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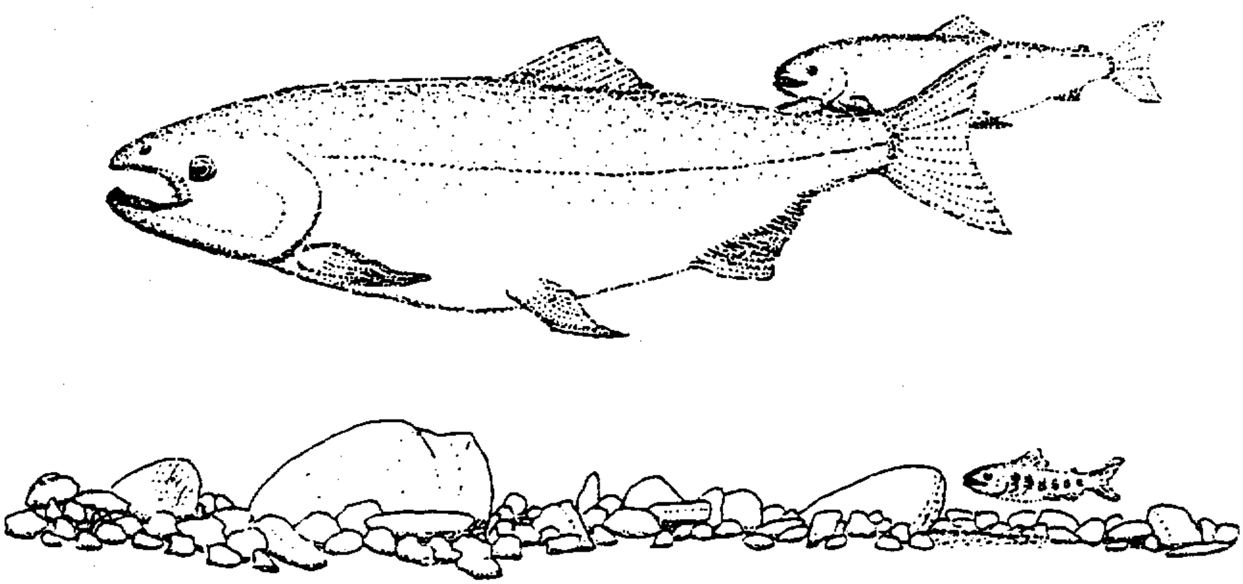
TIMING, EXIT SELECTION, AND SURVIVAL OF STEELHEAD AND COHO SMOLTS AT GLINES CANYON DAM



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Timing, Exit Selection, and Survival of Steelhead and Coho Smolts at Glines Canyon Dam

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ABSTRACT

We evaluated exit selection, emigration timing, spill-passage survival, and fry-to-smolt survival at Glines Canyon Dam on the Elwha River in 1988. We assessed exit selection, emigration timing, and fry-to-smolt survival with naturally reared steelhead and coho smolts, and we evaluated spill-passage survival with hatchery reared steelhead and coho smolts. Exit selection and emigration timing were evaluated via hydroacoustic monitoring at dam exits in combination with scoop and fyke trapping below the dam. Spill-passage and fry-to-smolt survival were estimated via scoop trap-based estimates of migrant passage. Loss of the scoop trap for nine days in mid May adversely affected timing and fry-to-smolt results.

Hydroacoustic and trap data indicated that emigration of steelhead, coho, and yearling chinook (residual emigrants from chinook fry planted in Lake Mills in 1987) had begun by early April, peaked in mid to late May, and declined to negligible levels by late June. Available scoop trap catches indicated that emigration timing of the three species was significantly different, however. Most emigrants passed Glines Canyon Dam via the spillway. Over the total monitoring period from April 4 to June 29, approximately 91% of emigrants used the spill exit. During the peak passage period from May 5 to June 5, nearly 97% of emigrants used the spill exit. Most spillway movement occurred at night, although both day and night spillway passage was significantly greater than turbine passage. Both day and night emigration over the spillway were significantly correlated with spill volume. Throughout the emigration period, turbine flow was essentially constant at 1,100 cfs (full generation), and spill flow was continuous and ranged from approximately 200 to 2,800 cfs.

Tests at spillgate 5 showed little or no passage mortality when spill exceeded approximately 450 cfs, but substantial mortality in coho tests at approximately 110 and 220 cfs. Based on review of spillflow records, plus recovery and injury rates for spill test groups in 1987 and 1988, we suspect that spill flows less than approximately 450 cfs may cause poor passage conditions in the spill pool and/or spill-pool exit.

Scoop trap data suggested that juvenile coho experienced excellent fry-to-smolt survival, but steelhead experienced only average fry-to-smolt survival compared to other measures of natural smolt production in the Puget Sound region. Firm estimates of wild smolt production were not achievable, however, because the trap was inoperable during the peak of the emigration.

Results of this study did not clarify the fate of chinook holdovers from fingerlings planted above Glines Canyon Dam in 1987. Available scoop trap data suggested that relatively few

yearling chinook passed Glines Canyon Dam in 1988, compared to the number believed to have residualized in Lake Mills based on hydroacoustic passage estimates in 1987.

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INTRODUCTION

Restoration of anadromous fish to the upper Elwha River requires safe passage of juveniles through the Elwha dams. Both Elwha dams (Figure 1) were constructed without provision for anadromous fish passage. At Glines Canyon Dam, available information suggested that spilling could be a relatively safe and effective means to pass steelhead and coho smolts. Both species appeared to favor the spillway rather than turbine exit in earlier evaluations, and spillway mortality appeared to be minimal (Schoeneman and Junge 1954; Wunderlich and Dilley 1985, 1986). However, only steelhead exit selection had been directly evaluated at Glines Canyon Dam (Dilley and Wunderlich 1987), and this involved only limited hatchery smolt releases from one brood year. No evaluation of natural run timing had been conducted to specify a passage window for naturally reared smolts. Moreover, estimated survival at the Glines spillway was based only on coho and chinook tests at unspecified spill and flow conditions (Schoeneman and Junge 1954), except for one subyearling chinook test conducted in 1987 by Wunderlich and Dilley (1988).

Information on survival-to-smolt for naturally reared Elwha steelhead and coho is also needed for anadromous restoration. No Elwha-specific information exists on this topic, and survival data of this type are needed to estimate natural Elwha production and adult returns.

To address these needs, we conducted a study of timing, exit selection, and survival of steelhead and coho smolts at Glines Canyon Dam in 1988. Specific study objectives were:

1) Identify emigration timing of naturally reared Elwha steelhead and coho smolts.

2) Evaluate exit selection of naturally reared Elwha steelhead and coho smolts at Glines Canyon Dam.

3) Determine mortality of steelhead and coho smolts passing Glines Canyon Dam spillway.

4) Estimate survival-to-smolt of steelhead and coho planted as fry in the upper Elwha watershed.

METHODS

Emigration Timing and Exit Selection

We evaluated emigration timing and exit selection of naturally reared Elwha coho and steelhead by hydroacoustically monitoring smolt passage at the Glines Canyon Dam exits. Smolts originated from fry planted in the upper Elwha watershed above Lake Mills (Table 1). Hydroacoustic monitoring occurred from April 4th until June 29th, 1988, which encompassed the total expected range of emigration. Hydroacoustic equipment and analysis procedures followed those used in 1987 Glines Dam studies (Wunderlich and Dilley 1988).

We requested spill augmentation during the 1988 emigration period at Glines Dam to ensure that smolt movement would not be affected by lack of a spill exit. Previous passage work (Schoeneman and Junge 1954; Wunderlich and Dilley 1985, 1986; Dilley and Wunderlich 1987) suggested that coho and steelhead smolts milled in the reservoir forebay unless a surface exit was available. Spill augmentation followed the spill rule proposed by James River Corporation (1988) (Table 2). Spilling occurred only at spillgate 5 (Figure 2) to enable comparison to previous passage studies. Hourly hydroacoustic counts at each exit during the day and at night were statistically tested with ANOVA. Results from 1988 were compared to those for steelhead in 1986. We log-transformed hourly counts to better approximate normality. We also regressed daily numbers of spillway fish on daily spill volume to examine the relationship between spill and smolt movement.

We operated a scoop trap at river mile 12.8 (Figure 1) and a fyke trap in the Glines Dam tailrace (Figure 2) to help verify hydroacoustic counts and assess species composition of downstream migrants. Trapping and data collection procedures followed those used in 1987 at Glines Dam (Wunderlich and Dilley 1988), with the exceptions noted below. Scoop and fyke trapping coincided with the hydroacoustic monitoring period in 1988. Relative migration timing, as indicated by available scoop trap catches of coho, steelhead, and chinook, was compared. The relative cumulative frequency distributions of each species' catch were statistically tested in 2-way K-S tests.

Spill-Passage Survival

We tested spill-passage survival at seven flows ranging from approximately 1/4-ft gate opening (~110 cfs) to 3 1/2-ft gate opening (~1,482 cfs). Coho smolt survival was tested at all seven flows, but steelhead survival at only two (Table 3) because test fish were lost when the scoop trap was washed out in mid May. (The scoop trap was rendered inoperable from May 12th to

May 20th, inclusive, due to high-flow damage caused by mechanical malfunction of the gate control at spillway 5 of Glines Dam.) These spill-test flows were selected because they typified the normal spring spill range at Glines Dam, and because they included proposed mitigation spills for fish passage (James River Corporation 1988). Spill-test fish were released into the spill stream on the downstream side of the tainter gate in the same manner as the chinook spill-passage test in 1987 at Glines Dam (Wunderlich and Dilley 1988). All spill tests were made at spillway 5 for comparison to the 1987 chinook test.

Delay in spill-test fish movement to the scoop trap precluded use of a paired-release technique (Wunderlich and Dilley 1985, 1988) to estimate spill-passage survival, so we used a regression-based technique (Wunderlich and Dilley 1988). We measured scoop trap efficiencies over a range of streamflows using control releases of hatchery coho and steelhead smolts (Table 3). Control fish were released near river mile 13 between the Glines Dam tailrace and the scoop trap. Predictive relationships between streamflow and trap efficiency were developed for coho (Figure 3) and steelhead (Figure 4). Scoop catches of spill-test releases (Table 3) were then expanded by the inverse of predicted trap efficiency at time of capture and summed over the recovery period to estimate survival. This method was essentially identical to that used in 1987 studies at Glines Dam (Wunderlich and Dilley 1988), except that we were unable to establish all desired trap-efficiency control points in 1988 due to the loss of the scoop trap, as described above. Limits for trap efficiency (Figures 3 and 4) were conservatively set because of lack of control points at extreme flows.

Fry-to-Smolt Survival

We used the regression-based technique described above to estimate abundance of naturally reared smolts resulting from fry planted upriver (Table 1). Scoop trap catches of adipose-clipped coho and steelhead were expanded by the inverse of predicted trap efficiency at time of capture and summed over the recovery period. Total expanded catches of naturally reared smolts were further expanded to reflect missed fishing during the trap-loss period described above, and to account for passage mortality at Glines Dam.

We estimated potential trap catches during the trap-loss period by expanding corresponding hydroacoustic estimates of smolt passage. Expansions were based on the average acoustic-to-trap passage ratio during a 9-day period immediately following trap loss (Figure 5). This period was chosen because migrant abundance and streamflow were considered comparable to the trap-loss period. We assumed species composition during these periods (trap-loss and succeeding 9-day passage periods) was the same, and apportioned potential trap catches by species accordingly.

