JUVENILE CHINOOK PASSAGE AT

GLINES CANYON DAM

ELWHA RIVER

1989 - 1990

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Olympia, Washington

October 1990

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ABSTRACT

We evaluated juvenile chinook passage at Glines Canyon Dam during 1989 and 1990. Our objective was to identify juvenile Elwha chinook emigration timing and exit selection at Glines Canyon Dam, as part of efforts to restore anadromous fish to the upper Elwha watershed. We planted chinook fingerlings in the upper Elwha watershed in April of 1989, and then continuously monitored their passage through the spillway and turbine exits of the dam over the ensuing 15 months. This was a follow-up effort to similar juvenile chinook passage work conducted at Glines in 1987.

We determined that peak passage occurred in late summer of 1989 by subyearling chinook, although downstream chinook movement occurred throughout the 15-month monitoring period. Approximately 50% of all juvenile chinook passed during the late summer peak. Peak movement in 1989 occurred approximately four weeks later than peak downstream movement in 1987. Lesser movement (26%) occurred in spring and early summer of 1989. Fall/winter movement accounted for most of the remaining downstream passage (21%). Yearling chinook passage in the spring of 1990 was negligible (<1%).

Juvenile Elwha chinook displayed a strong preference for the surface spillway exit at Glines Canyon Dam, with approximately 89% of all passage occurring via that exit. Cessation of spill for 45 days in late summer and early fall of 1989, for purposes unrelated to this evaluation, virtually stopped all downstream chinook passage. Numbers of subyearling chinook passing through the spill exit were not strongly related to either volume or percent of streamflow spilled during the spring of 1989. However, during a period of night-only spilling in late summer of 1989, approximately 39% of the variation in subyearling chinook passage could be related to volume of spill.

Juvenile Elwha chinook showed a preference for passage during hours of darkness, when a day or night passage choice was available.

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INTRODUCTION

Restoration of anadromous fish to the upper Elwha River watershed requires, among other conditions, safe downstream passage of juveniles. Fisheries Assistance Office (FAO), Olympia personnel have over the past seven years engaged in a series of studies aimed at better defining opportunities and requirements for safe and effective downstream passage of juvenile anadromous salmonids at the Elwha River dams (Figure 1).

This report describes further FAO evaluation of juvenile Elwha chinook passage at Glines Canyon Dam (Glines) on the Elwha River, Washington. Previous FAO chinook evaluations conducted in 1987 (Wunderlich and Dilley 1988) examined the movement of juvenile Elwha chinook through the spill and turbine exits of Glines. In that study, releases of juvenile chinook were made in the dam's forebay (Figure 2), and chinook movement through the dam's exits was monitored hydroacoustically. Although useful information on passage and exit selection was developed during the 1987 work, the extended passage period of the planted chinook raised questions about the timing of the Elwha chinook's emigration, and any effects an extended passage period may have had on exit selection at Glines. As well, atypically low flows occurred in the summer of 1987 that may have affected chinook movement through the dam. Further evaluation of Elwha chinook emigration and exit selection was therefore deemed necessary.

In 1989, we initiated such a further evaluation of Elwha chinook passage at Glines which incorporated two major improvements from the 1987 study. Presmolt chinook were distributed in the upper Elwha River watershed to simulate natural emigration, as opposed to the forebay release made in 1987. Concurrently, an intensive, 15-month fish-passage monitoring program was initiated at the exits of Glines to document emigrant timing and exit selection of the chinook outplant. Specific objectives of this further study, described herein, were to:

1. Identify emigrant timing of upriver-reared Elwha chinook juveniles.

2. Evaluate exit selection of upriver-reared chinook juveniles at Glines.

3. Examine the relation between numbers of fish passing the dam and flow and time-of-day factors.

METHODS

FISH PLANTING

On April 4 and 5, 1989, approximately 428,000 Elwha summer/fall chinook fingerlings (170 fish per pound; 60 mm mean forklength) were distributed to 30 planting sites in the upper Elwha River (Figure 3). These fish were obtained from the Washington Department of Fisheries (WDF) Soleduck Hatchery at 239 fish per pound on March 14, 1989, and transferred to the Lower Elwha Tribal Hatchery. From this location they were transferred to a staging site, Sweets Field, located in the Olympic National Park, and planted in the upper Elwha River (between river miles 19.3 and 41.0) via helicopter and fire bucket.

The fire bucket used was a "Bambi Bucket" and held approximately 80 gallons of water and 80 pounds of fish. Oxygen was supplied to the fish during transport via a small oxygen bottle strapped to the outside of the bucket. The oxygen was dispensed by a regulator connected to micropore tubing attached to the bottom of the bucket. Prior to transport, approximately 80 pounds of fish were weighed into a wooden box that contained 80 gallons of water being oxygenated by the same method described above. The box was in the back of a pickup truck. The fish and water were then transferred to the fire bucket by gravity via a 4-inch diameter hose located at the low point in the box. Transfer time to the fire bucket was less than 3 minutes, and the maximum time for helicopter transport to the uppermost planting site was approximately 20 minutes. The helicopter pilot released the fish by setting the bucket on the surface of the river and tripping the bottom opening. This method ensured no damage to the fish due to falling from the bucket.

HYDROACOUSTIC MONITORING

Passage Monitoring System. Fish passage monitoring at Glines was accomplished with a hydroacoustic system at Glines essentially the same as that used in 1986 (Dilley and Wunderlich 1987), 1987 (Wunderlich and Dilley 1988), and 1988 (Wunderlich et al. 1989), except that spill and turbine exit coverage was substantially increased. The system consisted of four, 15-degree, 420 kH_z transducers; one 6-degree, 420 kH_z transducer attached to a rotator that provided 360 degrees of rotation on both axes; an echo sounder/transceiver; a multiplexer/equalizer (MPX/EQ); two thermal chart recorders; an oscilloscope; and an equipment battery back-up. Table 1 lists model numbers of 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, echoes 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 recorders and oscilloscope via the MPX/EQ. Return signals were visually displayed on the oscilloscope for measurements of echo strength and duration. Individual fish traces were recorded by the thermal chart recorders 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 all five transducers in an operator-specified sequence. In addition, we employed a method known as fast multiplexing which allowed us to monitor the turbine intake and spillgate on separate thermal chart recorders virtually at the same time. Fast multiplexing, simply stated, involved rapid switching between two transducers at a very fast rate. The hydroacoustic system was operated 24 hours per day from April 4, 1989 to June 30, 1990 for a total of 15 months.

<u>Transducer Location</u>. The study design of the project called for hydroacoustically monitoring all possible fish exits during the entire length of the study. During the study, the fish had two possible exits: 1) through the single turbine intake located approximately 80 feet below the surface of the reservoir and about 100 feet upstream of the dam, or 2) under open spillgates near the top of the dam. Figure 2 illustrates these exits.

To achieve the best possible transducer location at both locations, three main criteria were considered: 1) maximize sample area, 2) minimize hydroacoustic turbulence, and 3) place the hydroacoustic beam in the closest proximity to the exit location.

We utilized three surface-mounted, 15-degree transducers to monitor spillgate 5 (Figure 2). These three transducers monitored approximately 75% of the spillgate's exit area. During the study, there were instances when two gates were in operation to handle high flows, or when a gate other than gate 5 was used. When this occurred, one of the transducers from gate 5 was transferred to the other gate spilling water.

To maximize the information returned from the spillgate transducers, fish direction, proximity to passageway, and turbulence were considered. In addition, to obtain directional information, the transducers were aimed off the vertical and parallel to fish movement. To achieve the best angle, we tested from 15 to 45 degrees and found an angle of 25 degrees provided the best information.

Initially, we utilized two transducers for monitoring the turbine intake: a 15-degree transducer mounted on the outside and a 6-degree transducer mounted on the inside of the intake. We deployed the inside-mounted transducer with scuba divers. We eventually discontinued the use of the outside transducer because we obtained superior monitoring information from the inside-mounted location. A full description and evaluation of the two locations can be found in Dilley (1990). For this report, only information from the inside location was used because of its superior quality.

<u>System Calibration</u>. To assure that echo information received from passing fish was recorded properly, the hydroacoustic system and transducers were calibrated prior to data collection. In addition, the 6-degree transducer inside the turbine intake was recalibrated on August 29, 1989, and the three 15-degree transducers above spillgate 5 were recalibrated on March 1, 1990. Based on this calibration information, the system sensitivity for each transducer was calculated and their equalization programmed into the MPX/EQ. This ensured that the data collected was comparable for all transducers throughout the monitoring period.

<u>Target Strength</u>. Since the hydroacoustic size of the fish determines the effective beam width of the transducer, the target strength of the fish determines the sample volume of the beam. For our purposes, Love's formula (Love 1971) was used to estimate the target strength. The smallest size fish of interest in this study, approximately 50 mm, would be detected by using a target strength of -56 dB on axis. This value was also used for setting the thermal chart recorders.

<u>Echogram Interpretation</u>. Validation parameters for fish passing under the spillgates by echogram traces were identical to those used in 1986 (Dilley and Wunderlich 1987), 1987 (Wunderlich and Dilley 1988) and 1988 (Wunderlich et al. 1989). The interpretation of the echograms obtained from the inside-mounted turbine transducer was different, however, since fish passing through the beam at this location were directly parallel with the beam. In the latter instance, short-to-long trace types with at lease six repetitive hits on the echogram were considered fish passing through the Glines turbine.

DATA REDUCTION

As in previous FAO studies, microcomputers were used for data storage and subsequent data analysis. Individual fish records on echograms were transformed to data files using a digitizing pad coupled with a data entry program developed by FAO personnel. Expanded detections, based on depth and beam size, were then summed by location and hour for the entire study. Corresponding hourly flow/gate records for each exit (as recorded by dam operators throughout the study) were also entered into hourly files. These summary files were used for graphic representations and statistical analyses.

DATA ANALYSIS

Due to the vast amount of emigration data collected over the 15-month study, we separated the information by calendar year. For reporting purposes, juvenile chinook emigrating in 1989 were considered subyearlings and those emigrating in 1990 were considered yearlings. We further divided calendar years into major events concerning spill flow, as described below. In addition, subyearling and yearling information from this study was compared with previous study results of emigrating chinook obtained for subyearlings in 1987 (Wunderlich and Dilley 1988) and yearlings in 1988 (Wunderlich et al. 1989).

SPECIES VERIFICATION

No anadromous fish, other than those for this study, were planted in the upper Elwha watershed either before or during this work; therefore, no other anadromous fish could have emigrated during our fish passage monitoring from April 1989 to July 1990. Because past work indicated that resident salmonid passage through Glines was negligible, we assumed all hydroacoustic detections in the indicated size range were juvenile chinook. Although previous FAO hydroacoustic monitoring and trapping of fish at Glines indicated this was a reasonable assumption, we installed a fyke trap in the Glines tail race to positively identify the species of fish passing through the turbine. This was the same trap used in past FAO studies. The trap opening measured 4 feet by 7 feet and thus strained only a small portion of the tail race flow. Trap catches were checked at least daily. Except for several brief maintenance periods, we fished the fyke trap continuously from April 7, 1989 to June 22, 1990. We recorded species, length, and physical condition of all fish captured.

SPILL REQUESTS

We requested spill augmentation during three periods over the study. During the spring of 1989 and 1990 (April, May, and June of each year), we requested a continuous minimum spill of approximately 170 cfs, or 0.4-foot opening of the Glines spillgate, during run-of-the-river operations to ensure that a surface exit was continuously available throughout this portion of the emigration period. Previous work (Wunderlich and Dilley

1988) suggested that this would permit passage of juvenile chinook at Glines. Additionally, during the summer low-flow period in 1989 (August to October), we requested variable nightly spills (approximately 150 to 320 cfs for 8 to 10 hours during hours of darkness) to allow chinook egress from the forebay, and to assess the effects of differing spill volume on nightly fish passage. Nightly spills were limited (in volume and extent), however, due to concerns over downstream temperature increases associated with spill of warmer surface water from Lake Mills during summer low flow.

