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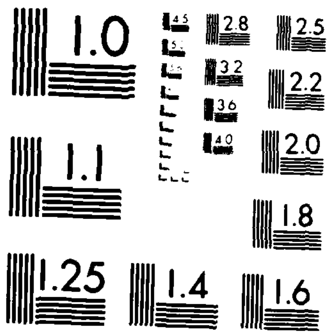

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An assessment of the studies of the Washington Departments of Fisheries and game on the effects of the Wynoochee River Dam and analysis of pertinent data relating to the decline of fish runs in that river.

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EFFECTS OF WYNOOCHEE DAM ON ANADROMOUS FISH

by

Stephen B. Mathews

October 1980

Prepared for United States Corps of Engineers
Seattle District

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INTRODUCTION

This report is an assessment of the studies of the Washington Departments of Fisheries and Game on the effects of the Wynoochee River dam, as well as an analysis of other pertinent data relating to the decline of fish runs in that river. The purpose is not to establish or even suggest what the numerical values for mitigation should be. These deliberations are the business of the two State agencies and the Corps. It was my purpose, as requested by the Corps, to review the available biological data relating to actual or potential declines in fish runs, and clarify certain aspects so that a rapid understanding on extent of fish loss can be agreed upon and speedy step taken for replacement or enhancement.

COHO SALMON

The sources consulted were 1) Washington Department of Fisheries' (WDF) progress report titled, "Evaluation of Downstream Fish Passage through Multi-Level Outlet Pipes at Wynoochee Dam," by Charles A. Dunn; 2) Canadian wire tag recoveries of certain experimental groups which were unavailable at time of preparation of the Dunn report; 3) an analysis of before and after dam construction spawning escapements by Robert Gerke (WDF) summarized in a November 28, 1979 letter from Gordon Sandison, WDF Director, to Mr. Steven F. Dice of the Corps; 4) catch and escapement trends for Grays Harbor; and 5) hatchery plant and return data for the WDF Simpson Hatchery.

The Dunn report presented results of a series of well-designed, well-executed field experiments covering three consecutive passage years of coho salmon outmigrants (1973-1975). The basic experimental procedure to evaluate dam passage mortality, migration delay, and overall effects to the adult population was the two-group, tagged fish procedure. In such experiments equal sized control and test lots are differentially marked and released simultaneously with the test lot exposed to the particular hazard of migration being evaluated and the control lot so released as to avoid it. Recovery of certain fractions of each group takes place far enough downstream to insure complete mixing, or in the fisheries as adult. The fraction of the experimental lot which survived the hazard of migration is estimated from the ratio of the fraction of test fish recovered divided by the fraction of the control lot recovered. The Dunn report indicates sufficient concern with the well-known assumptions that must be met for these tests. Furthermore, sample sizes--numbers marked and numbers recovered--were statistically adequate for most experiments. Thus, the results appear to be valid.

One series of experiments was to estimate the mortality rate associated with passage of coho smolts through the dam. Test groups were released directly into the downstream migratory outlets or the tailrace, and control groups below the tailrace. Recovery occurred near the barrier dam some 2 miles below Wynoochee dam.

A substantial number of experiments during 1973 indicated a fairly consistent mortality rate, averaging 14%, associated with dam passage. Tailrace and outlet release groups suffered similar mortality rates; therefore, it is likely that most of the mortality took place in the tailrace and not through the dam. Similar experiments were conducted during 1975 with the tailrace water level raised 4 ft to hopefully improve survival. However, mortality averaged some 60% during 1975 experiments, again apparently occurring in the tailrace. The tailrace water level was subsequently lowered to the 1973 level and this has been the operating procedure since then. Therefore, the 1973 experiments offer the best measure of the current dam-passage mortality rate, 14%.