We estimated overall passage survival of naturally reared smolts with a spreadsheet model incorporating hourly hydroacoustic estimates of smolt passage at each exit and associated exit flows. Hourly passage was adjusted to reflect survivals shown in Table 4, based on flow at time of passage. For this model, we assumed that exit selection and survival were the same for all species. Hourly survival estimates for each exit were then summed over the entire study period and compared to pre-passage estimates to approximate passage survival for the season.

We estimated yearling chinook emigration in 1988 with the regression-based technique described above. (Yearling chinook were residual emigrants from fingerlings planted in Lake Mills in 1987.) We assumed that capture efficiency of yearling chinook was similar to that of steelhead smolts because of their similar size (Table 5), so the steelhead efficiency relationship in Figure 4 was used to expand scoop catches of chinook. Further expansions for the trap-loss period and passage mortality followed that used for coho and steelhead as described above.

RESULTS AND DISCUSSION

Emigration Timing and Exit Selection

Hydroacoustic measurements showed that emigration had begun by early April, peaked in mid May, and declined to negligible levels by the end of June (Figure 6). Scoop and fyke trap catch data suggested that coho smolts dominated the 1988 emigration, with steelhead and yearling chinook smolts present in far fewer numbers (Table 6). Steelhead and chinook were present in greater numbers than coho very early in the season, however (Figure 7). Two-way K-S tests indicated that relative cumulative catch distributions of downstream migration timing were significantly different among all three species. Thus, even though these results were based on relatively low numbers of steelhead and chinook, care should be taken in applying this year's emigration timing data, based mostly on coho, to the other species. Available scoop trap catch data suggested that movement of each species peaked by the middle or latter part of May (Figures 8, 9, and 10).

The spillway (gate 5) was the preferred exit through virtually the entire season, especially during the peak period of emigration (Table 7, Figure 6). Spillway passage averaged approximately 91% over the entire study, but accounted for nearly 97% of movement during peak passage between May 5th and June 5th (Table 8). During this latter period, most migrants were probably wild coho smolts, based on scoop catches. In comparison, approximately 98% of hatchery steelhead smolts chose spillway 5 as an exit during May and early June of 1986 (Dilley and Wunderlich 1987). Similar proportions of wild steelhead, coho, and chinook in scoop and fyke catches (Table 6) suggested similar exit selection for all species in 1988.

Most spillway passage occurred at night (Table 7), with approximately 76% of movement over the season (10,149 emigrants) occurring from 2100 to 0500 hours (Table 8). This pattern was quite similar to that observed for hatchery steelhead in 1986 at Glines Dam on both an hourly and seasonal basis (Figure 11 and Table 7, respectively). The proportion of nighttime movement was greater during the peak of emigration than during either early or late portions (Figure 12). Available scoop trap catch data showed a similarly high rate of nighttime movement for all emigrants over the season (87%), with the highest nocturnal movement at the central part of the emigration (Figure 13). The number of smolts passing through the turbine was relatively constant (Figure 6) and there was no significant difference in turbine passage between day and night (Table 7). The pattern of greatest emigration over the spillway at night, the next greatest over the spillway during the day, and the least through the turbine both day and night mirrors the results for steelhead in 1986 (Table 7).

Fish passage and spill volume at spillway 5 are shown in Figure 14. Because turbine flow and reservoir elevation were essentially constant throughout this study (turbine flow was maximized at 1100 cfs, full generation), spill volume reflected changes in streamflow. Initial analyses of covariance demonstrated a significant day/night interaction effect in the relation of spill volume to fish movement. Thus, we investigated the relation between spill volume and fish movement independently for day and night. Over the entire period in Figure 14, daytime numbers of fish were significantly correlated ($P < 0.01$, $r^2 = 0.31$) with spill volume. There was a better correlation ($P < 0.01$, $r^2 = 0.63$) between numbers of fish and spill volume at night. Closer examination of the high-movement period (May 5th to June 5th) resulted in a substantially improved correlation in the day ($P < 0.01$, $r^2 = 0.64$) and a similar correlation at night ($P < 0.01$, $r^2 = 0.65$). Mean nightly spills ranged from approximately 200 to 2700 cfs from May 5th to June 5th.

Spill-Passage Survival

Table 9 shows estimated survival of the spill-test groups released in 1987 and 1988. Only two of the seven coho spill-test groups experienced low survival. These low-survival groups were released at 1/4-ft and 1/2-ft gate openings, and survived at estimated rates of only 34% and 64%, respectively. A chinook fingerling group released at 1/2-ft gate opening in 1987 survived at an estimated rate of only 42%. In contrast, both steelhead test releases in 1988 exhibited high survival, even the group released at 1/4-ft gate opening (Table 9).

Spill-passage survival appeared related to flow conditions in the spill pool and/or spill-pool exit, rather than factors such as spillgate opening or species-specific mortality. Review of streamflow records showed that the spill-test groups with low survival (1/4-ft and 1/2-ft coho and 1/2-ft chinook test groups) experienced lower natural spills after their release than did other groups, including the 1/4-ft steelhead test group (Table 9). Scoop trap recovery of the low-survival coho groups also lagged well behind other coho spill-test groups. Initial recovery of the 1/4-ft test group required two days, and the 1/2-ft test group one full day, whereas initial recoveries of other coho groups occurred within hours of release. The sole chinook test group in 1987 required one full day before initial recovery as well, however no other chinook movement rates are available for comparison.

Low-survival coho test groups also exhibited greater descaling and greater proportions of injured or dead at recovery than did other coho spill-test groups and controls (Table 10), and scale loss of the chinook spill-test group was relatively high compared to chinook control releases in 1987 (Wunderlich and Dilley 1988). Neither of the steelhead spill-test groups exhibited such differences in overall scale loss (Table 11) or delay in initial recovery.

Based on presently available information, we consider the survivals shown in Table 4 appropriate for juvenile emigrants passing spillgate 5. We suspect that lower spillflows (i.e., beginning at less than approximately 450 cfs) at gate 5 created poorer conditions for fish passage which, in turn, caused mortality, injury, and delay for low-survival coho and chinook groups. Spill-pool volume and/or spill-pool exit flow may be factors in this mortality. Higher ambient spillflows during the steelhead spill tests (Table 9) possibly favored survival. Species-related size differences are not expected to be a significant factor in juvenile survival in the 200-ft spill fall at Glines Dam (Milo Bell, pers. comm.).

<u>Fry-to-Smolt Survival</u>

We show estimates of pre-passage smolt abundance and their derivation in Table 12. The value of 49,854 pre-passage coho smolts equates to an estimated fry-to-smolt survival of 32.9%, which is better survival than any reported by Smith et al. (1985) in a recent review of outplanting. It is also considerably better than recent Washington Department of Fisheries' estimates of fed fry survival-to-smolt at Gorst Creek (Kitsap Peninsula), which have not exceeded 12% over the past four brood years (Tim Flint, Washington Department of Fisheries, pers. comm.).

The value of 2,699 pre-passage steelhead smolts in Table 12 equates to an estimated fry-to-smolt survival of 7.1%, which is substantially lower than one previous Elwha estimate of 31% developed from 1985 hydroacoustic estimates (Wunderlich and Dilley 1986), and also somewhat lower than the 7.9% mean emergent fry-to-smolt survival (range: 3.4% to 16.2%) measured for steelhead over the past nine years at Snow Creek (Olympic Peninsula) (Randy Cooper, Washington Department of Wildlife, pers. comm.). A portion of this steelhead outplant experienced stress during transport in 1986 (Table 1), which may have affected initial survival.

Fry-to-smolt estimates derived from Table 12 values suggested excellent survival for coho, but only average survival for steelhead. However, these estimates incorporated major assumptions, and thus should be viewed with caution. These assumptions, in order of significance, were:

1) <u>Potential scoop catch estimates accurately reflected smolt passage during the period of trap loss.</u> Values in Table 12 suggest that nearly 47% of the emigration (a total of 22,109 coho and steelhead smolts) occurred during the period of trap loss, and assumptions regarding species composition and abundance during this critical period have a major effect on fry-to-smolt survival estimates. Trap-to-acoustic passage values

(Figure 5), which formed the basis for abundance estimates during the outage, showed reasonably high correlation (r^2 = 0.69), but suggested a mean hydroacoustic detection rate of only 37% in 1988. Additionally, species composition, which was assumed to remain constant throughout the peak passage period, may have varied. Mid May was likely the peak movement period for both species, and high streamflows undoubtedly encouraged emigration as indicated by a continued high hydroacoustic detection rate at that time. If species composition varied during the trap outage, actual species abundance and fry-to-smolt survival rates may be markedly different than the values in Table 12 suggest.

2) Expanded scoop catch estimates (Table 12) accurately reflected abundance of naturally reared smolts. The scoop trap may have been slightly selective for larger coho and steelhead smolts, although growth could account for at least some of the length differences observed (Table 13). The smaller mean length of naturally reared coho (Table 5) compared to hatchery controls (Table 13) could have lead to a net underestimate of wild coho abundance. Steelhead, however, exhibited little difference in length between hatchery controls (Table 13) and naturally reared smolts (Table 5).

3) Passage survival at Glines Dam over the season averaged 89.6% (Table 12). This value incorporates exit survival estimates from Table 4. Because spilling was relatively high throughout the 1988 emigration (Figure 14), only a small net loss (4.8%) was attributed to spill passage over the season in our spreadsheet model, despite substantial use of this exit. Potential turbine loss over the season (5.6%) was based in part on fingerling-chinook survival tests conducted in 1987 (Wunderlich and Dilley 1988). Limited fyke trap data (Table 10) suggested that coho smolt mortality at this exit was similar to fingerling chinook mortality as reported by Wunderlich and Dilley (1988). Overall, the passage-loss estimate appeared reasonable for the 1988 emigration.

Relation to Previous Work

Recent passage studies at the Elwha dams (Wunderlich and Dilley 1988; Wunderlich et al. 1988) incorporated the preliminary exit survival rates shown in Table 4. Based on survival information described herein, we believe these survival values are still appropriate at this time.

The degree of residualism among fingerling chinook planted in

Lake Mills in 1987 remains unclear. Hydroacoustic monitoring at Glines Canyon Dam in 1987 suggested that up to 1/2 of 40,325 fingerling chinook planted in Lake Mills for purposes of passage evaluation may have residualized (Wunderlich and Dilley 1988). Results from this year's work suggested that approximately 594 yearling chinook emigrated during the study period (Table 12), although this estimate should be viewed cautiously as the above assumptions concerning coho and steelhead estimates apply here as well. Passage of 594 yearling chinook equates to an estimated survival rate of only 2.9% (from fingerling to yearling chinook smolt), whereas the limited information available on this topic suggests fry-to-smolt survival rates of 12% to 20% may be more appropriate for chinook (Smith et al. 1985). Emigration may have occurred before initiation of the 1988 monitoring. However, hydroacoustic sensors may not have detected the full degree of passage in 1987, based on comparisons between scoop trap and hydroacoustic estimates of emigration at Glines Dam in 1987 (Wunderlich and Dilley 1988) and 1988 (Figure 5). Recent scale analysis by Washington Department of Fisheries suggests that most wild Elwha chinook are subyearling emigrants (Sneva 1988).

