RESEARCH BRIEFS

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FOREWORD

These short reports are intended to inform the public, fishing industry, sportsmen, and fisheries scientists of research conducted by the Fish Commission. Reports will be published from time to time as studies are sufficiently complete. Most of the reports provide biological evidence upon which measures are based to enhance and conserve the fishery resource. Research Briefs are free and may be obtained upon request from the editor.

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The Length of Residence of Juvenile Fall Chinook Salmon In Selected Columbia River Tributaries

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ABSTRACT

Residency of juvenile fall chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), was studied in 11 Columbia River tributaries below Bonneville Dam. Juveniles were collected and adult and juvenile scales from the Klaskanine River, a tributary with short-term residence, and the Toutle River, a tributary with long-term residence, were compared. Juveniles remained in four larger tributaries at least until sampling during the fall, while seven smaller tributaries were devoid of juveniles by early summer. Disparity of fish size among the tributaries existed and was inversely related to the length of residence. Growth of fish remaining in the tributaries proceeded toward a size of 80-105 mm before migration. Counts of fresh-water circuli on scales of adult and juvenile chinook from the Klaskanine and Toutle rivers agreed with direct observations of residency. Klaskanine River adults and juveniles averaged 14 fresh-water circuli. Toutle River adults averaged 22 fresh-water circuli, but at last sampling in October the juveniles only averaged 16 circuli. This suggests that Toutle River fish may reside in fresh water until late fall or the following spring. The Toutle River Hatchery has been releasing its fish at small size during their first spring; these fish may be staying in fresh water instead of migrating to the ocean. This practice may limit hatchery contribution to the number of fish needed to achieve stream carrying capacity. The Kalama, Washougal, and North Fork Lewis rivers may have similar situations.

INTRODUCTION

The length of residence of juvenile fall chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), in selected Columbia River tributaries below Bonneville Dam was investigated during the summer and fall of 1963. The work was prompted by the results of adult chinook scale reading by Loeffel and Ellis (1962) which indicated that some fall chinook juveniles remain in fresh water up to a year, contrary to the popular concept that they migrate to sea soon after emergence. Management practices for fall chinook based on early migration need reviewing if extended stream residence proves important.

Scale samples from the catch of the Astoria area gill-net fishery in August 1959 were about 8% "stream-type"[1] while in the September-October season this component increased to 55%. In 4 succeeding years, the percentage of stream-type scales in the July-August and September-October seasons averaged 5 and 28%, respectively.[2] Smaller percentages of stream-type scales in the September-October fishery in later years may have resulted from the earlier termination of sampling in years following 1959. In all years, stream-type scales in the commercial catch increased in frequency after the main migration past Bonneville Dam, suggesting that these fish originate below Bonneville Dam.

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(1) Ocean-type and stream-type scales are from chinook migrating to the ocean in the first and second years of life, respectively (Gilbert, 1913).

(2) Unpublished data from Fish Commission of Oregon, Columbia River Investigation.

Chinook entering the Columbia River to spawn are divided into spring, summer, and fall runs. The generally accepted length of fresh-water residence of the spring and fall runs is distinctly different. Spring chinook juveniles are expected to remain in fresh water for a year before migrating to the ocean in their second spring. Fall chinook juveniles are expected to migrate to the ocean early in the first year of life, usually about 90 days after yolk absorption. The following papers undoubtedly contributed to this concept.

Rich (1920) summarized the normal time for seaward migration among Columbia River chinook as, ". . . during the summer next succeeding the fall in which the eggs are laid." Rich (1925) documents a change in scale pattern of adult chinook in the Columbia River from predominantly stream-type scales in the spring to predominantly ocean-type scales in the fall. Rich and Holmes (1929) conducted several marking experiments with hatchery-reared spring and fall chinook in the Columbia River. Experiments with spring chinook were found most successful when the young were released as yearlings. Best success with fall chinook was obtained when juveniles were reared only a short period. They conclude: "As fingerlings of the spring run normally spend the entire first year in fresh water, best return would be expected from the longer period of rearing. . . . In the case of fall chinook, which normally leave the stream soon after the yolk sac is absorbed, the shorter period of rearing might be expected to be the most successful." The part of these statements concerning the "normal" or natural fresh-water life history was probably based on the earlier scale reading of Rich (1925), but this was not clear from their report.

Deviation from the typical stream-type life history for natural populations of spring chinook has been found (Mattson, 1962, 1963; French and Wahle, 1959). However, since no previous work has been done with natural populations of juvenile fall chinook, investigation of variation in length of fresh-water residence by sampling in the spawning streams and by scale analysis is warranted. Consideration of factors causing the variation in fresh-water residence is also needed.

METHODS

Both large and small streams were selected for the study including the major fall chinook producing rivers in the Columbia River below Bonneville Dam (Figure 1). The Sandy, Willamette, and mainstem Cowlitz rivers were omitted because they contain both spring and fall runs, the juveniles of which, at present, are not separable.

Sampling stations were selected below known spawning sites in the lower sections of the streams. Initial sampling was conducted after June 1, 1963, to allow migration to the ocean of those fish leaving within the generalized "90-day period". Most streams where juveniles were found were irregularly sampled throughout the summer and fall or until they no longer yielded juveniles. Most sampling was done with seines of 12, 30, and 70 feet in length. A fyke net was also used in the Klaskanine River.

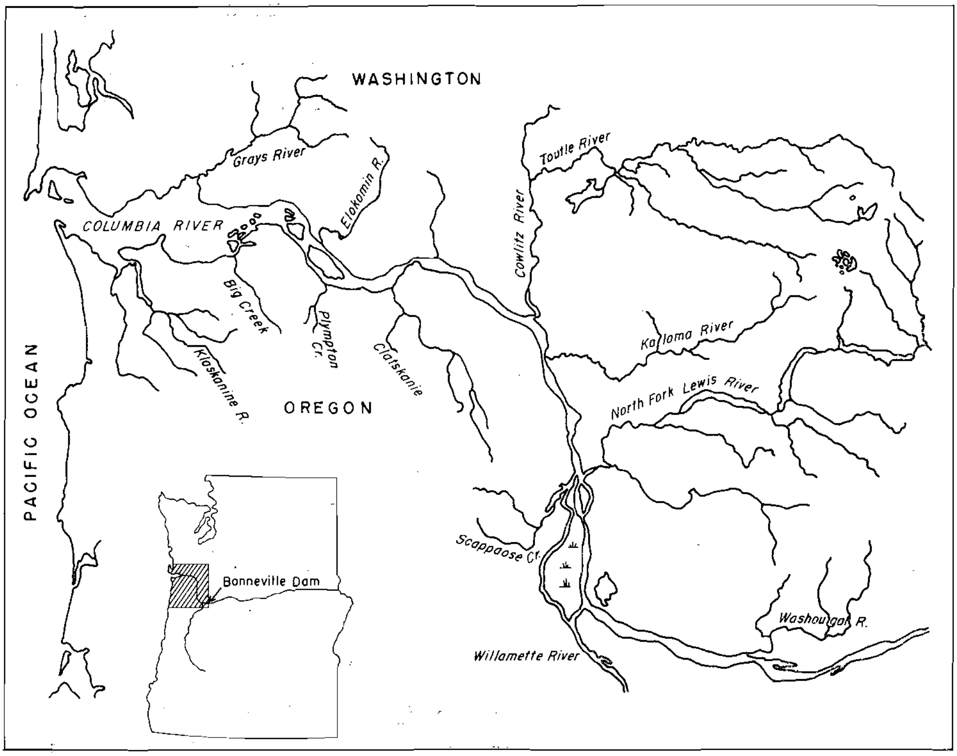

Figure 1—*Location of streams observed in the study.*

For most small catches, all fish were anesthetized in MS 222 and measured to the nearest millimeter fork length in the field. Some small catches were preserved in 10% formalin for later measuring and scale analysis. Samples for measurement were selected from the large catches while still in the seine.

Estimates of emergence dates used in the size analysis for selected streams were calculated using data on the time of egg deposition and the rate of embryonic development. Mean time of egg deposition in the Washington shore tributaries was estimated from peak spawning ground counts.① Peak spawning in the Klaskanine River was based on hatchery information and spawning ground observations. The length of the incubation period and the hatching date were calculated for the juveniles in each stream using a relationship between hatching time and temperature for summer chinook eggs② and the average monthly temperature information for each stream③. On the assumption that yolk absorption follows the time-temperature relationship of incubation, the length of the pre-emergence

① Personal communication from H. O. Wendler, Washington Department of Fisheries, January 9, 1964.

② Personal communication from B. D. Combs, U. S. Bureau of Sport Fisheries and Wildlife, January 17, 1964.

③ Data from U. S. Geological Survey, Water Supply Papers, 1950-1957.

period and the emergence date for the juveniles in each stream were estimated.

Scales were obtained from both adult and juvenile chinook in the Klaskanine and Toutle rivers. The inner portion of the scale from adult fish and the entire scale from juveniles were examined for numbers of fresh-water circuli which were counted or measured as encountered. The average inter-circular widths for circuli beyond the 10th circulus of scales from juveniles and for the 3rd (11 through 15) and 4th (16 through 20) groups of five circuli (starting at the focus) on adult scales were determined. Both counts and measurements were made along a line 40° off the bisector of the angle established by the division between the posterior and anterior fields of the scale. Measurements were made to the nearest millimeter under 96X magnification.

RESULTS AND DISCUSSION

Studies cited earlier suggested that some Columbia River fall chinook reside in fresh water through at least the first summer of life. This program investigates the degree and importance of extended residence among these fall chinook, regardless of origin.

Extended Residence

Initial sampling conducted with seines in early June 1963 in Big Creek, Plympton Creek, Clatskanie River, and Scappoose Creek disclosed no juveniles (Table 1). Initial sampling in Grays River on June 27 and 28 provided only six juveniles, so this stream was not sampled again. Juveniles in the Klaskanine River were collected by seine on June 3 and June 19, but could not be captured after July 1. Only two juveniles were caught in the Elokomin River on August 8, the final sampling date. The Toutle, Kalama, North Fork Lewis, and Washougal rivers all contained juveniles as late as October 10. Sampling on November 8 was nearly impossible due to high water, although one juvenile was taken in the Toutle River. Sampling was not attempted after November.

Daily fyke-trap catches of juvenile fall chinook salmon from the Klaskanine River declined from 46 fish on June 14 to 1 fish on June 25. Thereafter, catches did not exceed one fish per day. The trap was removed on July 1. This confirmed the seining results and indicated that out migration was complete by July 1.

Considerable disparity in the average size of juveniles collected at any one time was observed among streams. The streams having the smaller fish during earlier sampling periods were the ones in which extended residence occurred, viz. the Washougal, North Fork Lewis, Kalama, and Toutle rivers. Average lengths of the juveniles sampled in six selected streams are shown in Table 2.

Table 1—*Occurrence by sampling period of juvenile fall chinook in eleven selected tributaries of the Columbia River, 1963.*

Tributary	*June*			*July*			*Aug.*			*Sept.*			*Oct.*			*Nov.*
	1-10	*11-20*	*21-30*	*1-10*	*11-20*	*21-30*	*1-10*	*11-20*	*21-30*	*1-10*	*11-20*	*21-30*	*1-10*	*11-20*	*21-30*	*1-10*
Klaskanine River	X[1]	X		O[2]												
Big Creek	O															
Plympton Creek	O															
Clatskanie River	O															
Scappoose Creek		O														
Grays River			X													
Elokomin River	X						X									
Toutle River		X	X		X		X	X		X				X		X
Kalama River	X	X	X							X				X		O
N. F. Lewis River							X				X			X		O
Washougal River	X				X			X		X			X			O

[1] X=chinook present in sample.
[2] O=chinook absent in sample.

Table 2—*Average lengths of juvenile fall chinook taken in six selected tributaries of the Columbia River, 1963.*

Stream	Date	Size of sample	Length (mm) Mean	Range
Klaskanine River	June 3	11	90.2	83-97
	June 19	15	98.1	92-110
Elokomin River	June 5	27	62.7	45-78
	Aug. 6	2	100.0	95-105
Toutle River	June 20	12	45.7	37-49
	June 26	4	50.3	46-54
	July 14	13	61.2	55-65
	Aug. 6	7	65.9	54-74
	Aug. 15	19	70.6	59-77
	Sept. 5	16	73.8	64-84
	Oct. 12	21	80.3	74-88
	Nov. 8	1	84.0	—
Kalama River	June 10	8	52.1	41-62
	June 20	7	58.3	48-70
	June 27	70	50.5	42-68
	Sept. 4	23	74.9	65-88
	Oct. 11	4	84.7	75-97
N. F. Lewis River	Aug. 7	24	70.0	46-98
	Sept. 19	60	95.9	68-112
	Oct. 11	24	106.0	82-124
Washougal River	June 10	29	63.4	43-79
Highway 830 bridge	July 19	8	82.1	72-94
	Aug. 19	8	90.5	82-98
	Sept. 4	3	101.0	94-106
10.8 mi. upriver from	Aug. 19	9	87.1	76-97
Hwy. 830 bridge	Sept. 4	2	80.0	74-86
	Oct. 10	8	87.9	83-95

Juveniles collected at the upriver point were considerably smaller than those encountered earlier downstream. The reduction in average size of Kalama River juveniles on June 27, was probably caused by large numbers of small juveniles released from the Kalama Falls Hatchery 3 days earlier.

The average length of juveniles reached a maximum of about 100 mm in several streams, but only 80 mm in the Kalama and Toutle rivers during the sampling period (Figure 2). These observations suggest that juveniles with extended residence grew toward a migration size that in some cases was not reached until the following spring. This does not mean some emigration of small fish did not occur earlier. Indeed, emigration was indicated by the low catch-per-unit of effort in these streams and by finding small chinook in the estuary of the Columbia River during the spring. Some of these small fish (down to 50 mm) were fin clipped showing origin in lower Columbia River hatcheries (Reimers, 1964).

A Cause of Residence

Sampling showed that there was variation in size of fish among streams, and that extended residence was associated with streams having smaller fish. This suggested that the size-time relationship was a factor in producing extended residence.

Since size at a particular time is in part a function of the environment, the effect of one environmental factor—temperature—was investigated. Mean time of egg deposition and calculation of hatching and emergence dates were made for chinook in the Klaskanine, Elokomin, North Fork Lewis, Kalama, and Toutle rivers. Calculations for the Washougal River were not made because temperature data were not available.

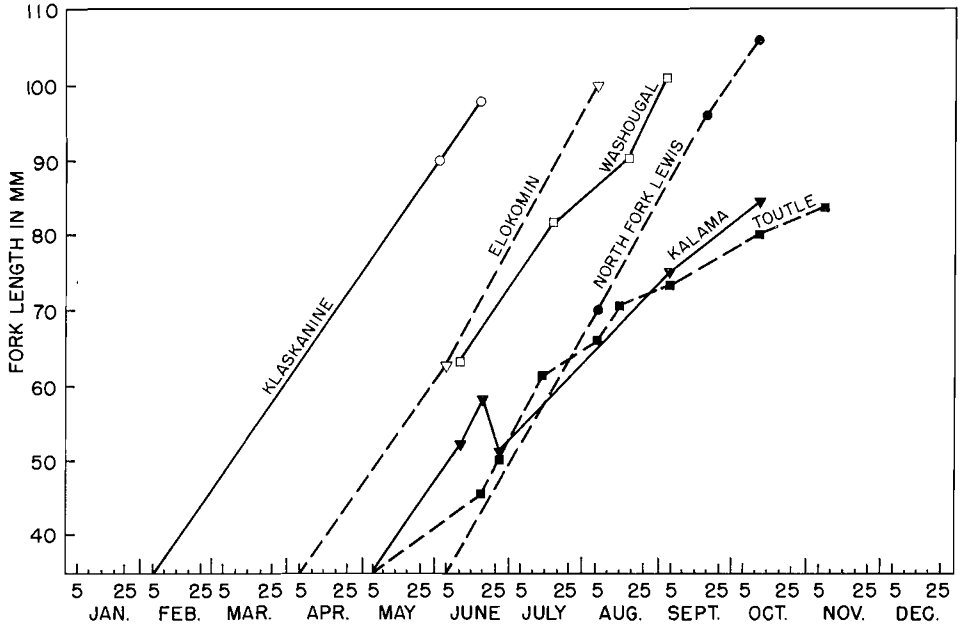

Figure 2—*Growth of juvenile fall chinook determined from calculated time of emergence and observed average lengths in six selected tributaries of the Columbia River, 1963.*

Variations in estimated emergence dates for each stream as shown in Figure 3 were similar to the size disparity among streams. This similarity is also shown in Figure 2 where the growth curves originate at an emergence size of 35 mm (Mattson, 1962). The slope of curves showing net growth between emergence and the first field observations were quite similar. This suggests that temperature as it controls emergence time was a factor in producing the size disparity found in fish from different streams, and the occurrence of extended residence.

Importance of Extended Residence

Complete emigration occurred in some streams by late spring of the first year of life or about 4 to 5 months after emergence. Other streams contained resident juveniles through the summer and fall. Examples are the Klaskanine and Toutle rivers, respectively.

By comparing the nuclear areas of scales, life history patterns leading to success as measured by return to fresh water can be determined. Under conditions of good growth, circuli and interspaces are wider and the rate of circulus deposition is greater than for conditions of poor growth (Clutter and Whitesel, 1956). Such a difference in scale growth exists between periods of fresh-water and ocean residence, providing a means of identifying these two portions of a scale. This technique is applied herein, although the scale analysis remains subject to criticism because: (1) small samples were used, (2) adult-juvenile comparisons were made on fish 2 to 4 year classes apart, and (3) variation in sampling site location existed within a stream. Environmental conditions among years and locations could not be expected to be similar.

Scales were read from 40 adult chinook selected at random from those returning to the Klaskanine Hatchery in the fall of 1963. A total of 98 scales were read from chinook returning in 1963 to the Green River Hatchery on the Toutle River.

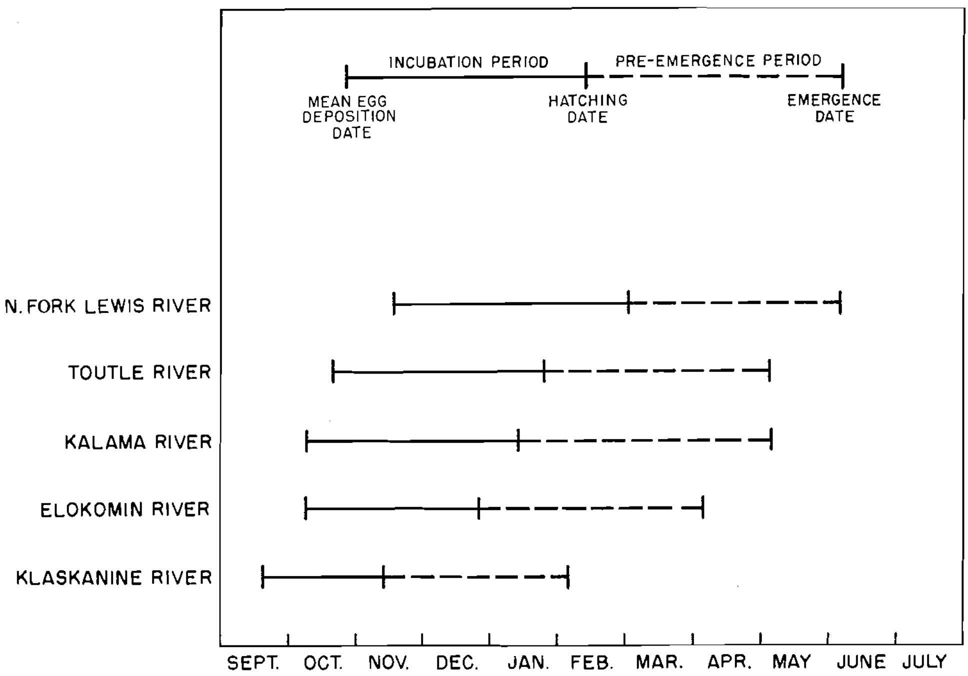

Figure 3—*Calculated date of mean egg deposition, incubation period, hatching date, pre-emergence period, and emergence date for fall chinook in five selected tributaries of the Columbia River.*

Fresh-water circulus counts for Klaskanine fish ranged from 9 to 23 and averaged 14.4, while Toutle fish averaged about eight more at 22.2 and ranged from 15 to 37 (Figure 4). Modes of the smoothed curves were also at 14 and 22 circuli. This large difference in the average number of fresh-water circuli on adult scales from these two streams supports the observation of length of residence.

Thirteen juveniles caught in the Klaskanine River in early June averaged 90.2 mm and had circulus counts ranging from 11 to 13 (Table 3). Although no scales were taken from 15 fish averaging 98.1 mm 2 weeks later, these fish would have had about 14 circuli on the average (Figure 5). This information agrees with the average fresh-water circulus counts on returning adults (Figure 4), strengthening the conclusion that fresh-water residence for most Klaskanine chinook was complete by late June.

Scales were taken from juveniles in the Toutle River over a greater time period than in the Klaskanine River and showed a progressive increase in the average number of circuli from June through November (Table 3). The combined October and November observations averaged the largest at 15.6 circuli. While occasional fish were observed that had a considerably larger count than others in the sample, there was no evidence of a fast growing group leaving the sampling area early in the study period. The October-November average of 15.6 circuli is well below the average fresh-water circulus count for Toutle River adults of 22.3, and is in fact, about equal to the lowest actual count observed on the adult scales (Figure 4). This disparity and the progressive growth mentioned above suggest that migration from the Toutle River, or at least from fresh water, was not imminent in October and probably would not have occurred until the following spring.

The possibility exists that differences observed in fresh-water circulus counts from adult and juvenile scales were due to misinterpretation of the

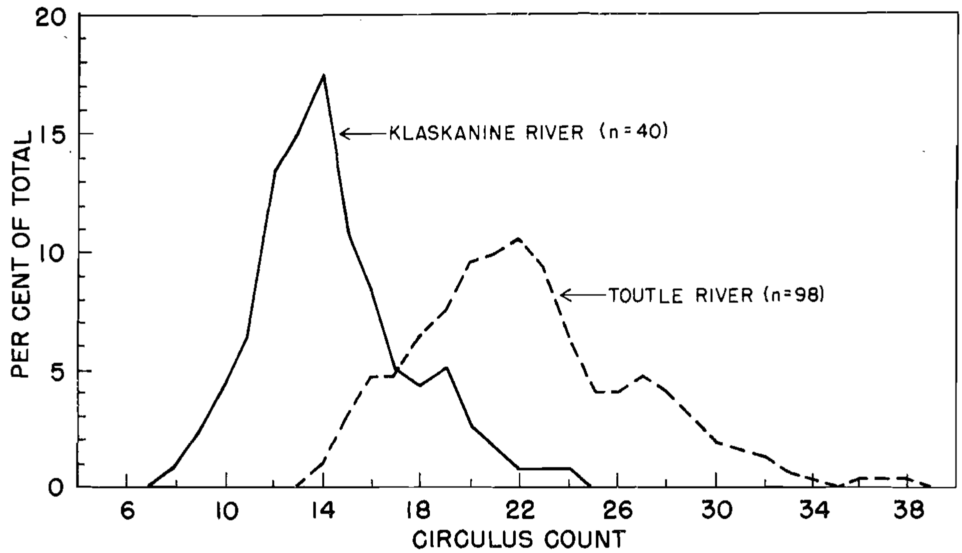

Figure 4—*Frequency distributions of fresh-water circuli on scales of adult chinook returning to Klaskanine and Toutle rivers in 1963. (Data smoothed by moving average of 3.)*

Table 3—*Temporal changes in circulus counts for juvenile fall chinook for the Klaskanine and Toutle rivers, 1963.*

Date	Circulus count 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Average
Klaskanine River																		
June 3								3	5	3								12.0
June 7								1		1								12.0
Toutle River																		
June 20	2	3	4	3														5.7
June 26				1		1	2			1								9.8
July 14			1		1	4	5	2										9.4
Aug. 6				1		2	3	4										9.9
Aug. 6								3	3			1						12.0
Aug. 15						1	1	4	5	5	2	1						12.2
Sept. 5								4	5	1	3	2			1			12.9
Sept. 5							1	1	1	2	4		2					13.4
Oct. 12								1		1	6		4	3	1	1	1	15.6
Nov. 8												1						15.0

adult scale pattern. This was explored by comparing the width of successive 5-circulus bands from both Klaskanine and Toutle river adult chinook scales. Using the premise that better growth results when salmon leave fresh water for ocean life, the fresh-water portion of adults scales was identified and the number of fresh-water circuli counted. By the same premise, measurable differences in intercirculus spaces and circulus

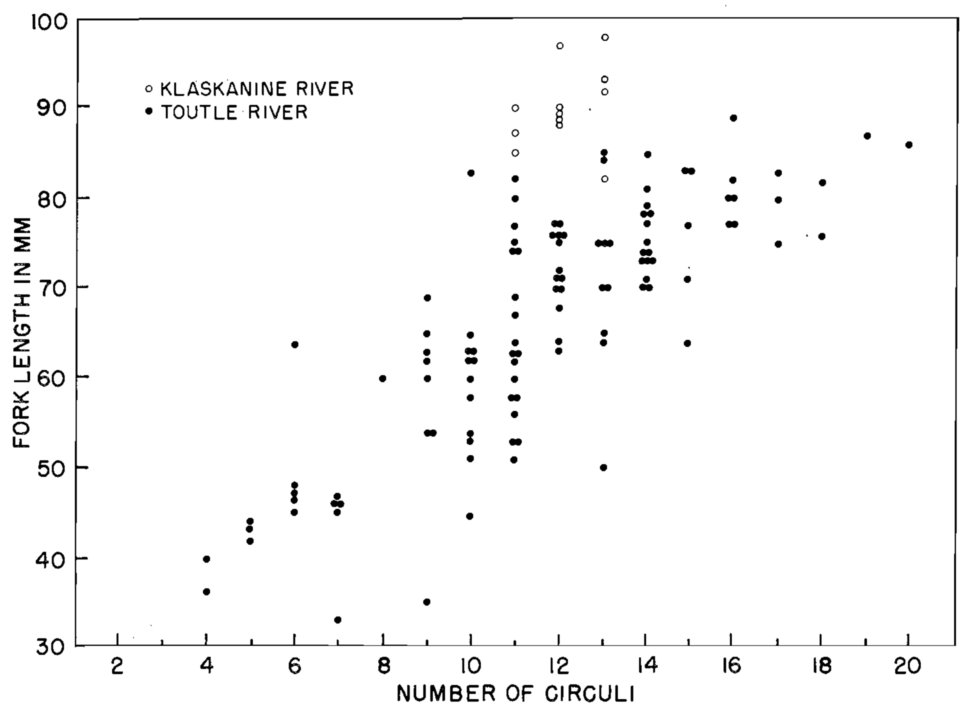

Figure 5—*Relationship between circuli count and body length for juvenile fall chinook from the Klaskanine and Toutle rivers, 1963.*

widths should be present. Measurements of the third and fourth sets of 5-circulus bands were used in the study because the circulus counts from adult scales indicated that a width change occurred between these points for Klaskanine fish. Measurement removes the subjectivity in identifying these circuli and facilitates a second type of comparison with scales from Toutle chinook at an important time in the life history of both groups.

The third 5-circulus band from Klaskanine scales varied from 8 to 15 units in width with the distribution being broadly unimodal and averaging 11.3 units (Figure 6). The width-frequency distribution for the fourth 5-circulus band on Klaskanine scales shows a marked increase in the average band width (13.5 units), a shift in position of the mode, and a change in the curve shape. This indicates that better growth conditions were experienced by many Klaskanine chinook at the time the fourth band was laid down than during the third band period, supporting the position that the transition from fresh-water to salt-water growth occurred at this time in the scale record. The skew to the left of the fourth band distribution suggests that some of the fish may still not have left fresh water by the completion of the fourth band.

A comparison of similar data for Toutle chinook also supports the results obtained when assignment of circuli to fresh-water or salt-water origin was made visually. The width-frequency distributions of the third and fourth bands were very similar in shape except that the right arm of the fourth band curve reflected some width increase (Figure 6). Since the average number of fresh-water circuli on Toutle adult scales was 22.3 or well above the upper limit (20) on the fourth band, the minor amount of change between the 2 bands is in contrast to the Klaskanine observations.

Application

From these data, fall chinook are shown to migrate from fresh water to salt water after residence periods varying from a few weeks or months to possibly 1 year. Some streams that were studied appeared to be vacated by chinook fingerlings early in the summer. Accordingly, the adults returning to these streams should show an early life history pattern on their scales in agreement with short-term, fresh-water residence. Such is the case for the Klaskanine fish that were studied as representative of this group. In the streams where longer residence was observed, it is possible for returning adults to have had either short-term or long-term fresh-water residence. Examination of the scales of adult Toutle River chinook revealed that a considerable portion had spent an extended time in fresh water as juveniles. In fact, only the overlap in the fresh-water circulus counts between fish from the two streams indicated that early migrating fish contributed to the adult return at all. Even this might be questionable since little evidence of a second mode at a low count position is present in the circulus-frequency curve (Figure 4). The spawning and hatching information resulting in an estimated time of emergence of Toutle chinook of early May casts further doubt. The cold water, which is an important factor in delaying emergence, could hardly be expected to produce growth conditions leading to 15 or more fresh-water circuli by late June.

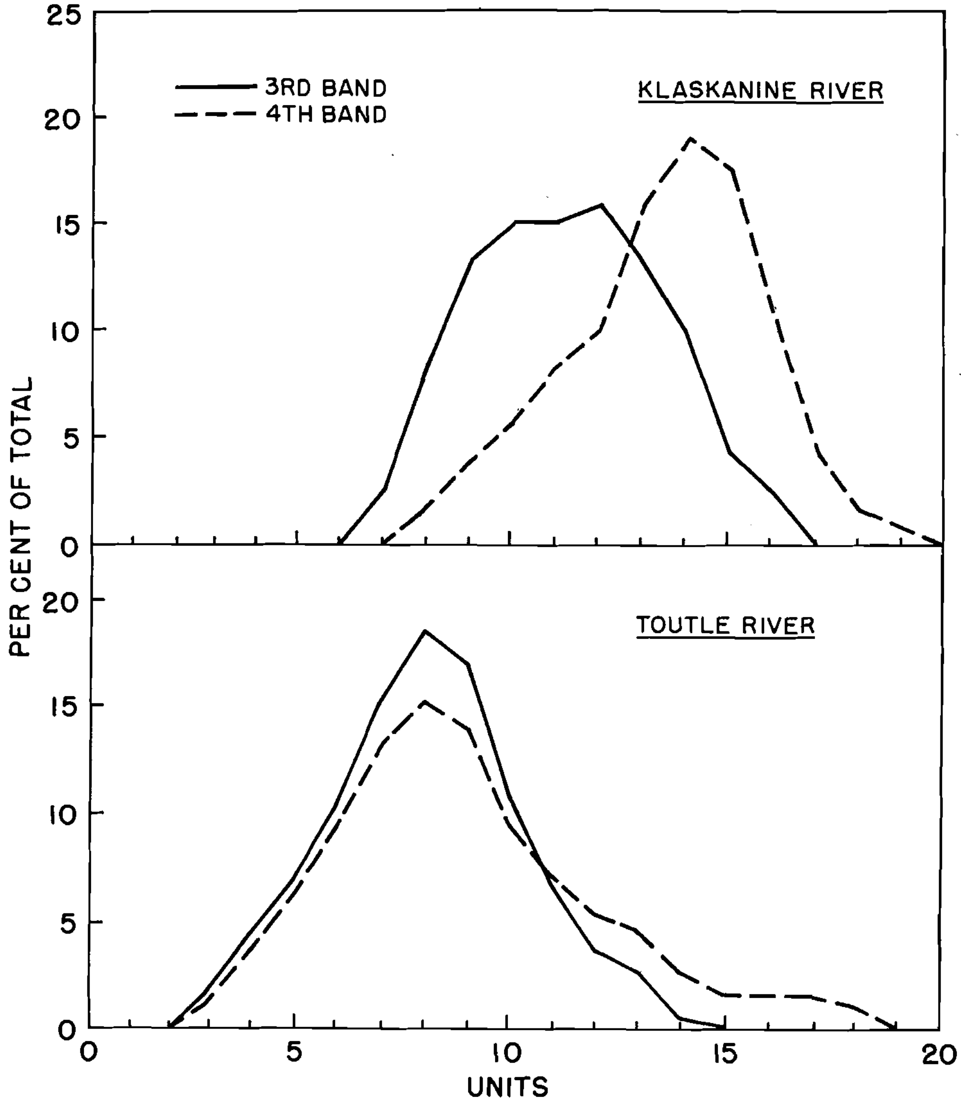

Figure 6—*Width of third and fourth 5-circulus interspaces on adult chinook scales from the Klaskanine and Toutle rivers.*

This work showed that the Toutle River adults examined went to the ocean either in the fall of their first year or the spring of their second year of life. These adults were taken at the Washington Department of Fisheries Toutle River Hatchery rack and so may be in part or entirely of hatchery origin. Examination of the fish planting records in the Department's annual reports showed that all fall chinook liberations were made at 366 to 217 fish per pound. At this weight they should have been about

45 to 60 mm in length (Leith and Wyatt, 1963)①. Fish of this size would possess from 6 to 11 circuli (Figure 5), which is less than the number of fresh-water circuli observed on adult scales, suggesting three possibilities: (1) the fish failed to survive to adulthood and return to the hatchery (this seems unlikely); (2) the fish resided in fresh water until fall or winter downstream from the Toutle (this may well be the case but is not developed further for lack of information); or (3) the fish resided in the Toutle River until fall or winter.

Hatchery fish residing in the Toutle River would not be distinguishable from wild fish in this study, but marked hatchery fall chinook have been captured late in the summer in the Washougal River (Reimers, 1964). If extended residence in the Toutle River is important, then the actual contribution of fall chinook by the Toutle River Hatchery may be limited to the number of fish needed to fully utilize the carrying capacity of the Toutle River during critical summer low water levels minus the fish that are contributed by natural production. Should natural production of salmonids in the Toutle River be sufficient to utilize the stream's productive ability then hatchery releases of fingerling chinook in June may not be adding to this system's net salmon production. The Washougal, Kalama, and Lewis rivers could have similar situations.

SUMMARY AND CONCLUSIONS

Observations of the early life history of late-run fall chinook salmon from analysis of scales taken from adults in the Columbia River gill-net fishery suggested that extended fresh-water residence was commonplace for these fish. Two approaches were employed to investigate this premise, viz. directly by sampling for juveniles in the spawning tributaries throughout the summer and fall, and indirectly by further analysis of scales taken from juveniles and adults in the tributaries.

Eleven tributaries of the Columbia River below Bonneville Dam were studied. Seven small streams studied were found to be devoid of juvenile chinook by early summer. The Toutle, Kalama, North Fork Lewis, and Washougal rivers contained juveniles in quantity at the time of last effective sampling in October. The mean lengths of these juveniles varied from about 80 to 105 mm when last observed. Disparity in fish size among tributaries at any one time was great and was related to the length of residence. It was suggested that different temperature regimes which affect spawning, incubation, and emergence, along with differential growth following emergence, caused the difference in size. The Toutle and Klaskanine rivers were given special attention as type streams for long- and short-term residence, respectively.

