot daily with a maximum seasonal variation of 85 feet anticipated. Downstream migrants may leave the reservoir by one of four exits: (1) the permanent collection facility at the dam which operates through a pool fluctuation of 22 feet; (2) a

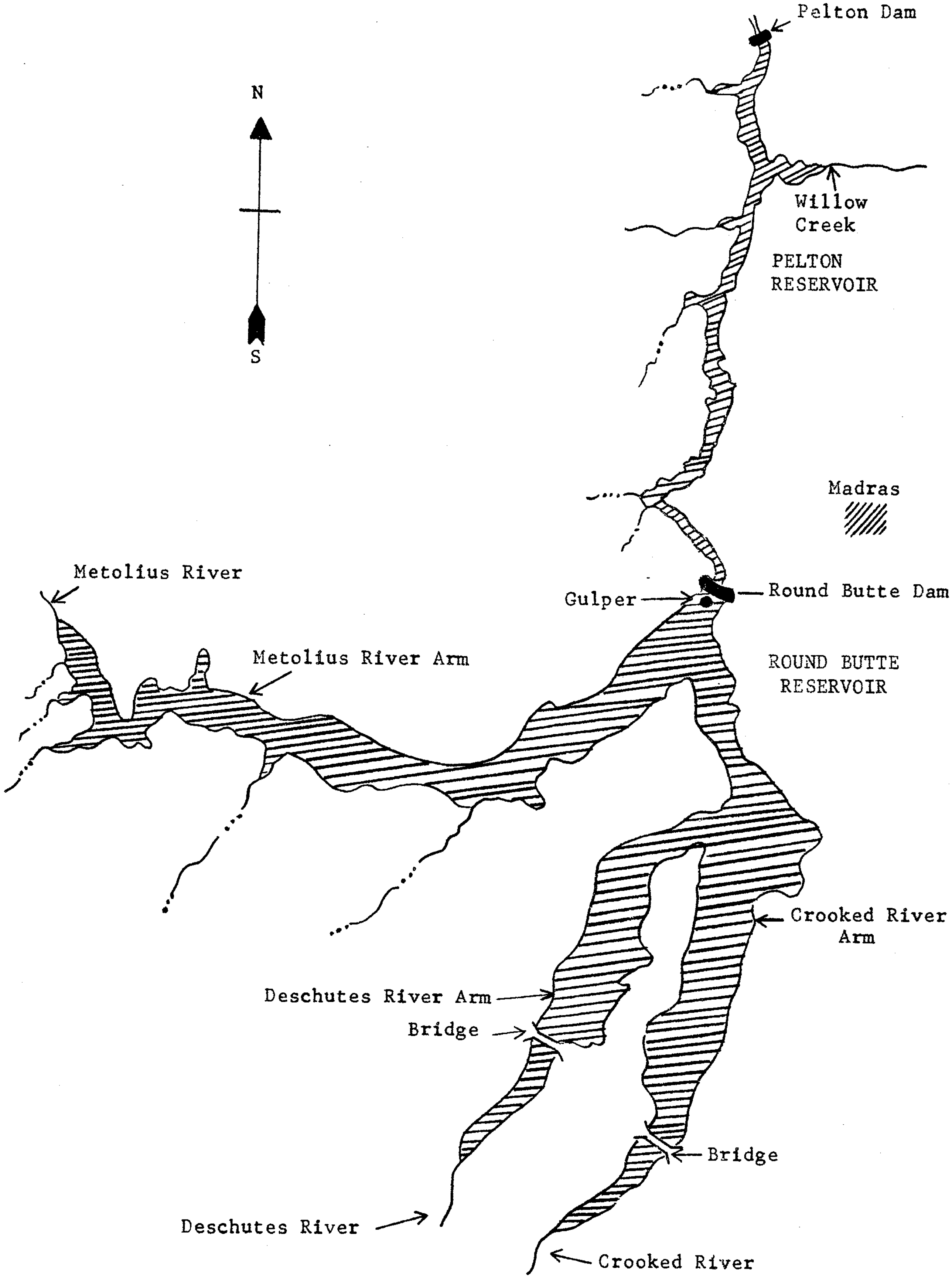


Figure 2. Diagram of Pelton and Round Butte Reservoirs.

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 over 200 feet below the surface during most of the spring migration period.

Spring chinook and sockeye salmon (O. nerka) and summer-run steelhead were present above these projects 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.

History of fish runs

Little data are available on the populations of anadromous fish in the Deschutes River prior to the completion of Pelton Dam in 1958. The counts of upstream migrants since construction indicate the chinook and steelhead stocks produced above the project may be in jeopardy (Table 3). While the total annual counts of chinook remained relatively stable from 1957 to 1965, the incidence of jacks increased markedly in the last 3 years. This could mean decreased potential production if the ratio of males to females in the adult runs remained constant over the entire period. The counts of steelhead in 1958 and 1959 were much greater than for the years following, but those of the past 6 years have varied little. Nonetheless, fewer adult chinook and steelhead were counted from 1962 to 1965 than adult parents 4 or 5 years previously. This indicates problems in perpetuating the runs of anadromous fish above Pelton Dam. Juvenile salmonids have not emigrated successfully from Round Butte Reservoir since it began to fill in January 1964. Even fewer adults will return in the future unless this situation is corrected.

EQUIPMENT AND METHODS

Gill nets and SCUBA gear were chosen as study equipment as a result of a literature survey and field program conducted previously to develop techniques

Table 3. Annual counts of upstream-migrant salmonids at Pelton Dam including a comparison of adults with parent runs, 1957-65.

Species and year	Total counts 1/	Adults	Parent adult 4 years previously	Parent adult 5 years previously
Chinook				
1957	623(135)	488	--	--
1958	485(13)	472	--	--
1959	512(112)	400	--	--
1960	741(194)	547	--	--
1961	583(104)	479	488	--
1962 2/	435(45)	390	472	488
1963 2/	523(353)	170	400	472
1964	588(237)	351	547	400
1965	456(248)	208	479	547
Steelhead 3/				
1958	1,619	1,619	--	--
1959	1,142	1,142	--	--
1960	521	521	--	--
1961	480	480	--	--
1962	354	354	1,619	--
1963	377	377	1,142	1,619
1964	274	274	521	1,142
1965	432	432	480	521

1/ Numbers of jacks in parentheses are included in totals.
2/ Does not include returns from marked hatchery releases.
3/ Counts of steelhead extend from June of one year to May of the following year. The counts are listed after the year migration ended.

for studying juvenile salmonids in reservoirs (Korn and Gunsolus, 1962). Floating traps, seines, and an electric shocker were tested as fish-capture gear under this study.

Traps

The Oneida Lake trap, designed to fish on the bottom of a lake or reservoir, was modified to float. The trap was constructed of 1/4-inch square mesh knotless nylon material, measured 31 feet between the ends of the wings and 48 feet long, possessed a variable length lead composed of two 50-foot- and one 32-foot-long sections, and had a floor which sloped from the lead depth of 15 feet to the crib depth of 6 feet. The traps were to show occurrence of fish and species composition. They were a source of fish for marking, tagging, recaptures, size composition, and scale samples.

Gill Nets

Monofilament nylon gill nets were chosen for use due to their demonstrated ability to capture fish day and night, at any depth, and through various types of water conditions. The nets were 60 feet long and 15 feet deep and hung on a 1/2 basis, i.e., 120 feet of netting was used to make a 60-foot-long net. When hung, the nets were composed of three 20-foot-long panels of the following mesh sizes: 7/8-, 1-1/8-, and 1-3/8-inch stretch measure. These mesh sizes were predetermined to be optimum for the juvenile salmonids found in North Fork and Pelton reservoirs. The net material was 0.16 mm diameter, the smallest available. Gill-net suspension apparatus developed in the preliminary study was utilized since it allowed the nets to be fished at various depths, was not affected by reservoir fluctuation, and was portable. A pancake-shaped concrete anchor having a low center of gravity was fabricated for positioning the gear; this anchor held its position on a steep bank.

Gill nets were used to obtain data on the seasonal, diel distribution of fish, by depth, through a cross section of each reservoir. The nets were fished both parallel and perpendicular to the shoreline to determine if the direction they faced affected the catch. Generally, nets were fished near the shoreline, at the surface midway between shorelines, at midwater depths off the bottom, and on the bottom at different depths down to the deepest location of the cross-sectional area.

To determine diel distribution, the nets were set in the morning and checked and reset during each of the following time periods: (1) near the end of the day but prior to the onset of dusk, (2) immediately after dark, and (3) near the end of the dark period but prior to the onset of dawn. The nets were pulled for the last time, during a given 24-hour period, in broad daylight following dawn. Setting and pulling of nets was relatively constant according to occurrence of day and night, but the hour of day varied.

SCUBA

Supplemental data were obtained on the depth distribution of fish at night by the use of SCUBA. Observations were originally scheduled according to regular time intervals, but variations in water visibility resulted in an irregular schedule. Counts were made on 50-yard-long measured transects at the surface and at depths of 15, 30, and 50 feet. These sections were marked at each end by lines laid from shore along the bottom to below the maximum desired depth of observation. The divers followed a given contour by the use of a depth gauge. There was some tendency to wander off course using this system, but the error was not considered excessive. The general inability of divers to observe fish during the daylight hours precluded transect counts at that time.

Miscellaneous fish equipment

At times traps proved to be ineffective for capturing fish alive. As a result seines, SCUBA hand traps, and 220- and 110-volt D. C. electric shockers were used to collect fish for marking and tagging, and to obtain size composition data. Seines were most effective when fish were concentrated in the surface waters, the electric shocker was best for capturing fish scattered along the shoreline, and SCUBA hand traps were the only method of capturing salmon alive when high surface water temperatures forced them into or below the thermocline.

Tags

Fish over 50 mm long were tagged with a vinyl-attached plastic, numbered pennant developed under the study. The pennant was 3/16 inch long, 3/32 inch wide, and 0.015 inch thick; and the solid vinyl thread was 0.016 inch diameter, was inserted with a number 8 embroidery needle, and connected with an overhand knot.

Fish were tagged and released into several areas of each reservoir to obtain information on intra-reservoir movements. Recoveries of tagged fish at the collection facilities provided data on survival and collection efficiency.

Limnology gear

Environmental conditions were measured and, where possible, related to the behavior of juvenile fish.

1. Water temperature profiles were obtained by recording the temperature from surface to bottom by 1 F units of change with a bathythermograph and thermistor, and temperatures from the surface of the reservoir and from the collection facilities were taken with hand, maximum-minimum, and recording thermometers.
2. Water visibility was measured by a Secchi disc.
3. Atmospheric pressure was measured by a recording barometer.
4. River flow was obtained from records of the U. S. Geological Survey and Portland General Electric Company.
5. Water currents--direction and a rough measure of velocity was determined by use of vane-shaped drogues constructed of tempered masonite and connected by a heavy monofilament line to a small styrofoam float at the surface of the water.
6. Dissolved oxygen--the modified Winkler titration method was used and samples were taken from the surface of the reservoir, the middle of the thermocline (when present), and just off the bottom.
7. Total alkalinity was determined by titrating with methyl orange at the beginning of the program, then methyl purple, and finally

with brom cresol green-methyl red indicator (had most distinguishable end point of the three), with samples obtained as in 6.

8. pH was determined by a LaMotte Block comparator with a range of 3.0 to 10.5, and samples taken as in 6.

RESULTS

North Fork Reservoir

Environment

Water temperature. Water temperature profiles were taken at regular intervals in North Fork Reservoir from May 1962 to June 1965. Through trial and error, we found that profiles at seven stations along the former river channel provided representative data. Profiles representative of the water temperature patterns found in the four seasons of each year are shown in Figure 3. Surface temperature in the summer did not exceed 73 F, and only the top 15-20 feet was stratified. The reservoir was warmest and most definitely stratified in the summer of 1962. It was weakly stratified in the other two years. Water temperatures declined rapidly in October of each year, and the reservoir was homothermous about the end of the month and remained so during two of the three winters. Temperature inversion occurred in January 1963 when ice floes were present in the reservoir. Surface temperatures were 34 F and the river was 38 F. The reservoir was weakly stratified during the peak of downstream migration in May of each year and cool water temperatures prevailed.

Water currents. The direction and velocity of water currents in North Fork Reservoir were calculated seven times between March 1964 and March 1965. Each time several drogues were positioned across the reservoir at each of four or five points along the reservoir. Their directions and times of travel over measured distances were then recorded. The drogues were usually set just beneath the surface of the water and at a depth of 20 feet. A few observations

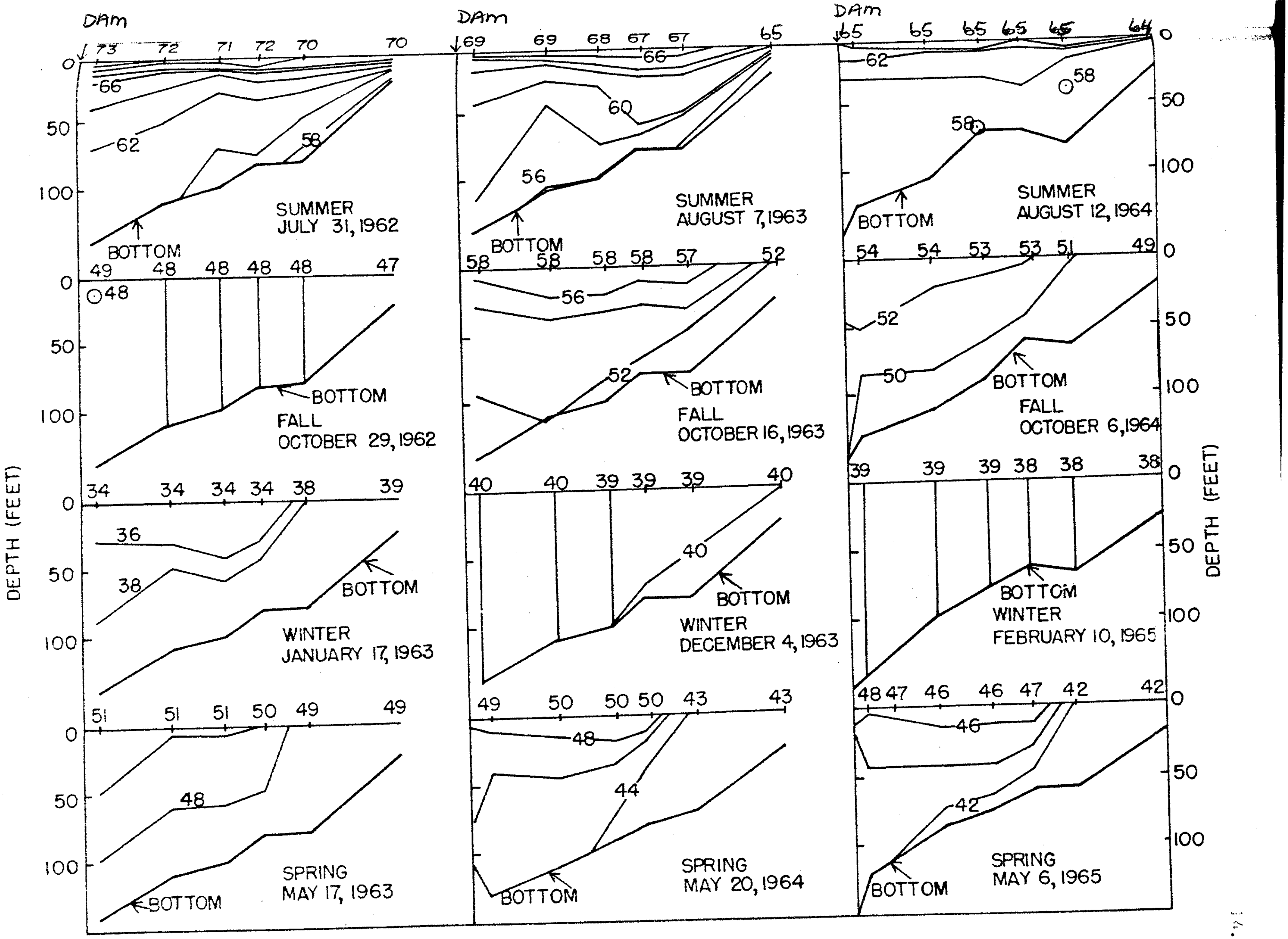


FIGURE 3. REPRESENTATIVE SEASONAL WATER TEMPERATURE PROFILES BY 2F ISOTHERMS, NORTH FORK RESERVOIR, JULY 1962-MAY 1965. LINEAR SCALE: 19MM=1 MILE.

occurred at a depth of 50 feet. Generally, drogues in a given location set near the surface and at 20 feet were propelled in the same direction. On most occasions water currents traveled in a down-reservoir direction, but sometimes the current was upstream, particularly when the wind was blowing in that direction. In Figure 4 slight upstream currents were found at mid-reservoir in April 1964 with no noticeable wind activity; while water currents in the upper reservoir traveled downstream. In March 1965 strong downstream currents prevailed in all areas even though wind patterns varied.

Flow and visibility. Daily river flows were recorded 1/4 mile downstream of River Mill Dam. Flows may differ slightly from those at North Fork because of some storage in River Mill Reservoir, but are reasonably accurate, particularly during freshets.

Flow varied considerably in the Clackamas River during the course of our study. During late summer and early fall, flows dropped as low as 300 cfs. Frequently in late fall and winter and occasionally in the spring flows reached 5,000-10,000 cfs. The largest flood of record in the Clackamas River was recorded on December 22, 1964, when 93,000 cfs was measured through the spillway and powerhouse of North Fork Dam. This flood damaged the gauge below River Mill Dam. The previous high flow in the Clackamas was 60,000 cfs recorded in November 1960. Maximum discharges in the intervening years did not exceed 20,000 cfs.

Water visibility was often influenced by flow. Secchi disc readings as low as 1 foot were coincident with fall and winter high flows. Readings up to 29 feet were made during the low flow periods of summer and early fall. Algae blooms occasionally limited water visibility during the summer months. Secchi disc readings up to 22 feet, but usually about 10 to 15 feet, were recorded during the spring migration periods. They dropped as low as 2-1/2 feet during the infrequent freshets in the spring.

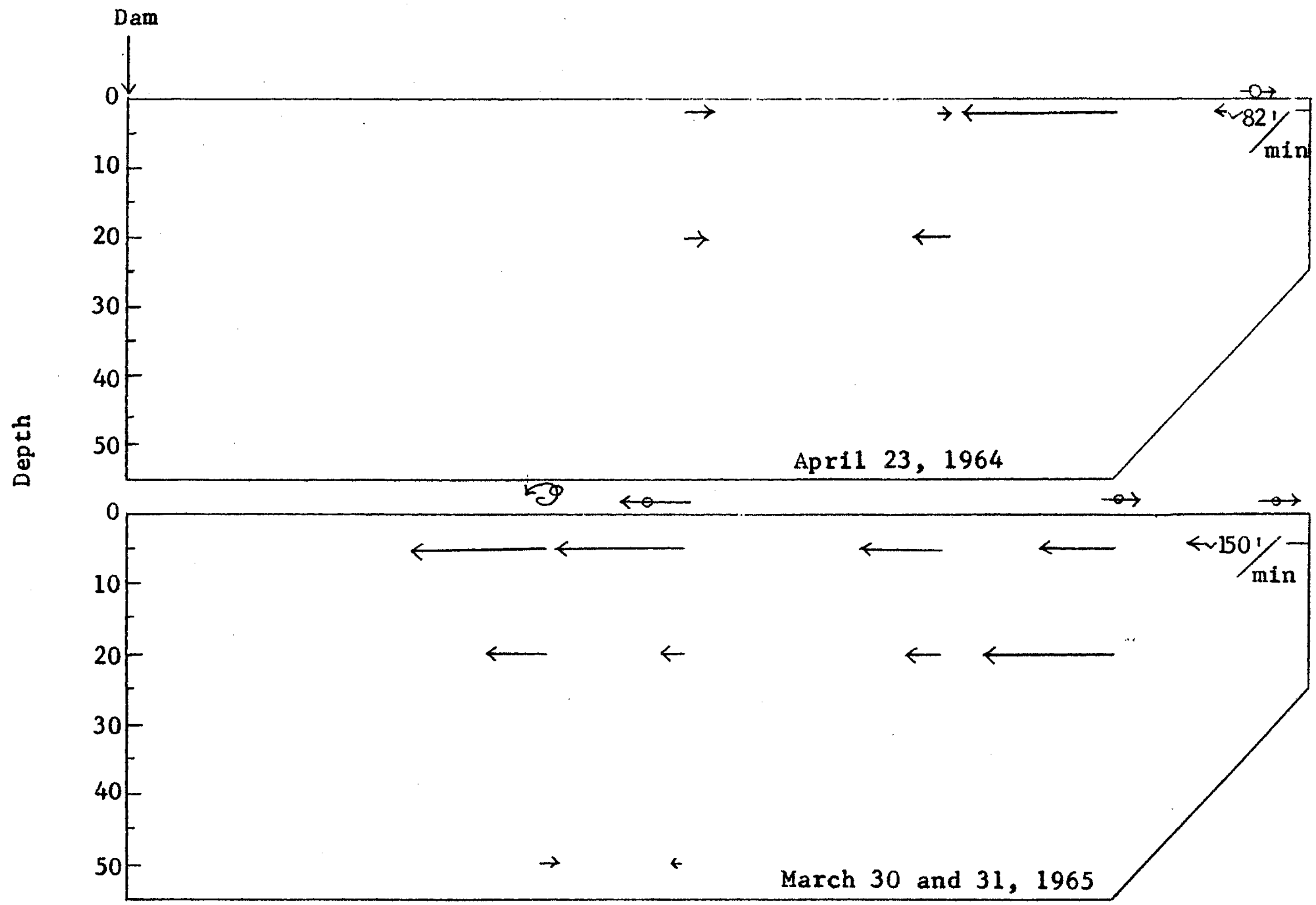


Figure 4. The direction and general velocity of water and wind[1/] currents, North Fork Reservoir, April 23, 1964, and March 30 and 31, 1965.[2/]

LEGEND

Drogues: ⟶ 1 mm = 1 foot/minute
Wind: variable =
slight =
moderate =
strong =
Reservoir not to scale

1/ Wind currents are not shown for areas where they were not discernible.
2/ Only the first 50 feet of depth is shown on each graph since observations were not made below that point.

Oxygen, alkalinity, and pH. Dissolved oxygen content, total alkalinity, and pH were measured beginning in the summer of 1963. Dissolved oxygen concentrations were adequate for salmonid life throughout each year of record with minimal values about 8.0 ppm. Total alkalinity values were relatively low and may be indicative of poor productivity. This was indirectly corroborated by the absence of large resident fish. The pH range was always within the limits necessary for fish life. Table 4 shows representative seasonal values of oxygen, total alkalinity, and pH taken at the entrance to the reservoir and near the dam. Oxygen concentrations were highest in the winter and lowest in the summer. Alkalinity was relatively high in the fall and lowest in the spring. Little variation in pH was observed throughout the year.

Fish behavior

Migrations. Juvenile anadromous salmonids were found in North Fork Reservoir during all seasons of each year. We did not determine quantitatively their time of entry into the impoundment, but catches made in a trap fished at the head of the reservoir, under a cooperative study by the Fish Commission and Portland General Electric Company to evaluate the effectiveness of fish facilities at North Fork (hereafter referred to as Evaluation Study), indicated that juvenile fish moved into the reservoir in the fall, winter, and spring.

Sightings from a boat and with SCUBA gear, and the capture of fish with a dip net and beach seine showed that chinook and coho fry were present in the reservoir when field work was initiated in May 1962. Fry rainbow-steelhead[1/] were first observed in early August 1962. In subsequent years chinook, coho, and rainbow-steelhead fry were found in the reservoir by February, May, and July, respectively. During these periods, coho were seen in groups ranging from less than 10 to several hundred. Rainbow-steelhead fry were abundant but gener-

1/ Rainbow-steelhead is a term applied to fish thought to be steelhead, but which may include rainbow trout.

Table 4. **Representative seasonal values of oxygen, total alkalinity, and pH taken from three depths and two areas in North Fork** Reservoir, 1963-65.

Area	Depth	Determination	Season: Winter	Spring	Summer	Fall	Year
Entrance to reservoir	Surface	Dissolved oxygen	--	--	9.0	11.0	1963
		Total alkalinity	--	--	35	30	
		pH	--	--	--	7.75	
Near dam	Surface	Dissolved oxygen	--	--	10.5	9.5	
		Total alkalinity	--	--	34	32	
		pH	--	--	--	7.5	
	Thermocline	Dissolved oxygen	--	--	9.0	9.0	
		Total alkalinity	--	--	33	32	
		pH	--	--	--	7.5	
	Bottom	Dissolved oxygen	--	--	8.0	9.5	
		Total alkalinity	--	--	36	32	
		pH	--	--	--	7.5	
Entrance to reservoir	Surface	Dissolved oxygen	12.0	12.5	9.6	10.8	1963-64
		Total alkalinity	24	16	29	30	
		pH	7.5	7.25	7.5	7.75	
Near dam	Surface	Dissolved oxygen	13.0	11.5	10.0	9.8	
		Total alkalinity	24	17	27	31	
		pH	7.5	7.25	7.75	7.75	
	Thermocline	Dissolved oxygen	--1/	11.0	9.6	--1/	
		Total alkalinity	--	18	29	--	
		pH	--	7.25	7.75	--	
	Bottom	Dissolved oxygen	12.5	11.0	8.8	10.2	
		Total alkalinity	25	16	29	31	
		pH	7.5	7.25	7.75	7.75	
Entrance to reservoir	Surface	Dissolved oxygen	12.6	12.2	--	--	1964-65
		Total alkalinity	21	21	--	--	
		pH	7.25	7.75	--	--	
Near dam	Surface	Dissolved oxygen	--	11.8	--	--	
		Total alkalinity	--	20	--	--	
		pH	--	7.75	--	--	
	Thermocline	Dissolved oxygen	--	--1/	--	--	
		Total alkalinity	--	--	--	--	
		pH	--	--	--	--	
	Bottom	Dissolved oxygen	--	11.6	--	--	
		Total alkalinity	20	20	--	--	
		pH	--	7.75	--	--	

1/ Thermocline not present.

ally more scattered than coho and in smaller groups. Chinook were never found in any numbers.

An estimated 145,746 1961-brood coho salmon were in the reservoir by September 1962, prior to the first spill that fall. This was based on the fin marking of 2,136 coho in late August and early September, and the recovery of 30 of these marked fish in a sample of 2,047 taken in a 24-hour period of gill-netting in October. Selectivity by size was not considered in this estimate. Calculated 90% confidence limits around this estimate are: lower = 108,154, upper = 196,404. While these limits are wide, it is obvious that significant numbers of coho were in the reservoir.

The presence and general abundance of juvenile anadromous salmonids in the reservoir is further indicated by examination of catches by the floating traps (Table 5). Juvenile salmonids were caught in the reservoir in every month that the traps were fished, and particularly large numbers of 1961- and 1962-brood coho were caught throughout each of the first two run-years. Recovery in the traps of less than 5% of 2,015 coho tagged between February and June 1963 and 4,884 coho tagged from July 1963 to June 1964 indicate the majority of the 20,545 and 16,038 fish caught in each of these run-years were part of much larger populations. It was not possible to use these data to make estimates of the numbers present due to the instability of the population resulting from emigration via the spillway and the extended period of tagging, but it is evident that large numbers of coho resided in the reservoir. The percentages of tagged rainbow-steelhead and chinook salmon recovered in the traps were also low. Good numbers of the former were probably present in the reservoir each year, but few chinook were found. This conception of the size of the fish populations, by species, was supported by the counts at the collection facilities, but counts were incomplete due to emigration via the turbines and spillway.

Table 5. Catches of chinook and coho salmon and rainbow-steelhead trout in floating traps by month and run-year, 1/ North Fork Reservoir, 1962-65.

Month	Chinook			Coho			Rainbow-steelhead 2/		
	1962-63	1963-64	1964-65	1962-63	1963-64	1964-65 3/	1962-63	1963-64	1964-65
July	143	48	-- 4/	1,384	538	--	332	61	--
August	74	0	227	135	9	172	603	287	1,037
September	132	8	114	1,943	163	300	605	172	1,071
October	25	17	--	287	1,106	--	240	265	--
November	69	88	--	2,642	7,736	--	283	371	--
December	37	1	--	2,160	526	--	320	111	--
January	11	26	41	494	400	33	95	30	165
February	109	15	141	5,888	607	205	775	37	374
March	16	26	108	1,094	696	406	134	46	391
April	8	47	92	1,796	2,829	1,052	322	421	918
May	18	23	21	2,476	1,162	1,587	678	320	797
June	58	52	0	246	266	39	58	49	44
Total	700	351	744	20,545	16,038	3,794	4,445	2,170	4,797

1/ A run-year extends from July of one year through June of the next. Emigration of a given age class of juvenile salmon from North Fork generally occurs on a run-year basis, but steelhead emigrate only in the spring.
2/ Fish thought to be steelhead, but may include rainbow trout.
3/ Catches of coho from March-June 1965 may include unmarked hatchery fish.
4/ A dash (--) means the traps were not fished that month.

Catches in the traps in three areas of the reservoir during October 1963 and in two areas in each of November and December showed that the size composition of coho salmon changed by time and location (Figure 5). The decreasing modal size of fish caught between October and December may be attributed to the immigration of small stream-reared fish into the reservoir, the downstream emigration of larger fish, or both. A freshet and subsequent spill at North Fork Dam during the second week of November allowed fish to leave through the spillway as well as through the collection facilities and turbines. The maximum size of fish caught in the traps was 16 cm in October and November. In December it was only 13 cm indicating the exodus of larger fish was involved with the general change in size composition.

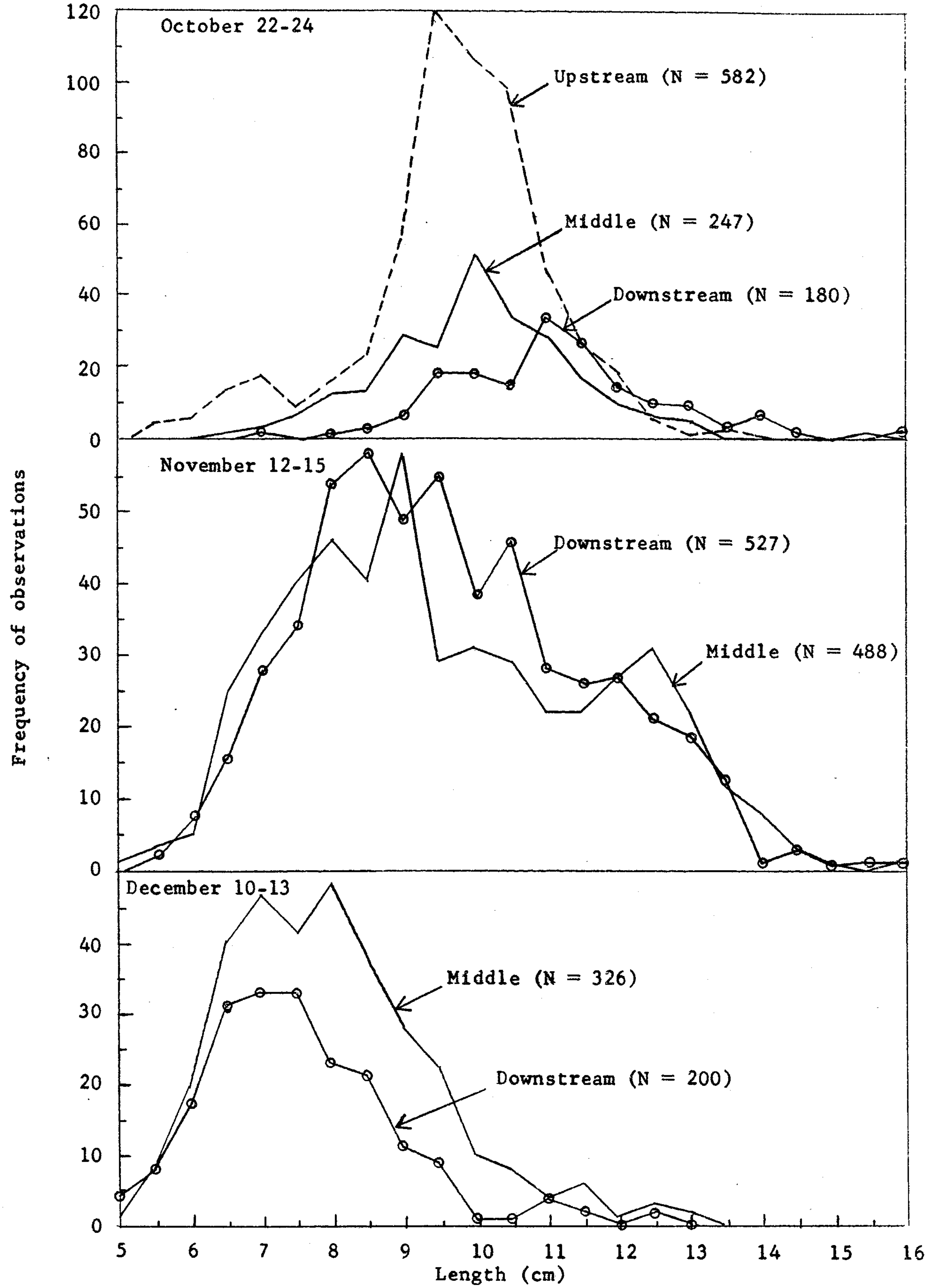


Figure 5. Differences in size composition of juvenile coho salmon trapped in the upstream, middle, and downstream areas of North Fork Reservoir during October, November, and December of 1963.

