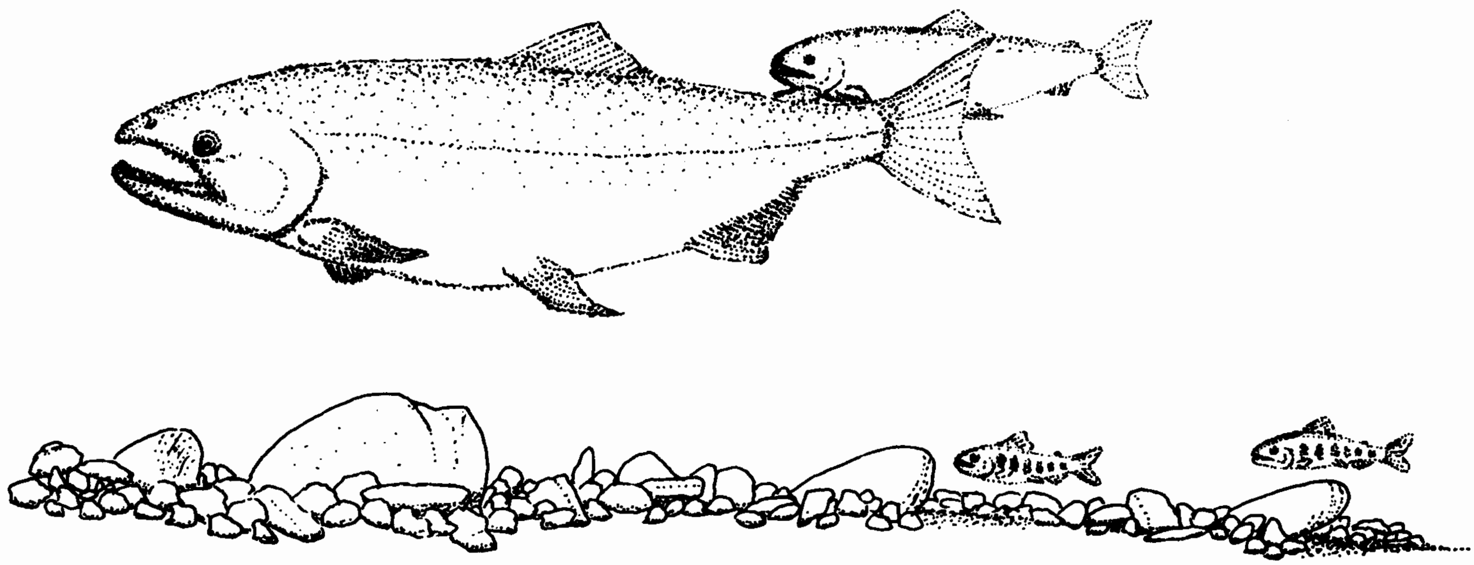
Fisheries Assistance Office
Olympia, Washington

FIELD TESTS OF DATA COLLECTION PROCEDURES FOR THE ELWHA SALMONID SURVIVAL MODEL



FIELD TESTS OF DATA COLLECTION PROCEDURES FOR THE ELWHA SALMONID SURVIVAL MODEL

R.C. Wunderlich
and
S.J. Dilley

U.S. Fish & Wildlife Service
Fisheries Assistance Office
Olympia, Washington

March, 1986

ACKNOWLEDGEMENTS

This study was funded by Olympic National Park under Interagency Agreement 1A-9000-3-0003. Don Cole (Olympic National Park) and Richard Comstock (Olympia Fisheries Assistance Office) proposed the Elwha salmonid survival model, for which these field evaluations were conducted.

In a concurrent agreement, Olympic National Park funded BioSonics, Inc. of Seattle to assist this office with hydroacoustic installation, trouble-shooting and data reduction. Bob Wright of BioSonics provided the principal help in these activities.

The Lower Elwha Tribe provided test fish in this study. The cooperation of Ken Gilliam, hatchery manager, is particularly appreciated.

Operational records for the Elwha Dam were provided by Dan Kelly of Crown Zellerbach Corp., who also arranged access for the acoustic monitoring equipment at Elwha Dam.

Ed Weiss of Pacific Power and Light arranged for use of the lake trap and offered suggestions on installation.

Steve Hager (Olympia Fisheries Assistance Office) provided considerable assistance with trapping and tagging procedures and trap installation.

The trapping and acoustic crew consisted of Jeff McKee, Andy Brastad, Shawn Fontana, Kurt Nelson, and Phil Bischoff.

Della McCrowell skillfully typed this report.

CONTENTS

Page

CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF TABLES

INTRODUCTION

Olympic National Park (ONP) has initiated a program to restore anadromous salmonids in the upper Elwha River system. Two dams currently in place on the lower river, Elwha and Glines Canyon Dams (Figure 1), have eliminated anadromous fish above river mile five since the early 1900's. The general restoration plan is to capture adult salmonids in the lower river and transport them above one or both dams to reseed the upper watershed.

To help guide this restoration effort, certain information is required. Included in this required information is the number and timing of outmigrants from upriver plants and their survival both to the estuary and to adulthood. This information will be used to determine the optimum species and numbers of adults to plant, as well as necessary changes, if any, in dam exits or operating procedures to improve downstream passage.

In 1985, under contract with ONP, the Olympia Fisheries Assistance Office (FAO) began development of a model that would provide estimates of the numbers of outmigrants and their survival. The model relies on coded-wire tagging of outmigrant populations, hydroacoustically monitoring their movement through Elwha Dam, and ultimately correlating survival with exit conditions at time of passage through the dam. Operation of the model therefore required identification and specification of field techniques for collecting and tagging downstream migrants and monitoring their passage through Elwha Dam.

In the spring and early summer of 1985, we conducted a feasibility study that evaluated field techniques to accomplish these tasks. This report describes this feasibility study and recommends, insofar as study results permit, procedures for accomplishing field work required for the model operation. A separate document will describe all facets of the model, including survival estimators. In this report, we also summarize and discuss incidental information gathered during the course of the 1985 feasibility study regarding the characteristics of steelhead and coho outmigration. This information includes choice of exit at the dams as it varied with environmental and operational factors, and other data related to downstream passage at the Elwha dams.

METHODS

General

Methods to accomplish the tasks of collecting, tagging, and monitoring the passage of downstream migrants at Elwha Dam were selected under the following considerations:

1. Collection gear should provide random, unbiased samples of the outmigrant population(s) of sufficient size to allow survival estimates through coded-wire tagging, and to predict species composition for passage monitoring at Elwha Dam. A provisional target sampling rate of at least 10% was established for this purpose. Collection should occur above Elwha Dam to avoid inclusion of lower river production, yet below all production areas of major potential (e.g., Indian Creek) in the upper watershed. Collection activities should not influence migratory behavior (e.g., choice of exit) at Elwha Dam, nor involve excessive costs.

2. Coded-wire tagging should occur at the collection site without causing excessive mortality, injury, or tag loss. The tagging process should allow replication within desired test period intervals (e.g., weekly).

3. Each species passing Elwha Dam should be enumerated at each exit at time of passage with sufficient accuracy throughout the outmigration period to allow calculation of total group size for each tag code, and eventual correlation with specific exit conditions (e.g., turbine or spillgate settings) at time of passage, if desired.

In consideration of the above, the overall approach towards field testing of model components involved three separate but related activities. These were: 1) collecting samples of outmigrant populations by means of a lake trap in Lake Aldwell), 2) coded-wire tagging of lake trap catches at the trap site using a portable field set up and, 3) continuous monitoring of outmigrant passage at Elwha Dam using fixed-aspect hydroacoustic gear at all exits of the dam. All collection and tagging activities were directed towards smolts rather than fry or fingerlings in order to minimize collection and tagging efforts. As no anadromous production presently occurs in the upper Elwha watershed, outmigrant populations used in field tests originated from experimental outplants from the Elwha Tribal Hatchery. Specific methods are detailed below.

Experimental Outplants

Two species, coho and steelhead, were used in 1985 field tests. These species were used because of availability, and because of the high probability of their use in future restoration efforts in the upper watershed.

The steelhead were Elwha strain winter run fish outplanted above Lake Mills in 1983 as fry. A total of 109,900 were released by ONP in the upper mainstem by helicopter between river miles 19 and 27. These fish were adipose clipped prior to release. Table 1 shows specific release data. The bulk of this outplant was expected to outmigrate naturally as 2+ smolts during the spring of 1985, and necessarily passed both dams during their downstream migration. These fish were used to test aspects of trap efficiency, tagging procedures, and acoustic monitoring.

The coho were also Elwha strain fish. They were released as yearling smolts at the Lake Aldwell boat ramp near the head of the reservoir (river mile 7, Figure 1). These fish were released in four groups over the expected natural outmigration period from late April to early June. On release dates, each group was distributed near mid day directly from the Elwha Tribal Hatchery via tank truck. All groups were seined from a common production lot, enumerated by electronic counter (Wunderlich and Dilley 1985), and length sampled at time of loading. No marks were applied to these fish, although their release dates were spaced sufficiently apart to separate the majority of each group at the trap. Table 2 shows specific release data. Coho release groups were specifically intended to test efficiency of the lake trap and calibrate acoustic monitors at Elwha Dam.

Relatively small numbers of hatchery steelhead smolts (1+) were also intermingled in each coho release, as steelhead and coho were reared in the same production lot at the Elwha hatchery and it was impractical to totally separate them at time of loading, despite careful hand sorting. Actual numbers of steelhead in release groups 3 and 4 were estimated; a similar proportion of steelhead to coho was believed to be in the first two release groups as well (Table 2). All hatchery steelhead observed at time of release had distinctly stubbed dorsal fins.

Smolt Collection and Tagging

A floating lake trap similar in configuration to that described by Hamilton et al. (1970) and Dunn (1978) was installed near river mile 6.0 in Lake Aldwell as a means to collect downstream migrants (Figure 1). This location satisfied siting considerations noted above, and the location appeared well suited for lake trapping. The narrow width of Lake Aldwell at rm 6.0 (approximately 200 ft) provided an opportunity to span the reservoir with trap leads and potentially maximize efficiency of the gear, which has been used effectively for smolt collection in certain other western Washington reservoirs (Fenton, Washington Department of Game; Dunn, U.S. Fish and Wildlife Service, personal communications).

The lake trap and leads were positioned as shown in Figure 2. The leads ran from each bank to the trap. The left and right bank leads were each 30 ft deep and approximately 100 and 160 ft long, respectively. The trap itself consisted of heart, pot, and spiller (Figure 3). Heart wings were 30 feet long and spaced 30 ft apart at their outer extremity. The heart floor tapered from a depth of 30 ft at the leading edge to 16 ft at the pot. The heart and jigger wings and center lead were sewn to the heart floor. A web entrance 16 ft deep and approximately 3 ft wide provided passage from the heart to the pot. Pot and spiller were each approximately 16 ft square and 16 ft deep and connected by a webbed tunnel. Heart, pot, and spiller were made of 5/8", stretched measure, knotless nylon webbing. Leads were of the same material and similar mesh size. The pot and spiller were supported by styrofoam floats with wooden walkways for workers, while the heart and leads were supported by floats and shorelines.

The trap was fished in two configurations. Initially, the left and right bank leads were attached to the heart wings as shown in Figure 3. However, prior to the fourth coho release, the left bank lead was attached instead to the center lead in an attempt to improve efficiency, as this is a more typical fishing configuration (shore lead to center lead). The left bank jigger wing was also attached to the center lead to create a blind. Additionally, during this change, the center lead was adjusted forward and weights were placed in the corners of the pot and spiller and at the base of the center lead in an effort to prevent distortion of the trap from the current and thereby improve efficiency.

A shallow, large mesh debris net was installed across the reservoir 100 ft upstream of the trap (Figure 2). This served as a log catcher to prevent larger floating debris from damaging the trap and leads.

The lake trap was operated continually from April 18th to July 5th. This period encompassed virtually all coho passage from the four test releases, and the period of expected steelhead outmigration from the upper watershed. Throughout this period of operation, the trap was checked daily at 0700 and 1700 hrs to separate day/night catches. At each check, the spiller catch was transferred to a live car for processing at the tagging dock, as discussed below.

Maintenance of the trap involved periodic checking of the netting for holes and tears, and cleaning algae and silt from wings and leads to prevent them from sinking. Cleaning occurred weekly until late May, after which higher streamflows required cleaning on a twice per week basis.

Catch processing occurred at the tagging dock situated downstream of the trap (Figure 2). At this location, trap catches were sorted and counted by species, length sampled, and examined for any injuries or marks to evaluate trap selectivity and efficiency. Each steelhead and coho catch was given a unique freeze brand to evaluate residualism. All adipose-clipped trout were coded-wire tagged using a Northwest Marine Technology tagging unit powered by a portable generator. Trout which appeared to be steelhead smolts, but had no adipose clips, were tallied but not coded-wire tagged. After processing, catches were released at the tagging dock, with the exception of one steelhead and one coho catch. One coho catch was given a unique brand and returned to the spiller for 24 hrs to check trap integrity, while one steelhead catch was held for 24 hrs to evaluate coded-wire tag loss and handling injury.

Acoustic Monitoring

The hydroacoustic system employed at Elwha Dam consisted of the following components: 420 kHz transducers, an echo sounder/ transceiver, a multiplexer/ equalizer, one to two chart records, and an oscilloscope. Table 3 lists model numbers of the equipment used.

The hydroacoustic system operated as follows (Raemhild, undated). When triggered by the Model 101 Echo Sounder, the transducer emitted short sound pulses toward 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 then 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 chart recorder and oscilloscope. Return signals were visually displayed on the oscilloscope for measurements of echo strengths and durations. Individual fish traces were displayed on the chart recorder's echograms which provided a permanent record of all targets detected during the study.

The Model 151 Multiplexer/Equalizer (MPX/EQ) permitted the single echo sounder to automatically interrogate up to 8 different transducers at Elwha Dam in an operator-specified sequence. The MPX/EQ channeled transmitted pulses from the echo sounder to the appropriate transducers and also equalized the return signals to compensate for differing receiving channel sensitivities.

The hydroacoustic system was operated from April 22nd, date of the first hatchery coho release, to July 5th, when smolt passage diminished to the point that continued monitoring appeared unnecessary. Over this time period, the acoustic system was operated 24 hrs per day during each test period (approximately 5 days following each coho release) and during late May and most of June as well when significant daytime smolt movement was observed. Otherwise, monitoring occurred nightly (approximately 1800-0700 hrs), with the exception of several brief mechanical breakdowns and a one-week evaluation following the first test period (4/28-5/5) when no monitoring occurred.

Transducer Location

The study design of the project called for subsampling all possible fish exits during the entire length of the study. The Elwha Dam has three types of fish exits: 1) through turbine intakes, 2) under open spillgates, and 3) over the top of closed or open spillgates.

Turbine Intake Transducer Location

To achieve the best possible transducer location, three main criteria were considered. They were: 1) maximize sample area, 2) minimize acoustic turbulence, and 3) install in closest proximity to the passageway.

The Elwha Dam has five turbine intakes (Figure 4). Only four of these intakes were monitored during the study. The small, 30-inch exiter turbine was eliminated from sampling because of its small size and minimal amount of fish attraction flow. The diameters of the four turbine intakes sampled were each 9'6".

The interior of intake 1 (Figure 4) was tested first because we felt that the farther down the system we could sample the more assured we could be that those fish detected would in fact pass through the system. The interior of the intake was accessed via a breather tube located approximately 10ft downstream of the mouth of the intake. However, this sampling location was found to be unsatisfactory because of small sample volume and high velocity turbulence through the sample area. Next, the gatewells (chambers between the trash racks and the headgates at the mouths of the intakes) of intake numbers 1 and 2 were tested. (Intakes 3 and 4 do not have gatewells as such.) Use of the gatewells was precluded however, because of numerous "I" beams, concrete benches, and trash rack structures that made echogram interpretation impractical.

The three main criteria for transducer location were finally satisfied by mounting the transducers on the outside of the trash rack on all four intakes, about 12" below the surface. In addition, a transducer was located at the bottom of intake 1.

Spillway Transducer Location

The Elwha Dam has a total of nine spillgates on both banks (Figure 4). When streamflow exceeds the combined turbine capacity (approximately 1,700 cfs as measured at Glines Canyon Dam), a designated spillgate on the left bank is opened. If flow still exceeds spillgate capacity, a designated gate on the right bank is next opened. With still higher flow, gates are opened on alternate banks in the same manner. Up to one foot of spill may also flow over the tops of unopened gates during higher flow periods.

During a typical spring, only two gates (one on each side) are usually opened. Surface-mounted transducers, as used on the four intakes, provided the optimum transducer location to monitor under-gate spill. Accordingly, surface mounted transducers were installed at the two gates designated for opening in spring 1985. These gates were numbers 3 and 7.

A bottom-mounted transducer was also installed at gate 2 to sample fish near the surface. This transducer was attached to the end of an "L" shaped pole so that it could be swung out to avoid transducer-beam contact with pier noses in the immediate area. The purpose of this transducer was to monitor potential fish passage over the spillgate during periods of overflow.

