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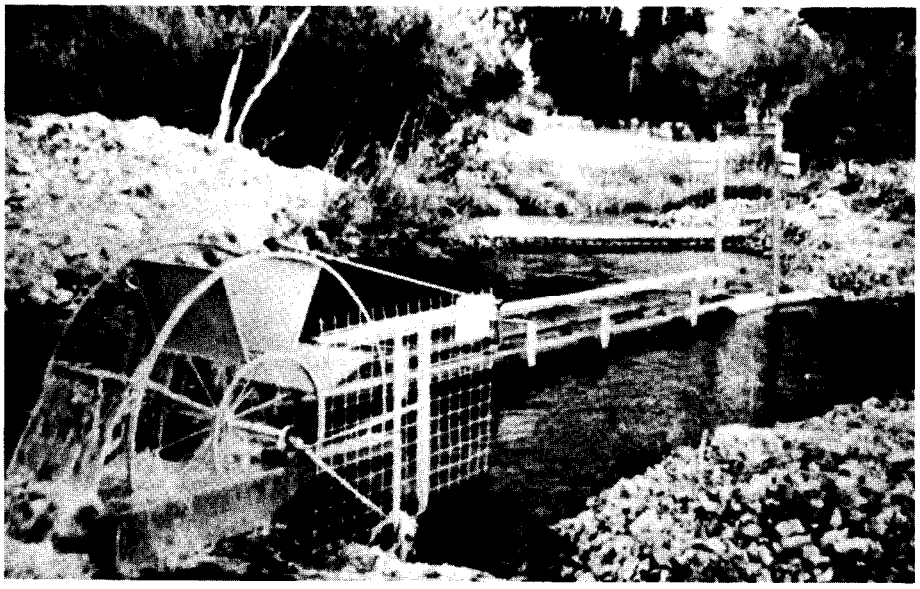
FISHERY RESEARCH

EVALUATING THE ANADROMOUS FISH SCREEN PROGRAM ON THE UPPER SALMON RIVER

Performed for the Columbia River Program Office of the National Marine Fisheries Service



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INTRODUCTION

The Salmon River originates in the Stanley Basin area of Central Idaho and flows 410 miles before entering the Snake River near Lewiston. The portion of the Salmon River drainage examined in this study includes the main river and associated tributaries above the town of North Fork (Fig. 1).

Irrigation has been practiced in this segment of the Salmon River since the first white settlement on the Lemhi River in 1855 (Gebhards 1959). Irrigation, along with mining and commercial harvest in the lower Columbia, contributed to the decline of anadromous fish in the drainage prior to 1933 (Fisher 1977). Losses of juvenile fish to irrigation diversions were particularly apparent in the heavily-irrigated Lemhi River and from 1920-1933 a U.S. Fish Cultural Station was operated at Salmon, Idaho for the artificial propagation of Lemhi River chinook salmon. Despite the presence of the hatchery, the run continued to decline and the facility was abandoned in 1933 (Gebhards 1958).

Unquantified losses of juvenile outmigrants to irrigation diversions in the drainage continued unabated into the mid-1950's. During 1957, Idaho Department of Fish and Game personnel utilized electrofishing equipment to document anadromous fish losses in 60 Salmon River diversions (Gebhards 1957). This study was conducted to identify the most damaging diversions and prioritize the placement of screens under the Columbia River Program (CRP) which had been expanded in 1956 to include that portion of the Columbia River Basin above McNary Dam.

Initial construction of screens on irrigation canals in the Salmon River Basin began in 1958. The Bureau of Commercial Fisheries (now the National Marine Fisheries Service) administered funds for the project and screens were constructed and maintained by the Idaho Department of Fish and Game. From 1958 to 1966 over 200 fish screens were installed in the Salmon River drainage (Herrig 1983). In the late 1960's CRP funds for new screen construction ran out before all major diversions were screened. CRP funding became limited primarily to the operation, maintenance and replacement of existing screens. In the late 1970's funds from the Bureau of Land Management and the Forest Service were utilized by Idaho Department of Fish and Game to screen about 25 additional diversions in the Stanley Basin. The Columbia River Program presently provides operation and maintenance funds for all screens in the Salmon River Basin.

The purpose of this study is to: 1) summarize existing data concerning the effectiveness of Salmon River fish screens; 2) examine the relationship between screen operation and maintenance costs and benefits derived from the program; 3) provide suggestions and guidelines for future evaluations of the fish screen program.