SUMMARY

We evaluated exit selection, emigration timing, spill-passage survival and fry-to-smolt survival at Glines Canyon Dam on the Elwha River in 1988. This work was initiated as part of an overall effort to restore anadromy in the upper Elwha watershed. Naturally reared coho and steelhead smolts were used for exit selection, timing, and fry-to-smolt survival evaluations. These smolts originated from fry planted in the upper Elwha watershed. Yearling chinook were also present from fingerlings planted in Lake Mills in 1987. Hatchery coho and steelhead smolts (Elwha Tribal stock) were used for spill-passage survival evaluations. Exit selection and timing were evaluated via hydroacoustic monitoring at dam exits in combination with scoop and fyke trapping below the dam. Spill-passage and fry-to-smolt survivals were estimated via scoop trap-based estimates of migrant passage. Loss of the scoop trap for a 9-day period in mid May adversely affected timing and fry-to-smolt results. Trap loss occurred from malfunction of a spillgate control at Glines Canyon Dam.

Hydroacoustic and trap data indicated that coho, steelhead, and chinook emigration had begun by early April, peaked in mid to late May, and declined to negligible levels by late June of 1988. Available scoop trap data indicated that emigration timing was significantly different for coho, steelhead, and chinook during the study period, however.

The spillway (gate 5) of Glines Dam was the principal route of passage over the emigration period. Spill flow was continuous and ranged from approximately 200 to 2,800 cfs, while turbine flow was essentially constant at 1,100 cfs. Over the total study period (April 4 to June 29), approximately 91% of emigrants used the spill exit. However, during the peak movement period from May 5 to June 5, nearly 97% of emigrants used the spill exit. Most spillway movement occurred at night but both day and night spillway movement was significantly greater than turbine movement. No significant difference existed between day and night movement through the turbine. Both day and night spillway movement were significantly correlated with spill volume.

Passage tests at spillgate 5 showed little or no mortality when spill flows exceeded approximately 450 cfs, but substantial mortality in coho tests at both 110 and 220 cfs. A fingerling-chinook test in 1987 also indicated substantial passage loss at approximately 220-cfs spillflow. Based on review of spillflow records, recovery rates, and injuries for all tests, we suspect that spill flows less than approximately 450 cfs may cause poor passage conditions in the spill pool and/or spill-pool exit.

Available scoop trap data indicated that the 1988 emigration was dominated by coho smolts, which apparently experienced excellent survival during their freshwater residence in the upper Elwha watershed. Steelhead were present in far fewer numbers,

and may have experienced only average survival compared to other measures of natural smolt production in the Puget Sound region. Because the trap was inoperable during the peak of the emigration, firm estimates of wild smolt abundance were not achievable, however.

Scoop trap estimates suggested that relatively few yearling chinook emigrated during the 1988 study period. Thus, the degree of residualism of fingerlings planted in Lake Mills in 1987 remains unclear.

ACKNOWLEDGEMENTS

This study was funded by James River Corporation. James River also assisted with installation of the scoop trap and with spill augmentation during the emigration period. The Lower Elwha Tribe and Washington Department of Wildlife provided fish for this evaluation, and we appreciate their assistance. Olympic National Park furnished the scoop trap and provided valuable logistical support for this study.

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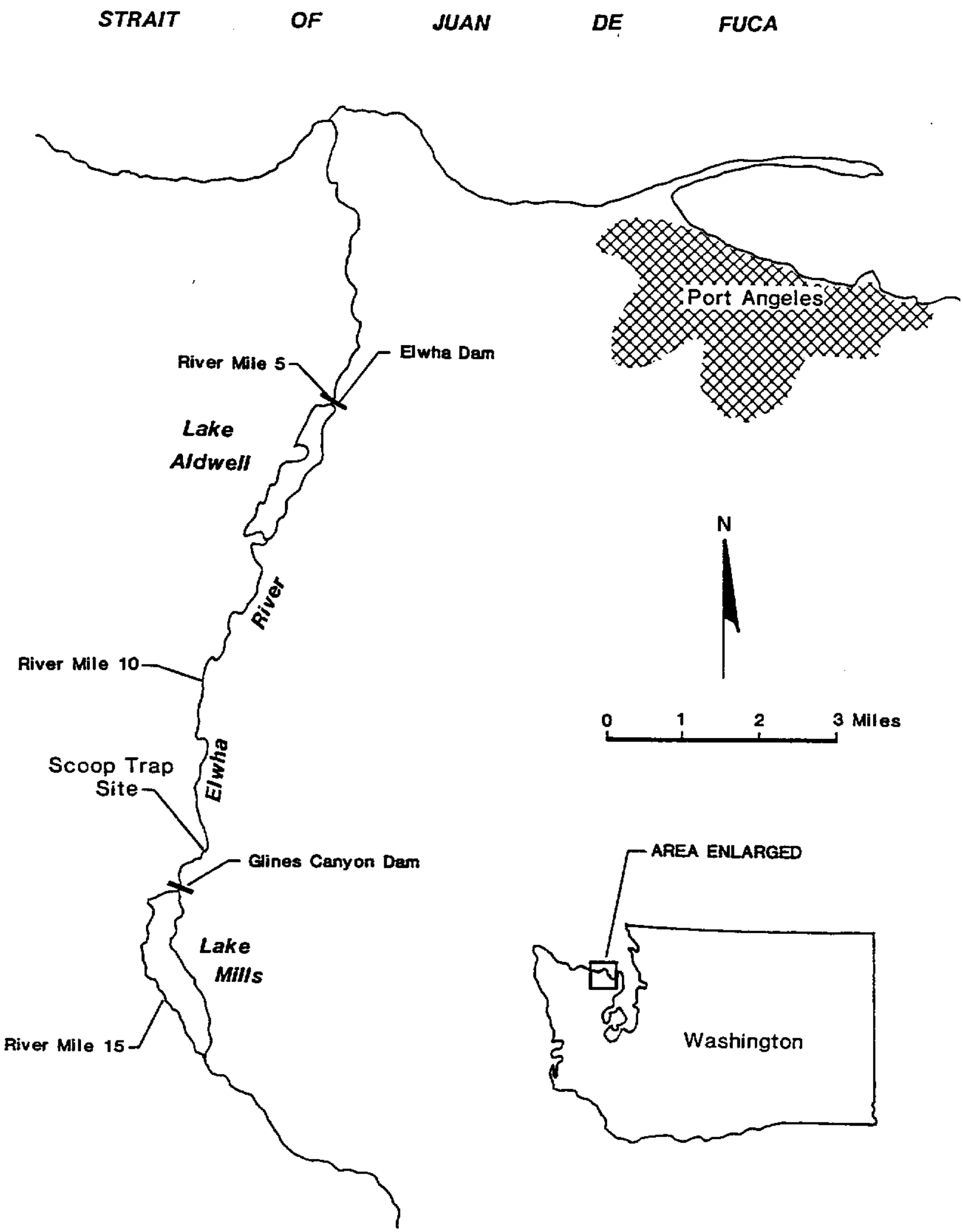

Figure 1. The Elwha River and project features.

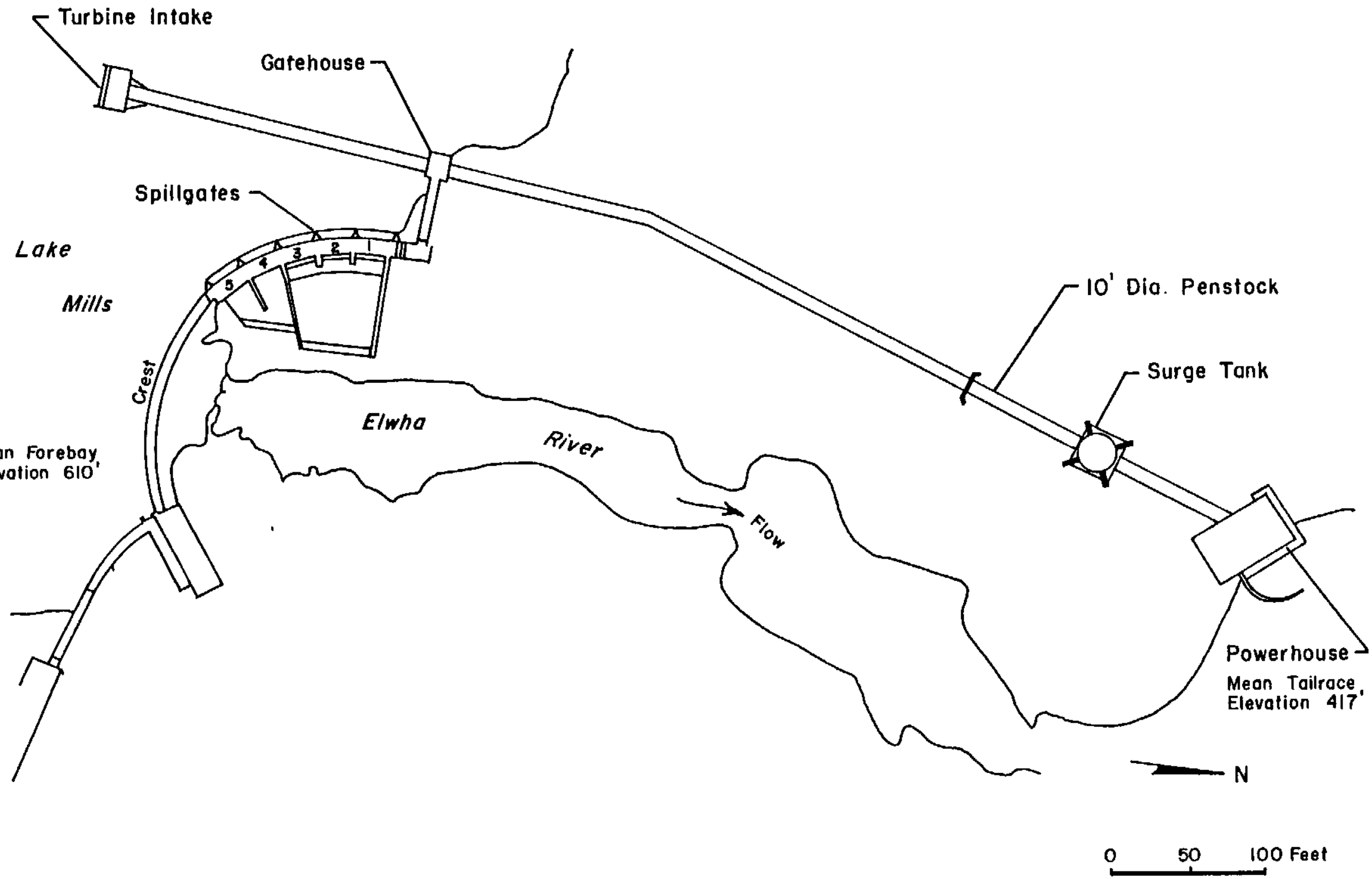

Figure 2. General features of Glines Canyon Dam.

