

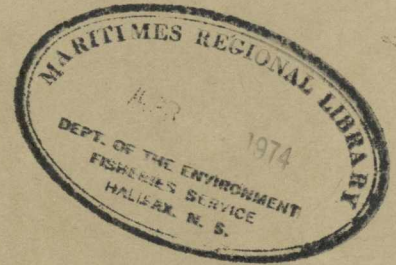


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# RESOURCE DEVELOPMENT BRANCH

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MORTALITY TESTS - TOBIQUE NARROWS DAM

by

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## ABSTRACT

An investigation was carried out to evaluate the mortality suffered by hatchery-reared Atlantic salmon yearlings passing through the turbines at Tobique Narrows Hydroelectric Dam during the 10,000 kW load. Fish were introduced into the penstock entrance and a sample was recovered by fishing downstream migrant traps in the tailrace. Mortality rate for fish ranging in size from  $3\frac{1}{2}$  to  $5\frac{1}{2}$  inches was 16.5 percent. Estimated mortality rate for fish ranging in size from  $5\frac{1}{2}$  to  $8\frac{1}{2}$  inches was 23.7 percent. Delayed mortalities for eight-day holding periods were included in this large size group.

## INTRODUCTION

In 1959 an investigation was carried out to evaluate the mortality suffered by downstream migrant salmon smolts using the turbine exits at the Tobique Narrows Hydroelectric Dam. Because of the difficulty anchoring the migrant traps in a suitable fishing position, only the recaptures from one test could be used to obtain a mortality estimate. Also, the number of fish taken by the sampling gear was very small. In order to obtain a larger sample for estimating the mortality rate, it was decided to double the number of traps fishing in the tailrace, and increase the number of salmon in each release during the 1960 investigation at Tobique Narrows.

## DESCRIPTION

Tobique Narrows Dam was built in 1953 by the New Brunswick Power Commission on the Tobique River about three-quarters of a mile above its confluence with the Saint John River. The plant produces 2,700 HP operating at a head of 70 feet and discharges 3,800 cfs. The powerhouse consists of two generators, each of which has a variable pitch Kaplan turbine, revolving at 225 rpm. This plant is operated by remote control from the Beechwood plant located approximately 20 miles below on the Saint John River.

Water for generating power is drawn in near the surface of the reservoir and is discharged from the turbines through four draft tubes. The water ejected from the draft tubes causes a very turbulent area in the tailrace. This tailrace level was raised about six feet in 1957 by water backed up from the Beechwood Dam. The pond-like area of the tailrace tends to reduce the velocity of the water moving downriver from the boil.

## METHODS

The method used to estimate mortalities on downstream migrant salmon at Tobique Narrows Dam consists of introducing hatchery salmon yearlings into the penstock, recovering a sample at the outlet and observing the live and killed fish in the sample. As the recovery rate for killed fish and live fish may not be the same, marked dead fish were released with the live fish to determine the true recovery rate of the killed fish. Thus, in any release using live and dead fish, the recovery group will consist of three different categories:

- 1) Live - fish released alive and recovered alive;
- 2) Live-dead - Fish released alive and recovered dead;
- 3) Dead-dead - Marked fish released dead and recovered dead.

From special studies carried out by Hamilton and Andrew (1) during their investigation of the effects of Baker Dam on downstream migrants, it was shown that live fish were more available to the nets than dead fish. It also was established that dead-dead fish and live-dead fish were equally available to the net.

To compensate for the disproportionate availability between live and dead fish in the catch, a correction factor was applied by Hamilton and Andrew (1). This was accomplished by comparing the recovery rate of marked live fish and marked dead fish. As live fish may be killed in their passage through the turbines and dead fish are less available to the traps, the true recovery rate must be computed. Calculations required for this are taken from the Baker Dam study (1).

"The rate of recovery of dead fish is known. Of a given number released alive, a certain number are recovered alive and a certain number are recovered dead. These two components of the marked live released are represented in the following formulae:

$$\text{Fish recovered alive} = X(P)R = x \quad (1)$$

$$\text{Fish recovered dead} = X(1-P)r = x_1 \quad (2)$$

Where  $X$  is the number of fish released alive,  $x$  is the number of live releases captured alive;

$x_1$  is the number of live releases captured dead (live-dead);

$P$  is the survival rate;

$R$  is the rate of recovery of live fish;

$r$  is the rate of recovery of dead fish (dead-dead).

