A Measured Delay in the Migration of Adult Chinook Salmon at Bonneville Dam On The Columbia River

Robert W. Schoning and Donald R. Johnson

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Portland, Oregon
Contribution No. 23
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ABSTRACT

A study was undertaken in the fall of 1948 by the Oregon Fish Commission to determine the possible presence and importance of a delay in the migration of adult chinook salmon (Oncorhynchus tshawytscha) at Bonneville Dam on the Columbia River. Approximately 650 chinook were captured, tagged, and released at the Oneonta trap 6.7 miles below Bonneville Dam and 200 were handled similarly at the dam and released above. The tag returns from Celilo Falls, the main commercial fishing area, 60 miles above Bonneville, were compared by location of tagging with regard to date of tagging and the number of days en route. The linear correlation between tagging date and days out was significant for the 39 recoveries tagged at Bonneville but not for the 35 from Oneonta. The later in the season the fish were tagged at Bonneville the more rapidly they migrated to Celilo Falls. With no adjustment for the difference in distance between the two tagging locations, the fish from Oneonta took a significant 3.4 days longer to make the trip to Celilo than the Bonneville-tagged fish. When correcting for the distance difference, the delay was reduced to 3.0 or 2.6 days, either of which was still significant. Although the number of recoveries is small, all of those used are believed to be reliable and sufficient for statistical analysis. The study represents only one year's work and investigations of another year may refute or substantiate these findings.

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INTRODUCTION

Ever since dams with facilities for the passage of fish have been constructed on rivers containing runs of migratory fish, the possible presence and importance of a delay to these fish at the various dams have been subject to discussion. The problem of delaying anadromous fish on their spawning migration is continually assuming greater importance with the increased number of dams proposed for the Columbia River and its salmon producing tributaries. In the spring of 1938 the fish-passage facilities at Bonneville Dam, 140 miles above the mouth of the Columbia River, were completed, and adult anadromous fish began using the fishways. Since that time there has been much speculation about a possible block to fish at the dam. Adult salmon and steelhead have been observed in the fish ladders with severe gashes and abrasions on their bodies and it has been suggested that these traumata were caused by the fish's encountering certain parts of the dam either in the fishways or elsewhere. Some of these injured fish probably do not survive to pass above the dam. The Oregon Fish Commission, during the fall of 1948, undertook a tagging experiment to determine the presence and importance of a possible delay to the upstream migration of chinook salmon (Oncorhynchus tshawytscha) at Bonneville Dam, and to gather data on the migration rates and time of appearance of the various runs of salmon.

It is recognized that there are two phases to the main problem. One is to show the delay in terms of days by means of the recovery of tags at Celilo Falls (the principal fishing area above the dam), while the other is to determine the mortalities caused by delay or injury at the dam. An analysis of the latter by means of a tagging program might well involve an accurate and complete sampling of the catch and a thorough coverage of the river above and below the dam as well as surveys of spawning grounds to determine percentage recoveries for fish tagged above and below Bonneville. The initial work has been directed toward the former—determining the effect of the dam on the migration of the fish. A joint Columbia River tagging program by the Washington State Department of Fisheries and the Oregon Fish Commission was initiated in 1947 and continued in 1948. As a result the groundwork for the recovery of tags had been laid and the fishermen were aware of the tagging program from the previous year's studies.

TAGGING AND RECOVERY

A commercial trap was available for tagging on August 22 and during the fall commercial fishing closed season (August 26 to September 10) at Oneonta, which is located 6.7 miles below the dam on the Oregon shore. Fish on their upstream migration could also be captured and tagged near the upper end of the Washington-shore fishways at Bonneville Dam. Fish released from the Oneonta trap had to swim the 6.7 miles to the dam, find the fishway openings, and successfully ascend the fishways to gain access to the forebay above the dam. The fish captured, tagged, and released in the Washington-shore fish ladder merely had to pass upstream through about 50 yards of ladder with a moderate gradient to enter the forebay.

