TRANSPORTATION OF CHINOOK SALMON, *ONCORHYNCHUS TSHAWYTSCHA*, AND STEELHEAD, *SALMO GAIRDNERI*, SMOLTS IN THE COLUMBIA RIVER AND EFFECTS ON ADULT RETURNS

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ABSTRACT

Chinook salmon, *Oncorhynchus tshawytscha*, and steelhead, *Salmo gairdneri*, were captured at Little Goose Dam in the Snake River during their seaward migration and transported 400 km downstream to the lower Columbia River below Bonneville Dam. Their survival was increased from 1.1 to 15 times as compared with control fish which passed by seven mainstem low-level dams and reservoirs. Variations in survival were mainly dependent on species and environmental conditions in the river during the period fish were transported.

The homing ability of the adult fish was not significantly diminished; less than 0.2% of strays occurred among adult returns from groups transported. Transportation did not affect ocean age or size of returning adult steelhead, but ocean age of returning adult chinook salmon may have been affected. Steelhead returned to Little Goose Dam at a substantially higher rate (1.4-2.7%) than chinook salmon (0.1-0.8%) from groups transported. The timing of adult returns of both species to Little Goose Dam was not related to the time of capture and downstream release of smolts.

Salmonid populations of the Snake River and its Idaho tributaries have declined rapidly in recent years to the point that the very survival of some stocks is threatened. The total run (i.e., catch plus escapement) of chinook salmon, *Oncorhynchus tshawytscha*, attributable to the Snake River dropped from 120,000 adults in 1972 to 50,000 in 1974 (Raymond 1979). Similarly, the total run of steelhead, *Salmo gairdneri*, an anadromous form of rainbow trout, declined from 100,000 adults in 1972 to below 20,000 in 1974. The downward trend of the anadromous salmonid populations has been ascribed to losses of juvenile migrants at the series of eight dams (Figure 1) and associated reservoirs in the Snake and Columbia Rivers through which the smolts must pass on their way to the sea (Raymond 1979).

With the goal of protecting the migrants from the hazards of dams, a system for transporting smolts around the dams was investigated by the National Marine Fisheries Service. The juvenile migrants were collected from the Snake River at Little Goose Dam (the uppermost dam—Figure 1), transported around the entire series of dams, and released below Bonneville Dam (the lowermost dam) on the Columbia River. The effects of such transportation on the survival and catch of the fish and on the ability of the adults to "home" to their natal streams must be known if fishery agencies are to evaluate the transportation system as a practical means of protecting Snake River salmonid runs. The main objectives of the research at Little Goose Dam were: to determine the effect of transportation on homing and survival of juvenile chinook salmon and steelhead collected at Little Goose Dam and released at two locations downstream from Bonneville Dam and to compare these results with an earlier study done at Ice Harbor Dam (Ebel et al. 1973) where fish were

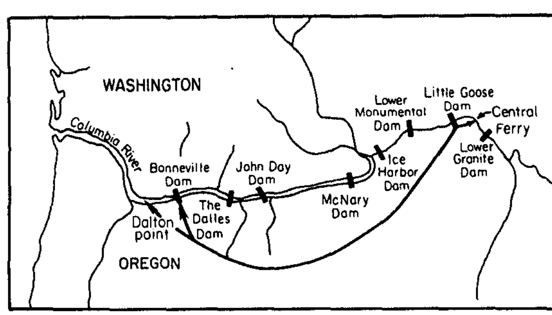

FIGURE 1.—Transportation routes and release location of experimental chinook salmon and steelhead collected and marked at Little Goose Dam, 1971-73.

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transported a shorter distance. Secondary objectives were: to determine any relation between timing of downstream juvenile migrants and timing of subsequent adult returns and to determine whether size and ocean age of adults (transported as smolts) were affected by the collection and transport process. The results of the experiments described in this report are also compared with the preliminary results of the current experiment at Lower Granite Dam.

BACKGROUND

The changes in abundance and the causes of changes in abundance of individual salmonid populations in the Columbia River drainage have been summarized by Chaney and Perry (1976). Raymond[2] analyzed the trends in abundance of Snake River runs in detail and clearly showed that the major causes of the decline of the Snake River stocks are due to the losses of juveniles during their seaward migration. These losses are caused by injury or death occuring when the fish attempt to pass the eight dams and reservoirs placed in their migratory path. These dams now inundate over 630 km of the migratory route. The main causes of the juvenile losses have been attributed to: passage through turbines (Bell et al.[3]; Long, Krcma, and Ossiander[4]; Long, Ossiander, Ruehle, and Mathews[5]); supersaturation of river water with atmospheric gas (Ebel and Raymond 1976); delay in migration (Raymond 1968, 1969); and increased predation (Chaney and Perry 1976).

The National Marine Fisheries Service (NMFS) has been conducting transportation experiments since 1965 in an attempt to find ways of reducing these losses. The first study where natually migrating juveniles were collected and transported was conducted by Ebel et al. (1973). This study showed that the homing ability of adult spring and summer chinook salmon and steelhead captured during their seaward migration as juveniles and then transported downstream (from Ice Harbor Dam to below Bonneville Dam) was not diminished. Data based on returning adults indicated that survival rate of adult fish that had been transported as juveniles increased 1.5-3 times the survival rate of those not transported, depending on environmental conditions in the river during the time of transport. Studies conducted prior to this study with hatchery stocks of salmonids showed that the majority of the adult fish that had been transported as juveniles returned to the release site, not to the parent location (Snyder 1928; Ellis and Noble 1960). Obviously, juvenile salmonids captured during their seaward migration and then transported differed in their responses from fish transported directly from hatcheries. The wild and hatchery stocks captured in the experiment conducted by Ebel et al. (1973) were smolting and had traversed several hundred kilometers before capture. These may be the main factors causing the different response (homing ability was not diminished) obtained in the experiment done in 1973.

Previous experiments (Hasler and Wisby 1951; Groves et al. 1968; Scholz et al. 1973) on mechanisms used by fish for homing indicated that the experience prior to and during the time that a juvenile salmon migrates is important in enabling the fish to receive visual and olfactory cues necessary for homing as an adult.

Only a portion of the migration route was eliminated by transporting the fish from Ice Harbor Dam to The Dalles and Bonneville Dams. Elimination of this portion of the migratory route apparently did not seriously affect the ability of either the chinook salmon or steelhead to home. However, the length of the migration route or amount of homing cues that can be eliminated and still achieve satisfactory homing is unknown.

The success of the experiment by Ebel et al. (1973) at Ice Harbor Dam encouraged the NMFS to begin a similar experiment at Little Goose Dam in 1971. As this dam is approximately 130 km upstream from Ice Harbor Dam, an additional 130

[2]Raymond, H. L. 1975. Snake River runs of salmon and steelhead trout: trends in abundance of adults and downstream survival of juveniles. Unpubl. manuscr., 11 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112.

[3]Bell, M. C., A. C. DeLacy, G. J. Paulik, and R. A. Winnor. 1967. A compendium on the success of passage of small fish through turbines. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112. (Contract DA-35-026-CIVENG-66-16, Report to U.S. Army Corps of Engineers, Portland, Oreg.)