Transducer Aiming Angle

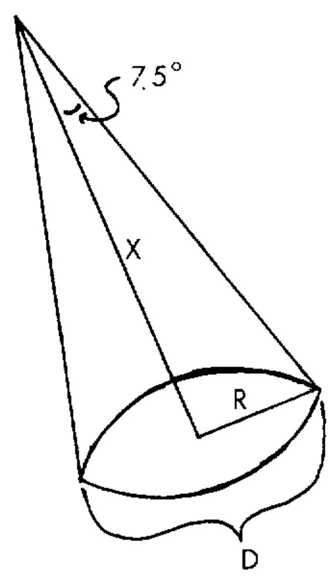
To maximize information returned by a transducer from the sample area, fish direction, proximity to passageway, and turbulence were considered. The maximum sample area is obtained at maximum range. To determine fish movement the transducer must be aimed off the vertical and parallel to fish movement. The sample area should be located as close to the exit as possible. This will increase the likelihood that fish moving through the sample area, toward the intake, actually exit the system.

All top-mounted transducers were tested every five degrees, looking down and upstream, from fifteen to forty-five degrees (zero degrees being straight down). An angle of thirty-five degrees was found to give the maximum range and minimum amount of turbulence for all top-mounted transducers. The bottom-mounted transducer at gate 2 was aimed directly upward (at zero degrees) to obtain data from as close to the surface as possible. The bottom-mounted transducer located at intake number 1 was aimed at a thirty-five degree angle upstream from the vertical.

Sample Area

The sample area of each transducer (diameter of the beam) was a function of the range from the transducer. The following algorithm was used to determine the diameter (D) of the fifteen-degree transducers at any range (X).

D = 2((Tan 7.5) * X)
R/X = Tan (7.5)
R = Tan (7.5) * X
D = 2 * R



System Calibration

To be assured that an echo from a desired fish was received and recorded properly the acoustic system was calibrated prior to data collection. Based on previous calibration information, the adjustable print threshold on the chart recorder was set so that only signals from fish larger than -56dB on axis would be printed. This target strength corresponded to the smallest juvenile salmonid of interest in this study. The calibration information was also used to equalize the system sensitivity for each receiving channel.

Target Strength

Since the acoustic 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 beam width for each transducer (Table 4) was calculated by applying the target strength derived from Love's formula and the particular characteristics of that transducer.

Echogram Interpretation

For an echogram trace to be a valid detection of fish moving into a turbine intake or under the spillgate, three criteria must be satisfied. These were:

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

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

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

Since the threshold was predetermined before data collection with the calibration of the acoustic equipment, the first criterion was satisfied. Targets that fell below the threshold (e.g., coho fry) were simply not printed out by the chart recorder. Targets of very similar size, e.g., coho and steelhead smolts, were inseparable with the system employed.

The high redundancy requirement in the second criterion (four consecutive pulses) was because of the relatively wide beam width of the transducers, the high pulse repetition rates, and the assumption that the fish are 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.

As a fish passes through the ensonified beam a succession of echoes indicates, on the echogram, a fish's change-in-range relative to the transducer. This change-in-range information indicates the fish direction of movement relative to the dam because of the known position of the transducer. Fish that were moving toward the intakes or spillgate were the only traces considered to be fish passing through the dam.

Trace Types

Traces on the echograms for each individual fish were classified as one of six different types. Below is a list of the six trace types and the characteristics that typified that particular trace.

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

2). BEND DECREASING - a target exhibiting a moderate change-in-range toward the transducer.

3). BEND INCREASING - a target exhibiting a moderate change-in-range away from the transducer.

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

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

6). NO CHANGE - a target with only a few sequential echoes which indicated no change-in-range.

Environmental parameters such as surface disturbance, floating or submerged debris, or water cavitation at times produced non-fish traces. Occasionally, these non-fish traces obscured fish traces. Therefore, each echogram was assessed for the level of background interference and given a "noise code". Noise codes ranged on a scale of 1 to 4 defined as follows:

1). No interference on echogram.

2). Slight interference on echogram.

3). Moderate interference on echogram.

4). Heavy interference on echogram.

Data Reduction

Microcomputers were used for data storage and subsequent analysis. Data recorded on the echograms for individual fish observations were transformed to computer data files using a Summagraphics "Bit Pad Two" digitizing pad coupled with BioSonics's Digistor fish data entry program. Raw data files contained the following information for each fish detection:

1). Date.
2). Start time of transducer interrogation.
3). Duration of transducer interrogation.
4). Transducer location.
5). Transducer depth.
6). Transducer beam width.
7). Transducer orientation.
8). Background interference level.
9). Time of entrance.
10). Time of exit.
11). Range of entrance.
12). Range of exit.
13). Trace type.

Raw data files were then processed with the BioSonics program "Integrity" which checked for mistakes or inconsistencies in the data base and created new files with condensed information. Integrity files were then converted to dBase II files. Software was then developed that created additional files that contained detections converted into the corresponding number of fish passing into each intake or passing under the spillgate. These detections were weighted individually using beam width and expansion width. Because the cross-sectional area at the sample location was only partially ensonified, individual fish detections were multiplied by a weighting factor to estimate the total relative number of fish passing the location at that particular range and time. To account for the cone-shaped geometry of the acoustic beam, the weighting factor was defined as the ratio of the width at the sample location to the width of the acoustic beam at the range of detection. Weighting factors ranged from 1.9 to 3.5 for individual detections, depending on range.

Additional files were created that contained the weighted detections summed for each individual location by hour for the entire study period. Weighted detections were then expanded to hourly values depending on sampling time, which ranged from approximately 7 to 24 minutes per hour. These summary files were then transferred into Lotus 1-2-3 for graphic representation.

All routine acoustic monitoring data were reduced as described above. However, data collected during the first test period (4/22-4/27) were reduced manually to facilitate the first evaluation of the acoustic system and were later entered into computer files. Additionally, echograms from the final week of acoustic operation (7/1-7/5) were only qualitatively examined to confirm that fish movement had essentially ended at that time.

RESULTS AND DISCUSSION

Trapping and Tagging

Percent recoveries of hatchery coho (and incidental hatchery steelhead as indicated by stubbed dorsals) at the lake trap are summarized in Table 5. As shown, recoveries of coho groups 1 and 4 surpassed the minimum target rate of 10%, whereas groups 2 and 3 did not. Percent recoveries of hatchery steelhead in groups 3 and 4 were encouraging, but only limited numbers are represented. In any event, inclusion of steelhead in total group recoveries did not materially affect the recovery rates, which were lower than anticipated.

Factors potentially affecting efficiency of the lake trap included configuration of the trap, environmental conditions at the trap site, and movement patterns of coho migrants.

Review of these factors provided no single, convincing explanation for the variability in trap catches among the four coho groups. The only common elements among the higher recovery groups (nos. 1 and 4) were a slower initial catch rate and a single large daytime catch rate during their initial recovery periods (Table 6). Relationships between streamflow or degree of overcast versus group recovery rates were not evident (Table 7). Residualism was also not apparent in any of the coho groups, as virtually no mark recaptures occurred ($<$0.5% of any coho group captured at the lake trap was subsequently recaptured). A small difference in size of recoveries was evident in the fourth group (Table 8), however the change in trap configuration prior to the fourth release may have influenced recovery sizes.

Among factors potentially affecting overall trap efficiency, configuration of the trap leads may have been most responsible for the low mean recovery rate of 7.6% for all groups. Scuba surveys of the net leads on 5/9 and 6/24 indicated the weighted lead lines were flared downstream due to the current. In this position, migrants may have had a greater tendency to pass under them rather than lead to the trap. Depth of water at the trap (approximately 70 ft) should not in itself have caused poor performance, as lake traps have fished successfully with shore leads to deep water trap sites (Fenton, Washington Department of Game (WDG), personal communication). Other possibilities, such as breaks or tears in the netting, were not detected in any surveys or inspections, and the holding test in the trap spiller showed no loss of fish after 24 hours. Elevated surface temperatures ($>60^{\circ}$F) have reduced effectiveness of lake traps by causing migrants to seek deeper, cooler waters (Fenton, WDG, personal communication). However, a temperature profile taken at the trap site on 6/4 indicated a constant 45°F down to the limit of the probe (50 ft depth). Moreover, the high turnover rate in L. Aldwell (2½ days at 1,500 cfs) likely prevented any thermal stratification during the spring months which might have influenced trapping success.

A total of 530 adipose-clipped steelhead from the upper watershed were recovered at the lake trap. Recoveries occurred at the start of trapping in late April, peaked in late May and early June, and declined substantially by early July. This recovery pattern coincided to a large extent with spill at Glines Dam (Figure 5), suggesting that spill is necessary to move steelhead past this dam as has been previously observed for yearling coho (Wunderlich and Dilley, 1985, Schoeneman and Junge 1954). Of additional interest was the relatively high descaling rate for steelhead versus coho smolts at the trap (Table 9), possibly resulting from passage over Glines Dam.

Lengths of upriver steelhead captured at the trap were relatively constant over the recovery period (Figure 6). Mean forklength for the season was 20.3 cm (n=523) and mean total length 21.4 cm (n=506). This was comparable to lengths of 1+ hatchery smolts released from the Elwha Hatchery (Table 6).

Daily recoveries of steelhead at the trap were not consistently high enough to permit direct testing of efficiency for steelhead, as the original intent was to mark and place several larger catches above the trap for subsequent recovery and evaluation. However, an indirect measure of trap efficiency for steelhead was developed using acoustic data, described below.

As with coho smolts, residualism was not evident among steelhead smolts captured at the lake trap. Less than 1% of the total trap catch was subsequently recaptured, according to mark recovery data.

Coded wire tagging of steelhead at the tagging dock proceeded satisfactorily. Tag retention of the one steelhead lot measured was 97%. Low catches precluded using multiple tag codes for replication purposes, and only five tag codes were eventually applied over the entire season (Table 10). Substantially greater numbers of fish could have been processed on site, however, with minimal apparent tag loss or handling injury, using multiple tag codes.

Most catches of steelhead smolts and similar-sized resident rainbows at the trap were easily distinguished by physical appearance, without benefit of the adipose clip applied to steelhead prior to release (Figure 7). However, the adipose-clip ratio of trap catches was lower than that measured in pre-release sampling. Approximately 85% of trout judged to be steelhead smolts at the trap bore adipose clips versus an estimated 95% clip rate in pre-release sampling. This 10% disparity may have been associated with the changing efficiency of the lake trap over the season introducing sampling error in the trap data. Another possibility, a naturally-occurring smolt-like appearance among a portion of the resident trout popoulation in Lake Aldwell, would not be expected (Thom Johnson, Washington Dept. of Game, personal communication).

In addition to juvenile steelhead, coho, and resident rainbow trout, the lake trap captured dolly varden, brook trout, cuthroat trout, and also experimental plants of adult steelhead in Lake Mills. Appendix A shows a complete listing of daily salmonid catches in the lake trap.

Hydroacoustic Passage Estimates

The total acoustic estimate for all valid detections of fish moving through Elwha Dam over the principal acoustic monitoring period (4/22-6/24) was 50,642. Assuming all hatchery coho smolts passed the dam during this period then, by subtraction, the total number of steelhead smolts that passed the dam was 34,084, or 31% of the original fry plant in the upper watershed.

A fry-to-smolt (2+) survival rate of 31% for steelhead is higher than expected, but not totally unreasonable. Work by Washington Department of Game at Snow Creek suggests that up to 9% survival to smolt could be expected from this plant (Thom Johnson, personal communication). Preliminary work on junvenile steelhead survival in British Columbia by Hume and Parkinson (1979, 1984) suggests similar rates of survival, although isolated examples of up to 42% survival from fry to fall parr (1+) and 18% survival to smolt (2+) were also reported. Factors such as lighter seeding rate, larger release size, later release date, and lesser competition positively influenced fry survival in these studies. These same factors were present in the 1983 Elwha fry plant, and probably exerted positive influences on survival.

Daily acoustic counts for all Elwha Dam exits combined are shown in Figure 8. These daily counts show four relatively rapid pulses (peaks) of hatchery coho smolts passing the dam shortly after each release, which is a movement pattern consistent with previous study of coho smolt movement in the system (Wunderlich, 1983). Daily background counts in Figure 8 are steelhead smolts passing Elwha Dam with an expected peak in numbers in late May and early June.

Due to the presence of steelhead smolts throughout much of the season, calibrating acoustic counts with hatchery coho releases was only feasible with the first release when steelhead numbers were very low. Table 11 indicates that 5,088 fish, or 83% of the first coho test group, were detected during the initial test period. Previous studies (Wunderlich, 1983; Wunderlich and Dilley, 1985) and concurrent trap catches suggest that nearly all of the release group should have passed the dam within several days of release. The 17% shortfall in detections is believed largely due to lack of daytime monitoring in the last two days of the test period (4/25-4/27), due in part to a mechanical breakdown. Some residualism was also possible, particularly in this early release. In light of these factors, we believe the acoustic counts compared favorably with the numbers of coho released in the first group.

As described above, acoustic counts indicated peak movement of steelhead smolts through Elwha Dam in late May and early June, while relatively low counts attributable to steelhead were recorded in early May and early July (the latter period based on qualitative examination of echograms). This general pattern of steelhead movement coincided to a large extent with the spill pattern at Glines Dam (Figure 9).

Choice of Exit

Over the season as a whole, migrants showed a strong preference for passage through the central turbines (nos. 2 and 3), although this preference varied somewhat early in the season. Figure 10 shows that, for the entire season, 39% of all migrants passed through intake 2 and 28% through intake 3, while only 17% passed through intake 1, 10% through intake 4 and 5% under the spillgate. (Virtually no fish were detected near the surface of spillgate 3 during periods of overgate spill.) Early in the season, however, intakes 1 and 4 passed relatively high numbers of fish in the first release periods, when coho were relatively more abundant (Table 11).

One important factor in exit selection was the milling behavior observed in the forebay between the cofferdam and the central intakes (Figure 4), which also created difficulty in echogram interpretation during periods of smolt abundance. During such periods (i.e., during late May and early June), smolts were observed milling in this area in large numbers, probably in response to the eddy effect created by the presence of the cofferdam. This evidently favored use of intakes 2 and 3 due to their proximity. However, as the number of milling fish increased, the ability to separate valid detections became more difficult and some duplicate detection probably occurred, although such error was not considered significant.

A relation between exit choice and flow through a given exit was not apparent. Virtually no correlation existed between hourly gate settings (both wicket and spillgate) and estimated hourly fish passage rates over the season, as depicted in Figures 11-14. (A brief period of no acoustic monitoring occurred in late April and early May as indicated in Figures 11-13.) The isolated peaks in hourly passage during June shown in these figures are believed to simply reflect greater availability of fish and not any response to operational conditions.

Identifying an additional factor or factors in exit selection would likely require additional monitoring in subsequent years. Factors such as species of fish or combinations of species, streamflow, turbidity of water (which is related to streamflow), and total number of fish present at a particular time (which may be related to Glines spill), or a combination of the above may influence exit selection at Elwha Dam.

Also of interest in Figures 11 and 14 are instances of "valid" detections of fish at intake no. 1 (during mid May) and spillgate no. 3 (during early June), respectively, when operational records showed these exits were closed. In these instances, fish passed the acoustic beam in a manner believed consistent with fish exiting the dam, when in fact the exit gates (spillgate or wicket gate) were closed. This obviously affected estimates of choice of exit and the total seasonal count. However, errors associated with such over detections were not considered significant for two reasons. First, the relative number of such over detections was few, particularly at the spillgate (Figure 14). Second, during turbine operation, we believe the likelihood of fish entering the turbine intake and then not passing through the penstock was low, as each unit has considerable attraction flow (approximately 500 cfs at full gate) when in operation.

Diel Passage Rates

Over the length of the study, daylight passage tended to increase (Figure 15). Beginning about May 21st, with the exceptions of June 3rd (no night monitoring) and June 17th (no day sampling), a shift from night to day passage occurred. This shift was greater than expected from available day/night passage data acquired in scoop trap sampling during 1984 (Wampler et al. 1985). This shift in day/night movement appeared largely due to increased streamflow beginning in mid May with a concomittant increase in turbidity levels.

Hourly movement rates across all exits for one-week periods in late April and June further illustrated the shift to daylight movement later in the season. Figure 16 shows percentage of hourly passage for these one-week periods. The first period, which was a low flow condition (approximately 1,000 cfs) with no spill and essentially only coho present, shows a majority of passage during night hours. The second period, which was a high flow condition with spill (approximately 2,200 cfs) and a mixture of steelhead and coho present, shows a definite shift to daylight passage with relatively constant movement both day and night. Examination of a third weekly period (6/12-6/17, not shown), with essentially only steelhead present, showed a diel movement pattern very similar to that of period 2, suggesting increased day movement was not species specific.

Examination of hourly movement rates at each exit for the above time periods indicated that diel movement rates were relatively uniform across individual exits as well. Figures 17 and 18 depict these movement rates by period.