Counts of fresh-water circuli on adult Klaskanine and Toutle chinook scales and comparisons with juvenile scales concurred with direct observations of residence. Toutle River chinook were concluded to have migrated to the ocean during the fall of the first year of life or the spring of the second year. Implications of this on Toutle River Hatchery practices were considered.

① Coho length-weight curve was used in lieu of similar data for chinook.

RECOMMENDATIONS

Even though deviation in the generally accepted early life history pattern of fall chinook salmon has been shown, little is known about this part of the fish's life history. Considering this lack of information and the decline in populations of Columbia River fall chinook, an ecological study seems to be needed. Important questions concern the extent and variation of fresh-water residence within and among streams, factors influencing the migration of juveniles, and the relation of these factors to survival to adulthood. Examination of the present hatchery practice of releasing juveniles early in the first year of life is also needed. Some juveniles may require longer periods of rearing. Because of the variable conditions that exist among streams, indiscriminate assignment of juveniles to gross life history groups is not desirable. Instead, fishery management on an individual stream basis should be practiced.

ACKNOWLEDGEMENTS

We appreciate the cooperation of the Washington Department of Fisheries and Washington Department of Game in encouraging our study. The Washington Department of Fisheries also provided aid for seining on several occasions. Manpower was contributed by the Pelagic Fisheries Investigation of the Fish Commission of Oregon. Part of the funds for this work were supplied by the Department of Fisheries and Wildlife, Oregon State University, for a Master of Science thesis study on the distribution of fishes in the lower Columbia River area. Drs. Carl E. Bond and James D. Hall reviewed the manuscript and provided helpful comments.

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A Comparison of Oregon Pellet and Fish-Meat Diets for Administration of Sulfamethazine to Chinook Salmon[1]

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JOHN L. FRYER[3] and K. S. PILCHER[4]

ABSTRACT

The absorption of sulfamethazine by yearling spring chinook salmon *(Oncorhynchus tshawytscha)* was compared when administered in the Oregon Pellet and a fish-meat diet. The pelleted diet delivered the drug to the fish approximately twice as efficiently as the fish-meat diet. Dosage levels are recommended for both diets, and the efficacy of administering drugs in fish feed is discussed.

INTRODUCTION

Sulfonamide drugs are used routinely to control bacterial infections of fish. Generally, the drugs are incorporated in the diet and fed at dosage levels expressed in grams per unit weight of fish per day. Optimal levels were determined almost 2 decades ago, using meat or meal-meat diets (Gutsell and Snieszko, 1949). However, the meat diets have now been replaced to a considerable extent with more efficient pelleted feeds. We may assume that less drug would be required when using pellets than when using meat diets, and overdoses may result if the levels recommended for meat diets are used in pellets. As an example, the Fish Commission of Oregon uses a therapeutic dosage level of 10 grams sulfamethazine per 100 pounds of fish per day in a fish-meat diet for 10 days and uses a prophylactic level of 2 grams of drug per 100 pounds of fish per day (Amend, Fryer, and Pilcher, 1965). A furunculosis *(Aeromonas salmonicida)* infection in coho salmon *(Oncorhynchus kisutch)* at the Fish Commission Big Creek Hatchery was treated with sulfamethazine incorporated in the Oregon Pellet diet (Hublou, 1963) at the therapeutic dosage level recommended for meat diets. Several days following initiation of treatment there was a large increase in loss of fish which was attributed to sulfamethazine toxicity.

Since the 10-gram level was believed to be toxic in the pellet diet, the therapeutic dose was arbitrarily reduced to 5 grams per 100 pounds of fish and the prophylactic dose to 1 gram. It was then necessary to determine the actual blood sulfonamide concentrations which could be expected from these reduced dosage levels in the pellet diet. Such determinations were made and compared with similar data obtained with a fish-meat diet using the new and originally recommended dosages for sulfamethazine.

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MATERIALS AND METHODS

The experiment was conducted at the Fish Commission of Oregon Clackamas Laboratory in the spring of 1962. Yearling spring chinook salmon *(O. tshawytscha)* which averaged 12 grams in weight, and had never received sulfonamide drugs, were divided into several experimental groups of 50 fish each. Three groups were fed sulfamethazine in the Oregon Pellet diet in doses of 1, 2, and 5 grams per 100 pounds of fish per day, and one control group received the pellets without medication. Three other groups were given the drug in a fish-meat diet in doses of 2, 5, and 10 grams per 100 pounds of fish. The pellet-fed fish received a daily amount of diet (containing the drug allotment) representing 1.6%, and the meat-fed fish 3.5% of their body weight. The meat diets were fed at a greater percentage of body weight than Oregon Pellets because they contained more moisture, but the per cent of food fed was the same on a dry-weight basis. The diets were fed by hand in a manner permitting the fish to consume all the diet. All fish were kept in spring water at 54 F.

Pellets of ⅛-inch diameter were prepared at the Oregon State University Seafoods Laboratory, Astoria, Oregon. Their composition has been described in detail (Hublou, 1963). The fish-meat diet consisted of equal parts of beef liver, pork liver, and pasteurized salmon viscera. The livers were obtained fresh and ground through a plate with ⅛-inch perforations. The salmon viscera, taken from hatchery food supplies, was already ground and fresh frozen. The ingredients were mixed and sulfamethazine blended in with a power mixer. The diets were weighed into quantities needed for daily rations, frozen at –20 C, and thawed as required. When the meat diets were thawed, sodium chloride (2% by weight) was added to improve the diet consistency, and it was then fed immediately. The sulfamethazine content of all diets was confirmed by chemical analysis (Amend, 1965) as shown in Table 1. The data show reasonably good agreement between the calculated amounts of drug added to the diets and that found by analysis.

Table 1—*Concentrations of sulfamethazine in experimental diets (grams drug/100 grams diet).*

	Drug dosage level in grams per 100 pounds of fish					
	Oregon Pellet diets			*Fish-meat diets*		
	1	*2*	*5*	*2*	*5*	*10*
Per cent drug added to diet	0.138	0.276	0.689	0.126	0.315	0.630
Per cent drug found by analysis	0.115	0.285	0.662	0.109	0.336	0.625

Daily blood samples were obtained by severing the caudal fin of the experimental fish and collecting the blood in dried heparinized test tubes. Each specimen consisted of pooled blood from seven individuals. Blood concentrations of sulfamethazine were determined by the spectrophotometric modification of the Bratton-Marshall method (Levinson and MacFate, 1956). Since fish were being removed from each group for blood sampling, lot weights were redetermined each day and the feeding schedule adjusted accordingly.

RESULTS AND DISCUSSION

Blood sulfonamide concentrations in each experimental group of fish are shown in Figure 1. Earlier work with sulfamethazine showed that the drug concentration increased gradually in the blood of treated fish until a peak level was attained (Amend, 1965; Snieszko and Friddle, 1950, 1952). The maximum concentration varied with dosage, but after the peak was reached there was very little change in the sulfonamide content of the blood as long as medication was continued. In this experiment, maximum concentrations were attained by the third or fourth day.

It is generally believed that a concentration of 10 to 15 mg of sulfamethazine per 100 ml of blood is needed for effective therapy of fish infected with furunculosis, and that higher concentrations are likely to

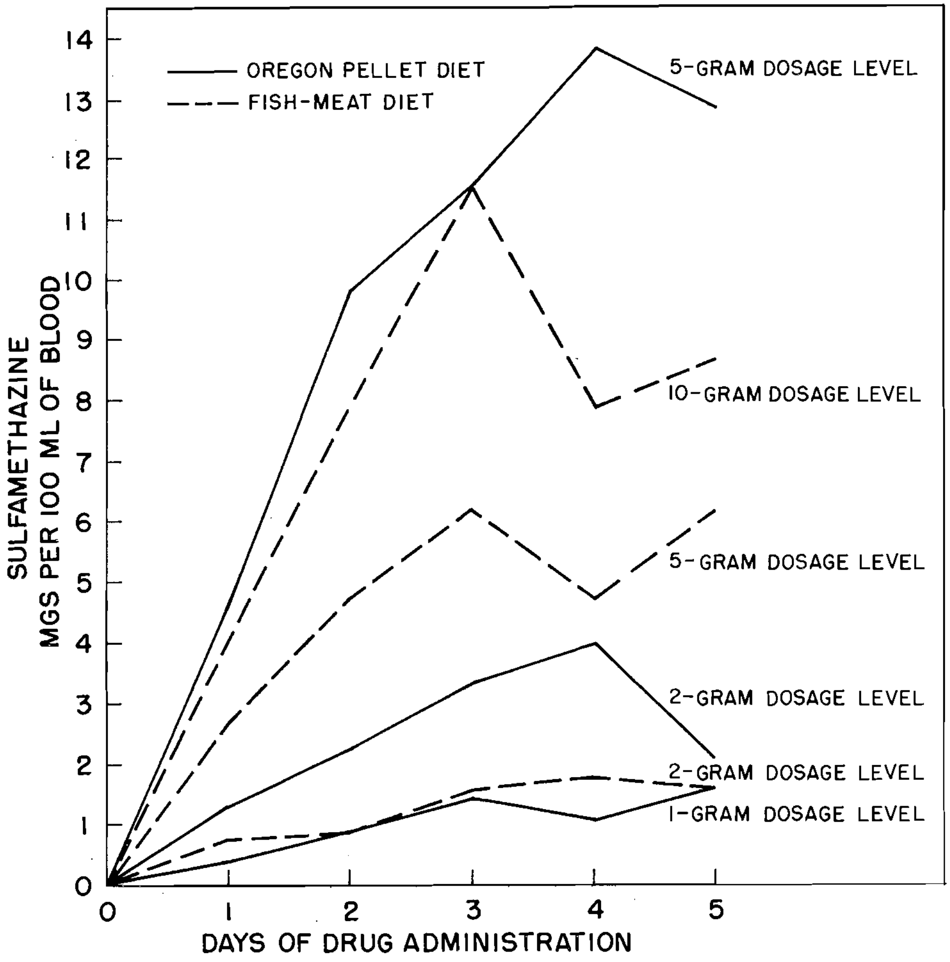

Figure 1—*Average blood concentration (mg per 100 ml) of free sulfamethazine in chinook salmon when the drug was administered at various dosage levels (grams per 100 pounds of fish) in Oregon Pellet and fish-meat diets.*

produce toxic side effects. Our study indicates that sulfamethazine administered in the pellet diet at a dosage level of 5 grams per 100 pounds of fish per day, or in the fish-meat diet at the 10-gram level, produced blood concentrations within or very close to the above-mentioned therapeutic range.

Requirements for prophylaxis of furunculosis in fish populations are uncertain, but it seems probable that the 5-gram dosage level in the fish-meat diet or the 2-gram level in the pellet diet would be satisfactory. The fish-meat diet containing the 2-gram dosage level, and the pellet diet with the 1-gram level gave very low and nearly identical concentrations of drug in the blood. Concentrations of drug this low would probably be ineffective.

No single drug level can be specified which is optimal for all susceptible bacterial infections of fish. Required drug levels vary with different drugs, pathogenic bacteria, environment, and the physiological condition of the host (Snieszko, 1964). Nevertheless, the dosages employed in this experiment may serve as a general guide for administration of sulfamethazine in fish diets. This drug probably should not be given to fish in the pellet diet in doses greater than 5 grams per 100 pounds of fish per day, because higher dosages produce concentrations of drug in the blood that may be toxic (Amend, 1965).

The most significant result of this work was the demonstration of the greater efficiency of the pellet diet over the fish-meat diet as a vehicle for administration of sulfamethazine to fish. The pellet diet containing the 5-gram dosage level and the fish-meat diet with the 10-gram dosage level contained nearly the same percentage of drug (Table 1). However, the fish-meat preparation tended to leach into the water and apparently much of the drug was lost because about twice as much food (and consequently sulfamethazine) had to be offered the fish to get a blood concentration of drug similar to that obtained with the pellet (Figure 1). Thus by using the Oregon Pellet as the drug vehicle, the cost of sulfamethazine treatment was reduced by half.

Although the pellet diet was twice as efficient in delivering drugs to fish as the meat diet in this study, it is evident that this may not be true in all cases. Snieszko and Friddle (1950, 1952) have shown that higher concentrations of drug in the blood, due to more efficient utilization of the meat diet and therefore drug consumption, can be attained when the ration is fed to larger fish. These authors also indicated better drug utilization by offering less food to the fish (reduction in the per cent body weight of food fed each day), but one should be aware of possible palatability problems with sulfonamides. Apparently any change in the meat diet or method of feeding which reduces the chance of leaching provides for more efficient utilization of the diet and drug.

SUMMARY

Sulfamethazine was administered to yearling chinook salmon in a fish-meat diet at 2, 5, and 10 grams per 100 pounds of fish per day and in Oregon Pellets at 1, 2, and 5 grams per 100 pounds of fish per day. Each

diet was fed at the same rate on a dry-weight basis. Drug concentrations in the blood were determined daily for 5 days. The Oregon Pellet was a more efficient vehicle for drug administration because the amount of drug required to produce effective blood concentrations was only half of that needed in the fish-meat diet: 5 grams per 100 pounds of fish per day with the pellets compared to 10 grams with the fish-meat diet to produce blood concentrations considered high enough for effective therapy for furunculosis (10 to 15 mg sulfamethazine per 100 ml blood). Five grams of drug per 100 pounds of fish per day in the fish-meat diet, or 2 grams in the pellet diet, resulted in blood concentrations of 3 to 6 mg per 100 ml, which might be considered satisfactory for prophylaxis of furunculosis. A dosage of 1 gram in the pellet or 2 grams in the meat diet produced blood levels of drug below 2 mg per 100 ml.

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An Evaluation of Adult Coho Salmon Transplants Into Willamette River Tributaries

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ABSTRACT

Approximately 6,700 adult coho salmon *(Oncorhynchus kisutch)* from the Fish Commission of Oregon Cascade Hatchery were transplanted to 11 tributaries of the Willamette River in which coho were absent or in low abundance. Surveys were made to evaluate the success of spawning, hatching, and rearing. Fish appeared to spawn successfully in all streams investigated. An average of 33% of the fish released were observed on spawning grounds, and there were 0.67 redds per released female. Most of the fish moved upstream after release and spawning activity was greatest in the general vicinity and above the release sites. Coho fry were observed in five of the seven streams examined. Juveniles were found rearing in the three streams checked in late August and early September. This experimental planting appeared to be successful and should be a useful procedure for establishing runs of coho salmon in new areas.

INTRODUCTION

In 1964 approximately 164,000 coho salmon *(Oncorhynchus kisutch)* returned to Fish Commission of Oregon hatcheries on the Columbia River and coastal streams. This number was well beyond the handling capacity of the hatcheries. Surplus spawners totalling 40,000 fish were transported from eight hatcheries to suitable streams for natural spawning in an effort to utilize them effectively. Approximately 6,700 adults from Cascade Hatchery (Columbia River near Bonneville Dam) were transplanted into Willamette River tributaries above Willamette Falls at Oregon City. Since this means of utilizing surplus hatchery fish was experimental, surveys were made on 11 Willamette River tributaries to evaluate the success of spawning, hatching, and rearing. Natural coho runs exist in five of these streams, however, it is believed that partial migration barriers have kept these runs below their production potential.

METHODS AND PROCEDURES

Transplanting

No specialized equipment was used to transplant the adult salmon. The fish were seined from hatchery ponds, carried in burlap sacks or lifted by a bucket hoist to a fingerling liberation truck, transported by truck to the release site, and unloaded by dip nets or by passage through the fingerling release tube.

A map of the Willamette River showing the tributaries into which transplants were made is given in Figure 1.

Spawning Ground Surveys

Spawning ground surveys were conducted on 10 of the 11 streams under study (Table 1). An attempt was made to survey the entire area upstream from the release site in which the fish had spawned on Mill (Yamhill), Mosby, Scoggin, Willamina, West Fork Dairy creeks, and the North Yamhill River, and above the lower of two release sites on Agency Creek. The Molalla River was checked to determine the approximate upper limit of migration. It is possible that some spawners observed on the Molalla surveys were returnees from fry plants made in this stream in 1962.

Lack of time precluded determination of the upper migration limit on the Mohawk River and Crabtree Creek and prevented spawning ground surveys from being made on Mill Creek (Salem).

The time between release of fish and spawning ground survey varied from 6 to 24 days. This time lap was adequate for the fish to locate a spawning area and begin spawning as judged from our surveys. During the surveys, records were kept on: (1) number of live fish; (2) number of dead fish; (3) sex of dead fish; (4) number of dead unspawned females; and (5) number of redds. All carcasses recovered were cut open to determine the sex and amount of egg retention in females.

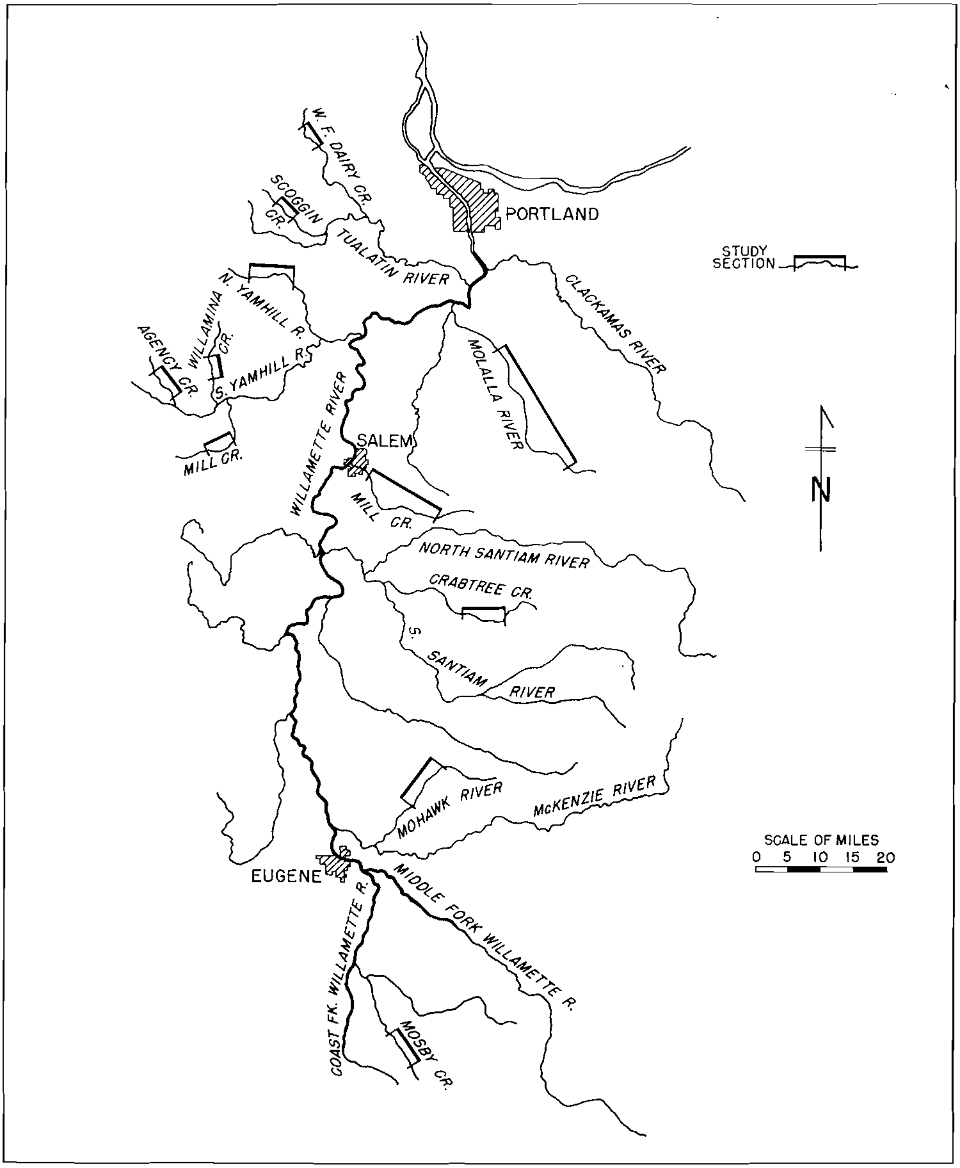

Figure 1—*Willamette River system showing study sections.*

Table 1—*Willamette River tributaries where observations were made on success of coho salmon transplants in 1964 and 1965.*

Stream	*River system*	*Limited natural production exists*	*Spawning survey conducted*	*Fry emergence checked*	*Summer survival checked*
Agency Creek	Yamhill	X	X		
Crabtree Creek	Santiam		X	X	
Mill Creek	Yamhill	X	X		
Mill Creek (Salem)	Willamette			X	X
Mohawk River	McKenzie		X		
Molalla River	Molalla		X	X	
Mosby Creek	Coast Fork Willamette		X	X	X
North Yamhill River	Yamhill		X	X	X
Scoggin Creek	Tualatin	X	X	X	
West Fork Dairy Creek	Tualatin	X	X	X	
Willamina Creek	Yamhill	X	X		

Fry Emergence Surveys

Seven streams were checked for fry emergence (Table 1), beginning in March 1965. Periodic visual checks were made of stream edges and slack water areas to obtain a measure of relative abundance of fry and to determine their distribution. Five streams—Molalla and North Yamhill rivers, and Crabtree, Mosby, and Mill (Salem) creeks—have no known natural runs of coho. Natural run coho are present in Scoggin Creek and, in some years, the West Fork of Dairy Creek, the other two streams checked. However, these two streams were surveyed in March, prior to the time natural coho fry would be expected to emerge from the gravel. The West Fork of Dairy Creek was rechecked in early July.

Rearing Success Surveys

North Yamhill River and Mosby and Mill (Salem) creeks were investigated during the latter part of August and early September to estimate the rearing success of young coho through the critical summer period when stream flows are lowest and temperatures are highest. These streams were investigated because a reasonable certainty existed that no coho were present from natural production or other introductions. The relative abundance and distribution of fingerling coho was determined by seining in the larger streams and by visual observation in the small tributaries.

RESULTS AND DISCUSSION

Spawning Ground Surveys

At the time fish were transplanted, the majority were considered to be ripe and many were overripe. Some eggs were released into the trucks when the fish were being loaded or unloaded. No jacks (2-year-old precocious males) were released. The time of spawning for the transplanted hatchery coho was approximately 1 month earlier than that of natural runs in western Oregon and stream flows were lower than those normally encountered by natural runs. Visibility was good to excellent on all streams during the surveys.

Table 2 presents release data for 10 streams in which 6,492 adults were planted. Spawning ground surveys were made on all streams except Mill Creek (Salem).

Table 3 shows spawning data collected on the 10 streams surveyed. A total of 1,053 coho and 939 redds was counted in a distance of 39.1 miles. Fish appeared to have spawned successfully in all streams investigated. All but 2 of 20 females checked had spawned and egg retention was negligible.

A high percentage of the fish released were seen on the spawning grounds. Table 4 records the percentage of fish and redds observed compared to the number of fish and females released on six streams where surveys were conducted over most of the area utilized by spawning

Table 2—*Date, location, number, and sex of adult coho released in 1964 into Willamette Basin streams.*

Release date	*Stream*	*Number released*			*Release location in miles above the mouth*
		Males	*Females*	*Total*	
Oct. 28	Agency Creek (S. Yamhill River)	75	75	150	Mile 2
Oct. 28	Agency Creek (S. Yamhill River)	75	75	150	Mile 5
Oct. 19	Crabtree Creek (S. Yamhill River)	225	225	450	Mile 21
Oct. 19	Crabtree Creek (S. Yamhill River)	125	125	250	Location uncertain
Oct. 20	Crabtree Creek (S. Yamhill River)	350	350	700	Mile 21
Oct. 26	Mill Creek (S. Yamhill River)	150	150	300	Miles 10 and 17
Oct. 19	Mill Creek (Willamette River at Salem)	159	148	307	Mile 4
Oct. 21	Mohawk River (McKenzie River)	225	225	450	Mile 8
Oct. 22	Mohawk River (McKenzie River)	225	225	450	Mile 8
Oct. 23	Mohawk River (McKenzie River)	225	225	450	Mile 8
Oct. 20	Molalla River	275	275	550	Mile 14
Oct. 21	Molalla River	225	225	450	Mile 14
Oct. 22	Molalla River	125	125	250	Mile 22
Oct. 23	Molalla River	125	125	250	Mile 22
Oct. 26	Mosby Creek (Row River)	125	125	250	Mile 13
Oct. 22	North Yamhill River	75	75	150	Mile 26
Oct. 23	North Yamhill River	75	75	150	Mile 26
Oct. 17	Scoggin Creek (Tualatin River)	175	175	350	Mile 7
Oct. 17	W. Fk. Dairy Creek (Tualatin River)	145	140	285	Mile 13
Oct. 27	Willamina Creek (S. Yamhill River)	75	75	150	Mile 8
	Total	3,254	3,238	6,492	

Table 3—*Spawning ground observations of adult coho salmon transplants in the Willamette River system, 1964.*

Stream	*Miles surveyed*	*Redds observed*	*Total fish observed*	*Number of dead fish observed*	*Dead females examined*	*Unspawned females*	*Known migration from upstream release site (miles)*	*Days between first release and survey*
Agency Creek	3.0	40	45	0	0	0	2.0[1]	9
Wind River	0.2	4	2	0	0	0	0.7[1]	9
Total	3.2	44	47	0	0	0		
Crabtree Creek	4.4	69	113	8	2	1	4.8	10
South Fork	0.4	8	15	0	0	0	5.2	10
Bald Peter Creek	0.1	0	2	0	0	0	5.1	10
Total	4.9	77	130	8	2	1		
Mill Creek (South Yamhill)	3.0	140	70	14	4	1	2.0[1]	16
Total	3.0	140	70	14	4	1		
Mohawk River	1.0	139	176	2	1	0	5.4	6
Mill Creek	0.4	4	2	0	0	0	6.0	6
Total	1.4	143	178	2	1	0		
Molalla River	4.5	157	164	0	0	0	19.0	7
Total	4.5	157	164	0	0	0		
Mosby Creek	5.7	61	111	2	0	0	5.2	7
Stell Creek	0.3	2	12	0	0	0	0.3[1]	7
Big Dry Creek	0.2	2	9	0	0	0	0.3[1]	7
Total	6.2	65	132	2	0	0		
N. Yamhill River	3.7	85	88	11	5	0	2.0	17
Fairchild Creek	0.8	11	3	2	0	0	0.5	17
Total	4.5	96	91	13	5	0		

Table 3—*Spawning ground observations of adult coho salmon transplants in the Willamette River system, 1964.*—Continued

Stream	*Miles surveyed*	*Redds observed*	*Total fish observed*	*Number of dead fish observed*	*Dead females examined*	*Unspawned females*	*Known migration from upstream release site (miles)*	*Days between first release and survey*
Scoggin Creek	1.0	51	94	1	1	0	0.6①	18
Tanner Creek	0.6	10	25	1	0	0	0.7①	18
Seine Creek	0.8	15	33	0	0	0	1.0	18
Total	2.4	76	152	2	1	0		
West Fork Dairy Creek	2.5	30	21	1	0	0	3.2①	24
Witcher Creek	0.4	16	4	1	1	0	0.8①	24
Menden Hall Creek	0.7	7	3	1	1	0	2.4①	24
Unnamed Tributary	1.2	12	8	0	0	0	3.0	24
Total	4.8	65	36	3	2	0		
Willamina Creek	2.7	60	47	10	4	0	2.0①	15
East Fork Willamina Creek	1.5	16	6	3	1	0	1.0	15
Total	4.2	76	53	13	5	0		
Grand total	39.1	939	1,053	57	20	2		

① Coho migration was considered blocked at the indicated mileage by obstructions during low stream flows.

Table 4—*Per cent of fish and redds observed compared to number of fish and females released.*

Stream	*Number of fish released*	*Number of fish observed*	*Per cent of released fish observed*	*Number of females released*	*Number of redds observed*	*Number of redds observed as per cent of females released*
Mill Creek (S. Yamhill)	300	70	23	150	140	93
Mosby Creek	250	132	54	125	65	52
N. Yamhill River	300	91	30	150	94	64
Scoggin Creek	350	152	43	175	76	43
W. Fk. Dairy Creek	285	36	13	140	65	47
Willamina Creek	150	53	35	75	76	101
Total	1,635	534		815	516	
Average			33			67

fish including tributaries to the study sections. An average of 33% of the fish released were observed spawning, and the average number of redds was 0.67 per released female.

Spawning activity began almost immediately after release. Observations on the North Yamhill River 3 days after the first release of 150 fish, revealed that some of them were already spawning. By the time surveys were conducted, as many or more redds were seen than fish on 8 of the 10 streams, indicating that spawning was near its peak.

It appeared that a fairly large percentage of fish remained at the liberation sites for some time although no accurate count of these fish could be obtained. In the Molalla, Mohawk, and North Yamhill rivers many fish remained at the release sites for at least 1 week. On Scoggin Creek, coho were temporarily blocked by a beaver dam and substantial numbers were observed at the liberation site 10 days after release.

On the West Fork of Dairy Creek many salmon may have delayed migration until better water conditions permitted passage to upper portions of tributaries past debris jams. This delayed migration would have taken place after the spawning surveys were completed. Supporting evidence is that in three tributaries fry were found during the spring of 1965 above low flow migration blocks that had been present in November 1964. In some years natural-run coho use tributaries of the West Fork of Dairy Creek, but natural fry have been found in only one tributary of the system in 1 of 3 years when the system was checked.

Generally the bulk of the fish moved upstream after release and spawning activity was greatest in the areas immediately above the release sites and gradually decreased with distance surveyed (Table 5).

Some fish moved considerable distances upstream. On the Molalla River, the largest stream studied, fish migrated 19 miles upstream from the upper release site at the Crown-Zellerbach Corporation Camp. On two other streams which did not contain migration blocks, the upstream limit of migration was ascertained to be 2.0 and 5.2 miles. On Willamina, Mill (Yamhill), and Agency creeks, fish migrated to blocks 2.0 to 2.5 miles above the release sites.

Downstream movement of spawners was investigated on the North Yamhill River and on Crabtree, Agency, Willamina, and Scoggin creeks (Table 6). The unusually large number of salmon that moved downstream on Scoggin Creek was due undoubtedly to a beaver dam located a short distance above the release site which blocked upstream migration at the prevailing low stream flow.

Tributary streams were used for spawning by significant numbers of fish. In all cases where a suitable tributary existed near the release site, it was utilized for spawning (Table 7).

Table 5—*Upstream distribution of spawning adult coho and redds in streams surveyed, 1964.*

Stream	*Miles above release site*	*Number of fish*	*Per cent of total fish observed*	*Number of redds*	*Per cent of total redds observed*
Crabtree Creek	0–1	58	45	39	53
	1–2	39	30	18	24
	2–3	10	8	7	9
	3–4①	21	17	10	14
	Total	128	100	74	100
Mill Creek (S. Yamhill River)	0–1	20	61	61	66
	1–2	13	39	31	34
	Total	33	100	92	100
Molalla River②	0–1	45	69	40	44
	1–2	16	25	15	16
	2–3	4	6	36③	40
	Total	65	100	91	100
Mosby Creek	0–1	36	27	15	23
	1–2	46	34	19	30
	2–3	37	28	24	37
	3–4	7	5	3	5
	4–5	5	4	1	2
	5–6	2	2	2	3
	Total	133	100	64	100
N. Yamhill River	0–1④	47	85	52	67
	1–2	8	15	26	33
	Total	55	100	78	100
Willamina Creek	0–1	24	73	35	73
	1–2	9	27	13	27
	Total	33	100	48	100

① South Fork of Crabtree Creek counts are included.
② Crown-Zellerbach Camp release site.
③ Some chinook redds may have been counted as coho redds.
④ Fairchild Creek counts included.

Table 6—*Movement of adult coho downstream from liberation sites.*

Stream	*Known distance of migration downstream from release site*	*Number of fish observed downstream from release site*	*Number of redds observed downstream from release site*
Agency Creek①	100 yards	5	4
Crabtree Creek	0	0	0
North Yamhill River	1.0 mile	2	5
Scoggin Creek②	0.5 mile	38	22
Willamina Creek②	0.4 mile	4	12

① Upper release site.
② Does not include fish that moved downstream a short distance and into a tributary.

Table 7—*Use of tributary streams by adult coho planted in 1964.*

Stream	*Number of suitable tributaries available*	*Per cent of observed fish seen in tributaries*	*Per cent of observed redds seen in tributaries*
Mosby Creek	2	15.0	6.2
North Yamhill River	1	3.3	11.5
Scoggin Creek	2	38 2	32.9
West Fork Dairy Creek	3	41.7	60.4
Willamina Creek	1	11.3	21.1

Fry Emergence

Coho fry were observed in five of the seven streams examined. In both North Yamhill and Mosby creeks, fry were observed only in and below the areas of heaviest spawning. Fry distribution on these two streams is shown in Figures 2 and 3. The reason they were not found in areas of light spawning was probably because of the effects of winter floods and in the case of Mosby Creek, extensive stream channeling which destroyed many redds.

A few fry were observed in Scoggin, West Fork Dairy, and Mill (Salem) creeks.

No fry were noted on Mill Creek (Salem) in the area from Salem upstream to Stayton. Here much of the flow consists of water which has been diverted from the North Santiam River. Four fry were seen in approximately 1 mile of the stream above Stayton. On the West Fork of Dairy Creek, fry were observed in early summer in three tributaries. These fry were attributed to the adult coho plants since the stream had been checked during 3 previous years and in only one, 1964, were coho juveniles observed, and then in but one of the tributaries. A few fry were observed in Scoggin Creek, but none in Crabtree Creek or Molalla River.

Rearing Success

Coho fingerlings were found rearing in the North Yamhill River, Mosby Creek, and Mill Creek (Salem) systems, which were the only ones investigated for rearing success during late August and early September.

Coho juveniles were abundant in 3 miles of the North Yamhill River and in ½ mile of Fairchild Creek (Figure 2).

In the Mosby Creek system, juvenile coho were found only in ¼ mile of Stell Creek (Figure 3), one of the two tributaries utilized for spawning. According to local residents, stream flow was lower and temperatures were warmer in Mosby Creek in 1965 than in prior years. Apparently, coho fry did not survive in the main stem. The possibility that fry moved downstream and survived seems remote, since conditions in the lower reaches normally become unsuitable for salmonids during the summer months. An Oregon Game Commission thermograph near the mouth of Mosby Creek recorded a temperature of 80 F on July 13, 1964.