[4]Long, C. W., R. F. Krcma, and F. J. Ossiander. 1968. Research on fingerling mortality in Kaplan turbines—1968. Unpubl. manuscr., 7 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112.

[5]Long, C. W., F. J. Ossiander, T. E. Ruehle, and G. M. Matthews. 1975. Final report on survival of coho salmon fingerlings passing through operating turbines with and without perforated bulkheads and of steelhead trout fingerlings passing through spillways with and without a flow deflector. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112. (Contract DACW68-74C-0113, Report to U.S. Army Corps of Engineers, Portland, Oreg.)

km of the migratory route would be eliminated, and the fish would be intercepted during their juvenile migratory life stage about 2-3 wk earlier than they were at Ice Harbor Dam. The results achieved at this site could be quite different from those obtained at Ice Harbor Dam. To facilitate the collection of fish, an orifice bypass system, juvenile fish diversion screens, and raceways for collection of juvenile fish were built into Little Goose Dam during its construction. This system provided substantial numbers of fish for the experiment, but there was the possibility that these fish might be injured or stressed during the diversion and collection process.

TABLE 1.—Number of transported and nontransported (control) juvenile chinook salmon and steelhead that were marked and released from Little Goose Dam, 1971-73.

Species and release year	Control fish	Transported fish[1]	
	No. released[2]	Dalton Point No. released[2]	Bonneville Dam No. released[2]
Chinook salmon:			
1971	20,673	30,637	35,252
1972	32,836	51,499	54,906
1973	88,170	57,758	83,606
Steelhead:			
1971	33,243	35,967	44,939
1972	32,488	22,831	27,326
1973	42,461	26,650	36,802

[1]Transported fish were released in the Columbia River at two sites downstream from Bonneville Dam: 2 km downstream on the Washington (side referred to in the table as Bonneville Dam) and 17 km downstream on the Oregon side at Dalton Point.
[2]Release totals adjusted for initial tag loss.

METHODS

Experimental Design

During the downstream migrations in 1971, 1972, and 1973 juvenile chinook salmon and steelhead were randomly selected from the raceways at Little Goose Dam and divided into three groups—one control and two transported groups. The adipose fin was removed from all experimental fish and each group was selectively marked with a thermal brand and magnetized wire tags. Thermal brands were changed every 5 d among all treatment groups except for the first 10-d marking period. During this period, marking continued for 10 d before a change was made. Codes for magnetized wire tags were changed yearly for each treatment group. The control group was released at Central Ferry, about 10 km upstream from Little Goose Dam; the transported groups were hauled in tank trucks to two locations downstream from Bonneville Dam (Figure 1). One release site was at Dalton Point, 17 km downstream from Bonneville on the Oregon side of the river; the other was at the Washington State boat launching site, about 2 km downstream from Bonneville Dam. Each year the goal was to mark at least 50,000 chinook salmon and 25,000 steelhead for each group. This goal was exceeded every year (Table 1) except for all groups of chinook salmon in 1971 and the control group of chinook salmon in 1972.

Collection and Marking of Fish and Fish Hauling Procedures

Juvenile chinook salmon and steelhead were collected at Little Goose Dam, using a fingerling collection and bypass system (Smith and Farr 1974). The system consisted of: 1) screens in the turbine intakes which diverted fish into the gatewells of each turbine intake; 2) a gatewell orifice and piping system which transported fish from the gatewells to a grader and counter; and 3) a fish grader and counter which sorted fish by size and electronically counted fish entering five raceways. When desired, fish could be diverted directly to the river—thus bypassing the grader, counter, and raceways.

Fingerling chinook salmon and steelhead were pumped with a 5-in Paco model fish pump into the marking building where they were anesthetized and sorted. Previously marked fish were returned to the river in the tailrace of the turbine discharge. Samples of at least 100 chinook salmon and steelhead were examined each day for percentage descaling to provide an index of fish condition. Any fish with >10% of the scales missing was considered descaled. Each of the remaining fish was cold-branded with liquid nitrogen (Park and Ebel 1974), had the adipose fin excised, and had a magnetic wire tag (Jefferts et al. 1963) inserted in the snout. Before passing into a transport truck, the fish went through a magnetic field and detection coil; an untagged fish was automatically rejected and returned to the marker for retagging. Initial tag loss was measured by examining samples of juveniles 48-72 h after tagging; subsequent tag loss was determined by examining returns of adult control and test fish at Rapid River Hatchery near Riggins, Idaho, and Dworshak National Fish Hatchery at Ahsahka, Idaho. A branded fish with an adipose fin clip that did not also have a coded

[6]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

wire tag was considered a fish that had lost its tag after marking. Steelhead and chinook salmon were kept in separate compartments in the tank truck whenever both species were hauled simultaneously. All fish were transported in a truck of 18,900 l (5,000 gal) capacity (Smith and Ebel 1973) that was equipped with aeration, refrigeration, and filtration systems. Load densities were governed by the size of the daily catch and were usually <0.12 kg/l (1 lb/gal) except during periods when unmarked fish were hauled. Maximum load density was kept <0.18 kg/l (1.5 lbs/gal) of water.

Water chemistry measurements were taken from the truck at the time of release for every load transported. Concentrations of ammonia, nitrogen, dissolved oxygen, carbon dioxide, pH, and total alkalinity were recorded for possible correlations with delayed mortality information. All releases were made at dusk. Records of mortality were kept during marking and at time of release; a sample of 50-100 fish was taken from each transported load and held for 48 h at Bonneville Dam to provide an indication of delayed mortality. This procedure was repeated during downstream migrations in 1971, 1972, and 1973.

Evaluation of Returning Adults

The effect of transportation on the survival and homing of adult fish was evaluated by comparing returns of transported and nontransported fish to the sport, commercial, and Indian fisheries in the lower Columbia River; to Little Goose Dam on the lower Snake River; to Rapid River Hatchery, Pahsimeroi Hatchery near Salmon, Idaho, and Dworshak Hatchery; and to the spawning grounds throughout the Snake River drainage.

All adult fish migrating upstream at Little Goose Dam must ascend one ladder located on the south side of the dam. An adult tag detection and fish separating device that intercepted tagged salmon and steelhead and diverted them into a holding pen was installed in this ladder in 1972 (Ebel 1974). Tagged fish from our study were readily identified by the missing adipose fin. All fish were anesthetized and further examined for brands. If the brand was recognizable, the origin of the fish could be determined without having to extract the magnetic tag from the snout.

Fish with recognizable brands were then weighed and measured, dart-tagged or jaw-tagged (Slatick 1976), and released to provide further information in the event of recapture upstream and to identify fish that fell back over the dam and ascended the ladder a second time. If a fish was known to be tagged but had a brand that was indistinguishable, it was held until maturity in holding tanks at the dam and artificially spawned. The tag was then extracted after spawning, and the test or control group was determined from the color code. Data obtained from these fish were combined with those obtained from reading brands.

The Columbia River gillnet fishery below Bonneville Dam, the Indian fishery above the dam, and the sport fishery (primarily below the dam) provided samples of chinook salmon throughout the spring run. The samples yielded information concerning the returns to the lower river of marked fish originating primarily in Idaho. Closure of the summer fishery on chinook salmon during all 3 yr and the spring fishery in 1974 and 1975 prevented sampling of this segment of the run in the lower river. The sport and commercial fisheries of the lower Columbia River and the sport fishery above Little Goose Dam provided samples of steelhead.