Anadromous Fishery Resources

The upper Salmon River system contains runs of chinook salmon (Oncorhynchus tshawytscha), sockeye salmon (Oncorhynchus nerka) and steelhead trout (Salmo gairdneri). Steelhead and chinook runs of varying magnitude currently exist in most upper Salmon River tributaries. Sockeye salmon historically reared in several lakes in the Stanley Basin including Alturas, Stanley, Yellowbelly, Petit and Redfish lakes (Bjornn et al. 1968). However, the Salmon River sockeye run has been limited to a remnant population in Redfish Lake in recent years. Alturas and Stanley lakes have received hatchery introductions since 1981 in an attempt to re-establish self-sustaining runs (Mel Reingold, IFG, pers. comm.).

The chinook salmon run consists of both spring and summer stocks. Spring chinook enter the Columbia from March to May and spawning in the Salmon River basin peaks in late August. Summer chinook enter the Columbia in June and July and spawn primarily in September (Mallet 1970).

In general, three periods of downstream movement occur in the life history of chinook salmon in the drainage (Miller 1969). Downstream movement of newly-emerged fry occurs in early spring and appears to be the result of dispersal to suitable rearing areas (Bjornn 1978). Pre-smolt (fingerling) movement peaks in late fall to early winter and the seaward migration of smolts occurs in March and April (Miller 1969, Bjornn 1968).

Salmon River steelhead spawn from late March to early June. Downstream movements of juvenile steelhead trout peak in spring and fall. Pre-smolt movement occurs primarily in September and seaward smolt migration occurs in April and May.

The numbers of wild chinook and steelhead returning to the Salmon River Basin have declined in recent years. Salmon redd counts from 1979-1982 are in the range of 10% of 1960-1965 counts (Pollard 1983). Declines in wild steel head abundance within the drainage are more difficult to document with the absence of redd counts but are probably of a similar nature. Most biologists agree that the Columbia River Basin hydroelectric projects have played a major role in decreasing runs of anadromous fish (Herrig 1983).

Large numbers of hatchery steelhead and chinook are also released into the upper Salmon River Basin and subsequently benefit from the screening program. The Pahsimeroi River steelhead hatchery program, •undertaken in 1966, was designed to relocate the Snake River steelhead run blocked by dam construction in Hells Canyon. Under this program hatchery steelhead smolts are reared at the Niagara Springs Hatchery near Jerome, Idaho and released into the Pahsimeroi River in March and April. A total of 23 million smolts have been released since the inception of the program at the expense of Idaho Power Company (Table 1).

Table 1. The number of juvenile steelhead trout and chinook salmon released at hatchery facilities on the Pahsimeroi River, 1966-1983.

Year	Steelhead smolts	Chinook salmon
1966	65,000	
1967	1,365,000	
1968	1,484,000	
1969	1,645,000	
1970	1,622,000	393,800
1971	1,630,000	400,300
1972	1,550,000	231,700
1973	1,292,000	217,100
1974	1,847,000	330,000
1975	1,331,000	114,600
1976	1,610,000	121,000
1977	1,448,000	234,400
1978	1,300,000	508,100
1979	1,372,000	
1980	1,097,000	
1981	863,000	
1982	995,000	
1983	621,000	451,022
Total	23,137,000	3,002,022

Chinook salmon have also been reared and released at the Pahsimeroi facility since 1970. The chinook rearing program was expanded in 1983 and currently calls for the production of one million smolts annually.

A total of 300,000 chinook smolts were released at the Sawtooth Hatchery site in the Stanley Basin during 1983. This facility, currently under construction, is funded under the Lower Snake River Compensation Plan and the program calls for the eventual release of 2.2 million smolts annually.

These two facilities comprise the major hatchery release sites in the upper Salmon drainage (Fig. 1). Smolts are also released in several other tributaries including the East Fork and the Lemhi River. Hatchery fry are planted in numerous Salmon River tributaries where wild runs have virtually been eliminated. In the past, large numbers of hatchery steelhead and chinook have been released into the Lemhi River at the Hayden Creek Research Station, but this facility is currently raising resident fish.

Irrigation

Although there have been improvements in equipment used in the flood irrigation process in recent years (primarily headgate structures), the basic techniques used by irrigators to divert water have remained the same for decades. Wing dams are usually constructed in the stream, thereby diverting water to the canal and subsequently into smaller laterals. The angle at which wing dams are constructed across the stream is highly variable. In many instances, the dams are constructed across the stream perpendicular to flow while others run upstream nearly parallel with the current. Some diversions have no wing dams at all. A variety of materials are used to build these structures including river gravel, rocks, timber, plastic sheeting and baled hay. A headgate structure normally controls the amount of water entering the canals from the parent stream.

Irrigation in the Salmon River drainage begins in April or May depending on rainfall, snowpack and individual water-user needs. Virtually all diversions are in use by mid-May. In general, irrigation continues until mid to late October depending on prevailing weather conditions. However, some ranchers maintain flow in ditches year-round for livestock.

