A FISHERIES EVALUATION OF THE WAPATO, SUNNYSIDE, AND TOPPENISH CREEK CANAL FISH SCREENING FACILITIES

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Annual Report

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PREFACE

The Bonneville Power Administration, the United States Bureau of Reclamation, and the Washington State Department of Ecology are funding the construction and evaluation of fish passage and protection facilities at irrigation and hydroelectric diversions in the Yakima River Basin, Washington State. This construction implements Section 903s (d) and 803 (b) of the Northwest Power Planning Council's 1984 and 1987 Columbia River Basin Fish and Wildlife Programs.[a] The programs provide offsite enhancement to compensate for fish and wildlife losses caused by hydroelectric development throughout the Columbia River Basin and address natural propagation of salmon to help mitigate the impact of irrigation in the Yakima River Basin.

The Wapato, Sunnyside, and Toppenish Creek Screens are three of the facilities in the basin. This report evaluates the effectiveness of the screens in intercepting and returning juvenile salmonids unharmed to the river from which they were diverted. Fish were released upstream of or within the screen facilities and captured in the diversion that transfers them back to the river. The screens safely divert fish from the canals to the river. Test fish were steelhead *Oncorhynchus mykiss* smolts; spring chinook salmon *O. tshawytscha* smolts; and fall chinook salmon fry. Evaluations were conducted during typical spring flows.

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[a]NPPC (Northwest Power Planning Council). 1984. Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council, Portland, Oregon.
NPPC (Northwest Power Planning Council). 1987. Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council, Portland, Oregon.

ACKNOWLEDGMENTS

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ABSTRACT

We evaluated the effectiveness of new screening facilities at the Toppenish Creek, Wapato, and Sunnyside canals in southcentral Washington State. Screen integrity tests indicated that fish released in front of the screens were prevented from entering the canal behind the screens. Screen efficiency estimates are 99% (±0.6%) for Toppenish Creek, 99% (±0.3%) for Wapato, and 98% (±0.5%) for Sunnyside. During 1987 at the Wapato Canal, we estimated screen efficiency was 97% (±1%).

We conducted descaling tests at the Toppenish Creek Screens. We estimated that 0.2% of steelhead *Oncorhynchus mykiss* smolts released during tests were descaled. None of the fish released through the fish return pipe were descaled.

We measured the time required for fish to move through the screen facilities. The time required for 50% of the

test fish to exit the Toppenish Creek Screen forebay was 4 to 9 h for rainbow trout fry and up to 39 h for steelhead smolts. The time for 50% of the test fish to exit the Wapato and Sunnyside screen forebays was less than 8 h. As with past studies, exit times varied with canal flow and species. After 39 h at Toppenish Creek, half the steelhead smolts were still in the forebay when canal flows were 20 cfs. At Sunnyside, half the chinook salmon fry exited the forebay in 1 h or less.

Methods used in 1988 were the same as those used at Sunnyside in 1985 and in subsequent years at Richland, Toppenish/Satus, and Wapato. The methods and previous results have been reviewed by the Washington State Department of Fisheries, U.S. Fish and Wildlife Service, National Marine Fisheries Service, Northwest Power Planning Council, and Yakima Indian Nation.

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INTRODUCTION

The Yakima River Basin historically has supported significant salmon runs. During the late 1800s, between 500,000 and 600,000 adult salmon and steelhead *Oncorhynchus* spp. returned yearly to the Yakima River and its tributaries (Bureau of Reclamation 1984). Salmon runs included several races: spring, summer, and fall chinook salmon *O. tshawytscha*, coho salmon *O. kisutch*, sockeye salmon *O. nerka*, and steelhead *O. mykiss*. Some runs are now extinct or are nearing extinction. In the early 1980s, spawning escapement averaged about 2000 salmonids (Bureau of Reclamation 1984). Today, there is no sockeye run in the Yakima River Basin, and in 1983 only 37 coho salmon passed the Prosser Diversion Dam (Hollowed 1984). Recent improvements in efforts to manage and enhance salmonid runs in the Yakima River increased the total spawning escapement to 5- to 10-thousand adults in the late 1980s (Fast et al. 1986).

Reduced numbers of salmonids returning to the Yakima River Basin reflect many factors. Spawning and rearing habitat is less because of reduced instream flow downstream from irrigation diversion dams. Ineffective fish passage facilities for adults and juveniles at diversion dams cause high mortality during migration. Additionally, many Yakima River fish are killed while passing hydroelectric dams on the mainstem Columbia River.

The Pacific Northwest Electric Power Planning and Conservation Act (Public Law 96-501) was passed to enable preparation and implementation of a regional Conservation and Electric Power Plan. The Northwest Power Planning Council, which administers the Plan, is charged with developing a program to protect and enhance fish and wildlife populations and to mitigate adverse effects from development, operation, and management of hydroelectric facilities.

The Yakima River Basin was selected as one site for enhancing salmon and steelhead runs. Under the Plan, the Bonneville Power Administration (BPA) and the Bureau of Reclamation (BR) fund the construction of fish passage and protection facilities at irrigation and hydroelectric diversions in the Yakima River Basin (Figure 1).

BPA also provides funds to the Yakima Indian Nation to increase production of spring chinook salmon in the Yakima River Basin.

Construction of the Wapato, Sunnyside, and Toppenish Creek Canal Fish Screening Facilities (Wapato, Sunnyside, and Toppenish Creek Screens) was completed in 1985, 1987, and 1988 respectively. During 1985, BPA asked the Pacific Northwest Laboratory (PNL) to evaluate the effectiveness of these diversion facilities in returning fish that had entered the canals to the river. The work plan for this study was designed to determine if diverted fish are safely and expeditiously returned to the river. Tests were conducted to 1) evaluate conditions or circumstances that affect fish survival as they pass through the screening facility; 2) determine if a screening facility provides conditions under which diverted fish may become more susceptible to predation; 3) evaluate whether fish are delayed at or upstream of the screening facilities; and 4) determine if fish pass through, around, or over rotary-drum screens and become trapped in the irrigation canal. Operating conditions at each facility vary, resulting in different conditions for bypassed or diverted fish. The work plan includes tests to determine the potential for adverse conditions resulting from changes in operating conditions.

This report covers work completed in 1988 by PNL fisheries staff at the Wapato, Sunnyside, and Toppenish Creek Screens. The report describes each screen facility, methods used to evaluate screen effectiveness, and test results. Our findings are discussed and compared with those from previous tests at the Sunnyside Screens (Neitzel et al. 1985), the Richland and Toppenish/Satus Screens (Neitzel et al. 1987), and the Richland and Wapato screens (Neitzel et al. 1988).

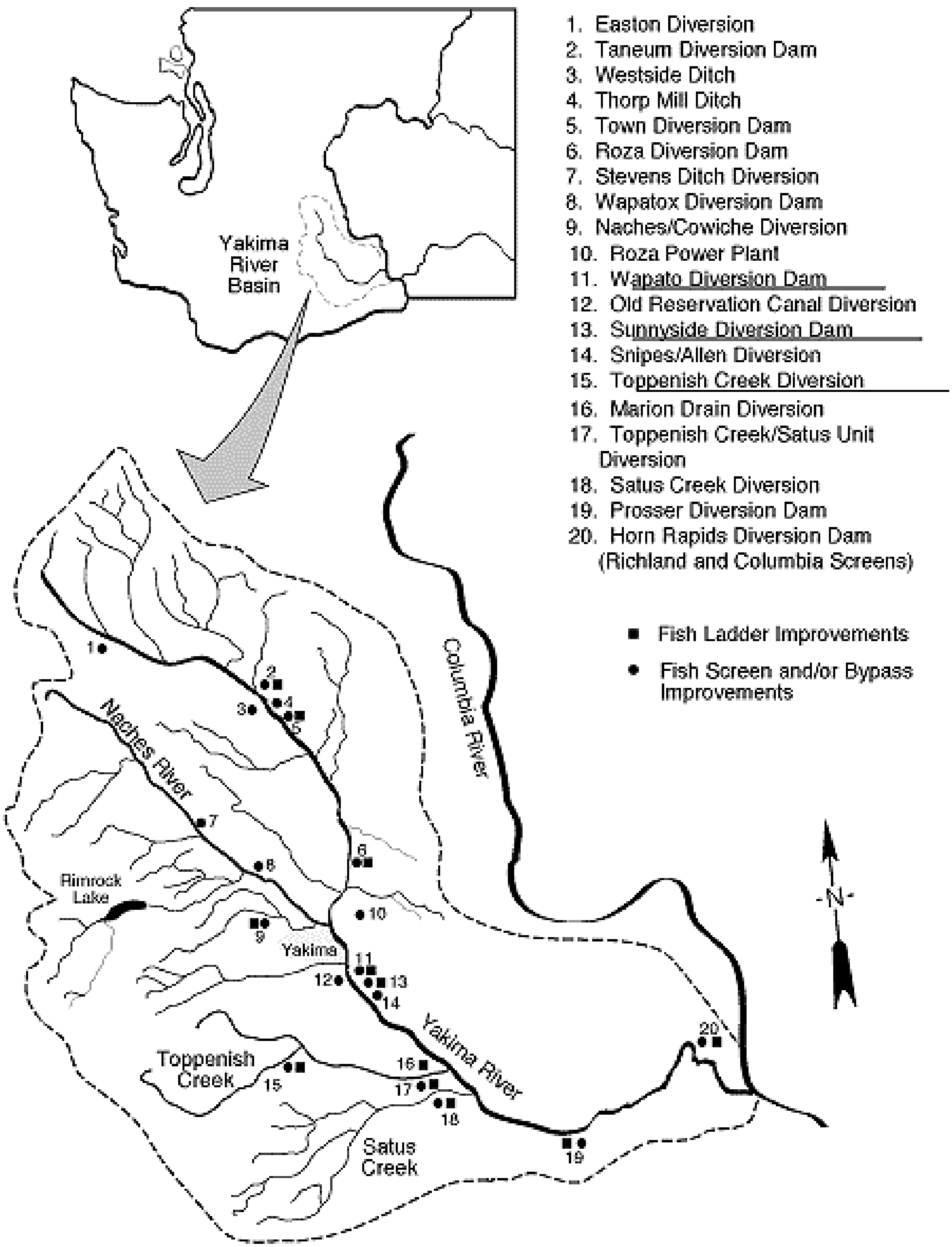

Figure 1. Yakima River Basin Showing Locations of the Toppenish Creek, Wapato, and Sunnyside Canal Fish Screening Facilities and Other Fish Protection and Passage Facilities

METHODS

Two types of studies were conducted in 1988: descaling tests at Toppenish Creek, and screen integrity tests, at Toppenish Creek, Wapato, and Sunnyside. In descaling tests, fish were released upstream of the screen facility and captured at the terminus of the fish bypass slot or released at the head of the fish return pipe and captured at the terminus of the pipe. Some fish were held for post-test observation. Native salmonids entering the diversion canal were also monitored during release/capture tests. In screen integrity tests, fish were released both in front of and behind the screens. Fish were recaptured as they appeared in the fish return or in fyke nets mounted behind the drum screens.

