Northwest and
Alaska
Fisheries Center

National Marine
Fisheries Service

U.S. DEPARTMENT OF COMMERCE

NWAFC PROCESSED REPORT 79-9

STATUS REPORT—1978
The Snake River Salmon and Steelhead Crisis:
Its Relation to Dams and the National Energy Shortage

September 1979

This report does not constitute a publication and is for information only. All data herein are to be considered provisional.

STATUS REPORT--1978; THE SNAKE RIVER SALMON AND STEELHEAD CRISIS: ITS RELATION TO DAMS AND THE NATIONAL ENERGY SHORTAGE

by

Wesley J. Ebel
George K. Tanonaka
Gerald E. Monan
Howard L. Raymond
Donn L. Park

Northwest and Alaska Fisheries Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112

September 1979

PREFACE

This report updates the information contained in the February 1975 report "The Snake River Salmon and Steelhead Crisis: Its Relation to Dams and the National Energy Crisis" (Collins et al. 1975).

CONTENTS

INTRODUCTION

Dams constructed on the Columbia and Snake Rivers in the past decade to provide hydroelectric energy have impounded most of the free-flowing sections of these rivers and created water conditions that in both high- and low-flow years are deadly to migrating salmon, Oncorhynchus spp., and steelhead, Salmo gairdneri (Exhibit 1). With high spills, the water becomes supersaturated with atmospheric gases to levels that are lethal to fish. In low-flow years, with no spill, an even more destructive situation develops in which all downstream migrants must pass through turbines where many are killed outright, and others are injured or stunned and left vulnerable to intensive predation. Young migrants from the Salmon River (a tributary of the Snake River) must pass through eight large impoundments and over eight major dams to reach the sea. Even small losses or delays at each dam become serious because of the large number of dams (Exhibit 2).

Exhibit 1. Location of main stem dams in the Columbia River Basin.

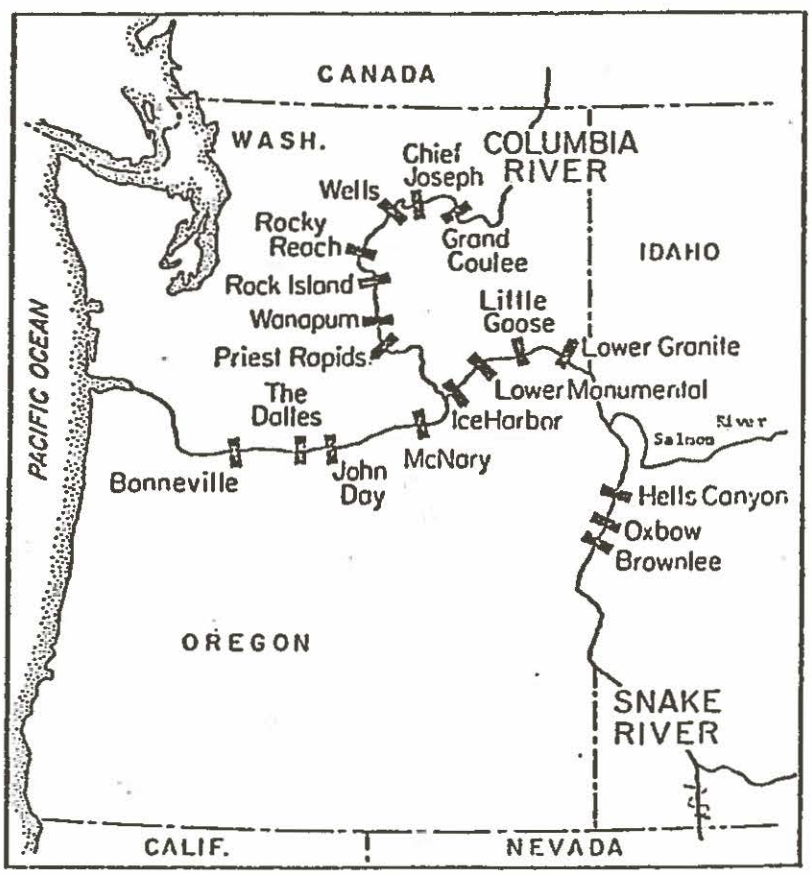
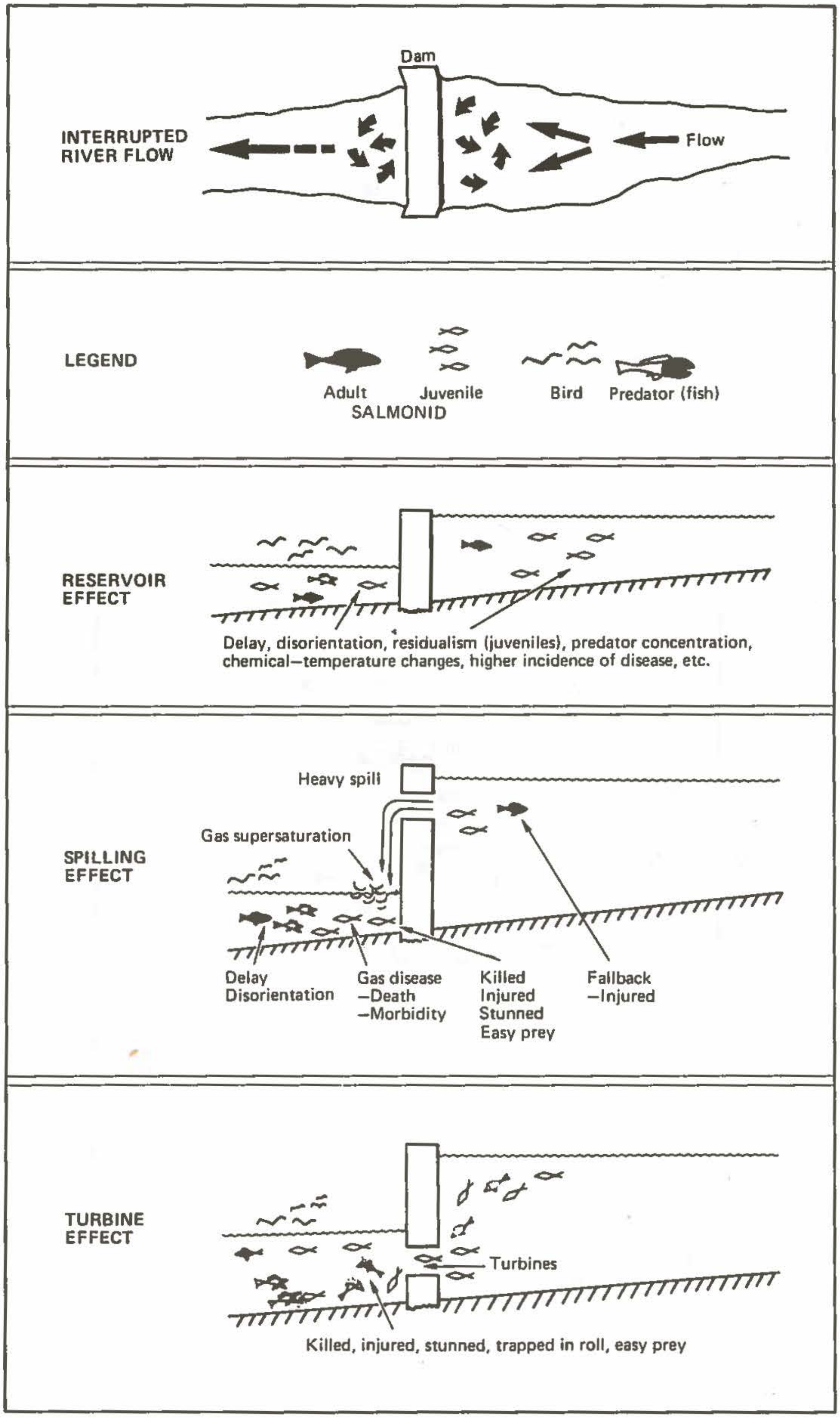


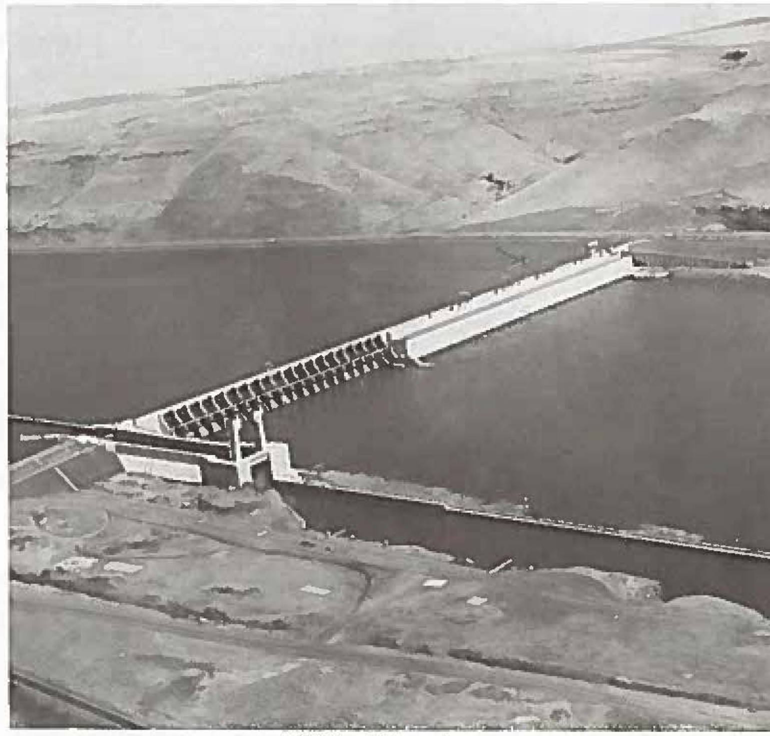
Exhibit 2. Consequences from a dam placed in the path of migrating juvenile and adult fish.



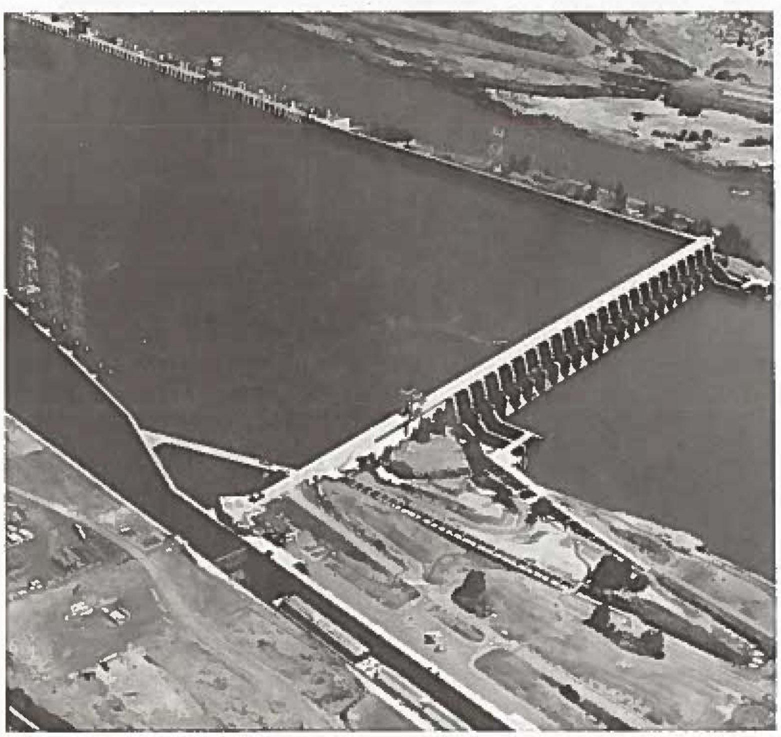
The rapid acceleration of powerhouse construction in the Columbia Basin in response to the national energy crisis means that very soon the disastrous "no spill" condition will occur with greater frequency and an even greater percentage of young migrants will pass through turbines. The time available to develop and refine solutions to fish passage problems has been severely shortened. Fortunately, our research has already pointed the way to several important practical steps to minimize salmon and steelhead losses due to dams. Several timely actions on corrective or protective measures by the U.S. Army Corps of Engineers (CofE) are contributing to solutions.