A second group of experiments measured the overall success of fish passing through the reservoir in terms of contribution to the adult run. Marked test groups of coho smolts were released .5 miles above the reservoir, and control groups .1 mile below. Fin clips were used in 1973 and coded wire tags in 1974 and 1975. Coded wire tags in the latter 2 years allowed an estimate of the entire ocean catch of each of the various groups.

The reservoir-release experiments provided data not only on overall adult contribution, but also on the percentage of fish that residualized or died in the reservoir. Estimates of residualism rates were made by comparing downstream recovery rates of the test group released above the reservoirs and the control group released below. The difference in these two rates is due to both residualism and dam passage mortality. Knowing mortality from outlet tests, residualism can be estimated. The technique followed by Dunn to do this is valid. The 1973 estimates of residualism average 26%; the 1963 estimate was 63%.

The adult recovery data from the reservoir tests were conflicting. From the first year's tests (1973 oumigration--1974 catch) the test fish survived at lesser rates than control groups, according to fin mark recoveries in the Grays Harbor net fishery and the Wynoochee River escapement. During the subsequent 2 years when use of wire tags provided recovery data from all fisheries, the test groups tended to survive at higher rates than the controls.

I have expanded on Dunn's analysis in Table 1 to include Canadian recovery data. Survival rates averaged about twice as high for the test groups as controls, from 1974 and 1975 releases; however, for the 1974 releases, the difference in survival declined the later the release. The survival rates of control fish ranged from about 2.0 - 4.0%, which is similar to survival rates for coho released from Washington coastal hatcheries at other times (Senn 1970a; Senn 1970b; Senn and Satterthwaite 1971).

The Dunn report also compares adult size of test and control groups concluding that fish in the test groups tended to average some .3 lb less than fish in the contol groups. Such differences were consistent and therefore probably significant.

An explanation for the higher test group survival rate in 2 of 3 yr and the smaller adult size of the test groups is given in the Dunn report and seems plausible: i.e., the test groups because of time delay in migration tended to reach the estuary later than control groups, favoring survival but decreasing total time for ocean growth. Several studies have shown that release timing of coho smolts can critically effect survival. Severalfold increases in survival rates of hatchery coho have been caused by delaying the release of coho on the order of 1 month (Mathews and Buckley 1976; Hopley and Mathews 1975; Bilton 1978).

Gerke's before and after dam comparison of coho escapements is reproduced in Table 2. I discussed with Mr. Gerke his basis for choice of certain parameter values, particularly the survival rates and the catch: escapement ratios. The evidence for allowing these values to change over the range of years is scanty and we agreed that perhaps an equally valid, straightforward analysis might be to use a constant 2% survival rate (the average for the 1973-1975 control groups) and a constant 3:1 catch: escapement ratio. Redoing the analysis with these constant values did not change the conclusion appreciably (Table 2).

Gerke concluded an average annual loss to the native run from the dam of 2,225 fish. This figure included the difference between the pre- and post-dam averages of run size (5,817-3,734) plus an additional 142 adult equivalents to account for the smaller weight of adult salmon due to migration delay. The latter quantity was computed by multiplying the post-dam average per fish weight loss, and dividing this product by 8 lbs, the average weight of an adult salmon.

Recomputing the loss for the same time period as the Gerke analysis 1971-1978, and assuming constant survival and catch: escapement ratios led to a total loss of 2,795 adult equivalents. This figure included

2,666 loss in numbers plus 129 adult equivalents due to weight loss. With 1979 added to the post-dam series, a similar analysis yield a total loss of 2,321 adult equivalents.

Thus, the Gerke analysis is reasonable, although it will be recognized that due to small sample sizes and extensive variability in the data, the average run sizes are not significantly different. For example, a t-test of the difference in average value of the native run from the Gerke analysis gave an t-value of .68, whereas a value of at least 1.44 would be needed for rejection of the null hypothesis of equal means against the alternatives of a lesser mean after the dam at the 10% level of significance. However, variability and small sample size are common problems in evaluating wildlife losses from environmental degradation, and adherence to strict rules of classical statistical hypothesis testing may not always be appropriate. It is often difficult to "prove" at the classical 5% or 10% significance levels that there has been a loss, and such strict rules would lead us to shortchange wildlife populations too often.