TEST FISH

The species selected for testing were recommended by fisheries biologists from the Washington State Department of Fisheries (WDF), the U.S. Fish and Wildlife Service (USFWS), and the Yakima Indian Nation. Species selection was based on the potential for a specific salmonid population encountering a screening facility during their rearing and outmigration. Selection was dependent on the species, race, and size of salmonids occurring in the Yakima River drainage upstream of each diversion.

Steelhead and resident rainbow trout use the Yakima River and its tributaries, including Toppenish Creek. Spring chinook salmon use the Yakima River and some of the tributaries above the Wapato and Sunnyside diversions. Fall chinook salmon, which now spawn only downstream of the Wapato Diversion, may use upriver areas as the population builds. Additionally, fall chinook salmon are currently reared in net pens in the Wapato Screen forebay. These fish are released as fingerlings in front of the screens.

Steelhead smolts were selected to evaluate descaling and rainbow trout fry (less than 50 mm) were chosen to evaluate screen integrity at the Toppenish Creek Screens. Fall chinook salmon fry (less than 60 mm) were selected for screen integrity tests at the Wapato and Sunnyside Screens.

Steelhead

Yearling steelhead were obtained from the Washington Department of Wildlife Lyon's Ferry Hatchery. Wells-strain steelhead were hatched, reared, and adipose fin-clipped at the hatchery prior to acquisition. Fish weighing about 15 fish/kg (6 to 8 fish/lb) were transferred to PNL on March 8, 1988. The fish were acclimated outdoors in fiberglass circular tanks supplied with a mixture of Columbia River and well water at 10 degrees C. Fish were cold-branded using stainless steel rods cooled by liquid nitrogen. Fish were acclimated to temperatures expected at Toppenish Creek at least 1 week before release.

Rainbow Trout

Rainbow trout fry used in the Toppenish Creek integrity tests were obtained from PNL-brood stock spawned in November 1987. Eggs were hatched in vertical-flow incubators supplied with 10 degrees C well water. Fry were transferred to troughs and reared at 10 degrees C until testing. Rainbow trout fry averaged 47.3 mm (2 in.) fork length (FL) and weighed 1.3 g (350 fish/lb) when tested.

Fall Chinook Salmon

Fall chinook salmon eyed eggs were obtained from the Bonneville Hatchery, operated by the Oregon

Department of Fish and Wildlife. Eggs were spawned at the WDF's Priest Rapids Hatchery near Mattawa, Washington, reared to the eyed stage at the Willamette Hatchery, and transferred as eyed eggs to the Bonneville Hatchery. Eggs were transferred to PNL on January 22, 1988. The eggs were hatched in vertical-flow incubators supplied with 10 degrees C well water. Fry were transferred to troughs and reared at 10 degrees C until used for screen integrity tests at Wapato and Sunnyside. Fry weighed 830 fish/kg (375 fish/lb) and measured 49 mm (2 in.) FL at testing.

SAMPLING EQUPIMENT

Fish were captured either within the screening facility, at the terminus of the primary fish-return pipe, or in the canal behind the screens, based on the test objective. Inclined planes were custom-built to fit the fish bypass structures at each site. A seine, dip nets, and an electroshocker were used to collect fish at the terminus of the Toppenish Creek fish return pipe. Fyke nets mounted in stoplog slots behind the rotary-drum screens were used to collect fish behind the screens. Temporary fish holding facilities were installed at each test site to acclimate test fish.

Inclined Plane

Fish were captured with an inclined plane in the fish return between the last rotary-drum screen and the head of the fish return pipe. The inclined plane at the Toppenish Creek Screens (Figure 6) was 1.9 m (6.3 ft) long and 0.9 m (3.0 ft) wide. The front face of the plane was hinged so that the slope of the plane could be changed to adjust the flow of water reaching the fish live box. Solid walls, tapering from 0.9 m (3 ft) at the entrance to 0.3 m (1.0 ft) at the live box, acted as splash guards to reduce fish loss from the plane. The live box [0.36 m (1.2 ft) long by 0.9 m (2.5 ft) wide, 100 L (26 gal) volume] was fastened at the end of the inclined plane. The inclined plane had an aluminum frame covered with a perforated aluminum sheet [0.32-cm- (1/8-in.-) diameter holes, staggered centers, 40% open]. Flow was directed over the plane by inserting dam boards in the upstream stoplog slot in the fish bypass slot. The height of the dam boards relative to the water depth determined the water volume through the fish bypass.

The inclined plane used at Wapato captured fish in the primary fish return downstream of Gate 4 at the terminus of the fish return slot (Neitzel et al, 1987). The plane was 1.5 m (5 ft) wide and 2.13 m (7 ft) long. The surface of the plane was covered with a perforated aluminum sheet [0.32-cm (1/8-in.) holes, 40% open]. A live box [0.3 m (1 ft) long by 0.61 m (2 ft) wide and 0.46 m (1.5 ft) deep] with a volume of 85 L (22 gal) was attached to the end of the plane. Aluminum walls [0.6 m (2 ft) high] were welded to the edges of the plane, and the corners of the plane surface were elevated 0.3 m (1 ft) to help guide the fish toward the live box. The volume of water entering the plane was controlled by stop-logging at Gate 4. Bureau of Reclamation personnel set Gate 4 to the specifications outlined in the operating criteria (Appendix C) before each test.

The inclined plane used at Sunnyside was similar to that used at Toppenish Creek, having a hinged front face and solid-metal splash guards. The plane was built to fit in the primary fish-return slot and was 0.56 m (1.8 ft) wide, 3.0 m (9.8 ft) long. A live box (0.3 m long, 0.56 m wide, and 0.3 m deep with a volume of 50 L) was attached to the end of the plane. The plane had an aluminum frame covered with a perforated aluminum sheet [0.32 cm- (1/8-in.-) diameter holes, staggered centers, 40% open]. Flow was directed over the plane by inserting dam boards in the upstream stoplog slot in the fish bypass slot.

Inclined planes were lowered into position with hand hoists. The perforated plates were brushed periodically to prevent clogging by vegetation and debris because clogging restricted the plane's ability to filter water and separate fish from the bypass water.

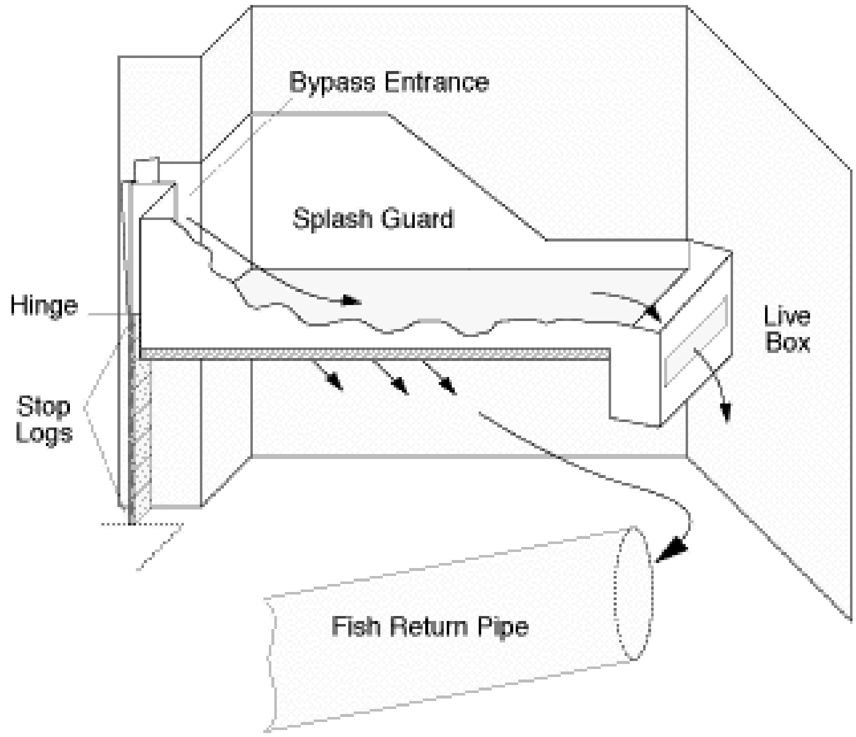

Figure 6. Inclined Plane Used at the Toppenish Creek Canal Fish Screening Facility, Spring 1988

Fyke Net

Fyke nets were used to capture fish in integrity tests at all sites. At Toppenish Creek, one net was placed behind each drum screen. The nets were 3.8 m (12.5 ft) wide and 1.2 m (4 ft) deep. Tops of the nets were above the waterline, and bottoms of the nets settled into the mud on the canal floor. The net tapered over a length of 2.4 m (8 ft) from a 12.5 by 4 ft mouth down to a 0.6 m- (2 ft-) square cod-end net. The cod-end net was 1.8 m (6 ft) long, resulting in an overall length of 4.3 m (14 ft). The cod-end net was tied shut with a rope. Fish and trash were removed from the cod-end of the nets without lifting the net mouths from the water.

Six fyke nets were used in the Wapato Canal screen integrity tests. Because of the screen width at Wapato, two nets were required behind one screen. The nets were fished immediately downstream of three selected screens during a test. The nets were 3.65 m (12 ft) square. Tops of the nets were above the waterline, and net bottoms settled into the mud on the canal floor. Nets tapered from a 3.65-m- (12-ft-) square mouth to a 1.22-m (4-ft) square over a distance of 6.1 m (20 ft). The 1.22-m- (4-ft-) square sock extended back another 6.1 m (20 ft) to make the total length of the net 12.2 m (40 ft). A zipper was installed near the end of the sock to facilitate fish removal. Net frames were raised from the water to recover fish in the nets.

Eight fyke nets were used at Sunnyside. Nets were fished immediately downstream of four selected screens during testing. Two nets, one fishing the upper one-third and one fishing the lower two-thirds of the water column, were used behind each of the four screens (Figure 7).

Two nets per screen were used because of the location of the intermediate fish bypass pipe behind the screens. The mouth of the top net was 3.7 m (12.2 ft) wide and 1.5 m (5 ft) deep, and the mouth of the bottom net was 3.7 m (12.2 ft) wide and 2.8 m (9.0 ft) deep. Both nets were 9.1 m (30 ft) long. The nets tapered from the mouth dimensions to a 0.6 m- (2 ft-) square cod-end net over a length of 6.1 m (20 ft). The cod-end nets were 3.0 m (10 ft) long and were tied shut. Each pair of net frames were bolted together to prevent fish from passing between the nets. Net frames were raised from the water to recover fish in the nets.