Trap Catches vs. Acoustic Counts

Comparing estimated steelhead counts at Elwha Dam to actual lake trap catches of steelhead (naturally emigrating) provided indirect estimates of trap efficiency over the season. The total trap catch during all periods of acoustic operation (542) divided by the total acoustic estimate (34,084) yielded a season mean of 1.6% for trap efficiency. Moreover, during the last three inter-release periods (when hatchery releases had essentially cleared Elwha Dam and naturally emigrating steelhead were relatively abundant) the estimated trap efficiencies for steelhead were 1.0%, 2.0%, and 2.2%, respectively, suggesting a relatively constant, albeit low, efficiency for steelhead throughout the trapping period.

Species composition at the trap (coho vs. steelhead migrants) did not correlate well with species composition at Elwha Dam, as estimated from acoustic data. For this comparison, 90% of each coho group was assumed to have passed the dam within five days of release (based on trap catch data and prior FAO studies (Wunderlich and Dilley, 1985; Wunderlich, 1983)). Ninety percent of each release group was therefore subtracted from acoustic counts in respective test periods to estimate steelhead abundance at the dam. Table 12 shows species composition at the trap and dam during each test period. As Table 12 indicates, a marked difference occurred in test periods 3 and 4 when steelhead were relatively abundant, suggesting that trap catches did not accurately reflect species composition during mixed species passage.

Daily trap catch (all migrants) and daily acoustic counts at the dam also varied, with generally poor correlation between the two most of the season. Figure 19 depicts trap catches and acoustic counts. The highest correlation (r^2 = 0.78) occurred during the first test period (4/23-27). Subsequent test period correlations were lower and variable (r^2 = 0.30 for 5/7-11, 0.29 for 5/21-25, and 0.17 for 6/6-10). Inter-test periods showed similarly poor correlations. The overall correlation for all periods of acoustic monitoring and trap operation combined was also low (r^2 = 0.19).

Utility of Lake Trapping

The lake trap did not perform up to expectations at the rm 6.0 site. Direct measures of efficiency for coho smolts were generally low and variable, and the estimated efficiency for steelhead smolts was likewise low. Daily catches at the trap were generally not well correlated with daily acoustic counts at the dam, nor was species composition at the trap well correlated with species composition at the dam, as estimated from acoustic data.

Position of the trap leads may have been most responsible for the marginal success of this gear at the rm 6.0 site. Correcting this problem with additional weighting of leads may improve trap performance at this site. Alternatively, installation of the lake trap at another site in the reservoir, such as the head or forebay, could substantially improve efficiency. Efficiency of lake traps in certain other western Washington reservoirs has been site dependent (Fenton, Washington Department of Game; Dunn, U.S. Fish and Wildlife Service, personal communications).

Inasmuch as this gear has been used successfully to consistently trap greater numbers of smolts at other locations (e.g., Wynoochee and Skookumchuck Reservoirs), and manpower requirements for installation and operation are not great, additional evaluation in Lake Aldwell is probably warranted. Other potential methods of smolt collection, such as mainstem weirs or seining, are likely much more manpower intensive and offer no greater probability of success.

Utility of Hydroacoustics

For the last several years, hydroacoustic technology has been developed to a state where accurate measurements of fish abundance, distribution, and behavior are possible. Hydroacoustics has proven to be an accurate technique for monitoring fish movement through the dams on the Columbia and Snake rivers.

In the Elwha situation, the acoustic results appeared reasonable as evidenced by the initial calibration test and the fact that the overall movement patterns agreed with other available information. Perhaps the greatest problem encountered was the milling behavior in front of intakes two and three which made accurate counts of valid traces difficult. It should be noted, however, that this was a transient condition that most affected intake two. This condition changed from day to day and even within hourly sample intervals. This phenomenon might be dealt with in future studies by not attempting to reduce data from sample intervals where trace types are, for the most part, obscured by milling fish.

Overall, the reliability of the acoustic equipment was very good. The only piece of equipment that suffered mechanical breakdown was the EPC 1600 graphic recorder. Two breakdowns, a worn out slot sensor and a stripped roller gear, were experienced and corrected within a short period of time.

Equipment installation and adjustments, excluding fabrication time for transducers, took approximately three days with experienced personnel. Operation of the equipment, however, required continuous monitoring of the EPC 1600 recorder. Stylus belts or individual styli could break down at any time, regardless of how recently a new belt was placed on the machine. In addition, a new roll of chart paper and belt were required approximately every four hours of operation.

SUMMARY AND RECOMMENDATIONS

This study evaluated means to collect, tag, and monitor the passage of downstream migrants through Elwha Dam. These activities were conducted for the purpose of developing a salmonid survival model for the upper Elwha watershed.

A lake trap, installed at rm 6.0 in Lake Aldwell, was evaluated as a means to collect random, unbiased samples of downstream migrants of sufficient size to allow survival estimates through coded-wire tagging, and to predict species composition for acoustic monitoring at Elwha Dam. Tests conducted with hatchery coho smolts showed trap efficiency ranged from 3.2 to 11.2% and averaged 7.6%, which was generally less than the minimum target level established (10%). Indirect estimates of trap efficiency for steelhead smolts also indicated less than desired performance. Further, daily trap catches were not well correlated with daily acoustic counts through the season. A probable reason for poor trap efficiency was flaring of the trap leads at the rm 6.0 site.

Incidental information gathered during the course of lake trapping included length and condition of steelhead smolts outmigrating from the 1983 fry plant in the upper watershed, and their movement in relation to spill at Glines Canyon Dam. These trap catches of steelhead averaged 20.3 cm in forklength, and exhibited some scale loss which may be attributed to passing Glines Canyon Dam. Additionally, the pattern of trap recoveries suggested that steelhead passed Glines Canyon Dam via the spillway.

Coded-wire tagging of steelhead smolts captured at the rm 6.0 site was accomplished satisfactorily with minimal apparent tag loss or handling injury. Tag retention of one steelhead lot measured was 97%. Results indicated that significantly greater numbers of fish could have been processed in the field, if necessary.

Hydroacoustic monitoring at Elwha Dam provided information on migrant passage through individual exits of Elwha Dam. This information was sufficiently specific to meet project objectives. Reliability of the acoustic data was evaluated by an initial calibration test with hatchery coho smolts and comparisons to expected outmigration patterns.

Based on hydroacoustic counts, we estimate approximately 34,000 steelhead smolts passed Elwha Dam during the principal monitoring period from late April to late June, 1985. This represents a 31% survival rate for the original fry plant in the upper watershed. This survival rate is high compared to other reported survivals for juvenile steelhead, however no major sources of error were detected in the acoustic analysis which could have led to a substantial overestimate of passage at Elwha Dam.

During the course of acoustic monitoring at Elwha Dam, incidental information was gathered on downstream migrant timing and choice of exit. These data indicated that steelhead smolt passage at Elwha Dam peaked in late May and early June and essentially ended by early July. This movement pattern coincided to a large extent with spill at Glines Canyon Dam. At

Elwha Dam, acoustic data indicated steelhead and coho smolts favored the central turbine intakes (nos. 2 and 3) for passage, probably due to the presence of a cofferdam in the forebay which induced milling behavior near these intakes. (Milling behavior also created problems in acoustic data reduction.) This choice of exit appeared unrelated to wicket or spillgate opening, however. Also, a substantial increase in daytime passage was detected during the latter portion of the emigration period. This increase was likely related to increased streamflow and associated turbidity levels, and apparently occurred at all exits of Elwha Dam.

Relative to further development and applications of the Elwha salmonid survival model, the following measures are recommended in field activities:

1) Further evaluation of the lake trap should be conducted to assure adequacy and randomness of trap catches. Alternate trapping sites at the head or forebay of the reservoir should also be considered.

2) Coded-wire tagging for purposes of model operation should utilize the field set up and procedures employed in 1985.

3) Hydroacoustic monitoring in future years at Elwha Dam should utilize the physical set up employed in the 1985 season. However, problems in acoustic data reduction due to milling behavior in the vicinity of the central intakes should be addressed, as higher natural production levels in the watershed may compound this problem.

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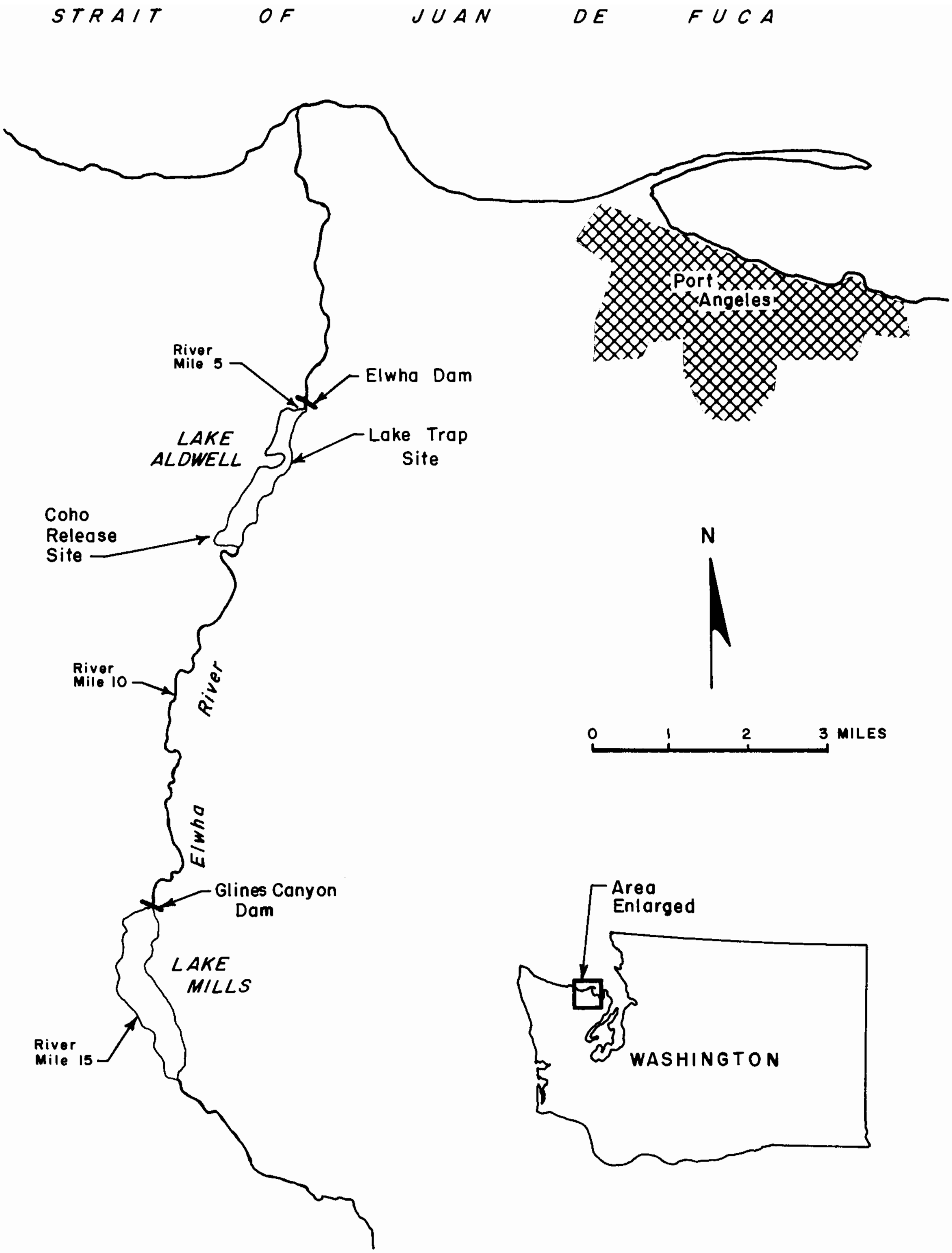

Figure 1. The lower Elwha River.

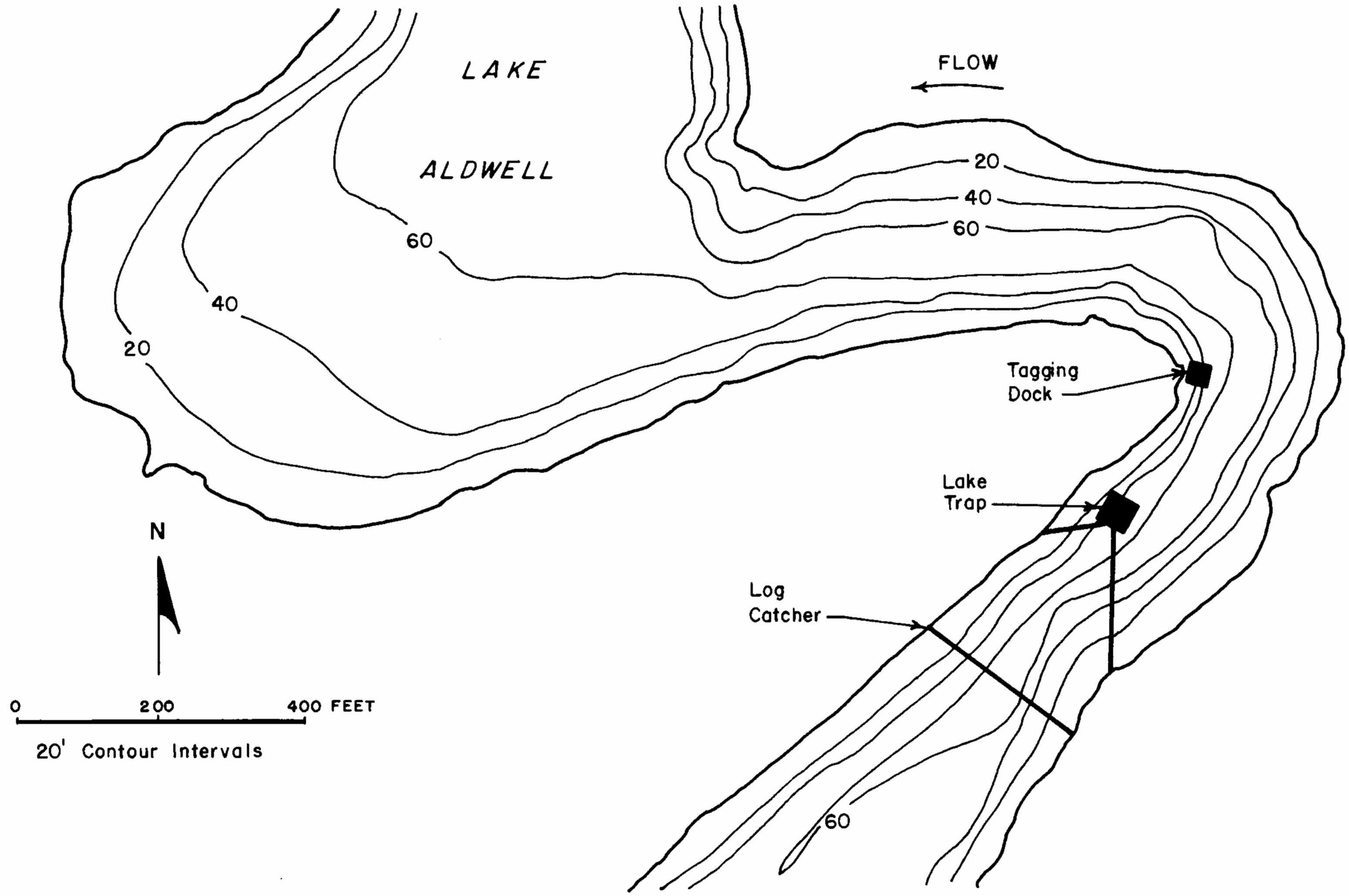

Figure 2. Locations of the lake trap, log catcher, and tagging dock near River Mile 6.0 in Lake Aldwell.