Other pertinent data relating to Grays Harbor coho salmon runs are summarized in Table 3. There are downward trends in total run, escapement, and hatchery return for the period 1967-1979. Such declines could be due to many factors such as industrial pollution in Grays Harbor or increasing trend in ocean harvest rate. To put the effects of Wynoochee dam in perspective, the returns to the dam should be considered in light of overall trends in Grays Harbor runs. One useful statistic for comparison is the percentage of the total Grays Harbor escapement contributed by the native run to Wynoochee dam. If the Wynoochee run has decline relative to the total escapement, an effect from the dam would then be indicated. I compared Gerke's estimates of native Wynoochee escapement with total Grays Harbor escapement and also with total Grays Harbor run (Table 4). The total escapment averaged almost the same for the pre-dam and post-dam periods, 35,130 vs. 37,244, while the Wynoochee native escapement averaged more before dam completion than after. In terms of weighted averages (weighted by total escapement) the Wynoochee escapement declined from 5.20% of the escapement pre-dam to 2.81% post-dam. In terms of simple averages, the pre-dam average was 4.08% of total escapement and the post-dam average was 3.39%. Again, none of these differences would be statistically significant if tested at the classical 5% or 10% levels.

COHO FRY

There was no direct experimental evidence in the Dunn report or elsewhere on mortality or blockage to migration of coho fry by the dam. Dunn found a high (40%) rate of mortality in 0-age chinook released directly into dam passage outlets. Furthermore, an experiment with 0-age chinook released above the dam indicated a low rate of passage through the reservoir. I estimated the residualism rate on this group to be 76%.

Thus one might infer that coho fry being smaller even than the 100/lb 0-age chinook fry used might experience considerable loss due to the dam.

From observations of coho fry entering the reservoir and from the numbers observed to rear there, Dunn concluded that, "coho fry moved downstream to the reservoir, reared for approximately 1 yr and egressed the following spring as 1+ smolts."

Delay and mortality of coho fry above the dam could have substantially depleted the seeding of coho fry to rearing waters of the main river between the dam and the major spawning tributaries below. This possible source of loss was not to my knowledge ever evaluated; however, there are many miles of river below the dam which may presently be underseeded and not producing coho smolts to potential. The distance to Shaeffer Creek, the first major tributary downstream of the dam is 23 miles.

STEELHEAD

The sources consulted included 1) the Dunn report; 2) a report titled "Evaluation of Adult Steelhead Returning to Wynoochee River from Smolt Releases 1973, 1974, and 1975 and Comparisons with Juvenile Studies" by Larrie LaVoy and James Fenton of the Washington Game Department; and 3) annual estimates of winter run steelhead catches for Grays Harbor Rivers in data compiled by WDG from punch card returns.

The Dunn report presents the results of two-group marked experiments similar to those for coho. The WDG report presents additional data from creel sampling the Wynoochee winter steelhead fishery to recover marked fish and estimate catches.

The two-group experiments of mortality through the dam indicated an average mortality rate of 24% during 1973, and 63% during 1975. Recall that in 1975, the tailrace water elevation was raised which probably was the cause for the high mortality that year. As with coho it was evident from comparing outlet with tailrace release groups that mortality tended to occur in the tailrace, not through the dam outlets. During 1973, an estimated 7% of the smolts released into the reservoir failed to migrate from the reservoir. This rate increased to 93% in 1975. Coho also had a higher rate of residualism in 1975 compared to 1973.