In October, fish caught in the lower reservoir were generally larger than those taken in the other two areas. It appears those in the lower end resided longer in the reservoir. After the onset of freshets in November, coho caught in the middle and lower areas showed a similar size distribution. Fishing was not possible in the upper area during freshets. By December the modal sizes of fish caught in the lower and middle areas of the reservoir were completely different from and smaller than those observed in October. The change was so drastic it appears that smaller fish entered and a disproportionate number of larger ones left the reservoir.

The length of time juvenile fish resided in the reservoir was determined, in part, by marking and tagging studies. A total of 2,132 coho fry was marked from May-June 1963. Of the 172 recoveries at the collection facilities, 160 emigrated in May and June 1964. An unknown number of marked fish survived and exited through the spillway during the winter of 1963-64 as evidenced by the recovery of 14 of these fish, from November 1963 to February 1964, in a trap fished in Faraday Lake.

Coho salmon of the 1961 brood were tagged from February to June 1963 and 1962-brood coho and chinook were tagged from July 1963 to June 1964. Their times of emigration by month of tagging are shown in Tables 6, 7, and 8. Some coho moved through the collection facilities (skimmer) soon after tagging in December, January, and February; however, regardless of the month of tagging, most chinook and coho were recovered at the facilities in April and May and May and June, respectively. Data are not included for fish tagged from July 1964 to June 1965 because of problems caused by the flood in December 1964.

Smolted steelhead tagged mainly in April and May were distinguished from unsmolted rainbow-steelhead tagged throughout the year. All steelhead were recovered at the skimmer during the season they were tagged. A relatively small percentage of tagged rainbow-steelhead was recovered at the collection facilities,

Table 6. Numbers of coho salmon tagged and released, and recovered at the collection facilities, by month, North Fork Reservoir, February-July 1963.

Month of tagging	February	March	April	May	June	Total
Numbers tagged	510	582	439	420	64	2,015
Numbers recovered by month						
February	2	--	--	--	--	2
March	21	--	--	--	--	21
April	3	6	2	--	--	11
May	63	100	104	148	--	415
June	137	178	144	162	43	664
July	14	14	8	8	3	47
Total recovered	240	298	258	318	46	1,160

Table 7. Numbers of coho salmon tagged and released, and recovered at the collection facilities, by month, North Fork Reservoir, July 1963-July 1964.

Yr. of tagging	1963						1964						
Mo. of tagging	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
Numbers tagged	209	6	99	349	191	411	354	561	667	884	918	235	4,884
Numbers recovered by year and month													
1963 December	1	0	0	0	0	0	--	--	--	--	--	--	1
1964 January	0	0	0	0	3	9	7	--	--	--	--	--	19
February	0	0	0	1	1	1	3	3	--	--	--	--	9
March	0	0	1	0	0	1	4	7	1	--	--	--	14
April	0	0	1	1	0	0	1	1	2	1	--	--	7
May	60	0	24	90	50	54	61	102	251	303	298	--	1,293
June	5	0	13	40	21	41	64	134	176	293	297	127	1,211
July	0	0	0	2	1	10	3	19	26	57	55	32	205
Total recovered	66	0	39	134	76	116	143	266	456	654	650	159	2,759

Table 8. Numbers of chinook salmon tagged and released, and recovered at the collection facilities, by month, North Fork Reservoir, July 1963-June 1964.

Yr. of tagging	1963					1964						
Mo. of tagging	July	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
Number tagged	44	6	14	37	1	26	15	26	41	8	3	221
Nos. recovered by year & month												
1964												
January	1	0	0	1	0	1	0	0	0	0	0	3
February	0	0	0	1	0	0	0	0	0	0	0	1
March	0	0	0	1	0	0	0	0	0	0	0	1
April	1	1	0	2	0	4	4	2	0	0	0	14
May	1	1	3	2	0	9	9	13	26	4	0	68
June	0	0	0	0	0	0	0	1	0	1	0	2
Total recovered	3	2	3	7	0	14	13	16	26	5	0	89

possibly because they were rainbow trout, they emigrated through the spillway, or they died. Most recoveries occurred in April and May of the run-year the fish were tagged, but some were recovered up to 1 year later.

Up-reservoir migrations of tagged fish did not appear significant. Relatively few tagged fish were recovered upstream of the tagging site, however some fish migrated upstream for the length of the reservoir.

Juvenile salmonids must sound 135 feet deep to pass through the penstocks of North Fork Dam. Unless it spilled, fish emigrating through the North Fork turbines would pass through the turbines of the two lower dams as well. Many coho and chinook and a few rainbow-steelhead were captured in Faraday Lake, in floating traps, prior to the first spill in the falls of 1963 and 1964. These fish could have passed over North Fork Dam as fry during spills of the previous winters, or they could have emigrated through the turbines. A few coho tagged and released into North Fork Reservoir were recovered in Faraday when the only route was through the penstocks. Also several coho and chinook were caught in gill nets fished to depths of 120 feet in the forebay of North Fork Reservoir, particularly during the daylight hours in the winter, showing that fish were near the penstocks.

The numbers of juveniles passing through the penstocks were not estimated; but a test conducted in cooperation with Evaluation Study personnel determined that 25.5 to 31.6% of the fish passing through the turbines were killed.

It spilled 13 times at North Fork Dam during the 3 years of field work, twice in the spring and 11 times in November through February. Spills were 1-10 days long, and most were 5 days or less.

The Fish Behavior and Evaluation Studies cooperated in attempts to obtain partial estimates of the numbers of juvenile salmon passing through the spillway. Fish leaving on spills at North Fork either passed over the spillway at Cazadero Dam, or entered the Faraday diversion and artificial lake from which they exited via the penstocks of Faraday powerhouse. Both groups then passed over the spillway or through the turbines of River Mill Dam. Experiments were conducted during three spills to estimate the numbers of wild chinook and coho salmon that passed through the spillway at North Fork and the proportions of these that were diverted into Faraday Lake. For each test, groups of fin-clipped hatchery chinook and coho were released into the tailrace of North Fork and into the Faraday Canal. The recovery gear consisted of fyke nets in the canal and floating traps in Faraday Lake. The following formulae were used to obtain the desired estimates.

1. $$\text{Estimated number diverted into Faraday Canal} = \frac{\text{Number of wild fish caught}}{\text{Per cent recovered of release into Faraday Canal}}$$

2. $$\text{Estimated number passing spillway at North Fork} = \frac{\text{Number of wild fish caught}}{\text{Per cent recovered of release into tailrace at North Fork}}$$

Separate estimates were made from the catches in each type of recovery gear since the fyke nets were usually more efficient at capturing chinook than coho, and the traps always captured coho more efficiently than chinook. The results of these tests are shown in Table 9. The estimated numbers of chinook passing the spillway at North Fork during the tests ranged from 1,000 to over 61,000, and the estimated percentages diverted into Faraday ranged from 25 to 71. For coho, the estimated numbers passing the spillway ranged from approximately 3,900 to 90,000, and the percentages diverted into Faraday ranged from 37 to 64. In some instances, similar estimates were obtained for the same spill period from data collected by the two types of gear, but in other cases the estimates diverged significantly.

The accuracy of these tests is questionable. The per cent of fish diverted into Faraday could have varied with the changing volume of spill, and the capture efficiency of the recovery gear may have varied with both water volume and turbidity. Also, the chinook moved rapidly downstream after release and were recovered over a short period of time; recoveries were generally low. Conversely, coho appeared to move downstream slowly and recoveries extended over long periods of time. Generally, the recovery rates for both species were higher in the traps than they were in the fyke nets, and the estimates from data collected by the traps were more conservative. Regardless of the qualifications which must be attached to the estimates, it is our opinion that they are indicative of significant emigration from North Fork via the spillway and turbines, and a large percentage of these are diverted into Faraday Canal. The consequences of fish passing through the turbines at Faraday were indicated by Brock (1937) when a diver observed serious losses and injuries to test fish.

Coincident with the above tests, marked hatchery chinook and coho were released through the spillway at North Fork to determine the per cent killed. The recovery rates for fish released through the spillway were compared to a control group released into the tailrace. The rates of recovery were not different statistically, and it was concluded that mortality was negligible.

Table 9. Estimates of the numbers of chinook and coho salmon passing over the spillway of North Fork Dam and entering the Faraday Canal during specific spill periods in 1963 and 1964.

Species	Recovery gear	Date marked fish released	Marked fish released into tailrace: No. released	Marked fish released into tailrace: Recovery at Faraday No.	Marked fish released into tailrace: Recovery at Faraday %	Marked fish released into Faraday Canal: No. released	Marked fish released into Faraday Canal: Recovery at Faraday No.	Marked fish released into Faraday Canal: Recovery at Faraday %	Estimated % diverted	No. of wild fish caught	Estimated no. of wild fish diverted	Estimated no. of wild fish passing spillway
Chinook	Fyke net	2-3-63 1/	5,180	16	0.3	5,329	63	1.2	25	3	250	1,000
		1-25-64 2/	5,925	42	0.7	5,229	80	1.5	47	235	15,667	33,334
		12-1-64 1/	15,176	74	0.5	7,658	55	0.7	71	305	43,571	61,368
Chinook	Floating traps	2-3-63 1/	5,180	47	0.9	5,329	108	2.0	45	9	450	1,000
		1-25-64 2/	5,925	0	0.0	5,229	2	0.0	No data	2	No estimate	No estimate
		12-1-64 1/	15,176	356	2.3	7,658	295	3.9	59	450	11,538	19,556
Coho	Fyke net	2-3-63 1/	5,146	8	0.2	5,284	25	0.5	40	49	9,800	24,500
		1-25-64 2/	5,992	41	0.7	5,180	56	1.1	64	638	58,000	90,625
		12-1-64 1/	15,075	279	1.9	7,698	386	5.0	38	155	3,100	8,158
Coho	Floating traps	2-3-63 1/	5,146	146	2.8	5,284	403	7.6	37	777	10,224	27,632
		1-25-64 2/	5,992	522	8.7	5,180	1,109	21.4	41	2,138	9,991	24,368
		12-1-64 1/	15,075	1,151	7.6	7,698	1,037	13.5	56	297	2,200	3,908

1/ Flow at North Fork - 25,000 cfs.
2/ Flow at North Fork - 7,800 cfs.

Further indication of passage through the spillway was obtained in May of 1963 when it spilled for 5 days during the peak of steelhead emigration, and just preceding the peak of emigration for coho. Groups of marked wild coho and steelhead were released into North Fork Reservoir prior to and following the spill. The differences between the percentages recovered in the collection facilities of the groups released in the two time periods can reasonably be attributed to passage through the spillway. The recovery rates for coho marked and released prior to and after the spill were 35 and 76%, respectively, and the rates of recovery for steelhead were 44 and 78%. Based on these returns, 41% of the coho and 34% of the steelhead marked and released prior to the spill emigrated through the spillway. Since the emigration of steelhead usually peaks and that for coho is increasing during this period, it is probable that several thousands of juveniles passed through the spillway.

would only relate to [illegible] present

Juvenile salmonids emigrated throughout the year at the collection facilities of North Fork Dam, but most fish were counted in the spring (Tables 10, 11, and 12). Counts of chinook were highest in the first 2 full years the dam operated (1959-60 and 1960-61), and the numbers counted annually thereafter were relatively low. In the early years, counts of chinook peaked in May, but in 2 of the last 4 years shown they peaked in April. The relatively high counts of chinook and coho in March 1963 were coincident with dewatering the fish ladder and may not represent a normal pattern of emigration. It may indicate that many juvenile fish reside in the ladder during the winter. Counts of coho salmon, the most abundant species, usually peaked in May, but many emigrated in June. Few steelhead were counted prior to April and the migration always peaked in May. The period of emigration for this species was relatively short.

A brood year of juvenile salmon emigrated through the skimmer from about November 15 of one year to June 30 of the next. This range of time was

Table 10. Numbers of downstream-migrant wild chinook salmon counted at the skimmer by run-year and month, North Fork Dam, 1959-65.

Month \ Run-year	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65 1/
September	26	0	14	0	3	70
October	496	250	29	86	46	114
November	312	3,306	44	234	238	487
December	36	936	85	363	230	782
January	58	654	66	144	516	4
February	155	47	32	209	118	--
March	100	131	23	497 2/	171	900
April	223	876	112	222	906	2,022
May	14,310	10,809	71	265	3,921	1,337
June	2,467	1,783	8	42	259	262
July	32	2	0	32	21	21
August	7	0	0	1	46	3
Total	18,222	18,794	484	2,095	6,475	6,002

1/ Collection facility out of operation from December 23, 1964, to March 10, 1965, except for five days in January, due to damage caused by floods in December 1964 and January 1965.

2/ Most of these fish entered the counting facility during and immediately after a brief period that the ladder was dewatered.

Table 11. Numbers of downstream-migrant wild coho salmon counted at the skimmer by run-year and month, North Fork Dam, 1959-65.

Month \ Run-year	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65 1/
September	0	0	2	0	8	38
October	75	673	3	20	10	22
November	679	2,920	7	3,200	4,154	65
December	394	1,247	8	1,824	1,876	230
January	186	525	5	429	3,044	4
February	218	57	7	3,689	951	--
March	146	49	4	10,801 2/	1,163	422
April	762	120	356	1,115	590	716
May	13,621	18,716	13,003	41,433	73,582	27,140
June	6,280	19,752	4,597	35,656	45,505	17,772
July	6	74	89	1,893	5,722	319
August	2	0	0	24	246	5
Total	22,369	44,133	18,081	100,084	136,851	46,733

1/ Collection facility out of operation from December 23, 1964, to March 10, 1965, except for five days in January, due to damage caused by floods in December 1964 and January 1965. Counts include an unknown number of unmarked hatchery yearlings released into Clackamas River and tributaries, above North Fork Reservoir, on March 2 and 3, 1965.

2/ Most of these fish entered the counting facility during and immediately after a brief period that the ladder was dewatered.

Table 12. Numbers of downstream-migrant wild steelhead trout counted at the skimmer by run-year and month, North Fork Dam, 1959-65.

Month \ Run-year	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65 1/
September	0	0	0	0	0	0
October	0	0	0	11	0	0
November	8	0	0	14	110	7
December	0	0	0	34	27	25
January	0	0	0	3	22	0
February	0	0	0	2	27	--
March	14	0	0	87	10	2
April	3,556	3,427	2,985	2,914	1,074	2,358
May	32,960	13,177	16,923	20,603	26,535	11,001
June	2,390	1,090	2,555	1,058	2,891	496
July	1	0	9	4	47	0
August	0	0	0	0	90	0
Total	38,929	17,694	22,472	24,730	30,833	13,889

1/ Collection facility out of operation from December 23, 1964, to March 10, 1965, except for five days in January, due to damage caused by floods in December 1964 and January 1965.

arbitrarily divided into two periods for analytical purposes since it was felt that factors affecting the relatively small and sporadic emigrations in the winter may have differed from those resulting in the mass migrations in the spring. The dividing point between the two periods was based on climatological changes (mainly increasing water temperatures), and generally preceded the major emigration of fish in the spring, without regard to species, by 1 to 2 weeks. At North Fork, the dividing date between winter and spring was April 15.

For the period 1962-65, counts of coho and smolted steelhead at the skimmer were compared to flows below River Mill Dam and water temperatures at the entrance to the skimmer at North Fork by regression analysis. Chinook were not studied because of the small numbers counted and steelhead were compared in the spring only since they did not emigrate in the winter. The spring season included the period April 16-June 30, but for purposes of analysis, the spring period ended when 60% of the spring migrants had passed downstream because counts were declining.

Figures 6, 7, and 8 show that significant positive relationships existed between flow and the counts of coho in the winter, and between water temperatures and the counts of coho and steelhead in the spring. All relationships were significant at the 5% level for all years examined, except in 1962 it was significant at the 10% level for coho. The individual points are not plotted for these and some other relationships shown in this report to avoid crowding. Relationships between water temperature and counts of coho for the two winters examined, and flows and counts of coho and steelhead over four spring periods were inconsistent. The comparison of flows and counts of coho during the spring was significant with a negative slope for two springs, significant with a positive slope for one spring, and not significant for one spring. This same relationship for steelhead was significant with the slope positive in two springs and negative in one. Other comparisons were not made because of insufficient data.

It is concluded from these analyses that flow was a significant variable affecting the counts of coho in the winter, and that water temperature was a significant variable affecting counts of coho and steelhead in the spring.

Depth distribution. Observations from a boat and by the use of SCUBA showed chinook, coho, and rainbow-steelhead fry inhabiting the surface waters of North Fork Reservoir in the late winter, spring, and early summer of each year. From May to July 1963, 118 yearling and 1,773 fry coho, 36 steelhead smolts, 368 fry chinook, and 3,008 fry rainbow-steelhead were captured with a

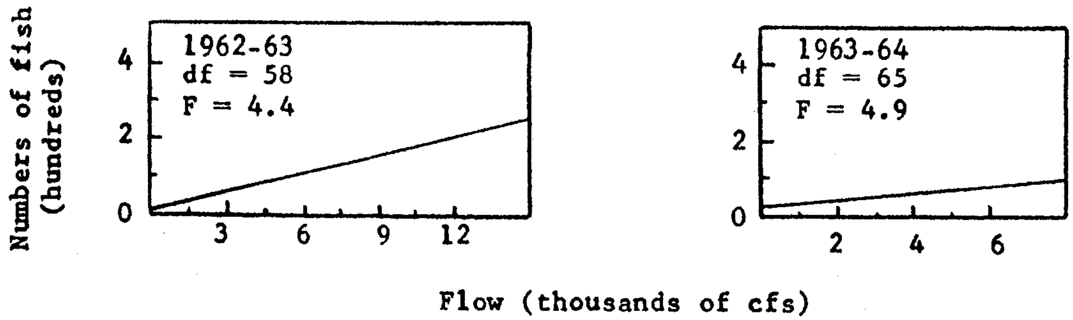


Figure 6. The relationship between volume of flow and counts of coho salmon at the collection facility during the winter, North Fork Reservoir, 1962-64.

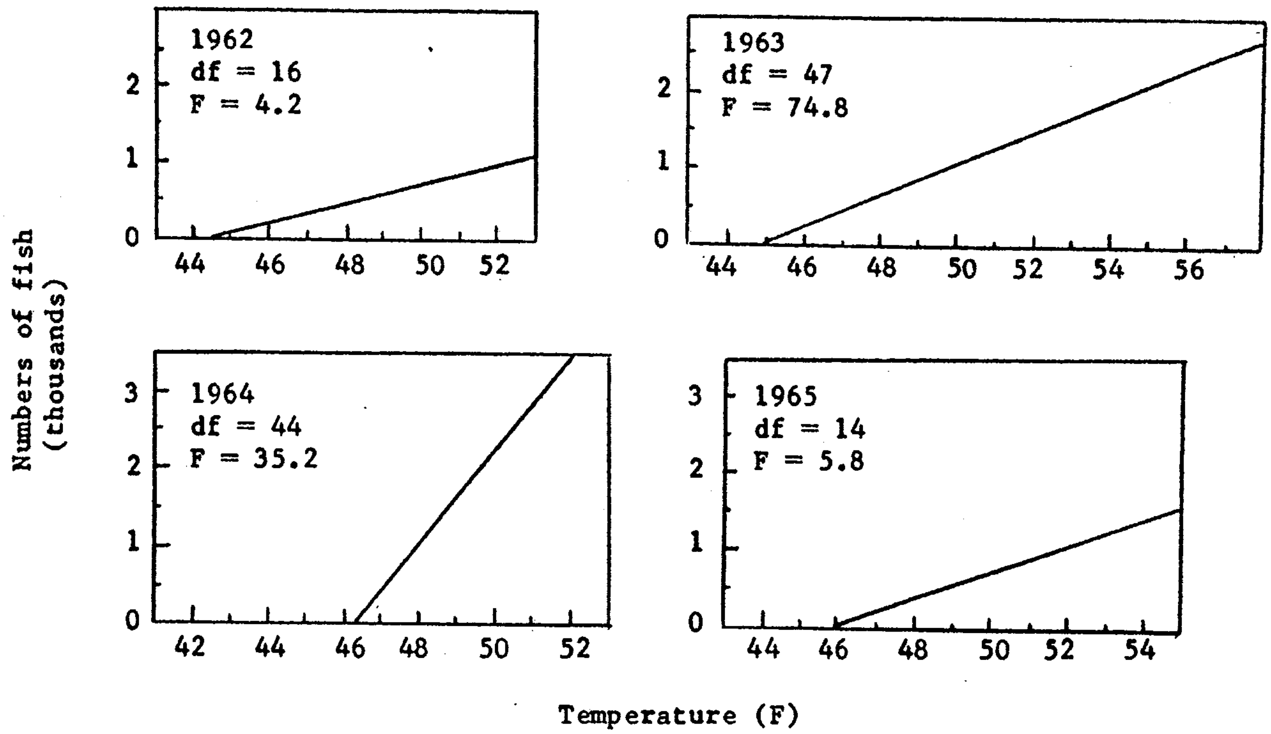


Figure 7. The relationship between water temperature and counts of coho salmon at the collection facility during the spring, North Fork Reservoir, 1962-65.

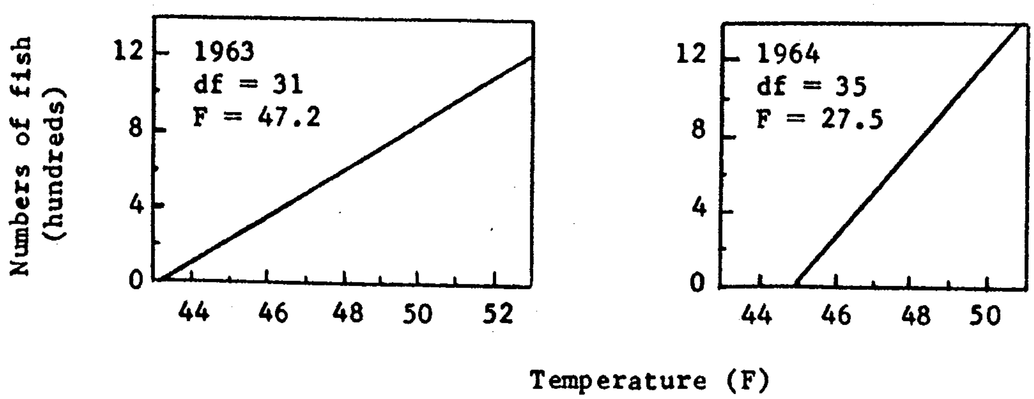


Figure 8. The relationship between water temperature and counts of steelhead trout at the collection facility during the spring, North Fork Reservoir, 1963-64.

seine and dip net. All fish were taken from the surface to 15 feet of depth. Observations with SCUBA showed that fry salmonids generally were not below a depth of 15 feet.

Gillnetting to determine diel variations in depth distribution, by season, was initiated in December 1962 when fish locations were standardized. The standard location for fishing five gill nets parallel to the shoreline approximately 2-1/2 miles up reservoir from North Fork Dam are shown in Figure 9. The maximum depth of water in this area was 75 feet. Each net location was assigned a number for ease of reference. For analysis, the seasons were divided according to changes in environmental conditions as follows:

1. Summer - July 1 to September 15 - thermal stratification present.
2. Fall - September 16 to November 14 - period of cooling water temperatures.
3. Winter - November 15 to April 15 - water temperature homothermous.
4. Spring - April 16 to June 30 - formation of thermal stratification.

We could not test the legitimacy of combining the catches from individual fishing days, for a given season and year, due to the small numbers of fish caught. Catches were arbitarily combined by season and diel period (day, dusk, night, and dawn) for each year. Chi-square tests showed that catches of coho were similarly distributed among the nets for all years of a given season by day and night fishing periods. The tests also indicated distribution of the catches made at dusk and dawn varied between years. It was decided to combine data obtained from different years, by season, since, as shown for coho and chinook salmon in Tables 13 and 14, the variations in the distribution of the catches at dusk and dawn appeared attributable to the fish having different patterns of distribution between day and night. Coho salmon were caught best during the day by the deepest net in the summer, fall, and in the winter when water visibility was 7 feet and greater. When water visibility was less than 7 feet in the winter, most coho caught during the day were taken in the two nets located between 15 and

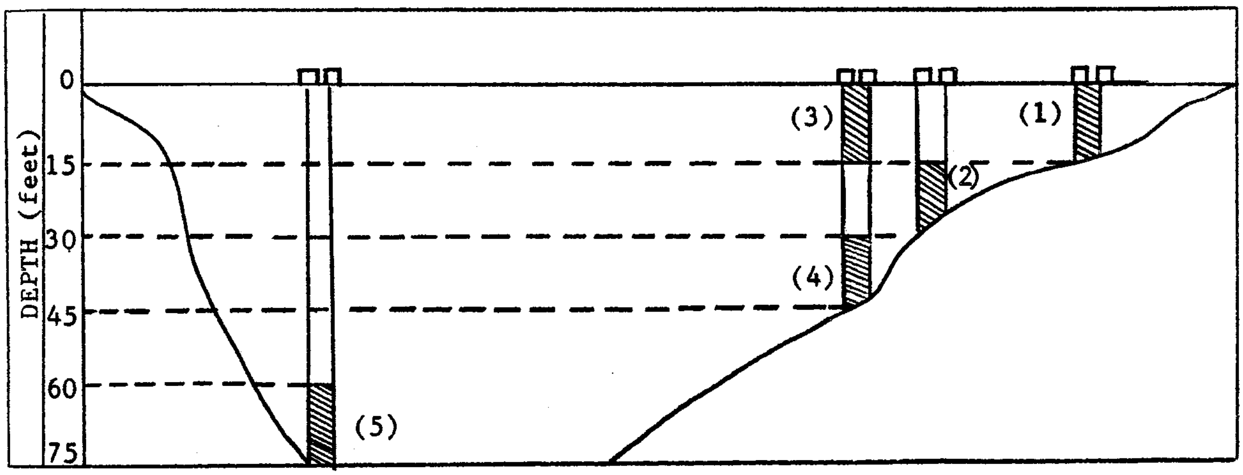


Figure 9. Diagram of standard locations for gill nets fished parallel to the shoreline, North Fork Reservoir.

Table 13. The numbers and percentages of wild coho salmon caught by gill-net location within diel periods, by season, North Fork Reservoir, December 18, 1962-November 23, 1964.

Summer: No. observations - 5

Net no.	Depth range fished (ft)	Depth of water (ft)	Catch by diel period							
			Day		Dusk		Night		Dawn	
			No.	%	No.	%	No.	%	No.	%
1	0-15	15	2	12.5	24	27.6	17	54.8	8	9.9
2	15-30	30	1	6.3	16	18.4	6	19.4	22	27.2
3	0-15	45	0	0	1	1.1	0	0	11	13.6
4	30-45	45	6	37.5	40	46.0	8	25.8	36	44.4
5	60-75	75	7	43.7	6	6.9	0	0	4	4.9
Total caught			16		87		31		81	

Fall: No. observations - 4

Net no.	Depth range fished (ft)	Depth of water (ft)	Catch by diel period							
			Day		Dusk		Night		Dawn	
			No.	%	No.	%	No.	%	No.	%
1	0-15	15	5	11.9	116	74.4	134	87.6	119	60.7
2	15-30	30	11	26.2	16	10.3	6	3.9	39	19.9
3	15	45	6	14.3	20	12.8	8	5.2	27	13.8
4	30-45	45	3	7.1	3	1.9	5	3.3	9	4.6
5	60-75	75	17	40.5	1	0.6	0	0	2	1.0
Total caught			42		156		153		196	

Table 13 (cont'd)

Net no.	Depth range fished (ft)	Depth of water (ft)	Day (vis. less than 7 feet) No.	%	Day (vis. 7 feet & greater) No.	%	Dusk No.	%	Night No.	%	Dawn No.	%
			Winter: No. observations - 10 1/									
1	0-15	15	0	0	0	0	129	73.3	115	89.8	92	20.9
2	15-30	30	55	44.4	0	0	25	14.2	8	6.3	88	20.0
3	0-15	45	2	1.6	0	0	3	1.7	4	3.1	30	6.8
4	30-45	45	53	42.7	16	9.3	14	8.0	1	0.8	121	27.4
5	60-75	75	14	11.3	156	90.7	5	2.8	0	0	110	24.9
Total caught			124		172		176		128		441	

Net no.	Depth range fished (ft)	Depth of water (ft)	Day No.	%	Dusk No.	%	Night No.	%	Dawn No.	%
			Spring: No. observations - 6							
1	0-15	15	21	14.7	253	67.6	93	57.4	129	55.8
2	15-30	30	53	37.0	44	11.8	17	10.5	36	15.6
3	0-15	45	8	5.6	53	14.2	37	22.8	19	8.2
4	30-45	45	25	17.5	22	5.9	10	6.2	30	13.0
5	60-75	75	36	25.2	2	0.5	5	3.1	17	7.4
Total caught			143		374		162		231	

1/ Number of observations during day: water visibility 7 feet and greater--6, water visibility less than 7 feet--4.

Table 14. The numbers and percentages of wild chinook caught in the summer, fall, and winter and hatchery chinook caught in the spring by gill-net location within diel periods, North Fork Reservoir, December 18, 1962-November 23, 1964.

Summer: No. observations - 5

Net no.	Depth range fished (ft)	Depth of water (ft)	Day No.	Day %	Dusk No.	Dusk %	Night No.	Night %	Dawn No.	Dawn %
1	0-15	15	1	2.2	26	18.6	26	25.8	24	16.3
2	15-30	30	12	26.7	34	24.3	49	48.5	50	34.0
3	0-15	45	1	2.2	36	25.7	7	6.9	16	10.9
4	30-45	45	28	62.2	42	30.0	16	15.8	52	35.4
5	60-75	75	3	6.7	2	1.4	3	3.0	5	3.4
Total caught			45		140		101		147	

Fall: No. observations - 4

Net no.	Depth range fished (ft)	Depth of water (ft)	Day No.	Day %	Dusk No.	Dusk %	Night No.	Night %	Dawn No.	Dawn %
1	0-15	15	3	23.1	36	52.9	43	58.1	30	37.0
2	15-30	30	2	15.4	13	19.1	12	16.2	22	27.2
3	0-15	45	4	30.7	16	23.6	14	18.9	13	16.0
4	30-45	45	2	15.4	2	2.9	5	6.8	8	9.9
5	60-75	75	2	15.4	1	1.5	0	0	8	9.9
Total caught			13		68		74		81	

Table 14 (cont'd)

Winter: No. observations - 10										
Net no.	Depth range fished (ft)	Depth of water (ft)	Catch by diel period							
			Day		Dusk		Night		Dawn	
			No.	%	No.	%	No.	%	No.	%
1	0-15	15	0	0	22	66.6	13	43.3	6	27.2
2	15-30	30	0	0	5	15.2	2	6.7	1	4.6
3	0-15	45	0	0	4	12.1	14	46.7	4	18.2
4	30-45	45	2	15.4	2	6.1	1	3.3	4	18.2
5	60-75	75	11	84.6	0	0	0	0	7	31.8
Total caught			13		33		30		22	

Spring: No observations - 6										
Net no.	Depth range fished (ft)	Depth of water (ft)	Catch by diel period							
			Day		Dusk		Night		Dawn	
			No.	%	No.	%	No.	%	No.	%
1	0-15	15	2	50.0	0	0	9	17.6	0	0
2	15-30	30	1	25.0	1	5.3	5	9.8	1	100.0
3	0-15	45	1	25.0	15	78.9	37	72.6	0	0
4	30-45	45	0	0	3	15.8	0	0	0	0
5	60-75	75	0	0	0	0	0	0	0	0
Total caught			4		19		51		1	

45 feet deep. In the spring, fish were caught in the daytime in all nets except the one on the surface over 45-foot-deep water. The latter net caught a small percentage of the coho taken during the day in each season, but it caught a significant percentage of the total taken at night during the spring. At night, a majority of the coho were taken in the net located nearest to the shoreline in each season. This occurrence was particularly striking in the fall and winter periods. The most distinct difference in distribution of coho salmon occurred between the day (with water visibility 7 feet and greater) and night periods in the winter. In general coho salmon were distributed comparatively deep during the day and shallow at night in all seasons. Since this indicates the fish move from one point to another at dusk and dawn, it seems reasonable to expect variations in the distribution of catches during these two periods. We concluded most coho oriented with the bottom because our catches were greatest in nets fished there.

Fewer chinook were caught than coho, except in the summer. Generally, chinook were distributed deeper during the day than at night. As with coho, the most distinct diel changes were in the winter. In the spring, catches were inadequate to describe distribution during the day, but at night most chinook were caught at the surface in water 45 feet deep.

The depth distributions of wild and hatchery steelhead smolts in the spring are shown in Table 15. Catches were generally poor. Data obtained during the day were inconclusive; but at night steelhead were caught in the net at the surface over deep water, similar to chinook.

Catches in gill nets fished perpendicular to the shoreline were less than for parallel-set nets, but results, though not shown, generally corroborate the data shown in Tables 13-15.