We requested that all spills occur at gate number 5 (Figure 2) throughout the study, insofar as possible, to ensure consistency with prior work and to enhance fish survival. (Spill was switched to another gate on several brief occasions over the study because of maintenance activities.) Use of spillgate number 5 ensured consistency with previous hydroacoustic evaluations of fish passage at Glines, as only this gate was used for spilling in prior FAO hydroacoustic studies at this dam. Better survival to the Glines plunge pool was also expected from this gate as opposed to the other spillgates, based on an interagency inspection of the plunge pool and spill channel in the spring of 1989.

RESULTS AND DISCUSSION

The general flow pattern for the 1989-1990 study period (Figure 4) was similar to that observed during FAO studies in the previous several years on the Elwha. Spring spills were in the same range in both years (Figure 5). Turbine flow for the same period was also similar between years during May and into June (Figure 6), except in 1989 when a few periods of requested spilling resulted in less than the maximum flow of 1100 cfs through the turbine.

During 1989, the Elwha River's natural flow pattern was altered. Lake Mills was drafted 10 feet for a sediment study in the reservoir delta during late summer and early fall. In addition, flow augmentation through the turbine, as requested by WDF and the Lower Elwha Tribe to reduce downstream temperature problems for adult chinook holding in the lower river (evening spills only, July 22 to September 6, and elimination of spill completely from September 7 to October 23), impacted normal run-of-the-river flow patterns. For the most part, a minimum of 0.4-foot spillgate opening, or approximately 170 cfs, was provided during 1989 until flow augmentation went into effect.

A graphic presentation of total river discharge and total daily fish emigration for the entire study period (Figure 7) is provided so that numbers of fish passing both the spill and turbine exits can be viewed as a whole. Figure 7 shows a predominant subyearling emigration in late summer for the native Elwha stock, as was suspected from the chinook monitoring conducted in 1987 at Glines (Wunderlich and Dilley 1988). Isolated peaks in movement also occurred in October immediately following the prolonged no-spill period, as discussed below.

Juvenile chinook length during peak passage in late summer ranged from 10 to 12 cm, based on fyke captures in the turbine tailrace (Appendix), while ATPase level approached 25, based on captures at the head of the reservoir by Hosey and Associates (1990). These values compare to a mean length of approximately 6.5 cm at time of planting, and to baseline ATPase levels of 5 to 10 in late May among fish captured at the head of the reservoir (Hosey and Associates 1990).

Figure 8 further illustrates the late-summer emigration phenomenon as indicated by cumulative passage over the entire study period, with associated major spill (and non-spill) periods noted. Approximately 50% of the entire emigration occurred during July and August of 1989, during a period of limited nighttime spilling, which will be discussed in more detail below. Some limited movement is evident during virtually the entire year as well, although the balance of the remaining movement occurred during the first spring. Table 2 also provides a numeric breakdown of passage through Glines over the entire study period.

In contrast to steelhead and coho, chinook typically display variability in emigration timing. Such variability may be related to both genetic and environmental influences (Randall et al. 1987; Carl and Healey 1984). The predominant late-summer passage pattern observed in 1989 at Glines is, however, consistent with emigration timing of a number of other regional stocks in the north Washington coast (Quinault Fisheries Division 1977), the Columbia River (Poe et al. 1988), and the Oregon coast (Nicholas and Hankin 1988). The Elwha chinook stock at the Elwha Rearing Channel typically displays a late-summer smolt which peaks in early August when the bulk of the volitional movement from the Channel occurs (Chuck Johnson, Washington Department of Fisheries, Salmon Culture Division, personal communication).

Although the bulk of chinook passage observed at Glines Dam is assumed to be smolted chinook, and is described as chinook "emigration" herein, undoubtedly some movement through Glines was simply related to redistribution of chinook within the watershed. Hosey and Associates (1990) observed higher ATPase levels in the late-summer Elwha emigrants, but Zaugg (1981), Ewing et al. (1980), and others have noted that chinook display complex patterns of rearing and seaward movement, not always associated with elevated ATPase levels. The influence of Lake Mills on downstream passage is also a factor, and the extent of juvenile chinook rearing within this reservoir was not resolved (Hosey and Associates 1990). At least some chinook rearing in Lake Mills would be expected from this upriver plant (Eugene Smith, Oregon Department of Fish and Wildlife, Research and Development Section, personal communication). Lack of a preferred exit (the spillway) in late fall was also a factor, as discussed below.

SUBYEARLING PASSAGE (1989)

Timing and Abundance. Hydroacoustic estimates show that the principal emigration period for subyearlings began in early May and continued into November (Figure 9), with 95% of the emigration occurring from April 27 to November 13. The total number of migrants estimated passing Glines Canyon Dam for 1989 was 118,396. This represents approximately 28% of the total chinook planted in April of 1989. It appears that the complete termination of spill for downstream flow augmentation, starting in early September, impeded the normal emigration pattern. This was particularly apparent when large numbers of fish were observed milling around the face of the dam. In addition, when a spillgate was briefly opened after the period of no spill, the average passage rate (282 fish per hour) was the highest recorded during the study (Figure 10).

The emigration pattern observed for chinook in 1989 was somewhat different from that observed in 1987. The 1987 subyearlings primarily peaked in late June/early July as compared to the 1989 subyearlings which peaked from early to late August, a difference of about four weeks (Figure 11). In 1987, ATPase level rose faster than in 1989, although differences in sample location may be a factor (all 1987 samples were taken from fish held in the hatchery, while all 1989 samples were taken from captures in the river above Lake Mills). Approximately 44% of the total subyearling emigrants passed the dam from August 20 through December in 1989. The subyearlings of 1987 did not show this late emigration trend. However, spilling was infrequent during this period in 1987, and fish movement was only occasionally monitored. Based on the results of the 1989 data, it is likely that chinook in 1987 could have passed the dam during non-monitored periods. In fact, the 1987 report noted that the effects of little or no spill on potential movement was unknown.

The predominantly late-summer passage timing of the Elwha chinook at Glines is of concern with regards to successful downstream passage in the Elwha system. The possibility of losses from predation and residualism in reservoirs is substantially heightened for stocks with protracted emigration patterns. For example, Rieman et al. (1988) estimated much greater predation losses (up to 54% greater) in John Day Reservoir for late-summer-migrating subyearling chinook compared to earlier, and generally larger, spring-migrating chinook, coho, and steelhead. The protracted movement of smaller migrants, at a season when predator activity is highest, was considered a significant factor in those greater losses (Rieman et al. 1988).

Exit Selection. A total of 107,171 subyearlings passed via the spill (91%) and 11,225 via the turbine (9%) in 1989. Figures 10 and 12 show daily passage rates in terms of fish per hour for spill and turbine exits, respectively. Passage rates for the spill indicate an increase in the passage rate at the end of June, a slight reduction in mid-July, and then a progressive increase to a relatively high rate until termination of spill at the beginning of September. In comparison, turbine passage rates relative to spill passage rates were substantially lower during this period (Figure 9). Substantial increases in turbine passage rates did not occur until about mid-October to mid-November.

Comparing percent of river spilled versus estimated percent of migrants using the spillway on an hourly basis during 1989 showed no clearly increasing trend in spillway use with greater percent of river flow spilled (Figure 13). In fact, a decrease in use was noted when the percent of spill exceeded 60%. However, only 3% of the observed data points are in this range, and represent only high flow conditions very late in the year. The information presented in Figure 13 does not account for possible effects of differing length (days) of spilling at each spill level for 1989. Spillway preference (or lack of) at the differing spill levels reflects exit choice for those migrants which were actively seeking an exit under the conditions that existed at the time of emigration.

During the spring/early summer period of continuous spill (April 4 to July 22), most chinook passed Glines via its spillway, but fish passage through the spillway was not strongly associated with spill flow. Poor relationships ($r^2 < 0.11$) were found between both volume of spill and number of chinook passing the spillway, and percent of river spilled and percent of chinook passing the spillway, during day and night. An estimated 29,238 chinook (92%) passed Glines via its spillway during this time period (Table 2). Mean rate of passage (number per hour) through the spill exit over this period was substantially greater than through the turbine exit, and substantially greater at night through both exits (Table 3).

During the period of requested evening spills (July 23 to September 6), virtually all chinook passed Glines by way of its spillway, and chinook movement through the spill exit showed an improved relation to volume, but not proportion, of river spilled. An estimated 59,117 chinook passed through the spill exit (Table 2) during the evening spill period, which was nearly 99% of all movement detected at this time of year. The 59,117 chinook also represented approximately 50% of all movement detected throughout the entire 15-month monitoring period. Volume of spill was significantly related to fish passage through the spillway, explaining 39% of the variation in fish passage observed ($r^2 = 0.39$, $P < 0.05$). The relation between percent of river spilled and percent of chinook passing the spillway was negligible, however ($r^2 = 0.06$, $P > 0.05$). In the latter comparison, the proportions of river spilled during the evenings ranged from 18% to 53% of total river flow (Table 4).

During the non-spill period (September 7 to October 23), overall passage was severely impeded, and movement through the deep-water turbine exit equalled only 2,801 fish (Table 2). However, mean rate of movement through the turbine exit during this period was significantly greater than mean movement through the turbine in a like time period (45 days) immediately preceding ($t = 3.12$, $P < 0.01$).

Exit selection during the remainder of 1989 was dominated by spillway usage, with an estimated 18,816 chinook using the surface exit at Glines (Table 2). This was approximately 79% of total fish passage at this time of the year. Because of the interruption in spill exit availability immediately preceding this time period, and the inconsistent availability of the spill exit during this period, further examination of exit selection for this period was not meaningful.

In 1989, fyke trap catches verified that chinook were passing through the turbine (Appendix), and while estimates of fish passage could not be obtained from the fyke trap, relative abundance coincided with hydroacoustic observations.

Diel Movement. Diel movement of subyearlings via the spillgate and turbine varied greatly on a daily basis during 1989. However, a month-by-month summary of this same information shows a preference toward night passage (Figure 14). During April, we observed about one-half of the migrants passing at night, with a shift to night passage preference for most of the rest of the year, when comparison was possible (lack of spill during some or all of August, September, and October prevented comparisons during those months). This same preference toward night movement was not observed in the 1987 study for June and early July. In 1987, a high proportion (76%) of subyearling chinook passed the Glines spillway during the day period. However, stream flow and water clarity may have influenced these different patterns, as well as the fact that the 1987 juveniles were held in the hatchery one to two months longer than the juveniles in this study, and were planted directly into Lake Mills.

YEARLING PASSAGE (1990)

Timing and Abundance. Hydroacoustic estimates show that the principal emigration period for yearlings began in January and continued to the end of June (Figure 15) with 95% of the emigration occurring from January 6 to June 15. The total number of migrants estimated passing Glines in 1990 was 3,694. This represents only 0.9% of the total chinook planted in April of 1989. This compares closely to the expanded scoop trap estimate of 0.8% for chinook yearlings in 1988 (Wunderlich et al. 1989). The emigration pattern for the 1990 yearlings was also similar to the 1988 yearlings for the same time period (April 4 to June 30). The 1988 yearlings primarily peaked in mid-May, and we also observed a peak at about the same time in 1990. However, we observed a large emigration of fish from February to mid-March in 1990 (Figure 15).

Exit Selection. Although exit selection was evenly split for yearlings in 1990, examination of the no-minimum-spill versus minimum-spill periods showed a marked contrast related to availability of the spill exit. For 1990 yearlings, a total of 1,853 passed via the spill (50%) and 1,841 via the turbine (50%). However, during the run-of-the-river, no-minimum spill period (January 1 to March 31), only 26% of the fish passed via the spillway. Spill was recorded only 48 of the 90 days, and spill averaged only 257 cfs during spill days in this time period. In contrast, during the 170-cfs, continuous-minimum spill period (April 1 to June 30), 90% of fish passed via the spillway. Spill was recorded on all days, as requested, and averaged 584 cfs.

Table 2 lists totals for these periods by exit, and Figure 16 graphically illustrates the shift in exit selection towards the spillway in 1990 on a daily basis.

No chinook yearlings were recovered from fyke trap catches. None were recorded during spring of 1988 either. Low numbers of yearling chinook, coupled with low efficiency of the fyke, were likely reasons for lack of any fyke captures in 1990.