Surveys of spawning grounds were conducted with the cooperation of the Washington Department of Fisheries, Fish Commission of Oregon, and the Idaho Department of Fish and Game. Most of the surveys were in the Snake River drainage of Idaho, but hatcheries and spawning grounds of spring and summer chinook salmon in the upper Columbia River were also checked for strays.

The G statistic, Student's t-test, and analysis of variance were used for analysis of most return data.

RESULTS

Factors Influencing Assessment of Data

Tag loss, tag detector efficiency, transport mortality, and delayed mortality were factors that influenced the assessment of the experimental data. Comparisons of tests and control releases could be biased if a differential effect among any of these factors occurred between test and control releases and was not considered in the analysis. For example, if tag loss was greater in control releases than in test releases, percentage return would be biased in favor of the test release if the data were not adjusted for this loss.

During the 3 yr of this study, average annual initial tag loss ranged from 0.45% in 1973 to 10.4%

in 1972; average tag loss for the 3 yr of marking was 3.7%. Release totals were adjusted for initial tag loss. Additional tag loss (occurring after initial tag loss), based on examination of 884 marked adult steelhead at Dworshak National Fish Hatchery and 154 marked adult chinook salmon at Rapid River Fish Hatchery, was nill (<0.1%) and did not affect data analysis.

About 4-8% of the juvenile chinook salmon and 4-10% (Park et al.[7]) of the juvenile steelhead released as controls were recaptured and released at Little Goose Dam. No attempt was made to adjust the data for a small bias that might have occurred from this procedure. It was assumed that survival of this portion of the controls that were handled and released after passing through the collection system was the same or greater than survival of the majority of the control fish that had to pass either through the turbines or over the spillway.

The primary recovery site for evaluation of tag returns was at Little Goose Dam where an automatic tag detector and fish trap were installed (Ebel 1974). The efficiency of the detector and trap was based on a comparison of known recovery of fish with magnetized wire tags at Little Goose Dam and subsequent recovery of these and other marked fish at Rapid River and Dworshak Hatcheries. For example, 54 fish were identified at Rapid River Hatchery in 1975 from treatment groups that had passed Little Goose Dam. Of these, 50 had jaw tags indicating they had been captured and identified at Little Goose Dam; 4 did not have jaw tags indicating these fish had passed the dam without being trapped or identified. The trap efficiency for chinook salmon in 1975 was therefore 50/54 or 0.92. Thus, a factor of 1.08 was used to expand recoveries of .2- and .3-age[8] chinook salmon captured and identified at Little Goose Dam in 1975 from experimental releases in 1972 and 1973. Similar calculations were made for each year of recovery of chinook salmon during 1972-76 in computing estimated percentage return for a particular treatment group. The same procedure was used to estimate trap efficiency for steelhead with data obtained from recoveries at Dworshak Hatchery. The efficiency of recovery varied among years from 43 to 90% during the spring and summer when tagged chinook salmon were recovered. One source of variation was due to periodic shutdowns of the detector and trap for special studies of passage of adult fish. The efficiency remained constant (72%) during the fall of each year when most adult steelhead were recovered. An examination of the timing of test and control fish returning to Little Goose Dam indicated there was no significant difference. Thus, variations in efficiency did not affect comparisons of recoveries of test and control fish because all experimental groups passed the detector throughout the recovery period, and both test and control groups were subjected to the same variations in recovery efficiency. Total estimates of adult returns were adjusted for detector efficiency for a given period of recovery.

The use of the above method of estimating total percentage return for treatment groups assumes: loss of jaw tags from fish identified at Little Goose Dam was nil and jaw-tagged fish survived at the same rate as fish not jaw tagged. The first assumption is valid, I believe, because examination of several hundred fish at both Dworshak and Rapid River Hatcheries each year of recovery did not reveal any evidence of lost tags. Data from recent radio tracking studies (see Monan and Liscom[9]) suggest that the second assumption is also valid. In these studies, adult chinook salmon were obtained from the fish ladder with a similar trap and handled in an identical manner before tagging, and mortality of tagged fish was nil.

Transport mortality was defined as the mortality which occurred as a result of handling, marking, and hauling; delayed mortality was considered mortality that occurred in samples held at Bonneville Dam immediately after hauling. Transport mortality of both species was <1% of the total number of smolts handled (Table 2). Delayed mortality (Table 3) was considerably more, ranging from 10 to 22% for chinook salmon and 1.0 to 4.5% for steelhead. Transport and delayed mortality obviously reduced the total number of

[7]Park, D. L., J. R. Smith, E. Slatick, G. Matthews, L. R. Basham, and G. A. Swan. 1978. Evaluation of fish protective facilities at Little Goose and Lower Granite Dams and review of mass transportation activities, 1977. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112. (Contract DACW68-77-0043, Report to U.S. Army Corps of Engineers, Portland, Oreg.)

[8]Age designations follow the formulas of Koo (1962). The number of winters at sea is shown by an Arabic numeral preceded by a dot.

[9]Monan, G. E., and K. L. Liscom. 1974. Radio-tracking of spring chinook salmon to determine effect of spillway deflectors on passage at Lower Monumental Dam, 1973. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112. (Contract DACW57-73-F-0534, Final Report to U.S. Army Corps of Engineers, Portland, Oreg.)

TABLE 2.—Mean mortality of juvenile chinook salmon and steelhead during transport from Little Goose Dam to release locations downstream from Bonneville Dam, 1971-73.

	Percentage mortality		
Species	1971	1972	1973
Chinook salmon	0.87	0.57	0.70
Steelhead	0.16	0.51	0.51

TABLE 3.—Mean delayed mortality of samples of juvenile chinook salmon and steelhead taken from marked groups transported from Little Goose to below Bonneville Dam. Fish were held from 48 to 72 h after transport.

	Percentage mortality		
Species	1971	1972	1973
Chinook salmon	22.8	10.0	17.2
Steelhead	1.0	1.4	4.5

transported smolts released and correspondingly reduced adult returns from transported groups. Control groups may have been less affected because of the shorter transport time (1 h vs. 6 h). However, the assessment of benefits or losses obtained from transport of salmonid smolts must include this mortality. Release totals were therefore not adjusted for either transport or delayed mortality. It was noted that over 90% of the dead fish in the delayed mortality group had obvious signs of descaling or injury.

Measurements of descaling (fish with >10% of the body area descaled) of chinook salmon smolts that were recorded during the marking process varied from 0 to as high as 50% of the individuals observed. The average annual descaling rate was 16.6% in 1972 and 19.6% in 1973. Incomplete records of descaling measurements made it impossible to determine the average rate of 1971. Descaling of steelhead was substantially less than descaling of chinook salmon; the overall average for 1972 and 1973 was <1%. It was determined from other studies being conducted that most of the descaling was caused by experimental diversion screens being tested in the turbine intakes (Ebel et al.[10]).

There was a relation between descaling rate and delayed mortality. Steelhead were less descaled than chinook salmon and had much less delayed mortality than chinook salmon. It appears that if the injury that occurred during diversion and handling could be eliminated, survival of transported chinook salmon could be substantially improved.