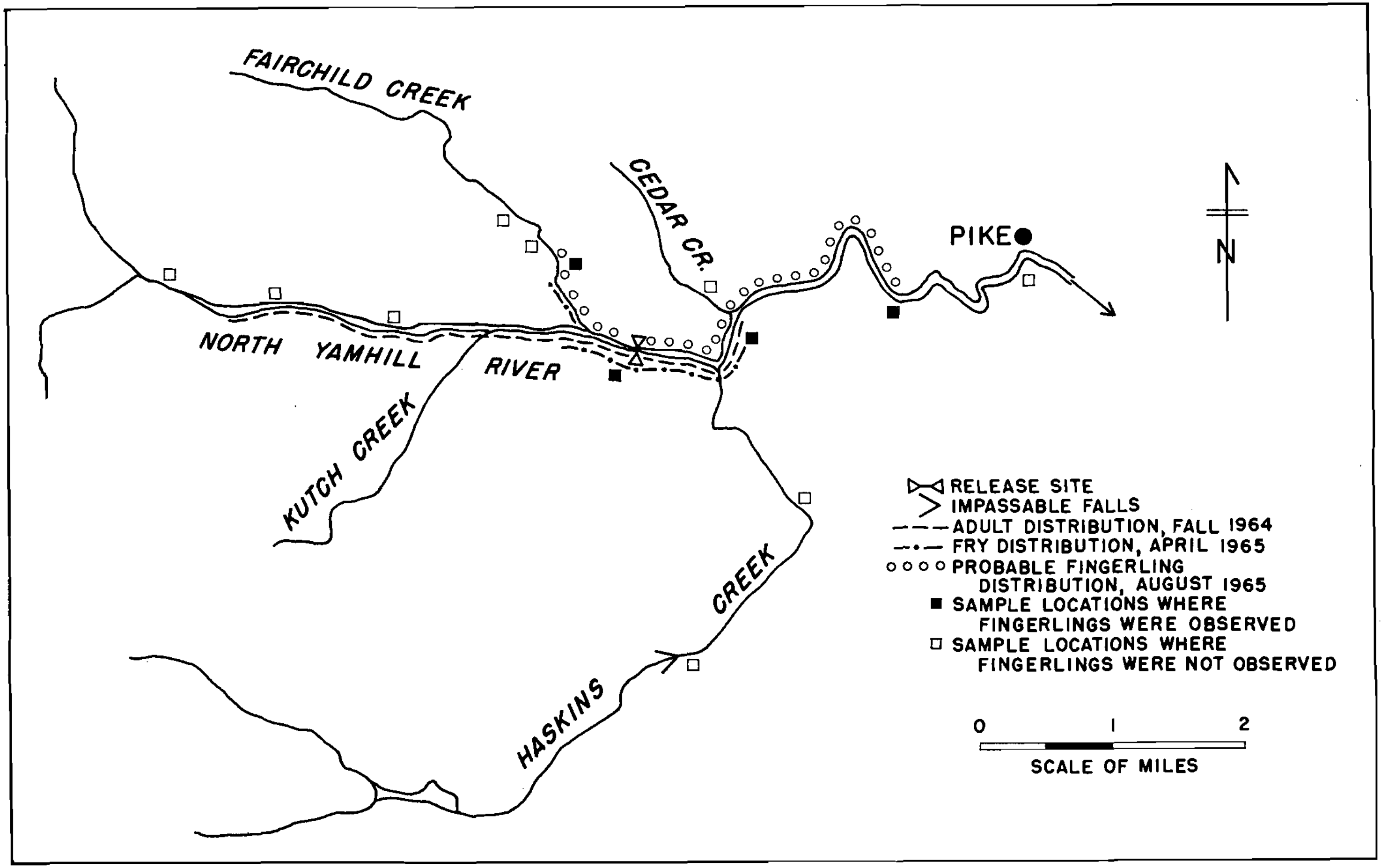

Figure 2—*Upper section of North Yamhill River showing distribution of coho adults, fry, and fingerling.*

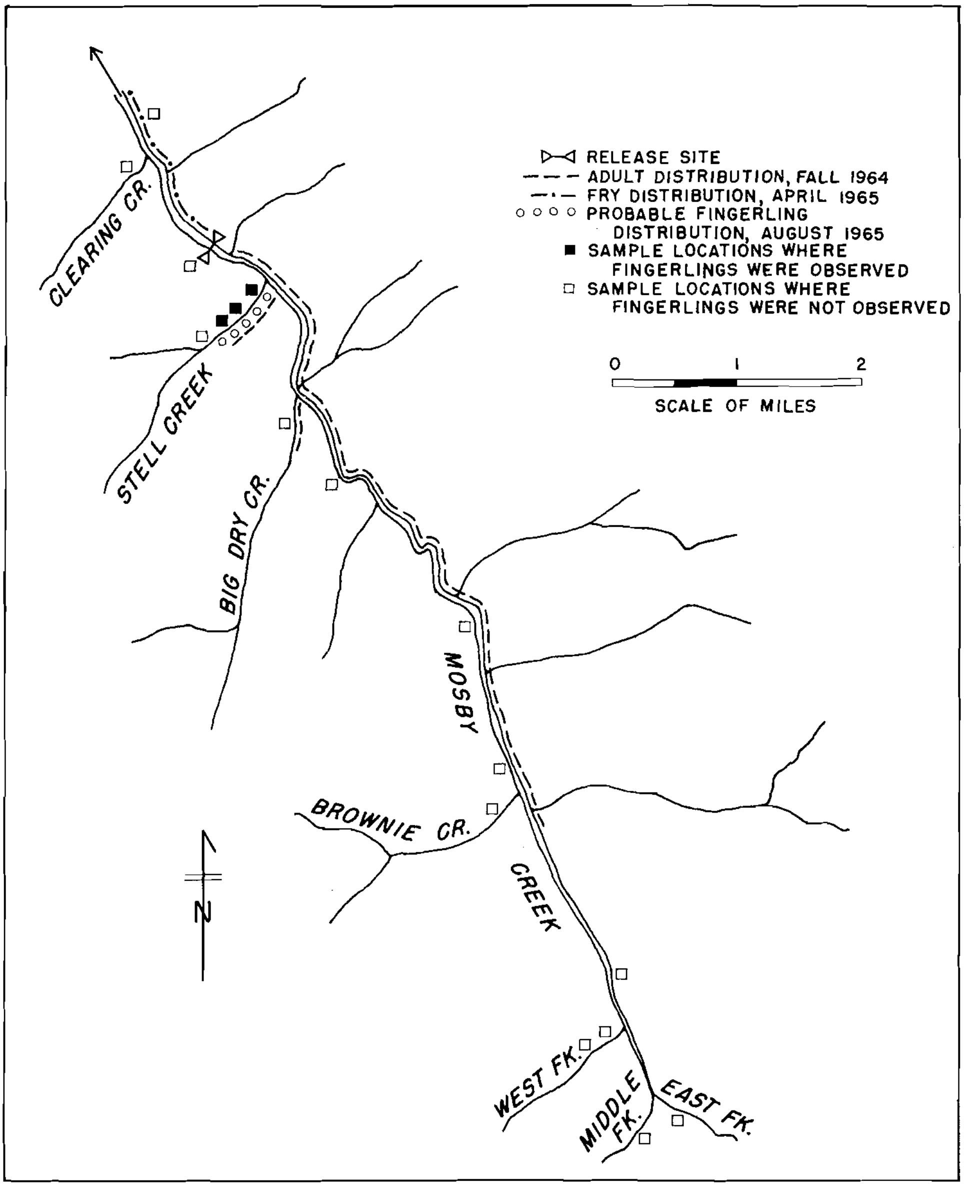

Figure 3—*Upper section of Mosby Creek showing distribution of coho adults, fry, and fingerlings.*

Coho fingerlings were present in September in Mill Creek above Stayton even though only a few fry were observed in April.

SUMMARY AND CONCLUSIONS

Approximately 6,700 adult coho salmon were transplanted into Willamette Basin streams from the Oregon Fish Commission Cascade

Hatchery. Surveys were made on these streams to evaluate the success of spawning, hatching, and rearing. The adult coho spawned successfully. During spawning ground surveys on 39 miles of stream, 1,053 fish and 939 redds were observed. Most of the spawning activity was in the general vicinity and upstream from release sites. Where faced with a barrier, many fish moved downstream in search of spawning areas. When a suitable tributary was located near the release site, some coho migrated into and spawned in the tributary.

Survival to the fry stage occurred in most of the streams under study although it occurred in only the areas of heaviest spawning and in the smaller tributaries. Poor survival in other areas was possibly due largely to the severe 1964-65 winter flood. Survival through the summer low flow period was observed in the three streams which were investigated in late August and early September.

This experimental program of planting adult coho salmon appeared to be successful. The method should help establish coho salmon throughout much of the Willamette Basin when problems of upstream and downstream passage at Willamette Falls are resolved.

Equipment and Methods for Studying Juvenile Salmonids in Reservoirs

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ABSTRACT

Equipment and methods for studying juvenile salmonids in reservoirs were evaluated at Pelton, Round Butte, and North Fork reservoirs in Oregon from 1959 to 1966.

Oneida Lake traps constructed of ¼-inch square mesh knotless nylon, and modified to float, effectively caught fish. The traps caught juvenile anadromous salmonids best when water was high and turbid, the traps were clean, and daily minimum surface water temperatures were below 60 F. Traps were used mainly to capture fish for tagging and to recover tagged fish.

Multifilament and monofilament nylon materials were used in gill nets 75 feet long, and only monofilament material was used in nets 60 feet long. Five mesh sizes were used in the 75-foot nets and three mesh sizes in the 60-foot nets. Nylon lead-core line weighted each net. A gill-netting technique, utilizing a portable suspension apparatus that permitted nets to fish at pre-determined distances below the surface of the water, was developed for fluctuating reservoirs. Similarly designated mesh sizes of monofilament and multifilament nylon caught fish of different size compositions. The mean size of coho salmon *(Oncorhynchus kisutch)* caught in ⅞- and 1⅛-inch mesh of both materials increased with time. Gill nets were used mainly to obtain information on depth distribution of salmonids.

Water clarity and temperature, and the capacity of the air tank were factors which limited SCUBA observations. Divers observed small salmonid fry during day and night, but larger fish were seen mainly at night. Smolt salmonids were difficult to observe during the spring migration period, but some were attracted to a mercury vapor light. A hand net was developed enabling SCUBA divers to capture fish.

A portable electric shocker, using direct current and powered by a 12-volt battery, was used occasionally to collect salmonids from reservoirs, but the effort required and results obtained did not justify continuous use. The shocker was used mainly to collect fish from streams above the reservoirs. The shocker was ineffective in large rivers.

INTRODUCTION

Collection and passage of downstream-migrant anadromous salmonids at high head dams has been attempted only in the past 10 to 15 years. Generally, collection systems have been constructed with little prior knowledge of the activities of fish in their reservoir environment. Such knowledge may be important to the proper design, location, and operation of facilities. Special equipment and methods are required to obtain the needed information.

Two contract studies conducted by the Oregon Fish Commission[1] provided opportunities for evaluating equipment and methods. A study by Korn and Gunsolus (1962) between October 1959 and February 1962 included a survey of equipment and a field program to develop methods

[1] Financed by the United States Bureau of Commercial Fisheries, contract numbers 14-17-0001-248, -597, -767, -917, -1093, and -1238.

for determining the behavior of juvenile salmonids in reservoirs. This led to a second study between February 1962 and July 1966 (Korn *et al.*, 1967) to determine the effect of relatively small impoundments on the behavior of juvenile salmonids.

The equipment was used in reservoirs formed by Pelton and Round Butte dams on the Deschutes River in arid central Oregon and North Fork Dam on the Clackamas River in wet western Oregon. Chinook *(Oncorhynchus tshawytscha)* and coho *(O. kisutch)* salmon and steelhead trout *(Salmo gairdneri)* were present in each reservoir.

Equipment used to collect and observe fish included Oneida Lake traps modified to float, multifilament and monofilament nylon gill nets, self-contained underwater breathing apparatus (SCUBA), and electric shockers.

FLOATING TRAP

In studies of fish behavior it is often necessary to capture juvenile salmonids alive, without injury. Thompson (1955) reported that floating traps fished along the shore of a lake in Alaska would capture all age classes of juvenile sockeye salmon *(O. nerka)*. The Oneida Lake trap, originally designed to fish the bottom of lakes and impoundments, was less expensive to construct and more easily moved than the floating trap referred to above. A study by Rees (1955) indicated salmon smolts migrating through reservoirs were mainly near the water surface. Consequently, it was decided to use Oneida Lake traps modified to float.

Description

The floating Oneida Lake trap (Figure 1) is constructed of ¼-inch square mesh, knotless nylon material. It is 48 feet long, measures 31 feet between the ends of the wings, and possesses a variable-length lead composed of two 50-foot and one 32-foot sections. The entire trap is floored and slopes from the maximum lead depth of 15 feet to the crib depth of 6 feet. Fish are removed through two nylon-zippered openings at the top of the crib. Larger floats are used on this trap than on a conventional Oneida Lake trap.

Preparatory to fishing, the trap is folded into the boat, crib end first. A desirable location is chosen, and the tapered lead tied to shore. One man feeds the net overboard while a second operates the boat in reverse, moving straight out from shore. When the entire net except the crib is in the water, the crib spreader bars, bridle, and tightening line are attached. The tightening line is played out and attached along with the anchor line to a styrofoam float. The anchor line is then extended full length and the anchor attached and dropped overboard. During these operations, tension is maintained on the net at all times to prevent its drifting out of position. After the anchor settles to the bottom, the trap is pulled tight by cinching up on the tightening line at the bridle. A pole is attached to the end of each wing to keep it erect; then a line is attached to each pole and the shoreline, and pulled taut to give the desired spread between the wings and lead. Anchors may be used on the wing lines if the distance to shore

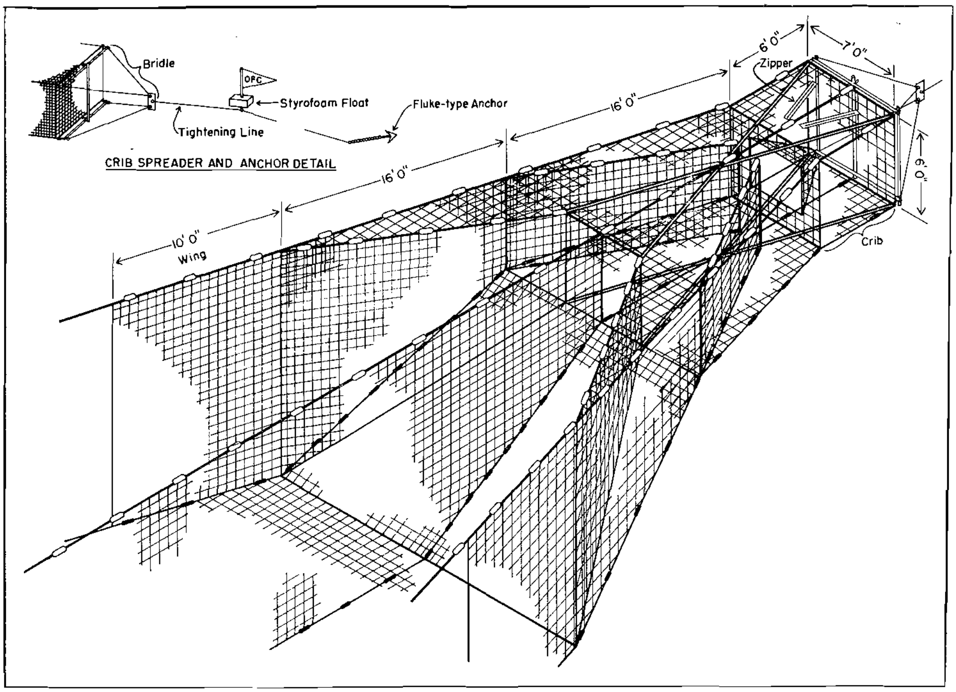

Figure 1—*Schematic drawing of Oneida Lake floating trap with detail of crib spreader and anchor.*

is too great, or if suitable objects for tying the lines to shore are not present.

Twenty-pound, fluke-type anchors are used to hold the trap in place. A sufficient length of line is attached to the anchor and bridle so tension is applied horizontally rather than vertically. Cement block anchors were also used; but they are heavy and difficult to retrieve when fishing locations are changed.

Fish are removed from the trap by loosening the line between the bridle and float, unsnapping the bridle from the top of the crib, and pulling the crib partially into the boat. The lower crib-spreader pole, still attached to the crib, is pulled into the boat, pocketing the fish in the shoreward corners. The crib openings are unzipped and fish are dipnetted either into tubs of water in the boat or a portable floating live box tied alongside.

Use of Traps

The slope of the bottom may be an important factor in the trap's efficiency since any fish below 15 feet deep will pass under the wings or lead and not be captured. Thus, it is important to select an area with a gradually sloping bottom so that the lead is on the bottom between the shoreline and outer edge of the trap floor. The composition of the bottom is of lesser importance; however, large boulders, submerged trees, or other obstacles that could hold the lead off the bottom should be avoided. Since the trap is made of small mesh material, it presents a large area of resistance to water currents and wind. Seemingly insignificant currents or winds would occasionally collapse a wing against the lead or pull the anchor toward shore and collapse the net.

Time involved in setting and fishing the trap depends on the proficiency of personnel. We found that two men with a 16-foot boat and 40 hp motor could pull, move, and reset a net 1 or 2 miles away in about 2 hours. Total time required to set a net should not exceed 1 hour if weather conditions are favorable. Fish can be removed from the trap by two men in approximately 15 to 20 minutes.

The trap was cleaned by spreading it out on a dock or float and hosing off the algae and detritus with a small, portable water pump. It was less efficient to hose off the net as it was pulled into the boat. Algae could not be entirely removed under water pressure and required treating the nets in a chlorine solution for about 30 minutes. This was accomplished by flooding the boat with a 12-inch depth of water, adding 2 gallons of commercial bleach, and soaking the net for the required time.

The nets required little maintenance other than periodic cleaning. Three nets were fished in Pelton and Round Butte reservoirs continually for 3 years without being removed. At the end of that time, only the surface portions needed repair, due to sunlight deteriorating the nylon. Nets fished at North Fork Reservoir during the same period were not subject to as much direct sunlight and were still usable.

The most important use of traps was to capture fish for tagging and to recover tagged fish. Tagging of juvenile salmonids was accomplished with a small, numbered pennant attached with solid vinyl thread, which provided information on the efficiency of the collection system, growth of individuals, and intra-reservoir migrations. The tag will be described in detail in another paper.

If the catch-per-unit effort by traps is to be used to describe the relative abundance of fish in reservoirs, we must determine if the gear's efficiency is constant. This appeared doubtful. The daily catches of coho and rainbow-steelhead[1] in a trap fished in one area of North Fork Reservoir are compared to water visibility and Clackamas River flow in Figure 2. Trapping did not occur continuously throughout the period, but traps were fished several days each month. Vertical lines connect peak catches of coho with catches of rainbow-steelhead, river flow, and water visibility on the same days. Generally, peak catches of coho and rainbow-steelhead occurred simultaneously; the main exception was in December 1962 when a high catch of coho was accompanied by a relatively low catch of rainbow-steelhead. The best catches usually occurred coincident with relatively high flows and low water visibilities (6 feet or less). The one exception to this pattern was in November 1962 when we caught large numbers of both species coincident with low flow and high water visibility. There is no explanation for this occurrence.

[1] Fish thought to be steelhead, but which may have included resident rainbow trout, were called rainbow-steelhead.

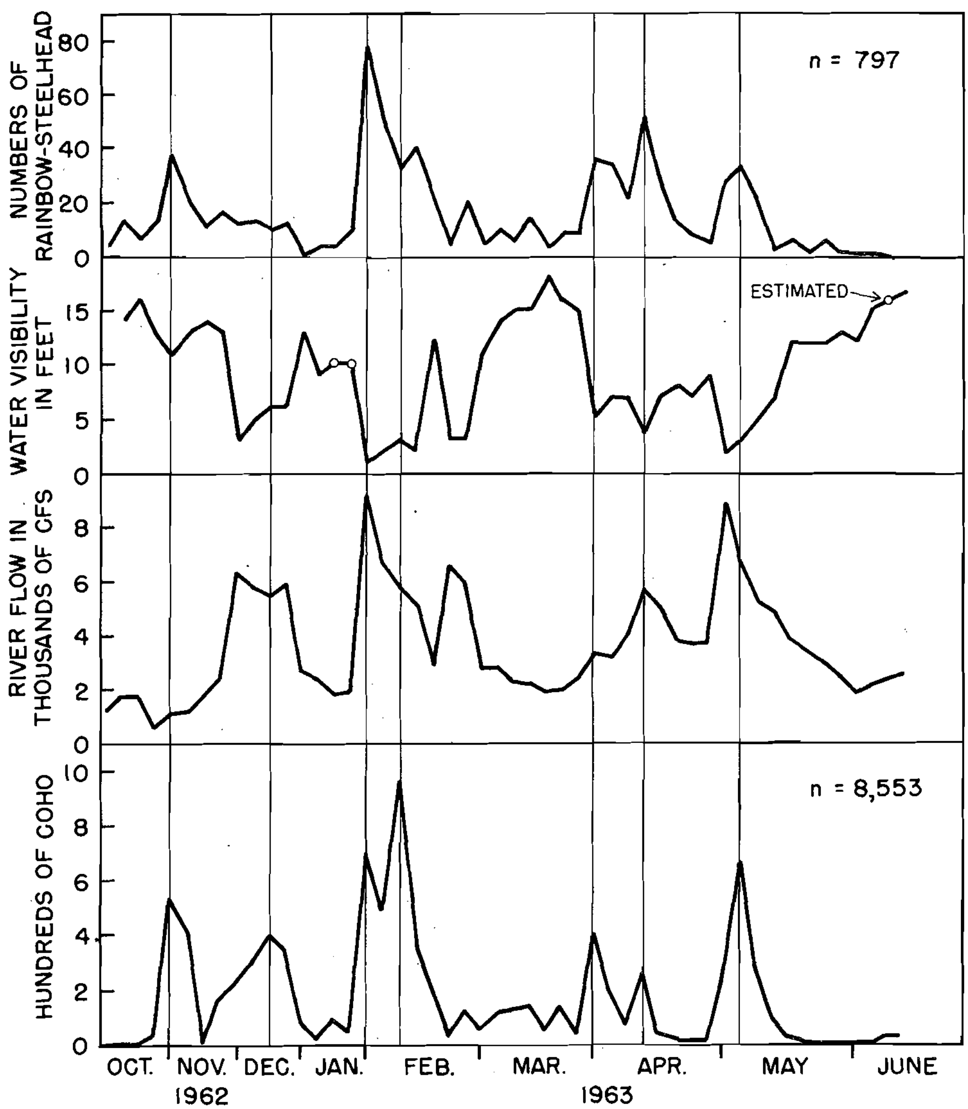

Figure 2—*Daily Clackamas River flow, water visibility, and catches of coho and rainbow-steelhead in traps fished in one area of North Fork Reservoir, October 1962-June 1963.*

It appeared that fluctuations in catches did not represent variation in population size. The population of fish could have fluctuated during much of the year due to fish immigrating to the reservoir with freshets and emigrating with spill. However, the absence of these factors from April through May leaves no explanation for the low catches in late April and relatively high catches prior to and after that period. It appeared that the traps did not catch fish effectively in late April.

There was no obvious selection of traps to size of fish caught except that fry were able to pass through the meshes and generally were not captured. By observation, it appeared that the size of coho smolts caught by the traps in the spring was similar to that of emigrants passing through the collection facilities at North Fork Dam (Figure 3). While tests showed significant statistical differences, these appear minor and could be explained by small sample sizes or by the emigrating population differing slightly from those remaining.

There were other qualifying considerations in the use of traps. It was generally observed that catches decreased as the traps became covered with algae and detritus. A brief test was conducted to determine if the efficiency of clean and dirty traps varied. A clean and a dirty trap were fished on alternate days, for 2 days each, in the same location at North

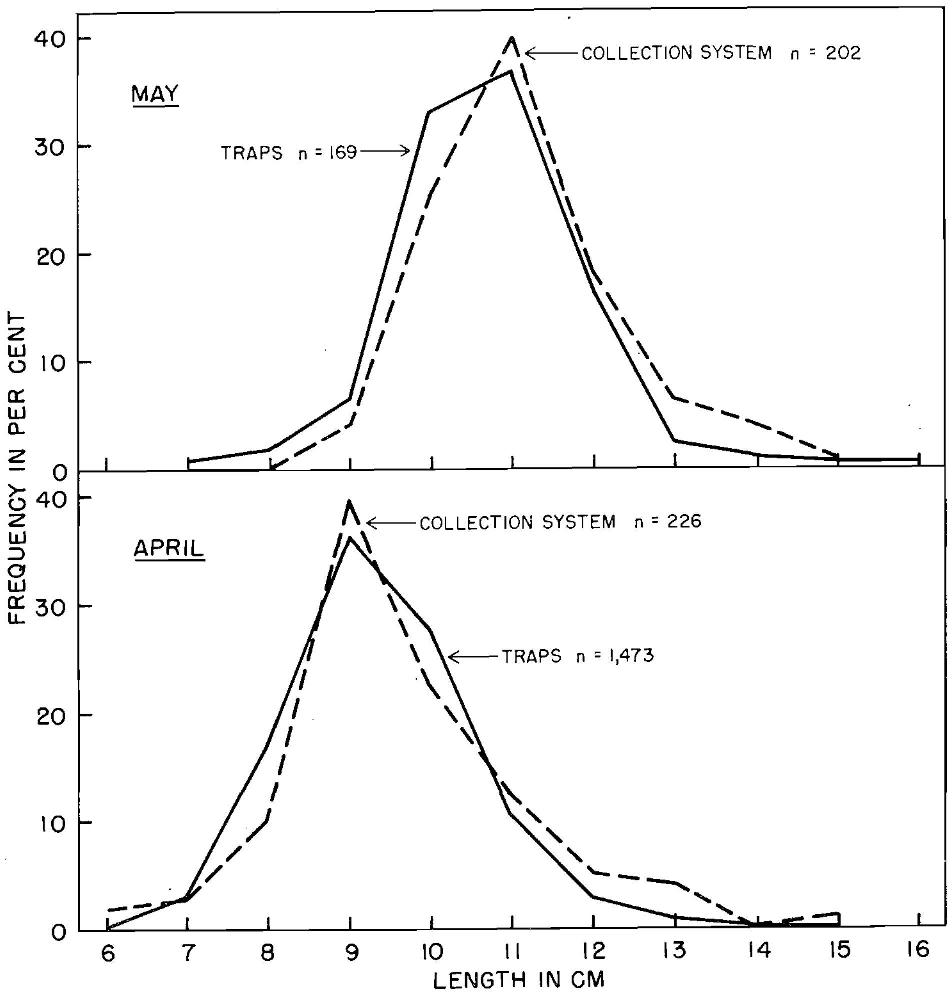

Figure 3—Size composition of coho salmon caught in traps and counted at the collection system, North Fork Reservoir, April-May 1963.

Fork Reservoir. The clean trap caught 158 coho and 51 steelhead and the dirty trap only 17 coho and 24 steelhead.

Thermal stratification may limit the vertical distribution of fish and reduce the trap's efficiency. During September 1962, traps were fished simultaneously in two areas of North Fork Reservoir having differing water temperatures. Catches are shown in Table 1. The upper reservoir trap was located at the juncture of the Clackamas River and the reservoir where temperatures varied between those in the reservoir and the river, due to fluctuations in pool elevation. The middle reservoir trap was located approximately 1 mile down-reservoir from the upper trap. Diel variations in water temperature occurred in both areas, but maximum surface temperatures were always higher in the middle reservoir area. Daily minimum temperatures were 8 to 10 F lower in the upper reservoir and were always below 60 F. Minimum temperatures in the middle reservoir were 60 F or higher. Large catches of coho and consistent catches of chinook were made in the upper reservoir, but almost none were caught in the middle area. Similar numbers of 1962-brood steelhead were caught in the two areas, but more older steelhead were taken in the colder water. In contrast to salmonids, suckers *(Catostomus* sp.) were caught best in the warmer water. Large numbers of salmonids were caught in the middle reservoir trap when water temperatures there were cooler indicating this was a good fishing location. It seems probable salmon were not in this area when temperatures were relatively warm. These experiences point out that the reaction of fish to their environment bears on the efficiency of fishing gear.

It is necessary to fish the traps daily if large numbers of predacious fish are captured along with juvenile salmonids. Examination of stomachs of large rainbow trout, Dolly Varden *(Salvelinus malma)*, and squawfish *(Ptychocheilus oregonensis)* caught in traps at Pelton Reservoir revealed numerous juvenile salmon. Since these fish were generally not digested and some were still alive, it appeared that they were ingested while confined in the trap.

GILL NETS

Gill nets have proven useful in determining the distribution of fish in lakes and impoundments. With such nets Cady, Dendy, and Haslbauer (1945) and Dendy (1946) obtained information on the distribution of warm-water fish in a Tennessee reservoir. In another reservoir study, Rees (1955) determined the vertical and horizontal distribution of downstream-migrating juvenile salmonids; four mesh sizes were used and each was selective to fish of a particular size.

Description

We used three types of gill nets in our studies. In the first study, we compared multifilament (thread size 210 d/2 ply) and monofilament (thread size 0.234 mm) nylon nets. The dimensions of the gill nets were arbitrarily set at 75 feet long and 15 feet deep hung on a ½ basis, i.e. 150 feet of netting was used to make a 75-foot-long net. When hung the nets were

Table 1—*A comparison of catches in traps fished in two areas having differing water temperatures, North Fork Reservoir, September 5-12, 1962.*

Date 1962	*Upper reservoir trap*							*Middle reservoir trap*						
			Steelhead							*Steelhead*				
	Coho	*Chinook*	*1962 brood*	*Older*	*Suckers*	*Total catch*	*Surface temp. range (F)*	*Coho*	*Chinook*	*1962 brood*	*Older*	*Suckers*	*Total catch*	*Surface temp. range (F)*
Sept. 5	194	18	11	37	0	260	53-64	0	0	0	1	17	18	63-74
6	141	17	10	24	0	192	53-67	0	0	26	4	89	119	64-70
7	172	19	14	19	4	228	56-67	0	1	8	2	42	53	64-70
8	440	18	10	33	78	579	52-56	0	0	15	2	224	241	62-68
11	151	10	4	23	20	208	51-63	3	0	2	5	7	17	62-65
12	256	20	8	46	0	330	50-64	1	0	0	4	58	63	60-67
Total	1,354	102	57	182	102	1,797		4	1	51	18	437	511	

composed of five, 15-foot-long panels of the following mesh sizes: $\frac{5}{8}$-, $\frac{7}{8}$-, $1\frac{1}{8}$-, $1\frac{3}{8}$-, and $1\frac{5}{8}$-inch stretch measure. These sizes were chosen after comparing sizes of fish caught in a gill-net experiment at Baker Dam, Washington (Rees, 1955), with the sizes of salmonids collected in the passage facilities at Pelton Dam. In the second study, monofilament (0.16 mm diameter) nylon nets were used because of their ability to capture fish day and night, and because cleaning nets and removing fish was easier than with multifilament nets. The gill nets were 60 feet long and 15 feet deep and hung on a $\frac{1}{2}$ basis. When hung, they consisted of three 20-foot-long panels of the following mesh sizes: $\frac{7}{8}$-, $1\frac{1}{8}$-, and $1\frac{3}{8}$-inch stretch measure. All the gill nets were weighted with nylon lead core line weighing approximately 50 pounds/100 fathoms, and had enough floats attached to give near-neutral buoyancy. The nets were hung by experienced commercial fishermen.

A portable float assembly was developed (Korn and Gunsolus, 1962) which permitted fishing at various depths and was not affected by reservoir fluctuation. The suspension apparatus (Figure 4) required two anchor lines located 60 or 75 feet apart (length of the nets). Each anchor (a) was made of concrete and reinforcing rod, weighed about 50 pounds, and was attached to a line (b) leading to a large styrofoam float (c). The anchor line traveled over two pulleys (d) attached to eye bolts (e) through each end of the float. Strips of metal (f) on the top and bottom of the float prevented the eye bolts from eroding the styrofoam. A 5- to 10-pound counterweight (g) was attached to the loose end of the anchor line which was long enough to allow for maximum reservoir fluctuation. Large swivel snaps (h), tied to each corner of the net, were fastened onto the anchor lines, enabling the net to travel freely down the lines. A line (i) connected the net to the float to control the depth at which the net fished. Additional weights were fastened to the bottom of the net (j) if it was desired to sink the net below the surface. The result was that the styrofoam floats rose or fell with any fluctuation in the reservoir and the anchor and counterweight lines remained taut (Figure 5). Thus the net remained at the same depth with relation to the water surface except when it was set on the bottom.

Use of Gill Nets

Gill nets were used primarily to determine depth distribution of salmonids in reservoirs. Nets were fished parallel and perpendicular to the shoreline on the bottom and in mid-water positions from the water surface to a depth of 175 feet. Figure 6 shows some of the different positions used.