Diel Movement. Due to the extremely low numbers of yearling chinook passing Glines in 1990, comparisons of diel passage were not meaningful.

SUMMARY

From April of 1989 through June of 1990, we examined emigration of juvenile Elwha summer/fall chinook at Glines Canyon Dam in the upper Elwha River watershed. The objectives of this study were to identify emigration timing and exit selection of Elwha chinook at Glines, and also to examine factors influencing Elwha chinook passage at Glines. This work was a follow-up to an earlier examination of juvenile chinook passage at Glines in 1987-1988, which suggested that the Elwha chinook emigrated in a very protracted fashion. However, in our earlier work, we were unable to comprehensively monitor chinook movement over the total emigration, and we also experienced atypically low summer flows that could have affected our results. As well, outplants were made in the Glines forebay, which also may have affected movement patterns of the chinook.

In this evaluation, we planted approximately 428,000 Elwha-stock chinook presmolts in the upper Elwha watershed above Lake Mills, and then monitored their downstream passage through Glines using hydroacoustic sensors at the dam's exits (spillway and turbine). Planting occurred in early April of 1989 using fish which averaged 6 cm forklength. Monitoring of chinook passage at the spill and turbine exits of Glines occurred round-the-clock for the ensuing 15 months. A fyke trap was fished in the turbine tailrace throughout the monitoring period to verify chinook passage.

We requested augmented spill in the spring and summer of 1989, and also in the spring of 1990, to help assess presence and exit selection of juvenile chinook at Glines. A total interruption in spill also occurred for 45 days in late summer of 1989 at Glines for reasons unrelated to this study.

The principal findings from this work were:

1) Downstream passage occurred throughout the 15-month monitoring period at Glines, but the major peak in downstream movement occurred in late summer of 1989 by subyearling chinook of approximately 10 to 12 cm forklength. During this important passage period, approximately 50% of all chinook passed Glines. When spill was interrupted in early September of 1989, downstream movement virtually ceased, but when spill resumed in late October, huge peaks in downstream passage occurred immediately after opening of the spillgate.

2) Peak movement in 1989 occurred about four weeks later than in 1987 among subyearling chinook, based on a comparison of available passage data from May through August in both years. Possible reasons for later peak movement in 1989

versus 1987 include differences in the hatchery holding period (less in 1989), release location (upriver in 1989 as opposed to the forebay in 1987), runoff (higher in 1989), and ATPase levels (lower in 1989).

3) Spring/early summer subyearling passage was next in numerical importance, accounting for about 26% of all downstream fish movement detected in 1989 and 1990.

4) Most of the remaining subyearling passage occurred in the fall of 1989, following the no-spill period, and accounted for about 20% of all detected passage.

5) Passage of yearling chinook in 1990 accounted for about 3% of all detected chinook movement through Glines. During the spring (April, May, and June) of 1990, yearling chinook accounted for less than 1% of all chinook passage. A similar proportion of spring yearlings resulted from the fingerling plant in Lake Mills in 1987.

6) The total hydroacoustic detections of chinook passage through Glines over the 15-month monitoring period equalled 122,090 fish, or 28.5% of the total chinook planted in the upper watershed in April of 1989.

7) Juvenile Elwha chinook displayed a strong preference for the Glines spill exit. Over the entire monitoring period, 89% of chinook passed Glines via the spillway. Degree of spilling was not strongly related to subyearling chinook movement through the spillway in spring and early summer, but did account for approximately 39% of the variation in subyearling passage in late summer during a period of night-only spilling. During the night-only spill period, nearly 99% of subyearling chinook passed Glines via its spillway. Cessation of spill for 45 days beginning in early September of 1989 totally impeded the chinook emigration, as only 2% of all movement occurred during this no-spill period (via the turbine exit). In 1990, 90% of yearling chinook used the spillway exit when it was continuously available (during April, May, and June), but only 26% of yearling chinook used the spillway exit when spilling was limited (during January, February, and March).

8) Subyearling Elwha chinook displayed a preference for nighttime passage through both spill and turbine exits of Glines, when a day or night passage choice was available.

ACKNOWLEDGMENTS

This study was funded by James River Corporation. James River also provided augmented spilling during spring and summer low-flow periods, and assisted with installation of the transducer in the Glines turbine intake.

Washington Department of Fisheries and the Lower Elwha Tribe provided juvenile chinook and hatchery holding space. We appreciate their support of this work.

Olympic National Park provided hydroacoustic monitoring equipment used in this evaluation, and helped coordinate the chinook planting operation in the Park.

Roger Wiswell and Cathy McDonough monitored the hydroacoustic equipment at the Glines gatehouse throughout this work, and we appreciate their efforts.

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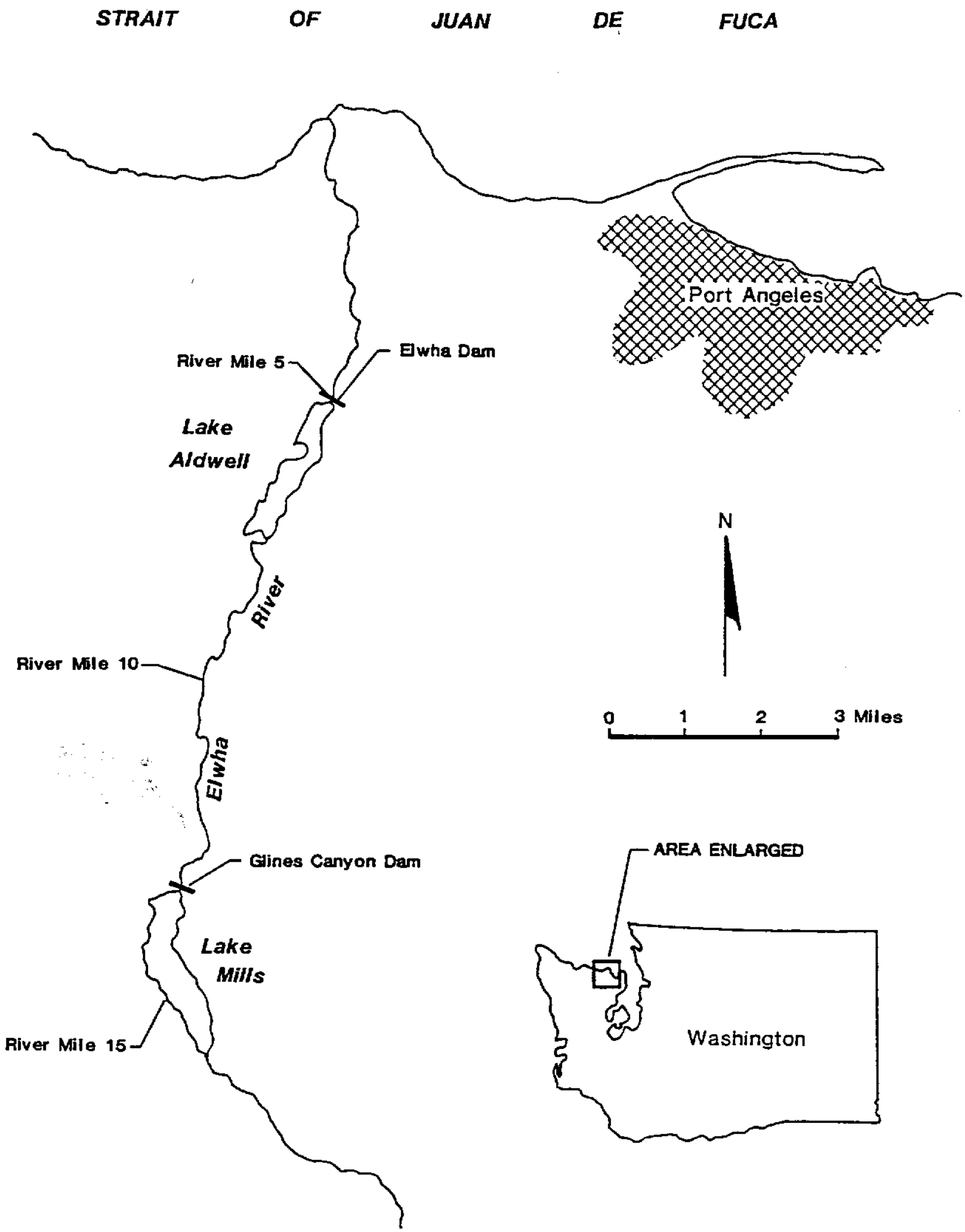

Figure 1. The Elwha River and project features.

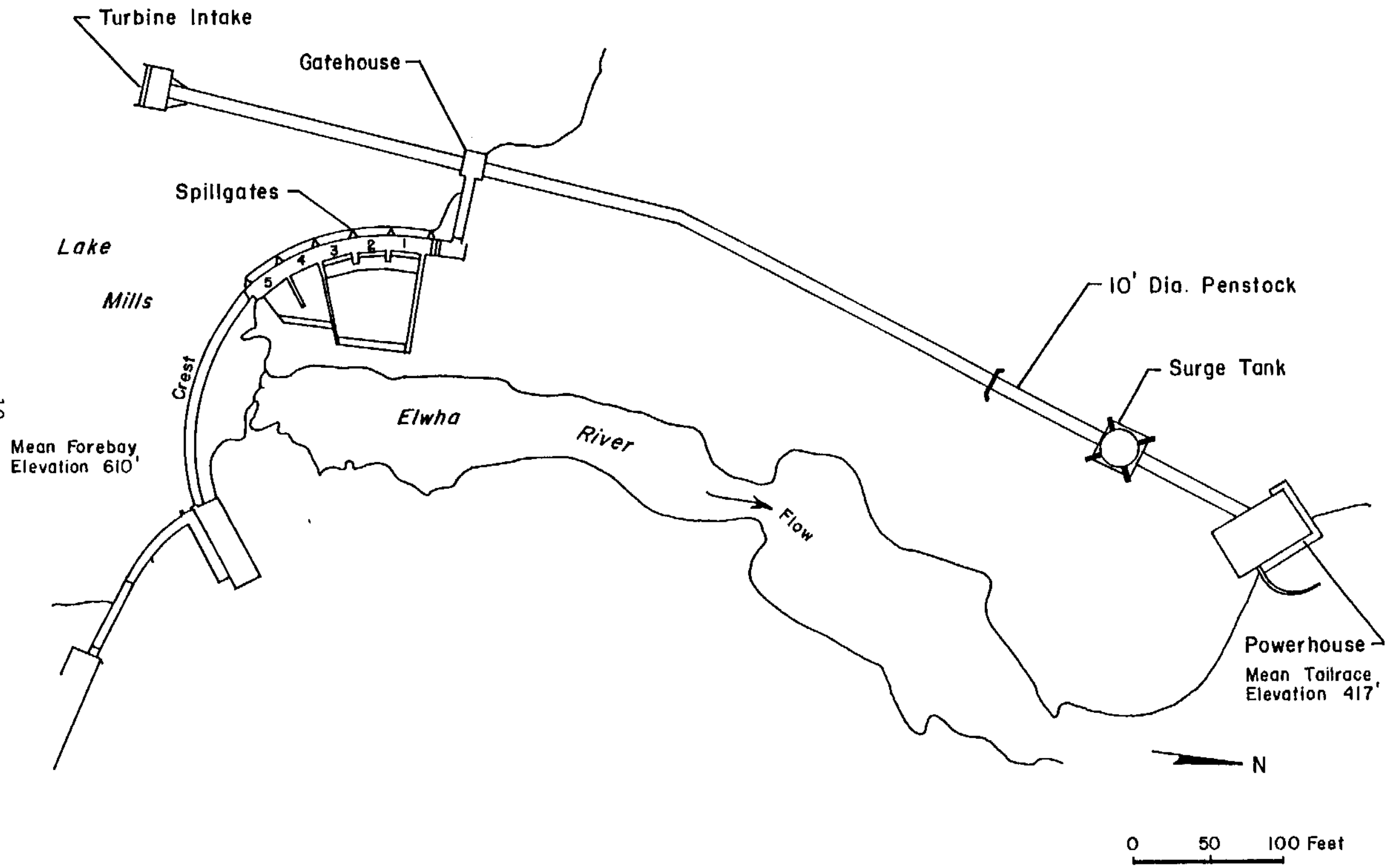

Figure 2. General features of Glines Canyon Dam.