The Present Screening Program

Fish screens are presently operated on about 200 of the 220 active irrigation diversions in the study area. Sixteen of the unscreened diversions are located on Carmen Creek. This tributary was originally screened but repeated dewatering apparently eliminated the anadromous

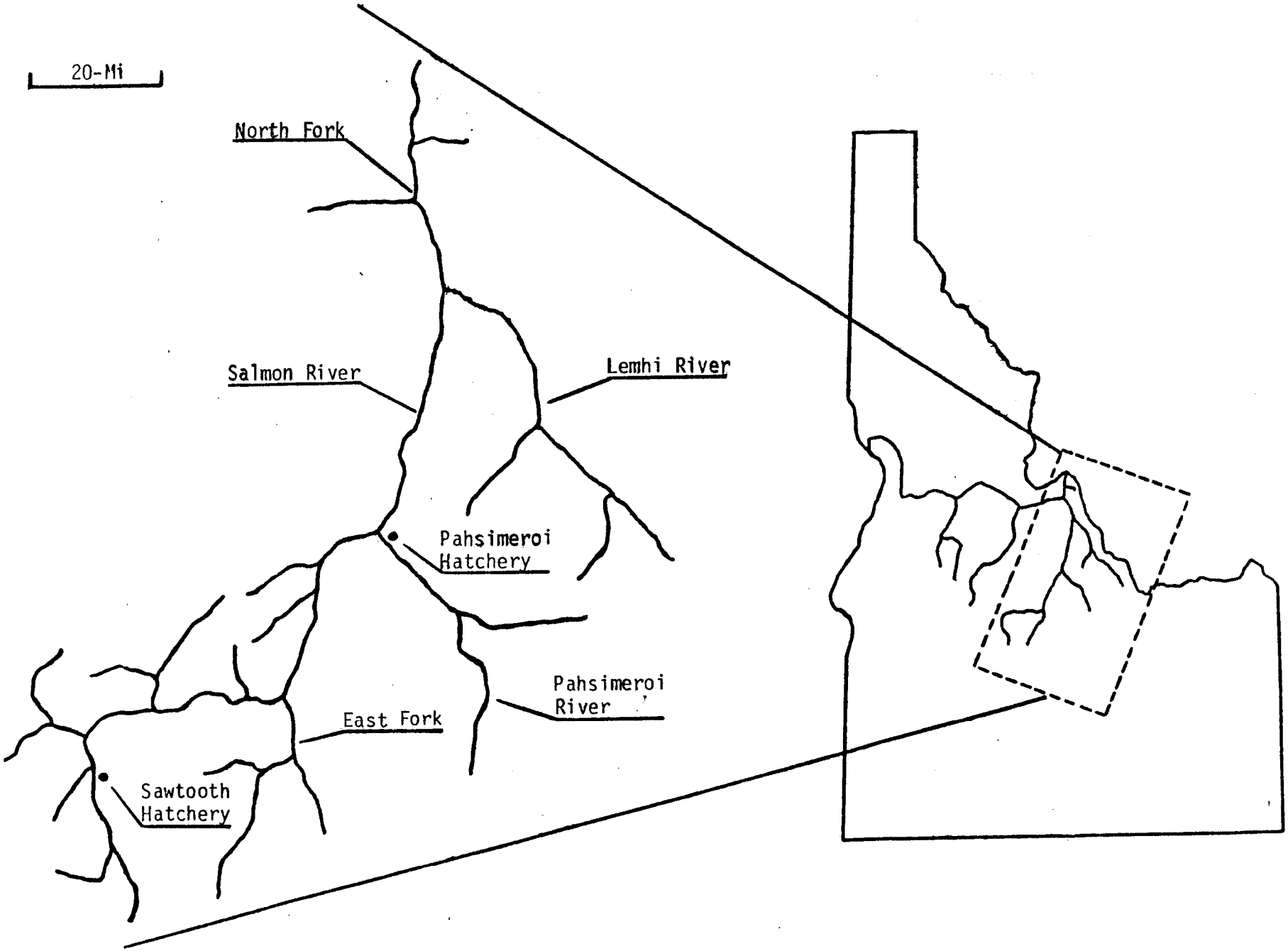

Figure 1. Location of study area on the Salmon River, Idaho.

fish runs (Kent Ball, pers. comm.). Nearly half of the active screens (88) are located in the Lemhi River system alone (Table 2). In general, diversions on the main Salmon River tend to be the largest while those on the North Fork are the smallest.

Table 2. Location of screened diversions in the Salmon River Basin, 1983.