Gill nets were fished in the deeper areas of the reservoir, during the day, to determine if salmon sounded to these areas. Nets fished at a depth of

Table 15. The numbers and percentages of wild and hatchery steelhead trout caught by gill-net location within diel periods, North Fork Reservoir, spring seasons 1963 and 1964.

Wild steelhead: No. observations - 6										
			Catch by diel period							
			Day		Dusk		Night		Dawn	
Net no.	Depth range fished (ft)	Depth of water (ft)	No.	%	No.	%	No.	%	No.	%
1	0-15	15	7	46.7	6	13.3	33	23.9	7	41.2
2	15-30	30	0	0	0	0	14	10.1	0	0
3	0-15	45	3	20.0	29	64.5	85	61.7	5	29.4
4	30-45	45	0	0	6	13.3	5	3.6	0	0
5	60-75	75	5	33.3	4	8.9	1	0.7	5	29.4
Total caught			15		45		138		17	

Hatchery steelhead: No. observations - 6										
			Catch by diel period							
			Day		Dusk		Night		Dawn	
Net no.	Depth range fished (ft)	Depth of water (ft)	No.	%	No.	%	No.	%	No.	%
1	0-15	15	0	0	6	27.3	7	35.0	10	34.5
2	15-30	30	1	14.3	1	4.6	1	5.0	0	0
3	0-15	45	5	71.4	13	59.0	11	55.0	18	62.1
4	30-45	45	0	0	0	0	1	5.0	1	3.4
5	60-75	75	1	14.3	2	9.1	0	0	0	0
Total caught			7		22		20		29	

120 feet usually caught fish. The catches of wild coho salmon on two days when four depths to 120 feet were checked are presented in Table 16. Fish at the maximum depth approximate the depth of the penstocks. Coho were not caught in the two shallowest nets on these occasions.

Table 16. The numbers and percentages of wild coho salmon caught during the day, by gill-net location in an area 1/4 mile above North Fork Dam, February 7 and 27, 1964. 1/

Depth range fished (ft)	Depth of water (ft)	Catch	
		No.	%
0-15	15	0	0
30-45	45	0	0
60-75	75	35	68.6
105-120	120	16	31.4
Total caught		51	

1/ Water visibility greater than 7 feet on both occasions.

The mean length of fish caught by net location was examined for all of the above data. While variations were observed in the average length of fish caught at different locations, the results lacked consistency and were inconclusive.

Additional information on depth distribution at North Fork was obtained by counting fish at night while using SCUBA gear to swim 50-yard-long transects near the shoreline and on the bottom at depths of 15, 30, and 50 feet (Table 17). In all seasons except the winter, the majority of the coho counted were near the shoreline. In the winter, the counts were evenly distributed between that location and depths of 15 and 30 feet. Few, if any, fish were seen at 50 feet in any season. All coho observed in the summer, fall, and winter were of the same brood year, but those counted in the spring were mainly composed of fry of the new brood with some yearlings included. These data cannot be compared directly to catches in the gill nets since SCUBA transects were at specific

Table 17. The numbers and percentages, by depth, of coho salmon counted by SCUBA divers at night on 50-yard-long transects, by season, North Fork Reservoir. 1/

Depth (feet)	Season							
	Summer		Fall		Winter		Spring 3/	
	No.	%	No.	%	No.	%	No.	%
Surface 2/	115	72.8	74	56.0	97	31.5	193	86.6
15	36	22.8	52	39.4	98	31.8	29	13.0
30	4	2.5	6	4.6	89	28.9	1	0.4
50	3	1.9	0	0	24	7.8	0	0
Total caught	158		132		308		223	

1/ Counts were made in the summers and springs of 1963 and 1964, the falls of 1962 and 1963, and the winters of 1962-63 and 1963-64.
2/ Counts made near shoreline.
3/ Counts composed mainly of fry, but includes yearlings.

depths while each net fished a depth range of 15 feet. Also SCUBA observations were essentially instantaneous, immediately after nightfall, while the nets were pulled and reset during this period and fishing at night extended over several hours. Nonetheless, both methods of observation indicated coho salmon preferred the 0- to 15-foot depth at night in all seasons. Too few chinook salmon and steelhead smolts were counted to reach conclusions.

Survival and collection efficiency. Survival and efficiency of collection of juvenile salmonids must be discussed together since determining survival depended on the ability of fish to enter the collection facilities. Survival and efficiency of collection were calculated as the per cent of marked and tagged juveniles collected at the skimmer as smolts. The factors affecting the recovery rates of marked and tagged fish included mortalities, availability (those emigrating via the spill would not be available), and efficiency of collection. Those fish marked or tagged early in their freshwater life may have been affected by all three factors; but in the spring, as yearlings, they were probably more influenced by collection because likelihood of the other factors was lessened.

Totals of 2,134 fingerling and 2,132 fry coho salmon were marked in the fall of 1962 and spring of 1963, respectively, and the recoveries at the collection facilities amounted to 572 (26.8%) for the former and 172 (8.1%) for the latter. Of 140 fingerling and 422 fry chinook marked at the same time as the coho, recoveries were 21 (15%) and 9 (2.1%). Although small numbers of chinook were marked, results indicated survival may have been adequate. Fish marked as fingerlings and fry were recovered mainly as yearlings in the spring of the years 1963 and 1964, respectively, but a few were collected as subyearlings. Additional numbers of the coho, 28 (1.3%) marked as fingerlings and 14 (0.6%) marked as fry, were recovered in traps fished in Faraday Lake, after leaving North Fork Reservoir via the spillway or penstocks. The numbers of marked fish leaving by way of these routes were undoubtedly much larger since the traps in Faraday only sampled on an intermittent basis.

Fish were tagged at North Fork from February 1963 through June 1965. Those recaptured in the reservoir and released were not considered in determining survival and collection efficiency as they may have been adversely affected by additional handling. The month of tagging was significantly related to the rate of recovery at the collection facilities of tagged coho and chinook salmon for each year of the study data were obtained (Figures 10 and 11). In all instances, the slopes of the calculated lines were positive.

For coho, the rates of recovery by run-year ranged from 50% in February 1963 to 77% in May 1963, from 32% in December 1963 to 77% in April and June 1964, and from 16% in August 1964 to 70% in May 1965. A lower rate of recovery for fish tagged in December 1963 than for fish tagged in previous months that run-year may be because the December fish were tagged during a freshet. Under those conditions, fish may have been adversely affected or stimulated by handling. The relatively low recovery rates for fish tagged in August and

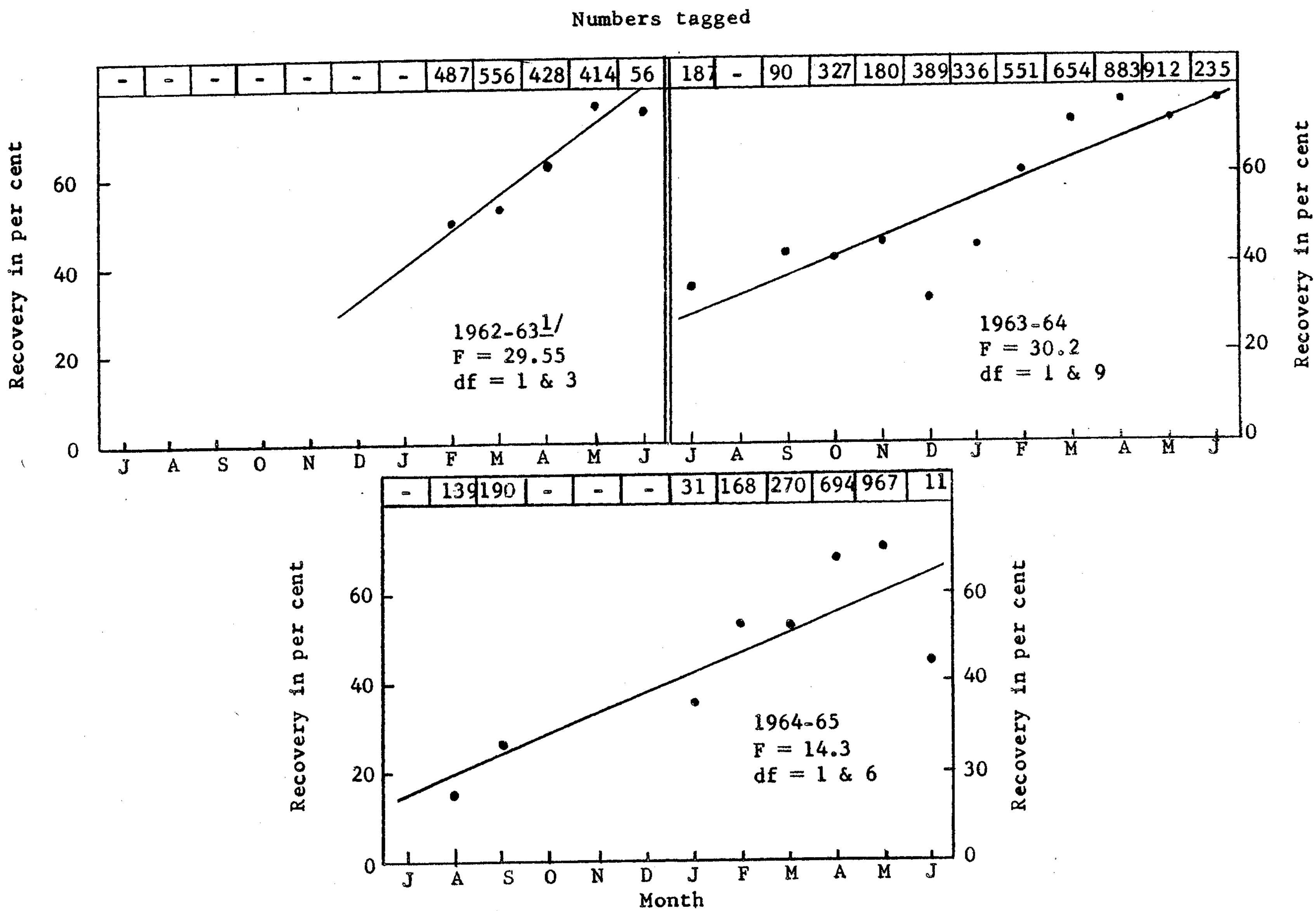


Figure 10. The relationship between month of tagging and rate of recovery of coho salmon, by run-year, North Fork Reservoir, 1963-65.

1/ Tagging initiated in February 1963 of this run-year.

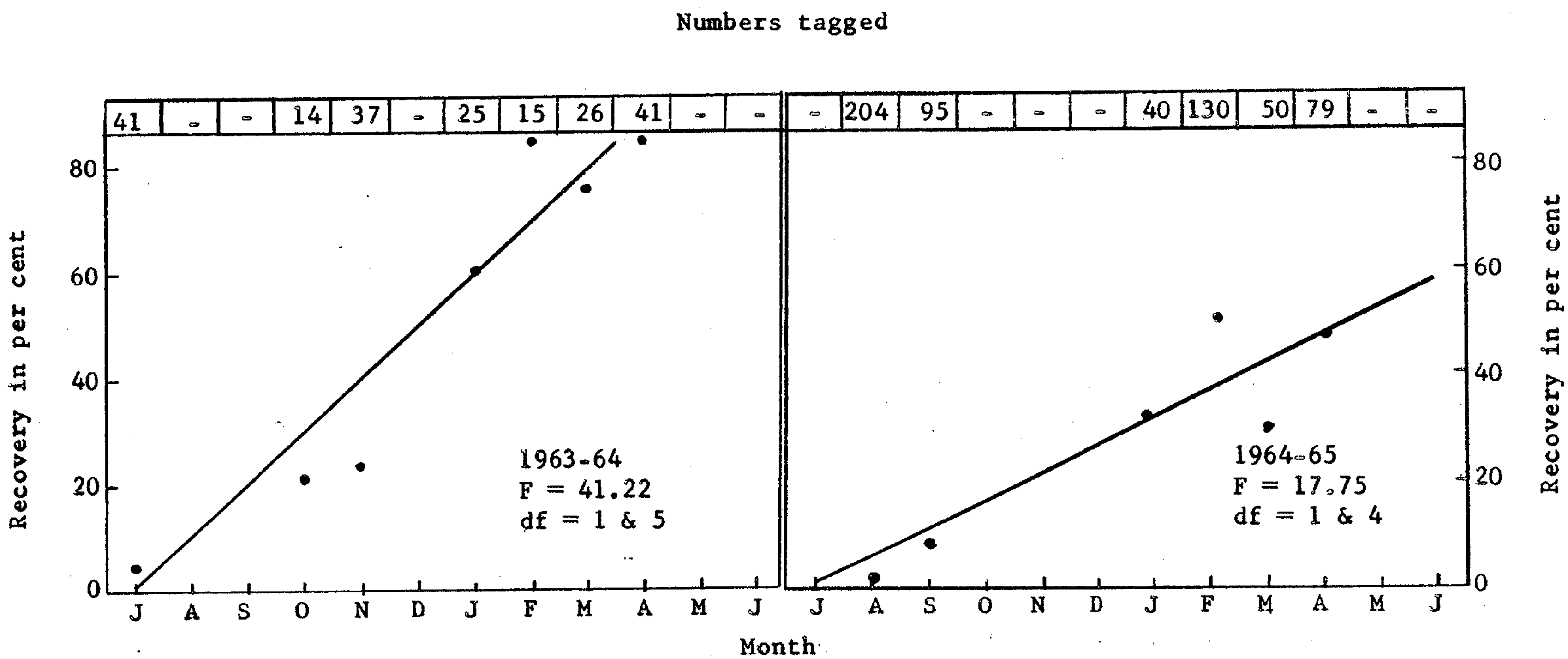


Figure 11. The relationship between month of tagging and rate of recovery of chinook salmon, by run-year, North Fork Reservoir, 1963-65.

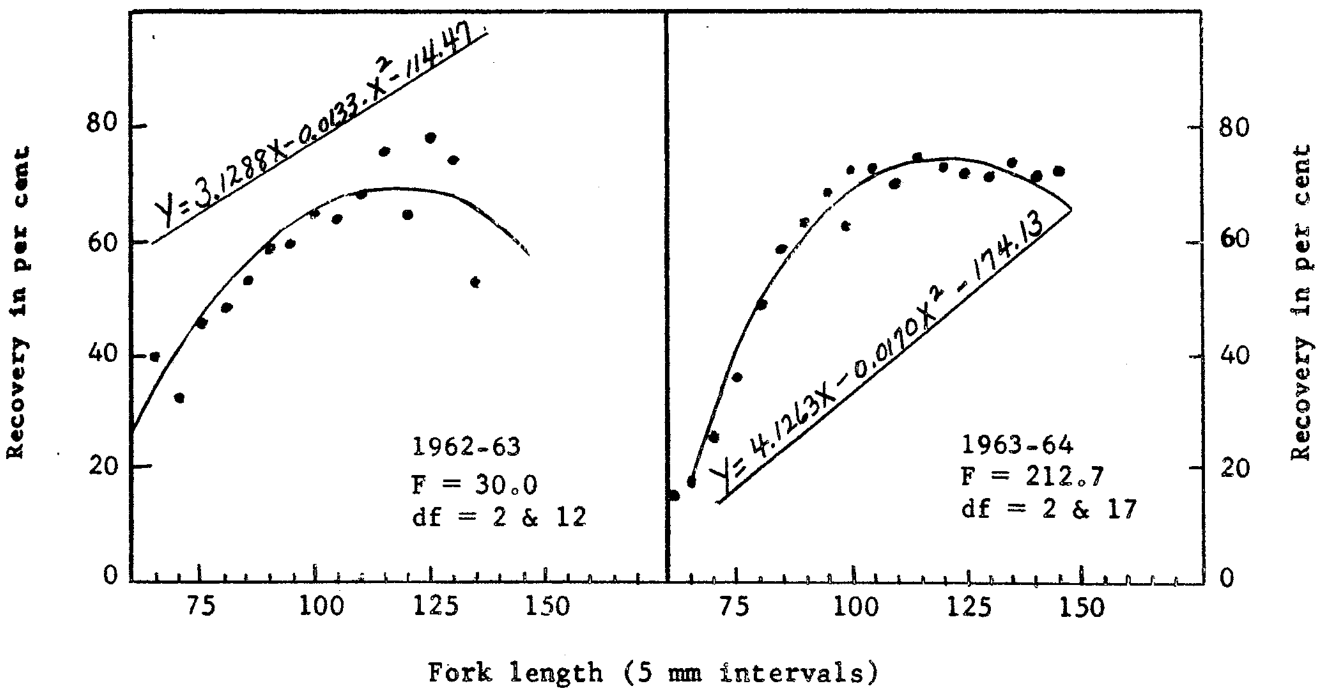
September 1964 were probably due to the floods in December 1964 and January 1965, while the low recovery of fish tagged in June 1965 was probably due to the small numbers released.

Relatively small numbers of chinook were tagged and released, but positive results were obtained. The rates of recovery for chinook ranged from 7% in July 1963 to 86% in February and April 1964 and from 5% in August 1964 to 50% in February 1965. The lower recovery rates from the second year of tagging may be due to the floods in December and January.

The numbers of steelhead smolts tagged and released in April and May of each year were as follows: 1963 - 145, 1964 - 424, and 1965 - 501. The respective rates of recovery for steelhead tagged in these years were 53%, 70%, and 70%. In all years the recovery rates were slightly higher for fish tagged in May than for those tagged in April. The significantly lower rate of recovery for fish tagged in 1963 was believed due to the spill at the peak of steelhead emigration in the first week of May.

The relationships between the length of coho salmon at tagging and their rates of recovery are shown in Figure 12. Relationships were significant and positive in all years. The lower rate of recovery for smaller fish may be related to a difference in tagging mortality due to size, a higher mortality of small fish due to predation and other natural causes, or both. A gross comparison of the rates of recovery for two size groups of coho salmon in 1963-64 shows a lower rate recovered for small fish regardless of month of tagging (Figure 13).

Success of passage of downstream migrants at the North Fork project was determined in the Evaluation Study by the percentage recovery in the collection system of marked wild and hatchery fish released at the head of the reservoir in the spring. The range in rates of recovery for each species was as follows: chinook, 39-73%; coho, 70-90%; and steelhead, 78-79%. Tests using hatchery steelhead were not included because many fish were considered too small to emigrate.



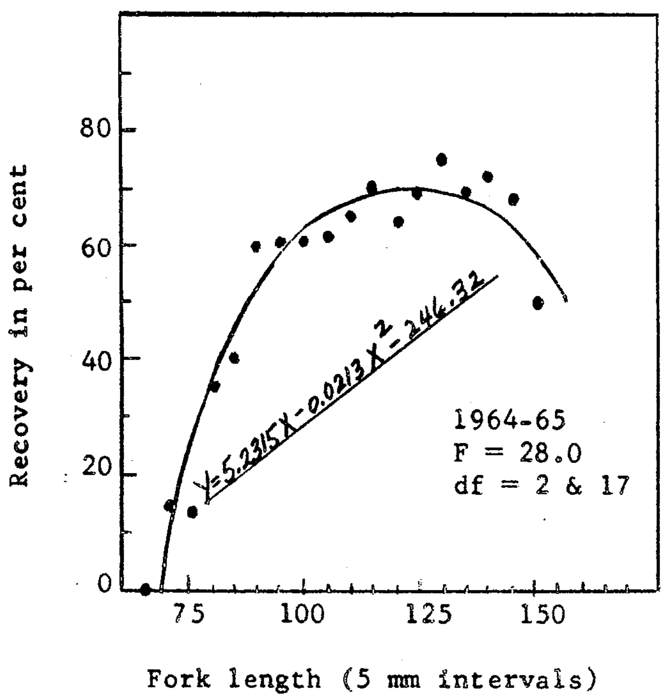


Figure 12. The relationship between length at tagging and rate of recovery of coho salmon, by run-year, North Fork Reservoir, 1962-65.

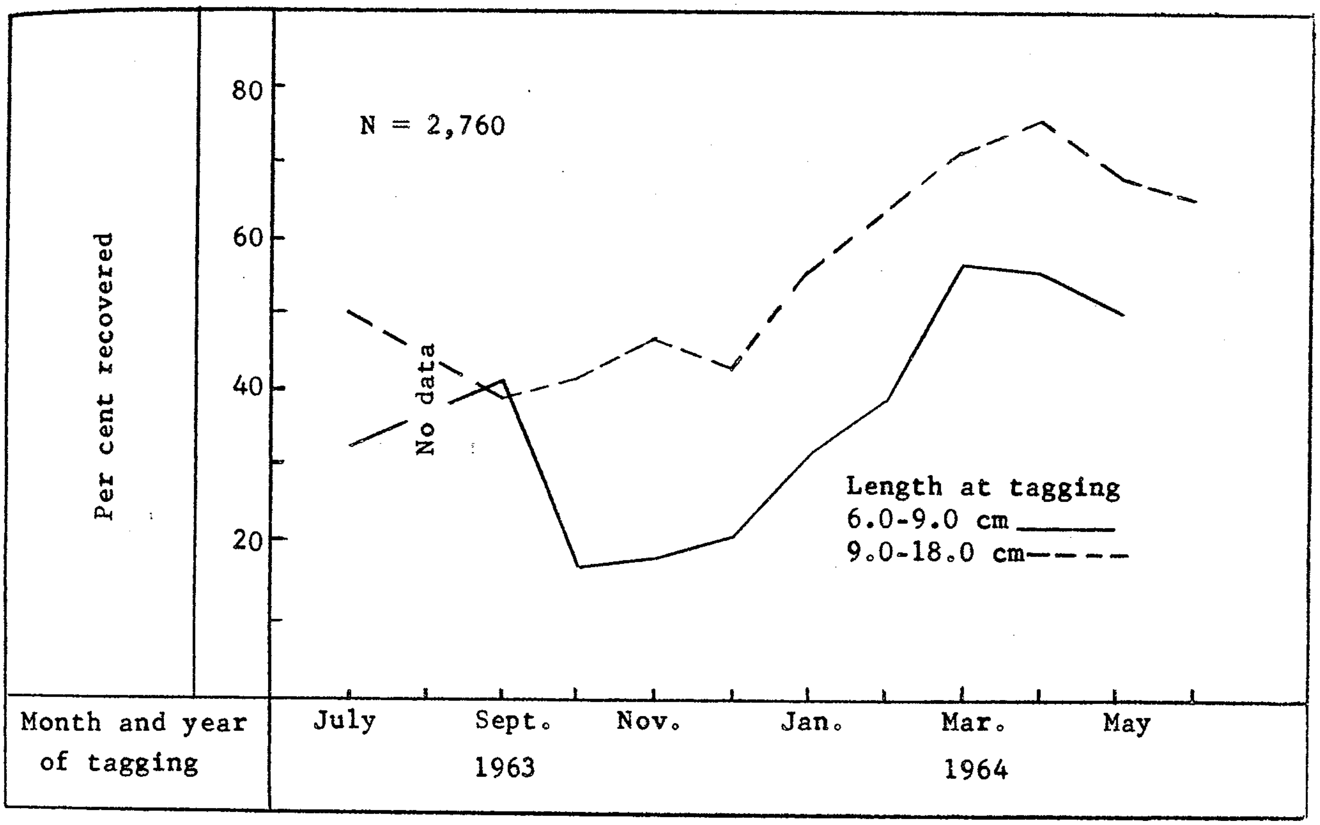


Figure 13. Per cent recovery at the collection system of two size groups of coho salmon, by month of tagging, North Fork Reservoir, July 1963-June 1964.

The survival and efficiency of collection at North Fork appeared good for all species, but was best for coho and poorest for chinook. Losses in the reservoir were believed greatest during the fry stage.

Cottids, rainbow trout, and yearling salmon were identified as predators on fry salmonids. Yearling coho were potentially the most serious predators as they were the most abundant. No other predators of consequence were present, and the major species of scrapfish were suckers and dace.

Sport census data obtained by the Evaluation Study during the spring of 1963 showed that 18% of the fish sampled were wild steelhead smolts. Estimates of the catch were not made. 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 bottom of the reservoir during the spring, most with hook wounds.

Age and growth. Chinook and coho salmon grew relatively fast after entering North Fork Reservoir early in their first year of life. Chinook salmon of the 1961 brood ranged in size from 10 to 15 cm with a mode at 11 cm by November 1962. By the same month in 1963, chinook of the 1962 brood ranged in size from 8.5 to 15 cm with a mode at 10 cm.

Coho salmon sampled at the same times as the chinook ranged in size from 6 to 15.5 cm with a mode at 9 cm for the 1961 brood, and a size range of 5.5 to 16 cm with a mode at 10 to 11 cm for the 1962 brood. The size of coho caught in the reservoir did not change appreciably after spills in November and December 1962; but in 1963 their modal size of 10-11 cm in November before a spill had changed to 8 cm by December.

It was shown earlier that many juvenile salmon left North Fork Reservoir on spills in the fall and winter. The size of coho emigrating via the spillway compared with that of fish leaving through the collection facilities shows that the larger fish present in November and December left on the spill (Figure 14).

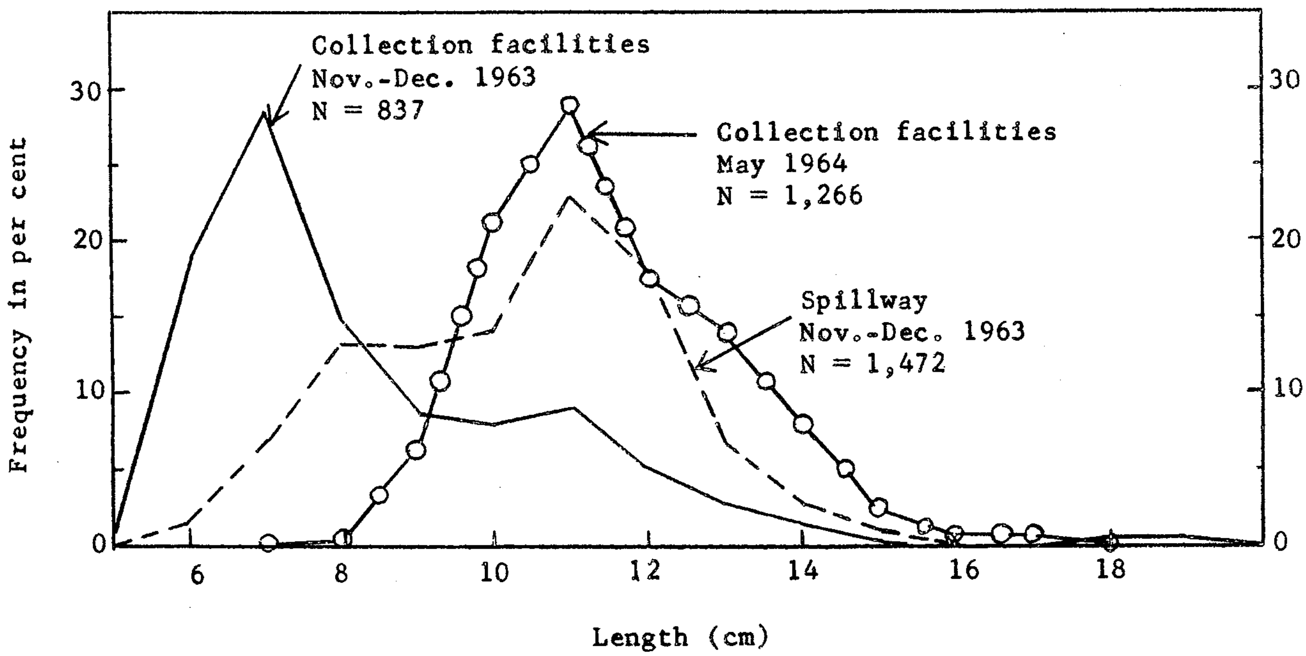


Figure 14. A comparison of the size compositions of 1962-brood coho salmon emigrating via the spillway in the fall of 1963 and by way of the collection facilities in the fall of 1963 and spring of 1964, North Fork Reservoir.

The modal size of coho salmon emigrating through the collection facilities increased from 7 cm in November and December 1963 to 11 and 12 cm, respectively, in May and June 1964. The data for June are not shown in the graph. The modal sizes of chinook salmon emigrating through the collection facilities in May of 1963 and 1964 and of coho emigrating in May 1963 were similar to those shown for coho in May 1964.

Figure 15 shows that, at emigration in May 1964, coho salmon marked and released into the reservoir as fry were about 2 cm larger than the general unmarked population. This leads to a hypothesis that fish reared entirely in the impoundment grew faster than those reared totally or partly in the stream. Most of the marked coho emigrated from the reservoir in May, and the comparison is confined to that month. This hypothesis is substantiated by comparing the size of coho caught by floating traps in the reservoir with that of samples seined in Fish Creek, a tributary of the Clackamas River. Figure 16 shows the size distributions of coho caught in the two areas in September 1963 are completely distinct from one another, with those fish taken in the reservoir larger than the ones from Fish Creek. The modal sizes differed by 3 cm.

The best information on times and rates of growth in the reservoir was shown by tagged fish. The mean growth of tagged coho salmon by monthly period and run-year is shown in Figure 17. Since most tagged fish were recovered in the spring, the mean growth per month of coho salmon was obtained by determining the average total growth of fish from each month of tagging to time of recovery at the skimmer and computing the difference in the growth of fish between successive months of tagging. The periods for which growth is shown extends from the 10th of one month to the 10th of the next. Tagging was not initiated until February 1963 and was discontinued from October 1964 through January 1965 due to the floods of that year. As a result, 1963-64 is the only complete run-year represented. Growth exceeded 15 mm per month be-

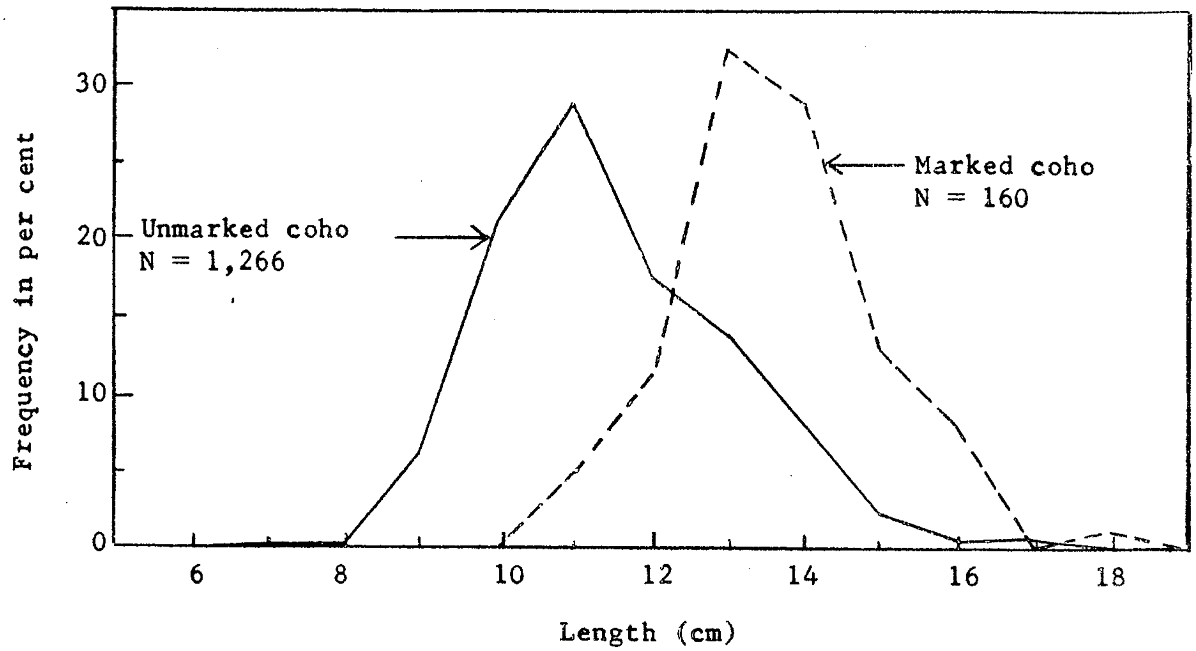


Figure 15. A comparison of the size compositions at emigration of coho marked and released into the reservoir as fry and the general unmarked population, North Fork Reservoir, May 1964.