The number of steelhead marked was sufficient statistically in all tests. Fin clips were used as marks. It is best when using fin clip in two-group experiments to use the paired fins, pectorals and ventrals, removing, say, the right one for controls and the left for test fish. Regeneration rates and mark induced mortality rates should be the same for right and left. However, in the Wynoochee studies single-fin marks--anal, dorsal, and caudal--had to be used since there were not enough combinations of the paired fins. In short-term tests, i.e., between the reservoir and the barrier dam, the unknown differential mortality or regeneration effects from various single fin marks are probably not significant. For longer term comparisons such as from adult returns, they are. Fortunately, and I expect by design, all comparisons of groups released above the reservoir with groups released below did utilize the paired fins, whereas individual outlet and tailrace experiments made use of single fins. This should be considered in interpretation of the adult marked fish returns.

The adult return data, as with coho, provides an overall assessment of the effects, positive or negative, of the dam from mortality, residualism, delayed migration, etc. After considering the analytical problems presented by single fin-marked experiments and the small numbers of adult returns from certain experiments, I concluded that there were two experiments for which the adult return data provided significant ancillary data. These were the 1973 and 1975 experiments wherein test groups were released above the reservoir. These data are reproduced in Table 5. Sport catches of marked fish in the WDG report were estimated by extrapolating from observed marked/unmarked fractions and total catch as estimated from the creel census. The creel census was of adequate design, as borne out by the close correspondence between total catch estimates from creel census and from punch card:

Season	Creel census estimate	Punch card estimate
74-75	578	627
75-76	284	354
76-77	376	261

At the barrier dam 75% of 1974-1975 season returns were examined for marks and 93% during the 1976-1977 season. It is unclear in the WDG report whether reported marks at the barrier dam included an extrapolation to account for the unobserved portion of the returns. This is not too significant since it is the relative occurrence of marks from each of two groups that is of primary concern.

The adult data tends to confirm the short-term barrier dam recovery data, i.e., residualism and dam mortality were significant. The test: control ratio from 1973 releases was 12:29 (Table 5). This is not significantly different from the ratio of test to control in smolts recovered at the barrier dam during outmigration; 1515:2336 ($X^2 = 1.88$). Therefore, there is no indication that the barrier dam recovery ratio is not a valid index of overall detriment to adult contribution.

The test: control ratio from 1975 releases was 0:17, again as expected given the low test: control recovery ratio at the barrier dam, 166:4773.

Residualism of steelhead is apparently highly variable from year to year. It averaged 51% for the two years with valid tests (9% in 1973 and 93% in 1975) and for an overall assessment the average may be useful. Combining this with the 1973 dam mortality rate estimate of 24%, I would conclude that the 63% of each years' smolt production above the dam would be lost on the average.

$$[1-(1-.51)(1-.24)] = .63$$

The adult returns to Wynoochee dam has dropped precipitously (Table 6) as have runs of cutthroat trout and whitefish. The average steelhead runs for the three seasons preceding the effects from the dam (71-72, 72-73, 73-74) was 1015 steelhead. For the six seasons thereafter, the run has averaged 221.

Steelhead runs in Grays Harbor have generally been trending downward over the past 12 yr (Table 7). The Satsop River, a Chehalis tributary close to the Wynoochee has declined from about 2,000 per year to only a few hundred per year. Total Grays Harbor catches, including Indian commercial catches since 1974, have declined from a 15,000 fish level to a 4,000 fish level. It is beyond the scope of the present analysis to analyze those declines; however, potential causes for losses of wild steelhead runs to the Wynoochee and adjacent systems include industrial pollution in the Aberdeen-Hoquiam area, overfishing, and siltation from logging and land clearing effecting spawning and rearing habitat.

Probably there is no single cause for these declines and the Wynoochee dam is simply another contributor. Practically speaking it is impossible to estimate how much of the decline in the run back to the dam is due to the dam itself and how much is due to these other factors which have been negatively effecting all of Grays Harbor runs. One basis for comparison is to note that the average Grays Harbor catch declined from 10,634 for the 3 years immediately prior to dam effects to 4,170 for the 5 years thereafter, a 60% decline, whereas the Wynoochee dam averages fell from 1,015 for the pre-dam 3-year period to 255, a 75% decline. Thus, the upper Wynoochee runs declined at a greater average rate than other runs close by.

