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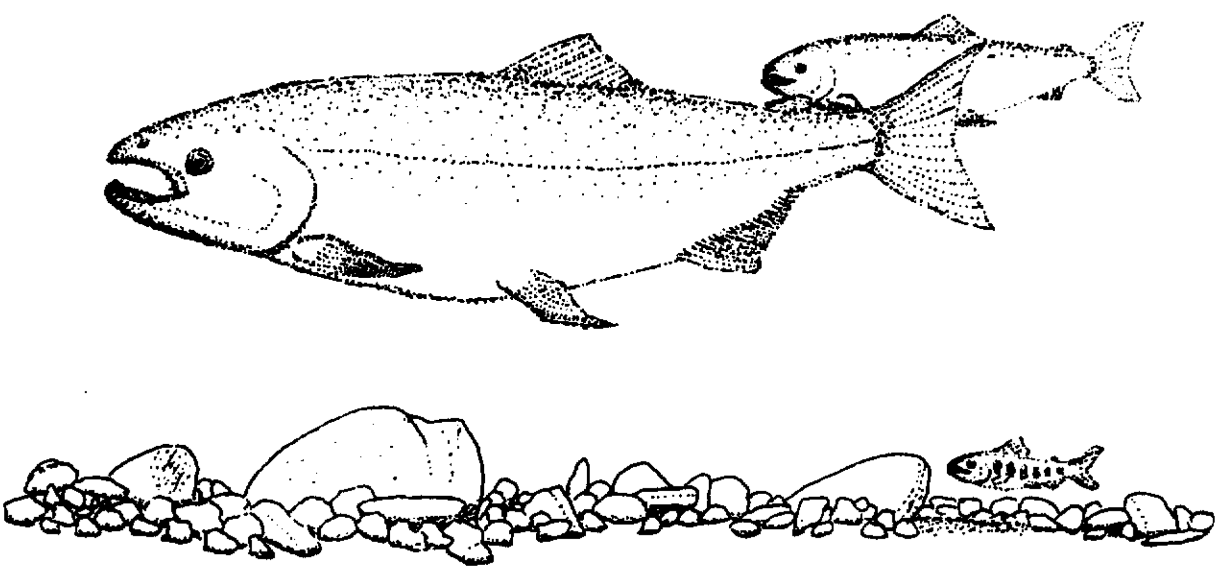
Evaluation of Juvenile Chinook and Juvenile Steelhead Passage at Glines Canyon Dam



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ABSTRACT

We evaluated juvenile chinook exit selection, emigration patterns, and survival at Glines Canyon Dam in 1987. We released Elwha-stock subyearling chinook in the reservoir forebay in May and June, and monitored their passage through dam exits with hydroacoustic equipment until late December. We also trapped emigrants passing the dam during May-July to enhance hydroacoustic passage estimates, because wild steelhead smolts (which are indistinguishable from juvenile chinook hydroacoustically) were also present from plants of adults in 1985. We determined that most chinook migrants used the spillway rather than the turbine, but degree of spillway passage was not stongly related to volume of water spilled. During the monitoring period, peak chinook movement was believed to occur in late June and early July, and peak steelhead movement occurred in May. The greatest proportion of chinook using the spillway rather than the penstock (89%) occurred during June and early July. Hydroacoustic detections accounted for only about one-half of the chinook released into the reservoir. Trap data suggested that hydroacoustic monitoring may have underestimated chinook movement, but we believe that a substantial number of chinook residualised in the reservoir. Atypical streamflows in 1987 may have also influenced chinook exit selection and emigration patterns. We estimated that approximately 32% of chinook survived passage through the Glines Canyon Dam turbine (at full generation) and 42% survived passage through spillgate number 5 (at 220 cfs spillflow). Scale loss was the dominant injury among chinook and steelhead survivors recovered 1/2 river mile below the dam, and scale loss was more pronounced among steelhead. We estimated that approximately 2,400 steelhead smolts passed Glines Canyon Dam during our monitoring period.

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INTRODUCTION

Development of effective passage measures for juvenile salmonids at Glines Canyon Dam is an essential step in restoration of chinook, coho, and steelhead to the upper Elwha River. Both Glines Canyon Dam and Elwha Dam (Figure 1) were constructed without provision for anadromous fish passage. Available information on downstream fish passage at the Elwha dams suggested that spilling could be a relatively safe and very effective means to pass certain species of downstream migrants at Glines Canyon Dam. Both coho and steelhead migrants favored the spillway rather than the turbine exit in earlier evaluations, and spillway mortality appeared to be minimal (Schoeneman and Junge 1954; Wunderlich and Dilley 1985, 1986; Dilley and Wunderlich 1987). Subyearling chinook, however, were observed to enter the Glines turbine intake and incur a relatively high mortality rate despite availability of the spillway exit (Schoeneman and Junge 1954). Identifying specific volumes of spill needed to sufficiently reduce turbine entry of chinook is therefore of major importance in developing downstream migrant passage measures at Glines Canyon Dam and was the principal objective of the work described in this report. Since wild steelhead smolts were also present at Glines Canyon Dam in 1987, we assessed their abundance, timing, and choice-of-exit as well.

We conducted additional, related passage work in 1988, but the results of that work have not been fully analyzed. Accordingly, some of the results reported herein are still preliminary pending final analysis of the 1988 data. Results that are still preliminary are so identified. A final report of the 1988 passage work at Glines Dam will be available in January 1989, and that document will incorporate any appropriate changes in the results described herein.

METHODS

General Study Design

Our general experimental approach in 1987 was to release subyearling chinook in Lake Mills (Figure 1) throughout the spring outmigration period, then monitor their passage hydroacoustically over a range of spills at Glines Canyon Dam to assess the effect of spill volume on exit selection. The chinook were Elwha hatchery stock released in three increments. During the spring, abundance of migrants was also estimated via scoop and fyke trapping below the dam to verify acoustic estimates, and to identify presence of wild steelhead smolts originating from adults planted in the upper watershed in 1985. (Steelhead were the only other anadromous emigrants in the upper watershed in 1987, but they were hydroacoustically inseparable from chinook and thus required independent assessment.) We also conducted tests at the exits of Glines Canyon Dam to assess survival and help reconcile hydroacoustic and trap estimates of migrant abundance. Due to uncertainties regarding the natural emigration pattern of Elwha-stock chinook, we continued hydroacoustic monitoring until December 1987, and examined ATPase as a biochemical index of smoltification in the chinook release groups.

Hydroacoustic Monitoring

The hydroacoustic monitoring system employed at Glines Dam in 1987 was essentially the same as that used by Fisheries Assistance Office (FAO) in 1986 (Dilley and Wunderlich 1987). It consisted of three 15-degree, 420-kHz transducers, an echo sounder/tranceiver, a multiplexer/equalizer (MPX/EQ), a thermal chart recorder, and an oscilloscope. Table 1 lists model numbers of the equipment used.

The hydroacoustic system operated as follows (Raemhild, undated). When triggered by the echo sounder, the transducer emitted short sound pulses towards the area of interest. As these sound pulses encountered fish or other targets, echos were reflected back to the transducer which then reconverted the sound energy to electrical signals. These returning signals were amplified by the echo sounder and equalized. A target's range from the transducer was determined by the timing of its echo relative to the transmitted pulse.

The echo sounder relayed the returning signals to the thermal chart recorder and oscilloscope. Return signals were visually displayed on the oscilloscope for measurements of echo strengths and durations. Individual fish traces were recorded by the thermal chart recorder as an echogram which provided a permanent record of all targets detected during the study.

The MPX/EQ permitted the echo sounder to individually interrogate multiple transducers at Glines Canyon Dam in an operator-specified sequence. The MPX/EQ channeled transmitted pulses from the echo sounder to the appropriate transducer and also equalized the return signals to compensate for differing receiving channel sensitivities.

We subsampled all possible fish exits during the entire study. Over this period, Glines Dam had two potential fish exits: 1) through the single turbine intake located about 80 feet below the normal surface elevation of the reservoir and about 100 feet upstream of the dam; and 2) under spillgate 5 in its opened position (Figure 2). Crest spilling was curtailed during the study period so sampling of crest passage was unnecessary.

To achieve the best possible transducer position at the turbine intake and spillway, three main criteria were considered: 1) maximize the sample area, 2) minimize hydroacoustic turbulence, and 3) place in closest proximity to the passageway. The Glines turbine intake is approximately 40 ft high and 20 ft wide and is located on the bottom of the reservoir in the old river canyon. At this location, the canyon is only slightly wider than the intake. Because of the proximity of the canyon walls to the turbine intake, a surface-mounted transducer could not be used because of noise produced by echos received from the canyon walls. To reduce this noise, the transducer was mounted on a frame and lowered down the face of the turbine intake tower until a calculated transducer beam width of 20 ft was achieved. This location was approximately 55 ft from the bottom. From this point, the frame was adjusted up and down until maximum range and minimum bottom noise were attained. The transducer mount was subsequently inspected by a scuba diver and found to be in a satisfactory orientation.

A surface-mounted transducer provided the best location to monitor spillway passage. Glines Canyon Dam has a total of five spillgates (Figure 2). During a typical spring, only one spillgate is opened. However, to insure that no data would be lost during an unusual flood condition, we mounted transducers above both the primary and alternate spillways designated for spring use (numbers 5 and 4, respectively). We recommended all spilling occur in spillway 5 because we had previously monitored smolt passage at this gate in 1986 and spillway 5 was more centrally located for migrant attraction in the reservoir forebay.

Both turbine and spillway transducers were tested for optimal aiming angle. The transducers were aimed in an angular fashion to permit assessment of the direction of fish movement with respect to the dam exit. For this purpose, the turbine-mounted transducer was tested every five degrees, looking down and upstream, from twenty-five to forty degrees (zero degrees being straight down). An angle of thirty-five degrees was considered optimal. In like manner, the surface-mounted transducers were tested from fifteen to forty-five degrees, and a twenty-five degree angle was chosen.

The hydroacoustic system was calibrated prior to data collection to assure that echoes from target fish were properly received and recorded. Based on previous calibration information, the adjustable print threshold on the thermal chart recorder was set so that only signals from fish larger than -56dB on axis (fingerling-size chinook) would be printed. The calibration information was also used to equalize the system sensitivity for each of the receiving channels.

Three criteria were used to assess whether an echogram trace was a valid detection of a fish moving into the turbine intake or under the spillgate. These were:

1). The strength of the target echo must exceed the predetermined threshold (-56dB).

2). The targets must be detected by no less than four consecutive pulses.

3). The targets must show a general movement toward the intake or spillgate.

Since the threshold was determined before data collection, the first criterion was satisfied. Targets that fell below the threshold (e.g., trout fry) were simply not printed out by the thermal chart recorder. The redundancy requirement in the second criterion (four consecutive pulses) was needed due to the relatively wide beam width of the transducers, the high pulse repetition rates, and the assumption that the fish were moving at about the same velocity as the water. This redundancy criterion enhanced fish detectability in the presence of background interference and provided sufficient change-in-range information to determine direction of fish movement. Only fish moving toward the intake or spillgate were considered to be passing through the dam.

Echogram traces for individual fish were initially classified as one of four different types. The four trace types and their characteristics were:

1). LONG-TO-SHORT - a target exhibiting a rapid change-in-range toward the transducer.

2). SHORT-TO-LONG - a target exhibiting a rapid change-in-range away from the transducer.

3). WALLOWER - a target which showed little or no change-in-range over an extended period of time.

4). NO-CHANGE - a target which showed little or no change-in-range over a short period of time.

Environmental parameters such as surface disturbances, floating or submerged debris, or gas bubbles from the lake bottom near the turbine intake, produced non-fish traces. Occasionally, these non-fish traces obscured fish traces. Therefore, each echogram sample period was assessed for the level of background interference and given a "noise code". Noise codes ranged on a scale of one to four as follows:

1). No interference on echogram.

2). Slight interference on echogram.

3). Moderate interference on echogram.

4). Heavy interference on echogram.

We used microcomputers for data storage and subsequent data analysis. Individual fish records on the echograms were transformed to data files using a digitizing pad coupled with a data entry program developed at FAO. Raw data files contained the following information for each fish detection:

1). Julian date.

2). Start time of transducer interrogation.

3). Duration of transducer interrogation.

4). Transducer location.

5). Background interference level (exterior noise, e.g., turbulence from wave action or high gate flow).

6). Quality code (clarity of trace).

7). Midpoint of trace in decimeters from the surface.

8). Trace type.

We appended raw data files to dBase III files, checked for mistakes or inconsistencies, and then created files containing detections converted to estimated numbers of fish passing into the turbine intake or under the spillgate. These detections were weighted individually using beam width and expansion width. Because cross-sectional areas at the exits were only partially covered by the acoustic pulse, individual fish detections were multiplied by a weighting factor to estimate the total number of fish passing an exit at a given range and time. To account for the cone-shaped geometry of the transducer beam, the weighting factor was defined as the ratio of the exit width to the width of the beam at the range of detection. Weighting factors, depending on range, varied from 2.99 to 32.89 for individual detections at the turbine intake and 3.14 to 15.68 at the spillgate. Only long-to-short trace types that fell within a range of 10 to 142 decimeters from the transducer were considered to be fish exiting the system via the turbine intake. This was necessary because of the difficulty of expanding a target near the surface to the rest of the cross section and because of high interference near the bottom of the exit opening. In the case of the spillgate, long-to-short trace types that fell within a range of 35 to 55 decimeters and short-to-long trace types within a range of 10 to 40 decimeters were considered to be fish exiting the system. These subjective ranges were determined by examining trace type locations over a variety of gate openings.

Weighted detections were then summed by location and hour for the entire study. Corresponding hourly gate/flow records for each exit (as recorded by dam operators throughout the study) were also entered in the files. These summary files were finally transferred into Lotus 1-2-3 for graphic representation and into Statgraphics for statistical analyses.

We compared hydroacoustic- and scoop trap-based estimates of migrant passage with a computer spreadsheet model (scoop trap operation is described below). To account for mortality and delay between hydroacoustic measurement of migrant movement at the dam exits and downstream recovery at the scoop trap (Figure 1), we incorporated preliminary estimates of exit survival and movement rates from 1988 FAO studies at Glines Canyon Dam. The 1988 values are still preliminary and subject to change (Table 2). Model outputs were compared to scoop trap estimates on a daily basis, examined for statistical correlation, and plotted for graphic presentation.

Hydroacoustic sampling of the Glines Canyon Dam exits occurred from May 5th, date of the initial chinook release in Lake Mills, until December 31st, 1987, when further sampling for chinook movement appeared unproductive. This sampling period was substantially longer than anticipated due to lack of significant chinook passage through the dam exits. Based on observations of volitional chinook releases at the Elwha Rearing Channel, and natural outmigration patterns of other Puget Sound and coastal Washington chinook stocks, we expected that a major portion of the chinook released in Lake Mills would likely emigrate by early July. However, less movement than anticipated was observed by that date, so we continued intensive sampling of dam exits on a 24-hr per day basis until early September. After that date, we sampled on a substantially reduced schedule to identify possible late fall or early winter movement associated with increased runoff and spill. Because of atypically low flows during 1987 and the associated drawdown of Lake Mills for flow augmentation beginning in September, much of the latter monitoring effort was directed towards late November and December. Table 3 summarizes hydroacoustic sampling frequency throughout the study.

To assess chinook exit selection over a range of springtime spills, we proposed a series of smaller spills (<400 cfs) during anticipated non-spill periods in May and June. These proposed spills were based on observed movement of steelhead smolts in relation to spill at Glines Canyon Dam in 1986 (Dilley and

Wunderlich 1987) and are shown in Table 4. Because of atypical 1987 streamflows, however, we were not able to fully implement this low-level spill plan. Typical higher spring spills (>400 cfs) also occurred coincident with normal spring runoff from the upper Elwha basin. These higher "natural" spills provided a full range of spill flows over the study period with which to assess chinook exit selection. Because juvenile steelhead and chinook are indistinguishable hydroacoustically, we assessed periods of high steelhead presence by means of scoop trapping (as described below). Periods without high steelhead presence were then specifically examined to address questions of juvenile chinook exit selection.

We also requested a series of variable spills during late July and August to assess possible chinook response during this otherwise non-spill period (Table 5). We proposed these spills when it became evident that the majority of chinook had not passed the dam, and substantial chinook milling was consistently observed both visually and hydroacoustically in the reservoir forebay near the spillgates. Because of this milling behavior, we also requested that the lighting on top of the dam be turned off for three nights during this period (including a requested spill during the night of August 22-23) to assess whether light was a factor in attracting substantial numbers of juvenile chinook to the reservoir forebay, thereby giving a false indication of readiness to emigrate.

Fish Marking, Holding, and Release Procedures

We used Elwha hatchery stock chinook for releases in Lake Mills, for exit survival tests, and for trap calibration. These chinook were 1986-brood fingerlings acquired from Washington Department of Fisheries' Soleduc Station, where they were being temporarily reared for the Elwha Channel. We transported the study fish to the Lower Elwha Tribal Hatchery on March 24, 1987, for marking and holding prior to release. At the tribal hatchery, the chinook were divided into 11 groups, uniquely marked by freeze branding during the first week of April, and then held separately in hatchery raceways until release. Three larger groups of approximately 10,000-15,000 fish were used for release in Lake Mills to assess exit selection, while eight remaining smaller groups were used for scoop trap calibration and exit survival tests. Two of the latter groups were used for two purposes simultaneously through careful release scheduling. Table 6 summarizes chinook releases in 1987.

During the holding period, each of the chinook groups destined for release in Lake Mills was sampled for degree of smoltification as indicated by ATPase. ATPase is one indicator of physiological readiness of salmonids for seaward migration (Zaugg et al. 1985, 1986). We sampled each test group for ATPase level (Na^+ - K^+ ATPase activity expressed as μmoles ATP hydrolyzed per mg protein per hour) at biweekly intervals beginning April 1st. We sacrificed 24 chinook for each sample until they reached 100 fish/lb size, after which a 12-fish sample was taken from each group until scheduled release. We further held a small portion of the last release group at the hatchery until late August for continued ATPase sampling when it became apparent that chinook were delaying in Lake Mills. These fish were crowded to the same density in the same raceway until the end of the ATPase sampling period. We also obtained one 8-fish chinook sample by hook-and-line from the forebay of Lake Mills on July 28th for comparison to the hatchery-held chinook. ATPase samples were processed by National Marine Fisheries Service.