Tributary	No. of diversions	Average size (cfs)[a]
Lemhi River	88	16.9
East Fork	25	10.9
North Fork	15	7.8
Pahsimeroi River	22	20.0
Main Salmon River	35	29.7
Miscellaneous	13	10.8

[a]Based on water permits:

Past Fish Screen Evaluations

The first detailed study of irrigation-related fish losses in the Salmon River drainage was completed in 1958 (Gebhards 1959). Electro-shockers, chemical treatment and Kray-Meekin traps were utilized to estimate losses of juvenile chinook salmon to irrigation diversions on the Lemhi River. The loss of juvenile outmigrants in 1958 was estimated at 422,000 fish and Gebhards suggested that a screening program could save over one million juvenile chinook during years of heavy outmigration.

The screen construction program became fully operational during 1959 and by January of 1960 there were 60 fish screens operating in the Salmon River drainage. A screen trapping evaluation was undertaken by Idaho Department of Fish and Game to assess the number of fish safely bypassed (Corley 1962). The trapping program was expanded in 1961 and 1962 as the number of completed screens increased. Juvenile chinook salmon were the most frequently captured game fish in all three study years (Table 3). The majority of chinook captured were young-of-the-year fish (55 and 81% in 1961 and 1962 respectively). Using 1962 trapping data and the average volume of water diverted per ditch, a mean of 0.65 salmon saved per cfs per day was calculated for all Lemhi River screens. This value, multiplied by the mean length of the irrigation season (days) and the average volume of Lemhi River flow diverted per day provided an estimate of 91,500 juvenile chinook bypassed by 84 screens in 1962 (Corley 1962). Using an identical

procedure, Corley estimated the number of chinook bypassed in 1961 at 279,000 fish.

Table 3. Numbers of game fish trapped at screen bypass pipes on Lemhi River diversions, 1960-1962 (Corley 1962).

Year	Chinook salmon Yearlings	Chinook salmon YOY	Trout[a]	Whitefish	Screens trapped	Total trap-days
1960	892	NR	147	190	8	557
1961	12,395	14,888	971	305	14	1,333
1962	2,940	12,327	651	1,120	17	1,760

[a]Includes rainbow trout and brook trout.

During 1966 and 1967 the Department of Fish and Game conducted a downstream marking program under contract to the U.S. Bureau of Commercial Fisheries. Juvenile chinook salmon and steelhead trout were collected at fish screens using bypass traps and all fish were marked with a freeze brand (Reingold 1967a). Marked fish were returned to the stream above the traps to obtain mark-recapture population estimates. Trapping was conducted at screens located on the Pahsimeroi River, East Fork Salmon and the main Salmon River during 1966 and 1967. The percentage of total downstream migrants bypassed by each screen was calculated (Table 4).

Between 1966 and 1971 hatchery steelhead were collected at a Pahsimeroi River irrigation screen (P-2&3). Fish were marked and released upstream to obtain estimates of total hatchery outmigrants produced by the Pahsimeroi Hatchery program (Reingold 1967b, 1971). An average of 2% of the total outmigration entered the P-2&3 diversion ditch between 1966 and 1971 but were screened and returned to the Pahsimeroi River (Table 5). The total number of hatchery steelhead trapped at the P-2&3 bypass within this time period was 61,857 fish.

In 1970 mark-recapture estimates were also conducted on screen P-5 for a brief time period. Between 4 and 20 May, 27,000 hatchery steelhead were captured at the screen (Reingold 1971). During that time period, the trap on P-2&3 collected approximately 3,500 fish. The operation of the P-5 trap ceased after May 20 due to excessive smolt injury and mortalities associated with trap crowding.

A single trapping evaluation has been conducted on the rotary drum type screens presently being constructed for use in the Salmon

Table 4. Numbers of chinook and steelhead juveniles trapped at bypass pipes of upper Salmon River irrigation screens (Reingold 1967), as summarized by Herrig (1983).

		Chinook			Steelhead		
Screen	Year	Est. no. captured	Est. no. migrants	% migrants captured	Est. no. captured	Est. no. migrants	% migrants captured
Salmon (S-14)	1966	11,016	1,572,000	0.7	141	---	---
Salmon (S-14)	1967	1,818	727,000	0.3	7	---	---
E. Fk. Salmon (E.F.-2)	1966	20,034	396,800	5.1	358	11,100	3.2
E. Fk. Salmon (E.F.-2)	1967	7,631	117,400	6.5	173	5,430	3.2
Pahsimeroi (P-2&3)	1966	3,963	150,000	2.6	544	20,500	2.7
Pahsimeroi (P-2&3)	1967	1,035	49,200	2.1	177	7,000	2.5
Averages		7,871	471,028	1.7	627[!"]	10,686	5.9

[a]Not including S-14 captures.

Table 5. The number of hatchery steelhead smolts bypassed at screen P-2&3 on the Pahsimeroi River (Reingold 1966-1971).