From equation (2)

$$1 - P = \frac{x_1}{Xr} \quad \text{and}$$

$$P = 1 - \frac{x_1}{Xr}$$

Substituting for  $P$  in equation (1)

$$x = X \left( 1 - \frac{x_1}{Xr} \right) R \quad \text{and}$$

$$R = \frac{x}{X - \frac{x_1}{r}}$$

Having determined the true rate of recovery of live fish ( $R$ ), it can then be compared with the known rate of recovery of dead fish ( $r$ ). This

will establish the relative availability of live and dead fish to the gears and the correction factor  $\left(\frac{R}{F}\right)$  necessary to compensate for the disproportionate availability of dead fish.

### RECOVERY GEAR

To capture and retain a sample of the test fish emerging from the draft tube exits, four downstream migrant traps were installed in the tailrace. Each migrant trap consisted of a steel frame covered with wire screening on the bottom and sides. This steel basket was twelve feet long, with a four by four opening in front. The bottom was an inclined plane back to a survival box at the rear for retaining captured live and dead fish. The survival box was fitted with a hinged screen which was a continuation of the inclined plane of the basket's bottom. This screen could be adjusted to control the flow of water entering the box. This basket and survival box were mounted between two wooden pontoons by cables attached to winches on the pontoon platform. In fishing position the basket was lowered until the top was level with the surface, and the screen on the survival box was adjusted so that 1 to 2 inches of water flowed over it into the box.

The traps were bolted together in units of two and 3/8 inch cable from the large winches on the inside of the unit extended to the front of the powerhouse and the 3/8 inch cable from the outside winches were tied at right angles to the shore. Because of the distance to the true right bank, additional 1/4 inch cable was used for this side. Nine 100-pound anchors were placed in the tailrace about 200 feet back of the traps and 1/4 inch cable was tied from these to the back of the traps. Side cables were not used the first time the traps were installed because of the difficulty in removing the traps if the spillway gate had to be opened. If spillage occurred, only one to two hours notice could be given before the gate was opened and both generators would be operating at full load during this period.

With these side cables attached to the shore and the heavy back anchor, the traps could be held in the required fishing position for most load conditions. The most unfavourable condition for holding the traps occurred when one generator was shut down for repair and the remaining generator was operated at full load. With this flow pattern, water washed over the top of the pontoons. The two new traps with the styrofoam pontoons were not affected but the water gradually leaked through the bung holes of the old set of pontoons, and they became partly submerged in about an hour. When this flow pattern occurred, the old set of traps had to be removed and the tests were carried out with only the two new traps.

The migrant traps were placed opposite no. 1 generator approximately 100 feet from the powerhouse. The two units fished adjacent each other and separated by 15 to 20 feet.

Checks of the velocity conditions at the entrance of the migrant traps were made for the different generator loads. Because of the surge of water

from the boil, accurate figures were not obtained but approximate velocities at each trap were made. These were determined by averaging a number of checks made by the float method.

For the first two tests with only one unit fishing, the velocity averaged 4 fps. For the third test with both the units fishing the velocity at the new units was over  $4\frac{1}{2}$  fps and  $3\frac{1}{2}$  fps at the old units. Both units were moved about 10 feet closer to the true right bank and all other checks for the remaining tests showed 4 fps at both units.

#### RELEASING PROCEDURE

Fish used in the tests were salmon yearlings supplied from Saint John and Coldbrook hatcheries. Approximately 20,000 large size salmon (over  $5\frac{1}{2}$  inches in total length) and 20,000 small size (under  $5\frac{1}{2}$  inches in total length) were supplied from these hatcheries, but as holding space was limited at Florenceville Hatchery, fish were delivered as space became available.

The group used for each test was counted out at the Florenceville Hatchery and delivered to Tobique Narrows the day before the test was run. At the dam the fish were held in large retention cages located in the headpond. Mortality resulting from transportation and holding amounted to less than 0.5%.

Dead fish used in the experiment were killed with chlorobutanol to delay rigor mortis. These fish were marked by immersion in a solution of neutral red dye. Chlorobutanol and neutral red were added to a 45-gal drum half full of water. About one-half an hour before the release was made, live fish were placed in the drum. In this way the fish were killed and dyed in the same operation. By this method, marked dead fish were not held for longer than an hour and in most cases it was less.