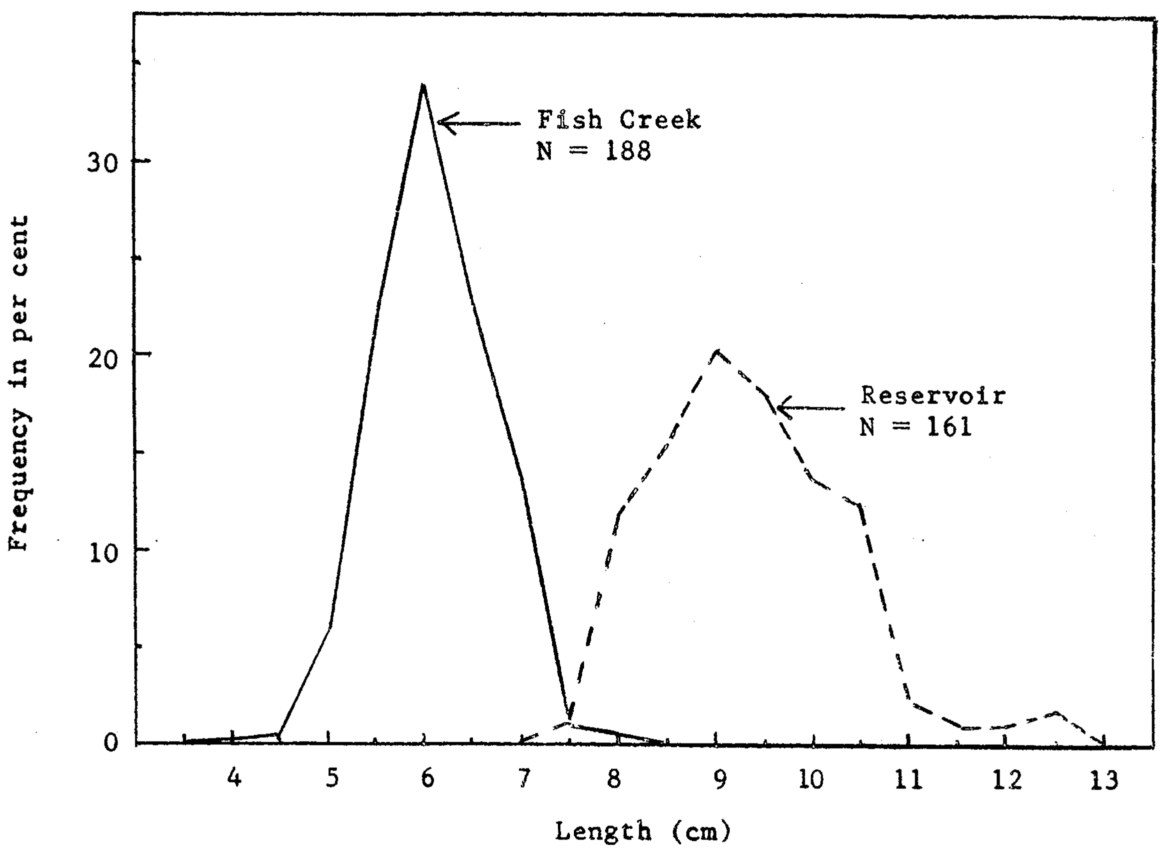


Figure 16. A comparison of the size compositions of coho salmon caught in Fish Creek and the upper end of North Fork Reservoir, September 1963.

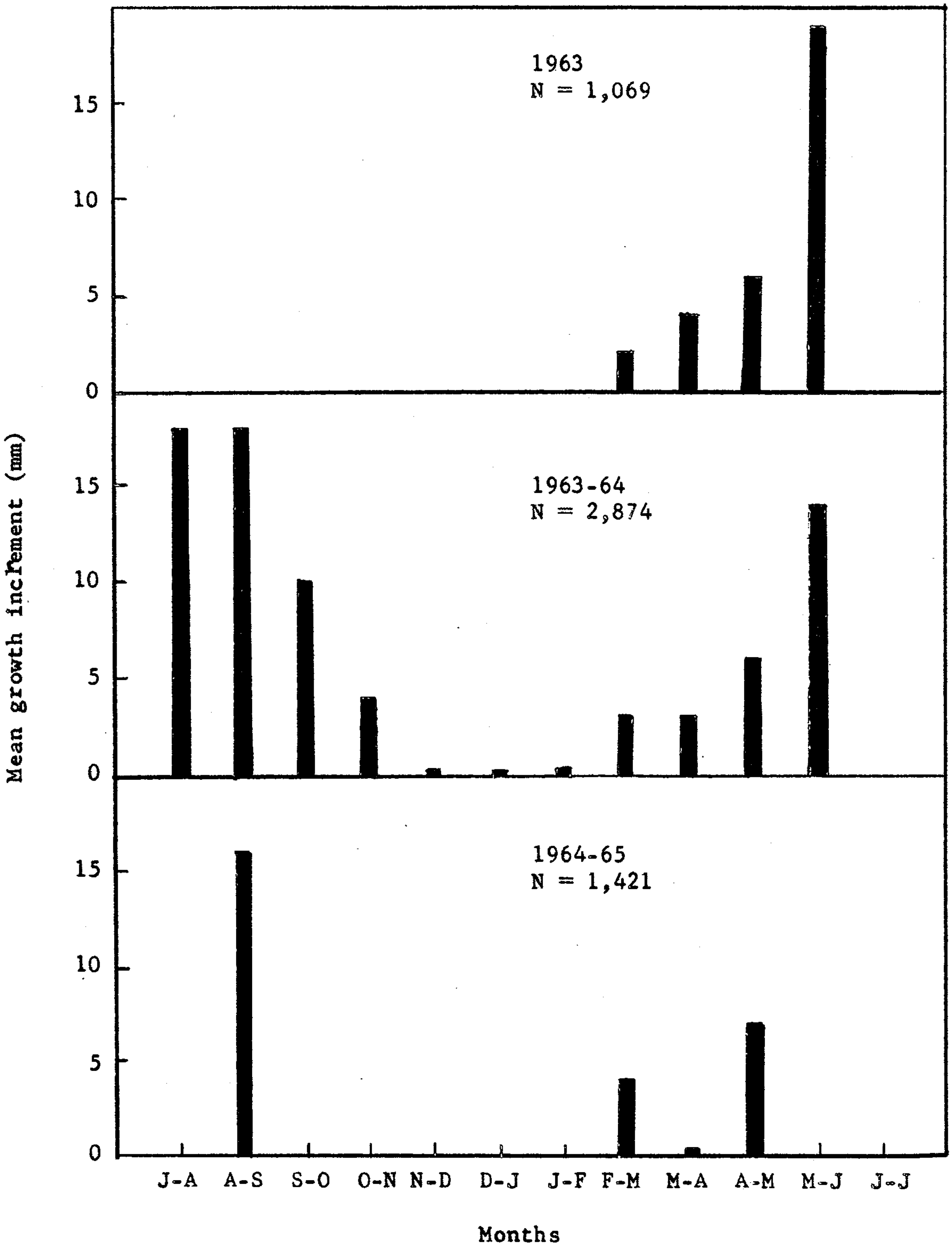


Figure 17. The mean growth of tagged coho salmon by month and run-year, North Fork Reservoir, February 1963-May 1965.

tween July and September 1963, was gradually reduced to nothing during the winter months (mid-November to mid-February), and gradually increased during the spring until the rate of growth at the height of the downstream migration in 1964 approximated that of the previous summer. The mean growth, by month, was generally similar between years where comparable data were available.

Since all sizes of fish grew fast in the summer and spring, the relationship between size when tagged in each of the two seasons and their subsequent size at emigration seemed important. This relationship is examined in Figures 18 and 19 for coho tagged in July 1963 and April 1964. Recoveries in May and June are divided into semi-monthly periods. The fish were 60 to 90 mm long when tagged in July 1963 and from 115 to 165 mm long at recovery. Of the 65 coho recovered from the July tagging, 60 (92%) were recovered in May; but of the 713 recovered from the April tagging, 299 (42%) were recovered in May. The reason coho tagged in July emigrated early appears due to the fact that by May they were larger than the fish tagged in April. This is substantiated by fish tagged in April. Those recovered in May were larger at both tagging and recovery than those recovered in June. As the recovery periods progressed for fish tagged in April, the difference between their size at tagging and at recovery became greater, i.e., the longer the fish remained in the reservoir after tagging the more they grew. By the end of June, coho were 3.5 cm larger than they were when tagged in April. This appears due to two reasons: the fish were growing rapidly in the spring, and the smaller the fish at tagging in April, the later they emigrated. This indicates either conditions influenced the smaller fish to remain in the reservoir until they were larger, or a larger size was necessary to their emigration.

Data were inadequate to describe growth of chinook in the reservoir, but suggested that they showed less total growth than coho during the entire spring period. This may be because the chinook emigrated earlier and had less time to grow.

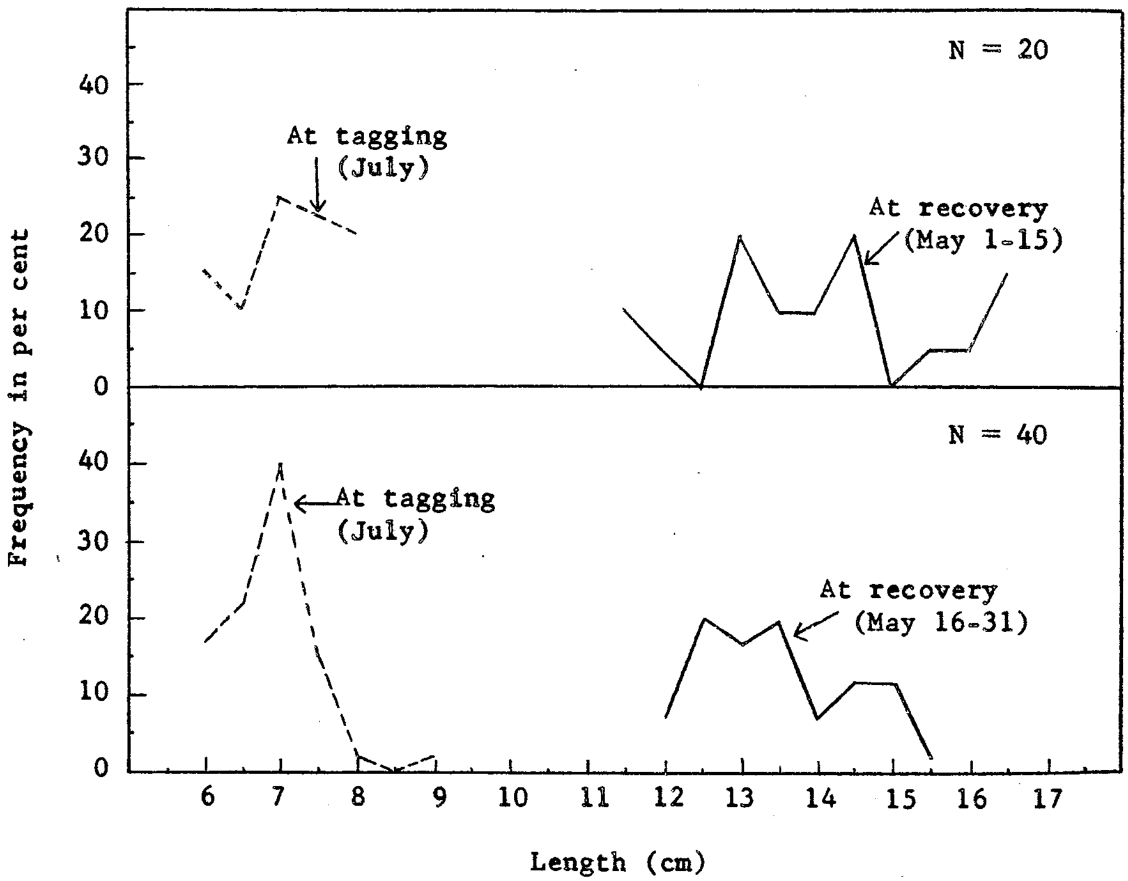


Figure 18. Size compositions of coho salmon at tagging in July 1963 and at recovery in the North Fork collection facilities in May 1964.

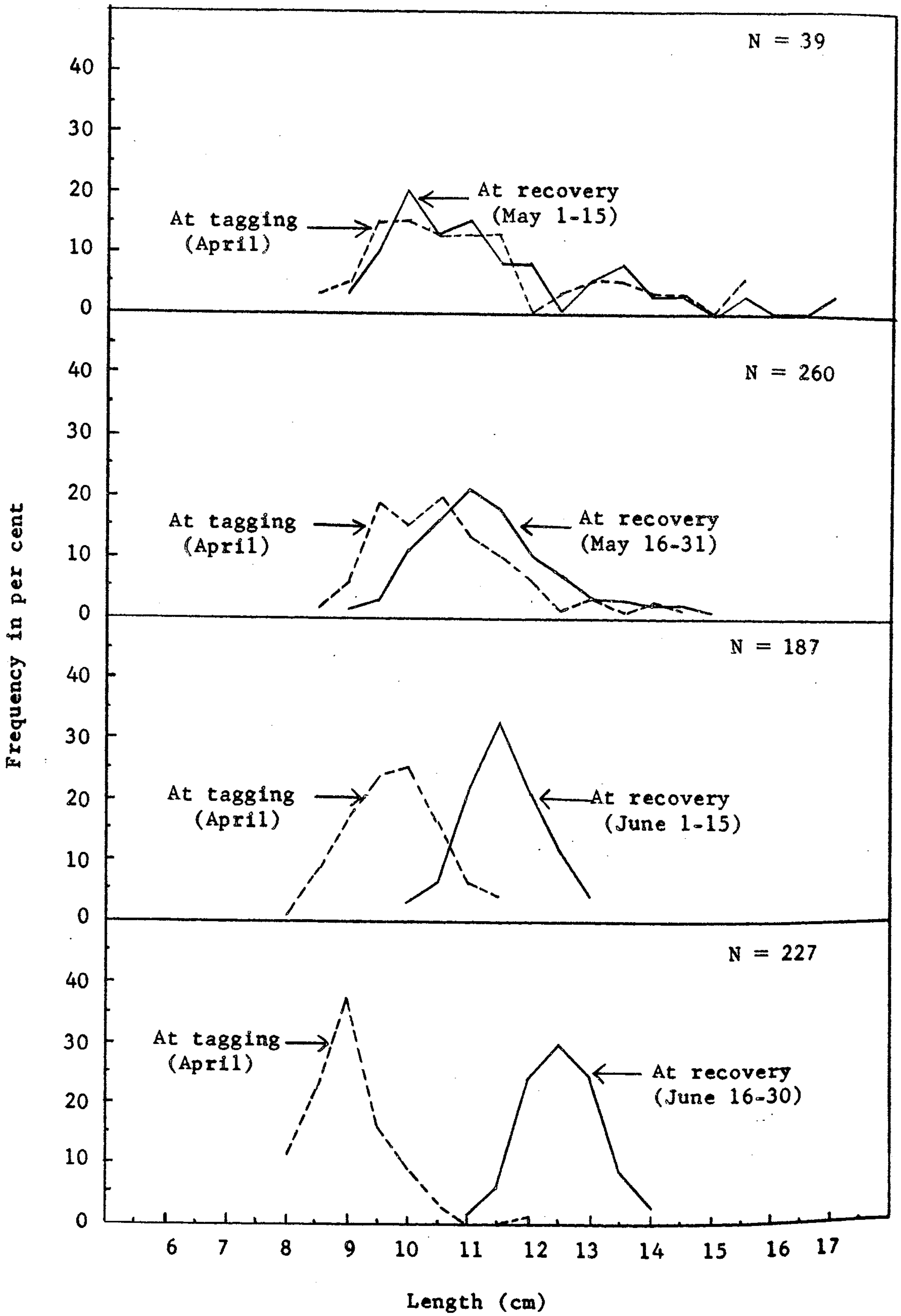


Figure 19. Size compositions of coho salmon at tagging in April 1964 and at recovery in the North Fork collection facilities in May and June 1964.

Emigrating steelhead smolts tagged during each spring of the 3 years of study grew little between tagging and recovery. However, most of the fish recovered left the reservoir within 20 days after tagging and steelhead emigrated earlier than either chinook or coho, thus missing the period of optimum growing conditions. A few smolts remained in the reservoir from 1 to 1-1/2 months after tagging and grew between 5 and 10 mm. Steelhead emigrants sampled at the collection facilities ranged in size from 13 to 24 and 13 to 28 cm in the spring of 1963 and spring of 1964, respectively; the modal size in each year was 16 cm.

The ages of emigrating salmon and steelhead were read from stratified samples of scales obtained during the first 2 years of the study. The numbers of scales read varied between one and 18 for each 1 cm length interval depending on the year, species, number of samples having regenerated scales, and availability of fish at the extremes of the size distributions. Scales were read for coho and chinook for each month from October of one year through June of the next; and steelhead scales were from May, their main month of emigration. Virtually all chinook and coho leaving North Fork Reservoir during each run-year were sub-yearlings and yearlings of the same brood year. The annulus was first observed on scale samples obtained from these species in April. By May, scales from many of the fish sampled showed an annulus.

Steelhead emigrated from North Fork Reservoir as 1-, 2-, and 3-year-old fish. Table 18 shows the age by length of emigrating steelhead smolts. More scales were read in 1963 than in 1964. In 1963 samples from all length intervals from 13 through 20 cm were composed mainly of 2-year-old fish; but in 1964 a significant portion of the scales from fish 16 cm long and longer were 3 years old. The size and age compositions of steelhead emigrants at North Fork in 1963 and 1964 as shown in Tables 19 and 20 were determined by obtaining length-frequency samples from the main parts of the runs, which were of rela-

Table 18. The age by length of emigrating steelhead smolts as shown by stratified samples of scales taken at the collection facilities, North Fork Reservoir, spring seasons 1963 and 1964.

Length (cm)	1963							1964						
	Age						Total no. in sample	Age						Total no. in Sample
	1		2		3			1		2		3		
	No.	% 1/	No.	%	No.	%		No.	%	No.	%	No.	%	
13	0	0	1	100	0	0	1	1	20	4	80	0	0	5
14	1	10	9	90	0	0	10	3	43	4	57	0	0	7
15	1	6	15	88	1	6	17	0	0	10	100	0	0	10
16	1	5.5	16	89	1	5.5	18	0	0	4	57	3	43	7
17	0	0	17	100	0	0	17	0	0	3	38	5	62	8
18	0	0	18	100	0	0	18	0	0	4	44	5	56	9
19	0	0	11	73	4	17	15	0	0	5	71	2	29	7
20	0	0	6	75	2	25	8	0	0	4	50	4	50	8
21 2/	0	0	8	42	11	58	19	0	0	2	29	5	71	7
22 3/	-	-	-	-	-	-	-	0	0	0	0	12	100	12
Total	3		101		19		123	4		40		36		80

1/ The percentages of the three age classes should total 100 for each length interval.
2/ Includes all samples from fish exceeding 21 cm in length in 1963.
3/ Includes all samples from fish exceeding 22 cm in length in 1964.

Table 19. The size and age composition of steelhead emigrating from North Fork Reservoir in the spring of 1963.

Length (cm)	Age 1	Age 2	Age 3	Total	Size composition in per cent
13	0	5	0	5	0.7
14	1	12	0	13	1.8
15	6	91	6	103	14.1
16	9	140	9	158	21.7
17	0	148	0	148	20.3
18	0	138	0	138	19.0
19	0	49	18	67	9.2
20	0	30	10	40	5.5
21 and over	0	23	32	55	7.7
Total	16	636	75	727	100.0
Age composition in per cent	2.2	87.5	10.3	100.0	

Table 20. The size and age composition of steelhead emigrating from North Fork Reservoir in the spring of 1964.

Length (cm)	Age 1	2	3	Total	Size composition in per cent
13	1	5	0	6	0.6
14	13	18	0	31	3.2
15	0	148	0	148	15.2
16	0	131	99	230	23.7
17	0	84	138	222	22.8
18	0	61	77	138	14.2
19	0	55	22	77	7.9
20	0	29	29	58	6.0
21	0	8	20	28	2.9
22 and over	0	0	35	35	3.5
Total	14	539	420	973	100.0
Age composition in per cent	1.4	55.4	43.2	100.0	

tively short duration, and by applying the length-age relationships obtained from the stratified samples to these distributions. The size compositions of the runs were similar for the 2 years, but the age compositions varied significantly. In 1963, it was calculated that 87.5% of the emigrating steelhead were 2-year-old fish and only 10.3% were 3 years of age. In 1964 only 55.4% were 2 years old while 43.2% were age 3. One-year-old fish were a minor percentage of the run in each year. It appears from this that the fish emigrating as 2's in 1963 and 3's in 1964 probably resulted from a strong year class in 1961.

Pelton Reservoir

Environment

Water temperature. Water temperature profiles were taken at regular intervals in Pelton Reservoir from August 1962 to May 1965. Stations were established at North Fork. Sampling during the first year indicated little variation in temperature patterns across the width of the reservoir, and subsequent observations were made only in the former river channel. Figure 20 shows representative temperature profiles by season in Pelton Reservoir. Stratification was weak in August 1962, but more definite in the following two summers. Maximum surface temperatures were in the low 70's, and stratified little below a depth of 15 to 20 feet. Surface water temperatures were generally higher in the upstream part of the reservoir than those near the dam. The reservoir was nearly homothermous by the end of October each year, and generally remained that way throughout the winter. Warming of the water, and subsequent stratification, occurred in May. While it is not shown by these data, Pelton Reservoir warmed faster in the spring than North Fork, but maximum water temperatures at the two impoundments were similar. Although Pelton is located in an arid region having high air temperatures in the summer, water temperatures in the Deschutes River did not raise excessively due to large springs in the Metolius and Crooked rivers.

Water currents. The direction of water currents in Pelton was determined eight times between December 1963 and July 1964. Drogues were released at six stations and their movements recorded. Each time period was 1 to 3 days long depending on the number of areas sampled and the time required for the drogues to travel the course. On all but two occasions the drogues at the surface traveled predominantly down reservoir, regardless of the wind patterns. On the two exceptions, both in April 1964, the drogues traveled mainly up reservoir even though the air currents were in the opposite direction. At a depth of 20 feet, the current was predominantly downstream on the five occasions sampled, including the two times surface currents moved upstream.

Flow and visibility. Daily river flows have been recorded by Portland General Electric Company since construction of Pelton Dam. Due in part to large springs, the Deschutes River is a relatively stable stream, and between

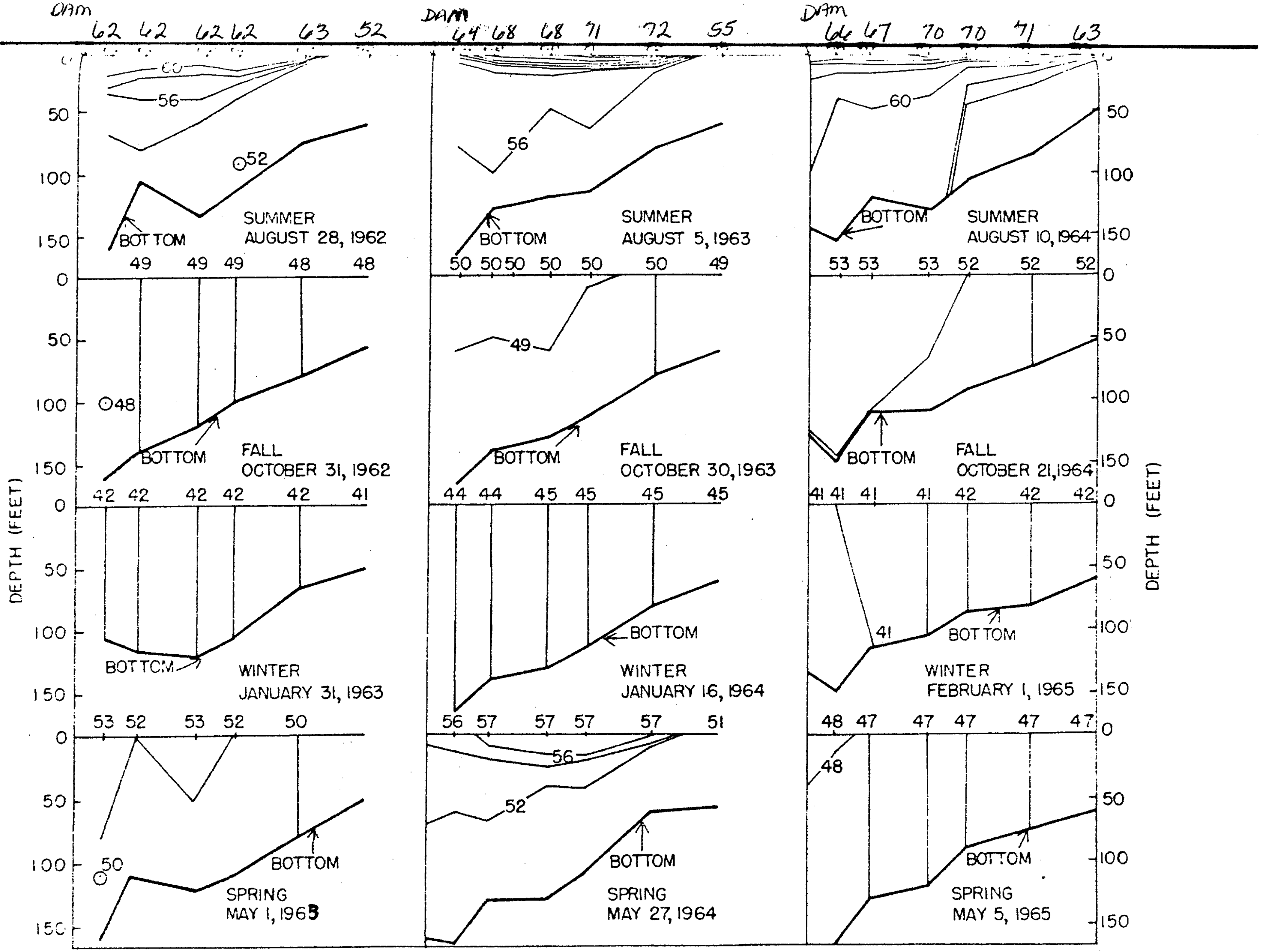


FIGURE 20 REPRESENTATIVE SEASONAL WATER TEMPERATURE PROFILES BY 2 F ISOTHERMS, PELTON RESERVOIR, AUGUST 1962-MAY 1965 LINEAR SCALE: 8.5 MM = 1 MILE

July 1962 and the river closure at Round Butte Dam in January 1964, the flows ranged between 3,800 and 7,100 cfs with the high flows in the spring months. Discharges were 3,500 cfs or less during filling of Round Butte Reservoir in the spring of 1964. The only spill on record due to high water was during the flood of December 1964 and January 1965. The maximum flow of record at Pelton, 15,200 cfs, was at this time.

Construction of Round Butte Dam adversely affected water clarity in Pelton Reservoir throughout most of the 2 years fish were studied. Secchi disc readings were taken regularly about 1 mile upstream from Pelton Dam. Visibility recorded between August 1962 and June 1964 ranged between 0.5 and 20 feet, and frequently was 5 feet or below. Secchi disc readings up to 33 feet were recorded in the same area previous to construction of Round Butte, and the water was clear for long periods, particularly during the winter (unpublished data). Water visibilities were reduced by occasional freshets during the winter and algae blooms in the summer.

Oxygen, alkalinity, and pH. Dissolved oxygen concentrations were adequate for fish life throughout the study period with a minimal value of 8.4 ppm. Total alkalinity was over two times greater than that measured at North Fork, and may be an indicator of productivity since fish at Pelton attained larger maximum sizes. All values of pH were within the limits necessary for fish life. Table 21 shows representative seasonal values of oxygen, total alkalinity, and pH taken at the entrance to the reservoir and near the dam. Oxygen values were lowest in the fall for the one full year of record (1963-64). Alkalinity values were noticeably lower in the winter and spring of 1964-65 than those recorded previously, probably due to floods of that winter. Little variation was observed in pH.

Table 21. Representative seasonal values of oxygen, total alkalinity, and pH taken at the entrance to Pelton Reservoir, and near the dam from the surface, middle of thermocline, and bottom, 1963-65.

Area	Depth	Determination	Season: Winter	Spring	Summer	Fall	Year
Entrance to reservoir	Surface	Dissolved oxygen	--	--	10.0	10.5	1963
		Total alkalinity	--	--	76	71	
		pH	--	--	--	7.75	
Near dam	Surface	Dissolved oxygen	--	--	--	10.5	
		Total alkalinity	--	--	--	68	
		pH	--	--	--	7.75	
	Thermocline	Dissolved oxygen	--	--	--	-- 1/	
		Total alkalinity	--	--	--	--	
		pH	--	--	--	--	
	Bottom	Dissolved oxygen	--	--	--	10.5	
		Total alkalinity	--	--	--	71	
		pH	--	--	--	7.75	
Entrance to reservoir	Surface	Dissolved oxygen	11.5	10.5	10.4	8.4	1963-64
		Total alkalinity	61	61	62	65	
		pH	7.75	7.75	8.75	7.75	
Near dam	Surface	Dissolved oxygen	11.0	12.5	12.8	8.6	
		Total alkalinity	66	65	65	68	
		pH	7.75	8.50	8.75	7.75	
	Thermocline	Dissolved oxygen	-- 1/	12.0	9.8	-- 1/	
		Total alkalinity	--	64	62	--	
		pH	--	8.00	8.25	--	
	Bottom	Dissolved oxygen	11.5	10.0	8.4	8.8	
		Total alkalinity	61	64	64	68	
		pH	7.75	7.75	8.25	7.75	
Entrance to reservoir	Surface	Dissolved oxygen	10.8	9.6	--	--	1964-65
		Total alkalinity	59	60	--	--	
		pH	7.75	7.75	--	--	
Near dam	Surface	Dissolved oxygen	10.8	12.4	--	--	
		Total alkalinity	56	57	--	--	
		pH	7.75	8.25	--	--	
	Thermocline	Dissolved oxygen	-- 1/	-- 1/	--	--	
		Total alkalinity	--	--	--	--	
		pH	--	--	--	--	
	Bottom	Dissolved oxygen	10.8	11.0	--	--	
		Total alkalinity	54	55	--	--	
		pH	7.75	7.75	--	--	

1/ Thermocline not present.

Fish behavior

The construction of Round Butte Dam prevented the 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 this impoundment was studied. A cooperative study by the Fish Commission and Portland General Electric Company to evaluate fish passage facilities at Pelton Dam (hereafter called Evaluation Study) yielded results (Gunsolus and Eicher 1962) which will be used to supplement that collected by the Fish Behavior Study.

Conditions in Pelton prior to, during, and after construction of Round Butte differ. Results obtained during the study will not apply in the future.

Migrations. Movements of juveniles in Pelton Reservoir were monitored primarily by catches in traps and gill nets and observations by SCUBA. Catches by traps and gill nets were generally low (Tables 22 and 23). Rainbow-steelhead caught in the traps during April-June 1963 were mainly smolted steelhead. The catch of 570 smolts (most were known individuals since 468 were tagged) was considered good since only 8,127 steelhead were counted at the collection facilities that year. The catches of 494 and 458 chinook in the traps and gill nets, respectively, were low compared to the 13,275 chinook counted at the skimmer. Closure of Round Butte Dam on January 1, 1964, interfered with the movement of fish into Pelton, and all fishing gear was transferred to Round Butte Reservoir by mid-April 1964.

In November 1962 and January 1963 dozens of 1961-brood chinook and 1962-brood rainbow-steelhead were counted along shoreline areas in the Round Butte cofferdam pool by snorkel-equipped divers, but few were seen in extensive areas examined in Pelton Reservoir. Poor water visibility prevented additional observations until April 1963 when several dozen chinook and rainbow-steelhead were counted in the same areas of Pelton Reservoir as surveyed in January. Fish apparently had moved into Pelton in the intervening period.

Table 22. Catches of chinook salmon and rainbow-steelhead trout in floating traps by month and run-year, 1/ Pelton Reservoir, 1962-64.

Month	Species and run-year			
	Chinook		Rainbow-steelhead 2/	
	1962-63	1963-64	1962-63	1963-64
July	4	2	7	21
August	2	2	33	10
September	7	8	35	6
October	8	12	14	39
November	14	29	222	16
December	7	5	17	11
January	21	93	27	63
February	245	10	224	33
March	67	1	188	18
April	16	6	192(108) 4/	8
May	59	-- 3/	486(278)	--
June	44	--	287(184)	--
Total	494	168	1,532(570)	225

1/ A run-year extends from July of one year through June of the next. Emigration of a given year class of juvenile chinook salmon occurs mainly on a run-year basis, but some chinook migrate in their second year and steelhead leave only in the spring.

2/ Fish thought to be steelhead, but may include rainbow trout.

3/ A dash (--) means the traps were not fished that month.

4/ Numbers of steelhead smolts in parentheses are included in totals.

Table 23. Catches of chinook salmon and rainbow-steelhead trout in gill nets by month and run-year, Pelton Reservoir, 1962-64.

Month	Species and run-year			
	Chinook		Rainbow-steelhead	
	1962-63	1963-64	1962-63	1963-64
July	136	94	0	6
August	27	74	19	47
September	--	54	--	28
October	42	33	6	19
November	32	35	7	7
December	33	5	3	11
January	23	93	0	63
February	45	10	17	33
March	49	1	25	18
April	55	6	60	8
May	16	--	137	--
June	0	--	4	--
Total	458	405	278	240

Snorkel-equipped divers surveyed shoreline areas of Pelton between November 1960 and May 1961 under a previous study (Korn and Gunsolus 1962), and found dozens of chinook fingerlings at a location only 1/4 mile above Pelton Dam. In mid-April 1961 over one hundred fry chinook salmon were counted in the upper and middle areas of Pelton Reservoir.

Scoop traps fished during the Evaluation Study showed that fry and yearling chinook entered Pelton Reservoir from the Metolius River and steelhead smolts entered Pelton from the Deschutes River during the spring months. A trap fished in the Metolius River in the fall of one year captured some chinook fingerlings.

The results from marking and tagging were inadequate to describe the duration of residence of anadromous fish in Pelton Reservoir. However, 6,727 chinook and 826 steelhead were counted at the Pelton skimmer between January 1 and June 30, 1964, after closure of Round Butte Dam on January 1. Although 4,296 chinook and 248 steelhead were caught in Round Butte Reservoir and released into Pelton and others could have entered through the Round Butte penstocks, many of the fish counted at the Pelton skimmer entered the reservoir prior to January 1. The length of residence of chinook in Pelton was not clearly defined, but the observations of fry implied that some fish reared in the impoundment for at least several months. The relatively small numbers of steelhead smolts counted at the Pelton skimmer and the capture of several thousand of this species in Round Butte Reservoir throughout the spring of 1964 indicated they did not rear extensively in Pelton Reservoir.