We also acquired yearling steelhead from the Lower Elwha Tribal Hatchery to calibrate the scoop trap and to conduct pilot tests of survival through the spillway. These fish were divided into six groups, uniquely marked with freeze brands on April 6th and 7th, 1987, then held in circular tanks at the tribal hatchery until release (Table 6).

All study groups were distributed via tank truck. At time of loading, each group was randomly sampled for length, condition, and legibility of the freeze brand. All releases were made during daylight hours, usually near mid-day. Release group size was estimated by direct hand count at time of marking, minus observed mortalities during the holding period.

Release of the three large groups into Lake Mills occurred at the boat ramp in the reservoir forebay (Figure 1). Release of control groups occurred at a point immediately below the Glines turbine tailrace (Figure 2).

Releases of small test groups into the specific exits of Glines Canyon Dam were made with a length of flexible hose (4" diameter) extending from the distribution truck (positioned at the top of the dam) directly into the spillbay or turbine penstock. This release procedure followed that used by Schoeneman and Junge (1954). Spillway releases were first attempted by lowering the flexible hose on the forebay side of the spillgate. However, not all released fish were entrained in the spill flow, so we subsequently released test fish on the downstream side of the spill gate directly above the spill stream. For these reasons, initial releases of both steelhead and chinook were invalidated and only one release of chinook was subsequently accomplished in the spillway during 1987. All spill tests were made with "extra" study groups as evaluation of spillway survival was beyond our scope of work in 1987.

We released test fish into the turbine penstock by inserting a pre-measured length of flexible hose down the manway adjacent to the headgate shaft such that the end of the hose extended into the penstock flow. Water flow in the penstock exceeded the swimming ability of the test fish (fingerling chinook) at the point of release, thus ensuring that the fish passed down the penstock to the turbine. As a precaution, we refilled the tank truck and flushed remaining fish from the distribution hose after each release from the distribution truck. An initial test using oranges indicated that this technique, indeed, accessed the penstock flow. Turbine survival tests were made at maximum generation level (100% wicket gate opening) which was the operating norm during the spring.

Fish Recovery Procedures

The primary fish recovery gear was an inclined plane scoop trap. The scoop trap consisted of two 38-ft long pontoons spaced about 10 ft apart supporting an inclined screen section 6-ft deep at the mouth and 18-ft long. This 12-ton trap was lowered in sections off the Altaire Bridge near river mile 12.5, assembled below the bridge, and then winched upriver to the fishing site near river mile 12.8 below Glines Canyon Dam (Figure 1). This fishing site is a canyon area having the requisite higher stream flows for scoop trap operation, and was likely the same recovery site used by Schoeneman and Junge (1954) in their early Glines Canyon Dam survival studies. In operation, downstream migrants were swept up the inclined screen by the current and deposited in the live box. Flow into the trap was regulated by positioning the trap (side to side and fore and aft) in the current with the main winch cables anchored to each bank, and by adjusting the level and angle of the inclined screen through its four winches.

Scoop trap position was checked at least daily and adjusted as necessary to ensure direct alignment into the main current and water velocities of approximately 7 to 8 ft/sec at the trap mouth. This provided optimum trapping efficiency for steelhead and chinook smolts without excessive turbulence in the live box which, at higher flows, could lead to fish injury as well as mechanical damage to the trap. Velocities were checked at least several times daily with a Price AA current meter suspended over a 30-lb sounding weight in the center of the trap mouth. During several brief periods of current meter failure, we estimated velocities visually.

Scoop trap catches were removed and examined at regular intervals to reduce potential stress or predation on captured fish and to clean any debris from screen surfaces and the live box. We routinely checked the trap at approximately 2-hr intervals throughout the entire trapping period. At each trap check, we transferred captured fish to temporary holding containers at a work table on the deck of the trap. There, all fish were anesthetized, a subsample of lengths was taken, and any apparent injuries among mark recoveries were noted. Types of injuries recorded were: external injury (bulging or lost eye, torn fin or operculum, abrasions), scale loss (light, moderate, or heavy), and general loss of equilibrium or moribund condition. Following examination and recovery from anesthesia, fish were released off the stern of the trap. Numbers and lengths of non-study salmonids were also recorded as time permitted.

The scoop trap was operated from May 5th, date of the first chinook release in Lake Mills, until June 27th, when steelhead smolt captures diminished to the point that further trapping to assess their presence was not necessary. During this period, we operated the trap continuously, except for several minor periods of maintenance and one 22.5-hr period over May 11th and 12th when a main anchor winch failed.

We also installed a fyke trap in the Glines Canyon Dam tailrace to assess presence of turbine migrants and thus help validate hydroacoustic estimates of turbine passage. The trap was supported by cables from the powerhouse walkway and guide wall in a manner similar to that reported by Schoeneman and Junge (1954). The trap opening measured 4 by 6 ft and thus strained only a portion of the tailrace flow. The trap was constructed of 1/4-inch nylon mesh and was 15 ft long with a live box attached to the cod end. A holding test with live chinook indicated that no major scale loss or injury resulted from trap holding. Trap catches were checked at the same frequency as scoop catches and were treated in an identical manner. Except for several brief maintenance periods, we fished the fyke trap continuously for 54 days during the period of scoop trap operation, and for 23 additional days during July and August (Table 7).

Trap Data Analysis

Estimates of reservoir migrants (chinook and steelhead migrants) were based on expanded scoop trap catches summed over the recovery period. We developed expanded catch estimates by estimating trap efficiency with control releases over a range of streamflows, as streamflow at the trap was considered the primary determinant of trap efficiency. We used streamflow measurements at the dam (spill and turbine flows combined) to estimate trap flows. Travel time and tributary inflow between the dam and trap were considered inconsequential in this analysis. We regressed percent recoveries of control groups at the scoop trap against trap flows to develop the relationships shown in Figures 3 and 4 for chinook and steelhead, respectively. These expressions were used to predict trap efficiencies for these species over the majority of flows experienced during the trapping period. We placed predictive limits for flow extremes, however (greater than 2,600 cfs for steelhead and 2,900 cfs for chinook or less than 1,100 cfs for either species). The principal effect of these limits was to slightly reduce estimates of expanded catch at extremely high flows, as virtually all trap flows were within or only slightly above these limits. Hourly catches of reservoir migrants (chinook and steelhead) were then expanded by the inverse of the predicted hourly trap efficiencies and summed over the recovery period to estimate their total abundance at the scoop trap site.

We computed survival of the chinook group released in the Glines Canyon Dam spillway with the method described above. Hourly catches of chinook spill test survivors were expanded by the inverse of the predicted scoop trap efficiency at capture, summed over the recovery period, and compared to original release group size to estimate survival.

To account for the missed fishing period due to mechanical breakdown of the scoop trap on May 11th and 12th, we averaged the catches for each species during the preceeding and succeeding two time periods. We then used these average values as a basis for catch expansions as described above.

Estimates of turbine mortality were computed using the "delta" method as described by Dunn (1978). For these tests, we used recoveries of paired test and control groups at the scoop trap. Evaluation of turbine mortality was beyond our scope of work in 1987, but we developed estimates of turbine mortality by timing releases of test groups (whose principal purpose was to measure efficiency of the fyke trap) with that of control groups (whose principal purpose was calibration of the scoop trap). Simultaneous recovery of test and control groups at the scoop trap allowed direct estimation of turbine mortality with confidence limits.

We compared length samples of each group at release and recovery to evaluate scoop trap selectivity. Differences in lengths between release and recovery were tested statistically using a t-test. We also compared lengths of wild and hatchery steelhead captured at the scoop trap to qualitatively assess the trap's effectiveness in estimating abundance of wild steelhead emigrants.

Fyke trap data were used to estimate presence of turbine migrants for comparison to hydroacoustic counts of turbine passage. Actual fyke catches of reservoir migrants were expanded using turbine test groups as trap calibration groups. Unlike the scoop trap, we assumed the fyke trap equally recovered both live and dead migrants due to its proximity to the turbine exit and high velocity flow in the tailrace area. For this reason, we further assumed recovery of turbine test groups indexed the fyke trap for both efficiency and mortality, so we expanded fyke catches only by the inverse of the average turbine test group recovery rate to estimate total numbers of turbine migrants for comparison to acoustic counts. However, we regarded fyke trap expansions as only approximations because of the relatively low recovery rate of turbine migrants in the fyke trap. Further, turbine flow declined appreciably in late July, so efficiency of the trap may have been affected during this period. (Turbine test groups were only released at full turbine flow, characteristic of the spring outmigration period.)

We summarized injuries of all groups recovered at both traps to gain additional insight into the nature of passage losses and to evaluate the potential for delayed mortality. We used three categories of scale loss: less than 10% (light), 10-50% (moderate), and greater than 50% (heavy). These criteria were based in part on the results of work by Bouck and Smith (1979), who related increased mortality to increased descaling of coho smolts subjected to seawater challenges. These broad descaling categories provided the most consistent measure of scale loss practical under field conditions at the scoop and fyke traps. We assumed that progressively greater scale loss (as represented by our light, moderate, and heavy descaling categories) reflected greater potential for delayed mortality due to the proximity of seawater (the Strait) to our collection sites. Differences in scale loss of turbine migrants were assessed by means of a 2 x 2 contingency analysis (Snedecor and Cochran 1967).

RESULTS AND DISCUSSION

The streamflow pattern during the 1987 study period was atypical in several respects that may have influenced the results of this work. Instead of the typically higher spring runoff in late May and early June, we experienced relatively high runoff in early May followed by generally decreasing flows well into the latter part of the year. Moreover, progressively decreasing flows in the late summer resulted in the need to draft Lake Mills approximately ten feet in September to alleviate downstream temperature problems, and high-volume spills did not occur until December after the basin was refilled (Figure 5). This atypical run-off pattern generally reduced the expected volume and duration of spring spilling, and also effectively precluded any surface exit from the reservoir in late summer, fall and early winter. These events, in turn, probably affected exit selection and overall movement rates in 1987, as described below.

Exit Selection

For purposes of presentation, we divided the hydroacoustic monitoring into four periods based on monitoring frequency, principal migrants present, and streamflow conditions (Table 8). The first period (May 5 to May 31) was characterized by relatively high streamflow with continuous spilling and, importantly, encompassed the period when steelhead and chinook were both passing Glines Canyon Dam in relatively high numbers, as indicated by scoop trap catches. The second period (June 1 to July 5) was characterized by somewhat lower but still continuous spilling with relatively few steelhead present, again as indicated by scoop trap catches. The latter two periods (July 6 to September 2 and September 3 to December 31) were both characterized by continued low streamflow with essentially only FAO-requested spills occurring (except for spilling during a high flow event in December). Only chinook migrants were assumed to be present during the latter two periods based on time-of-year and on limited fyke trap catches during July and August (scoop trapping was discontinued on June 27). In the very last period (September 3 to December 31), only intermittent hydroacoustic monitoring occurred.

Most emigration was believed to occur during the initial three periods of hydroacoustic monitoring (May 5 to September 2), with most movement detected at the spillway in late June and early July (Figure 6). Some relatively high rates of movement were also detected at the spillway in late July and early August in response to our requested spills, despite continued availability of the turbine exit (Figure 6). In all, approximately 83% of the hydroacoustically detected movement occurred at the spillway between May 5th and September 2nd. Table 9 includes a breakdown of hydroacoustically estimated movement at each exit for these periods.

A comparison of percent of river spilled versus estimated percent of migrants using the spillway during the May 5 to September 2 periods showed no clearly increasing trend in spillway passage with greater spilling. Figure 7 shows this comparison, which has been referred to as "spill effectiveness" (Biosonics 1984, Raemhild et al. 1985, and others). Statistical correlation between spill volume and spillway use in Figure 7 was relatively low and not statistically significant ($r^2 = 0.28$, $P > 0.05$). Spill effectiveness assumes that migrants have an equal tendency to use either spill or turbine exits. Unlike recent studies of steelhead and coho smolt passage at Glines Canyon Dam (Wunderlich and Dilley 1985, Dilley and Wunderlich 1987), an earlier study by Schoeneman and Junge (1954) suggested that chinook may have a much greater tendency to use the turbine exit, which suggested the use of this comparison. Throughout most of the comparison period, chinook were numerically dominant over steelhead.

Spillway usage depicted in Figure 7 does not account for possible effects of differing length (days) of spilling at each spill level over the comparison period shown. However, we did not consider length (days) of spilling an important factor in this instance because of the substantial delay in chinook emigration from the reservoir. Spillway preference (or lack of) at differing spill levels in Figure 7 reflects exit choice for those migrants which were actively seeking an exit under the conditions that existed at time of emigration. As Figure 7 indicates, numbers of emigrants at each spill level were relatively evenly distributed.

Comparison of period 1, when steelhead were present (May 5 to May 31), and period 2, when they were largely absent (June 1 to July 5), showed differences in diel movement. Allowing for travel time between the dam and scoop trap (provisionally three days) and assuming that most migrants passed the dam via the spillway, the catch data in Figure 8 show that most steelhead passed the Glines Canyon Dam spillway during May. Comparing May passage versus June/early July passage (steelhead present versus largely absent but continuous, variable spill throughout) yielded the markedly different diel movement rates shown in Figure 9. We attribute the greater degree of daytime movement in June/early July to an apparently higher preference by subyearling Elwha chinook for daytime movement. Wampler et al. (1985) reported an increasing percentage of daytime Elwha chinook migration from April to July. The percentage of daytime migration was highest in July at 54%. This differs from the strong preference by Elwha hatchery steelhead for nighttime passage evident in 1986 (Dilley and Wunderlich 1987), which apparently occurred again in 1987 with naturally reared Elwha steelhead. Hourly movement rates for these same periods are shown in Figures 10 and 11, and these suggest similar differences in time-of-day movement due to the species present. Streamflow and associated water clarity may influence these patterns, as greater daytime passage of steelhead and coho smolts was observed at Elwha Dam in 1985 during higher, more turbid flow conditions (Wunderlich and Dilley 1986).

During these same periods, we compared spill flow and spillway passage for evidence of species-related differences in attraction flows at the spillway. Figures 12 and 13 depict spill and spill migrants with chinook/steelhead and chinook present, respectively. Virtually no statistical correlation exists in either situation ($r^2 < 0.02$ for both), suggesting greater spill flow had no measurable effect on combined chinook/steelhead or chinook only movement through spillway 5 of Glines Canyon Dam. Two additional measures, percent spill versus spill migrants and percent spill versus percent spill migrants, had similarly poor correlations ($r^2 < 0.02$ for both) during periods 1 and 2. An examination of hatchery steelhead smolt movement through this spillgate in 1986 produced similar results (Dilley and Wunderlich 1987). A substantially better fit between chinook movement and spill volume alone was evident in the latter half of period 2 (beginning June 18th in Figure 13). Multiple regression analysis showed significant correlation with spill volume in the latter half of period 2 when the overall effects of fish migration were included in the model ($r^2 = 0.79$, $P < 0.01$). The lack of comparable movement in relation to spill earlier in the period is unexplained, however (Figure 13).

Spills requested by FAO to induce movement of juvenile chinook from Lake Mills during the low-flow period in July and August (period 3) resulted in substantially increased fish passage, but this movement was largely unrelated to actual volume of water spilled. Figure 14 depicts spills and associated spill movement during this time period. In all, about 28% additional spill passage occurred, but correlation between spill fish passage and spill volume itself was poor ($r^2 = 0.27$). Additional measures of percent spill versus spill migrants and percent spill versus percent spill migrants showed no improved correlation.

We believe a continued low level of turbine passage occurred in period 4 until early December, when a flow event induced relatively greater movement at both exits. As Figure 5 indicates, virtually no spilling occurred during these four months until the December event, thus a spillway exit was not available for comparison over much of this period. A low rate of turbine passage is evident (Figure 15). At the December event, relatively high movement occurred at both exits, and turbine passage substantially exceeded spillway movement at this time (Figure 15). Because of the limited availability of the spillway exit and limited monitoring during this period in general, the higher degree of turbine movement may not be representative, however.

Exit Survival

Results of the turbine tests with subyearling chinook indicated survivals of 28.1 and 35.4% for an average value of approximately 32% in this Francis-style turbine at 100% generation (Table 10).

These estimated survivals were substantially poorer than those measured by Schoeneman and Junge (1954), who reported survival of 67% for fingerling chinook through this device. However, we believe our 1987 tests better measured fingerling chinook survival, primarily because Schoeneman and Junge noted difficulties with fish marking and recovery in this particular test which could have affected the results of their experiment. Also, Schoeneman and Junge failed to note generation level during their tests. If generation at the time of their testing was hydroelectrically more efficient (at reduced generation), fish survival could be much higher in this style of turbine (Bell 1981, 1984).

Results of the spillway test indicated a survival of approximately 42% at 1/2-foot opening of spillgate 5 (Table 10). This survival is substantially lower than anticipated, as Schoeneman and Junge (1954) reported a survival rate of 94% for fingerling chinook over the Glines Canyon Dam spillway. However, we believe their survival value was derived from tests at higher gate openings (≥ 1.5-foot spillgate opening, except for one reported test at 0-foot gate opening when fish were poured directly into the spill pool from the top of the dam). Preliminary results from our 1988 spillway tests at greater spillgate openings (≥ 1.5-foot spillgate opening) appear to be comparable to the Schoeneman and Junge work. Other possible reasons for this difference are that survival may be markedly different at different spillgates (Schoeneman and Junge did not record what spillgate they tested) and/or conditions in the spill pool or spill pool exit have changed in the intervening years such that fish survival is now substantially poorer at lower spill levels.

Injuries

The dominant injury recorded for chinook recovered at the scoop trap was descaling; other injury types were probably insignificant (Table 11). Of note in Table 11 is the high level of descaling among Lake Mills releases and the spillway release, which far exceeded those of the control groups and even turbine release group 2. As descaling (and other injuries) was generally far less among control groups than any of the test groups, particularly in the light and moderate descaling categories, injuries were clearly related to dam passage rather than handling in release and recovery operations.

We believe spillway passage was a prime reason for elevated scale loss in chinook, especially in the light descaling category. Scoop trap recoveries of the chinook spillway release show relatively greater light descaling (Table 11). Interestingly, the spillway-released group survived at an estimated rate of only 42% (Table 10). This greater descaling may be related to turbulence in the plunge pool at lower spills which occurred during this particular test (~220 cfs). The three Lake Mills releases also show high descaling in the light category (Table 11) and, according to our hydroacoustic monitoring, these groups were predominately spill migrants during the scoop trap recovery period (Table 9).

