# A REVIEW OF SMOLT TRANSPORTATION TO BYPASS DAMS ON THE SNAKE AND COLUMBIA RIVERS

by

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# INTRODUCTION

Chinook salmon and steelhead runs in the Snake River Basin began to significantly decline after 1970 because of existing and newly constructed dams on the Snake and Columbia Rivers (Raymond 1979). The dams created passage problems which resulted in serious mortality to seaward-bound juvenile salmon and steelhead due to gas bubble disease, passage through turbines, predation, and delay in migration.

National Marine Fisheries Service (NMFS) scientists theorized that survival of salmonid smolts could be substantially increased if the fish were collected at an uppermost dam, transported to a safe release site below Bonneville Dam, and released into the Columbia River--thereby bypassing as many as eight dams and their associated problem areas. Although preliminary research began in 1965, the concept was first studied on the Snake River at Ice Harbor Dam during 1968-70 and then continued at Little Goose Dam during 1971-73 and 1976-78 and at Lower Granite Dam during 1975-80. Transportation research expanded to include McNary Dam during 1978-80.

The objectives of the transportation research were to determine if the expected increase in salmonid smolt survival would be followed by a corresponding increase in adult fish returning to the collection site (i.e., point of initial transport). Further, researchers desired to know what impacts, if any, transportation had on homing capabilities of adults returning to the Columbia and Snake Rivers. In some related transportation studies, researchers found that when juvenile salmonids were transported directly from hatcheries to distant downstream release sites, homing of returning adults was impaired (Slatick et al. 1980; Bjornn et al. 1984). On the other hand, in a study conducted at Dworshak National Fish Hatchery (NFH) situated on the Clearwater River in Idaho, Slatick et al. (1982) found that while some homing impairment of transported steelhead was observed, survival was apparently increased so that approximately 60% more transported fish returned to the hatchery than did the non-transported control fish.

The transportation studies described herein relate only to naturally migrating salmonid smolts that were intercepted on their seaward journey at dams and then transported to safe release sites downstream from Bonneville Dam. A summary of published data and a review of recent research are presented in this report.

## RECENT DEVELOPMENT OF HYDROELECTRIC PROJECTS AND FISH PROTECTION FACILITIES

A realistic appraisal of salmonid smolt transportation and its effect on returning adult populations cannot be made without considering the number of dams and generating turbines and the development of protective traveling screens and bypasses. It is beyond the scope of this report to provide an evaluation of protective systems for juveniles, I will only describe in a general way their contribution or influence on evolving transportation studies and practices.

Since transportation studies began in 1968 at Ice Harbor Dam, many significant changes impacting juvenile salmonid passage have taken place. In 1968, there were no fingerling protection systems at Ice Harbor Dam, and the passage of seaward bound smolts from rearing areas in the Salmon River and other upstream tributaries was unimpeded by other Snake River dams. Also in 1968, John Day Dam was constructed on the lower Columbia River (Fig. 1). The dam's bypass system subsequently proved to be largely ineffective in passing juvenile fish from gatewells to the river downstream from the dam (Sims et al. 1977). Lower Monumental and Little Goose Dams were placed in operation on the Snake River in 1969 and 1970, respectively, with similar ineffective bypass systems. In 1975, Lower Granite Dam was constructed with a bypass system with the following fingerling protection features not available in any prior construction (Matthews et al. 1977): (1) specific placement of traveling screens to direct fingerlings from turbine intakes (Farr 1974); (2) two 8-inch diameter orifices in each gatewell, whereas single 6-inch diameter orifices were featured in the John Day Dam construction; (3) a fingerling collection area that was capable of separating smolts from debris; and (4) a holding system of raceways that could accommodate several hundred thousand migrants. The Lower Granite Dam system (Fig. 2) has had numerous minor modifications since 1975, but it is the model for current collection systems now in use at Little Goose and McNary Dams. A further major improvement in operating bypass systems occurred in 1978 when 12-inch diameter orifices were incorporated into the new bypass system at McNary Dam.

In general, the relationship between transportation studies and the development of screening and bypass facilities may be summarized as follows:

1. At Ice Harbor Dam (1968-70) no traveling screens were used and a rudimentary bypass system was being developed.

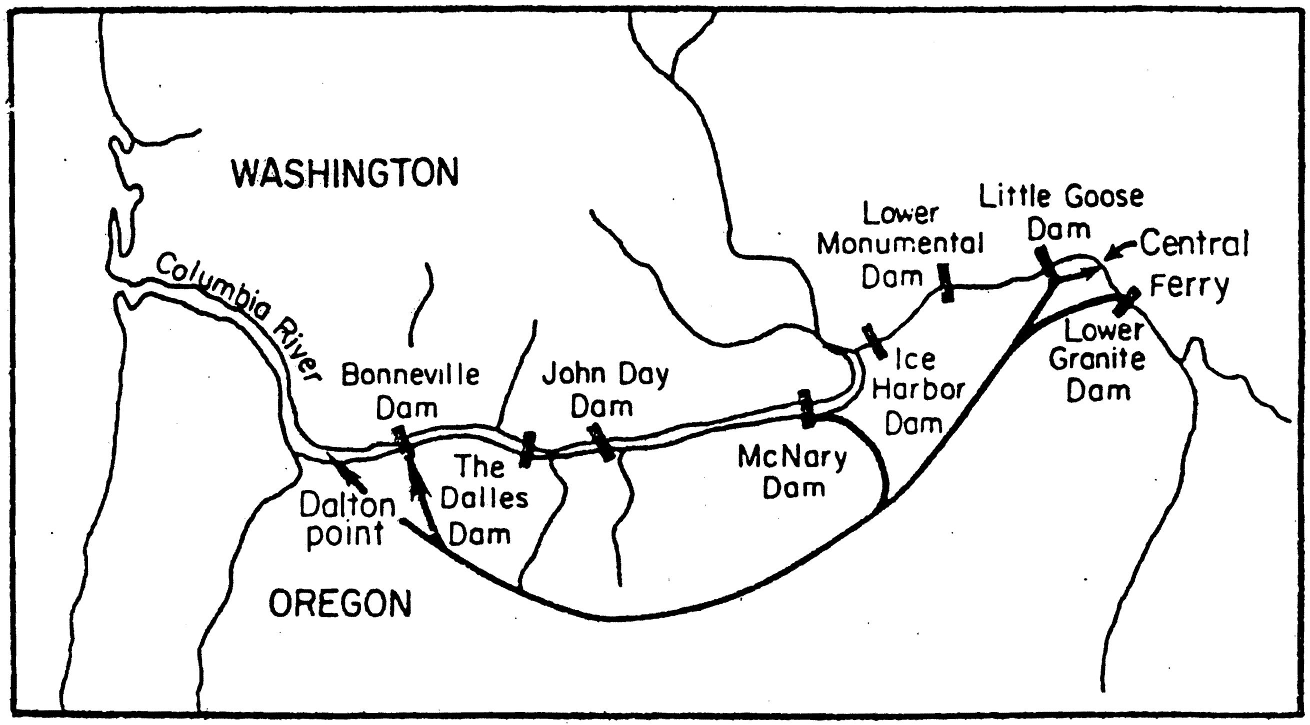



Figure 1.--Transportation routes and release locations of experimental chinook salmon and steelhead collected and marked at Ice Harbor, Little Goose, Lower Granite, and McNary Dams.

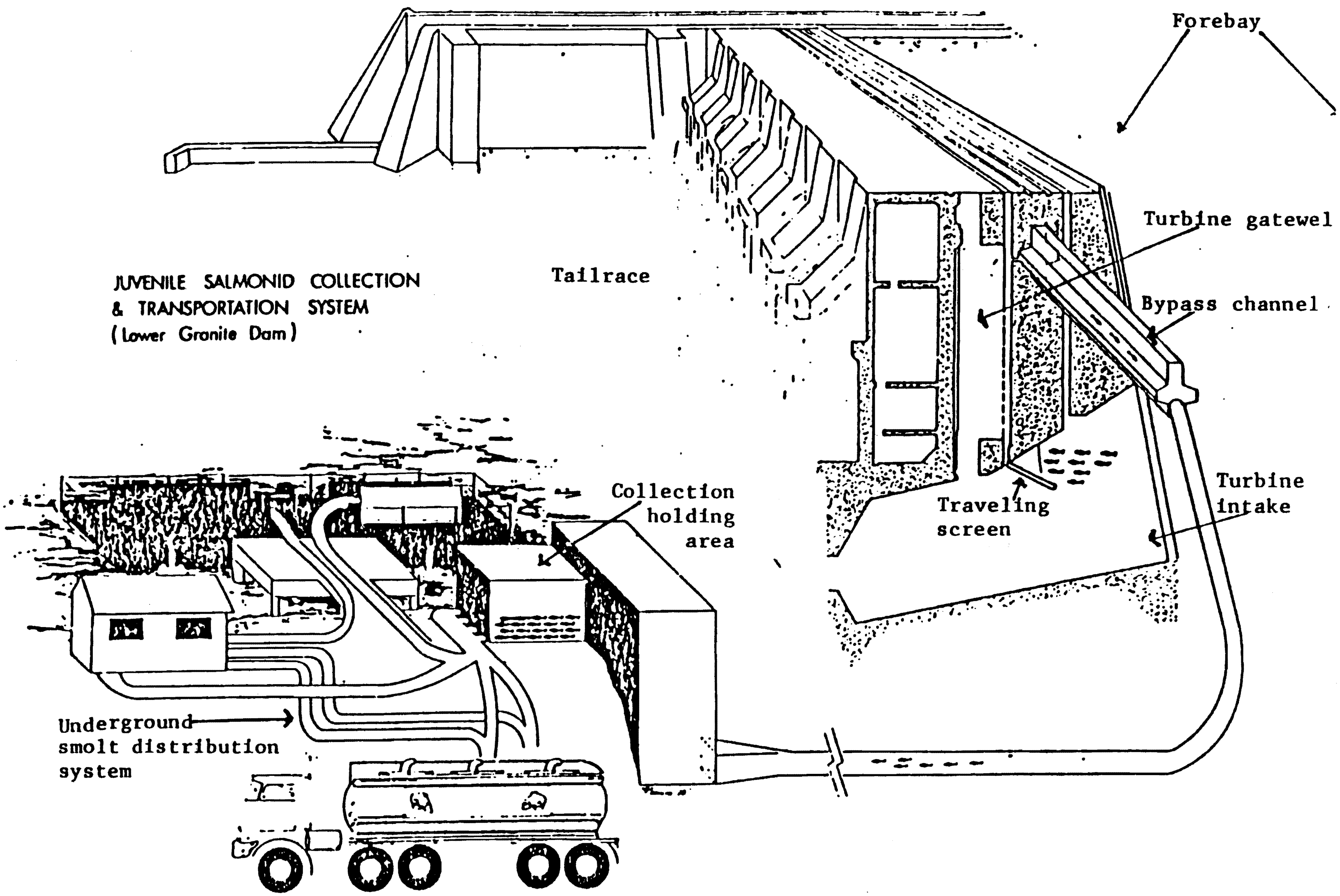



Figure 2.--A cross section of a powerhouse at a major collector dam showing the typical collection and transport system including traveling screen placement, bypass channel and pipe to tailrace, holding ponds, and distribution system to trucks or barges.

2. At Little Goose Dam (1971-78) traveling screens were developed, and by 1978 all generating units were screened. Throughout this period, the bypass system operated poorly [e.g., smolts were descaled to a high degree and/or they were delayed in passage from gatewells (Ebel 1980)].

3. At Lower Granite Dam (1975-80) and McNary Dam (1978-80) traveling screen and bypass systems were fully developed by 1976 and 1981, respectively.

Turbine generating capacity increased tremendously in recent years on the Columbia River system. When Snake River dams first became operational only three of six generator units were completed at each project. Between 1969 and 1979, the number of turbines on-line increased from 3 to 24 (Table 1). On the lower Columbia River, additional generating capability was completed at The Dalles Dam in 1980 and a second powerhouse was constructed at Bonneville Dam in 1983.

By 1972, there was nearly complete flow regulation on the Columbia River. Large storage reservoirs in Canada made it possible to store water during the spring runoff for release later in the year when there was more need for power. With more regulated river flows and increased power generation at each dam, spilling at dams would be minimal, except in years of above average runoff. Without spill, the entire smolt migration would have to pass through the turbines where they would experience significant mortalities. With the lower runoff, there would also be additional delays and subsequent mortalities in passing through the increasing number of reservoirs enroute to the sea.