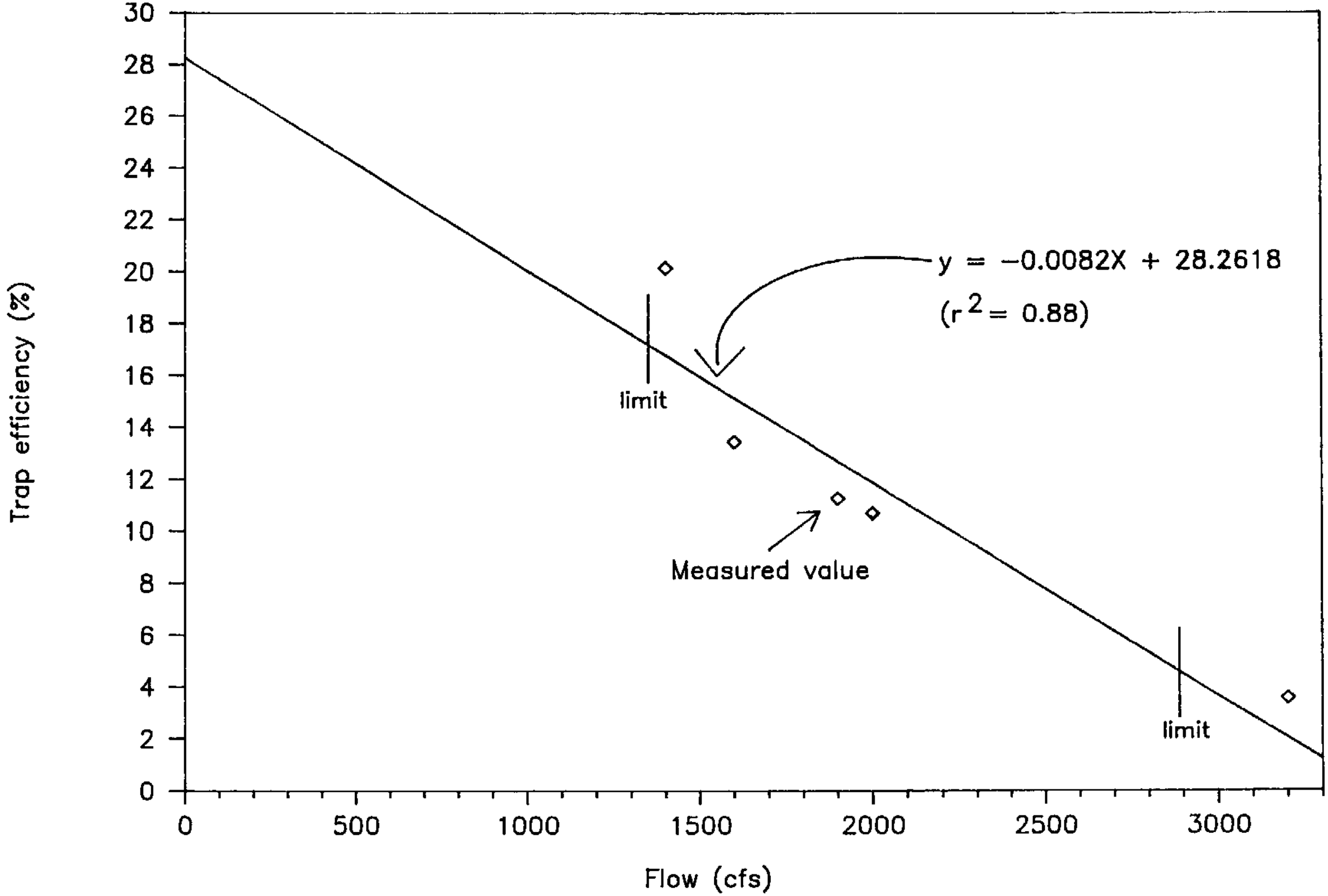

Figure 3. Scoop trap efficiency for coho smolts versus streamflow at the trap site. Predictive limits of the associated regression line are indicated.

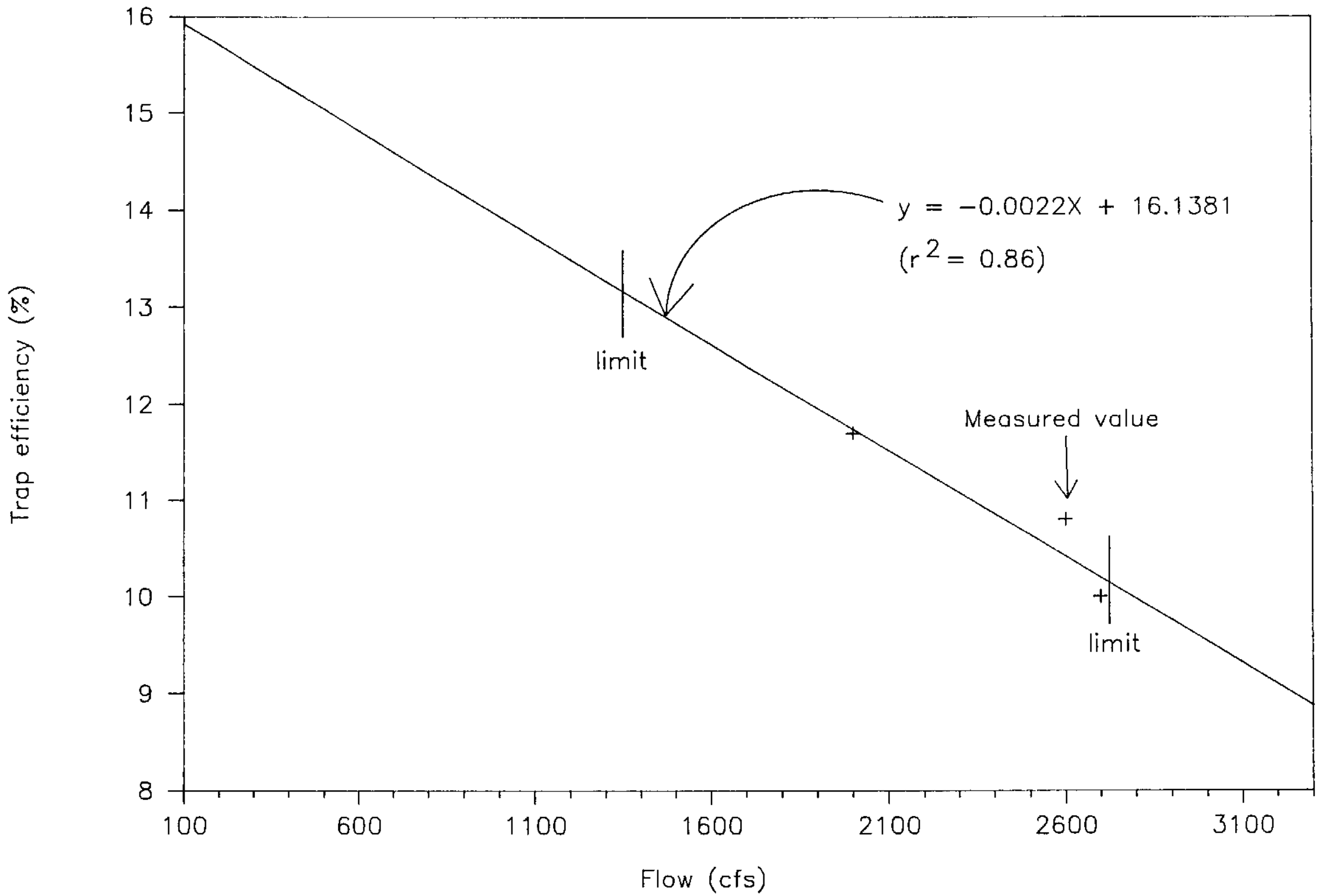

Figure 4. Scoop trap efficiency for steelhead smolts versus streamflow at the trap site. Predictive limits of the associated regression line are indicated.

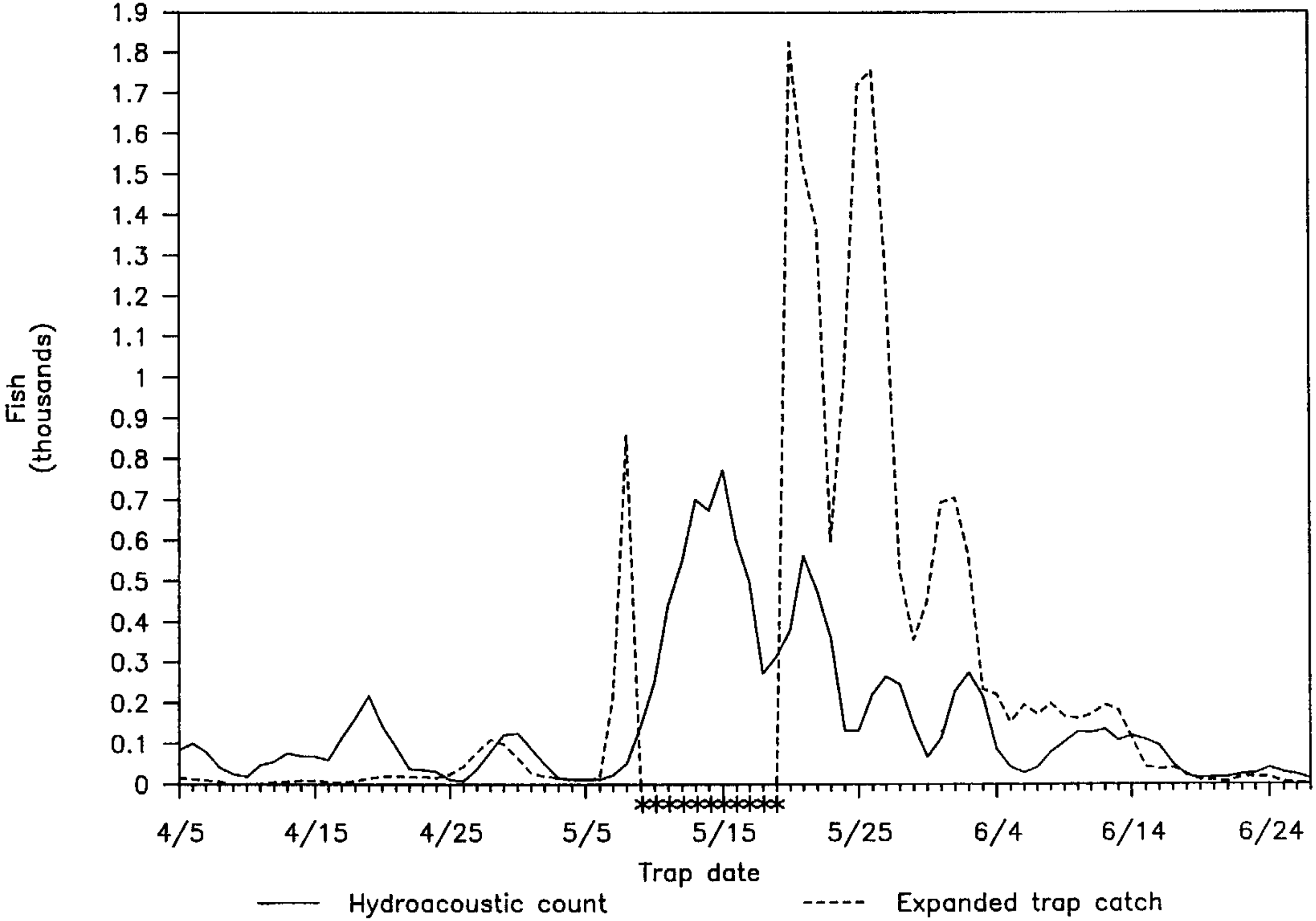

Figure 5. Hydroacoustic versus scoop trap estimates of migrant abundance (all species) at the trap site. Both estimates are moving averages of threes. Hydroacoustic values incorporate a one-day travel time between spillway and scoop trap. Asterisks indicate days of no comparable trap data.