Returns of Adult Experimental Fish to Little Goose Dam

A comparison of ratios of transport and control percentage returns of adults to Little Goose Dam from releases of chinook salmon and steelhead for the 3 yr of this study (Figure 2) indicated that survival of both species was substantially increased in 1973 by transporting the fish to the Dalton Point and Bonneville Dam release sites.

The percentage increase in survival varied from year to year and, I believe, was dependent primar-

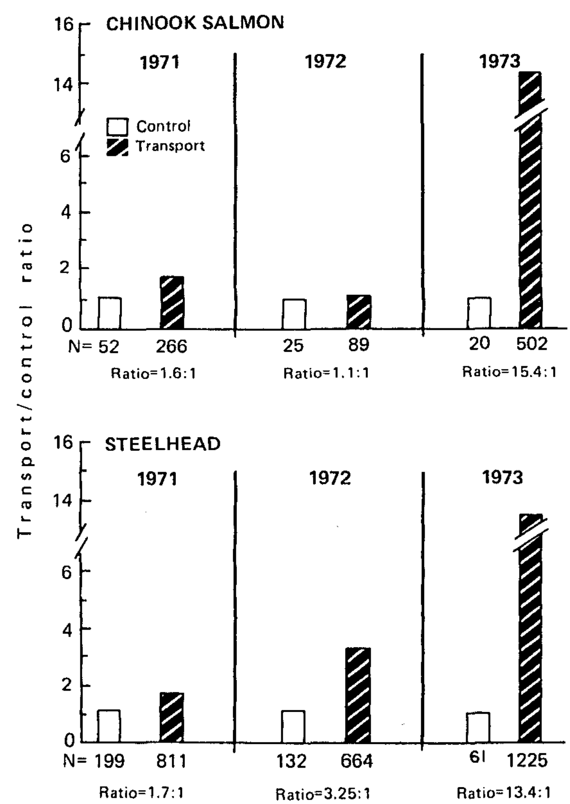

FIGURE 2.—Comparison of ratios of adult percentage return to Little Goose Dam from control and transported juvenile chinook salmon and steelhead. (Returns from Dalton Point and Bonneville Dam releases combined.) Percentage return of controls was set at unity for each year and species; the increase (transport percentage return ÷ control percentage return) is shown by darkened bar.

[10]Ebel, W. J., R. F. Krcma, and H. L. Raymond. 1973. Evaluation of fish protective facilities at Little Goose Dam and review of other studies relating to protection of other salmonids in the Columbia and Snake River, 1973. 62 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112. (Contract DACW68-71-0093, Progress Rep. to U.S. Army Corps of Engineers, Portland, Oreg.)

ily on river conditions. During years when survival of natural migrants (hatchery and wild stocks migrating naturally) was low, there was correspondingly low survival of control releases and greatest benefit from transportation. For example, in 1973, natural migrant survival estimates (Raymond 1979, see footnote 2) indicated an all-time low survival rate for both juvenile chinook salmon and steelhead migrants; in contrast, transport-control ratios were highest—15.4:1 for chinook salmon and 13.4:1 for steelhead (Figure 2). Raymond (1979) compared survival estimates of control releases from this study and other earlier studies (Ebel et al. 1973; Slatick et al. 1975) with survival estimates of naturally migrating smolts and found a high correlation (r = 0.95 for chinook salmon; 0.92 for steelhead) between survival of controls from transportation studies and his estimates of survival of natural migrants for the years 1968 to 1975. These data indicated there were close relationships between survival of releases of control fish marked for the transportation studies and hatchery and wild stocks migrating naturally. Raymond also correlated low survival with adverse river conditions; thus benefits from transportation would be highest when river conditions are the most adverse.

Statistical analysis of the return percentages (Table 4) was done by analysis of variance. A test of normality (Shapiro and Wilk 1965) of the percentage return data showed that the data were normally distributed ($P<0.05$); thus, transformation of percentage figures was not necessary. Analysis of variance of the return percentages indicated that the differences between "treatments" (test and control releases) were significant at the 1% level (Table 5). Interactions of the treatment × species were significant at the 5% level, indicating that the effects of treatment varied between chinook salmon and steelhead. For example, the mean transport/control ratio for returning chinook salmon in 1972 was 1.1:1, whereas the mean ratio for steelhead was 3.25:1. An analysis of the test of treatment effects—to compare the two downstream releases (both transported) and the control vs. the transported groups (Table 5)—clearly showed that there were no differences between recoveries from the Dalton Point and Bonneville Dam release sites and that the differences shown between test and control groups (Figure 2) were highly significant ($P<0.01$). Since interactions of the treatment × species were significant ($P<0.05$), I also analyzed the chinook salmon and steelhead percentages separately (Table 6). These analyses confirmed that differences shown between test and control groups were significant ($P<0.05$) for both steelhead and chinook salmon and that there were no differences between re-

TABLE 4.—Releases and recaptures of experimental fish.

Species, release site, and year	Number released	Ocean age[1] (no.) .1	.2	.3	Total	Adult returns (%) Observed	Estimated[2]	Transport/control ratio[3]
Chinook salmon[4]:								
Control:								
1971	20,673	5	28	19	52	0.252	0.470	
1972	32,836	4	12	9	25	0.076	0.106	
1973	88,170	2	11	7	20	0.023	0.026	
Transport:								
Dalton Point:								
1971	30,637	9	70	40	119	0.388	0.760	1.6:1
1972	51,499	4	20	20	44	0.085	0.114	1.1:1
1973	57,758	35	130	76	241	0.417	0.730	28.1:1
Bonneville Dam:								
1971	35,252	11	83	53	147	0.417	0.785	1.7:1
1972	54,906	5	28	12	45	0.082	0.110	1.0:1
1973	83,606	34	142	85	261	0.312	0.438	12.2:1
Steelhead:								
Control:								
1971	33,243	75	121	3	199	0.599	0.833	
1972	32,488	75	57	—	132	0.406	0.564	
1973	42,461	20	41	—	61	0.144	0.199	
Transport:								
Dalton Point:								
1971	35,967	124	237	6	367	1.020	1.418	1.7:1
1972	22,831	187	130	1	318	1.393	1.936	3.6:1
1973	26,650	276	276	5	517	1.940	2.698	13.5:1
Bonneville Dam:								
1971	44,939	166	287	11	464	1.033	1.436	1.7:1
1972	27,326	202	139	5	346	1.266	1.750	3.1:1
1973	36,802	352	353	3	708	1.924	2.673	13.4:1

[1]Age designation follows the formulas of Koo (1962). The number of years at sea is shown by an Arabic numeral preceded by a dot.
[2]Return percentage adjusted according to tag detector and trap efficiency.
[3]Transport/control ratios determined by dividing estimated percentage return of controls into estimated return of transported fish.
[4]Adult returns of spring and summer chinook salmon combined.

TABLE 5.—Analysis of variance of comparative percentage returns of adult chinook salmon and steelhead to Little Goose Dam for transported and nontransported (control) juveniles, 1971-73.