The fishing technique was successful on both a level bottom and steep mud bank. It was difficult, however, to prevent the anchors from sliding on a steep, rocky slope. The nets were fished in clear and turbid water, and through most algae growths; however, a green filamentous algae (*Ulothrix* sp.) prevented them from fishing by clogging the meshes and weighting the nets into an unnatural position. Nets were fished at any depth in slack water; but current caused them to bag, drawing the styrofoam floats toward one another. The resulting bow in the anchor lines

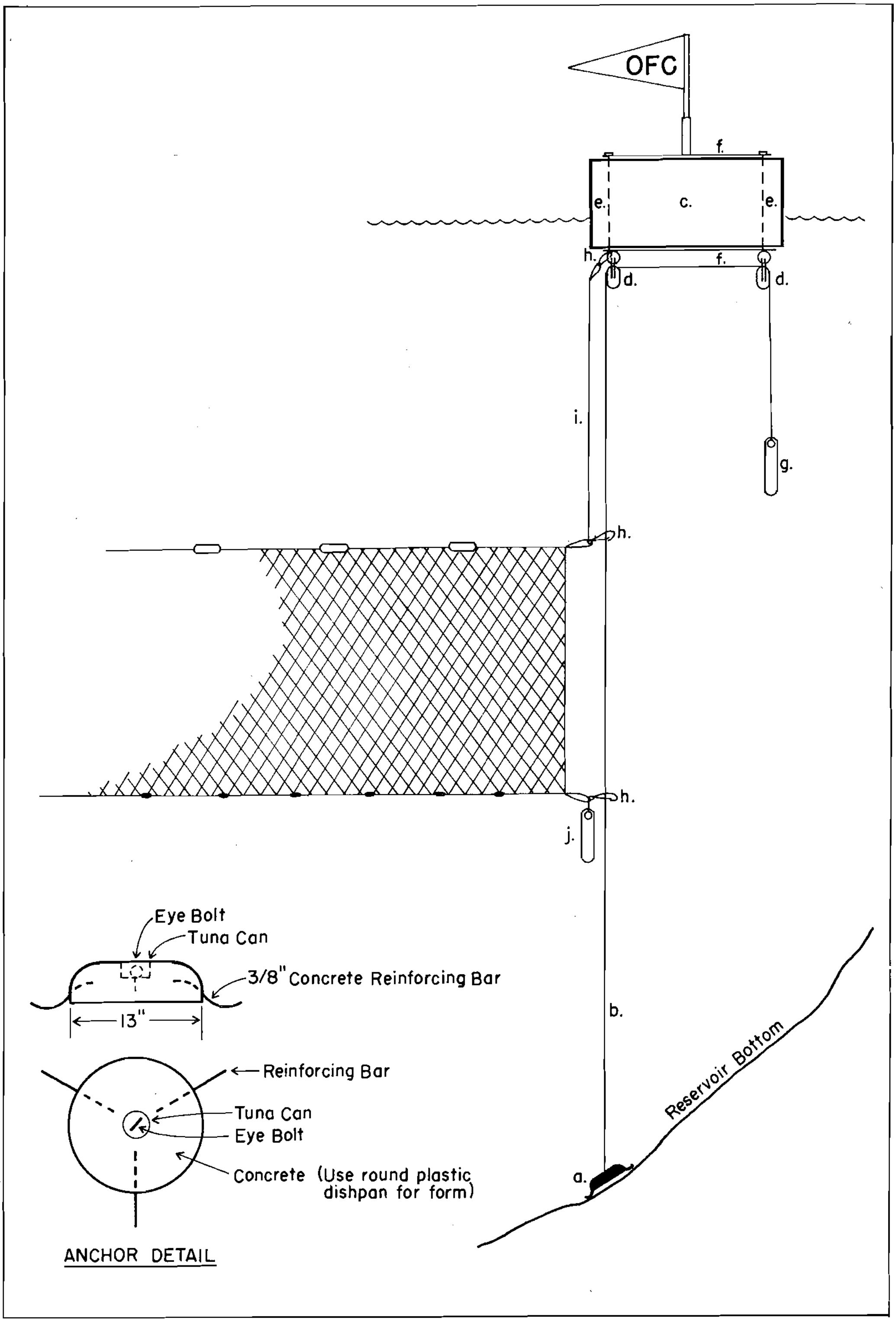

Figure 4—*Diagram of gill-net suspension apparatus and anchor detail.*

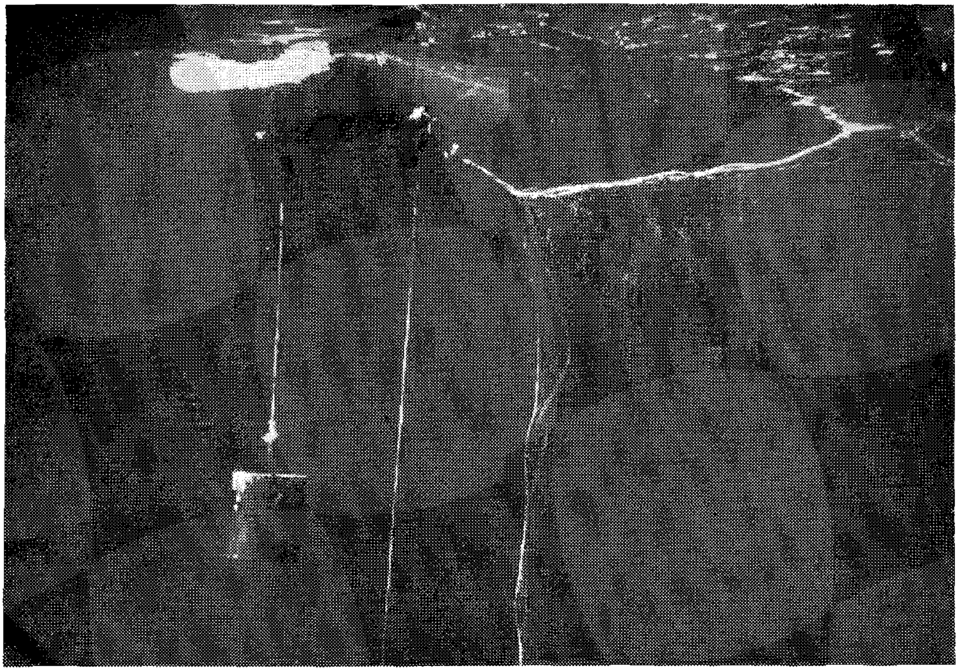

Figure 5—*Portable gill-net suspension apparatus used in fluctuating reservoirs, as seen from below the water surface (float assembly is not as described in text but operates on same principal).*

prevented the nets from slipping down the lines below a depth of 30 feet. Bagging did not appear to interfere with their fishing ability. The nets fished satisfactorily in all velocities encountered in the reservoirs studied. Trees, sagebrush, stumps, and large boulders easily damaged the fine mesh nets. Damage could be reduced by having SCUBA divers clear the bottom of the reservoir at the fishing sites prior to setting nets.

Predation by crayfish reduced the catches in gill nets fished on the bottom of Pelton Reservoir. SCUBA divers observed crayfish devouring fish of all species and sizes caught in the nets. Fish skeletons up to 1 foot long and partially eaten fish (including salmon fingerlings) were found in the nets. Salmon fingerlings, generally 4 to 6 inches long, could have been easily devoured before the nets were checked after an overnight set.

During the early study (Korn and Gunsolus, 1962), length frequencies of salmonids caught in each mesh size were compared for multifilament and monofilament (0.234 mm diameter) nets to determine if the two materials fished on the same segment of the population. Figures 7, 8, and 9 show the sizes of chinook and coho salmon and rainbow-steelhead trout for those mesh sizes capturing enough fish for comparative purposes at North Fork Reservoir. In the case of coho and chinook a difference is evident between the two materials for a given mesh size. Chi-square tests showed that monofilament nets caught significantly larger fish. Size compositions of rainbow-steelhead taken in 1⅜-inch monofilament and multifilament nets did not differ statistically. The size composition of fish

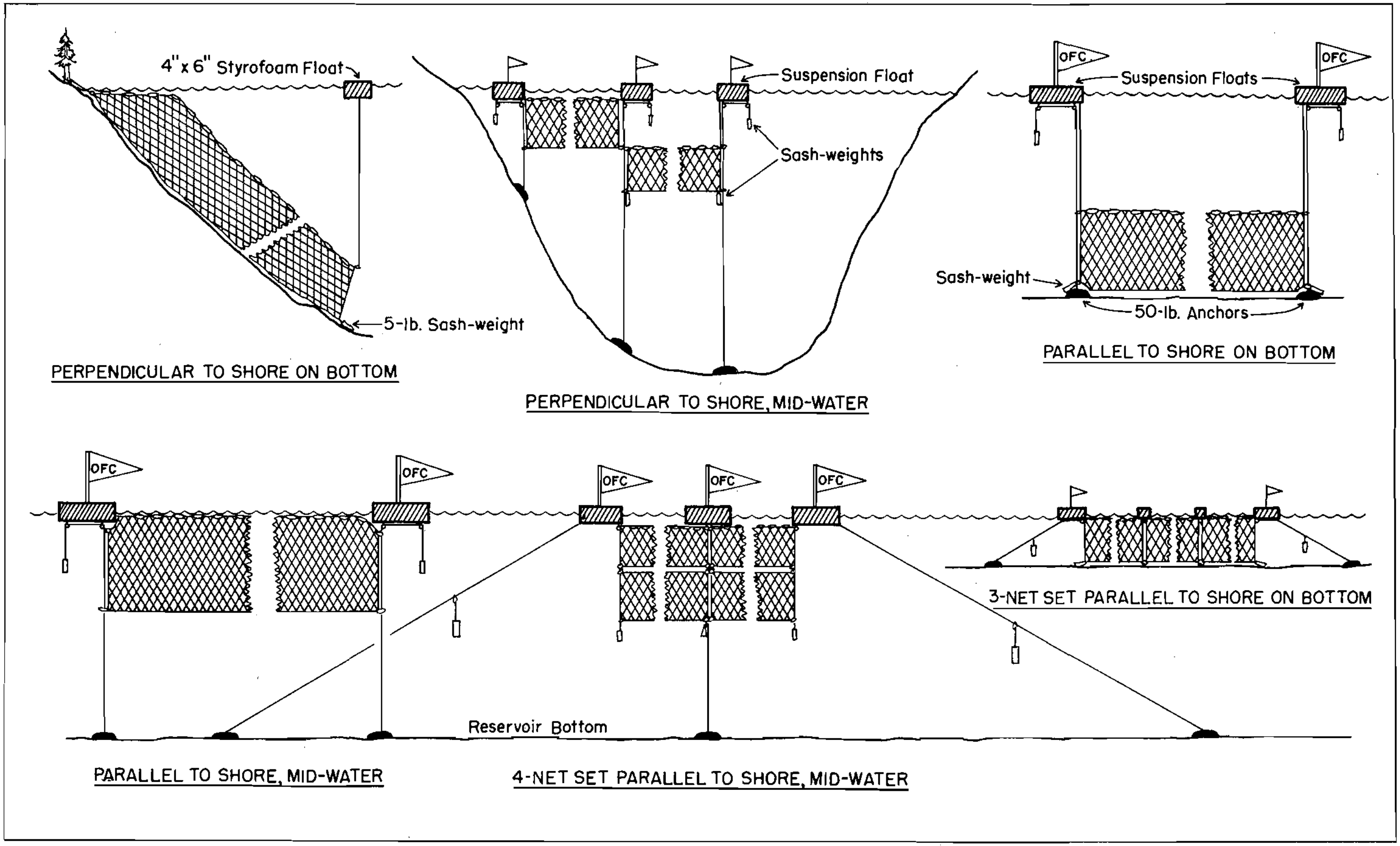

Figure 6—*Diagram showing different types of gill-net sets.*

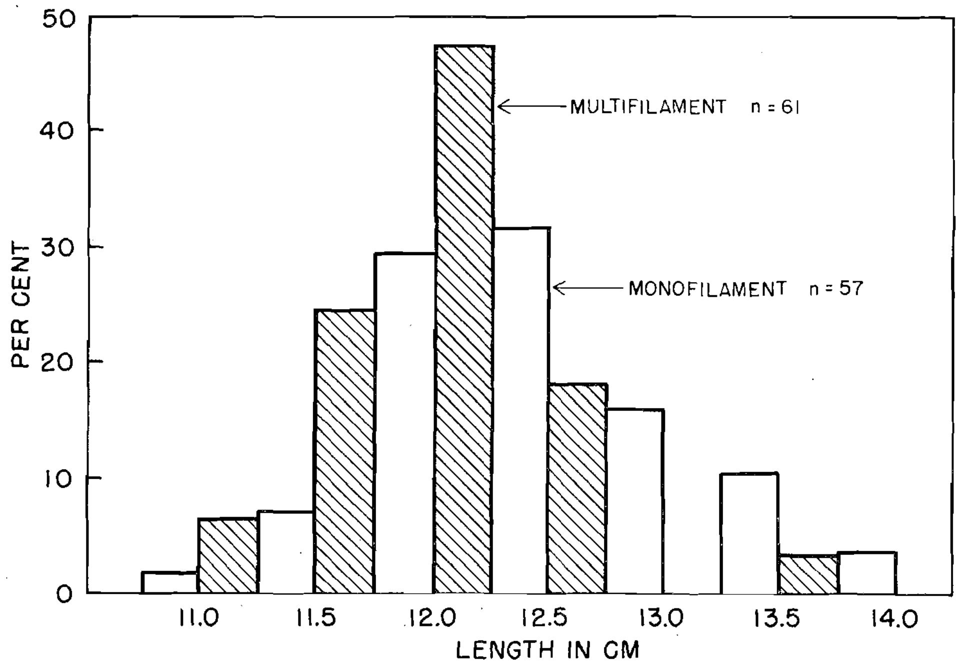

Figure 7—*Size composition of chinook salmon caught in 1-1/8-inch monofilament and multifilament nylon gill nets, North Fork Reservoir.*

caught in 0.16 mm diameter monofilament gill nets was not compared to that of fish caught in the other two types of nets since the former were not fished in the same year as the others and size of fish varied annually.

It was determined that the mesh of monofilament netting averaged 0.040 inch larger than multifilament in the 7/8-inch size and 0.059 inch larger in the 1 1/8-inch mesh size than specified. The two net materials also differed in texture. Multifilament netting was soft and fish caught were entangled and usually dead, while monofilament netting was stiff and the fish were often gilled in only one or two meshes and generally alive. Fish occasionally fell out of the monofilament nets as they were pulled into the boat. It was not determined whether the length-frequency differences were attributable to the fractional differences in the mesh sizes, differences in net material quality, or both. Fishing efficiency of monofilament and multifilament nets was not compared because of sampling problems and because similar mesh sizes caught different size segments of the chinook and coho populations. Insufficient numbers of rainbow-steelhead were caught for comparative purposes.

An analysis of variance showed the mean size of coho salmon caught in 7/8- and 1 1/8-inch mesh for both types of nylon increased with time (Figure 10). Generally differences were between the periods November-December, January-April combined, and May-June. Similar treatment of chinook salmon catches in 1 1/8-inch mesh size of both materials showed no significant difference in mean lengths of fish caught in monofilament material, but a significant value for fish caught in multifilament nets (Figure 11).

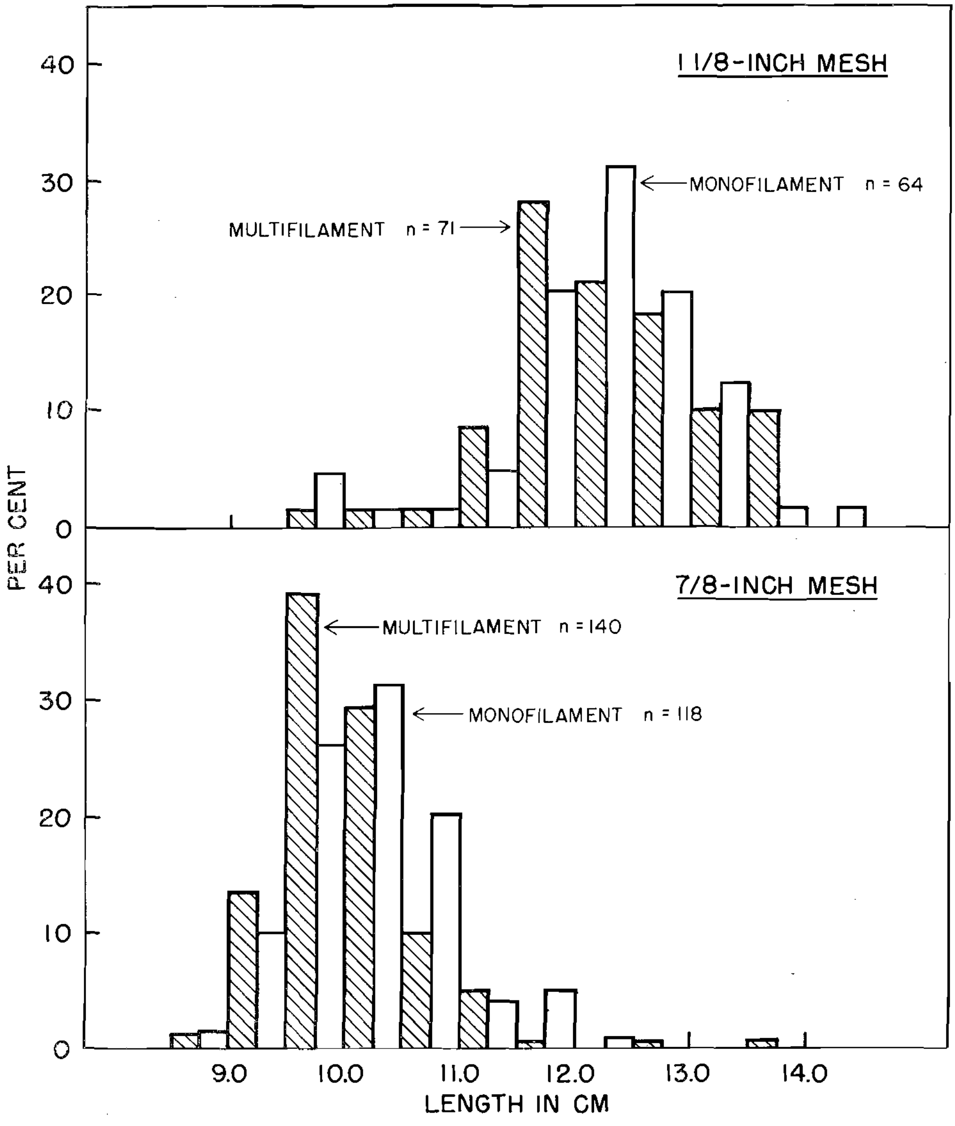

Figure 8—*Size composition of coho salmon caught in 7/8- and 1-1/8-inch monofilament and multifilament nylon gill nets, North Fork Reservoir.*

SCUBA GEAR

Since World War II SCUBA (self-contained underwater breathing apparatus) has been widely used by sport and commercial divers and recently has spread to fisheries research. The Scripps Institution of Oceanography used SCUBA in studies of the ecology of kelp beds, fish populations, observations of underwater gear, and geological mapping (Bascom and Revelle, 1953). SCUBA gear was used by Boyd (1959) to

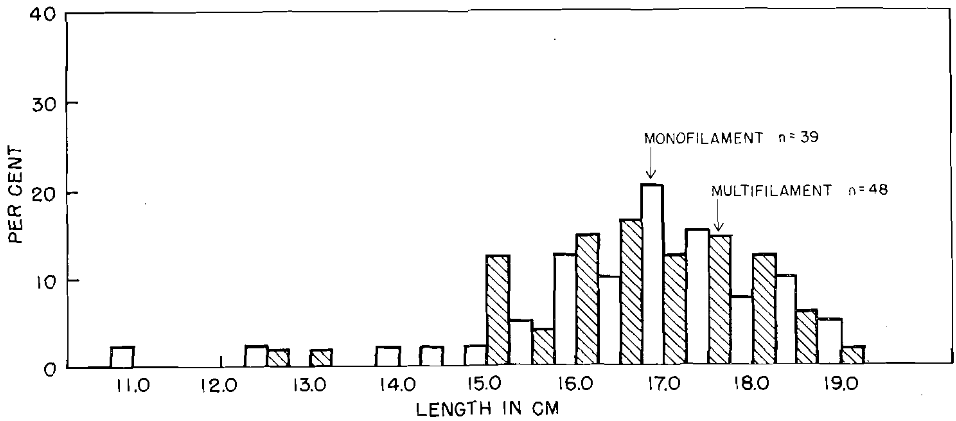

Figure 9—*Size composition of rainbow-steelhead trout caught in 1⅜-inch monofilament and multifilament nylon gill nets, North Fork Reservoir.*

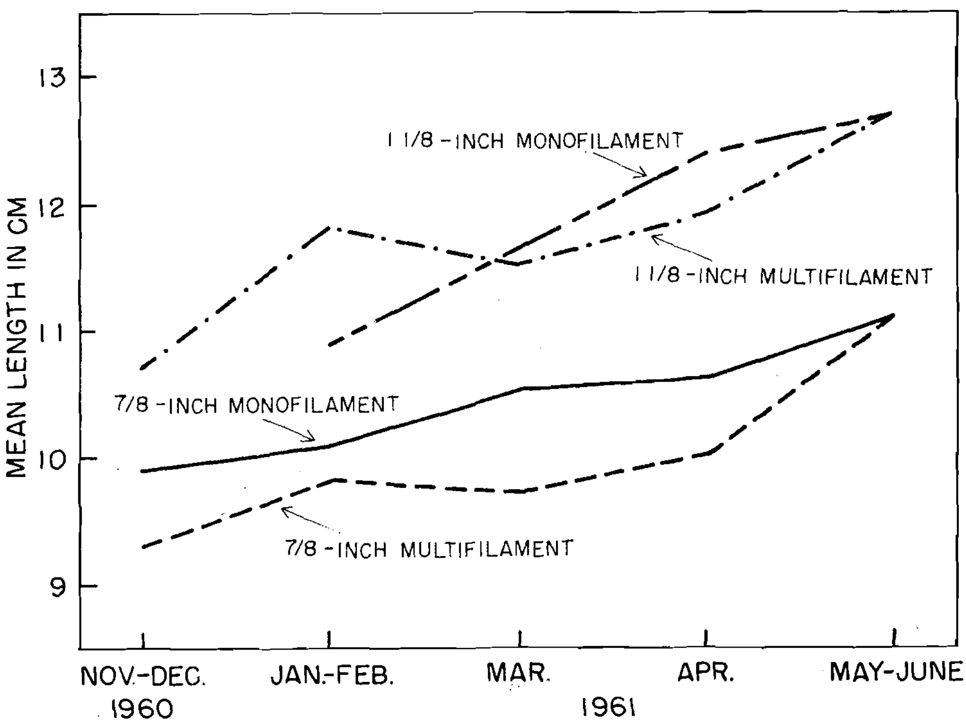

Figure 10—*Mean length by time period of coho salmon caught in 7/8- and 1-1/8-inch monofilament and multifilament nylon nets, North Fork Reservoir.*

study spawning sockeye salmon in Great Central Lake, Vancouver Island, at depths of 40 to 70 feet.

In our studies diving gear (SCUBA and snorkel) was used to make direct visual observations of fish, and as an aid in fish capture. SCUBA

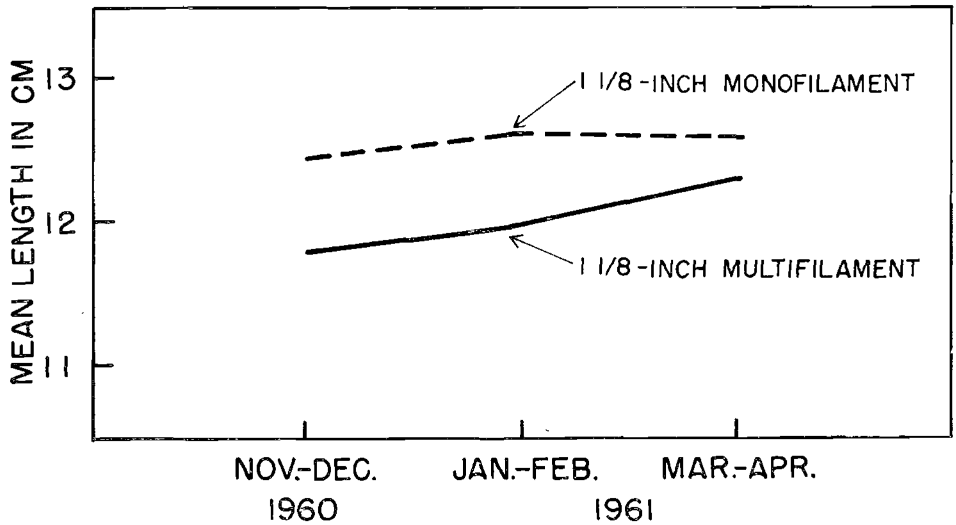

Figure 11—*Mean length by time period of chinook salmon caught in 1-1/8-inch monofilament and multifilament nylon gill nets, North Fork Reservoir.*

supplemented gill nets in determining depth distribution of fish, and snorkels permitted extensive surface observations.

Description

The diving equipment was selected with the aid of experienced commercial divers. Each observer was equipped with a nylon-lined wet suit of ¼-inch neoprene with a vest for added warmth, mask, fins, snorkel, 96 or 72 cc air tank with an s-j valve providing a reserve air supply, weight belt, and a two-stage regulator. Several accessories were acquired. Depth gauges were used to maintain constant depths while swimming transects. Compasses were valuable in maintaining direction while swimming on a flat bottom. Knives were supplied as a safety precaution and proved valuable in freeing fouled anchors and nets. Underwater lights were needed for observations at night. Two kinds of lights were used. The canister type, with battery enclosed in a watertight container, proved inferior because the wiring corroded and leaked in the canister and ruined the batteries. The exposed battery type, in which the light unit is attached to the terminals was effective.

Divers were trained by a qualified instructor. Every individual took a course of classroom instruction in diving physics, physiology of diving, and accident prevention. They were also required to pass a swimming test, received approximately 20 hours of pool experience in the use of equipment, and were supervised on one to five dives to depths of 100 feet in a lake, reservoir, bay, and the ocean.

Use of SCUBA

Water visibility was an important consideration when making observations with SCUBA. A minimum Secchi disc reading of 8 feet was desirable;

at a reading of 5 feet fish were observed only with much tedious searching. Turbid water due to freshets in the winter and algae blooms in the summer often hindered observations.

The time spent under water was limited by the capacity of the air tank. The time required to expend the air from a given size of tank varied with the divers, and decreased with increased depth. Multiple-tank blocks were available, but it was more convenient to use single tanks since many observations were made at shallow depths where the gear was cumbersome.

Low water temperatures also limited the time spent on a given dive. At 40 F and lower dives were generally limited to a maximum of 30 to 45 minutes, while above 60 F divers could spend 2 to 3 hours in the water.

SCUBA divers readily observed salmonid fry (fish up to 50 mm long), but seldom saw larger fish during the day. The most significant observations occurred at night when juvenile anadromous fish of all sizes were seen.

SCUBA divers obtained information on depth distribution of juvenile fish at night, supplemental to that obtained with gill nets, by swimming standard 50-yard-long transects near the shoreline and on the bottom at depths of 15, 30, and 50 feet. With SCUBA, we observed fish similar in size to and smaller than those caught in gill nets. Catches in gill nets and counts of fish using SCUBA could be compared only generally since salmonids were counted at specific depths when swimming while each net fished a depth range of 15 feet. Also, SCUBA observations occurred instantaneously and were made immediately after nightfall, while fishing of nets at night extended over several hours. We had difficulty observing smolt salmonids with SCUBA in the spring.

On one occasion a mercury vapor light was used in North Fork Reservoir in the spring of 1961 to attract smolts. Divers swam a section of the bottom, outside the area to be lighted, at depths ranging from the surface to 20 feet. Numerous chinook and coho fry were observed along the shoreline, but only three yearling coho were seen in the entire area. Divers swam the area below the lamp before it was turned on but no fish were seen. The mercury lamp, located approximately 1½ feet above the surface of the water, was then lighted and the area below was not disturbed for 20 minutes. Then the divers entered the water and stationed themselves on the bottom just below the lamp, at a depth of 7 feet. A school of yearling salmon (probably coho) was observed milling in the lighted area. They moved constantly and shied away at the divers' slightest action. A total of 51 fish was counted by one observer in 10 minutes; some fish were undoubtedly counted twice.

Fish were counted along the shorelines at night using snorkels to compare concentrations of salmonids at different locations within a reservoir. Just prior to dark, three divers traveled by boat to the upper end of the reservoir. Two men entered the water at different locations and swam downstream along the shoreline for 15 minutes, counting fish by species if possible. The third man remained in the boat and maintained sight contact with the divers' lights. This procedure was repeated at several predetermined locations.

A hand net was developed to enable divers to capture juvenile salmonids. The net was constructed of a series of supported, concentric wire rings (Figure 12). The bottom ring forms the mouth of the net and has the smallest diameter. The netting slopes out from this ring to a second, larger ring forming the outside edge of the trap floor. The net floor was attached to the second ring at 4-inch intervals, allowing small slits through which fish could enter the trap. The third and largest ring was located at the same level as, and outside of, the second ring, creating an overhang of the trap floor which prevented fish from escaping. A fourth ring, with an attached handle, formed the top of the trap. The covering over the framework and the trap floor consisted of ⅝-inch stretch measure nylon monofilament netting. Captured fish were removed through a funnel-shaped opening of netting at the top of the trap. This device proved successful for capturing and retaining fish.

Fish were captured only if they were near the bottom. The net was placed over the fish, the lowest ring in contact with the bottom. Fish would first circle the lowest ring, then swim up the sloped netting and push through the slitted opening in the floor. Once in the trap, fish did not appear frightened. Up to 2 dozen fish could be caught before it was necessary to empty the trap.

ELECTRIC SHOCKER

In the past decade various investigators have adapted electro-fishing methods, using alternating and direct current, for use in lakes and impoundments. Alternating current stuns or paralyzes fish entering the electric field (Haskell, 1954), while direct current causes an involuntary migration to the positive electrode (Haskell, MacDougal, and Geduldig, 1954). Larimore, Durham, and Bennett (1950) used an alternating current shocker on the bow of a rowboat to capture fish in areas of lakes where seining and wading were impossible. Loeb (1955 and 1957) describes an electric scow used to take game and scrap fish primarily at night. All boat-mounted electric shock devices depended on dipnetting to capture shocked fish. Any reduction in water visibility due to high turbidity or wave action made collection difficult.

Description

The electric shocker used was a portable direct current unit designed and built by the Bureau of Commercial Fisheries. A small control unit enabled the operators to select frequencies of 40 or 75 pulses per second and recorded time in use. Power was supplied by a standard 12-volt automobile battery attached to the control unit. Electrodes were attached to the control unit by approximately 40 feet of cable; operation was controlled with a touch switch on the positive electrode. The positive electrode consisted of a 12½ by 11¼-inch wire-mesh grid attached to a 7-foot-long insulated aluminum handle. The negative electrode had slightly different dimensions. At least two men were required, one to operate the

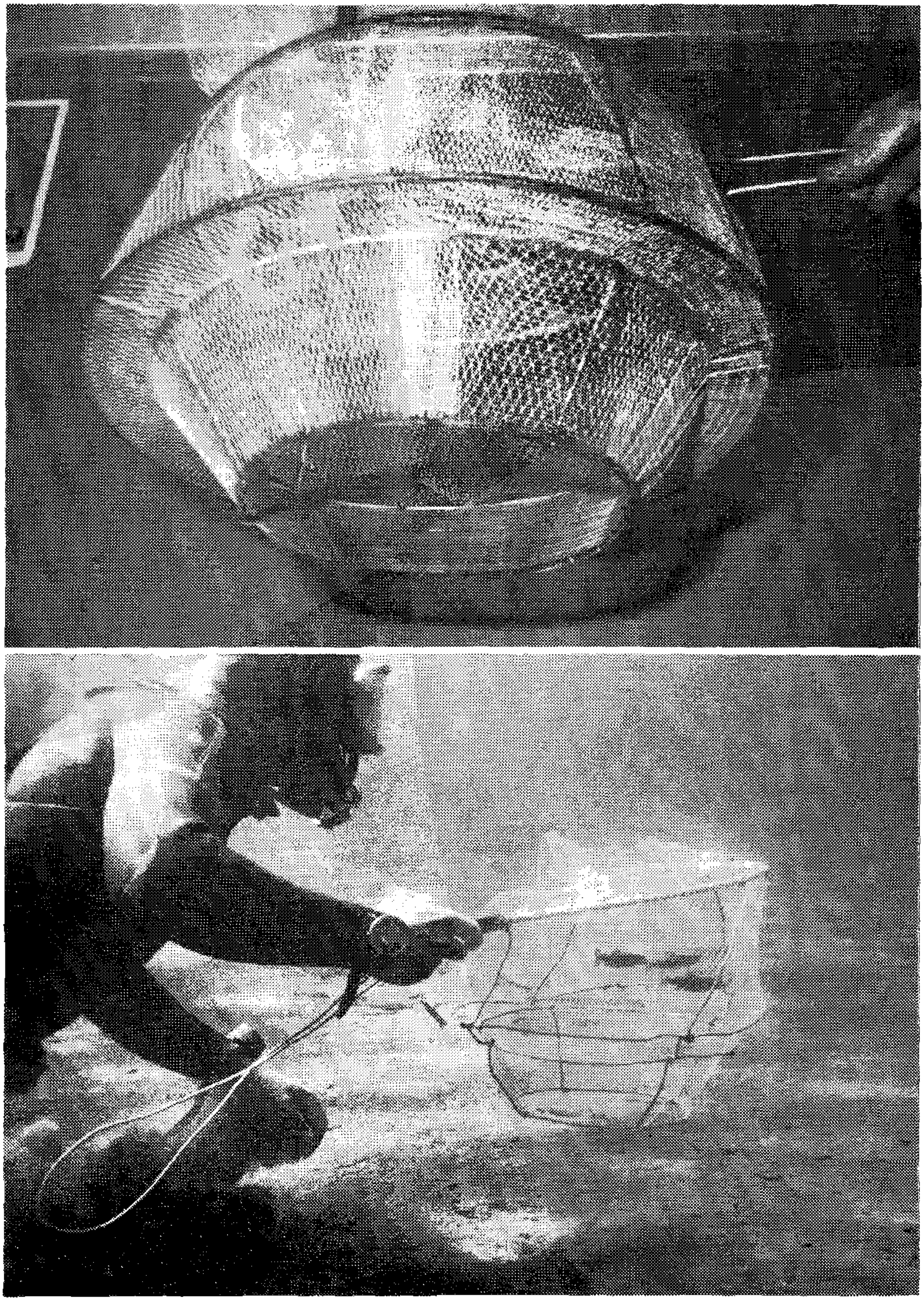

Figure 12—*SCUBA hand net for capturing juvenile salmonids (top) and early model being used by diver (bottom—note salmonids inside net oriented in same direction as diver).*

electrodes and the other to collect the stunned fish. Both men wore rubber gloves. Fish were deposited in a portable floating live box.

Use of Shocker

The electric shocker was used only to a limited degree in reservoirs. Salmonids were occasionally caught along shoreline areas during the day, but catches were consistently better at night when fish were more likely to be found inshore. Salmonids were caught for tagging and size composition data by use of electro-fishing at night, but the relatively small catches did not justify the effort involved. Generally, more salmonids were taken in a floating trap fished overnight unattended than were caught by three people in an evening of electro-fishing.

Extensive electro-fishing was conducted in certain tributaries and at the headwaters of the Metolius River, above Round Butte Reservoir, to obtain length-frequency samples of juvenile salmon and to compare the growth of fish between stream and reservoir. Fish were captured effectively in some of these areas; however, use of the equipment in swift-flowing and deep-pool areas of the main Metolius and Clackamas rivers was ineffective.

CONCLUSIONS

The Oneida Lake trap, modified to float, effectively caught juvenile salmonids in reservoirs, but catches did not necessarily indicate relative abundance of fish. The traps caught fish best when flows and turbidity were high and water temperatures relatively low. More fish were caught in clean than in dirty traps.

A gill-netting technique, utilizing a portable suspension apparatus which allowed nets to fish continuously at predetermined distances below the water surface, was developed for fluctuating reservoirs. Monofilament and multifilament nylon gill nets were used. For a given mesh size, 0.234 mm diameter monofilament nets caught significantly larger fish than multifilament gear, but nets of the two materials differed slightly in dimensions and considerably in texture. The mean size of coho salmon caught in a given mesh size increased with time. Size of chinook caught in a given mesh of multifilament nylon also increased, but those caught in monofilament nets did not increase in size.

Observations with SCUBA gear were limited by water visibility, capacity of the air tank, and water temperature. Juvenile salmonids were observed best at night. SCUBA was useful for determining depth distribution of fish and distribution of fish at the surface throughout the reservoir, and for capturing fish with a hand net.

An electric shocker caught fish best at night. However, catches were generally not large enough to justify the effort.