Since only 312 chinook and 468 steelhead smolts were tagged and released into Pelton Reservoir in 1962-63 and fewer of each in 1963-64, little information was obtained on their migrations within the reservoir. However, the recovery of 14 tagged steelhead smolts which migrated from the vicinity of Pelton Dam to the upper end of the reservoir late in the spring of 1963 indicated fish were not emigrating properly.

Most anadromous fish emigrated from Pelton Reservoir by way of the downstream-migrant collection facilities since it spilled, other than for brief test purposes, only once since construction, and the Evaluation Study indicated few chinook or steelhead passed through the turbines. Some fish did leave uncounted via the exit to the fish ladder which is near the skimmer. Fish were counted at the Pelton collection facilities throughout the year, but emigration was primarily in the spring (Tables 24 and 25). Two run-years were excluded because they did not show a true picture of time of migration. Counts of chinook in 1958-59 include an unknown number of unmarked hatchery fish and the timing of emigration in 1963-64 was abnormal due to Round Butte Dam. In 3 of 4 years shown, the counts of chinook peaked in April. The peak in May 1963 may be attributable to migrating fish being delayed behind the Round Butte cofferdam. Steelhead generally emigrated later than chinook. In the 4 years shown, counts peaked twice in May and twice in June.

March 15 was arbitarily chosen as the date dividing winter and spring climatological conditions at Pelton. For the winter and spring periods, the daily counts of chinook were compared to flows and water temperatures. Data on steelhead were analyzed for the spring only since this species did not emigrate in significant numbers in the winter.

Regression analyses were made for the 2 years of data examined. Figures 21, 22, and 23 show that significant positive relationships at the 5% level were found between the counts of chinook and flows during the winter, and the counts of chinook and steelhead and water temperatures in the spring. It was also found that water temperatures did not have a significant relationship with the counts of chinook in the winter. The relationships between counts of chinook and steelhead and flows in the spring were not significant in one year for each species and were significant in the other year. However, in the year showing

Table 24. Numbers of downstream-migrant wild chinook salmon counted at the skimmer by run-year and month, Pelton Dam, 1959-63.

Month \ Run-year	1959-60	1960-61	1961-62	1962-63
September	0	8	54	0
October	8	769	98	86
November	631	1,515	620	992
December	171	655	1,277	1,119
January	144	213	565	105
February	111	1,536	124	1,973
March	2,865	1,201	1,513	860
April	15,208	9,967	6,528	2,037
May	3,472	5,503	2,959	5,474
June	1,660	944	309	569
July	123	458	67	41
August	0	3	0	19
Totals	24,393	22,772	14,114	13,275

Table 25. Numbers of downstream-migrant wild steelhead counted at the skimmer by run-year and month, Pelton Dam, 1959-63.

Month \ Run-year	1959-60	1960-61	1961-62	1962-63
September	0	0	191	0
October	0	3	277	2
November	18	17	93	4
December	2	2	93	3
January	1	1	29	1
February	4	19	127	1,226
March	177	34	111	224
April	2,005	774	873	305
May	3,792	1,897	2,633	3,337
June	4,243	1,548	3,840	2,840
July	114	277	64	174
August	1	50	0	11
Totals	10,357	4,622	8,331	8,127

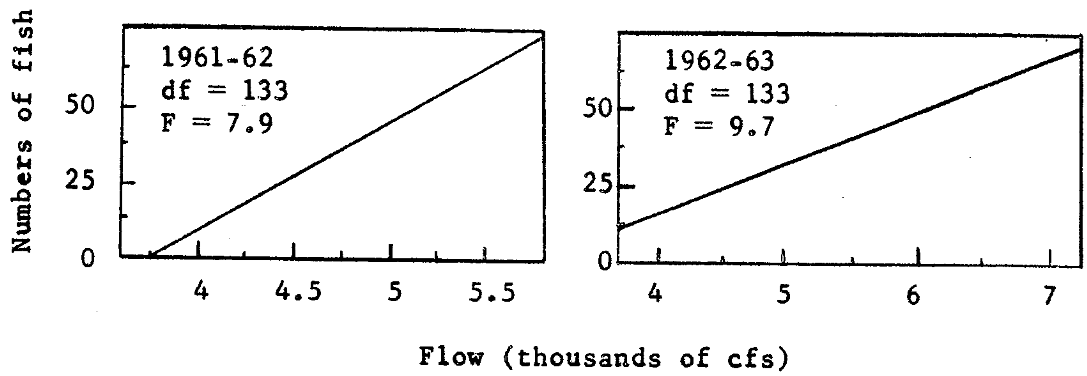


Figure 21. The relationship between volume of flow and counts of chinook salmon at the collection facility during the winter, Pelton Reservoir, 1961-63.

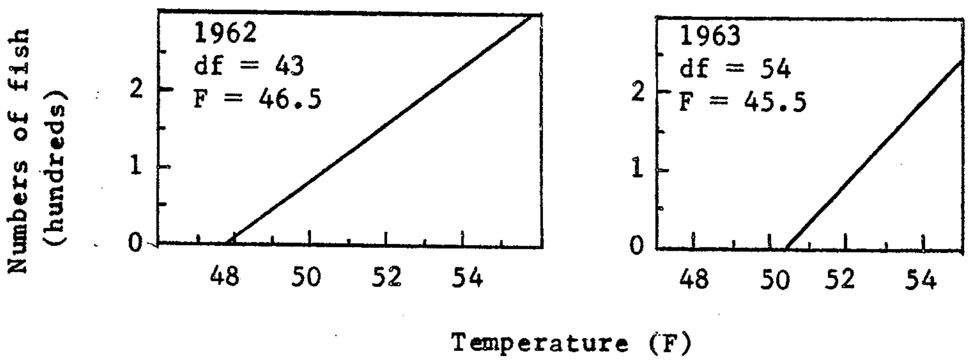


Figure 22. The relationship between water temperature and counts of chinook salmon at the collection facility during the spring, Pelton Reservoir, 1962-63.

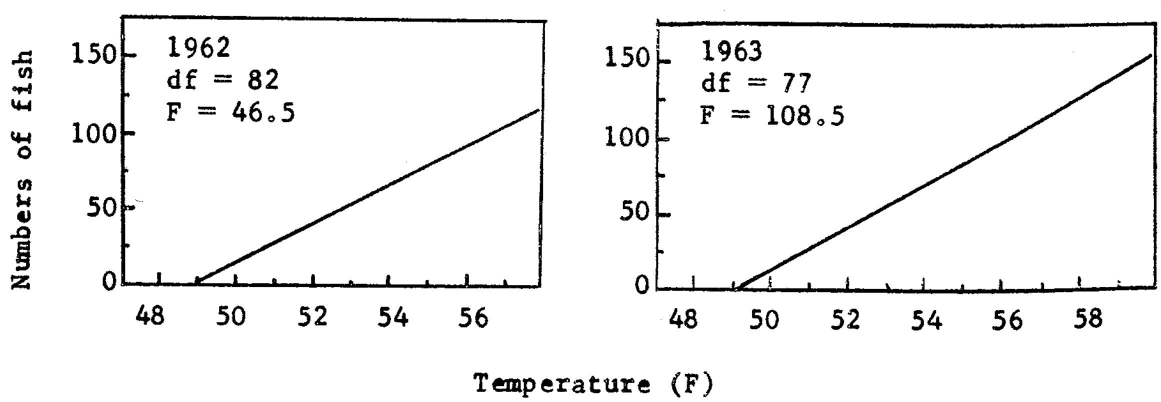


Figure 23. The relationship between water temperature and counts of steelhead trout at the collection facility during the spring, Pelton Reservoir, 1962-63.

significance for each, the slope of the calculated line was positive for chinook and negative for steelhead. It is concluded from these analyses that flow was a significant variable affecting the counts of chinook in the winter and that water temperature was a significant variable affecting the counts of chinook and steelhead in the spring.

Depth distribution. A lack of data restricted our ability to describe the distribution of fish in Pelton Reservoir. Information was pieced together from several sources. Few fry chinook were seen in Pelton Reservoir during the Fish Behavior Study, but they were observed along the shoreline in the surface waters at night during a previous study (Korn and Gunsolus 1962). Counts of yearling chinook by SCUBA divers swimming measured transects in that study indicated fish were located mainly near the surface, shoreline area at night.

In the winter of 1962-63, observations made at night by divers swimming 50-yard-long transects along the bottom at depths of 0, 15, 30, and 50 feet in Pelton Reservoir and the Round Butte cofferdam pool showed that 45 of 47 fingerling chinook observed were at the surface; the other two fish were seen at a depth of 15 feet.

Gill nets were fished at predetermined depths in the reservoir to determine diel and seasonal depth distribution of fish. Diagrams showing the standard positions of these nets are presented in Figures 24 and 25. Catches were not adequate to describe depth distribution by diel periods, but do show 24-hour distributions for each season. The seasonal periods established on the basis of changes in environmental conditions at Pelton are: summer, July 1-September 30; fall, October 1-30; winter, November 1-March 15; and spring, March 16-June 30.

The numbers and percentages of wild chinook salmon caught by gill-net position and season for nets fished perpendicular to the shoreline are pre-

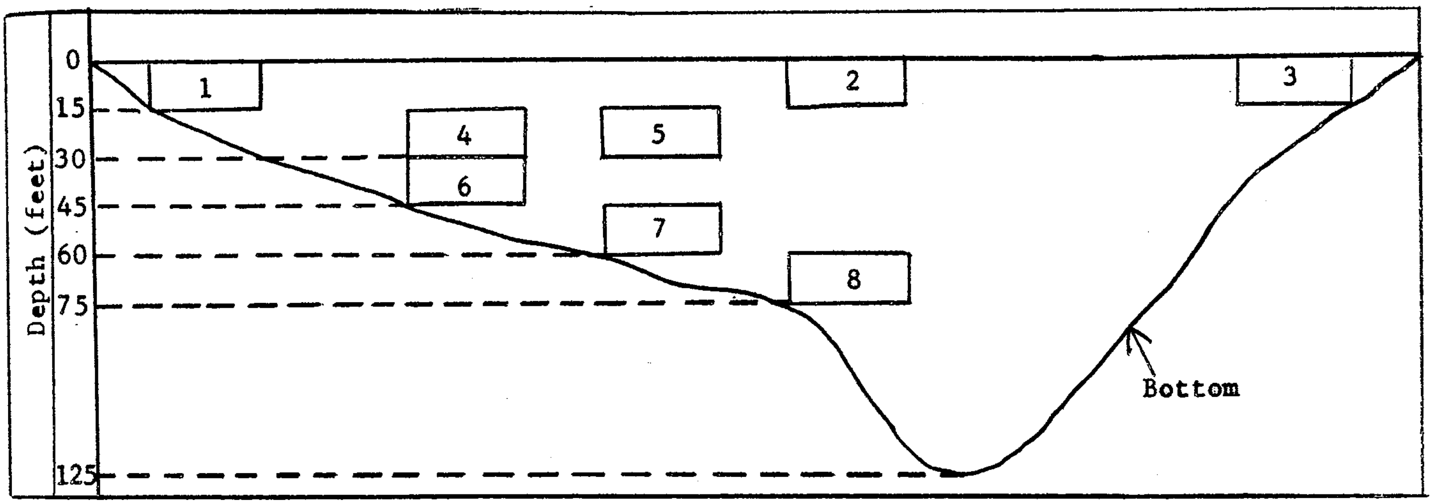


Figure 24. Diagram of standard locations for gill nets fished perpendicular to the shoreline, Pelton Reservoir.

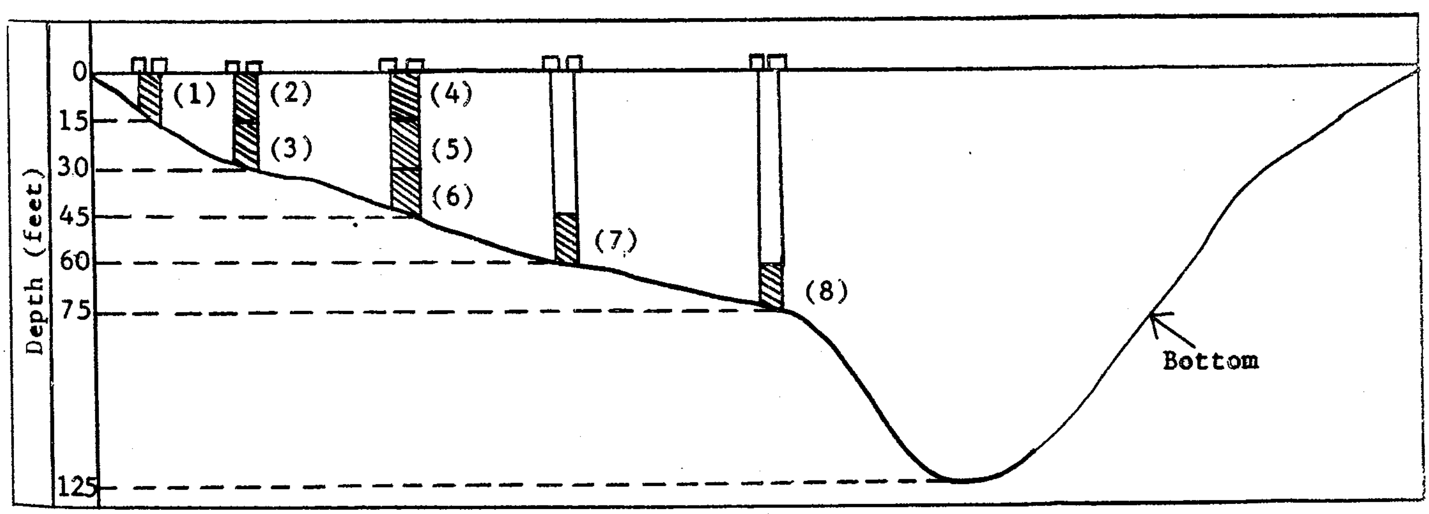


Figure 25. Diagram of standard locations for gill nets fished parallel to the shoreline, Pelton Reservoir.

sented in Table 26. The catches shown were made in three areas of the reservoir and were combined for presentation. The eight fishing positions were identical in the three areas, but the maximum depths of these areas differed slightly. Small numbers of fish were caught in each season. In the summer and fall, most fish were caught at depths of 0-15 and 15-30 feet; and in the winter and spring almost all chinook were caught between 0 and 15 feet. In the winter, each of the nets near shore caught more fish than the one at the surface midway between shorelines; while in the spring, the mid-reservoir net caught more chinook than all others combined.

The distribution of steelhead smolts caught by these gill nets in the spring of 1963 is shown in Table 27. As with chinook, most fish were caught at a depth of 0 to 15 feet. Although they were found at all points across the reservoir, most were taken near the shore.

The nets fished parallel to the shoreline did not catch adequate numbers of chinook salmon to describe distribution except in the summer of 1963 (Table 28). Again, most fish were caught at depths of 0-15 and 15-30 feet.

Survival and collection efficiency. We could not capture enough wild fry in Pelton Reservoir to conduct studies of survival. Therefore, 400,000 unmarked and 7,888 right pectoral fin marked hatchery coho fry were released into the reservoir in April 1963. The respective numbers of these two groups recovered at the Pelton skimmer as yearlings in the spring of 1964 were 1,920 (0.5%) and 27 (0.3%). The survival of unmarked fish was maximal because recoveries may have included coho released into the Metolius River prior to the closure of Round Butte Dam.

A combined total of 249 wild and hatchery migrant-size chinook was tagged and released into Pelton Reservoir from February to June 1963. Of the total, 33 (9.0%) were recovered at the collection facilities. The rates of recovery

Table 26. The numbers and percentages of wild chinook salmon caught by gill-net location 1/ and season, Pelton Reservoir, October 11, 1962-July 2, 1963.

Net no.	Depth range fished (ft)	Depth of water (ft) 2/	Summer No.	Summer %	Fall No.	Fall %	Winter No.	Winter %	Spring No.	Spring %
1	0-15	15-30	4	17.4	2	12.5	18	38.3	3	10.7
2	0-15	75-125	2	8.7	6	37.5	10	21.3	16	57.1
3	0-15	15-35	5	21.7	2	12.5	16	34.0	7	25.0
4	15-30	45-60	4	17.4	2	12.5	2	4.3	1	3.6
5	15-30	60-75	7	30.4	2	12.5	0	0	0	0
6	30-45	45-60	0	0	0	0	1	2.1	1	3.6
7	45-60	60-70	1	4.3	1	6.3	0	0	0	0
8	60-75	75-125	0	0	1	6.3	0	0	0	0
Total caught			23		16		47		28	

1/ Nets fished perpendicular to the shoreline.
2/ Approximate values.

Table 27. The numbers and percentages of steelhead smolts caught by gill-net locations 1/, Pelton Reservoir, spring 1963.

Net no.	Depth range fished (ft)	Depth of water (ft)	Catch No.	Catch %
1	0-15	15-30	13	28.2
2	0-15	75-125	11	23.9
3	0-15	15-35	16	34.8
4	15-30	45-60	4	8.7
5	15-30	60-75	1	2.2
6	30-45	45-60	1	2.2
7	45-60	60-70	0	0
8	60-75	75-125	0	0
Total caught			46	

1/ Nets fished perpendicular to the shoreline.

Table 28. The numbers and percentages of wild chinook salmon caught by gill-net location 1/, Pelton Reservoir, summer 1963.

Net no.	Depth range fished (ft)	Depth of water (ft)	Catch	
			No.	%
1	0-15	15	15	16.1
2	0-15	30	8	8.6
3	15-30	30	30	32.3
4	0-15	45	16	17.2
5	15-30	45	15	16.1
6	30-45	45	7	7.5
7	45-60	60	2	2.2
8	60-75	75	0	0
Total caught			93	

1/ Nets fished parallel to the shoreline.

by month of tagging were as follows: February--25%, March--2%, May--10%, June--6%. Only 4 were tagged in April; the numbers tagged for the other months ranged from 31-88. Between July 1963 and April 1964 totals of 169 chinook and 129 coho juveniles were tagged and released into the reservoir; 28 (16.6%) chinook and 21 (16.3%) coho were recovered at the skimmer. Fish were not tagged after April 1964 since all fishing gear was transferred to Round Butte Reservoir. Steelhead smolts were tagged at Pelton only in the spring of 1963. Of 461 fish tagged, 126 (27.3%) were recovered. The recovery rates of steelhead, by month of tagging from April to June, declined progressively from 48% to 21%.

The poor rates of recovery of tagged fish is believed due to tagging mortality, predation, the sport fishery, or to residualism. The term "residualism" is defined as the tendency of salmonid smolts to remain in fresh water beyond the normal time of emigration. These fish could leave the reservoir after an additional year of growth in fresh water. Since those chinook and steelhead tagged earliest in the spring were recovered at the highest rate, we might suspect the cause was tagging mortality or residualism, which may have resulted from the relatively high, late-spring surface water temperatures.

Tagging mortality was not determined, but residualism may have been a factor. An abnormal migration pattern was discovered when 14 steelhead smolts tagged near Pelton Dam were recovered at the upper end of the reservoir late in the migration season. Also, the presence of 2-year-old wild and hatchery chinook indicated these fish did not emigrate normally as yearlings.

The Pelton Evaluation Study measured the ability of marked wild and hatchery fish released into the Metolius and Deschutes rivers to pass through the reservoir and enter the collection facility. The efficiency of passage for the 2 years of the study differed for each species as follows: chinook--54-69% in 1960, and 21-30% in 1961; steelhead--35-44% in 1960, and 13-44% in 1961. Thousands of hatchery and some wild fish were used in each of these tests.

To provide continuity to the experiments conducted under the Evaluation Study, 48,785 1961-brood marked hatchery spring chinook were released into Spring Creek, a tributary entering the Metolius River near its source, on April 1, 1963. By the end of the migration season in July, only 9,604 or 19.6% were counted at the Pelton skimmer. Passage of these fish may have been influenced by the presence of the Round Butte cofferdam. Some of these fish became residuals.

In the spring of 1965, the study of passage through Pelton was incidental to the work at Round Butte. Some reservoir-reared coho salmon marked to study passage through Round Butte Reservoir were collected at the Round Butte skimmer and released into Pelton Reservoir. Of 621 marked fish released, a total of 401 (64.6%) was subsequently recovered at the Pelton skimmer. Since few chinook and steelhead were released into Pelton in 1965, passage of these fish was not evaluated.

The efficiency of passage as determined by the recovery rates of smolts at the collection system was considered minimal because some fish may have passed through the turbines and fish ladder exit. The Evaluation Study determined that few fish leave by these routes.

It was generally concluded that survival and efficiency of collection ranged from poor to fair for juvenile anadromous salmonids at Pelton Reservoir. The presence of the Round Butte cofferdam appeared to create passage problems additional to those caused by Pelton.

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 April 1963, stomach analyses showed that Dolly Varden, brown and rainbow trout, suckers, squawfish, chiselmouth, and yearling chinook salmon were predators.

Catches of wild steelhead by the sport fishery in the reservoir were estimated by the Bureau of Sport Fisheries and Wildlife as 3,390 in 1960 and 3,153 in 1961. A comparison of these catches with the respective counts at the fish facility of 10,357 and 4,622 fish indicated the sport fishery had a significant effect on the steelhead runs.

Age and growth. The apparently small populations of salmonids in Pelton Reservoir resulted in variable-sized samples and poor data on size composition and growth. The effect of Pelton Reservoir on growth of chinook was not determined. Coho salmon, released into the reservoir as fry in April 1963 ranged in size from 12 to 20 cm with a mode at 15.5 cm when emigrating through the collection facilities as yearlings in April and May 1964. Some of these may have reared wholly or partly in the Round Butte cofferdam pool and Metolius River, but closure of Round Butte Dam in January 1964 probably restricted emigrants mainly to those reared in Pelton.

Size composition samples of wild chinook salmon emigrating through the Pelton skimmer were taken in most months between December 1962 and June 1963

(Figure 26). Bimodal size distributions were observed in 3 of the 5 months sampled, and the smaller size group always predominated. The two modal groups were distinct. Scale patterns indicated the smaller fish were virtually all 1961-brood fish, while the larger ones were all 1960 brood. However, if the chinook grew as coho did, then chinook of the large modal group may include 1961-brood fish and our age determinations may be questioned. The larger chinook emigrated prior to May, the main month of emigration at Pelton in 1963, and composed only 8.3% of the total sample.

Several yearling chinook were tagged and released into Pelton Reservoir and recovered at the skimmer in the spring of 1963. Of 16 tagged fish recovered, which were out between 1 and 3 weeks between tagging and recovery, only one showed any perceptible growth. Eight other chinook, at liberty between 3 weeks and over 2 months, grew up to 20 mm.

The age for each centimeter of length of emigrating steelhead smolts at the Pelton skimmer is presented in Table 29. Age was determined from stratified samples of scales. Relatively small samples were obtained for each length interval. Fish from 13 to 17 cm were predominantly 1 year old, while those 18 cm and larger were almost entirely 2 years of age. Only one fish was identified as a 3 year old. The size and age compositions of steelhead emigrating from Pelton in the spring of 1963 are shown in Table 30. The modal size of summer steelhead leaving Pelton was 19 cm in 1963 as compared to 16 cm for winter steelhead emigrating from North Fork in 1963 and 1964 (Tables 19 and 20). Also, steelhead at Pelton were more even in size than at North Fork. Emigrants at Pelton included a significant proportion of 1-year-old fish and virtually none 3 years of age, while the reverse occurred at North Fork. Two-year-old fish predominated at both locations.

Recoveries of 83 tagged steelhead at the Pelton skimmer showed these fish grew little from time of tagging. Although most were at liberty only 1-21 days, some were out up to 64 days.

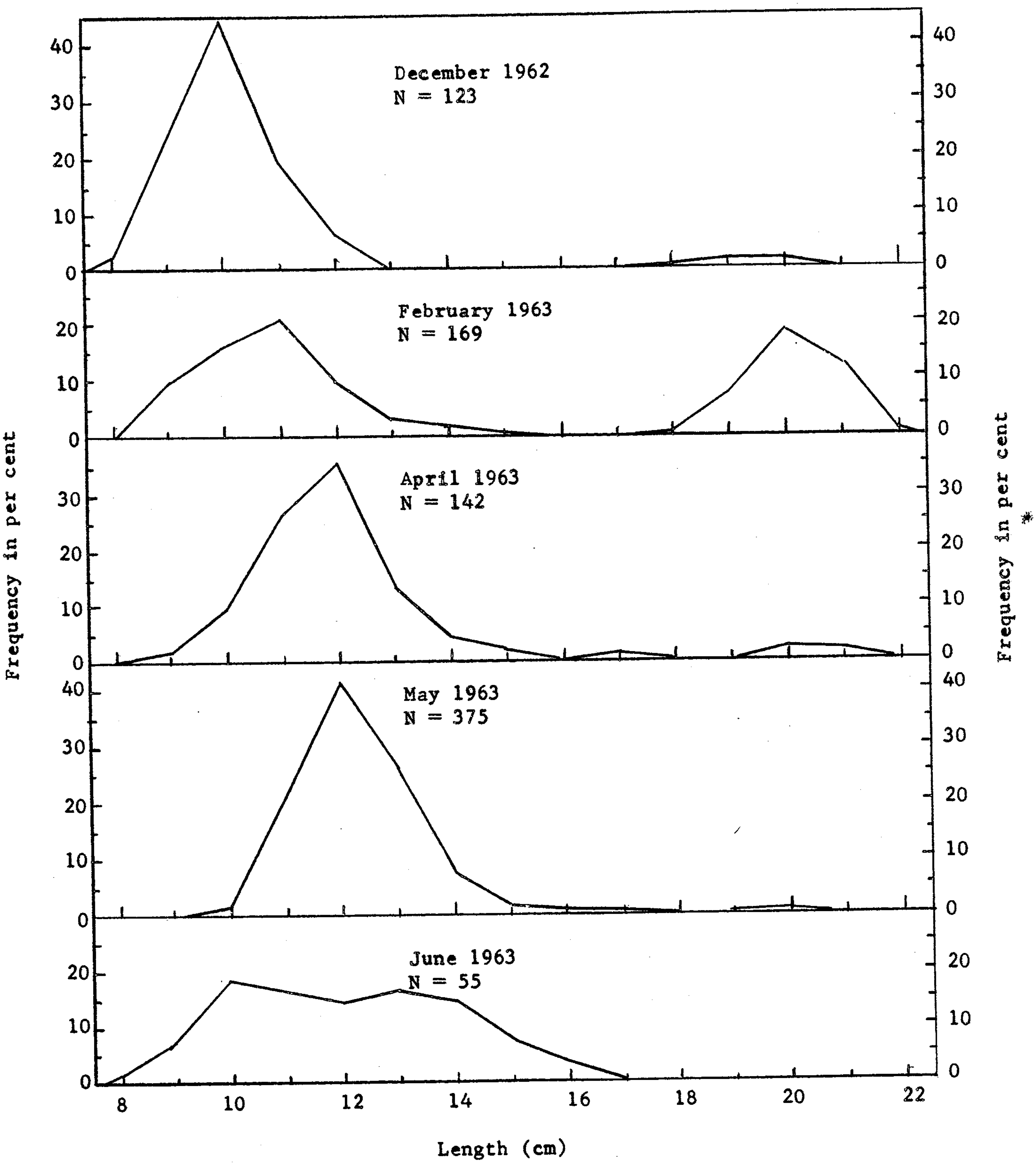


Figure 26. The size composition of wild chinook salmon, Pelton skimmer, December 1962-June 1963.

Table 29. The age by length of emigrating steelhead smolts as shown by stratified samples of scales taken at the collection facilities, Pelton Reservoir, spring 1963.

Length (cm)	Age 1 No.	Age 1 %	Age 2 No.	Age 2 %	Age 3 No.	Age 3 %	Total number sampled
13	3	100	0	0	0	0	3
14	4	100	0	0	0	0	4
15	7	100	0	0	0	0	7
16	3	60	2	40	0	0	5
17	5	62.5	3	37.5	0	0	8
18	1	33.3	2	66.7	0	0	3
19	1	12.5	7	87.5	0	0	8
20	0	0	6	100	0	0	6
21	0	0	6	100	0	0	6
22	0	0	8	100	0	0	8
23	0	0	10	100	0	0	10
24	0	0	6	85.7	1	14.3	7
25	0	0	5	100	0	0	5
26	0	0	0	0	0	0	0
27	0	0	2	100	0	0	2
Total	24		57		1		82

Table 30. The size and age composition of steelhead emigrating from Pelton Reservoir in the spring of 1963.

Length (cm)	Age 1	Age 2	Age 3	Total sample	Size composition in per cent
13	6	0	0	6	1.4
14	12	0	0	12	2.8
15	21	0	0	21	4.8
16	18	12	0	30	6.9
17	29	18	0	47	10.8
18	17	35	0	52	12.0
19	8	57	0	65	14.9
20	0	52	0	52	12.0
21	0	44	0	44	10.1
22	0	32	0	32	7.4
23	0	28	0	28	6.4
24	0	19	3	22	5.1
25	0	14	0	14	3.2
26	0	5	0	5	1.1
27	0	2	0	2	0.5
28	0	1	0	1	0.2
29	0	1	0	1	0.2
30	0	0	0	0	0
31	0	1	0	1	0.2
Total	111	321	3	435	100.0
Age composition in per cent	25.5	73.8	0.7	100.0	

Round Butte Reservoir

Environment

Water temperature. Water temperature profiles were taken at regular intervals in Round Butte Reservoir between closure of the dam in January 1964 and May 1965. Figures 27, 28, and 29 show representative temperature profiles by season for the Metolius, Deschutes, and Crooked River arms of the reservoir, respectively. Some parts of the graphs are repeated since each of the three arms includes the forebay area adjacent to the dam. The diagrams show the increase in length and depth of the impoundment as it filled, but the bottom contour also varies due to differences in the sampling positions between observations for a given station. Round Butte Reservoir stratified in January 1964, shortly after closure of the diversion tunnel, due to the relatively warm, spring-fed water of the Crooked River overlying the cooler water of the Metolius and Deschutes rivers. All arms of the reservoir stratified weakly during the spring of 1964 with water temperatures generally in the mid-50's. The inflow from the Deschutes and Crooked rivers was noticeably warmer at 53 and 56 F than that of the Metolius River at 44 F. In August 1964, the Deschutes and Crooked arms were strongly stratified with maximum surface water temperatures in the low 70's, but the upper Metolius Arm was only 64 F and weakly stratified. Round Butte Reservoir cooled in October 1964, but stratification deteriorated more slowly than at Pelton and North Fork. The inflow of large volumes of cold water during the floods of December 1964 and January 1965 resulted in significantly colder temperature patterns for that period than in January 1964. Temperature inversion occurred in the winter of 1964-65 due to the heavy silt load in the Crooked River water, which was somewhat warmer and much more alkaline than the other two streams. Surface water temperatures in the spring were slightly higher in 1965 than in 1964, and the Metolius River was again colder than the other two water sources.

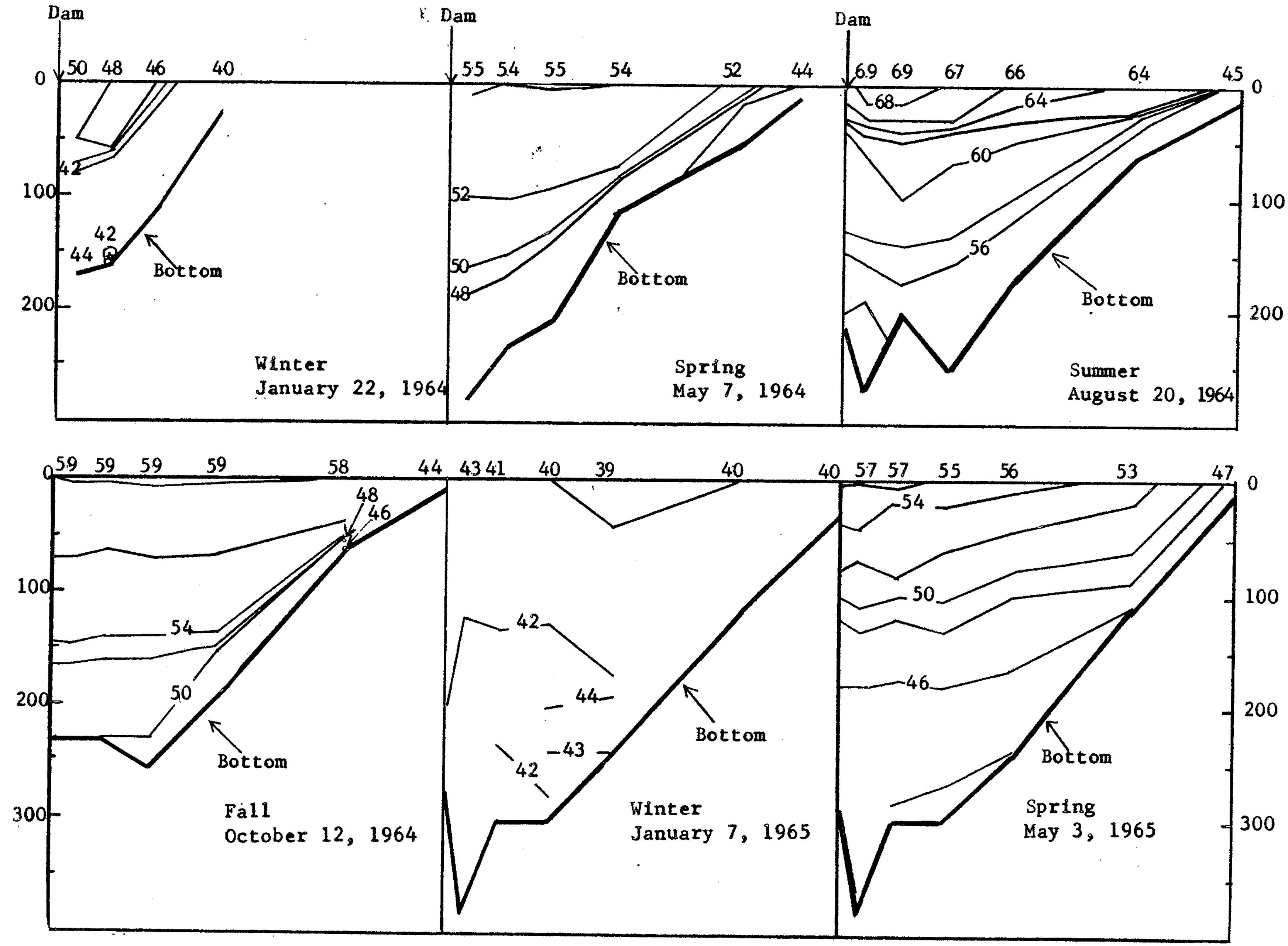


Figure 27. Seasonal water temperature profiles by 2 F isotherms, Metolius Arm of Round Butte Reservoir, January 1964-May 1965. Linear scale: 6 mm = approximately 1 mile.