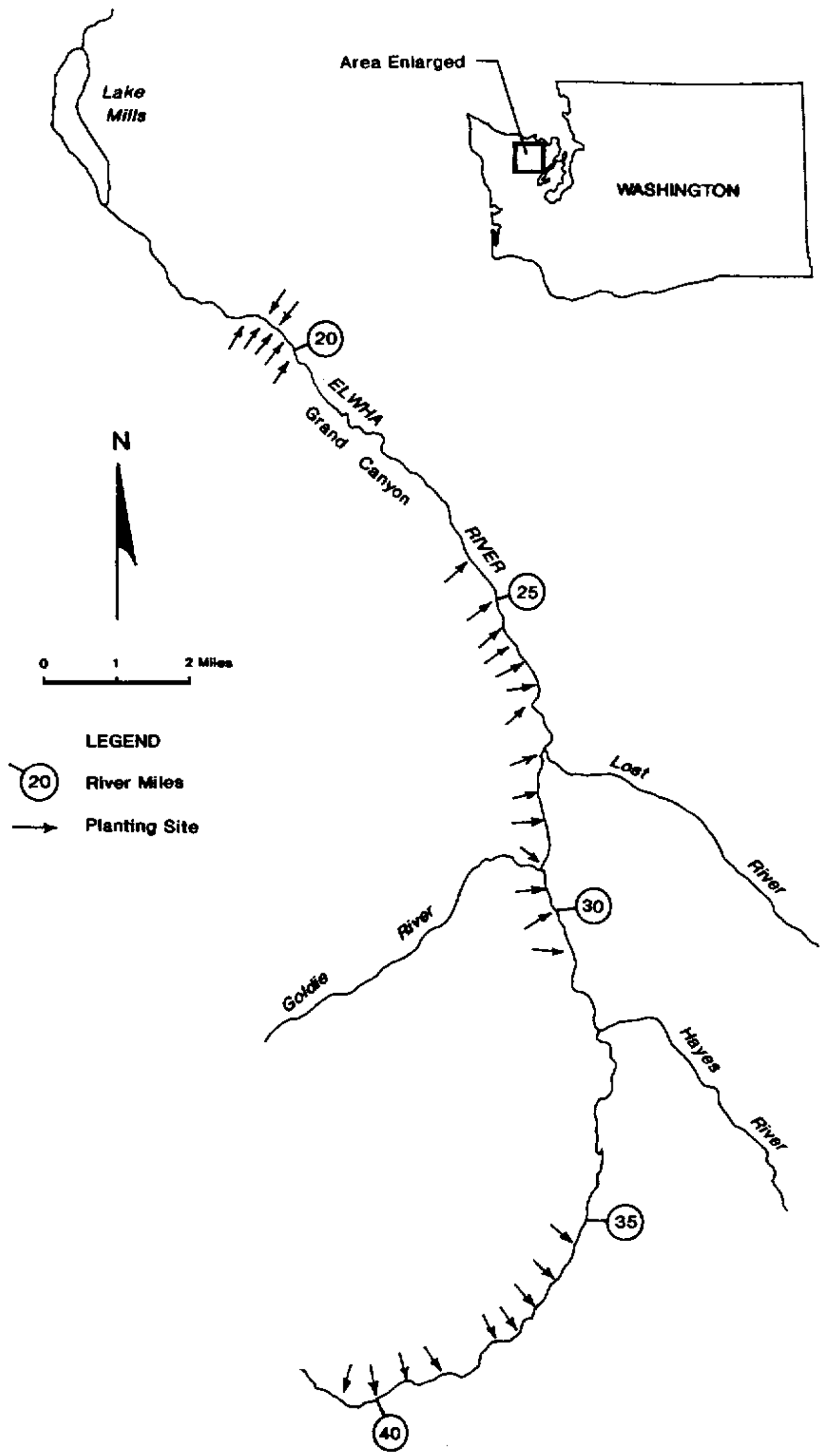

Figure 3. Upriver planting sites for juvenile Elwha chinook.

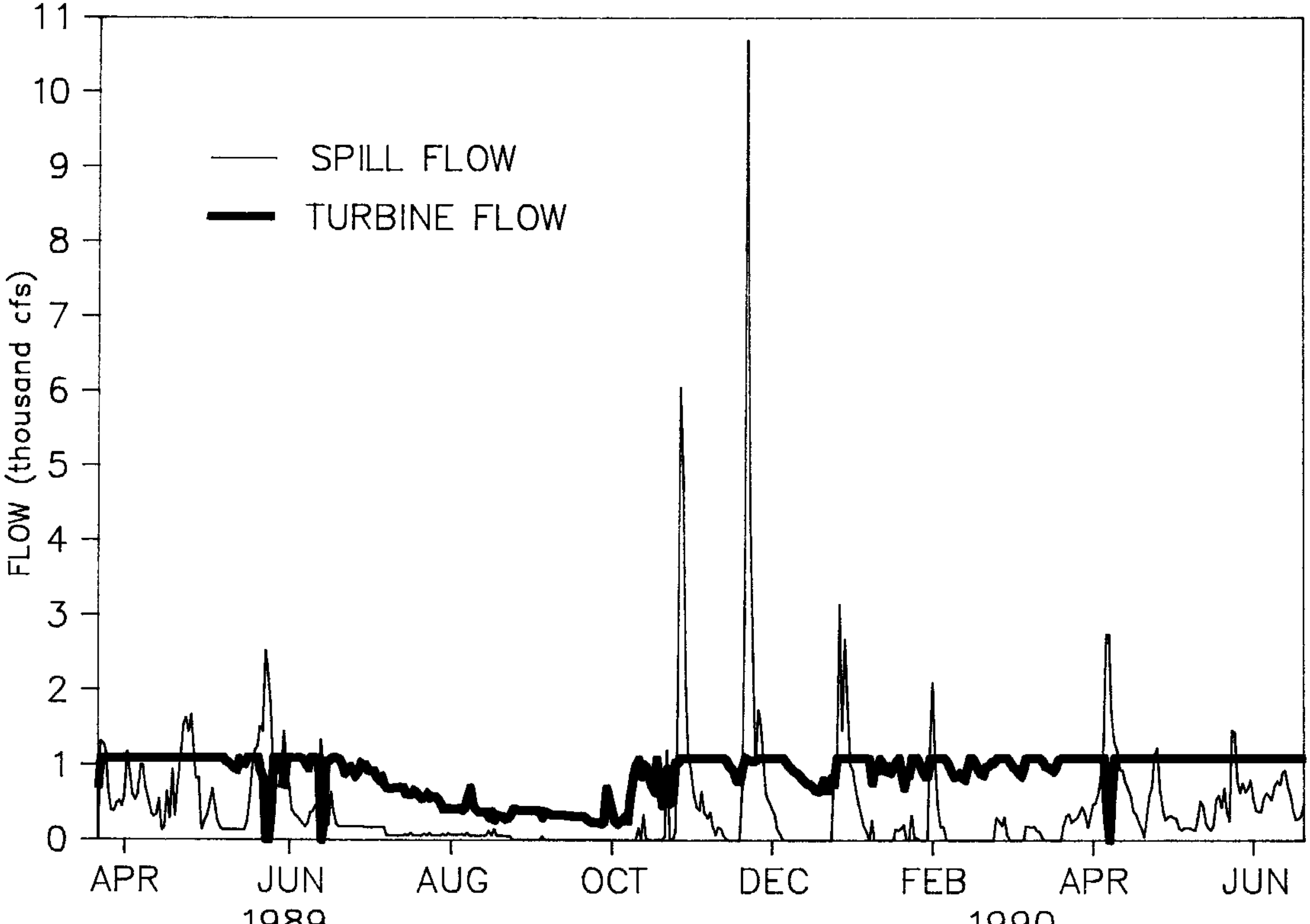

Figure 4. Daily spill and turbine flow at Glines Canyon Dam from April 4, 1989 to June 30, 1990. The time scale shows mid-months.

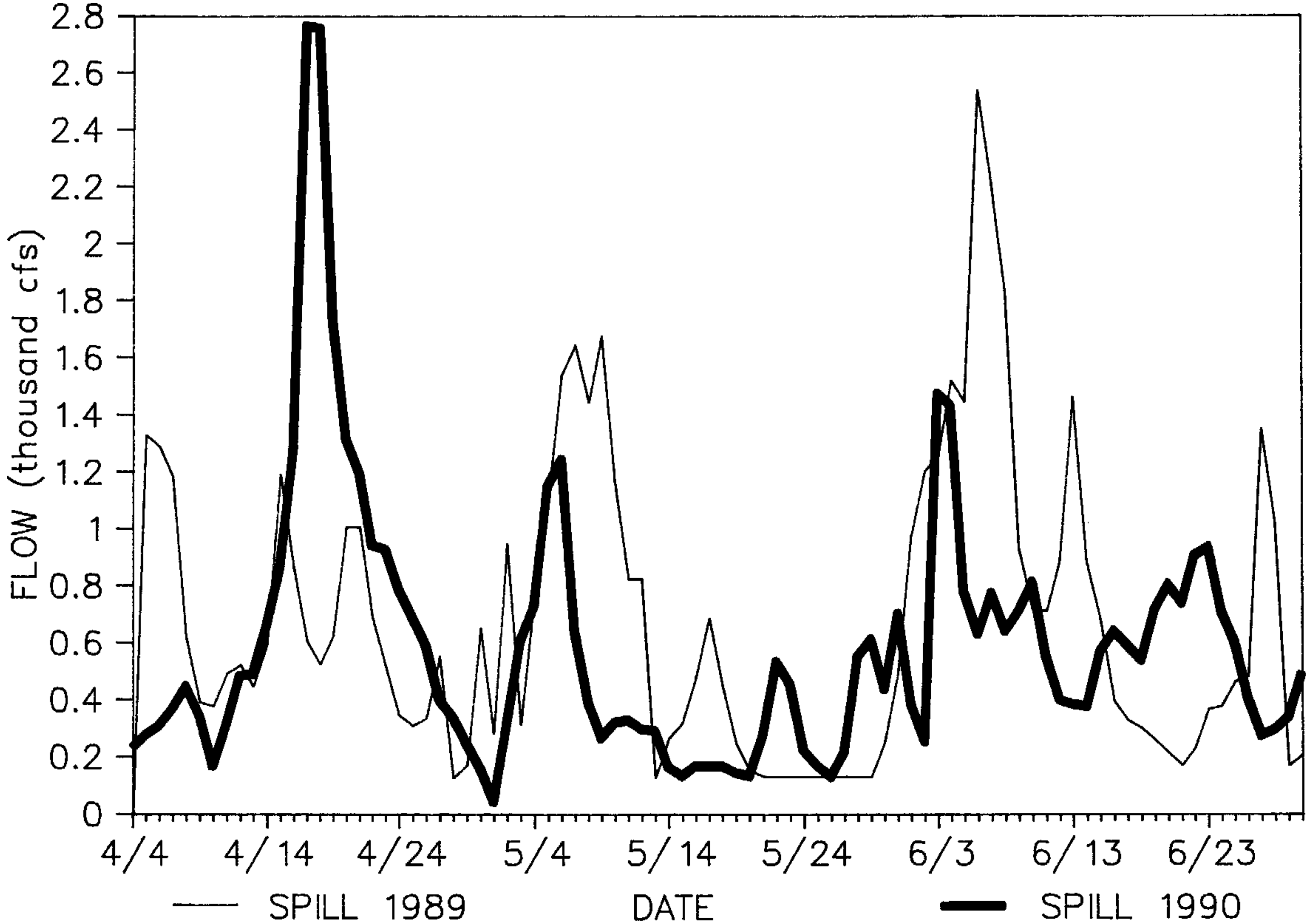

Figure 5. Mean daily spills from April 4 to June 30 in 1989 and 1990.