Throughout the tagging program there was only one day of tagging common to both Bonneville and Oneonta. As a result the same men were able to do most of the tagging. The conventional Petersen-type plastic button tag was attached by a nickel pin immediately below the dorsal fin. A total of 1,051 fish, of which 646 were chinook salmon, was tagged at Oneonta on August 22 and 31, and September 1, 3, 6, and 7. The Bonneville tagging dates were at irregular intervals between May 11 and September 16, and during this period 6,115 fish, including 3,471 chinook, were tagged. Between August 24 and September 8, a total of 200 chinook was tagged and released at the dam.

Regulations prohibit commercial fishing within 5 miles below and 15 miles above Bonneville Dam. Some gill-netting is done immediately below the lower boundary, and fishing is resumed 15 miles above the dam, continuing for another 45 miles to Celilo Falls. By far the heaviest concentration of commercial fishing above Bonneville, especially in the late summer and autumn, is centered in the Celilo area. The greatest number of fish is normally taken by the Indian dip-nets, although 2 large beach-seines and 40 or 50 gill-nets make appreciable catches. By comparing returns of tags put on at both Bonneville and Oneonta and later recaptured by the intensive fishery at the falls, it was anticipated that conclusive data concerning a possible delay at the dam might be obtained.

It is realized that tagging itself can affect the fish and its subsequent actions, and it is possible that tagged fish could experience greater difficulty in ascending the dam than untagged ones as a result of the tagging operations. However, this was deemed unlikely and it is assumed that the effect of tagging on the Bonneville and Oneonta fish was the same.

Since the largest and most important fall run of fish in the Columbia River is composed of chinook salmon, only this species is considered in the analysis at this time even though recoveries for other species were made.

Of considerable interest is the fact that a far greater percentage of "tules" (fish well advanced toward spawning and recognized by the dark and frequently greenish-yellow hue on the external surface) was caught at Oneonta than in the Washington-shore ladder at the dam. Consequently, it appeared that the population of fish using the Washington ladder was different in composition from the one entering the Oneonta trap during this period. However, in the present studies it is only important that the Celilo recoveries in the two groups be from the same population. In neither group were tules recovered at Celilo. Table 1 shows the numbers released and recovered, by area, for the two locations of tagging and reveals the preponderance of Oneonta-tagged fish recovered in the hatcheries. It should be mentioned, however, that 51 of the Oregon hatchery recoveries from Oneonta tagging were obtained from the Bonneville Hatchery, the entrance of which is below Bonneville Dam. Consequently, the fish tagged at Bonneville Dam very likely were not destined for this particular hatchery. These differences obviously preclude the possibility of directly comparing the percentage recovery at Celilo for fish tagged above and below Bonneville Dam.

During the recovery program, returns were received of tagged fish which were caught below Oneonta as well as between the dam and Celilo Falls (Table 1). A number were also received from hatchery installations on tributary streams. In addition, some of each type were returned with

TABLE 1. **TOTAL RECOVERIES OF CHINOOK SALMON TAGGED AT BONNEVILLE DAM AND ONEONTA TRAP IN 1948**

	Tagging Location	
	Bonneville *(8/24—9/8)*	***Oneonta*** *(8/22—9/7)*
Recoveries		
Tagging site to Celilo (excluding hatcheries)	45	47
Hatcheries (Bonneville to Celilo):		
Washington side	0	86
Oregon side	1	95①
Tagging site	1	27
Below tagging site	0	5
Unknown and other	0	6
Total	47	266
Number tagged	200	646
Per cent recovered	23.5	41.1

① Includes 51 from Bonneville Hatchery, the entrance of which is immediately below Bonneville Dam.

part of the necessary information lacking, e.g., exact location, or date of capture, or the tag number itself.