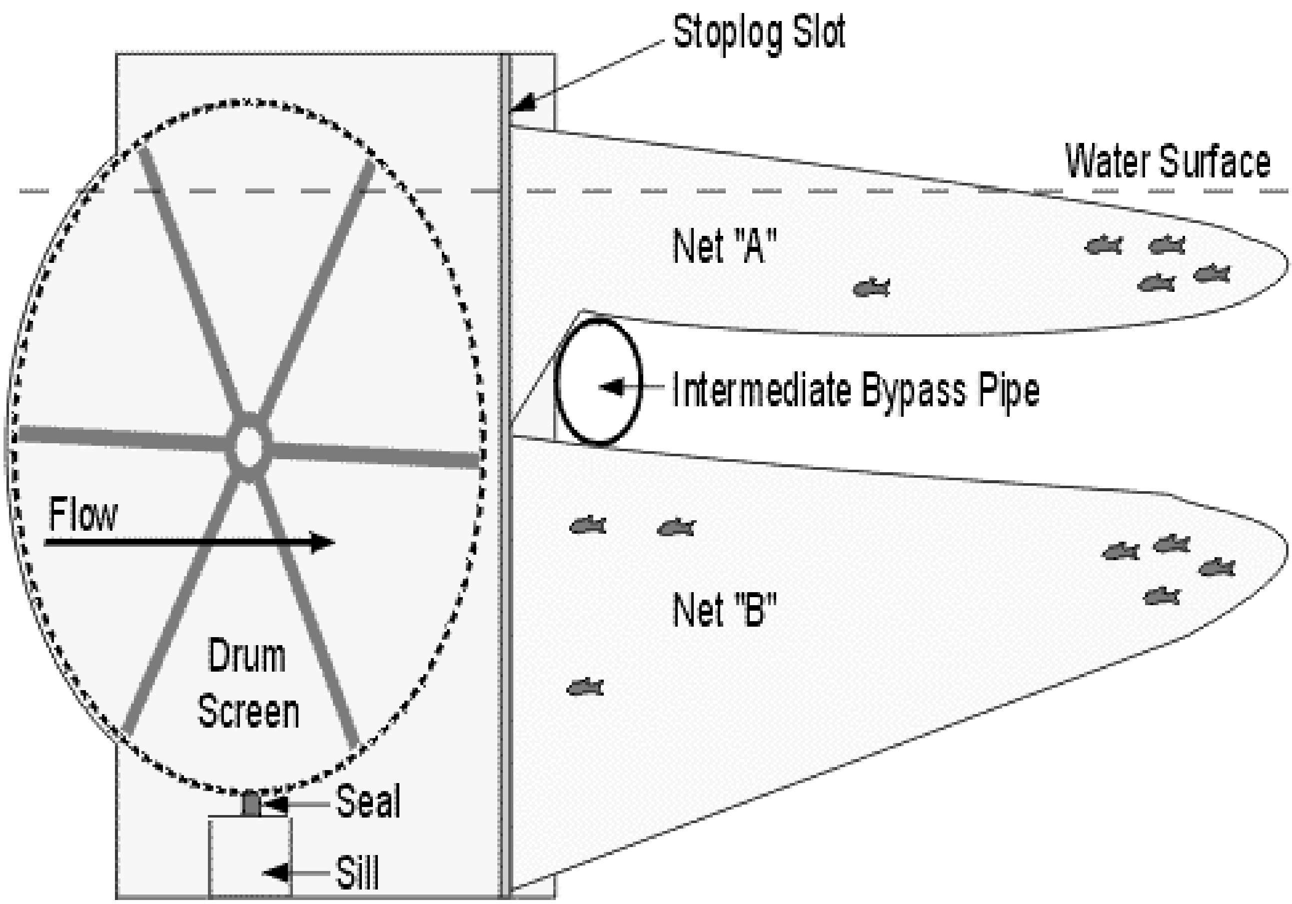

Figure 7. Fyke Nets Used in Integrity Tests at the Sunnyside Screens, Spring 1988

Electrofishing

At the Toppenish Creek Screens, an alternator and gas-powered generator were used to electrically stun fish. Stunned fish were collected with a beach seine at the terminus of the fish return pipe. The shocker probes were placed near the end of the pipe, and the seine was used to confine stunned fish until they could be captured by dip net.

Holding Facilities

Temporary facilities were installed to hold fish during descaling evaluation and to retain some fish for 96 h after capture. A mobile laboratory containing three fiberglass troughs [3 m (10 ft) long by 0.56 m (1.8 ft) wide, 0.25 m (0.8 ft) deep, and 540 L (140 gal) in volume] , and two fiberglass circular tanks [1.22 m (4 ft) in diameter by 0.6 m (2 ft) deep] were installed at each site. All tanks were supplied with canal water pumped from behind the screens. The mobile lab was equipped with fluorescent lighting to evaluate fish captured during both the day and night for descaling under similar light conditions.

DESCALING EVALUATION

The evaluation system developed by the U.S. Army Corps of Engineers (Basham et al. 1982) was used to monitor the condition of fish. Evaluation criteria included modifications established in 1985 (Neitzel et al. 1985). Baseline descaling condition was determined by randomly sampling groups of test fish before release. Descaling was evaluated in each of 10 areas, 5 on each side of the fish. When 40% or more scale loss was observed in any 2 areas on one side of a fish, the fish was classified as descaled.

TEST PROCEDURE

Descaling evaluations at the Toppenish Creek Screens involved introducing branded steelhead at the trash rack and capturing the fish when they appeared on the inclined plane in the primary fish return (Phase IIa, Appendix A). Tests were conducted in late March. Tests were initiated under low canal flow conditions. Flows were increased to maximum flows during the tests (Phase III, Appendix A). Fish were also released at the head of the fish return pipe and captured at the end in tests to evaluate effects of passage through the pipe (Phase IIb, Appendix A). Native salmonids were monitored during tests at the Toppenish Creek Screens (Phase IVa, Appendix A).

Screen integrity was evaluated at the Toppenish Creek, Wapato, and Sunnyside Screens by releasing branded rainbow trout or fall chinook salmon in front of and behind the rotary screens (Phase IVb, Appendix A). Fish were collected as they appeared either on the inclined plane in the fish return or in fyke nets placed in the canal behind the screens.

Test Stock Identification

Steelhead, rainbow trout, and fall chinook salmon were cold branded to identify specific test groups. Fish were marked in one of three locations: right anterior, left anterior, or right dorsal. Brands were applied at least 1 week before release. Brands were approved by the National Marine Fisheries Service (NMFS) and were distinguishable from all other brands used in the Columbia River Basin.

Fish Transport and Release

Test fish were transported at acclimation temperature in an insulated tank [400 L (125 gal) in volume] supplied with oxygen. Transit times from PNL to the Toppenish Creek and Wapato or Sunnyside Screens were 2.0 h and 1.3 h, respectively. Loading densities did not exceed 120 g of fish/L (1 lb/gal). Water temperature in the transporter changed less than 1 degree C during transit. Test fish were netted from the transporter and placed in holding tanks at the facility for acclimation before release. There were no losses attributable to transporting stress.

Fish Release Locations

For descaling evaluation, test fish were released uniformly across the canal downstream of the trash rack at the Toppenish Creek. To evaluate the fish return pipe at Toppenish Creek, fish were released into the head-end of the pipe. Fish used in screen integrity tests were released in two locations. At Toppenish Creek, fish were released just upstream of the first rotary screen near the structure wall and uniformly across the mouth of the fyke nets positioned on the downstream side of the rotary screens. At Wapato and Sunnyside, fish were released in three locations: next to the concrete piers just upstream of the screens, in the fish bypass below each set of screens, and in fyke nets behind the screens.

Release Controls

Baseline condition of test fish was estimated by sampling each group before release at the Toppenish Creek Screens. Baseline-condition evaluations were conducted inside the mobile laboratory under artificial light. For Phase IIa tests, 210 fish were sampled for baseline condition and 755 fish were released into the Toppenish Creek Canal.

Fish Capture and Evaluation

Fish captured during Phase IIa tests were dip-netted from the live box of the inclined plane and placed in a holding tank before evaluation. Evaluations were made at half-hour intervals. Fish were anesthetized in MS-222, examined to determine the extent of scale loss, and returned to a holding tank. About 150 of the test fish were held 96 h to monitor delayed mortality. After fish recovered from the anesthetic, they were released to the creek or river via the fish return pipe.

Fish were captured by electroshocker and beach seine in Phase IIb tests at the Toppenish Creek Screens. Fish were dipnetted from the seine quickly to reduce damage caused by turbulence in Toppenish Creek. Fish were anesthetized with MS-222, examined, held in a bucket until they had recovered from the anesthetic, and then were released into the creek.

Fish captured in Phase IVb tests were not evaluated for descaling. The purpose of Phase IVb tests was to determine the effectiveness of screening facilities in preventing fish from entering the canal behind the screens and to monitor the rate at which fish moved through the fish bypass. Fish were identified by brand group and enumerated as they appeared on the inclined plane in the fish return. The brands identified when and where fish were released within the screening facility.

In tests at Toppenish Creek, the inclined plane was fished up to 41 h after fish were released. Groups of fish were released both in front of and behind the screens at three different times: early afternoon, late afternoon, and evening. The fyke nets were left in place throughout the Phase IVb tests. Nets were cleaned and the fish were retrieved from the cod-end of the nets several times each day.

STATISTICAL ANALYSIS

The amount of time for test fish to move from their release point to the inclined plane is estimated by the hours required to capture 50% of a test group. Capture efficiency of the inclined plane and the fyke nets used for screen integrity tests are estimated from the number of fish captured during a test. These data are used to estimate the efficiency of the screen in preventing fish from passing from the screen forebay to the canal downstream of the screens.

Descaling and Mortality Estimates

Estimates of the percent of fish descaled or killed were based on the number of test fish caught. Descaled fish were considered dead in evaluating results. The lower and upper confidence intervals, LCI and UCI, respectively, are estimated by

$$LCI = \frac{B}{B+(n-B+1)F}$$

and

$$UCI = 1 - \frac{n-B}{n-B[n-(n-B)+1]F}$$

where B equals the number of dead or descaled fish, n equals the number of fish caught, and F equals a ratio of the estimates for the mean and individual sample variances. The estimates were calculated from Mainland's Tables (Mainland et al. 1956).