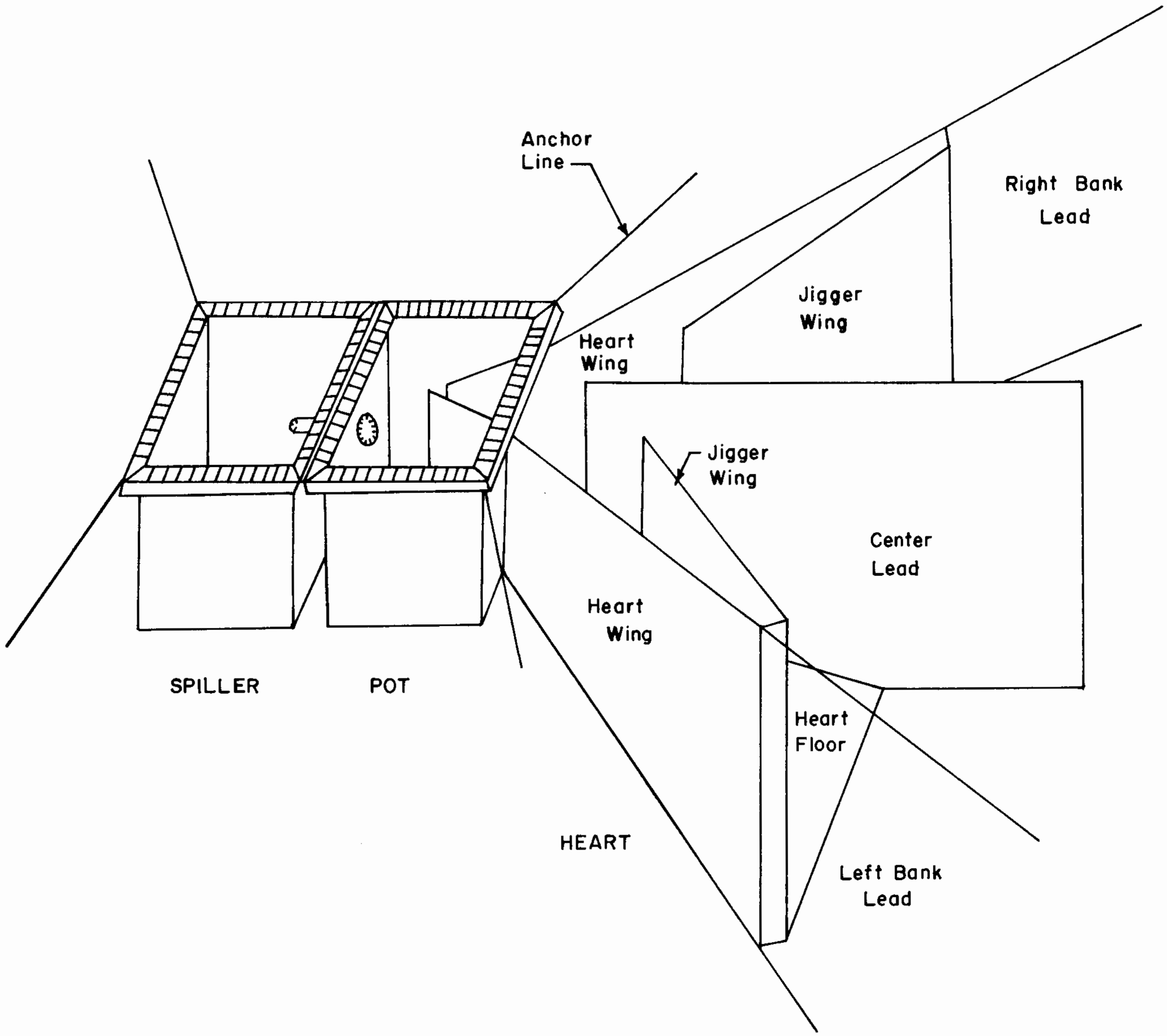

Figure 3. The lake trap used in Lake Aldwell. (Figure adapted from Hamilton et al, 1970.)

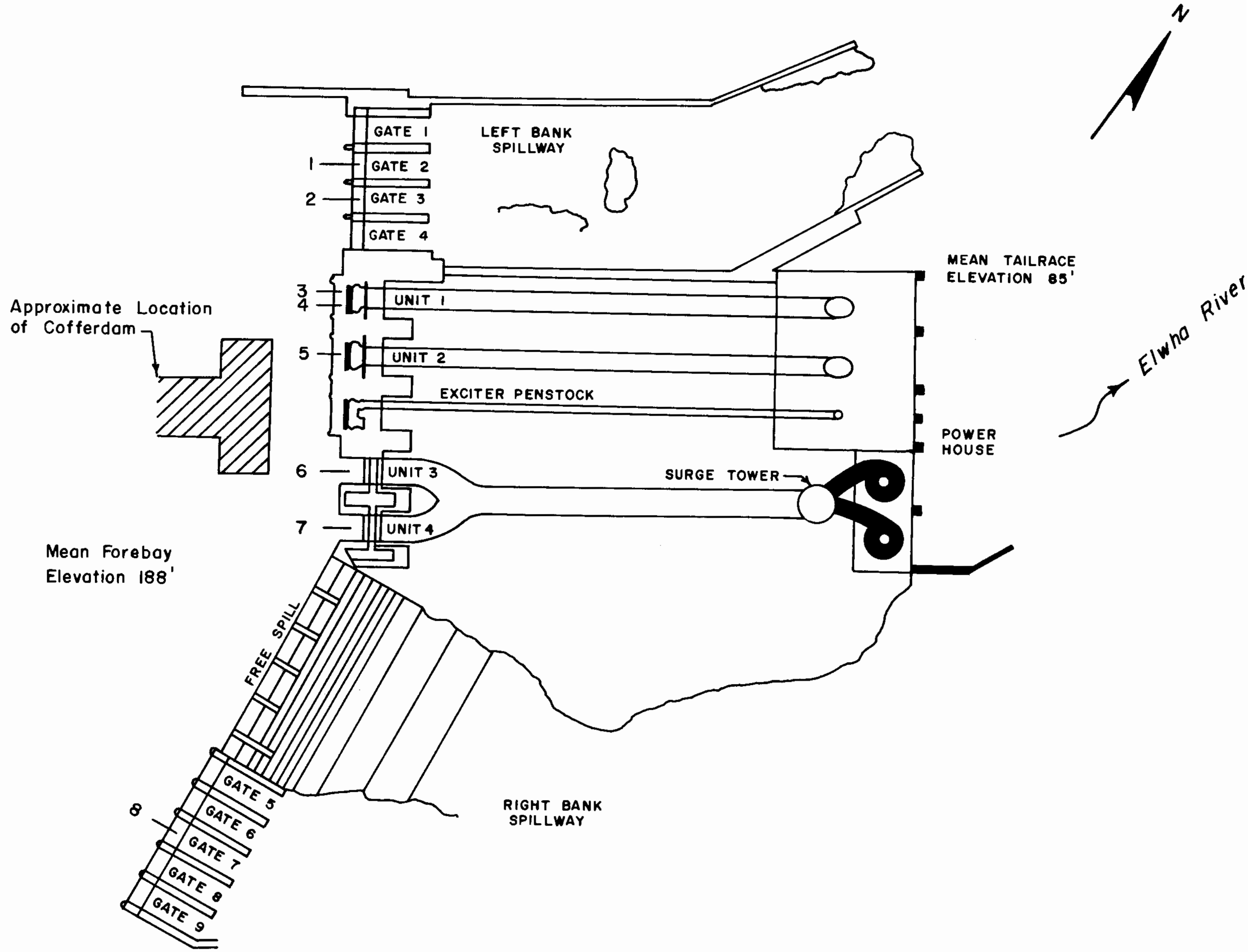

Figure 4. General features of Elwha Dam. Transducer locations are indicated by number at the various dam exits.

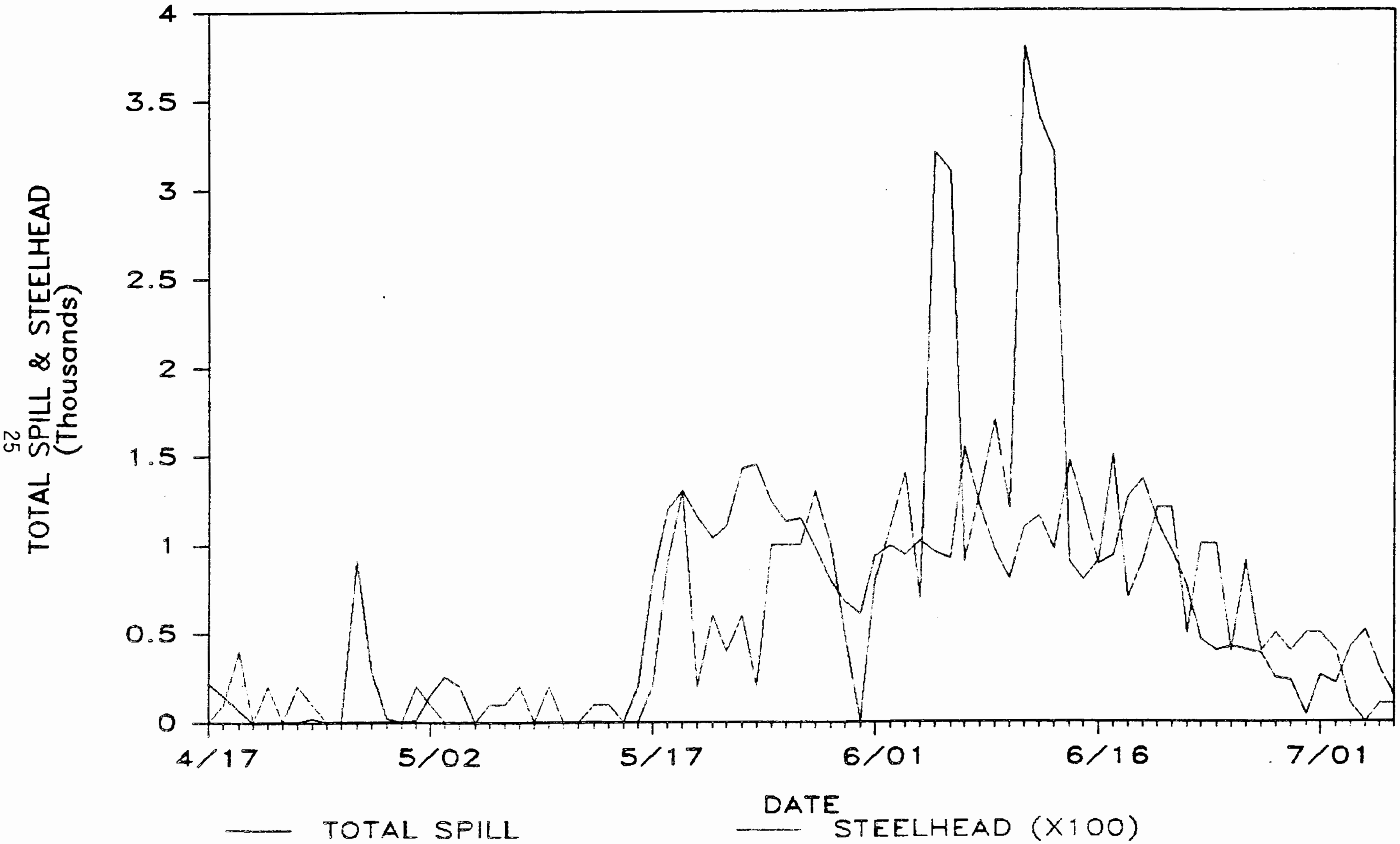

Figure 5. Glines spill (cfs) versus lake trap catches of steelhead over the 1985 outmigration.

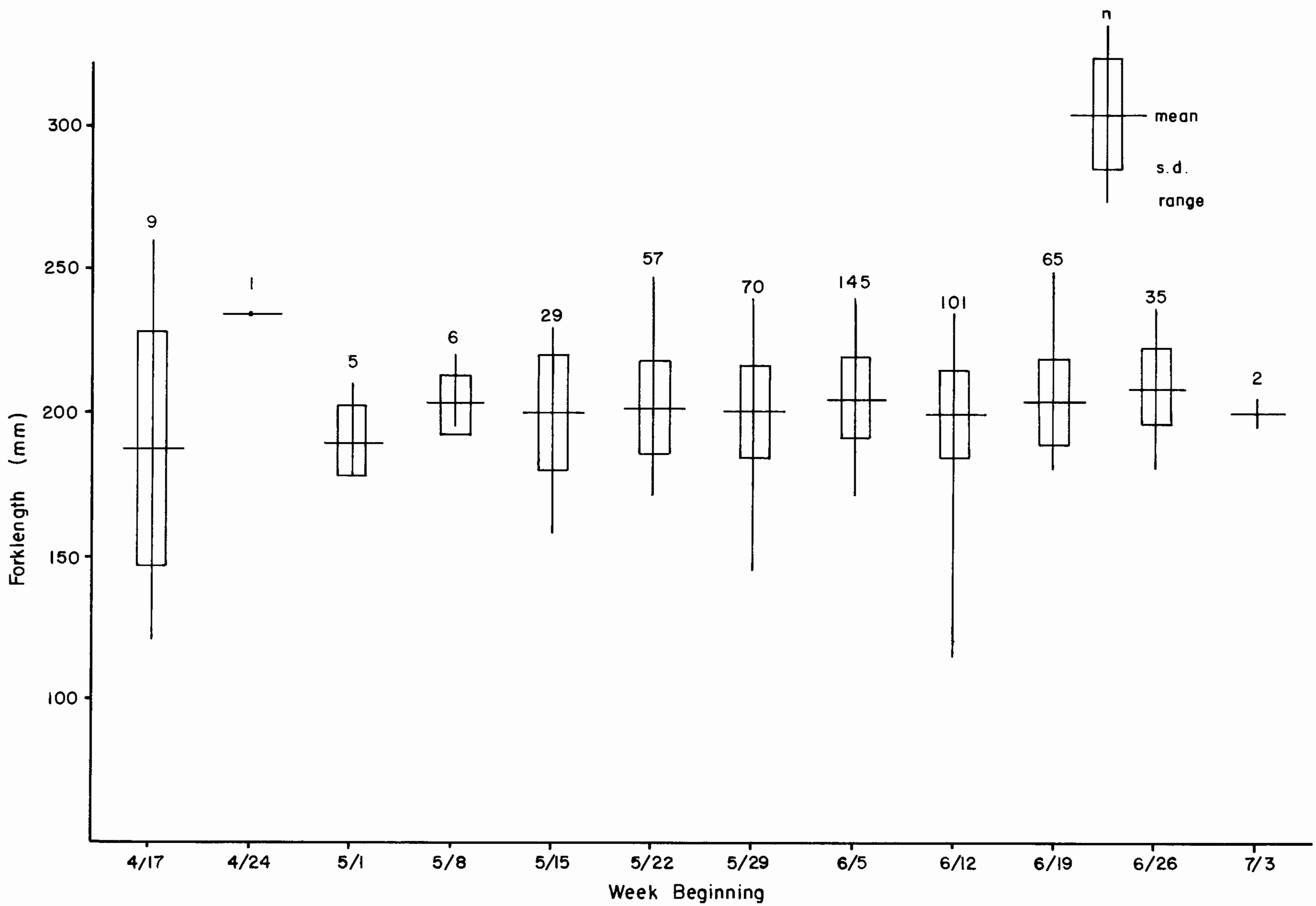

Figure 6. Weekly forklength data for lake trap catches of steelhead planted above Lake Mills in 1983.

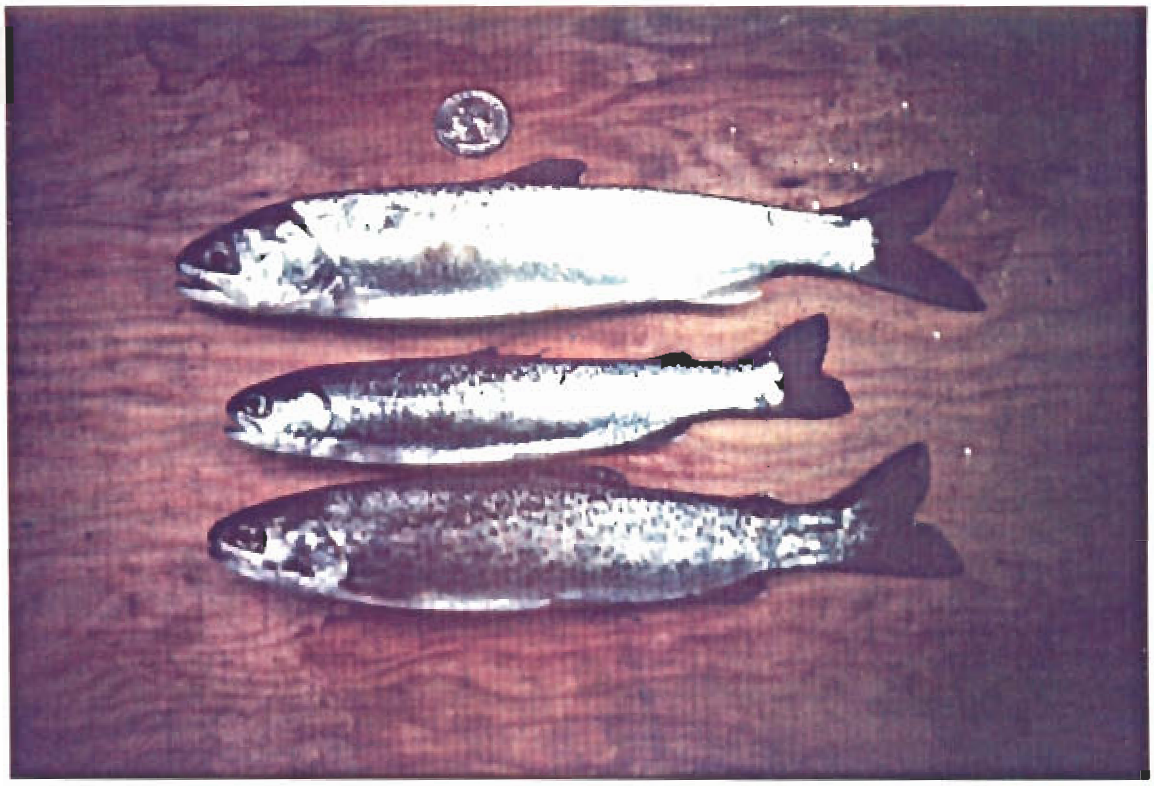

Figure 7. Trap catches of a steelhead smolt from the 1983 fry plant (top), a 1985 hatchery steelhead smolt (middle), and a resident rainbow trout in Lake Aldwell (bottom).