Some of the Oneonta-tagged fish dropped back downstream and were caught in the commercial fishery below where they were tagged. The opportunity for Bonneville-tagged fish to do this was less, and no such recoveries were made in this program, although it has been found in previous studies that fish tagged in the Bonneville ladder and released above have passed down over the dam only to be caught in the fishery below or to reascend the ladder. If any of these fish passed up over the dam twice and were caught at Celilo Falls, the migration rate would be slower because of the presence of the dam and would reduce the difference in rates for recoveries from the two tagging sites.

It was felt that returns from tributaries, especially hatchery streams, would be of little value for rate of migration studies because chinook are known to linger around the mouths of some streams varying lengths of time before ascending them to spawn. Likewise, incomplete returns could not be used. Usable recoveries from the main Columbia River other than those at Celilo Falls were scattered and few in number. Consequently, it was decided to use only the recoveries with complete information and from Celilo Falls, which included the entire dip-net and seine fisheries as well as the uppermost gill-nets. As a result only 39 of the 47 recoveries of Bonneville tags and 35 of the 266 recoveries of Oneonta tags were used in the migration rate analysis. In computing the rate, the tagging day and the recovery day were both included, e.g., a fish tagged on August 22 and caught on August 23 was considered to be out 2 days.

Although the number of recoveries is small, all are believed to be reliable, and they are deemed sufficient for statistical analysis. Almost all the tags were obtained by a biologist who actually removed many of them from the fish soon after capture.

EFFECT OF DAM ON MIGRATION RATE

Although tagging had been carried on at Bonneville Dam from May until mid-September, only that portion comparable in time of appearance with the fish tagged at Oneonta was used in the analysis. Tagging of more closely similar stocks of upriver fish under comparable river conditions was assured by this procedure. The spread of tagging dates, then, was August 22 to September 7 at Oneonta and August 24 to September 8 at Bonneville. As mentioned before, the number of tag recoveries involved was 39 for Bonneville and (after elimination of 1 tag) 35 for Oneonta. The recovery that was eliminated was a fish that had been tagged at Oneonta on August 22 and recovered 50 days dater. Although the information pertaining to its capture was complete and seemed to be authentic, there was something definitely abnormal about the actions of this particular fish. Using this tag in the data would give too much weight to a single recovery, and since it did seem to be abnormal, it was eliminated from the analysis. Although the elimination of this recovery may have biased the results to some degree, the action of the bulk of the fish is of primary concern. With the exception of this tag the greatest number of days out for any of the 74

other tags was 23 (Table 2). The time individual tagged fish required to reach Celilo Falls from each of the two tagging locations is given in Table 2.

It was realized that the fish tagged later in the fishing season might be subjected to the fishery for a shorter time than those tagged at the beginning of the season, if they did not move right through the fishing area. This would reduce the possibility of getting recoveries from the commercial fishery of fish tagged late in the season and out for long periods. As is shown in Table 2, relatively few tagged fish were captured at Celilo Falls after being en route more than 18 days. With the exception of the

TABLE 2. **TIME REQUIRED FOR 39 BONNEVILLE- AND 35 ONEONTA-TAGGED FALL CHINOOK TO REACH CELILO FALLS IN 1948**

Days Out	*Tagging Date at Bonneville*					*Number Recovered*
	8/24	*8/26*	*9/1*	*9/2*	*9/8*	
3	.....	.....	.....	.....	1	1
4	.....	1	1	1	4	7
5	1	.....	.....	.....	5	6
6	1	.....	1	.....	5	7
7	.....	.....	.....	2	2	4
8	.....	2	.....	.....	.....	2
9	.....	1	.....	1	.....	2
11	.....	.....	3	.....	.....	3
12	1	.....	.....	.....	.....	1
13	2	.....	.....	.....	.....	2
15	1	.....	.....	.....	.....	1
20	2	.....	.....	.....	.....	2
23	.....	.....	.....	1	.....	1
Number Recovered	8	4	5	5	17	35
Average Days Out	13.0	7.2	8.6	10.0	5.2	8.1 (mean)