I have provided an analysis to roughly indicate the significance of the spawning areas above Wynoochee Dam relative to total spawning in the Wynoochee River. To estimate total runs, I divided the total sport catch from punch cards by the average 3-year exploitation rate on marked fish (Table 8). The punch card catches may be relatively unbiased estimates of actual catch for this river, according to correspondence between creel survey and punch card catch estimates. The exploitation rate estimates followed from the estimated catch of marked steelhead from the Lavoy-Fenton report and the number of marks observed at the barrier dam. The mark-sampling time period at the barrier dam generally corresponded with the fishing season--creel census period. The assumption in estimating the exploitation rate this way is that all fish initially marked at the dam which survived to spawn, returned to the dam for counting.

In Table 9, total runs and total spawning escapements are estimated. The barrier dam count is expressed as a percentage of the estimated total escapement. For the 1971-78 period, an average of 41% of the spawners have apparently been destined upstream of the barrier dam. Although rough, this analysis indicates that a substantial proportion of the Wynoochee native production originated from spawning above the dam site.

CHINOOK

Deschamps et al. (1966) concluded that spring chinook runs in the Wynoochee were so small that the effects from the dam would be negligible. This report further concluded that there was little fall chinook spawning above the dam site and that on balance the dam would have an overall positive affect on fall chinook in the Wynoochee since flows for upstream passage of spawners in the lower river would be improved.

Since the building of the dam, the following counts of chinook spawners to the barrier dam have been made:

Year	No. of chinook
1971	147
1972	0
1973	0
1974	11
1975	34
1976	41
1977	0
1978	16
1979	7

A number of marked fish experiments with fall chinook are detailed in the Dunn report. During 1973, mortality rate for test groups of age 1+ chinook averaging about 6 fish/lb and released directly into dam outlets averaged 28%, similar to steelhead and more than for coho. No tailrace test releases were made, so there is no basis for determining if the major cause of mortality was due to entrapment in the tailrace, as was apparently the case for coho and steelhead. From one 1973 experimental release of 1+ chinook in the reservoir, I estimate the rate of residualism (those remaining in the reservoir) to be 34%. A 1973 test with 0+ age chinook averaging 100/lb in size indicated 40% mortality through the dam mostly occuring in the tailrace and 76% residualism.

Chinook may not be a significant native run species above the dam site, but the mortality and residualism rate from experiments with this species tend to strengthen the results found for coho and steelhead. All point to significant passage delay, residualism, and mortality of downstream salmon migrants.

SUMMARY AND CONCLUSIONS

Table 10 summarizes the direct experimental evidence on dam effects to time of barrier dam passage. Direct mortality from dam passage ranges from 14% for coho to 40% for 0+ chinook, mostly occurring from tailrace entrapment. The percentages that residualize in the reservoir are higher, varying from 40% for coho to 76% for 0+ chinook. Assuming that few of the fish which residualize will eventually migrate and contribute, the detrimental effects on downstream migration are summarized in the last column of Table 10. These computations are:

$$M = 1-[(1-M_1)(1-M_2)]$$

M = loss from both sources
M_1 = rate dam mortality
M_2 = ~~passage~~ rate of residualism

Values for total loss rates range from .53 for coho to .86 for 0+ chinook.

Adult recovery data indicated some possible, potential, compensatory survival effects for coho, but none for steelhead. Delayed migration of coho in 2 of 3 years caused increased survival rate for test releases. However, whether or not naturally migrating coho would benefit from delay is unknown. The experimental results were based upon releases of hatchery fish which may not have been physiologically ready for migration. Naturally, migrating fish, one must assume, have undergone or are undergoing those physiological changes which adapt them to salt water survival. There is no assurance that they would benefit from delay, and in fact, I would expect the reverse. The complexities of the physiological, adaptive processes involved in smoltification and migration, and the extreme variability in survival rates found from various experiments or timing and migration preclude direct extension of the Wynoochee ocean survival results from hatchery released fish to naturally migrating fish.