THE RIVER AND THE GAUNTLET

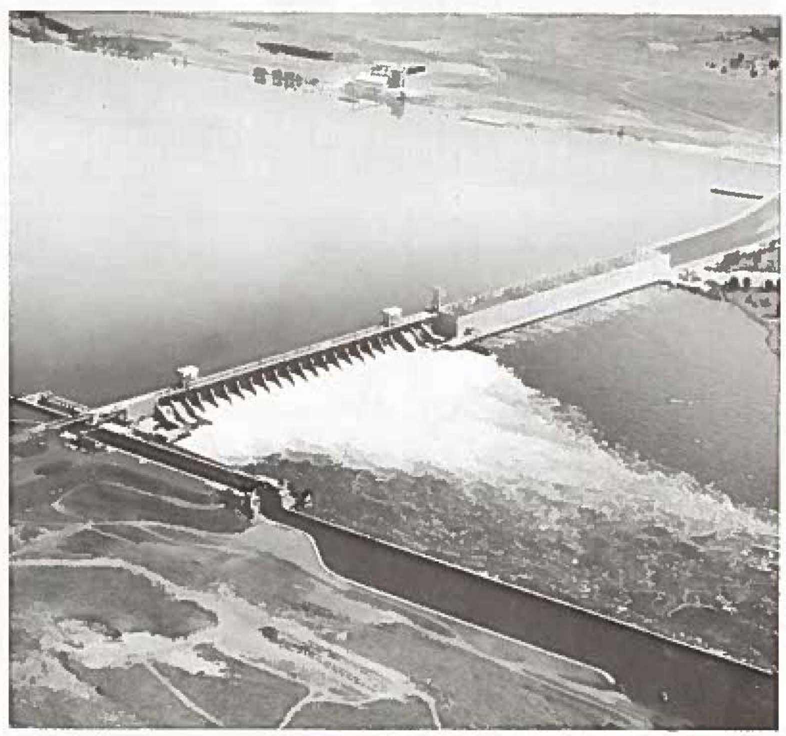
BONNEVILLE DAM



JOHN DAY DAM



THE DALLES DAM

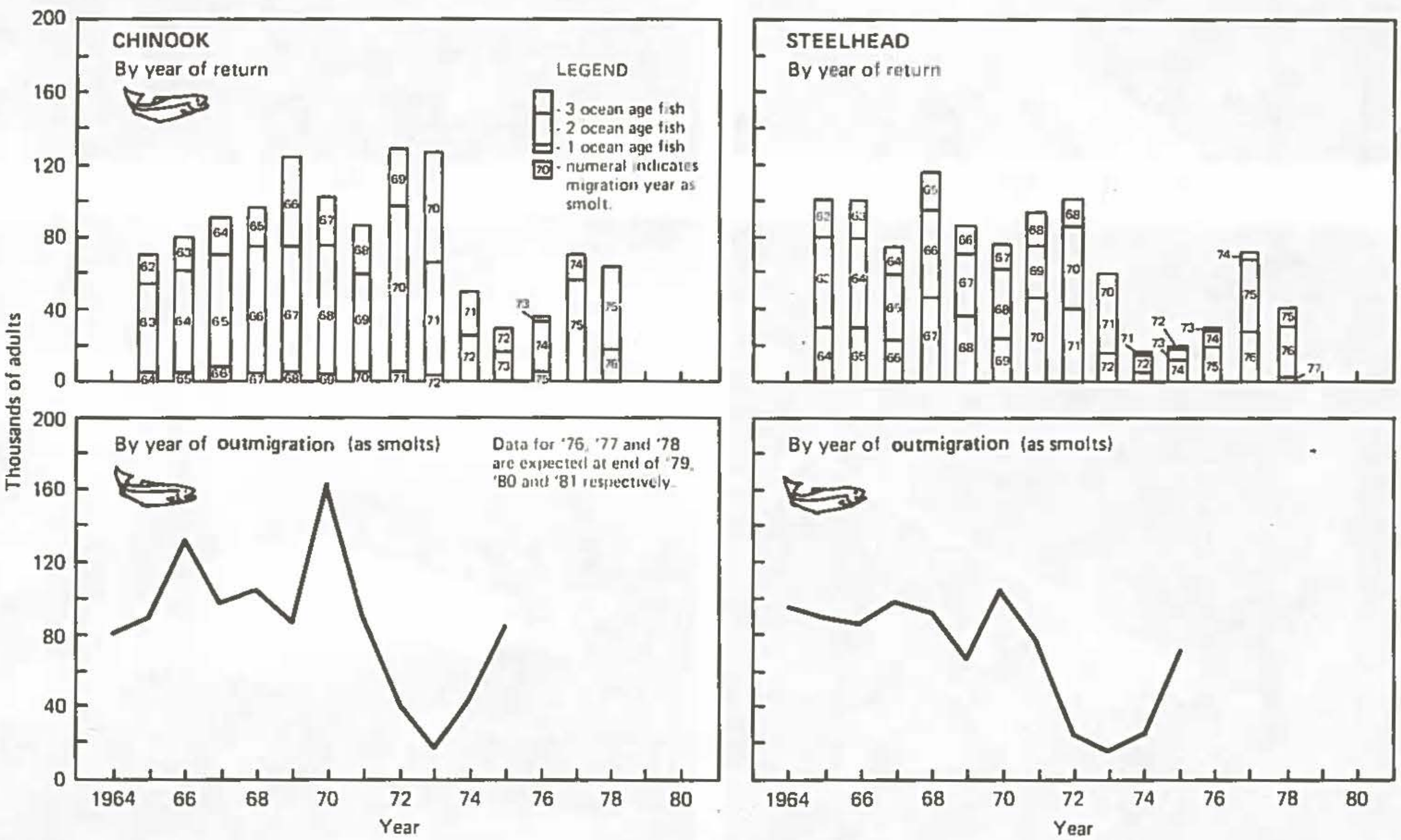


MCNARY DAM

TRENDS IN THE SNAKE RIVER SALMON AND STEELHEAD POPULATIONS

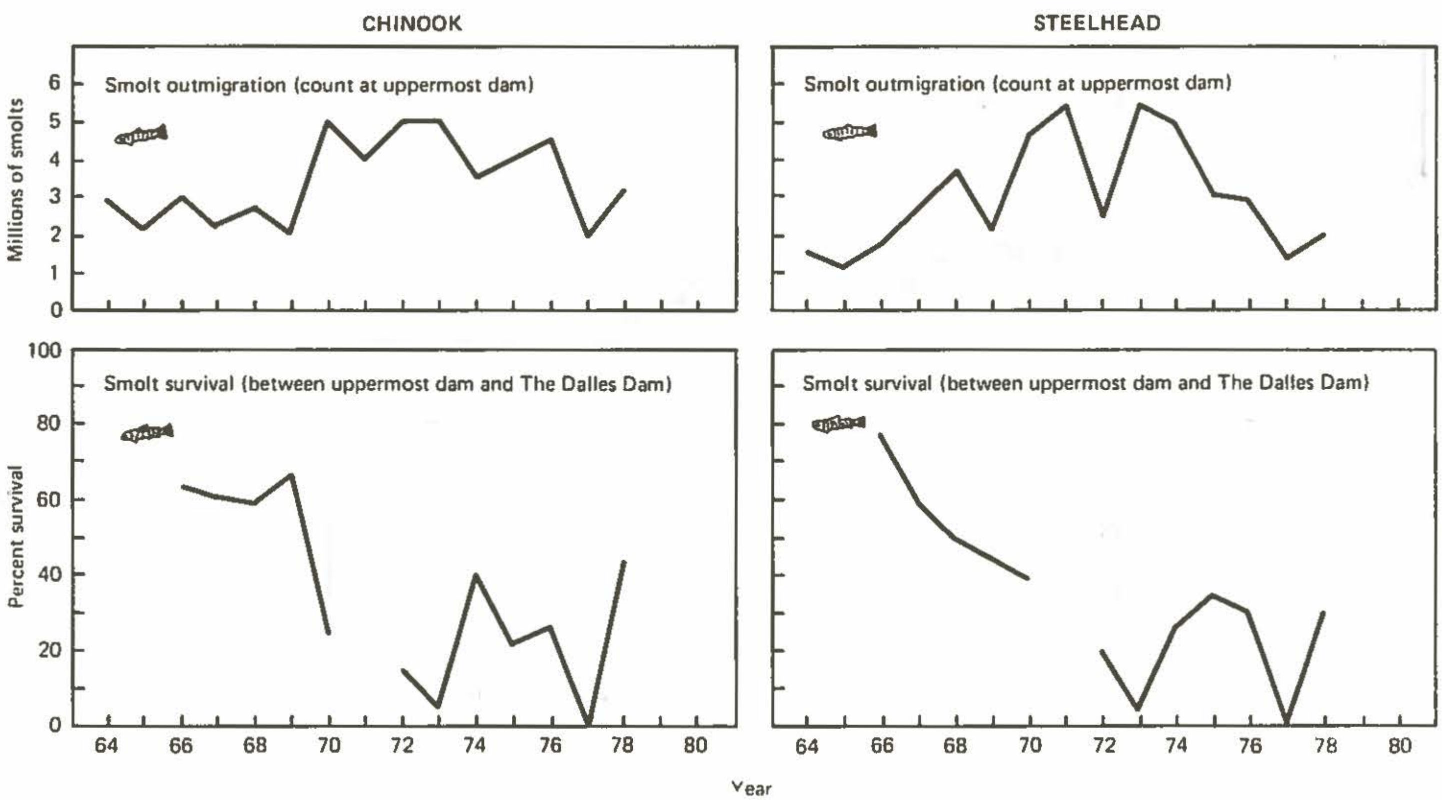
A superficial examination of data on return of adult fish (Top panels, Exhibit 3) indicates there was no serious decline in chinook salmon, _O. tshawytscha_, and steelhead runs to the Snake River until 1974. However, in terms of adult return by year of outmigration as smolts (Bottom panels, Exhibit 3) the decline began in 1972. This is because the adult run of chinook salmon and steelhead migrating up the Columbia River each year consists of survivors from three separate years of juvenile downstream migrations; therefore, one very successful juvenile outmigration in any given year can result in that year class dominating the adult run for several years. Note, for example, the influence of the strong 1970 and 1971 chinook salmon migrant year classes on adult chinook salmon returns in 1972 and 1973 and, inversely, the effects of the 1972, 1973, and 1974 migrant year classes on adult chinook salmon returns in 1974, 1975, and 1976. These adult return data, in turn, provide only a partial perspective. In reality, the decline in productivity of Snake River populations of chinook salmon and steelhead started in 1970 and around 1966, respectively, for these species. This happened even when increased smolt (juvenile fish migrating down to the ocean) production was taken into account.

Exhibit 3. Estimated return of adult chinook salmon and steelhead to the Snake River, 1964-78.



Smolt production increased substantially starting in 1970 for chinook salmon while steelhead production began to increase around 1967 (Top panels, Exhibit 4). On this basis, the decline in adult fish returns should not have taken place. In fact, because of the increased smolt production, a greater number of adult fish should have resulted than shown in Exhibit 3. Increased smolt productions were negated by the alarming decline in smolt survival as measured between the uppermost dam and The Dalles/John Day Dams (Bottom panels, Exhibit 4). For both species, lowest survivals were recorded in 1973 and 1977 when river flows were extremely low. Survivals were estimated at only 5% and 4% in 1973, and 1% and less than 1% in 1977 for chinook salmon and steelhead smolts, respectively.

Exhibit 4. Trends in outmigration of Snake River chinook salmon and steelhead smolts, 1964-78.1/

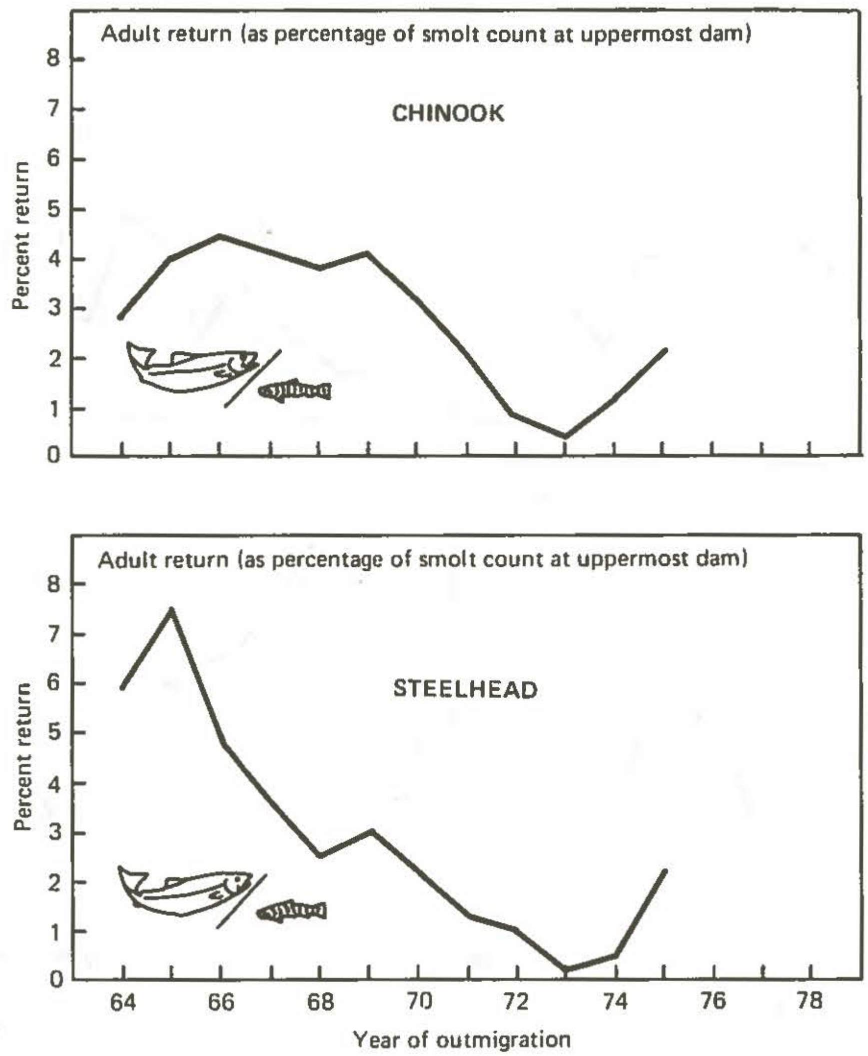


1/ On the basis of estimated smolt counts at the uppermost dam. Uppermost dams are:
Ice Harbor, 1964 to 69
Little Goose, 1970 to 74
Lower Granite, 1975 to 78
Source: Exhibit 6.

These increased smolt productions thus masked the seriousness of the problem—the decline in productivity was taking place far earlier than indicated by adult fish returns only. The devastating, cumulative effects of dams and impoundments on survival of juvenile fish migrating downriver is the "Crisis" brought to attention in this and the earlier 1975 Report.

Another way of looking at the "Crisis" is by the trend in the ratio of adult fish return to smolt outmigration (Exhibit 5). Even with increased smolt production, the percentage return of adults declined at an alarming rate starting in 1970 for chinook salmon and in 1966 for steelhead. The drop in adult return percentages reflects primarily the losses of juveniles due to fish passage problems in the Snake and lower Columbia Rivers and to adult fish losses at dams[1] but not to ocean mortality, nor to increased fishing pressure in the ocean, nor even to the river gillnet fishery.

Exhibit 5. Trends in returns of adult chinook salmon and steelhead as a percentage of smolt outmigration count at uppermost dam, 1964-75.



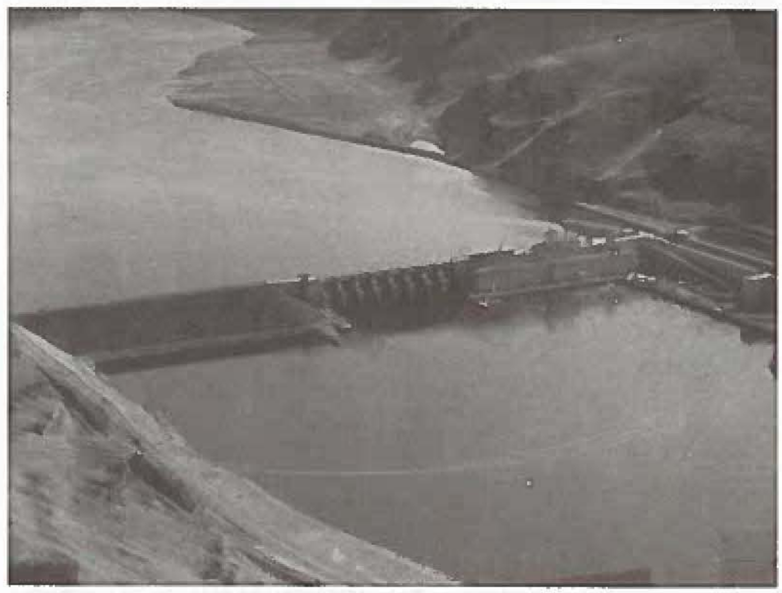
[1]The loss of adult fish in the river (between Bonneville and Ice Harbor Dams) is estimated at up to 20% depending on species and on river flow conditions (Junge and Carnegie 1976; Young et al. 1978). Higher river flow resulted in greater adult fish losses.

If the declines in fish populations were due to increased fishing pressure in the ocean, then chinook salmon should be the only species showing a drop, since there is no significant harvest of steelhead in the ocean. If the declines were due to the river fishery, then it would have to be due to unreported catches since both sport and commercial fisheries are included in adult return calculations. Furthermore, a comparison of adult return percentages based on the uppermost dam to the percentages at The Dalles/John Day Dams attest to juvenile fish losses in the river as responsible for the decline in productivity. As shown by the last two columns in Exhibit 6, the percentage adult return based on smolt count at the uppermost dam declined; whereas, the corresponding percentage adult return based on smolt count at The Dalles/John Day Dams remained between 4.8 to 9.6% (exceptions being the high 13.5% for chinook salmon in 1970 and the lows for both species in 1974).

To reiterate, running the gauntlet of dams and impoundments has resulted in high losses of juvenile fish and, in part, of adult fish. The primary causes of fish losses in the river are examined next.

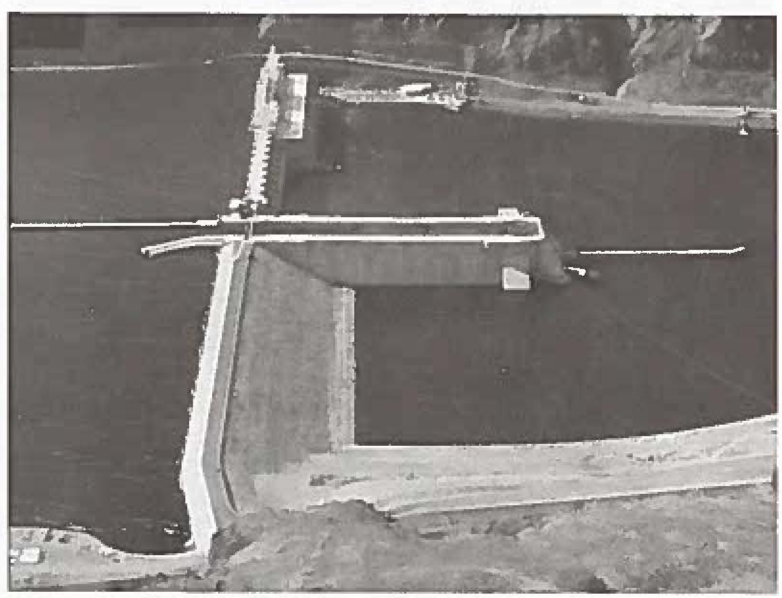
THE RIVER AND THE GAUNTLET

ICE HARBOR DAM



LITTLE GOOSE DAM

LOWER MONUMENTAL DAM



LOWER GRANITE DAM

Exhibit 6. Smolt migration and adult fish return--Snake River chinook salmon and steelhead, 1964-78.