Year	Trap catches	Total estimated outmigration	% outmigrants screened[a]
1966	1,250	48,200	2.6
1967	15,859	931,900	1.7
1968	10,730	1,228,200	1.3
1969	7,637	598,700	1.4
1970	13,281	1,211,000	1.7
1971	13,100	---	3.0

[a]Includes rainbow trout and brook trout.

River drainage. In 1973 Idaho Department of Fish and Game personnel trapped the bypass pipe of S-32, a new drum screen constructed on the Salmon River in 1972 that replaced an existing perforated plate screen. The S-32 bypass pipe was trapped for a 64-day period between 26 June and 31 August. The 85,944 juvenile chinook salmon captured during the evaluation comprised 97% of all fish diverted by the screen (Table 6).

A final study documenting the loss of anadromous fish to unscreened diversions in the Salmon River drainage was conducted by the U.S. Forest Service in 1973 and 1974. Portions of two unscreened diversions in the Sawtooth National Recreation Area were sampled with electrofishing equipment to quantify losses of juvenile chinook salmon (Munther 1975). By assuming that fish densities in samples were representative of the entire ditch, Munther estimated total losses to the diversions. An estimated 1,440 and 1,820 juvenile chinook were diverted into the Brekenridge ditch (S-43) in July and August 1973 respectively. A Valley Creek diversion (VC-4) had monthly chinook losses of 1,020 in July and 2,070 in August.

Table 6. Number of fish trapped on the S-32 bypass pipe and returned to the Salmon River, 1973 (IF&G unpublished data).

Dates	Rainbow-steelhead[a]	Chinook fry & yearlings	Non-game fish
June 26-30	37	332	16
July 1-31	166	22,227	958
August 1-31	495	63,385	717
Total (64 days)	695	85,944	1,691

[a]May include small number of bull trout and cutthroat.

Operation and Maintenance Costs

Funds provided by NMFS are used for the operation, maintenance and replacement of screens when necessary. The O&M funds are not allocated on a per screen basis, but instead in a lump sum estimated to keep the entire program operating. Consequently, it is difficult to determine the O&M funds required to operate individual screens. Funds necessary to operate and maintain an average irrigation screen in recent years are presented in Table 7. All expenditures necessary to maintain the screening program are reflected in the cost/screen

average including employee salaries, benefits, travel and the replacement of deteriorating screens.

Table 7. Dollars expended on the Salmon River screening program, 1979-1983.

Year	Expenditures	Average expenditures per screen
1983	$239,000	$1,196
1982	210,329	1,051
1981	210,185	1,050
1980	193,570	968
1979	138,839	694

Screening Program Benefits

In order to assess benefits derived from the screening program, I estimated the dollar value of individual migrants screened. The net monetary value of escaping Columbia River chinook and steelhead spawners have recently been estimated at $550 and $350 per fish respectively (Koski 1982). I used these benefit estimates and the average smolt-to-adult survival rates of both species to calculate the average value of outmigrating smolts.

Since 1975, the average smolt-to-adult return rate for the Salmon River has been 0.8 and 0.6% for wild steelhead and chinook respectively (John Coon, Anadromous Fishery Manager, IF&G, pers. comm.). These return rates indicate that, on the average, 125 steelhead or 167 chinook salmon smolts are needed to return each adult spawner. Using Koski's net monetary values per adult, I estimated net monetary values of salmon and steelhead smolts at $3.30 and $2.87 per fish respectively. However, a large percentage of fish screened at diversions are fry (Corley 1962, Reingold 1967). I assumed 10% fry-to-smolt survival for chinook and 5% for steelhead. Using these survival rates, the estimated benefits from screening fry are $0.33 per chinook and $0.14 per steelhead.

The studies summarized previously constitute all the trapping information collected from the Salmon River screening program. The majority of the data was generated prior to 1967 and populations of chinook salmon and steel head have declined markedly since then. In order to use old trapping data in the estimation of chinook salmon screened in recent years, I used several variables I believed to be the most critical in determining the number of migrants screened; the total number of migrants available and stream discharge.

I used redd counts (Pollard 1983) as an index of total salmon outmigrants available in a given year. Because fish trapped at screens

include both fry and yearlings, I used the sum of redd counts from the two previous years to calculate this index value.

Screens on Oregon streams that have been trapped for a number of consecutive years consistently capture more migrants during low flow years than high ones (Adam Schumaker, Oregon Department of Fish and Wildlife, pers. comm.). A similar situation exists on Salmon River screens although the relationship has not been quantified. I used total flow in acre feet (U.S.G.S.) during the irrigation season (Apr-Sept) as the second major variable.

I used the following formula to estimate the number of salmon screened in recent years:

Estimated fish saved (year x) = original estimate of screened fish x ratio of redd counts between study years (RCI) x ratio of flow between study years.