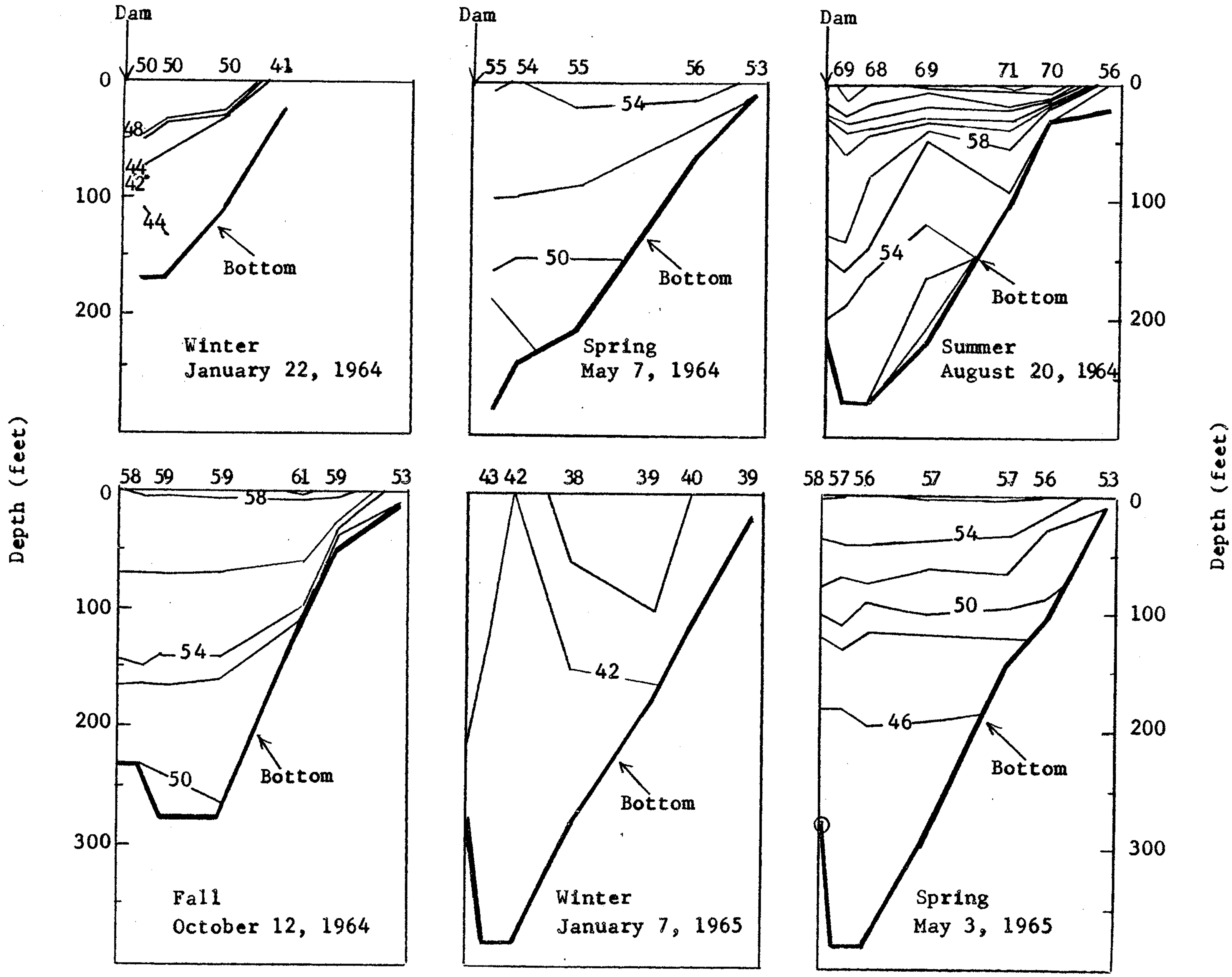


Figure 28. Seasonal water temperature profiles by 2 F isotherms, Deschutes Arm of Round Butte Reservoir, January 1964-May 1965. Linear scale: 6 mm = approximately 1 mile.

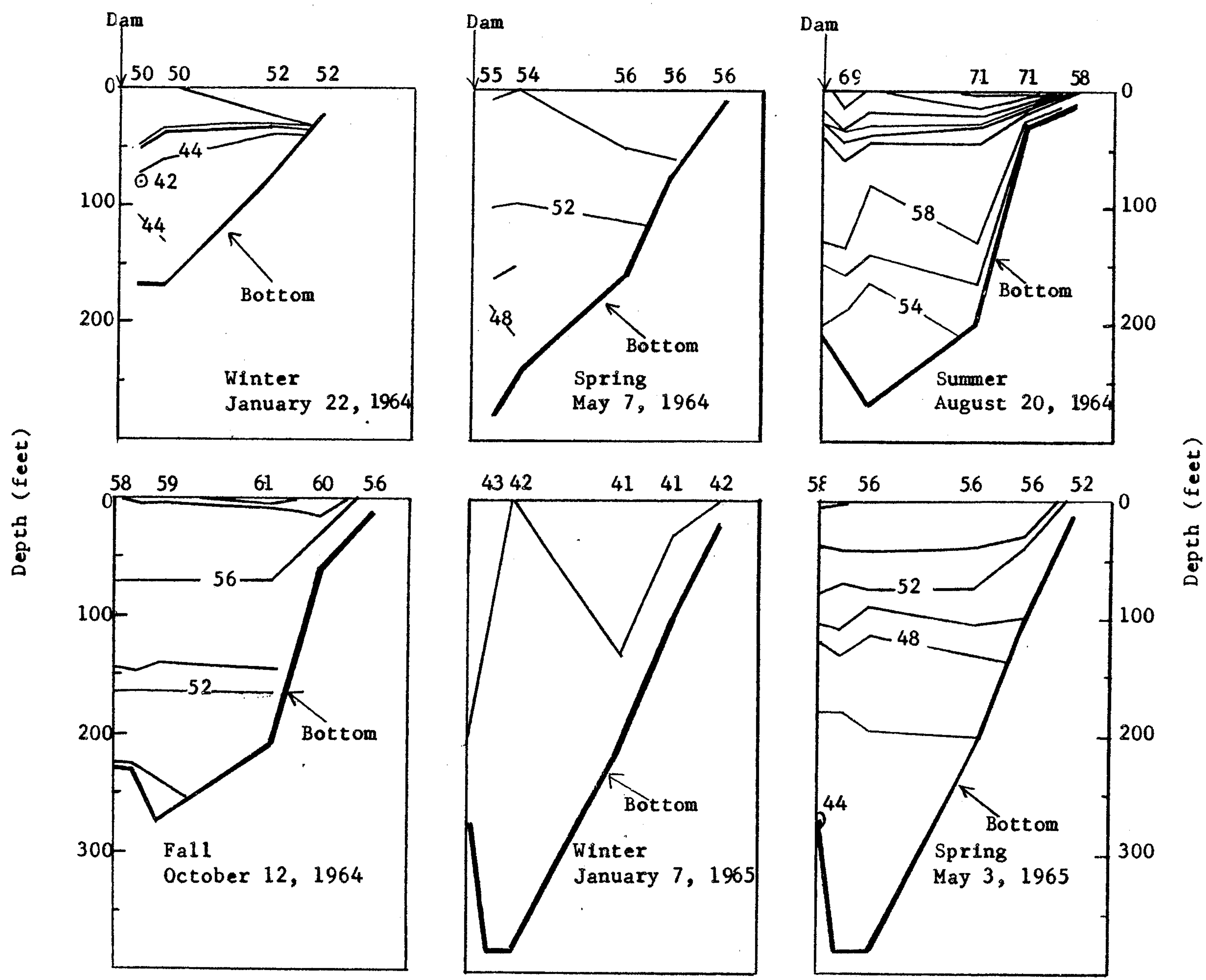


Figure 29. Seasonal water temperature profiles by 2 F isotherms, Crooked Arm of Round Butte Reservoir, January 1964-May 1965. Linear scale: 6 mm = approximately 1 mile.

<u>Water currents</u>. The direction and general velocity of water currents in Round Butte Reservoir were computed in April, May, and December 1964 and January, March, April, and June 1965. All areas were not checked each of these months. In most cases currents just beneath the surface of the water and at a depth of 20 feet moved in the same direction. Generally, water flowed down the Deschutes and Crooked River arms. The current moved up the Metolius River Arm coincident with the air masses. However, in January 1965, after a flood in the preceding month, the silt-laden Crooked River moved below the other water masses, and the water in the surface 20 feet of the Crooked Arm traveled upstream. Observations made in June 1965 are shown in Figure 30 and illustrate the patterns of water movement most commonly found in Round Butte, except that slight upstream currents were usually observed in the lower Metolius Arm. Strong upstream currents were found in the upper and middle portions of the Metolius Arm.

<u>Flow and visibility</u>. Daily river flows have been recorded by the USGS in the lower reaches of the Deschutes, Metolius, and Crooked rivers and may be compared to each other and to discharges at Pelton Reservoir. The monthly average of the mean daily flows of the Deschutes, Metolius, and Crooked rivers combined, the per cent of the total contributed by each, and their combined discharge at Pelton Reservoir for the period October 1962-September 1964 are shown in Figure 31. The Metolius and Crooked rivers contributed similar amounts and the Deschutes River consistently discharged less than either of the other two throughout the period. The Deschutes contributed significantly less during the spring and summer than it did at other times due to extensive use of that stream for irrigation. Data are not available to compare the flows of the three streams after September 1964.

The discharge at Pelton from October 1962 to December 1963 was consistently higher than the combined flows of the three major tributaries because of springs,

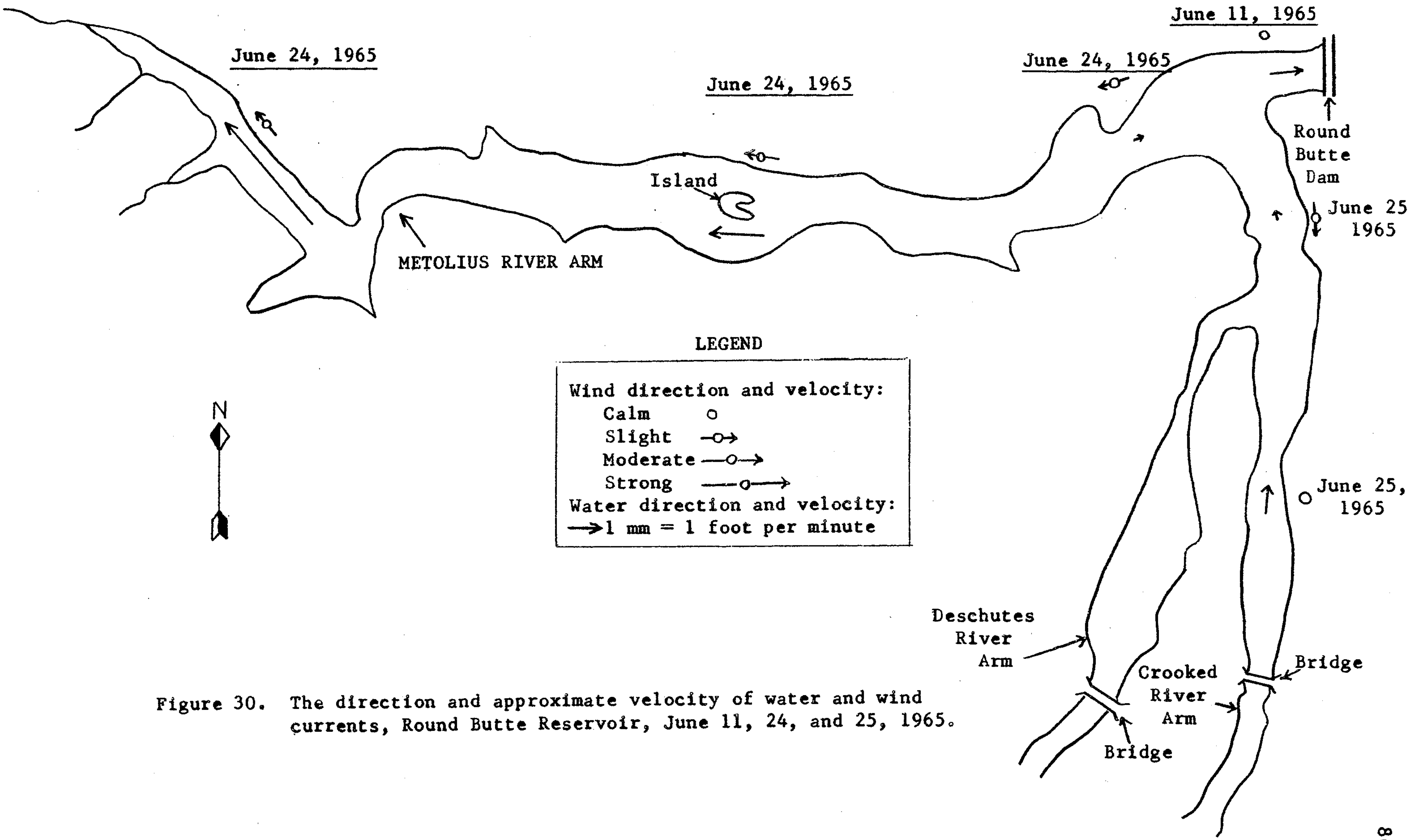


Figure 30. The direction and approximate velocity of water and wind currents, Round Butte Reservoir, June 11, 24, and 25, 1965.

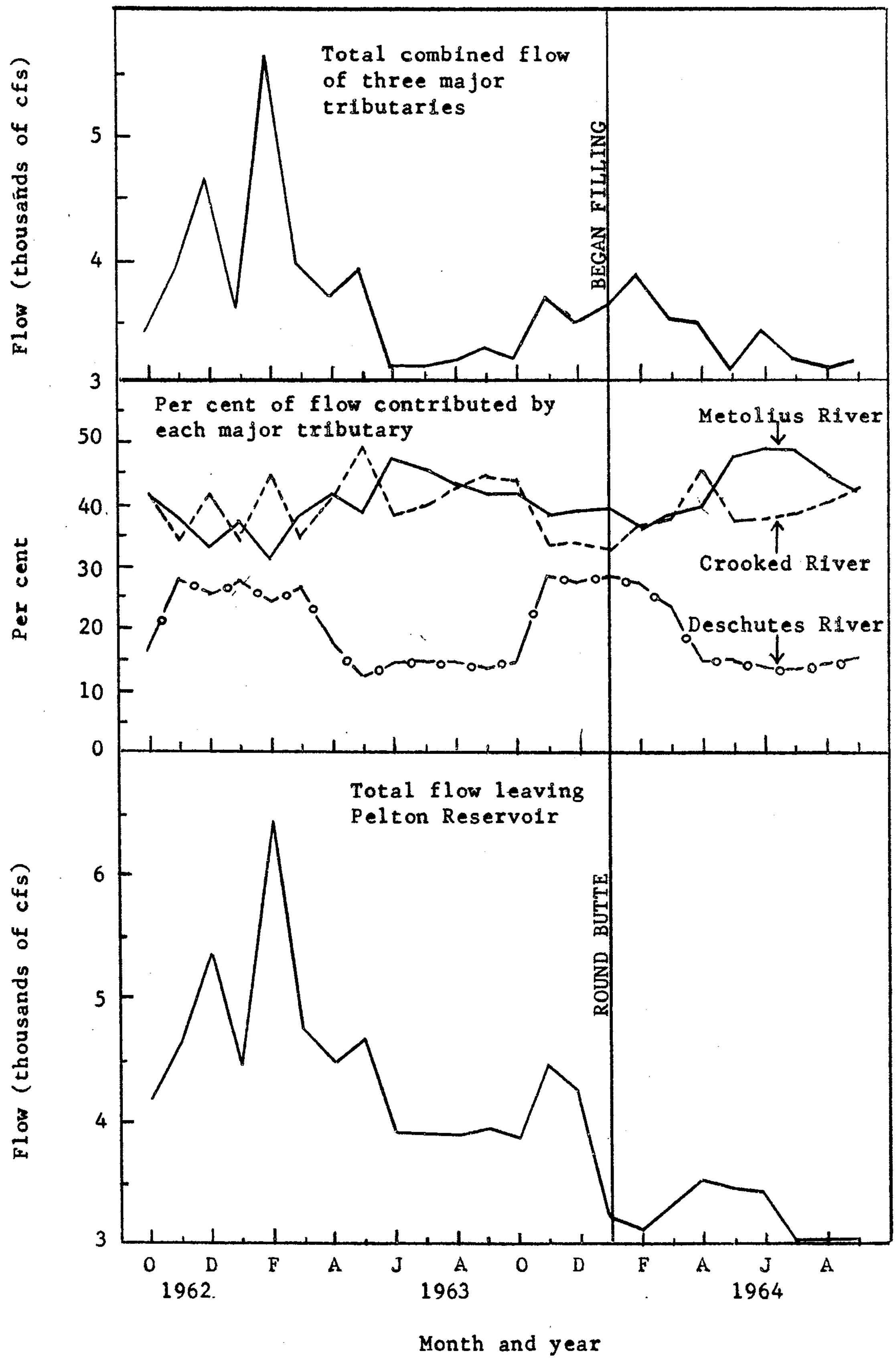


Figure 31. The monthly average of the mean daily flows of the Deschutes, Metolius, and Crooked rivers combined, the per cent of the total contributed by each, and their combined discharge at Pelton Reservoir, October 1962-September 1964.

small tributaries, and irrigation returns between the gauging stations on the Metolius, Deschutes, and Crooked rivers and the one at Pelton. After closure of the Round Butte diversion tunnel in January 1964, the flow below Round Butte and Pelton dams was reduced to 3,000-3,500 cfs, but the inflow remained relatively low and Round Butte Reservoir filled slowly. The discharge of at least 3,000 cfs to maintain required minimum flows in the Deschutes River below Pelton prevented faster impounding of the reservoir. The water level of Round Butte Reservoir was 70-80 feet below full pool during the spring migration period in 1964, and was 50-60 feet below full pool by early December of that year. A flood in late December 1964 rapidly filled the reservoir and caused a 9-day spill. The impoundment remained at full pool throughout the spring migration in 1965.

Water visibility in Round Butte Reservoir varied from 0.5-foot in the Crooked River Arm immediately after the flood in December 1964 to 35 feet in the Metolius River Arm in March 1964. Secchi disc readings in the Metolius Arm were generally higher in the spring of 1965, when the reservoir was at full pool, than they were during impounding in the spring of 1964.

Oxygen, alkalinity, and pH. Representative seasonal values of oxygen, total alkalinity, and pH taken from the Metolius, Deschutes, and Crooked rivers and from the surface, middle of the thermocline, and bottom of Round Butte Reservoir, near the dam, are shown in Table 31. Dissolved oxygen content in the reservoir was adequate for fish life from closure of the dam in the winter of 1964 through the spring of 1965, but some oxygen deficiencies (low of 2.5 ppm) were found in the Crooked River Arm at depths below 150 feet in June and July 1964. Total alkalinity was highest in the Crooked River, lowest in the Metolius River, and intermediate in the Deschutes. Generally alkalinities in the reservoir were highest at the surface and lowest near the bottom, except

Table 31. Representative seasonal values of oxygen, total alkalinity, and pH taken from the Metolius, Deschutes, and Crooked rivers and from the surface, middle of thermocline, and bottom of Round Butte Reservoir near the dam, 1964-65.

Area	Depth	Determination	Season				Year
			Winter	Spring	Summer	Fall	
Metolius River	Surface	Dissolved oxygen	11.5	10.6	10.2	10.8	1964
		Total alkalinity	48	37	37	39	
		pH	7.75	7.75	8.25	7.75	
Deschutes River	Surface	Dissolved oxygen	11.5	10.6	10.0	9.6	
		Total alkalinity	52	64	69	70	
		pH	7.75	8.25	8.75	8.25	
Crooked River	Surface	Dissolved oxygen	10.0	10.4	10.2	9.6	
		Total alkalinity	92	82	94	97	
		pH	8.25	8.25	8.25	8.00	
Reservoir near dam	Surface	Dissolved oxygen	10.0	10.4	9.8	11.6	
		Total alkalinity	84	87	90	92	
		pH	8.0	8.75	8.75	8.75	
	Thermocline	Dissolved oxygen	10.0	8.6	9.0	10.0	
		Total alkalinity	74	66	86	92	
		pH	8.0	8.25	8.25	8.75	
	Bottom	Dissolved oxygen	10.5	9.6	5.8	6.0	
		Total alkalinity	64	51	68	62	
		pH	7.75	8.25	8.25	7.75	
Metolius River	Surface	Dissolved oxygen	11.2	11.2	--	--	1964-65
		Total alkalinity	38	36	--	--	
		pH	7.75	7.75	--	--	
Deschutes River	Surface	Dissolved oxygen	11.8	10.0	--	--	
		Total alkalinity	40	61	--	--	
		pH	7.75	8.25	--	--	
Crooked River	Surface	Dissolved oxygen	11.4	10.4	--	--	
		Total alkalinity	90	98	--	--	
		pH	8.25	8.25	--	--	
Reservoir near dam	Surface	Dissolved oxygen	10.6	11.2	--	--	
		Total alkalinity	66	81	--	--	
		pH	7.75	8.75	--	--	
	Thermocline	Dissolved oxygen	--	8.4	--	--	
		Total alkalinity	--	78	--	--	
		pH	--	7.75	--	--	
	Bottom	Dissolved oxygen	10.4	10.2	--	--	
		Total alkalinity	73	60	--	--	
		pH	8.25	7.75	--	--	

this arrangement reversed after the flood in the winter of 1964-65. While not shown in these data, occasional pH values of 9.0 were found in the surface waters of the reservoir, and may have been caused by phytoplankton.

Fish behavior

Migrations. Only fragmentary information was obtained on the time of entry of juvenile salmonids into Round Butte Reservoir. Fry chinook salmon were observed in the spring in the Metolius Arm of Round Butte Reservoir in 1964 and 1965. Fry coho of the 1963 brood were released into the reservoir and near the source of the Metolius River in February 1964 to aid in the study of fish behavior. Large numbers of 1962-brood coho, incubated in hatching troughs located in the Spring Creek tributary of the Metolius River, remained near their area of release through March 1964, and appeared in the upper Metolius Arm of the reservoir in mid-April 1964 as indicated by catches of these fish in the traps. The inclusion in the catches of fish tagged while in the Metolius River corroborated the appearance of this group. The time of entry of chinook and steelhead smolts into Round Butte was not learned.

While Round Butte Reservoir began impounding in January 1964, a facility for collecting emigrants was not available until a floating gulper was installed in the forebay in April 1964. After a period of testing, this facility operated continuously from May 1 to July 21, 1964, and collected 4,323 chinook, 5,718 coho, and only 321 steelhead for transport below the project. Peak numbers of chinook and coho were counted at the gulper in late May and early June, respectively. Some fish emigrated through the penstocks or by-pass tunnel after closure of Round Butte Dam as shown by catches of several dozen chinook and coho in a gill net fished in the gate well, but counts at the Pelton skimmer indicated passage by those outlets was not significant. Two coho salmon captured in the gate well had been tagged and released into the reservoir when the depth of water over the penstocks was approximately 250 feet, and since the reservoir continued to fill they must have sounded at least to that depth.

The pattern of intra-reservoir migrations of salmonid smolts in the spring of 1964 indicated the fish did not readily find the gulper. All species tended to congregate in the upper Metolius Arm of the reservoir, where the water temperatures were coldest. Up-reservoir surface water currents in the Metolius Arm may have contributed to the movement to this area. On the other hand, 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.

Floating traps fished in the upper Deschutes Arm and in the middle and upper Metolius Arm of the reservoir captured fish for tagging. A few chinook and coho migrated to the gulper from all tagging points in the reservoir, but several were caught in the upper Metolius Arm, where they were tagged. Steelhead smolts, which appeared the most confused, originated mainly in the Deschutes River; but 2,592 known individuals were trapped in the upper Metolius Arm of the reservoir (713 were tagged and released into the reservoir and 1,879 were removed from the reservoir). This is a significant figure when compared to the previous annual counts of approximately 8,000 to 10,000 steelhead smolts at the Pelton skimmer. Tag recoveries showed that steelhead moved between all points of tagging and those of potential recovery (Figure 32). The recovery rates cannot be compared quantitatively since sampling and fishing pressure was not and efficiency may not have been equal among all areas. Tagged fish traveled in both directions between the Metolius and Deschutes arms of the reservoir. The highest rates of recovery from all areas of tagging occurred in the upper Metolius Arm, but sampling and sport fishing were most intense there. Few tagged steelhead were recovered at the gulper.

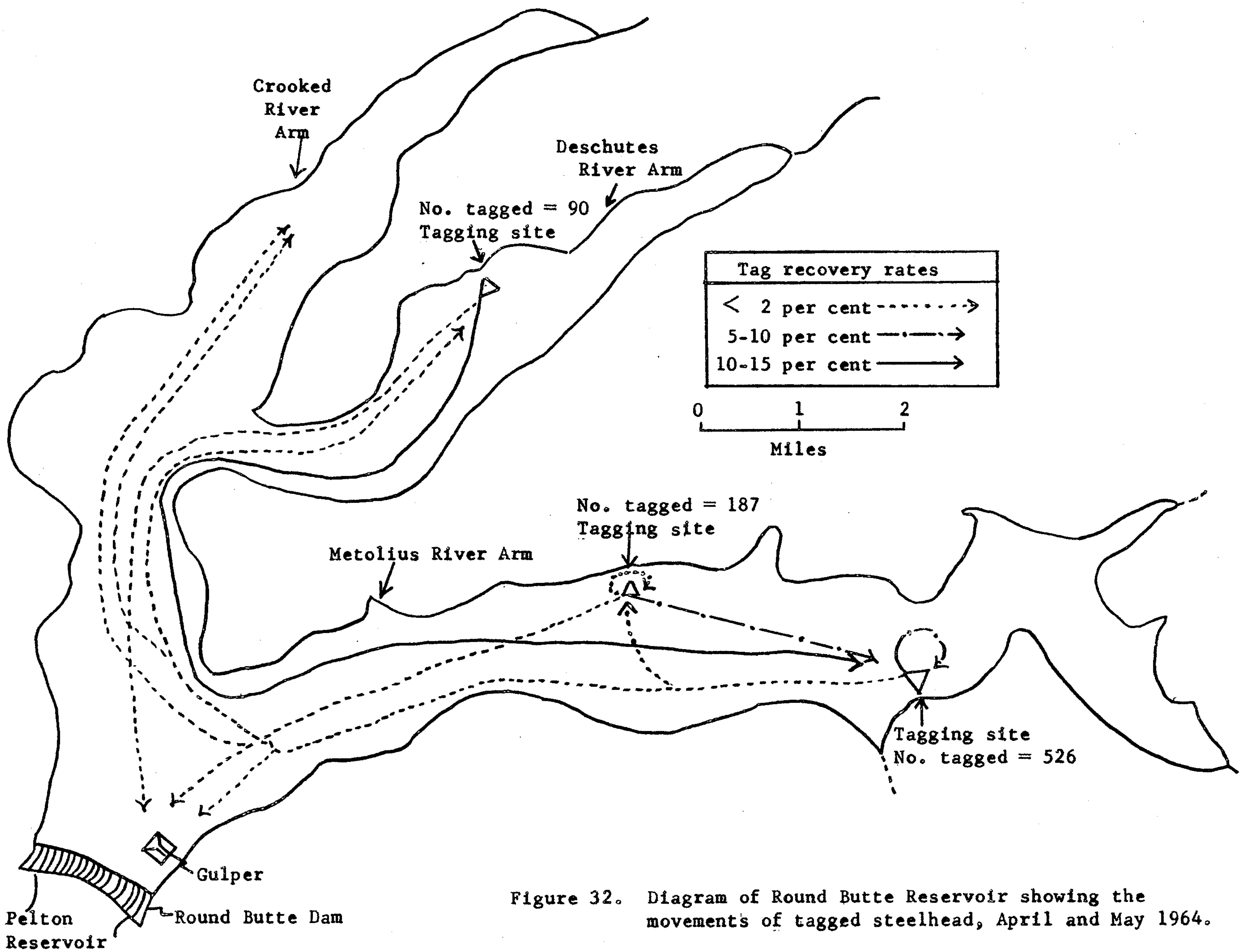


Figure 32. Diagram of Round Butte Reservoir showing the movements of tagged steelhead, April and May 1964.

On June 4, 1964, all three 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. Between June 4 and July 1, 1964, the traps collected 739 chinook, 3,796 coho, and 1,879 steelhead. The total numbers of anadromous salmonids collected by the gulper and traps for transport in the spring of 1964 was 5,062 chinook, 9,514 coho, and 2,200 steelhead; and the respective percentages of the totals caught by the traps located in the upper Metolius Arm were 14.6, 39.9, and 85.4. The use of the Fish Commission traps to collect smolts for transport curtailed the collection of data on intra-reservoir migrations.

A permanent collection facility (skimmer), built as an integral part of Round Butte Dam, began operating on April 8, 1965, and was the sole method of collecting smolts for transport below the project for the remainder of that spring. It was operated with an attraction flow of only 200 cfs, half of the 400 cfs capacity, through May 20, and with 300 cfs thereafter during that season, due to malfunctions of the pumps. The floating gulper was moved to the upper Metolius Arm in April 1965 to capture fish for marking studies. Totals of 465 chinook, 371 coho, and 5 steelhead were captured by the gulper for transport below the dam between December 1964 and March 18, 1965, the date it was deactivated for relocation. Between April 8 and July 31, 1965, totals of 604 chinook, 60,899 coho, and 1,245 steelhead were collected by the skimmer. During the same period the gulper caught 3,961 chinook, 9,689 coho, and 313 steelhead indicating migrants, particularly chinook, were again congregating in the upper Metolius Arm of the reservoir. The marking and release of a large proportion of the fish caught at the gulper, and a low percentage recovery of these fish at the skimmer (detailed in Survival and Collection Efficiency) indicated passage from the one area to the other was poor.

Between September 1964 and May 1965 floating traps were fished at the upper end of each arm of the reservoir. Relatively small numbers of chinook, but over 800 steelhead were tagged and released into the reservoir in 1965. Few tagged fish were recovered, and these merely showed that the tagged fish were migrating between the three arms and not to the skimmer.

Significant numbers of coho salmon tagged and released into the upper Metolius and upper Crooked arms were recovered (Figure 33), but as for steelhead in the previous year, the rates of recovery generally could not be compared quantitatively. However, tagged fish recovered at the skimmer from the two points of tagging may be compared since fish arriving in that area should be equally susceptible to collection, regardless of their area of tagging. The higher rate of recovery at the skimmer for coho tagged in the Crooked Arm indicates they moved to the forebay of Round Butte Reservoir better than fish tagged in the upper Metolius. Coho tagged in the upper Metolius were recovered as well in the area of tagging by the gulper as they were at the dam in the skimmer. There was also some movement of fish between the two areas of tagging, and from those areas to the Deschutes Arm of the reservoir.