There probably are some compensating effects occurring for coho since the decline in the runs as indicated by return to the barrier dam is not as great as one would expect from a 53% loss rate each year. On balance, the Gerke memorandum is probably a fair assessment of the coho losses or if anything is light since he did not consider fry seeding losses to the lower river.

For steelhead, the presence of declining trends in runs throughout Grays Harbor leads me to believe that the 1971-1979 sharp decline at the Wynoochee dam is not totally due to the effects of the dam. However, mortality and particularly residualism are high combining to cause a 63% reduction in average annual smolt outmigration from spawning areas above the dam. Since there are no indicated compensating benefits from delay of migration, a continuing loss rate at this level would eventually reduce the upper Wynoochee run to a negligible level even if other factors reducing Grays Harbor runs generally were corrected.

Thus on balance, I would conclude that steelhead runs could not maintain themselves by adult hauling of the adults that return each year to the Barrier dam in the upper Wynoochee with the dam present, while coho runs could, but at some reduction in potential.

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Table 1. Total recoveries as jacks and adults of Wynoochee Dam coho experimental releases.

Release information	Test	Control	Test	Control	Test	Control	Test	Control
Date	5/1/74	5/1/74	5/15/74	5/15/74	5/29/74	5/29/74	4/25/75	4/25/75
Tag no.	1-5-10	1-5-15	1-5-12	1-5-13	1-5-14	1-5-15	13-1-3	1-15-7
No. released	22,570	23,877	26,789	23,763	24,442	24,247	49,350	49,412
Size	16/1b	16/1b	16/1b	16/1b	16/1b	16/1b	16/1b	16/1b
Puget S. sport	0	0	0	0	0	5	2	5
Ore. sport	0	4	0	5	21	5	22	20
Ore. troll	44	5	27	0	27	35	170	122
B.C. troll	16	1	117	11	134	147	607	523
B.C. net	2	0	0	0	0	2	10	7
Wash. troll	59	15	142	66	220	183	498	268
Wash. sport	54	3	91	51	150	142	221	71
Wash. net	83	32	78	43	180	142	79	68
River sport	0	0	0	0	0	0	0	0
Escapement	62	34	92	34	156	137	360	209
Total	320	94	547	210	888	782	1,969	1,293
Survival rate	1.40	.40	2.00	.90	3.60	3.20	4.00	2.60
Ocean fish. rate	.54	.30	.69	.63	.62	.64	.77	.79
Terminal fish. rate	.58	.48	.83	.56	.54	.52	.19	.25
C/E ratio	4.16:1	1.76:1	4.95:1	5.18:1	4.69:1	4.82:1	4.36:1	5.19:1

Table 2. Upper Wynoochee River coho returns.