Data for replicate tests were combined to obtain a mean estimate. The estimate assumes each fish behaved independently (i.e., fish within a test did not behave more similarly than did fish between tests and there were no interactions among fish within a test). Although some interaction among fish is expected, it is an assumption necessary for the analytical methods used. All tests were conducted in the same manner to reduce nonindependent behavior.

Screen Efficiency Estimates

The number of screens and bypass systems are different at the three facilities tested. Therefore, the number of nets and the computation of screen efficiency varied. For Toppenish Creek, which has three screens, screen efficiencies were computed for each screen and for the entire facility. The 15 rotary-drum screens at the Wapato Screens are divided into three sections of five screens each separated by intermediate wing walls and bypass pipes. Screen efficiency estimates were computed for each of the screen sections in addition to an overall estimate. The 17 rotary-drum screens at Sunnyside are divided into 2 sections of eight and nine screens, separated by an intermediate wing wall.

At Toppenish Creek, three tests with three groups of fish were conducted. Fyke nets were placed behind each screen for each test. Four screen efficiency tests were performed at Wapato. The first involved all three screen sections, specifically screens 5, 10, and 15; the second, Section 3, screens 13, 14, and 15; the third test, Section 1, screens 3, 4, and 5; and the fourth, Section 3, screen 15. Although the method for estimating each section and the system is the same, input data are different in each case.

Three quantities must be computed to estimate screen efficiency. These are inclined plane efficiency (EFF_{ip}), net capture efficiency (EFFnc), and net retention efficiency (EFF_{nr}). Net retention is assumed to equal net efficiency at some sites, in which case net retention equals 1. Given these quantities, the formula for computating screen efficiency (EFF_{sc}) is

$$EFF_{sc} = 1 - \frac{X_{net}}{EFF_{nc} EFF_{nr} N}$$

where X_{net} equals the number of fish released upstream of the screens and caught in the nets and N is defined as follows:

$$N = \frac{X_{net}}{EFF_{nc} EFF_{nr}} + \frac{X_{ip}}{EFF_{ip}}$$

where X_{ip} equals the number of fish released upstream of the screens and caught in the inclined plane. N represents the total number of fish released into the section being estimated. For some estimates and the overall estimate, after the efficiencies (EFF_{ip}, EFFnc, and EFF_{nr}) have been considered, some fish are still not accounted for. To avoid making assumptions about what might have happened to these, an effective N has been computed that is smaller than the actual number released. Thus, N is not an actual accounting of all fish caught in different locations (inclined plane, fyke nets, bypass) but an estimate based on the actual numbers, adjusted by efficiencies for net losses and human error.

Efficiencies per set must also be defined. Input data for each section are as explained, combining across relevant tests. The general forms are

$$EFF_{ip} = \frac{n_{ip}}{N_{ip}} \qquad EFF_{nc} = \frac{n_{nc}}{N_{nc}} \qquad EFF_{nr} = \frac{n_{nr}}{N_{nr}}$$

where n_{ip} is the number of fish released in the bypass and caught in the inclined plane for the section estimated, N_{ip} is the number released in the bypass, n_{nc} is the number released in the net mouth and caught in the net, N_{nc} is the number released in the net mouth, n_{nr} is the number that remaining in the cod-end, and N_{nr} is the number originally placed in the net cod end.

For overall efficiencies, individual section efficiencies cannot be simply averaged; rather, the efficiency is computed by combining all data. Averaging the separate sections would assume equal numbers were released in each test and weight them as such. By computing the overall estimates from all data lumped as one test, the varying N values are incorporated and differences in test size are compensated.

The confidence intervals were computed using the standard normal-approximation method (Mood et al. 1974). For a 95% confidence interval, the following equation is used:

$$P\left[EFF_{sc} - 1.96\sqrt{var(EFF_{sc})} \le true\,[EFF_{sc}] \le EFF_{sc} + 1.96\sqrt{var(EFF_{sc})}\right] = .95$$

Here EFF_{sc} indicates our estimate while true [EFF_{sc}] indicates the true or actual value of screen efficiency. EFF_{sc} is a binomial proportion, and the form for its variance is EFF_{sc} (1-EFF_{sc})/N. However, because we used efficiencies (EFF_{ip}, EFFnc, EFF_{nr}) in the computation of EFF_{sc} with their own inherent errors, these errors must be propagated and incorporated into the variance of EFF_{sc}. If $EFFncr_{ncr}$ is defined to be the combined catch-and-retain efficiency (EFFnc x EFF_{nr}), then the variance of EFF_{sc} is

$$\mathrm{var}\left[\mathrm{EFF}_{sc}\right] = \left(\frac{\partial \mathrm{EFF}_{sc}}{\partial \mathrm{EFF}_{ncr}}\right)^2 \mathrm{var}\left[\mathrm{EFF}_{ncr}\right] + \left(\frac{\partial \mathrm{EFF}_{sc}}{\partial \mathrm{EFF}_{ip}}\right)^2 \mathrm{var}\left[\mathrm{EFF}_{ip}\right] + \left(\frac{\partial \mathrm{EFF}_{sc}}{\partial X_{net}}\right)^2 \mathrm{var}\left[X_{net}\right]$$

where all variables are as previously defined. This formula is the first term of a Taylor's series expansion (Holman 1971). Second and higher-order effects have been neglected. We assumed that EFF_{ip}, $EFFncr_{ncr}$, and X_{net} are independent of each other, which is reasonable in this case.

The variances of EFF_{ip} and $EFFncr_{ncr}$ were computed by assuming them to be binomial proportions and using the appropriate N for the section in the EFF(1-EFF)/N formula as stated above. In the case of $EFFncr_{ncr}$, variances were computed individually for EFFnc and EFF_{nr} and propagated throughout. The variable X_{net}, the number of fish caught in the nets from those that were released upstream of the screens, is distributed binomial (N,EFF_{sc}), making its variance equal to N[EFF_{sc} (1-EFF_{sc})].

RESULTS

At Toppenish Creek, fish that passed through the bypass system were not descaled or killed, and moved out of the forebay of their own volition. The angled rotary-drum screen design at Toppenish Creek, Wapato, and Sunnyside prevented most fish from entering the canal downstream of the screens. Improperly installed or maintained side and bottom seals will allow fish to swim through the screen facility.

PHASE I TESTS

Phase I tests were designed to evaluate components within the fish diversion system other than the rotary drum screens. The Toppenish Creek fish bypass system contains no structures other than the drum screens; therefore, no Phase I tests were conducted. Phase I tests were conducted at Sunnyside during 1985 (Neitzel et al. 1985). Phase I tests have not been conducted at Wapato (Neitzel et al. 1988) because fish are not descaled as they move from the trash racks to the fish return pipe.

PHASE II TESTS

Phase II tests evaluate the effects on fish of either the entire fish bypass system from the trash racks through the fish return pipe (Phase IIa) or specific components of the fish return system (Phase IIb). During 1988 we conducted Phase IIa and IIb tests at Toppenish Creek. Phase II tests were completed at Sunnyside in 1985 (Neitzel et al. 1985) and at Wapato in 1987 (Neitzel et al. 1988). At Toppenish Creek, we released fish at the trash racks and captured them before they entered the fish return pipe. In addition to evaluating fish descaling and mortality, we estimated how long released fish remained in the Toppenish Creek screen forebay. We also tested the potential effects of passage through the fish return pipe.

Phase IIa

Tests at the Toppenish Creek Screens were conducted in late March. Three groups of branded steelhead smolts were released behind the trash racks, one group of 250 fish was released during low canal flow (20 cfs), and groups of 255 and 250 fish were released during full canal flow (50 cfs). Of 250 steelhead planted during low canal flow, 144 (58%) were captured on the inclined plane in the fish return during the next 72 h. The plane was not fished for 2 h during the day following the low flow release because the inclined plane became plugged with detritus when the canal flow was changed from 20 to 50 cfs. Of 505 steelhead released during full canal flow, 395 (78%) were caught during the following 48 h. A total of 539 test fish were examined for descaling; only one fish (0.2%) was descaled (Table 1). This rate was within the 95% confidence interval for the condition controls. None of the 143 fish held for 96 h died.

Downstream movement of steelhead released for descaling evaluations was monitored each half-hour as the fish appeared on our sampling plane in the fish return. The rate and percent recovery for steelhead (Figure 8 and Table 2) indicate that salmonid smolts are not flushed from the Toppenish Creek screen forebay; rather, they move through the screen forebay of their own volition. The recovery rate was lower for steelhead released during low canal flow.

TABLE 1. Descaling and Mortality Data from Release and Capture Tests with Steelhead *Oncorhynchus mykiss* Smolts at the Toppenish Creek Fish Screening Facility, Spring 1988

Canal Flow (cfs)	Number				Percent		95% Confidence
	Released	Captured	Descaled	Dead	Captured	Descaled	Interval
20	250	144	0	0	57.6	0.00	0-2
50	255	199	1	0	78.0	0.50	0-3
50	250	196	0	0	78.4	0.00	0-2
Total	755	539	1	0	71.4	0.19	0-1
Wild Fish		462	1	0	-	0.22	0-1

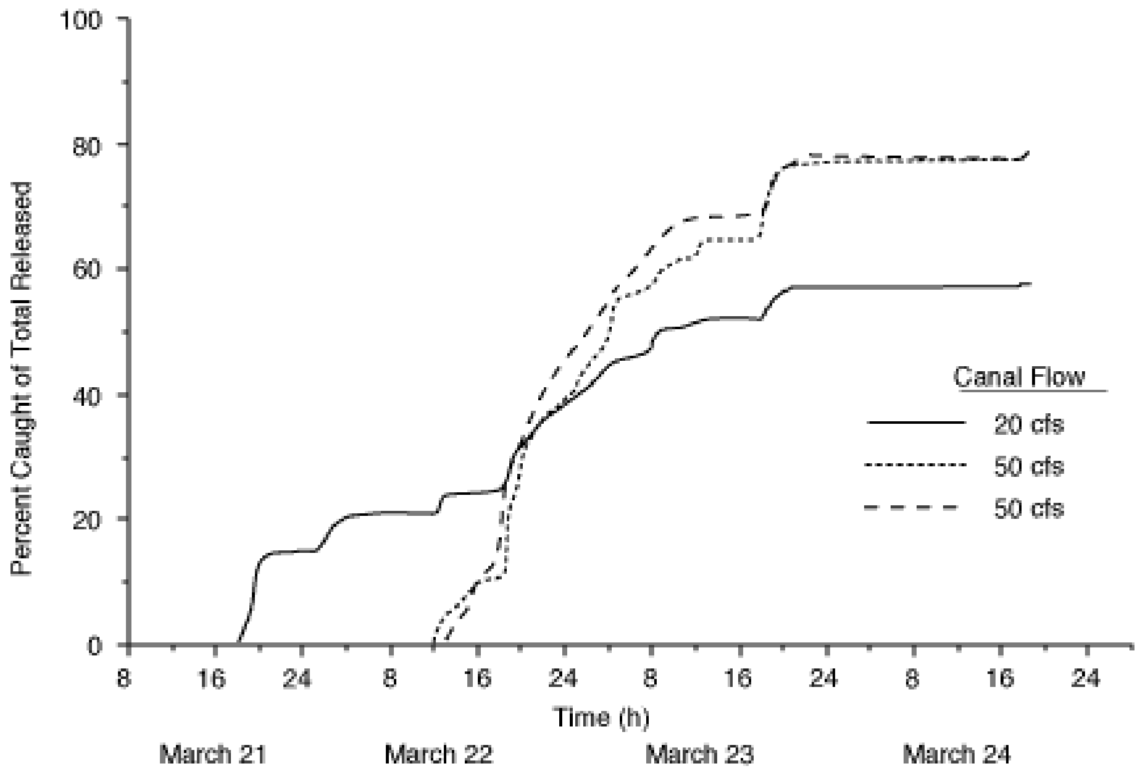

Figure 8. Movement of Steelhead Oncorhynchus mykiss Smolts Based on Capture of Release Fish at the Toppenish Creek Canal Fish Screening Facility, Spring 1988