Source	df	SS	MS	Pooled residual (*F*)	Residual (*F*)
Treatments (test and control returns)	2	3.053	1.526253	8.924**	12.717**
Years (1971-73)	2	0.398	0.198794	1.162	1.657
Species (chinook and steelhead)	1	5.520	5.520057	32.276**	46.005**
Treatment × years	4	0.890077	0.223	—	1.858
Treatment × species	2	1.356179	0.678	3.965	5.650*
Years × species	2	0.698503	0.349	2.042	2.908
Residual	4	0.478141	0.120	—	—
Pooled residual	8	1.368218	0.171	—	—
Total	17	13.762118			
Partition of treatment SS (above), comparing adult chinook salmon and steelhead returns for control vs. transport and Dalton Point vs. Bonneville Dam.					
Control vs. transport	1	3.035	3.035	17.743**	
Bonneville vs. Dalton Point	1	0.018	0.018	0.105	

*$P<0.05$; **$P<0.01$.

TABLE 6.—Analysis of variance of comparative percentage returns of adult chinook salmon and steelhead to Little Goose Dam for transported and nontransported (control) juveniles, 1971-73 (returns analyzed by species).

Source	df	SS	MS	*F*
Chinook salmon return data				
Treatments (test and control returns)	2	0.179	0.089	2.70
Years (1971-73)	2	0.473	0.237	7.14*
Error	4	0.132	0.033	
Total	8	0.7849		
Partition of treatment sum of squares (above) comparing adult chinook salmon returns for control vs. transport and Dalton Point vs. Bonneville Dam.				
Control vs. transport	1	1.604	1.604	48.45**
Bonneville vs. Dalton Point	1	0.014	0.014	0.4342NS
Steelhead return data				
Treatments (test and control returns)	2	4.230	2.115	6.845
Years (1971-73)	2	0.623	0.311	1.006
Error	4	1.236	0.309	
Total	8	6.089		
Partition of treatment sum of squares (above) comparing adult steelhead returns for control vs. transport and Dalton Point vs.Bonneville Dam.				
Control vs. transport	1	4.223	4.223	13.667*
Bonneville vs. Dalton Point	1	0.062	0.062	0.020NS

* = $P<0.05$; ** = $P<0.01$; NS = nonsignificance.

coveries from the Dalton Point and Bonneville Dam release sites for either chinook salmon or steelhead.

Percentage Adult Returns of Transported Releases

Analysis of the transport/control ratio provides the best insight as to the possible benefits from the transportation system, but total percentage return obtained from the groups transported must also be examined to accurately assess the effectiveness of the system as it operated. If both transport and control groups were excessively stressed during the diversion, collection, marking, and transport operations, then percentage returns would have been abnormally low even though transport/control ratios were favorable. I, therefore, compared percentage returns of the transport groups with percentage returns of production releases achieved at Dworshak and Rapid River Hatcheries and with estimated percentage returns of steelhead and chinook salmon to Little Goose Dam.

Returns from production releases of juvenile steelhead at Dworshak Hatchery (Olson[11]) were 0.25% in 1971, 0.20% in 1972, and 0.052% in 1973. Corresponding estimated percentage returns of steelhead from those transported from Little Goose Dam in 1971, 1972, and 1973 (returns from Dalton Point and Bonneville Dam releases combined) were 1.4, 1.8, and 2.7%, respectively. Although the sport fishery for steelhead above Little Goose Dam in 1973 would have reduced the percentage returns to Dworshak for releases in 1971, the estimated catch of 2,459 (Petit[12]) when added to the total hatchery returns, resulted in a return percentage of <0.50 for the 1971 release. The sport fishery was closed from 1974 to 1976; thus returns from releases in 1972 and 1973 at Dworshak Hatchery were not affected.

I also compared percentage adult returns of steelhead with the estimated percentage adult returns from populations of natural migrants passing Little Goose Dam in 1971, 1972, and 1973 by Raymond (1979, see footnote 2). His estimates of percentage returns were based on counts of adults passing the dam and estimates of populations of smolts (both hatchery and wild) passing Little Goose Dam for a given year. His estimates of percentage adult returns of steelhead to Little Goose

[11]Wayne Olson, Hatchery Manager, Dworshak National Fish Hatchery, Ahsahka, Idaho, pers commun. 1973-76.

[12]Steven Petit, Senior Fisheries Research Biologist, Idaho Fish and Game Dep., Lewiston, Idaho, pers. commun. June 1974.

Dam for 1971, 1972, and 1973 were 0.8, 0.4, and 0.2%, respectively. These estimates did not include fish that were transported. 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.

Percentage returns from production releases of juvenile chinook salmon to Rapid River Hatchery (Parrish[13]) in 1971, 1972, and 1973 were 0.59, 0.12, and 0.15%, respectively. The corresponding percentage returns from juvenile chinook salmon transported from Little Goose Dam were 0.77, 0.11, and 0.52%, respectively. Estimated adult returns (Raymond 1979, see footnote 2) of the mixture of wild and hatchery populations of juvenile chinook salmon passing Little Goose Dam in 1971, 1972, and 1973 were 1.3, 0.6, and 0.4%, respectively. While some benefit can be shown when percentage return data from transported groups are compared with only the Rapid River Hatchery returns for 1971 and 1973, only those transported in 1973 showed a benefit when returns were compared with estimated percentage returns of adults from mixed wild and hatchery smolts passing Little Goose Dam.

When the combined returns of spring and summer chinook salmon were divided into seasonal races (Table 7) and compared for the 3 yr of this study, the benefits or losses from transportation were defined by time. Transport/control ratios indicated that spring chinook salmon received greater benefit from transportation in 1971 and 1973 than summer chinook salmon. Summer chinook salmon appeared to receive more benefit than spring chinook salmon in 1972, but returns from all chinook salmon releases were low in 1972.

Several factors could be responsible for the differential in transport/control ratios between spring and summer chinook salmon among the years. Probably the most important factor was the timing of seaward migration of the two races of salmon. The race migrating downstream during the most favorable river conditions would receive the least benefit from transport in any particular year.

[13]Evan Parrish, Hatchery Manager, Idaho Fish and Game Dep., Rapid River Hatchery, Riggins, Idaho, pers commun. 1973-76.

Timing of Adult Returns of Chinook Salmon

Analysis of data on timing of adult returns in comparison with timing of the juvenile seaward migration (Table 8) indicated that the timing of adult returns of chinook salmon to Little Goose Dam was independent of timing of juvenile seaward migration ($G = 0.518, 0.516$, and 0.293: $df = 1, P<0.05$ for 1971, 1972, and 1973, respectively). This is in contrast to what Ebel et al. (1973) found in adult chinook salmon returning from groups marked at Ice Harbor Dam in 1968. In this study most of the chinook salmon marked early in the spring migration returned early as spring chinook salmon, and most of those marked late returned later as summer chinook salmon. Perhaps intercepting the fish 130 km farther upstream eliminated the relation indicated from the earlier study. It is also possible that races of chinook salmon that exhibited this behavior in 1968 were absent or very low in numbers during 1971-73.

TABLE 8.—G-statistic test of relationship between timing of adult returns of chinook salmon to timing of juvenile seaward migration at Little Goose Dam, 1971-73.