To insure that all the test fish were drawn into the penstock, they were released through an opening in the platform at the front of the dam, just forward of the trash racks. A 45-gal drum, fitted at the bottom with a 20 foot section of four-inch suction hose, was placed over the opening. The suction hose extended down the opening into the penstock. A wooden plug with a long handle was inserted in the hole at the bottom of the barrel, so that it could be filled with water. When it was three-quarters full, live and marked dead fish were dumped into the barrel. Then the wooden plug was released, and the water and fish were flushed down the suction hose into the penstock. After the last release was made, the barrel was filled again with water and flushed into the hose to insure that all fish moved into the penstock.

All releases except the final one were into the penstock of No. 1 generator. On the day of the test, the generator was held at the required load for approximately two hours. It had been planned to have both generators operating when the fish were released, but a breakdown in No. 2

during the first part of July and a shutdown of No. 1 for general overhaul during the middle of July left only one generator operating for tests number one, two and seven. Also for number seven, fish had to be released into the penstock entrance of No. 2 generator.

All releases were made when the generator was operating under full load or approximately 10,000 KW (1920 cfs). No tests were carried out under lower loads because of the difficulty of capturing a sample with reduced velocity in the tailrace.

The number and size of salmon yearlings released for each test are listed in Table 1, along with the generator loads and number of traps fishing in the tailrace. As only 20,000 large size fish (5½ inches to 8½ inches) were available for the tests, the small size group were used mainly for establishing the best fishing position of the traps.

TABLE 1. Number and size of live and marked dead fish released into the penstock entrance at a generator load of 10,000 KW.

Date	Test no.	Live releases	Marked dead releases	Size	No. of traps fishing	Generator load KW no. 1	Generator load KW no. 2
Jul 1	1	3,000	3,000	S	2	10,000	0
5	2	3,000	3,000	L	2	10,000	0
9	3	3,000	3,000	S	4	10,000	4,000
11	4	2,000	2,000	L	4	10,000	10,000
13	5	2,000	2,000	L	4	10,000	4,000
15	6	3,000	1,500	S	4	10,000	10,000
19	7	2,900	2,700	L	2	0	10,000

After releasing the fish into the penstock, the four migrant traps were checked. All fish were removed from the survival boxes at the traps, sorted into dead-dead, live-dead and live and the number in each group was recorded. Live and live-dead fish were examined for external injuries.

All live fish recovered in the traps were removed to holding cages to check on delayed mortality. If more than fifty were recovered, a random sample of fifty were placed in the holding cages. Fish were retained in these cages for eight days. Fifty control fish placed in adjacent cages were held for similar periods with each test group.

## AUXILIARY EXPERIMENTS

As auxiliary experiments were made in 1959 to determine the effects of retention on fish captured in the live box of the traps, no assessment was made when the test started this year. Because of the large number of live-dead fish removed from two of the four traps after the second test run (test no. 3) with small size fish, auxiliary experiments were carried out to check on trap mortalities.

Before the release of test no. 4, twenty-five large size fish were placed in the live box of one of the new units and observed for three-quarters of an hour. In attempting to escape from the live box, some of the fish would be carried back by the current and held against the back screen of the box for one or two minutes depending on the surge water entering the trap. After about 20 to 25 minutes, two of the fish stayed against the screen and did not swim back down under the baffle when the current was reduced for two or three seconds. When the box was lifted after three-quarters of an hour, two or 0.8% of the fish had died in the survival box. The tails on both of these dead fish were in very poor condition from fin rot.

Adjustments were made to the baffle screens of the two new traps so as to reduce the flow of water against the back screen.

Similar tests were carried out before starting test no. 5 and no. 6. With proper adjustments to the baffle screen of the live box, fish could be retained in the live box for periods of 30 to 40 minutes without suffering any bad effects. For the last four tests the time between the release and removal from the trap was one-half hour or less.

## RESULTS

Recaptures at the migrant traps from the seven releases have been divided into three groups. Table 2 shows the recaptures from the three releases of small size fish (under 5½ inches) through no. 1 generator, Table 3 lists the recaptures from the three releases of larger size fish (over 5½ inches) through no. 1 generator, and Table 4 lists the recaptures from one release of large size fish through no. 2 generator.