Migration year	Smolt migration: Number of smolts (millions) passing Lower Granite	Little Goose	Ice Harbor	The Dalles or John Day 2/	Percent survival to The Dalles or John Day 3/	Adult fish return 1/: Number of adults (thousands)	Adult return as % of smolts passing: Uppermost dam 4/	The Dalles
				Chinook Salmon				
1964	-	-	2.9	na	na	80	2.8	na
1965	-	-	2.2	na	na	89	4.0	na
1966	-	-	3.0	1.9	63	132	4.4	6.9
1967	-	-	2.3	1.4	61	97	4.2	6.9
1968	-	-	2.7	1.6	59	104	3.8	6.5
1969	-	-	2.1	1.4	67	87	4.1	6.2
1970	-	5.0	1.6	1.2	24	162	3.2	13.5
1971	-	4.0	1.9	- 5/	-	89	2.2	-
1972	-	5.0	1.8	0.75	15	41	0.8	5.5
1973	-	5.0	0.6	0.25	5	18	0.4	7.2
1974	-	3.5	1.7	1.4	40	43	1.2	3.1
1975	4.0	-	1.3	0.9	22	86	2.1	9.6
1976	5.0	-	2.7	1.3	26	6/	6/	6/
1977	2.0	-	<0.1	0.02	1	7/	7/	7/
1978 9/	2.2+(1.0)	1.3+(0.6)	1.1	0.7	44	8/	8/	8/
1979								
1980								
1981								
				Steelhead				
1964	-	-	1.6	na	na	95	5.9	na
1965	-	-	1.2	na	na	90	7.5	na
1966	-	-	1.8	1.4	78	86	4.8	6.1
1967	-	-	2.7	1.6	59	97	3.6	6.1
1968	-	-	3.7	1.9	51	91	2.5	4.8
1969	-	-	2.2	1.0	45	66	3.0	6.6
1970	-	4.7	4.0	1.9	40	103	2.2	5.4
1971	-	5.5	3.4	- 5/	-	74	1.3	-
1972	-	2.5	1.5	0.5	20	26	1.0	5.2
1973	-	5.5	1.4	0.22	4	12	0.2	5.4
1974	-	5.0	4.0	1.3	26	23	0.5	1.8
1975	3.2	-	1.7	1.1	34	70	2.2	6.4
1976	3.0	-	1.8	0.9	30	6/	6/	6/
1977	1.4	-	<0.1	0.01	<1	7/	7/	7/
1978 9/	1.1+(1.0)	0.6+(0.4)	0.5	0.21	30	8/	8/	8/
1979								
1980								
1981								

Source: Smolt data (Sims et al. 1978; Raymond ms); adult return data (Raymond 1975; Raymond ms). Smolt data for 1978 are preliminary (Sims, personal communication).

na = not available.

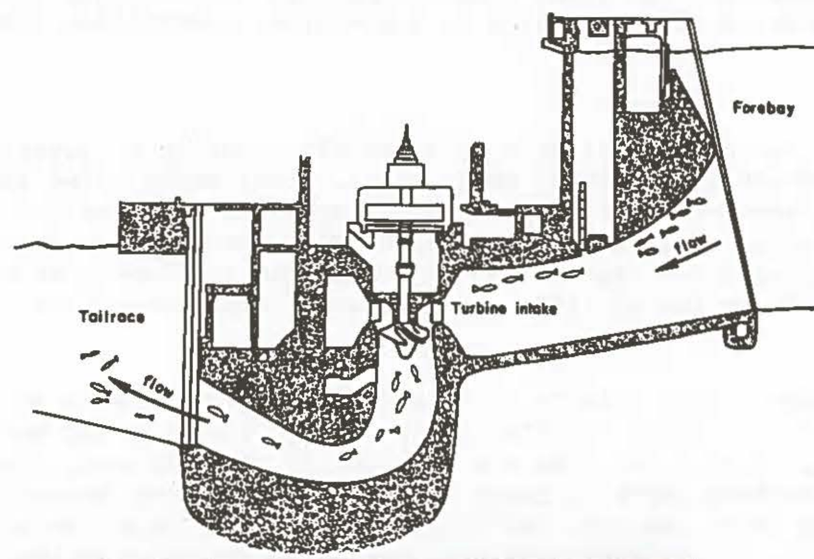
1/ Total return from smolt migration.
2/ Counts at The Dalles Dam (1966-75) and John Day Dam (1976-78).
3/ Survival from uppermost dam to The Dalles Dam (1966-75) and John Day Dam (1976-78), excluding transported fish at the dams.
4/ Uppermost dam: Ice Harbor, 1964-69.
Little Goose, 1970-74.
Lower Granite, 1975-78.
5/ Not sampled in 1971.
6/ Data expected at end of 1979.
7/ Data expected at end of 1980.
8/ Data expected at end of 1981.
9/ First estimate is the count at the tailrace, and the second estimate (in parenthesis) is the number transported. Example, total number of chinook smolts passing Lower Granite Dam is 2.2+(1.0) = 3.2 million.

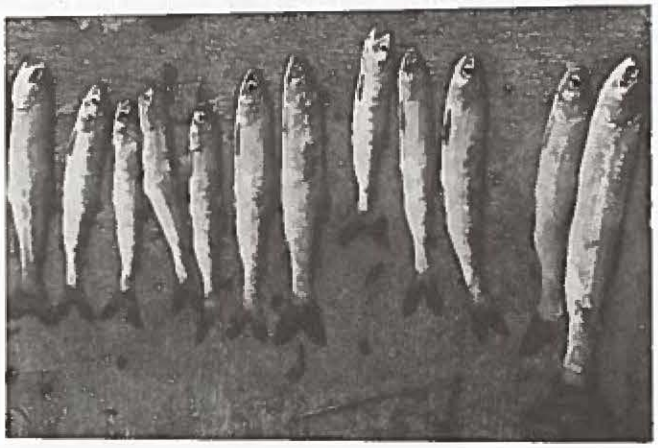
CAUSES OF THE DECLINE

TURBINES

Numerous experiments have been conducted to measure survival of salmonids passing through turbines (Exhibit 7). Bell et al. (1967) summarized these experiments and analyzed the effect of numerous variables such as wicket gate opening, water head, size of fish, etc., on fish survival through turbines. Tests pertinent to the Kaplan turbines of the Columbia River indicated a mean loss of 7%. However, these data frequently included only direct mortality. Indirect mortality, such as increased predation on temporarily debilitated fish slightly injured or stunned by passing through the turbines, can be substantial. More recent studies by Long et al. (1968, 1975) showed that mortality of juvenile coho salmon, O. kisutch, passing through turbines at Ice Harbor and Lower Monumental Dams was as high as 30% when indirect mortality from predation was included. Losses from predation will vary from dam to dam and year to year depending on the fluctuating populations of predators. However, when the predation loss at dams is combined with the direct loss in turbines, it becomes apparent that the turbine-related mortality occurring to a population of downstream migrants passing over a long series of dams can be significant. In the low-flow years of 1973 and 1977 when almost all of the young migrants had to pass through turbines, losses of 95% and 99% were recorded for both chinook salmon and steelhead populations from the uppermost dams in the Snake River to The Dalles Dam (1973) and John Day Dam (1977) (Sims et al. 1978).

Exhibit 7. Schematic diagram of fish passage through a turbine.





DEAD FISH COLLECTED FROM THE TAILRACE

SUPERSATURATION

Columbia River water supersaturated by nitrogen was recognized as a problem to anadromous fish in 1965 when levels as high as 125% of saturation were recorded. A comprehensive study (Ebel 1969) of dissolved gas levels done in 1966-1967 throughout the Columbia River from Grand Coulee Dam to the estuary at Astoria, Oregon, substantiated that high levels of dissolved gases occurred throughout the study area. The study also showed that water plunging over spillways is the main cause of supersaturation and that little equilibration of supersaturated gases occurs in the reservoirs associated with the dams.

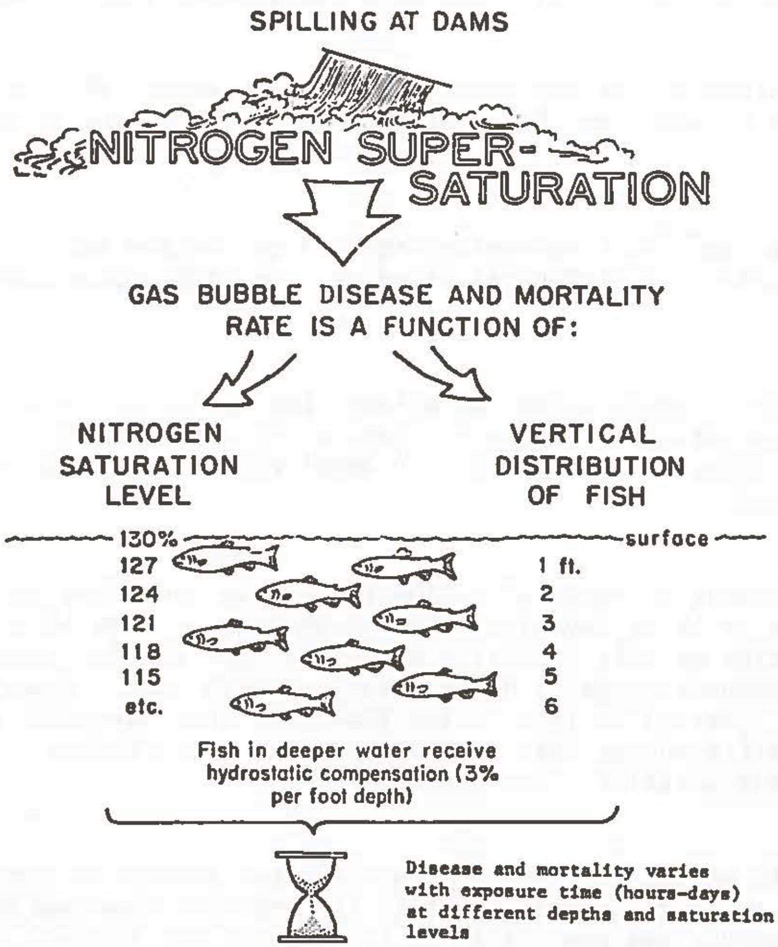
There is ample evidence, both in laboratory and field studies, that adult and juvenile salmon and steelhead are jeopardized by gas bubble disease in the Columbia River Basin (Ebel et al. 1975). The severity of the disease and its consequences depend on the level of supersaturation, duration of exposure to supersaturation, water temperature, general physical condition of fish, and the swimming depth maintained by the fish (Exhibit 8).

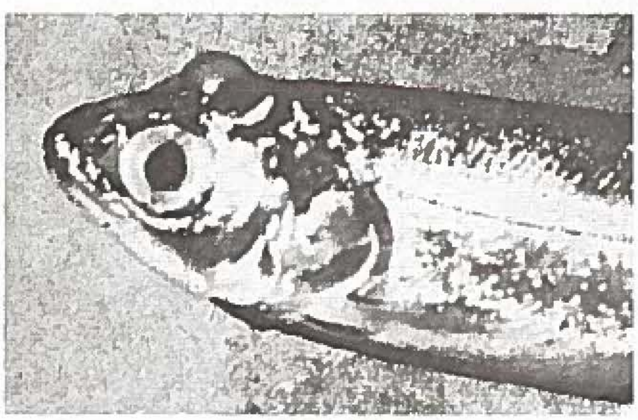
During spill, levels of dissolved gases measured at and between major dams (135 to 140%) were well above critical levels. Unfortunately, even with maximum utilization of turbine capacities, the dissolved gas levels during the average- and high-flow years continued high enough to cause problems for upstream and downstream migrants. Because all reaches of the Columbia and Snake Rivers through which adult and juvenile salmon and steelhead must migrate were significantly supersaturated, the total time of exposure was serious, and any undue delays that fish encountered resulted in substantial mortalities from gas bubble disease.

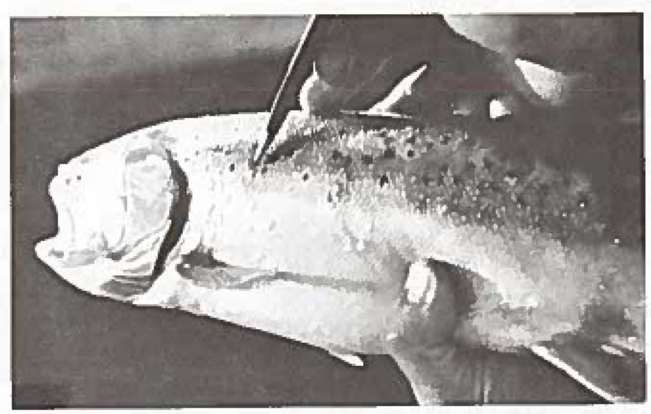
Information currently available on depth distribution of juveniles (Mains and Smith 1964; Smith et al. 1968; Monan et al. 1969; Smith 1974) all indicate that the largest percentage of downstream migrants are found in the top 5 feet of water. This means that the average hydrostatic compensation achieved is about 7.5% of saturation--insufficient to compensate for levels as high as 135 to 140% when levels as low as 115% can cause substantial mortality.

Even if migrants were able to gain relief by traveling deep in the river, adults are forced to utilize restricted depths when entering and negotiating fishways at dams. During the time the fish are in the fishways, they are restricted to a maximum depth of about 7 feet. Observations at various dams (Monan and Liscom 1973) indicate the fish are frequently near the surface in the fishways. Even though there was some reduction in the dissolved gas levels in the ladder, the restricted depth places an additional stress on fish previously equilibrated to high levels of gas supersaturation.

Exhibit 8. Gas supersaturation.







Gas bubbles beneath the skin of the head of a young chinook salmon and beneath the skin of an adult fish. When bubbles burst, infections may set in and kill the fish. Dissolved gases absorbed into the bloodstream form bubbles when the gases leave solution. These embolisms may block the circulatory system and cause death.

Several conclusions regarding the effect of supersaturation of atmospheric gas on fish in the Columbia River were made from the laboratory and field data presented by Ebel et al. (1975). The main conclusions reached were:

1. Supersaturation of atmospheric gas has exceeded 130% over long stretches of the Columbia and Snake Rivers during the spring of several years since 1968.

2. Juvenile and adult salmonids confined to shallow water (1 m) suffered substantial mortality at 115% total dissolved gas (TDG) saturation after 25 days of exposure.

3. Juvenile or adult salmonids allowed the option to sound and obtain hydrostatic compensation either in the laboratory or in the field still suffer substantial mortality after more than 20 days' exposure when saturation levels of TDG exceed 120%.

4. On the basis of survival estimates made in the Snake and Columbia Rivers from 1966 to 1978, juvenile fish losses ranging from 40 to 95% occurred and a major portion of this mortality was attributed to fish exposure to supersaturation of atmospheric gases during years of high flow. However, the greatest mortality (95%) occurred in 1973, a low-flow year when virtually no spilling occurred. Mortality during this year was due to other factors such as delay in migration, turbine mortality, and predation.

5. Juvenile salmonids subjected to sublethal periods of exposure to supersaturation can recover when returned to normally saturated water, but adults do not recover and generally die from direct and indirect effects of the exposure to supersaturation.

Spillway deflectors have now been installed on the dams resulting in reduction of gas saturation levels. We believe the losses caused by supersaturation are minimal at this time. Spillway deflectors are discussed in more detail later.

DELAYS IN MIGRATION

Salmon and steelhead are creatures of a free-flowing river ecology. This ecology is tied in with optimal conditions permitting juvenile fish to enter into the ocean and survive (to feed and grow) on the one end, and optimal conditions for adults to return to natal streams and spawn on the other end. The pristine ecology of the Columbia River and most of its major tributaries has been destroyed in less than half a century. Snake River salmon and steelhead, for example, are now confronted with a series of eight large impoundments during their downriver and upriver migrations. The effects of these impoundments on timing of migrating fish to optimal ocean and spawning ground conditions are not yet completely understood. Consequences may be much more serious than we realize.

Data from migration rate and timing studies (Raymond 1968a, 1968b, 1969) indicate that juvenile chinook salmon move about one-third as fast through impounded areas of the river as through free-flowing areas. During low-flow years, we estimate (Exhibit 9) that juvenile chinook salmon and steelhead migrating from the Salmon River will take 78 days to reach the estuary; arriving there about 40 days later than they did before the dams were constructed. The total effect of this drastic change in the timing of anadromous fish with a life cycle precisely tuned to specific environmental patterns is not yet completely known. One immediate effect in low-flow years is a tendency for some fish to residualize and spend several months in fresh water. Of even greater consequences are the effects of prolonged exposure to intensive predation, exposure to disease organisms, and exposure to stresses imposed by pollution. The impoundment of river flows by dams has more than doubled the time required for the hazardous migration of juvenile salmon and steelhead to the sea.

Adult migrants are delayed at dams during high-flow years. This results in increased exposure to high nitrogen supersaturation which has caused direct mortality to substantial numbers of fish (Beiningen and Ebel 1970). Delayed indirect mortality from increased disease incidence caused by prior exposure to high nitrogen supersaturation has also been measured (Ebel et al. 1975).