Further information on intra-reservoir migrations of coho salmon in Round Butte was obtained by periodically fishing gill nets in the upper ends of each arm of the reservoir, and comparing the catches by area (Figure 34). Four nets were fished at similar depths and attitudes in each area, and the topography of the areas was similar. The nets were fished two days each month between September 15, 1964 and June 21, 1965, except they were fished only one day each in November 1964 and March 1965. While the fishing intensity was identical for the three areas, efficiency of fishing could not be determined since the nets may have fished more affectively in one area than in another. Between the inception of fishing in September 1964 and the first fishing date in December, coho were caught predominantly in the Metolius Arm of the

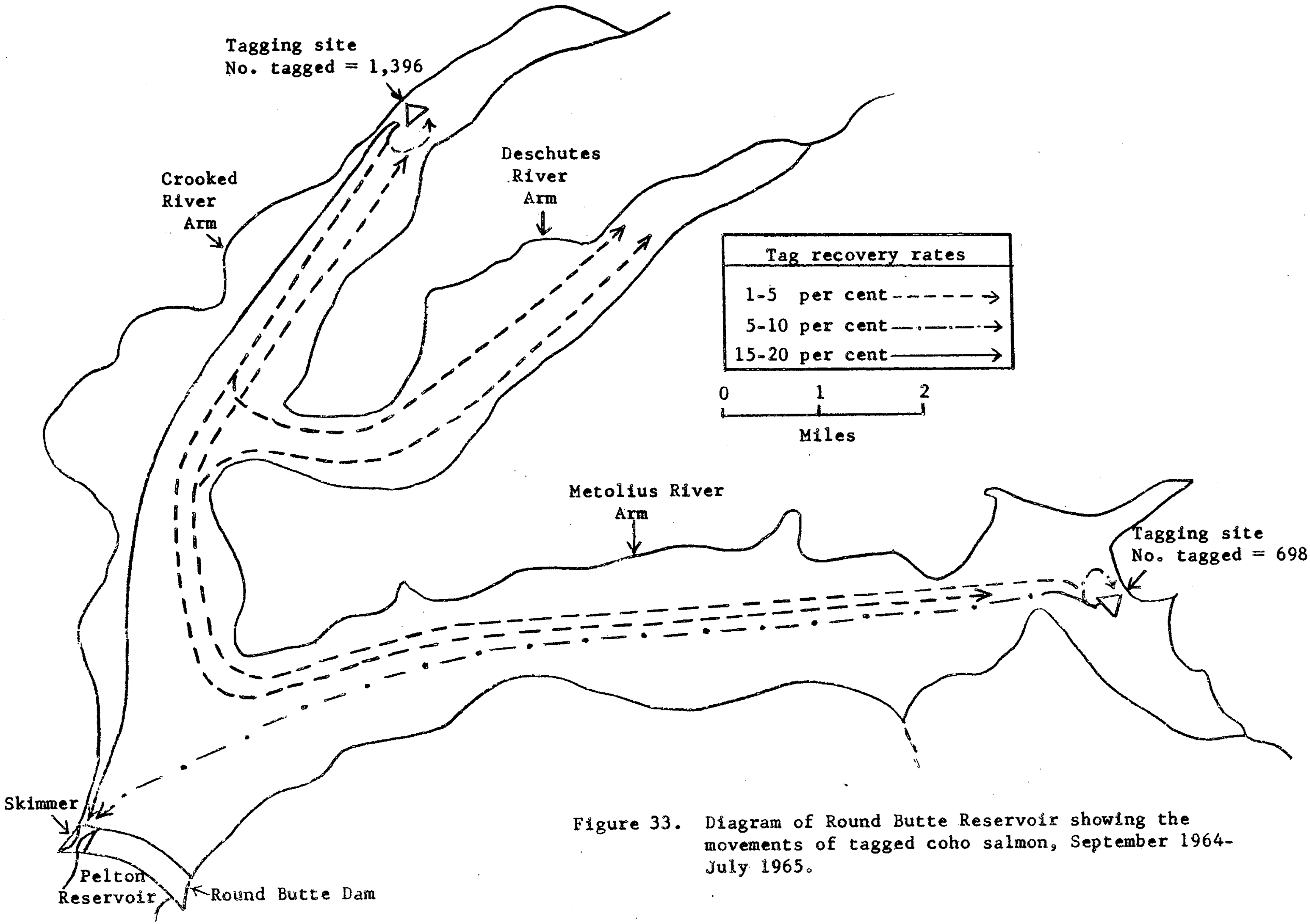


Figure 33. Diagram of Round Butte Reservoir showing the movements of tagged coho salmon, September 1964-July 1965.

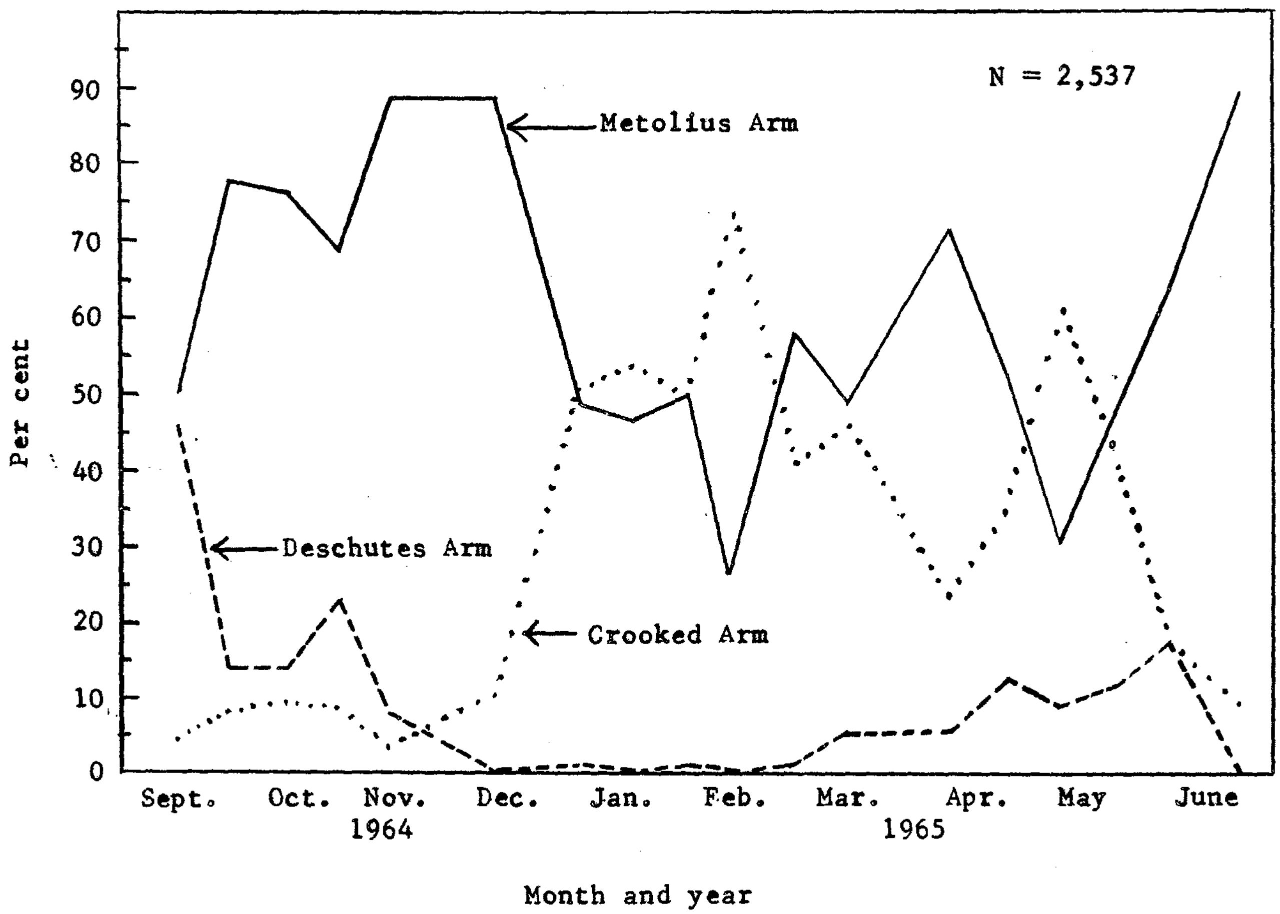


Figure 34. The catch of coho salmon in gill nets fished in the upper Metolius, Crooked, and Deschutes arms of Round Butte Reservoir expressed as a percentage of the total for each fishing day, September 1964-June 1965.

reservoir. Coincident with the flood in late December 1964, catches in the Crooked Arm approximated those in the Metolius. At that time the silt-laden Crooked River water was heavier than the colder Metolius River water resulting in upstream surface currents in the Crooked Arm of the reservoir. Surface water currents in the Metolius Arm moved downstream during this period. This condition persisted for an indeterminate period, and the area of largest catches fluctuated between the Crooked and Metolius arms through May 1965. During the spring of 1965 water currents in the reservoir returned to their former pattern with downstream surface currents in the Crooked Arm and upstream currents in the Metolius Arm. By June 1965, the largest catches again occurred in the Metolius Arm of the reservoir. The catch in the Deschutes Arm was a significant percentage of the total on the first day of fishing in September 1964, but was negligible thereafter.

We concluded from these observations that of the three areas studied, coho salmon congregated only in the upper Metolius Arm of the reservoir prior to the flood in December 1964. During and immediately after the flood fish congregated in both the upper Crooked and upper Metolius arms. By June 1965, coho were found congregated only in the Metolius. It appeared that coho never congregated in the upper Deschutes Arm.

The inability of juvenile salmonids to leave Round Butte Reservoir culminated in the attempted spawning of 3-year-old coho salmon, reared entirely in fresh water, in the fall of 1965. An estimated 200 of these fish were observed near the source of the Metolius River and in Spring Creek. A sample of 50 fish included 45 males and 5 females. The males contained free-flowing milt, but the eggs in all females generally appeared abnormal in size and development.

Depth distribution. Hatchery-incubated coho salmon fry, released directly into Round Butte Reservoir, and wild chinook fry were observed only near the surface of the water during the day and at night.

Gill nets were fished parallel to the shoreline in the Metolius Arm of the reservoir, as in the five positions shown for North Fork in Figure 10; a sixth net, positioned on the bottom at a depth of 175 feet, was added at Round Butte. The maximum depth of water in the area fished was 225 feet. Coho salmon was the only species caught in adequate numbers by gill nets to describe depth distribution. The distribution of coho by diel period within each season is shown in Table 32. Small numbers of fish were caught during the day in any season. In the daytime, most fish were caught from 15 to 30 feet deep in all seasons except the spring when coho were found at most depths fished. At night, the largest catches were made from 0 to 15 feet deep, except during the summer when a majority of the catch was at a depth of 30-45 feet. Fish were not caught in the deepest net. During the spring migration period, coho were caught principally in the surface 15 feet.

Gill nets were also fished perpendicular to the shoreline, on a 24-hour basis, in the upper and middle areas of the Metolius Arm as shown in Figure 35. Only three nets were fished in the upper end of the arm due to the restricted area available, and the distribution of the catch, by season, is shown in Table 33. Good numbers of coho were caught by all three nets, but most coho were caught near the shoreline. In the summer, significant numbers were also caught from 15-35 feet deep.

Gill nets were also fished in the upper ends of the Crooked and Deschutes arms of the reservoir, and the catches of coho were made at depths similar to catches in the Metolius. The distribution of coho caught by nets fished in the middle of the Metolius Arm is shown in Table 34. The largest catches were

Table 32. The numbers and percentages of coho salmon caught by gill-net location 1/ within diel periods, by season, Round Butte Reservoir, summer 1964-spring 1965.

Summer: No. observations - 1

Net no.	Depth range fished (ft)	Depth of water (ft)	Catch by diel period: Day No.	%	Dusk No.	%	Night No.	%	Dawn No.	%
1	0-15	15	0	0	10	24.4	8	19.5	40	38.1
2	15-30	30	31	83.8	22	53.6	4	9.8	42	40.0
3	0-15	45	1	2.7	4	9.8	2	4.9	14	13.3
4	30-45	45	5	13.5	5	12.2	24	58.5	9	8.6
5	60-75	75	0	0	0	0	3	7.3	0	0
6	160-175	175	0	0	0	0	0	0	0	0
Total caught			37		41		41		105	

Fall: No. observations - 1

Net no.	Depth range fished (ft)	Depth of water (ft)	Catch by diel period: Day No.	%	Dusk No.	%	Night No.	%	Dawn No.	%
1	0-15	15	0	0	24	48.0	105	54.7	38	62.3
2	15-30	30	3	42.8	8	16.0	26	13.5	8	13.1
3	0-15	45	1	14.3	17	34.0	47	24.5	12	19.7
4	30-45	45	1	14.3	0	0	14	7.3	3	4.9
5	60-75	75	2	28.6	1	2.0	0	0	0	0
6	160-175	175	0	0	0	0	0	0	0	0
Total caught			7		50		192		61	

1/ Nets fished parallel to shoreline.

Table 32. (cont'd)

Winter: No. observations - 3										
			Catch by diel period							
			Day		Dusk		Night		Dawn	
Net no.	Depth range fished (ft)	Depth of water (ft)	No.	%	No.	%	No.	%	No.	%
1	0-15	15	1	4.5	12	25.5	42	63.6	12	19.4
2	15-30	30	10	45.5	13	27.7	9	13.6	8	12.9
3	0-15	45	2	9.1	9	19.1	10	15.2	10	16.1
4	30-45	45	1	4.5	11	23.4	5	7.6	19	30.6
5	60-75	75	8	36.4	2	4.3	0	0	13	21.0
6	160-175	175	0	0	0	0	0	0	0	0
Total caught			22		47		66		62	

Spring: No. observations - 2										
			Catch by diel period							
			Day		Dusk		Night		Dawn	
Net no.	Depth range fished (ft)	Depth of water (ft)	No.	%	No.	%	No.	%	No.	%
1	0-15	15	3	23.1	19	33.3	37	48.7	20	46.5
2	15-30	30	2	15.4	6	10.5	3	3.9	7	16.3
3	0-15	45	4	30.7	28	49.2	36	47.4	7	16.3
4	30-45	45	1	7.7	4	7.0	0	0	4	9.3
5	60-75	75	3	23.1	0	0	0	0	5	11.6
6	160-175	175	0	0	0	0	0	0	0	0
Total caught			13		57		76		43	

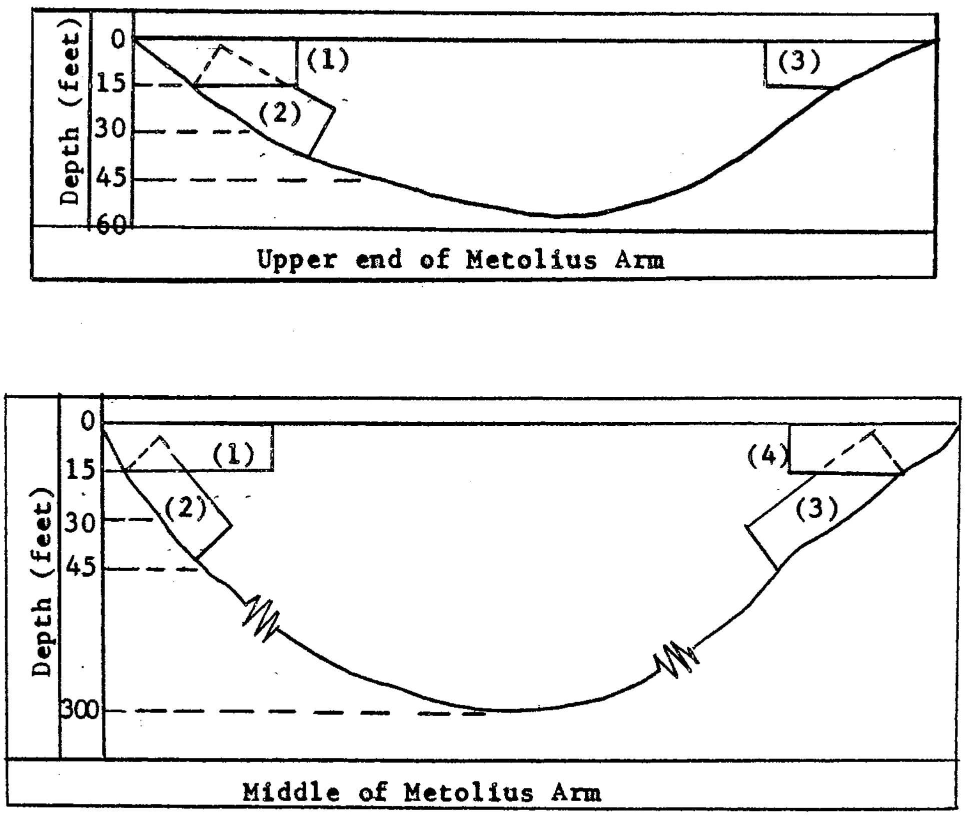


Figure 35. Diagram of standard locations for gill nets fished perpendicular to the shoreline in the upper and middle areas of the Metolius Arm, Round Butte Reservoir.

Table 33. The numbers and percentages of coho salmon caught in the upper end of the Metolius Arm, by gill-net location 1/ and season, Round Butte Reservoir, summer 1964-spring 1965.

Net no.	Depth range fished (ft)	Summer		Fall		Winter		Spring	
		No.	%	No.	%	No.	%	No.	%
1	0-15	81	19.0	86	31.4	241	37.8	180	47.7
2	15-35	163	38.2	33	12.0	112	17.6	47	12.5
3	0-15	183	42.8	155	56.6	284	44.6	150	39.8
Total caught		427		274		637		377	

1/ Nets fished perpendicular to shoreline.

Table 34. The numbers and percentages of coho salmon caught in the middle of the Metolius Arm, by gill-net location 1/ and season, Round Butte Reservoir, summer 1964-spring 1965.

Net no.	Depth range fished (ft)	Summer		Fall		Winter		Spring	
		No.	%	No.	%	No.	%	No.	%
1	0-15	94	22.1	75	31.6	161	22.5	132	27.1
2	15-40	127	29.9	19	8.0	128	17.9	57	11.7
3	15-45	134	31.5	25	10.6	164	23.0	82	16.8
4	0-15	70	16.5	118	49.8	261	36.6	216	44.4
Total caught		425		237		714		487	

1/ Nets fished perpendicular to shoreline.

made near the shorelines in every season except the summer when the deeper nets caught most of the fish. The deeper distribution of coho salmon in the summer may be attributed to relatively high surface water temperatures at that time.

Survival and collection efficiency. The marking of 50,536 1963-brood chinook (left pectoral fin clip) and 117,553 1963-brood coho (right pectoral fin clip), and their subsequent release in February 1964, into the Spring Creek tributary of the Metolius River and Round Butte Reservoir, respectively, provided data on the survival and collection of fish marked and released as fry. Both groups of fish were from hatchery stock. Recoveries made in the gulper in the forebay, and in the skimmer, from January to July 1965 included 99 (0.2%) of the chinook and 5,590 (4.8%) of the coho.

The determination of survival and efficiency of collection through tagging was initiated with 1962-brood coho. As at North Fork, tagged fish recaptured in the reservoir and released were deleted from the numbers tagged and recovered as they may have been adversely affected by the additional handling. A total of 2,917 fingerlings was captured, tagged, and returned to the upper Metolius River and Spring Creek from September 1963 to March 1964. Of this total, 57 (1.95%) were collected in the floating gulper in May and June 1964. An additional 21 were recovered in the Round Butte skimmer in the spring of 1965, resulting in a total collection of 78 fish or 2.67% of those tagged. The modal sizes of these fish at tagging ranged from 65 mm in September 1963 to 90 mm in March 1964, while coho captured in the reservoir for tagging in April and May 1964 (the only period of tagging during that season) had a modal length of 125 mm. Fish tagged and released into the reservoir emigrated at a higher rate than those tagged and released into the stream.

Fish were tagged in three areas of Round Butte Reservoir during the spring of 1964. The numbers tagged and released into the reservoir, and recovered at the gulper, are shown in Table 35. The rates of recovery were low in all cases.

Coho were tagged in the upper Metolius River Arm of the reservoir from September 1964 through May 1965 and in the upper Crooked River Arm from January through May 1965. Steelhead were tagged only when identified as smolts from February-May 1965, and too few chinook were tagged to obtain meaningful data. Few fish were tagged in the Deschutes Arm. The relationships between month of tagging and the rates of recovery at the skimmer of coho salmon tagged in each arm of the reservoir are shown in Figure 36. A significant negative

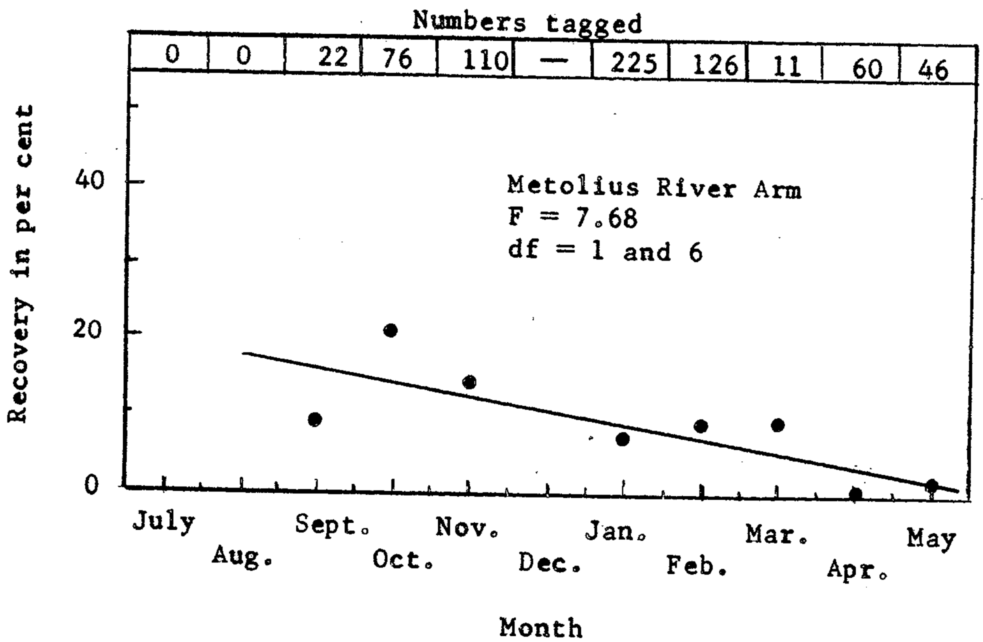
Table 35. Numbers of chinook and coho salmon and steelhead trout tagged, by area, and recovered in the gulper located in the forebay of Round Butte Reservoir, spring 1964. 1/

Species	Area of tagging	Number tagged	Number recovered	Per cent recovered
Chinook	Upper Metolius Arm	135	9	6.7
	Middle Metolius Arm	72	13	18.1
Coho	Upper Metolius Arm	335	40	11.9
	Middle Metolius Arm	113	17	15.0
Steelhead	Upper Metolius Arm	526	2	0.4
	Middle Metolius Arm	187	5	2.7
	Upper Deschutes Arm	90	1	1.1

1/ Fish were tagged in April and May and recovered mostly in May and June.

relationship existed between month of tagging in the Metolius Arm and rate of recovery. Contrary to the results at North Fork, the rates of recovery for coho tagged and released into the Metolius Arm during the spring months were significantly less than they were for tagging in the fall months. The recovery rates by month of tagging for fish tagged and released into the Crooked Arm were less variable than for those tagged in the Metolius Arm, and they did not differ significantly. The rates of recovery were generally low, ranging from 0 in April 1965 to 21% in October 1964 for fish tagged in the Metolius Arm, and from 4% in April 1965 to 20% in February 1965 for tagging in the Crooked Arm of the reservoir. The overall recovery rate from tagging in the latter area was higher (16%) than that from tagging in the Metolius Arm (6%) for comparable periods (January-May 1965).

The relationships between length at tagging and the rate of recovery of coho salmon tagged and released into the Metolius and Crooked River arms of the reservoir from October 1964 to May 1965 are shown in Figure 37. It was found significant in the Crooked Arm that larger coho were recovered at a lower rate than smaller ones. This might be because many of the larger fish were in their third year of life. Dozens of fish of this size and age were ob-



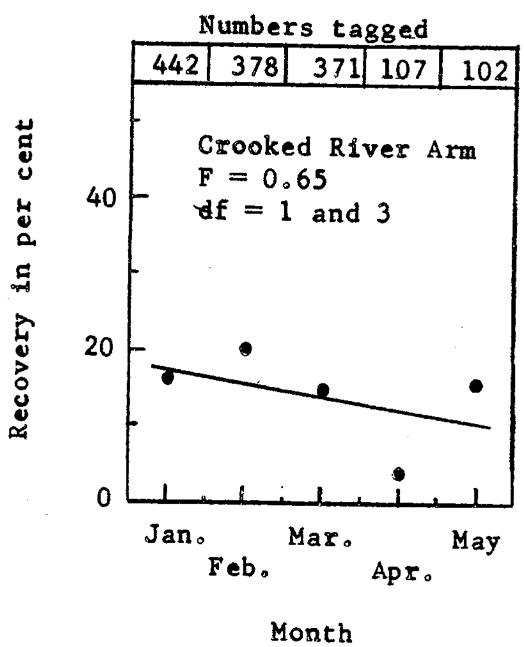
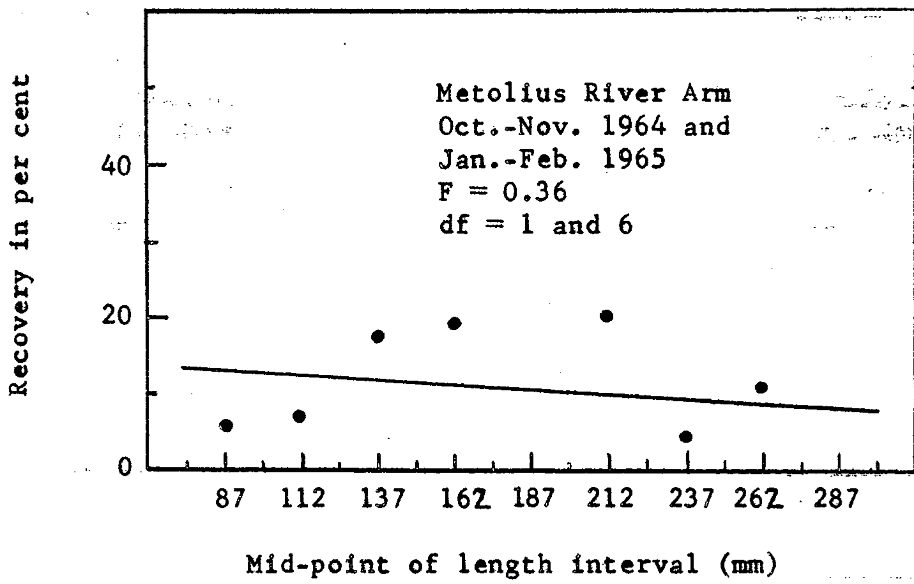


Figure 36. The relationship between month of tagging and the rate of recovery of coho salmon tagged and released in the Metolius and Crooked River arms of Round Butte Reservoir, September 1964-May 1965.



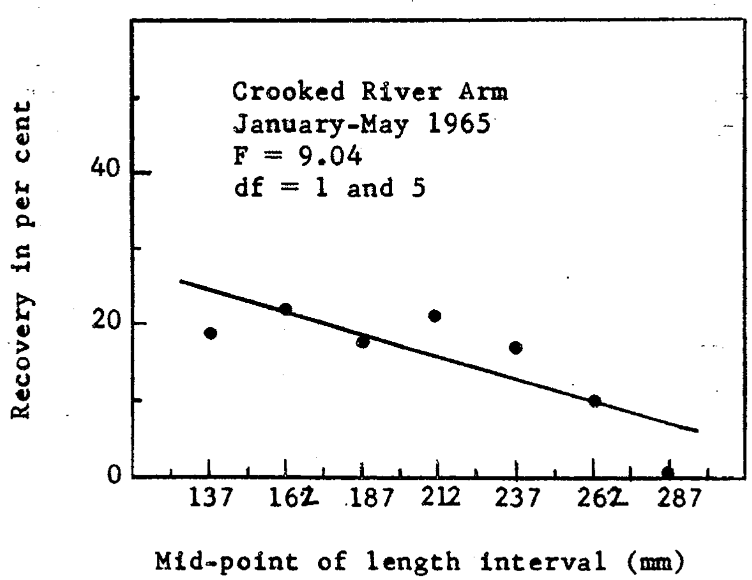


Figure 37. The relationship between length at tagging and the rate of recovery of coho salmon tagged in the Metolius and Crooked River arms of Round Butte Reservoir, by 25 mm length interval, 1964-65.

served attempting to spawn near the source of the Metolius River and in Spring Creek in the fall of 1965. By the spring of 1965, these fish may have lost the urge to migrate to the ocean. Tagged steelhead smolts were collected by the passage facilities at a lesser rate than coho in 1965. Of 139 and 456 steelhead tagged and released into the Metolius and Crooked River arms, respectively, only 1 (0.7%) and 2 (0.4%) were recovered.

A total of 49,169 1962-brood marked (right pectoral fin clip) hatchery spring chinook was released in Spring Creek on April 1, 1964, to determine success of passage during the filling of Round Butte Reservoir. Only 1,425 (2.9%) were collected at the gulper during that spring. These fish appeared to behave abnormally as they were not captured in the reservoir in numbers until late May, and some were recovered in Spring Creek over several months. An additional 300 entered the collection facilities in 1965, increasing the total emigration to 1,728 (3.5%).

Personnel of the Fish Behavior and Round Butte Evaluation studies cooperated in marking and recovering salmonid smolts to determine the efficiency of passage and collection during the spring of 1965. Wild fish were captured and marked at the floating gulper in the upper Metolius Arm of the reservoir, and were collected at the fixed collection system at the dam. Totals of 3,528 chinook (anal fin clip), 7,768 coho (right ventral fin clip), and 273 steelhead (left pectoral fin clip) were captured, marked, and released. Of these, 10 (0.3%) chinook, 1,065 (13.7%) coho, and 3 (1.1%) steelhead were collected. To complement the marked wild steelhead, 10,000 marked hatchery steelhead were released into the upper Deschutes Arm of the reservoir, of which 248 (2.5%) were recovered at the skimmer. These results were qualified because a group held for 24 hours at the time of release suffered a 25% mortality, however they were crowded in the holding facility. Despite this qualification, the 2.5% recovery rate obtained for these fish was as good as for any other group of steelhead marked or tagged during the study.

An intensive sport fishery occurred in Round Butte Reservoir in the spring and summer of 1964. It was not possible to estimate the catch, but general observations indicated significant numbers of salmon and steelhead smolts were caught. As a result, a comprehensive creel census was designed for the fishery in the Metolius Arm and a lesser one for that in the Crooked Arm to measure the catch during the period April 24-June 30, 1965. The fishery in the Deschutes Arm was not sampled. The procedure used to estimate the catch was as follows:

1. Separate estimates were made for boat anglers in each of the Metolius and Crooked River arms of the reservoir and bank anglers in the former.
2. The catch was sampled 16 days during the April 24-June 30 period. Week days and weekend days were equally represented and, within each group, were chosen at random.
3. Counts of boats fishing in each of the areas sampled and of the bank anglers fishing in the Metolius Arm were made on approximately 50% of the days in the sampling period.
4. The mean daily catch per boat, mean daily number of boats fishing, mean daily catch per bank angler, and mean daily number of bank anglers fishing was calculated for week days and weekend days.

The catch for the entire sampling period was extrapolated from these data.

The estimated catches by species and mark are shown in Table 36. Rainbow trout was the most abundant species in the catch, but substantial numbers of coho were also caught. A significant number of wild steelhead was taken by anglers compared to annual counts made previously at Pelton (Table 25). Relatively small numbers of chinook were caught. These data are particularly striking when it is considered that the estimates do not include the entire

Table 36. Estimated total catch of salmonids by anglers in the Metolius Arm and the estimated catch by boat anglers in the Crooked River Arm, Round Butte Reservoir, April 24-June 30, 1965. 1/

Species	Mark	Brood year	Metolius River Arm			Crooked R. Arm boat	Grand total	Grand total 90% confidence limits
			Boat	Bank	Total			
Chinook wild	--	62-63	689	127	816	230	1,046	732- 1,473
Chinook wild	An	62-63	15	0	15	0	15	11- 20
Chinook hatchery	RP	62	105	25	130	66	196	136- 280
Coho wild-reared	--	62-63	22,592	6,008	28,600	6,009	34,609	24,166- 48,889
Coho " "	LP	62	30	38	68	0	68	46- 100
Coho " "	RP	62-63	1,903	152	2,055	706	2,761	1,944- 3,860
Coho " "	RV	62-63	347	0	347	164	511	361- 714
Steelhead wild	--	62-64	3,371	621	3,992	1,954	5,946	3,932- 8,463
Steelhead hatchery	RP	64	270	0	270	66	336	239- 461
Steelhead kelts	--	--	0	0	0	16	16	11- 25
Sockeye wild	--	--	75	13	88	82	170	117- 245
Rainbow	--	--	43,565	8,417	51,982	19,439	71,421	49,809-101,172
Brown	--	--	30	0	30	16	46	33- 65
Dolly Varden	--	--	1,318	393	1,711	66	1,777	1,248- 2,488
Combined catch	--	--	74,310	15,794	90,104	28,814	118,918	82,785-168,255

1/ No estimate was made of the sport catch in the Deschutes Arm or the catch by bank anglers in the Crooked River Arm.

sport fishery in the reservoir for the period sampled or catches made during the previous summer of fish which were potential emigrants in the spring of 1965.