Days Out	*Tagging Date at Oneonta*						*Number Recovered*
	8/22	*8/31*	*9/1*	*9/3*	*9/6*	*9/7*	
6	.....	.....	1	.....	.....	1	2
7	1	1	2	.....	1	1	6
8	.....	.....	.....	1	.....	.....	1
9	1	.....	.....	1	.....	.....	2
10	1	1	2	3	.....	1	8
11	1	.....	.....	2	.....	.....	3
12	.....	.....	1	2	.....	.....	3
13	.....	.....	1	1	.....	.....	2
15	.....	2	.....	.....	.....	.....	2
17	.....	.....	1	.....	.....	.....	1
18	.....	1	1	.....	.....	.....	2
21	.....	1	.....	.....	.....	.....	1
22	1	.....	1	.....	.....	.....	2
Number Recovered	5	6	10	10	1	3	35
Average Days Out	11.8	14.3	12.2	10.6	7.0	7.7	11.5 (mean)

single Oneonta tag out 50 days, it is noted that the chinook with the longest migration time was tagged at Bonneville Dam on September 2 and was out 23 days between release and recapture at Celilo on September 24. Commercial fishing was permitted at Celilo Falls from September 10 until December 15, although the intensity rapidly declined in early October. However, a few Indians dip-netted until the first of the year. In spite of the fact that appreciable landings were made during October, only 1 tag was recovered during that month and it was caught on October 1. This relatively intense fishing, which continued well past the last tagging date, reduced the possibility that any changing rate of migration observed could have been due to an aberration caused by a cessation of commercial fishing. From the complete recoveries as shown in Table 2, it can be seen that the mean days out for the Bonneville releases was 8.1 and for the Oneonta releases 11.5 indicating a gross delay of 3.4 days for the Oneonta group (Table 3).

TABLE 3. **RECAPITULATION OF TAGGING OPERATIONS AND INFORMATION OBTAINED FROM RECOVERIES AT CELILO FALLS OF FALL CHINOOK TAGGED AT BONNEVILLE DAM AND ONEONTA TRAP IN 1948**

Tagging Location	*Bonneville*	*Oneonta*	*Difference*
Tagging Period	*8/24—9/8*	*8/22—9/7*	
Mean tag date (August 22 = 1)	11.9	10.6	1.3
Mean days out	8.05	11.51	3.46
Number of recoveries	39	35	.....
Correlation coefficient (r) (Tag date and days out)	−0.56	−0.21	.....
Probability	<0.01	>0.05	.....
Slope of tag date—days out	−0.43	①	.....
Correction for distance			
Oneonta to Bonneville distance ÷ rate	0.4 ②	0.4 ②	.....
	0.8 ③	0.8 ③	.....
Correction for days out			
Slope × difference in mean tag dates	−0.4 ②	①	.....
	−0.2 ③	.....	.....
Least squares line (x=tagging date, y=days out)	y=13.19−0.43x		

① No entries because there is no significant linear correlation.
② For 15.3 miles/day.
③ For 8.5 miles/day.

A correction for the difference in distance was necessary since the fish tagged at Oneonta had to travel 6.7 miles to get to the forebay of the dam while the Bonneville fish had only to travel about 50 yards. From results of the tagging program in 1947, indications were that fall chinook tagged near the mouth of the Columbia River and caught at various places between there and Celilo Falls tended to remain near the place of tagging for several days, after which they migrated at an average rate of 15.3 miles a day. It is as yet impossible to determine whether fish destined to pass Celilo

Falls were actually among those that dawdled only to move rapidly thereafter. Consequently, it is conceded that this segment of the run could have moved steadily up the river without any period of adjustment. With this possibility in mind, in the 1947 tagging study all of the recoveries which were made at Celilo Falls were considered separately, and it was found that the average rate of migration for these fish was 8.5 miles per day. Until the uncertainties noted above can be resolved, the two rates of travel must each be considered, so both of these values (15.3 and 8.5 miles per day) were used in correcting for the time required to migrate from Oneonta to Bonneville. The time necessary to travel this distance was 0.4 or 0.8 day depending on the rate of migration used.