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Observations on the Limnology of Round Butte Reservoir, Oregon

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ABSTRACT

The limnology of newly formed Round Butte Reservoir on the Deschutes River in central Oregon was studied from January 1, 1964 through June 30, 1965 as part of a program relating environmental factors to behavior of juvenile anadromous salmonids. The impoundment has three arms formed by the Metolius, Crooked, and Deschutes rivers which contribute 40%, 40%, and 20%, respectively, of the total flow to the reservoir. Water temperatures ranged between 38 and 75 F. The Metolius River was cooler than the Deschutes and Crooked rivers throughout the spring and summer. Crooked River water was sometimes identifiable by its high turbidity. Surface water currents appeared to be affected by wind and generally moved up the Metolius Arm and down the Deschutes Arm. Total alkalinity ranged between 33 and 101 ppm, and was lowest in the Metolius River and highest in the Crooked River. Highest alkalinities in the reservoir were at the surface and lowest near the bottom. Dissolved oxygen content was 6.4 ppm or higher in the epilimnion and thermocline; some low concentrations to 0 ppm occurred in the hypolimnion of the Crooked River Arm. The pH ranged from 7.2 to 9.2, and was lowest in the Metolius River and highest in the Crooked River. Diptera were the only macrobenthos collected in the reservoir. Cladocera and Copepoda were the only zooplankton found and were present during all months of sampling. Small numbers of zooplankton were present in the winter; they increased simultaneously with water temperature during March and April and appeared most numerous in May. Catches in floating traps indicated suckers *(Catostomus* sp.), rainbow trout and juvenile steelhead *(Salmo gairdneri)*, coho salmon *(Oncorhynchus kisutch)*, and chiselmouth *(Acrocheilus alutaceus)* were the most abundant species of fish present. Cladocerans, copepods, and Diptera larvae were the most abundant organisms found in the stomachs of coho salmon. The consumption of food organisms was greater in April than any other month.

INTRODUCTION

One of the problems in predicting success in passing juvenile anadromous salmonids through reservoirs is the lack of information on the effect of reservoir environment on fish behavior. Round Butte Reservoir on the Deschutes River in Oregon, which has downstream-migrant passage facilities, permits the study of fish behavior and the environment. Studies of the physical, chemical, and biological aspects of reservoir limnology, as well as the food habits of juvenile anadromous salmonids, were initiated when filling of the reservoir began on January 1, 1964, and continued through June 30, 1965.

DESCRIPTION OF THE AREA

Round Butte is the uppermost of two Portland General Electric Company dams on the Deschutes River about 100 miles above its confluence with the Columbia River. The impoundment has three arms formed by the Metolius, Deschutes, and Crooked rivers (Figure 1) with respective lengths of 12, 8½, and 6 miles. The dam has a hydraulic head of 365 feet and the reservoir a maximum depth of 415 feet, surface area of almost

4,000 acres, and storage capacity of 525,022 acre feet. Pool fluctuation averages 1 foot daily with an anticipated maximum seasonal variation of 85 feet. The Round Butte project is at the head of Pelton Reservoir, about 7 miles above Pelton Dam.

The arid surroundings receive an average of only 11.1 inches of precipitation per year (1961 to 1964). Streams tributary to the reservoir are relatively stable. The native vegetation consists largely of bunch grass, big sage, and juniper along the Crooked River and bunch grass, big sage, juniper, bitter brush, rabbit brush, and pine forests along the Metolius and Deschutes.

RESEARCH PROCEDURES

Data were collected semimonthly when a thermocline was present and monthly when a thermocline was not present. Included were water temperature profiles, water transparency, dissolved oxygen, total alkalinity, and pH. Water samples for chemical determinations were taken near the surface, the middle of the thermocline (if present), and 10 feet above the bottom of the reservoir.

The reservoir was arbitrarily divided into areas with sampling stations located in each (Figure 1): I, II, and III referred to the Metolius, Deschutes, and Crooked arms, respectively. In each arm, area A included the confluence of the river and reservoir, and B, C, D, E, F, and G designated additional areas, moving downstream. The Metolius Arm consisted of five areas (A-E), the Deschutes seven (A-G), and the Crooked three areas (A-C).

Data were also collected once a month on a diel basis, i.e., each day during daylight, dusk, dark, and dawn, from Area C in the Metolius Arm when a thermocline was present. When a thermocline was absent, samples were taken only at dusk and dawn. In addition, zooplankton and salmonids were collected to compare the presence and distribution of food organisms with the food preferences and distribution of the fish and to determine if diel variations existed.

Water temperatures were determined with a Whitney underwater thermometer having a range between 30 and 100 F and enough cable for measurements to a depth of 300 feet. Surface water temperatures were taken at each station with a precision standard thermometer to which the underwater thermometer was calibrated. Profiles were obtained by recording the depth for each 1 F change in temperature.

Water transparency was measured with a white and black Secchi disc 20 cm in diameter. The disc was observed through a glass viewer on the shady side of the boat and the depths where the disc disappeared and reappeared were averaged and recorded to the nearest lower 0.5 foot.

Turbidity was determined in ppm of SiO_2 by using a Hellige turbidimeter with a No. 8010-50 turbidimeter tube of 50 mm viewing depth, bulb A-460, and no filter. The method is described by Welch (1948, p. 132-135).

The direction and velocity of water currents and wind were measured seasonally at several locations in the reservoir. Water currents were

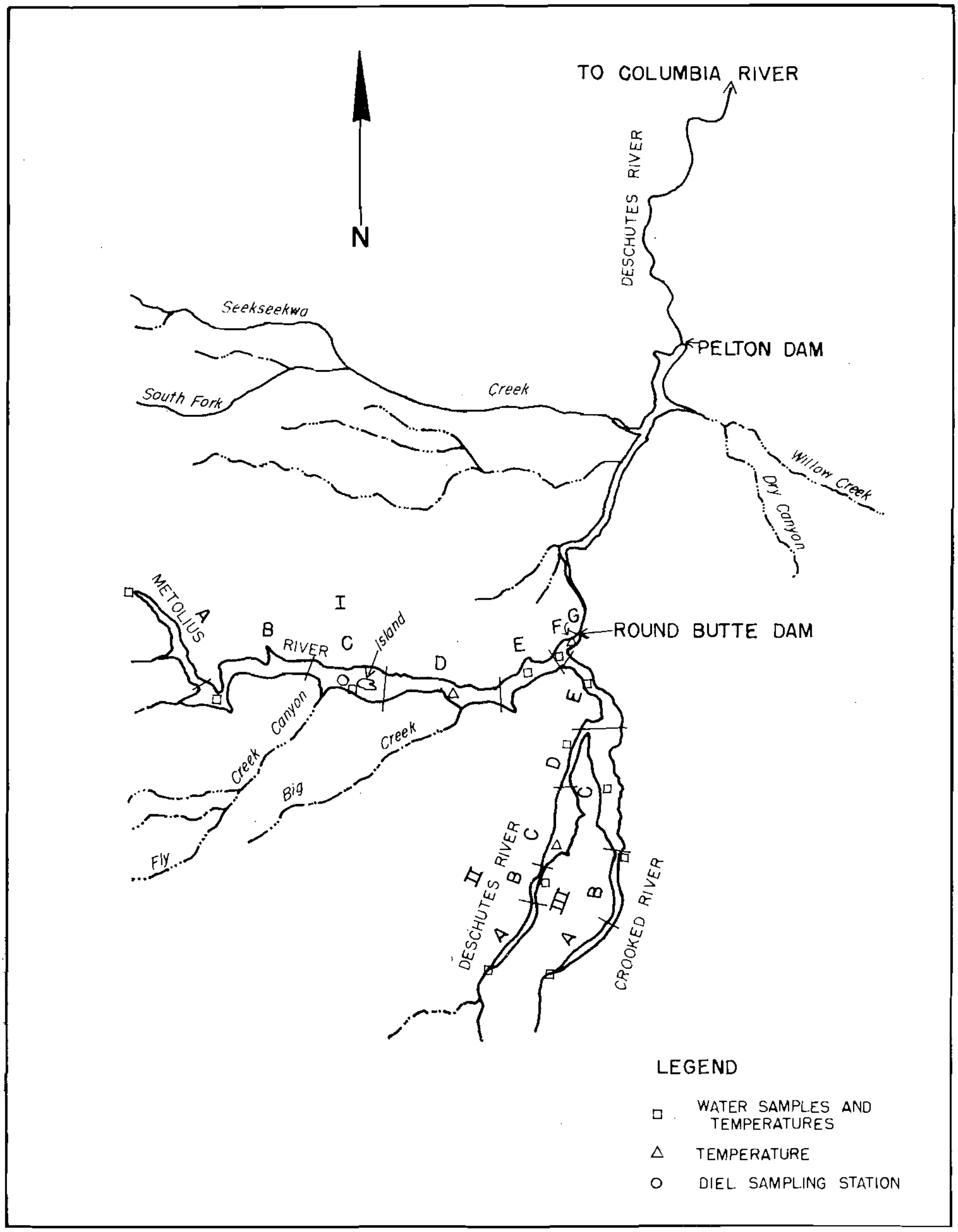

Figure 1—*Map of Round Butte Reservoir showing its three arms, relative position to Pelton Reservoir, tributary division into study areas, and sampling locations.*

observed by using drogues constructed by project personnel (Figure 2). Vanes were made of two 1-foot square, ¼-inch thick pieces of tempered hardboard. The vanes were suspended to the desired depth with 12-pound test monofilament line and supported by a 3x4-inch block of styrofoam. Velocity of the water current was calculated in feet per minute by recording the time it took the drogues to pass through a measured course. Wind velocity was recorded as calm, slight, moderate, or strong.

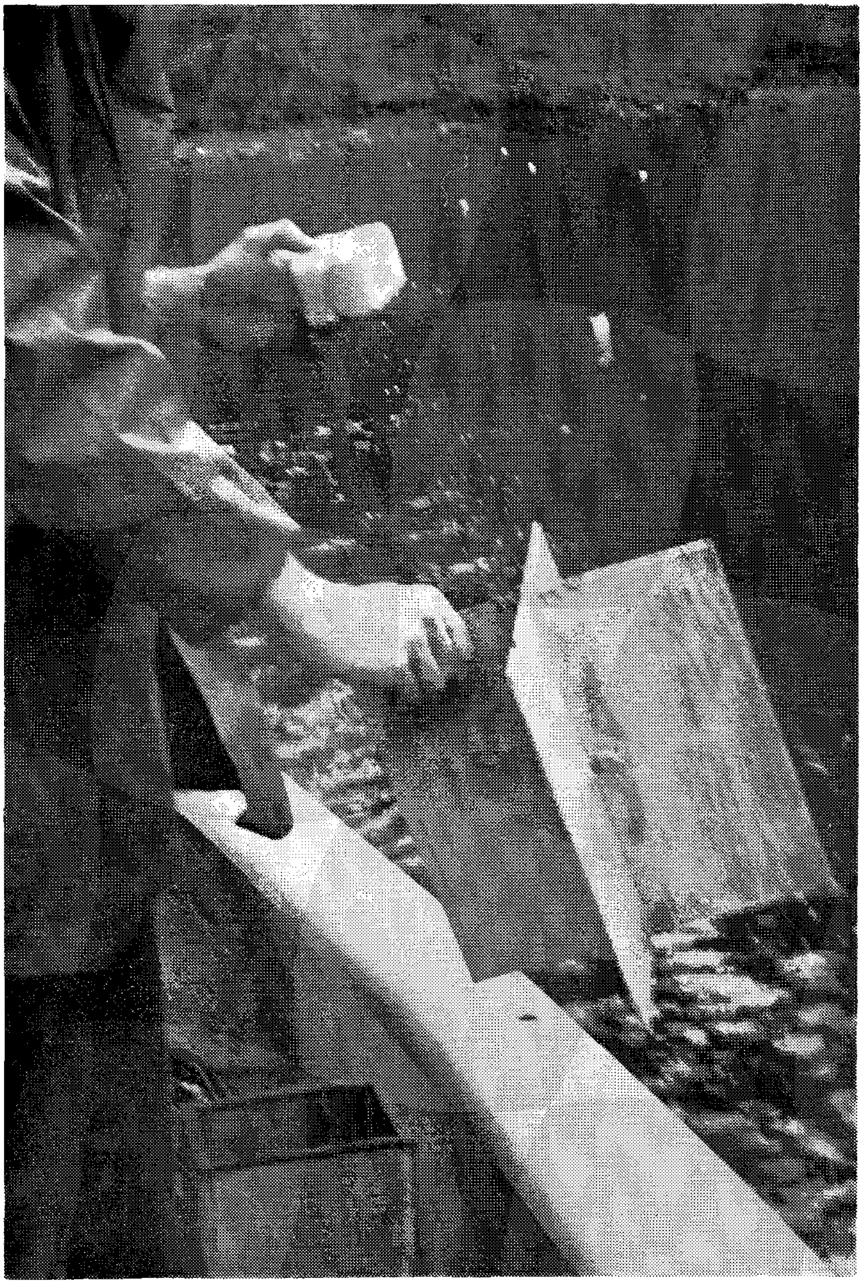

Figure 2—*The drogue used to measure water currents in reservoirs. (Small floats supporting vanes of other drogues are visible in background.)*

Chemical factors measured were total alkalinity, dissolved oxygen, and pH. Water samples were collected with a 1,200 cc Kemmerer sampler and transported to the laboratory in 300 ml B.O.D. bottles. Total alkalinity was determined by titrating with either methyl orange, methyl purple, or brom cresol green-methyl red indicator. The latter was found most satisfactory. Samples for dissolved oxygen determinations were fixed in the field and titrated at the laboratory by the modified Winkler method. A LaMott Block comparator with a range of 3.0 to 10.5 was used to determine pH.

Biological collections consisted of benthos, zooplankton, and fish. Benthic samples were collected at dawn with an improved Petersen-style dredge from depths of 15, 30, and 75 feet at locations where gill nets rested on the bottom of the reservoir. A 1-quart subsample was taken from the dredge and washed through a Tyler screen, 28 meshes to the inch. The benthos were picked from the screen and counted fresh, or preserved in 70% isopropyl alcohol and counted later. Organisms were identified by order, generally not requiring magnification.

Zooplankton were collected by the pump and hose method described by Welch (1948). A 1½-gallon sample of water was pumped from the desired depth (surface, 15, 30, or 60 feet) through a high pressure hose with a vacuum pump, and strained through a Wisconsin-type net fitted with No. 20 silk bolting cloth in the straining cone and cup. The organisms were preserved in a 4% solution of formalin. Each sample was poured into a Petri dish having lines drawn on its bottom forming pie-shaped segments. The organisms were magnified 22.5 times and counted by rotating the dish under the microscope to each segmented area. If too many organisms were present to count the entire sample, an aliquot or fraction was counted and multiplied by the fractional factor to obtain the total number. Zooplankton were classified by order and recorded by the percentage which each order contributed to the sample. They were also recorded numerically with magnitudes of 1, 2, 3, and 4, respectively, equalling 1-10, 11-100, 101-1,000, and over 1,000 organisms.

Fish were collected in floating Oneida Lake traps (Ingram and Korn, 1967) for determining species composition. The traps fished from the surface to a depth of 15 feet and appeared less selective to size of fish than the gill nets. Stomach samples were collected from anadromous salmonids caught in monofilament nylon gill nets 60 feet long and 15 feet deep that sampled a representative cross section of the reservoir from the surface to a depth of 75 feet (Figure 3). A monthly collection of four fish of each species from every depth and diel time period was desired, but catches often failed to meet this goal. The abdomen of each salmonid was slit and all fish preserved in a 10% formalin solution. Contents of stomachs were counted similarly to zooplankton samples described and were categorized by the percentage each order of organisms contributed to the total volume. Several samples containing large quantities of zooplankton were counted, and the relative volumes in magnitudes 3 and 4 compared. Thereafter, samples were classified as magnitude 3 or 4 by visual inspection and periodic total counts of these larger samples were made to assure reasonable accuracy. Organisms that were not zooplankton were always counted in their entirety.

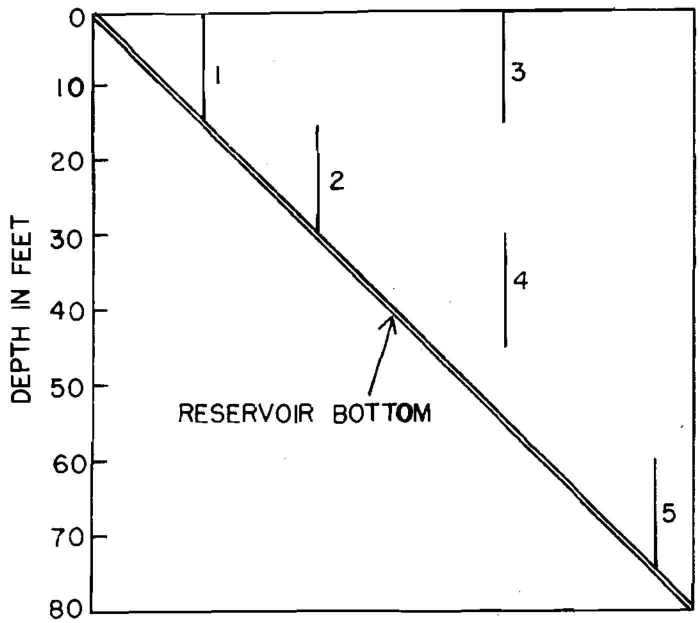

Figure 3—*Numerical designations and positions of gill nets fished on a diel basis in area C of the Metolius Arm of Round Butte Reservoir (maximum depth of the area is not shown).*

RESULTS

Physical Factors

Water flow.—The average monthly flow entering Round Butte Reservoir was obtained by combining the flows of the Deschutes, Metolius, and Crooked rivers taken at appropriate U. S. Geological Survey gauging stations. Average monthly discharge from Round Butte was calculated from daily discharges maintained by Portland General Electric Company in the Deschutes River below Pelton Dam.

The Metolius and Crooked rivers each contributed about twice as much of the total flow to the reservoir (40%) as the Deschutes River (20%) from October 1962 through September 1964, based upon yearly averages (Table 1). The monthly average of the mean daily flows of the Deschutes, Metolius, and Crooked rivers, the percentage of the total contributed by each, and their combined discharge at Pelton Dam for the period October 1962-September 1964, are shown in Figure 4. Later data are not available. The Deschutes contributed significantly less flow during the spring and summer than at other times, due to extensive use of that stream for irrigation. The average daily flow entering Round Butte Reservoir by month fluctuated between 5,651 and 3,096 cfs. The discharge from Pelton, from October 1962 until Round Butte began filling on January 1, 1964, was 600 to 800 cfs greater than the inflow, due to extensive underground springs, minor tributaries, and irrigation returns between the gauging stations on the major tributaries and Pelton Dam.

Table 1—*Annual maximum, minimum, and mean flows of Metolius, Deschutes, and Crooked rivers into Round Butte Reservoir, 1962-63 through 1964-65.*①

Date		Flow in cfs		
		Metolius River	*Deschutes River*	*Crooked River*
1962-63	Max.	2,640	1,800	3,280
	Min.	1,280	435	1,140
	Mean	1,481	765	1,544
1963-64	Max.	1,920	1,250	1,870
	Min.	1,300	425	1,100
	Mean	1,418	677	1,298
1964-65	Max.	7,100	No	6,130
	Min.	1,290	data	1,230
	Mean	1,811		1,922

After closure of the Round Butte diversion tunnel in January 1964, the discharge from the Pelton-Round Butte project 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 impoundment. The water level was 70-80 feet below full pool during the spring of 1964, and 50-60 feet below full pool by early December of that year. A flood in late December 1964 resulted in rapid filling and a spill lasting 9 days. The impoundment remained at full pool level from then through the spring of 1965.

Water temperature.—Water temperature is a factor in controlling organisms that maintain themselves in an aquatic environment. Brett (1956) states that salmonids have the lowest thermal tolerance of any freshwater fish, with the maximum upper lethal temperature barely exceeding 25 C (77 F). Water temperature in Round Butte appeared favorable for salmonids with a maximum of 75 F recorded at the surface on July 24, 1964 in the channel of the Deschutes Arm at area II C. Near the shoreline during diel sampling periods temperatures were up to 2 F warmer than in the channel for a given period. Although temperatures were not measured in the shoreline areas when maximums were observed elsewhere, it appears that lethal levels may have occurred for short periods in the C areas of the three arms, where the highest temperatures were recorded. The minimum water temperature was 38 F on January 7, 1965 in the Deschutes Arm.

Figures 5, 6, and 7 show representative seasonal temperature profiles for the Metolius, Deschutes, and Crooked river arms, respectively. All three graphs show the area just above the dam. The diagrams show the increase in length and depth of the impoundment as it filled. Designations IA, IIA, and IIIA refer to the three rivers regardless of reservoir length. Variations in the bottom contour are due to differences in the sampling positions for a given station between observations. Temperatures ranged from 52 F at the surface of the reservoir to 42 F at mid-depths in

① Data courtesy of U. S. Geological Survey. Water year runs from October through September.

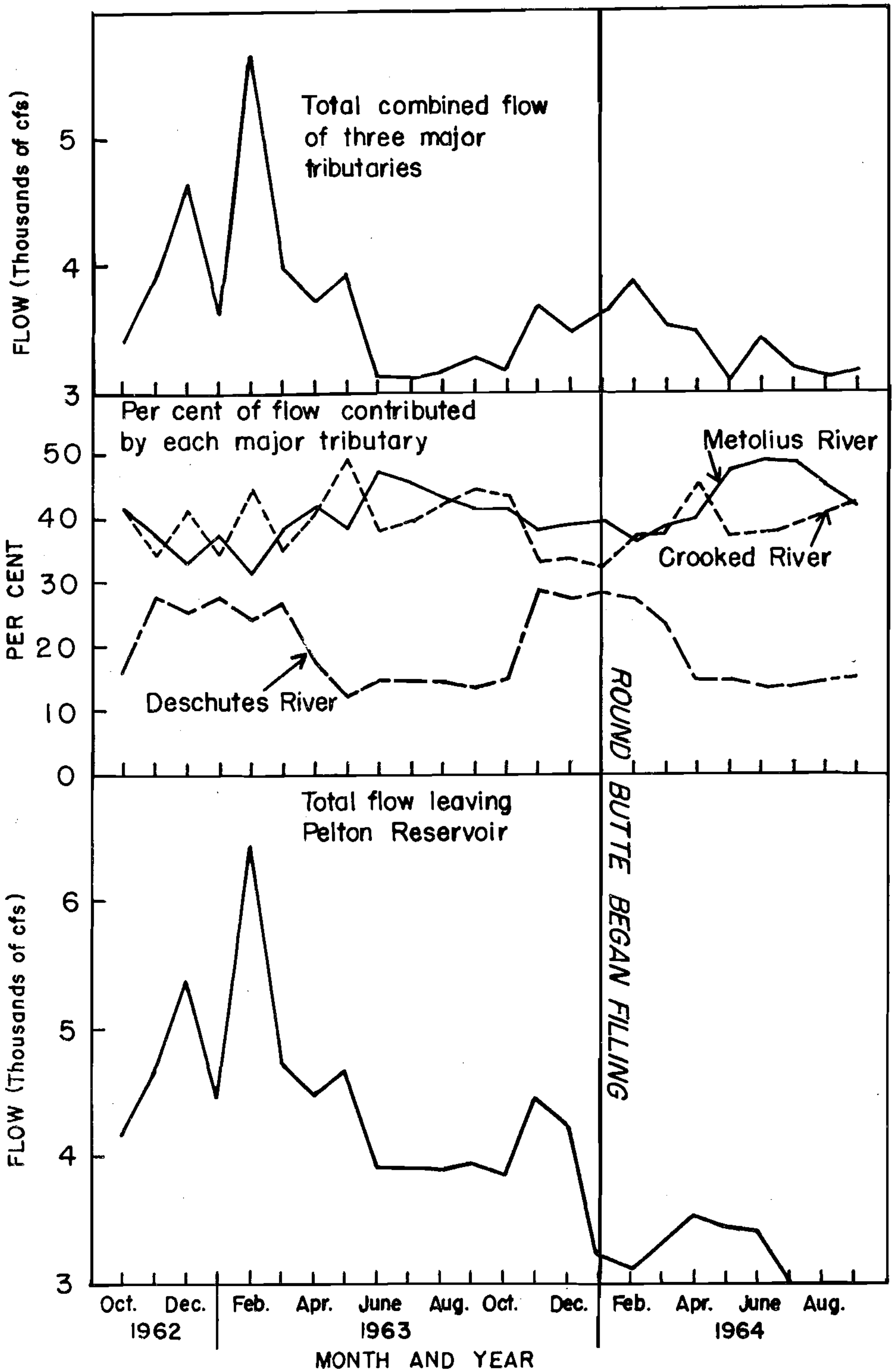

Figure 4—*The monthly average of the mean daily flows of the Deschutes, Metolius, and Crooked rivers combined, the percentage of the total contributed by each, and their combined discharge at Pelton Dam, October 1962-September 1964.*

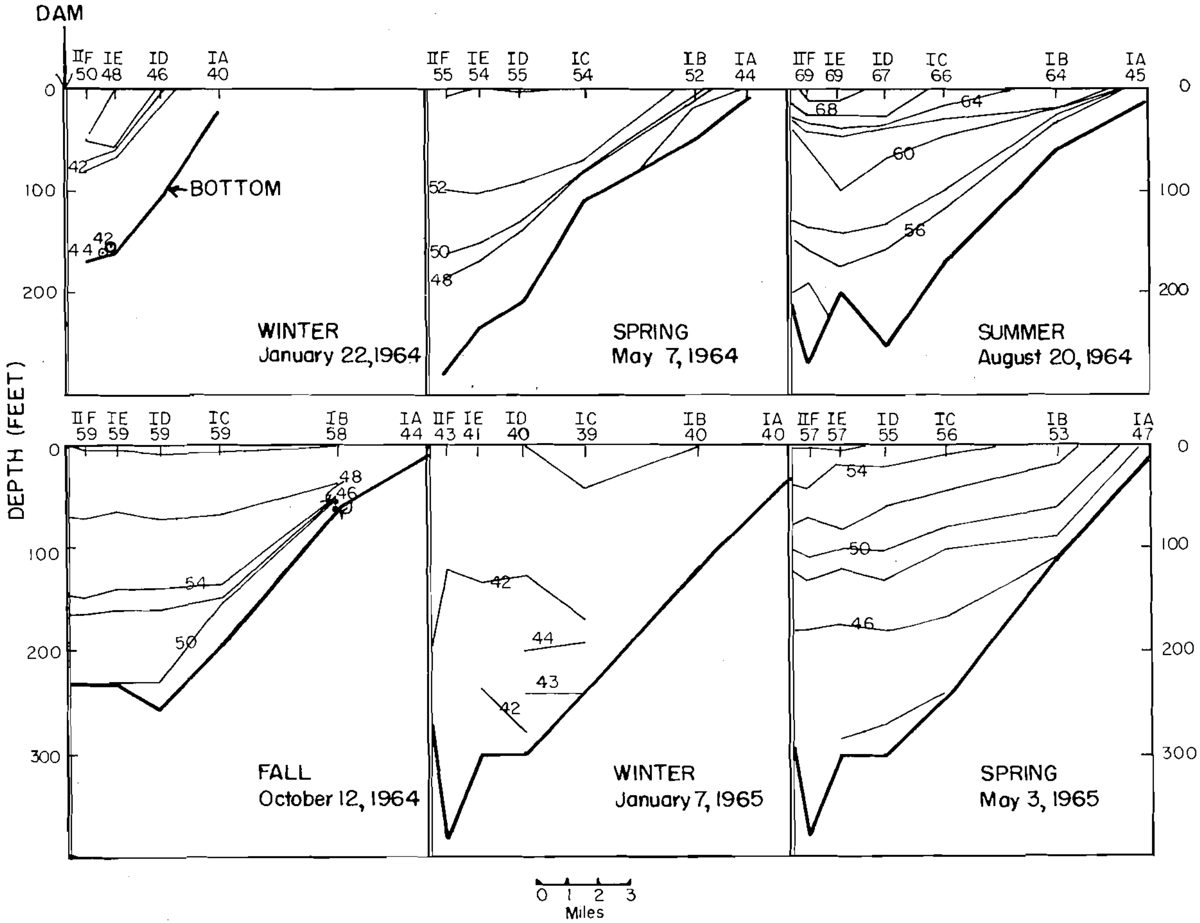

Figure 5—*Seasonal water temperature profiles by 2 F isotherms, Metolius Arm of Round Butte Reservoir, January 1964-May 1965.*

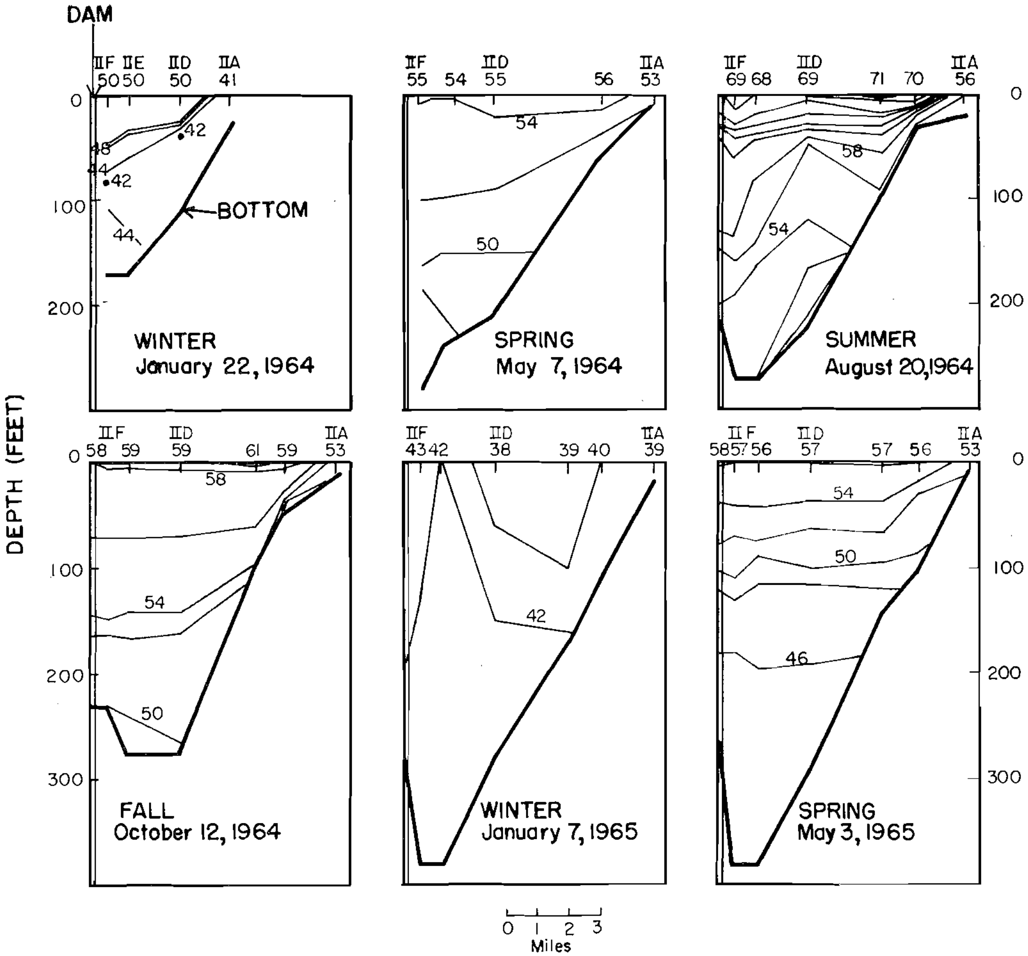

Figure 6—*Seasonal water temperature profiles by 2 F isotherms, Deschutes Arm of Round Butte Reservoir, January 1964-May 1965.*

January 1964, shortly after closure of the diversion tunnel, due to the relatively warm water of the Crooked River overlying the cooler water of the Metolius and Deschutes rivers. Water was weakly stratified in all arms during the spring of 1964 with temperatures generally in the mid-50's at the surface and high 40's near the bottom. In May the inflow from the Deschutes and Crooked rivers was noticeably warmer at 53 and 56 F, respectively, than that of the Metolius at 44 F. Maximum surface temperatures were generally in the low 70's and the Deschutes, Crooked, and lower Metolius arms were stratified during August 1964, but the surface water of the upper Metolius Arm was only 64 F and this area was only weakly stratified due to the significantly cooler inflow from the river. Minimum

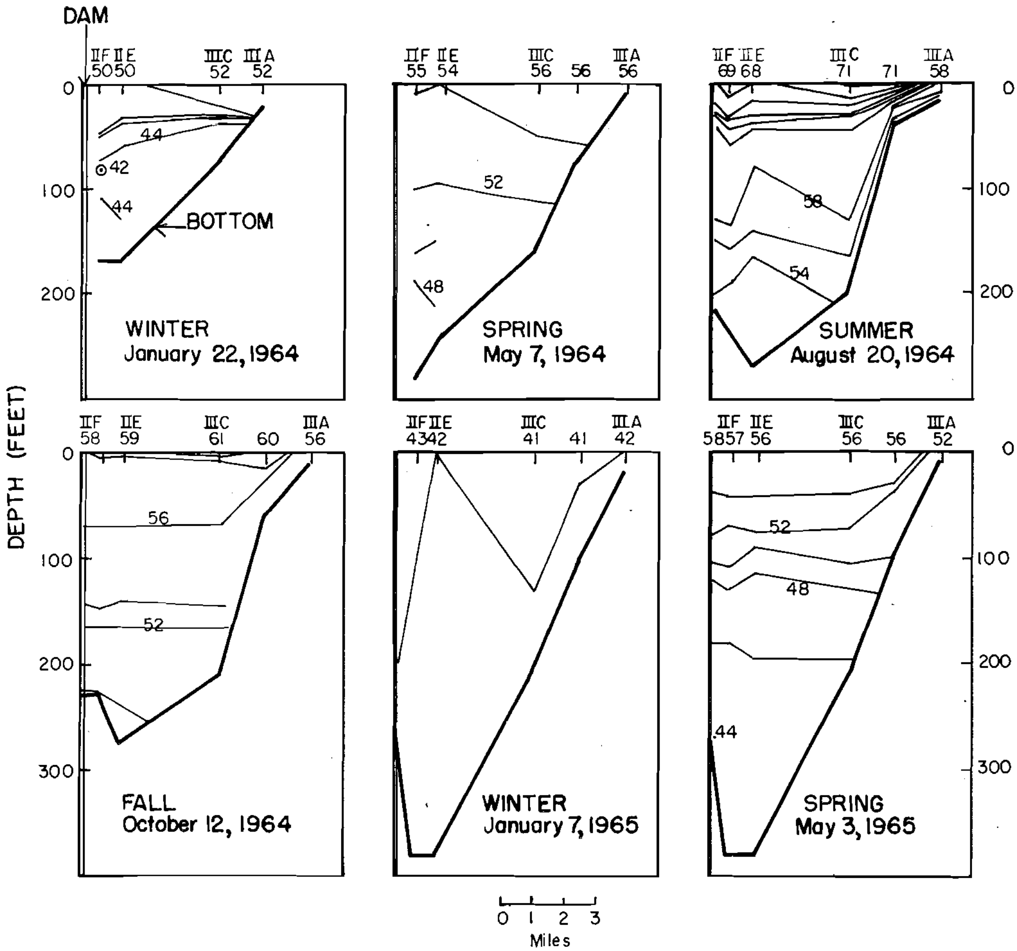

Figure 7—*Seasonal water temperature profiles by 2 F isotherms, Crooked Arm of Round Butte Reservoir, January 1964-May 1965.*

temperatures near the bottom of each arm were in the mid-50's. Temperatures cooled throughout the reservoir in October 1964, ranging from the high 50's at the surface to low 50's at the bottom. The inflow of large volumes of cold water during the floods of December 1964 and January 1965 resulted in surface temperatures ranging from 38 to 43 F, significantly colder than the 46 to 52 F temperatures found in the reservoir in January 1964. Temperature inversion occurred in the winter of 1964-65 because of the heavy silt load in the Crooked River, which was somewhat warmer and more alkaline than the other two streams. Near the bottom of the reservoir, temperatures were then up to 5 F higher than those at the surface. In the spring of 1965 surface temperatures were up to 3 F higher than in the spring of 1964, and the Metolius was again several degrees colder than the other two rivers.