The deteriorating conditions in relation to smolt passage made it clear that if we wished to maintain upriver runs of salmon and steelhead

Table 1.--Number of turbine units at hydroelectric dams on the Snake River, 1968 to 79.[a]

| | Cumulative number of turbine units in place | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River/dam | 1968 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 |
| Snake River | | | | | | | | | | | | |
| Lower Granite | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 6 | 6 |
| Little Goose | 0 | 0 | 0 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 6 | 6 |
| Lower Monumental | 0 | 0 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 6 |
| Ice Harbor | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 6 | 6 | 6 | 6 | 6 |
| Total | 3 | 3 | 6 | 9 | 9 | 9 | 9 | 15 | 15 | 15 | 21 | 24 |

a/ Data source: Bell et al. (1976).

that a means of increasing smolt survival was essential. NMFS anticipated this increased mortality of smolts from the accelerated development of hydroelectric power facilities and recommended that transportation studies be continued and expanded at several dams from 1968-80.

## METHODS AND PROCEDURES

During the transportation studies, juvenile salmon and steelhead were collected from gatewells at Ice Harbor Dam (1968-70) or from holding raceways at Little Goose Dam (1971-78), Lower Granite Dam (1975-80), and McNary Dam (1978-80). Fish to be marked were selected randomly and placed into control and transport (test) lots. The adipose fin was excised from all experimental fish (except 1975) to identify them in the fishery and each group was identified by a common thermal brand and magnetic coded wire tag (CWT). The brand permitted identification of fish at dams without having to sacrifice the fish to remove the CWT. Control groups were released above the dam (study site) in each year of the study through 1976 and through 1977 at Lower Granite Dam. Thereafter, control groups were released below the dam at the study sites.

Fish were transported by truck, barge, or airplane (transportation by plane was only tested briefly). Fish transported by truck were released in the Columbia River below Bonneville Dam or at Dalton Point (approximately 10 km downstream from Bonneville Dam). Fish transported by barge were released in the Columbia River at Beacon Rock, about 8 km downstream from Bonneville Dam. Fish were hauled in 18,900-liter (5,000-gallon) or 13,200-liter (3,500-gallon) tanker trucks with recirculating water supplies or in a barge with a capacity of 412,500 liters (110,000 gallons) and flow-through water supply.

Throughout the season samples of fish were taken from the transport vehicles upon arrival at Bonneville Dam. The fish were held for observation for 45 or 48 h to determine delayed mortality.

Water quality was monitored in both the trucks and barges. Water quality data were taken from fish transport trucks in the early studies (Ebel, Park, and Johnsen 1973; Ebel 1980); however, the practice was discontinued in 1976 because the need was no longer justified. During barge transportation, dissolved oxygen was monitored during the journey by an attending biologist on the vessel (McCabe et al. 1977).

Beginning in 1971, a descaling index was established by examining a random sample of 100 chinook salmon and 100 steelhead daily at the marking facility. Fish were considered to be descaled if >10% of the scales were missing (Ebel 1980). Generally, the same individuals made observations throughout the season, but not necessarily from year to year.

The survival and homing capabilities of adults returning following transportation were evaluated by comparing the number of transported and nontransported fish returning to the study site. A tag detection device activated a trapping mechanism placed in one of the normal fishways at the dam so that each fish properly detected could be held for observation of the brand previously placed on the fish as a juvenile (Ebel 1974). This system was relatively efficient in recovering tagged adults at Ice Harbor, Little Goose, and Lower Granite Dams but not at McNary Dam. At McNary Dam, the detection apparatus was placed in the north fishway which was used only secondarily to the preferred south fishway by all species of migrating adults.

To obtain additional information on adult returns and to gather more data on straying and survival of adults, tagged adults were also recovered from all Columbia and Snake River hatcheries, natal spawning areas in upper tributaries (spring chinook salmon), spawning areas in the Columbia River (fall chinook salmon), river commercial and sport fisheries, and ocean fisheries. The latter area was particularly important to establish benefit ratios between transported and nontransported coho and fall chinook salmon marked at McNary Dam.

The G-statistic, student's t-test, and analysis of variance were used for analysis of the adult return data for studies conducted from 1968-73. For studies conducted in 1975-80, only the G statistic was used.

# RESULTS

## Factors Affecting Analysis

When assessing the effects of transportation on experimental groups of fish there are three elements that require special consideration: (1) direct transport mortality and delayed mortality due to transportation, (2) wire tag loss in fish from test and control groups, and (3) detectability or rate of recovery of experimental lots of adults returning to the collection site (dam). A fourth consideration may be included when comparing returns of experimental groups (marked fish) with returns of unmarked fish.

Ebel, Park, and Johnsen (1973) reported that direct transport mortality (i.e., those fish that actually died during transportation) were enumerated and substracted from the total transported. Beginning in 1975, this practice was discontinued because unmarked fish were frequently hauled in the same load with experimental fish, and we reasoned that if the transportation concept was to be used as an operational system, then all aspects of mortality due to transportation would be included in later analyses (delayed mortality following transportation will be reviewed in a later section).

In any coded wire tagging experiment, some wire tag loss is inherent. Losses occur primarily because of faulty tagging initially or because of tissue rejection from the fish (Jefferts et al. 1963). In studies at Ice Harbor and Little Goose Dams, the average tag loss was 9.2 and 3.7%, respectively, (Ebel, Park, and Johnsen 1973; Ebel 1980). In subsequent studies, tag loss was not measured because tag loss was believed to be minimal (tag loss did not affect analysis of data from the Little Goose Dam study in 1971-73), and the same marking crews marked both test and control groups at each dam so that any tag loss that did occur was more likely to be random through all experimental groups within each year.

The detection efficiency for the recovery of tagged adults at dams varied each year. Detection efficiency was described by Ebel (1980). Trap efficiency was used to make estimates of total returns each year. For example, if tag recovery at the dam was 50% (efficiency), the estimated return would have been double that of the observed return. Park et al. (1980 and 1984) reported that low detection efficiency can be due to faulty or marginally operating detection equipment. Other factors that influence detection efficiency are alternate routes of migration (i.e., fish may pass through a fishway where no detection device is operating or fish may be passed upstream via navigation locks, bypassing fishways altogether). Analysis of the recovery data revealed no bias between experimental groups within a given year from the above factors. Total returns from each transport year were expanded based on each year's detection efficiency. Observed returns, however, were used for statistical analysis and to establish test to control ratios.

## Transportation from Ice Harbor Dam, 1968-70

Results of transportation experiments conducted at Ice Harbor Dam in 1968-70 have been reported by Ebel, Park, and Johnsen (1973) and Slatick et al. (1975). These early studies represented the first time smolts that were intercepted at a dam on their downstream journey and transported below a downstream dam (Bonneville) successfully homed back to the interception point. The studies also indicated true homing was achieved as evidenced by returns to hatcheries and natal spawning areas. Homing impairment was considered minor.

The smolt release data and adult returns to the Snake River are summarized in Table 2. The number of adult chinook salmon and steelhead returning from transported groups (Bonneville Dam releases) was either significantly or measurably higher than the number of adults returning from comparative control groups. Adult returns of transported juveniles released below John Day Dam were less than those released below Bonneville Dam. Ebel, Park, and Johnsen (1973) indicated that high nitrogen gas supersaturation below John Day Dam adversely impacted juvenile survival. Slatick et al. (1975) concluded that dam-related passage problems at The Dalles and Bonneville Dams (downstream from John Day Dam) negated any initial transport benefits.

Transport benefits were strongly positive for spring chinook salmon in the lower Columbia River net fisheries (1968). The transport/control ratio was similar to that observed at Ice Harbor Dam indicating that survival of transported fish was increased whereas straying or homing impairment was minimal.

Table 2.--Percentage return and benefit ratio of transported to nontransported chinook salmon and steelhead released in 1968-70 at Ice Harbor Dam.

| Release site and experimental group of fish | Number juveniles released | Number recaptured as adults | Percentage return as adults | | Transport to control ratio |
|---|---|---|---|---|---|
| | | | Observed | Estimated | |
| Chinook salmon | | | | | |
| 1968 | | | | | |
| Ice Harbor Dam (control) | 80,335 | 117 | 0.14 | 4.3 | - |
| John Day Dam (test) | 40,895 | 64 | 0.16 | 4.7 | 1.14:1 |
| Bonneville Dam (test) | 42,420 | 128 | 0.30 | 9.0 | 2.14:1 |
| 1969 | | | | | |
| Ice Harbor Dam (control) | 24,217 | 47 | 0.194 | 0.497 | - |
| John Day Dam (test) | 14,782 | 19 | 0.129 | 0.356 | 0.66:1 |
| Bonneville Dam (test) | 13,529 | 33 | 0.244 | 0.581 | 1.26:1 |
| 1970 | | | | | |
| Ice Harbor Dam (control) | 8,624 | 17 | 0.197 | 0.323 | - |
| John Day Dam (test) | 10,159 | 7 | 0.069 | 0.113 | 0.35:1 |
| Bonneville Dam (test) | 10,173 | 29 | 0.286 | 0.467 | 1.45:1 |
| Steelhead | | | | | |
| 1969 | | | | | |
| Ice Harbor Dam (control) | 25,313 | 46 | 0.182 | 0.792 | - |
| John Day Dam (test) | 20,430 | 102 | 0.499 | 1.600 | 2.74:1 |
| 1970 | | | | | |
| Ice Harbor Dam (control) | 18,347 | 71 | 0.387 | 0.729 | - |
| John Day Dam (test) | 20,935 | 75 | 0.358 | 0.610 | 0.93:1 |
| Bonneville Dam (test) | 31,282 | 178 | 0.569 | 0.924 | 1.47:1 |

Slatick et al. (1975) noted two factors which likely contributed to poorer survival of experimental fish in 1969 and 1970: (1) changes in fish handling techniques at the time of marking that required pumping the fish (added stress) and (2) Lower Monumental Dam was completed in 1969 and Little Goose Dam constructed the following year--both dams contributed to high nitrogen gas supersaturation in the Snake River, and gas bubble disease symptoms were observed in smolts at Ice Harbor Dam.

Transportation from Little Goose Dam, 1971-73

These studies represent the first time that the collection of juveniles was aided by traveling screens and a bypass system whereby the fish could exit gatewells of their own volition, travel via an enclosed pipe, and descend to the tailrace level of the powerhouse to a holding facility (Smith and Farr 1975). It should be pointed out, however, that the traveling screen system was in a series of experimental stages. All turbine units were not screened, and existing screens were frequently repaired or modified during the spring smolt migration. Also, the bypass system did not function as designed, which resulted in high descaling rates and many fish being delayed in the gatewells. The annual average descaling rate for chinook salmon was 16.6% in 1972 and 19.6% in 1973. Descaling was most likely caused by traveling screens and adverse conditions in the bypass system (Ebel et al. 1973).