Without making any corrections, for a difference of 3.4 in mean days out, a t value of 3.1 is obtained which has a probability of occurrence of less than 0.01 (Table 4). Correcting for distance gives a value for t of 2.8 with a probability of less than 0.01 for the aforementioned 15.3 migration rate and a t of 2.4 with a probability of less than 0.02 for the 8.5 miles per day rate. Both are still significant.

It should be noted that in computing a t value with a correction for the distance between Oneonta and Bonneville, the variation in the unobstructed migration rates of individual fish was not studied. Since the estimated

TABLE 4. **SIGNIFICANCE OF DIFFERENCE IN MIGRATION RATES OF CELILO RECOVERIES OF 39 BONNEVILLE- AND 35 ONEONTA-TAGGED FALL CHINOOK IN 1948**

		Tagging Date (x)	*Days Out (y)*
Bonneville	Mean	11.9	8.1
	Standard Deviation	6.20	4.81
	Standard Error of Mean	0.99	0.77
Oneonta	Mean	10.6	11.5
	Standard Deviation	4.45	4.47
Combined	Standard Error of Mean	0.75	0.76
Uncorrected	①Difference between means	1.3	3.4
	Denominator for t test	1.27	1.08
	②t	1.0	3.1
	Probability	0.3	<0.01
		Days Out (y)	
		at 8.5 mi./day	*at 15.3 mi./day*
Corrected for distance	①Difference in mean days out	2.6	3.0
	Denominator for t test	1.08	1.08
	②t	2.4	2.8
	Probability	<0.02	<0.01
Corrected for distance and tagging date	①Difference in mean days out	2.4	2.6
	Denominator for t test	1.08	1.08
	②t	2.2	2.4
	Probability	<0.05	<0.02

① Numerator for t test.
② From table 3.8, p. 65, Snedecor, 1948.

standard deviation of the days out for the Oneonta group is not significantly greater than for the Bonneville group (in fact, numerically smaller) such variation is apparently not an important factor. In any case, since all evidence indicates strongly that the slow rate of 8.5 miles per day is certainly a minimum, the test applied should be conservative in this respect, so that the probability level may be much less than 0.02.

It is important that the groups of fish recovered from the Oneonta and Bonneville operations be comparable. Whether or not this is the case can be partially determined by studying tagging dates. Consequently, the difference of the mean tagging dates was tested by the standard t test. As a result t was found to be 1.0. The probability of such a result's occurring by chance is 0.3, (Table 4) which is not statistically significant since it is considerably greater than the commonly used 0.05 level. In other words, a difference in mean tagging date as small as the one evidenced between Bonneville and Oneonta could be expected to occur approximately 30 per cent of the time in random samples from a normal population. Therefore, there is no indication that an adjustment for the difference in tagging date should be made.

The linear correlation coefficient for the days out with the tagging date for Bonneville was highly significant (probability less than 1 per cent), being –0.56 for 37 degrees of freedom (Figure 1 and Table 3). The corre-