Injuries among turbine release groups (Table 11) were paired against their respective control groups in Table 12. This pair-wise comparison subtracted specific background injuries due to release and recovery operations and indicated that scale loss was the dominant injury for turbine migrants which survived at least until scoop-trap recovery. Chi-square analysis affirmed that significantly greater descaling occurred in all categories of turbine fish in the first trial, and in the light descaling category in the second trial ($P < 0.005$). Also, scale loss in aggregate (all three categories combined) was significantly greater in both turbine groups, as was proportion injured or dead ($P < 0.005$). Descaling (in the light category) was also the dominant injury among scoop trap recoveries of juvenile coho passing the Elwha Dam turbines in 1984 as indicated by pair-wise comparison (Wunderlich and Dilley 1985).

The dominant injury among fyke trap recoveries of chinook turbine migrants was scale loss, but pressure (e.g., eye damage) and other mechanical injury types were quite evident (Table 13). Of the turbine release groups, group 1 again showed generally higher injury and mortality than did group 2, as the scoop trap recoveries indicated. Table 13 shows 30% and 38% mortality for these turbine groups, which is less than the scoop-trap-based mortality estimate of 65% and 72%, respectively (Table 10). We assume that the higher rates of descaling, eye damage, and other visible injuries observed in fyke trap recoveries of these groups caused additional mortality before scoop trap recovery occurred, and thus account for the difference. The proximity of the fyke trap to the tailrace allowed this gear to recover severely injured fish which may not have even survived the 1/2 mile downstream to the scoop trap site.

Recoveries of Lake Mills releases in the fyke trap showed unexplainably greater heavy descaling and greater mortality than the two chinook turbine groups (Table 13). We note, however, that relatively few chinook from the Lake Mills releases were examined in comparison to the turbine releases, and this may invalidate direct comparison of the two. Also, the Lake Mills releases were subject to reservoir residence before entering the turbine intake which could have had some additional influence on their survival (e.g., predation, post-release stress, entry through turbine intake).

Scoop trap recoveries of steelhead showed generally high descaling in the light category among all groups, plus some evidence of greater descaling among the spillway migrants (Table 14). Descaling injuries among steelhead control recoveries were uniformly greater than among our chinook controls (Table 11), suggesting that steelhead were generally more sensitive to scale loss. Sensitivity to scale loss could be related to a higher degree of smolting in the steelhead or to larger size of steelhead than chinook.

Although few steelhead spillway test fish were recovered at the scoop trap, their injury pattern was similar to that of wild steelhead recoveries. For both groups, descaling in the moderate category was far greater than in three of the four control groups (Table 14). We assume this elevated scale loss was associated with spillway passage of wild emigrants as well as the spill test group, since most steelhead passing Glines Canyon Dam likely passed via the spillway based on 1986 FAO exit-selection work (Dilley and Wunderlich 1987). As further evidence, no steelhead were recovered in the tailrace fyke trap (Table 15).

The effect of descaling on long-term survival of these fish is difficult to quantify. Bouck and Smith (1979) found a significant, positive correlation between scale loss and mortality for coho subjected to immediate seawater challenge. Further, they estimated that about 50% of coho in their study would die in seawater with the loss of only about 10% of their scales. However, mortality was substantially reduced if seawater challenge was delayed even one day.

Extending the above findings to this work, we expect that high incidence of scale loss observed in dam passage could potentially cause latent mortality. At the same time, travel time between the upper dam and saltwater could substantially reduce this mortality. In 1984, for example, we found a 16-day median travel time beween Lake Mills and river mile 3 for the fastest moving group of coho smolts tested (Wunderlich and Dilley 1985). Review of the injury data collected in this study suggests that light and moderate scale loss associated with spill passage may not by themselves have a significant latent effect on survival, considering travel time to saltwater. However, very heavy scale loss, particularly as observed in turbine passage, may result in additional latent mortality, especially when scale loss is associated with other injuries.

Timing and Abundance

Hydroacoustic measurements suggest that the principal emigration for juvenile chinook in 1987 occurred in late June and early July. This assumes few steelhead were present after May, based on scoop trap catches. Some periods of increased chinook movement also occurred in late July and August, but they were smaller than the late June/early July peak (Figure 6). Limited hydroacoustic sampling from September to December suggested little movement occurred (Figure 15), but no spill exit was available for most of this time and the effect on potential movement is unknown.

Trap catches of each chinook group occurred soon after release, with earlier release groups dominating the catch. Figure 16 shows scoop catches and Figure 17 shows fyke catches of individual release groups. Neither trap was fished during the late June/early July peak, so catch composition was not available for that high movement period. The higher catches of earlier release groups (Table 15) may only be functions of longer trapping periods, and larger release group size (Table 6).

Measurement of ATPase levels suggested that the Lake Mills chinook had developed high activity (suggestive of migratory behavior) by late June (Figure 18). Depending on the stage of smoltification, juvenile fall chinook ATPase levels can range from 11-60, and seldom get above 20-30 in the hatchery environment (Wally Zaugg, National Marine Fisheries Service, pers. comm.). The lake sample (Figure 18) suggested that activity remained high after release.

Virtually all subyearling fall chinook had volitionally left the Elwha Rearing Channel by mid-August, 1987 (Greg Travers, Elwha Rearing Channel Manager, pers. comm.). Although the rearing channel environment is markedly different than the Lake Mills forebay, this also suggested that a high movement period occurred in this stock prior to late summer.

Continued presence of milling chinook in the Lake Mills forebay was markedly affected by lighting at the top of the dam in late August. During each night when lighting was turned off, hydroacoustic detections of milling behavior in the spillgate vicinity were substantially reduced, including the night of August 22-23 when spilling was in progress. We concluded, therefore, that light was a major attractant to the reservoir forebay and milling at night in this area, of itself, was not an indication of readiness to emigrate during this period.

Wild steelhead movement peaked in May and declined appreciably by early June at Glines Canyon Dam (Figure 8). We assume that high streamflow and spill during May encouraged their movement at that time. In contrast, wild steelhead catches peaked in June during 1985 lake trapping in Lake Aldwell (Wunderlich and Dilley 1986). In that year, high and continuous spilling did not occur until June, however.

Scoop-trap and hydroacoustic-based estimates of migrant abundance are compared in Figure 19. Over the time period shown, hydroacoustically detected migrants (steelhead and chinook) were expected to pass the scoop trap, based on a spreadsheet model incorporating survival and movement rates to the scoop trap (Table 2). Trap catches during this period suggest that more total migrants passed the dam than were hydroacoustically detected (3,919 estimated survivors of hydroacoustic detections versus a 6,585 scoop-trap estimate). Daily trap and hydroacoustic estimates were essentially uncorrelated (r^2 = 0.0003). Reasons for differences in this comparison include possible inaccuracies in:

1) Movement rate estimates. Available information includes

preliminary movement rate data from our 1988 studies at Glines Canyon Dam. Analysis to date suggests a range of movement rates between Glines Canyon Dam and the scoop trap may occur depending on spillflow, species, and time-of-year. The rates used in this comparison typify expected values, but movement rates actually ranged from approximately 1 to 5 days and these differences could substantially affect the comparisons. We suspect that, in general, higher spills early in the trapping period increased movement, and lower spills towards the end of the trapping period slowed movement. This could account for the larger differences at the start and end of the comparison period in Figure 19.

2) Survival rate estimates. Most available survival information was from our preliminary 1988 data. Applying survival rate data in Table 2 to the estimated hourly migrations at each exit resulted in a 29% net reduction in the numbers of migrants predicted to pass the scoop trap site. Much of this reduction could be attributed to spillway mortality as most migrants used this exit (Table 9), and these mortality values are still subject to change.

3) Scoop trap calibration. Expanded scoop-trap estimates, based on trapping of control groups (Figures 3 and 4), were sensitive to high flow extremes, so additional calibration points at the highest flows could have improved the predictive relationships used.

4) Scoop trap expansions due to size selection at the trap. Table 16 shows that mean length of control group recoveries exceeded those at release. Unlike chinook, differences between steelhead control lengths were statistically significant ($P < 0.05$). Growth between release and recovery length measurements could account for at least a portion of these differences. We expect that the net effect on scoop trap expansions for hatchery steelhead would be slight, however, due to the small absolute differences measured. The smaller mean length of wild steelhead (Table 16) could lead to a net underestimate of abundance. (Wild steelhead mean length was about 10 mm less than that of wild Elwha-reared steelhead captured in 1985 by lake trap in Lake Aldwell (Wunderlich and Dilley 1986).)

5) Spillway hydroacoustic detections. The transducer sampled only about 5 feet in the center of the spillgate exit, which is approximately 20 feet in total width. Unlike previous evaluations of steelhead (Dilley and Wunderlich 1987), chinook milled in the vicinity of the exit to a much greater extent and may not have been equally distributed while passing under the gate, particularly on the right side which deepens to the reservoir center. If greater movement occurred in that portion of the exit, the hydroacoustic expansions would tend to underestimate total spillway movement.

Daily fyke-trap and hydroacoustic-based estimates of migrant passage through the turbine were also poorly correlated (r^2 = 0.01) (Figure 20). We believe the poor efficiency of the fyke trap at full turbine generation (5.1% average catch) and possible varying efficiency at lower turbine generation (during July) contributed to observed differences in daily passage. The fyke trap did confirm, however, presence of chinook migrants at the turbine exit. Over the period illustrated in Figure 20, approximately 2,764 chinook were estimated to have passed through this exit (Table 15), versus 2,811 hydrocoustic detections for this same period.

It is probable that many of the chinook released in Lake Mills residualized. Mortality may also have occurred. Of the total 40,325 chinook planted in the reservoir, hydroacoustic detections during the period of continuous monitoring (May 5 - September 2) indicated passage of only about 1/2, or 19,760 fish, through both exits (Table 9). An additional 2,668 were detected between September 3rd and December 31st. Although this latter period was monitored only intermittently, the lack of a spill exit through much of this time, and low turbine passage when monitoring did occur, suggested little additional emigration. Total acoustic detections of 22,428 fish (19,760 + 2,668) also included steelhead migrants whose numbers at the scoop trap were estimated to be 2,066 (Table 15). Allowing for possible passage losses at the spillway, up to 2,400 steelhead may also be included in this total acoustic value (pre-passage steelhead numbers were approximated by back-calculating trap catches to account for mortality with our spreadsheet model). We believe a hydroacoustic underestimate of up to 50%, as these values suggest, is unlikely. Previous, similar work has accounted for the vast majority of hatchery steelhead released in Lake Mills (Dilley and Wunderlich 1987). Also, yearling chinook were captured emigrating from Lake Mills in 1988, but an estimate of their numbers is not yet available.

SUMMARY

In 1987, FAO personnel conducted a study of subyearling chinook exit selection at Glines Canyon Dam. The object of this study was to identify spill volume needed to induce spillway passage of subyearling chinook. Spill passage was deemed desirable as available information had suggested that turbine passage would cause high mortality to emigrants.

We evaluated exit selection by releasing subyearling, Elwha-stock, hatchery chinook in the Lake Mills forebay in May and June of 1987, and then monitoring their passage through spill and turbine exits with hydroacoustic sensors over a range of spills. We anticipated conclusion of field work by early summer, but lack of substantial emigration by that date required that we continue monitoring on a full-time basis until early September, and on an intermittent basis until late December 1987 to more fully assess exit selection. We requested additional spilling in late summer to evaluate chinook response to augmented spilling.

During spring and early summer of 1987, abundance of emigrants was also estimated via scoop and fyke trapping below the dam to verify acoustic estimates, and to identify presence of wild steelhead smolts originating from adults planted in Lake Mills in 1985. Steelhead smolts were the only other emigrants present at Glines Canyon Dam in 1987, but they were not separable hydroacoustically and thus required independent assessment via trap capture.

We also conducted survival tests through Glines Canyon Dam exits to complement available survival information, and to help reconcile acoustic and trap estimates of emigration. Preliminary exit survival information from 1988 FAO studies was incorporated as well. Incidental information on migrant injuries was collected to assess potential latent mortality. Additionally, ATPase was monitored in chinook releases to help evaluate timing and potential response to spill.

The principal findings from this work were:

1) Overall, we detected little increased movement of juvenile chinook through the spillway at greater spill flows. An exception occurred in late June and early July when higher chinook movement occurred with higher spill flows. Spills during periods of essentially chinook-only movement ranged from approximately 140 to 2800 cfs, or 11% to 82% of total streamflow, and occurred in spillway 5 only.

2) We estimated that up to 1/2 of the 40,325 juvenile chinook released in Lake Mills for this evaluation may have residualized in the reservoir. Yearling chinook emigrants from this release were recovered during spring of 1988, but an estimate of their numbers is not yet available.

3) The bulk of the emigration in 1987 was believed to occur from early May to early September. During these months, peak chinook passage occurred in late June and early July, and coincided with higher ATPase levels. Peak steelhead passage occurred in May and declined appreciably by June, based on scoop trap catches.

4) From early May to early September 1987, 83% of all migrants were hydroacoustically detected passing via the spillway and 17% via the turbine. During May, when steelhead and chinook were both present, 76% passed via spill and 24% via turbine. During June and early July when chinook were predominant, 89% were estimated to have passed via spill and 11% via turbine. From mid-July to early September, when we requested augmented spills to pass delaying chinook, 74% passed via spill and 26% via turbine. During the latter time period, however, the spill exit was not continuously available. In contrast, steelhead exit choice in 1986 at Glines Canyon Dam was approximately 98% spillway (same gate) and 2% turbine. There was no indication that steelhead used the turbine exit to any extent in this study either, based on lack of fyke-caught steelhead in the turbine tailrace.

5) More chinook movement occurred during daylight than at night compared to steelhead smolt passage at this dam in 1986 and scoop catches of fingerling chinook in the lower Elwha River in 1984. Interannual variability in streamflow and associated water clarity may influence this movement pattern, however.

6) From early September to late December of 1987, a low level of chinook turbine passage was believed to occur, based on intermittent hydroacoustic monitoring. During most of this time period, a spill exit was not available so a spill versus turbine passsage comparison was not possible. In early December, however, a high flow event with spill produced movement through both exits.

7) Juvenile chinook survival through spill and turbine exits of Glines Canyon Dam was lower than anticipated. We estimated that approximately 32% of juvenile chinook survived turbine passage (at full generation) and 42% survived spillway passage (at a spill of approximately 220 cfs) based on scoop trap catches. Work in 1954 by Washington Department of Fisheries suggested survivals of 67% and 94% for turbine and spill passage, respectively. Differences in test conditions and procedures may account, at least in part, for our lower estimates. Preliminary results from our 1988 spill tests suggest survival more comparable to the 1954 work, at least at higher flows.

8) The dominant injury among chinook and steelhead migrants which passed Glines Canyon Dam and were recovered 1/2 river mile downstream in the scoop trap was descaling, especially in the light category (<10% scale loss). Latent mortality

may therefore not be significant for those fish which survived to the scoop trap site. Steelhead descaling was greater than chinook in scoop trap recoveries.

9) Comparison of scoop trap and hydroacoustic estimates of migrant abundance suggested that hydroacoustic monitoring may have underestimated passage. The degree of underestimation is difficult to estimate, especially with limited information on exit survival and movement rate to the scoop trap. We believe that a major underestimation is unlikely, however.

10) Atypical streamflows coupled with an apparent high degree of residualism among chinook releases may have affected exit selection and emigration timing of chinook in 1987. Although spring release of fingerling chinook in Lake Mills was intended to simulate spring/summer emigration patterns of Elwha chinook, an alternate strategy (e.g., upriver fry planting and subsequent monitoring of movement through dam exits) will likely be necessary to fully address questions of chinook emigration and exit selection at Glines Canyon Dam.

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REFERENCES

Bell, M.C. 1981. Updated compendium on the success of passage of small fish through turbines. U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Bell, M.C. 1984. Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps of Engineers, North Pacific Division, Fish Passage Development and Evaluation Program, Portland, Oregon.

Biosonics, Inc. 1984. Hydroacoustic assessment of downstream migrating salmon and steelhead at Wanapum Dam in 1984. A Special Report to the FERC Mid-Columbia Studies Committee.

Bouck, G.R., and S.D. Smith. 1979. Mortality of experimentally descaled smolts of coho salmon (Oncorhynchus kisutch) in fresh and salt water. Trans. Amer. Fish. Soc. 108:67-69.

Dilley, S. and R. Wunderlich. 1987. Steelhead smolt exit selection at Glines Canyon Dam. U.S. Fish and Wildlife Service, Fisheries Assistance Office, Olympia, Washington.

Dunn, C. 1978. Evaluation of downstream fish passage through multi-level outlet pipes at Wynoochee Dam. Progress Report 45. Washington Department of Fisheries, Olympia, Washington.

Raemhild, G., T. Steig, E. Kuehl, S. Johnston, and J. Condiotty. 1985. Hydroacoustic assessment of downstream migrating salmonids at Rock Island Dam in spring 1984. Biosonics, Inc., Seattle, Washington.

Raemhild, G. undated. The application of hydroacoustic techniques in solving fishery problems related to hydroelectric dams. Biosonics, Inc., Seattle, Washington.

Schoeneman, D. and C. Junge. 1954. Investigations of mortalities to downstream migrant salmon at two dams on the Elwha River. Research Bulletin No. 3. Washington Department of Fisheries, Olympia, Washington.

Snedecor, F. and W. Cochran. 1967. Statistical Methods. Iowa State University Press, Ames, Iowa. 593 p.

Wampler, P., R. McVein, J. Hiss, and R. Wunderlich. 1985. A review of and proposed solution to the problem of migrant salmonid passage by the Elwha River dams. U. S. Fish and Wildlife Service, Fisheries Assistance Office, Olympia, Washington.

Wunderlich, R. and S. Dilley. 1985. An assessment of juvenile coho passage mortality at the Elwha River dams. U.S. Fish and Wildlife Service, Fisheries Assistance Office, Olympia, Washington.

Wunderlich, R. and S. Dilley. 1986. Field tests of data collection procedures for the Elwha salmonid survival model. U.S. Fish and Wildlife Service, Fisheries Assistance Office, Olympia, Washington.

Zaugg, W., E. Prentice, and F. Waknitz. 1985. Importance of river migration to the development of seawater tolerance in Columbia River anadromous salmonids. Aquaculture 51:33-47.