Studies conducted at Little Goose Dam in 1971-73 are reported by Ebel (1980). The data for releases of juvenile fish and returning adults to the Snake River are summarized in Table 3. Analysis of variance was used to analyze the data, and return of transported fish was significantly higher

Table 3.--Percentage return and benefit ratio of transported to nontransported chinook salmon and steelhead released in 1971-73 at Little Goose Dam.

| Species, release site, and year | Number released | Adults returning | Percent adults returning | | Transport/control ratio |
|---|---|---|---|---|---|
| | | | Observed | Estimated | |
| Chinook salmon | | | | | |
| Control | | | | | |
| 1971 | 20,673 | 52 | 0.252 | 0.470 | - |
| 1972 | 32,836 | 25 | 0.076 | 0.106 | - |
| 1973 | 88,170 | 20 | 0.023 | 0.026 | - |
| Transport/Dalton Point | | | | | |
| 1971 | 30,637 | 119 | 0.388 | 0.760 | 1.6:1 |
| 1972 | 51,499 | 44 | 0.085 | 0.114 | 1.1:1 |
| 1973 | 57,758 | 241 | 0.417 | 0.730 | 18.1:1 |
| Transport/Bonneville Dam | | | | | |
| 1971 | 35,252 | 147 | 0.417 | 0.785 | 1.7:1 |
| 1972 | 54,906 | 45 | 0.082 | 0.110 | 1.0:1 |
| 1973 | 83,606 | 261 | 0.312 | 0.438 | 13.5:1 |
| Steelhead | | | | | |
| Control | | | | | |
| 1971 | 33,243 | 199 | 0.599 | 0.833 | - |
| 1972 | 32,488 | 132 | 0.406 | 0.564 | - |
| 1973 | 42,461 | 61 | 0.144 | 0.199 | - |
| Transport/Dalton Point | | | | | |
| 1971 | 35,967 | 367 | 1.020 | 1.418 | 1.7:1 |
| 1972 | 22,831 | 318 | 1.393 | 1.936 | 3.6:1 |
| 1973 | 26,650 | 517 | 1.940 | 2.698 | 13.5:1 |
| Transport/Bonneville Dam | | | | | |
| 1971 | 44,939 | 464 | 1.033 | 1.436 | 1.7:1 |
| 1972 | 27,326 | 346 | 1.266 | 1.750 | 3.1:1 |
| 1973 | 36,802 | 708 | 1.924 | 2.673 | 13.4:1 |

(P<0.1) than the return of controls released at Little Goose Dam. This was true for chinook salmon and steelhead. There was variability among the transport to control ratios between species and between years except in 1971 when it was 1.6:1 and 1.7:1 for chinook salmon and steelhead, respectively. There was no significant difference among returns from the two transport release sites (Bonneville Dam and Dalton Point) for either species.

The rates of return for all groups of chinook salmon were low in 1972. The cause was unknown, although slotted bulkhead gates used in three empty turbine bays at Little Goose Dam for nitrogen gas saturation abatement may have killed some of the control fish and other naturally migrating fish. This rationale offers no explanation for low survival of transported fish. Many fish collected at Little Goose Dam in 1972 however, showed symptoms of BKD (Ebel et al. 1973). Therefore, disease, especially among hatchery reared fish, may have contributed to poor survival. A major discussion of factors affecting the low return rate of spring chinook salmon is contained in a subsequent section of this report.

In assessing the effectiveness of transportation, Ebel (1980) states "A substantial increase in survival of transported steelhead is indicated by both analysis of test/control ratios and comparisons of percentage returns of adults from transported groups with percentage returns of adults to Dworshak Hatchery and Little Goose Dam." Similar comparisons were made for chinook salmon using adults returning to Rapid River Hatchery; results were similar, though not as dramatic as shown for steelhead. Consideration was given for sport harvest of affected fish in upper tributaries.

Transportation did increase the survival of both chinook salmon and steelhead at Little Goose Dam and at Ice Harbor Dam, as noted earlier. The percentage return of chinook salmon was lower than observed in the earlier study, and Ebel (1980) concluded that survival of chinook salmon may be increased by reducing injuries, descaling, and handling stress at the collection dam.

## Transportation from Little Goose and Lower Granite Dams, 1975-80

Transportation experiments began at Lower Granite Dam in 1975--the year the dam was completed. Research at Lower Granite Dam was considered especially important because the dam, located at River Kilometer 107.5 was only about 100 km downstream from major smolt production and rearing areas (Park et al. 1976). Earlier studies indicated substantial benefits could be achieved by transporting spring chinook salmon and steelhead from Ice Harbor and Little Goose Dams, but it was unknown if similar results could be expected at Lower Granite Dam which is located nearer to smolt rearing areas.

In 1975, transportation of all fish collected at Little Goose Dam began without further evaluation by marking studies (mass transportation). This action, endorsed by fishery agencies of the Pacific Northwest, was evaluated later by marking comparative transported and non-transported groups of fish during 1976-78.

During 1975-80, the transportation experiments became more complex as various transport modes (truck, barge, and aircraft) and alternate truck transport media (5 ppt and 10 ppt salt water) were tested (Table 4). At Little Goose Dam, only trucking tests with fresh water and 10 ppt salt

Table 4.--Summary of tests to determine effective transport modes, transport media, and release sites for spring chinook salmon and steelhead during studies at Lower Granite, Little Goose, and McNary Dams--1975-80.

| Transport mode (media) | Dam | | |
|---|---|---|---|
| | Lower Granite | Little Goose | McNary |
| Truck, fresh water | 1975, 76, 78 | 1976-78 | 1978-80 |
| Truck, 5 ppt salt water | 1976-77 | - | - |
| Truck, 10 ppt salt water | - | 1976-78 | - |
| Barge | 1977-80 | - | 1979-80 |
| Alternate release site | 1977 | - | - |

water were compared, whereas at Lower Granite Dam, fish were trucked with fresh water and 5 ppt salt water (1975-78). Barge transport was implemented in 1977, and tests continued through 1980. Aircraft were used as a transport mode for spring chinook salmon only in 1976-77, but results were poor, and the method was discarded as a viable transport operation.

When considering the results of Snake River transport tests in 1975-80, the reader should be aware that mass transport (unmarked fish transported with marked fish) occurred each year beginning in 1975 at Little Goose Dam and in 1976 at Lower Granite Dam. Note that the number of spring chinook salmon and steelhead transported increased substantially each year through 1980 (Table 5). Mass transportion also began at McNary Dam in 1979 (Park et al. 1980). Therefore, controls released in the Snake River likely received the benefit of later transport at Lower Granite, Little Goose, or McNary Dams depending on release location and year of release. Analysis of the data does not account for this action and transport benefits are therefore conservative.

Chinook salmon returning to Little Goose Dam following transportation as smolts in 1976 were not significantly greater than those not transported (Table 6). In 1977-78, there were too few returns for analysis. As previously mentioned, the bypass system at Little Goose Dam was not operating fully satisfactorily and fish were injured or at least stressed prior to transportation. The use of 10 ppt salt water as transport media was tested in an effort to mitigate effects of collection and transport stresses. The use of salt water did not produce desired results and no significant benefits were observed.

Table 5.--Number of yearling chinook salmon and steelhead smolts arriving at the upper dams on the Snake River, and the number and percent of the total Snake River outmigration transported below Bonneville Dam 1971-1983 (includes experimental fish marked for transport evaluation).

| | Yearling chinook smolts | | | Steelhead smolts | | |
|---|---|---|---|---|---|---|
| | No. at upper dam (1,000) | No. hauled (1,000) | Percent hauled | No. at upper dam (1,000) | No. hauled (1,000) | Percent hauled |
| Transport from Little Goose Dam | | | | | | |
| 1971 a/ | 4,000 | 109 | 3 | 5,550 | 154 | 3 |
| 1972 | 5,000 | 360 | 7 | 2,500 | 227 | 9 |
| 1973 | 5,000 | 247 | 5 | 5,550 | 176 | 3 |
| 1974 | 3,500 | 0 | 0 | 5,000 | 0 | 0 |
| Transport from Lower Granite and Little Goose Dams combined | | | | | | |
| 1975 | 4,000 | 414 | 10 | 3,200 | 549 | 17 |
| 1976 | 5,000 | 751 | 15 | 3,200 | 435 | 14 |
| 1977 | 2,000 | 1,365 | 68 | 1,400 | 895 | 64 |
| 1978 | 3,180 | 1,623 | 51 | 2,120 | 1,355 | 64 |
| 1979 | 4,270 | 2,109 | 49 | 2,500 | 1,712 | 67 |
| 1980 b/ | 5,600 | 3,254 | 58 | 3,600 | 2,860 | 79 |
| 1981 b/ | 3,200 | 1,549 | 46 | 3,700 | 2,737 | 74 |
| 1982 b/ | 2,100 | 581 | 28 | 4,300 | 2,271 | 53 |
| 1983 c/ | 3,900 | 1,029 | 26 | 2,900 | 1,939 | 69 |

a/ Data for years 1971-79 from Smith et al. (1980).
b/ Number of smolts estimated at upper dam from Sims et al. (1981, 1982 1983).
c/ Number of smolts estimated at upper dam from pers. commun. Carl Sims, Fishery Research Biologist, Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, Wash.

Table 6.--Percentage return and benefit ratio of transported to non-transported chinook salmon and steelhead released in 1976-78 at Little Goose Dam or transported to below Bonneville Dam by truck in freshwater or saltwater media.

| Species, release site, year | Number of juveniles released | Number adults recaptured | Percentage return as adults | | Transport/ control ratio |
|---|---|---|---|---|---|
| | | | Observed | Estimated | |
| Chinook salmon | | | | | |
| Control | | | | | |
| 1976 | 42,046 | 10 | 0.024 | 0.094 | - |
| 1977 | 38,346 | 0 | 0 | a/ | - |
| 1978 | 36,441 | 5 | 0.013 | a/ | - |
| Transport/fresh water | | | | | |
| 1976 | 68,605 | 29 | 0.042 | 0.164 | 1.75:1 |
| 1977 | 41,677 | 0 | 0 | a/ | a/ |
| 1978 | 49,391 | 5 | 0.010 | a/ | 0.77:1 |
| Transport/10 ppt salt water | | | | | |
| 1976 | 82,082 | 24 | 0.029 | 0.113 | 1.21:1 |
| 1977 | 43,334 | 0 | 0 | a/ | a/ |
| 1978 | 47,661 | 1 | 0.002 | a/ | 0.15:1 |
| Steelhead | | | | | |
| Control | | | | | |
| 1976 | 29,414 | 89 | 0.303 | 0.515 | - |
| 1977 | 22,204 | 4 | 0.018 | 0.049 | - |
| 1978 | 30,364 | 67 | 0.221 | 0.616 | - |
| Transport/fresh water | | | | | |
| 1976 | 43,287 | 497 | 1.148 | 1.952 | 3.79:1* |
| 1977 | 24,272 | 28 | 0.115 | 0.424 | 6.39:1* |
| 1978 | 35,375 | 365 | 1.032 | 2.869 | 4.67:1* |
| Transport/10 ppt salt water | | | | | |
| 1976 | 53,874 | 639 | 1.186 | 2.016 | 3.91:1* |
| 1977 | 22,916 | 35 | 0.153 | 0.524 | 8.5:1* |
| 1978 | 32,170 | 334 | 1.038 | 2.972 | 4.72:1* |

* "G" statistic analysis is significant at $P<0.05$, df=1.

a/ Insufficient returns to make estimate.

The returns of chinook salmon from tests at Little Goose Dam--both transport and control fish--were alarmingly low. The percentage return was far lower than observed in earlier studies at Ice Harbor or Little Goose Dams in 1971-73. The poor return of adults from the 1976 tests are inexplicable. In 1977, one of the most severe droughts of the century occurred throughout the Columbia River Basin. The drought caused serious delays in the migration of smolts and presumably caused severe stress due to unusual rigors of migration (Park et al. 1978). In 1978, descaling measurements indicated 20% of the fish at Little Goose Dam were descaled compared to only 7% at Lower Granite Dam. I assume that either the bypass system at the dam caused some descaling and/or fish that passed by Lower Granite Dam (not collected) were descaled in passage. There are other potential reasons for poor survival that will be discussed later.

At Lower Granite Dam return ratios of chinook salmon varied from year to year. Chinook salmon that were transported by truck returned in significantly greater numbers than the fish released in the Snake River as controls in 1975 and 1978 (Table 7). In 1976, significantly fewer transported fish returned than controls. In 1977 and 1980, too few fish returned for analysis. It is also noteworthy that in 1975, the percent return of transported fish (1.7%) was the highest since 1968--more than twice the rate of return of controls. As noted in the tests at Little Goose Dam, saltwater media used in truck transport did not produce significantly greater adult returns.