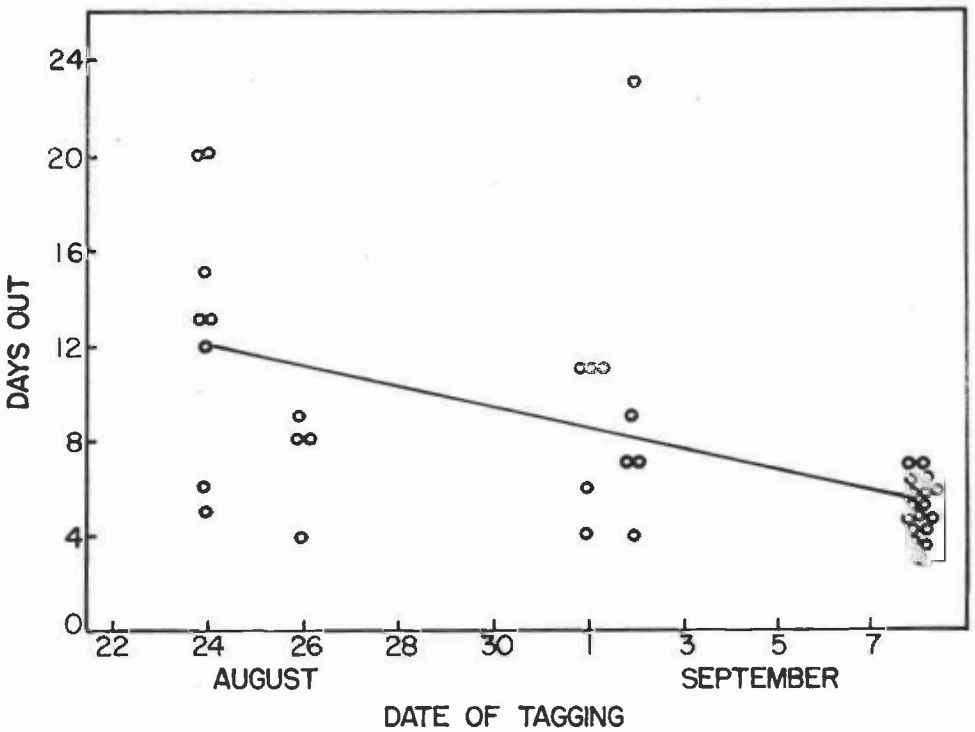

FIGURE 1. CHANGE IN RATE OF MIGRATION OF 39 CHINOOK SALMON TAGGED ON THE COLUMBIA RIVER AT BONNEVILLE DAM AND RECOVERED AT CELILO FALLS IN 1948. THE LINE SHOWS THE COMPUTED TREND WITH THE FORMULA OF y=13.19–0.43x (AUGUST 22 EQUALING 1). THE CORRELATION (r=0.56) IS HIGHLY SIGNIFICANT.

lation for the Oneonta data was –0.21 for 33 degrees of freedom, which was not significant—greater than 5 per cent probability (Figure 2). This in itself is an important fact. The fish and their subsequent movements apparently are affected in some manner by the dam. The significant correlation for Bonneville tagging indicates there is a definite change of rate of migration during the period considered once the fish are above the dam, and that as the season progresses the fish move faster. The non-significant correlation for Oneonta tagging means that for the period and data studied there is no significant relationship between the days out and the tagging date. The fish which were tagged early at Oneonta did not take significantly longer to make the trip to Celilo Falls than those tagged later in the season. The manner in which the migration pattern of Oneonta fish was disturbed has not been ascertained. It is certainly possible, however, that all of the fish were not affected to a similar degree.

A regression line was fitted by least squares for the Bonneville recoveries (since there was a significant linear correlation) and the formula was found to be y=13.19–0.43x with x as the date of tagging coded so that August 22=1 and y as the days out (Figure 1). The absolute mean tagging dates prior to any adjustments differed by 1.3 days. However, to obtain the true time