Zaugg, W., J. Bodle, J. Manning, and E. Wold. 1986. Smolt transformation and seaward migration in 0-age progeny of adult spring chinook salmon (Oncorhynchus tshawytscha) matured early with photo-period control. Can. J. Fish. Aquat. Sci. 43:885-888.

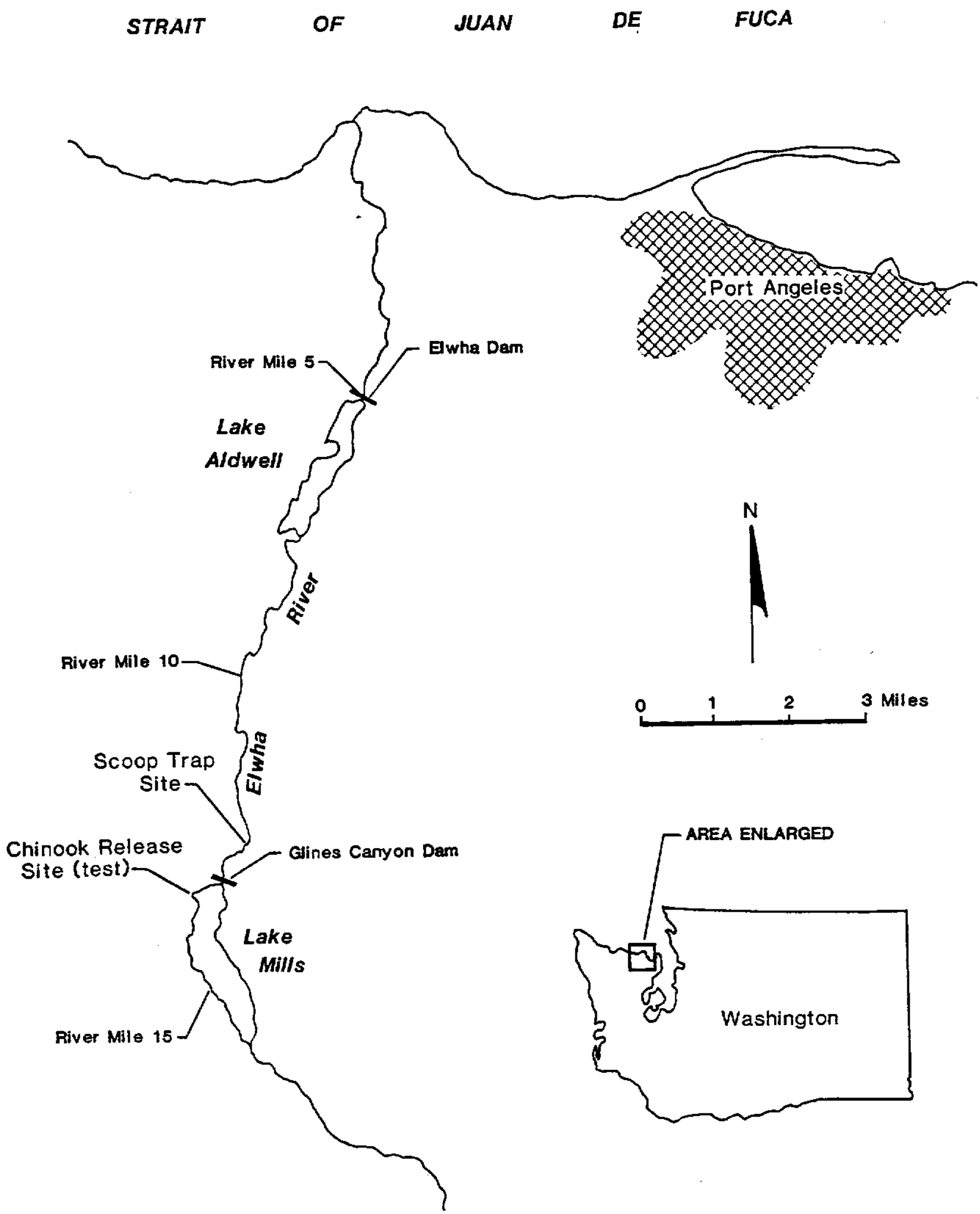

Figure 1. The Elwha River and project features.

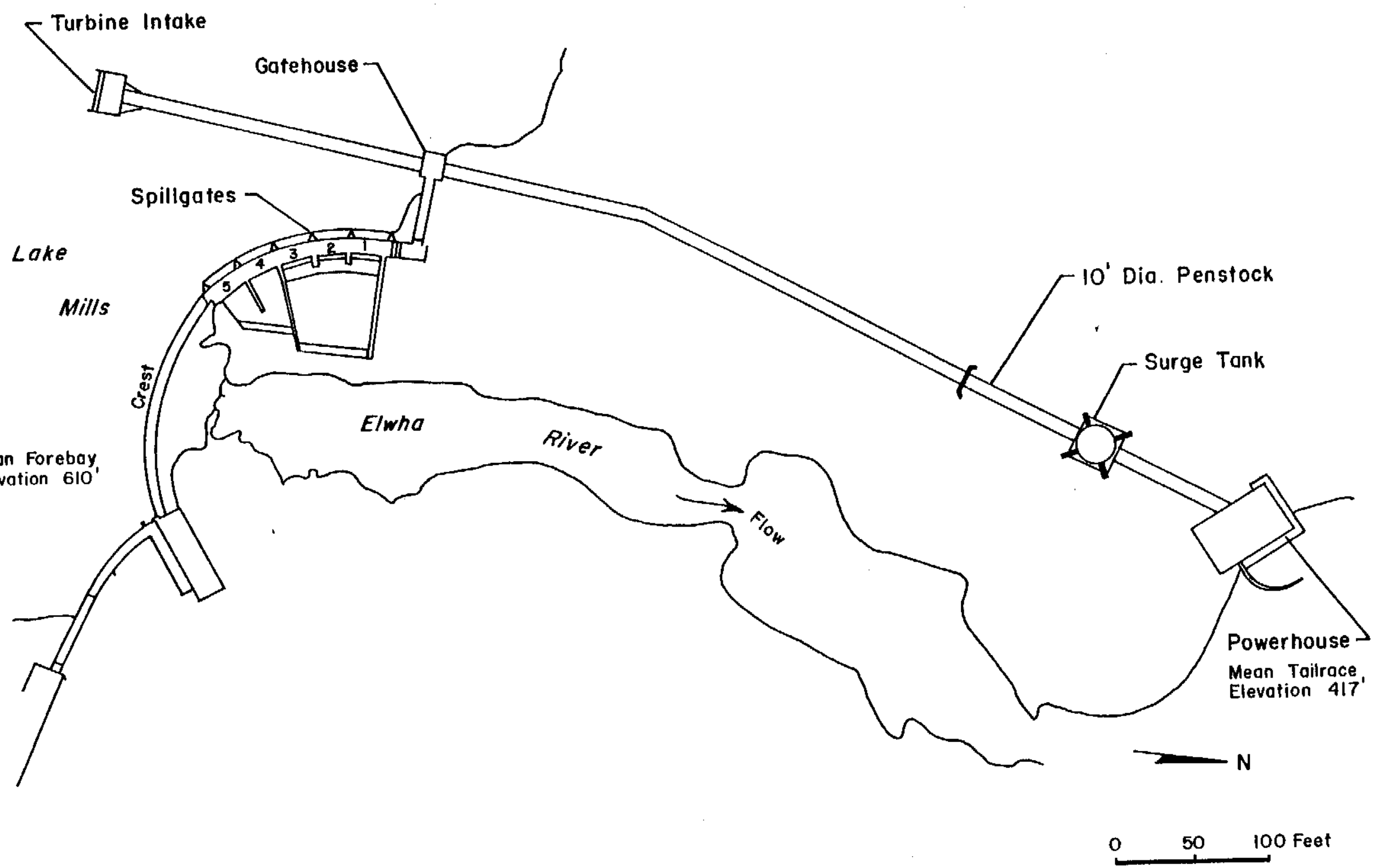

Figure 2. General features of Glines Canyon Dam.

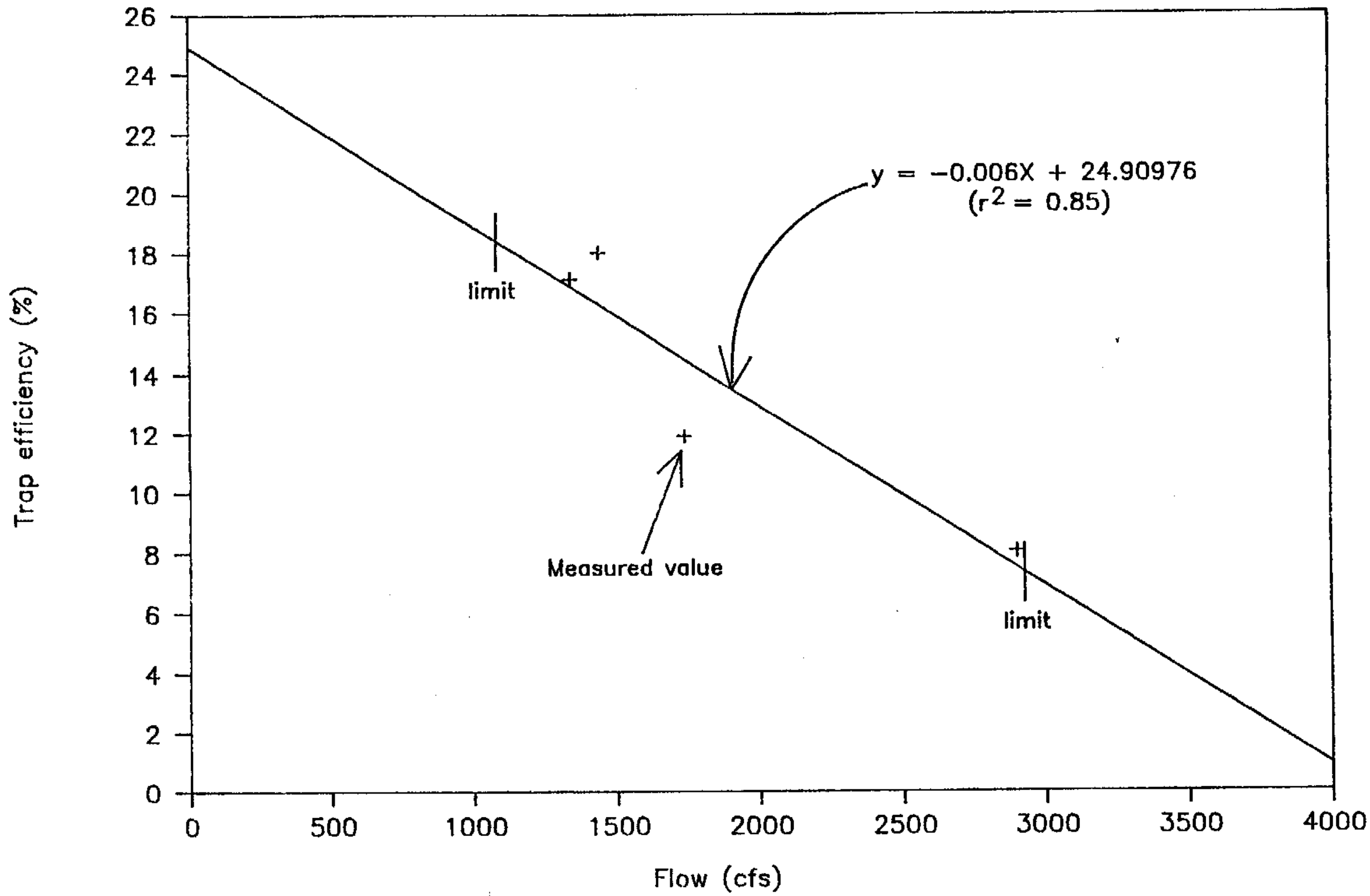

Figure 3. Scoop trap efficiency for juvenile chinook versus streamflow at the trap site. Predictive limits of the associated regression line are indicated.

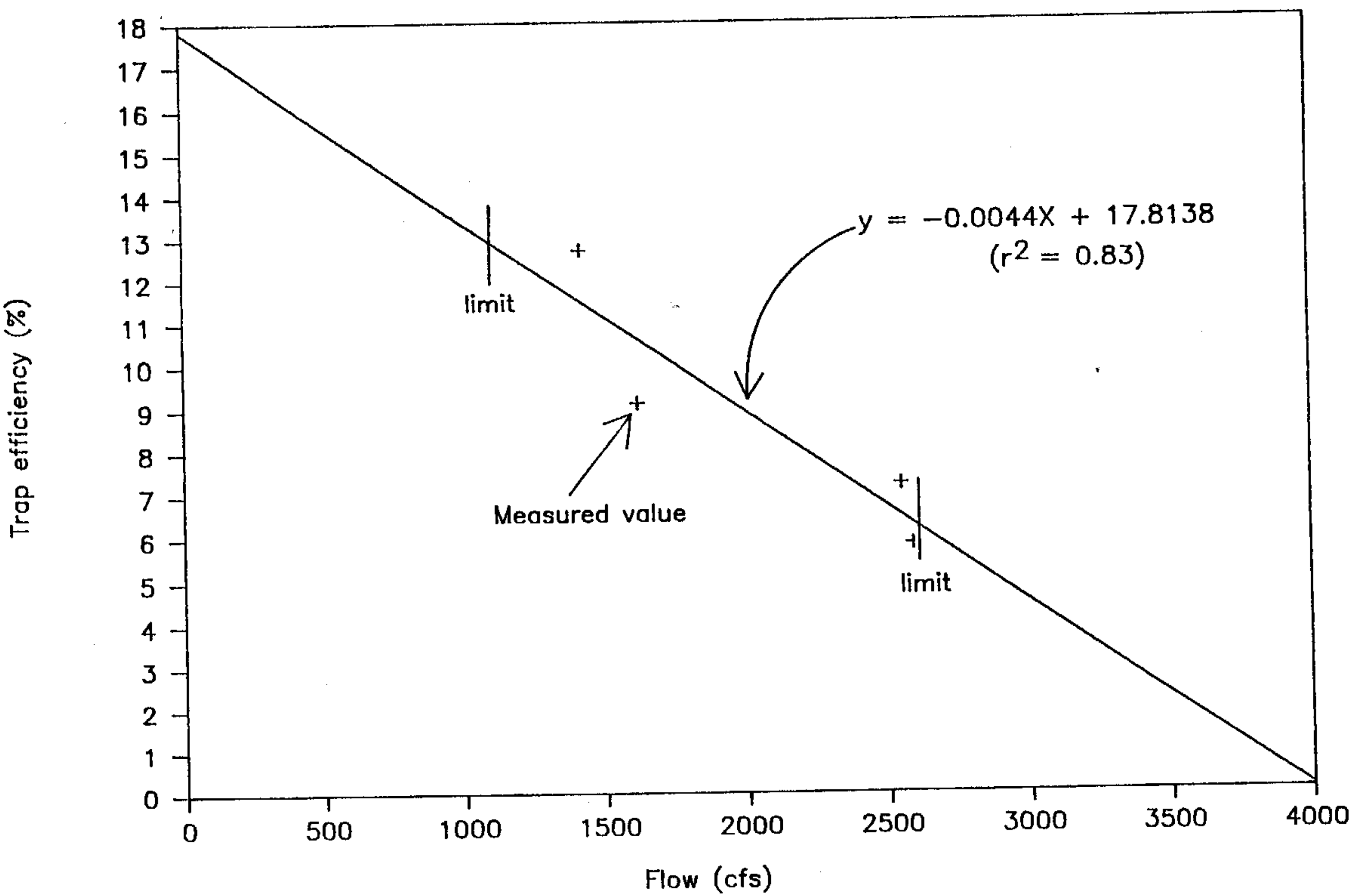

Figure 4. Scoop trap efficiency for steelhead smolts versus streamflow at the trap site. Predictive limits of the associated regression line are indicated.

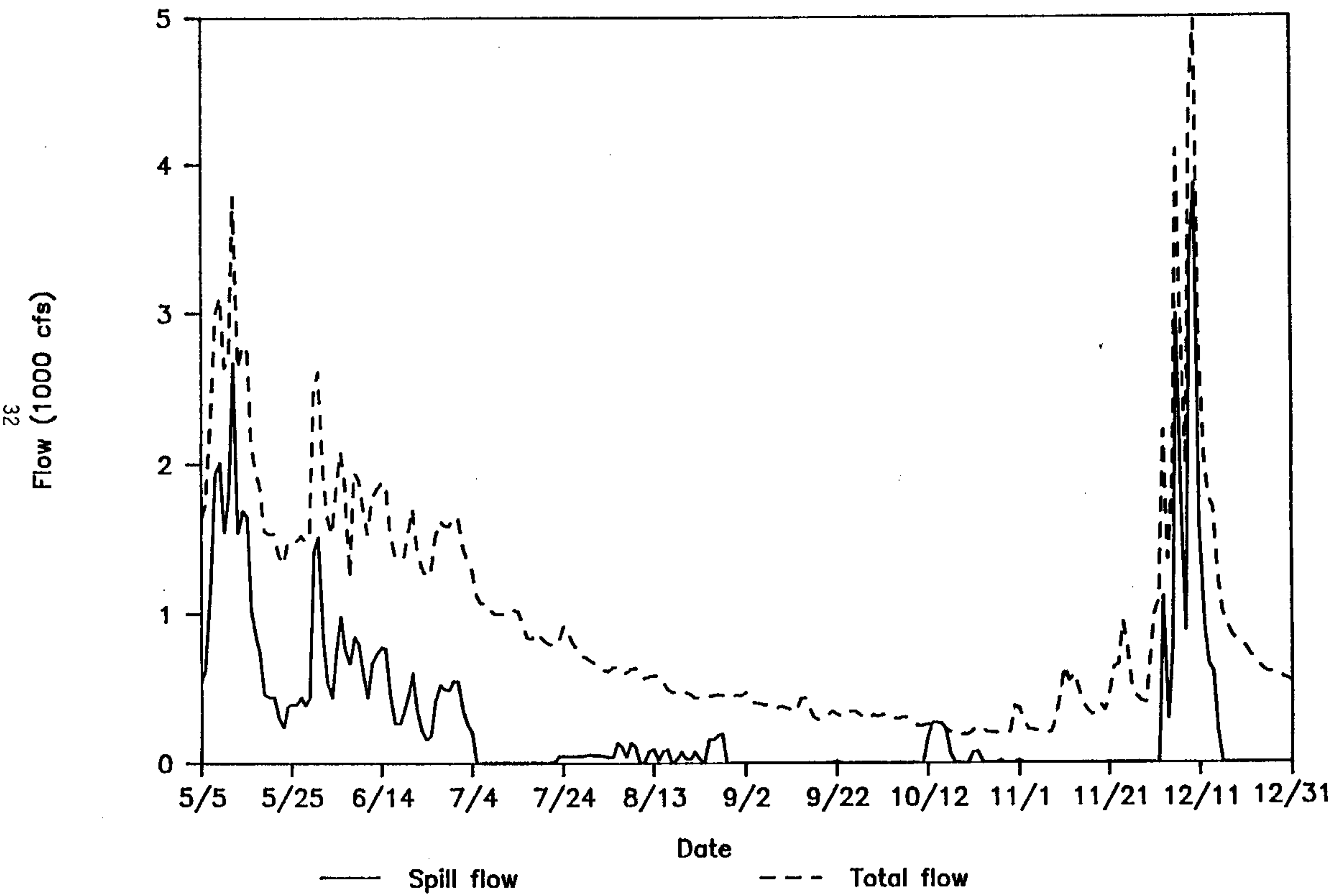

Figure 5. Daily streamflow and spill at Glines Canyon Dam from May 5 to Dec. 31, 1987.