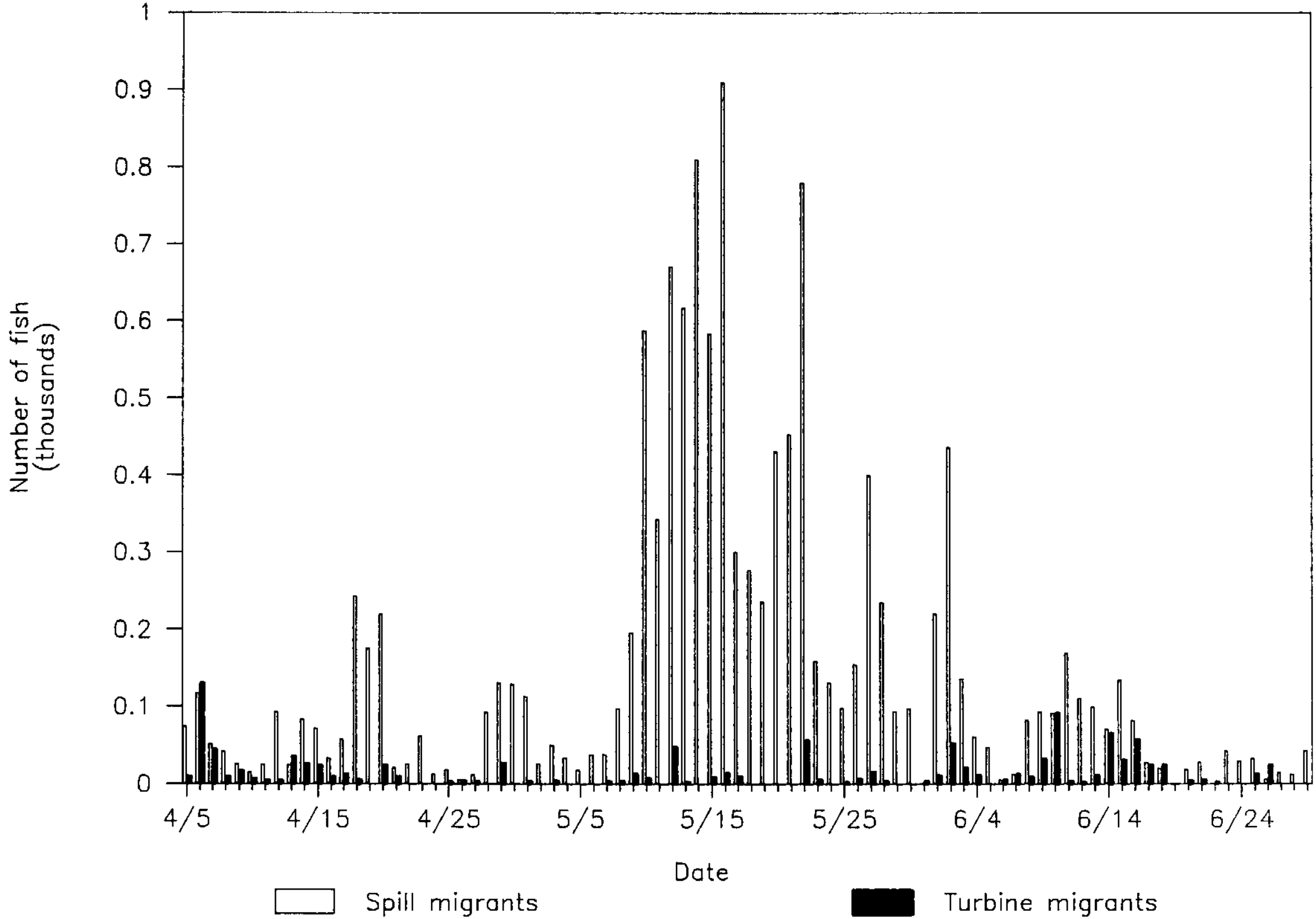

Figure 6. Hydroacoustically estimated daily migration through the turbine and spillway from April 5 to June 29, 1988.

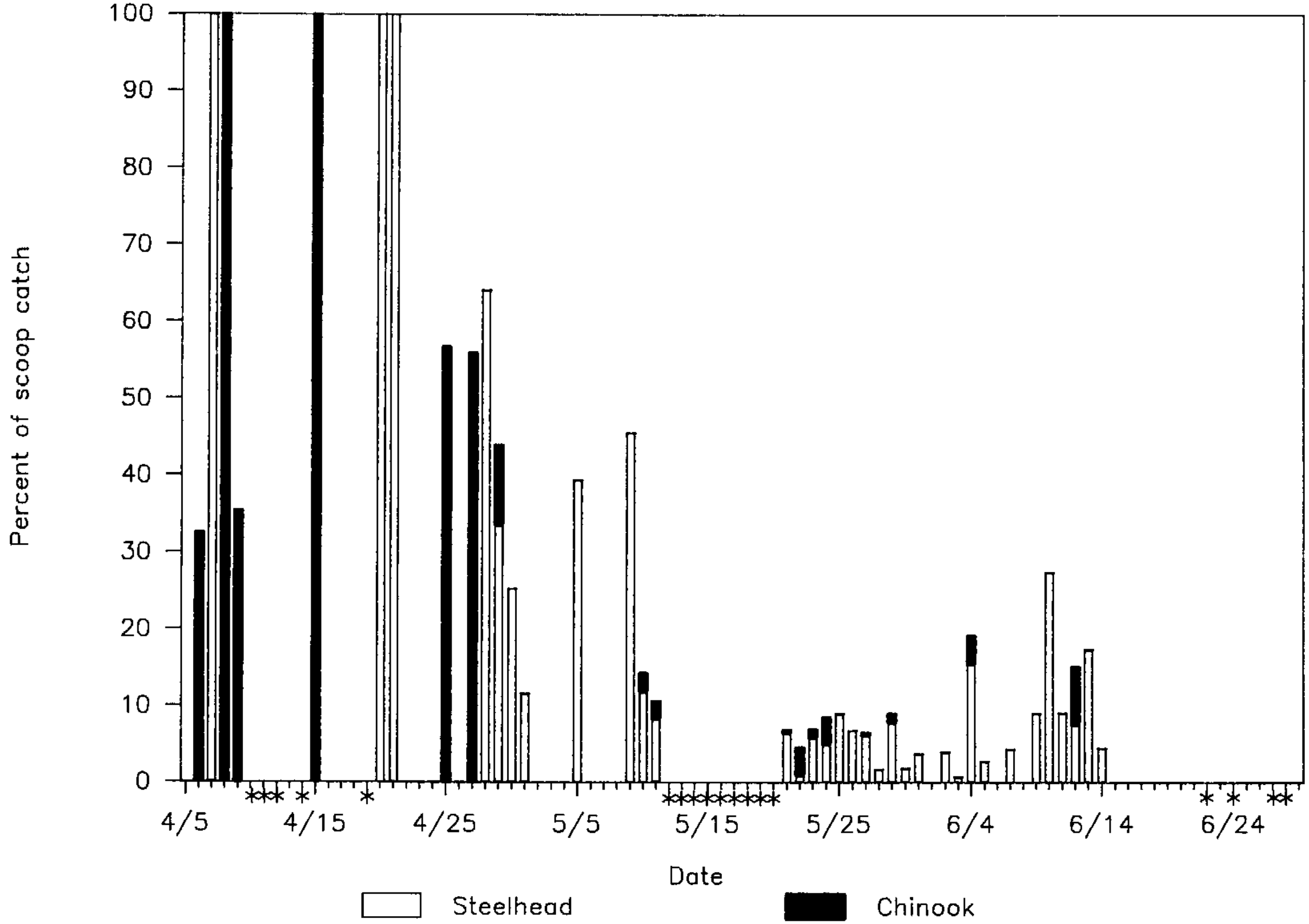

Figure 7. Percentages of naturally reared steelhead and chinook in smolt catches at the scoop trap over the season. Asterisks indicate lack of any migrant catch and the period of trap loss (5/12 – 5/20).

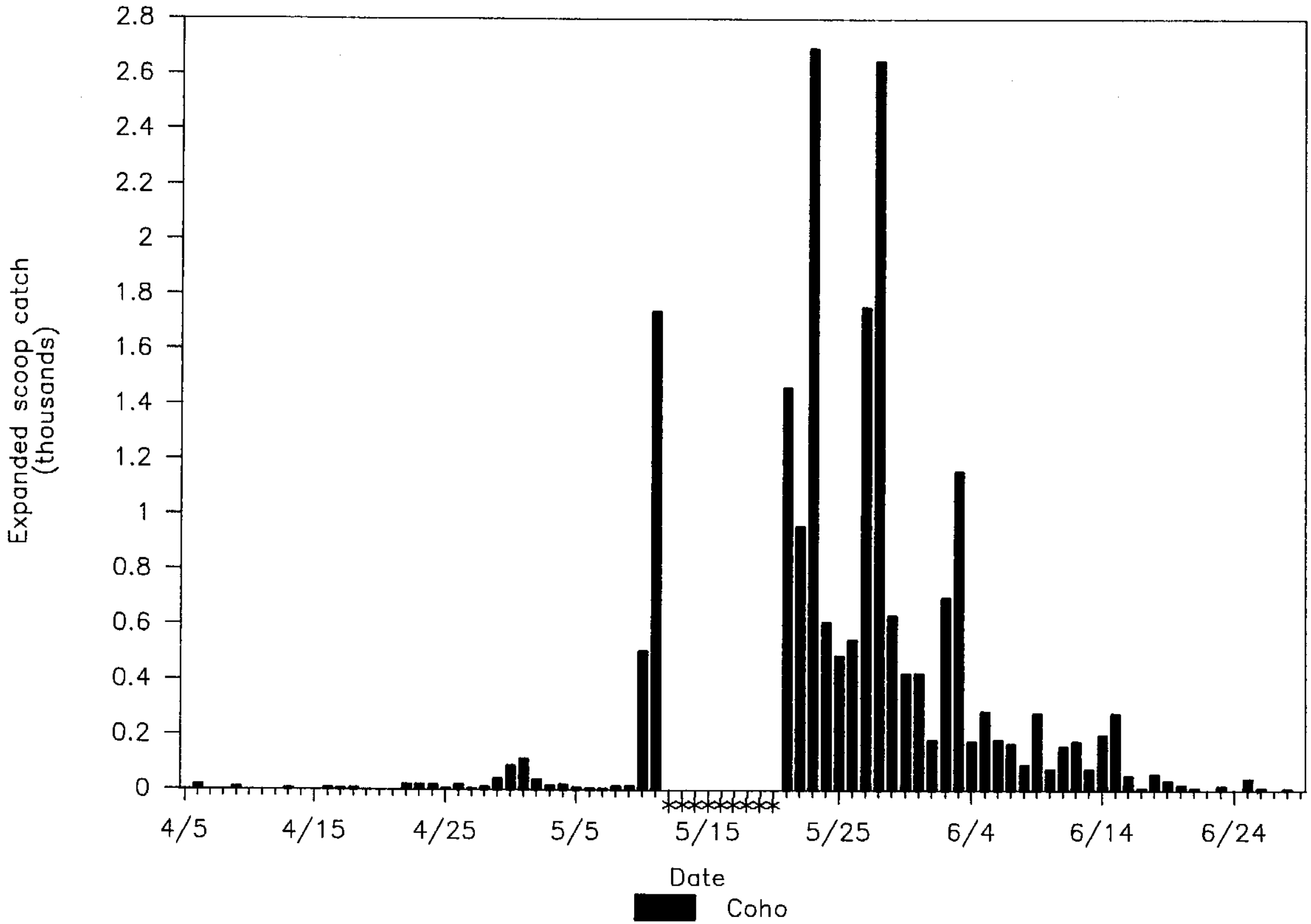

Figure 8. Expanded scoop catches of naturally reared coho smolts. Asterisks indicate period of trap loss.