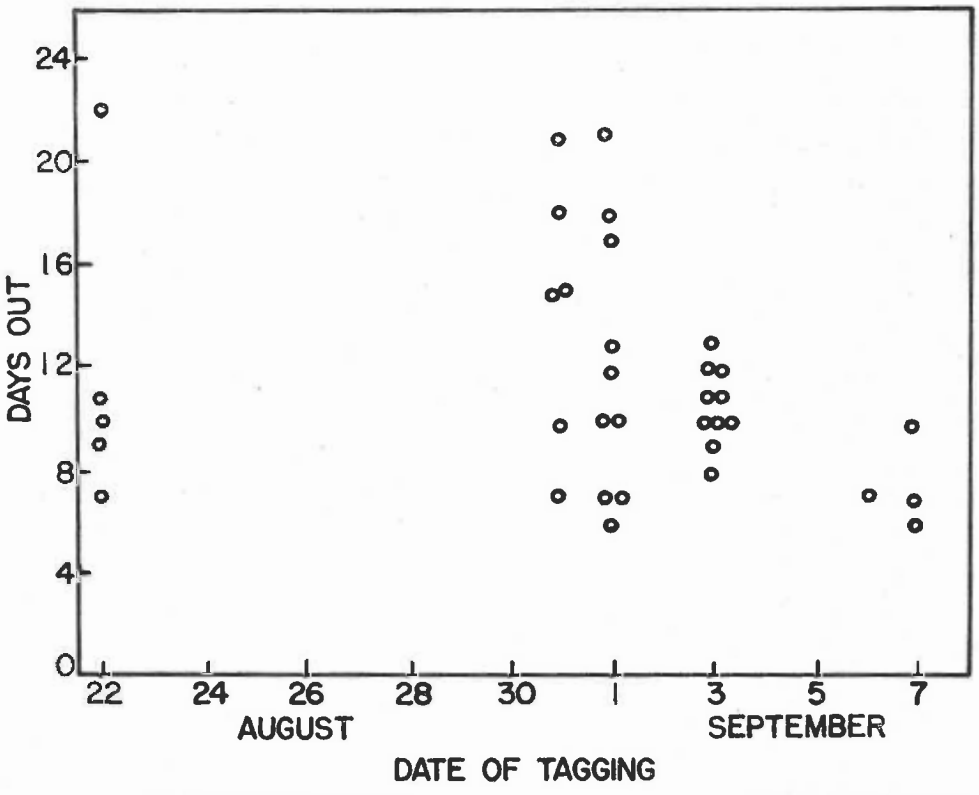

FIGURE 2. CHANGE IN RATE OF MIGRATION OF 35 CHINOOK SALMON TAGGED ON THE COLUMBIA RIVER AT ONEONTA AND RECOVERED AT CELILO FALLS IN 1948. NO TREND LINE IS SHOWN, AS THE CORRELATION (r=–0.21) IS NOT SIGNIFICANT.

difference between the two tagged groups, one must compare the times at which the two groups of fish pass the same place in the river. This, therefore, necessitates subtracting the unobstructed migration time from Oneonta to Bonneville (0.4 or 0.8 day depending on the rate used) from the 1.3 days difference. The difference in time of migration then is 0.5 or 0.9 day. If we take into account the average observed delay of 3.4 days (which would occur before the fish reach the forebay of the dam) then the situation is reversed, and the fish tagged at Bonneville in this experiment represent, on the average, a group passing Oneonta 2.1 days earlier than those tagged at Oneonta, and hence a slower group.

Since even the observed difference in tagging date of 1.3 days is not significant (P=0.3), certainly differences of 0.5 or 0.9 would not be significant; and since, in addition, the correlation between tagging date and days out for the Oneonta group is not significant, there is no indication than an adjustment for the difference in tagging date should be made. Further, if even a small portion of the indicated delay is real, the Bonneville recoveries would, on the average, represent an earlier and therefore slower group than the Oneonta group. For a very conservative test, however, it was initially assumed that no delay occurred at the dam, and each of the recoveries from Oneonta tagging was corrected by subtracting 0.5 or 0.9 times 0.43 day (difference in time of migration for 15.3 or 8.5 miles per day times regression slope) from the observed days out. Using this correction in addition to the previous correction for distance, the difference in mean days out is 2.4 days for the 8.5 miles per day rate and 2.6 days for the 15.3 miles per day rate with corresponding probability levels less than 0.05 and 0.02, respectively (Table 4). Although the standard t test is of questionable applicability in a situation in which the migration rate is dependent upon time and where the two groups studied may not be random choices from the same population, the conservative technique used and the resulting low probability levels give indication that a delay is occurring at Bonneville Dam.

Summarizing, without any corrections the data show that the delay at the dam was 3.4 days. Depending on which of the two migration rates is used, on the average, it took the Oneonta fish 3.0 or 2.6 days longer to get to Celilo Falls than it did the Bonneville fish after correcting for the distance between the two tagging sites. When one also corrects for the difference in mean tagging date at the two locations, the difference becomes 2.6 or 2.4 days.