Fish transportation by barge was tested at Lower Granite Dam for the first time in 1977 (McCabe et al. 1977). In tests from 1977 to 1980, significantly greater numbers of fish transported by barge returned in

Table 7.--Percentage return and benefit ratio of transported to non-transported spring chinook salmon released in 1975-80 at Lower Granite Dam.

| Release group, year | Number of juveniles released | Number adults recaptured | Percentage return as adults | | Transport/ control ratio |
|---|---|---|---|---|---|
| | | | Observed | Estimated | |
| Control | | | | | |
| 1975 | 43,902 | 138 | 0.313 | 0.861 | - |
| 1976 | 28,686 | 11 | 0.038 | 0.109 | - |
| 1977 | 38,346 | 0 | 0 | a/ | - |
| 1978 | 36,441 | 5 | 0.013 | 0.039 | - |
| 1979 | 25,532 | 3 | 0.011 | 0.077 | - |
| 1980 | 21,876 | 0 | 0 | a/ | - |
| Transport/truck/fresh water | | | | | |
| 1975 | 68,550 | 436 | 0.635 | 1.746 | 2.03:1* |
| 1976 | 72,918 | 18 | 0.025 | 0.072 | 0.66:1* |
| 1978 | 43,855 | 33 | 0.075 | 0.225 | 5.77:1* |
| 1980 | 32,772 | 0 | 0 | a/ | a/ |
| Transport/truck/salt water (5ppt) | | | | | |
| 1976 | 61,446 | 24 | 0.039 | 0.112 | 1:1 |
| 1977 | 45,404 | 1 | 0.002 | a/ | a/ |
| Transport/barge | | | | | |
| 1977 | 31,628 | 1 | 0.003 | a/ | a/ |
| 1978 | 56,546 | 66 | 0.116 | 0.348 | 8:92:1* |
| 1979 | 27,336 | 12 | 0.043 | 0.301 | 3.91:1* |
| 1980 | 40,719 | 1 | 0.002 | a/ | a/ |
| 1983 | [illegible] | ?4 | .278 | | |

* "G" statistic analysis is significant at P<0.05, df=1.

a/ Insufficient returns to make estimate.

1978-79 than the nontransported controls. Extremely poor survival of all chinook salmon groups tested in 1977 and 1980 resulted in insignificant returns of marked groups of barged fish.

In 1978, fish trucked (fresh water) and fish barged were compared for the best mode of transportation. In this test, significantly more barged fish returned. This comparative test should be repeated because it was done for only 1 year, and similar comparisons with steelhead and fall chinook salmon have shown no significant benefit for barging.

Transportation of steelhead from Little Goose and Lower Granite Dams has consistently provided substantial benefits. All steelhead test groups in all years at both dams have positive transport to control ratios (Tables 6 and 8). All transport groups had a significantly higher number of returning fish than the corresponding control groups. In a test to compare effects of transport media (Lower Granite Dam, 1976), the fish hauled in fresh water returned in greater numbers than those hauled in 5 ppt salt water, but there was no significant difference ($P<0.05$). Salt water as used in the Snake River experiments provides no increase in long term survival as measured by adult returns. In 1978, the transport/control ratio of trucked fish and barged fish was 4.44 and 5.18:1, respectively, however, the number of returning fish from the two groups were not significantly ($P<0.05$) different.

In general, the same factors that influenced the survival of transported smolts at Little Goose Dam applied to smolts collected for transport at Lower Granite Dam. If physical passage through a dam caused injury or stress to the fish, smolts collected at Lower Granite Dam would be at an advantage since it is the first dam encountered on the seaward

Table 8.--Percentage return and benefit raito of transported to non-transported (control) steelhead released in 1975-80 at Lower Granite Dam.

| Release group, year | Number of juveniles released | Number adults recaptured | Percentage return as adults | | Transport/ control ratio |
|---|---|---|---|---|---|
| | | | Observed | Estimated | |
| **Control** | | | | | |
| 1975 | 49,601 | 222 | 0.447 | 0.809 | - |
| 1976 | 41,987 | 149 | 0.354 | 1.618 | - |
| 1977 | 22,204 | 4 | 0.018 | 0.049 | - |
| 1978 | 30,364 | 67 | 0.221 | 0.616 | - |
| 1979 | 21,050 | 102 | 0.484 | 2.040 | - |
| 1980 | 19,273 | 20 | 0.103 | 2.857 | - |
| **Transport/truck/fresh water** | | | | | |
| 1975 | 60,475 | 977 | 1.615 | 2.923 | 3.61:1* |
| 1976 | 54,696 | 307 | 0.561 | 2.564 | 1.58:1* |
| 1978 | 47,899 | 514 | 1.073 | 2.732 | 4.44:1* |
| **Transport/truck/salt water (5ppt)** | | | | | |
| 1976 | 69,145 | 327 | 0.473 | 2.162 | 1.34:1* |
| 1977 | 42,777 | 95 | 0.222 | 0.903 | 18.43:1* |
| **Transport/barge** | | | | | |
| 1977 | 30,330 | 64 | 0.211 | 0.859 | 17.53:1* |
| 1978 | 43,770 | 499 | 1.140 | 2.854 | 5.18:1* |
| 1979 | 30,495 | 261 | 0.855 | 3.604 | 1.77:1* |
| 1980 | 32,559 | 56 | 0.171 | 4.743 | 1.66:1* |

* "G" statistic analysis is significant at $P<0.05$, df=1.

migration. On the other hand, since Lower Granite Dam is the uppermost project, it became an accumulation point for debris. Smith et al. (1980) identified a major debris problem at Lower Granite Dam, and debris could have contributed to injury or stress of smolts prior to their transportation in 1975-80.

Descaling and injury to fish were identified as possible factors influencing survival of transported fish--especially spring chinook salmon (Ebel 1980). Descaling, stress, injury, and subsequent delayed mortality following transportation are interrelated and logically would influence the survival of smolts whether transported or not.

Annual descaling rates for smolts collected at Little Goose, Lower Granite, and McNary Dams in 1975-80 are shown in Table 9. The descaling rate for spring chinook salmon at Lower Granite Dam was highest in the first year (1975) and then began a decline. From a high of 13.0% in 1975, it has dropped to 2.8% in 1983 (Delarm et al. 1984). I believe the steady decline is a result of: (1) improved traveling screen design, inspection, and maintenance; (2) improved modifications made throughout the bypass system; and (3) debris removal and control initiated by the U.S. Army Corps of Engineers (CofE) in 1981. Descaling at Little Goose Dam was higher than observed at Lower Granite Dam during 1977-78. As mentioned previously, this may have been caused by a combination of a poor bypass system at Little Goose Dam and the fact that collected fish had to pass two dams and therefore increased chances of injury.

In a special delayed mortality test in 1981, the mortality of descaled spring chinook salmon was about 10 times the mortality of fish not descaled (Park et al. 1982) (Fig. 3). This provides corroborating evidence that

Table 9.--Descaling of spring chinook salmon and steelhead sampled from the marking facility at Lower Granite, Little Goose, and McNary Dams--1975-80.

| | Descaling | | | |
|---|---|---|---|---|
| | Spring chinook salmon | | Steelhead | |
| Dam/Year | Average (%) | Range (%) | Average (%) | Range (%) |
| Lower Granite | | | | |
| 1975 | 13.0 | - | - | - |
| 1976 | 7.0 | 4.0-13.0 | - | - |
| 1977 | - | 14.0-33.0[a] | - | - |
| 1978 | 7.0 | - | 5.8 | - |
| 1979 | 5.3 | 1.0-12.0 | 5.7 | 0-15.5 |
| 1980 | 4.0 | 1.0-11.0 | 8.2 | 1.0-24.0 |
| Little Goose | | | | |
| 1977 | 23.9 | 6.0-49.2 | 30.2 | 7.1-42.0 |
| 1978 | 20.0 | 6.0-44.0 | 11.3 | 1.0-27.0 |
| McNary | | | | |
| 1978 | 10.0 | - | 6.0 | - |
| 1979 | -----No data----- | | -----No data----- | |
| 1980 | 20.0 | - | - | - |

[a] Descaling data taken from fish collected in gatewells.

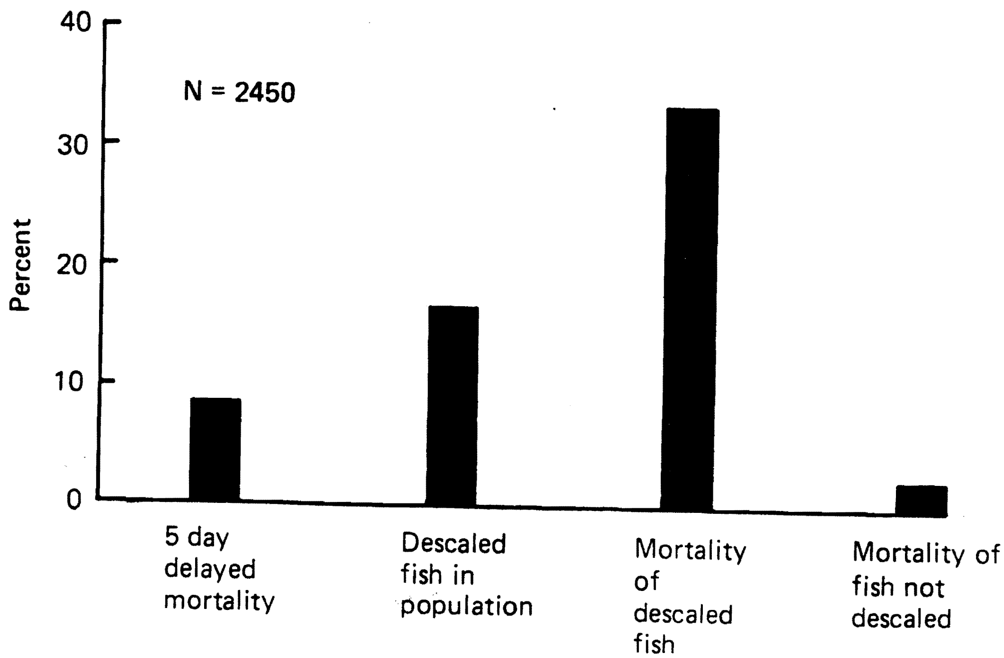



Figure 3.--Delayed mortality and descaling of spring chinook salmon following transportation from Lower Granite Dam to Bonneville Dam in 1981.

descaling reduces the long-term survival of spring chinook salmon. In the same test, the observed mortality of non-descaled fish was low (2.5%), indicating that fish collected and transported in good condition will have the best opportunity to survive.

Descaling of steelhead was relatively unimportant compared to descaling of spring chinook salmon because steelhead appeared to survive whether descaled or not. Also, any improvements in passage facilities which would reduce descaling rates in chinook salmon should tend to reduce descaling of steelhead.

Delayed mortality measured in 1975-80 was highly variable (Table 10). For example, for chinook salmon transported from Lower Granite Dam it ranged from 1.9% in 1980 to 30.0% in 1977. Delayed mortality following transport appears to provide an index for fish health or at least general condition of the fish transported in a given year. However, there does not seem to be any relationship between observed <u>low</u> delayed mortality and subsequent adult returns for spring chinook salmon. The low delayed mortalities observed in 1976 and 1980 were followed by low adult return rates, and the moderate to higher delayed mortalities observed in 1975 and 1978 were followed by the highest adult returns. Sampling fish from transport trucks is difficult at best, and sampling error could be in part a factor in reported delayed mortality variability (Smith et al. 1981).

For steelhead there does appear to be a strong relationship between <u>low</u> delayed mortality rates and later high adult return rates. Delayed mortality of steelhead following transport was low at all dams and adult returns were high in all years except 1977 (the drought year).

Table 10.--Delayed mortality (2 d) of juvenile spring chinook salmon and steelhead that were marked and subsequently transported by truck in fresh water from Lower Granite, Little Goose, and McNary Dams to release sites downstream from Bonneville Dam--1975-80.

| | 2-d delayed mortality | | | |
|---|---|---|---|---|
| | Spring chinook salmon | | Steelhead | |
| Dam/Year | Average (%) | Range (%) | Average (%) | Range (%) |
| Lower Granite | | | | |
| 1975 | 11.5 | 0.5-34.0 | < 1.0 | 0-1.8 |
| 1976 | 4.7 | 0-31.6 | 0 | 0 |
| 1977 | 30.0 | 2.3-62.8 | 6.5 | 0-29.6 |
| 1978 | 17.1 | 6.5-43.7 | < 1.0 | 0-4.2 |
| 1979 | 3.1 | - | < 1.0 | - |
| 1980 | 1.9 | - | - | - |
| Little Goose | | | | |
| 1977 | 42.5 | 16.7-73.8 | 11.1 | 0-30.2 |
| 1978 | 13.1 | 0-52.0 | 2.6 | 0.8.3 |
| McNary | | | | |
| 1978 | 19.1 | 0-60.0 | 3.1 | 0-15.0 |
| 1979 | 20.4 | - | 3.8 | - |
| 1980 | 6.8 | - | - | - |

## Transportation From McNary Dam, 1978-80

In 1978, a series of transportation experiments was begun at McNary Dam on the Columbia River. Test designs were similar to those conducted on the Snake River. Throughout the study, when fish were transported in trucks only fresh water was used.