TABLE 2. Releases and recoveries of small size live and marked dead salmon yearlings introduced into no. 1 generator operating at the 10,000 KW load.

Test no.	Date	Releases			Recoveries		
		Live	Marked dead	Size	Live	Live-dead	Dead-dead
1	Jul 1	3,000	3,000	S	50	12	37
3	9	3,000	3,000	S	123	48	96
6	15	3,000	1,500	S	85	19	57

TABLE 3. Releases and recoveries of large size live and marked dead salmon yearlings introduced into no. 1 generator operating at 10,000 KW load.

Test no.	Date	Releases			Recoveries		
		Live	Marked dead	Size	Live	Live-dead	Dead-dead
2	Jul 5	3,000	3,000	L	35	7	56
4	11	2,000	2,000	L	65	8	63
5	13	2,000	2,000	L	28	8	59
Total		7,000	7,000		128	23	178

TABLE 4. Releases and recoveries of large size live and dead salmon yearlings introduced into no. 2 generator operating at 10,000 KW load.

Test no.	Date	Releases			Recoveries		
		Live	Marked dead	Size	Live	Live-dead	Dead-dead
7	Jul 19	2,900	2,700	L	50	5	56

The recovery rate of fish was much better than in 1959, possibly due to a better fishing position of the gear. Recovery rate of dead fish varied from 1.2% to 3.8% and live fish from 1.17% to 4.1%. As more fish were used this year for each release and the number of fishing units was increased, the number of fish recovered after each test was larger than in 1959.

Because of the disproportionate availability between live and dead fish to the gear, a correction factor will have to be applied to the live-dead recaptures before the figure can be used to estimate the mortality. The calculated true recovery rate of live fish and correction factor necessary to compensate for the disproportionate availability of dead fish have been listed in Table 5.

In Table 6, the correction factor from Table 5 will be applied to the live-dead catches from the trap and a mortality estimate has been calculated by comparing the number of live and corrected live-dead recaptures from the traps. The estimated mortality rate for test no. 1 and 3 are high because during these tests an unknown number were killed from retention in the live box of the two new traps. Test no. 6 with small size fish is estimated at 16.5% which is very close to last year's estimate of 17.1%.

TABLE 5. The calculated true rate of recovery of live fish and correction factor necessary to compensate for the disproportionate availability of dead fish.

Test no.	No. of live fish released	Recoveries of live fish released		Rate of recovery of dead releases	Cal. true rate of recovery of live releases	Correction factor
		Live	Dead			
	X	x	x <sub>1</sub>	r	R	$\frac{R}{r}$
1	3,000	50	12	.012	.025	2.08
3	3,000	123	48	.032	.082	2.56
6	3,000	85	19	.038	.034	0.89
2	3,000	35	7	.015	.013	0.86
4	2,000	65	8	.031	.037	1.19
5	2,000	28	8	.029	.016	0.55
7	2,900	50	5	.020	.019	0.95

TABLE 6. Corrected estimate of mortality of two size groups of hatchery salmon yearlings through the turbines at 10,000 KW load.

Test no.	Live	Live-dead	Correction factor	Mortality estimate %
<u>Fish under 5½"</u>				
1	50	12	2.08	33.3
3	123	48	2.56	50.0
6	85	19	0.89	16.5
<u>Fish over 5½"</u>				
2	35	7	0.86	14.6
4	65	8	1.19	12.5
5	28	8	0.53	13.0
7	50	5	0.95	8.5

Test numbers 2, 4 and 5 were releases of large size fish into the penstock of no. 1 generator and the average of the three tests indicated a mortality rate of 13.3%.

Large size fish were used for no. 7 test but releases were made into no. 2 generator under adverse conditions. Because of the difficulty of handling fish in this area, some escaped during the releasing procedures

so calculations were made on an estimated number released, not on an accurate count.

#### DELAYED MORTALITIES

Results of the holding tests to check on delayed mortality are listed in Table 7 for the large size group of salmon yearlings. Fish held from test number four were accidentally mixed with the control group, so the results have not been included. The difference between the mortality suffered by the test group and the control group indicates the delayed mortality. Averaging these percentage values for the three groups shows a delayed mortality of 12 percent.