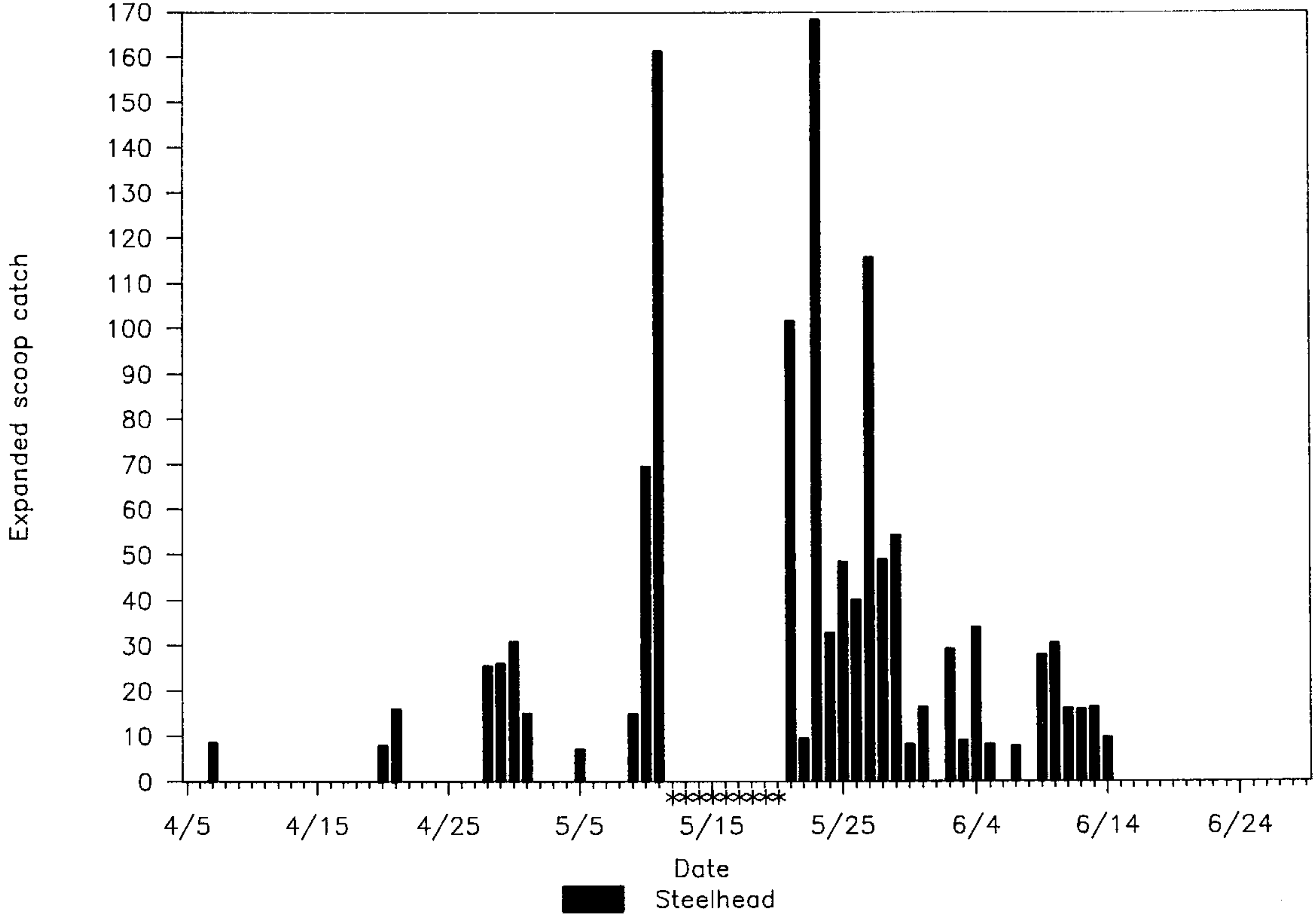

Figure 9. Expanded scoop catches of naturally reared steelhead smolts. Asterisks indicate period of trap loss.

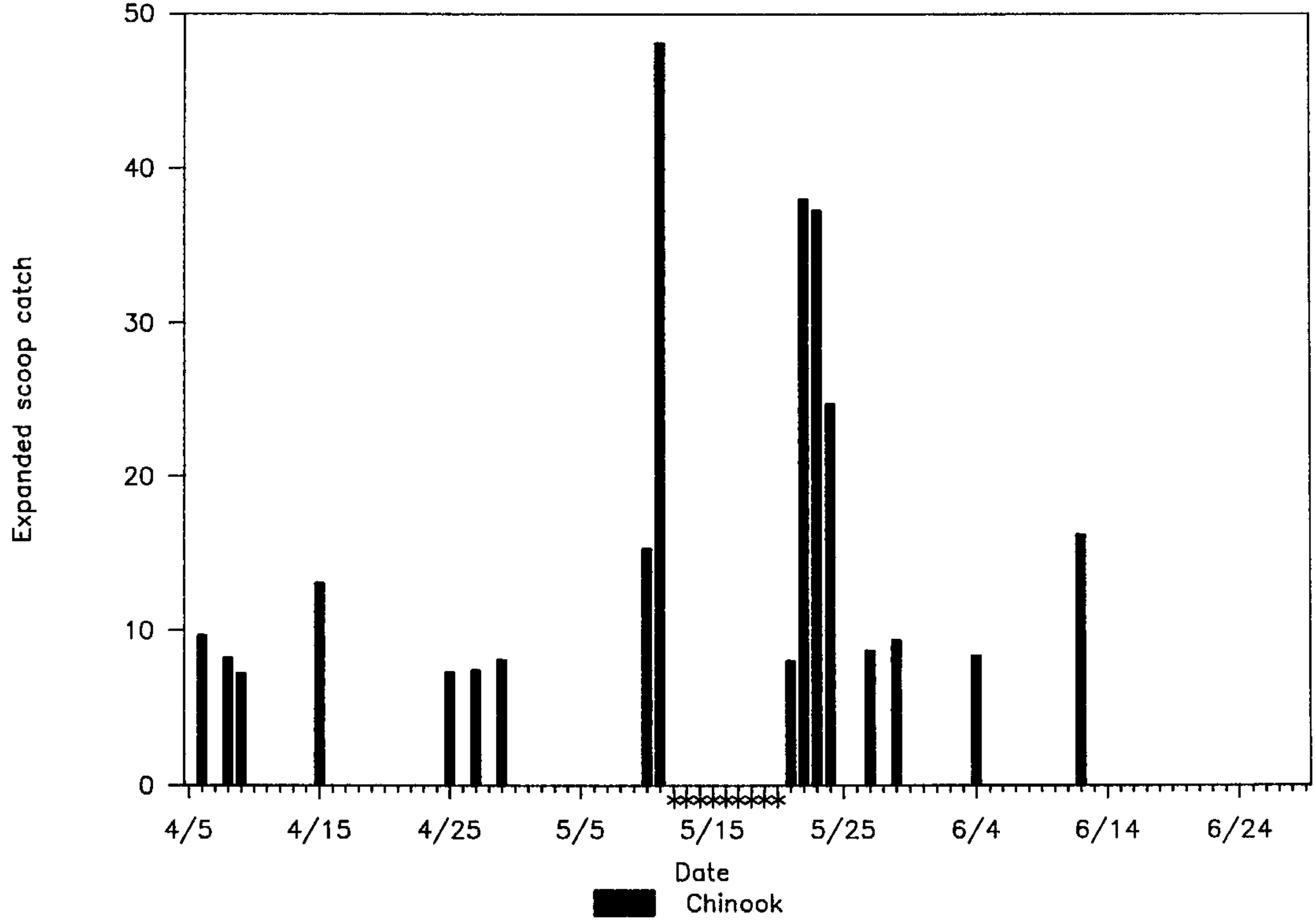

Figure 10. Expanded scoop catches of yearling chinook resulting from fingerlings planted in Lake Mills during 1987. Asterisks indicate period of trap loss.

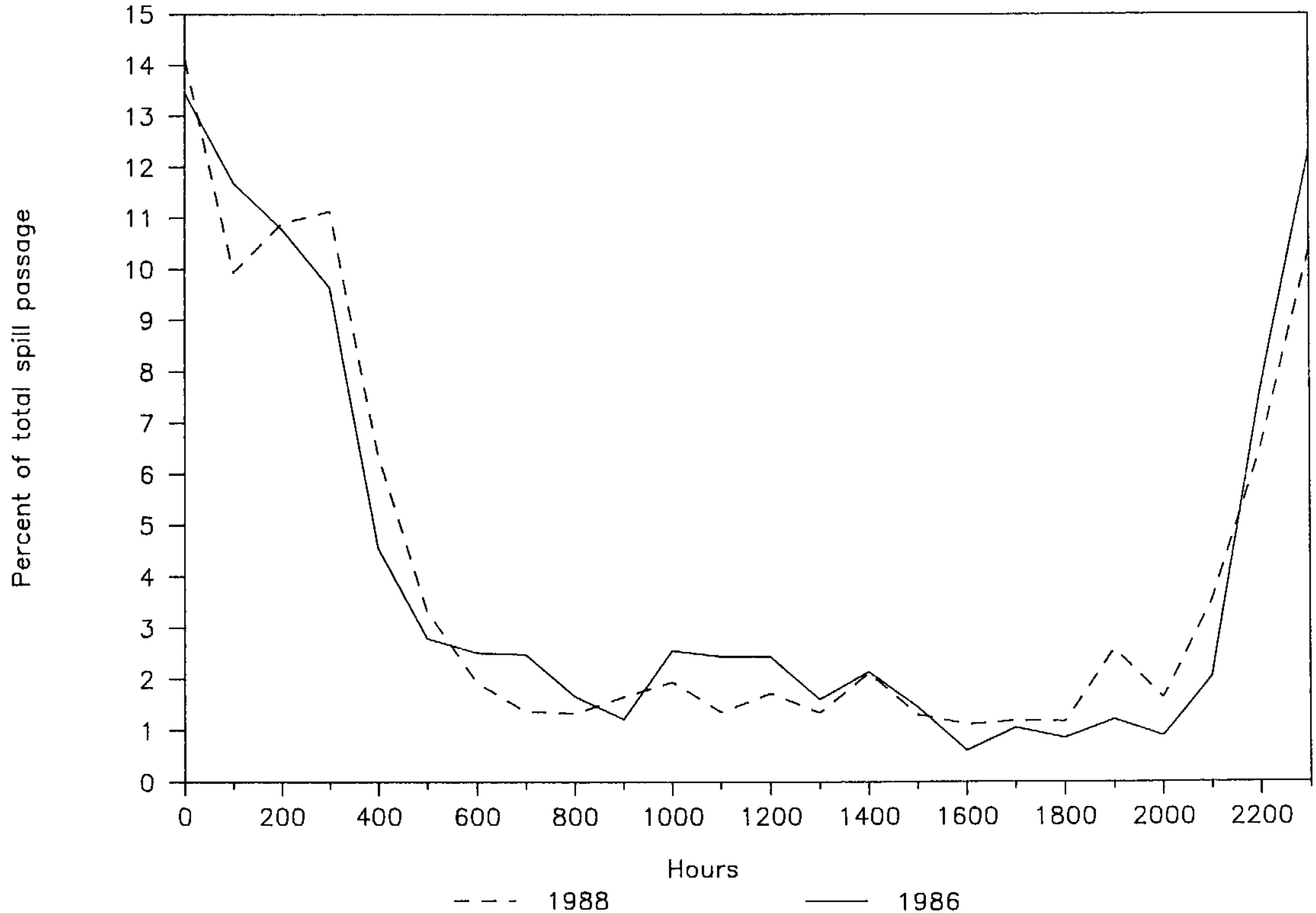

Figure 11. Hourly percentages of smolt passage through the Glines Canyon Dam spillway in 1988 and 1986. The 1986 data pertains to hatchery steelhead reported in Dilley and Wunderlich (1987).

