INTERNATIONAL PACIFIC SALMON
FISHERIES COMMISSION

BULLETIN VI

AN INVESTIGATION OF THE EFFECT OF BAKER DAM ON DOWNSTREAM-MIGRANT SALMON

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NEW WESTMINSTER, B. C.
CANADA
1954

ABSTRACT

The effects of a hydroelectric plant and dam 250 feet high on the downstream migration of sockeye and coho salmon were investigated at Baker Dam in Western Washington. The migrating population was sampled with survival-type fyke nets in order to determine the pattern of migration from the reservoir, the effect of the spillway and the Francis-type turbines on survival, and the causes of mortality. It was found that over 95 per cent of the migrants leaving the reservoir used the surface spillway as their exit route and that less than 5 per cent left through the turbine intake, which was submerged 85 feet at full reservoir. It was concluded that 64 per cent of the native sockeye and 54 per cent of the native coho were killed in passing down the spillway when one spillway gate was open. The mortality rates in passing through the turbines were calculated to be 34 per cent for native sockeye and 28 per cent for native coho under full load conditions. These findings are supported by data showing that sockeye marked as downstream migrants and released over the spillway and through the turbines, upon return as adults had experienced a spillway mortality of 63 per cent and a turbine mortality of 37 per cent. Further confirmation of the effects of the structure is provided by the decline of 55 per cent in the sockeye run since the dam was constructed. Much of the injury and mortality to the yearling salmon was caused by abrasion on the spillway and pressure changes and cavitation in the spillway and turbines. It was concluded that a dam of this type has a very detrimental effect on the downstream migrants and that the spillway is responsible for the major part of the mortality.

SUMMARY AND CONCLUSIONS

A research program was undertaken at Baker Dam in Western Washington to determine the effect of a high dam on downstream-migrant salmon. The experiments, conducted from 1950 to 1952, utilized native runs of sockeye and coho salmon augmented by hatchery fish. The research was aided by the State of Washington Department of Fisheries and the Department of Fisheries of Canada. The specific objectives of the investigation were: first, to determine the character of the downstream migration from the reservoir; second, to evaluate the effect of the turbines and spillway on survival of the seaward migrants; third, to isolate the cause or causes of any existing mortality.

The work conducted in 1950 was largely of an exploratory nature to determine what method or methods might best be employed to accomplish the above objectives. The principal method adopted in 1951 and 1952 consisted of sampling the native sockeye and coho seaward-migrant population with fyke nets located in the tailrace below the power house and in the river below the spillway pool. Two additional methods were employed for measuring the mortalities incurred by downstream-migrant sockeye passing over the spillway and through the tunnel. In the first of these, marked downstream-migrant sockeye were released over the spillway and into the tunnel and the rates of return of these fish as adults were compared with the rate of return of marked control fish that had been released as seaward migrants into the river. A comparison between the average annual production of sockeye salmon before and after construction of the dam served as the second of these two supplementary methods for measuring the mortality incurred by yearling migrant sockeye salmon.

The data indicated that the migration of sockeye from the reservoir occurred from April 25 to June 18 whereas the coho migration began before April 11 and had not ended by June 18. The peak of migration of both coho and sockeye occurred about May 15 but the sporadic spilling made it difficult to define the date exactly.

Although no measure of the vertical distribution of the coho or sockeye in the forebay was attempted it seemed that a significantly large portion of the migrating fish were present in the surface layers of the reservoir. These fish were observed to move in the shadows around the margin of the reservoir during bright days, but during periods of overcast or during twilight the fish could be seen dispersed throughout the whole area of the forebay.

The fyke net catches in the tailrace and in the river below the spillway revealed that the migration was principally over the spillway. The tunnel with its entrance 85 feet below the surface at full reservoir was used by less than 5 per cent of the migrating stock. Even during periods when the spillway gates remained closed there was no increase, or at best, an insignificant increase in the number of fish using the tunnel. It was found, however, that when the reservoir was low and the tunnel was only 44 feet below the surface a significantly greater number of coho passed through the tunnel and as the reservoir filled there was a gradual and pronounced decline in the number of fish using the tunnel. Other environmental variables such as turbidity and temperature gradients, and approach

velocities may also have influenced use of the tunnel as an exit but their effects could not be separately assessed.