TABLE 2. Estimated Time to Capture 50% of Steelhead *Oncorhynchus mykiss* Smolts Released in Descaling Tests at Toppenish Creek Fish Screening Facility, Spring 1988

Canal Flow (cfs)	Number Released	Number Caught	Percent Caught	Time to Catch 50% (h)
20	250	144	57.6[a]	39.0
50	255	199	78.0	16.0
50	250	196	78.4	14.0

(a) The inclined plane was removed for 2 h when canal flow was changed from 20 cfs to 50 cfs. During this period, some fish from Test Group 1 may have moved out of the screen forebay. This may have contributed to the lower percent caught for Test Group 1.

Phase IIb

Because test fish were more easily captured at the flow control structure, the potential effect of passage through the fish return pipe was evaluated separately. Because this tested a specific component of the fish return system, results are presented with Phase IIb.

Thirteen groups of 10 steelhead each were released at the head of the Toppenish Creek Screens fish return pipe. Of 130 steelhead released, 106 were captured and evaluated for descaling; none of the fish were descaled.

PHASE III TESTS

Test fish were released during two canal flows at Toppenish Creek: 20 cfs, which represents canal flow during the early spring, and 50 cfs, representing canal flow during the major irrigation-withdrawal period. Fish were not descaled at either flow. Movement of steelhead smolts from the screen forebay through the fish return was slower during low canal-flow conditions.

PHASE IV TESTS

The inclined plane was used during release and capture tests to note the presence of predatory fish and the occurrence and condition of native salmonids. Drum screens were monitored to determine if fish were impinged. Rainbow trout fingerlings were released at the Toppenish Creek screens and fall chinook salmon fingerlings were released at the Wapato and Sunnyside screens to test for possible passage through, around, or over the rotary drum screens. Additionally, fyke nets were placed downstream of the Wapato and Sunnyside screens while Yakima Indian Nation biologists released fall chinook salmon from rearing pens in the Wapato Screen forebay.

Phase IVa. Toppenish Creek Screens

The only native salmonids captured during tests at the Toppenish Creek Screens were juvenile rainbow trout and/or steelhead. The 462 fish we examined (average of 13 cm FL, range 7.0 to 19.5 cm) did not have strong smoltification characteristics. Three adult steelhead kelts (~ 60 cm FL) were caught on the inclined plane, indicating that steelhead spawning occurs upstream of the Toppenish Creek Diversion.

No predacious fish other than rainbow trout/steelhead were caught at the Toppenish Creek Screens. Both the native rainbow trout and test fish that were released during descaling tests preyed on the smaller rainbow trout that were released in the forebay for screen integrity tests (Phase IVb).

Phase IVb. Toppenish Creek Screens

A total of 3073 rainbow trout fry (47.3 mm FL) were released in front of the screens and 900 were released in the mouth of fyke nets behind the screens to evaluate the effectiveness of angled rotary drum screens in preventing fish from entering the irrigation canal behind the screens (Table 3). Of 3073 fish released in front of the screens, 2373 (79%) were recovered in the fish return and 11 (0.4%) were recovered in the fyke nets, 2 behind screen 1, and 9 fish behind screen 3. Additionally, 6 native rainbow trout (8.5 - 19.6 cm FL) were caught in the fyke nets; 2 behind screen 1, and 4 behind screen 3. No fish were caught behind screen 2 except for net control fish. Of 900 rainbow trout released in the mouths of fyke nets behind the drum screens, 522 (58%) were recovered from fyke nets, and 37 (4%) were recovered on the inclined plane (Table 4).

Approximately 20% of the rainbow trout fry released in front of the screens were not recovered. Predation in the screen forebay by test fish and wild steelhead was confirmed by examining the gut contents of fish captured on the inclined plane. Rainbow trout fry were not flushed from the Toppenish Creek Screen forebay (Table 5). Some fish were captured on the inclined plane immediately after release. Most fish were recovered on the plane after sunset on the first night following their release (Figure 9). Few fish were captured after more than 24 h of release

TABLE 3. Capture Data for Rainbow Trout Fry *Oncorhynchus mykiss* Released During Screen Integrity Tests at the Toppenish Creek Fish Screening Facility, Spring 1988

		Number of Control Fish				Number of Test Fish			
		Released	Captured	Released	Captured		Captured In		
Test Group	Screen Number	Fyke Net		Plane		Released	Plane	Fyke Net	Other
1	1	100	36	100	100	1024	868	1	2
1	2	100	66	-	-	-	-	0	-
1	3	100	39	-	-	-	-	0	-
2	1	100	63	100	96	1024	724	1	0
2	2	100	54	-	-	-	-	0	-
2	3	100	58	-	-	-	-	3	-
3	1	100	80	100	100	1025	781	0	4
3	2	100	75	-	-	-	-	0	-
3	3	100	51	-	-	-	-	6	-
Total		900	522	300	296	3073	2373	11	6

TABLE 4. Capture Efficiency of the Inclined Plane and Fyke Nets Used During Screen Integrity Tests at the Toppenish Creek Fish Screening Facility, Spring 1988

Screen	Capture Probability Estimate		Screen Efficiency	95% Confidence Interval
	Inclined Plane	Fyke Net		
1	0.987	0.597	0.999	1.00-1.00
2	0.987	0.650	1.000	1.00-1.00
3	0.987	0.493	0.992	1.00-1.00
a	0.966	0.580	0.966	0.95-0.98
All Screens	0.987	0.580	0.991	0.99-1.00

(a) During tests, 37 control fish placed in fyke nets were caught on the inclined plane. Assuming the 37 fish were test fish that passed from the forebay to the area behind the screens, we calculated a "worst case" screen efficiency of 0.97 (±0.015).

TABLE 5. Estimated Time to Capture 50% of Rainbow Trout *Oncorhynchus mykiss* Fry Released in Screen Integrity Tests at Toppenish Creek Fish Screening Facility, Spring 1988

Test Group	Number Released	Number Caught	Percent Caught	Time (h) to Catch 50%
1	1024	868	84.8	4.0
2	1024	724	70.7	9.0
3	1025	781	76.2	4.0

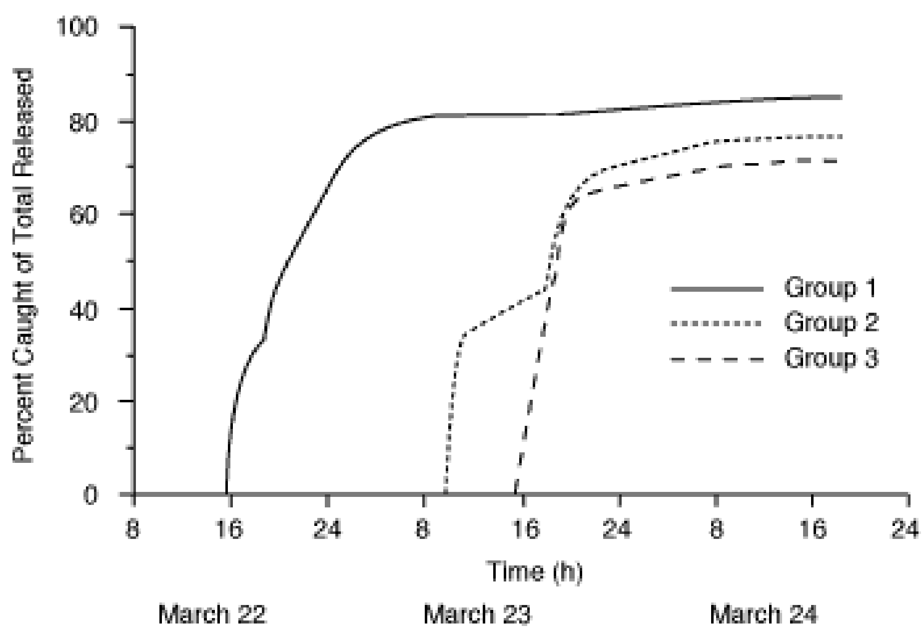

Figure 9. Movement of Rainbow Trout Fry *Oncorhynchus mykiss* Based on Capture of Released Fish in the

Phase IVa. Wapato Canal

Phase IVa observations were completed at the Wapato Screens in 1987 (Neitzel et al. 1987) and were not repeated. Some predatory fish (largemouth bass *Micropterus salmoides*, smallmouth bass M. dolomieui, northern squawfish *Ptychocheilus oregonensis*) were caught during tests in 1987, although losses to predation were minimal. However, this year, massive numbers of hatchery-reared coho salmon *O. kisutch* released in early May were present in the Wapato Screen forebay and preyed on the chinook salmon fry released during Phase IVb tests.

Phase IVb. Wapato Canal

A total of 8235 fall chinook salmon fry were released in screen integrity tests at the Wapato Screens (Table 6). Fish were released in front of the screens, in the intermediate and terminal fish bypasses, and in the mouths and cod ends of fyke nets positioned behind the screens.

Of 500 fish released in the intermediate and terminal bypasses during the first three tests at Wapato Screens, 385 (77% average, range 71%-85%) were captured on the inclined plane. Of 100 fish released in the terminal bypass in the fourth test, 96 (96%) were captured on the inclined plane. The difference in catch rate between the first three tests and the fourth test probably reflects predation on fall chinook salmon by coho salmon smolts in earlier tests. Catch efficiency of fyke nets varied from 79% to 97%, and net retention efficiency ranged from 85% to 90% (Table 7).