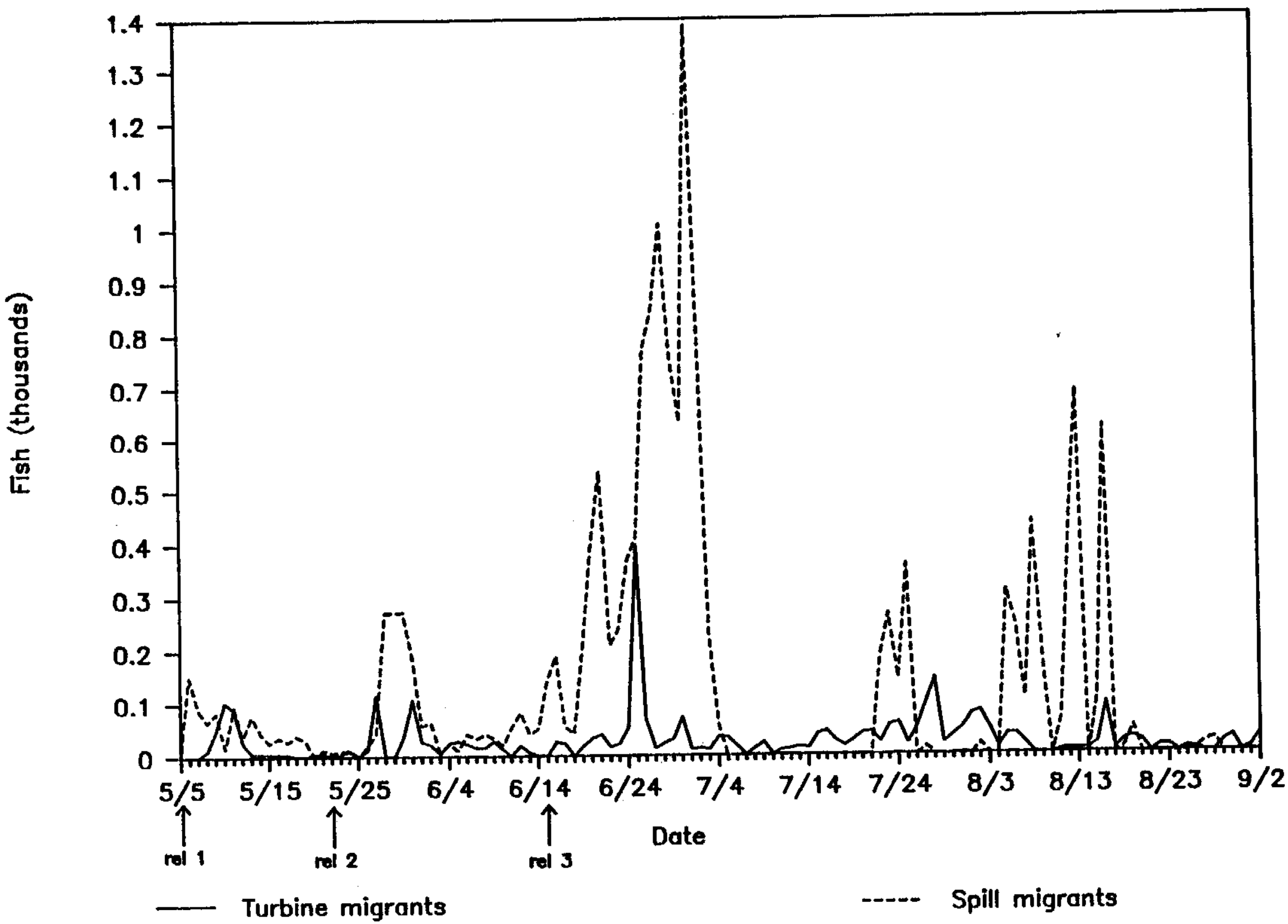

Figure 6. Estimated daily migration through the turbine and spillway (gate 5) of Glines Canyon Dam from May 5 to Sept. 2, 1987. Arrows denote release dates for chinook groups.

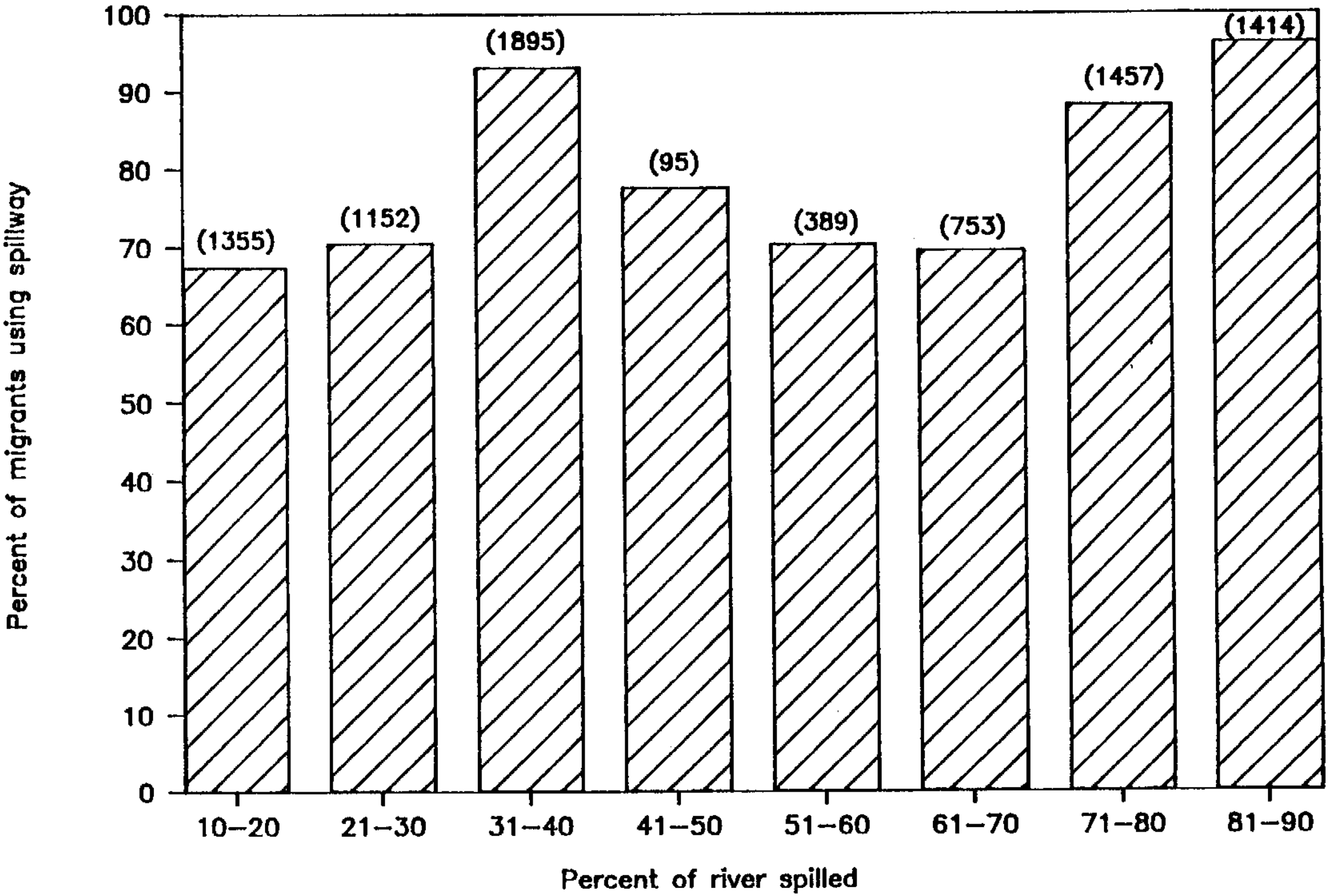

Figure 7. Estimated percent of spillway migrants versus percent of streamflow spilled during the period May 5 to Sept. 2, 1987. Values in parentheses indicate the estimated number of spillway migrants at each spill level.

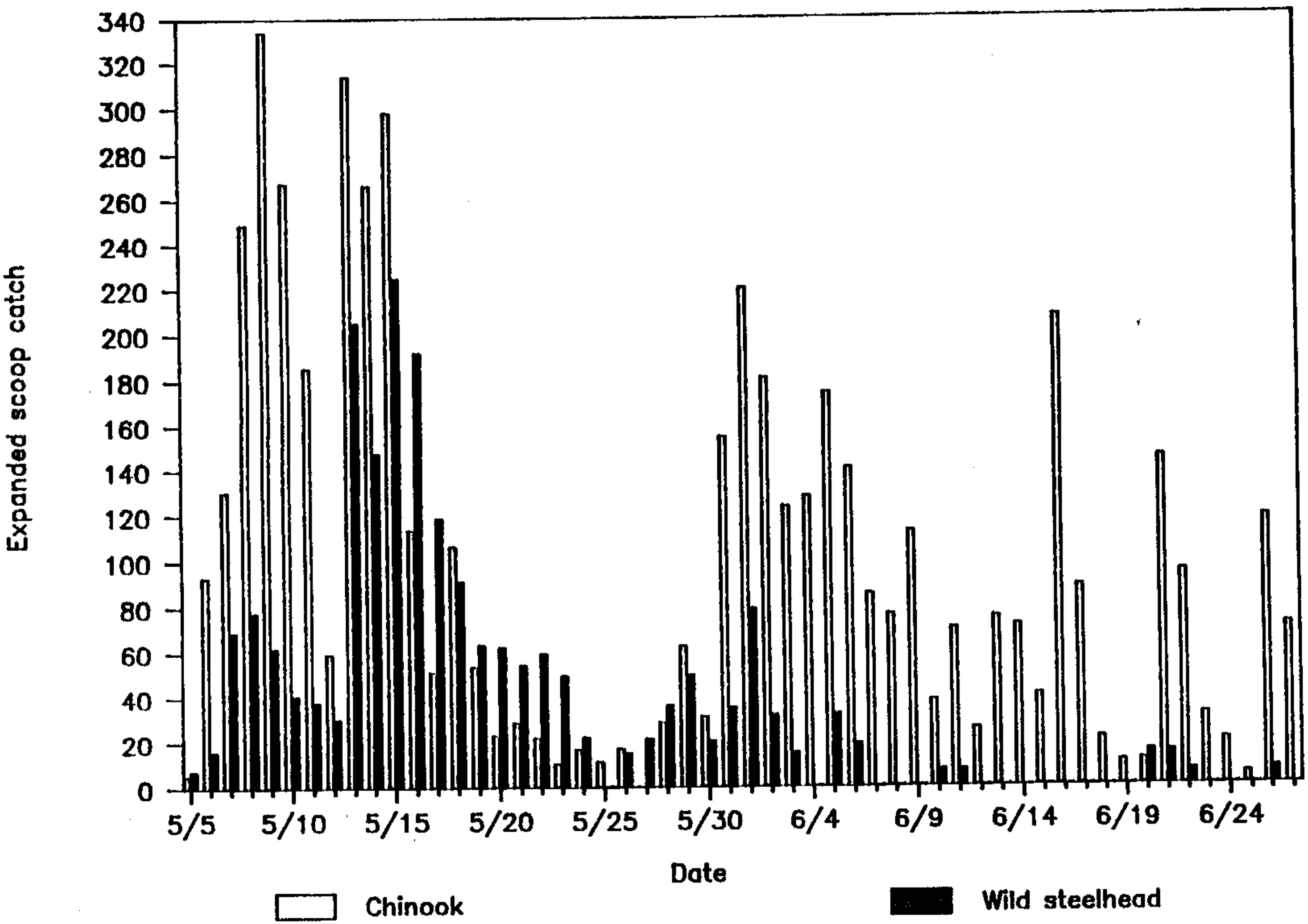

Figure 8. Expanded scoop trap catches of wild steelhead and reservoir–released hatchery chinook in 1987.

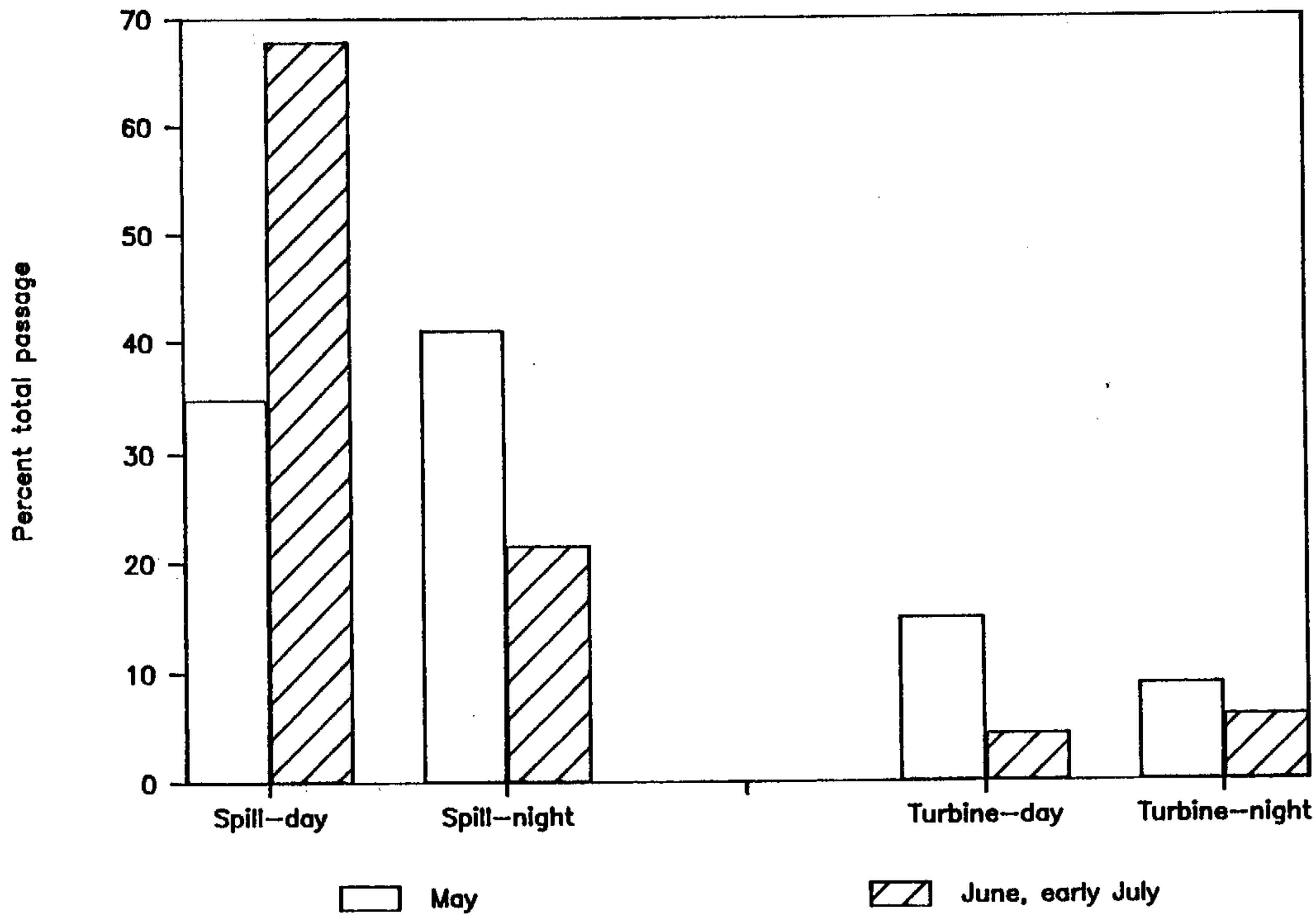

Figure 9. Estimated percentage of fish passage through the Glines Canyon Dam spillway and turbine during day and night periods from May 5 to May 31, and June 1 to July 5, 1987. The night period was defined as 2100 to 0500 hours.