	Return year	Wynoochee trap count	Number of smolts planted	Expected survival rate[1]	Estimated hatchery adult production	Estimated hatchery adults to trap	Estimated native adults to trap	Catch to escapement ratio	Estimated total native run
Gerke analysis	1971	5,714	307,000	1.2%	3,684	1,228	4,486	2:1	13,458
	1972	1,019	202,000	1.2%	2,424	606	413	3:1	1,652
	1973	873	96,000	1.2%	1,152	288	585	3:1	2,340
	Pre-dam average	2,535		1.2%	2,420	707	1,828		5,817
	1974	2,762	162,000	3.18%	5,157	1,289	1,473	3:1	5,892
	1975	1,054	146,000	1.49%	2,182	436	618	4:1	3,090
	1976	3,049	273,000	1.42%	3,883	1,213	1,836	2.2:1	5,875
	1977	444	63,000	1.2%	756	151	293	4:1	1,465
	1978	708	99,000	1.2%	1,188	238	470	4:1	2,350
	Post-dam average	1,603			2,633	665	938		3,734
Constant parameters	1971	5,714	307,000	2.0%	6,140	1,535	4,179	3:1	16,716
	1972	1,019	202,000	2.0%	4,040	1,010	9	3:1	36
	1973	873	96,000	2.0%	1,920	480	393	3:1	1,572
	Pre-dam average	2,535							6,108
	1974	2,762	162,000	2.0%	3,240	810	1,952	3:1	7,808
	1975	1,054	146,000	2.0%	2,920	730	324	3:1	1,296
	1976	3,049	273,000	2.0%	5,460	1,365	1,684	3:1	6,736
	1977	444	63,000	2.0%	1,260	315	129	3:1	516
	1978	708	99,000	2.0%	1,980	495	213	3:1	852
	1979[2]	(1,618)	0	(2.0%)	0	0	(1,618)	(3:1)	(6,400)
	Post-dam average ('74-'78)								3,442

[1] U.S. catch plus escapement.
[2] 1979* Excluded from analysis, but see text for discussion.

Table 3. Statistics on Grays Harbor coho salmon runs.[1]

Year i	Indian and non-Indian net catch	Total wild spawning escapement	Hatchery spawning escapement (Satsop)	Total run	Hatchery smolts released year i-1	% of smolts returning to hatchery
1967	21,804	98,108	6,970	126,882	-	-
1968	36,489	80,766	12,462	129,717	-	-
1969	25,426	50,467	5,220	81,113	-	-
1970	64,827	95,638	8,051	168,516	825,504	0.97
1971	58,698	68,218	9,477	136,393	1,060,380	0.89
1972	46,552	21,932	4,913	67,791	989,805	0.50
1973	40,162	15,239	4,311	59,712	1,391,580	0.31
1974	49,515	81,056	9,219	139,790	1,933,000	0.48
1975	20,985	10,705	1,781	33,471	532,328	0.33
1976	34,741	31,289	2,015	68,045	693,349	0.29
1977	6,089	30,411	318	36,818	667,944	0.05
1978	6,822	35,000	1,251	43,073	803,923	0.16
1979	8,728	35,000	10,860	54,588	969,111	1.12

[1] Catch and escapement data provided by William Hopley (WDF Coastal Harvest Management Biologist); hatchery data by Robert Hager (WDF Hatchery Research Chief).

Table 4. Comparison of native coho escapement to Wynoochee Dam to total Grays Harbor escapement and run.

Year	Estimated native adults to trap	Grays Harbor escapement	Wyn esc/G Hbr esc x 100	Grays Harbor run	Wyn esc/G Hbr run x 100
1971	4,486	68,218	6.52	136,393	3.29
1972	413	21,932	1.88	67,791	0.61
1973	585	15,239	3.84	59,712	0.98
Pre-dam average	1,828	35,130	4.08	87,965	1.63
1974	1,473	81,056	1.82	139,790	1.05
1975	618	10,705	5.77	33,471	1.85
1976	1,836	31,289	5.87	68,045	2.70
1977	293	30,411	0.96	36,818	0.80
1978	470	35,000	1.34	43,073	1.09
1979	1,600	35,000	4.57	54,588	2.93
Post-dam average	1,048	37,244	3.39	62,631	1.74

Table 5. Adult returns of marked steelhead.

	Mark	Date released	No. released	No. smolts recovered at barrier dam	Adult sport catch	Adult barrier dam return	Total adult return
1974-75 catch; 1973 releases							
Test group released above dam	RP	5/3/73	2,500	1,515	8	4	12
Control group released below dam	LP	5/3/73	2,500	2,336	8	21	29
1976-77 catch; 1975 releases							
Test group released above dam	LV	4/29/75	10,042	166	0	0	0
Control group released below dam	RV	5/3/75	9,741	4,773	9	8	17

Table 6. Counts of trout and whitefish at Wynoochee barrier dam.