A large number of salmonid smolts, primarily coho salmon, were present in the Wapato Screen forebay during our tests. When major movement through the fish return commenced after sunset, fish collection in the bypass was terminated and the inclined plane was removed from the return. Fyke nets were fished only until 1900 h during the first test but were fished overnight in the second, third and fourth tests.

Of 6235 fish released in front of the screens, 4380 (70% average, range 51% to 92%) were caught in the fish return, and 43 (0.7%) were caught in the fyke nets behind the screens. Other salmonids were also caught in the fyke nets. Forty coho salmon smolts were caught behind screen 15 in the second test (Table 6).

Fall chinook salmon fry released in the fish bypasses were not flushed as rapidly through the separation chamber and into the fish return slot (Figure 10, Table 8) as was observed during integrity tests conducted at the Wapato Screens in 1987 (Neitzel et al. 1987). Lower bypass flows caused by an inoperable vertical traveling screen in the separation chamber may have contributed to the slower movement rate and lower fish recoveries.

In addition to the integrity tests, we monitored screens 13 - 15 at Wapato with fyke nets during release of the Yakima Indian Nation's (YIN's) fall chinook salmon from net pens in the Wapato forebay. About 200,000 salmon were released on the evening of May 18. An additional 50,000 fall chinook salmon were released earlier in the afternoon before our fyke nets were in place. The nets were fished overnight and removed about 0700 h May 19. The inclined plane was not used during the monitoring.

Most fall chinook salmon released from the pens moved out of the screen forebay overnight. A total of 190 fall chinook salmon (80 mm FL) were caught in our fyke nets (Table 9). Some recovered fish were badly cut and crushed. Screens 13 and 14 prevented fish from passing into the canal behind the drum screens. The 185 fish recovered from fyke nets behind screen 15 represent less than 0.1% of the total number of fish released.

TABLE 6. Capture Data for Fall Chinook Salmon Fry *Oncorhynchus tshawytscha* Released During Screen Integrity Tests at the Wapato Canal Fish Screening Facility, Spring 1988

		Number of Control Fish						Number of Test Fish			
		Released	Captured	Released	Captured	Released	Captured		Captured In		
Test Group	Screen Number	Fyke Net	Cod End	Fyke Net	Mouth	Plane	Plane	Released	Plane	Fyke Net	Other
1	5	50	35	100	68	100	85	1044	775	5	0
1	10	50	45	100	95	100	77	1041	816	2	0
1	15	50	39	100	87	100	71	1042	535	24	1
2	13	50	44	100	90	100	76	1041	620	2	0
2	14	50	46	100	90	-	-	-	-	0	0
2	15	50	49	100	97	-	-	-	-	4	41
3	3	50	47	100	78	100	76	1028	675	0	0
3	4	50	42	100	84	-	-	-	-	0	0
3	5	50	46	100	87	-	-	-	-	1	0
4	15	50	44	100	95	100	96	1039	959	5	1
Total		500	437	900	871	600	481	6235	4380	43	43

TABLE 7. Capture Efficiency of Inclined Plane and Nets and Retention Efficiency for Fyke Nets Used During Screen Integrity Tests at the Wapato Canal Fish Screening Facility, Spring 1988

	Probability Estimate				95%
Screen Section[a]	Plane Capture	Net Capture	Net Retention	Screen Efficiency	Confidence Interval
1-5	0.805	0.793	0.850	0.995	0.99-1.00
6-10	0.770	0.950	0.900	0.998	0.99-1.00
11-15	0.810	0.918	0.888	0.984	0.98-0.99
15	0.960	0.950	0.880	0.994	0.99-1.00
1-15	0.802	0.968	0.874	0.991	0.99-1.00

(a) Screens are numbered from the upstream (NUMBER 1) to the downstream screen nearest the separation chamber (NUMBER 15).

TABLE 8. Estimated Time to Capture 50% of Fall Chinook Salmon *Oncorhynchus tshawytscha* Fry Released in Screen Integrity Tests at the Wapato Fish Screening Facility, Spring 1988

Test Group	Screens	Number Released	Number Caught	Percent Caught	Time to Catch 50% (h)
1	5	1044	775	74.2	6.5
1	10	1041	816	78.4	7.0
1	15	1042	535	51.3	7.5
2	13-15	1041	620	59.6	4.5
3	3-5	1028	675	65.7	0.5
4	15	1039	959	92.3	1.0

TABLE 9. Capture Data from Fyke Nets Behind Selected Screens at the Wapato Canal Fish Screening Facility After the Release of Yakima Indian Nation (YIN) Fall Chinook Salmon *Oncorhynchus tswhawytscha* from Net Pens in the Wapato Screen Forebay, Spring 1988

Screen	Net(a)	Fyke Net Captures: YIN Fish	Fyke Net Captures: Other Salmonids
13	A	(b)	(b)
13	B	1	0
14	A	1	0
14	B	3	1
15	A	37	2
15	B	148	1
Total		190	4

(a) Net "A" mounted in upstream half of the screen; Net B mounted in the downstream half of the screen bay.
(b) Cod end of net not secure; net contents lost.

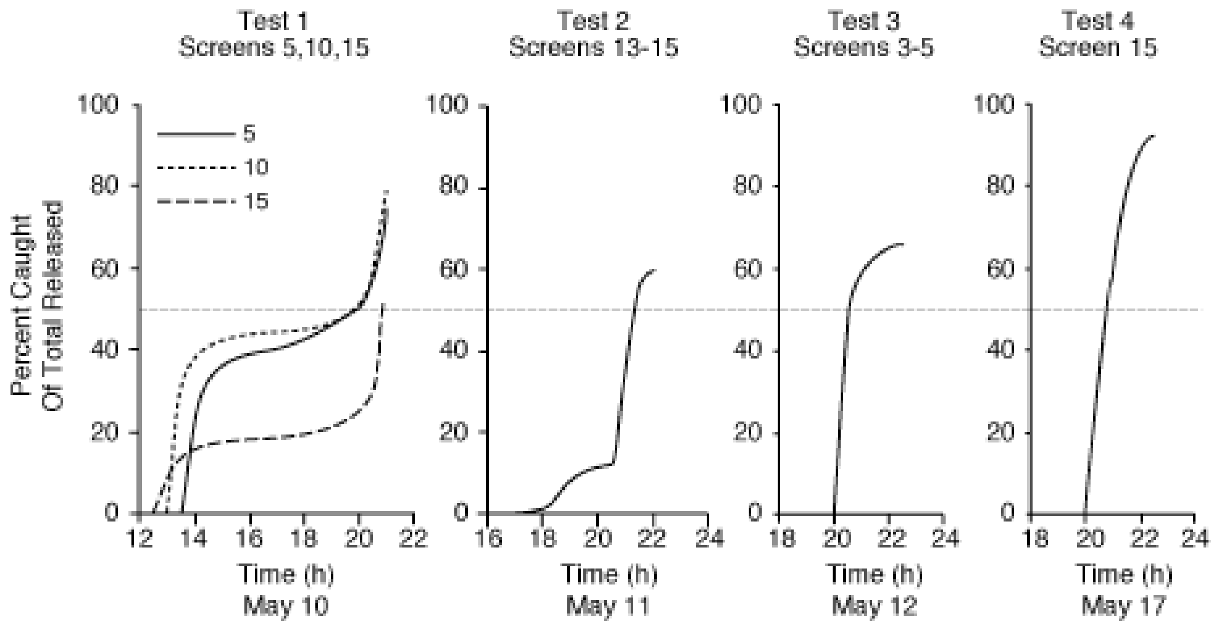

Figure 10. Movement of Fall Chinook Salmon Oncorhynchus tshawytscha Fry Based on Capture of Released Fish in the Bypass During Screen Integrity Tests at the Wapato Canal Fish Screening Facility, Spring 1988

Phase IVb. Sunnyside Canal

A total of 6185 fall chinook salmon fry were released at the Sunnyside Screens (Table 10) in front of the screens, in the intermediate and terminal fish bypasses, and in the mouths of fyke nets behind the screens. Of 400 fish released in the intermediate and terminal bypasses, 317 (79%) were captured in the fish return. Of 1599 fish planted in the mouths of fyke nets, 1310 (82%) were recovered from the nets (Table 11).

Coho salmon smolts were also present at the Sunnyside Screens during our tests. When major movement of salmonid smolts commenced after sunset, fish collection in the fish return was terminated and the inclined plane was removed. Fyke nets were fished overnight for all tests. Of 4186 fish released in front of the screens, 3273 (78% average, range 71% - 85%) were caught in the fish return, and 60 (1.4%) were caught in the fyke nets behind the screens. Eleven salmonids, including some of our test fish that were not identifiable, 1 coho and 2 chinook salmon smolts, were also caught in fyke nets behind the drum screens.

Fall chinook salmon fry released in the fish bypasses were flushed rapidly through the separation chamber and into the fish return slot. All fish released in the bypasses were recovered within 30 minutes of release. Test fish released in front of the screens also moved quickly through the bypass system (Figure 11 and Table 12). Most fish were collected on the inclined plane during the first hour after release; however, small numbers were caught throughout the period when the inclined plane was monitored.

We also monitored screens 8 and 17 at the Sunnyside Screens with fyke nets during the release of YIN's fall chinook salmon from net pens in the Wapato Screens forebay. About 200,000 salmon were released on the evening of May 18. An additional 50,000 salmon were released earlier in the afternoon before our fyke nets were in place. The fyke nets were fished overnight and removed the next morning. The inclined plane was fished until 2100 h to determine the first arrival of released fish at Sunnyside Screens. The first arrival of fall chinook salmon occurred about 2 h after release at the Wapato Screens. A total of 185 fall chinook salmon (80 mm FL) were caught in fyke nets (Table 13). Some fish were badly cut and crushed. Screen 8 prevented passage of fish into the canal behind the drum screens. The 183 fish recovered from fyke nets behind screen 17 represent <0.1% of the total released.