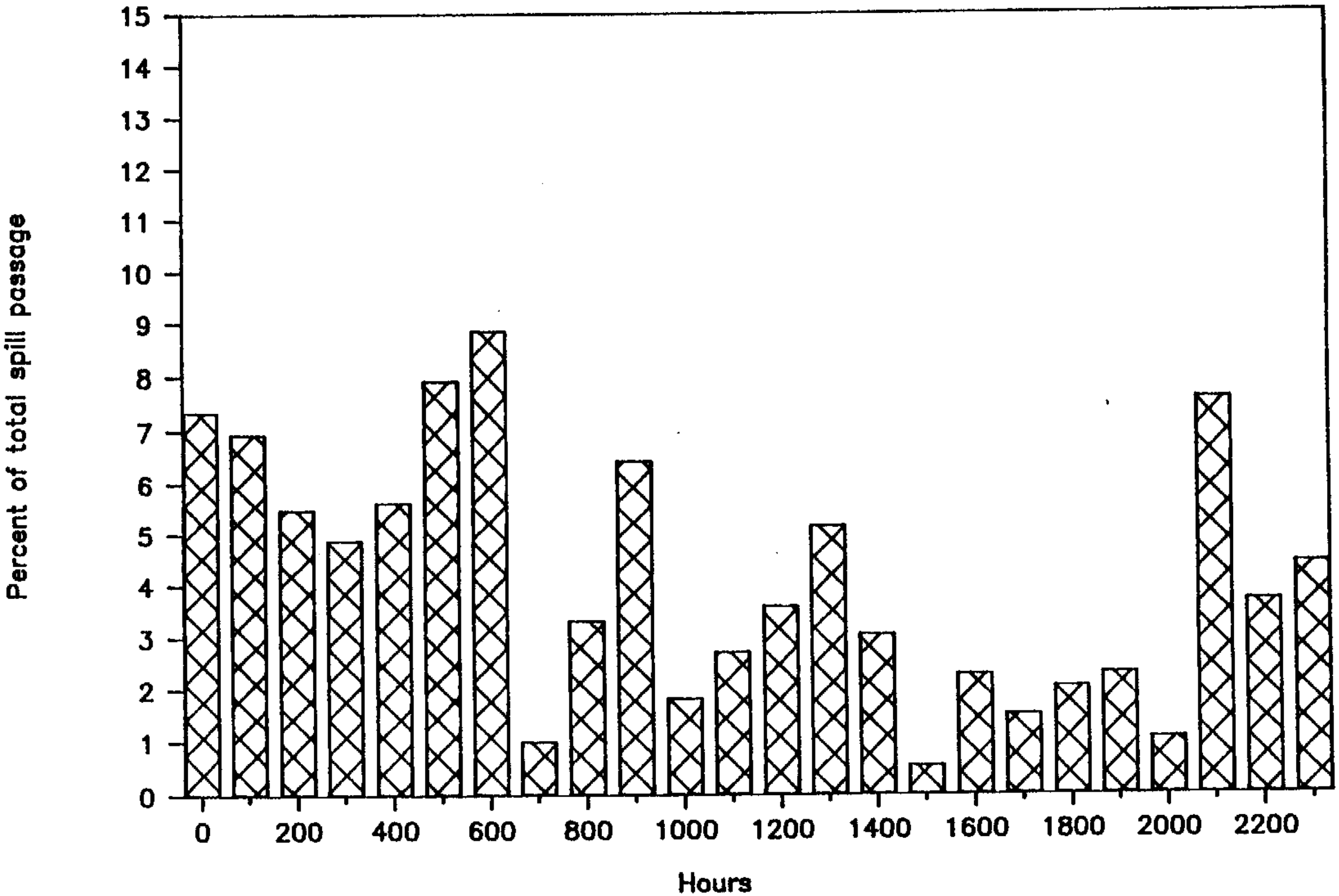

Figure 10. Hourly percentage of fish passage through the Glines Canyon Dam spillway between May 5 and May 31, 1987.

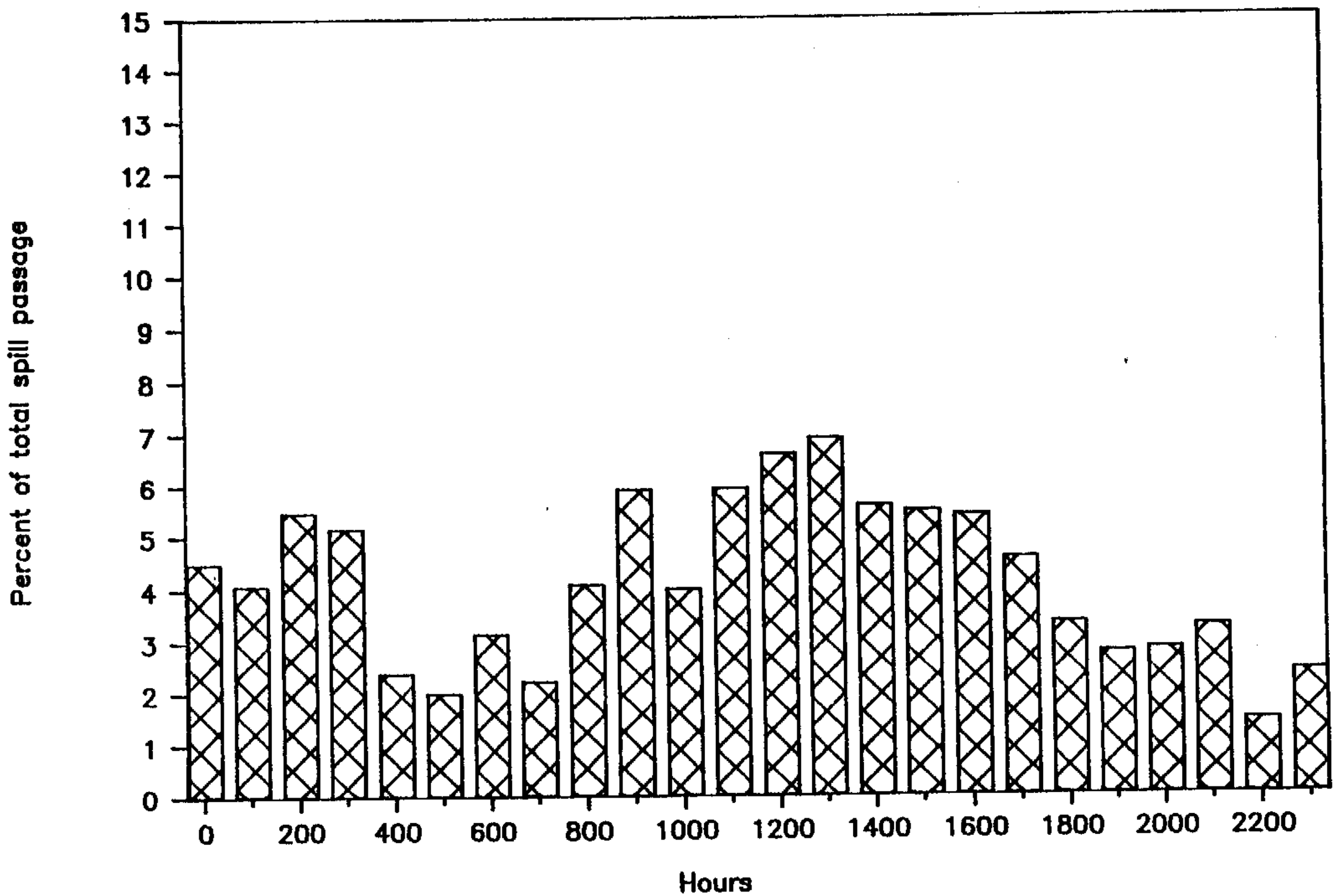

Figure 11. Hourly percentage of fish passage through the Glines Canyon Dam spillway between June 1 and July 5, 1987.

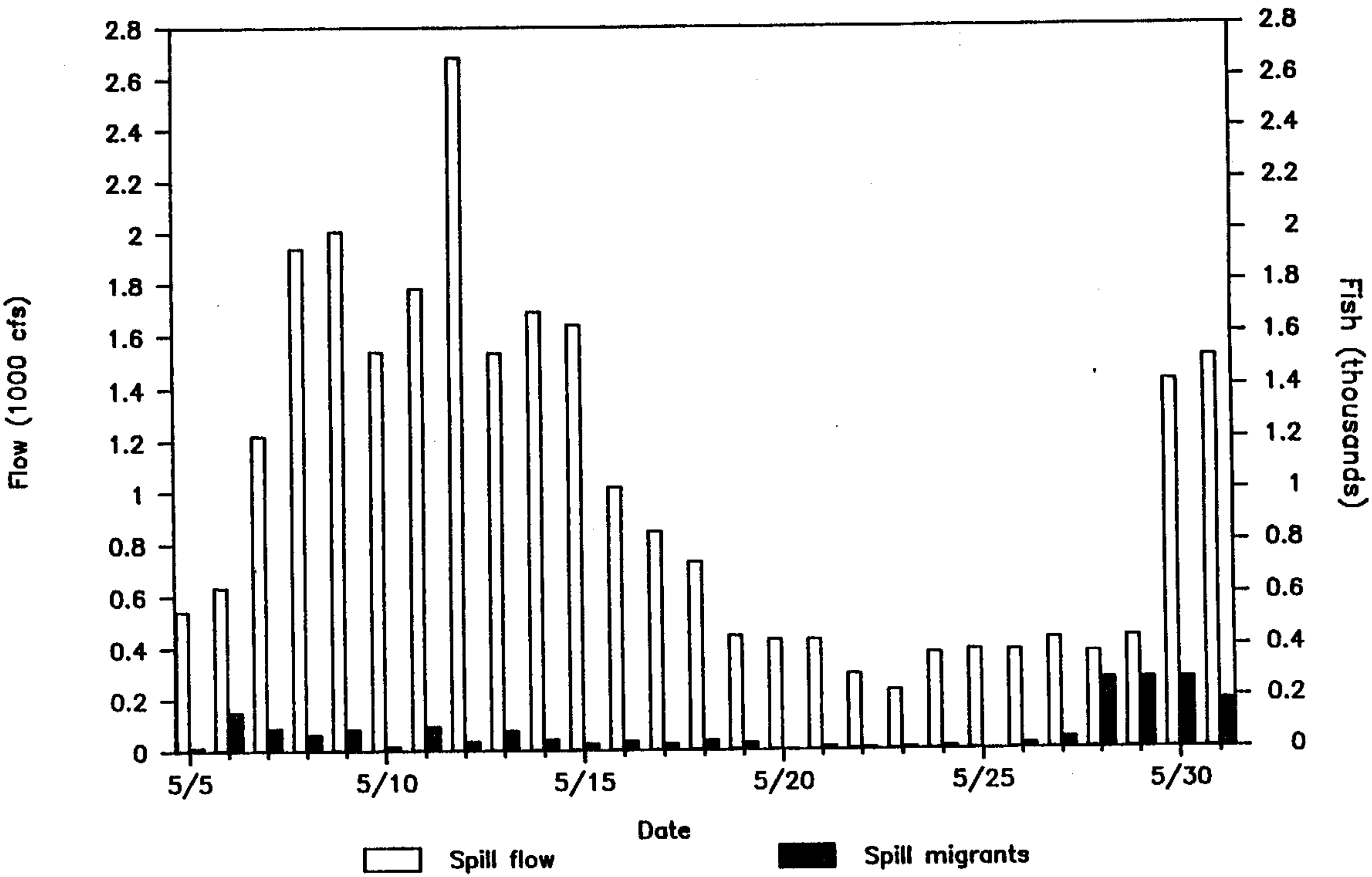

Figure 12. Daily spill and estimated daily spill migrants (chinook and steelhead) during May, 1987.

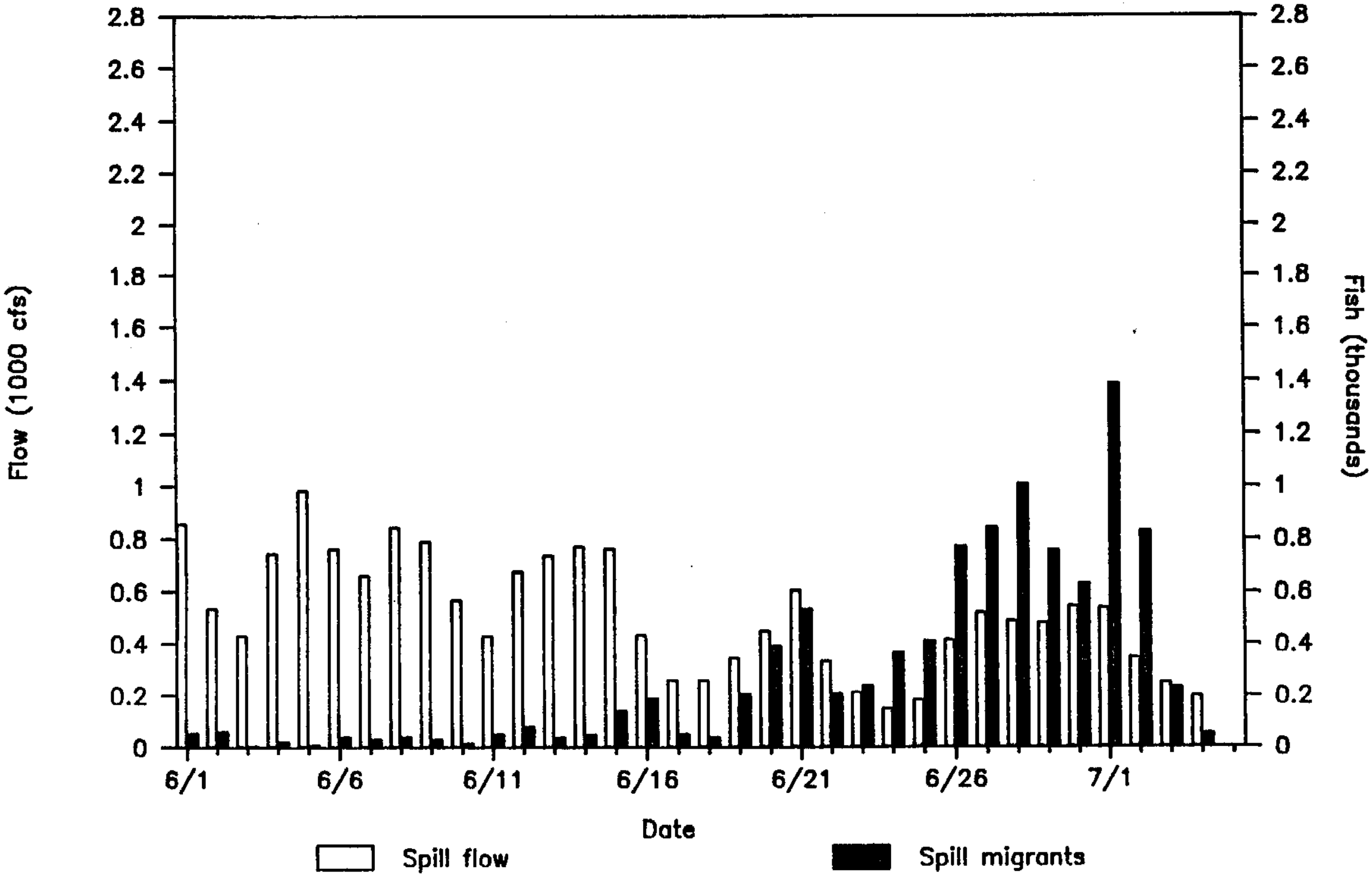

Figure 13. Daily spill and estimated daily spill migrants (largely juvenile chinook) during June and early July, 1987.

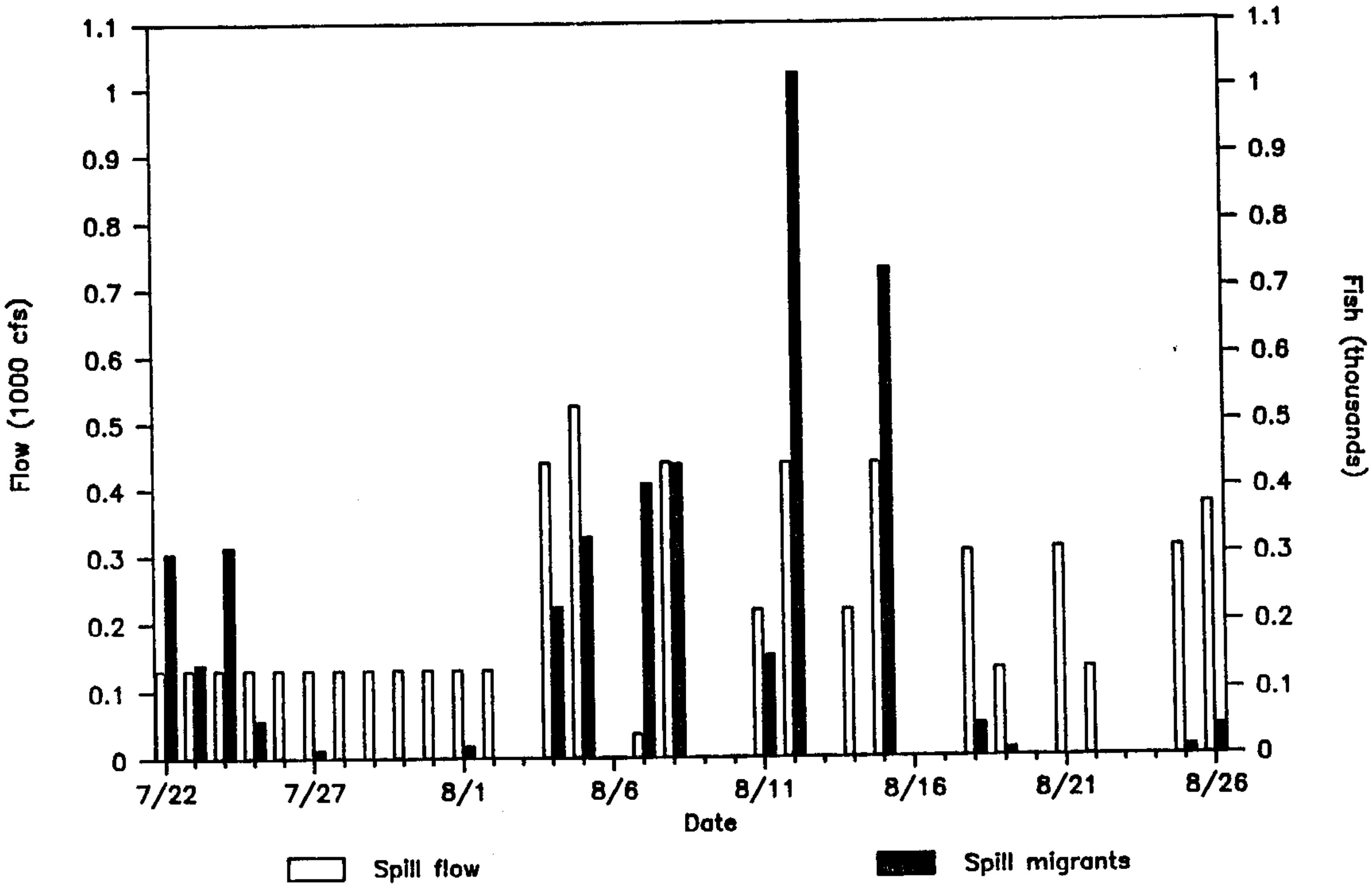

Figure 14. Requested spills and estimated spill migrants during late July and August. All spills were 7 hours in duration, except on 8/25 and 8/26 when spills were for 23 hours.