The results of the tests to determine efficiency of passage show that the rate of collection of smolt salmonids was low for all species, but that coho were collected best. It may be premature to condemn passage at Round Butte based on these results since the collection facilities were not fully operable in either year studied, however the poor collection rates obtained and the abnormal migration habits observed are not encouraging. Since efficiency of collection was low, it was not possible to obtain an accurate measure of survival. The only available information reflecting survival of salmon from the fry to smolt stage in Round Butte Reservoir, was from a release of marked 1963-brood coho fry. Of 117,553 released, 5,590 (4.8%) were captured in the collection facilities, 2,761 were estimated caught in the sport fishery, and 730 fish killed by experimental fishing gear. The minimum survival based on these data was 9,081 fish or 7.7% of the release. The actual survival to migrant size could have been significantly higher.

Age and growth. Fry chinook salmon (1963 brood) were marked with a left pectoral fin clip and released into Spring Creek in the upper Metolius River system in late February 1964 as 3 to 4 cm-long fish. Over 100 of these fish were recovered as smolts at the gulper and skimmer in Round Butte Reservoir in April and May 1965. At recovery, they were 10 to 20 cm long with a mode of 14 cm. Their area of rearing was not determined, but based on the size of known reservoir-reared coho salmon, the larger chinook probably reared partly or totally in the reservoir.

Figure 38 shows the progression in size of 1963-brood coho salmon marked (right pectoral fin clip) and released into Round Butte Reservoir as fry in

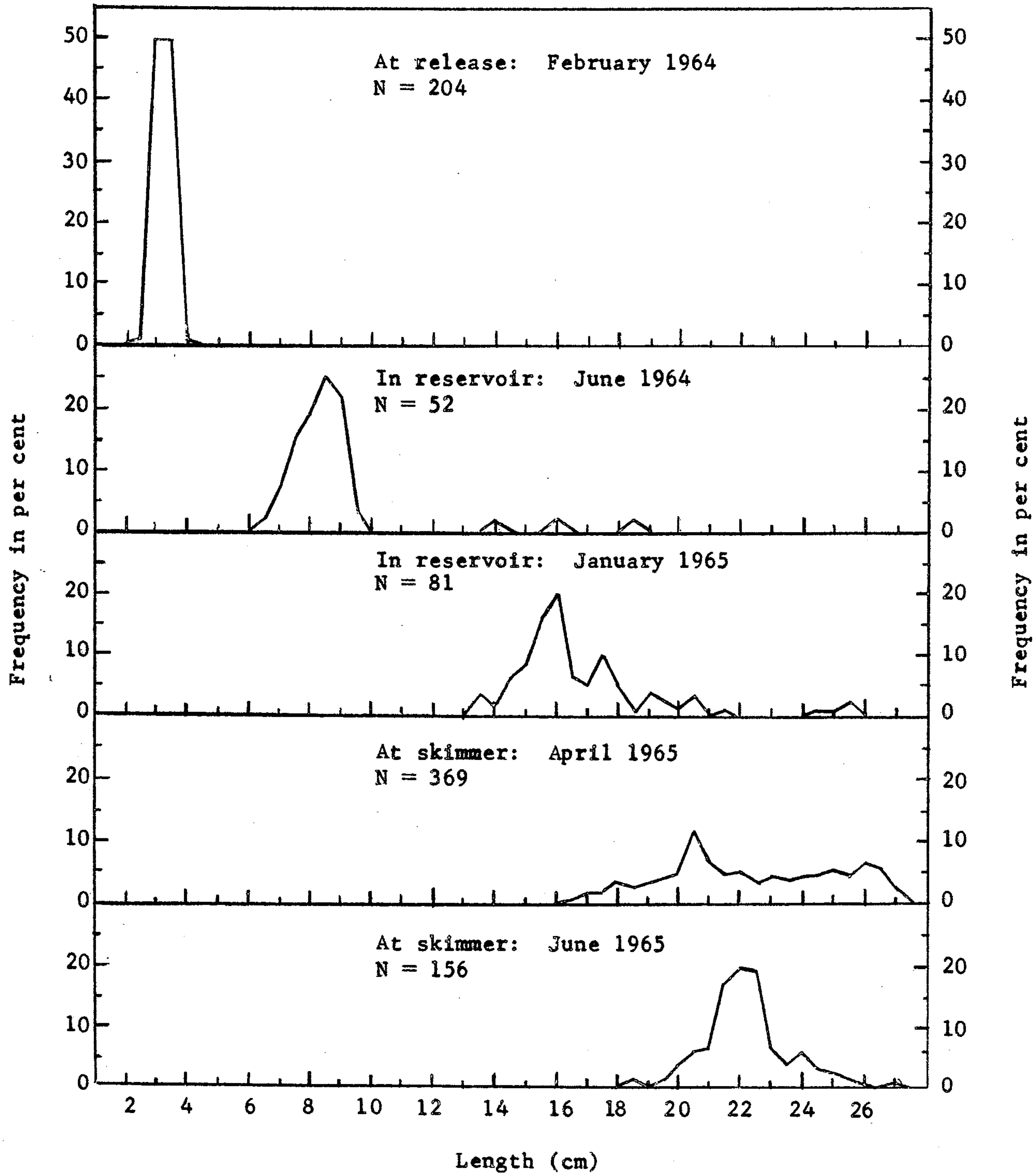


Figure 38. The size of marked coho salmon at release into Round Butte Reservoir as fry in February 1964, at sampling in the reservoir in June 1964 and January 1965, and at the skimmer in April and June 1965.

February 1964 and subsequently sampled in the reservoir as fingerlings and at the skimmer as smolts. These fish had modal sizes of 3-3.5 cm at release, and 8.5 and 16 cm when sampled in the reservoir in June 1964 and January 1965, respectively. At emigration through the skimmer in April and June 1965, they showed respective modal sizes of 20.5 and 22 cm. Coho marked and released into North Fork Reservoir as fry and recovered at the skimmer as yearlings in May 1964 ranged in size from 10 to 18 cm with a mode of 13 cm at emigration (Figure 16) while marked coho emigrating from Round Butte as yearlings in May 1965 (not shown in above graph) had a size range of 17.5 to 24 cm and a mode of 20 cm.

Unmarked fry coho were released into the headwaters of the Metolius River and nearby tributaries in February 1964. Figure 39 shows the size of fish sampled with an electric shocker in three of the areas of release in September 1964, the only period adequate samples were obtained from the streams. Coho reared in the headwaters of the Metolius River were the largest with a modal size of 8.5 cm, while fish sampled in Spring and Canyon creeks had respective modal sizes of 8 and 7 cm. In the reservoir, coho had already reached this size in June, 3 months earlier (Figure 38).

Growth of tagged fish in Round Butte Reservoir by month was not determined, but recoveries of coho salmon tagged and released into the Crooked River Arm and forebay indicated growth from January and February 1965 until emigration the following April, May, and June (Figure 40). The few fish recovered in April showed irregular distributions at tagging and recovery. Coho recovered in May and June were generally smaller at tagging, than those emigrating in April, and increased 5 and 6 cm, respectively, in modal size since tagging in January and February.

Only 20 tagged chinook were recovered at the gulper in May and June 1964. Of this total, 14 were at liberty between 2 and 24 days between tagging and

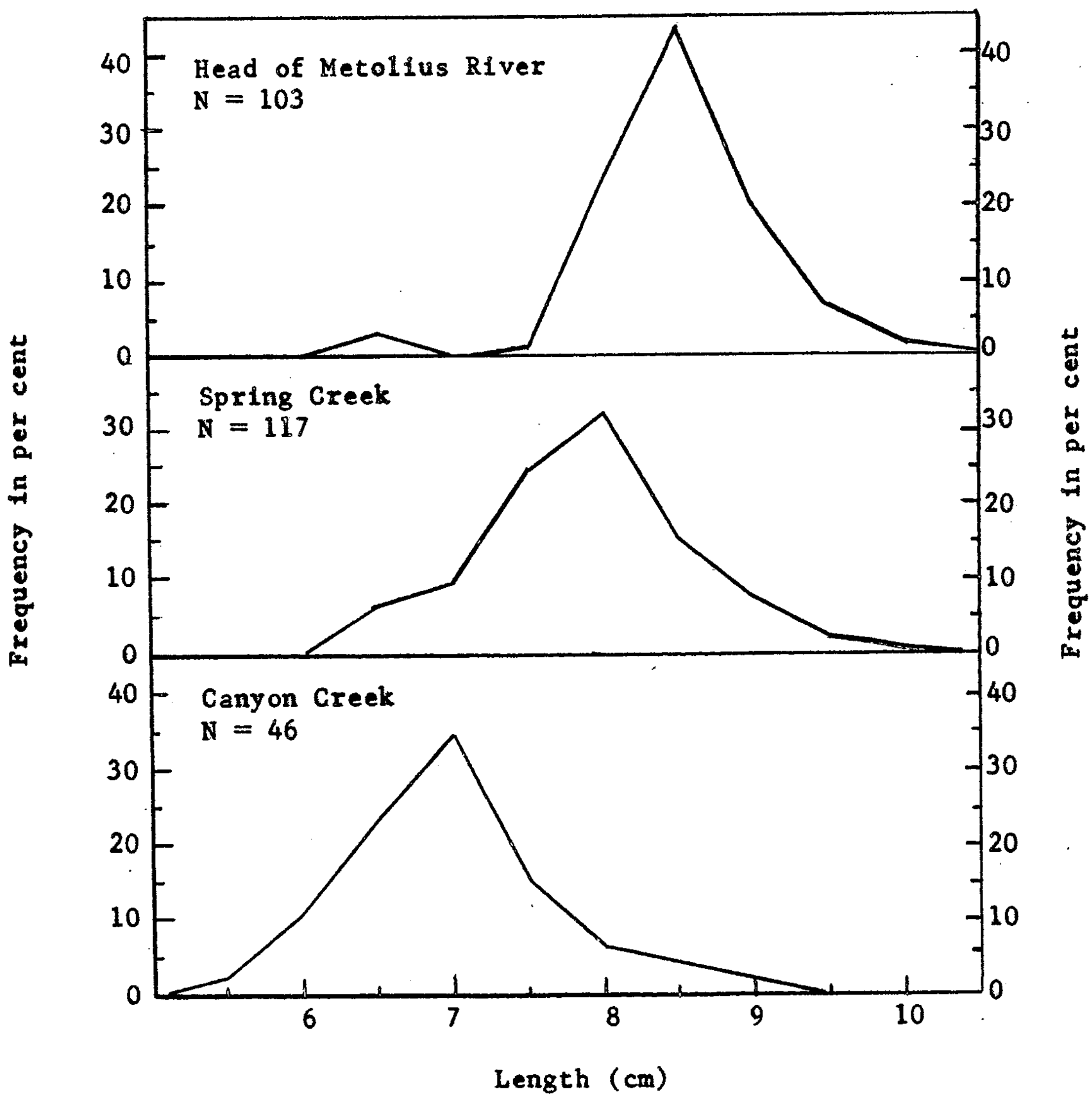


Figure 39. The size of coho salmon caught with an electric shocker in the headwaters of the Metolius River, and Spring and Canyon creeks, September 1964.

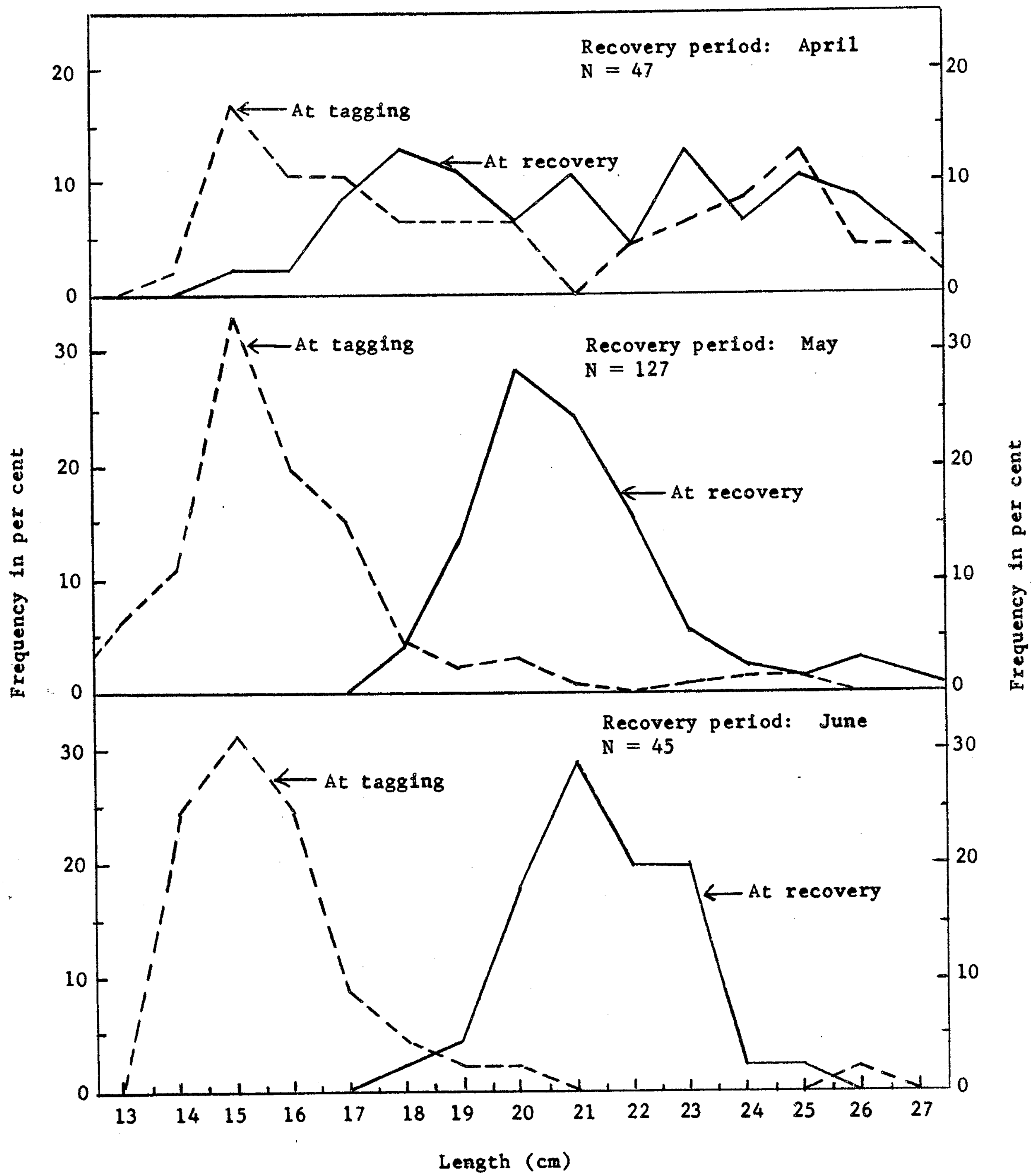


Figure 40. The size compositions at tagging in January and February 1965, and at recovery in April, May, and June 1965, of coho salmon tagged in the Crooked River Arm and forebay of Round Butte Reservoir and recovered in the skimmer.

recovery without showing any growth. Of the remainder, four grew 5 mm in a 4- to 28-day period and two grew 15 mm in 20 and 33 days, respectively.

Chinook salmon smolts ranged in size from 10.5 to 17 cm in April 1964, their main month of emigration, and 10.5 to 24 cm in April 1965. Their modal size was 13 cm in each year. Coho salmon emigrating through the skimmer in the spring of 1965 evidenced different size distributions by time period as follows:

1. April 30-May 6: size range, 16-29 cm; mode, 19 cm
2. May 28-June 3: size range, 13-30 cm; mode, 21 cm
3. June 25-July 1: size range, 13-30 cm; modes 17 and 22.5 cm

Age determinations were not made by the use of scales for coho salmon; but based on the size of marked fish reared in the reservoir, most emigrants collected at the skimmer in 1965 were yearling fish (Figure 41). The comparison is restricted to May, the month most coho emigrated. The ages of chinook salmon were not determined.

The size of most steelhead smolts caught in Round Butte Reservoir during the spring of 1964, the year the largest numbers were caught, ranged from 14.5 to 26.5 cm with no mode evident. A few fish exceeded 30 cm. Age determinations were not made for steelhead.

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 regarding the effect of the three projects on the fish are as follows:

1. Some fish of all species entered the reservoirs as fry. Emigration of smolts in the spring began first at Pelton and started with chinook. Steelhead emigrated earlier at North Fork than at Pelton or Round Butte.

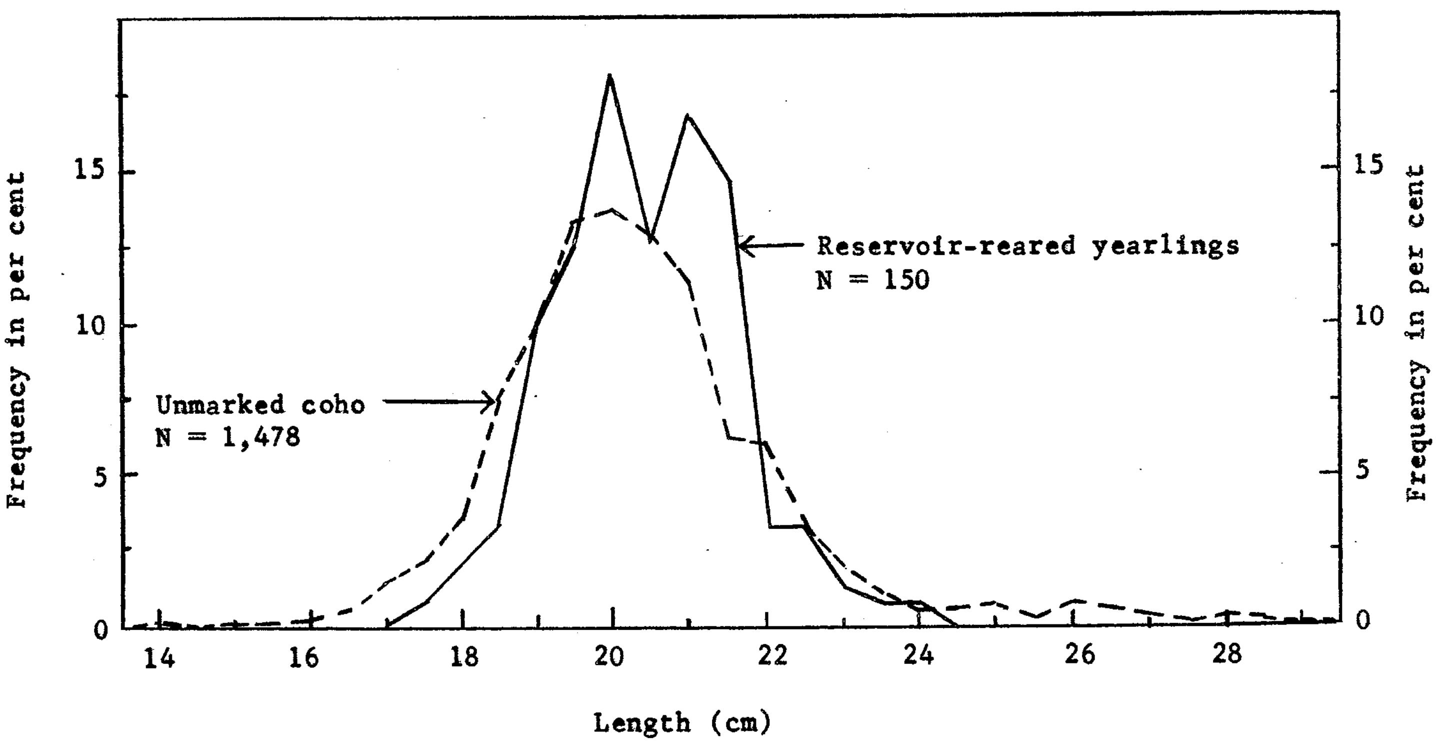


Figure 41. The size compositions of marked reservoir-reared yearlings and unmarked coho salmon sampled at the skimmer, Round Butte Reservoir, May 1965.

2. Movement of salmonids in all reservoirs was stimulated by freshets in the winter, and the emigration of salmon through the collection facilities at North Fork and Pelton in that season was related to flows. Significant positive correlations were found between the emigration of smolts and water temperatures in the spring at North Fork and Pelton; flows did not appear to be related to emigration in the spring. Steelhead and salmon smolts moved directly through North Fork, but wandered in Pelton and Round Butte.
3. Smolts and holdover juveniles concentrated in the upper Metolius Arm of Round Butte Reservoir, and this was peculiar mainly to this area.
4. Significant emigration of salmonids through the spillway occurred only at North Fork since it commonly spilled there but seldom spilled at the other dams.
5. Smolts were found at similar depths in the spring in all three reservoirs.
6. Survival of coho and chinook from fry to smolt was good at North Fork and survival of coho was poor at Pelton. Survival of coho in Round Butte immediately after impounding appeared good, but the presence of predator species and their potential for expansion may ultimately have an adverse effect on anadromous fish. While comprehensive data on survival were not obtained for all anadromous species at each reservoir, it is our opinion that they generally survived well in North Fork and Round Butte but did not in Pelton.
7. Species composition differed between the reservoirs in that squawfish and spiny-rayed fish were found in Pelton and Round Butte but not in North Fork. Their presence may result from certain characteristics of the environment and may indicate predation.

8. Steelhead smolts commonly entered the sport fishery at all three reservoirs, but appeared most seriously affected at Pelton and Round Butte. The later time of emigration for summer steelhead at Pelton and Round Butte than that for winter steelhead at North Fork resulted in the former being subjected to the sport fishery over a longer period of time. Salmon attained legal size as yearlings and entered the sport fishery in significant numbers at Round Butte Reservoir. Most salmon caught by sport fishermen at North Fork were of sub-legal size.

9. Passage of smolts through North Fork Reservoir was successful. Efficiency of passage at Pelton was about one-half that of North Fork, and success at Round Butte was low.

10. 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 migrations. Coho reared in Round Butte Reservoir for 3 years attempted to spawn in the Metolius River, but their eggs did not appear viable.

11. Juvenile salmonids grew better in the reservoirs than they did in the streams above the reservoirs. Fish attained a larger size in Round Butte Reservoir than they did in North Fork. Growth in Pelton appeared intermediate, but data are lacking there.

Since the anadromous species studied at these reservoirs are similar, differences in behavior are possibly 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 water temperatures were a few degrees higher than at North Fork,

2. North Fork was least alkaline of all the reservoir areas, and the upper 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 water currents were more prominent and deeper in the Metolius Arm of Round Butte than other reservoir areas tested.
5. Spill occurred commonly only at North Fork.
6. Large variations in flow occur in the Clackamas River, while the Deschutes is a relatively stable stream. Freshets in the Clackamas during the fall, winter, and spring exceeded those in the Deschutes, but the latter had higher flows during the summer.
7. 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.
8. The climate is wet at North Fork and arid at Pelton and Round Butte.
9. 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 fish 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 adult fish and comparing the number of returning adults to the number of parent spawners. Stocks at North Fork appear in good condition. Generally the returns of adult fish to this project were larger than the parent runs of 4 or 5 years previously, while at Pelton the numbers of returning adults were less than the parent runs for all years of record. While Round Butte has not existed long enough to make similar comparisons, it is unlikely that the numbers of juveniles emigrating from that reservoir in 1965 could produce returns equivalent to the parent runs of 1962 and 1963. The maintenance of the anadromous fish runs produced above North Fork Dam is probably influenced by a passage facility constructed as part of that project which successfully by-passes juveniles around the three-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. Based on the results of this study, failure to maintain the runs above Pelton appears due to factors above the dam.

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.

SUMMARY

A study to determine the relationship between the environments of North Fork and Pelton reservoirs and the behavior of juvenile anadromous salmonids was conducted by the Fish Commission of Oregon from February 20, 1962 to June 30, 1965, with funds provided by the Bureau of Commercial Fisheries under the Accelerated Fish Passage Research Program. Activities were transferred from Pelton to Round Butte Reservoir in January 1964.

North Fork is the uppermost of a three-dam complex on the Clackamas River. Cazadero and River Mill dams are located 2 and 7 miles downstream. Emigrants may leave North Fork Reservoir via a surface collection facility coincident with the ladder exit, the penstocks, or the spillway. Spring

chinook and coho salmon and winter-run steelhead trout are the anadromous species produced above the project.

Pelton is the lower of two dams located on the Deschutes River. Emigrants may leave the reservoir through the collection facility, the exit from the fish ladder, the penstocks, or the spillway. Round Butte Dam is located at the upper end of Pelton Reservoir. Emigration may occur through the permanent collection facility at the dam, a floating facility operated anywhere in the reservoir, the penstocks, or the spillway. Spring chinook and sockeye salmon and summer-run steelhead were present above these projects at the outset of the study; coho salmon were released for study purposes.

Fish were caught for marking, tagging, and recovery by Oneida Lake traps modified to float. Fish were tagged with a vinyl-attached numbered plastic pennant inserted with an embroidery needle. Gill nets and SCUBA were used to determine depth distribution. Size composition and scale samples were obtained from fish caught in the reservoir and collected at the outmigrant facilities. Water temperature and visibility, atmospheric pressure, river flow, water currents, dissolved oxygen, total alkalinity, and pH were measured at each reservoir.

Water temperatures at the surface of North Fork Reservoir did not exceed 73 F during the summer, and stratification was only in the top 15 to 20 feet of depth. The reservoir was nearly homothermous throughout each winter, and cool water temperatures generally prevailed during each spring. Water currents in North Fork traveled mainly in a down-reservoir direction. Dissolved oxygen concentrations were adequate for salmonid life throughout each year of record. Total alkalinity was relatively low and may be indicative of poor productivity.

Chinook, coho, and rainbow-steelhead fry were found in North Fork Reservoir by February, May, and July, respectively. An estimated 145,000 1961-brood coho salmon were in the reservoir by September 1962. Significant numbers of rainbow-steelhead probably resided in the reservoir each year, but the numbers of chinook present never appeared large.

Regardless of month of marking or tagging within a run-year, most chinook and coho were recovered at the collection facilities in April and May and May and June, respectively; all of smolted steelhead were recovered during the season they were tagged.

Tests to determine the numbers of fish passing through the spillway at North Fork Dam and the percentages of these diverted into Faraday Lake resulted in qualified estimates, but were considered indicative of significant emigration and diversion.

Emigration of juvenile salmonids occurred throughout the year at the collection facilities of North Fork Dam, but the major counts for each species were in the spring. Steelhead emigrated earliest, and counts of coho occurred later than for the other species. Regression analysis indicated that significant positive relationships existed between the volume of flow and the counts of coho in the winter and between water temperature and the counts of coho and steelhead in the spring.

Fry salmonids inhabited the surface waters of North Fork Reservoir during the late winter, spring, and early summer of each year. Generally coho salmon fingerlings and smolts were distributed comparatively deep during the day and shallow at night in all seasons. Chinook were distributed similarly to coho, but data were poor in most seasons. Steelhead smolts were caught mainly at the surface over deep water at night, during the spring; catches were inadequate to describe their distribution during the day.

The results of our marking and tagging and of tests conducted by the North Fork Evaluation Study indicated survival and efficiency of collection was good for all species of anadromous salmonids at North Fork.

Chinook and coho salmon grew relatively fast after entering North Fork Reservoir early in their first year of life. By late fall of 1962 and 1963, chinook showed modal sizes of 11 and 10 cm, respectively. For the same years, the respective modal sizes of coho were 9 and 10-11 cm. The modal size of coho and chinook emigrating through the collection facilities at North Fork in May 1963 and 1964 was 11 cm.

Growth of tagged coho salmon in North Fork exceeded 15 mm per month between July and September, was gradually reduced to nothing during the winter, and increased during the spring until it approximated that of the previous summer. The modal size of coho tagged in April 1964 and recovered in the collection facilities the last half of June 1964 increased 3.5 cm between tagging and recovery. Little information was collected on the growth of chinook in North Fork. Steelhead smolts showed little growth between tagging and recovery in the spring.

Virtually all chinook and coho leaving North Fork Reservoir during each run-year were sub-yearlings and yearlings of the same brood year. Steelhead emigrants in 1963 and 1964 were mainly 2 years old, but those in 1964 included a significant proportion of 3-year olds.

Maximum surface water temperatures in Pelton Reservoir were in the low 70's, and stratification occurred only in the first 15 to 20 feet of depth during the summer. The reservoir was homothermous throughout the winter, and warmed faster than North Fork in the spring.

Surface water currents traveled predominantly down reservoir regardless of wind patterns.

Construction of Round Butte Dam adversely affected water clarity in Pelton Reservoir throughout the 2 years fish were studied in the latter.

Dissolved oxygen in Pelton Reservoir was adequate for fish life throughout the study, and total alkalinity was twice that measured at North Fork.

Fry and fingerling chinook readily entered Pelton Reservoir prior to construction of the Round Butte cofferdam. After construction, the cofferdam appeared to retard the entry of fish into Pelton. The rearing of chinook in Pelton Reservoir from fry to smolt stage was indicated, but steelhead did not appear to rear extensively there.

Salmonids emigrated from Pelton throughout the year, mainly via the collection facilities, but the highest counts were in the spring. Steelhead emigrated later than chinook. Significant positive relationships were found between the counts of chinook and flows during the winter, and between the counts of chinook and steelhead and water temperatures in the spring.

Fry and fingerling chinook were found mainly in the surface shoreline waters at night. Chinook fingerlings were caught best between the surface and 30 feet of depth in the summer and fall and from 0 to 15 feet deep during the winter and spring. Steelhead smolts were caught best near the shorelines in the spring.

Recoveries of marked and unmarked coho salmon released as fry indicated survival was poor in Pelton Reservoir. The results of tests conducted during this study and in the Pelton Evaluation Study led to the conclusion that efficiency of collection for juvenile anadromous salmonids ranged from poor to fair. The estimated catch by sport fishermen indicated significant numbers of steelhead smolts were caught.

Coho salmon released into Pelton Reservoir as fry had a modal size of 15.5 cm when emigrating as yearlings. Bimodal size distributions were observed for chinook salmon in three of five months sampled between December 1962 and June 1963. Chinook tagged as yearlings did not appear to grow well in Pelton Reservoir.

Steelhead emigrants were mainly 2-years old, but significant numbers were 1-year-old fish. The modal size of summer steelhead leaving Pelton was larger than that for winter steelhead leaving North Fork.

Round Butte Reservoir was thermally stratified after closure of the dam in January 1964 due to relatively warm water from the Crooked River overlying the cooler water of the Deschutes and Metolius rivers. The reservoir was weakly stratified during the spring of 1964 and 1965. The Deschutes and Crooked River arms of the reservoir were thermally stratified during the summer of 1964; but the upper Metolius Arm was weakly stratified due to the cooler inflow to this area.

Water currents at the surface and at a depth of 20 feet generally moved down the Deschutes and Crooked River arms and up the Metolius River Arm. Air currents commonly moved up the latter.

Data from Round Butte in 1964 were collected while the reservoir filled.

Dissolved oxygen content was adequate for fish life in most areas of the reservoir throughout the study period, but a low of 2.5 ppm occurred below a depth of 150 feet in the Crooked River Arm in June and July 1964. The total alkalinity of the three rivers varied.

Fry chinook salmon were present in the Metolius Arm of Round Butte Reservoir in the spring of the years 1964 and 1965. Coho salmon (1962 brood), released as fry into the Spring Creek tributary of the upper Metolius River and tagged as fingerlings between September 1963 and March 1964, first appeared in the reservoir in mid-April 1964.

A floating gulper installed in the forebay of Round Butte Reservoir in April 1964 collected several thousand chinook and coho but only 321 steelhead during the spring of 1964; peak counts occurred in late May and early June. Floating traps fished in the upper end of the Metolius Arm caught several thousand additional migrants for transport; most steelhead smolts were taken with this gear. The permanent collection facility built into the dam operated at less than full capacity in the spring of 1965. Small numbers of chinook and steelhead and a substantial number of coho were collected for passage that year.

Tagging studies and gillnetting showed smolts were migrating between the different arms of the reservoir each spring; fish concentrated in the upper Metolius Arm.

Fry chinook and coho were observed near the surface of Round Butte Reservoir during the day and at night. Coho salmon were caught best during the day at a depth of 15 to 30 feet in all seasons. At night the largest catches occurred in nets fished from 0 to 15 feet deep, except during the summer when most fish were caught at a depth of 30 to 45 feet.

The recovery of coho salmon marked and released into Round Butte Reservoir as fry indicated survival was good. All tests using marked and tagged fish showed efficiency of collection was poor at Round Butte. Rates of collection were lower for fish tagged and released into the reservoir during the spring than for those tagged and released the previous fall. Coho were collected best and steelhead were poorest. It was estimated that substantial numbers of coho and significant numbers of steelhead were caught by anglers.

Coho salmon marked and released into Round Butte Reservoir as fry had a modal size of 22 cm at emigration as yearlings. These fish were significantly larger than coho reared in North Fork Reservoir. Coho reared in the headwaters of the Metolius River were larger than those reared in selected tributaries, but all stream-reared fish were smaller than those inhabiting the reservoir. The modal sizes of tagged coho emigrating from Round Butte Reservoir in May and June 1965 increased 5 and 6 cm, respectively, since tagging in January and February.

Differences in fish behavior and environment at North Fork, Pelton, and Round Butte reservoirs are reflected in the apparent success of the salmon and steelhead runs in the Clackamas River system and seeming failure of the runs produced above the projects on the Deschutes.

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