TABLE 10. Capture Data for Fall Chinook Salmon Fry *Oncorhynchus tshawytscha* Released During Screen Integrity Tests at the Toppenish Creek Fish Screening Facility, Spring 1988

Test Group	Screen Number	Number of Control Fish: Released (Fyke Net)	Captured (Fyke Net)	Released (Plane)	Captured (Plane)	Number of Test Fish: Released	Captured In: Plane	Fyke Net	Other
1	5	100	98	100	75	1045	746	9	0
1	6	100	95	-	-	-	-	1	0
1	7	100	88	-	-	-	-	18	3
1	8	100	82	-	-	-	-	3	0
2	5	100	93	100	80	1047	791	2	0
2	6	100	94	-	-	-	-	0	0
2	7	100	95	-	-	-	-	6	0
2	8	100	73	-	-	-	-	3	0
3	13	100	62	100	75	1047	891	2	4
3	14	100	60	-	-	-	-	0	0
3	15	100	78	-	-	-	-	3	0
3	16	100	75	-	-	-	-	7	5
4	14	100	76	100	87	1047	845	0	0
4	15	100	81	-	-	-	-	0	0
4	16	100	83	-	-	-	-	1	0
4	17	99	77	-	-	-	-	5	0
Total		1599	1310	400	317	4186	3273	60	12

TABLE 11. Capture Efficiency of the Inclined Plane and Fyke Nets During Integrity Tests at the Sunnyside Canal Fish Screening Facility, Spring 1988

Screen Section[a]	Probability Estimate: Plane Capture	Net Capture	Screen Efficiency	95% Confidence Interval
3-8 (test 1)	0.750	0.908	0.967	0.96-0.98
3-8 (test 2)	0.800	0.888	0.988	0.98-1.00
3-8	0.775	0.898	0.977	0.97-0.98
9-17 (test 3)	0.750	0.688	0.986	0.98-1.00
9-17 (test 4)	0.870	0.794	0.992	0.99-1.00
9-17	0.810	0.741	0.989	0.98-0.99
3-17	0.793	0.819	0.983	0.98-0.99

(a) Screens are numbered from the upstream screen (NUMBER 1) to the downstream screen nearest the separation chamber (NUMBER 17). Screens 1 and 2 are permanently out of service.

TABLE 12. Estimated Time to Capture 50% of Fall Chinook Salmon *Oncorhynchus tshawytscha* Fry Released in Integrity Tests at the Sunnyside Fish Screening Facility, Spring 1988

Test	Number		Percent	Time (h) to Catch
Group	Released	Caught	Caught	50%
1	1045	746	71.4	1.0
2	1047	791	75.5	1.0
3	1047	891	85.1	<0.5
4	1047	845	80.7	<0.5

TABLE 13. Capture Data from Fyke Nets Behind Selected Screens at the Sunnyside Canal Fish Screening Facility After Release of Yakima Indian Nation (YIN) Fall Chinook Salmon *Oncorhynchus tshawytscha* Fingerlings from the Wapato Screens Forebay, Spring 1988

Screen		Fyke Net Captures	
Number	Net[(a)]	YIN Fish	Other Salmon[(b)]
8	A	2	2
8	B	0	0
17	A	26	2
17	B	157	5
Total		185	9

(a) Net A is the top net. Net B is the bottom net (Figure 7).
(b) Includes smolt-sized and 0-age salmonids.

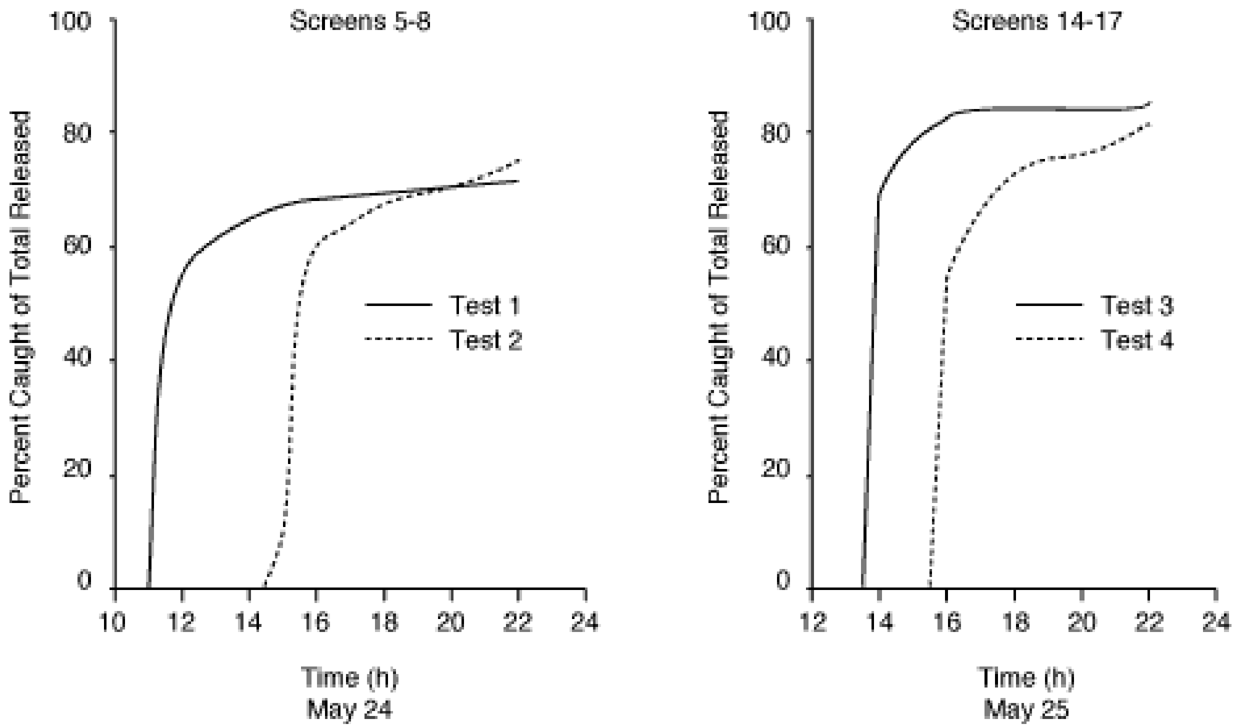

Figure 11. Movement of Fall Chinook Salmon *Oncorhynchus tshawytscha* Fry Based on Capture of Released Fish in the Bypass During Screen Integrity Tests at the Sunnyside Canal Fish Screening Facility, Spring 1988

DISCUSSION

Screening facilities in the Yakima River Basin are designed to direct fish that have been diverted from the river and into irrigation canals back to the river without killing or injuring them or delaying their migration. This section discusses data collected at Toppenish Creek, Wapato, and Sunnyside during 1988, and relates the 1988 data to those collected at Sunnyside, Toppenish/Satus, Richland, and Wapato (Neitzel et al. 1986, 1987, 1988) from 1985 through 1987.

FISH SURVIVAL AT SCREENING FACILITIES

Based on release and capture data at five screening facilities, fish are not descaled or killed during passage in front of the rotary drum screens or through the fish bypass systems. As in previous descaling evaluations at the Sunnyside, Richland, Toppenish/Satus, and Wapato screens, the condition of test fish after passing through the bypass system at Toppenish Creek is similar to that of control fish.

POTENTIAL FOR PREDATION AT SCREENING FACILITIES

Screening facilities could affect predator/prey relationships if the screens concentrate prey or increase the exposure of prey to predators because of stress, injury, or delayed migration. Based on samples we have collected, loss to predation by native species does not appear to occur. However, hatchery-released salmonids diverted into the screen forebay may increase predation pressure at screen sites. We observed hatchery reared steelhead smolts feeding on our test fish at Toppenish Creek, and coho salmon smolts feeding on our test fish at Wapato and Sunnyside. Low bypass flows may prolong smolt residence time in screen forebays, thus increasing predation pressure on salmonid fry.

Toppenish Creek Screens

Some predation was observed at the Toppenish Creek Screens following release of 0-age rainbow trout fry in the forebay. Juvenile rainbow trout and steelhead, primarily fish released during descaling evaluation, were present in the forebay and opportunistically fed on the smaller fry. Predation, therefore, appeared to be related to the artificial and temporary predator-prey population structure created by the release of test fish.

Emergence of salmonid alevins in Toppenish Creek may commence later than the peak steelhead smolt migration. No native 0-age rainbow trout fry were captured during 4 days of sampling at the Toppenish Creek Screens. Regardless, the natural predator-prey population structure in the screen forebay should be similar to that in Toppenish Creek because fish movement through the forebay is not impaired when adequate bypass flows are provided.

Wapato Screens

Coho salmon released in the Yakima River upstream of the Wapato Screens were present in the forebay and preyed on fall chinook salmon that we released on May 10 through 13. Predation occurred in front of the screens as well as in the fish bypass system. We conclude this from the following. During 1987, more than 90% of the test fish released into the bypass and in the forebay were caught on the plane. In similar tests conducted during 1988, with coho smolts in the forebay, less than 80% of the test fish were caught on the plane (Table 14). After the coho smolts were "flushed" out of the forebay; more than 90% of the test fish were caught. An inoperable traveling screen in the separation chamber, during 1988 tests, resulted in bypass flows that were less than those recommended in the operating criteria. Flow through the fish return pipe was increased to more than 35 cfs from May 13 through 17. The increased flow was provided to compensate for the reduced bypass flow through the traveling screens and to "flush" the coho salmon from the screen forebay. Few coho salmon smolts were captured in a test conducted on May 17, and the capture rate for test fish was similar to rates observed in 1987 tests.

TABLE 14. A comparison of capture efficiency data during screen efficiency tests at the Wapato Canal Fish Screening Facility, Spring 1987 and 1988

Year	Number of Fish: Released in Bypass	Number of Fish: Caught on the Plane	Percent
1987	600	571	95
1988[a]	600	481	80
1988[b]	100	95	95

Year	Number of Fish: Released in Forebay	Number of Fish: Caught on the Plane	Percent
1987	6614	6011	90
1988[a]	6235	4380	70
1988[b]	1039	959	92

a Coho smolts were in the forebay and bypass during these tests.
b Coho smolts migrated out of the facility before this test started

Sunnyside Screens

Few predacious fish were observed at the Sunnyside Screens on May 24 through 26 and fewer salmonid smolts were observed than during tests at the Wapato Screens. Although no predatory activity was apparent in the screen forebay, the capture rate for test fish in the fish return was lower than expected based on the catch rate of test fish at the Wapato Screens in similar tests. Failure to completely seal the primary fish return so that all bypass water crossed our inclined plane (i.e., reduced plane efficiency), and not predation, may have resulted in lower capture rates.

POTENTIAL FOR FISH DELAY AT SCREENING FACILITIES

One objective of the angled screen facility design is to provide a facility that safely and rapidly returns fish from the diversion canal to the river (Easterbrooks 1984). Although, fish are not "flushed" from the screen forebay back to the river, the screening facilities do not impede voluntary movement and migration under normal operating conditions. Conversely, inadequate bypass flows resulting from improper operation, inoperable components in the bypass system, low canal flows or forebay elevations, or blockages in the fish return can impair fish movement through the bypass system and contribute to migration delays.