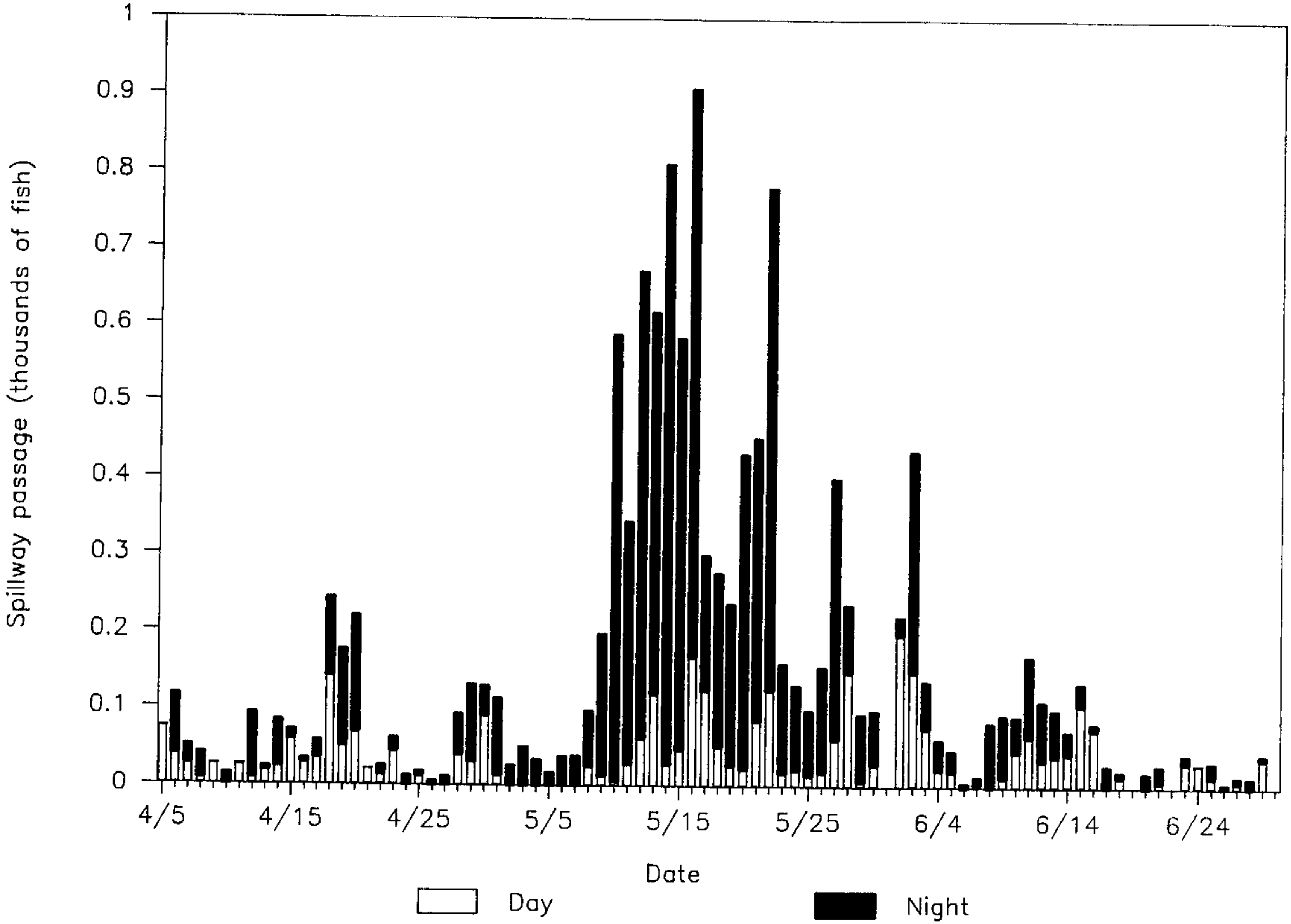

Figure 12. Day versus night passage at spillgate 5. The night period was defined as 2100 to 0500 hours.

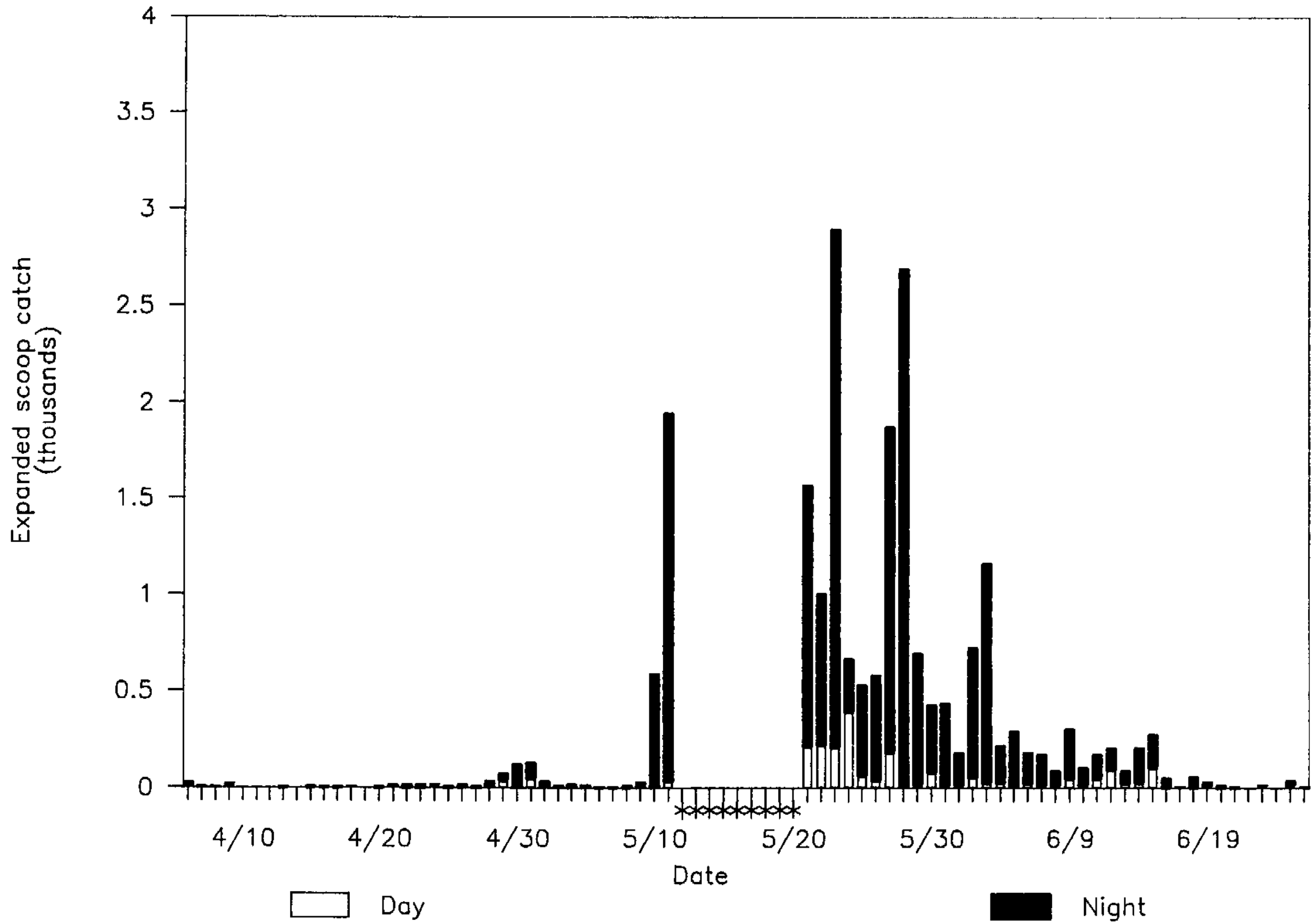

Figure 13. Day versus night catches of naturally reared smolts (coho, steelhead, and chinook) at the scoop trap. The night period was defined as 2100 to 0500 hours. Asterisks indicate period of trap loss.

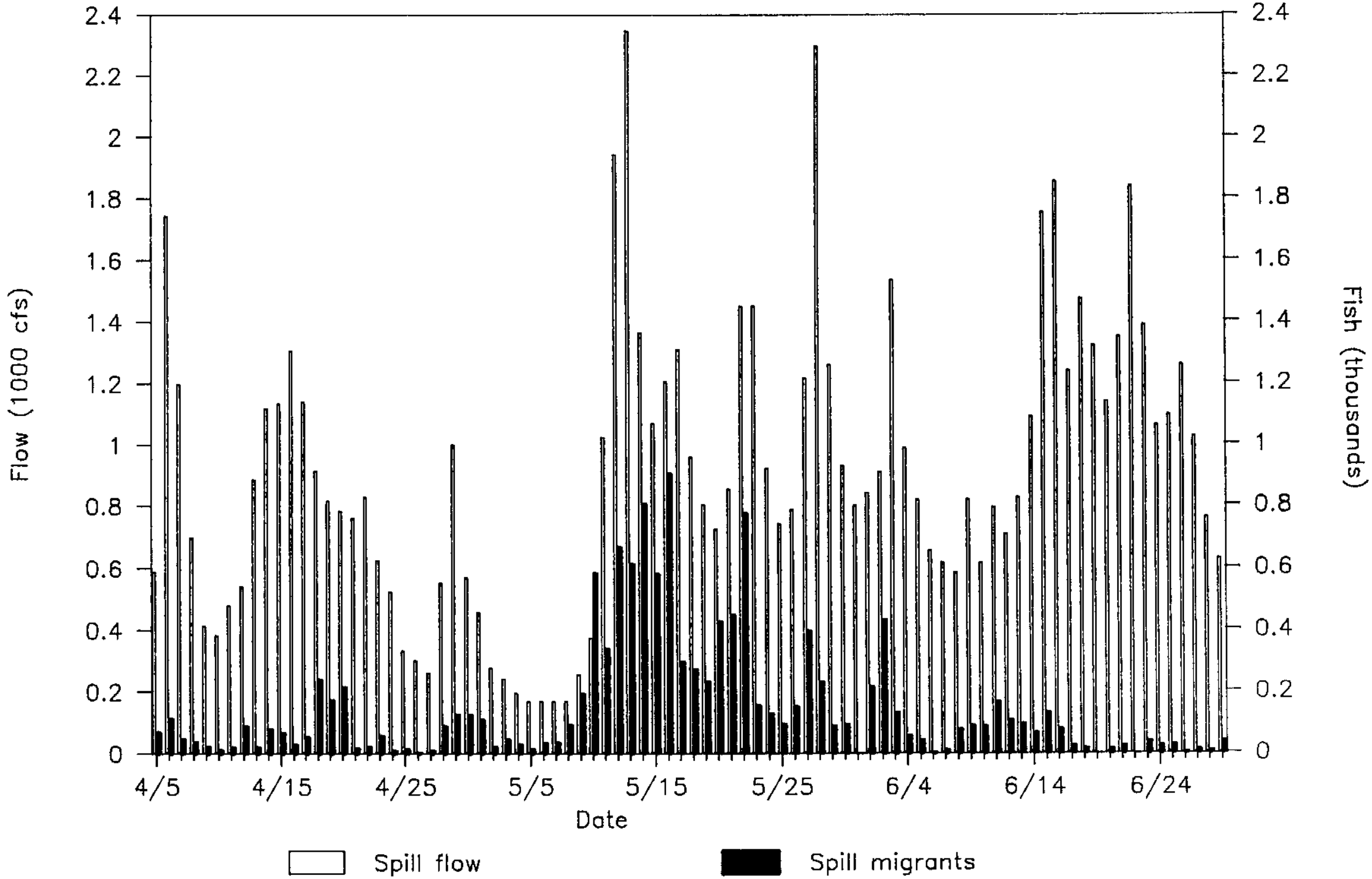

Figure 14. Average daily spill and daily spill migrants during April, May and June of 1988.