Juvenile migration		Adult returns				
Year	Period[1]	Spring[2] (no.)	Summer[3] (no.)	Total (no.)	G	Significance[4]
1971	Early	73	25	98		
	Late	120	33	153		
	Total	193	58	251	0.518	NS
1972	Early	22	23	45		
	Late	14	10	24		
	Total	36	33	69	0.516	NS
1973	Early	149	86	235		
	Late	122	63	185		
	Total	271	149	420	0.293	NS

[1]Early = marked as juveniles from beginning of migration to 5 May. Late = marked as juveniles after 5 May.
[2]Prior to 15 June.
[3]After 14 June.
[4]$P>0.05$, df = 1; NS (nonsignificance) indicates timing of adult returns is independent of timing of seaward migration.

TABLE 7.—A comparison of adult returns to Little Goose Dam of transported and nontransported (control) spring and summer chinook salmon smolts, 1971-73. Percentage values indicate adult returns from transported group.

Seasonal race of chinook	1971 Control No.	1971 Control %	1971 Transport No.	1971 Transport %	1971 Ratio transport/control	1972 Control No.	1972 Control %	1972 Transport No.	1972 Transport %	1972 Ratio transport/control	1973 Control No.	1973 Control %	1973 Transport No.	1973 Transport %	1973 Ratio transport/control
Spring	37	0.179	200	0.303	1.70:1	18	0.055	65	0.061	1.1:1	10	0.011	329	0.232	21.2:1
Summer	15	0.073	66	0.100	1.37:1	5	0.009	24	0.022	2.4:1	10	0.011	161	0.114	10.4:1

Size and Years-in-Ocean of Adult Experimental Fish

Since transported fish (chinook salmon and steelhead) had the opportunity to enter the ocean more than 1 mo earlier than control fish that migrated naturally, the size and ocean age of returning adults were examined to determine whether a difference existed. The average weights of chinook salmon and steelhead released as controls were compared with the average weights of transported groups returning at the same ocean age. A paired comparison t-test using the data from Table 9 showed no significant differences in average weights for chinook salmon and steelhead (chinook salmon: $t = 0.315, P > 0.5$; steelhead: $t = 0.297, P > 0.5$ df = 8).

The ratio of age .3 to age .2 chinook salmon and the ratio of age .2 to age .1 steelhead were compared (Table 10) between transported and control groups. These comparisons indicated whether transporting affected the time that fish spent in the ocean before their return to Little Goose Dam. An analysis of variance of the ratios for the 3 yr of the study (Table 11) showed that the differences in ocean age between transported and control steelhead were not significant ($P < 0.05$). A significant ($P < 0.05$) difference in ocean age between control and transported chinook salmon did occur with a slightly higher ratio of .3/.2-age chinook salmon indicated among control returns. By these analyses, the transportation of smolts to locations downstream from Bonneville Dam was not shown to influence either the age or size of returning adult steelhead but may have influenced age of returning adult chinook salmon.

TABLE 9.—Average weights (kilograms) of returning chinook salmon and steelhead to Little Goose Dam from control (C) and transported (T) releases of smolts, 1971-73.

Species and year of release	Jacks		2-yr-in-ocean fish		3-yr-in-ocean fish	
	C	T	C	T	C	T
Chinook salmon:						
1971	1.66	1.40	5.06	4.74	8.22	9.20
1972	1.41	1.39	4.19	4.28	10.08	9.27
1973	1.86	1.51	4.40	4.46	7.77	9.02
Steelhead:						
1971	2.42	2.37	5.80	5.16	6.19	5.75
1972	2.39	2.53	4.38	4.24	4.44	4.84
1973	2.32	2.25	4.47	4.73	3.74	4.70

TABLE 10.—Comparison of transport and control age ratios on adults returning to Little Goose Dam, 1971-73. Chinook salmon age .3/.2 and steelhead age .1/.2 were used to determine ratios.

Year	Control			Transported		
	Ocean age[1] (no.)			Ocean age[1] (no.)		
	.2	.3	Ratio	.2	.3	Ratio
Chinook salmon:						
1971	28	19	0.68	153	93	0.61
1972	12	9	0.75	48	32	0.67
1973	11	7	0.64	272	161	0.59
	.1	.2		1	.2	
Steelhead:						
1971	75	121	1.61	290	524	1.81
1972	75	57	0.76	389	269	0.69
1973	21	41	1.95	628	629	1.00

[1]Age designation follows the formulas of Koo (1962). The number of years at sea is shown by an Arabic numeral preceded by a dot.

TABLE 11.—Analysis of variance of ratios of ocean age .3 to .2[1] chinook salmon and age .2 to .1 steelhead adults returning to Little Goose Dam from transported and control releases.

Species	Source	df	SS	MS	F
Chinook salmon	Treatments (transport and controls)	1	0.00657	0.00657	23.6*
	Years (1971-73)	2	0.00931	0.00465	33.3*
	Error	2	0.00394	0.000197	
	Total	5	0.016274		
Steelhead	Treatments (transport and controls)	1	0.114	0.114	0.633NS
	Years (1971-73)	2	1.058	0.529	2.94NS
	Error	2	0.359	0.180	
	Total	5	1.532		

*$P < 0.05$.
[1]Age designation follows the formulas of Koo (1962). The number of winters at sea is shown by an Arabic numeral preceded by a dot.

Recovery of Marked Chinook Salmon in the Commercial and Sport Fisheries

The experimental plan to evaluate recoveries of adult chinook salmon in the commercial, Indian, and sport fisheries required sampling of these fisheries each year from 1973 to 1975. However, the spring chinook salmon run began a rapid decline in 1973, which forced the commercial fishery to close in 1974 and 1975. As a consequence, sufficient data on chinook salmon were obtained only in 1973 for comparison of transported and control recoveries. A test fishery was conducted in 1974 and 1975, but only 18 salmon were recovered from the experimental releases during these years—too few to make comparisons of recoveries. Sixty-one salmon (Table 12) were recovered in 1973 from the 1971 experimental releases. The combined transport/control ratio of these recoveries, computed after adjusting the number of juveniles released, indicated that chinook salmon transported as juveniles were captured at 2.86 times the rate of control fish. This is a substantially higher test/control ratio than the 1.6:1 computed for returns to Little Goose Dam, indicating that transported groups were captured at a higher rate in the fishery than at Little Goose Dam. This

TABLE 12.—Comparison between transported and nontransported (control) chinook salmon of 1971 that were captured during 1973 as adults in the commercial, Indian, and sport fisheries in the lower Columbia River. (Numbers observed, not estimated.)

	Transported				Control	
	Dalton Point Recaptures		Bonneville Dam Recaptures		Recaptures	
Item	No.	%	No.	%	No.	%
Upstream from Bonneville Dam (Indian fishery)	14	0.046	14	0.040	4	0.019
Downstream from Bonneville Dam (commercial and sport fisheries)	9	0.029	18	0.051	2	0.010
Total	23	0.075	32	0.091	6	0.029
Combined recoveries (Dalton Point and Bonneville Dam)[1]				0.083	6	0.029

[1]Transport/control ratio = 2.86:1.

suggests that perhaps the adult fish from transported stocks were spending a longer time in the lower river, thus allowing a greater catch of these groups.

