MFR PAPER 1255

Use of Salt (NaCl) Water to Reduce Mortality of Chinook Salmon Smolts, *Oncorhynchus tshawytscha*, During Handling and Hauling

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ABSTRACT—A major research program on the Columbia and Snake Rivers is designed to increase survival of juvenile salmon and trout by capturing them at an upriver dam, transporting them around a series of dams, and releasing them into the Columbia River. Excellent results have been obtained with steelhead trout, Salmo gairdneri. *However, the mortality of chinook salmon,* Oncorhynchus tshawytscha, *immediately following their transportation has adversely affected the percentage that return as adults.*

In a small-scale study conducted in 1975 at Bonneville Dam, adding salt (NaCl) to the water during handling and hauling increased the survival of juvenile chinook salmon and protected test fish against Saprolegnia spp., *a fungus that infected several of the control fish. The addition of salt to the water in future transportation studies should reduce delayed mortality of juvenile chinook salmon and thereby increase the percentage that return as adults.*

INTRODUCTION

Reducing the mortality of juvenile chinook salmon, *Oncorhynchus tshawytscha*, during handling and hauling by truck tanker is becoming increasingly important to the success of a major research program on the Columbia and Snake Rivers. This research, a cooperative study by the National Marine Fisheries Service (NMFS) and the U.S. Army Corps of Engineers, is aimed at reducing the loss of migrating (smolting) juvenile chinook salmon and steelhead trout, *Salmo gairdneri*, that must pass through eight dams before reaching the Pacific Ocean. The program involves collecting the downstream migrants at an upstream dam, transporting the fish around the remaining dams, and releasing them back into the river (Trefethen and Ebel, 1973). This method averts the major problems associated with passage at and between dams, such as passage through river water supersaturated with atmospheric gases, passage through turbines, predation, and excessive delay of the migrating fish.

Survival of both transported steelhead trout and chinook salmon in terms of returning adults has been dramatically increased, compared with nontransported controls. However, the survival of transported steelhead trout has been consistently higher than that of transported chinook salmon. One reason for this difference is the excessive delayed mortality of chinook salmon smolts occurring immediately after truck transport. Decrease of the mortality associated with handling and hauling may increase the percentage of chinook salmon smolts that return as adults to levels approximating those of steelhead trout.

Disease and stress were suspected as causing the excessive delayed mortality among chinook salmon smolts. Diseases have been identified in both steelhead trout and chinook salmon stocks being transported. These conditions led to studies for developing effective countermeasures. To minimize stress on the fish, NMFS researchers streamlined the methods of handling the fish and made several improvements in the truck transport design. In spite of these improvements, excessive delayed mortality of chinook salmon continued in some loads. Researchers then examined the possible use of salt water to reduce mortality of salmon and trout during handling and hauling by tank trucks.

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LITERATURE SEARCHED FOR INFORMATION ON USE OF SALT WATER

Available evidence implies that stress due to handling and hauling can be alleviated by adding NaCl to the water containing the fish. Sykes (1950) and later Chittenden (1971) showed that transporting American shad fingerlings, *Alosa sapidissima*, in seawater diluted to salt concentrations of about 5 parts per thousand (ppt) increased their survival. Wedemeyer (1972) showed that with both coho salmon, *O. kisutch*, and steelhead trout fingerlings, stress due to handling — as measured by blood chemistry changes—was alleviated by the addition of 3 ppt NaCl to the water prior to handling the fish. Collins and Hulsey (1963) reported that hauling loss of threadfin shad, *Dorosoma petenense*, was reduced from 50 percent to 5 percent by transporting the fish in a combination of 5 ppt NaCl and an anesthetic (MS222). Similar benefits were reported by Hattingh et al. (1974) for a variety of freshwater fish found in Africa. Although the Washington (State) Department of Fisheries has been transporting chinook salmon smolts in salt water, no data have been generated to quantify benefits[1].

Besides alleviating the effects of stress, salt water has therapeutic value

[1] J. W. Woods, Washington Department of Fisheries, M-5 Fisheries Center, Univ. Wash., Seattle, WA 98195, pers. commun.

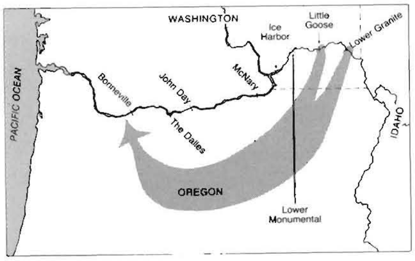


Figure 1.—Ongoing fish-transportation studies involve collecting seagoing juvenile salmonids at upstream dams, hauling the fish by truck around a series of dams, and releasing the fish into the Columbia River to continue their migration to the Pacific Ocean.

and can prevent the transmission of freshwater diseases from one fish to another. Davis (1953) reported that salt water constitutes an effective treatment for certain noxious protozoa and fungi. The transmission of *Flexibacter columnaris*, the freshwater bacterium that causes columnaris disease, is prevented in water containing 8.5 ppt salt[2].