Table 1. Steelhead and coho fry (Elwha stock) planted in the upper Elwha watershed. All releases were adipose-fin clipped and coded-wire tagged.

Species	Release number	Release size		Release date	Release location
		No./lb	Mean forklength (mm)		
Steelhead	17,750	300	-	7/22/86	Camp Wilder (rm 35.5)
Steelhead	15,696	300	-	7/22/86	Tipperary Camp (rm 30.8)[a]
Steelhead	4,736	300	-	7/22/86	Humes Ranch (rm 19.3)
Total:	38,182				
Coho	48,982	160	61	7/14/87	Camp Wilder (rm 35.4)
Coho	51,286	160	61	7/14/87	Tipperary Camp (rm 30.8)
Coho	51,332	160	61	7/14/87	Humes Ranch (rm 19.3)
Total:	151,600				

[a] An estimated 15% of this group appeared stressed upon arrival at the release site due to transport, but no mortality or stress was noted immediately after release.

Table 2. Spill rule for the 1988 emigration at Glines Canyon Dam.

Dates	Spill volume and timing
April 4 - 30	Spill at least 100 cfs every other night (1900 - 0700 hrs).
May 1 - June 30	Spill at least 100 cfs continuously.
July 1 and later	Spill at least 100 cfs for 24 hrs every other day until emigration is negligible.

Table 3. Hatchery coho and steelhead releases at Glines Canyon Dam in 1988. All releases were Elwha stock from the Elwha Tribal Hatchery.

Group	Release location	Release date	Number released	Mark legibility (%)[a]	Marks released
		Coho			
Control 1	Rm 13.2	Apr 7	1,989	100.0	1,976
Control 2	Rm 13.0	Apr 21	1,977	99.4	1,965
Control 3	Rm 13.0	Apr 25	2,022	99.4	2,010
Control 4	Rm 13.0	Jun 8	1,958	89.4	1,750
Control 5	Rm 13.0	Jun 15	2,046	Unmarked	2,046
1/4-ft Spill test	Spillgate 5	Apr 25	1,952	99.4	1,940
1/2-ft Spill test	Spillgate 5	Apr 26	1,999	94.4	1,887
1-ft Spill test	Spillgate 5	May 26	1,918	98.1	1,882
1 1/2-ft Spill test	Spillgate 5	Jun 1	1,931	81.9	1,581
2-ft Spill test	Spillgate 5	Apr 20	1,998	100.0	1,998
2 1/2-ft Spill test	Spillgate 5	Apr 7	2,023	Unmarked	2,023
3 1/2-ft Spill test	Spillgate 5	Jun 9	1,931	98.8	1,908
		Steelhead			
Control 1	Rm 13.0	May 11	1,217	100.0	1,217
Control 2	Rm 13.0	Jun 13	1.855	95.6	1,773
Control 3	Rm 13.0	Jun 14	1,950	91.2	1,778
1/4-ft Spill test	Spillgate 5	Jun 9	1,845	91.9	1,696
1-ft Spill test	Spillgate 5	May 26	1,777	97.5	1,733

[a] Each group was uniquely freeze-branded, except as noted.

Table 4. Provisional survival rate estimates for all juvenile migrants passing turbine and spill exits of Glines Canyon Dam. Values shown are based on results described in this report and results obtained from 1987 exit studies at this dam (Wunderlich and Dilley 1988).

Exit	Exit flow	Estimated survival
Spillgate 5	<250 cfs	0.35
Spillgate 5	250-450 cfs	0.50
Spillgate 5	>450 cfs	1.00
Turbine	1,100 cfs	0.32

Table 5. Mean length of naturally reared coho, steelhead, and chinook smolts recovered in the scoop trap in 1988.

Species	Mean recovery fork length (mm)	s.d.	(n)
Coho	120.2	9.5	1451
Steelhead	197.0	20.2	151
Chinook[a]	190.2	21.3	35

[a] Yearling chinook smolts originating from 1987 fingerling releases in Lake Mills.

Table 6. Total scoop and fyke trap catches (and percent of catch) of naturally reared coho, steelhead, and chinook smolts in 1988.

	Scoop trap catch				Fyke trap catch	
Species	Actual		Expanded[a]		Actual	
Coho	1,883	(90.4)	23,562	(93.1)	26	(92.9)
Steelhead	162	(7.8)	1,416	(5.6)	2	(7.1)
Chinook[b]	37	(1.8)	325	(1.3)	0	(0.0)

[a] Not expanded for the period of trap loss in mid May.
[b] Yearling smolts originating from fingerling releases in Lake Mills during May and June of 1987.

Table 7. Mean numbers of smolts passing through the turbine and spillway exits in both day and night in 1986 and 1988. Probabilities of a greater t for the hypothesis that means were equal were calculated on log-transformed hourly values.

Exit	Day/ night	Mean number per hour	Code	Probability of a greater t		
				1	2	3
			1988-Coho[a]			
Spillway	Day	2.47	1			
Spillway	Night	13.08	2	0.0001		
Turbine	Day	0.56	3	0.0001	0.0001	
Turbine	Night	0.72	4	0.0001	0.0001	0.4169
			1986-Steelhead[b]			
Spillway	Day	5.98	1			
Spillway	Night	30.35	2	0.0001		
Turbine	Day	0.38	3	0.0001	0.0001	
Turbine	Night	0.40	4	0.0001	0.0001	0.8477

[a] Steelhead and yearling chinook smolts were also present in relatively low numbers.
[b] Hatchery steelhead smolts (Dilley and Wunderlich 1987).

Table 8. Hydroacoustic detections of migrant passage through spill and turbine exits of Glines Canyon Dam in 1988.

Exit	Estimated migrants (%)			
	Apr 4 - Jun 29[a]		May 5 - Jun 5[b]	
Spillway[c]				
Day	3,200		1,707	
Night[d]	10,149		7,996	
Total:	13,349	(91.2)	9,703	(96.6)
Turbine				
Day	733		206	
Night[d]	557		132	
Total:	1,290	(8.8)	338	(3.4)
Grand Total	14,639		10,041	

[a] Overall monitoring period.
[b] Higher passage period.
[c] Spillgate number 5.
[d] The night period was defined as 2100 to 0500 hrs.

Table 9. Estimated survival of spillway test groups at associated spill flows. All tests occurred at spillgate 5.

Species	Estimated survival (%)	Spillgate opening at release (ft)	Spill flow at release (cfs)	Spill flow after release (cfs)[a]
Coho	34	1/4	110	266
Coho	64	1/2	220	397
Coho	100[b]	1	441	767
Coho	100[b]	1 1/2	662	864
Coho	100[b]	2	882	814
Coho	93	2 1/2	1.090	1,073
Coho	100[b]	3 1/2	1,482	1,444
Steelhead	97	1/4	110	694
Steelhead	94	1	441	818
Chinook[c]	42	1/2	220	407

[a] Mean spill flow for 6-hr period after each test release. These values typified flows for up to 18 hours after each release.

[b] No detectable mortality.

[c] This test occurred in 1987 using fingerling-size chinook (Wunderlich and Dilley 1988).

Table 10. Injuries observed among scoop and fyke trap recoveries of coho smolts in 1988. Injuries are expressed as a percentage of each group recovered at the scoop trap. Those fish recovered with more than one injury type are represented in all applicable categories.

Study group	Injuries by category (%)						Percent of recoveries injured or dead	Number of smolts examined
	Light descaling[a]	Moderate descaling[b]	Heavy descaling[c]	Eye damage[d]	Other external injuries[e]	Moribund		
				Scoop				
Naturally reared[f]	19	5	1	0	2	0	29	1,606
1/4-ft Spill test	31	28	2	0	1	0	67	83
1/2-ft Spill test	35	13	1	0	4	0	51	140
1-ft Spill test	24	4	0	0	1	0	29	229
1 1/2-ft Spill test	20	8	0	0	3	0	31	218
2-ft Spill test	17	3	1	0	2	0	29	299
2 1/2-ft Spill test	26	4	1	0	3	1	36	214
3 1/2-ft Spill test	10	0	0	0	0	0	10	104
Control 1	8	2	1	0	1	0	10	124
Control 2	17	3	3	0	2	0	31	189
Control 3	21	13	5	0	0	1	40	129
Control 4	5	0	0	0	0	0	6	119
Control 5	11	0	0	0	0	2	16	44
				Fyke				
Naturally reared[f]	3	3	73	0	7	7	92[g]	26

[a] Less than 10% scale loss on the body surface
[b] Between 10 and 50% scale loss on the body surface.
[c] Greater than 50% scale loss on the body surface.
[d] Bulging or lost eye.
[e] Torn fin, operculum, or other external injury with or without bleeding.
[f] These smolts originated from fingerlings planted into the upper watershed in 1987.
[g] Sixty-five percent of these smolts were dead at recovery.

Table 11. Injuries observed among scoop trap recoveries of steelhead smolts in 1988. Injuries are expressed as a percentage of each group recovered at the scoop trap. Those fish recovered with more than one injury type are represented in all applicable categories.

Study group	Injuries by category (%)						Percent of recoveries injured or dead	Number of smolts examined
	Light descaling[a]	Moderate descaling[b]	Heavy descaling[c]	Eye damage[d]	Other external injuries[e]	Moribund		
Naturally reared[f]	26	9	1	0	2	1	38	162
1/4-ft Spill test	19	5	0	0	1	0	25	148
1-ft Spill test	22	8	3	0	2	1	34	119
Control 1	11	4	1	0	0	1	18	135
Control 2	13	21	3	0	0	0	36	151
Control 3	11	7	1	0	0	1	21	104

[a] Less than 10% scale loss on the body surface.
[b] Between 10 and 50% scale loss on the body surface.
[c] Greater than 50% scale loss on the body surface.
[d] Bulging or lost eye.
[e] Torn fin, operculum, or other external injury with or without bleeding.
[f] These smolts originated from fingerling plants in the upper watershed in 1986.

Table 12. Estimated pre-passsage smolt abundance.

Species	Expanded scoop catch	Potential scoop catch[a]	Estimated passage survival[b]	Pre-passage smolt abundance[c]
Coho	23,562	21,107	.896	49,854
Steelhead	1,416	1,002	.896	2,699
Chinook	325	207	.896	594

[a] Potential catches during the period of trap loss. These values were derived from the hydroacoustic-to-trap ratio in a like time period following loss of the trap. Species composition was assumed to remain constant during and after trap loss (see text).

[b] Derived from a spreadsheet model incorporating estimated passage and survival rates at each exit over the season (see text).

[c] Expanded plus potential scoop catch divided by estimated passage survival.

Table 13. Release and recovery lengths of hatchery coho and steelhead control groups. Recovery occurred at the scoop trap.

Group	Mean release fork length (mm)	Mean recovery fork length (mm)	Difference (mm)
		Coho	
Control 1	133.0	134.5	+1.5
Control 2	135.2	139.6	+4.4[a]
Control 3	136.9	140.3	+3.4[a]
Control 4	147.2	147.5	+0.3
Control 5	151.1	155.0	+3.9[a]
		Steelhead	
Control 1	179.3	183.6	+4.3[a]
Control 2	192.2	196.6	+4.4[a]
Control 3	193.8	196.9	+3.1

[a] Statistically significant at 0.05 level.