Recovery of Marked Steelhead in the Indian and Sport Fisheries

The Indian fishery of the lower Columbia River in 1973 and 1974 was not sampled because of closures during most of the season. However, in 1975 a substantial fishery was in progress. Sampling of this fishery yielded 39 marked steelhead from 1973 experimental releases. Thirty-eight of these were from transported groups; only one fish of a control group was recovered. The ratio of transport to control was 30:1, again indicating a higher catch rate of transported steelhead in 1973 than was recorded at Little Goose Dam where the transport/control ratio was 13.4:1.

TABLE 13.—Recoveries of adult steelhead from the sport fishery upstream from Little Goose Dam. Juveniles were released, 1971-73, as controls at Central Ferry; transported groups were released at Dalton Point and Bonneville Dam.

	Control		Transported groups		
Year released	No. of fish	Percentage return	No. of fish	Percentage return	Transport/ control ratio[1]
1971	50	0.150	149	0.184	1.2:1
1972	24	0.074	63	0.126	1.7:1
1973	0	—	24	0.037	—
Total	74		236		

[1]Transport/control ratios computed from the combined recoveries of the Bonneville Dam and Dalton Point releases.

The sport fishery upstream from Little Goose Dam in the Snake River was intensive in 1972 and 1973 but was closed for a portion of 1974. Sampling of this fishery yielded 310 marked steelhead (Table 13) from experimental releases in 1971-73. The transport/control ratio estimated from these recoveries indicated a benefit from transport, but the benefit was about half that indicated downstream at Little Goose Dam from releases in 1971 and 1972. The benefit was substantial in all recovery locations from releases in 1973.

Returns of Adult Experimental Fish to Hatcheries and Spawning Grounds

Spawning ground surveys and examination of adult fish in Idaho hatcheries provided further information concerning transport/control ratios of chinook salmon and steelhead at their "home" destination.

Adult chinook salmon returns were examined at Rapid River Hatchery; steelhead returns were examined at Dworshak National Fish Hatchery and at the Pahsimeroi Hatchery (Table 14). Ex-

TABLE 14.—Returns of adult chinook salmon and steelhead to hatcheries of the upper Snake River drainage, 1971-73.

		Released 1971			Released 1972			Released 1973		
		Recoveries			Recoveries			Recoveries		
Species and hatchery of origin	Release site and experimental group[1]	No.	%	Transport/ control ratio	No.	%	Transport/ control ratio	No.	%	Transport/ control ratio
Chinook salmon Rapid River	Bonneville Dam (T)	33	0.094	4.95:1	5	0.009	—	24	0.029	14.5:1
	Dalton Point (T)	25	0.082	3.32:1	7	0.014	—	42	0.073	36.5:1
	Total	58	0.088	4.63:1	12	0.011	—	66	0.047	23.5:1
	Central Ferry (C)	4	0.019		0	0	—	2	0.002	
Steelhead Dworshak	Bonneville Dam (T)	96	0.214	1.37:1	26	0.095	3.80:1	104	0.283	13.5:1
	Dalton Point (T)	49	0.136	0.87:1	17	0.074	3.00:1	114	0.428	20.4:1
	Total	145	0.179	0.87:1	43	0.086	3.44:1	218	0.344	16.4:1
	Central Ferry (C)	52	0.156		8	0.026		9	0.021	
Pahsimeroi	Bonneville Dam (T)	8	0.018	—	11	0.040	3.33:1	18	0.049	24.5:1
	Dalton Point (T)	5	0.014	—	9	0.039	3.25:1	18	0.068	34.0:1
	Total	13	0.016	—	20	0.040	3.33:1	36	0.057	28.0:1
	Central Ferry (C)	0			4	0.012		1	0.002	

[1]T = transported group; C = control.

cept for steelhead returns to Dworshak Hatchery from releases in 1971, transport/control ratios computed from these data indicated that the benefits from transportation were greater than those indicated from returns to Little Goose Dam.

This was particularly evident in returns of chinook salmon and steelhead from releases in 1973. At Little Goose Dam the combined transport/control ratio was 15.4:1 for chinook salmon and 13.4:1 for steelhead; the ratios at the hatcheries were 23.5:1 for chinook salmon (Rapid River Hatchery) and 16.4:1 (Dworshak) and 28:1 (Pahsimeroi) for steelhead. One possible reason for the difference might be a differential in benefit which favored hatchery stocks. Because returns to Little Goose Dam were a mixture of hatchery and wild stocks, the proportion of each stock in a sample could alter the transport/control ratio.

Spawning ground surveys for adult chinook salmon were conducted in 1972, 1973, 1975, and 1976. No surveys were made in 1974 because of the small number of marked fish available for recovery. The location of streams surveyed was identical to that described by Ebel et al. (1973). Fourteen marked fish were recovered during the 4 yr of surveys. Of these, 12 were identified as having been released as transports and 2 as controls. Although the recoveries of adults on the spawning grounds were very low, recoveries at Rapid River Hatchery were substantial (Table 14). The fact that 12 adult fish, transported as juveniles from Little Goose Dam, were recovered on the spawning grounds indicates that transported wild stocks as well as hatchery stocks continued their upstream migration after leaving Little Goose Dam.

Straying of Experimental Groups

The chinook spawning grounds of the Okanogan and Methow Rivers and other spring chinook hatcheries in the Columbia River drainage were checked to determine if adult returns from release groups had "strayed" to spawning locations other than their parent stream or hatchery. No strays were indicated in checks of hatcheries and spawning areas in the Columbia River above the mouth of the Snake River, but a few strays (16 chinook salmon and 3 steelhead) were recovered at Pelton Dam on the Deschutes River in Oregon. Of the 16 chinook salmon recovered, 10 were from groups transported as juveniles, 2 from controls, and the remaining 4 could not be positively identified as to release group because tag codes were lost. The three steelhead recovered were also from groups transported. These recoveries indicate that the homing behavior of a portion of the chinook salmon transported as juveniles may have been adversely affected. However, the proportion of the transported groups affected to this degree must have been small; 857 chinook salmon and 2,720 steelhead were identified at Little Goose Dam from the same release groups. The homing behavior of these fish obviously was not damaged. Additional data are needed to quantify the degree of straying that occurs from transporting steelhead and chinook salmon from Little Goose Dam.

DISCUSSION

Comparison of Results With Other Studies

The results of this study are similar to an earlier study done by Ebel et al. (1973) in which survival was definitely increased by transporting the fish downstream as juveniles. Percentage returns of adults to Little Goose Dam from transported fish were greater than that from control fish for the Dalton Pòint as well as the Bonneville Dam release sites for all 3 yr. However, the estimated percentage returns of chinook salmon were much lower than those reported by Ebel et al. (1973) when fish were collected and transported from Ice Harbor Dam in 1968. Estimated returns of adult chinook salmon, transported as juveniles from Ice Harbor Dam, ranged from 4.3 to 9.0%; whereas, returns of adult chinook salmon, transported as juveniles from Little Goose Dam in this study, ranged from 0.11 to 0.78%—substantially lower than achieved at Ice Harbor Dam.