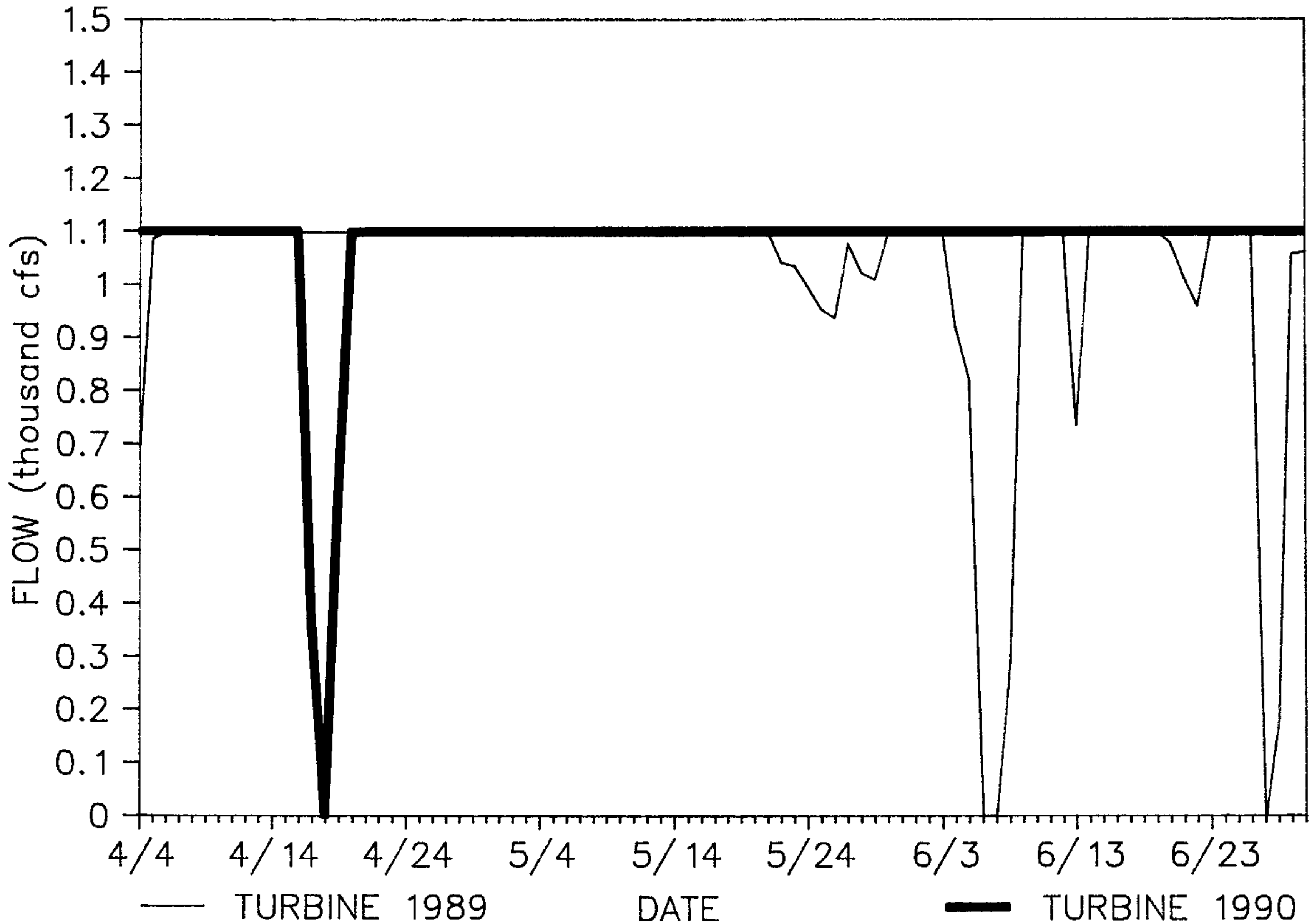

Figure 6. Mean daily turbine flows from April 4 to June 30 in 1989 and 1990.

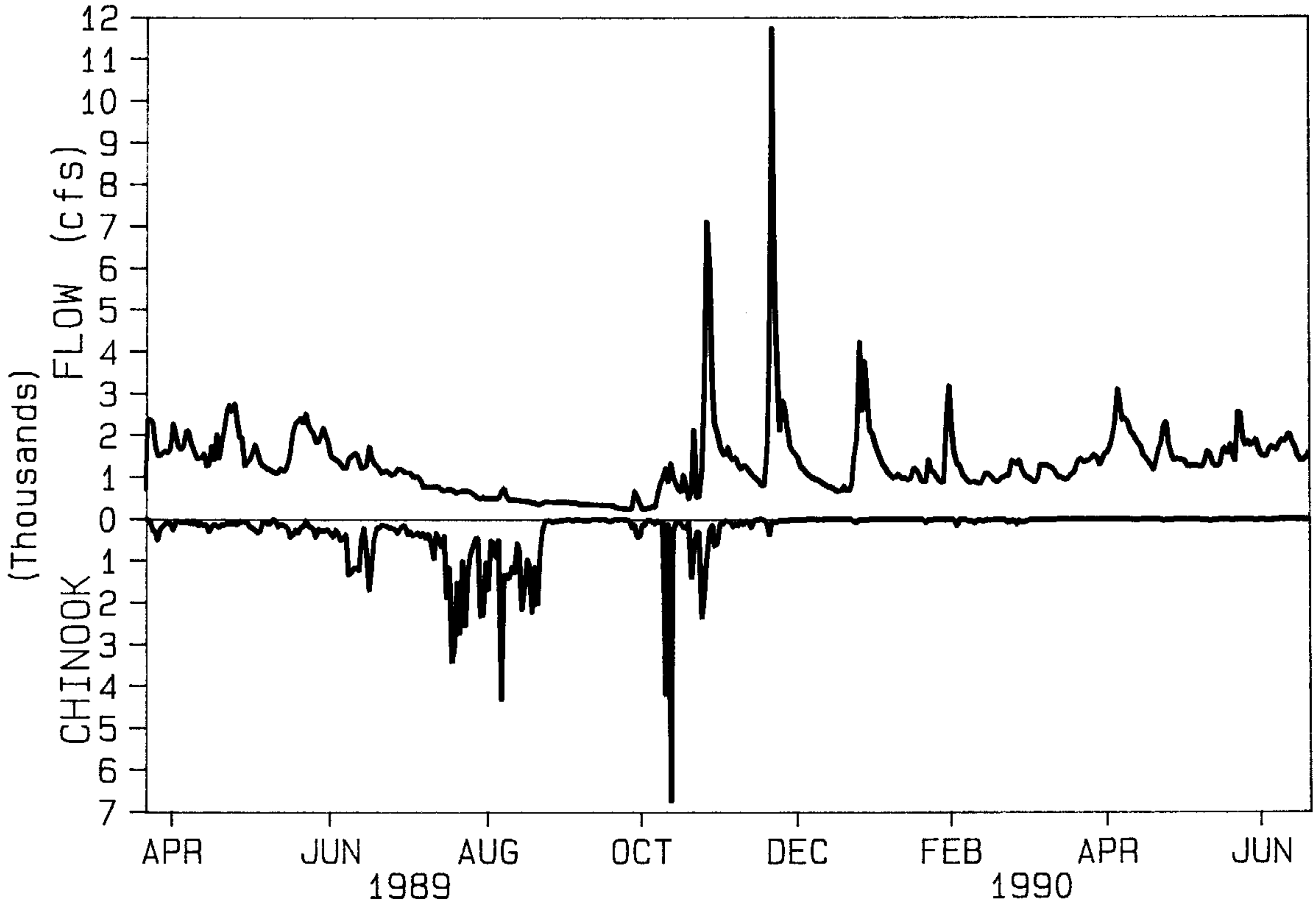

Figure 7. Daily mean flow versus estimated chinook passage from April 4, 1989 to June 30, 1990. The time scale shows mid-months.

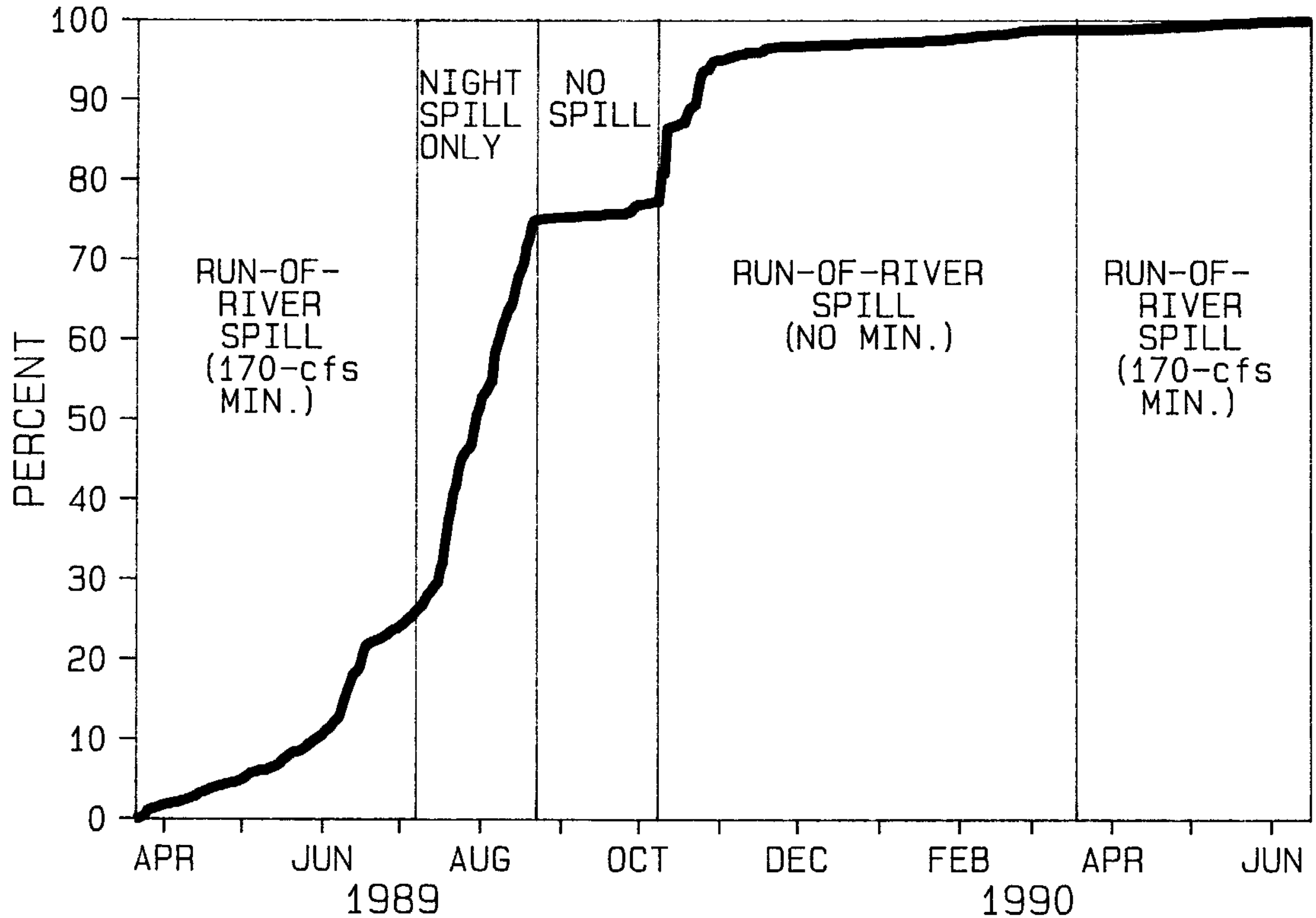

Figure 8. Cumulative chinook passage and major spill and no-spill periods at Glines Canyon Dam from April 4, 1989 to June 30, 1990. The time scale shows mid-months.