Tests were initially designed to provide an evaluation for all species migrating past McNary Dam, i.e., spring, summer, and fall chinook salmon; sockeye salmon; coho salmon; and steelhead. Summer chinook salmon (mid-Columbia River stock) migrate seaward at the same time as fall chinook salmon and are so morphologically similar to fall chinook salmon that the two subspecies are considered as one for this report. Analyses for 3 years are presented for fall chinook salmon and steelhead (see smolt marking data, Table 11) and 1 year (1978) for coho salmon because smolts were not available for tests in 1979-80. In all years, not enough sockeye salmon were collected to provide sufficient fish for marking test lots. Spring chinook salmon were marked for transport/control comparisons in all years, but too few adults were recovered for statistical comparisons (Park et al. 1982).

Tagged adults recovered at special trapping facilities in the north fishway at McNary dam were desired for comparisons between transport and control groups (see Methods Section). Recovery efficiency was so low, however, that we combined recovery data from Bonneville, Lower Granite, and McNary Dams. Any adult from the study recovered in these trapping facilities was jaw tagged so identification of jaw tagged fish recaptured at a second facility was assured. Only the initial recovery was used for analysis in transport/control comparisons.

Table 11.--Experimental design for transportation tests at McNary Dam, 1978-80. Year, species, test group, release location, and number of fish marked per group are indicated.

| Year | Species | Test group | Release location | Number of fish marked |
|---|---|---|---|---|
| 1978 | | | | |
| | Fall chinook salmon | Control | Below McNary | 38,137 |
| | | Test/truck | Below Bonneville | 40,361 |
| | Coho salmon | Control | Below McNary | 21,767 |
| | " " | Test/truck | Below Bonneville | 22,065 |
| | Steelhead | Control | Below McNary | 15,580 |
| | " | Test/truck | Below Bonneville | 20,416 |
| 1979 | | | | |
| | Fall chinook salmon | Control | Below McNary | 112,718 |
| | | Test/truck | Below Bonneville | 132,919 |
| | Steelhead | Control | Below McNary | 8,595 |
| | " | Test/truck | Below Bonneville | 15,379 |
| | " | Test/barge | Below Bonneville/ Beacon Rock | 18,182 |
| 1980 | | | | |
| | Fall chinook salmon | Control | Below McNary | 84,587 |
| | | Test/truck | Below Bonneville | 80,213 |
| | Steelhead | Control | Below McNary | 21,291 |
| | | Test/truck | Below Bonneville | 22,362 |
| | | Test/barge | Below Bonneville/ Beacon Rock | 30,382 |

Fall chinook salmon recoveries for experiments conducted at McNary Dam are summarized in Figure 4. Tests for this species continued beyond 1980 through 1983. However, returns for these years are not complete and adults will continue to be recovered in later years. The preliminary data are substantial and statistically significant. The returns to date indicate that benefit ratios are strongest for comparisons measured at dams, followed by returns to fisheries and then returns to hatcheries/spawning grounds.

The substantial transport benefit ratios for all years are encouraging (Table 12). The positive transport benefit ratios in all recovery areas, together with significantly higher numbers of transported fish in all areas, clearly suggests that survival of these fish is enhanced by transportation from McNary Dam.

Homing and migrational behavior of fall chinook salmon does not appear to be altered by transportation. This is indicated by nearly identical benefit ratios for each recovery area for each year of analysis. Marked fish also returned to hatcheries and natal spawning areas upstream from McNary Dam indicating that homing was complete.

The returns of adult coho salmon to Columbia River dams and to fisheries from a single test (1978) are shown in Figure 5. Although only 30 fish were recovered at the dams, "G" statistic analysis indicates the return of transported fish was significantly greater than the return of controls ($G = 4.778$; $P<0.05$, $df=1$). A similar analysis for fish recovered in the fisheries is highly significant in favor of transported fish. This single year's data indicate that transportation of coho salmon can increase survival of smolts and provide benefit to the resource users. Further

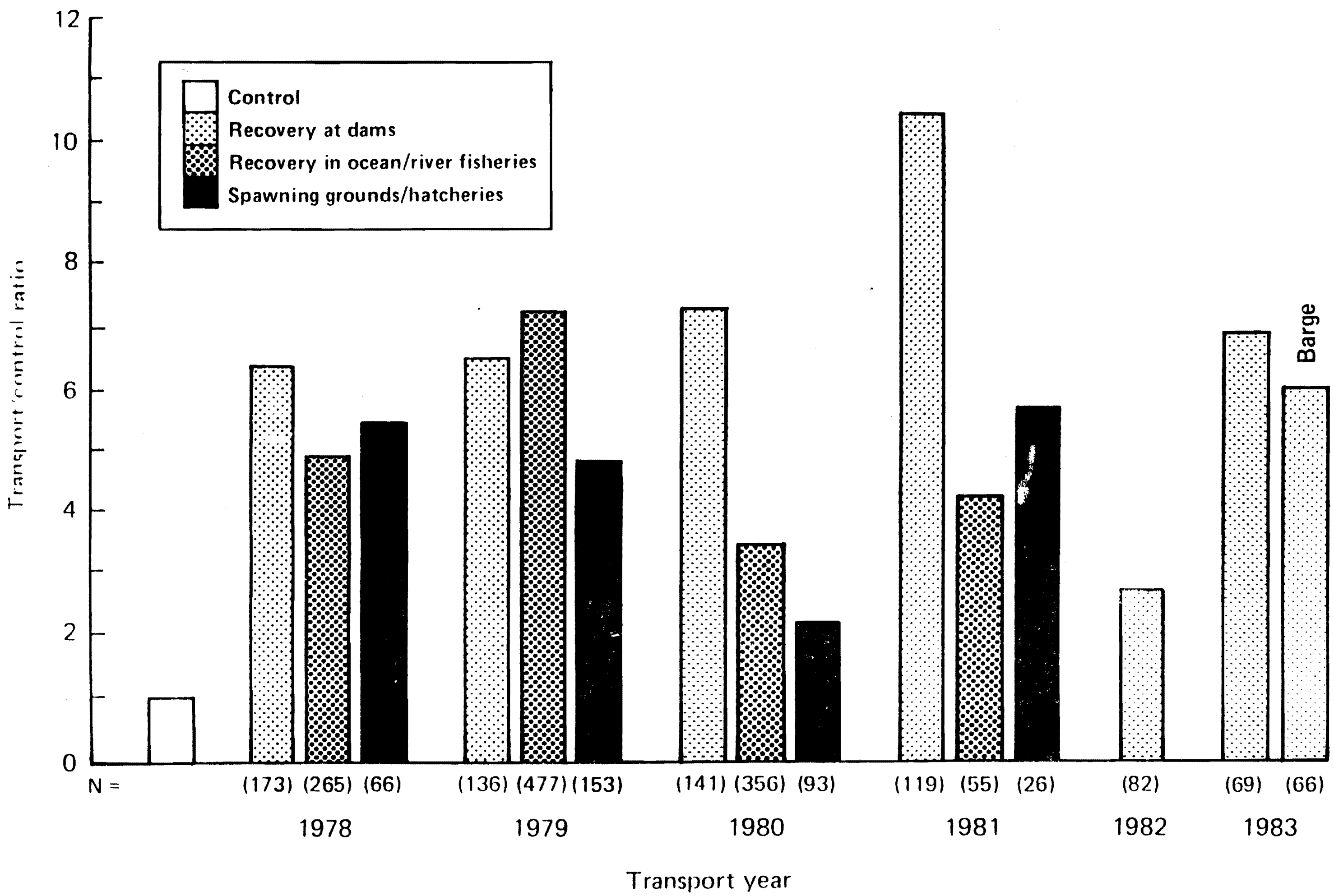
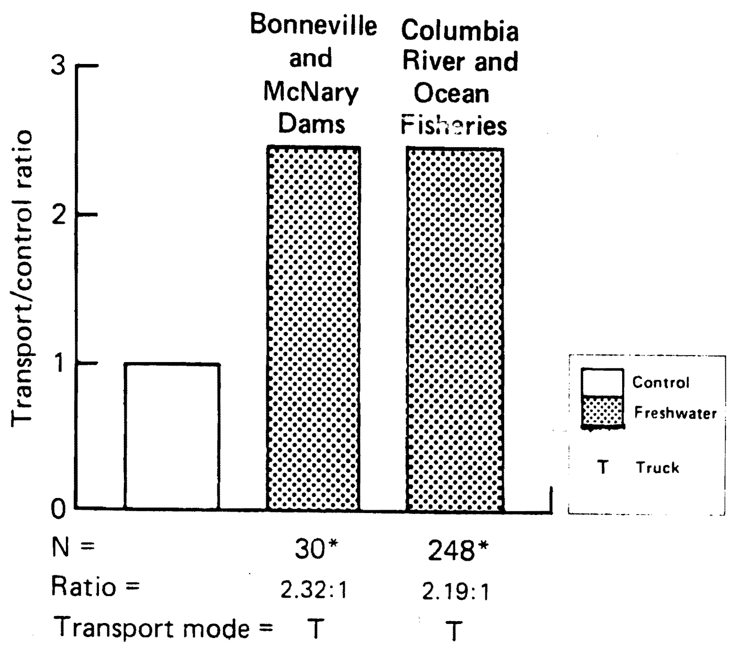



Figure 4.--Transport/control ratios for McNary Dam truck transportation tests with fall chinook salmon, 1978-83 (includes barge test group for 1983).

Table 12.--Transport benefit ratios and statistical significance for fall chinook salmon 1978-82.

| Year of release | Adult recovery area | Number returns Transport | Control | Benefit ratio[a] | "G" statistic; probability |
|---|---|---|---|---|---|
| 1978 | Col. R. traps | 150 | 23 | 6.2:1 | "G"=97.344; P<0.001 |
| | Combined fisheries | 219 | 44 | 4.7:1 | "G"=117.716; P<0.001 |
| | Spawning grounds-hatcheries | 56 | 10 | 5.3:1 | "G"=32.823; P<0.001 |
| 1979 | Col. R. traps | 120 | 16 | 6.4:1 | "G"=73.829; P<0.001 |
| | Combined fisheries | 420 | 50 | 7.2:1 | "G"=275.651; P<0.001 |
| | Spawning grounds-hatcheries | 126 | 23 | 4.8:1 | "G"=62.423; P<0.001 |
| 1980 | Col. R. traps | 111 | 16 | 7.3:1 | "G"=85.068; P<0.001 |
| | Combined fisheries | 250 | 72 | 3.7:1 | "G"-714.036; P<0.001 |
| | Spawning grounds-hatcheries | 32 | 19 | 1.8:1 | "G"=4.078; P<0.001 |

[a] Adjusted for number of smolts released in each group.




* Includes controls

Figure 5.--Transport benefit ratios for adult coho salmon that returned to McNary and Bonneville Dams and the ocean fisheries in 1978-79 from juveniles transported from McNary Dam in 1978.

tests should be conducted to provide more data on effects of transporting coho salmon.

Transportation of steelhead from McNary Dam to below Bonneville Dam during 1978-80 showed positive transport benefits in all years. The benefit ratios ranged from 1.3 to 1 (1980 trucked group) to over 3.0 to 1 (1978 truck and 1979 barge groups) (Fig. 6).

The success of the transportation study at McNary Dam has been evaluated primarily by the number of adults recovered at the trapping facilities at Bonneville, McNary, and Lower Granite Dams. All test lots returned in significantly greater numbers than the corresponding control lots in 1978-79 ("G" statistic--$P<0.05$). In 1980, only barged fish returned in significantly greater numbers than controls. Trucked fish returned in greater numbers than controls, but the difference was not significant. There was no significant difference in returns in truck/barge comparisons.

As shown for tests on the Snake River, calculations of estimated returns of transported fish best demonstrate the benefits of transportation. I have examined the possibility of making similar calculations for McNary Dam operations by obtaining measures of trapping efficiency at McNary Dam. Recovery of adults at hatcheries has been so erratic from year to year, however, that it was impossible to make estimates of trapping efficiency. Consequently, I have not attempted to estimate overall percentage rate of return to McNary Dam of transported fish.