Turbidity.—Turbidity measurements at times identified water masses in Round Butte Reservoir. This is illustrated by seasonal values from each river and a station (II F) near the dam (Table 2). The turbidity of the three rivers was nearly the same, ranging from 0 to 3.0 ppm SiO_2 throughout 1964. Measurements at the surface in Area II F averaged slightly higher

Table 2—*Seasonal turbidity in ppm SiO_2 from the Metolius, Deschutes, and Crooked rivers and the forebay of Round Butte Reservoir.*

	SiO_2, readings by depth①				
	Surface	Thermocline		Bottom	
Season and area		Depth (feet)	Value	Depth (feet)	Value
1964					
Winter (January)					
Metolius River	3.0				
Deschutes River	......				
Crooked River	......				
Forebay	7.5	45	6.0	130	125.0
Spring (May)					
Metolius River	1.25				
Deschutes River	1.25				
Crooked River	1.25				
Forebay	1.75	160	2.0	275	2.25
Summer (August)					
Metolius River	2.5				
Deschutes River	1.0				
Crooked River	1.0				
Forebay	2.5	25	2.5	230	5.0
Fall (October)					
Metolius River	0.0				
Deschutes River	0.0				
Crooked River	0.0				
Forebay	2.5	30	1.0	220	0.5
1965					
Winter (January)					
Metolius River	4.5				
Deschutes River	19.5				
Crooked River	360.0				
Forebay	28.5	No thermocline		300	525.0
Spring (May)					
Metolius River	0.0				
Deschutes River	1.0				
Crooked River	33.0				
Forebay	9.0	50	10.0	300	5.5

① Readings from the rivers were uniform from surface to bottom and are all indicated under the heading "Surface."

than in the rivers. The value of 125 ppm from the bottom depth in January 1964 was probably caused by continued construction of Round Butte Dam. In January 1965, the turbidity was 4.5, 19.5, and 360.0 ppm in the Metolius, Deschutes, and Crooked rivers, respectively. At II F, the surface value was 28.5 ppm and the bottom 525 ppm suggesting that either the turbid Crooked River was forming the bottom layer of water or that silt was settling to the bottom. Water in all areas cleared by May 1965, but the Crooked River remained significantly more turbid than the Metolius or Deschutes.

Water transparency.—Water transparency as measured by a Secchi disc is affected by particulate matter such as silt, sand, plankton, and detritus. Transparency (Table 3) ranged from a low of 0.3 foot in the Crooked River to a high of 40.0 feet in the Metolius, which was usually the clearest. Minimum values for the entire reservoir were recorded between January and March 1965 and appeared to be due to silt brought by high water. The middle of the Crooked River Arm (Area III B) was turbid longer than other areas in the reservoir; while the upper Metolius Arm (Area I A) was always relatively clear, even during high flows in early 1965.

Water currents.—Currents were studied to determine if there was a specific pattern of water movement in the reservoir and whether the pattern of discharge from the dam and wind direction and velocity had an effect upon the movement. Currents were measured at irregular intervals in each of the three arms by suspending drogues at depths of 2 and 20 feet. Drogues at both depths moved in the same direction on 21 of 24 observations and the pattern of discharge at the dam did not have a perceptible influence on the surface water currents (Table 4). Generally, currents moved in the same direction as the wind. Since wind currents commonly moved up the Metolius River Arm, surface water currents generally went in the same direction. When the wind was calm or moving down the Deschutes River Arm, water currents also moved in that direction. Water flowed up the Deschutes Arm only when moderate winds blew up that arm. An up-reservoir water current occurred in the Crooked River Arm on January 4, 1965 (Figure 8), when the more heavily silted Crooked River (Table 2) formed the lower layer in the reservoir, forcing the Metolius and Deschutes rivers to flow on the surface as indicated by water temperatures measured on January 7, 1965 (Figures 5, 6, and 7). Observations in June 1965 (Figure 9) illustrate the patterns of water movement most commonly found in Round Butte, except that slight upstream currents were often observed in the Metolius Arm just above its confluence with the Deschutes Arm. Strong upstream currents occurred in the upper and middle Metolius arms, while those in the Crooked River Arm and forebay moved downstream.

Chemical Factors

Total alkalinity.—Total alkalinity in the Metolius, Deschutes, and Crooked rivers ranged between 33 and 48 ppm, 38 and 70 ppm, and 82 and 101 ppm, respectively. The Metolius and Crooked rivers did not show a seasonal pattern in their fluctuations, but total alkalinity in the Deschutes was

Table 3—*Water transparency values taken with a Secchi disc in Round Butte Reservoir, January 1964-June 1965*[1]

Date	*Metolius Arm*					*Deschutes Arm*							*Crooked Arm*		
	IA	*IB*	*IC*	*ID*	*IE*	*IIA*	*IIB*	*IIC*	*IID*	*IIE*	*IIF*	*IIG*	*IIIA*	*IIIB*	*IIIC*
1-30-64	27.0	......	......	......	7.5	20.0	......	......	20.0	25.0	11.0	......	32.0	......	32.0
2-11-64	27.0	......	28.0	......	12.5	18.5	......	......	36.0	27.0	15.0	......	36.0	......	36.0
3-19-64	40.0[2]	......	14.5	17.0	17.5	15.0	......	......	19.5	20.5	16.0	......	29.5	......	29.5
4-14-64	32.5	......	5.0	5.5	5.0	21.0	33.0	......	9.0	5.5	4.5	......	11.5	12.0	5.0
5- 7-64	33.0	21.0	13.5	12.5	12.0	25.0	6.0	......	11.5	10.5	10.5	......	32.0	29.0	16.0
6-17-64	20.5	14.5	9.5	9.5	9.5	27.0	8.0	......	8.5	9.0	8.0	......	19.5	8.0	9.0
7-24-64	21.5	22.0	13.0	13.0	15.0	25.0	25.0	12.0	16.0	14.0	14.0	......	22.0	15.0	11.5
8-20-64	13.0	8.0	8.0	8.0	8.0	21.0	8.0	7.0	9.0	8.0	5.0	......	21.0	4.0	8.0
9-23-64	16.5	13.0	12.0	11.5	12.0	28.0	7.0	6.0	10.5	11.5	12.0	12.0	8.5	7.0	28.0
10-12-64	30.0	6.0	9.5	10.0	9.0	33.0	8.0	8.0	9.0	9.5	9.0	9.0	33.0	3.0	9.5
11-12-64	28.0	11.0	16.0	18.0	16.0	19.0	11.0	12.0	15.0	15.0	15.0	16.0	......	......	15.0
12- 9-64	35.0	25.0	27.0	26.0	28.0	10.0	20.0	20.0	23.0	25.0	25.0	26.0	8.0	9.0	12.0
1- 7-65	14.0	**5.0**	4.0	**3.0**	**3.0**	10.0	5.5	**2.0**	**2.0**	3.0	**3.0**	**2.0**	**0.3**	**1.0**	2.0
2- 3-65	**9.0**[3]	8.0	**3.5**	4.0	4.0	**3.0**	**3.0**	**2.0**	2.5	5.0	5.0	5.0	0.5	2.5	3.0
2-23-65	27.0	12.0	6.0	6.5	6.0	5.0	10.0	6.0	5.5	6.5	6.0	5.0	1.0	**1.0**	......
3- 8-65	30.0	30.0	11.0	11.0	7.0	9.0	12.0	12.0	7.0	**2.0**	7.0	7.0	1.5	1.5	**1.0**
3-22-65	30.0	30.0	7.5	4.0	5.0	9.0	14.0	12.0	4.0	4.0	4.0	4.0	4.5	2.5	4.0
4- 5-65	25.0	7.0	5.5	5.0	5.0	11.0	13.0	12.0	6.0	5.0	5.0	5.0	2.0	2.0	3.0
4-22-65	20.0	9.0	5.5	4.5	4.0	14.5	15.5	4.5	4.0	5.0	4.0	3.5	2.0	2.0	4.0
5- 3-65	10.0	7.0	5.0	5.0	5.0	11.0	6.0	5.0	6.0	5.0	4.5	5.0	2.0	3.5	5.0
5-17-65	27.0	12.0	12.0	12.0	12.5	12.0	15.0	15.0	14.0	15.0	13.0	8.0	10.5	9.5	15.0
6- 1-65	25.0	10.5	13.5	15.0	16.0	25+	26.0	21.5	19.0	16.5	18.0	18.0	18.0	15.0	21.0
6-28-65	25.0	13.0	12.0	10.0	11.0	13+	8.0	9.0	15.0	15.0	12.0	13.0	10.0	5.0	9.0

[1] Measurements in feet.
[2] Maximum transparency values are underlined.
[3] Minimum transparency values in bold type.

Table 4—*Pattern of discharge at the dam, wind direction and velocity, and direction of surface water currents in Round Butte Reservoir.*

Arm of res.	*Area within each arm*	*Date*	*Discharge*	*Wind Direction*①	*Wind Velocity*	*Direction of water currents*
Metolius Arm (I)	A	6-24-65	Constant	Upstream	Slight	Upstream
	B	4-30-64	Irregular	Variable	Slight	Downstream
	B	5-11-64	Constant	Upstream	Slight	Upstream
	C	4-30-64	Irregular	Variable	Moderate	Upstream
	C	12- 2-64	Increase	Calm	....	Upstream
	C	6-24-65	Constant	Upstream	Slight	Upstream
	E	5- 1-64	Constant	Upstream	Strong	Upstream
	E	5-14-64	Constant	Upstream	Slight	Upstream
	E	12- 3-64	Decrease	Downstream	Slight	Upstream
	E	6-24-65	Constant	Upstream	Slight	Downstream (slowly)
Deschutes Arm (II)	D	1- 4-65	Constant	Calm	....	Downstream
	D	3-24-65	Irregular	Upstream	Moderate	Upstream
	E	5- 1-64	Constant	Downstream	Strong	Downstream
	E	5-14-64	Constant	Downstream	Slight	Downstream
	E	12- 3-64	Decrease	Upstream	Moderate	Upstream
	E	6-25-65	Irregular	Calm to Up	Slight	Downstream
	F	5- 1-64	Constant	Downstream	Strong	Downstream
	F	5-14-64	Constant	Upstream	Moderate	Upstream
	F	4- 2-65	....	Calm	....	Downstream
	G	6-11-65	....	Calm	....	Downstream
	G	6-11-65	Increase	Calm	....	Downstream
Crooked Arm (III)	C	1- 4-65	Constant	Calm to down	Moderate	Upstream
	C	3-24-65	Constant	Upstream	Slight	Downstream
	C	6-25-65	Irregular	Calm	....	Downstream

① Relative to the reservoir.

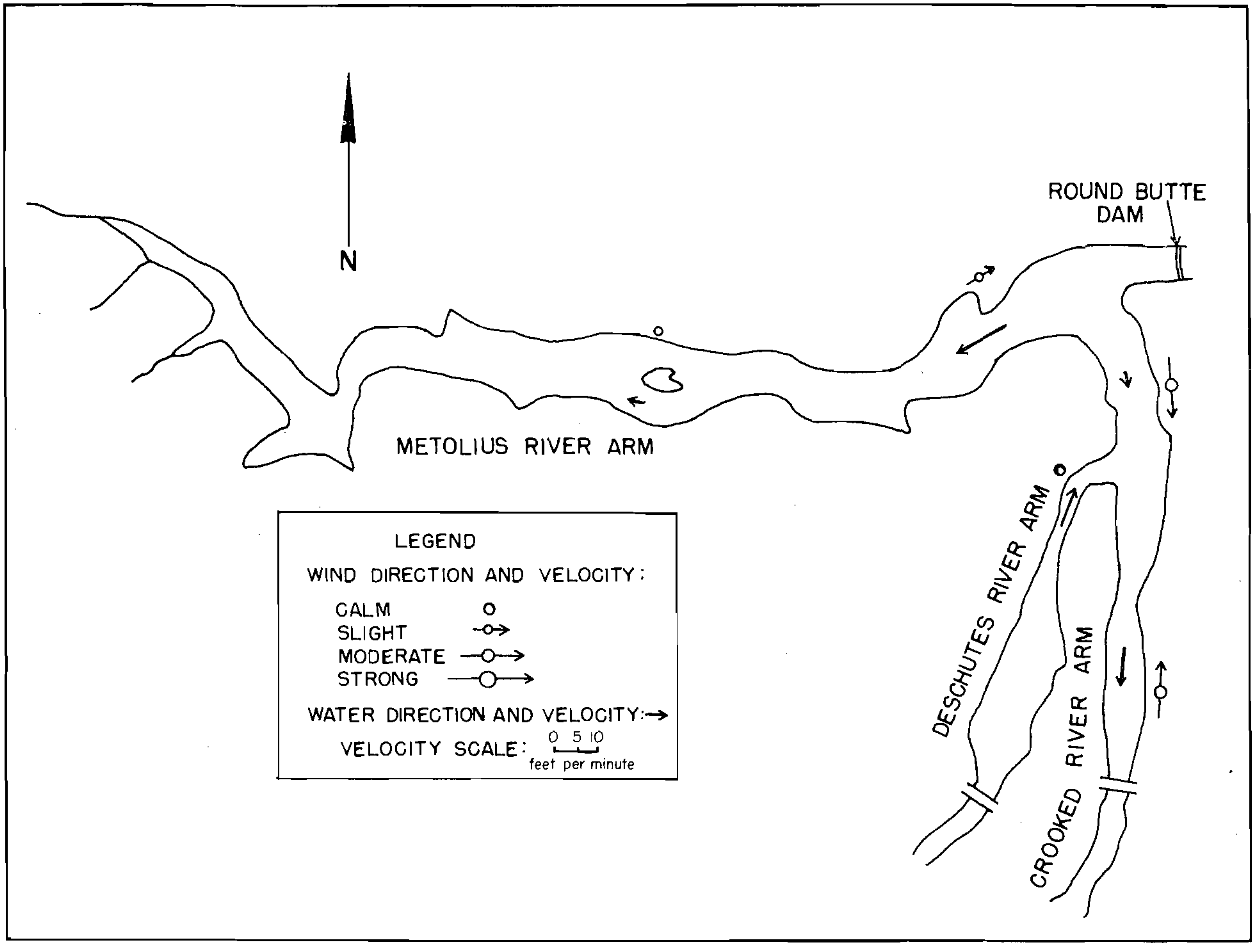

Figure 8—*The direction and approximate velocity of surface water and wind currents, Round Butte Reservoir, December 2 and 3, 1964 and January 5, 1965.*

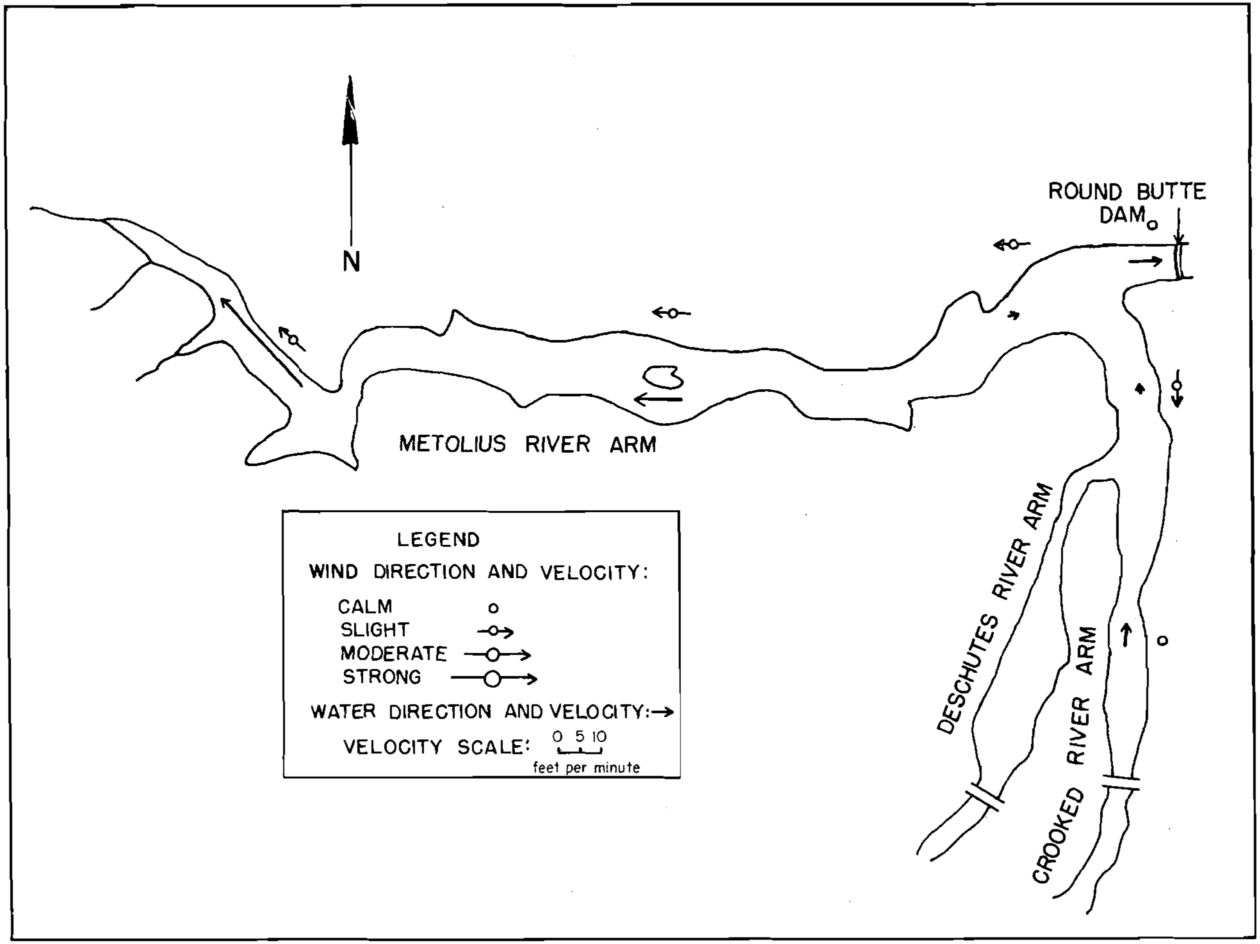

Figure 9—*The direction and approximate velocity of surface water currents and wind, Round Butte Reservoir, June 11, 24, and 28, 1965.*

lowest during the winter (Table 5). Generally alkalinities in the reservoir were highest at the surface and lowest near the bottom; however, the reverse occurred in January 1965 after a flood. It appeared that prior to January 1965 the surface water in the forebay (II F) came primarily from the Crooked River. Alkalinity may be a good indicator of the source of water masses in the reservoir even though mixing was apparent.

Dissolved oxygen.—The dissolved oxygen content in Round Butte Reservoir ranged between 0.0 and 16.0 ppm. The low value was recorded from the hypolimnion in area C of the Crooked River Arm in July 1964, and

Table 5—*Representative seasonal values of total alkalinity in ppm from the Metolius, Deschutes, and Crooked rivers and the forebay of Round Butte Reservoir.*

	*Alkalinity readings by depth*①				
	Surface	*Thermocline*		*Bottom*	
Season and area		*Depth (feet)*	*Value*	*Depth (feet)*	*Value*
1964					
Winter (January)					
Metolius River	38				
Deschutes River	....				
Crooked River	....				
Forebay	82	45	83	130	62
Spring (May)					
Metolius River	37				
Deschutes River	64				
Crooked River	82				
Forebay	87	160	66	275	51
Summer (August)					
Metolius River	37				
Deschutes River	69				
Crooked River	94				
Forebay	90	25	86	230	68
Fall (October)					
Metolius River	39				
Deschutes River	70				
Crooked River	97				
Forebay	92	30	92	220	62
1965					
Winter (January)					
Metolius River	38				
Deschutes River	40				
Crooked River	90				
Forebay	66	No thermocline		300	73
Spring (May)					
Metolius River	36				
Deschutes River	61				
Crooked River	98				
Forebay	81	50	78	300	60

① Readings from the rivers were uniform from surface to bottom and are all indicated under the heading "Surface."

the high at the surface of area E in the Deschutes River Arm in April 1964. A level of 6.4 ppm or greater was maintained in the epilimnion and thermocline for all sampling stations and periods. Table 6 shows representative seasonal values of dissolved oxygen in the Metolius, Deschutes, and Crooked rivers and the forebay of Round Butte Reservoir. Oxygen concentrations in the rivers were 9.0 ppm or higher throughout the study, with the lowest values usually found in the Crooked River. Throughout 1964, similar and relatively high oxygen values were found at the surface

Table 6—*Representative seasonal values of dissolved oxygen from the Metolius, Deschutes, and Crooked rivers and the forebay of Round Butte Reservoir.*

	*Ppm of oxygen by depth*①				
	Surface	*Thermocline*		*Bottom*	
Season and area		*Depth (feet)*	*Value*	*Depth (feet)*	*Value*
1964					
Winter (January)					
Metolius River	11.5				
Deschutes River	11.5				
Crooked River	10.0				
Forebay	10.0	50	10.0	130	10.5
Spring (May)					
Metolius River	10.6				
Deschutes River	10.6				
Crooked River	10.4				
Forebay	10.4	160	8.6	275	9.6
Summer (August)					
Metolius River	10.2				
Deschutes River	10.0				
Crooked River	10.2				
Forebay	9.8	25	9.0	230	5.8
Fall (October)					
Metolius River	10.8				
Deschutes River	9.0				
Crooked River	9.6				
Forebay	11.6	30	10.0	220	6.0
1965					
Winter (January)					
Metolius River	11.2				
Deschutes River	11.8				
Crooked River	11.4				
Forebay	10.6	No thermocline		300	10.4
Spring (May)					
Metolius River	11.2				
Deschutes River	10.0				
Crooked River	10.4				
Forebay	11.2	50	8.4	300	10.2

① Readings from the rivers were uniform from surface to bottom and are all indicated under the heading "Surface."

and in the thermocline of the forebay, while those near the bottom dropped to less than 6.0 ppm in the summer. Davison (1954) showed that young coho salmon *(Oncorhynchus kisutch)* can live and grow with a dissolved oxygen of 3 ppm under controlled conditions at 64 F. Indications were that dissolved oxygen was generally adequate for salmonid life in most areas in Round Butte Reservoir throughout the study period; possible exceptions were the hypolimnion of areas C in the Crooked Arm and D of the Deschutes Arm where respective concentrations of 0.0 and 3.0 ppm were found during the summer of 1964.

pH.—Doudoroff and Katz (1950) concluded from a literature survey that most, if not all, fully developed fresh-water fish can live indefinitely in waters with a pH between 5.0 and 9.0. The pH in Round Butte Reservoir usually ranged from 7.75 to 8.75 with extremes of 7.25 and 9.25. Generally, the Metolius River had the lowest and the Crooked River the highest pH (Table 7). As with total alkalinity, the highest pH values were usually

Table 7—*Representative seasonal values of pH from the Metolius, Deschutes, and Crooked rivers and the forebay of Round Butte Reservoir.*

Season and area	pH readings by depth①				
	Surface	Thermocline		Bottom	
		Depth (feet)	Value	Depth (feet)	Value
1964					
Winter (January)					
Metolius River	7.75				
Deschutes River	7.75				
Crooked River	8.25				
Forebay	8.0	50	8.0	130	7.75
Spring (May)					
Metolius River	7.75				
Deschutes River	8.25				
Crooked River	8.25				
Forebay	8.75	160	8.25	275	8.25
Summer (August)					
Metolius River	8.25				
Deschutes River	8.75				
Crooked River	8.25				
Forebay	8.75	25	8.25	230	8.25
Fall (October)					
Metolius River	7.75				
Deschutes River	8.25				
Crooked River	8.00				
Forebay	8.75	30	8.75	220	7.75
1965					
Winter (January)					
Metolius River	7.75				
Deschutes River	7.75				
Crooked River	8.25				
Forebay	7.75	No thermocline		300	8.25
Spring (May)					
Metolius River	7.75				
Deschutes River	8.25				
Crooked River	8.25				
Forebay	8.75	50	7.75	300	7.75

① Readings from the rivers were uniform from surface to bottom and are all indicated under the heading "Surface."

found at the surface and the lowest near the bottom of the reservoir; however, the high value observed in Round Butte was near the bottom of area D in the Deschutes Arm in February 1964. In January 1965, pH near the bottom of the reservoir was indentical to that in the Crooked River, but it was lower at the surface. This occurrence further indicated that Crooked River water formed the lower strata of the reservoir at that time.

Biological Factors

The biological factors studied consisted of benthic fauna, zooplankton, food preferences of salmonids, and species composition of fish. Diel information for zooplankton and food preferences of fish was obtained and analyzed for the day, dusk, dark, and dawn periods, but is presented only for the dusk and dawn periods. Occasional references will be made to the other periods. Only information from coho stomachs will be utilized in discussing food preference since small numbers of chinook *(O. tshawytscha)* and steelhead *(Salmo gairdneri)* were collected.

Benthic fauna.—The macrobenthos collected in Round Butte Reservoir consisted entirely of Diptera. The occurrence of this order and no others may be attributed to the newness of the reservoir. The benthos of Pelton Reservoir, formed several years earlier, consisted mainly of Oligochaeta and relatively small numbers of Diptera.

Zooplankton.—Cladocera and Copepoda were present in Round Butte Reservoir during all months sampled from September 1964 through June 1965. Zooplankton were not sampled during December or January, but Cladocera and a few Copepoda were found in stomachs of salmonids in January. Fish were not collected for stomach analysis in December. In the fall, Cladocera were more numerous than Copepoda in 62% of the zooplankton samples collected during the dusk and dawn periods (Figure 10). Cladocera were never less numerous than Copepoda during this season. Small numbers of zooplankton were collected in the winter when surface water temperatures were 41 to 43 F. An increase to 51 F was paralleled by greater quantities of zooplankton in April 1965, when copepods were more abundant than cladocerans in 62% of the samples. By May the population reached its maximum density with every collection containing organisms from each order in a magnitude of three. At this time, Copepoda were always present in equal or greater numbers than Cladocera. Merrell (1957) stated that at Brooks Lake, Alaska, plankton density was greatest in early summer and decreased gradually through the summer and fall. This was also true in Round Butte. The numbers of zooplankton collected by month fluctuated similarly for the dusk and dawn sampling periods.

Food preferences of coho salmon.—Stomach samples were taken from juvenile salmonids caught in gill nets during the day and at dusk, dark, and dawn. However, analysis was limited to coho obtained at dusk and dawn. The organisms of primary abundance in the diet were Cladocera, Diptera larvae, and Copepoda. Small numbers of Diptera adults, Coleoptera, Ephemeroptera, Hemiptera, Hymenoptera, Araneae, and Tri-

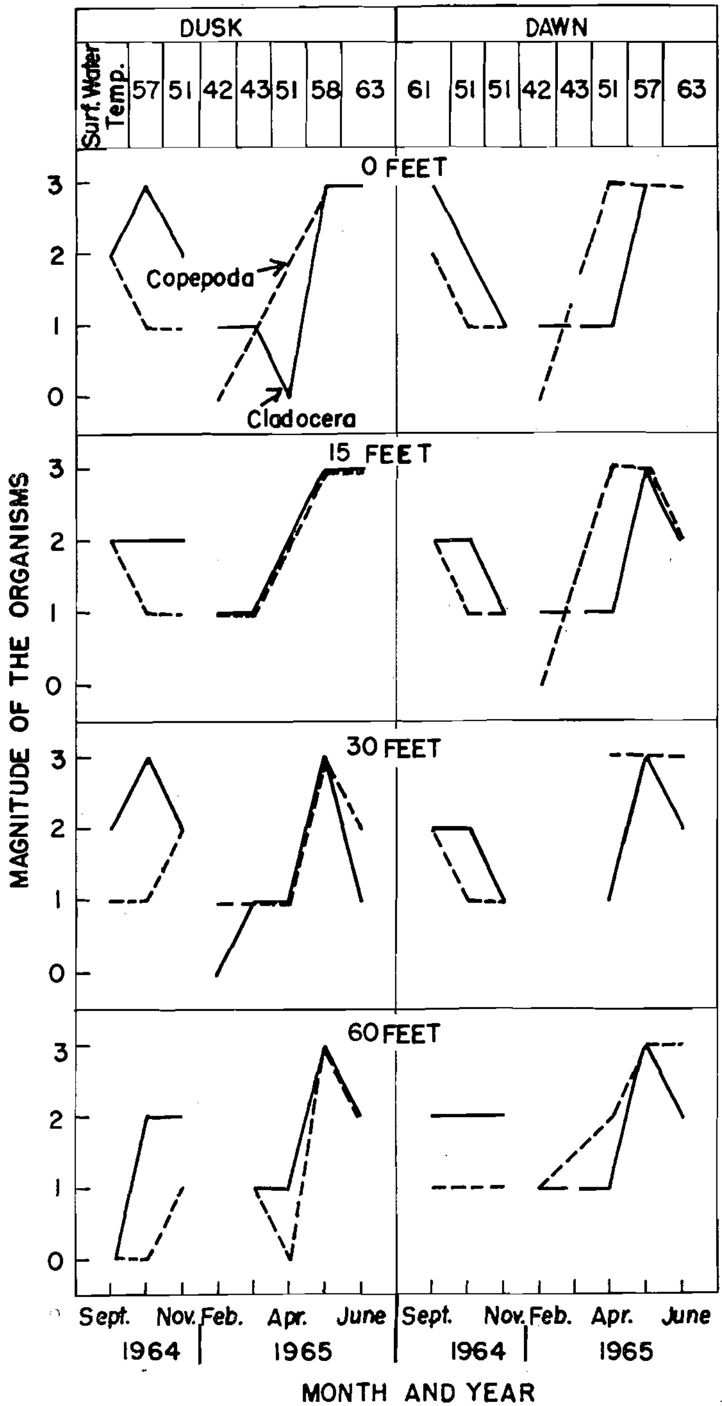

Figure 10—*The relative abundance, by month, of Cladocera and Copepoda collected at dusk and dawn from four depths in area C of the Metolius River Arm, September 1964-June 1965.*

choptera were also found. Salmon were not obtained for two dusk periods and were inadequately preserved in two dawn periods. During the rest of the time, the size of the sample varied between four and 14 fish. Results are therefore qualified by the relatively small numbers of fish stomachs in each sample.

Figure 11 shows the most frequent magnitude of major organisms found in coho stomachs and percentage of stomachs containing each of the major organisms at dusk and dawn in each monthly sample. More fish with empty stomachs were collected in October than any other month, and they were generally more numerous at dawn than at dusk. Diptera larvae were ingested by a large percentage of coho in January and April compared to other months. Fewer fish consumed Cladocera and Copepoda in January than in any other month, possibly due to the low abundance of organisms at that time. In February the percentage of fish eating Diptera decreased, and those eating zooplankton increased. Consumption of food organisms was greater in April than in any other month; no empty stomachs were then found at dusk, and only one of six stomachs was empty at dawn. The apparently greater feeding activity of young fish in April may be attributed to a rise in surface water temperature from 43 to 51 F and a consequent increase in food organisms. Samples were not obtained in May, and were taken only at dusk in June. There was lesser incidence of food in coho stomachs in June than in April. Copepods were not found in stomachs collected in June even though they were at least as abundant as Cladocera (Figure 10). Although always present in zooplankton samples, copepods were absent from stomachs taken at dawn on any sampling date.