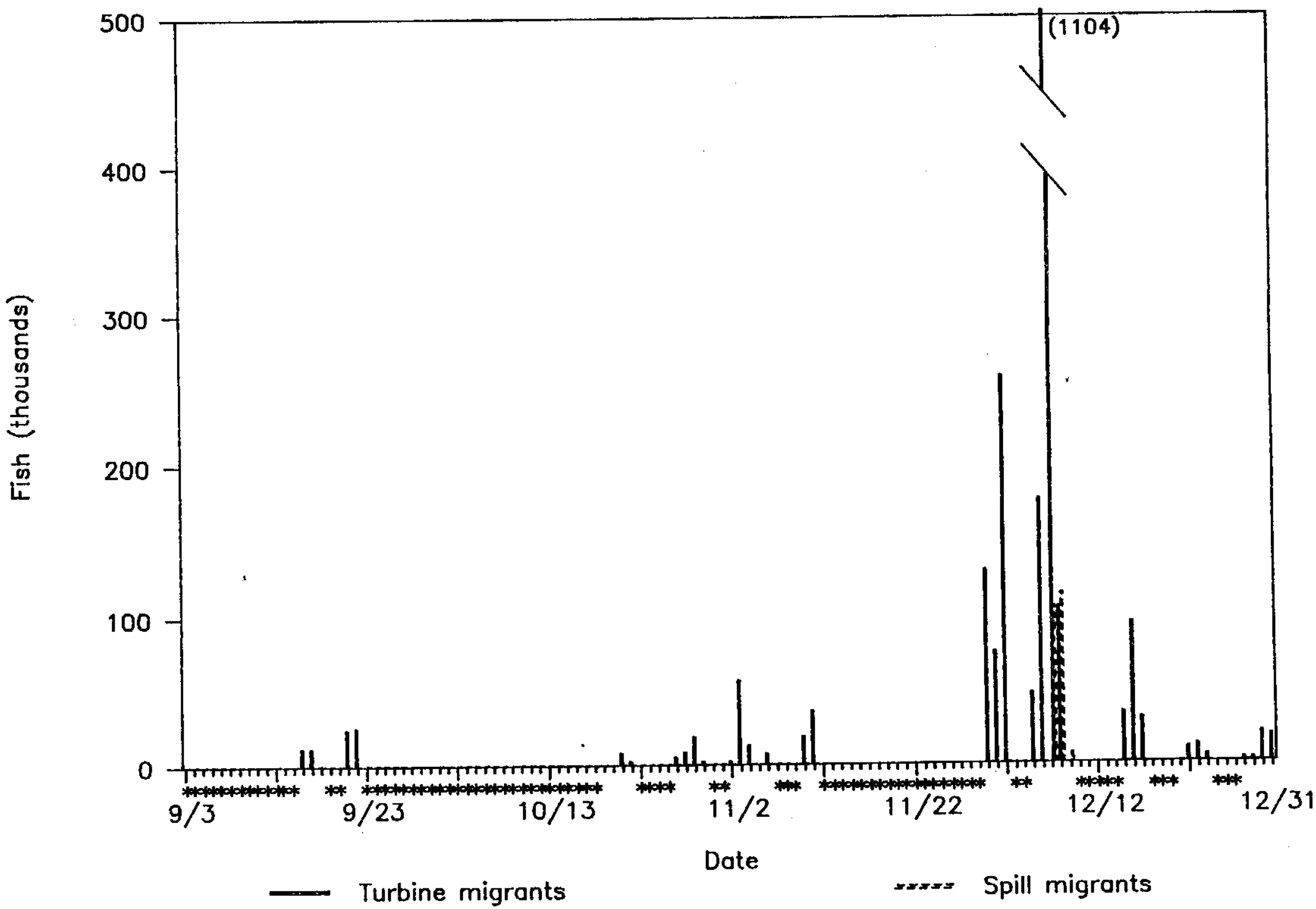

Figure 15. Estimated daily migration through the turbine and spillway (gate 5) of Glines Canyon Dam from Sept. 3 to Dec. 31, 1987. Asterisks indicate days which were not monitored.

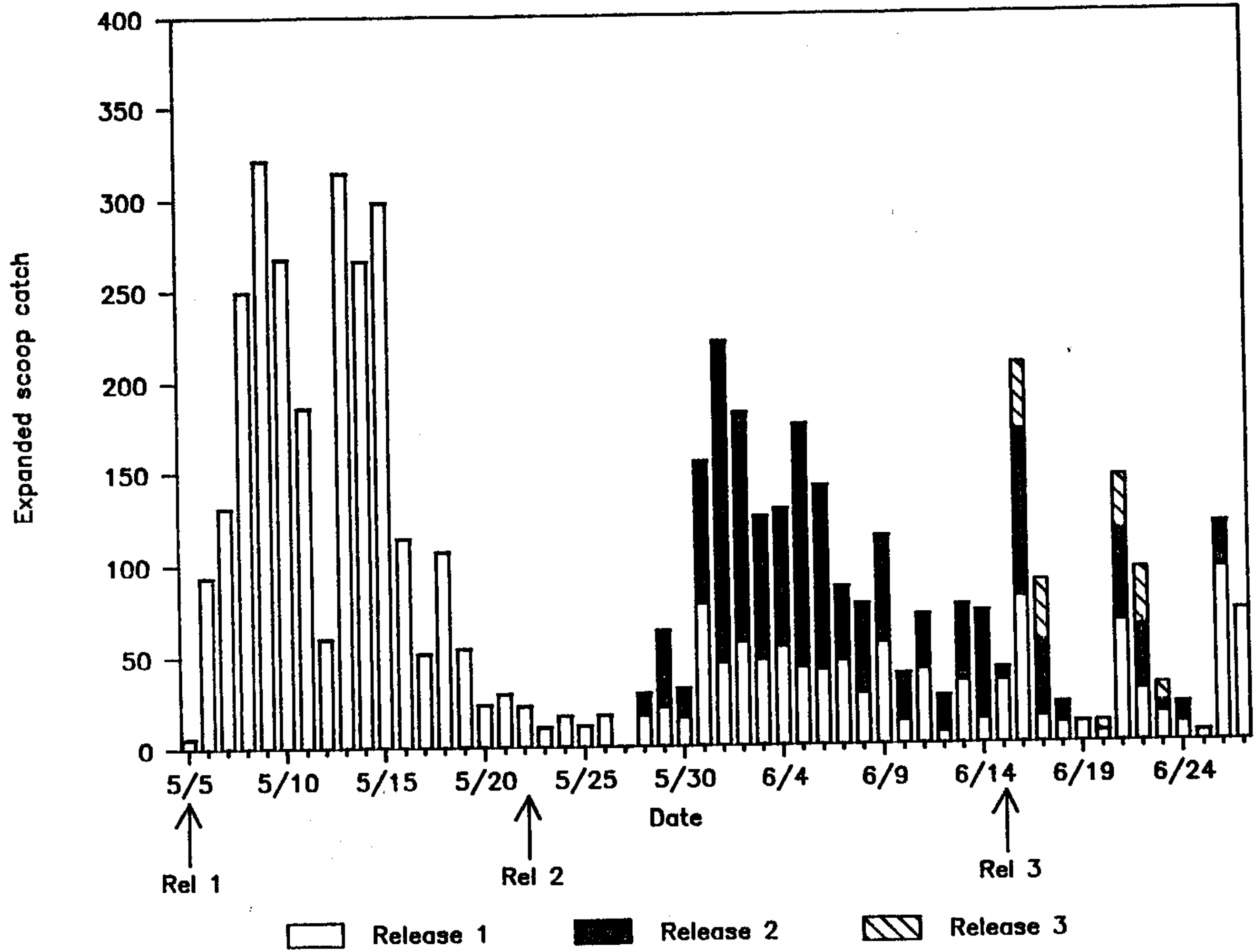

Figure 16. Expanded scoop trap catches of each chinook group released in Lake Mills. Arrows denote release dates of each chinook group.

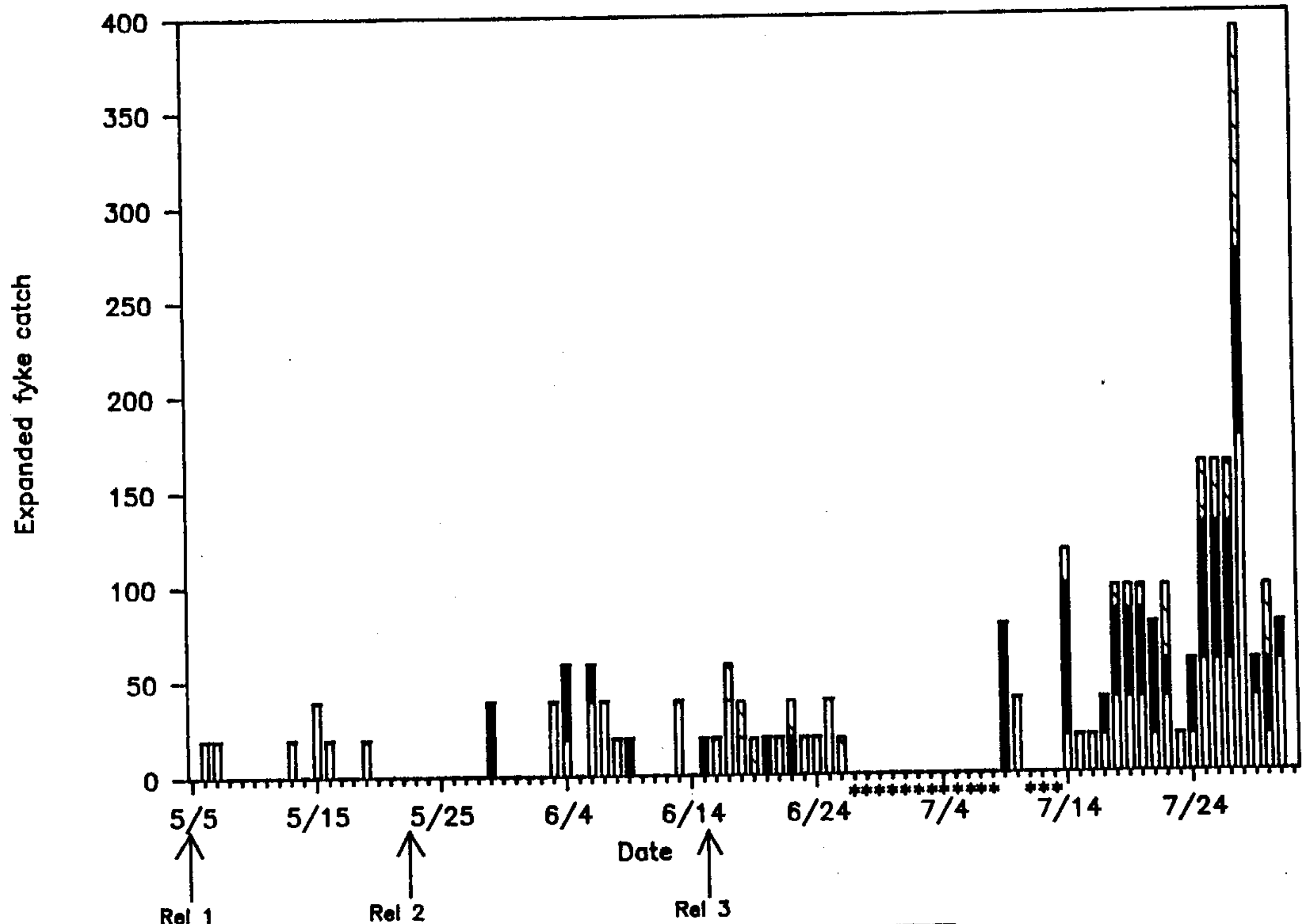

Figure 17. Daily fyke catches (expanded estimates) of the three chinook groups released in Lake Mills. Asterisks indicate days when the trap was not fished. Arrows denote release dates of the three groups.

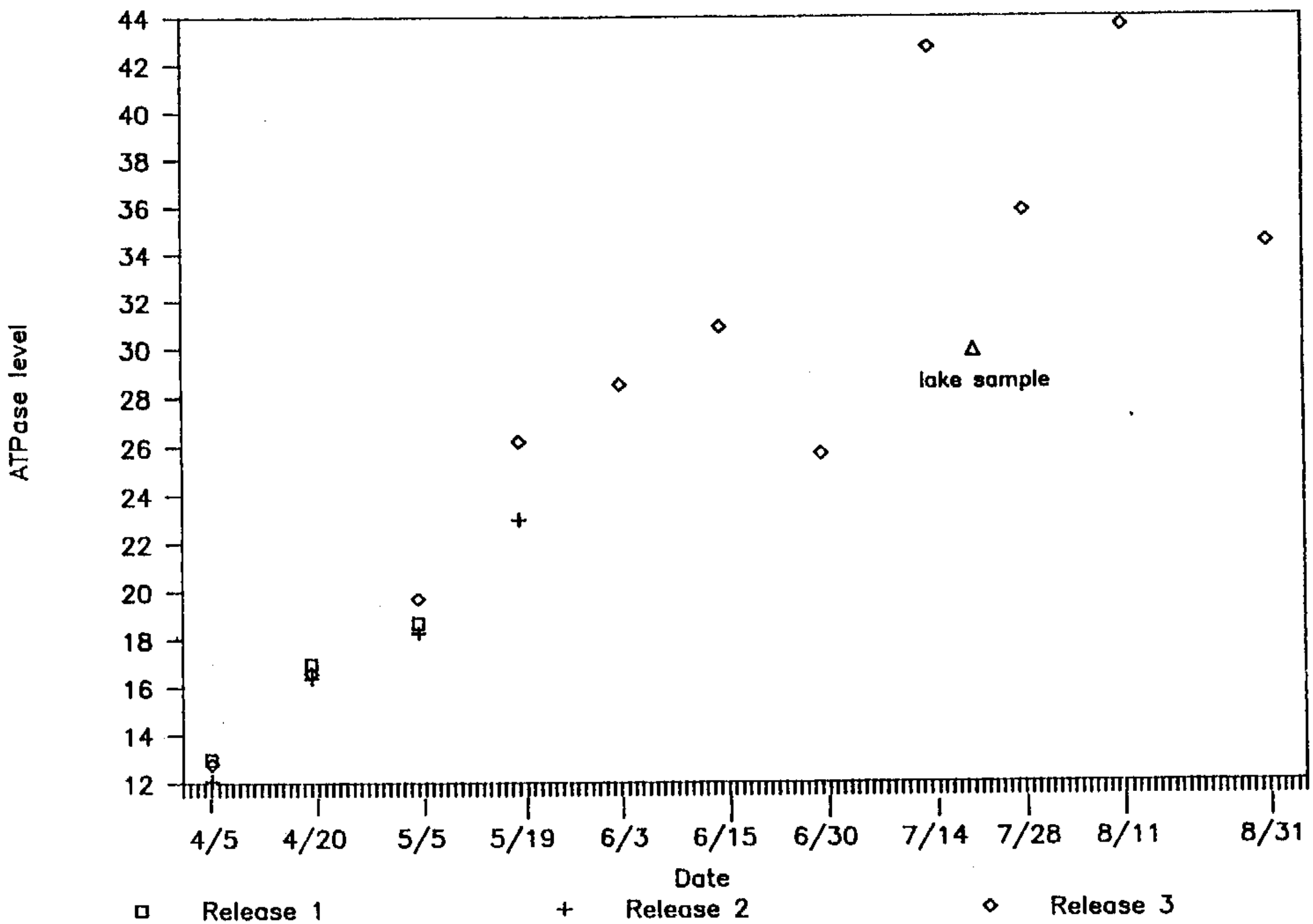

Figure 18. ATPase levels of the three chinook groups released in Lake Mills and of the one hook–and–line sample from the Lake Mills forebay. ATPase level refers to Na^+ – K^+ ATPase activity expressed as μmoles ATP hydrolyzed per mg protein per hour.

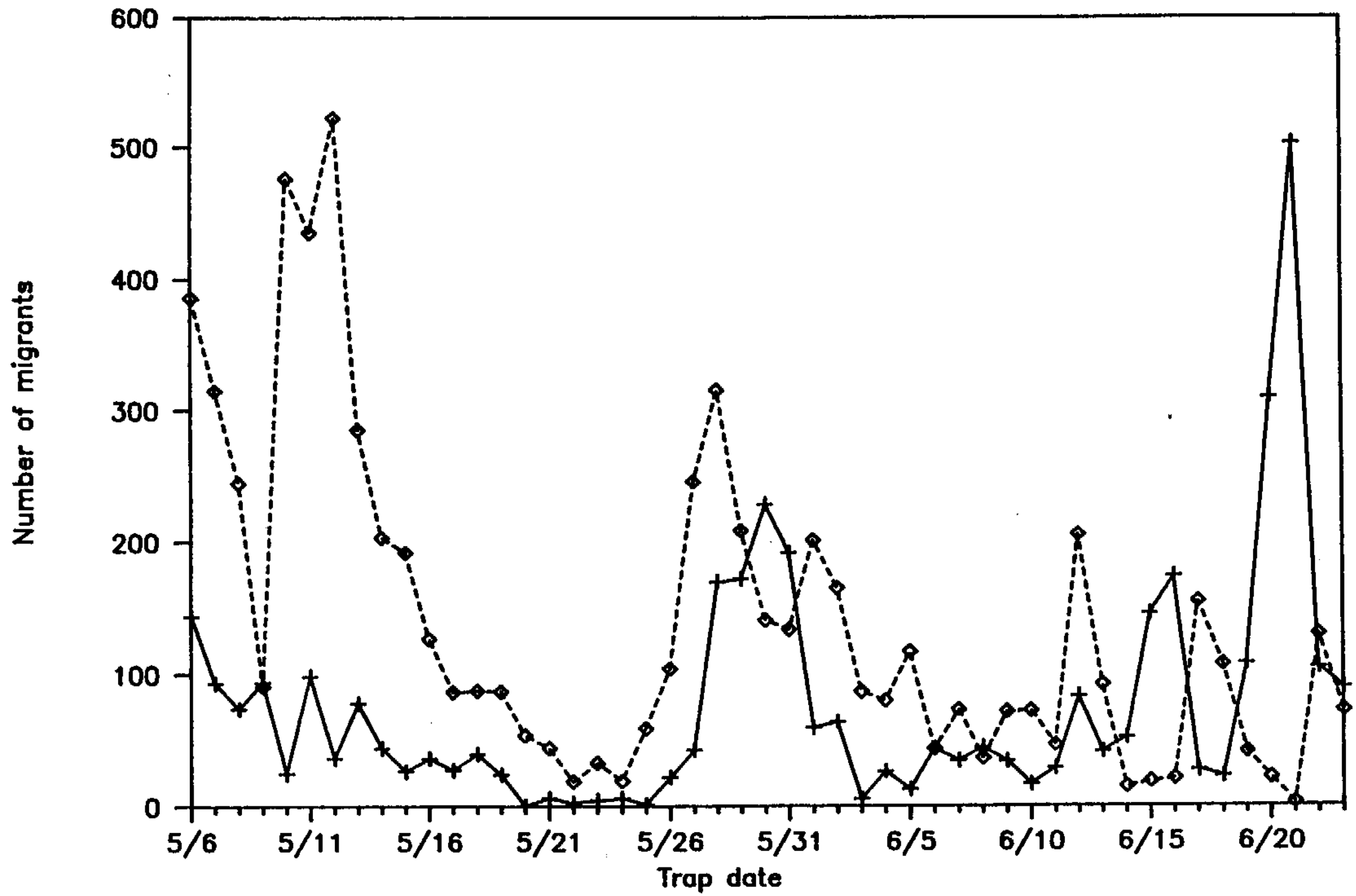

Figure 19. Daily estimates of migrant passage at the scoop trap site based on scoop trap and hydroacoustic monitoring. Hydroacoustic estimates were adjusted to reflect travel time and mortality between the dam and scoop trap (see text).