There are several factors which could have caused the lower percentage returns from Little Goose Dam: 1) some homing ability may have been lost because the fish were intercepted and transported from a location about 130 km farther upstream; 2) the fish collected at Ice Harbor Dam may have been more hardy individuals because they migrated a greater distance, which would have allowed more of the weaker individuals to be eliminated from the populations; 3) the stocks collected at Ice Harbor Dam in 1968 were primarily wild stocks and thus hardier—more able to stand the stress of handling, marking, and hauling; or 4) the general condition of the fish at the time of marking may have been better because the collection, handling, and hauling system used at Ice

Harbor Dam could have resulted in less stress than that at Little Goose Dam. Further examination of the data, however, implies that the condition of the fish (factor 4) may have been the main factor. Estimated adult returns of chinook salmon to Ice Harbor Dam from fish transported in 1969 and 1970 (Slatick et al. 1975) were much lower (0.113-0.581%) than recorded from experimental groups released in 1968. The authors attributed the lower returns to stress caused by the placement of two new dams (Lower Monumental and Little Goose) in the migratory path of the juveniles and from stress caused by the use of a fish pump in the handling operation. The descaling and delayed mortality percentages in the study at Little Goose Dam indicated that stress in the collection, handling, and hauling procedures was a factor.

Steelhead were not affected in the same manner as chinook salmon in either this study or the earlier studies at Ice Harbor Dam. In both studies steelhead returned at a substantially higher rate than chinook salmon. Estimated percentage returns to Little Goose Dam of steelhead that had been transported as juveniles ranged from 1.4 to 2.6%; returns from releases at Ice Harbor Dam in 1969 and 1970 ranged from 0.6 to 1.6%. Since steelhead smolts are larger than chinook salmon smolts, they may have been able to withstand the rigors of collection, handling, and marking; the very low delayed mortality percentages, shown in this study for steelhead, support this reasoning.

Effect of Transportation on Homing

The transport/control ratios provide information on the effect of transportation on homing. For example, if no differential mortality occurred between groups, a steadily decreasing ratio of transport/control numbers from the commercial and sport fisheries below Bonneville Dam to the spawning ground would indicate a loss of homing ability or straying.

During the 3 yr of study, this type of comparison could only be made from 1971 releases of juvenile chinook salmon because the lower river commercial fishery was closed after 1973. A comparison of recovery ratios of adult fish from these releases showed that the transport to control ratios were 2.86, 1.65, and 3.95:1 in the commercial fishery at Little Goose Dam and the spawning grounds,[14] respectively. Although there was a variation in the ratios from the lower river to the spawning grounds, these ratios indicated that ability of transported chinook salmon to home to either their parent stream or Rapid River Hatchery was not seriously damaged by transporting the fish around the seven dams and reservoirs between Little Goose and Bonneville Dams.

The ratios also imply that hatchery stocks were benefited to a greater degree than wild stocks. When returns to the spawning grounds were separated from returns to Rapid River Hatchery and separate transport/control ratios were computed, the ratio for wild stocks became 1.5:1 and hatchery stocks, 4.6:1. However, more data are needed regarding this aspect (only six fish were recovered on the spawning grounds from releases in 1973) before conclusions can be made on the differential effect that transportation might have on hatchery and wild stocks of chinook salmon. A comparison between the ratio in the commercial fishery (2.8:1) and at Little Goose Dam (1.6:1) also indicates that transported chinook salmon may have been affected differently from controls—if one assumes that no differential mortality occurred between control and transported fish as they moved upriver and that wild and hatchery stocks were captured at the same rate in the fishery as they were at Little Goose Dam. Returning adults transported as smolts may have been slightly disoriented or remained for a longer period in the lower river, thus permitting the fishery to take a disproportionate number of transported fish.

Ebel et al. (1973) found no difference in transport/control ratios from the commercial fishery to the spawning grounds when data from releases at Ice Harbor Dam in 1968 were analyzed.

Disproportionate straying of adults from groups transported as juveniles would also be an indication that homing behavior had been affected by the transportation. No straying of either chinook salmon or steelhead was observed in the earlier study at Ice Harbor Dam. On the basis of recoveries of marked chinook salmon in the Deschutes River, some straying of chinook salmon that had been transported as juveniles occurred in this study. This instance of straying and the variations of transport/control ratios from the fishery to Little Goose Dam indicate that the migratory route lost by collecting the juveniles 130 km upstream at Little Goose Dam may be of some importance in determining homing behavior. A current

[14]Return to the hatcheries included in computation of transport/control ratio.

study (Park[15]) being conducted at Lower Granite Dam (about 200 km upstream from Ice Harbor Dam) by NMFS should provide further information on this subject. Preliminary data obtained from adult steelhead and chinook salmon returning to Lower Granite Dam show that transport/control ratios (2.5-2.7:1) obtained from experiments in 1975 and 1976 are similar to those obtained at Little Goose Dam. Insufficient data are available at this writing to determine variations in ratios from the lower river to the estuary or to determine degree of straying.

SUMMARY AND CONCLUSIONS

The main objectives of the research at Little Goose Dam were to determine the effect of transportation on homing and survival of juvenile chinook salmon and steelhead collected at Little Goose Dam and released downstream and to compare these results with an earlier study done at Ice Harbor Dam where fish were transported a shorter distance. The data clearly show that homing ability was not seriously diminished in either chinook salmon or steelhead, and that survival of both species was increased by transporting the fish to release locations downstream from Bonneville Dam.

A comparison of the results of this study with an earlier study done by Ebel et al. (1973) and by Slatick et al. (1975) at Ice Harbor Dam indicates that the effect of collecting the fish about 130 km farther upstream did not seriously diminish their homing ability in comparison with homing ability obtained in the experiment at Ice Harbor Dam. The increases in survival of transported fish noted in the study at Little Goose Dam were also similar to those noted at Ice Harbor Dam, but estimated percentage return of chinook salmon was substantially lower than that achieved at Ice Harbor Dam. Observations made throughout the study indicated that chinook salmon returns might be increased by reducing injury or stress during diversion, collection, and handling process.

The main conclusions bearing on the effect of transporting juveniles from Little Goose Dam to release locations downstream from Bonneville Dam were:

1) Analysis of transport/control ratios obtained from returning adults indicated that returns from naturally migrating juvenile chinook salmon and steelhead that were transported from Little Goose Dam to release locations downstream from Bonneville Dam were increased from 1.1 to 15 times in the fishery and to Little Goose Dam.

2) A significant ($P<0.01$) difference in benefit from transportation was noted between chinook salmon and steelhead; the greatest return and, hence, the greatest benefit occurred with steelhead.

3) Homing of adult fish that had been collected as juveniles at Little Goose Dam and transported several hundred kilometers downstream to Bonneville Dam apparently was not seriously diminished although a small portion ($P<0.02\%$) of the transported adult chinook salmon was known to have strayed.

4) There was no significant ($P<0.05$) difference in adult returns from two release sites tested (Dalton Point and Bonneville Dam) of either steelhead or chinook salmon.

5) Timing of migration of juvenile migrants was not related to timing of adult returns to Little Goose Dam.

6) Neither size nor ocean age of adult steelhead transported experimentally as juveniles was significantly ($P<0.05$) different from controls. Thus transporting the fish did not appear to affect either size or age of returning adult steelhead.

7) Although size of adult chinook salmon transported as juveniles was not significantly ($P<0.05$) different from controls, ocean age was. Transportation, therefore, may have influenced ocean age of returning adult chinook salmon.

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[15]Donn L. Park, Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112, pers. commun. December 1977.

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