It was clear from the literature that salt water provides benefits in handling and hauling operations, but the degree to which survival of chinook salmon smolts could be increased remained a matter of speculation.

FISH TRANSPORTATION SYSTEM ON THE SNAKE AND COLUMBIA RIVERS

The salt studies conducted in 1975 and reported here were designed within constraints dictated by the ongoing fish-transportation program. In general, the fish to be transported are diverted out of turbine intakes at Little Goose and Lower Granite Dams on the Snake River with submersible traveling screens and into fish bypasses that transport the fish around the dams (Smith and Farr, 1975). The fish are removed from the bypass, anesthetized, and marked (by removing the adipose fin, by "branding," and by insertion of a magnetized wire into the cartilage of the nose); they are then placed in transport trucks (Ebel et al., 1973; Smith and Ebel, 1973). The trucks haul the fish to a point downstream from Bonneville Dam (Fig. 1), a trip of 8-10 hours, where they are released into the Columbia River to continue their migration to the Pacific Ocean.

To estimate mortality that may occur after the fish are released, a sample is removed from the truck and kept for 48 hours in holding tanks at Bonneville Dam. For 1971 through 1975, results of these delayed mortality studies have indicated that 15 to 20 percent of the chinook salmon die within 48 hours after release from the truck, but steelhead trout smolts incur less than 1 percent mortality.

SALT USED IN EXPLORATORY STUDIES

Attempts to increase the survival of transported chinook salmon smolts by adding salt (NaCl) to the water were conducted at Bonneville Dam where studies on delayed mortality of transported fish were underway (Figs. 2-4). Three experiments were conducted. In the first two experiments, we obtained samples of fish from the regular transport trucks carrying fish to Bonneville Dam in fresh water. In the third experiment, in addition to the standard freshwater loads, three loads were hauled from Little Goose Dam in salt water.

In the first experiment, groups of 25 fish were placed in fresh water and in salinities of 1, 3, and 5 ppt. All groups received a 10-count stress (Fig. 5) every 2 hours for the first 12 hours of the test period. This four-group comparison was replicated four times.

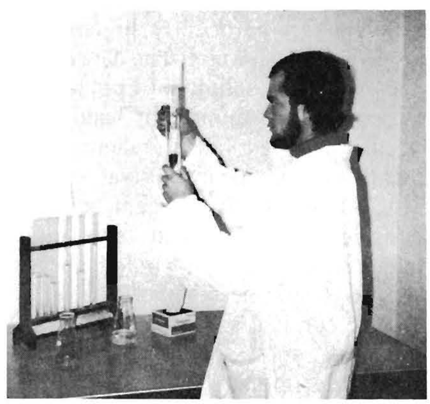
In the second experiment, groups of 25 fish were placed in fresh water and in salinities of 5, 10, and 15-20 ppt. This four-group comparison was replicated three times—however, the first replicate received a 10-count stress; the second, a 15-count stress; and the third, a 20-count stress every 2 hours for the first 8 hours of the test period.

In the third experiment, groups of 25 fish hauled in salt water (5 ppt) or fresh

Figure 2.—Technicians removing a sample of chinook salmon smolts from 5,000-gallon fish-transport truck.

Figure 3.—NMFS personnel preparing a brine solution.

Figure 4.—Scientist measuring salt concentrations of water sample removed from fish-transport truck.



[2]P. M. Fujihara, Battelle Northwest, Richland, Wash., pers. commun.