Flow through the fish return pipe at Toppenish Creek Screens was severely restricted before we initiated testing. Normal bypass flows were not attainable because the fish return slot was backed up with water. The fish return was plugged by boulders that had washed into the mouth of the pipe during high stream flows in winter. The creek bed is unstable at the end of the fish return pipe, and the pipe may become plugged again. Besides restricting water flow, a partially plugged pipe would probably injure fish. No injuries were observed for fish passing through the unobstructed pipe.

An inoperable traveling screen in the separation chamber resulted in low bypass flows during integrity tests at the Wapato Screens. With one screen plugged, bypass flows were reduced so that the inclined plane in the fish return could be operated effectively. Lower bypass flows contributed to slower movement through the fish separation chamber, lower fish capture in the return, and increased predation of our test fish by hatchery-released coho salmon smolts in the screen forebay and separation chamber.

FISH PASSAGE THROUGH OR OVER ROTARY DRUM SCREENS

The designed sweeping/approach velocity ratio helps guide fish into the fish bypass, and screen mesh openings (3.18 mm, 1/8 in.) are small enough to prevent fish passage through the drum screens. Tests were conducted at the Toppenish Creek, Wapato, and Sunnyside Screens to determine if any fish were impinged by or passed through the screens.

Toppenish Creek Screens

No fish passed over the drum screens at the Toppenish Creek; some fish, including two smolt-size rainbow trout, were caught in fyke nets behind two of the three screens. No native fish or fish released in front of the screens were captured in the fyke net behind screen 2. Faulty screen seals were the probable avenue of passage. Fish released in the fyke nets were also captured in the fish return, indicating that fish could move in either direction through the screen seals.

Wapato Screens

Results from integrity tests at Wapato Screens were similar to those observed in 1987 (Neitzel et al. 1987). Test fish passed through the seals on some drum screens, and over some screens as they rotated. Passage over the screens ("rollover") was generally limited to test fish released close to the screen face at the water surface. We observed one wild spring chinook salmon fry passing over screen 15. Rollover also appeared to be related to fish size. Fall chinook salmon (75 mm FL) released from YIN net pens did not pass over screens. Although several weak or disoriented fish were impinged briefly on the screen face, their mass prevented them from rolling over the drum screens. Additionally, the new seals installed along the circumference at each end of the drum screens appeared to be tighter than was the case before 1988.

Almost half the test fish recovered in fyke nets behind the screens probably resulted from rollover. Sixty test fish were caught in fyke nets (Table 6); 27 rolled over the screens. Capture of coho salmon smolts indicated that screen seals were poor at screen 15. After screen seals were repaired, few coho salmon smolts were captured behind screen 15. The lower catch could reflect the improved seals, fewer coho present in front of the screens, or a combination of both. Captures of fall chinook salmon in fyke nets behind screens 13-15 during release of fish from YIN net pens indicated that passage continued to occur at screen 15 despite repairs. The few fish caught behind screens 13 an 14, and some of the fish caught behind screen 15, were severely cut and crushed. Although the number of fish captured in nets was less than 0.1% of release, their presence confirms the need for meticulous maintenance and care of screen seals.

Sunnyside Screens

Monitoring of screens 8 and 17 during YIN release of fall chinook salmon indicated that seals at screen 17 were faulty. Repairs were made just prior to tests at Sunnyside Screens. Although few smolt-size fish were caught at the Sunnyside Screens after the seal repairs were made, fewer fish were present in the screen forebay than during tests at Wapato Screens.

Most test fish captured in fyke nets behind the screens were the result of rollover. However, some fish counted as "rollovers" were injured or were stuck in the seal at the downstream end of the screens. Several fish passed over screen 7 with their heads crushed between the seal and screen face

SUMMARY

Release and capture and monitoring studies have been conducted at five diversion screen facilities in the Yakima River Basin: Sunnyside Screens (Neitzel et al. 1985), Richland Screens (Neitzel et al. 1986, 1987), the Toppenish/Satus Screens (Neitzel et al. 1986), Wapato Screens (Neitzel et al 1987), and Toppenish Creek Screens. The objective was to determine if fish diverted into an irrigation canal are safely diverted back to the river. The objective is met by determining if: 1) fish that pass through the diversion are killed, injured, or eaten by predators; 2) fish migration is delayed at the screen structure; or 3) fish are prevented from passing through or over the screens. These possibilities are addressed in various phases of the work plan.

PHASE I

Phase I tests were conducted at Sunnyside Screens with chinook salmon and steelhead smolts. Test data indicated that fish safely pass through all components of the bypass system. No Phase I tests were conducted at Richland, Toppenish/Satus, or Toppenish Creek screens because the fish bypass systems do not incorporate intermediate and terminal bypasses, traveling screens, or fish water pumpback systems in their designs. No Phase I tests were conducted at Wapato Screens because components of the fish passage facility did not significantly differ from components at the Sunnyside Screens, which were proven safe for fish passage.

PHASE II

Phase IIa tests are complete at five screening facilities. At Sunnyside Screens, fish were released at either the trash racks or head gates. Fish captured after moving through the screen forebay and diversion system were not injured or killed. At Richland, Toppenish/Satus, Wapato, and Toppenish Creek screens, fish were released only at the trash racks. Captured fish were not killed or injured. Tests at Sunnyside, Wapato, and Richland Screens were conducted with chinook salmon and steelhead smolts. Tests at Toppenish/Satus and Toppenish Creek Screens were conducted with steelhead smolts.

Phase IIb tests were conducted at Sunnyside, Richland, Toppenish Creek, and Wapato screens. At Sunnyside, tests were conducted to evaluate the intermediate bypass system, terminal bypass system, secondary separation chamber, and primary fish return pipe. At Richland, Toppenish Creek and Wapato Screens, the fish return pipe was evaluated. Fish successfully passed through each component without injury or delay.

PHASE III

Phase III tests were conducted at Richland, Toppenish Creek, and Wapato screens. Pipe tests were conducted under two bypass flows at the Richland Screens. Fish were not injured or killed at either bypass flow. Evaluations at Toppenish Creek and Wapato Screens were conducted during low and full canal flows. Although fish were not injured or killed in either test, movement rate was slower during low canal flows. Opportunities to conduct tests under different canal flows were limited because of delays in construction and startup at Sunnyside, Richland, and Toppenish/Satus screens. Sunnyside and Toppenish/Satus screens were evaluated only under full canal flows and Richland Screens only under minimum flows.

PHASE IV

Native fish were collected during all bypass tests. Gut contents of predacious fish were examined. Predacious bird activity was monitored near each screening facility. Although predation by native species does not appear to occur at screening facilities, hatchery-released salmonids sometimes congregate in the screens forebay, and prey on salmonid fry. The data we have collected cannot be used to infer that predation at the screens is greater than predation in the river.

Rotary drum screens were examined to determine if fish were impinged on or passed over the screens. Successful integrity tests were completed at the Richland, Toppenish Creek, Sunnyside, and Wapato screens.

Richland Screens are effective at preventing fish from entering the irrigation canal; although some fish passed over screens and through faulty screen seals at the Toppenish Creek, Sunnyside, and Wapato screens, screen efficiency is near 99%. Screen integrity tests at Toppenish/Satus were unsuccessful because we did not collect any fish, including our control fish, downstream of the screens.

RECOMMENDATIONS

Fisheries evaluations have been conducted at five screening facilities: Sunnyside, Richland, Toppenish/Satus, Wapato, and Toppenish Creek screens. Data were collected to address five areas of concern: fish survival, predation, migration delays, screen passage, and effects of operating conditions. Test results addressing each concern were integrated to evaluate screens effectiveness.

Although data indicate that fish are not descaled or killed as they are diverted by the screening facilities, descaling tests should continue at future diversion sites to assess potential site-specific problems and correlate descale to canal operations (Phase III). Canal operating conditions are of greatest concern during canal startup, and during peak migration of native salmonid stocks in the vicinity of each screening facility.

We have not observed increased predation on juvenile salmonids in or near screen facilities that could be directly attributed to the screens. However, increased predation on fish that pass through the screening facilities should be quantified relative to predation in the river. Although native predacious fish populations do not appear to concentrate within the screening facilities, hatchery-released salmonids can pose a predation threat if the fish do not migrate from the river following release. The location and operation of irrigation diversions should be considered in planning future hatchery releases.

Operating criteria should stress that fish bypass flow is important to achieving effective fish bypass. Fish are not involuntarily delayed at or within the screening facilities when bypass flows are set according to operating criteria and properly maintained. The potential for fish delay in screen facilities should be compared to migration rates for fish that remain in the river. At Wapato Screens, low bypass flows, whether caused by low forebay elevation or malfunctioning components in the bypass system, may contribute to slower fish movement through the facility. Boulders that blocked the mouth of the fish return pipe at Toppenish Creek Screens resulted in reduced bypass flows and were a potential site for fish injury. The fish bypass system should be thoroughly checked and calibrated at each screening facility at the beginning of each irrigation season.

Tests to evaluate screen integrity should have a high priority. Screen integrity tests at Toppenish Creek, Sunnyside, and Wapato indicate that screen seals play a vital role in preventing fish from entering the irrigation canal. Although annual inspection and replacement of screen seals might reduce losses, a new seal design may be necessary if the present loss rate is not acceptable.

Passage of salmonids over the drum screens is rare. High approach velocities at some screens may result in a small number of salmonid fry being lost over the screens; however, larger fingerlings and fry cannot pass over the drum screens. Passage over screens appeared related to the presence of driftwood or other floating matter at the water surface in front of screens with high water flow. Stoplog adjustments behind screens to achieve uniform flow appeared to reduce rollover of test fish at Wapato Screens.

Operating criteria for each screening facility should be reviewed annually to address changes in screens operations. Criteria must correspond with measurement facilities at the screens. Some staff gauges needed to adjust bypass at the Wapato Screens are not installed. Additionally, changes in operations resulting from inoperable components in the bypass system need to be addressed. For example, when the traveling screens are inoperable, there are several options for operating the bypass. Traveling screens can be removed and water and fish will return to the river through the waste-water pipe over Gates 5 and 6. This could result in injuring fish because the waste-water pipe is not designed to transport fish.

With one traveling screen out of service, it could be left in place and twice the flow passed through the operable screen. This increases the probability of impinging fish on the traveling screen. Although flow could be increased through the primary fish return pipe, the capacity of this pipe to safely return fish to the river has not been assessed. Another option may be to reduce flows in the bypass when only one traveling screen is in service. With this option, fish travel time may be affected. For those options that may be used regularly or for long periods of time, potential fisheries impacts of the operational and maintenance procedure should be assessed.

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