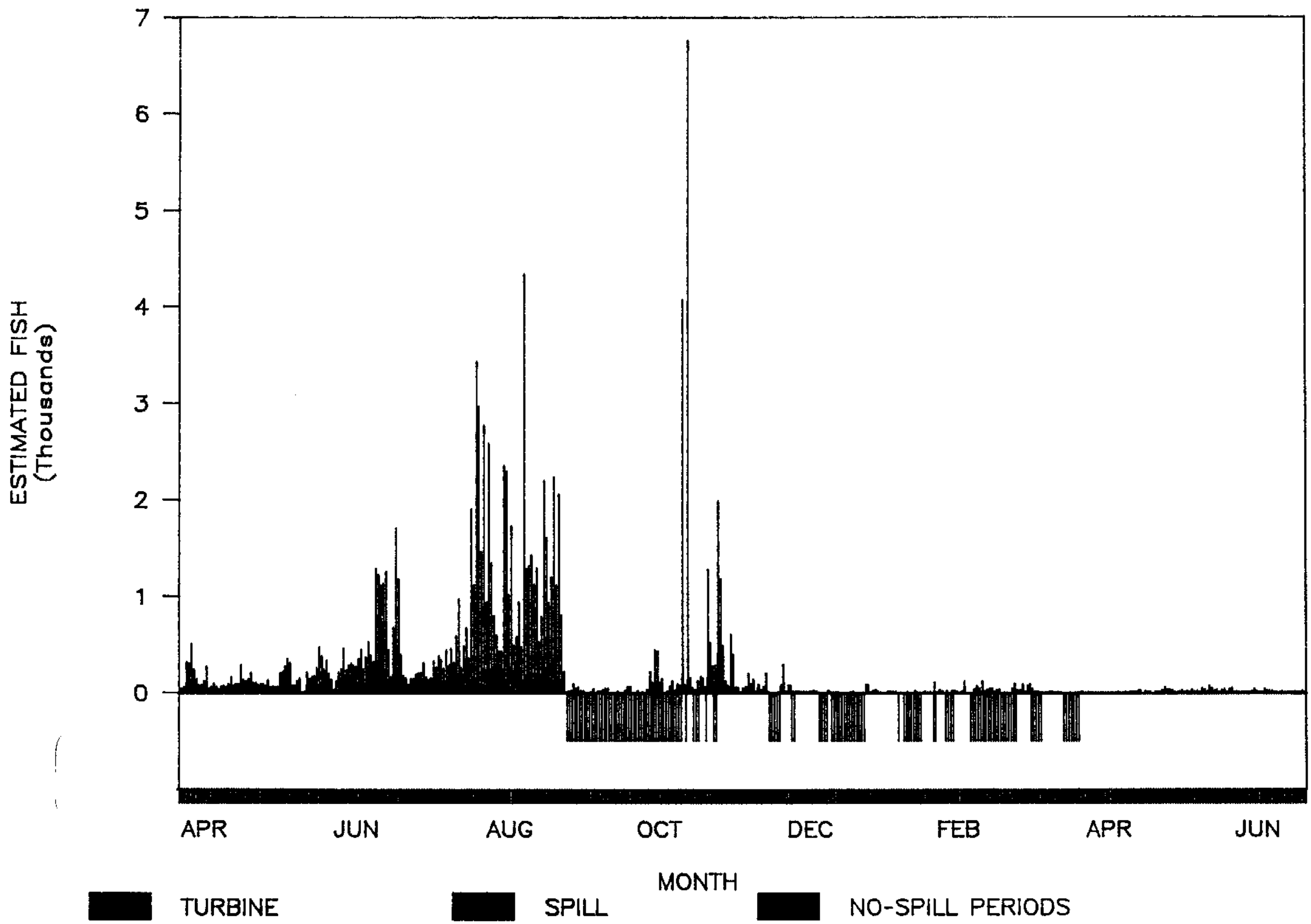

Figure 9. Chinook passage through spill and turbine exits, and no-spill periods, from April 1989 through June 1990.

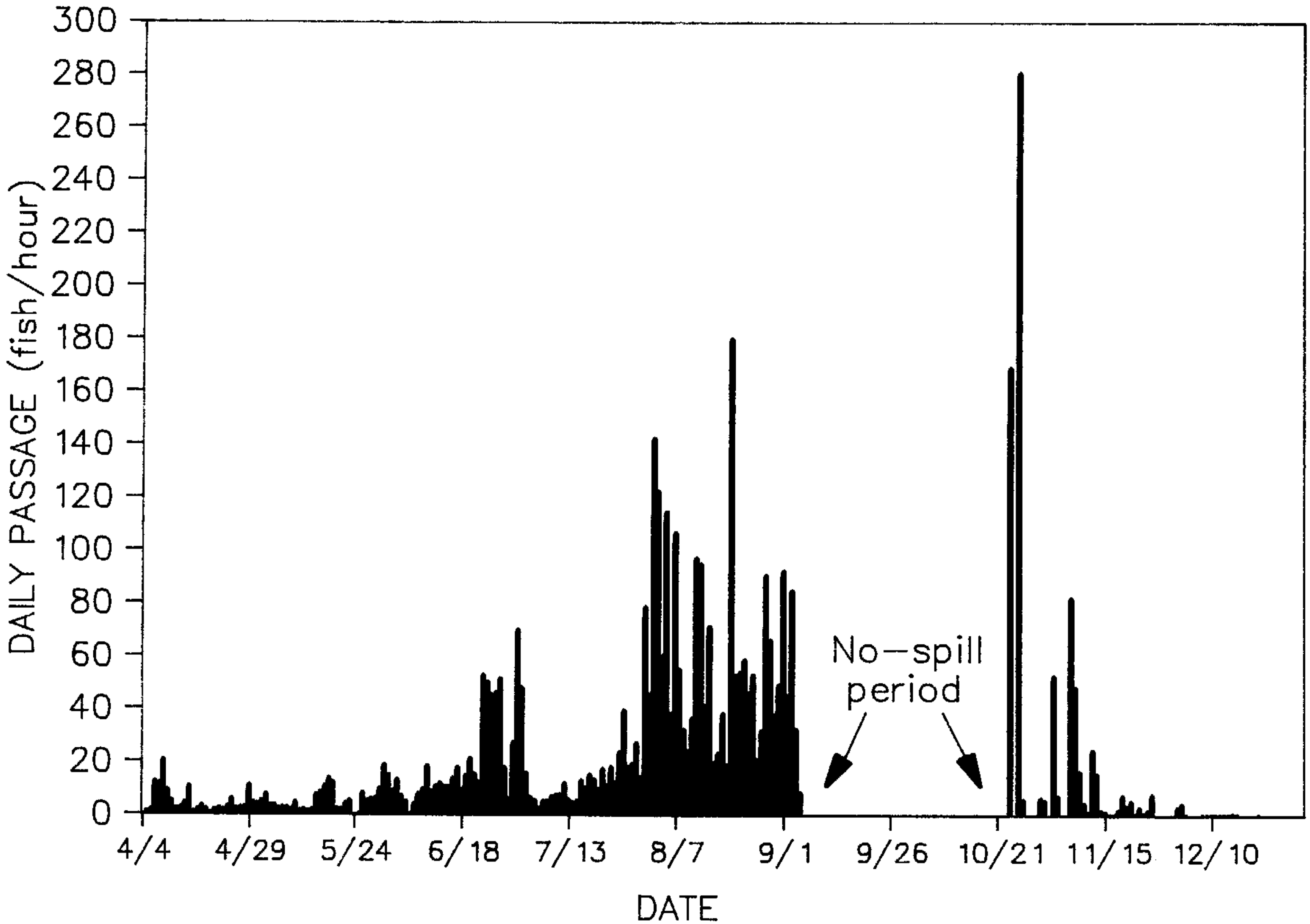

Figure 10. Estimated daily chinook passage rate (fish/hour) through the spillway in 1989.

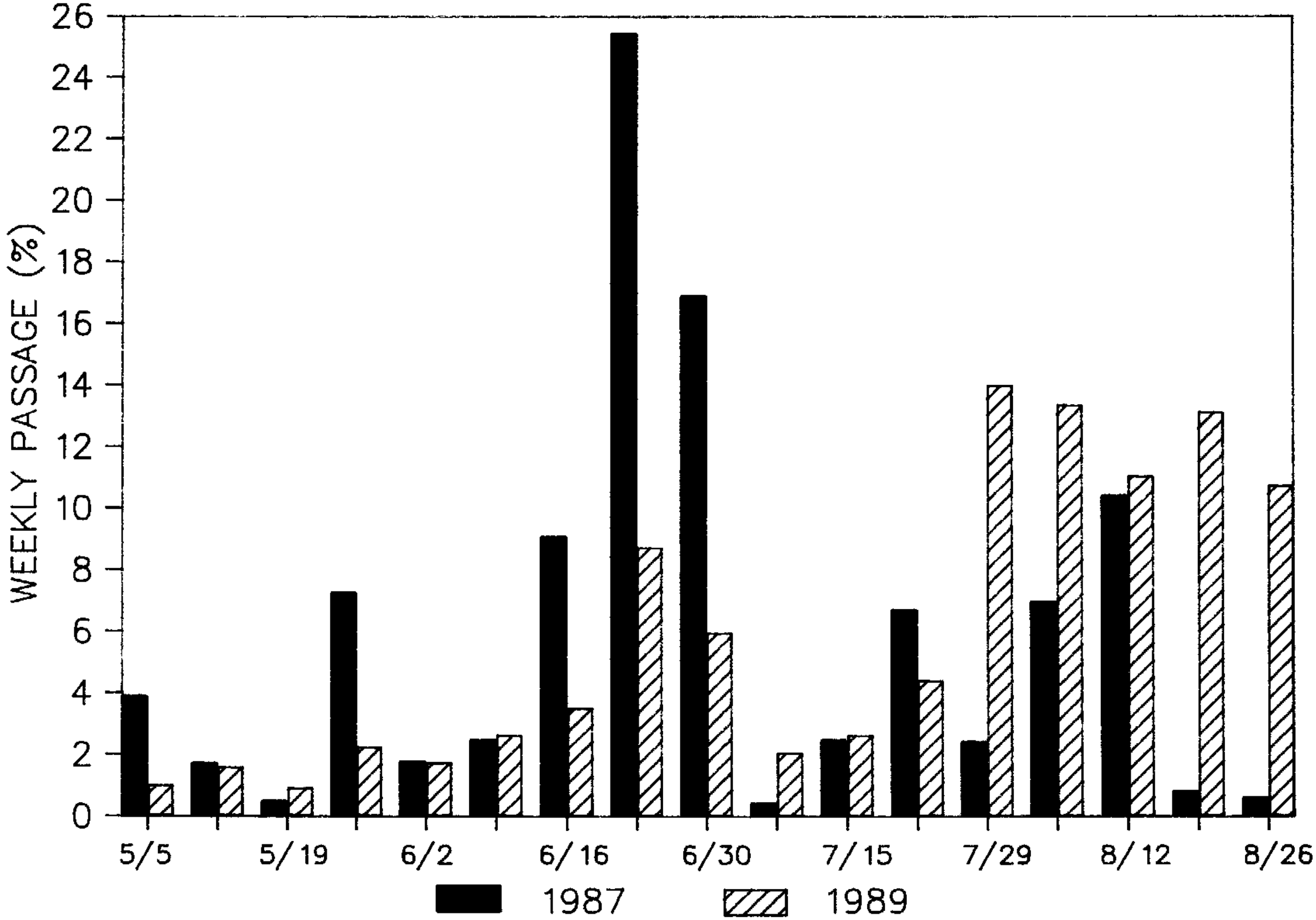

Figure 11. Weekly chinook passage from May through August in 1987 and 1989. Beginning dates of each week are shown.