MIGRATING ADULT SALMON

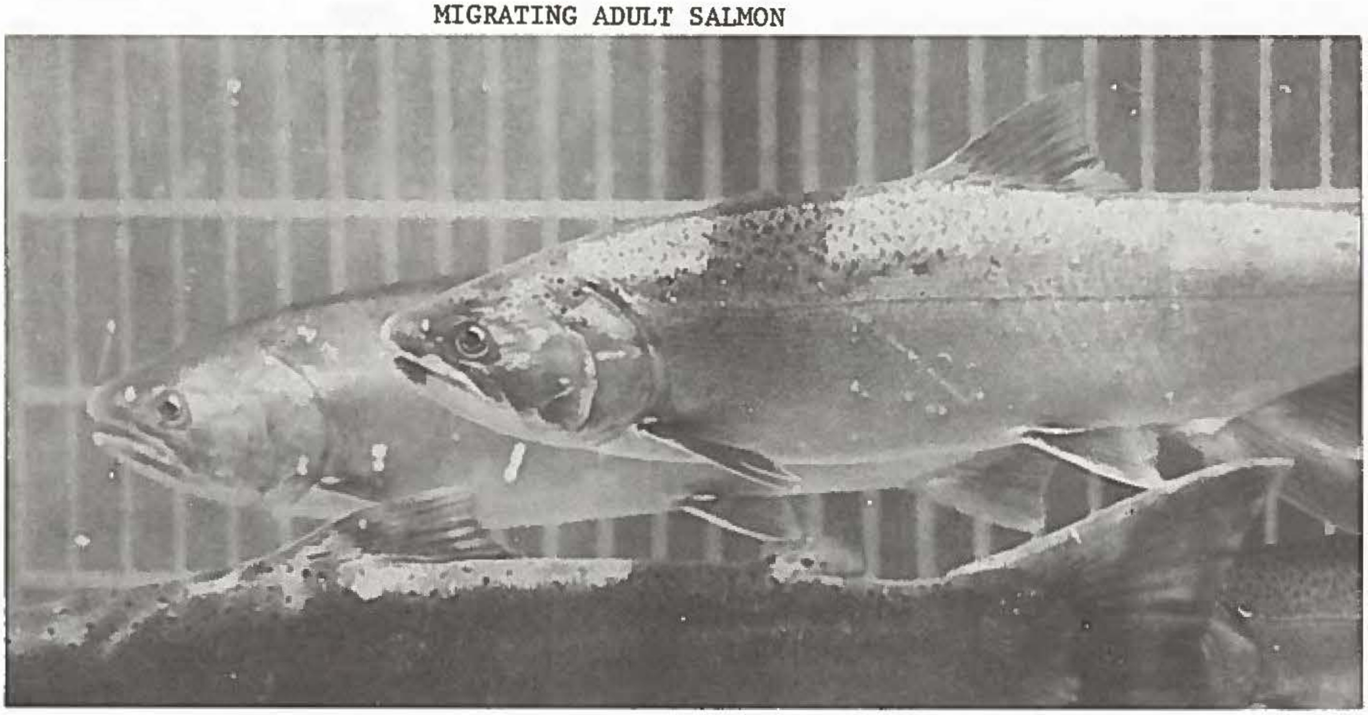


Exhibit 9. Travel time[1/] estimates in days for Snake River juvenile chinook salmon and steelhead from the Salmon River (Idaho) to the estuary.

Stretch of River	Flow[2/] Low	Moderate	High
Salmon River to Lewiston (115 miles)-free flowing	8	5	3
Lewiston to Lower Granite Dam (35 miles)-impounded	7	4	2
Lower Granite to Little Goose Dams (40 miles)-impounded	8	5	3
Little Goose to Ice Harbor Dams (63 miles)-impounded	13	8	4
Total Snake River	36	22	12
Ice Harbor to The Dalles Dams (143 miles)-impounded	29	18	10
The Dalles Dam to the estuary (192 miles)-like free flowing	13	8	6
Total Columbia 335 miles	42	26	16
Grand Total	78	48	28

[1/]Travel time based on following immigration rates:

	Low	Moderate	High
free flowing	15m/day	25m/day	34m/day
impounded	5m/day	8m/day	15m/day

[2/]low flow	Snake River 30,000 to 50,000 cfs	Col. River	150,000 to 180,000 cfs
med. flow	" " 80,000 to 100,000 cfs	" "	200,000 to 300,000 cfs
high flow	" " 120,000 to 180,000 cfs	" "	350,000 to 500,000 cfs

(Estimated from the data of Raymond 1968b, 1959; Bentley and Raymond 1975)

RECOMMENDED MEASURES FOR REDUCING LOSSES

COLLECT AND TRANSPORT

One pratical way to reduce losses of juveniles during their downstream migration is by a collection and transportation system whereby fish are collected at an upstream dam and transported to the estuary around many dams. This would eliminate losses of juveniles from predation turbines, nitrogen supersaturation, pollution, and delays at a large number of dams and reservoirs.

A summary of the recent collection and transportation experiments follows:

Since 1971, the National Marine Fisheries Service (NMFS) has been concentrating on an experiment where migrating juvenile salmon and steelhead are collected at Little Goose, Lower Granite, and McNary Dams and transported to two locations downstream from Bonneville Dam (Exhibit 10). Summaries on transport experiments to date (1971 to 1978) are presented in Appendix A (chinook salmon) and in Appendix B (steelhead). The experiments are designed to determine the effect of transportation on homing and survival. The data, obtained at Little Goose and Lower Granite Dams and summarized in Exhibit 11, indicate that survival of both chinook salmon and steelhead can be increased by collection and transportation. The percentage increase in survival varies from year to year depending on river conditions. During years when survival of natural migrants was very low, survival of control releases was also low and the percentage benefit from transport was greatest. For example, in 1973 survival estimates (see Exhibit 4) indicated an all time low survival rate for both juvenile chinook salmon and steelhead migrants; transport/control ratios obtained from adults returning were the highest (15.4:1 for chinook salmon and 13.5:1 for steelhead--Exhibit 11) recorded to date.

Exhibit 10. Transportation routes and release locations of experimental chinook salmon and steelhead collected and marked at Little Goose, Lower Granite, and McNary Dams.

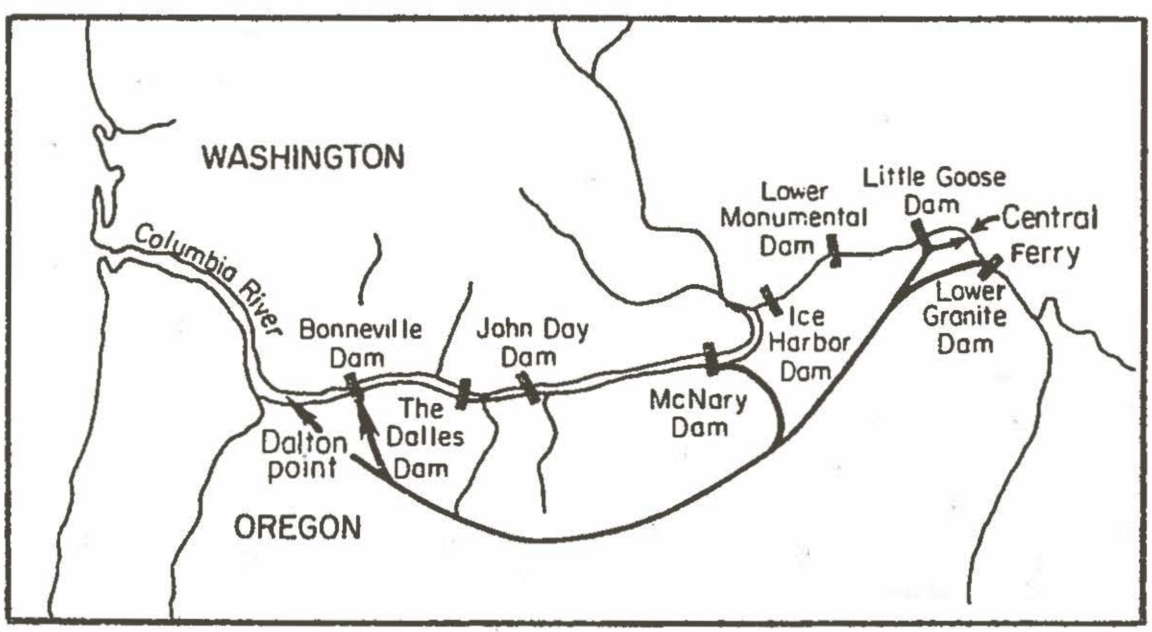
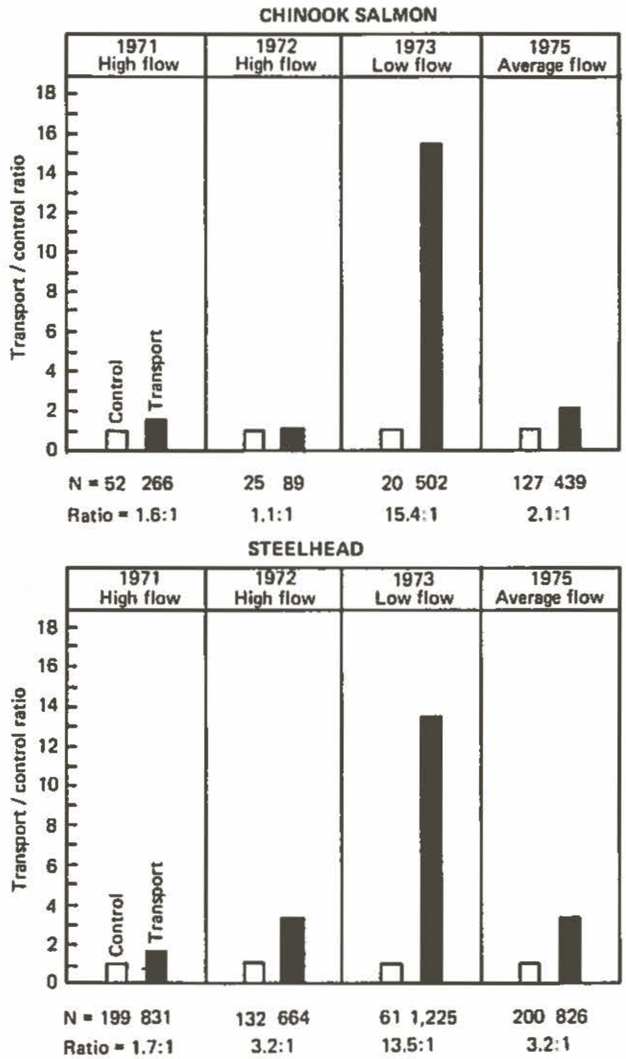


Exhibit 11. Comparison of adult returns from control and transport releases of juvenile chinook salmon and steelhead, 1971 to 73 and 1975.



Analysis of the test-to-control ratios provides the best insight to the benefits possible 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 now operates. If both test and control groups are excessively stressed during the diversion, collection, marking, and transport operation, then percentage return will be abnormally low even though test-to-control ratios are favorable. Therefore, we have been comparing percentage returns of the transport groups with percentage returns achieved at Dworshak and Rapid River Hatcheries and with estimated percentage return of steelhead and chinook salmon to Little Goose Dam (1971 to 1973) and Lower Granite Dam (1975) from naturally migrating populations that were not transported.

"Estimated" percentage of marked steelhead returning to Little Goose Dam from those transported from Little Goose Dam in 1971, 1972, and 1973 were 1.44, 1.80, and 2.70%, respectively. The adult return from fingerlings transported from Lower Granite Dam in 1975 was 2.4% (Exhibit 12). Corresponding percentage returns from release of steelhead at Dworshak Hatchery were 0.25, 0.20, 0.05, and 0.77% (Exhibit 12). Estimated percentage returns of adults from a mixture of wild and hatchery populations of juvenile steelhead passing Little Goose Dam in 1971, 1972, and 1973 were 0.80, 0.40, and 0.20%, respectively (Raymond 1974). Percentage return from juvenile steelhead passing Lower Granite Dam in 1975 was 1.2%.

Exhibit 12. Adult returns of Snake River chinook salmon and steelhead used in transport experiments, 1971 to 73 and 1975. (Source: Appendixes A and B)

(Steelhead)

Year	Riv. flow[1/]	Collection site	Experiment: Test group	Experiment: Transport method	Experiment: Release site[2/]	Juveniles released[3/]	Adults recaptured	Adult return in % of juveniles released: Observed	Adult return in % of juveniles released: Estimated[4/]	Transport/control ratio	Dworshak return (percent)
1971	High	L.Goose Dam	Control	--	L.Goose Dam	33,243	199	0.599	0.832	1.7:1	0.25
		"	Transpt	Truck	Bonneville[2/]	80,906	831	1.027	1.443		
1972	High	L.Goose Dam	Control	--	L.Goose Dam	32,488	132	0.406	0.564	3.2:1	0.20
		"	Transpt	Truck	Bonneville[2/]	50,157	664	1.324	1.804		
1973	Low	L.Goose Dam	Control	--	L.Goose Dam	42,461	61	0.144	0.201	13.5:1	0.05
		"	Transpt	Truck	Bonneville[2/]	63,452	1,225	1.930	2.703		
1975	Avg.	L.Granite Dam	Control	--	L.Granite Dam	46,823	200	0.427	0.773	3.2:1	0.77
		"	Transpt	Truck	Bonneville[2/]	60,475	826	1.366	2.472		

(Chinook Salmon)

Year	Riv Flw[1/]	Collection site	Experiment: Test group	Experiment: Transport method	Experiment: Release site[2/]	Juveniles released[3/]	Adults recapt'd	Adult return in % of juveniles released: Observed	Adult return in % of juveniles released: Estimated[5/]	Transport/control ratio	Rapid R. return (percent)
1971	High	L.Goose Dam	Control	--	L.Goose Dam	20,674	52	0.250	0.370	1.6:1	0.59
		"	Transpt	Truck	Bonneville	65,889	266	0.403	0.610		
1972	High	L.Goose Dam	Control	--	L.Goose Dam	32,836	25	0.076	0.106	1.1:1	0.12
		"	Transpt	Truck	Bonneville	106,405	89	0.084	0.116		
1973	Low	L.Goose Dam	Control	--	L.Goose Dam	88,170	20	0.023	0.026	15.4:1	0.15
		"	Transpt	Truck	Bonneville	141,364	502	0.355	0.401		
1975	Avg.	L.Granite Dam	Control	--	L.Granite Dam	42,915	127	0.296	0.813	2.1:1	0.33
		L.Granite Dam	Transpt	Truck	Bonneville	68,550	439	0.640	1.742		

Data source: 1971, 1972, and 1973 experiments (Ebel et al. 1974); 1975 (Park et al. 1976); 1976 (Park et al. 1977); 1977 (Park et al. 1978); 1978 (Park et al. 1979).

1/ Low = 35,000 to 60,000 cfs; Average = 70,000 to 100,000 cfs; High = 110,000 to 190,000 cfs.

2/ The two release groups of transported fish (Dalton Point and below Bonneville releases are combined for purpose of evaluation.

3/ Adjusted for initial tag loss except for 1978 releases.

4/ Based on comparison of known recovery of fish with magnetized wire tags at Little Goose and Lower Granite Dams and the subsequent recovery of these and other marked fish at Dworshak National Hatchery upstream from Little Goose. Returning fish identified at the dams were marked with jaw tags and released to continue their migration upstream. Numbers of externally-tagged fish arriving at Dworshak Hatchery were compared with the recovery of other wire tagged fish arriving at Dworshak Hatchery not previously detected and identified at Little Goose and Lower Granite Dams.

5/ Based on comparison of known recovery of fish with magnetized wire tags at Little Goose and Lower Granite Dams and the subsequent recovery of these and other marked fish at Rapid River Hatchery upstream from Little Goose Dam. Returning fish identified at the dams were marked with jaw tags and released to continue their migration upstream. Numbers of externally-tagged fish arriving at Rapid River Hatchery were compared with the recovery of other wire tagged fish arriving at Rapid River Hatchery not previously detected and identified at Little Goose and Lower Granite Dams.

Substantial increase in survival of steelhead as a result of transportation is indicated by either test/control type analysis or percentage return comparisons. These comparisons are based only on marked steelhead transported from Little Goose and Lower Granite Dams. In 1975, over 460,000 unmarked fish were also transported. Return of unmarked steelhead from those transported ranged from 4.0 to 7.0%. When this percentage return range is compared in the same manner with those above, a much greater increase in survival for those transported is indicated.

"Estimated" percentage returns of marked chinook salmon from those transported from Little Goose Dam in 1971, 1972, and 1973 were 0.61, 0.12, and 0.40%, respectively. The return of marked chinook salmon of those transported from Lower Granite Dam in 1975 was 1.74% (Exhibit 12). Corresponding percentage adult returns from the releases of chinook salmon at Rapid River Hatchery were 0.59, 0.12, 0.15, and 0.33% (Exhibit 12). Estimated percentage returns of adults from a 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 (Raymond 1974). Percentage return from juvenile chinook salmon passing Lower Granite Dam in 1975 was 1.9%.

For chinook salmon, a definite benefit is shown by test/control type analysis, and some benefit can be shown when percentage return data from transported groups are compared with only the Rapid River Hatchery returns for 1971, 1973, and 1975. However, a benefit is shown only in 1973 when marked transported returns are compared with estimated percentage returns to Little Goose and Lower Granite Dams from naturally migrating populations that were not transported.