Year	Steelhead	Cutthroat	Whitefish
1971-72	1,765	303	162
1972-73	562	11	21
1973-74	719	83	1
1974-75	523	31	11
1975-76	417	11	52
1976-77	153	19	4
1977-78	143	4	0
1978-79	42	0	0
1979-80	46	0	0

Source: Nov. 23, 1979 FACT SHEET provided by Jack Thompson, Corps of Engineers. 1979-80 by J. Thompson, personal communication.

Grays Harbor drainage winter steelhead catches, 1967-68 season to 1978-79 season.

Year	Chehalis	Cloquallum	Hoquiam	Humptulips	W. Fk. Humptulips	Johns	Newaukum	Satsop	Skookumchuck	Wishkah	Wynoochee	Total sport	Indian catch: Chehalis	Indian catch: Humptulips	Total sport and commercial catch
67-68	4,060	39	47	8,818	8	297	115	2,053	330	318	1,197	17,282	-	-	17,282
68-69	5,547	94	93	7,022	-	641	160	2,216	96	134	1,679	17,682	-	-	17,682
69-70	2,663	115	84	3,186	-	249	80	997	65	177	1,036	8,652	-	-	8,652
70-71	3,328	113	55	6,641	31	427	103	1,493	52	293	1,371	13,876	-	-	13,876
71-72	4,196	103	98	7,446	25	557	99	1,421	217	351	1,760	16,273	-	-	16,273
72-73	1,402	43	52	3,262	46	33	104	1,380	641	244	1,222	8,429	-	-	8,429
73-74	1,511	20	44	3,014	8	198	38	1,023	324	171	849	7,200	-	-	7,200
74-75	1,113	31	20	2,559	2	142	38	602	151	126	627	5,411	731	-	6,142
75-76	391	12	18	795	19	47	30	283	32	31	354	2,012	435	1,131	3,578
76-77	205	19	7	916	72	55	7	345	22	35	261	1,944	665	927	3,536
77-78	281	30	54	1,608	66	66	15	274	21	51	109	2,575	622	636	3,833
78-79	447	-	4	1,592	4	44	4	210	48	217	246	2,816	348	597	3,761

Table 8. Exploitation rate on marked steelhead.

Season	Est. sport catch of marked steelhead	Marked 1-1, 1-2, 1-3 steelhead at barrier dam	Est. exp. rate
1974-75	50	53	.48
1975-76	21	140	.13
1976-77	17	24	.41

$\bar{x} = .34$

Table 9. Analysis of Wynoochee River steelhead catch and escapement data.

Year	Total sport catch, from punch cards	Total run (sport catch ÷ ave. exp. rate)	Est. total spawning esc. (run-catch)	Barrier dam count	Est. % of spawning headed up-stream of dam
1971-72	1,760	5,176	3,416	1,765	52%
1972-73	1,222	3,594	2,372	562	24%
1973-74	849	2,497	1,648	719	44%
1974-75	627	1,844	1,213	523	43%
1975-76	354	1,041	687	417	61%
1976-77	261	768	507	153	30%
1977-78	109	320	211	143	68%
1978-79	246	723	477	42	9%

$\bar{x}$ = 41%

Table 10. Summary of experimentally determined direct effects of Wynoochee Dam on salmonids.

Species and age	Size tested	Dam passage mortality rate (years)	Rate of residualism (years)	Combined loss from dam passage and residualism
Coho 1+	16/lb	.14(73)	.45(73,75)	.53
Steelhead 1+	5/lb	.24(73)	.51(73,75)	.63
Chinook 0+	100/lb	.40(73)	.76(73)	.86
Chinook 1+	6/lb	.28(73)	.66(73)	.75

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