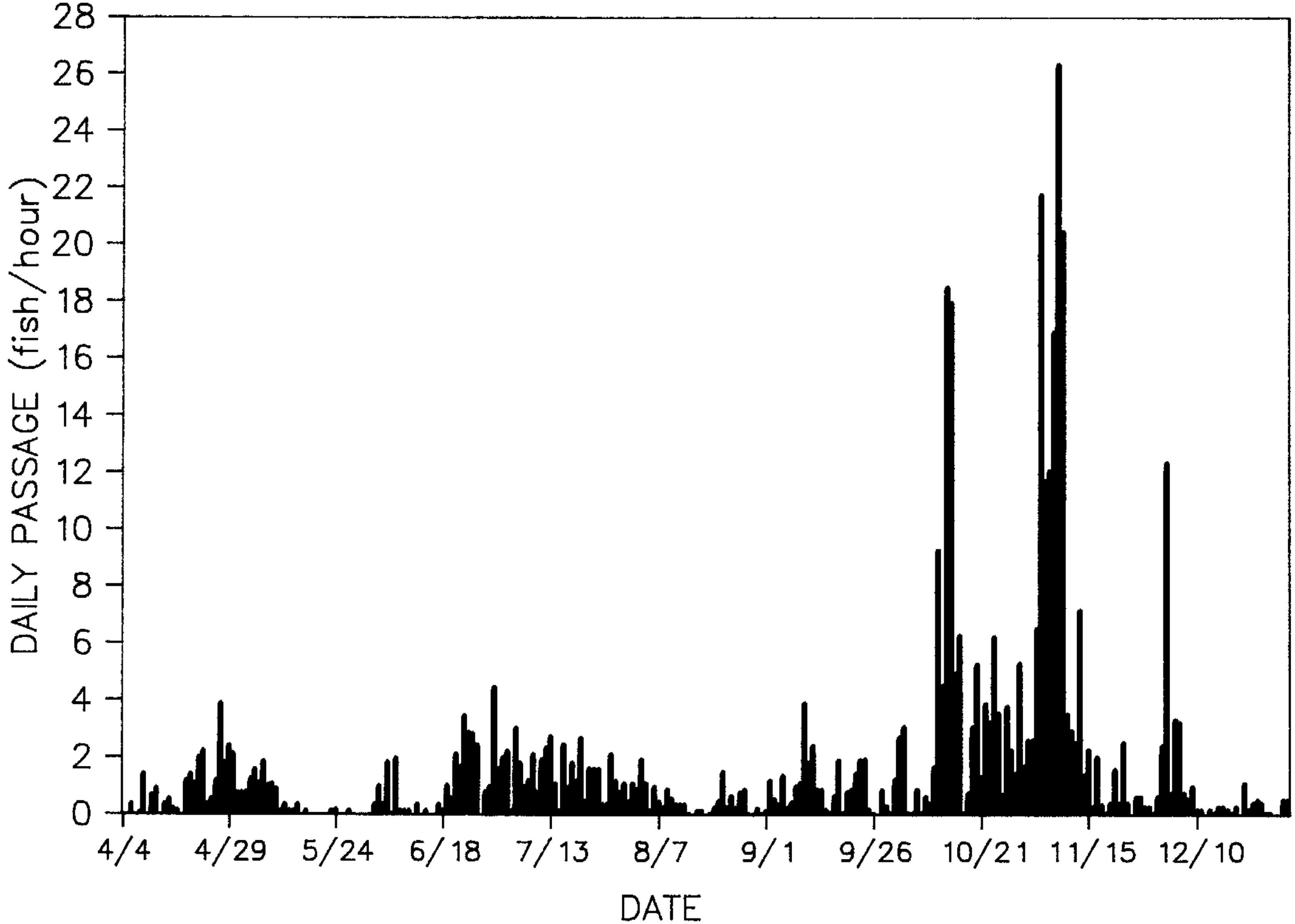

Figure 12. Estimated daily chinook passage rate (fish/hour) through the turbine in 1989.

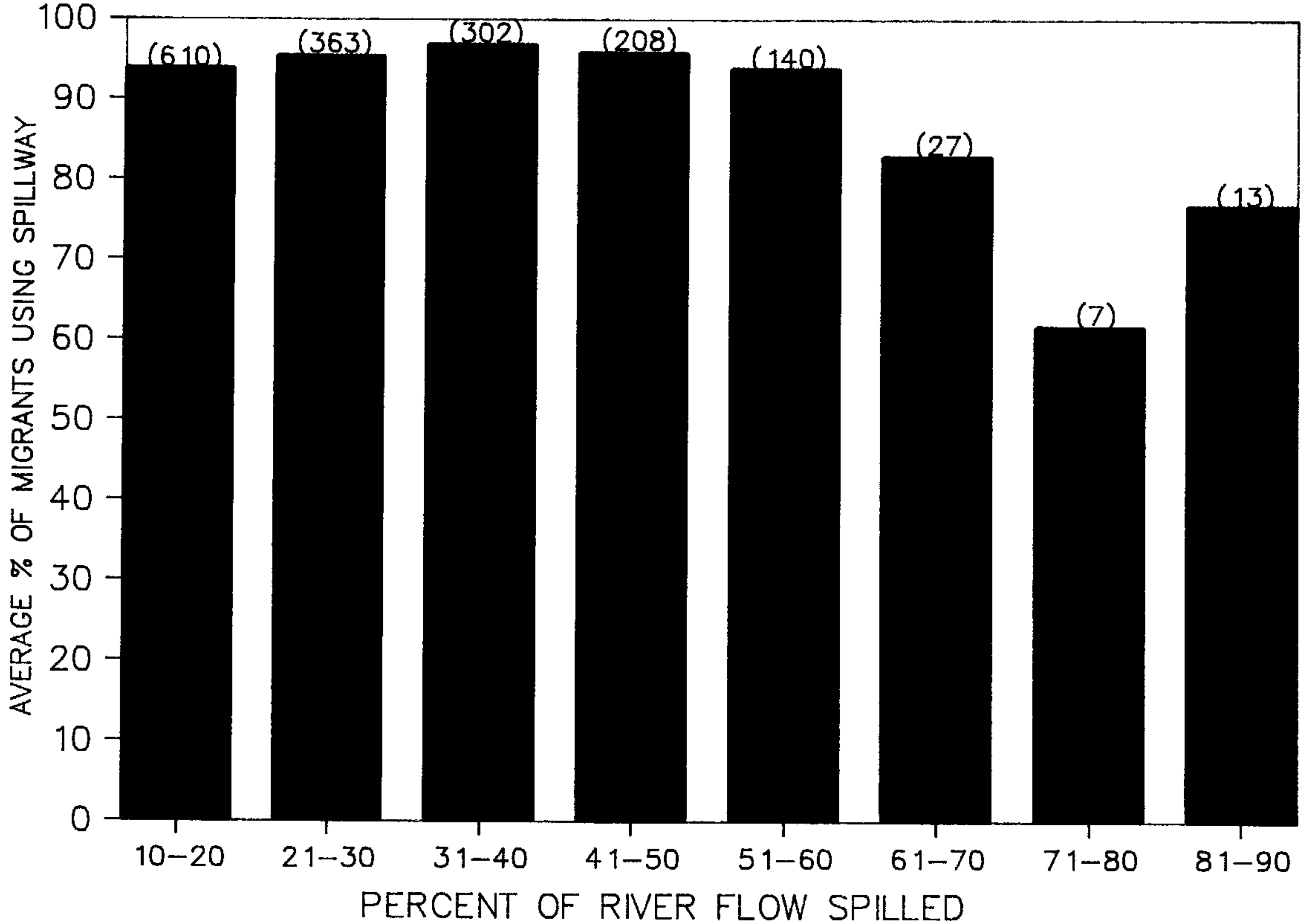

Figure 13. Percent of chinook passing the spillway versus percent of river spilled in 1989. Values in parentheses represent the number of observations at each flow level.

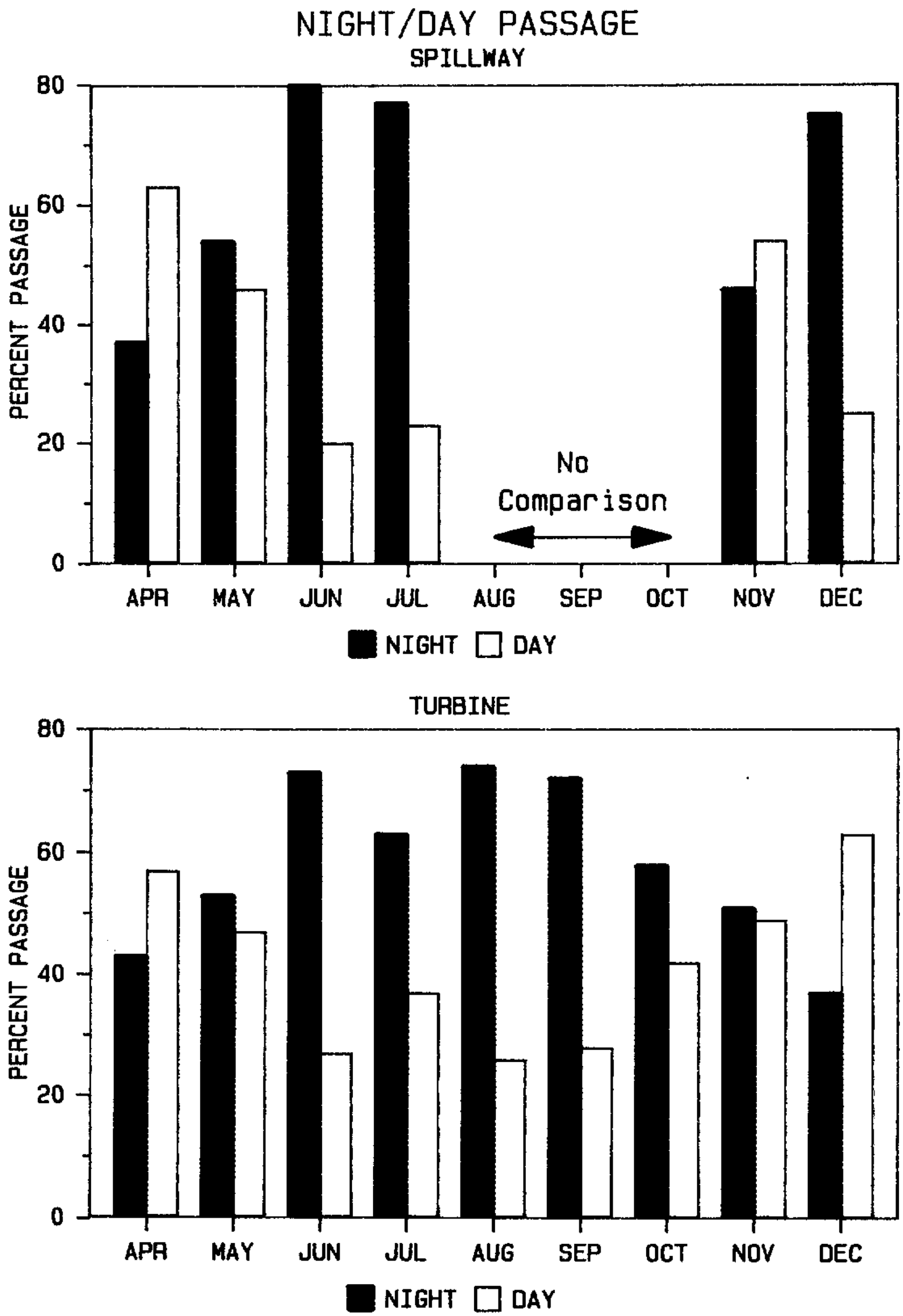

Figure 14. Monthly proportions of subyearling chinook passing through the spillway and turbine exits during night and day in 1989.