Actual returns for the 1978-80 period to all in-river traps, the fishery, and hatcheries provided data that strongly indicate positive

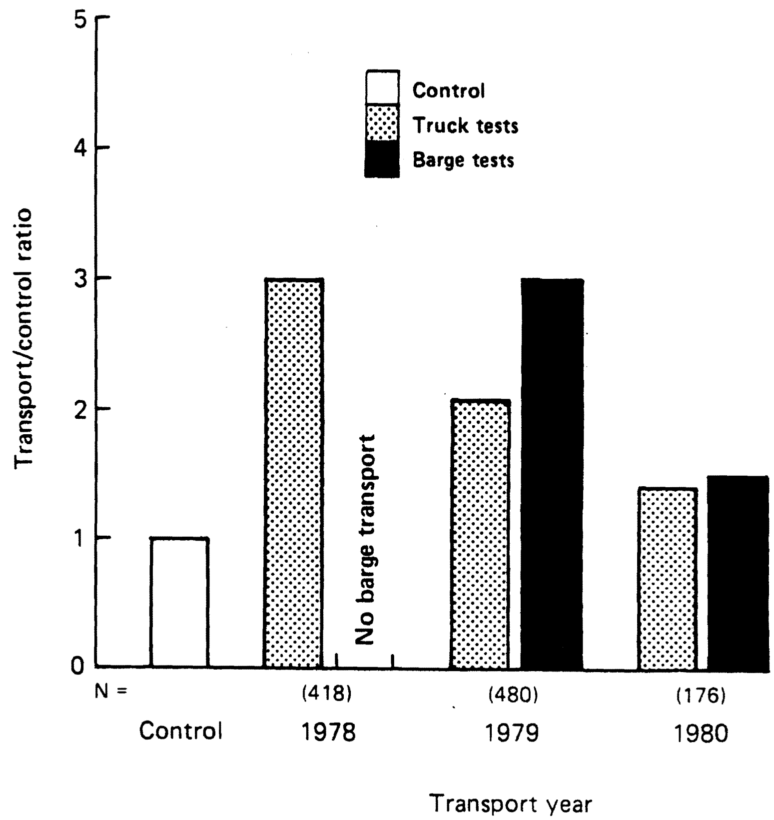



Figure 6.--Transport/control ratios for McNary Dam truck and barge transportation tests with steelhead, 1978-80.

benefits from transporting steelhead from McNary Dam. First, overall returns to hatcheries showed a positive transport benefit of about 2.5:1, closely approximating the benefits shown for all fish transported from McNary Dam during those years (Fig. 6). The Yakima Hatchery, especially, received positive benefits from transportation in 1979 and 1980. These data not only indicate that survival was enhanced, but homing of those hatchery fish was not impaired by hauling from McNary Dam. Second, when observed returns to all sources are combined, the return rate of fish transported from McNary Dam compares closely to those transported from Lower Granite Dam for comparable years.

## DISCUSSION

### Homing, Straying, and Delay in Migration

The precise effect of transportation on homing of various species and stocks of fish to their natal spawning area could not be determined because smolts utilized in the studies were of mixed origin. However, data obtained from spawning ground surveys and from upstream hatcheries indicated homing to these areas was not seriously impaired. Straying was monitored during all the NMFS studies.

During studies at Little Goose Dam in 1971-73, Ebel (1980) noted that 16 spring chinook salmon and 3 steelhead were recovered at Pelton Dam on the Deschutes River, Oregon. Ebel noted that even though the homing behavior of the above fish was altered, over 3,500 adults were recovered at Little Goose Dam from the same release groups. Straying was considered minor; however, more data are required to define total impacts on homing behavior.

In recent studies (1975-80), 11 spring chinook salmon and 16 steelhead were identified as strays (less than 1%) (Table 13). All of the strays were from fish transported from either Lower Granite or Little Goose Dams. No fish transported from McNary Dam were observed to stray as returning adults. It is interesting to note that all the spring chinook salmon observed to stray were recovered in the Deschutes River, Oregon. Also among steelhead strays, 11 of the 16 occurred in 1976. In all, only 27 fish were recovered as strays during the 1975-80 studies, and I agree with Ebel's assessment that straying has minimal impact on transport/control ratios and homing of adults to expected spawning areas.

Delays in migration of returning adults following transportation as juveniles were different for chinook salmon and steelhead. No delays in migration of returning spring and fall chinook salmon were detected in the NMFS studies. In analyzing steelhead returns, however, I determined there was a consistent but small delay during their upstream migration. The steelhead run in the Snake River begins in June, peaks in October, then diminishes rapidly as water temperature decreases during the winter. The run increases in March as water temperatures also increase prior to spawning in April and May. I examined the returns of adults at the upper dam (Little Goose Dam or Lower Granite Dam) comparing fall and spring arrivals among transported fish and non-transported controls for 1971-76 (Table 14). The years were purposely selected because in 1971-76 few if any controls were transported by the developing mass transportation program. The data indicate that the proportion of transported fish returning in the spring in each year was higher than the proportion of controls (indicating delay of transported fish). Conversely, the

Table 13.--Straying of spring chinook salmon and steelhead transported from Lower Granite, Little Goose, or McNary Dam, 1975-80.

**Spring/chinook salmon**

| Year of release and transport location | Number of strays and location | | Total number returns in expected locations |
|---|---|---|---|
| 1975 | | | |
| Lower Granite | | 0 | 518 |
| 1976 | | | |
| Lower Granite | Deschutes R. (OR) | 4 | 105 |
| Little Goose | | 0 | 97 |
| 1977 | | | |
| Lower Granite | Deschutes R. (OR) | 2 | 38 |
| Little Goose | | 0 | 5 |
| 1978 | | | |
| Lower Granite | Deschutes R. (OR) | 4 | 150 |
| Little Goose | | 0 | 10 |
| McNary | | 0 | 39 |
| 1979 | | | |
| Lower Granite | Deschutes R. (OR) | 1 | 34 |
| McNary | | 0 | 136 |
| 1980 | | | |
| Lower Granite | | 0 | 7 |
| McNary | | 0 | 43 |
| | TOTALS | 11 | 1,182 |

**Steelhead**

| Year of release and transport location | Number of strays and locations | | Total number returns in expected locations |
|---|---|---|---|
| 1975 | | | |
| Lower Granite | | 0 | 1,248 |
| 1976 | | | |
| Lower Granite | Wells Hatchery | 2 | |
| | Deschutes River | 1 | 1,203 |
| Little Goose | Wells Hatchery | 7 | |
| | Deschutes River | 1 | 1,680 |
| 1977 | | | |
| Lower Granite | | 0 | 592 |
| Little Goose | | 0 | 225 |
| 1978 | | | |
| Lower Granite | Big Creek H. | 1 | |
| | Deschutes R. | 2 | 1,606 |
| Little Goose | Chelan H. | 1 | 996 |
| McNary | | 0 | 429 |
| 1979 | | | |
| Lower Granite | Yakima H. | 1 | 503 |
| McNary | | 0 | 743 |
| 1980 | | | |
| Lower Granite | | 0 | 197 |
| McNary | | 0 | 378 |
| | TOTALS | 16 | 9,800 |

Table 14.--A comparison of the percent of transported and nontransported steelhead returning to Little Goose and Lower Granite Dam during the fall and spring migration periods (1971-76).

| Year of outmigration/ transport | Group | Fall returns and (% of total) | | Spring returns and (% of total) | |
|---|---|---|---|---|---|
| 1971 | Transport | 678 | (81.6) | 153 | (18.4) |
| | Control | 184 | (92.5) | 15 | (7.5) |
| 1972 | Transport | 553 | (85.6) | 93 | (14.4) |
| | Control | 122 | (94.6) | 7 | (5.4) |
| 1973 | Transport | 1,039 | (84.8) | 186 | (15.2) |
| | Control | 54 | (88.5) | 7 | (11.5) |
| 1975 | Transport | 615 | (74.5) | 212 | (25.6) |
| | Control | 182 | (90.5) | 19 | (9.5) |
| 1976 | Transport | 1,374 | (85.9) | 225 | (14.1) |
| | Control | 184 | (95.3) | 9 | (4.7) |
| | Average: | | | | |
| | Transport all years | 4,259 | (83.1) | 869 | (16.9) |
| | Control all years | 726 | (92.7) | 57 | (7.3) |

proportion of controls was higher than transports in the fall indicating normal passage or no delay. The percent of transported and nontransported fish arriving in the fall in all years was 83.1 and 92.7%, respectively, indicating that about 10% of the transported fish delayed during migration.

The steelhead run to the Snake River is made up of two components--"B" and "A." Fish from the Dworshak NFH (Clearwater River, Idaho) are a major component of the "B" run which normally enters the Columbia River in late August. Historically, many of these fish spend the fall and winter in the lower Snake River before migrating into the Clearwater River to spawn in the spring. The "A" run (Pahsimeroi Hatchery, Idaho) on the other hand typically enters the Columbia River in early July with most fish migrating rapidly upriver into the Salmon River and other tributaries in early fall.

To determine if fish from Dworshak NFH or Pahsimeroi Hatchery were being delayed, I examined returns to the respective hatcheries of transported fish and control fish (1971-78) that had been previously intercepted at the upper dam (Table 15). Since each fish intercepted at the dam was jaw tagged, I could determine the exact day of passage at the dams. The analysis indicates that few transported fish (5) and no controls from the Pahsimersoi Hatchery group passed the upper dam in the spring. On the other hand, 18.0% of the transported fish and 10.5% of the controls representing the Dworshak NFH stock passed the upper dam in the spring. Moreover, when the two stocks are combined, timing of their passage at the upper dam appears to match that shown for the average of all test fish in Table 15. Therefore, it appears the transport of Clearwater River steelhead causes a minor delay in upstream passage. However, the large

Table 15.--Returns to Pahsimeroi and Dworshak Hatcheries from 1973-80 of adult steelhead that were intercepted at Snake River adult collectors from transport and control release of juveniles from Little Goose and Lower Granite Dams in 1971-78.

| Test group and year of release | Pahsimeroi Hatchery | | | | Dworshak Hatchery | | | | Combined Pahsimeroi & Dworshak Hatcheries | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fall returns | | Spring returns | | Fall returns | | Spring returns | | Fall returns | | Spring returns | |
| | (no.) | (%) | (no.) | (%) | (no.) | (%) | (no.) | (%) | (no.) | (%) | (no.) | (%) |
| 1971-77 | | | | | | | | | | | | |
| Transport groups | 263 | 98.1 | 5 | 1.9 | 492 | 82.0 | 108 | 18.0 | 755 | 87.0 | 113 | 13.0 |
| Control groups | 44 | 100.0 | 0 | 0.0 | 94 | 89.5 | 11 | 10.5 | 138 | 92.6 | 11 | 7.4 |
| 1977-78 | | | | | | | | | | | | |
| Transport groups | 52 | 100.0 | 0 | 0.0 | 55 | 64.7 | 30 | 35.3 | 107 | 78.1 | 30 | 21.9 |
| Control groups | 12 | 100.0 | 0 | 0.0 | 2 | | 1 | | 14 | 93.3 | 1 | 6.7 |

surplus of fish provided by transportation more than offsets any loss of fish to anglers or to spawning populations in the river.

## Factors Affecting the Return of Spring Chinook Salmon

Marking mortality is one factor that may have limited the number of spring chinook salmon returning from all experimental groups. In 1978, delayed mortality tests were conducted to show the comparative survival of marked and unmarked fish following transport (Park et al. 1979). In all tests (5), the 45-h delayed mortality for marked fish was higher than for unmarked fish. Also, Park et al. (1983) showed that stress in chinook salmon increased approximately five-fold during marking. No comparisons were made to show differences in stress among transported marked fish and transported unmarked fish. I believe that the adult return rate for marked spring chinook salmon is much lower than for unmarked fish, however, more data are required to quantify the different return rates.

Regardless of marking mortality, the rate of return of adult spring chinook salmon from naturally and hatchery produced smolts has caused spawning populations to dip to threateningly low levels. In only 2 of 13 years of study, have adults returned at a rate exceeding 1.5% for transported fish. In 1968, the adult return rate was 9.0%, and in 1975, 1.7%. In all other years, the rate was less than 1% and usually substantially less. Since 1976, the return rate for spring chinook salmon has been dismal whether transported or not. Raymond (1979) reported that the rates of return to the Snake River for both spring chinook salmon and steelhead declined from about 3-5% before dams to as low as 0.5% in 1973 after new dams were constructed on the Snake River.