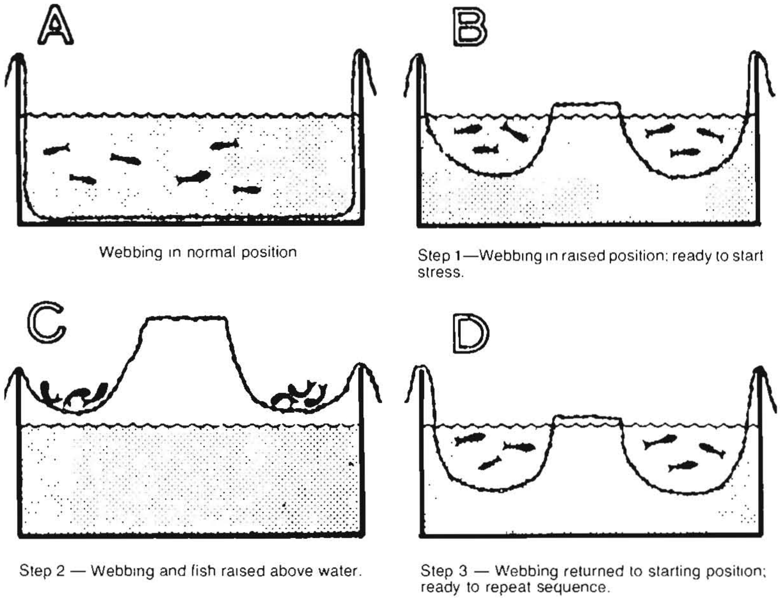


Figure 5.—Procedure for imposing a controlled stress on fish in test tanks. Raising the webbing and fish out of the water 10 times (steps 1, 2, and 3 repeated 10 times at the rate of once per second) is referred to as a 10-count stress.

water were placed in test tanks for 72-114 hours. Half of the test tanks were filled with fresh water and the other half with salt water at a salinity of 5 ppt. A 10-count stress every 2 hours for the first 16 to 24 hours of the holding period was imposed on half of the groups of fish in both the fresh and salt water.

SALTWATER MEDIUM BENEFICIAL

The results of the first experiment are shown in Figure 6 which compares the survival, over a 24-hour period, of four groups of transported chinook salmon smolts subsequently held in either fresh water or salt water at salinities of 1, 3, or 5 ppt. Survival of fish in all salinities tested was significantly higher than survival in fresh water. The data imply, however, that a salinity of 1 ppt was not as beneficial as salinities of 3 and 5 ppt. A chi-square test failed to demonstrate that this difference in survival was significant at the 90 percent level of confidence. Additional tests using larger numbers of fish would be necessary to determine whether this difference in survival is significant.

Figure 7 shows the results of the second experiment by comparing the survival, over a 24-hour period, of transported chinook salmon smolts subsequently held in either fresh water or salt water at salinities of 5, 10, or 15 to 20 ppt. Survival of fish in all salinities tested and for all levels of stress was nearly 100 percent; only one mortality occurred in 225 fish tested. On the other hand, survival of fish in fresh water was only 80 percent for the 10-count stress and decreased to 16 percent for the 20-count stress.

Figure 8 portrays the average survival under different conditions, of chinook salmon smolts taken from each of three truckloads of fish hauled in salt water and three truckloads of fish hauled in fresh water (third experiment). As in the previous two experiments, the addition of salt had definite benefits. Fish hauled and held in salt water had a survival of 98.2 percent whether they received the controlled stress or not. Fish hauled in salt water and held in fresh water without stress had a survival of 97.3 percent—not significantly different from those groups hauled in salt water and held in salt water. Of the fish hauled in salt water and held in fresh water, the stressed groups had a significantly lower survival (93.3 percent) than the unstressed groups (97.3 percent). Being

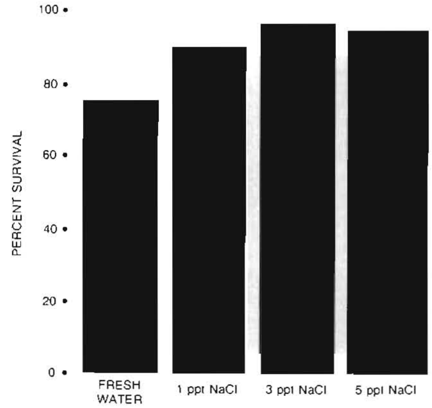


Figure 6.—Results of a 24-hour experiment comparing survival of chinook salmon smolts held in fresh or salt water. All groups were given a 10-count stress every 2 hours for the first 12 hours.

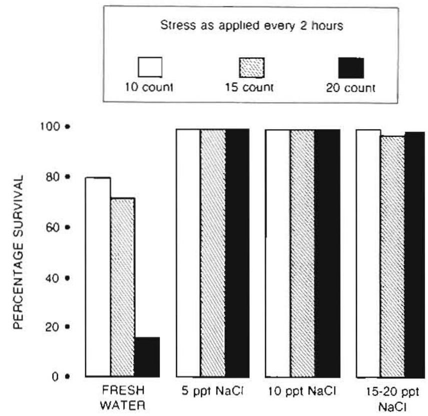


Figure 7.—Results of a 24-hour experiment showing increased survival of chinook salmon smolts held in salt water by comparison with fish held in fresh water. Stress was applied at the level indicated every 2 hours for the initial 8 hours.