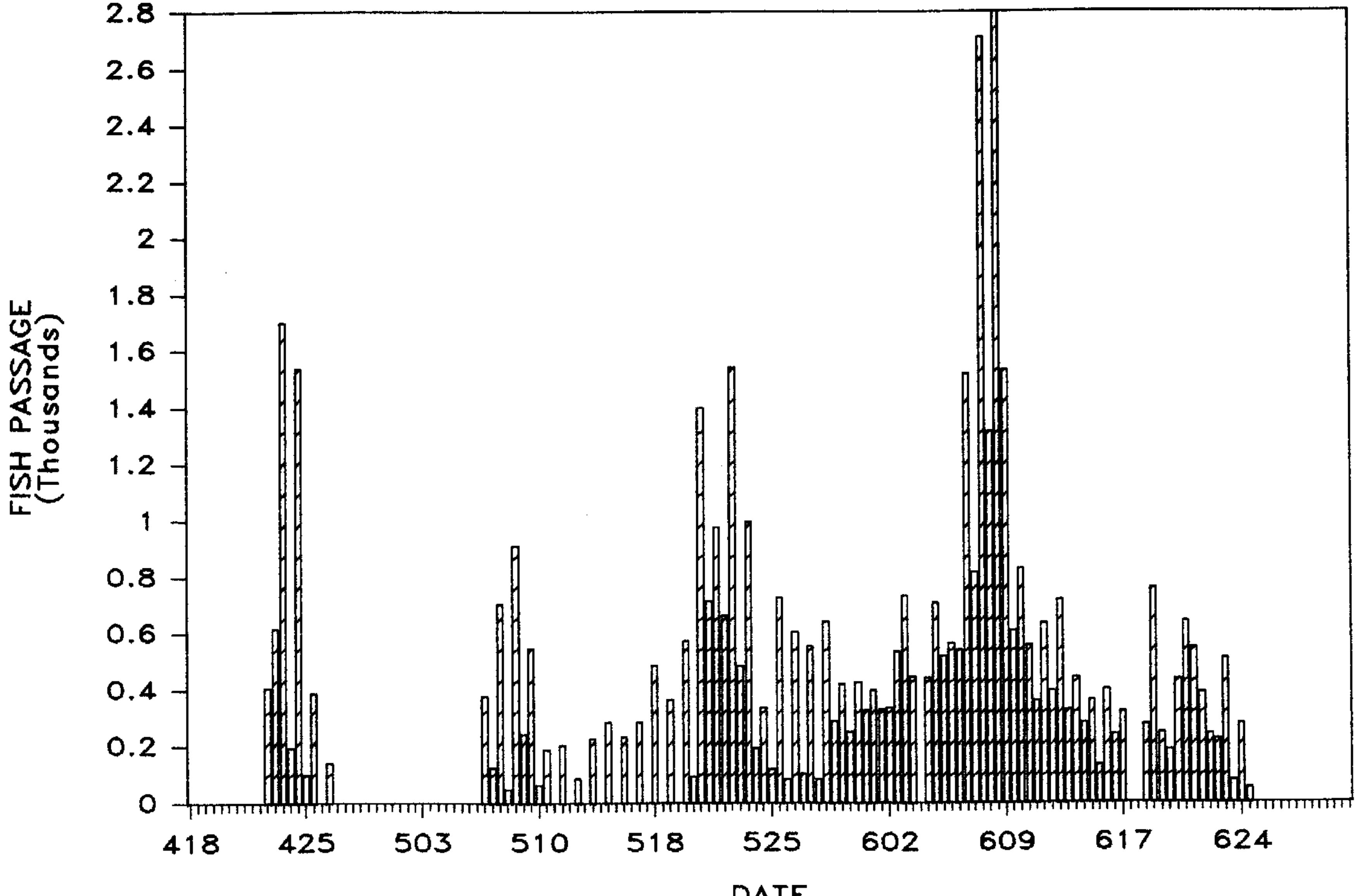

Figure 8. Daily acoustic counts during spring 1985.

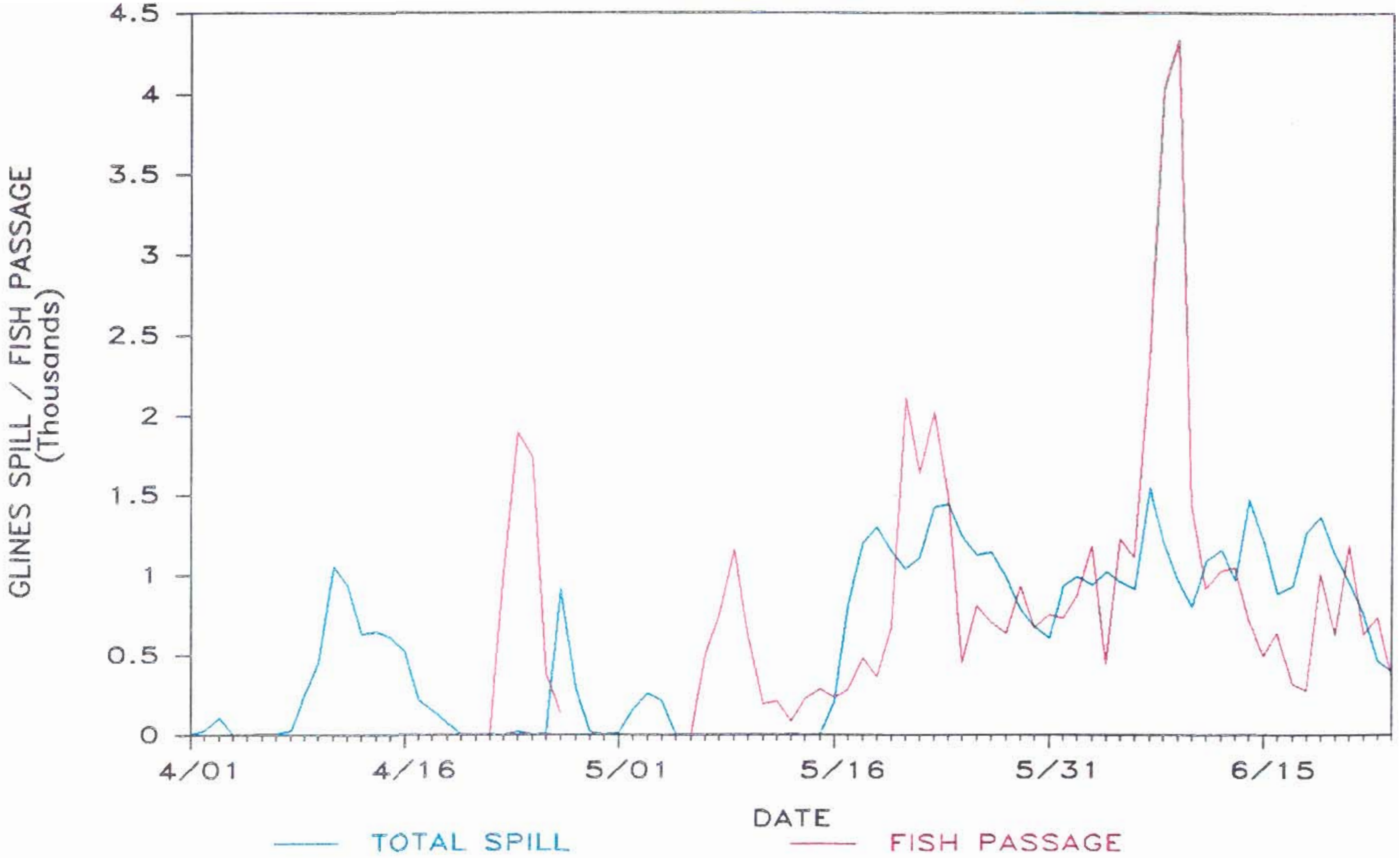

Figure 9. Daily acoustic counts vs. spill (cfs) at Glines Canyon Dam.

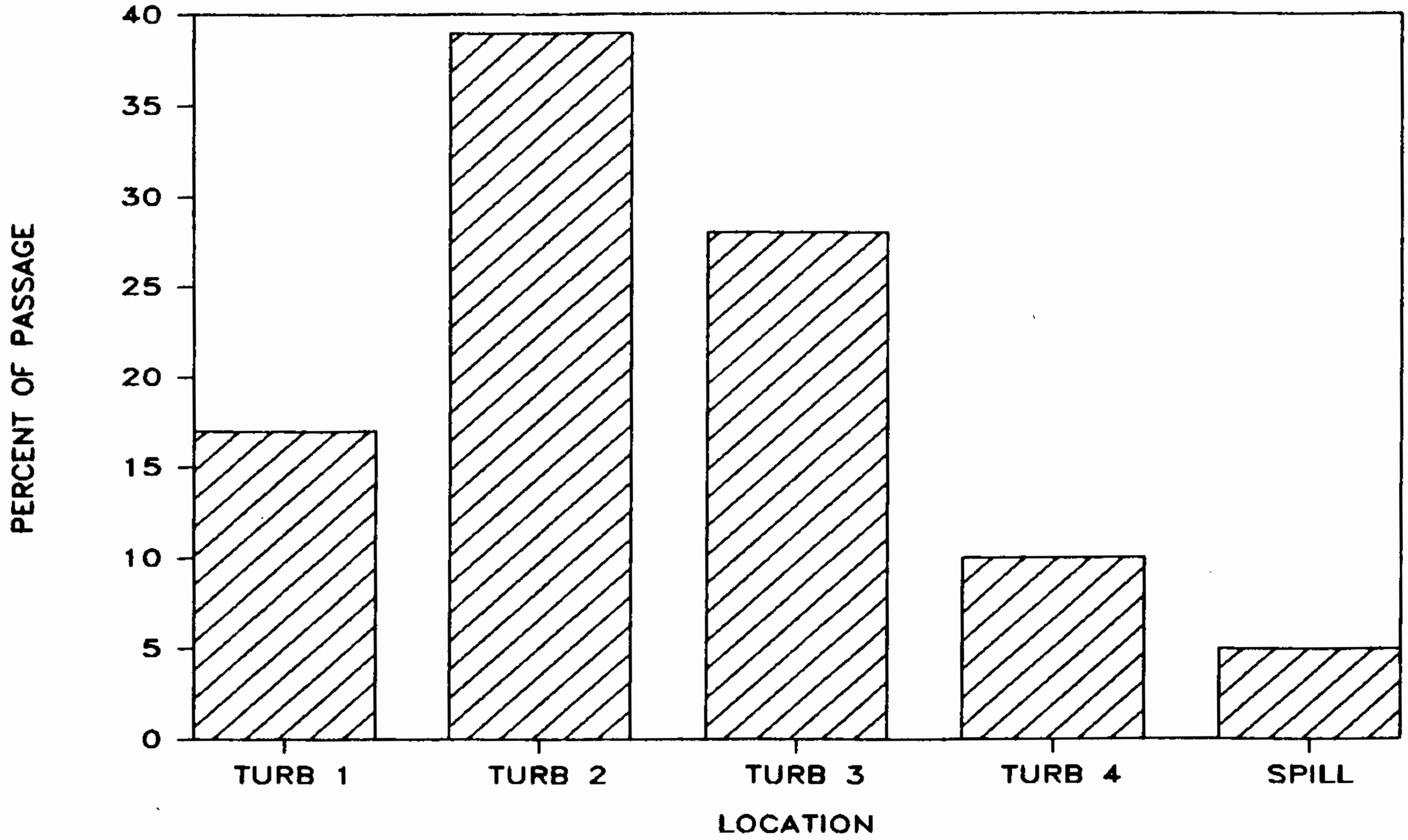

Figure 10. Season composite of migrant passage through Elwha Dam exits.

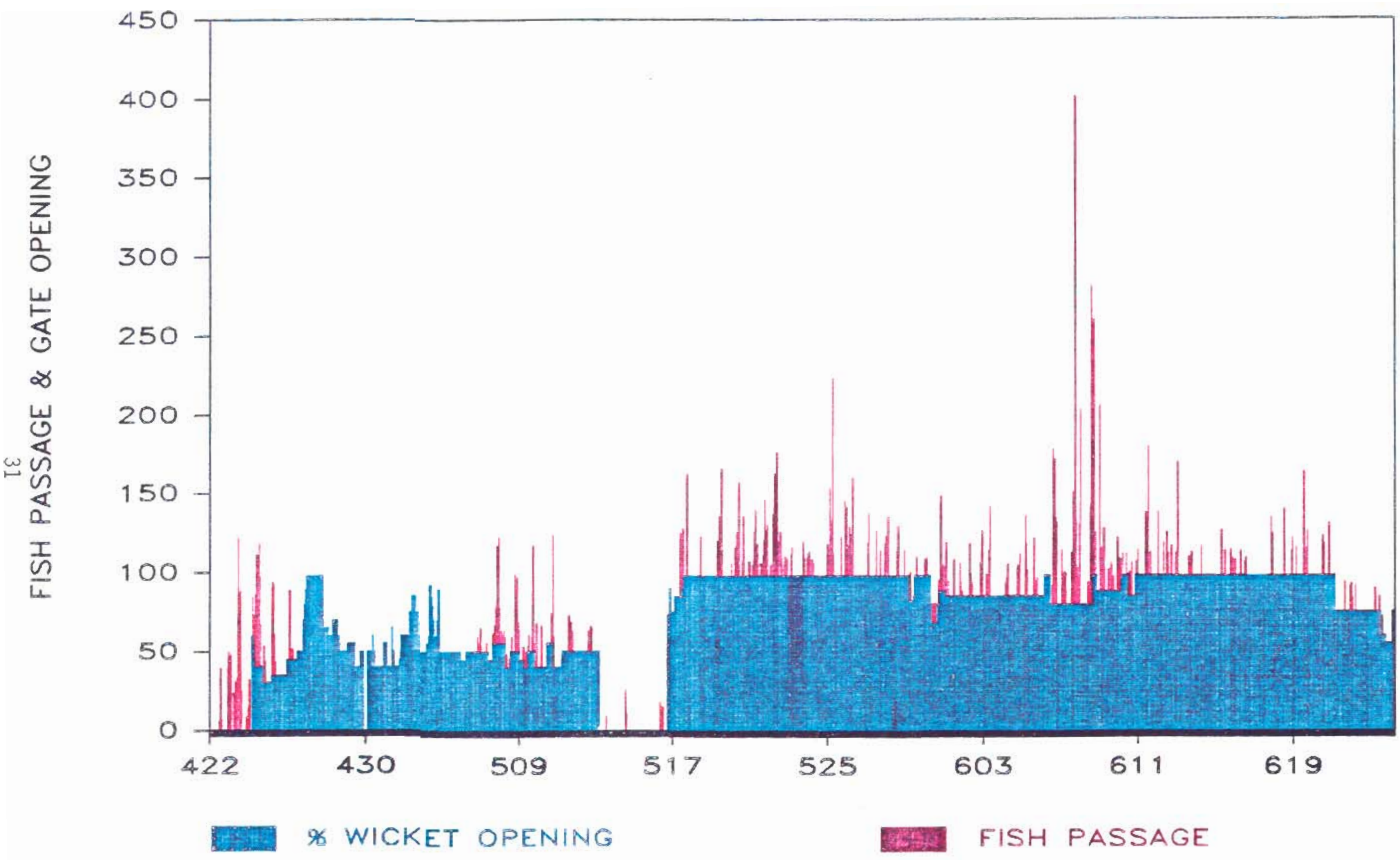

Figure 11. Fish passage vs. wicket gate opening for intake no. 1.