It should be emphasized that these comparisons are based only on marked chinook salmon transported from Little Goose and Lower Granite Dams (over 345,000 were transported in 1975). Although the data available regarding percentage return of these fish are sparse, we believe it ranged between 2.0 and 4.0%. When this percentage return range is compared in the same manner with those above, an increase in survival of those transported in 1975 is indicated.

In summary, we believe sufficient data exist to recommend continued mass transport of steelhead and chinook salmon from Little Goose and Lower Granite Dams with continued evaluation.

Mass transportation of juvenile fish was not fully implemented until 1977. The expected low-river flow condition in 1977 prompted emergency actions by the CofE and the fishery agencies in the form of mass transportation of both Snake River and Columbia River fish by truck and barge (Exhibit 13).

In 1977, totals of 4.3 million juvenile chinook salmon and 1.1 million juvenile steelhead were collected and transported by truck, barge, and air (experimental) from Little Goose and Lower Granite Dams and from hatcheries in the Snake and Columbia Rivers. In 1978, 1.6 million juvenile chinook salmon and 1.4 million steelhead were collected at the dams and transported. The majority of the adult returns from juveniles transported in 1977 will return in 1979; for the 1978 transport, the returns will be in 1980.

Exhibit 13. Total numbers of juvenile fish collected and transported past dams, 1971 to 78 (includes experimental fish marked for transport evaluation).

Year	Smolts at upper dam (1,000)	Number transported (1,000)	Percent transported	Truck (1,000)	Barge (1,000)	Air (1,000)	Snake R. Barge (1,000)	Col. R. Barge (1,000)	Transport grand total (1,000)
	Little Goose and Lower Granite Dams collection sites, Snake R.			Method			Collected at hatcheries		
				Chinook Salmon					
1971	4,000	109	3	109	0	0	0	0	109
72	5,000	360	7	360	0	0	0	0	360
73	5,000	247	5	247	0	0	0	0	247
74	3,500	0	0	0	0	0	0	0	0
75	4,000	414	10	414	0	0	0	0	414
76	5,000	751	15	675	0	76	0	0	751
77	2,000	1,365	68	1,074	215	76	361	2,536	4,262
78	3,180	1,623	51	972	651	0	0	0	1,623
				Steelhead					
1971	5,500	154	3	154	0	0	0	0	154
72	2,500	227	9	227	0	0	0	0	227
73	5,500	176	3	176	0	0	0	0	176
74	5,000	0	0	0	0	0	0	0	0
75	3,200	549	17	549	0	0	0	0	549
76	3,200	434	14	434	0	0	0	0	434
77	1,400	895	64	731	164	0	173	48	1,116
78	2,120	1,355	64	528	827	0	0	0	1,355

Data source: Park et al. 1976, 1977, 1978, 1979.

The mass transportation of juvenile fish in 1977 was undertaken as an emergency measure because of the expected low-river flow condition. As it turned out, 1977 was an extreme drought year and represented the lowest river flow ever recorded. Unfortunately, these extreme hydrologic conditions in turn affected the condition of migrating juvenile fish. In general, the juvenile fish collected and transported were found to be in very poor physical condition. Furthermore, it was estimated that over one-half of the migrating populations available from upstream production areas never reached Lower Granite and Little Goose Dams. We, therefore, do not expect a high percentage return from fish mass transported in 1977, and program analysis should be conducted with this provision in mind. Final evaluation of mass transportation should not be attempted until returns from juveniles released in 1978 are complete.

Juvenile loss data and adult return data (Exhibit 6) indicate that decisions regarding mass transportation of juvenile chinook salmon and steelhead in future years may be critical in determining the ultimate survival of the Snake River populations. Careful examination of the predicted river flows and the results of ongoing transportation studies will provide the necessary data to determine the degree to which mass transport should be implemented during a given year. Complete return data will not be available until 1980 and 1981 from groups (experimental and mass transport) transported from Lower Granite Dam in 1977 and 1978. However, as indicated earlier, sufficient data regarding effects of collection and transportation of chinook salmon and steelhead from Little Goose and Lower Granite Dams are available now and decisions can be made now.

OPERATION FISH RUN

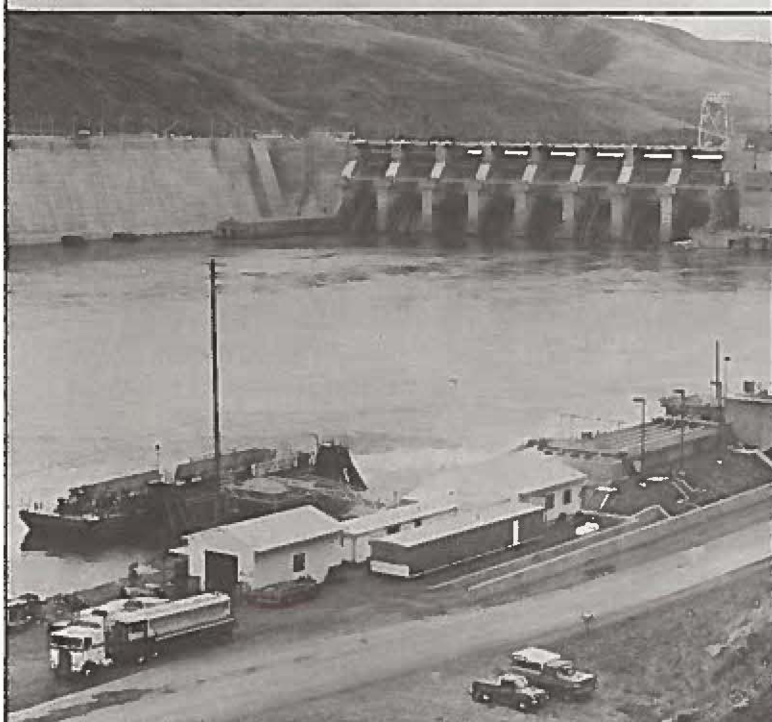
Mass fish transport activities on the Snake and Columbia Rivers

(Left) Fish loaded from hatchery raceway via fish pump to transport truck for long distance haul.

(Center left) At dams juvenile fish can be loaded into trucks or barges for transport to release sites below Bonneville Dam.

(Center right) Barge with fish in raceway-like holding compartments in navigation lock at Bonneville Dam.

(Bottom) Barge and accompanying tug underway near release site on Columbia River downstream from Bonneville Dam.



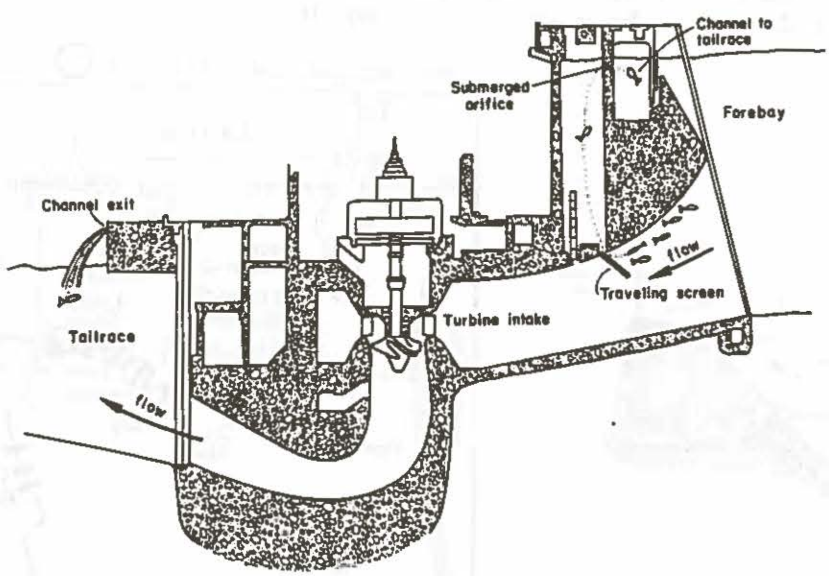
SCREEN AND BYPASS

Collection and transportation can provide one practical solution to turbine mortality. Another solution would be to install traveling screens in every turbine intake and bypass the fish around the turbines (Exhibit 14). However, the cost would be very high; and at some dams, such as John Day, where the juvenile fish bypass system functions poorly, the losses might by greater from screening and bypassing than from passing them through the turbines. In addition, the problems of migration delay and predation at many dams would still exist.

Additional studies are needed to determine how screening and bypass systems can be made more effective at dams like John Day. The intake traveling screen system currently in use at Little Goose Dam, for example, is adequate for collection and bypass of steelhead but could be improved for collection and bypass of chinook salmon. Improvement of this system is now underway, but it will not be operational until the spring of 1980. We anticipated the collection and bypass system at Lower Granite Dam would be an improvement over that operating at Little Goose Dam and current data on the condition of fish collected at Lower Granite Dam indicate that the system at Lower Granite is in fact a substantial improvement.

Of great concern at all existing dams is the potential for predation where young fish are concentrated at a bypass exit. Bypass systems must be carefully evaluated on a dam by dam basis before the use of screens is recommended. Bonneville Dam, which will soon have a second powerhouse, should receive a high priority for consideration of a screening and bypass system. Several million juvenile salmonid migrants will have to pass through the turbines of this dam in the near future. However, even at the new Bonneville installation, the bypass system should be evaluated to determine whether further improvements can be made.

Exhibit 14. Schematic diagram of the system used to bypass juvenile migrants around turbines.



Young fish entering a turbine intake concentrate near the ceiling. Approximately 75% of the fish are diverted by traveling screens into the gatewell, then the fish pass through submerged orifices into a channel connected to the tailrace. With this system fish may be bypassed around the turbines of a single dam or the fish may be collected and transported around many dams.

REDUCE SUPERSATURATION

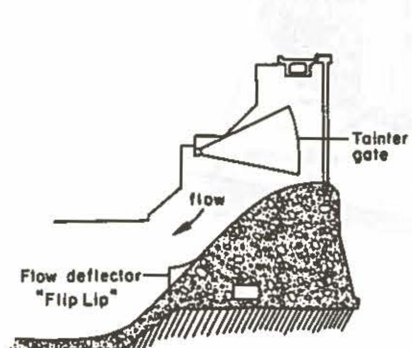
Spillway deflectors [concrete sills placed near the base of the spillway (Exhibit 15) to direct flow horizontally into the stilling basin] are the most promising way to reduce gas supersaturation at this time. The lateral deflection of the water prevents deep plunging action where air entrainment, the primary source of supersaturation, takes place. Studies by Ebel et al. (1973); Long and Ossiander (1974); Johnsen and Dawley (1974); and Monan and Liscom (1974, 1975) show that supersaturation of the water with air (primarily nitrogen) is substantially reduced, and no injury or adverse effect on either adults or juveniles can be measured.

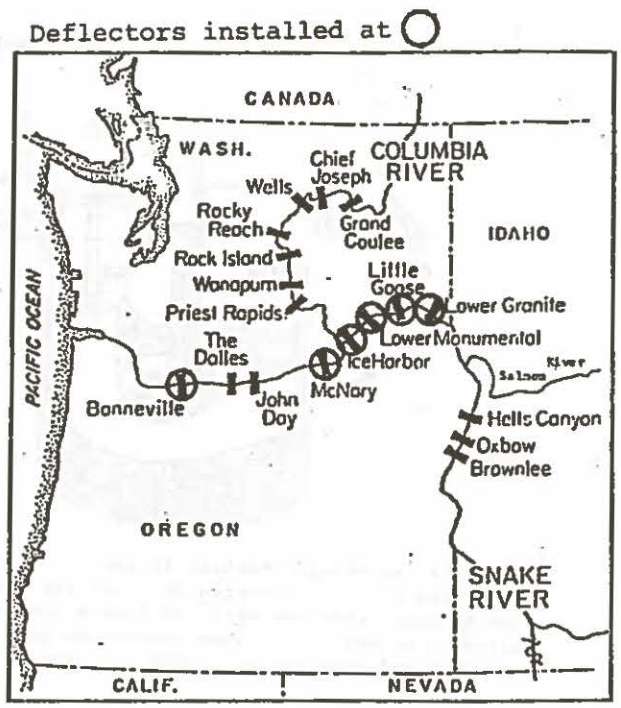
Spillway deflectors have been installed by the CofE at Lower Monumental, Lower Granite, Little Goose, Ice Harbor, McNary, and Bonneville Dams. Turbine capacity has also been increased at the Snake River dams and at John Day Dam. The installation of spillway deflectors coupled with increased turbine capacity (i.e., more of the water is diverted to the turbine intakes) has substantially reduced atmospheric gas supersaturation in the Snake and lower Columbia Rivers.

Additional turbines are also nearing completion at Rock Island, Grand Coulee, and Chief Joseph Dams on the middle Columbia River. The increased turbine capacity at these dams coupled with the increased control of flow as a result of recently completed Canadian storage dams should also result in lower gas supersaturation in the middle Columbia River.

In our opinion, the problem of gas supersaturation in high-flow years will be for all practical purposes under control in the Snake and lower Columbia Rivers and will be substantially reduced in the middle Columbia River.

Exhibit 15. Schematic diagram of spillway deflector and map showing locations of dams that have these spillway deflectors.





MINIMIZE DELAY IN MIGRATION

There are two possible ways to reduce delay of migrating juveniles: 1) flow control (utilization of upstream storage) and 2) collection and transportation.

A committee was established recently to recommend minimum flows in the Snake and Columbia Rivers, and it was suggested that spillways at a series of dams may be operated sequentially or simultaneously during the juvenile migration to provide more favorable conditions to speed downstream migration during low- and high-flow years. Power producers indicate this may be possible if energy demands can be met. The concept is currently being tested, but detailed data on benefits (for power and fish) that can be achieved are not complete at this time.

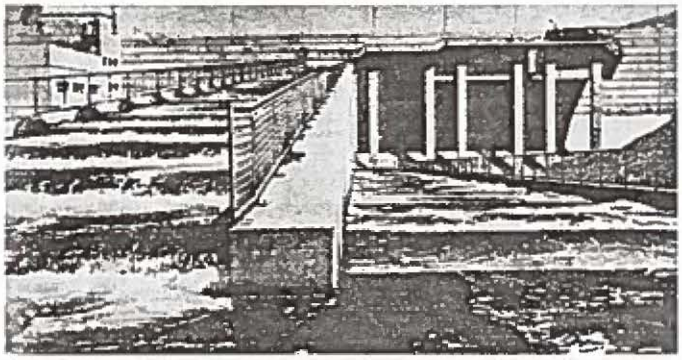
Information obtained from migration rates, timing, and survival studies indicates that delays in migration of juveniles during high-flow years will not be as serious a problem now that nitrogen supersaturation is reduced by the spillway deflectors.

Collection and transportation systems provide, in our opinion, the best opportunity for overcoming the hazards of delayed migration. Transported fish would arrive at the estuary 16 days early (rather than 40 days late) having avoided a prolonged exposure to predation, pollution, and disease in many impoundments as well as avoiding the effects of turbines at many dams.

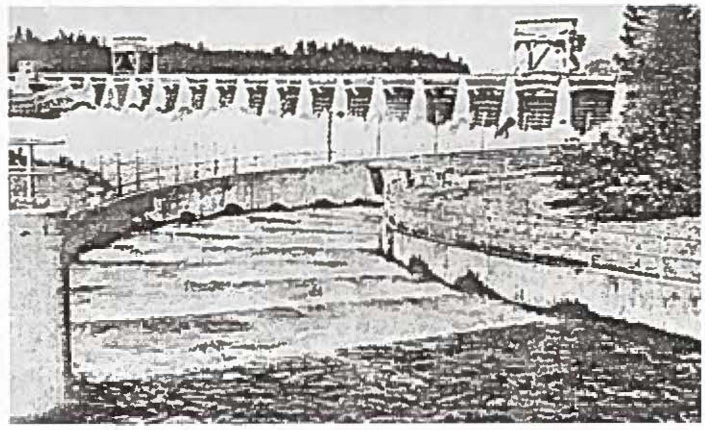
Effects of delay on adults during low-flow periods are not critical; in fact, adults progress rapidly upstream in low-flow years. Recent information indicates that optimum spill patterns and attraction flows can be arranged to improve upstream passage even during moderately low flows (Junge and Carnegie 1974). Studies in progress by CofE and NMFS biologists indicate that improvements in adult fishway collection systems can also reduce delays.

Delays to adult migrants during high-flow periods can be serious (Junge and Carnegie 1976). However, these delays can be reduced by perfecting operation of spillways and turbines at the dams to provide the best possible attraction flows for entrance of adults to the fishways.