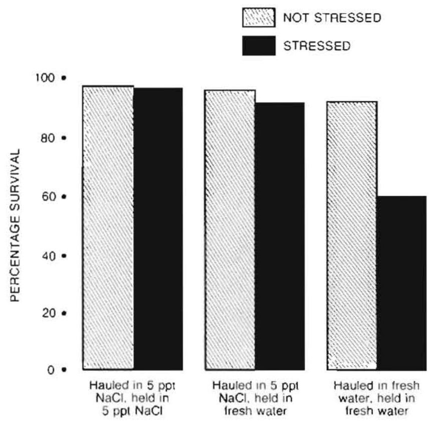


Figure 8.—Survival of chinook salmon smolts hauled in 5 ppt salt water or fresh water when held and stressed in salt water or fresh water. All stressed groups were given a 10-count stress every 2 hours for the first 16-24 hours.

hauled in salt water, however, obviously benefited the fish even after they were placed in fresh water; their counterpart (stressed) group hauled in fresh water had a survival of only 60.5 percent.

Our tests also provided evidence of the value of salt in disease prevention. Figure 9 portrays graphically the time of occurrence of mortality during the third and final test for those groups of test and control fish that received the controlled stress. Note that the initial occurrence of high mortality for fish hauled and held in fresh water was associated with the period during which stress was imposed. When the stress treatment was stopped, mortality lessened. The sudden increase in mortality at about hour 80 was due primarily to *Saprolegnia*, a fungus which commonly infects weakened fish. On the other hand, fish that had been transported in 5 ppt salt water were free of this disease whether they were being held in fresh or salt water.

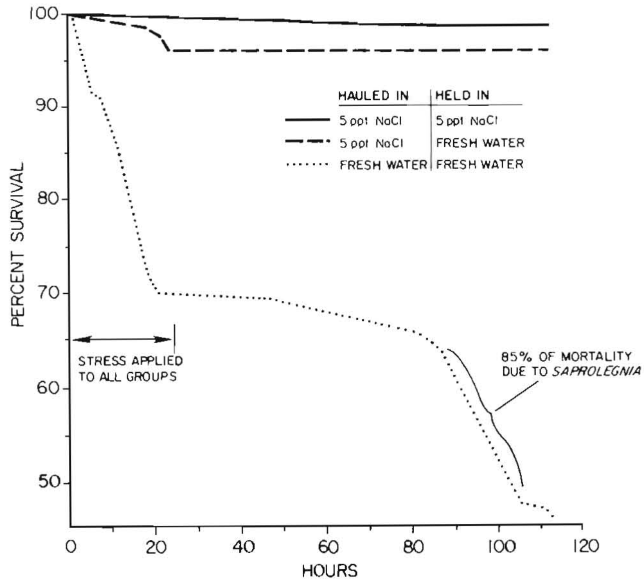


Figure 9.—Cumulative survival of groups of fish while held and stressed in salt or fresh water after having been hauled in either salt or fresh water. Fish hauled in salt water had increased resistance to stress and the disease *Saprolegnia* by comparison with fish hauled in fresh water.

IMPLICATIONS OF SALTWATER USE

These studies show clearly that adding salt (NaCl) to water dramatically increases the survival of yearling chinook salmon smolts subjected to stressful conditions caused by handling and hauling.

We believe that the benefits to be gained by using salt water during the transportation program will be even greater than indicated by these limited studies—the test fish we used were the survivors of fish that had already undergone the stresses of the handling system at Little Goose or Lower Granite Dams. The addition of salt to the water used to hold, anesthetize, and mark the fish before hauling should yield additional benefits.

Additional studies will determine the concentration of salt that will yield optimum benefits for both the stress and disease problems. In this study, a salinity of 15 ppt was not too high for successfully mitigating the effects of stress, and *Saprolegnia* was successfully controlled using only 5 ppt salt. Higher salinity levels may yield more rapid and effective benefits against disease.

We see no serious constraints to implementing large-scale use of salt in the handling and hauling studies to be conducted in the future on the Snake and Columbia Rivers. Benefits could be determined by using salt on only a portion of the smolts for the first 1 or 2 years and comparing the percentage of individuals of each group that return as adults 1 to 3 years later.

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MFR Paper 1255. From Marine Fisheries Review, *Vol. 39, No. 7, July 1977. Copies of this paper, in limited numbers, are available from D825, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235. Copies of* Marine Fisheries Review *are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 for $1.10 each.*