The proportions were set up assuming that a reduction in redds or an increase in streamflow would result in a decrease in screened fish.

Estimates of fish screened on the Lemhi River during a recent year were calculated using trapping information (Corley 1962) and data from Table 8. I calculated these estimates using trapping data from both 1961 and 1962 to see if comparable results were obtained.

Example 1. Estimated chinook salmon screened in 1978 using 1961 trapping data:

$$\text{Fish screened (1978)} = 279{,}000 \times \frac{715}{1958} \times \frac{60{,}380}{103{,}600} = 59{,}379 \text{ migrants.}$$

Example 2. Estimated chinook salmon screened in 1978 using 1962 data:

$$\text{Fish screened (1978)} = 91{,}000 \times \frac{-715}{3305} \times \frac{105{,}980}{103{,}600} = 20{,}139 \text{ migrants.}$$

I conducted a similar procedure for an individual screen on the East Fork No. 2 diversion trapped by Reingold (1967). Flow data was not available for this stream so trapping data was adjusted using only the redd count index (RCI).

The following data and procedures were utilized:

Chinook salmon screened - 1966 - 20,034
1967 - 7,631

RCI 1966 - 980
RCI 1967 - 996
RCI 1980 - 126

Table 8. Chinook salmon redd count indices and irrigation season flow data on the Lemhi River for various outmigration years.

Year	RCI[a]	Apr-Sept streamflow (Acre-feet)
1961	1,958	60,380
1962	3,305	105,980
1978	715	103,600
1979	1,270	85,910
1980	950	141,870
1981	201	110,450
1982	289	123,660

[a]RCI for a given outmigration year is the sum of salmon redd counts (Pollard 1983) conducted in two previous years.

Salmon screened (1980) = original fish screened (1966 or 1967) x ratio of RCI between study years.

Example 3. Estimated salmon screened (1980) using Reingold's 1966 trapping data:

$$\text{Fish screened} = 20{,}034 \times \frac{126}{980} = 2{,}576.$$

Example 4. Estimated salmon screened (1980) using Reingold's 1967 trapping data.

$$\text{Fish screened} = 7{,}631 \times \frac{126}{996} = 965$$

Steelhead redd counts are not conducted in the upper Salmon River tributaries. As a result, it is not feasible to estimate the numbers of steelhead screened using similar techniques.

DISCUSSION

The sample calculations just presented indicate that adequate information does not exist to reliably estimate the number of fish screened at diversions. Estimates of fish screened in a given year varied substantially depending on the reference year used to provide trapping data, stream discharge and redd counts. The reason for the lack of precision in these estimates appears to be partly attributable to a number of additional variables that would affect the number of fish screened in any given year.

The length of the irrigation season varies between years as a result of prevailing weather conditions. In springs with abundant precipitation, many irrigators may not require irrigation water until early May, while in. warm dry springs, the majority of diversions begin operating in early April. These fluctuations have a substantial effect on the numbers of fish screened because a large percentage of smolts emigrate in the month of April. A similar situation exists in the fall when much of the pre-smolt movement may overlap the irrigation season depending on weather conditions.

Seasonal variations in streamflow or yearly variations in the period of peak outmigration could also influence the number of fish screened from year to year. For example, unusually low flows during the peak migration period would result in a higher percentage of migrants being screened than in a normal year. The use of streamflow data for the entire irrigation season may mask the effect of this variable because the total streamflow (acre-feet) may remain relatively constant between the two years.

A final factor that may play a major role in the number of fish screened per year is the survival rate of juvenile fish. Recent adult

salmon returns to the upper Salmon drainage have dwindled to about 10% of 1960-1965 levels (Pollard 1983). As a result of these declines, the survival rate of juveniles may have increased markedly since the early 1960's because of reductions in density-dependent mortalities. If increases in juvenile survival rates have occurred since years when large scale trapping was conducted, the use of redd counts as an index of juvenile migrants screened in recent years would result in under-estimates of screening benefits.

Each of these factors may explain errors involved in estimating the number of fish screened at diversions on a year-to-year basis using limited trapping data. However, problems also exist with some of the techniques used in the past to estimate numbers of fish trapped at diversions within a single year. For instance, the number of fish trapped per volume of flow diverted (fish/cfs) has been used by most previous investigators to estimate numbers of fish screened at untrapped diversions (Gebhards 1959, Corley 1962, Munther 1976). However, much of their data reveals that diversion flow is not, in itself, a consistent indicator of the number of fish trapped at screens. Several other factors appear to play a significant role in the number of migrants entering individual screens.