ADULT FISH PASSAGE FACILITIES



ICE HARBOR DAM FISH LADDER



BONNEVILLE DAM FISH LADDER

PREDICTED BENEFITS OF REMEDIAL ACTION

Steps have been taken on two major actions to minimize the losses caused by dams: 1) reduction of supersaturation by installation of spillway deflectors at Bonneville, McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams; and 2) initiation of a full-scale test of the collection of juvenile chinook salmon and steelhead migrants from the two uppermost dams (Lower Granite and Little Goose) and transportation to below Bonneville Dam.

In Exhibit 16, we have attempted to predict the benefits that can be realized from these actions. The method of calculating levels of benefit is outlined in Exhibit 17. Benefits resulting from installation of spillway deflectors are derived from data in Ebel et al. (1975). Benefits from transport of fish are derived from the data on the 1971, 1972, 1973, and 1975 transport experiments reported earlier in Exhibit 12. Complete data on the 1976, 1977, and 1978 transport experiments will not be available until 1981.

All predictions require assumptions about future events. The major assumptions upon which predictions are based are listed in Exhibit 18.

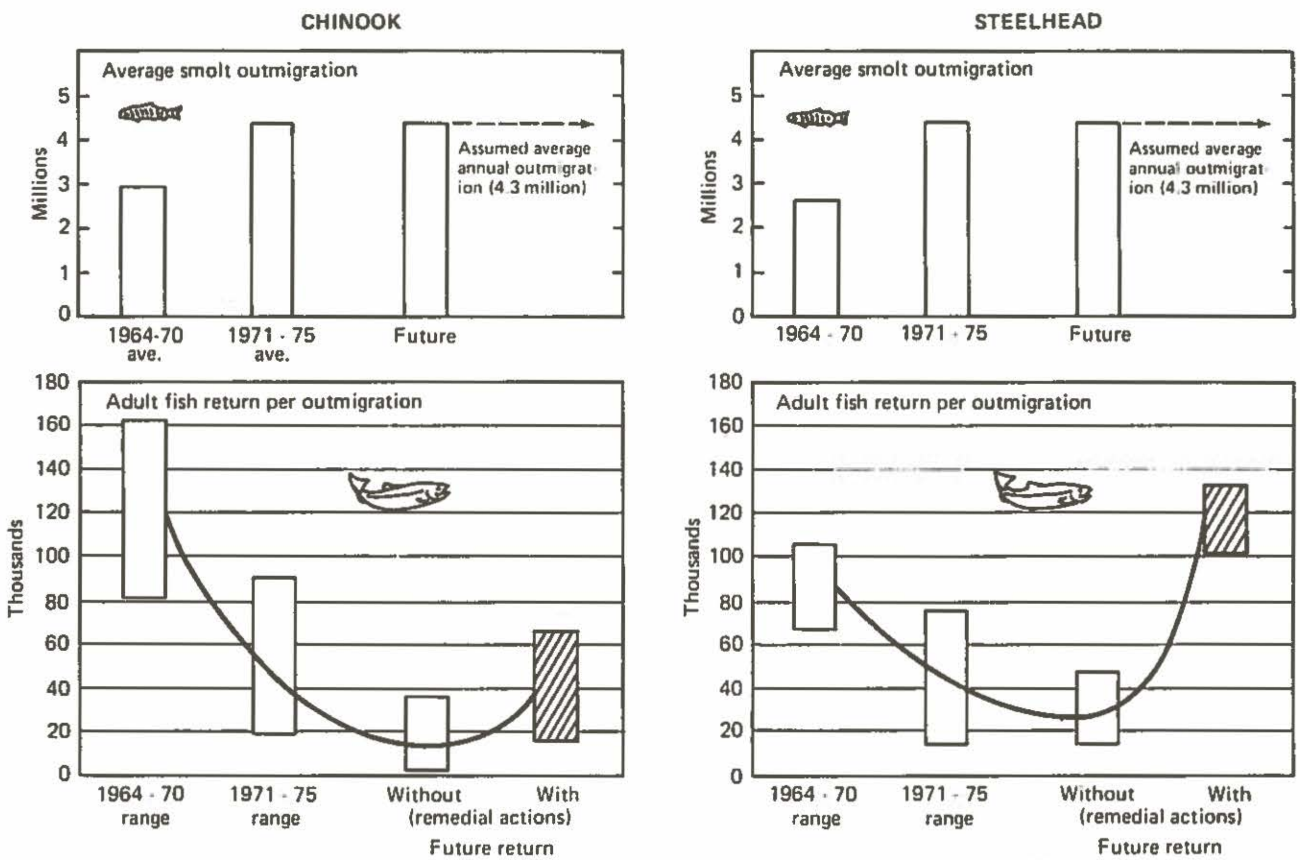
Prior to 1975 (Exhibit 16), the average annual outmigration of chinook salmon was 2.9 million smolts from 1964 to 1970 and 4.3 million smolts from 1971 to 1975; for steelhead it was 2.6 million smolts from 1964 to 1970 and 4.3 million smolts from 1971 to 1975. The corresponding adult fish returns from these annual outmigrations were as follows:

1. Chinook salmon, 1964 to 1970, 80 to 162 thousand fish.
2. Chinook salmon, 1971 to 1975, 18 to 89 thousand fish.
3. Steelhead, 1964 to 1970, 66 to 103 thousand fish.
4. Steelhead, 1971 to 1975, 12 to 74 thousand fish.

Assuming an average annual smolt outmigration of 4.3 million fish, the predicted consequences, depending upon river flow condition at time of outmitragion, are (Exhibit 16):

1. Without any remedial actions--return of adult chinook salmon in the probable range of 1,000 to 35,000 fish per outmigration.
2. With remedial actions--return of adult chinook salmon in the probable range of 14,000 to 63,000 fish per outmigration.
3. Without any remedial actions--return of adult steelhead in the probable range of 12,000 to 46,000 fish per outmigration.
4. With remedial actions--return of adult steelhead in the probable range of 100,000 to 131,000 fish per outmigration.

Exhibit 16. Graphs of predicted benefits of remedial actions under assumed annual outmigration of 4.3 million smolts.[1/]



1/ Average smolt outmigration and adult fish returns for 1964 to 70 and 1971 to 75 were estimated from data in Exhibit 6.

Increased hatchery production has been recommended to compensate for large losses in natural spawning grounds of salmon and steelhead. If realized, this increased production, together with the remedial actions, will help to restore and perhaps even increase the production of Snake River salmon and steelhead to levels far above that once believed feasible.

Exhibit 17. Derivation of predicted benefits from remedial actions.

Percent adult fish return estimates

Item/Event	Chinook salmon River flow Low (%)	Ave. (%)	High (%)	Steelhead River flow Low (%)	Ave. (%)	High (%)
Without remedial action						
Percent adult fish return 1/	0.026	0.813	0.238	0.201	0.773	0.698
Adjusted for contribution to lower river fisheries 2/	0.026	0.813	0.359	0.277	1.066	0.963
With remedial action						
A. Collect and transport:						
Percent adult fish return 3/	0.401	1.742	0.363	2.703	2.472	1.624
Adjusted for contribution to lower river fisheries 2/	0.401	1.742	0.548	3.730	3.411	2.241
Collection and transport capability 4/	80	70	40	80	70	40
B. Spillway deflectors:						
Percent net increase in adult fish return 5/	0	0	1.40	0	0	1.40

Number of returning adult fish per 4.3 million smolt outmigrants

Item/Event	Chinook salmon River flow Low (No.)	Ave. (No.)	High (No.)	Steelhead River flow Low (No.)	Ave. (No.)	High (No.)
Without remedial action						
Total return 6/	1,118	34,959	15,437	11,911	45,838	41,409
With remedial action						
Transport benefit 7/	13,794	52,434	9,426	128,312	102,671	38,545
Spillway deflector benefit 8/	0	0	36,120	0	0	36,120
Other returns 9/	224	10,488	9,262	2,382	13,751	24,845
Total return	14,018	62,922	54,808	130,694	116,422	99,510

1/ The "estimated" percentage adult fish return from control groups related to river flow at time of outmigration. Source: Exhibit 12 of this report. The estimates under "High" river flow are averages of the 1971 and 1972 percentages.

2/ Adjusted to account for the catch of adult chinook salmon and steelhead by the lower river commercial and sport fisheries that were not included in the return counts of the transport experiments. Adjustment factors are the catch to escapement ratios (chinook salmon = 0.51; steelhead = 0.38) estimated from data in Ore. Dept. Fish. Wild. - Wash. Dept. Fish. (1976) and Snake River contribution factors reported in Tables 1 and 2, Raymond (1974). Chinook salmon: 1) no adjustments to the 1973 (low flow) and 1975 (average flow) percentage returns since the fisheries on the adult returns from these outmigrants were closed starting in 1975; and 2) a factor of 1.51 for the 1971-72 (high flow) percentage (e.g., (1.51)(0.00238)=.0.00359). Steelhead percentage returns were adjusted by the factor 1.38.

3/ The "estimated" percentage adult fish return from transport groups. Source: Exhibit 12 of this report.

4/ Reflects the different capabilities in collecting and transporting smolt outmigrants under those river flow conditions.

5/ Derived from Table 19 of Ebel et al. (1975).

6/ Example calculation: (4.3 million smolts)(0.00026)=1,118 adults.

7/ Example calculation: (4.3 million smolts)(0.80)(0.00401)=13,794 adults.

8/ Based on nontransported fish. Example calculation: (4.3 million smolts)(1.0-.40)(0.014)=36,120 adults.

9/ Return from nontransported fish. Example calculation: (4.3 million smolts)(1.0-.80)(0.00026)=224 adults.

Exhibit 18.--Assumptions on which "Predicted Benefits" are based.

1. Production of steelhead and chinook salmon smolts will remain equal to the level of 4 million smolts annually.

2. Construction of structures affecting supersaturation, such as spillway deflectors and additional turbines, are complete on dams operated by the CofE.

3. Turbine intake traveling screens for the collection of downstream migrants to be installed with the new turbines at Little Goose and Lower Granite Dams.

4. Collection and handling procedures for chinook salmon fingerlings will be successfully developed and evaluated by the end of the 1983 migration season. At this stage of our research, this appears to be a safe assumption.

5. Attritional losses due to water diversion and pollution will be kept at the present level. This requires screening of water intakes and control of thermal pollution, industrial pollution, and agricultural pollution by enforcement of water quality standards.

HAZARDS OF INACTION

The predicted benefits from taking two specific remedial actions indicate that Snake River chinook salmon and steelhead runs can begin to be restored and the wild fluctuations in abundance leveled out (Exhibit 16). The hazards to taking no remedial action require additional consideration. Of major concern is the impact of the national energy crisis on the existing depressed runs of fish. Power developments once visualized as needed by the year 2000 are urgently demanded today. Many additional turbines have been installed to provide the "peaking" capacity needed to meet short periods of maximum power demand. This is a necessary complement to the base power to be provided by expanded thermal power production. However, with the additional turbines come additional hazards to migrant fish.

The gravity of the situation for Snake River chinook salmon and steelhead can be appreciated by noting the rapid decline in the runs in recent years and realizing that this happened largely because of the addition, since 1970, of Lower Granite, Lower Monumental, and Little Goose Dams to the existing Ice Harbor Dam in the Snake River. There are now four dams with a total of 24 turbine units affecting fish passage in the Snake River alone--the number of turbines increased from the 3 units at Ice Harbor Dam in 1969 to the 24 units at the four dams by 1979 (Exhibit 19).

Juvenile migrants passing the dams and turbines in the Snake River are also confronted with four additional dams in the lower Columbia River. Here too, the number of turbine units has increased since 1968--from the 44 units in 1968 to 62 units by 1979, with 14 additional units authorized for construction thereafter (Exhibit 19).

Exhibit 19. Number of turbine units at hydroelectric dams on the Snake and lower Columbia Rivers, 1968 to 79 and authorized for the future.1/

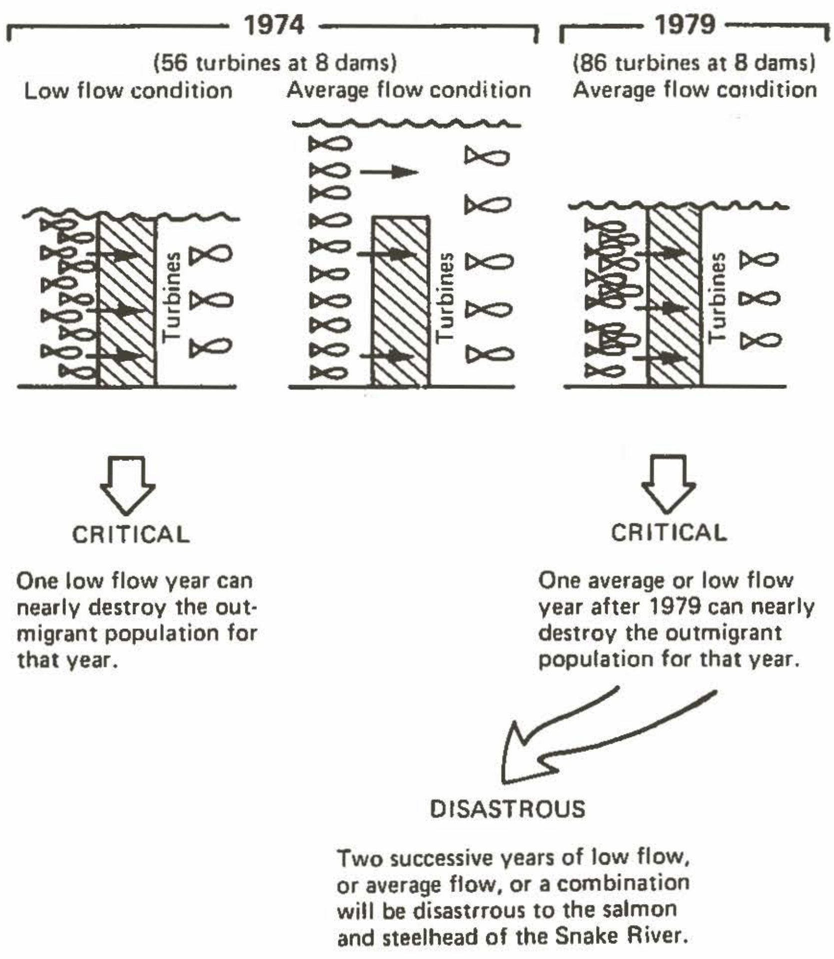
River/dam	Cumulative number of turbine units in place													
	1968	69	70	71	72	73	74	75	76	77	78	79	Authorized	Total
Snake River														
Lower Granite	0	0	0	0	0	0	0	3	3	3	6	6	0	6
Little Goose	0	0	0	3	3	3	3	3	3	3	6	6	0	6
Lower Monumental	0	0	3	3	3	3	3	3	3	3	3	6	0	6
Ice Harbor	3	3	3	3	3	3	3	6	6	6	6	6	0	6
Total	3	3	6	9	9	9	9	15	15	15	21	24	0	24
Lower Columbia River														
McNary	14	14	14	14	14	14	14	14	14	14	14	14	0	14
John Day	4	10	14	16	16	16	16	16	16	16	16	16	0	20
The Dalles	16	16	16	16	16	22	22	22	22	22	22	22	2	24
Bonneville	10	10	10	10	10	10	10	10	10	10	10	10	8	18
Total	44	50	54	56	56	62	62	62	62	62	62	62	14	76
Grand Total	47	53	60	65	65	71	71	77	77	77	83	86	14	100

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

It is obvious that turbine-related mortalities will occur with greater frequency as a greater percentage of the juveniles are exposed to turbines. This will occur because more of the water will be diverted to the turbine intakes and less water spilled over the spillways. The diagrams in Exhibit 20 illustrate the situation for Snake River salmon and steelhead in 1974 in contrast to their situation in 1979 and thereafter. From 1979 on, almost all of the juvenile migrants will be passing through turbines even during average river flow conditions. Critical turbine-related losses that in the past occurred only during low-flow years will also be expected during average-flow years. With the Snake River salmon and steelhead populations fluctuating at low levels in recent years, two or more successive years of low- and/or average-flow years could be disastrous to the resources and to the people that benefit from their utilization.

In the opinion of the authors, the salmon and steelhead runs of the Snake River will be unable to survive long after 1979 unless corrective action already initiated continues to be carried out without delay.

Exhibit 20. Schematic diagram of reduced juvenile fish survival to be caused by additional turbines if no action is taken--Lower Granite Dam through John Day Dam.