Results of the holding test for the small size group of salmon yearlings are listed in Table 8. Because of the unknown loss from retention in the trap survival box for the first two tests, only the delayed mortality for test number six is considered. As the difference in mortality between the test group and control group was indicated as only 2 percent, it was not considered significant.

TABLE 7. Results of holding tests to measure delayed mortalities of large size salmon yearlings after passage through the turbines operating at 10,000 KW.

	Test no.	Number held	Number dying after eight days	Percent dying after eight days	Percent difference between test and control
Test	2	35	6	17.1	13.1
Control		50	2	4.0	
Test	5	26	5	19.2	9.2
Control		50	5	10.0	
Test	7	50	7	14.0	14.0
Control		48	0		

TABLE 8. Results of holding tests to measure delayed mortalities of small size salmon yearlings after passage through the turbine operating at 10,000 KW.

	Test no.	Number held	Number dying after eight days	Percent dying after eight days	Percent difference between test and control
Test	1	50	23	46	16
Control		50	15	30	
Test	3	50	5	10	2
Control		50	6	12	
Test	6	50	5	10	2
Control		50	4	8	

#### FINAL CORRECTED MORTALITY ESTIMATE

The 12 percent higher mortality between the test group and the control group of large size fish must be attributed to injuries suffered in their passage through the turbines. As these are potential mortalities, adjustments of this amount must be made in the sample recovered at the traps, before calculating the final mortality estimate for this group.

Therefore in Table 9 the recaptures from tests 2, 4 and 5 are combined. The number of live recaptures have been reduced 12 percent and this amount has been added to the corrected live-dead recoveries. A comparison of the live and dead recaptures indicated a final mortality of 23.7 percent for salmon  $5\frac{1}{2}$  to  $8\frac{1}{2}$  inches in length.

As no significant delayed mortality was indicated in the group ranging in size from  $3\frac{1}{2}$  to  $5\frac{1}{2}$  inches, the final corrected mortality was calculated at 16.5 percent. Last year's mortality estimate was 17.1 percent for this group.

TABLE 9. Final corrected estimate of mortality of large size salmon yearlings using the turbine exits.

Generator load	Corrected recaptures		Final estimated mortality in percent
	Live	Dead	
10,000 KW	112.7	35	23.7

## SUMMARY AND CONCLUSION

To evaluate the mortality suffered by salmon smolt using the turbine exits at Tobique Narrows Hydroelectric Dam, mortality tests were conducted with hatchery-reared Atlantic salmon yearlings. Two size groups were used: 1) the small size, used mainly for testing the equipment, ranged from  $3\frac{1}{2}$  to  $5\frac{1}{2}$  inches in total length; 2) the second group, closely represented the native smolts' size, ranged from  $5\frac{1}{2}$  to  $8\frac{1}{2}$  inches in total length. These fish were introduced into the penstocks when the generator was operating at full load (10,000 KW). Mortality rate was calculated by comparing the number of live and killed fish recovered by the migrant traps anchored in the tailrace about 100 feet from the powerhouse.

Because of the disproportionate availability between live and dead fish to the traps, a correction factor was applied to the live-dead recaptures before the mortality rate was estimated.

As fish were killed in the recovery gear during tests one and three with small size fish, only recaptures from the third test with this group was used to furnish a mortality estimate. This was calculated to be 16.5 percent. No significant mortality was found after holding the recaptures from the trap for eight days.

Of four releases made with large size fish only recaptures from three are used for a mortality estimate. Because of adverse conditions during the fourth and final release some fish escaped, so only an estimate could be made of the numbers of fish introduced into the penstock. Using only the recaptures from the first three releases, a mortality rate of 13.2 percent was obtained.

The difference in the mortality rate between the test fish and a control group held for eight days was 12 percent. As they are considered as potential mortalities similar adjustments were made in the recapture at the trap before calculating the final mortality rate. The final estimated mortality for large size fish ( $5\frac{1}{2}$  to  $8\frac{1}{2}$  inches) using the turbine exits during the 10,000 KW load was 23.7 percent.

## LITERATURE CITED

- (1) Hamilton, J.A.R. and F.J. Andrew. 1954. An investigation of the effects of Baker Dam on downstream migrant salmon.