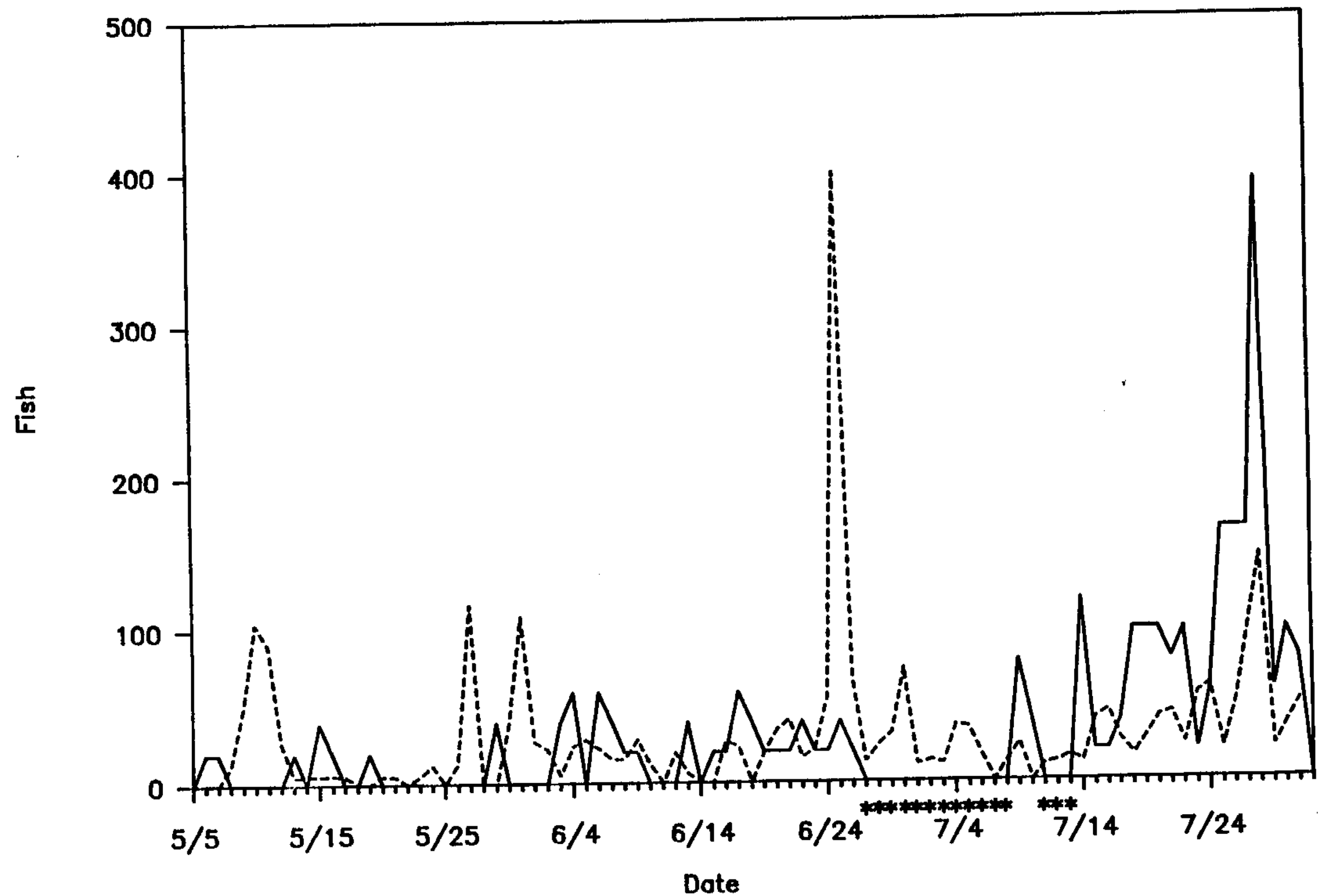

Figure 20. Daily acoustic and fyke trap estimates of fish passage through the Glines Canyon Dam turbine. Fyke trap catches were expanded to reflect trap efficiency. Asterisks indicate days when the fyke trap was not fished.

Table 1. Hydroacoustic equipment used at Glines Canyon Dam during 1987.

Item	Manufacturer	Model no.
Echo sounder/transceiver	Biosonics, Inc.	101
Multiplexer/equalizer	Biosonics, Inc.	151
Thermal chart recorder	Biosonics, Inc.	111
Transducer (15^{o})	Biosonics, Inc.	-
Oscilloscope	Hewlett Packard	1703A

Table 2. Preliminary survival and movement rate estimates for migrants passing turbine and spill exits of Glines Canyon Dam. These values are based in part on FAO studies conducted at Glines Canyon Dam in 1988, the results of which are still preliminary and subject to change.

Exit	Exit flow	Estimated survival	Travel time to trap
Spillgate 5	<250 cfs	0.35	3.0 days
Spillgate 5	250-450 cfs	0.50	3.0 days
Spillgate 5	>450 cfs	1.00	3.0 days
Turbine	1100 cfs	0.32	2.0 days

Table 3. Hydroacoustic sampling periods at Glines Canyon Dam in 1987.

Start		End		Monitoring hours
Date	Time	Date	Time	
May 5	0800	May 9	1200	100
May 9	1600	Jul 13	0600	1,550
Jul 13	1900	Jul 16	1300	66
Jul 16	1800	Jul 21	1800	120
Jul 22	0000	Jul 25	2300	95
Jul 26	1300	Aug 4	0500	208
Aug 5	0000	Aug 13	1800	210
Aug 14	0000	Aug 20	0300	147
Aug 20	1400	Sep 2	0700	329
Sep 16	1200	Sep 17	0200	14
Sep 17	0900	Sep 18	1200	27
Sep 21	1300	Sep 22	0200	13
Oct 19	1000	Oct 19	1900	9
Oct 20	0700	Oct 20	1800	11
Oct 21	0700	Oct 22	0700	24
Oct 27	1000	Oct 30	1600	78
Nov 2	1300	Nov 4	0500	40
Nov 5	1700	Nov 6	0900	16
Nov 10	1700	Nov 11	2000	27
Nov 30	1700	Dec 2	1100	42
Dec 5	0000	Dec 5	0700	7
Dec 6	1600	Dec 8	0600	38
Dec 9	0800	Dec 9	1600	8
Dec 15	1100	Dec 17	0900	46
Dec 21	0600	Dec 24	0900	75
Dec 28	0700	Dec 31	0800	73

Table 4. Proposed spill regimen for Glines Canyon Dam during spring 1987.

Day[a]	Gate opening (ft)	Spill (cfs)	Time period
1	0	0	1900 - 0700 hrs
2	2/3	290	1900 - 0700 hrs
3	1/3	145	1900 - 0700 hrs
4	0	0	1900 - 1900 hrs
5	2/3	290	1900 - 1900 hrs
6	1/3	145	1900 - 1900 hrs

[a]Sequence to be initiated on May 4th and continued as long as streamflow permits. When sequence interrupted by higher flow than proposed, sequence to be resumed at first opportunity.

Table 5. Spills provided to induce chinook movement during July and August at Glines Canyon Dam. No spills exceeded 24 hours in duration.

Date spill initiated	Spill (cfs)	Gate opening (ft)	Percent of streamflow spilled	Spill hours
Jul 22	133	0.3	16	2200 - 0500
Jul 23	133	0.3	16	2200 - 0500
Jul 24	133	0.3	14	2200 - 0500
Jul 25	133	0.3	16	2200 - 0500
Jul 26	133	0.3	17	2200 - 0500
Jul 27	133	0.3	18	2200 - 0500
Jul 28	133	0.3	19	2200 - 0500
Jul 29	178	0.4	25	2200 - 0500
Jul 30	133	0.3	20	2200 - 0500
Jul 31	133	0.3	20	2200 - 0500
Aug 1	133	0.3	21	2200 - 0500
Aug 2	133	0.3	27	2200 - 0500
Aug 4	441	1.0	67	2200 - 0400
Aug 5	528	1.2	84	2200 - 0400
Aug 7	441	1.0	72	2200 - 0400
Aug 8	528	1.2	83	2200 - 0400
Aug 11	220	0.5	39	2200 - 0400
Aug 12	440	1.0	75	2200 - 0400
Aug 14	220	0.5	38	2200 - 0400
Aug 15	440	1.0	82	2200 - 0400
Aug 18	306	0.7	67	2200 - 0400
Aug 19	132	0.3	28	2200 - 0400
Aug 21	310	0.7	75	2200 - 0400
Aug 22	133	0.3	31	2200 - 0400
Aug 25	310	0.7	69	1200 - 1100
Aug 27	375	0.9	81	1200 - 1100

Table 6. Chinook and steelhead releases at Glines Canyon Dam.

Species	Release location	Purpose of release	Number released	Mark legibility (%)	Marks released	Release date	Mean fork length (mm)	s.d.	n
Chinook	Tailrace	Scoop calibration, turbine control	3058	95.0	2905	5/5	70.3	4.2	100
Chinook	L. Mills	Exit selection	15,161	97.0	14,706	5/5	69.0	4.4	100
Chinook	Penstock	Turbine survival	3443	88.0	3030	5/5	71.6	4.6	100
Chinook	Tailrace	Scoop calibration	3283	94.0	3086	5/9	72.5	5.2	100
Chinook	L. Mills	Exit selection	15,418	94.0	14,493	5/22	74.4	4.8	100
Chinook	Penstock	Turbine survival	3127	91.7	2867	5/22	76.4	4.8	100
Chinook	Tailrace	Scoop calibration, turbine control	3189	94.0	2998	5/22	78.0	5.2	100
Chinook	L. Mills	Exit selection	9746	99.1	9658	6/15	86.7	5.4	107
Chinook	Tailrace	Scoop calibration	3040	89.2	2712	6/16	85.3	6.1	103
Chinook	Spillway	Spillway survival	3269	97.9	3200	6/16	85.7	5.1	100
Chinook	Spillway	Spillway survival	3112	90.9	2829	6/20	86.2	6.2	100
			65,846						
Steelhead	Tailrace	Scoop calibration	2001	99.0	1981	5/6	202.2	20.0	99
Steelhead	Tailrace	Scoop calibration	2007	100.0	2007	5/9	205.4	14.7	100
Steelhead	Tailrace	Scoop calibration	1569	100.0	1569	5/22	208.8	22.9	130
Steelhead	Tailrace	Scoop calibration	2111	98.1	2701	6/19	214.4	19.9	105
Steelhead	Spillway	Spillway survival	1999	97.1	1941	6/19	208.9	14.2	105
			9,687						

Table 7. Summary of fyke trap operational periods at the Glines Canyon Dam tailrace in 1987.

Start		End	
Date	Time	Date	Time
May 5	1233 hrs	June 27	0745 hrs[a]
July 8	1720 hrs	July 10	2040 hrs
July 13	1730 hrs	Aug. 1	2102 hrs

[a]Minor interruptions in operation occurred during this period for trap maintenance.

Table 8. Hydroacoustic monitoring periods at Glines Canyon Dam in 1987.

Period	Dates	Hydroacoustic monitoring frequency	Principal migrants present	Comment
1	May 5 - May 31	Continuous	Steelhead & chinook	Relatively high and variable spilling on continuous basis
2	Jun 1 - Jul 5	Continuous	Chinook	Generally lower, but variable spilling on continuous basis
3	Jul 6 - Sep 2	Continuous	Chinook	Low streamflow, requested spilling only on 26 separate occasions.
4	Sep 3 - Dec 31	Intermittent	Chinook	Continued low streamflow without major spilling until December; reservoir drawdown from Sept. to November.

Table 9. Hydroacoustic detections of migrant passage through spill and turbine exits of Glines Canyon Dam in 1987.

Exit	Estimated migrants				
	May 5-May 31	Jun 1-Jul 5	Jul 6-Sep 2	Sep 3-Dec 31[a]	May 5 - Dec 31
Spillway					
Day[b]	894	7,504	--	--	
Night	1,052	2,384	--	--	
Total	1,946 **(76%)**	9,888 **(89%)**	4,581 **(74%)**	229	16,644
Turbine					
Day[b]	384	488	--	--	
Night	229	678	--	--	
Total	613 **(24%)**	1,166 **(11%)**	1,566 **(26%)**	2,439	5,784
Grand total	2,559 **(100%)**	11,054 **(100%)**	6,147 **(100%)**	2,668	22,428

[a]Monitoring was not continuous during this period.
[b]The day period was defined as 0600 to 2000 hrs.

Table 10. Juvenile chinook survival through spill and turbine exits at Glines Canyon Dam.

Exit	Exit flow	Test date	Estimated survival(%)	95% Conf. interval (%)	Mean fork length (mm)
Turbine	1,100 cfs[a]	5/5/87	28.1	22.2 - 34.0	72
Turbine	1,100 cfs[a]	5/22/87	35.4	29.6 - 41.2	76
Spillgate 5	220 cfs[b]	6/20/87	42.2	---	86

[a]Full generation.
[b]Approximately 1/2-foot gate opening.

Table 11. Injuries observed among scoop trap recoveries of juvenile chinook in 1987. 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 chinook examined
	Light descaling[a]	Moderate descaling[b]	Heavy descaling[c]	Eye damage[d]	Other external injuries[e]	Moribund		
L. Mills release 1	18	6	8	1	1	0	38	421
L. Mills release 2	28	11	5	1	1	0	47	207
L. Mills release 3	26	4	0	0	0	0	30	23
Spillway release	29	3	2	1	2	2	36	192
Turbine release 1	17	11	7	1	1	1	44	147
Turbine release 2	11	2	2	1	0	1	20	212
Control release 1	1	0	0	1	0	1	3	363
Control release 2	2	1	2	0	0	0	11	258
Control release 3	4	2	1	0	0	1	9	541
Control release 4	9	2	0	0	0	0	12	515

[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.

Table 12. Injury differences observed among scoop trap recoveries of turbine test/control pairs. Values are test minus corresponding control group percent injuries by category.

Study pair	Injuries by category (%)						Percent of recoveries injured or dead	Number of chinook examined
	Light descaling[a]	Moderate descaling[b]	Heavy descaling[c]	Eye damage[d]	Other external injuries[e]	Moribund		
Test/control pair 1 (Turbine release 1-control release 1)	16	11	7	0	1	0	41	510
Test/control pair 2 (Turbine release 2-control release 3)	7	0	1	1	0	0	11	753

[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.

Table 13. Injuries observed among fyke trap recoveries of juvenile chinook in 1987. Injuries are expressed as a percentage of each group recovered at the fyke trap. Those fish recovered with more than one injury type are represented in all applicable categories.

Study group	Injuries by category (%)							
	Light descaling[a]	Moderate descaling[b]	Heavy descaling[c]	Eye damage[d]	Other external injuries[e]	Moribund	Percent of recoveries dead	Number of chinook examined
L. Mills releases 1,2, and 3	10	8	60	5	8	3	78	40
Turbine release 1	21	19	31	5	2	5	38	175
Turbine release 2	1	13	22	2	3	5	30	125

[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.

Table 14. Injuries observed among scoop trap recoveries of steelhead smolts in 1987. 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 steelhead examined
	Light descaling[a]	Moderate descaling[b]	Heavy descaling[c]	Eye damage[d]	Other external injuries[e]	Moribund		
Spillway release[f]	24	36	6	0	0	0	67	33
Wild steelhead	28	19	3	0	2	1	51	195
Control release 1	28	3	0	0	1	0	40	159
Control release 2	15	3	0	0	0	0	19	97
Control release 3	9	2	0	0	0	0	10	222
Control release 4	39	22	2	0	0	0	62	161

[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]An unknown portion of this group escaped into the reservoir forebay at release.

Table 15. Total scoop and fyke trap catches of chinook and steelhead originating from Lake Mills.

Group	Scoop trap catch[a]		Fyke trap catch[b]	
	Actual	Expanded	Actual	Expanded
Chinook release 1	421	3,774	67	1,313
Chinook release 2	207	1,433	51	1,000
Chinook release 3	23	150	23	451
Total chinook	651	5,357	141	2,764
Steelhead[c]	195	2,066	0	--

[a]The scoop trap operated from May 5 to June 27, 1987.
[b]The fyke trap operated from May 5 to June 27, July 8 to July 10, and July 13 to August 1, 1987.
[c]These smolts originated from a release of 97 winter steelhead adults (44 females and 53 males) in Lake Mills in 1985.

Table 16. Release and recovery lengths for juvenile chinook and steelhead. Recovery occurred at the scoop trap.

Species	Group	Mean release fork length (mm)	Mean recovery fork length (mm)	Difference (mm)
Chinook	Control 1	70.3	73.3	+3.0
Chinook	Control 2	72.5	74.5	+2.0
Chinook	Control 3	78.0	79.4	+1.4
Chinook	Control 4	85.3	89.0	+3.7
Chinook	Test 1[a]	69.0	84.5	+15.5
Chinook	Test 2[a]	74.4	86.5	+12.1
Chinook	Test 3[a]	86.7	92.7	+6.0
Steelhead	Control 1	202.2	205.4	+3.2
Steelhead	Control 2	205.4	209.5	+4.1
Steelhead	Control 3	208.9	212.0	+3.1
Steelhead	Control 4	214.4	217.1	+2.7
Steelhead	Naturally reared[b]	---	192.9	--

[a]Released in Lake Mills forebay.
[b]Progeny of adults planted above Glines Canyon Dam in 1985.