A review of the annual return of Baker River adult sockeye to the commercial fishery and to the dam provided evidence that delayed spillway opening at the time of seaward migration had little or no effect on the number of yearling migrants eventually leaving the reservoir nor on the ultimate production of adults.

The effect of the spillway and turbines on the migrating sockeye and coho was assessed from the relative numbers of active, weak and dead fish present in the fyke net catches. These catches, however, were not representative of the stocks of fish that were emerging from the spillway pool and from the draft tubes. It was found from the recoveries of marked dead releases and marked live releases that the dead fish were less available than the live fish. Consequently a correction for the lower availability of dead fish was applied. It was shown by auxiliary experiments that the survival gears used in the mortality studies captured and retained the active swimming fish and that they had no noticeable injurious effect on the captives providing the fish were not retained for too long a period. The delayed effect of injuries was examined by holding live fish for several days. It was concluded from these special studies that about 18 per cent of the active spillway fish, 8 per cent of the active tunnel fish and 54 per cent of all weak fish would ultimately die as a result of their injuries. They were therefore considered as potential mortalities.

Taking into consideration the disproportionate availability of live and dead fish to the nets and the delayed effect of injuries, the mortalities to sockeye and coho migrants passing over the spillway during one gate of spill were estimated to be 63.5 per cent and 54.0 per cent respectively. The turbines killed 33.6 per cent of the sockeye and 28.3 per cent of the coho.

The return of marked adult sockeye to Baker Dam in 1953 from the spillway, tunnel, and river releases of 1951 provided another measure of spillway and tunnel mortality. Comparison of the rates of adult returns indicated that the sockeye passing over the spillway suffered a mortality of 62.7 per cent whereas 37.0 per cent of the tunnel releases were killed. The returns of marked adult coho, while not directly providing a measure of spillway and tunnel mortality, did serve to confirm the relationship between the tunnel and spillway mortalities obtained from the fyke net studies.

All captured fish were examined for injuries and a study was made to determine the possible causes of these injuries. Many fish that had passed over the spillway had superficial injuries such as damaged operculi, ruptured and crushed eyes, scraped and crushed heads, and scraped and torn body walls, which were directly attributable to the rough and irregular nature of the spillway face. Internal hemorrhaging and distended eyes were also evident, indicating that the fish also suffered from the effects of pressure change and cavitation. To determine the effect of the extremely turbulent spillway pool, a number of hatchery coho were released from a high-line bucket at the most turbulent point of the upstream end of the pool. In these special tests fish passing over the spillway had a mortality rate 2.5 times greater than fish released directly into the pool. Injuries to fish released over the spillway exceeded those sustained by fish released into

the pool in number and severity. It was concluded that mortalities and injury to fish using the spillway exit were incurred primarily during the fall from crest to pool and were caused principally by abrasion and pressure change. The fish passing through the tunnel suffered comparatively few injuries. The injuries that were evident were mainly distended eyes, hemorrhages and body scrapes. It is possible that reduced cavitation resulting from an abnormally high tailrace level may have been responsible for a lower mortality and injury rate than might otherwise occur to fish passing through Francis turbines under 250 feet of head. All experiments were conducted when the turbines were operating at full load, and it is thought that this also tended to minimize the injuries.

The records of production of Baker River sockeye before and after the construction of the dam were examined to determine whether or not the estimated mortalities to the downstream migrants caused a proportionate reduction in the total numbers of adult sockeye returning to the commercial fishery and to the spawning grounds. The data showed that the production of adult sockeye has declined 54.5 per cent since the construction of the dam. This information agrees quite closely with the results previously obtained which established that at least 95 per cent of the sockeye used the spillway in gaining access to the river and that these migrants suffer a mortality for one gate of spill of 63.5 per cent as determined by fyke net studies or 62.7 per cent based on adult returns of marked releases of sockeye.