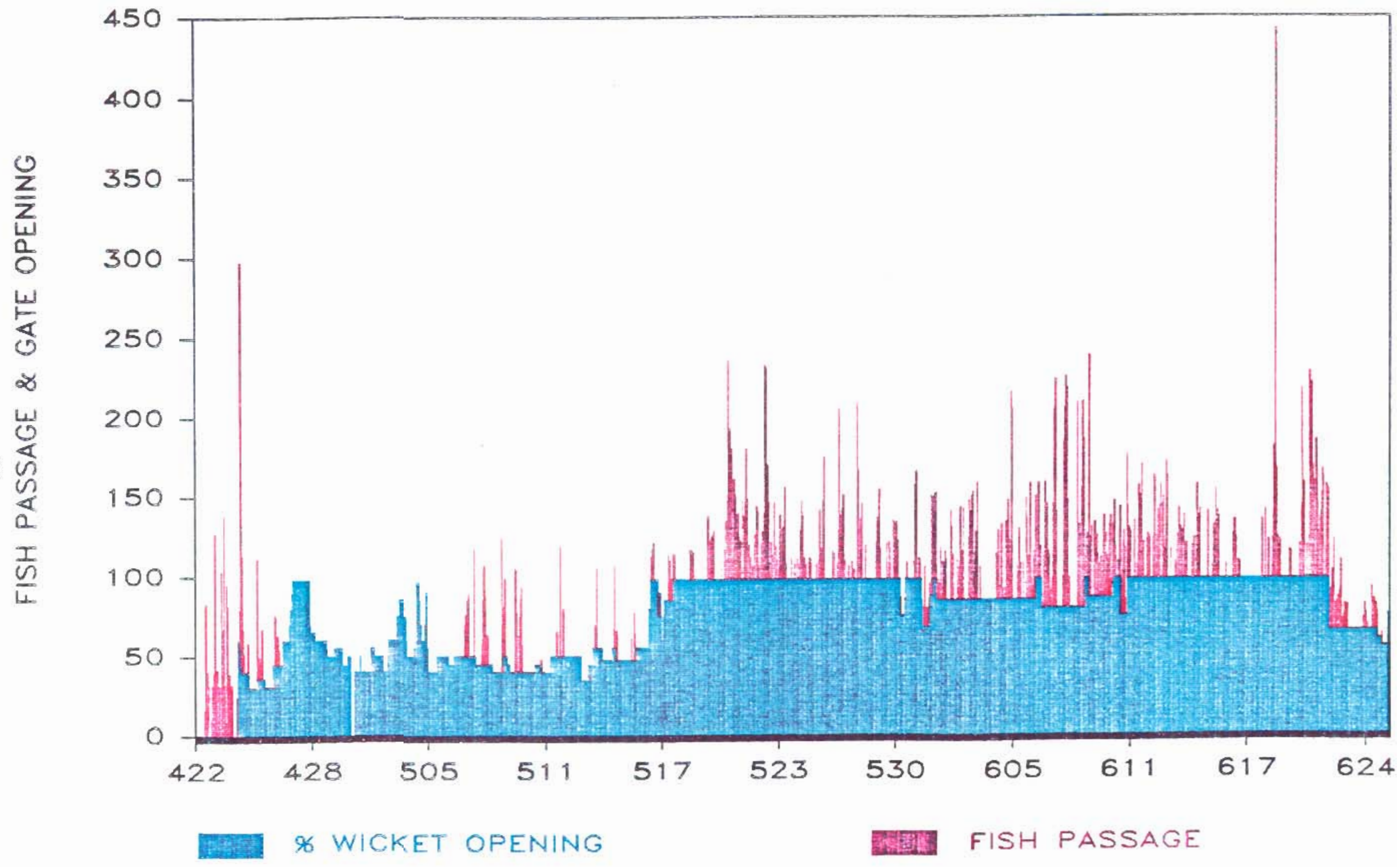

Figure 12. Fish passage vs. wicket gate opening for intake no. 2.

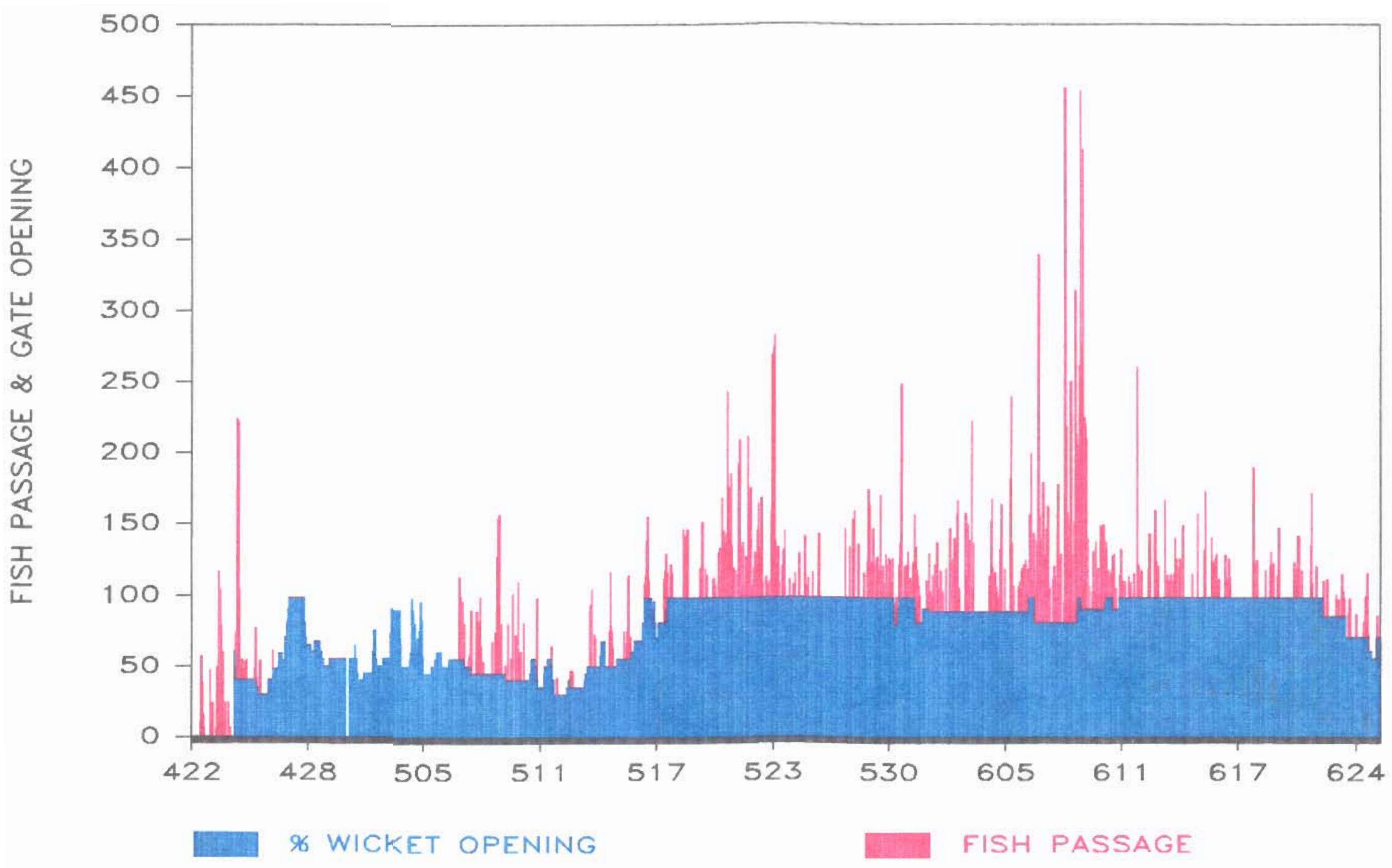

Figure 13. Combined fish passage vs. average wicket gate opening for intake nos. 3 and 4.

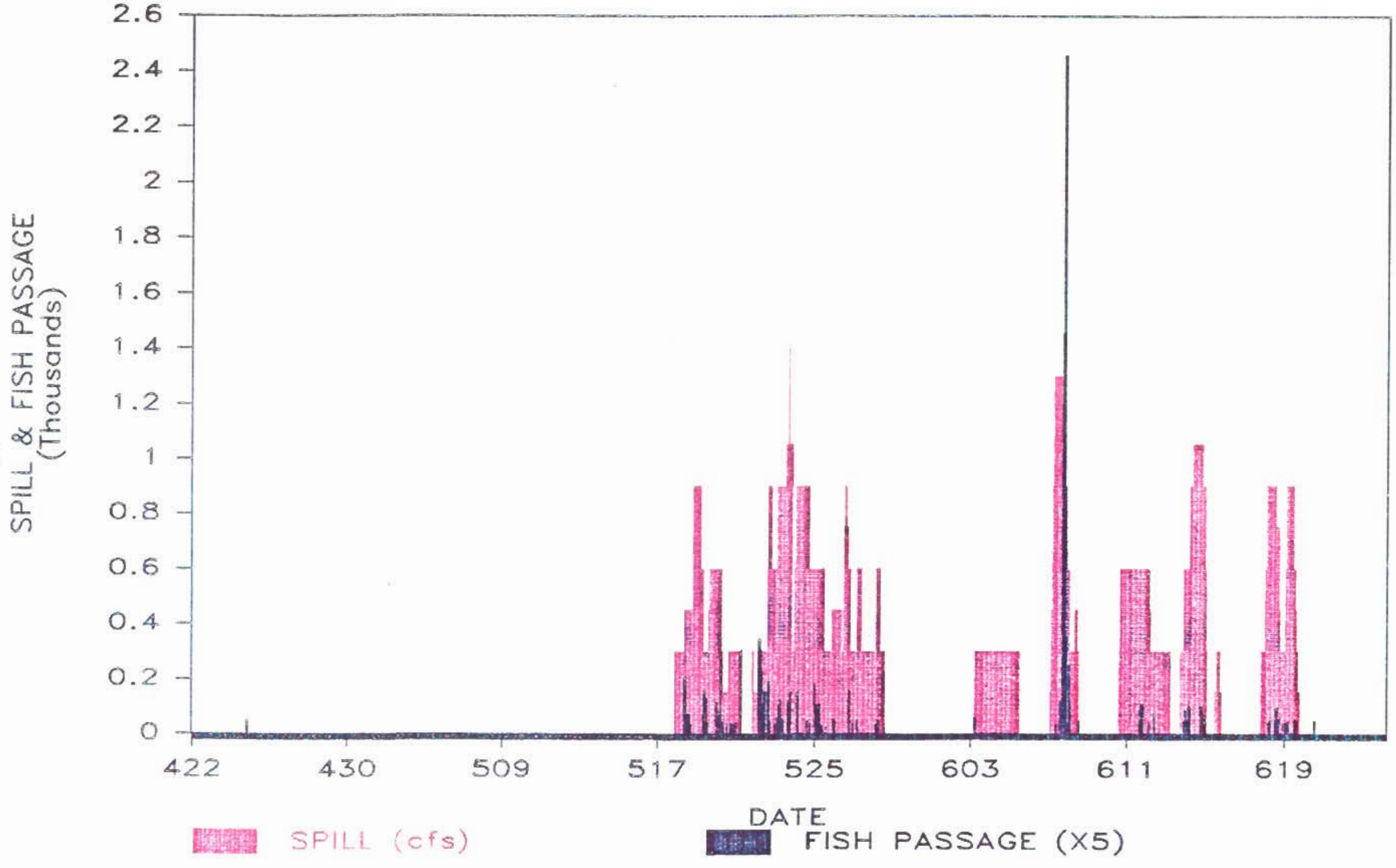

Figure 14. Fish passage vs. opening of spillgate no. 3.

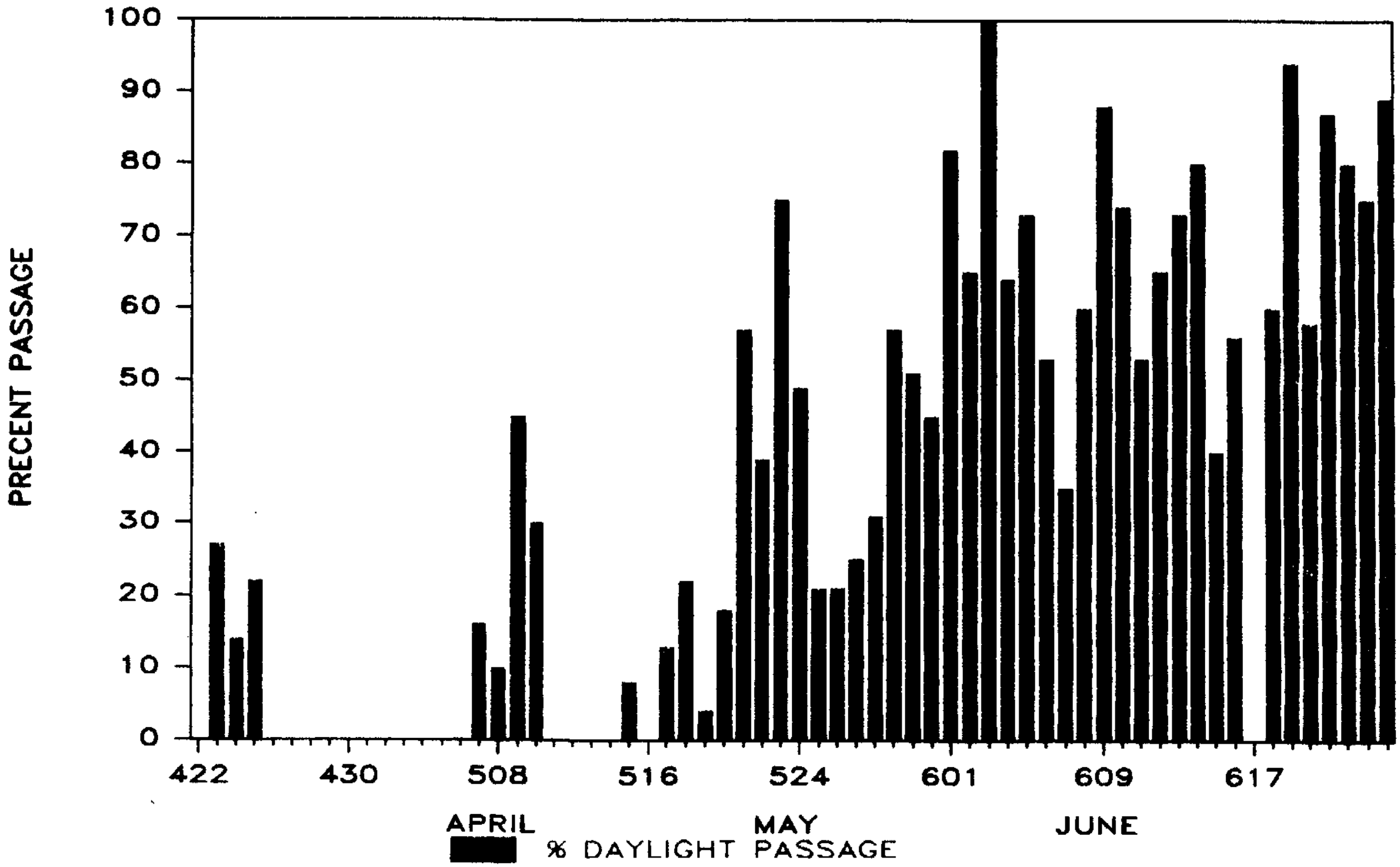

Figure 15. Percent of fish passage at Elwha Dam during daylight hours (0700-1700 in April, 0600-2000 in May, and 0500-2200 in June).

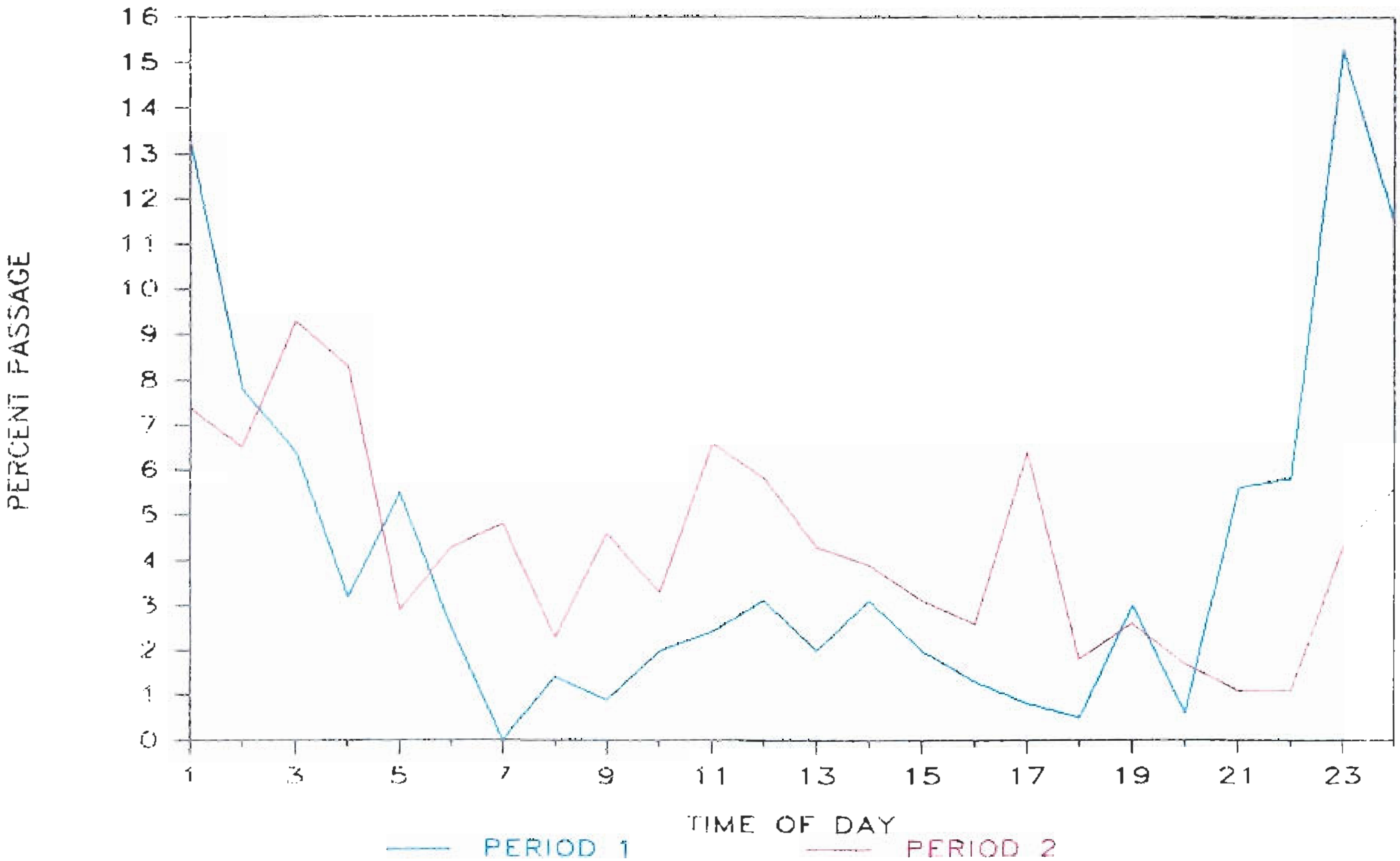

Figure 16. Hourly percentage of fish passage for all exits during period 1 (4/23-4/27) and period 2 (6/6-6/11).