Raymond[1/] has extended his rate of return analyses to the mid-Columbia River through the 1982 outmigration year. Raymond's new data show that the demise of the spring chinook salmon runs after the 1975 outmigration year are not the result of transportation or passage of juveniles through the dam complex. The data show that the rates of return of spring chinook salmon to both reaches of river were nearly identical between 1970 and 1980 with a consistently dismal 0.5% rate of return between 1976 and 1982 (Fig. 7). This seems to rule out transportation as the culprit because the numbers of fish transported from each reach varied considerably from year to year during this period. For the Snake River, about 15% of the chinook salmon population was transported in 1976; increasing to about 50% each year through 1981 and back to 28% in 1982 when the fisheries agencies opted for increased spill and reduced collection for survival enhancement. In contrast, a fewer fish were hauled from the mid-Columbia reach at McNary Dam. There was no transportation through 1978, an estimated 10% in 1979, and 16% in 1980. Over 1.2 million fish were hauled in 1981, up 50% from 1980. However, estimates of magnitude and percent hauled were not available because there was no smolt monitoring at McNary Dam in 1981. Numbers transported dropped back to 800,000 in 1982 because of high spill.

In Figure 8, Raymond's data show that through 1975, the rate of return of chinook salmon was slightly higher than steelhead, and fluctuations in return rate generally reflected passage problems at dams (i.e., 1973 low flow and only 0.3% return). After 1975, chinook salmon remained at about 0.5% each year regardless of efforts to enhance survival through

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1/ Pers commun. Howard Raymond, Fishery Research Biologist, Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, Wash.

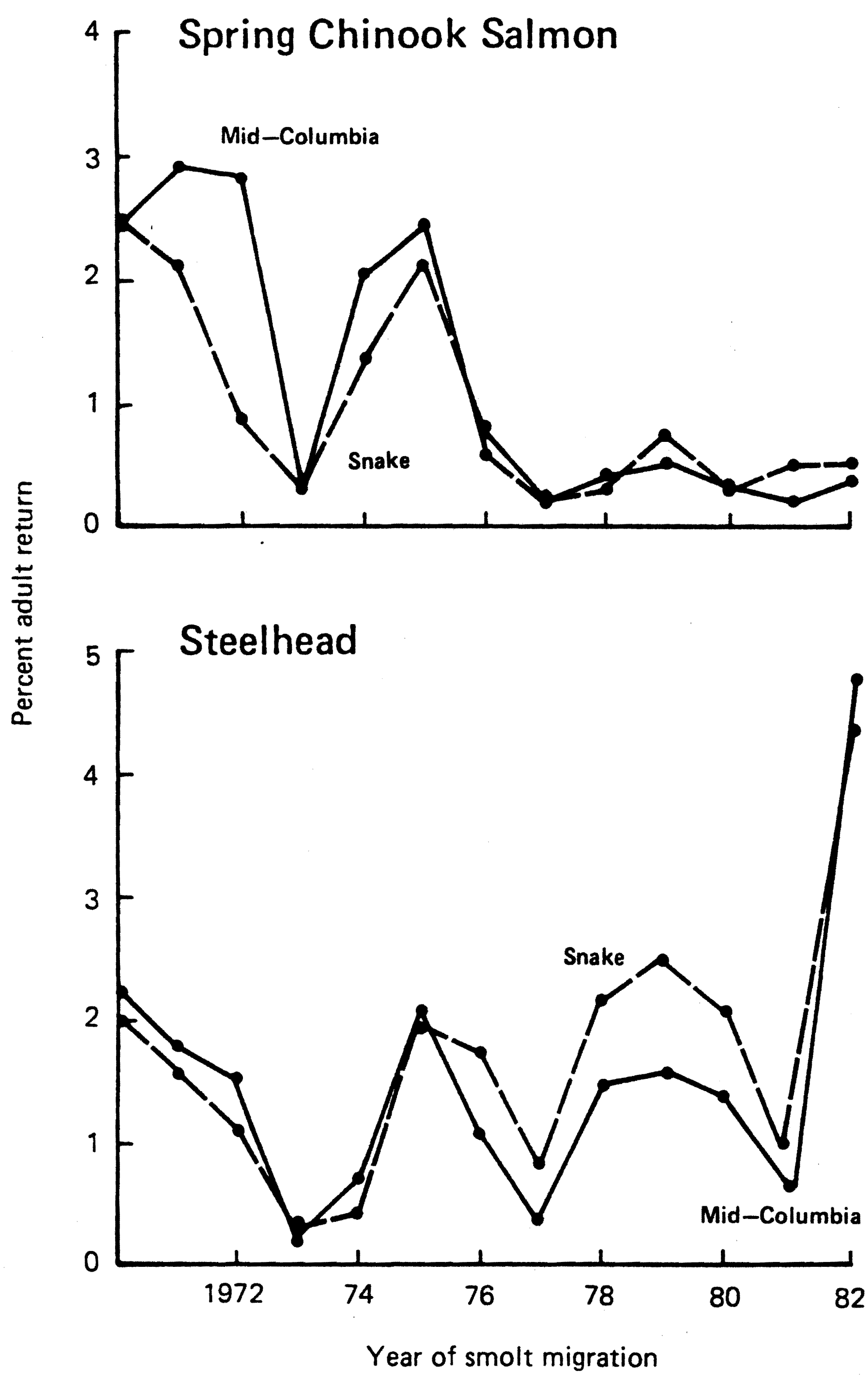


Figure 7.--Percent return of spring chinook salmon and steelhead to the Snake and mid-Columbia Rivers from smolt migrations, 1976-1982.

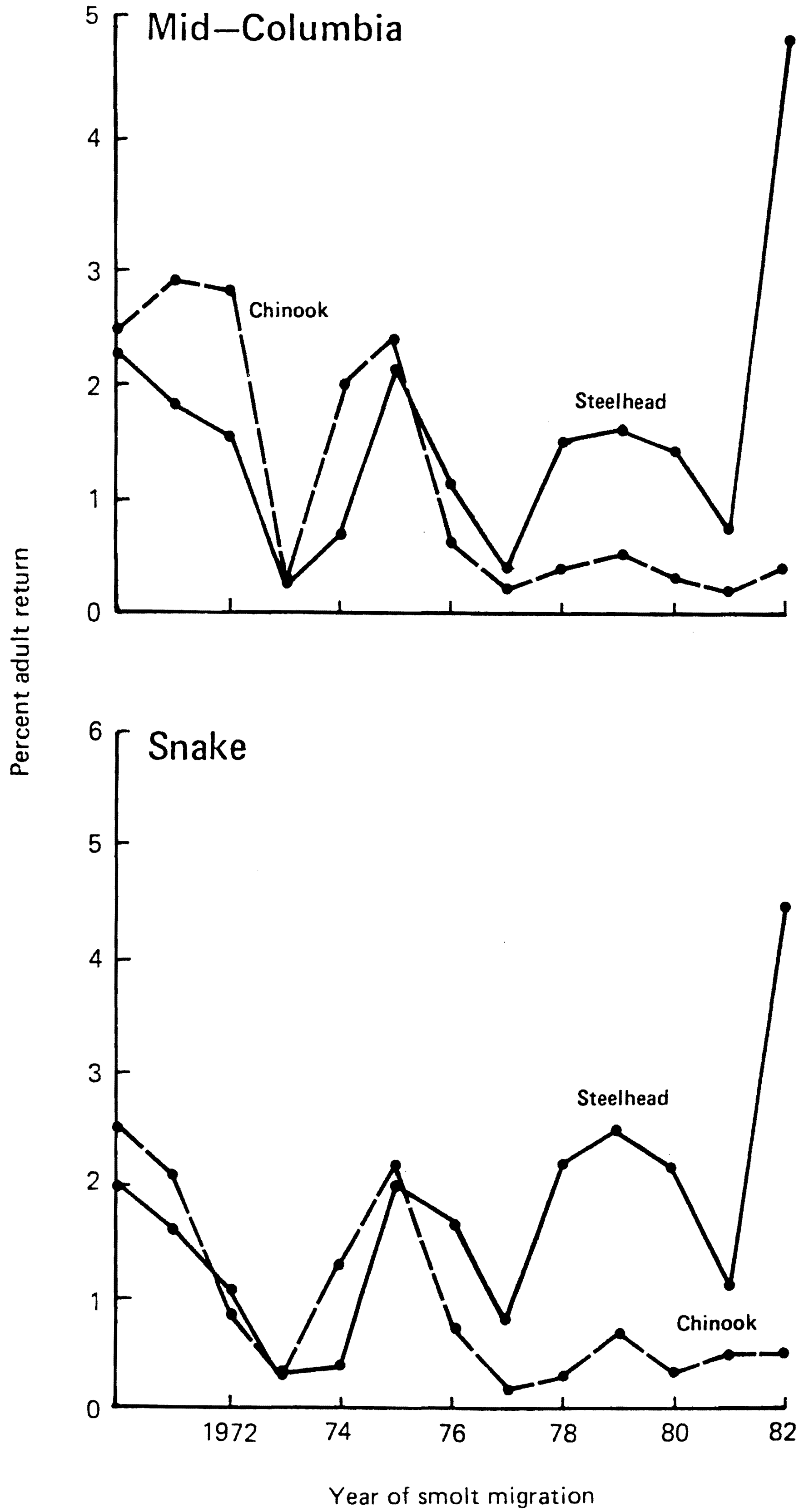


Figure 8.--Percent return of spring chinook salmon and steelhead to the Snake and mid-Columbia Rivers from smolt migrations, 1970-1982.

transportation, increased hatchery releases, and spill. In contrast, steelhead have responded to transportation and other efforts to enhance their survival. Record steelhead runs, for example, have returned from the 1982 outmigration to both reaches of the river. I feel that the inability of chinook salmon to similarly respond is most likely due to their inability to survive in seawater. One possible reason for this poor survival may be related to poor health of fish being released from hatcheries. Fish in poor health generally respond poorly to stresses incurred during downriver migrations and the subsequent seawater transition.

I have shown earlier that stress to spring chinook salmon during collection and subsequent transportation does occur. Stress will also occur to nontransported fish passing through the dam in varying degrees depending on passage route--whether it be the bypass system, the turbine, or the spillway. Therefore, we must consider all stresses including transportation stress. Transportation stress may be minor compared to the cumulative stress of fish passing eight or nine dams by other routes.

All smolts surviving in the Columbia River estuary must be fit for seawater entry or ensuing survival will be low. There is evidence that smolt quality has declined in recent years. Bacterial Kidney Disease (BKD) is a problem amplified in recent years because most fish are now produced in hatcheries (where disease outbreaks are more likely to occur) and natural production in all upriver tributaries is low. During our research, smolts have been observed with gross symptoms of BKD. There is virtually no chance that fish with gross symptoms of BKD could survive 30 d in a seawater environment. Recent studies by Banner et al. (1982) indicate that mortality attributed to BKD ranged from 45 to 81% in three hatchery stocks of Oregon chinook salmon when held 200 d in salt water. They conclude that elimination or reduction of the pathogen Renibacterium salmoninarium would improve ocean survival. The NMFS is conducting similar tests to determine the survival of Snake River spring chinook salmon following seawater entry.

## Contribution to Commerical and Sport Fisheries

The primary commercial harvest of spring chinook salmon occurs in the Columbia River. Little or no harvest occurs in ocean fisheries based on CWT returns from the NMFS studies. During the commercial fishing season in the Columbia River in 1968-69, transported fish were harvested in a ratio of 1.7:1 and 1.19:1, respectively (Ebel, Park, and Johnsen 1973; Slatick et al. 1975). The observed ratios were about the same as measured for voluntary returns to Ice Harbor Dam.

The contributions of fall chinook salmon in ocean and Columbia River commercial fisheries were substantial in all years (1978-80); few fish were observed in all years from sport fisheries. The transport benefit ratios ranged from 3.7:1 (1980) to 7.2:1 (1979). In all fisheries, 1,077 adults were recovered from smolt release in 1978-80. Recoveries by geographical area were: Alaska 547 (50.8%), British Columbia 168 (24.9%), Washington Coastal 31 (2.9%), Oregon Coastal 4 (0.4%), and all Columbia River fisheries 227 (21.0%). Transportation benefits (i.e., T/C ratios) were substantial in all measurable areas. I should emphasize that all of the above data reflect observed recoveries, and the field sampling rate may be higher for Columbia River fisheries. The true harvest rate would be greater in ocean fishing regions compared with the Columbia River fisheries.