As a conclusion, some hypothetical examples on the effects on adult fish return from low downstream survival of steelhead migrants are presented to provide a general idea on the "Crisis". The examples are hypothetical, and the procedure used in deriving the estimates is highly simplified.

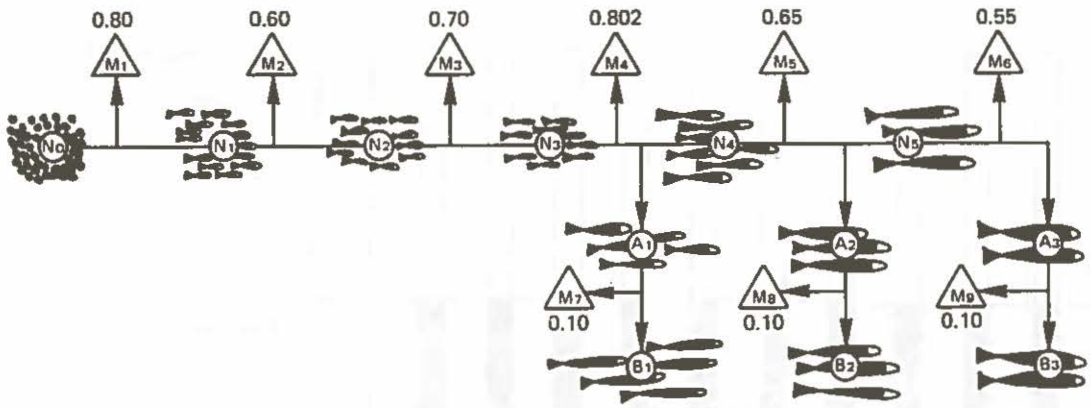
A simplified diagram on Snake River steelhead production cycle with hypothetical mortality estimates is presented in Exhibit 21. The juvenile fish outmigration (N_1) results in 3 successive years of returning adults symbolized as A_1 (1-ocean age fish), A_2 (2-ocean age fish) and A_3 (3-ocean age fish). The escapement (spawning fish) from A_1 combines with the A_2 escapement of the previous outmigration year and the A_3 escapement of two outmigration years before to produce N_0 (fertilized eggs) for that year.

The effects (on adult fish returns and egg production) of increased mortality to downstream migrants (from M_2 = 0.60, or 60% mortality, to M_2 = 0.95, or 95% mortality) are shown in Exhibit 22. Panel A of Exhibit 22 shows the effects of increased downstream mortality during 1 year (1979) on subsequent adult fish returns in 1980, 1981, and 1982. Panel B shows the effects of 2 consecutive years of high downstream mortality. Panel C shows the effects of 3 consecutive years of high downstream mortality. Panel D shows the effects of 3 years (occurring every other year) of high downstream mortality. Although hypothetical and extremely simplified, the effects from increased mortality in downstream migrants are felt anywhere from 3 to 7 years and in varying degrees. Assuming a minimum escapement of 6,000 fish, the social benefits (catch) are drastically reduced to one-half to zero of the catch experienced under equilibrium conditions. Even minimum escapement is affected as shown in Panels B and C.

Exhibit 23 shows the derivation of the estimates in Exhibit 22. Shown are the effects of high downstream mortality on total adult fish returns by year of return (totals on bottom of the tables) and by year of outmigration (totals in the last column of each table), and the effects of reduced escapement on return of adults in subsequent years [for example, the effects of the reduced number of eggs (10.4 million) in 1981, Panel B on adult fish returns during 1983, 1984, and 1985]. Although hypothetical, these examples nevertheless provide an idea as to the potential consequences of increased mortality during only one stage (downstream migration) in the life history of steelhead.

The "Crisis" is evident and upon our society today. Corrective actions must be undertaken and continued; otherwise the Snake River salmon and steelhead resources will no longer be of benefit to our society.

Exhibit 21. Snake River steelhead production cycle (with hypothetical mortality estimates).



Legend

N_o = Number of fertilized eggs
N_1 = Number surviving to smolt stage (as outmigrants)
N_2 = Number of smolts surviving to The Dalles Dam
N_3 = Number surviving to coastal area
N_4 = Number surviving after 1 year in ocean
N_5 = Number surviving after 2 years in ocean

A_1 = Number of 1-ocean age mature adults returning to the river
A_2 = Number of 2-ocean age mature adults returning to the river
A_3 = Number of 3-ocean age mature adults returning to the river

B_1 = Number of 1-ocean age adults available for catch and escapement
B_2 = Number of 2-ocean age adults available for catch and escapement
B_3 = Number of 3-ocean age adults available for catch and escapement

M_1 = Mortality during egg to smolt stage
M_2 = Mortality during downriver migration (between production area and The Dalles Dam)
M_3 = Mortality between The Dalles Dam and coastal area
M_4 = Mortality during 1st year in ocean
M_5 = Mortality during 2nd year in ocean
M_6 = Mortality during 3rd year in ocean
M_7 = Mortality during upriver migration (1-ocean age adults)
M_8 = Mortality during upriver migration (2-ocean age adults)
M_9 = Mortality during upriver migration (3-ocean age adults)

Assumptions

1. A 1:1 sex ratio for mature adults (i.e., 50% are females)
2. Fecundity of 4,000 (i.e., 4,000 eggs per female)
3. Ocean age composition of returning adults from an outmigration:
   42% as 1 ocean age $[A_1 = (N_3)(1-M_4)(0.164)]$
   44% as 2 ocean age $[A_2 = (N_4)(1-M_5)\ (0.586)]$
   14% as 3 ocean age $[A_3 = (N_5)(1-M_6)(1.0000)]$
4. Minimum escapement of 6,000 fish.

Exhibit 22. Hypothetical examples depicting the general effects of low outmigrant survival on adult fish return.

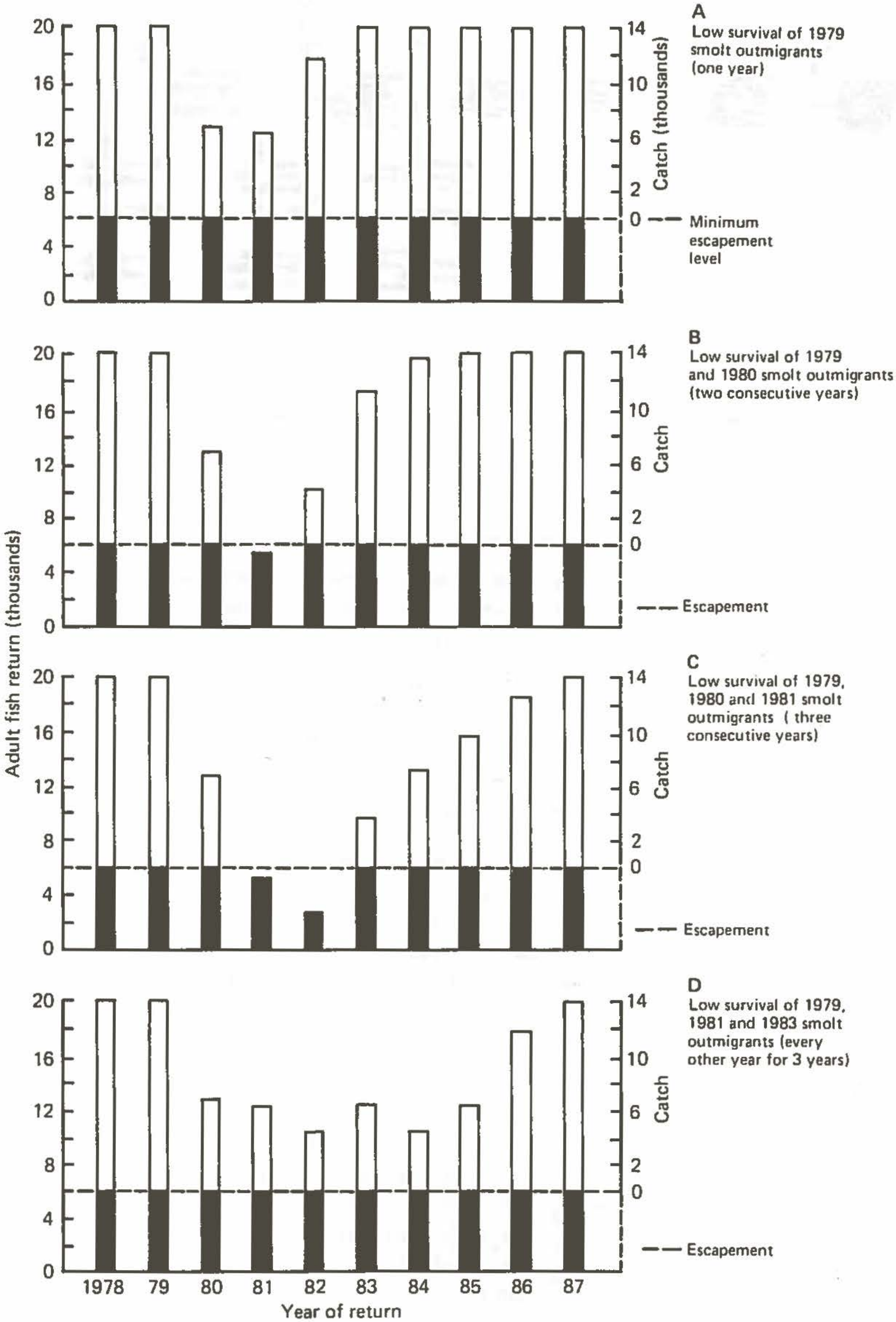


Exhibit 23. Derivation of hypothetical estimates for Exhibit 22.

Low Survival of Outmigrants in 1979

Brood year	Outmigrant year	Adult return (Number of fish by year) 1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Total return
1974	1975	2,800										(20,000)
1975	1976	8,800	2,800									(20,000)
1976	1977	8,400	8,800	2,800								20,000
1977	1978	-	8,400	8,800	2,800							20,000
1978	1979	-	-	1,167	1,222	389						2,778
1979	1980	-	-	-	8,400	8,800	2,800					20,000
1980	1981	-	-	-	-	8,400	8,800	2,800				20,000
1981	1982	-	-	-	-	-	8,400	8,800	2,800			20,000
1982	1983	-	-	-	-	-	-	8,400	8,800	2,800		20,000
1983	1984	-	-	-	-	-	-	-	8,400	8,800	2,800	20,000
1984	1985	-	-	-	-	-	-	-	-	8,400	8,800	(20,000)
1985	1986	-	-	-	-	-	-	-	-	-	8,400	(20,000)
Total return---		20,000	20,000	12,767	12,422	17,589	20,000	20,000	20,000	20,000	20,000	
Catch---		14,000	14,000	6,767	6,422	11,589	14,000	14,000	14,000	14,000	14,000	
Escapement---		6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	
Eggs(millions)---		12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	1.20	

Low Survival of Outmigrants in 1979 and 1980 (2 consecutive years)

1974	1975	2,800										(20,000)
1975	1976	8,800	2,800									(20,000)
1976	1977	8,400	8,800	2,800								20,000
1977	1978	-	8,400	8,800	2,800							20,000
1978	1979	-	-	1,167	1,222	389						2,778
1979	1980	-	-	-	1,167	1,222	389					2,778
1980	1981	-	-	-	-	8,400	8,800	2,800				20,000
1981	1982	-	-	-	-	-	8,105	8,473	2,694			19,272
1982	1983	-	-	-	-	-	-	8,400	8,800	2,800		20,000
1983	1984	-	-	-	-	-	-	-	8,400	8,800	2,800	20,000
1984	1985	-	-	-	-	-	-	-	-	8,400	8,800	(20,000)
1985	1986	-	-	-	-	-	-	-	-	-	8,400	(20,000)
Total return---		20,000	20,000	12,767	5,189	10,011	17,294	19,673	19,894	20,000	20,000	
Catch---		14,000	14,000	6,767	0	4,011	11,294	13,673	13,894	14,000	14,000	
Escapement---		6,000	6,000	6,000	5,189	6,000	6,000	6,000	6,000	6,000	6,000	
Eggs(millions)---		12.0	12.0	12.0	10.4	12.0	12.0	12.0	12.0	12.0	12.0	

Low Survival of Outmigrants in 1979, 1980, and 1981 (3 consecutive years)

1974	1975	2,800										(20,000)
1975	1976	8,800	2,800									(20,000)
1976	1977	8,400	8,800	2,800								20,000
1977	1978	-	8,400	8,800	2,800							20,000
1978	1979	-	-	1,167	1,222	389						2,778
1979	1980	-	-		1,167	1,222	389					2,778
1980	1981	-	-	-	-	1,167	1,222	389				2,778
1981	1982	-	-	-	-	-	8,105	8,473	2,694			19,272
1982	1983	-	-	-	-	-	-	4,286	4,481	1,424		10,191
1983	1984	-	-	-	-	-	-	-	8,400	8,800	2,800	20,000
1984	1985	-	-	-	-	-	-	-	-	8,400	8,800	(20,000)
1985	1986	-	-	-	-	-	-	-	-	-	8,400	(20,000)
Total return---		20,000	20,000	12,767	5,189	2,778	9,716	13,148	15,575	18,624	20,000	
Catch---		14,000	14,000	6,767	0	0	3,716	7,148	9,575	12,624	14,000	
Escapement---		6,000	6,000	6,000	5,189	2,778	6,000	6,000	6,000	6,000	6,000	
Eggs(millions)---		12.0	12.0	12.0	10.4	5.5	12.0	12.0	12.0	12.0	12.0	

Low Survival of Outmigrants in 1979, 1981, and 1983 (3 years at every other year)

1974	1975	2,800										(20,000)
1975	1976	8,800	2,800									(20,000)
1976	1977	8,400	8,800	2,800								20,000
1977	1978	-	8,400	8,800	2,800							20,000
1978	1979	-	-	1,167	1,222	389						2,778
1979	1980	-	-	-	8,400	8,800	2,800					20,000
1980	1981	-	-	-	-	1,167	1,222	389				2,778
1981	1982	-	-	-	-	-	8,400	8,800	2,800			20,000
1982	1983	-	-	-	-	-	-	1,167	1,222	389		2,778
1983	1984	-	-	-	-	-	-	-	8,400	8,800	2,800	20,000
1984	1985	-	-	-	-	-	-	-	-	8,400	8,800	(20,000)
1985	1986	-	-	-	-	-	-	-	-	-	8,400	(20,000)
Total return---		20,000	20,000	12,767	12,422	10,356	12,422	10,356	12,422	17,589	20,000	
Catch---		14,000	14,000	6,767	6,422	4,356	6,422	4,356	6,422	11,589	14,000	
Escapement---		6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	
Eggs(millions)---		12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	

1978 1979 1980 1981 1982 1983 1984 1985 1986 1987

LITERATURE CITED

Beiningen, Kirk T., and Wesley J. Ebel.
1970. Effect of John Day Dam on dissolved nitrogen concentrations and salmon in the Columbia River, 1968. Trans. Am. Fish. Soc. 99:664-671.

Bell, Milo C., Allen C. DeLacy, Gerald J. Paulik, and Richard A. Winnor.
1967. A compendium on the success of passage of small fish through turbines. Fisheries Engineering Research Program. U.S. Army Corps of Engineers, North Pacific, Portland, Oregon. Contract DA-35-026-CIVENG-66-16. 54p. Text, 213 app. p. (Processed.)

Bell, Milo C., Zell E. Parkhurst, Russell G. Porter, and Marjorie Stevens.
1976. Effects of power peaking on survival of juvenile fish at lower Columbia and Snake River Dams. Rep. to U.S. Army Corps of Engineers, Contract No. DACW57-75-C-0173. 35 p., 106 tab. and fig. (Processed.)

Bentley, Wallace W., and Howard L. Raymond.
1975. Delayed migrations of yearling chinook salmon since completion of Lower Monumental and Little Goose Dams on the Snake River, NOAA, Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, WA 10 p. (Typescript, ms in review).

Collins, Gerald B., Wesley J. Ebel, Gerald E. Monan, Howard L. Raymond, and George K. Tanonaka.
1975. The Snake River salmon and steelhead trout crisis: Its relation to dams and the national energy crisis. Processed Report. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center. Seattle, WA., 30 p.

Ebel, Wesley J.
1969. Supersaturation of nitrogen in the Columbia River and its effect on salmon and steelhead trout. U.S. Fish Wildl. Serv., Fish. Bull. 68:1-11.

Ebel, Wesley J., Richard F. Krcma, and Howard 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 Rivers, 1973. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center., Seattle, WA., Prog. Rep. to U.S. Army Corps of Engineers, Contract DACW68-71-0093. 62 p. (Processed).