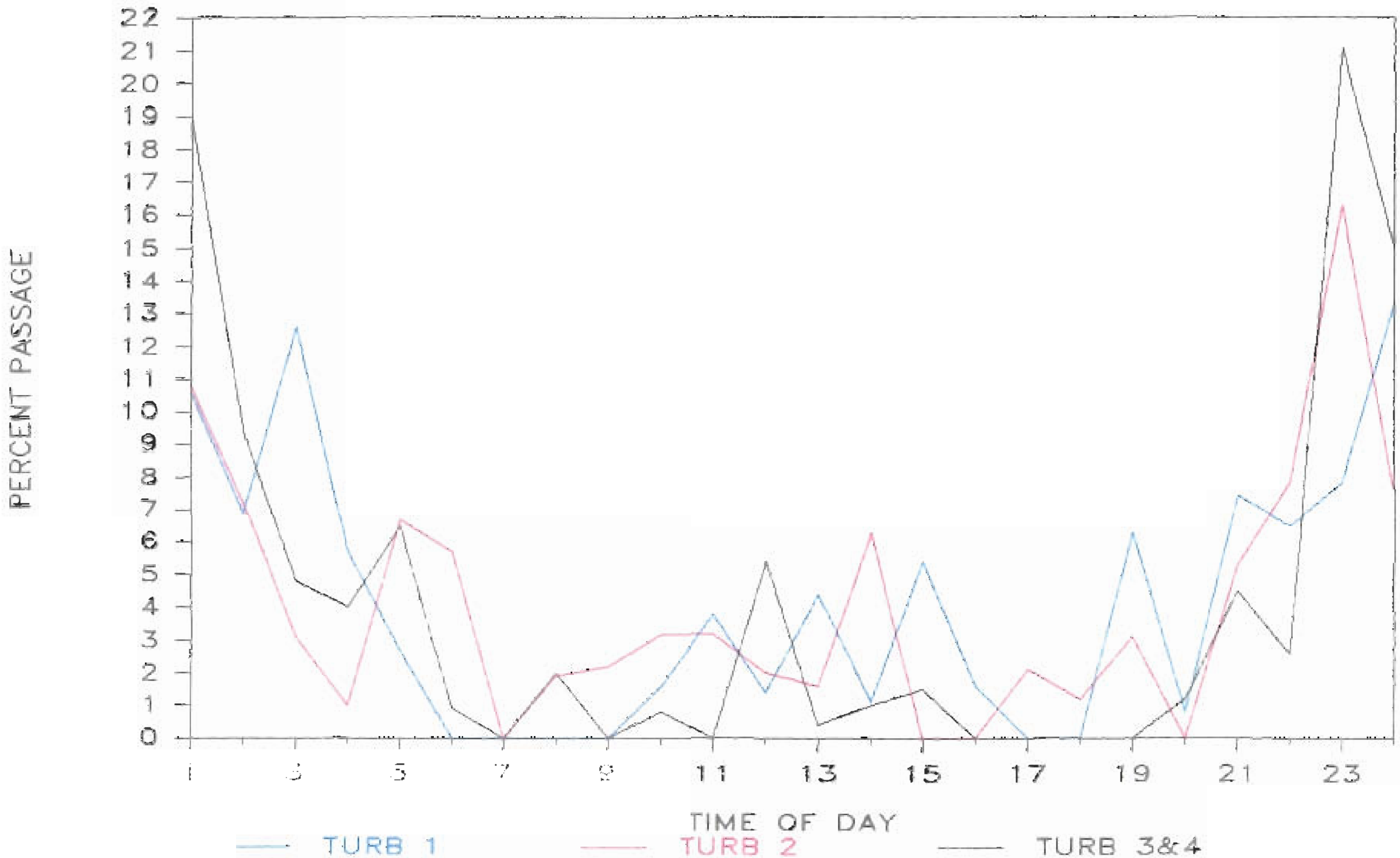

Figure 17. Hourly percentage of fish passage at each of the turbine intakes during period 1 (4/23-4/27).

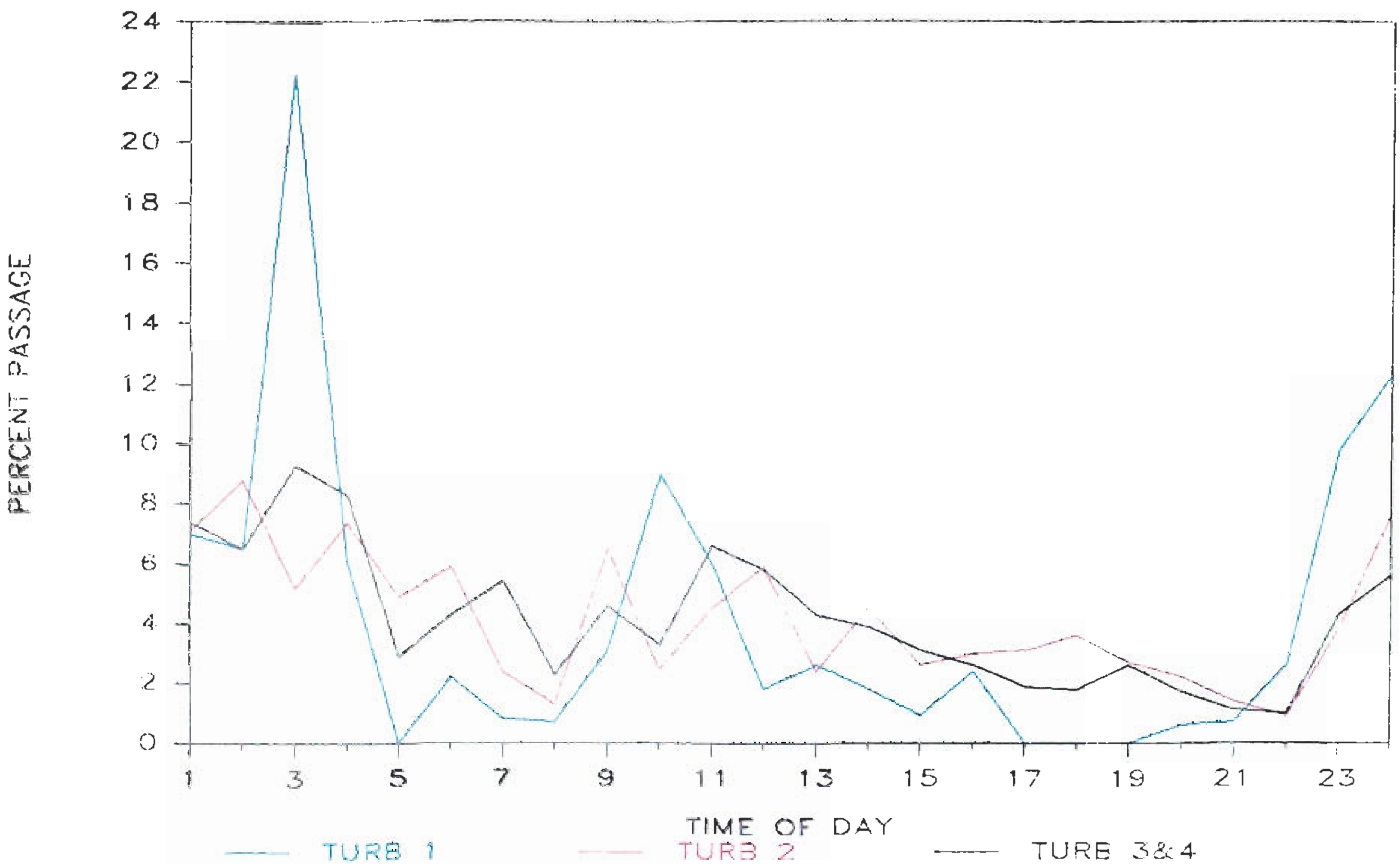

Figure 18. Hourly percentage of fish passage at each of the turbine intakes during period 2 (6/6-6/11).

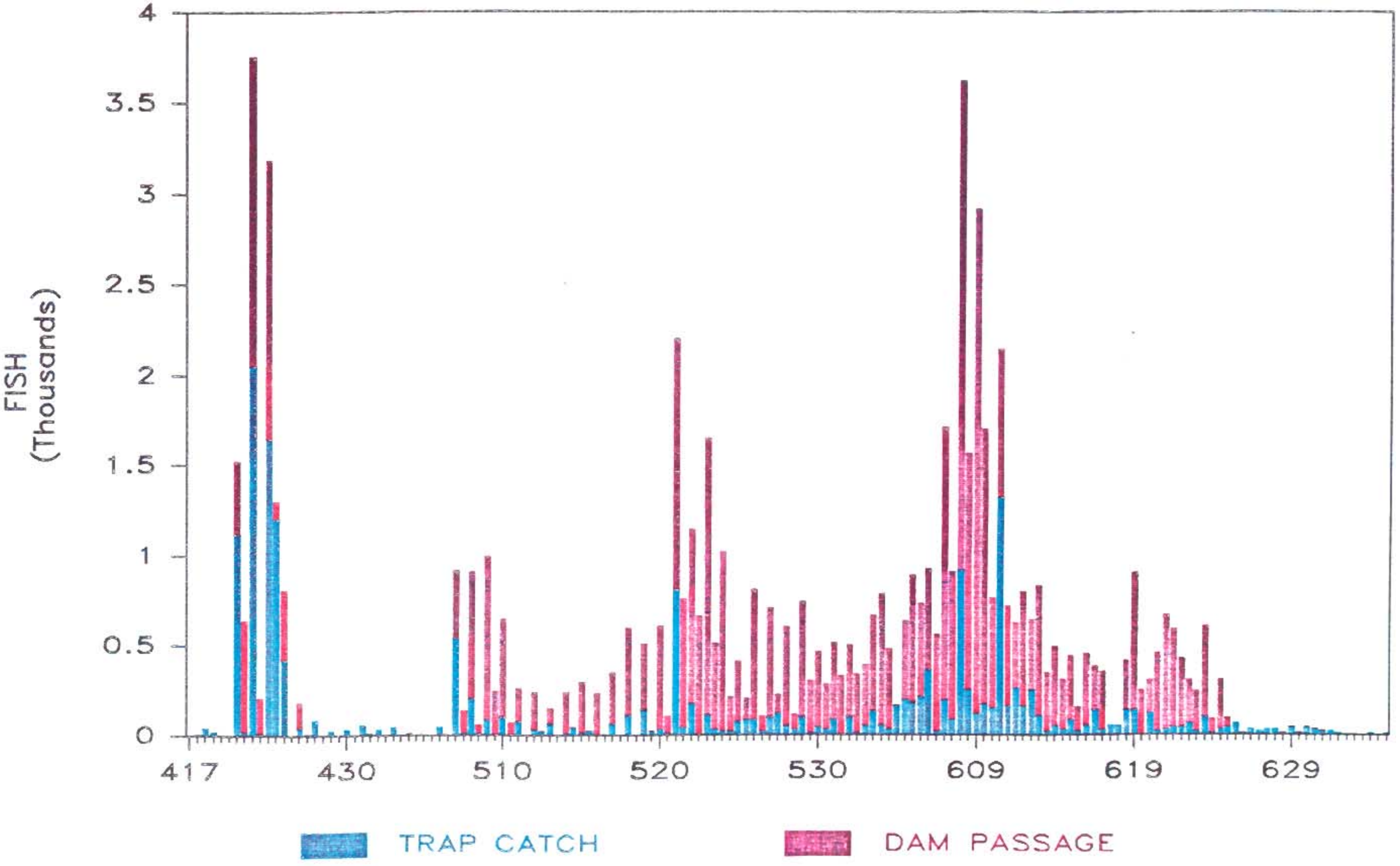

Figure 19. Trap catches (all migrants) vs. acoustic counts at Elwha Dam.

Table 1. Release data for experimental plants of winter steelhead in the upper Elwha River in 1983.

Release Location	River Mile	Release Data	Days Reared	Size	Release Number
Humes Ranch	19.4	7/18/83	61	500/lb	24,000
Marys Falls	20.6	7/18/83	69	400/lb	16,400
Marys Falls	20.6	7/18/83	61	500/lb	15,500
Tipperary Camp	23.6	7/18/83	86	350/lb	25,550
Camp Wilder	26.9	7/18/83	86	350/lb	5,250
Camp Wilder	26.9	7/18/83	69	400/lb	23,200
				Total =	109,900

Table 2. Release data for coho and steelhead plants at the Lake Aldwell boat ramp (rm 7.5).

Species	Group	Release Date	Release No.	Mean Forklength (mm)
Coho	1	4/22/85	6,028	138
Coho	2	5/6/85	3,575	140
Coho	3	5/20/85	3,911	146
Coho	4	6/5/85	2,900	144
Steelhead	3	5/20/85	87	203
Steelhead	4	6/5/85	57	205

Table 3. Hydroacoustic equipment used at Elwha Dam during spring of 1985.

Item	Manufacturer	Model No.
Echo Sounder/Transceiver	BioSonics, Inc.	101
Multiplexer/Equalizer	BioSonics, Inc.	151
Chart Recorder Interface	BioSonics, Inc.	165
Chart Recorders	EPC	1600
Transducers (15^0)	BioSonics, Inc.	-
Oscilloscope	Hewlett Packard	1703A

Table 4. Transducer beam widths.

Transducer #	Beam Width (degrees)
1	23
2	21
3	23
4	22
5	23
6	22
7	22
8	21

Table 5. Percent recovery of each coho group planted at the Lake Aldwell boat ramp (rm 7.5) and recovered by lake trap (rm 6.0). Incidental release and recovery of steelhead are included where available.

Release No.	Release Date	Coho Release	Coho Recovery	% Coho Recovery	Steelhead Release	Steelhead Recovery	% Steelhead Recovery	Total % Recovery
1	4/22/85	6,028*	662	11.0	No count	14	-	11.2
2	5/6/85	3,575*	77	2.2	No count	47	-	3.5
3	5/20/85	3,911	115	2.9	87	13	14.9	3.2
4	6/5/85	2,900	305	10.5	57	17	29.8	10.9

* Figure includes unknown number of hatchery steelhead smolts (see text).

Table 6. Cumulative percent recoveries of each coho release group at the lake trap for 14-day periods* following each release.

Release	No. Days After Release													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	17	47	89	95	96	97	97	98	98	99	99	100		
2	58	74	75	82	87	91	91	91	91	91	95	97	100	
3	70	82	87	89	93	93	93	93	95	96	96	96	100	
4	10	15	47	53	89	91	94	94	94	94	96	96	99	100

* Essentially 100% of each group was estimated to have passed the trap within 14 days, based on trap catch rates and extended trapping of the last release group.

Table 7. Coho trap recovery data and factors potentially affecting trap efficiency.

Release Group	Total % Recovery	% Day Catch During Principal Recovery Period 1/	Estimated % Sky Cover During Day Catch Period 2/	Estimated Mean Streamflow (cfs) During Principal Recovery Period 3/	Comments
1	11.0	20.9	74	974	
2	2.2	0.0	51	1,014	
3	2.9	2.0	69	2,302	Minor trap adjustment prior to 3rd release.
4	10.5	57.9	61	2,203	Major change in configuration of trap heart prior to 4th release

1/ Principal recovery period was first 3-5 days following release when approximately 90% of group recoveries occurred. Day catch period was 0700-1700 hrs.

2/ Sky cover was estimated from hourly observations recorded at Port Angeles airport. (Data source: National Weather Service records).

3/ Streamflow as measured at Glines Canyon Dam (Data source: Crown Zellerbach).

Table 8. Differences in mean forklength for coho and steelhead groups released at the head of Lake Aldwell and recovered by lake trap.