The location of the canal intake in relation to river flow is an important factor in determining the relative efficiency of screens in diverting migrants. Losses of legal-sized game fish on the West Gallatin River were almost three times as great for those canals with intakes located on river bends when compared to those originating from straight sections of the river (Spindler 1955). A similar situation exists on Lemhi River screens. Small diversions located on the outside of river bends often collect many more migrants than larger diversions with intakes on a straight portion of the river (Kent Ball, IF&G, pers. comm.).

Differences in wing dam structure affect the percentage of down-stream migrants entering diversions even if total flow rates are similar. Losses of game fish were twice as great at diversions possessing wing dams when compared to those lacking them completely (Spindler 1955). Gebhards (1959) noted that juvenile salmon captures on one diversion doubled after the extension of the wing dam across the entire river channel. Wing dams in the study area are constructed in a variety of shapes, sizes and angles to water flow. In addition, the need for wing dams and their size may vary between years depending on individual water user needs and stream discharge.

Wide variations in flow within individual diversions further complicate the use of fish/cfs in the estimation of fish losses. A common practice on small canals where only one irrigator is involved is to run water for about a week and then shut the canal off for a similar period of time. On larger canals, where a number of water users are involved, water flow is more constant but still varies considerably throughout the season.

The most critical information not available from past studies is the average number of times an individual fish may be screened on Salmon River tributaries. Until this type of data is collected, estimates of net dollar benefits attributable to the screening program are not feasible. For example, the estimate of fish screened on the Lemhi River in 1962 is actually an estimate of the total number of times salmon entered diversions, not the number of fish saved by the program. If a substantial number of salmon in the Lemhi River were screened more than once, the 1962 estimate of 279,000 fish bypassed does not reflect the total number of fish saved. Corley recognized this problem and attempted to estimate the frequency of screening for individually marked fish during the 1960 trapping season. However, this evaluation was unsuccessful, probably as a result of marked fish being lost in the numerous diversions where screen construction had not yet been completed.

Because migrants may be screened at more than one diversion, any benefit analysis should be conducted at the tributary level rather than on individual screens. A salmon or steelhead migrant is worth a given amount, regardless of how many times it is screened. If an individual fish is screened more than once, its value must be proportioned among each screen involved.

It is obvious that the existing data is inadequate to fully meet the objectives of this study, but several generalizations can be made concerning the value of the screening program. A total of $239,000 were spent on the screening program in 1982. I.f anadromous smolts are currently worth about $3.00 apiece, only 80,000 wild smolts need to be screened to offset the cost of the program. This averages out to 400 smolts per screen and ignores the benefits derived from screening fry.

While it is probably true that some small screens may not save 400 smolts per year, other larger screens certainly save enough fish to offset the majority of the total program's 0&M costs. For example, in 1973 screen S-32 screened a total of 85,000 chinook during two months generally considered to be a period when minimal downstream movement occurs. The total number of chinook screened by S-32 in 1973 may have exceeded 200,000 fish. If this screen saved only one-third as many chinook in 1982 and 40% were smolts, the net benefits derived from this screen would have been $101,200. This example assumes that fish screened at S-32 were not screened at other locations in the drainage and as a result, would probably be an overestimate of actual dollar benefits. Nonetheless, it demonstrates the capacity for several particularly effective screens to offset the cost of the entire screening program.

Net benefits derived from the screening program would be expected to increase in the future. Improvements in downstream dam passage would result in higher adult returns and a greater number of juveniles rearing in the tributaries. In addition, large increases in hatchery fish releases are anticipated. By 1990, approximately 6.7 million salmon and steelhead smolts will be released each year in the upper

Salmon River Basin, almost five times the current level. Combined fry releases of both species, presently numbering about 2 million, are expected to double in the same time period.

RECOMMENDATIONS

A substantial amount of information must be acquired before the relationship between screen operation and maintenance costs and benefits could be more adequately evaluated. I have divided the necessary data into five main topics and have provided suggestions and guidelines for future evaluations. Some of the data may be difficult and expensive to obtain, but I believe that each of the following types of data would be essential if a more thorough evaluation is desired.

Flow Data

The previous discussion concerning the variability of flow in irrigation diversions points to the need for detailed stream flow information in any fish screen assessment. Data collected must include both flow into the ditch and the stream channel immediately below the diversion. For those screens actually being trapped, flow data should be collected daily. A series of calibrated staff gauges would simplify this procedure. Similar data should be collected on untrapped diversions, but only as often as necessary to ensure a reasonably accurate mean diversion rate (% of stream discharge) for the entire irrigation season. Flow data and numbers trapped should be correlated daily to avoid masking trends through averaging.