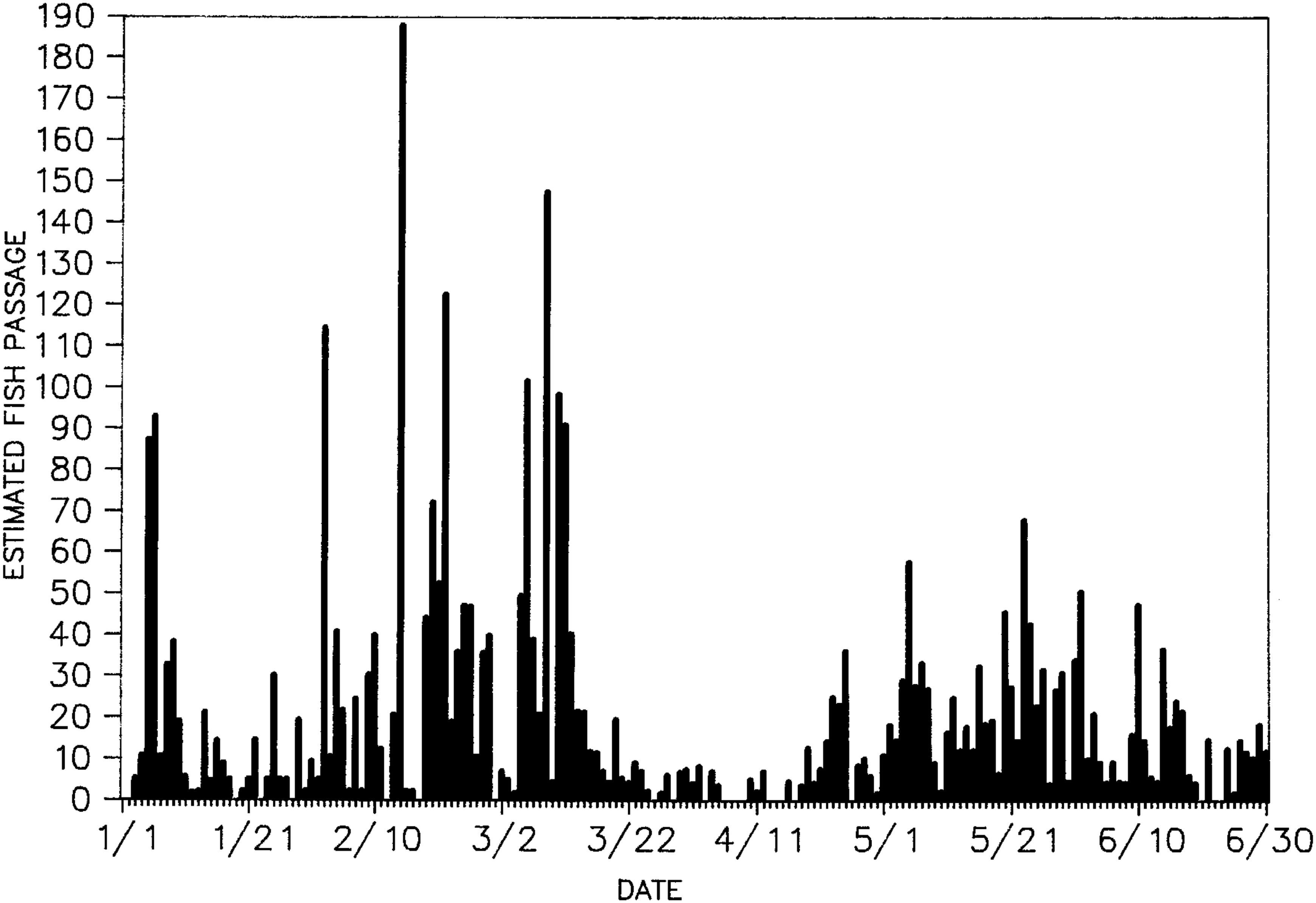

Figure 15. Estimated total daily passage of chinook in 1990.

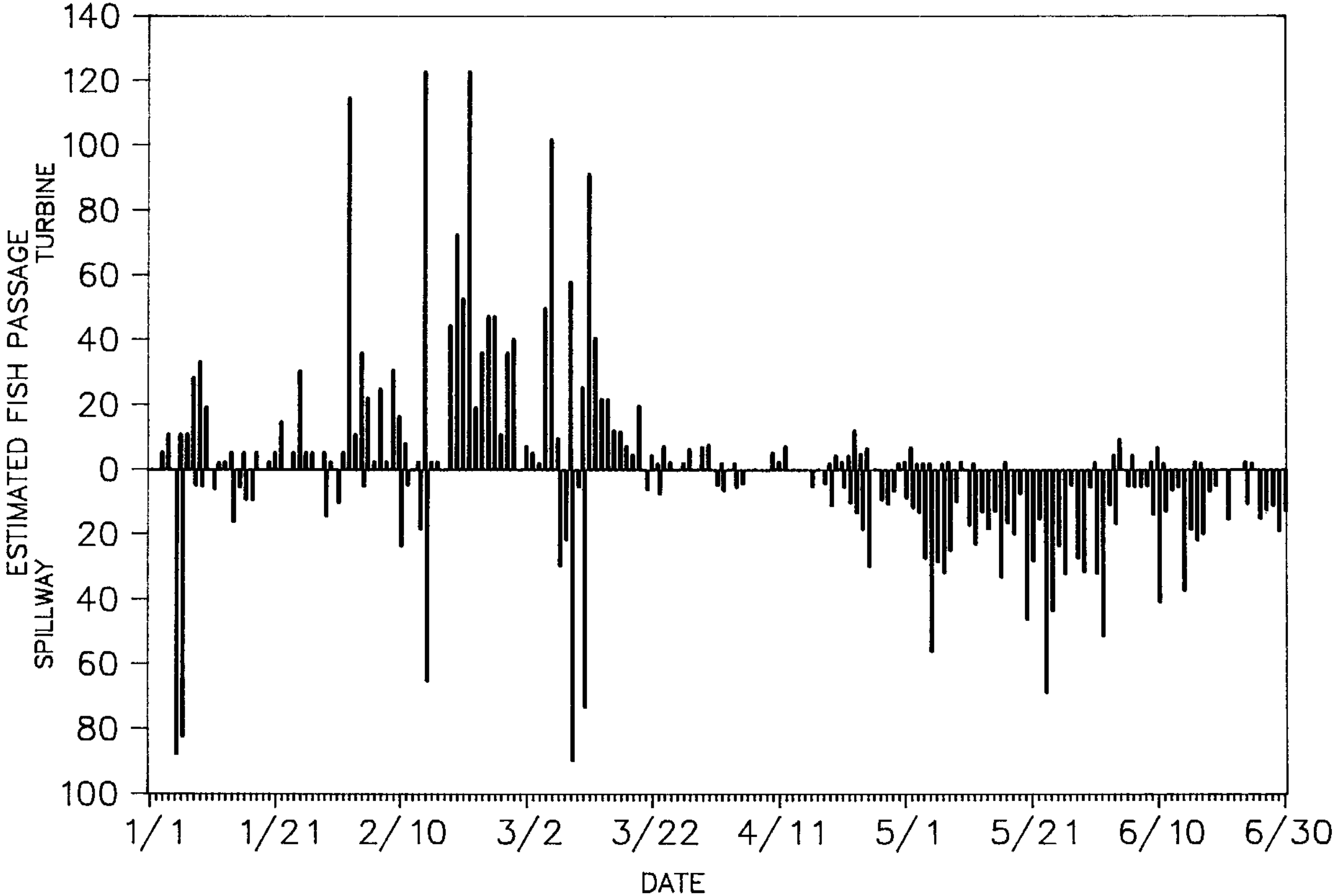

Figure 16. Estimated daily passage of chinook through the spillway and turbine in 1990.

Table 1. Hydroacoustic equipment used at Glines Canyon Dam during 1989-1990.

Item	Manufacturer	Model No.
Battery back-up	Best	MD1.5KVA
Echo sounder/transceiver	Biosonics, Inc.	101
Multiplexer/equalizer	Biosonics, Inc.	151
Thermal chart recorder	Biosonics, Inc.	111
Transducers (6- and 15-degree)	Biosonics, Inc.	-
Oscilloscope	Hitachi	V-423U

Table 2. Hydroacoustic detections of juvenile chinook passage through spill and turbine exits of Glines Canyon Dam during major spill (and no-spill) periods in 1989-1990.

Exit	Estimated migrants					
	1989				1990	
	4/4-7/22[A]	7/23-9/6[B]	9/7-10/23[C]	10/24-12/31[D]	1/1-3/31[D]	4/1-6/30[A]
Spillway	29,238	59,117	0	18,816	600	1,253
Turbine	2,623	746	2,801	5,055	1,704	137
Total:	31,861	59,863	2,801	23,871	2,304	1,390

[A] Run-of-river operation with a 170-cfs minimum spill.

[B] Variable nighttime spilling only.

[C] Non-spill period with continuous turbine operation.

[D] Run-of-river operation without a minimum spill level.

Table 3. Mean rates of subyearling chinook passage through spillway and turbine exits from April 4 to July 22, 1989.

Exit	Day/ night	Mean number per hour[a]
Spillway	Day	5.44
Spillway	Night	21.14
Turbine	Day	0.85
Turbine	Night	1.91

[a] Mean numbers per hour are all significantly different from each other ($P < 0.001$).

Table 4. Nightly spills at Glines Canyon Dam in 1989. Spilling typically began at 9:00 P.M. PDT on the start date indicated.

Start date	Mean nightly spill (cfs)	Percent of nightly flow spilled	Duration of spill (hours)
Jul 22	153	18	10
23	154	18	10
24	153	18	9
25	161	19	8
26	154	18	9
27	154	18	9
28	247	33	8
29	162	23	8
30	292	36	8
31	163	19	8
Aug 1	162	23	8
2	162	22	8
3	162	25	8
4	248	38	8
5	162	23	8
6	290	40	8
7	162	22	8
8	162	23	8
9	162	25	8
10	162	26	8
11	246	40	8
12	172	34	8
13	319	53	7
14	172	34	8
15	173	33	9
16	173	33	9
17	173	32	9
18	259	48	8
19	173	35	8
20	302	49	8
21	174	18	8
22	174	31	8
23	174	34	8
24	174	40	8
25	174	40	8
26	173	37	8
27	173	37	8
28	173	40	8
29	172	38	8
30	172	40	8
31	172	41	8

Table 4 (continued).

Start date		Mean nightly spill (cfs)	Percent of nightly flow spilled	Duration of spill (hours)
Sep	1	172	46	8
	2	172	42	8
	3	172	43	8
	4	172	43	8
	5	172	43	8

Appendix. Daily fyke trap catches at the Glines Canyon Dam tailrace in 1989.

Date		Chinook catch	Mean length (mm)
April	7	5	62.5
	8	3	66.0
	9	3	66.6
	10	2	70.5
	11	3	63.6
	12	1	
	16	2	64.5
	20	1	65.0
	21	2	
	23	1	69.0
	27	1	69.0
	28	2	72.0
	29	1	74.0
	30	1	
May	1	1	78.0
	14	1	76.0
June	10	1	
	14	2	95.0
	15	1	103.0
	16	2	99.5
	17	1	98.0
	18	3	100.0
	19	3	101.0
	20	9	97.8
	21	2	102.0
	22	11	96.7
	23	15	98.2
	24	3	107.0
	25	9	101.0
	28	4	96.3
	29	6	101.5
	30	1	99.0
July	1	14	98.2
	2	18	99.3
	3	10	103.5
	4	17	112.2
	5	9	101.1
	6	2	108.5
	7	6	103.5
	8	8	101.1
	9	12	102.5
	10	6	104.7
	11	3	108.3
	12	14	103.5

Appendix (continued).

Date	Chinook catch	Mean length (mm)
July 13	12	103.1
15	20	104.2
16	21	105.1
17	11	103.1
18	4	108.0
19	4	101.0
20	7	108.9
21	3	112.0
22	5	110.4
23	10	110.3
24	6	113.7
25	7	109.7
26	3	107.0
27	7	110.3
28	15	108.5
29	1	118.0
30	5	112.8
31	4	105.0
August 1	7	112.0
2	7	110.3
3	15	113.2
4	5	107.8
5	1	118.0
6	6	111.0
7	2	113.0
8	1	103.0
9	6	111.0
10	3	114.3
11	2	114.5
17	1	125.0
19	1	119.0
21	1	124.0
22	8	117.8
23	1	118.0
October 21	1	132.0
23	20	147.4
24	15	140.6
25	4	152.3
26	1	143.0
27	2	135.0
28	5	144.4
29	4	145.3
30	1	148.0
31	4	147.5
November 1	1	145.0
2	1	146.0

Appendix (continued).

Date	Chinook catch	Mean length (mm)
November 3	5	146.8
4	3	134.0
5	2	141.5
7	1	149.0
14	1	136.0