Since the effect of tagging date was difficult to control either directly or statistically, it is of interest to group the recoveries according to the tagging date. In Table 5 the fish tagged at either Oneonta or Bonneville from August 22 to August 26 are classified as "early run" fish. Those tagged at either station between August 31 and September 3 are classified as "middle run" fish. Those tagged between September 6 and September 8 are classified as "late run" fish. It is noted that a delay is indicated in every period with the greatest delay of 2.8 days occurring in the period of the passage of the middle run. Grouping reduces the difference in mean days out indicating a differential result due to tagging date.

Further insight into the effect of the dam may be obtained by a study

TABLE 5. **DIFFERENCES IN MEAN DAYS OUT OF CELILO RECOVERIES AMONG EARLY, MIDDLE, AND LATE RUN FALL CHINOOK TAGGED AT BONNEVILLE AND ONEONTA IN 1948**

Tagging Dates	Number Recovered		Mean Days Out		Difference
	Bonneville	Oneonta	Bonneville	Oneonta	
8/22–8/26 (early run)	12	5	11.1	11.8	0.7
8/31–9/3 (middle run)	10	26	9.3	12.1	2.8
9/6–9/8 (late run)	17	4	5.2	7.5	2.3

of the median time out. To avoid fractional numbers, 1 day rather than 0.4 or 0.8 day was subtracted from each Oneonta-tagged recovery to correct for the time of unobstructed migration between Oneonta and Bonneville, although all data indicate the use of the considerably smaller correction. Grouping these corrected values with the Bonneville-tagged recoveries, the median was between 8 and 9 days, with 38 recoveries in 8 days or less and 36 recoveries in 9 days or more. In Table 6 the breakdown comparing recoveries from Bonneville and Oneonta tagging is studied. For Bonneville-tagged recoveries 27 out of 39 or 69 per cent were out 8 days or less, while for the corrected values at Oneonta, only 11 out of 35 or 31 per cent were out 8 days or less. A chi-test indicates a significant difference with a probability level of 0.001. This serves as a rough test to indicate that the median of the days out from Bonneville for those fish tagged at Bonneville is significantly less than for those tagged at Oneonta. It must be noted that any effect of differential tagging date is not taken into account in this test.

TABLE 6. **CHI-SQUARE TEST OF MEDIAN TIME OUT OF CELILO RECOVERIES OF FALL CHINOOK AT BONNEVILLE AND ONEONTA IN 1948**

Tagging Point	No. of fish 8 days out or less	No. of fish 9 days out or more	Total Number	Expected no. 8 days out or less	Difference	Chi-square
Bonneville	27	12	39	20.03	6.97	4.9878
Oneonta①	11	24	35	17.97	–6.97	5.5585
Total	38	36	74	.....	.....	10.5463 P<0.001

① In the above tabulation 1 day was subtracted from the days out for each of the Oneonta recoveries to correct for the time of migration between Oneonta and Bonneville.

DISCUSSION

The 2.6 to 3.0 day delay that has been found among upstream migrant adult chinook salmon at Bonneville Dam does not appear to be catastrophic. However, studies of sockeye salmon in the Fraser River indicated that any delay was deleterious and that the longer the delay the greater were mortalities among migrants. Only fish not delayed at all or but slightly delayed reaching their spawning ground in numbers (Thompson, 1948). Consequently, in view of other existing and proposed dams in the Columbia River system, there appears to be a significant present and potential problem. The cumulative delay is definitely a factor for concern even though the dams be passable. Obviously, successful migration of adult fish to the spawning grounds must include both passage past the dam as well as up the river at a rate of migration compatible with the physiological requirements of the species involved.

It is realized that this study is concerned with only the fall chinook salmon run of one year, and investigations of another year may or may not agree with these findings. The need for additional investigation of migrating salmon at major dams plus additional work (now underway under U. S. Army Corps of Engineers financing) to improve the efficiency of fishways is indicated.

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