Species	Release Date	Mean Release Length (mm)	Mean Recovery Length (mm)	Difference (mm)	T-value
Coho	4/22/85	137.9	138.0	+0.1	0.1472
Coho	5/6/85	140.4	138.9	-1.5	1.9956
Coho	5/20/85	146.4	144.3	-2.1	1.5500
Coho	6/5/85	144.4	150.0	+5.6	4.2908*
Steelhead	5/20/85	202.7	198.0	-4.7	1.0139
Steelhead	6/5/85	205.4	200.9	-4.5	1.4337

* Indicates significance at the 0.05 level.

Table 9. Injuries observed among steelhead (wild) and coho salmon smolts captured at the Lake Aldwell lake trap. Injuries are expressed as a percentage of the total captures of each species.

Species	Injury						
	Descaling 1/			Other Injury (%)			
	Light(<10%)	Mod(10-50%)	Heavy(>50%)	Eye Damage 2/	Other External 3/	Internal 4/	Moribund/Equil. Loss
Steelhead	12.5	6.0	2.1	0.2	1.1	0.0	0.2
Coho	0.4	0.0	0.0	0.0	0.0	0.0	0.1

1/ Estimated percentage of scale loss on the body surface.

2/ Buldging or lost eye.

3/ Torn fin, operculum, or other external injury with or without bleeding.

4/ Internal injury evidenced by bleeding at vent, eyes, and/or mouth.

Table 10. Coded-wire tag data for steelhead trapped and tagged at Lake Aldwell, river mile 6.0. Steelhead were released at the tagging site immediately after tagging, except as noted.

Tag Code	Tagging Dates	Fish Size(cm)	No. Tagged	Comments
5-17-17	4/23-5/8/85	19.7	9	
5-17-18	5/10-5/19/85	19.9	27	
5-17-19	5/20-5/26/85	20.5	39	
5-17-20	5/27-7/5/85	20.3	345	One 33-fish sample held for 24 hrs to estimate tag retention.
5-17-21	6/11-6/12/85	20.1	75	
		Total	495	

Table 11. Summary of acoustic passage data.

Release Period	Spillgate 3 #	Spillgate 3 %	Intake 1 #	Intake 1 %	Intake 2 #	Intake 2 %	Intake 3 #	Intake 3 %	Intake 4 #	Intake 4 %	Totals #
Rel #1 4/22-4/27	9	2	1454	28	2014	39	740	15	870	17	5088
Post Rel #1 4/28-5/6	0	0	10	5	46	22	57	28	94	45	207
Rel #2 5/7-5/11	0	0	904	29	874	28	539	17	777	25	3094
Post Rel #2 5/12-5/20	318	10	636	20	929	30	776	25	477	15	3136
Rel #3 5/21-5/25	701	10	941	13	2634	36	2609	36	365	5	7250
Post Rel #3 5/25-6/5	155	2	1550	17	3890	43	2840	31	660	7	9095
Rel #4 6/6-6/10	1193	10	2113	16	3872	29	4862	36	1285	9	13325
Post Rel #4 6/11-6/22	269	3	1115	12	5415	57	1948	21	700	7	9447
Totals	2645	5	8723	17	19674	39	14371	28	5229	10	50642

Table 12. Species composition (juvenile coho vs. steelhead) in lake trap catches versus Elwha Dam counts, as estimated with acoustic data.

Test Period	Dates (inclusive)	Percentage Coho	
		Trap Catch	Acoustic Counts
1	4/23-4/27	100%	100+%
2	5/7-5/11	93%	100%
3	5/21-5/25	74%	48%
4	6/6-6/10	70%	20%

Appendix A. Salmonid catches at the lake trap. Column headings are: AM/PM - AM or PM trap check, COS-hatchery coho smolt, STTW - adipose clipped steelhead smolt, STTH - hatchery steelhead smolt, RBT - resident rainbow trout (>70 mm forklength), STTA - adult steelhead, CUT - cutthroat (>70mm forklength), DOV - dolly varden, BKT - brook trout, TRT - trout fry (<70 mm forklength), RBTS - non adipose-clipped steelhead smolt, COS - coho fry.

Mo	Dy	AM/PM	COS	STTW	STTH	RBT	STTA	CUT	DOV	BKT	TRT	RBTS	COSF	Notes
4	17	AM	0	0	0	4	0	0	0	0	0	0	0	
4	18	AM	0	1	0	6	0	0	2	0	0	0	0	
4	19	AM	0	4	0	3	0	1	0	0	0	0	0	
4	21	AM	0	2	0	12	0	0	0	0	0	0	0	
4	22	AM	0	0	0	0	0	0	0	1	0	0	0	
4	22	PM	0	0	0	0	0	0	0	0	0	0	0	
4	23	AM	108	2	2	5	0	0	0	0	0	0	0	
4	23	PM	2	0	0	0	0	0	0	0	0	0	0	
4	24	AM	198	1	6	8	0	0	0	1	0	0	0	
4	24	PM	1	0	0	1	0	0	0	0	0	0	0	
4	25	AM	159	0	6	0	0	1	0	2	0	0	0	
4	25	PM	120	0	0	1	0	1	0	4	0	0	0	

Appendix A. (continued)

Mo	Dy	AM/PM	COS	STTW	STTH	RBT	STTA	CUT	DOV	BKT	TRT	RBTS	COSF	NOTES
4	26	AM	42	0	0	1	0	0	0	0	0	0	0	
4	26	PM	0	0	0	0	0	0	0	0	0	0	0	
4	27	AM	4	0	0	1	0	0	0	0	0	0	0	
4	27	PM	1	0	0	0	0	0	0	0	0	0	0	
4	28	AM	8	0	0	2	0	0	0	0	0	0	0	
4	28	PM	0	0	0	1	0	1	0	0	0	0	0	
4	29	AM	2	0	0	1	0	0	0	0	0	0	0	
4	29	PM	0	0	0	0	0	0	0	0	0	0	0	
4	30	AM	3	0	0	2	0	1	0	0	0	0	0	Adult female steelhead observed near trap.
4	30	PM	0	0	0	0	0	0	0	0	0	0	0	
5	1	AM	3	2	0	0	0	0	0	0	0	0	0	
5	1	PM	1	0	0	1	0	0	0	0	0	0	0	
5	2	AM	2	1	0	0	1	3	1	0	0	0	0	Adult steelhead was spawned-out female with 2 right opercular punches.
5	2	PM	0	0	0	0	0	0	0	0	0	0	0	
5	3	AM	4	0	0	1	0	0	0	0	0	0	0	
5	3	PM	0	0	0	0	0	0	0	0	0	0	0	

Appendix A (continued)

Mo	Dy	AM/PM	COS	STTW	STTH	RBT	STTA	CUT	DOV	BKT	BRT	RBTS	COSF	
5	4	AM	1	0	0	0	0	0	0	0	0	0	0	
5	4	PM	0	0	0	0	0	0	0	0	0	0	0	
5	5	AM	0	0	0	1	0	0	0	0	0	0	0	
5	5	PM	0	0	0	0	0	0	0	0	0	0	0	
5	6	AM	3	1	0	1	0	0	0	0	0	0	0	
5	6	PM	0	0	0	0	0	0	0	0	0	0	0	
5	7	AM	45	1	8	5	0	1	0	1	0	0	0	
5	7	PM	0	0	1	2	0	0	0	0	0	0	0	
5	8	AM	12	2	6	2	0	1	0	1	0	0	0	
5	8	PM	0	0	1	0	0	0	0	0	0	0	0	
5	9	AM	1	0	7	3	0	0	0	0	0	0	0	
5	9	PM	0	0	0	0	0	0	0	0	0	0	0	
5	10	AM	5	2	3	5	0	1	0	0	0	0	0	
5	10	PM	0	0	0	0	0	0	0	0	0	0	0	
5	11	AM	4	0	3	1	2	2	0	0	0	0	0	Adult steelhead were both females; one with 2 left opercular punches (71.1 cm length) and one with 2 right opercular punches (63.5 cm length). Spawning condition was not noted.

Appendix A (continued)

Mo	Dy	AM/PM	COS	STTW	STTH	RBT	STTA	CUT	DOV	BKT	BRT	RBTS	COSF	NOTES
5	11	PM	0	0	0	0	0	0	0	0	0	0	0	
5	12	AM	3	0	0	3	0	1	0	0	0	0	0	
5	12	PM	0	0	2	0	0	0	0	0	0	0	0	
5	13	AM	0	1	5	2	0	0	0	1	0	0	0	
5	13	PM	0	0	0	0	0	0	0	0	0	0	0	
5	14	AM	0	1	0	0	0	0	0	0	0	0	0	
5	14	PM	0	0	4	0	0	1	0	0	0	0	0	
5	15	AM	0	0	1	0	0	1	0	0	0	0	0	Adult steelhead was spawned-out male with 2 left opercular punches (66.0 cm length).
5	15	PM	0	0	2	0	1	0	0	0	0	0	0	
5	16	AM	0	0	0	2	0	2	0	0	0	0	0	
5	17	AM	3	2	1	0	0	1	0	0	0	0	0	
5	17	PM	0	0	0	0	0	0	0	0	0	0	0	
5	18	AM	0	9	2	3	0	0	0	0	0	0	0	
5	18	PM	0	0	0	0	0	0	0	0	0	0	0	
5	19	AM	2	11	1	1	0	0	0	0	0	1	0	
5	19	PM	0	2	0	1	0	1	0	0	0	0	0	

Appendix A. (continued)

Mo	Dy	AM/PM	COS	STTW	STTH	RBT	STTA	CUT	DOV	BKT	TRT	RBTS	COSF	NOTES
5	20	AM	2	1	0	3	0	0	0	0	0	0	0	
5	20	PM	0	1	0	0	0	0	0	0	0	0	0	
5	21	AM	76	4	1	1	0	1	0	0	0	0	0	
5	21	PM	1	2	1	1	0	0	0	0	0	0	0	
5	22	AM	13	4	0	2	0	0	0	0	0	4	0	
5	22	PM	0	0	0	1	0	0	0	0	0	1	0	
5	23	AM	6	3	2	1	0	0	0	0	0	2	0	
5	23	PM	0	3	0	0	0	0	0	0	0	0	0	
5	24	AM	1	1	0	1	0	0	0	0	0	0	0	
5	24	PM	1	1	0	2	0	0	0	0	0	0	0	
5	25	AM	3	3	1	1	0	0	0	0	0	1	0	
5	25	PM	1	7	0	1	0	0	0	0	0	0	0	
5	26	AM	0	8	0	2	0	0	0	0	0	1	0	
5	26	PM	0	2	0	3	0	0	0	0	0	0	0	
5	27	AM	0	10	0	1	0	0	0	0	0	3	0	
5	27	PM	0	10	2	0	0	0	0	0	0	0	0	

Appendix A. (continued)

Mo	Dy	AM/PM	COS	STTW	STTH	RBT	STTA	CUT	DOV	BKT	TRT	RBTS	COSF	NOTES
5	28	AM	0	3	2	0	0	0	0	0	0	2	0	
5	28	PM	0	2	1	0	0	0	0	0	0	0	0	
5	29	AM	2	8	0	3	0	0	0	0	0	2	0	
5	29	PM	0	1	0	1	0	0	0	0	0	0	0	
5	30	AM	0	4	0	0	0	0	0	0	0	2	0	
5	30	PM	2	0	1	0	0	0	0	0	0	0	0	
5	31	AM	0	8	0	0	0	0	0	0	0	2	0	
5	31	PM	0	0	0	1	0	0	0	0	0	0	0	
6	1	AM	0	10	0	1	0	0	0	0	0	1	0	
6	1	PM	0	1	0	1	0	0	0	0	0	0	0	
6	2	AM	3	10	0	0	0	0	0	0	0	0	0	
6	2	PM	1	4	0	1	0	0	0	0	0	2	0	
6	3	AM	0	4	1	2	0	0	0	0	0	6	0	
6	3	PM	0	3	0	0	0	0	0	0	0	0	0	
6	4	AM	0	16	0	1	0	0	0	0	0	2	0	

Appendix A. (continued)

Mo	Dy	AM/PM	COS	STTW	STTH	RBT	STTA	CUT	DOV	BKT	TRT	RBTS	COSF	NOTES
6	4	PM	2	16	1	2	0	0	0	0	0	2	0	
6	5	AM	3	15	0	3	0	3	0	0	0	5	0	
6	5	PM	4	16	1	0	0	0	0	0	0	3	0	
6	6	AM	1	0	1	0	0	0	0	0	0	1	0	
6	6	PM	25	9	2	2	0	0	0	0	0	0	0	
6	7	AM	11	8	0	2	0	2	0	0	2	2	0	
6	7	PM	3	5	1	0	0	0	1	0	1	1	0	
6	8	AM	83	8	0	3	0	0	0	0	1	6	0	
6	8	PM	13	9	3	0	0	0	0	0	0	0	0	
6	9	AM	9	7	1	0	0	0	0	0	0	3	0	
6	9	PM	7	5	0	2	0	0	0	1	0	0	0	
6	10	AM	5	9	1	8	0	0	0	1	0	5	0	
6	10	PM	102	29	1	1	0	0	0	0	1	5	0	
6	11	AM	2	13	1	12	0	0	1	0	0	1	0	
6	11	PM	3	21	2	1	0	0	0	0	0	4	0	
6	12	AM	3	13	0	9	0	0	0	0	0	0	0	

Appendix A. (continued)

Mo	Dy	AM/PM	COS	STTW	STTH	RBT	STTA	CUT	DOV	BKT	TRT	RBTS	COSF	NOTES
6	12	PM	6	19	0	3	0	0	0	0	0	2	1	
6	13	AM	2	8	1	1	0	0	0	0	1	4	0	
6	13	PM	0	1	1	0	0	0	0	0	0	2	0	
6	14	AM	0	5	0	5	0	2	0	0	1	0	0	
6	14	PM	0	3	0	0	0	0	0	0	0	0	1	
6	15	AM	1	7	0	3	0	0	0	0	0	0	0	
6	15	PM	0	2	0	1	0	0	0	0	0	0	0	
6	16	AM	0	5	0	3	0	0	0	0	0	2	0	
6	16	PM	4	10	0	4	0	1	0	0	0	1	0	
6	17	AM	1	2	0	11	0	0	0	0	0	0	0	
6	17	PM	0	5	0	3	0	0	0	1	0	1	0	
6	18	AM	2	2	1	1	0	1	0	0	0	0	0	
6	18	PM	7	7	0	0	0	0	0	0	1	1	0	
6	19	AM	2	12	0	8	0	1	0	0	0	0	0	High winds prevented PM trap check.
6	20	AM	2	10	0	6	0	1	0	0	2	1	0	
6	20	PM	0	2	0	0	0	0	0	0	0	1	0	

Appendix A. (continued)

Mo	Dy	AM/PM	COS	STTW	STTH	RBT	STTA	CUT	DOV	BKT	TRT	RBTS	COSF	NOTES
6	21	AM	0	3	0	4	0	1	0	1	1	0	0	
6	21	PM	2	2	0	2	0	0	0	0	0	0	0	
6	22	AM	0	4	0	2	0	0	0	1	2	0	0	
6	22	PM	0	6	0	1	0	0	0	0	1	1	0	
6	23	AM	0	2	0	6	0	0	0	0	2	1	0	
6	23	PM	2	8	0	2	0	1	0	0	0	2	0	
6	24	AM	0	1	0	8	0	0	0	0	1	0	0	
6	24	PM	0	3	0	2	0	0	0	1	0	0	0	
6	25	AM	0	4	0	5	0	2	0	0	0	0	0	
6	25	PM	1	5	0	3	0	2	0	0	0	0	0	
6	26	AM	0	1	0	6	0	0	0	1	0	0	0	
6	26	PM	0	3	0	1	0	2	0	1	1	1	0	
6	27	AM	0	2	0	0	0	1	0	0	0	0	0	
6	27	PM	0	3	0	0	0	0	0	0	0	0	0	
6	28	AM	0	3	0	3	0	2	0	0	0	0	0	
6	28	PM	0	1	0	0	0	0	0	0	1	0	0	

Appendix A. (continued)

Mo	Dy	AM/PM	COS	STTW	STTH	RBT	STTA	CUT	DOV	BKT	TRT	RBTS	COSF	NOTES
6	29	AM	0	4	0	2	0	0	0	0	0	0	0	
6	29	PM	0	1	0	2	0	0	0	0	0	1	0	
6	30	AM	2	2	0	3	0	0	0	0	0	0	0	
6	30	PM	0	3	0	2	0	0	0	0	0	0	0	
7	1	AM	0	2	0	4	0	1	0	0	0	0	0	
7	1	PM	0	2	0	2	0	0	0	0	0	1	0	
7	2	AM	0	1	0	0	0	0	0	0	0	0	0	
7	2	PM	0	0	0	1	0	0	0	0	0	0	0	
7	3	AM	0	0	0	0	0	0	0	0	0	0	0	
7	3	PM	0	0	0	0	3	0	0	0	0	0	0	
7	4	AM	0	1	0	1	0	0	0	0	0	0	0	
7	4	PM	0	0	0	2	0	0	0	0	0	0	0	
7	5	AM	0	1	0	4	0	0	0	0	1	0	0	
	Total:		1159	530	91	278	4	44	5	20	20	92	2	