Species composition of fish.—Three floating traps were fished in Round Butte Reservoir. Generally, one was fished in the upper end of each arm, but occasionally all were in the Metolius Arm, or one was moved to a different location for a brief period. The fishing depth for the traps was 0-15 feet. Fishing effort varied, since the three traps were not fished continuously. The number of trap days was computed by accumulating the number of days all traps fished each month. The catch of each species (Table 8) varied from month to month, and during the same month in different years, for several reasons: (1) the reservoir was filling between April and December 1964 and was full the remainder of the study period; (2) the catch depended in part on the numbers of fish available to the traps, and this varied for salmonids because of the introductions of hatchery fish into the reservoir, namely, some chinook salmon and rainbow trout *(S. gairdneri)* and all of the coho; (3) scrap fish were more readily caught in summer, when they were active, than in winter, when they were dormant; and (4) large numbers of salmonids were caught during winter freshets and in the spring migration but not in late summer, when relatively high surface water temperatures often forced them below a depth of 15 feet (Korn *et al.*, 1967). For these reasons, catches in traps were probably not a good indicator of the relative abundance of each species. However, the catch seems to represent the species present in the reservoir

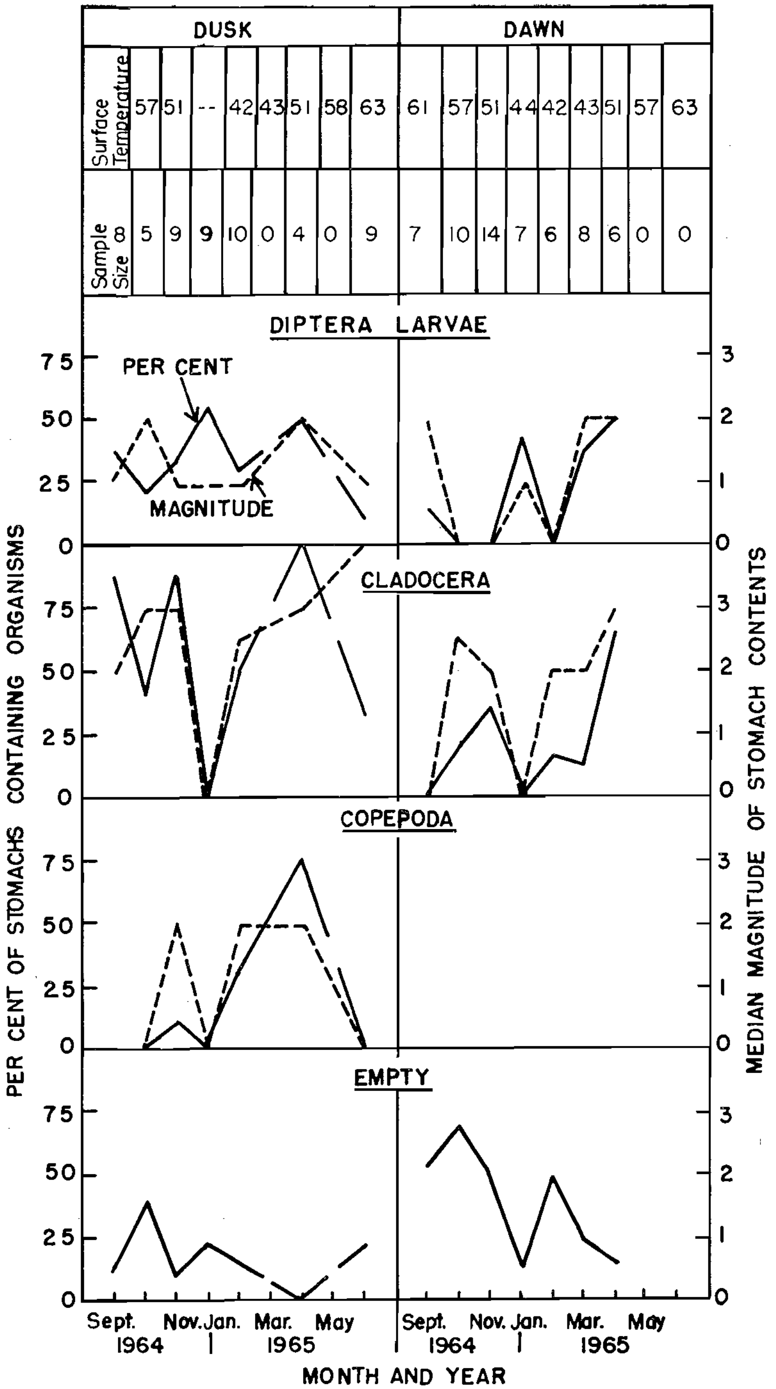

Figure 11—*Monthly percentages of feeding coho salmon and median magnitude of stomach contents by organisms ingested, Round Butte Reservoir, September 1964-June 1965.*

Table 8—*Numbers of fish caught, by species, in traps fished in Round Butte Reservoir, April 1964-May 1965.*

Year	1964									1965						
Month	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*Total*	*% of Total*
Trap-Days Fished	**30**	**42**	**79**	**12**	**12**	**42**	**42**	**42**	**12**	**47**	**70**	**90**	**52**	**87**	**659**	
Species																
Chin. Salmon—Wild	123	293	791	8	0	2	8	27	0	57	58	51	5	5	1,428	2.20
Chin. Salmon—Hatchery	11	103	937	3	3	2	1	9	1	86	41	15	3	5	1,220	1.89
Coho Salmon—Hatchery	73	660	4,331	54	0	27	87	197	3	973	558	449	194	270	7,876	12.22
Sockeye Salmon	1	0	16	0	0	0	0	0	97	1	0	0	2	9	126	0.19
Rainbow-Sthd.	427	1,364	2,247	40	54	78	100	218	20	643	177	893	381	517	7,159	11.10
Rainbow Trout—Hatchery	80	259	225	1	592	557	522	516	36	446	212	78	68	48	3,640	5.64
Rainbow Trout—Wild	126	63	97	7	57	76	111	400	97	5,065	3,484	4,923	1,256	1,110	16,872	26.18
Brown Trout	3	3	6	0	0	1	0	4	1	8	3	3	1	2	35	0.05
Dolly Varden	107	401	631	33	34	83	42	41	2	48	26	37	39	98	1,622	2.51
Whitefish	3	10	14	0	2	6	3	3	0	16	19	16	13	22	127	0.20
Squawfish	9	99	79	3	125	804	78	6	0	0	5	9	26	126	1,369	2.12
Sucker	201	235	381	52	3,179	11,177	561	128	0	6	44	31	207	1,033	17,235	26.74
Chiselmouth	7	65	150	6	280	2,594	250	299	63	28	90	164	98	85	4,179	6.48
Other①	58	81	328	31	244	273	19	27	5	163	100	125	43	63	1,560	2.42
															64,448	99.94

① Includes dace, brown bullhead, goldfish, roach, lamprey, cottids, and adult anadromous salmonids.

and suggests that suckers *(Catostomus* sp.), rainbow trout and juvenile steelhead, coho salmon, and chiselmouth *(Acrocheilus alutaceus)* were the most abundant.

CONCLUSION

Limnological differences among the Metolius, Deschutes, and Crooked rivers resulted in a varied environment in Round Butte Reservoir in all seasons. The Metolius and Crooked rivers each contributed about twice as much flow to the reservoir as the Deschutes. The Deschutes contributed less during the spring and summer than in other seasons.

Water temperatures in Round Butte generally appeared favorable for salmonids with a maximum of 75 F recorded. Temperatures differed from the surface to the bottom in all seasons; variations in winter were attributed to the relatively warm water of the Crooked River overlying colder water of the Metolius and Deschutes rivers. During spring and summer, the Metolius was noticeably colder than the Deschutes and Crooked rivers, resulting in weaker stratification in the upper Metolius Arm than in other parts of the reservoir. A heavy silt load in the Crooked River in January 1965 apparently contributed to temperature inversion in the reservoir.

The Crooked River was much more turbid than the other streams during a flood in January 1965. At that time, water near the bottom of the forebay appeared to be influenced mainly by the Crooked River as it was more turbid than surface water. Water visibility was generally higher in the Metolius than in the other rivers, and the upper Metolius Arm was always relatively clear.

Water currents at depths of 2 and 20 feet generally moved in the same direction, and were seemingly controlled by the wind. Usually, water currents in the reservoir moved up the Metolius Arm and down the Deschutes and Crooked river arms.

Total alkalinity varied among the three rivers; the Crooked River was most and Metolius least alkaline. In the reservoir, alkalinity was usually highest at the surface and lowest near the bottom. Based on alkalinity, the surface water in the forebay came primarily from the Crooked River prior to the January 1965 flood.

Dissolved oxygen concentrations appeared to be adequate for salmonid life in most areas of the reservoir throughout the study. However, some low values were found in hypolimnal areas of the Deschutes and Crooked river arms.

Diptera was the only order of macrobenthos collected in newly formed Round Butte Reservoir. Cladocera and Copepoda were present in all months sampled, but they varied seasonally in relative abundance. In the fall Cladocera were more numerous than Copepoda. Small numbers of zooplankton were found in winter, but their numbers, especially Copepoda, increased in April with rising water temperatures. Maximum density of each order of zooplankton occurred in May.

More juvenile coho salmon with empty stomachs were found in October than any other month; consumption of food organisms was greatest in April. More coho ingested Diptera larvae in January and April than in other months, and fewer fish consumed zooplankton in January than any other month. Copepods were absent from fish stomachs in June even though they were as abundant as Cladocera in the reservoir.

Suckers, rainbow and steelhead trout, coho salmon, and chiselmouth appeared to be the most abundant species of fish in Round Butte Reservoir.

ACKNOWLEDGMENTS

I wish to express my appreciation to Lawrence Korn, Project Leader, Fish Passage Research, for his guidance and assistance throughout the project; to Thomas F. Gaumer, field supervisor for the first year of the limnological study, for his initiative and dedication; and to Franklin R. Young, who worked with me during the final year of the study, for his constructive criticism and enthusiasm.

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The Relationship Between Size of Juvenile Coho Salmon and Their Time of Emigration from Three Oregon Reservoirs

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ABSTRACT

Juvenile coho salmon *(Oncorhynchus kisutch)* were captured, tagged, and released in North Fork, Pelton, and Round Butte reservoirs, and later recovered in the downstream-migrant collection facilities at each dam. Data were analyzed by area, week, and year of tagging. Regression analysis of data from North Fork and Round Butte reservoirs indicated that once emigration began, large fish remained in the reservoir less time after tagging than small fish. Results at Pelton Reservoir were inconclusive.

INTRODUCTION

The Fish Commission of Oregon studied the behavior of juvenile anadromous salmonids in North Fork, Pelton, and Round Butte reservoirs from July 1962 through June 1965 under contract with the Bureau of Commercial Fisheries. A major part of the study included tagging and releasing juvenile coho salmon *(Oncorhynchus kisutch)* in each reservoir and recovering emigrants in the collection facilities at the dams. This paper examines the relationship between the length of coho at tagging and the elapsed number of days until they emigrated from the reservoir on their seaward migration.

STUDY AREAS

North Fork Reservoir

North Fork Dam is on the Clackamas River, about 29 miles upstream from its confluence with the Willamette, in northwestern Oregon. It is the farthest upstream of a complex of three hydroelectric dams operated by the Portland General Electric Company (Figure 1). Faraday and River Mill dams are located 2 and 7 miles downstream, respectively. North Fork Reservoir, 4 miles long, is entered at the upstream end by the Clackamas River. A facility for collecting downstream migrants is provided at North Fork Dam; however, fish may also leave via the spillway and turbines. Those fish entering the collection system swim down the ladder about 1.5 miles to the "separator" where they are diverted into a trap and counted, measured, and examined for marks and tags. The fish are then released into a pipeline which discharges them below River Mill Dam.

Spring-run chinook salmon *(O. tshawytscha)* and winter-run steelhead trout *(Salmo gairdneri)* are also present in the reservoir.

Pelton Reservoir

Pelton is the lower of two dams (Figure 2) on the Deschutes River, about 103 miles upstream from its confluence with the Columbia, in central Oregon. The reservoir extends 7 miles upstream to the base of Round

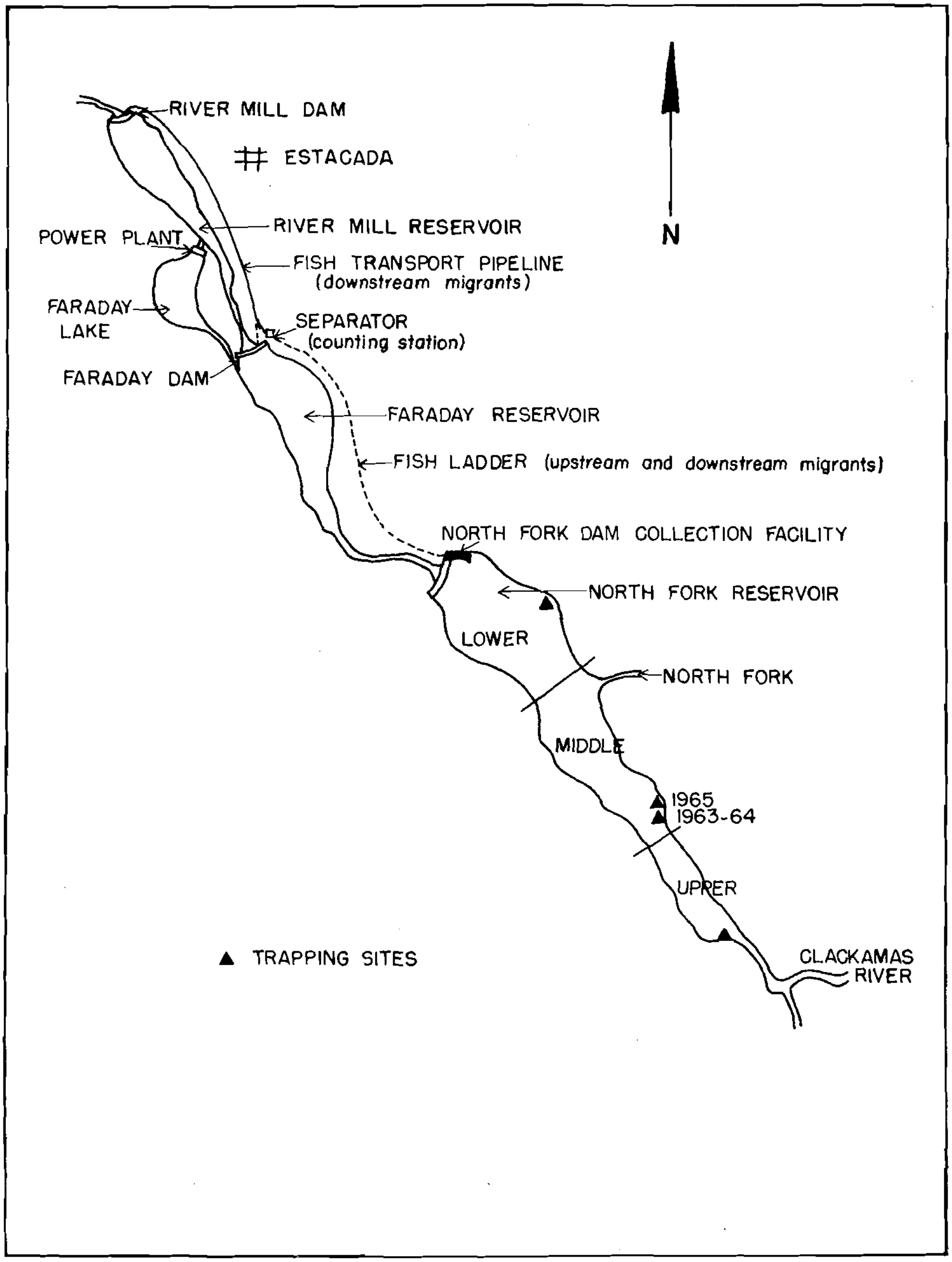

Figure 1—*Diagram of three-dam complex located on the Clackamas River.*

Butte Dam. Downstream migrants may leave Pelton via a fish collection facility at the dam, or go through the turbines or the spillway (spills are rare). A ladder provided for upstream migrants is also used by downstream migrants at Pelton.

Spring-run chinook and sockeye *(O. nerka)* salmon and summer-run steelhead trout are native to the Deschutes system. Coho salmon were introduced for study purposes.

Round Butte Reservoir

Round Butte Dam forms an impoundment composed of the Metolius, Deschutes, and Crooked River arms which at full pool level are 12, 8, and 6 miles long, respectively (Figure 2). Downstream migrants may leave the reservoir via the collection facility, or go through the turbines or the spillway (spills are rare). The reservoir was filled in December 1964 and the permanent collection facilities were used in the spring of 1965. Round Butte Reservoir contains the same species of salmonids as the Pelton impoundment.

METHODS

Fish were captured in floating Oneida Lake traps, anesthetized with MS-222, measured, and tagged. They were released at the trapping site after becoming conscious again. All fish were tagged with a 3 x 5 mm numbered green plastic pennant attached at the origin of the dorsal fin with 0.016-inch diameter solid vinyl thread. The tagging thread was applied with a number 8 embroidery needle. All tag recoveries used in the analysis came from collection facilities at the dams. Tagged fish recaptured in fishing gear in the reservoir, released, and subsequently recovered in the collection facilities, were eliminated from the analysis since they may have been delayed in emigrating.

We were primarily concerned with determining the relationship, if any, between the size of fish during spring migration (generally April through June) and the length of time they subsequently spent in the reservoir prior to emigrating. However, we also tried to determine if fish tagged prior to spring migration reacted like those tagged during the spring. As a result, the analysis included coho tagged and recaptured from January 1 to July 1 of each year. Generally fish were tagged each week during that period. Week of tagging was numbered as shown in Table 1.

Each reservoir was divided into areas for analysis of data since distances between tagging locations and collection facilities varied. North Fork Reservoir was divided into three areas (Figure 1); however, since few coho tagged in the upper area were recovered, these data were deleted from the analysis. Adequate data were collected from fish tagged in the other 2 areas in each of the 3 years (1963, 1964, and 1965) studied. Pelton and Round Butte were also divided into several areas, but sufficient recoveries for analysis were obtained from only one tagging location and 1 year in each of these impoundments.

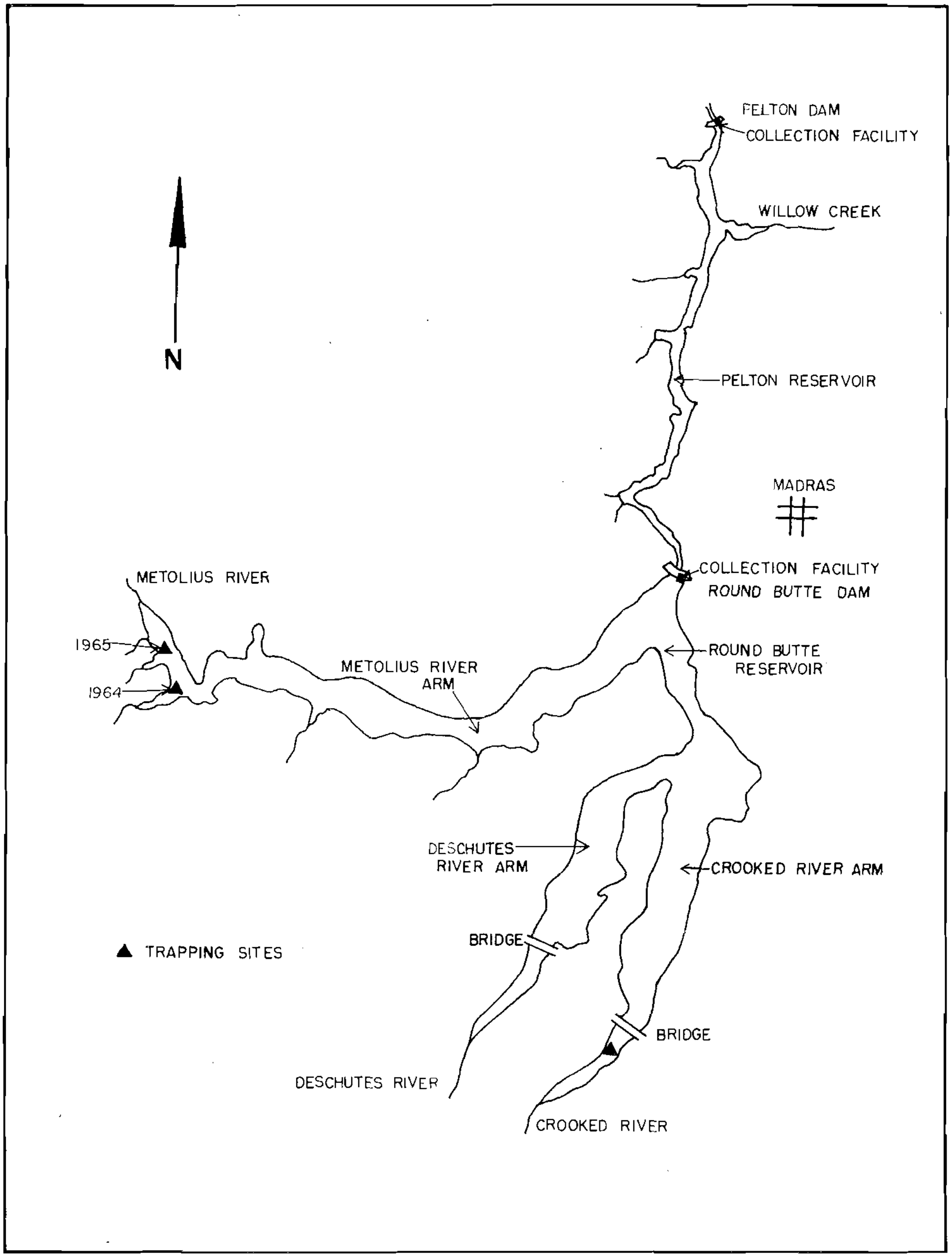

Figure 2—*Diagram of Pelton and Round Butte reservoirs.*

Table 1—*Tagging weeks for 1963, 1964, and 1965.*

Week No.	1963	1964	1965
3	1/13-19	1/12-18	1/10-16
4	1/20-26	1/19-25	1/17-23
5	1/27-2/2	1/26-2/1	1/24-30
7	2/10-16	2/9-15	2/7-13
8	2/17-23	2/16-22	2/14-20
10	3/3-9	3/1-7	2/28-3/6
11	3/10-16	3/8-14	3/7-13
12	3/17-23	3/15-21	3/14-20
13	3/24-30	3/22-28	3/21-27
14	3/31-4/6	3/29-4/4	3/28-4/3
15	4/7-13	4/5-11	4/4-10
16	4/14-20	4/12-18	4/11-17
17	4/21-27	4/19-25	4/18-24
18	4/28-5/4	4/26-5/2	4/25-5/1
19	5/5-11	5/3-9	5/2-8
20	5/12-18	5/10-16	5/9-15
21	5/19-25	5/17-23	5/16-22
22	5/26-6/1	5/24-30	5/23-29
23	6/2-8	5/31-6/6	5/30-6/5
24	6/9-15	6/7-13	6/6-12

RESULTS

We collected data on three variables that might have influenced the number of days which tagged coho were at liberty between release and recovery. The variables were: (1) length of fish at tagging, (2) area released, and (3) week tagged. Multiple variable regression analysis comparing the three variables with number of days between tagging and recovery was processed by computer at Oregon State University.

North Fork Reservoir

At North Fork Reservoir, we compared length of fish at tagging and area of tagging with the number of days from tagging until recovery (days out) for each year. A total of 3,780 observations was included. A significant negative relationship existed in all instances except that between tagging area and days out in 1963 (Table 2). Calculated regression lines and mean days out by length of fish at tagging are plotted in Figure 3 and show that large juvenile coho spent fewer days in the reservoir between tagging and recovery than small juvenile coho. Tests comparing areas of tagging with days out indicated significant differences between tagging sites in the time fish were at liberty during 2 of the 3 years (Table 2). The differences were due in part to variation in the distance traveled by fish tagged in different parts of the reservoir. These results indicated that the data should be treated separately by tagging area to determine if the length of fish at tagging was related to the time they subsequently spent in the reservoir.

We also felt it necessary to determine if the relationships between length of fish at tagging and subsequent days out until collection were similar for the 3 years. Analysis of covariance (Table 3) indicated significant differences among years. Therefore the data were separated by year of tagging for further analysis.

Table 2—*Results of regression analysis comparing length of juvenile coho salmon at time of tagging with the elapsed days until recovery at the collection facilities at North Fork Dam, by area of tagging, January 1-July 1, 1963-65.*

Year	*Statistic*	*Comparison of length at tagging and days out*	*Comparison of area of tagging and days out*	*Number of observations*
	F	739.5	1.8	
1963	b	−1.8294	−3.2299	1,055
			Not significant	
	F	425.0	28.6	
1964	b	−1.2525	−7.8820	1,497
	F	770.0	277.6	
1965	b	−1.1068	−29.0770	1,228

$F_{.05}$=3.8 with 1 and ∞ d.f.

Table 3—*Results of analysis of covariance testing for differences among three years of the study in the relationship between size of coho at tagging and days out, North Fork Dam, 1963-65.*

Source of variation	*SS*	*D.f.*	*M.S.*	*F*	*Conclusion*
Regression due to $\bar{b}$	1,494,612	1	1,494,612	1,677	Significant
Variation among b's	66,612	2	33,306	37.4	Significant
Pooled residual	3,362,154	3,774	891		
Within sample	4,923,378	3,777			

$F_{.05}$=254.3 with 1 and ∞ d.f. and 19.5 with 2 and ∞ d.f

The mean length of juvenile coho generally increased in successive weeks of tagging (Figure 4). In order to eliminate the effect that changing size composition may have had, we analyzed the data by week of tagging and chose 3 selected weeks for presentation: week 7, prior to the normal period of smoltification; week 16, during smoltification and at the beginning of emigration; and week 21, when most fish appeared smolted and emigration neared its peak.

Regressions comparing size of fish with number of days out for each of the 3 tagging weeks, by area and year, are shown in Figure 5. The results for fish tagged in week 7 were not significant; i.e., there was no

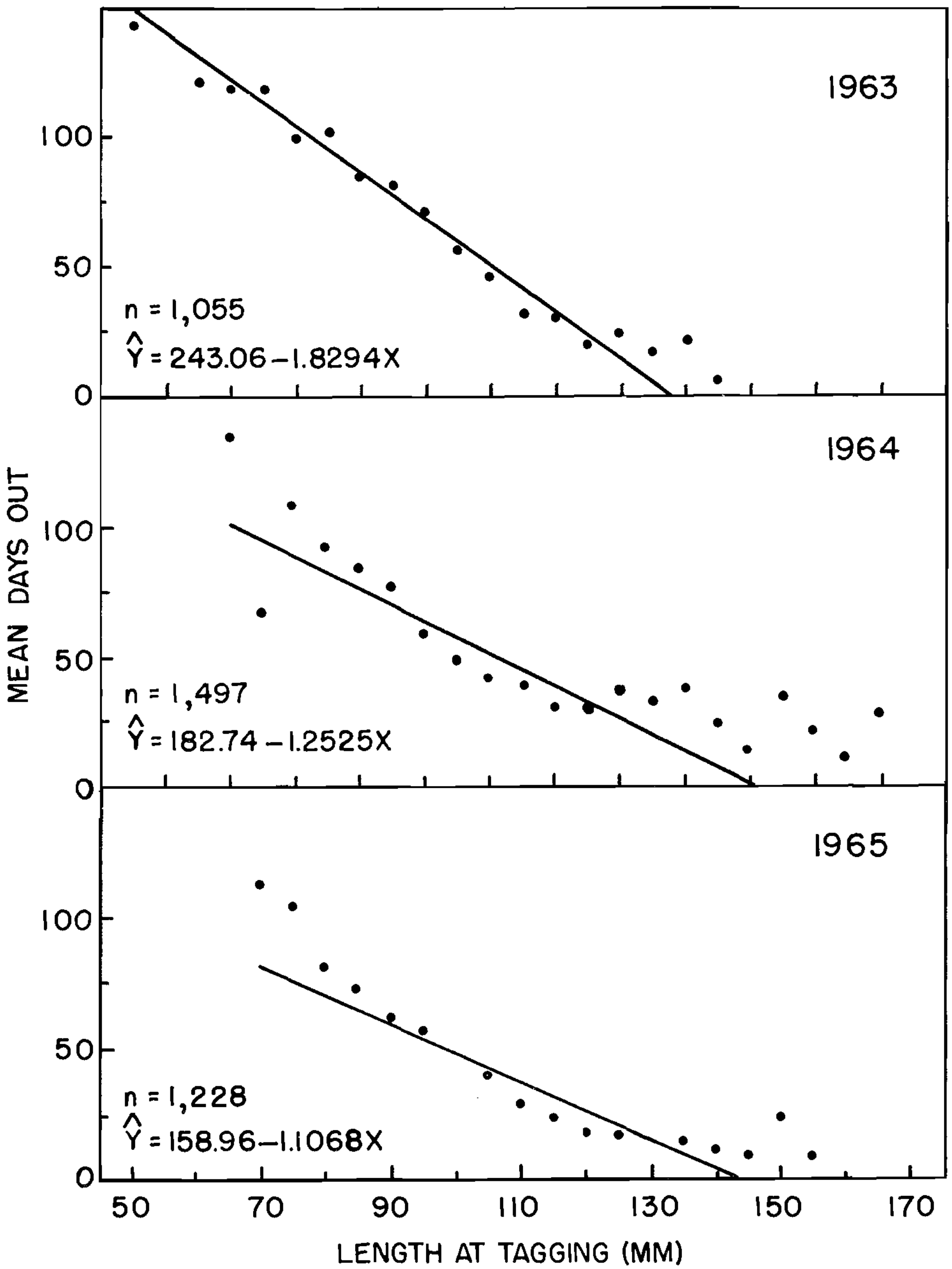

Figure 3—*Relationship between length of coho salmon at tagging and the number of days fish were at liberty, North Fork Dam, January 1-July 1, 1963-65. (Mean days out plotted for fish of each length interval due to large number of observations.)*

correlation between days out and length of fish tagged during the pre-smolt period. However, during weeks 16 and 21 there were significant negative correlations between days out and length in all cases except one (week 16, middle reservoir, 1963). Generally, these tests indicated that once smoltification and emigration began, the larger fish emigrated earlier than the smaller, regardless of area or year of tagging.

Further verification of the tendency for larger coho to emigrate before the smaller ones was obtained by comparing the mean number of days spent in the reservoir by fish 80 and 120 mm long, for each tagging week. Figure 6 shows the results of this comparison for coho tagged in the

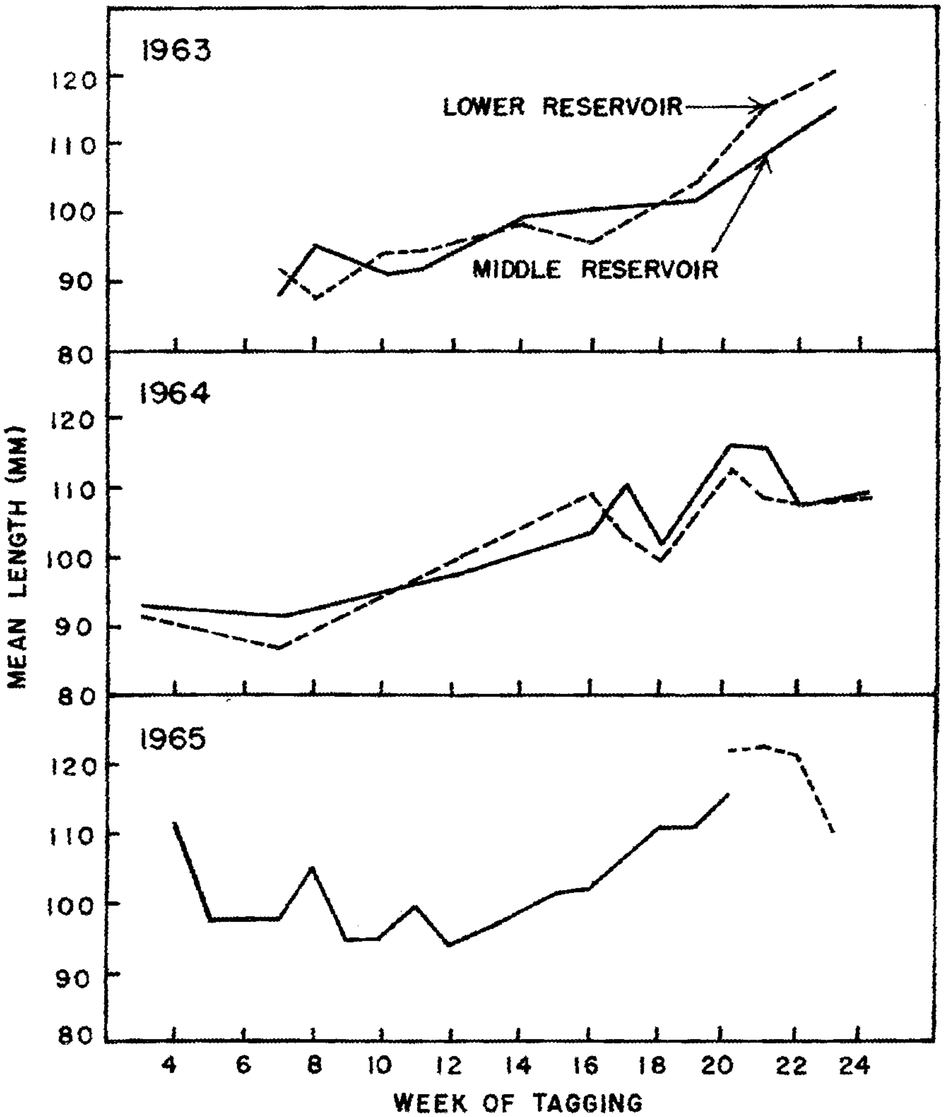

Figure 4—*Mean length of juvenile coho salmon in the lower and middle areas of North Fork Reservoir, by week of tagging, 1963-65.*

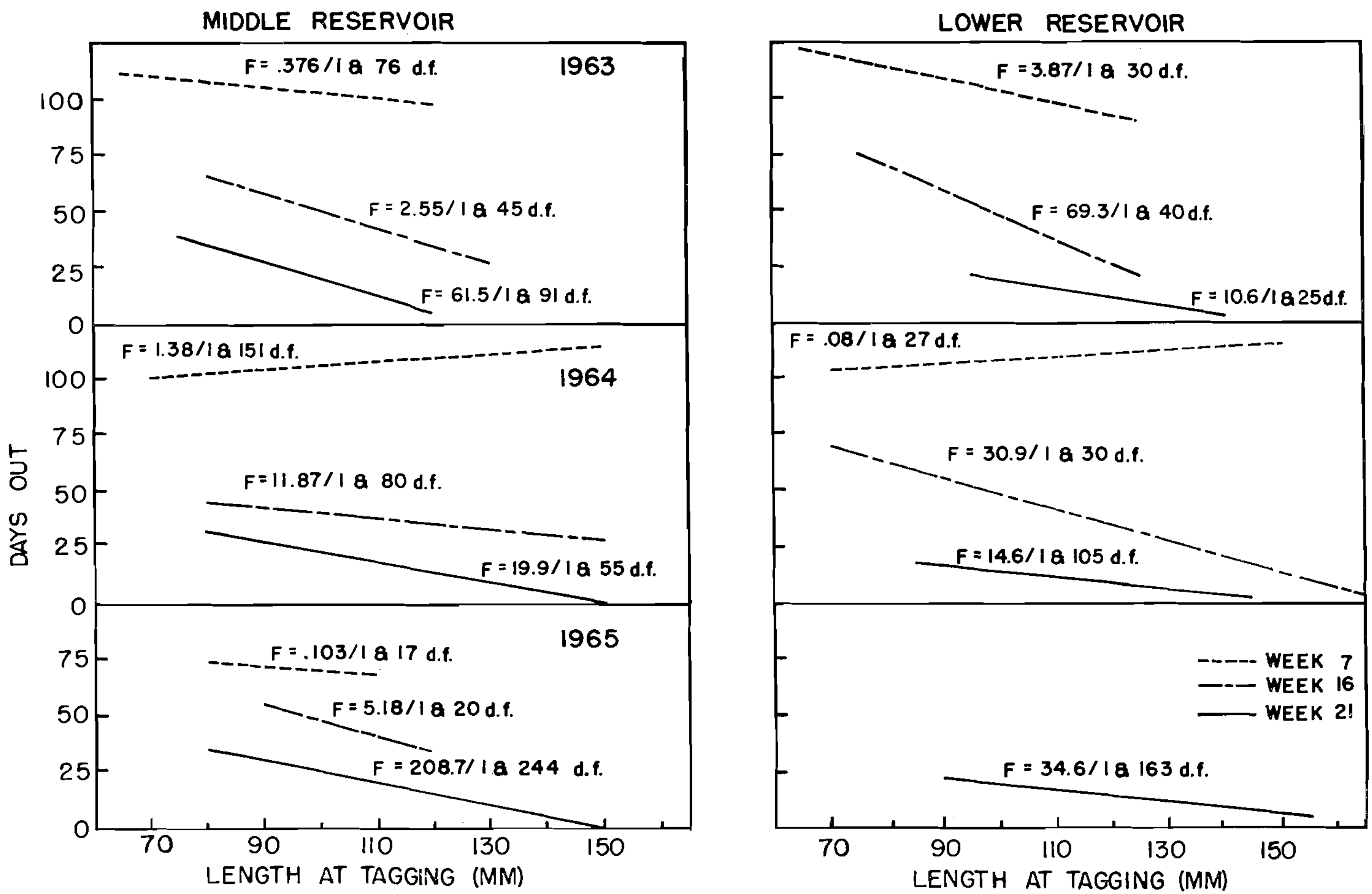

Figure 5—*The relationship between number of days out from tagging to emigration and size at time of tagging for coho released into the middle and lower areas of North Fork Reservoir during weeks 7, 16, and 21, 1963-65. (Values not plotted as there are a large number of points for each line.)*

middle and lower reservoir in each year of the study. In almost all instances, the larger coho at tagging emigrated earlier than the smaller ones.