Trapping

Trapping should be conducted on a representative sample of screens on a tributary using diversion size (% of stream flow diverted), type of screen and river configuration at the screen site as major factors in stratifying and selecting the screens to be trapped. The primary trapping data required is the % of total downstream migrants diverted at the various representative screens (i.e., the probability that an individual fish will be screened at a given diversion). Mark-recapture techniques similar to those of Reingold (1967) would be applicable. Recapture rates of chinook and steelhead should be considered separately to determine if screening is more beneficial to either of the two species. By stratifying the screens, the probability of fish entering untrapped diversions could be estimated more accurately than has been done in past studies. The likelihood of an outmigrant entering a single diversion while moving from one point to another on the stream could then be calculated by summing the probability values associated with the appropriate screens. The percentage of the

outmigrants that are "saved" by the screening program could then be calculated. This type of trapping program would require considerable manpower but would avoid the overestimation of screening benefits, particularly in heavily irrigated tributaries where an individual fish may be screened numerous times. Trapping should be conducted for several years to evaluate the effects of varying water years on the number of migrants saved by the program. An extensive trapping program, such as the one just described, would also permit an evaluation of mortality and the rate of descaling associated with screen passage.

Operation and Maintenance Costs

Assuming that the trapping program briefly outlined above would yield the desired information concerning the number of fish saved, a more accurate assessment of O&M costs per screen may be desirable. A representative group of screens could be selected based primarily on size and type (drum or perforated plate). A record of the following should be kept each day these screens are tended:

1. Routine maintenance including parts and labor.

2. Labor (time) involved in the removal of stream debris.

3. Condition of bypass pipe (clogged or open).

4. Operational condition of the screens; examples - tripgate down, no flow in ditch.

A coded form could easily be devised to simplify the recording and summarizing of this data. The average costs attributable to routine maintenance and labor (items 1 and 2) could then be calculated for each screen type. Other more general costs such as administrative overhead, screen tender transportation and engineer salaries would still have to be divided by the total number of screens to get an average per screen value. However, this type of procedure would result in more accurate estimation of O&M costs for various sized screens than is currently available. On the negative side, this procedure would cause O&M costs to be higher.

Migration Delay

Because smoltification is a physiological state that exists in salmon and steelhead for a limited period of time, significant delays in the downstream migration process may result in the reversion of actively migrating smolts to parr. Raymond (1979) suggested that delays in salmon and steelhead outmigration, caused by dam construction in the Columbia River Basin, are sufficient to cause residualism.

In 1980, there was an 89% increase in survival to Lower Granite Dam for hatchery steelhead smolts released at the mouth of the Lemhi River when compared to fish released 40 miles upstream (Ted Bjornn, Idaho Cooperative Fishery Research Unit, pers. comm.).

No information is currently available concerning the number of times migrants in the Salmon River are screened or the amount of time required for fish to exit through screen bypass pipes after entering diversions. The delay for downstream migrants may be particularly important in the Lemhi River where some individuals may be screened 20 times or more in low flow years.

The frequency in which smolts enter irrigation diversions could be estimated by placing individually marked fish at various locations along the river and noting their appearance in those screens trapped downstream. A substantial percentage of the total screens on a tributary would need to be trapped to obtain a reliable estimate. The major problem associated with this method would be the susceptability of smolts to handling and marking mortality. A rough estimate might be derived from probability data collected using the trapping techniques described previously.

The length of time needed for anadromous fish to enter and exit a typically screened diversion could be accomplished by placing marked groups of migrants immediately below the headgate structures of representative screens and trapping the bypass pipes. Only actively migrating fish should be used in this procedure to avoid an overestimation of delays. In addition to providing an estimate of migration delay per screen, this procedure would be useful in identifying screens where migrants are delayed for atypically long periods of time. Steps could then be taken to improve passage at "problem" screens if they do in fact exist.

Perforated-Plate vs Rotary-Drum Screens

Many of the above procedures would aid in a comparison between perforated-plate and rotary-drum screens in terms of O&M costs and screening success. The major problem associated with the older perforated-plate screens is debris buildup which occurs rapidly and requires frequent removal by screen tenders. Despite frequent cleaning, some of these screens continue to clog and the safety trip-gate opens allowing the passage of juveniles into the irrigation ditch. Clogging problems occur primarily in the spring and fall when stream debris and anadromous fish migration are a maximum (Kent Ball, IF&G; pers. comm.).

In contrast, rotary-drum screens require considerably less cleaning and fewer repairs. More importantly, the frequency of trip-gate activation is much lower and few migrants are lost during periods of heavy debris transport.

The problem involved in replacing old perforated-plate screens with more efficient drum screens is, of course, the initial construction costs. The differences in O&M costs and fish "savings" between the two types of screens needs to be quantified. It is conceivable that cummulative savings from lower O&M costs and a larger number of fish screened may justify the cost of new drum screen construction in a surprisingly short time period.

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