Ebel Wesley J., Richard F. Krcma, Donn L. Park, Howard L. Raymond, Emil Slatick, Earl M. Dawley, and George A. Swan.
1974. Evaluation of fish protective facilities at Little Goose Dam and review of other studies relating to protection of juvenile salmonids in the Columbia and Snake Rivers, 1974. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, WA,, Prog. Rep. to U.S. Army Corps of Engineers, Contract No. DACW68-71-C-0093. 50 p., 3 App. Tab. (Processed.)

Ebel, Wesley J., Howard L. Raymond, Gerald E. Monan, Winston E. Farr, and George K. Tanonaka.
1975. Effect of atmospheric gas supersaturation caused by dams on salmon and steelhead trout of the Snake and Columbia Rivers. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, WA., 75 p. Text, 35 app. p. (Processed.)

Johnsen, Richard C. and Earl M. Dawley.
1974. The effect of spillway flow deflectors at Bonneville Dam on total gas supersaturation and survival of juvenile salmon. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, Wash., Prog. Rep. to U.S. Army Corps of Engineers, Contract No. DACW-57-74-F-0122. [18 p.] (Processed.)

Junge, Charles and Burton E. Carnegie.
1974. Operational studies (1973-74). Fish. Comm. of Oregon, Clackamas, Oregon., Prog. Rep. to U.S. Army Corps of Engineers, Contract DACW68-74-C-0500. 26 p. (Processed.)

Junge, Charles O. and Burton E. Carnegie.
1976. Dam operations and adult fish passage, 1975. Ore. Dept. Fish Wild., Clackamas, Ore. Rep. to U.S. Army Corps of Engineers, Contract No. DACW68-75-C-0129. 31 p. (Processed.)

Long, Clifford W., Richard F. Krcma, and Frank J. Ossiander.
1968. Research on fingerling mortality in Kaplan turbines 1968. Bur. Comm. Fish. Bio. Lab. 2725 Montlake Blvd., Seattle, WA. Progress Rep. 7 p.

Long, Clifford W. and Frank J. Ossiander.
1974. Survival of coho salmon fingerlings passed through a perforated bulkhead in an empty turbine bay and through flow deflectors (with and without dentates) on spillway at Lower Monumental Dam, Snake River April-May 1973. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, WA., Rep. to U.S. Army Corps of Engineers, Contract No. DACW-68-72-C-0101. 20 p. (Processed.)

Long, Clifford W., Frank J. Ossiander, Thomas E. Ruehle, and Gene 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. Natl. Oceanic Atmos. Admin. Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, WA., Rep. to U.S. Army Corps of Engineers, Contract No. DACW-68-74C-0113. 5 fig., 3 tables. 16 p., (Processed.)

Mains, Edward M. and John M. Smith.
1964. The distribution, size, time and current preferences of seaward migrant chinook salmon in the Columbia and Snake Rivers. Wash. Dep. Fish., Fish. Res. Pap. 2(3):5-43.

Monan, Gerald E. and Kenneth L. Liscom.
1973. Radio tracking of adult spring chinook salmon below Bonneville and The Dalles Dams, 1972. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, WA., Report to U.S. Army Corps of Engineers, Delivery order DACW57-72-F-0398. 37 p. (Processed.)

1974. Radio-tracking of spring chinook salmon to determine effect of spillway deflectors on passage at Lower Monumental Dam, 1973. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv. Northwest and Alaska Fish. Center, Seattle, WA., Rep. to U. S. Army Corps of Engineers, Delivery order DACW57-73-F-0534. 20 p. (Processed.)

1975. Radio-tracking studies to determine the effect of spillway deflectors and fallback on adult chinook salmon and steelhead trout at Bonneville Dam, 1974. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, WA., Rep. to U. S. Army Corps of Engineers, Delivery order DACW57-74-F-0122. 38 p. (Processed.)

Monan, Gerald E., Robert J. McConnell, John R. Pugh, and Jim R. Smith.
1969. Distribution of debris and downstream-migrating salmon in the Snake River above Brownlee Reservoir. Trans. Am. Fish. Soc. 98:239-244.

Oregon Department of Fish and Wildlife and Washington Department of Fisheries.
1976. Columbia River fish runs and fisheries, 1957-1975. Status report. Ore. Dept. Fish Wildl.-Wash Dept. Fish., Vol. 2, No. 1. 74 p. (Processed.)

Park, D. L., E. M. Dawley, R. F. Krcma, C. W. Long, E. Slatick, J. R. Smith, and G. A. Swan.
1976. Evaluation of fish protective facilities at Little Goose and Lower Granite Dams, and review of other studies relating to protection of juvenile salmonids in the Columbia and Snake Rivers, 1975. NOAA, NMFS, Northwest Fisheries Center, Seattle, WA. Report to U. S. Army Corps of Engineers, Contract No. DACW68-75-6-0111. 50 p. with appendix. (Processed.)

Park, D. L., J. R. Smith, E. Slatick, G. A. Swan, E. M. Dawley, and G. M. Matthews.
1977. Evaluation of fish protective facilities at Little Goose and Lower Granite Dams, and review of nitrogen studies relating to protection of juvenile salmonids in the Columbia and Snake Rivers, 1976. NOAA, NMFS, Northwest and Alaska Fisheries Center, Seattle, WA. Rep. to U.S. Army Corps of Engineers, Contract No. DACW68-75-C-0111. 47 p. with appendix. (Processed.)

Park, Donn L., Jim Ross Smith, Emil Slatick, Gene M. Matthews, Larry R. Basham, and George A. Swan.
1978. Evaluation of fish protection facilities at Little Goose and Lower Granite Dams and review of mass transportation activities, 1977. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Center, Seattle, WA. Rep. to U. S. Army Corps of Engineers, Contract No. DACW68-77-C-0043. 60 p. (Processed.)

Park, Donn L., Jim Ross Smith, Gene M. Matthews, Larry R. Basham, George A. Swan, George T. McCabe, Thomas R. Ruehle, Jarrell R. Harmon, and Bruce H. Monk.
1979. Transportation activities and related research at Lower Granite, Little Goose, and McNary Dams, 1978. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Center, Seattle, WA. Rep. to U. S. Army Corps of Engineers, Contract No. DACW68-78-C-0051. 65 p., 36 App. Tab. (Processed.)

Raymond, Howard I.
1968a. A summary of the 1968 outmigration of juvenile salmon and steelhead trout from the Snake River. Bur. Commer. Fish., Bio. Lab., Seattle, WA 12 p (Processed.)

1968b. Migration rates of yearling chinook salmon in relation to flows and impoundments in the Columbia and Snake Rivers. Trans. Am. Fish. Soc. 97:356-359.

1969. Effect of John Day Reservoir on the migration rate of juvenile chinook salmon in the Columbia River. Trans. Am. Fish. Soc. 98:513-514.

1974. Snake River runs of salmon and steelhead trout: trends in abundance of adults and downstream survival of juveniles. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, WA., Processed Rep. 6 p., 5 figs., 2 tables, 6 app. tables.

1975. Snake River runs of salmon and steelhead trout: Trends in abundance of adults and downstream survival of juveniles. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, WA. 20 p. (Processed.)

Ms. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead trout from the Snake River, 1966 to 1965. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Center, Seattle, WA. 72 p. (Typescript.)

Sims, Carl W., Wallace W. Bentley, and Richard C. Johnsen.
1978. Effects of power peaking operations on juvenile salmon and steelhead trout migrations--progress 1977. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Center, Seattle, Wash., Prog. Rep. to U.S. Army Corps of Engineers, Contract No. DACW68-77-C-0025. 52 p. (Processed.)

Smith, Jim Ross.
1974. Distribution of seaward-migrating chinook salmon and steelhead trout in the Snake River above Lower Monumental Dam. Mar. Fish. Rev. 36(8):42-45.

Smith, Jim Ross, John R. Pugh, and Gerald E. Monan.
1968. Horizontal and vertical distribution of juvenile salmonids in upper Mayfield Reservoir, WA. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 566. 11 p.

Young, Franklin R., Ray T. Michimoto, and Gary Gibson.
1978. Passage problems of adult chinook salmon during 1976 and 1977 and steelhead trout during 1974 and 1975 in the Columbia River between Bonneville and McNary Dams. Ore. Dept. Fish Wild. Annual Prog. Rep. to U.S. Army Corps of Engineers, Contract No. DACW57-77-C-0072. 43 p. (Processed.)

Appendix A. Collection, release, and recapture data from transportation experiments on Snake River chinook salmon, 1971 to 1978.

(Chinook Salmon)

Year	Riv Flw 1/	Experiment: Collection site	Experiment: Test group	Experiment: Transport method	Experiment: Release site	2/ Juveniles released	3/ Adults recap'd	Adult return in % of juveniles released: Observed	Adult return in % of juveniles released: Estimated 4/	Transport/ control ratio	Rapid R. return (percent)
1971	High	L.Goose Dam	Control	--	L.Goose Dam	20,674	52	0.250	0.370	1.6:1	0.59
		"	Transpt	Truck	Bonneville	65,889	266	0.403	0.610		
1972	High	L.Goose Dam	Control	--	L.Goose Dam	32,836	25	0.076	0.106	1.1:1	0.12
		"	Transpt	Truck	Bonneville	106,405	89	0.084	0.116		
1973	Low	L.Goose Dam	Control	--	L.Goose Dam	88,170	20	0.023	0.026	15.4:1	0.15
		"	Transpt	Truck	Bonneville	141,364	502	0.355	0.401		
1975	Avg.	L.Granite Dam	Control	--	L.Granite Dam	42,915	127	0.296	0.813	2.1:1	0.33
		L.Granite Dam	Transpt	Truck	Bonneville	68,550	439	0.640	1.742		
1976	High	L.Granite Dam	Control	V.trk	Clarkston, Wa.	24,558					
		"	Transpt	Trk in sw	Bonneville	61,446					
		"	Transpt	Trk in fw	Bonneville	72,918	(Final results expected at end of 1979)				
		"	Transpt	Airpln	Beacon Rock	37,118					
		"	Transpt	Airpln	Tongue Point	38,796					
		L.Goose Dam	Control	V.trk	Central Ferry	39,570					
		"	Transpt	Trk in sw	Bonneville	82,082	(Final results expected at end of 1979)				
		"	Transpt	Trk in fw	Bonneville	68,605					
1977	Low	L.Granite Dam	Control	V.Trk	Clarkston, Wa.	38,325					
		"	Transpt	Trk in sw	Dalton Point	43,065					
		"	Transpt	Trk in sw	Bonneville	45,404	(Final results expected at end of 1980)				
		"	Transpt	Airpln	Bonneville	41,092					
		"	Transpt	Airpln	Estuary	35,333					
		"	Transpt	Barge	Bonneville	31,628					
		Spr.Crk. H.	Transpt	Barge	Bonneville	76,057					
		Kooskia H.	Transpt	Barge	Bonneville	31,200	(Final results expected at end of 1980)				
		Wells Spng.Chan	Transpt	Barge	Bonneville	99,113					
		L.Goose Dam	Control	--	L.Goose Dam	38,346					
		"	Transpt	Trk in sw	Bonneville	43,334	(Final results expected at end of 1980)				
		"	Transpt	Trk in fw	Bonneville	41,677					
1978	Avg.-High	L.Granite Dam	Control	--	L.Granite Dam	8,249					
		"	Control	V.Trk	Clarkston, WA.	46,094	(Final results expected at end of 1981)				
		"	Transpt	Truck	Bonneville	82,925					
		"	Transpt	Barge	Beacon Rock	56,546					
		L.Goose Dam	Control	--	L.Goose Dam	36,440					
		"	Transpt	Trk in sw	Bonneville	48,614					
		"	Transpt	Trk in fw	Bonneville	50,975	(Final results expected at end of 1981)				

Data source: 1971, 1972, and 1973 experiments (Ebel et al 1974); 1975 (Park et al 1976); 1976 (Park et al. 1977); 1977 (Park et al. 1978); 1978 (Park et al. 1979).

1/ Low = 35,000 to 60,000 cfs; Average = 70,000 to 100,000 cfs; High = 110,000 to 190,000 cfs.

2/ The two release groups of transported fish (Dalton Point and below Bonneville releases) are combined for purposes of evaluation.

3/ Adjusted for initial tag loss except for 1978 releases.

4/ Based on comparison of known recovery of fish with magnetized wire tags at Little Goose and Lower Granite Dams and the subsequent recovery of these and other marked fish at Rapid River Hatchery upstream from Little Goose Dam. Returning fish identified at the dams were marked with jaw tags and released to continue their migration upstream. Numbers of externally-tagged fish arriving at Rapid River Hatchery were compared with the recovery of other wire tagged fish arriving at Rapid River Hatchery not previously detected and identified at Little Goose and Lower Granite Dams.

Appendix B. Collection, release, and recapture data from transportation experiments on Snake River steelhead, 1971 to 1978.

(Steelhead)

Year	Riv. flow[1]	Experiment: Collection site	Test group	Transport method	Release site[2]	Juveniles released[3]	Adults recaptured	Adult return in % of juveniles released: Observed	Estimated[4]	Transport/control ratio	Dworshak return (percent)
1971	High	L.Goose Dam	Control	--	L.Goose Dam	33,243	199	0.599	0.832	1.7:1	0.25
		"	Transpt	Truck	Bonneville[2]	80,906	831	1.027	1.443		
1972	High	L.Goose Dam	Control	--	L.Goose Dam	32,488	132	0.406	0.564	3.2:1	0.20
		"	Transpt	Truck	Bonneville[2]	50,157	664	1.324	1.804		
1973	Low	L.Goose Dam	Control	--	L.Goose Dam	42,461	61	0.144	0.201	13.5:1	0.05
		"	Transpt	Truck	Bonneville[2]	63,452	1,225	1.930	2.703		
1975	Avg.	L.Granite Dam	Control	--	L.Granite Dam	46,823	200	0.427	0.773	3.2:1	0.77
		"	Transpt	Truck	Bonneville[2]	60,475	826	1.366	2.472		
1976	High	L.Granite Dam	Control	V.trk.	Clarkston, Wa.	33,905					
		"	Transpt	Trk.in sw	Bonneville	69,145	(Final results expected at end of 1979)				
		"	Transpt	Trk.in fw	Bonneville	54,696					
		L.Goose Dam	Control	V.trk.	Central Ferry	29,414					
		"	Transpt	Trk.in sw	Bonneville	53,874	(Final results expected at end of 1979)				
		"	Transpt	Trk.in fw	Bonneville	43,287					
1977	Low	L.Granite Dam	Control	V.trk.	Clarkston, Wa	33,152					
		"	Transpt	Trk in sw	Dalton Point	40,899	(Final results expected at end of 1980)				
		"	Transpt	Trk in sw	Bonneville	42,777					
		"	Transpt	Barge	Bonneville	30,330					
		Dworshak H.	Transpt	Barge	Bonneville	17,178	(Final results expcted at end of 1980)				
		Leavenworth H.	Transpt	Barge	Bonneville	48,455					
		L.Goose Dam	Control	--	L.Goose Dam	22,204					
		"	Transpt	Trk in sw	Bonneville	22,916	(Final results expected at end of 1980)				
		"	Transpt	Trk in fw	Bonneville	24,272					
1978	Avg.	L.Granite Dam	Control	--	L.Granite Dam	12,567					
	High	"	Control	V.trk	Clarkston, Wa.	43,1[illegible]2					
		"	Transpt	Truck	Bonneville	47,899	(Final results expected at end of 1981)				
		"	Transpt	Barge	Beacon Rock	43,770					
		L.Goose Dam	Control	--	L.Goose Dam	30,364					
		"	Transp	Trk in sw	Bonneville	32,731	(Final results expected at end of 1981)				
		"	Transpt	Trk in fw	Bonneville	36,878					

Data source: 1971, 1972, and 1973 experiments (Ebel et al. 1974); 1975 (Park et al. 1976); 1976 (Park et al. 1977); 1977 (Park et al. 1978); 1978 (Park et al. 1979).

1/ Low = 35,000 to 60,000 cfs; Average = 70,000 to 100,000 cfs; High = 110,000 to 190,000 cfs.

2/ The two release groups of transported fish (Dalton Point and below Bonneville releases are combined for purpose of evaluation.

3/ Adjusted for initial tag loss except for 1978 releases.

4/ Based on comparison of known recovery of fish with magnetized wire tags at Little Goose and Lower Granite Dams and the subsequent recovery of these and other marked fish at Dworshak National Hatchery upstream from Little Goose. Returning fish identified at the dams were marked with jaw tags and released to continue their migration upstream. Numbers of externally-tagged fish arriving at Dworshak Hatchery were compared with the recovery of other wire tagged fish arriving at Dworshak Hatchery not previously detected and identified at Little Goose and Lower Granite Dams.