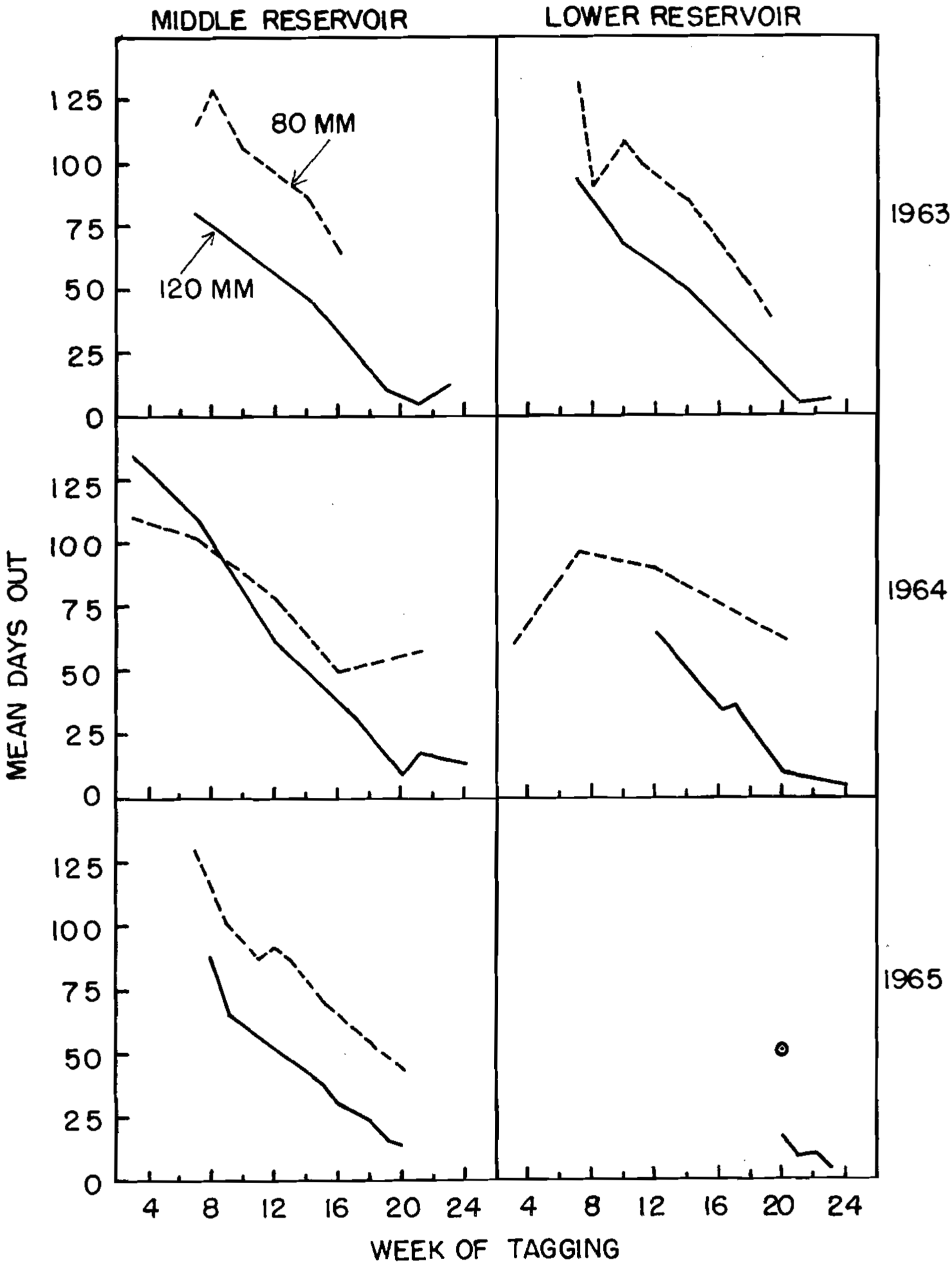

Figure 6—*Comparison of mean days out by week of tagging for coho 80 mm and 120 mm long, mid- and lower-reservoir tagging sites, North Fork Reservoir, 1963-65.*

Pelton Reservoir

Few coho trapped and tagged in Pelton Reservoir were recovered at the collection facilities. Fish used in studying Pelton were coho that had been tagged in Round Butte Reservoir in the spring of 1965, recaptured in the collection system at Round Butte Dam, and then released into Pelton Reservoir at the foot of Round Butte Dam.

We consider "days out" to be the interval between the time tagged fish from Round Butte were released into Pelton Reservoir and the time they were captured at the Pelton collection facilities. Size at tagging was their length at time of release into Pelton Reservoir.

Regression analysis comparing the size of fish with days out for all 7 weeks of data available (weeks 17-23) resulted in a slope that did not differ significantly from zero (Figure 7).

The mean length of coho by week of tagging varied (Figure 8) and changing size composition may have affected the results. We therefore analyzed the data by week of tagging.

We then compared length of fish with days out, by week of release into Pelton, and found no significant correlation for 6 of the 7 weeks. Week 17 showed a significant positive correlation but there were only eight observations ($F = 8.5$ with 1 and 6 d.f.). It seemed desirable to stratify the data by week of tagging for analysis, since fish were growing; however, the number of observations by week were too few to yield conclusive results at Pelton.

Round Butte Reservoir

Adequate data comparing size of coho at tagging with days out were obtained from Round Butte Reservoir only in 1965. Coho were tagged and released into the Metolius and Crooked River arms of the reservoir (Figure 2). Since few fish tagged in the Metolius Arm were recovered, analysis

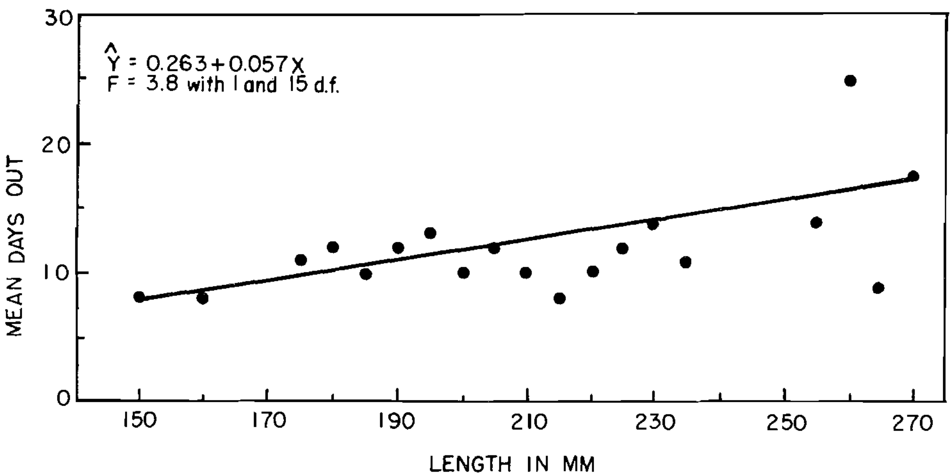

Figure 7—*Relationship between length of tagged coho released into Pelton Reservoir from Round Butte and mean number of days out until recovery in Pelton collection facilities, April-June 1965. Based on 101 tagged fish recoveries.*

was limited to those tagged in the Crooked River Arm and recovered in collection facilities at the dam (211 observations). Most of the fish were tagged between January 10 and March 20, but some were tagged the first week of May. Figure 9 shows that a negatively significant relationship existed at the 1% level between size of coho at tagging in the Crooked River Arm and time out, indicating that larger fish emigrated earlier than smaller ones.

The mean length of coho by week of tagging, as shown in Figure 8, increased from weeks 9 through 12. To eliminate the effect of changing size composition, we analyzed the data by week of tagging. It should be noted that mean length, by week, of fish tagged was much larger at Round Butte than at North Fork (Figures 4 and 8). We found significant negative correlations for 6 of the 10 weeks for which data were available. The results of tests yielding significant relationships are shown in Figure 10. Since the results of tests with data combined and 6 of 10 tests with data stratified by week of tagging were significant, we concluded that large fish emigrated before small ones.

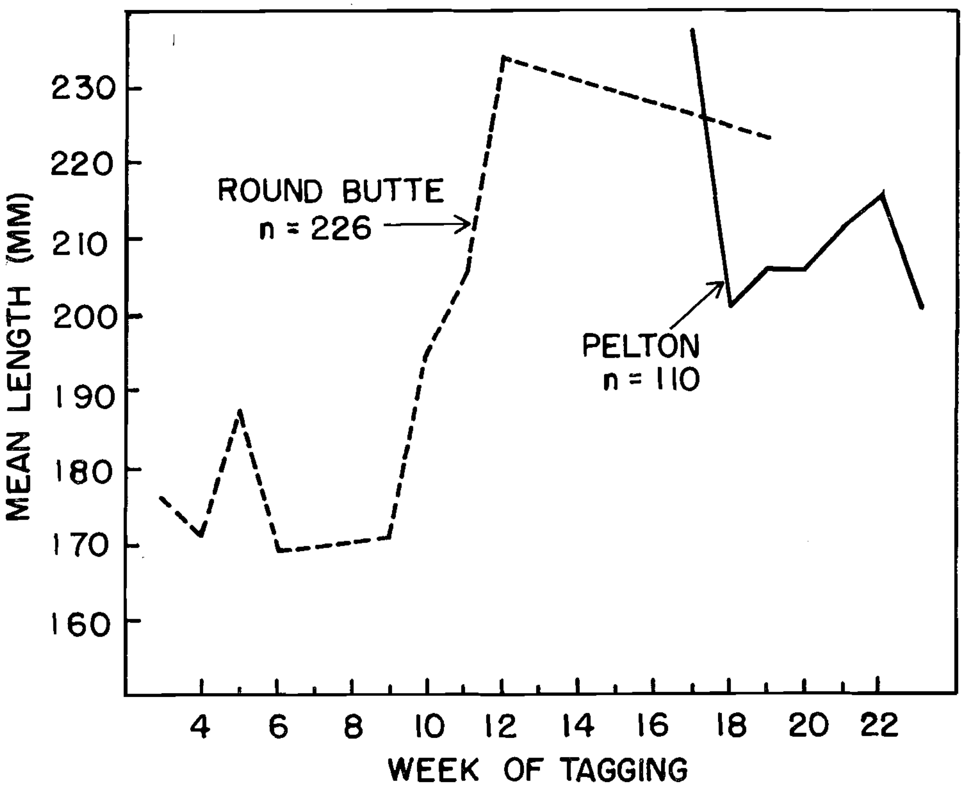

Figure 8—*Mean length of tagged coho recovered at collection facilities, by week of release into Pelton and Round Butte reservoirs, January-June 1965.*

DISCUSSION AND CONCLUSIONS

The results of tests to determine if a relationship existed between length of coho at tagging and time until emigration varied among the three reservoirs studied. At North Fork, where passage was good and fish did not remain beyond their normal age of emigration (Korn *et al.*, 1967), the large number of observations yielded definite and consistent results. Data showed that once coho began to emigrate in the spring, large juveniles spent less time in the reservoir than small ones. This relationship was true when analyzing all data combined, and when separated by year, week, and area of tagging.

Results at Pelton were inconclusive possibly because of the small number of recoveries. Since tagged coho used at Pelton were collected at Round Butte, anesthetized and measured prior to release, the additional handling may have adversely affected fish of all sizes. Also, the late dates of release may have contributed to the small number of recoveries.

Observations at Round Butte in the spring of 1965 also indicated that

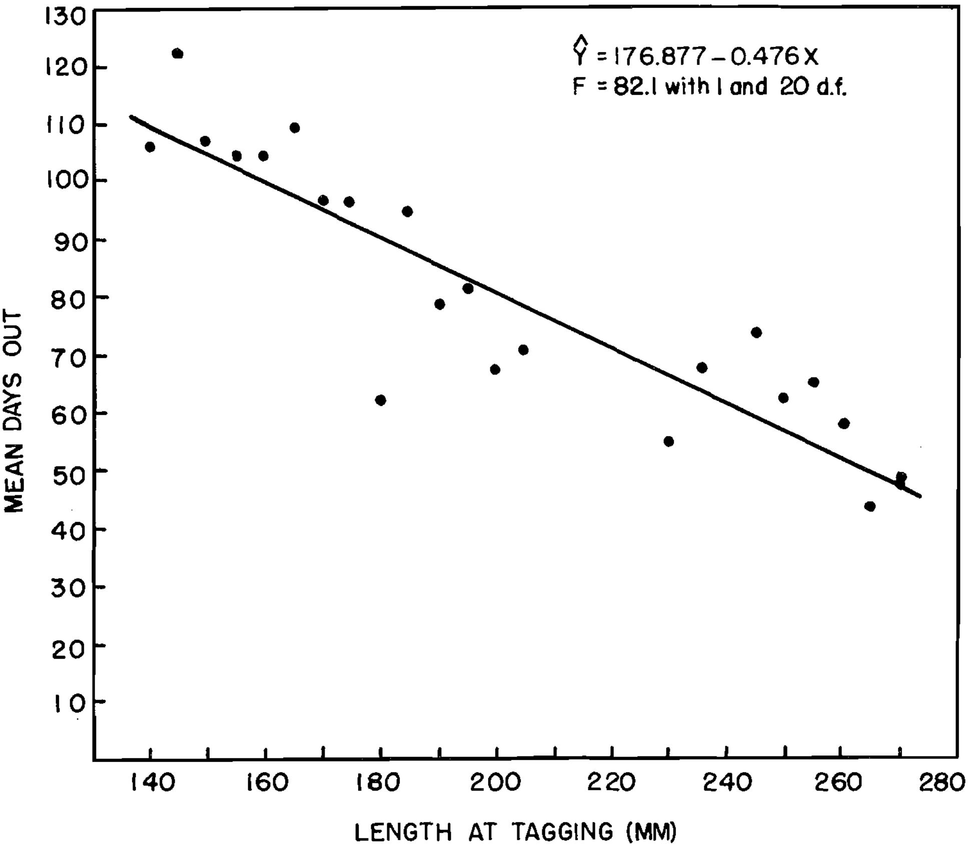

Figure 9—*Relationship between length of coho salmon at tagging in the Crooked River Arm and their subsequent days out until recovery in the collection facilities at Round Butte Dam, January-May 1965. Based on 211 tagged fish recoveries.*

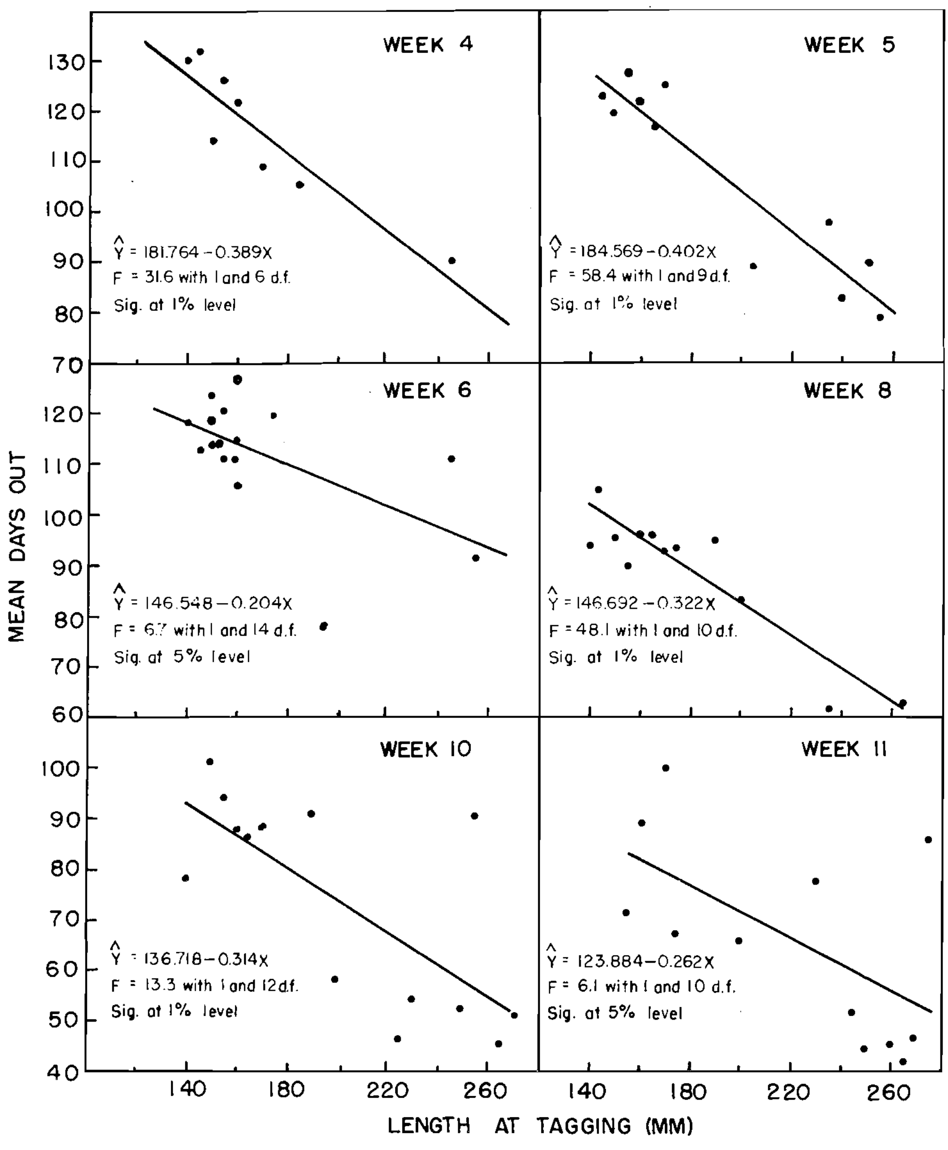

Figure 10—*Relationship between length of coho salmon at tagging in the Crooked River Arm and number of days out until collection at Round Butte Dam, for selected weeks of tagging, January-March 1965. (Mean days out plotted for all weeks except 6, individual fish plotted for week 6.)*

large fish spent less time in the reservoir after tagging than small ones. However, results were not as conclusive here as at North Fork. Coho in the two reservoirs were different in that they were generally larger in Round Butte than at North Fork. Also, many remained in the former beyond their normal age of emigration, while at North Fork they emigrated normally.

ACKNOWLEDGMENTS

I wish to express my appreciation to Earl F. Pulford for his help and guidance during the data analysis and Robert T. Gunsolus and Lawrence Korn for their guidance and patience during the entire study. I am indebted to the field crew who devoted long hours of hard work to gather the data.

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Korn, Lawrence, L. H. Hreha, R. G. Montagne, W. G. Mullarkey, and E. J. Wagner. 1967. The effect of small impoundments on the behavior of juvenile anadromous salmonids. Fish Comm. Oregon, Proc. Rept. 127 p.

Index to Fish Commission of Oregon Research Publications

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Fish Commission of Oregon, Research Division
Clackamas, Oregon

This index covers the Commission's published papers in the series Contributions, numbered 1 through 29, and Research Briefs Volume 1, Number 1 through Volume 13, Number 1. Volumes 1, 2, 3, and 6 of the Research Briefs had two numbers each whereas the remaining volumes were complete in one issue. Roman numerals indicate the number of the Contribution; if the arabic numeral, indicating page number, is omitted the reference is pertinent to the whole paper. Volume, number, and page of a reference to a paper in the Research Briefs is given as 1(1)10. There are four divisions: a subject index, an author index, a species index, and a list of Contributions and Research Brief papers. Another series of publications is called Investigational Reports. These are generally lengthy, processed reports prepared for limited distribution to make data available to workers in certain fields. They are listed by title and author, but are not included in the subject index. Those reports marked with an asterisk are available in limited quantity.

The earlier authors referred to coho and sockeye salmon, *Oncorhynchus kisutch* and *O. nerka*, in the manner of fishermen and other workers in the region as silver and blueback salmon. Starting in 1964 the nomenclature has followed that recommended by the American Fisheries Society in its Special Publication Number 2 (1960), "A List of Common and Scientific Names of Fishes from the United States and Canada."

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1. Local populations and migration in relation to the conservation of Pacific salmon in the western states and Alaska. W. H Rich. (The *Migration and Conservation of Salmon, Publication* No. *8 of* the American Association for the Advancement of Science. 1939).
2. Dams and the problems of migratory fishes: A symposium presented before a joint meeting of the American Society of Ichthyologists and Herpetologists, Western Division, and the Western Society of Naturalists, held at Stanford University on June 29, 1939. (Stanford Ichthyological Bulletin, Vol. 1, No. 6. 1940).
3. The present state of the Columbia River salmon resources. W. H. Rich, (Proceedings of the 6th Pacific Science Congress, Volume III. University of California Press. 1941).
4. Note on the young of the Sablefish *(Anoplopoma fimbria)*. V. E. Brock. (Copeia, No. 4. 1940).
5. Seasonal variations in weight of Columbia River chinook salmon. W. H. Rich, (Copeia, No. 1. 1940).
6. The future of the Columbia River salmon fisheries. W. H. Rich, (Stanford Ichthyological Bulletin, Volume 2, No. 2. 1940).
7. The salmon runs of the Columbia River in 1938. W. H. Rich. (Fishery Bulletin No. 37, U. S. Fish and Wildlife Service. 1942).
8. An application of the control chart method to the analysis of fisheries data. W. H. Rich. (Science, Vol. 97, No. 2516. 1943).
9. Age, length, and weight studies of three species of Columbia River salmon *(Oncorhynchus keta, O. gorbuscha* and *O. kisutch)*. J. C. Marr. (Stanford Ichthyological Bulletin, Vol. 2, No. 6. 1943).
10. Contribution to the biology of the albacore *(Germo alalunga)* of the Oregon coast and other parts of the North Pacific. V. E. Brock. (Stanford Ichthyological Bulletin, Vol. 2, No. 7. 1943).
11. The effects on salmon populations of the partial elimination of fixed fishing gear on the Columbia River in 1935. D. R. Johnson, W. M. Chapman, and R. W. Schoning. June 1948.
12. Some factors influencing the trends of salmon populations in Oregon. D. L. McKernan, D. R. Johnson, and J. I. Hodges. (Transactions of the 15th North American Wildlife Conference. December 1950).
13. Salmon fisheries of the coastal rivers of Oregon south of the Columbia. J. T. Gharrett and J. I. Hodges. December 1950.
14. Striped bass studies on Coos Bay, Oregon in 1949 and 1950. A. R. Morgan, and A. R. Gerlach. December 1950.

*15. The ocean salmon troll fishery of Oregon. J. M. Van Hyning. August 1951.

*16. Fisheries statistics of Oregon. F. C. Cleaver. September 1951.

17. The Indian dip net fishery at Celilo Falls on the Columbia River. R. W. Schoning, T. R. Merrell, Jr., and D. R. Johnson. November 1951.
18. Analysis of factors affecting the production of chum salmon *(Oncorhynchus keta)* in Tillamook Bay. K. A. Henry. September 1953.

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*24. The fishery and biology of the Dungeness crab *(Cancer magister,* Dana) in Oregon waters. K. D. Waldron. May 1958.
*25. Tuberculosis in Pacific salmon and steelhead trout. J. W. Wood and E. J. Ordal. December 1958.
*26. A winter steelhead tagging program on the Columbia River. L. Korn. August 1961.
*27. Growth and mortality rates of the razor clam *(Siliqua patula)* on Clatsop Beaches, Oregon. G. Hirschhorn. June 1962.
*28. Oregon coastal salmon and steelhead tagging programs. Part I. Tillamook Bay, 1953. K. A. Henry. Part II. Siletz River, 1954. A. R. Morgan. May 1964.
*29. A microcytic anemia of juvenile salmon resulting from diets deficient in Vitamin E. C. M. Whitmore. March 1965.

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5. Length-frequency and sex composition data for pink shrimp landed in Oregon, 1951-65.
   J. G. Robinson and G. S. Milburn. February 1967.
6. Length-frequency and age-length-frequency distributions for Dover sole, English sole, petrale sole, and Pacific ocean perch landed in Oregon, 1948-65.
   R. L. Demory and H. A. Bailey. April 1967.

Occurrence of Greenland Halibut and Asiatic Flounder Off Oregon

A Greenland halibut *(Reinhardtius hippoglossoides,* Walbaum, family Pleuronectidae) was netted by Arthur Paquet, captain of the trawler *Marian F.* on July 9, 1964. This species had not been previously recorded off Oregon. The fish was caught at a depth of 80 fathoms at latitude 46°04′ N., longitude 124°32′ W., approximately 26 miles due west of Gearhart, Oregon. Mr. Paquet stated that a similar "black halibut" was taken by his vessel during midsummer 1962 from the same area, but it escaped the attention of biologists. The Greenland halibut has a velvety appearance and the ventral or blind side is black or cobalt blue. This specimen was a male measuring 585 mm in total length (504 mm standard length), and weighed 2.8 pounds, but some loss of weight occurred due to dehydration in frozen storage. Dorsal fin ray counts were 88 and anal fin rays 68. Dr. Carl Hubbs (personal communication) states that these counts are on the low side, but within expected limits.

Best (1963) reported the first occurrence of Greenland halibut off California in the Gulf of the Farallons at a depth of 50 fathoms or less during August 1962. Since then, five additional specimens have been taken off California and one off Baja, California (Hubbs and Wilimovsky, 1964). These authors consider *R. hippoglossoides* to be a uniquely undifferentiated amphiboreal taxon, found both in the north Atlantic and north Pacific oceans. Since 1930 *Reinhardtius* has maintained a population of commercial significance from northern Japan to northwestern Bering Sea and is common in the eastern Bering Sea and the tip of the Alaska Peninsula. Hubbs and Wilimovsky believe that fish found off Japan and California are nonbreeding expatriates whose wanderings are attributable to their free-swimming habits and prolonged early pelagic development. The Greenland halibut in its northern range inhabits deep water, generally beyond the continental shelf. Hubbs and Wilimovsky suggest that its southward spread in the Pacific is probably affected largely by the two main northern cold currents—Oyashio and California. Larvae from populations in the northwestern Pacific and from the population that likely exists off the south side of the Aleutian chain are possibly carried eastward by the North Pacific Drift. Those on the south side of the drift are carried far southward where occasional individuals may find bottom along the California coast. These authors state that the lack of records between the Alaska Peninsula and northern California may be explained by the pattern of the currents. The reported taking of a specimen in 1962 by Mr. Paquet corresponds to the finding of specimens off California during the same year.

Hubbs and Wilimovsky also state that the occurrence of Greenland halibut in the northeastern as well as northwestern Pacific finds a partial parallel in the occurrence of the large Asiatic or rough-scaled flounder, *Clidoderma asperrimum* (Temminck and Schlegel), off western America as reported by Welander, Alverson, and Bergman (1957). On June 14, 1964, A. H. Mather, skipper of the trawler *Trask,* caught one of these fishes in a tow off Tillamook Rock, Oregon (latitude 45°56′N., longitude 124°03′W.) at a depth of 17 to 28 fathoms. This fish is distinguished from the flatfishes common off the Oregon coast by its ovate body, rows of rough tubercles on the body, and the long maxillary on the blind side of the head. Soft fin rays numbered 86 in the dorsal fin and 65 in the anal. Coloring was brown on the eyed side and slate gray on the blind side. Total length was 390 mm. The snout appeared mutilated, as if it had been bitten and later healed. This record appears to be a new extension of the range of the species (Dr. A. D. Welander, personal communication).

Both the Asiatic flounder and Greenland halibut are in the collection of the Oregon Fish Commission Research Laboratory, Astoria.

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Cessation of Chinook Salmon Spawning During A Lunar Eclipse

On December 18, 1964, a total lunar eclipse was potentially visible over Oregon. The moon began entering the earth's shadow at 4:59 p.m., totality occurred between 6.07 p.m. and 7:07 p.m., and the moon left the earth's shadow at 8:15 p.m.[1] That evening Orris Smith, a Port Orford commercial fisherman, and I were tagging adult fall chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), in Edson Creek, a tributary of Sixes River, Curry County, Oregon. Our interest centered on one female and her nine male companions and four or five other spawning groups observed during previous daylight hours.

We arrived at the spawning site about 7:00 p.m. Because it was cloudy and raining lightly, and the eclipse was in progress, the area was "absolutely" dark. Even after our eyes adjusted to the darkness, we could not see to walk along the stream without a flashlight and the outlines of the trees along the stream were not visible against the cloud-covered sky. We observed no fish spawning and found none near the redds. The fish we were able to find were resting close to shore in shallow water, and made little or no motion when approached from behind, spotted with a flashlight, and picked up by the caudal peduncle.

Although it was impossible to observe the end of the eclipse because of the cloud-cover, the sky brightened considerably around 8:00 p.m. The outlines of the trees became clearly visible and flashlights were no longer needed. Shortly we heard fish moving up through the riffles and about 8:15 p.m. four females were observed digging in their redds with males positioning themselves behind.

These cursory observations suggest interesting questions concerning the relationship between light intensity and spawning. If these fish are sensitive to minor changes in illumination, is night spawning reduced during the dark of the moon? Could peak spawning be related to the phase of the moon in addition to freshet and other conditions? Is there any survival advantage to night spawning? Since chinook in Sixes River spawn before and after the winter solstice, the effect of decreasing and increasing day length on some of the above questions would also be interesting to examine.

I have observed fall chinook spawning on relatively dark evenings. In each case, however, the outlines of trees along the shore were plainly visible against the sky, possibly providing visual orientation. Increased light may also illuminate references within the stream.

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[1] December 18th Lunar Eclipse Preview. Sky and Telescope Magazine. December 1964. p. 368.

The Calico Surfperch New to Oregon Waters

A calico surfperch *(Amphistichus koelzi)*, previously unknown to Oregon fauna, was collected on May 25, 1965, near Brookings, Oregon. The fish was recovered with a dip net during surveillance of blasting operations to remove a navigation hazard from the mouth of the Chetco River. It was a 267 mm (214 mm SL) female. This is the greatest length reported for the species.

Prior to its discovery in Oregon, the range of the calico surfperch was from Little Head, Trinidad, California, to Santa Tomas Bay, Baja California (Tarp, 1952). On July 3, 1965, a specimen was collected 10 miles south of Cape Flattery, extending the northern range into Washington (Peden and Best, 1966). Failure to recognize this species in Oregon previously was probably due to similarities in appearance between the calico surfperch and the redtail surfperch *(A. rhodoterus)*. The species can be distinguished by a single external character—the dorsal fin profile of the calico surfperch is fairly uniform in height while the redtail surfperch has a high spinous portion (Miller, Gotshall, and Nitsos, 1965).

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Comparison of Returns from Dart and Petersen Disc Tags on Dover Sole

A study was initiated in May 1961 to evalute the difference in recoveries of dart and Petersen disc tags on Dover sole *(Microstomus pacificus)*. A total of 5,436 Dover sole were tagged and released in two areas off the Oregon coast during exploratory fishing cruise No. 50 of the Bureau of Commercial Fisheries vessel *John N. Cobb;* 4,310 were released in 109-272 fathoms off Stonewall and Heceta banks between Newport and Coos Bay; and 1,126 were released in 100-350 fathoms of water in an area southwest of the mouth of the Columbia River.

Fish were caught with a 400-mesh commercial otter-trawl net with 1½-inch mesh liner in the cod end, during tows of 15- to 60-minute duration. At the end of a tow, the catch was spilled on the deck and 30-500 viable Dover sole were sorted into a live tank containing fresh sea water supplied by the vessel's pump. Two types of tags were used: ⅝-inch fluorescent orange Petersen discs, with soft-tempered stainless steel pins; and 8-inch orange double-barb dart tags of vinyl tubing. Disc and dart tags were chosen in a random manner and put on separate fish with about an equal number bearing each type.

Between May 25, 1961, and December 31, 1966, trawl fishermen operating out of Oregon ports returned 303 tags. Of these, 161 were dart and 142 disc tags. Table 1 shows the numbers of each returned by year.

Table 1—*Recoveries of dart and disc tags on Dover sole, 1961-66.*

Type of tag	*Number released*	*Recoveries by year*						*Total*
		1961	*1962*	*1963*	*1964*	*1965*	*1966*	
Dart	2,710	10	46	50	37	16	2	161
Disc	2,726	11	50	35	29	14	3	142
Total	5,436	21	96	85	66	30	5	303

Statistical tests on the number of tag recoveries indicated no significant difference between returns of dart and disc tags. A chi-square value of 1.398 with 1 d.f. was derived.

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Mature Stream-Reared Spring Chinook Salmon

Stream-reared spring chinook salmon *(Onchorhynchus tschawytscha)* with mature testes have been noted from time to time, but the extent of this early maturing tendency is unknown. Burck (1965) reported several specimens in the stomachs of spent adult spawners.

Between August 18 and October 10, 1966, 259 sexually mature male chinook appeared in the downstream-migrant by-pass trap on Lookingglass Creek, a tributary of the Grande Ronde River in Union County, Oregon. These fish ranged from 90 to 152 mm fork length with a mean of 115 mm. Most specimens had the gaunt appearance and external coloration of the typical adult male spawner, and many were badly fungused. Milt could be expressed from nearly every fish. Some individuals were still quite active, but many displayed the lethargic attitude which immediately precedes death. Specimens held in the trap died within a few days to a week. Examination of scale samples showed that the fish were in the second year of life and had not gone to sea.

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Observations on Deformed Juvenile Coho Salmon

Juvenile coho salmon *(Oncorhynchus kisutch)* with aberrant spinal columns occur at most Fish Commission of Oregon hatcheries. Incidence of deformed fish varies between hatcheries and in different years. It is always greatest at hatcheries where cold water disease *(Cytophaga psychrophila)* was most severe; deformed fish are rarely found where cold water disease does not occur. Deformed fish are usually first noted when water temperatures exceed 50 F and symptoms of cold water disease disappear. Afflicted fish become more evident and spinal aberration more pronounced as the season progresses.

When the fish are 150-200 per pound, small inflamed cysts develop just under the skin on the caudal peduncles of most fish that are starting to show spinal abnormality. At first, the cysts are soft and underlying tissue is hemorrhagic. As the fish grow, the cysts become firm, underlying tissue is necrotic and spinal curvature is more evident. Later in the season, spinal aberration is pronounced and small hard cysts that are not necrotic or hemorrhagic overlay fused caudal vertebrae. Deformed fish may be scoliotic, lordotic, or lordoscoliotic.

In 1965 and 1966, a gram negative, nonmotile bacterium was repeatedly isolated from the kidneys and cysts of deformed fish. The organism has the same morphology and cultural characteristics as *Cytophaga psychrophila*. We were unable to culture the bacterium from the cysts after they became hard and non-necrotic, but it was routinely isolated from the kidneys of deformed coho throughout the rearing season.

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