For another comparison of the contribution that transported fall chinook salmon smolts released in 1978 made to the fisheries, I examined the combined ocean and Columbia River fisheries harvest rates of: (1) fish transported from McNary Dam, (2) fish released in the tailrace at McNary Dam (control), and (3) fish released from the Washington Department of Fisheries hatcheries at Priest Rapids and Ringold (the hatcheries are located just upstream from the McNary Dam reservoir). The data should be comparable because most fall chinook salmon transported or released as controls at McNary Dam are represented by mid-Columbia River smolts--including substantial numbers of fish from Priest Rapids and Ringold hatcheries. I assumed that all groups entered the fisheries at the same rate, and sampling rates for all groups were comparable.[2/]

The data in Table 16 indicate that significantly more transported fish were harvested (based on the number of smolts released) than fish released from hatcheries or from the group released below McNary Dam (observed returns used for "G" statistic analysis in two by two comparisons, where $P<0.01$, $df=1$). Fish from the control group were also harvested at a measurably higher rate than the hatchery group, but the difference was not significant.

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2/ The source of estimated and observed recoveries for the hatchery fish are "CWT estimated recoveries" and "CWT observed recoveries." Both are data summaries published by the Pacific Marine Fisheries Commission, Portland, Oregon, February 1984.

Table 16.--A comparison of estimated and observed harvest rates in combined ocean and Columbia River fisheries of three groups of mid-Columbia River fall chinook salmon released as smolts in 1978.

| Release group | Number released | Release site | Harvest Estimated | Harvest Observed | Harvest rate (%) |
|---|---|---|---|---|---|
| Truck/transport McNary Dam | 40,361 | Below Bonneville Dam | 953 | (220) | 2.361 |
| Control/ McNary Dam | 38,137 | Below McNary Dam | 191 | (44) | 0.501 |
| Priest Rapids and Ringold Hatchery Production | 298,828 | Hatchery | 1,213 | (280) | 0.406 |

The contribution of transported steelhead to sport fisheries and the Zone 6 tribal fishery has been substantial (Table 17). The extremely positive transport benefit as measured in both fisheries leaves little doubt transportation of steelhead has provided more fish than could have been achieved without transportation.

The minor delay in migration of transported steelhead noted earlier has probably contributed to the higher transport benefits noted in the tribal fishery. I assume that any delay in migration would make the fish more vulnerable to harvest. However, in spite of higher tribal harvest rates, more fish are returning to the up-river sport fishery and spawning areas than would have returned without transportation.

The contribution of steelhead transported from McNary Dam to sports fisheries--especially those of the mid-Columbia River region--is also encouraging. For example, the Washington Department of Game estimated that 699 1-ocean age steelhead were harvested in the Methow River in the 1980-81 season (Schuck et al. 1981). Of the total 1-ocean age fish harvested, 519 (74%) were estimated to have been transported as smolts in 1979, even though less than 200,000 smolts were transported from McNary Dam in 1979. It was further estimated that the sport fishery harvest of fish transported by barge would have exceeded 1% if harvests in all fishing areas were combined (Park et al. 1981).

## Transportation and Restoration of Salmon and Steelhead Runs

Record low runs of spring chinook salmon and steelhead to the Snake River in 1974 and 1975 resulted from significant mortalities to smolts

Table 17.--Transport/control benefit ratios for Snake River steelhead in sports fisheries and tribal fishery, 1975-80.

| Year | Returns to sport fishery | | Returns to tribal fishery | |
|---|---|---|---|---|
| | No. | Benefit ratio | No. | Benefit ratio |
| Lower Granite Dam | | | | |
| 1975 | 84 | 4.10:1 | a/ | |
| 1976 | 43 | 1.43:1 | 138 | 1.95:1 |
| 1978 | 107 | 4.58:1 | 36 | 7.02:1 |
| 1979 | 75 | 2.54:1 | 74 | 2.5:1 |
| 1980 | 44 | 1.58:1 | 31 | 4.0:1 |
| Little Goose Dam | | | | |
| 1976 | 55 | 3.05:1 | 76 | 2.19:1 |
| 1977 | 1 | b/ | 13 | 6.25:1 |
| 1978 | 54 | 2.67:1 | 27 | 7.02:1 |

a/ No sampling in Tribal Fishery.

b/ Sport fishery in Idaho was severely restricted, therefore no benefit to fishery is computed.

during their 1972 and 1973 migrations to the sea (Raymond 1979). Fortunately, by 1975 there were encouraging results of transportation studies available (1968-73) which prompted an inter-agency decision to proceed with mass transportation at Lower Granite and Little Goose Dams. This practice was also established at McNary Dam in 1979, although full collection capability was not established until 1981.

Coinciding with mass transportation activities, there were also management efforts to substantially increase the number of spring chinook salmon and steelhead smolts released from hatcheries (Raymond 1979). Unfortunately, the increased numbers released from hatcheries; transportation; and improved passage through the dam complex in the form of spill, new fingerling bypasses, and increased river flows has had little measurable impact because of previously stated survival problems (Figs. 7 and 8). This does not mean spring chinook salmon should not be transported. It does indicate, however, that smolt quality of hatchery production fish should be maximized so that survival of both transported and nontransported fish can be enhanced.

Data show that transportation of steelhead has been an important factor in the rebound of steelhead runs to historic high levels in 1984 from the extreme low levels in 1975. The following review of how a 2:1 transport benefit ratio will increase the number of returns illustrates the point.

Assumptions are:

1. 5,000,000 smolts arriving at the upper dam.
2. Collection and transportation equals 60% of outmigration.

3. Rate of return is 1.0% for nontransported fish.

4. Rate of return is 2.0% for transported fish.

Therefore, the nontransported adult returns is 0.01 x 2,000,000 = 20,000, and the transported adult return is 0.02 x 3,000,000 = 60,000 providing a total of 80,000 adults. However, if no transportation occurs, survival of nontransported fish remains constant (1%) and 50,000 adults return. Therefore, if transportation is used, the net increase is 30,000 fish. The example used is conservative in that benefit ratios have generally exceeded 2:1, and adult return rates for transported fish usually exceed 2.0%.

Contributions from most up-river steelhead hatcheries to the overall run has been significant, especially in recent years (Pettit 1984; Ball 1984). The higher numbers of steelhead released coupled with higher survival of all steelhead in recent years has contributed to record runs in the mid-Columbia and Snake Rivers.

Fall chinook salmon runs passing McNary Dam have rebounded from less than 40,000 fish in the 1981 run to over 100,000 fish in 1984. The reversed trend has resulted from a combination of a significant transport benefit ratio (4:1) and increased numbers of fish being released from Priest Rapids Hatchery beginning in 1981. Future runs will depend on: (1) number of natural and hatchery fish produced, (2) quality of hatchery fish produced, (3) North Pacific Ocean and Columbia River fisheries harvest rates, (4) ocean mortality other than fishing, and (5) contribution of an effective mass transportation program. The latter factor should continue to be evaluated through an annual marking program at McNary Dam. It has been demonstrated that marking has little impact on the survival of fall chinook salmon (Park et al. 1983 and 1984). The knowledge gained through a continuous evaluation would far outweigh the small costs and minimal damage to the resource.

Remarkable improvements in smolt collection and transport operations have been a major contribution to the success of transportation in recent years. It is easy to forget that as recently as 1978 there were only three operating traveling screens at McNary Dam; now there are 42. Less dramatic but equally important are the continuing improvements in the collection and transportation operations themselves. Up to 1980, NMFS made recommendations to the CofE for collection and transportation operations improvements; similar actions have been made each year since 1981 by the Fish Transportation Oversight Team (FTOT). The FTOT annual report details numerous small changes that have occurred during the year as well as recommended future changes (Delarm et al. 1984).

## SUMMARY AND CONCLUSIONS

1. Transportation studies were conducted on the Snake River at Ice Harbor Dam in 1968-70, at Little Goose Dam in 1971-73 and 1976-78, and at Lower Granite Dam 1975-80. Eighteen tests were made comparing truck (with both freshwater and saltwater media) and barge transportation with nontransported lots of chinook salmon. In eight tests, significantly more tranported fish returned than corresponding control fish. In eight tests, measurably more transported fish returned. In one test (1977), no fish from either group returned. In one test, significantly more control fish returned than transported fish. Transport benefit ratios ranged from 0:66:1 to over 18.1:1. Through 1975, estimated rates of return for chinook salmon transported to release sites below Bonneville Dam exceeded 0.60% but ranged between 0.11 and 9.0%. Since 1975, the highest return was 0.3%, and in many experiments returns were insufficient for analysis.

2. In 17 identical tests with steelhead, all 17 transported groups returned in significantly higher numbers than the controls. Transport to control ratios ranged from 1.3:1 to 17.53:1. Estimated return rates for transported steelhead ranged from 0.4 to over 4%. In contrast to chinook salmon, the rates of return of steelhead since 1976 ranged between 2 and 4% except 0.97% during the 1977 drought year.

3. In tests comparing use of saltwater media and fresh water during truck transport, there were no significant differences in the numbers of adults returning for either spring chinook salmon or steelhead. I conclude that fresh water can be used during truck transportation. In a single test comparing barge vs. truck (fresh water) transport, spring chinook salmon returned in signifcantly higher numbers from the barge group. There was no significant difference for steelhead. There may be economic, logistical, or other factors influencing decisions on the use of one method or the other, but I believe further research should be conducted before drawing final conclusions.

4. Prior to 1975, the rates of return for spring chinook salmon were generally good, with transportation showing positive benefits. Since 1975, the rates of return of spring chinook salmon were less than 0.5% whether the fish were transported or not. There is evidence to suggest that the problem is more related to poor smolt quality (increased BKD, hatchery vs wild migrants, etc.) than to passage problems. I conclude that transportation of spring chinook salmon should substantially improve adult returns if smolt quality is high and collection/transport standards are maintained which minimize stress and injury.

5. Steelhead transported from Snake River dams have consistently returned at much higher rates than those not transported. Overall rate of return has consistently been above 2%. Steelhead should be transported from all collector sites.

6. At Snake River dams, descaling of chinook salmon and steelhead ranged from 4.0 to 23.9% and 5.7 to 30.2% (annual average), respectively. Delayed mortality for transported spring chinook salmon ranged from 1.9 to 42.5%. Delayed mortality for transported steelhead was low (nil to 11.1%). In one test (1981), the delayed mortality of descaled spring chinook salmon was about 10 times that of fish that were not descaled, indicating that collection and transport related injuries must be minimized.

7. Minor straying of spring chinook salmon and steelhead has been observed for Snake River stocks. In recent studies (1975-80), 11 spring chinook salmon and 16 steelhead strayed. Straying is inconsequential when compared to the number of returns to expected spawning or homing areas.

8. A minor delay in upstream migration of steelhead, mostly from Dworshak NFH, following transportation was detected.

9. At McNary Dam, transportation was evaluated for fall chinook salmon in 1978-80 (additional studies in 1981-83 are being evaluated), for coho salmon in 1978, and for steelhead in 1978-80. Evaluation was attempted for spring chinook and sockeye salmon, but either too few fish were marked or too few adults returned to draw any conclusion from the data. Transportation benefit ratios were about 4:1 for fall chinook salmon, 2:1 for coho salmon, and 2.5:1 for steelhead. Fish from all transported groups for all species returned in significantly higher numbers than fish from control groups, except steelhead from the 1980 trucked group

(measurably more transported fish--but not significantly more). The data strongly suggest all three species should be transported from McNary Dam.

10. Over 1,000 marked fall chinook salmon from studies in 1978-80 were recovered in ocean and Columbia River fisheries. Transport benefit ratios in the fisheries were comparable to that measured for returning adults collected at river trapping sites (about 4:1). Contributions of transported steelhead have been substantial in the Zone 6 tribal fisheries and in tributary sport fisheries; more fish were made available to user groups than could have occurred without transportation.

11. Mass transportation of smolts began in 1975 and reached full implementation in 1981. Mass transportation has contributed heavily to record runs of steelhead in recent years and increased numbers of upriver (bright) fall chinook salmon each year since 1981.

12. Through coordination interagency actions and steadily improving facility operations provided by the CofE, the current transportation program is in position to provide fisheries managers a productive enhancement tool for the restoration of the Columbia River salmon and steelhead resources.

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